ENHANCING THE STRENGTH OF CONCRETE USING ULTRA-FINE SLAG

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CERTIFICATE

This is to certify that the work entitled "**ENHANCING THE STRENGTH OF CONCRETE USING ULTRA-FINE SLAG**" submitted by **Simranjeet Singh (111612)** and **Peeyush Gupta (111629)** in partial fulfilment for the award of degree of Bachelor of Technology in Civil Engineering of Jaypee University of Information Technology has been carried out under my supervision. This work has not been submitted wholly to any other University or Institute for the award of this or any other degree or diploma.

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We gratefully acknowledge the Management and Administration of Jaypee University of Information Technology for providing us the opportunity and hence the environment to initiate and partially complete our project till now.

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ABSTRACT

Concrete is a composite construction material made primarily with aggregates, cement and water. There are many formulations of concrete, which provide varied properties and concrete is the most used man-made product in the world.

Concrete is widely used for making architectural structures, foundations, pavements, etc. Famous concrete structures include Burj Khalifa (world's tallest building), Hoover Dam and the Panama Canal.

Concrete technology was known by Ancient Romans and was widely used within the Roman Empire. Colosseum is largely built of concrete and the concrete dome of the Pantheon is the world's largest. After the Empire passed, use of concrete became scare until the technology was re-pioneered in the mid-18th century. There are inorganic materials that also have pozzolanic or hydraulic properties. Fine-grained materials are added to the concrete mix to improve the properties of concrete (mineral admixtures), or as a replacement for Portland cement.

CHAPTER-1
INTRODUCTION

Concrete is no longer made of aggregates, Portland cement and water only. Often, if not always it has to incorporate at least one of the additional ingredients such as admixtures, supplementary cementious material or fibers to enhance its strength and durability. During last few decades requirement of high performance and highly durable concrete has been on rise. The use of mineral admixture in combination with chemical admixture has allowed the concrete technologists to tailor the concrete for many specific requirements. Amongst the mineral admixture, silica fume, because of its finely divided state and very high percentage of amorphous silica, proved to be most useful, if not essential for the development of very high strength concretes and concrete of very high durability i.e. high performance concrete. Therefore it is being used on a worldwide scale in concrete, for the making of high performance concrete. In spite of its numerous advantages silica fume suffers from one major disadvantage that it is imported therefore, very costly. In this work an attempt has made to find a suitable alternate of alccofine.

1.1 OBJECTIVE

- The main purpose of the present investigation is to determine the optimum percentage of ALCCOFINE as a partial replacement of cement for M50 grade of concrete.
- Increase the strength of concrete by using admixture (alccofine).
- Perform various tests on cement and concrete.

1.2 NECESSITY

This project mainly includes the increase in strength of concrete with the help of admixture alccofine. It is very important to do that as there is a high demand of high strength concrete in skyscrapers, dams etc. Also there is dense reinforcement in skyscrapers, dome etc. due to which the concrete does not get filled properly in reinforcement (even after compaction) and there are defects like honey combing, segregation etc. So in order to avoid that we need concrete with very high workability without compromising with strength.

1.3 MATERIALS

- Ordinary Portland cement of 43 grade obtained from a single source.
- Locally available sand.
- Alccofine.

CHAPTER 2
LITERATURE REVIEW

2.1 PAST INVESTIGATION

- Study on Strength Development of High Strength Concrete Containing Alccofine and Fly-Ash. By Suthar Sunil B ** Dr. (Smt.) B. K. Shah.
  They concluded that ternary cementitious blends of Ordinary Portland cement, Alccofine, and fly ash offer significant advantages over binary blends and even greater enhancements over plain Portland cement. The combination of Alccofine and fly ash is complementary: the alccofine improves the early age performance of concrete with the fly ash continuously refining the properties of the hardened concrete as it matures. In terms of durability, such blends are vastly superior to Ordinary Portland cement concrete..
- Experimental Study on High-Performance Concrete, with Mixing of Alccofine and Flyash by Deval Soni, et al.
  They concluded that alccofine has better performance compare to other slag materials and microsilica. It is helpful to make concrete workable. By increasing or trying various dosage of Alccofine and fly ash we get better result on 8% of Alccofine and 16% of flyash.
- Study on durability of HPC with Alccofine and Fly Ash by Yatin H Patel, et al.
  They concluded that compressive strength achieved by using Alccofine (8%) + Fly Ash (20%) is 54.89Mpa and 72.97 Mpa at 28 and 56 days respectively. The minimum loss of weight and loss of compressive strength of concrete in Chloride Resistance test and Sea water test due to addition of Alccofine. Due to its more compactness and less permeability of concrete effect of Chloride Attack is reducing. This is converts leachable calcium hydroxide into insoluble non- leachable cementanious product. This pozzolanic action is responsible for impermeability of concrete. Secondly, the removal of calcium hydroxide reduces the susceptibility of concrete to attack by Chloride.

2.2 GENERAL INVESTIGATIONS

Concrete is most commonly used material in civil construction work all over the country. There is hardly any major original civil construction work where concrete is not used. Concrete is a mixture of cement, sand, stone aggregates and water. A cage of steel rods used together with the concrete mix leads to the formation of Reinforced Cement Concrete popularly known as RCC. Concrete has two main stages

1) Fresh Concrete

2) Hardened Concrete

2.2.1 FRESH CONCRETE

Fresh Concrete should be stable and should not segregate or bleed during transportation and placing when it is subjected to forces during handling operations of limited nature. The mix should be cohesive and mobile enough to be placed in the form around the reinforcement and should be able to cast into the required shape without losing continuity or homogeneity under the available techniques of placing the concrete at a particular job. The mix should be amenable to proper and through compaction into a dense, compact concrete with minimum voids under the existing facilities of compaction at the site. A best mix from the point of view of compatibility should achieve a 99 percent elimination of the original voids present.

2.2.2 HARDENED CONCRETE

One of the most important properties of the hardened concrete is its strength which represents the ability if concrete to resist forces. If the nature of the force is to produce compression, the strength is termed compressive strength. The compressive strength of hardened concrete is generally considered to be the most important property and is often taken as the index of the overall quality of concrete. The strength can indirectly give an idea of the most of the other properties of concrete which are related directly to the structure of hardened cement paste. A stronger concrete is dense, compact, impermeable and resistant to weathering and to some chemicals. However, a stronger concrete may exhibit higher drying shrinkage with consequent cracking, due to the presence of higher cement content. Some of the other desirable properties like shear and tensile strengths, modulus of elasticity, bond, impact and durability etc. are generally related to compressive strength. As the compressive strength can be measured easily on standard sized cube or cylindrical specimens, it can be specified as a criterion for studying the effect of any variable on the quality of concrete. However, the concrete gives different values of any property under different testing conditions. Hence method of testing, size of specimen and the rate of loading etc. are stipulated while testing the concrete to minimize the variations in test results. The statistical methods are commonly used for specifying the quantitative value of any particular property of hardened concrete.

2.3 DEFECTS

SEGREGATION The stability of a concrete mix requires that it should not segregate and bleed during the transportation and placing. Segregation can be defined as separating out of the ingredients of a concrete mix, so that the mix is no longer in a homogeneous condition. Only the stable homogeneous mix can be fully compacted. The segregation depends upon the handling and placing operations. The tendency to segregate, amount of coarse aggregate, and with the increased slump. The tendency to segregate can be minimized by:

a. Reducing the height of drop by concrete.

b. Not using the vibration as a means of spreading a heap of of concrete into a level mass over a large area.

c. Reducing the continued vibration over a longer time, as the coarse aggregate tends to settle to the bottom and the scum would rise to the surface.

d. Adding small quantity of water which improves cohesion of the mix.

BLEEDING is due to the rise of water in the mix to the surface because of the inability of the solid particles in the mix to hold all the mixing water during settling of particles under the effect of compaction. The bleeding causes formation of a porous, weak and non durable concrete layer at the top of placed concrete. In case of lean mixes bleeding may create capillary channels increasing the permeability of the concrete. When the concrete is placed in different layers and each layer is compacted after allowing certain time to lapse before the next layer is laid, the bleeding may cause a plane of weakness between two layers. Any laitance formed should be removed by brushing and washing before a new layer is added. Over compacting the surface should be avoided.

2.4 PROPERTIES

COMPRESSIVE STRENGTH of concrete is defined as the load which causes the failure of specimen, per unit area of cross-section in uniaxial compression under given rate of loading. The strength of concrete is expressed as N/mm2. The compressive strength at 28 days after casting is taken as a criterion for specifying the quality of concrete. This is termed as grade of concrete. IS 456 —2000 stipulates the use of 150 mm cubes.

TENSILE STRENGTH The concrete has low tensile strength; it ranges from 8-12 per cent of its compressive strength. An average value of 10 per cent is generally adopted.

SHEAR STRENGTH The concrete subjected to bending and shear stress is accompanied by tensile and compressive stresses. The shear failures are due to resulting diagonal tension. The shear strength is generally 12-13 per cent of its compressive strength.

BOND STRENGTH The resistance of concrete to the slipping of reinforcing bars embedded in concrete is called bond strength. The bond strength is provided by adhesion of hardened cement paste, and by the friction of concrete and steel. It is also affected by shrinkage of concrete relative to steel. On an average bond strength is taken as 10 per cent of its compressive strength.

2.5 FACTS ABOUT CEMENT AND CONCRETE

Water required by 1 bag of cement is something in the range of 25-28 litres Quality of concrete has nothing to do with its color. The mortar / concrete should be consumed as early as possible after addition of water to it. The hydration of cement starts the moment water is added to it. As the hydration progresses the cement paste starts stiffening and loses its plasticity. The concrete should not be disturbed after this. Normally, this is about 45 — 50 minutes. MPa is abbreviated form of mega Pascal, which is a unit of pressure. 1 MPa is equivalent to a pressure of 10Kg /cm2. The strength of concrete & cement is expressed in terms of pressure a standard cube can withstand. The Ordinary Portland Cement, commonly called OPC is available in three grades namely 33, 43 & 53 grades. Thus, for 43 grade cement standard cement & sand mortar cube would give a minimum strength of 43 MPa or 430 Kg /cm2 when tested under standard curing conditions for 28 days.

2.6 COMPRESSIVE STRENGTH OF CONCRETE DEPENDS ON FOLLOWING FACTORS

(i) w/c ratio.

(ii) Characteristics of cement.

(iii) Characteristics of aggregates.

(iv) Time of mixing.

(v) Degree of compaction.

(vi) Temperature and period of curing.

(vii) Age of concrete.

(viii)Air entertainment.

(ix) Conditions of testing.

2.7 PRECAUTIONS FOR WATER TO BE USED IN CONCRETE

1. It is good to use potable quality of water.

2. It should be free from impurities and harmful ingredients.

3. Seawater isn't recommended.

4. The water fit for mixing is fit for curing too.

5. Use of minimum quantity of mixing water, consistent with the degree of workability required to enable easy placing and compaction of concrete, is advisable.

6. Ensure that water is measured and added.

7. Low water to cement ratio is essential for good performance of the structure in the long run.

2.8 COMMON REASONS FOR LACK OF QUALITY IN CONCRETE WORK

1. Use of too much or too little water for mixing, or water carelessly added.

2. Incomplete mixing of aggregate with cement.

3. Improper grading of aggregates resulting in segregation or bleeding of concrete.

4. Inadequate compaction of concrete.

5. Using concrete which has already begun to set.

2.9 ADMIXTURES

Admixtures are those ingredients/materials that are added to cement, water, and aggregate mixture during mixing in order to modify or improve the properties of concrete for a required application.

1. Broadly the following five changes can be expected by adding an admixture

(I) Air entertainment.

(II) Water reduction for better quality.

(III) Acceleration of strength development.

(IV) Improving the workability.

(V) Water retention

2. Some of the important purposes for which the admixtures could be used are

1. Acceleration of the rate of strength development.

2. Retardation of the initial setting of the concrete.

3. Increase in strength.

4. Improvement in workability.

5. Reduction in heat of evolution.

6. Increase in durability to special conditions of exposure.

7. Control of alkali-aggregate expansion.

8. Reduction in the capillary flow of water.

9. Reduction in segregation.

10. Production of coloured concrete or mortar

CHAPTER 3
ALCCOFINE

3.1 GENERAL

It is a new generation supplementary Cementations material which means particle size below 5 microns. The main raw material is ungrounded granulated blast furnace slag .It is manufactured by grinding granulated blast furnace slag in a mill attached with high efficiency classifier which classifies the required micron size material. ALCCOFINE makes cement to improve its workability, cohesiveness etc. and in hardened state improves strength and durability. It has low heat of hydration as compared to OPC. There are several mineral additives such as silica fume, fly ash, rice husk ash etc. All of them are siliceous rich. ALCCOFINE on other hand is a Cementations material.

3.2 FIELD OF APPLICATIONS

1. Rock injection: Tunnels, mines, etc.

2. Ground water sealing and ground stabilisation.

3. Soil injection: example ground stabilisation.

4. Contact injection

3.3 BENEFITS

1. Standard cement injection equipment can be used.

2. Better penetration in tight joints and spaces.

3. Fast setting and better workability.

4. Durable.

5. High Strength

CHAPTER 4
EXPERIMENTAL INVESTIGATION

4.1TESTS ON CEMENT

4.1.1 SOUNDNESS TEST

4.1.1.1 OVERVIEW

In the soundness test a specimen of hardened cement paste is boiled for a fixed time so that any tendency to expand is speeded up and can be detected. Soundness means the ability to resist volume expansion.

4.1.1.2 PROCEDURE

Before commencing setting time test, do the consistency test to obtain the water required to give the paste normal consistency (P).

Prepare a paste by adding 0.78 times the water required to give a paste of standard consistency (i.e. 0.78P).

Lightly oil the Le-chatelier mould and place it on a lightly oiled glass sheet.

Fill the mould with the prepared cement paste. In the process of filling the mould keep the edge of the mould gently together.

Cover the mould with another piece of lightly oiled glass sheet, place a small weight on this covering glass sheet.

Submerge the whole assembly in water at a temperature of 27 ± 2^0 C and keep there for 24 hours.

Remove the whole assembly from water bath and measure the distance separating the indicator points to the nearest 0.5 mm (L_1).

Again submerge the whole assembly in water bath and bring the temperature of water bath to boiling temperature in 25 to 30 minutes. Keep it at boiling temperature for a period of 3 hours.

After completion of 3 hours, allow the temperature of the water bath to cool down to room temperature and remove the whole assembly from the water bath.

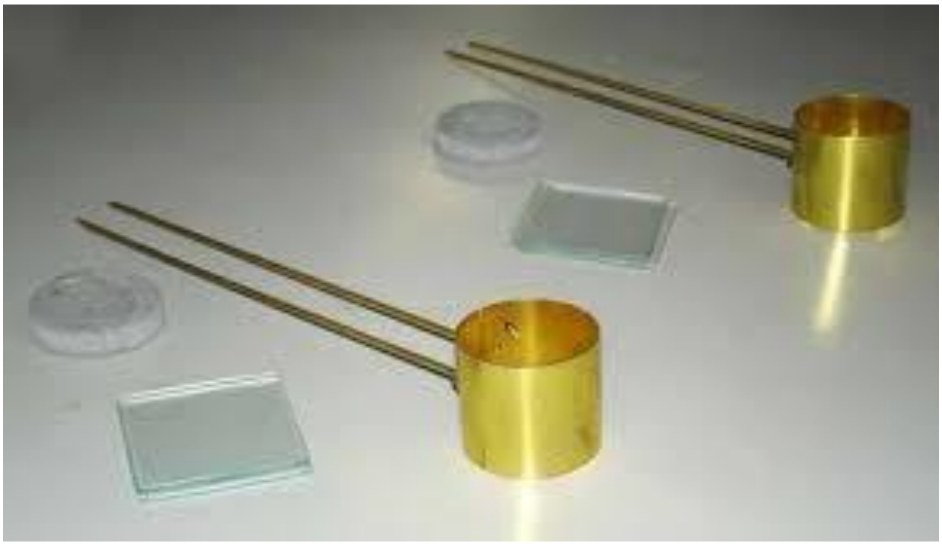

FIGURE 1 – Le Chatelier Appratus

4.1.1.3 CALCULATIONS

Soundness/expansion of cement = L_1-L_2

L_1=Measurement taken after 24 hours of immersion in water at a temp. of 27 ± 2^0 C

L_2=Measurement taken after 3 hours of immersion in water at boiling temperature.

L_1 = 2.2cm

L_2 = 1.9cm

Soundness = 2.2 - 1.9 = 3mm

4.1.2 NORMAL CONSISTENCY

4.1.2.1 OVERVIEW

Standard consistency of a cement paste is defined as that consistency which will permit a vicat plunger having 10 mm dia and 50 mm length to penetrate to a depth of 33-35 mm from top of the mould.

4.1.2.2 PROCEDURE

Take 400 g of cement and place it in the enameled tray.

Mix about 25% water by weight of dry cement thoroughly to get a cement paste. Total time taken to obtain thoroughly mixed water cement paste i.e. "Gauging time" should not be more than 3 to 5 minutes.

Fill the vicat mould, resting upon a glass plate, with this cement paste.

After filling the mould completely, smoothen the surface of the paste, making it level with top of the mould.

Place the whole assembly (i.e. mould + cement paste + glass plate) under the rod bearing plunger.

Lower the plunger gently so as to touch the surface of the test block and quickly release the plunger allowing it to sink into the paste.

Measure the depth of penetration and record it.

Prepare trial pastes with varying percentages of water content and follow the steps (2 to 7) as described above, until the depth of penetration becomes 33 to 35 mm.

4.1.2.3 RESULT

Normal Cosistency of cement comes to be 35%.

4.1.3 INITIAL AND FINAL SETTING TIME

4.1.3.1 OVERVIEW

Initial setting time is that time period between the time water is added to cement and time at which 1 mm square section needle fails to penetrate the cement paste, placed in the Vicat's mould 5 mm to 7 mm from the bottom of the mould.

Final setting time is that time period between the time water is added to cement and the time at which 1 mm needle makes an impression on the paste in the mould but 5 mm attachment does not make any impression.

4.1.3.2 PROCEDURE

(a)Test block preparation

1. Before commencing setting time test, do the consistency test to obtain the water required to give the paste normal consistency (P).
2. Take 400 g of cement and prepare a neat cement paste with 0.85P of water by weight of cement.
3. Gauge time is kept between 3 to 5 minutes. Start the stop watch at the instant when the water is added to the cement. Record this time (t_1).
4. Fill the Vicat mould, resting on a glass plate, with the cement paste gauged as above. Fill the mould completely and smooth off the surface of the paste making it level with the top of the mould. The cement block thus prepared is called test block.

(b)Initial setting time

1. Place the test block confined in the mould and resting on the non-porous plate, under the rod bearing the needle.
2. Lower the needle gently until it comes in contact with the surface of test block and quick release, allowing it to penetrate into the test block.
3. In the beginning the needle completely pierces the test block. Repeat this procedure i.e. quickly releasing the needle after every 2 minutes till the needle fails to pierce the block for about 5 mm measured from the bottom of the mould. Note this time (t_2).

(c)Final setting time

1. For determining the final setting time, replace the needle of the Vicat's apparatus by the needle with an annular attachment.
2. The cement is considered finally set when upon applying the final setting needle gently to the surface of the test block; the needle makes an impression thereon, while the attachment fails to do so. Record this time (t_3).

FIGURE 2 – Vicat's Appratus

FIGURE 3 – Normal Consistency

4.1.3.3 CALCULATIONS

Initial setting time=t_2-t_1

Final setting time=t_3-t_1,

Where,

t_1=Time at which water is first added to cement

t_2=Time when needle fails to penetrate 5 mm to 7 mm from bottom of the mould

t_3=Time when the needle makes an impression but the attachment fails to do so.

t_1 = 0 mins

t_2 = 43 mins

t_3 = 7 hrs 30 mins

4.2 TEST ON AGGREGATES

4.2.1 SPECIFIC GRAVITY OF COARSE AGGREGATES

4.2.1.1 OVERVIEW

Aggregate specific gravity is used in a number of applications including Superpave mix design, deleterious particle indentification and separation, and material property change identification.

4.2.1.2 PROCEDURE

1. The sample of above 2Kg shall be thoroughly washed to remove finer particles and dust, drained and then placed in the wire basket and immersed in distilled water at a temperature between 22°C and 32°C with a cover of at least 5 cm of water above the top of the basket.

2. Immediately. after immersion the entrapped air shall be removed from the sample by lifting the basket containing it 25 mm above the base of the tank and allowing it to drop 25 times at the rate of about one drop per second.

3. The basket and the sample shall then be jolted and weighed in water at a temperature of 22 to 32°C. If it is necessary for them to be transferred to a different tank for weighing, they shall be jolted 25 times as described above in the new tank before weighing.

4. The basket and the aggregate shall then be removed from the water and allowed to drain for a few minutes, after which the, aggregate shall be gently emptied from the basket on to one of the dry clothes, and the empty basket shall be returned to the water, jolted 25 times and weighed in water.

5. The aggregate placed on the dry cloth shall be gently surface dried with the cloth, transferring it to the second dry cloth when the first will remove no further moisture. The aggregate shall then be weighed.

6. The aggregate placed on the dry cloth shall be gently surface dried with the cloth, transferring it to the second dry cloth when the first will remove no further moisture. It shall then be removed from the oven, cooled in the airtight container and weighed.

4.2.1.3 CALCULATIONS

Specific Gravity = Dry weight of aggregate/Weight of equal volume of water.

= 2.64 / (2.64 - 1.65)

= 2.66

Dry weight of Aggregate = 2.64

Weight of equal volume of water = 1.65

4.2.2 SPECIFIC GRAVITY OF FINE AGGREGATES

4.2.2.1 PROCEDURE

1. Using the pycnometer - A sample of about 500 g if finer than 4.75 mm, shall be placed in the tray and covered with distilled water at a temperature of 22 to 32°C. Soon after immersion, air entrapped in or bubbles on the surface of the aggregate shall be removed by gentle agitation with a rod.

2. The sample shall remain immersed for 24 hours. The water shall then be carefully drained from the sample, by decantation through a filter paper, any material retained being return & to the sample. The saturated and surface-dry sample shall be weighed (weight A).

3. The pycnometer shall be topped up with distilled water to remove any froth from the surface and so that the surface of the water in the hole is flat. The pycnometer shall be dried on the outside and weighed (weight B).

4. The contents of the pycnometer shall be emptied into the tray, care being taken to ensure that all the aggregate is transferred. The pycnometer shall be refilled with distilled water to the same level as before, dried on the outside and weighed (weight C).

5. The water shall then be carefully drained from the sample by deeantation through a filter paper and any material retained returned to the sample. The sample shall be

placed in the oven in the tray at a temperature of 100 to 110°C for 24 hours, during which period it shall be stirred occasionally to facilitate drying. It shall be cooled in the air-tight container and weighed (weight D).

4.2.2.2 CALCULATIONS

Specific Gravity = (D / A – (B – C))

= (530 / (550 – 347))

= 2.61

A = weight in g of saturated surface-dry sample

B = weight in g of pycnometer or gas jar containing sample and filled with distilled water

C = weight in g of pycnometer or gas jar filled with distilled water only

D = weight in g of oven-dried sample.

CHAPTER 5
WORKABILITY

5.1 SLUMP TEST

Slump Test is perform to measure the consistency and workability of fresh concrete through an idea which it gives of water content needed for concrete to be used for different ideal works. A concrete is called as workable if it can be easily mixed, placed, compacted and finished and does not show any segregation or bleeding.

Apparatus Required:-

(a) Iron Pan to mix Concrete

(b) Slump cone

(c) Spatula for mixing purpose

(d) Trowels

(e) Tamping Rod

(f) Graduated Cylinder

5.1.1 PROCEDURE

Step 1:- Mix all dry ingredient thoroughly and carefully to get uniform result and then add water.

Step 2:- The slump test cone is placed on a smooth, level surface with the smaller opening at the top. Slump cone is filled in three layers of equal volume, each approximately ¼ of the height of the mould. and each layer is to be compacted 25 times with a standard rod having a hemispherical tip

Step 3:- Struck off the rod, and then cone is slowly lifted and set beside the unsupported concrete Such that the tamping rod should penetrate in to the underlying layer.

Step 4:- The rod is laid across the cone and a measure of the distance from the bottom of the rod to the average top of the concrete is taken .A very stiff mix will have near zero slumps.

Lean mixes tend to be harsh and slumps can vary from true to shear in different sample of the same mixes.

FIGURE 4a – Slump Test

FIGURE – 4b

5.1.2 RESULT

SLUMP VALUE

Simple concrete 37 mm

OPC (5% Alccofine) 43 mm

OPC (10% Alccofine) 45 mm

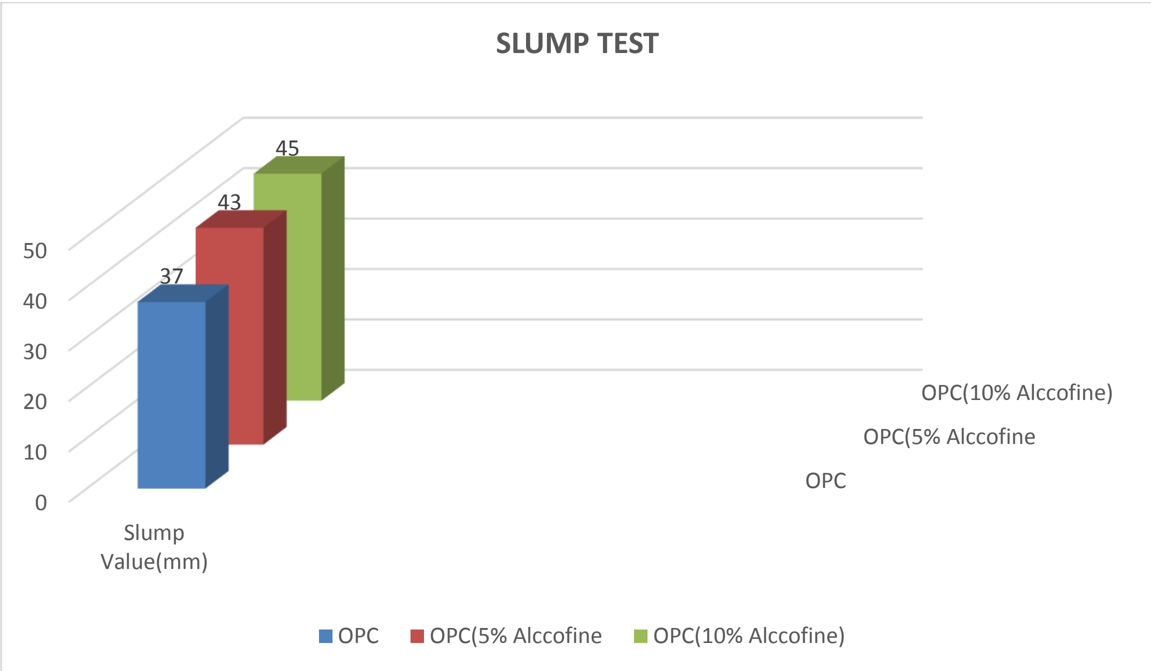

CHART – 1 Slump Test

5.2 COMPACTING FACTOR TEST

This test is usually used in laboratory and determines the workability of fresh concrete when size is about 40 mm maximum. The test is carried out as per specification of IS: 1199-1959.

Apparatus Required:-

(a) Compacting Factor apparatus

(b) Trowels

(c) Graduated cylinder

(d) Balance

(e) Tamping rod and iron buckets

5.2.1 PROCEDURE

Step 1:- keep the apparatus on the ground and apply grease on the inner surface of the cylinders.

Step 2:- Measure the mass as w1 kg by weighing the cylinder accurately and fix the cylinder on the base in such a way that the central points of hoppers and cylinder lie on one vertical line and cover the cylinder with a plate.

Step 3:- For each 5 kg of aggregate mixes are to be prepared with water-cement ratio by weight with 2.5 kg sand and 1.25 kg of cement and then add required amount of water thoroughly until and unless concrete appears to be homogeneous.

Step 4:- With the help of hand scoop without compacting fill the freshly mixed concrete in upper hopper part gently and carefully and within two minutes release the trap door so that the concrete may fall into the lower hopper such that it bring the concrete into standard compaction.

Step 5:- Fall the concrete to into the cylinder by bringing the concrete into standard Compaction immediately after the concrete has come to rest and open the trap door of lower hopper and then remove the excess concrete above the top of the cylinder by a pair of trowels, one in each hand will blades horizontal slide them from the opposite edges of the mould inward to the center with a sawing motion.

Step 6:- Clean the cylinder from all sides properly. Find the mass of partially compacted concrete thus filled in the cylinder and say it W2 kg. After this refill the cylinder with the same sample of concrete in approximately 50 mm layers, by vibrating each layer heavily so as to expel all the air and obtain full compaction of the Concrete.

Step 7:- Struck off level the concrete and weigh and cylinder filled with fully compacted concrete. Let the mass be W3 kg.

Step 8:- Calculate compaction factor by using the formula

5.2.2 RESULT

Simple Concrete = 0.72

OPC (5% Alccofine) = 0.76

OPC (10% Alccofine) = 0.77

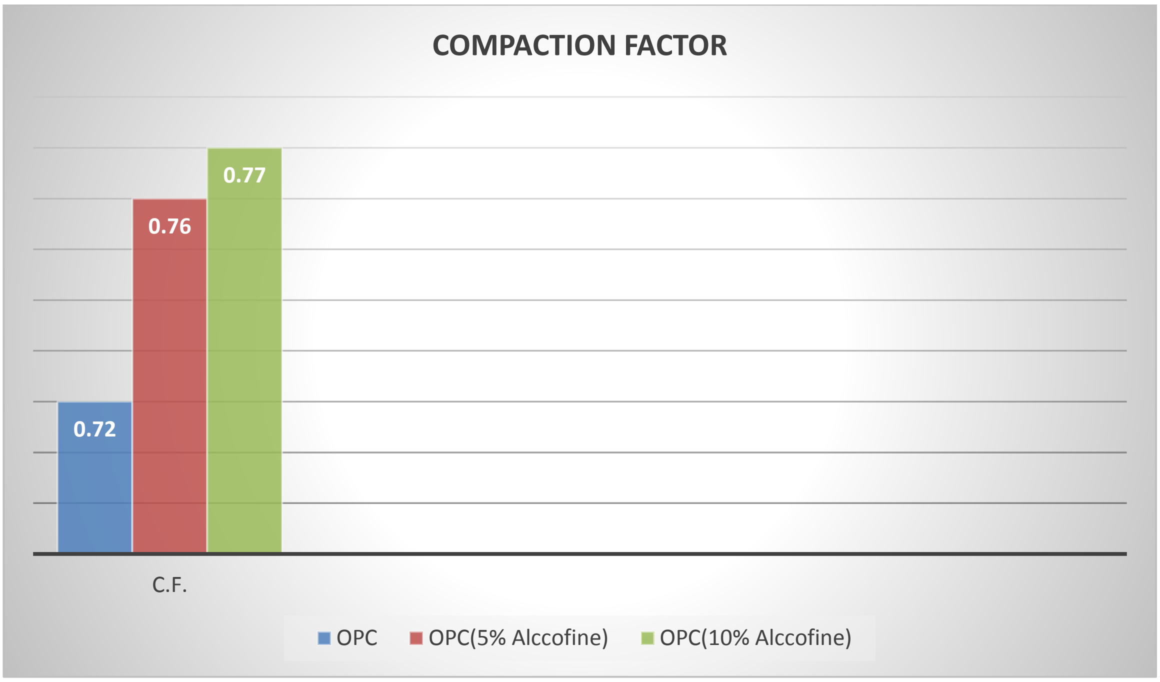

CHART – 2 Compation Factor

CHAPTER 6
CONCRETE MIX DESIGN

6.1 GENERAL

The process of selecting suitable ingredients of concrete and determining their relative amounts with the objective of producing a concrete of the required, strength, durability, and workability as economically as possible, is termed the concrete mix design. The proportioning of ingredient of concrete is governed by the required performance of concrete in 2 states, namely the plastic and the hardened states. If the plastic concrete is not workable, it cannot be properly placed and compacted. The property of workability, therefore, becomes of vital importance.

The compressive strength of hardened concrete which is generally considered to be an index of its other properties, depends upon many factors, e.g. quality and quantity of cement, water and aggregates; batching and mixing; placing, compaction and curing. The cost of concrete is made up of the cost of materials, plant and labor. The variations in the cost of materials arise from the fact that the cement is several times costly than the aggregate, thus the aim is to produce as lean a mix as possible. From technical point of view the rich mixes may lead to high shrinkage and cracking in the structural concrete, and to evolution of high heat of hydration in mass concrete which may cause cracking.

The actual cost of concrete is related to the cost of materials required for producing a minimum mean strength called characteristic strength that is specified by the designer of the structure. This depends on the quality control measures, but there is no doubt that the quality control adds to the cost of concrete. The extent of quality control is often an economic compromise, and depends on the size and type of job. The cost of labor depends on the workability of mix, e.g., a concrete mix of inadequate workability may result in a high cost of labor to obtain a degree of compaction with available equipment.

6.2 REQUIREMENTS OF CONCRETE MIX DESIGN

The requirements which form the basis of selection and proportioning of mix ingredients are:

a) The minimum compressive strength required from structural consideration

b) The adequate workability necessary for full compaction with the compacting equipment available.

c) Maximum water-cement ratio and/or maximum cement content to give adequate durability for the particular site conditions

d) Maximum cement content to avoid shrinkage cracking due to temperature cycle in mass concrete.

6.3 TYPES OF MIXES

1. **Nominal Mixes**

In the past the specifications for concrete prescribed the proportions of cement, fine and coarse aggregates. These mixes of fixed cement-aggregate ratio which ensures adequate strength are termed nominal mixes. These offer simplicity and under normal circumstances, have a margin of strength above that specified. However, due to the variability of mix ingredients the nominal concrete for a given workability varies widely in strength.

2. **Standard mixes**

The nominal mixes of fixed cement-aggregate ratio (by volume) vary widely in strength and may result in under- or over-rich mixes. For this reason, the minimum compressive strength has been included in many specifications. These mixes are termed standard mixes.

IS 456-2000 has designated the concrete mixes into a number of grades as M10, M15, M20, M25, M30, M35 and M40. In this designation the letter M refers to the mix and the number to the specified 28 day cube strength of mix in N/mm^2. The mixes of grades M10, M15, M20 and M25 correspond approximately to the mix proportions (1:3:6), (1:2:4), (1:1.5:3) and (1:1:2) respectively.

3. **Designed Mixes**

In these mixes the performance of the concrete is specified by the designer but the mix proportions are determined by the producer of concrete, except that the minimum cement content can be laid down. This is most rational approach to the selection of mix proportions with specific materials in mind possessing more or less unique characteristics. The approach results in the production of concrete with the appropriate properties most economically. However, the designed mix does not serve as a guide since this does not guarantee the correct mix proportions for the prescribed performance.

For the concrete with undemanding performance nominal or standard mixes (prescribed in the codes by quantities of dry ingredients per cubic meter and by slump) may be used only for very small jobs, when the 28-day strength of concrete does not exceed 30 N/mm^2. No control testing is necessary reliance being placed on the masses of the ingredients.

6.4 Factors affecting the choice of mix proportions

The various factors affecting the mix design are:

1. **Compressive strength**

It is one of the most important properties of concrete and influences many other describable properties of the hardened concrete. The mean compressive strength required at a specific age, usually 28 days, determines the nominal water-cement ratio of the mix. The other factor affecting the strength of concrete at a given age and cured at a prescribed temperature is the degree of compaction. According to Abraham’s law the strength of fully compacted concrete is inversely proportional to the water-cement ratio.

2. **Workability**

The degree of workability required depends on three factors. These are the size of the section to be concreted, the amount of reinforcement, and the method of compaction to be used. For the narrow and complicated section with numerous corners or inaccessible parts, the concrete must have a high workability so that full compaction can be achieved with a reasonable amount of effort. This also applies to the embedded steel sections. The desired workability depends on the compacting equipment available at the site.

3. Durability

The durability of concrete is its resistance to the aggressive environmental conditions. High strength concrete is generally more durable than low strength concrete. In the situations when the high strength is not necessary but the conditions of exposure are such that high durability is vital, the durability requirement will determine the water-cement ratio to be used.

4. Maximum nominal size of aggregate

In general, larger the maximum size of aggregate, smaller is the cement requirement for a particular water-cement ratio, because the workability of concrete increases with increase in maximum size of the aggregate. However, the compressive strength tends to increase with the decrease in size of aggregate.

IS 456:2000 and IS 1343:1980 recommend that the nominal size of the aggregate should be as large as possible.

5. Grading and type of aggregate

The grading of aggregate influences the mix proportions for a specified workability and water-cement ratio. Coarser the grading leaner will be mix which can be used. Very lean mix is not desirable since it does not contain enough finer material to make the concrete cohesive.

The type of aggregate influences strongly the aggregate-cement ratio for the desired workability and stipulated water cement ratio. An important feature of a satisfactory aggregate is the uniformity of the grading which can be achieved by mixing different size fractions.

6. Quality Control

The degree of control can be estimated statistically by the variations in test results. The variation in strength results from the variations in the properties of the mix ingredients and lack of control of accuracy in batching, mixing, placing, curing and testing. The lower the difference between the mean and minimum strengths of the mix lower will be the cement-content required. The factor controlling this difference is termed as quality control.

6.5 MIX PROPORTION DESIGINATIONS

The common method of expressing the proportions of ingredients of a concrete mix is in the terms of parts or ratios of cement, fine and coarse aggregates. For e.g., a concrete mix of proportions 1:2:4 means that cement, fine and coarse aggregate are in the ratio 1:2:4 or the mix contains one part of cement, two parts of fine aggregate and four parts of coarse aggregate. The proportions are either by volume or by mass. The water-cement ratio is usually expressed in mass

Factors to be considered for mix design

1. The grade designation giving the characteristic strength requirement of concrete.
2. The type of cement influences the rate of development of compressive strength of concrete.
3. Maximum nominal size of aggregates to be used in concrete may be as large as possible within the limits prescribed by IS 456:2000.
4. The cement content is to be limited from shrinkage, cracking and creep.
5. The workability of concrete for satisfactory placing and compaction is related to the size and shape of section, quantity and spacing of reinforcement and technique used for transportation, placing and compaction.

Procedure

1. Determine the mean target strength f_t from the specified characteristic compressive strength at 28-day f_{ck} and the level of quality control.

   $f_{t.} = f_{ck} + 1.65\ S$

   Where S is the standard deviation obtained from the Table of approximate contents given after the design mix.
2. Obtain the water cement ratio for the desired mean target using the emperical relationship between compressive strength and water cement ratio so chosen is checked against the limiting water cement ratio. The water cement ratio so chosen is checked against the limiting water cement ratio for the requirements of durability given in table and adopts the lower of the two values.
3. Estimate the amount of entrapped air for maximum nominal size of the aggregate from the table.

4. Select the water content, for the required workability and maximum size of aggregates (for aggregates in saturated surface dry condition) from table.
5. Determine the percentage of fine aggregate in total aggregate by absolute volume from table for the concrete using crushed coarse aggregate.
6. Adjust the values of water content and percentage of sand as provided in the table for any difference in workability, water cement ratio, grading of fine aggregate and for rounded aggregate the values are given in table.
7. Calculate the cement content form the water-cement ratio and the final water content as arrived after adjustment. Check the cement against the minimum cement content from the requirements of the durability, and greater of the two values is adopted.
8. From the quantities of water and cement per unit volume of concrete and the percentage of sand already determined in steps 6 and 7 above, calculate the content of coarse and fine aggregates per unit volume of concrete from the following relations:

$$V = \left[W + \frac{C}{S_c} + \frac{1}{p}\frac{f_a}{S_{fa}}\right] \times \frac{1}{1000}$$

$$V = \left[W + \frac{C}{S_c} + \frac{1}{1-p}\frac{C_a}{S_{ca}}\right] \times \frac{1}{1000}$$

Where V = absolute volume of concrete

= gross volume ($1m^3$) minus the volume of entrapped air

S_c = specific gravity of cement

W = Mass of water per cubic metre of concrete, kg

C = mass of cement per cubic metre of concrete, kg

p = ratio of fine aggregate to total aggregate by absolute volume

f_a, C_a = total masses of fine and coarse aggregates, per cubic metre of concrete, respectively, kg, and

S_{fa}, S_{ca} = specific gravities of saturated surface dry fine and coarse aggregates, respectively

9. Determine the concrete mix proportions for the first trial mix.
10. Prepare the concrete using the calculated proportions and cast three cubes of 150 mm size and test them wet after 28-days moist curing and check for the strength.
11. Prepare trial mixes with suitable adjustments till the final mix proportions are arrived at.

Concrete mix design is the process of choosing suitable ingredient of concrete and determining their relative quantities with the object of producing as economically as possible concrete of certain minimum properties, notable workability, strength and durability.

CHAPTER 7
MIX DESIGN FOR M 50 GRADE

7.1 PARAMETERS

Grade Designation = M50

Type of cement = O.P.C.43 grade

Fine Aggregate = Zone-II

Specific Gravity

Cement = 3.15

Fine Aggregate = 2.61

Coarse Aggregate (20mm) = 2.65

Coarse Aggregate (10mm) = 2.66

Minimum Cement = 400 kg / m^3

Maximum water cement ratio = 0.4

7.2 MIX CALCULATIONS

1. Target Mean Strength = 50 + (5 X 1.65) = 58.25 MPa.

2. Assume water cement ratio = 0.35

3. Approximate water content for 20mm max. Size of aggregate = 180 kg /m^3 (As per Table No. 5, IS: 10262).

4. Water Cement ratio = .35

Water content per cum of concrete = 144 kg

Cement content = 144/0.35 = 411.4 kg / m^3

Say cement content = 412 kg / m^3 (As per contract Minimum cement content 400 kg / m^3)

5. Calculation for C.A. & F.A.

Volume of concrete = 1 m^3

Volume of cement = 412 / (3.15 X 1000) = 0.1308 m^3

Volume of water = 144 / (1 X 1000) = 0.1440 m^3

Volume of Admixture = 4.994 / (1.145 X 1000) = 0.0043 m^3

Total weight of other materials except coarse aggregate = 0.1308 + 0.1440 +0.0043 = 0.2791 m^3

Volume of coarse and fine aggregate = 1 – 0.2791 = 0.7209 m^3

Volume of F.A. = 0.7209 X 0.33 = 0.2379 m^3 (Assuming 33% by volume of total aggregate)

Volume of C.A. = 0.7209 – 0.2379 = 0.4830 m^3

Therefore weight of F.A. = 0.2379 X 2.61 X 1000 = 620.919 kg/ m^3

Say weight of F.A. = 621 kg/ m^3

Therefore weight of C.A. = 0.4830 X 2.655 X 1000 = 1282.365 kg/ m^3

Say weight of C.A. = 1284 kg/ m^3

Considering 20 mm: 10mm = 0.55: 0.45

20mm = 706 kg.

10mm = 578 kg.

Hence Mix details per m^3

Increasing cement, water, admixture by 2.5% for this trial

Cement = 412 X 1.025 = 422 kg

Water = 144 X 1.025 = 147.6 kg

Fine aggregate = 621 kg

Coarse aggregate 20 mm = 706 kg

Coarse aggregate 10 mm = 578 kg

Admixture = 1.2 % by weight of cement = 5.064 kg.

Water: cement: F.A.: C.A. = 0.35: 1: 1.472: 3.043

7.3 ALCCOFINE MIX

1. For 5% alccofine mix replace 5% cement with alccofine by weight.

2. For 10% alccofine mix replace 10% cement with alccofine by weight.

3. For 15 % alccofine mix replace 15% cement with alccofine by weight.

7.4 COMPRESSIVE STRENGTH TEST

7.4.1 SAMPLING

i) Clean the mounds and apply oil

(ii) Fill the concrete in the molds in layers approximately 5cm thick

(iii) Compact each layer with not less than 35strokes per layer using a tamping rod (steel bar 16mm diameter and 60cm long, bullet pointed at lower end)

(iv) Level the top surface and smoothen it with a trowel

FIGURE – 5 Concrete Mould

7.4.2 CURING

The test specimens are stored in moist air for 24 hours and after this period the specimens are marked and removed from the molds and kept submerged in clear fresh water until taken out prior to test.

FIGURE – 6a Compression Test

7.4.3 PROCEDURE

(I) Remove the specimen from water after specified curing time and wipe out excess water from the surface.

(II) Take the dimension of the specimen to the nearest 0.2m

(III) Clean the bearing surface of the testing machine

(IV) Place the specimen in the machine in such a manner that the load shall be applied to the opposite sides of the cube cast.

(V) Align the specimen centrally on the base plate of the machine.

(VI) Rotate the movable portion gently by hand so that it touches the top surface of the specimen.

(VII) Apply the load gradually without shock and continuously at the rate of 140kg/cm2/minute till the specimen fails

(VIII) Record the maximum load and note any unusual features in the type of failure.

FIGURE- 6b Compression Test

FIGURE – 6c Compression Test

FIGURE – 6d Sample Testing

7.4.4 CALULATIONS

Size of the cube =10cm x10cm x10cm

Area of the specimen (calculated from the mean size of the specimen) =100 cm^2

Characteristic compressive strength (f ck) at 7 days = LOAD / AREA

CONCRETE	Compressive Strength (MPa) (7 days)
O.P.C.	(38+35+36)/3 = 36.33
O.P.C.(5% alccofine)	(39+35+40)/3 = 38.00
O.P.C.(10% alccofine)	(41+39+38)/3 = 39.33
O.P.C(15% alccofine)	(37+38+37)/3 = 37.33

TABLE – 1 Compressive Strength of Concrete in 7 days

CONCRETE	**Compressive Strength (MPa) (28 days)**
O.P.C.	(51+58+56)/3 = 55.00
O.P.C.(5% alccofine)	(55+60+57)/3 = 57.33
O.P.C.(10% alccofine)	(60+61+58)/3 = 59.67
O.P.C.(15% alccofine)	(57+59+59)/3 = 58.33

TABLE – 2 Compressive Strength of Concrete in 28 days

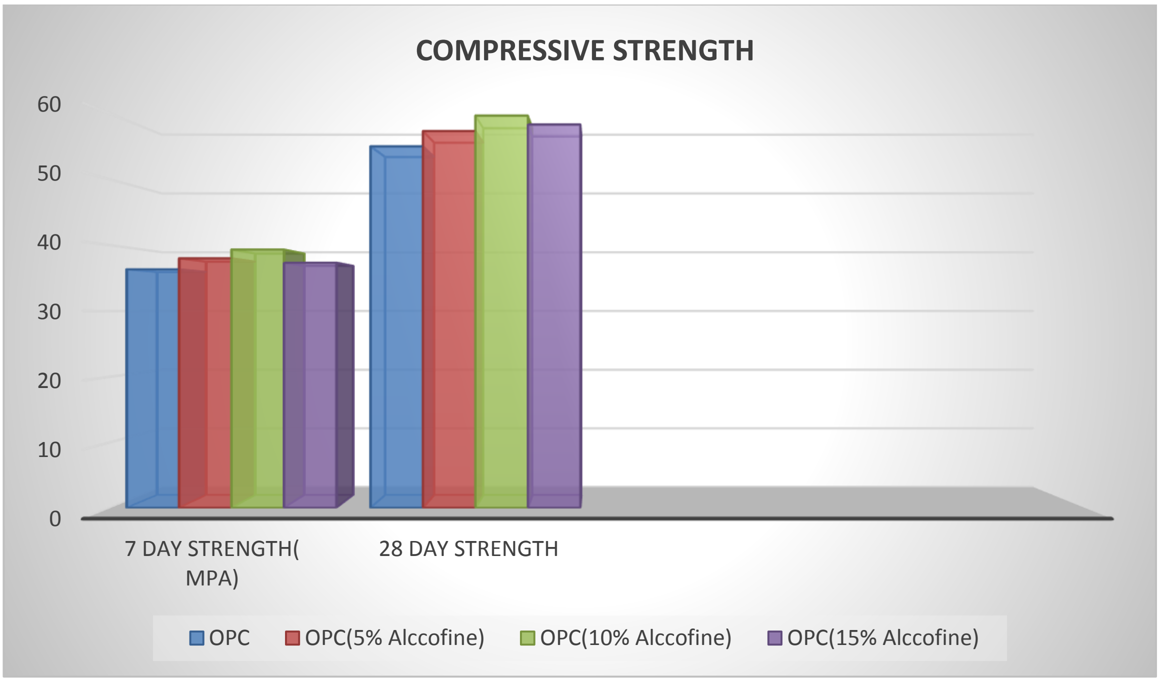

CHART – 3 Compressive Strength

FIGURE – 7 Sample after testing

CONCLUSION

Concrete is a composite construction material made primarily with aggregates, cement and water. There are many formulations of concrete, which provide varied properties and concrete is the most used man-made product in the world.

Alccofine is an ultra-fine slag which is used as an additive to increase the strength of concrete. Concrete with 10 % Alccofine shows high strength from the various test we conducted with adequate workability.

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