# TO STUDY MECHANICAL AND DURABILITY PROPERTIES OF HIGH STRENGTH CONCRETE BY REPLACING CEMENT WITH RICE HUSK ASH

**A**

**PROJECT**

***Submitted in partial fulfilment of the requirements for the award of the degree of***

**BACHELOR OF TECHNOLOGY**

**IN**

**CIVIL ENGINEERING**

Under the supervision of

**Dr. Ashok Kumar Gupta**
**&**
**Mr. Saurav**

***By***

**Mohit Thakur**

**(131653)**

**Kshitij Tandon**

**(131681)**

**JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY**

**WAKNAGHAT, SOLAN – 173234**

**HIMACHAL PRADESH, INDIA**

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# CERTIFICATE

This is to certify that the work which is being presented in the project report titled **"TO STUDY MECHANICAL AND DURABILITY PROPERTIES OF HIGH STRENGTH CONCRETE BY REPLACING CEMENT WITH RICE HUSK ASH"** in partial fulfillment of the requirements for the award of the degree of Bachelor of Technology in Civil Engineering and submitted to the Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat is an authentic record of work carried out by MOHIT THAKUR (Enrolment no. 131653) and KSHITIJ TANDON (Enrolment no. 131681) during a period from July 2016 to May 2017 under the supervision of **Dr. Ashok Kumar Gupta** (Professor and Head) and **Mr. Saurav (**Assistant Professor), Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

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

Date: - ………………………

| | | |
|---|---|---|
| **Dr. Ashok Kumar Gupta** | **Mr. Saurav** | External Examiner |
| Professor & Head of Department | Assistant Professor | |
| Civil Engineering Department | Civil Engineering Department | |
| JUIT Waknaghat | JUIT Waknaghat | |

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# ABSTRACT

Cement is generally considered the most expensive ingredient of the concrete and its demand is also increasing day by day. This demand for cement and concrete can be met by the partial cement replacement. Energy and cost savings can result when industrial and agricultural by-products such as fly ash, silica fumes, pond ash, and marble dust powder are used as a partial replacement. Among these various products, use of rice husk ash in the production of concrete is very important for India. India is one of the largest rice producers in the world. India produces about 122 million ton of paddy every year. It has been estimated that each ton can lead to 40 kg of rice husk ash. Rice husk when burnt in a controlled manner does not cause pollution. When properly burnt it produces high $SiO_2$ content and thus it has excellent pozzolanic properties. Various researches have shown that rice husk ash can increase the strength and impermeability of the concrete. Our work which is presented in this report mainly deals with evaluating one type of commercially available RHA and to determine the properties such as workability, mechanical properties (compressive strength, split tensile strength and flexural strength) and durability properties (Acid attack and Chloride attack).

In this study, many tests were performed to determine the various properties of concrete which are namely workability, mechanical properties and durability of concrete. To determine the workability we have performed the compaction factor test. Mechanical properties such as compressive strength, split tensile strength and flexural strength were determined by compressive strength test, split tensile strength test and flexural strength tests in accordance with Indian standards. Durability tests like acid attack test and chloride attack tests were also performed on the concrete. All these tests were performed for various percentages of rice husk ash in the concrete. As Fly ash based Portland Pozzolana Cement was used the variation of rice husk ash had to be limited because in Portland Pozzolana cement, the cement is already replaced with fly ash. We varied percentage of rice husk ash with an increment of 2.5% from 0% up to 10%. We have also compared results of all these tests with variation in replacement percentages (0%, 2.5%, 5%, 7.5%, and 10%) of rice husk ash in cement in form of graphs, bar charts and tables in this report.

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# CHAPTER 1

# INTRODUCTION

## 1.1 GENERAL:

Concrete is the most widely used material in the world for construction. Concrete has been in use for centuries and its main constituent is cement.Cement is the binding material in concrete. But also it is the most expensive ingredient of concrete. Its production is based on the availability of raw materials which are either calcareous materials such as lime stone or chalk or argillaceous materials such as shale and clay. These materials are limited on our planet earth and getting depleted day by day. Another problem with the concrete is its high energy requirements and $CO_2$ emissions in making of Portland concrete.

The use of pozzolanic materials in concrete has been increasing day by day. These materials not only reduce the amount of the cement in the concrete but also have been known to enhance the properties such as durability, strength and impermeability of the concrete. Incorporation of these materials reduces the problem of waste disposal as most of them are byproducts of industrial and agricultural wastes. Different types of pozzolanic materials are in use today such as fly ash, granulated blast furnace slag, marble powder. In our Indian scenario use of rice husk ash is of great importance as in India 122 million of rice husk is produced every year.

Compressive strength of concrete is one of the most important characteristic of concrete as it is well known that the concrete is strong in compression and very weak in tension. Silica ($SiO_2$) from pozzolanic material in presence of water reacts with Calcium Hydroxide (Hydration product of concrete) and gives CSH (Calcium Silicate Hydrate) which is the main product responsible for the strength of the concrete matrix. Hence, the strength of concrete increases.

## 1.2 CONCRETE:

In a wider scope the concrete can be defined as the any product or mass that can be utilised for a cementing medium. The cementing medium is the product of the reaction between cement and water. Today, such a definition cover a wide range of products i.e. several types of cement, different pozzolans, recycled aggregates, additives, polymers, fibers etc. Concrete more precisely can be defined as the mixuture of the cement (Portland or any other type), fine aggregate, coarse aggregates and the water. It is a construction material which is in use from the time of the Roman Empire and it is still in use today.

The concrete constitutes of hydrated cement, coarse and fine aggregates and water. These various components when come together make concrete. These components with their normal percentages have been listed in the table 1.1 of this report. The components are air, fine aggregates, coarse aggregates, hydrated cement (cement and water). The concrete is classified into various grades on the basis of its compressive strength such as M60, M30, M20 etc. where M designates designed concrete mix and 60, 30, 20 are the compressive strengths of the concrete in MPa ($N/mm^2$)

**Table 1.1: Components of concrete**

| Component of the concrete | Normal Percentage |
|---|---|
| Air | 0-3% |
| Aggregates (Fine and coarse) | 60-70% |
| Fine aggregates | 40-50% |
| Coarse aggregates | 20-30% |
| Hydrated cement(Cement and Water) | 20-40% |
| Cement | 5-15% |
| Water | 5-20% |

## 1.3 CEMENT HYDRATION:

Cement as we know is the main strength giver, main ingredient and binder of the concrete. So, it is very much important to know about the cement composition. Before explaining hydration, the composition of the cement is described below:

The cement comprises of various oxides such as Calcium oxide (CaO 60 to 64%), Silica dioxide ($SiO_{2,\ 19}$ to 23%), Aluminum oxide ($Al_2O_{3,}$ 3 to 10%), Iron oxide ($Fe_2O_{3,}$ 0.5 - 6.0%) Magnesium oxide (MgO, 0.5 to 5.0%) , Sodium Oxide and Potassium oxide ($Na_2O+K_2O$ , 0.4 - 1.2%) and gypsum(1.5 to 3.5%). Out of these oxides the most important ones are calcium oxide, Silica dioxide which are the main strength contributors. Alumina oxide acts as an accelerator and contributes to the strength a little. Gypsum is added in the cement at last to presvent flash set of concrete it acts as an retarder. These oxides combine when they undergo clinkerisation and thus making bouge compounds which are the phase composition of the cement. These compounds are:

- Tri-calcium silicate – $C_3S$ (≈ 30 – 48%),
- Di-calcium silicate – $C_2S$ (≈ 27 -45%),
- Tri-calcium aluminate – $C_3A$ (≈ 4 – 10%),
- Tetra-calcium alumino ferrite – $C_4AF$ (≈ 5 – 15%).

Each of these phases have different contribution to setting, strength development and heat evolution.

Cement hydration is the main phenomenon behind the strength development of the concrete. Hydration of the cement is an exothermic reaction occurring between water and cement which is attributed with a high rate of reaction and a high rate of evolution of the heat. The hydration process has been explained below in respect of the four phases as given in the paragraph above:

**Tri-calcium silicate – $C_3S$:**

Hydration reaction for tricalcium silicate ($C_3S$) is given below:

$$\mathbf{2C_3S + 6H \text{ -------------> } C\text{-}S\text{-}H + 3\ Ca(OH)_2}$$

The tricalcium silicate reacts with water to form calcium silicate hydrate and calcium hydroxide.

Calcium Silicate Hydrate (C-S-H) consists of 50-60% of solids in paste. This compound forms continuous binding matrix as shown in figure 1.1.The calcium silicate hydrate is amorphous and fibrous in nature which has a large surface area. The C-S-H matrix grows over the period of time as the hydration reaction progresses and fills pore spaces inside the concrete matrix. Thus, C-S-H is the main compound which provides strength to the concrete.

Calcium Hydroxide (C-H) is the other reaction product that is formed. C-H constitutes about 20% of solids in paste. The compound calcium hydroxide exists in form of thick hexagonal plates embedded in C-S-H matrix as shown in figure 1.1 and does not contribute to strength. This calcium hydroxide takes part in the sulphate attack and other chemical attacks and thus can cause deterioration of the concrete over time. Efflorescence is mainly due to the involvement of calcium hydroxide .This calcium hydroxide is thus a unwanted product and when a pozzolan is used this product is eliminated and also excess C-S-H is formed.

The reaction rate is fast resulting in high heat of hydration. The $C_3S$ is responsible for the early development of the strength in concrete.

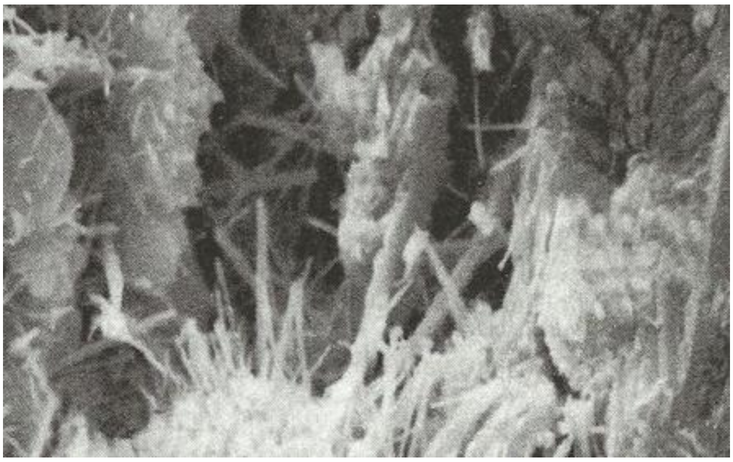

**Fig 1.1: Calcium Silicate Hydrate and Calcium Hydroxide crystals.**

**Di-calcium silicate – $C_2S$:**

Hydration reaction for Dicalcium silicate($C_2S$) is given below:

$$\mathbf{2C_2S + 4H \text{ ---------------> } C\text{-}S\text{-}H + Ca(OH)_2}$$

The hydration process is similar to that of tricalcium silicate. The same products are formed which are Calcium Silicate Hydrate and Calcium Hydroxide which are shown in figure 1.2. The main difference between the hydration of calcium dioxide and calcium trioxide is that the calcium dioxide ($C_2S$) reacts slowly and generates less heat and contributes to the strength.

**Tri-calcium aluminate – $C_3A$:**

Hydration reaction for Tricalcium aluminate($C_3A$) is given below:

$$C_3A + 6H \text{ ------------> } C_3AH_6$$

If the tricalcium aluminate reacts directly with water then it forms calcium aluminate hydrate which can cause flash setting of the mix that's why gypsum is added during the manufacturing of the cement so the actual reactions which occur keeping in the mind the role of gypsum are:

$$C_3A + 3\ CaSO_4 + \text{Water} \rightarrow \text{ettringite}$$

Tricalcium aluminate in presence of water reacts with gypsum to form a chemical product known as hydrous calcium aluminate sulphate which is called ettringite commonly.

$$C_3A + \text{ettringite} + \text{Water} \rightarrow \text{Monosulphoaluminate}$$

Tricalcium aluminate in presence of water reacts with gypsum to form a chemical product known as hydrous Monosulphoaluminate.

The hydration of tricalcium aluminate is characterized by high heat and fast rate of reaction. The hydration rate of $C_3A$ is further explained below in the following paragraphs in detail:

The presence of ettringite depends on the ratio of calcium sulphate to tri-calcium aluminate ($C_3A$).When this ratio is low, ettringite forms during early hydration and then converts to the calcium aluminate monosulphate.When the ratio is intermediate, only a portion of the ettringite changes to aluminate monosulphate and thus these two can coexist together, while ettringite is unlikely to change into aluminate monosulphate at high ratios. If the amount of Gypsum is very small in amount, Tricalcium aluminate reacts fast and can cause 'Flash Set'. Too much gypsum will delay the setting and cause undue expansion.

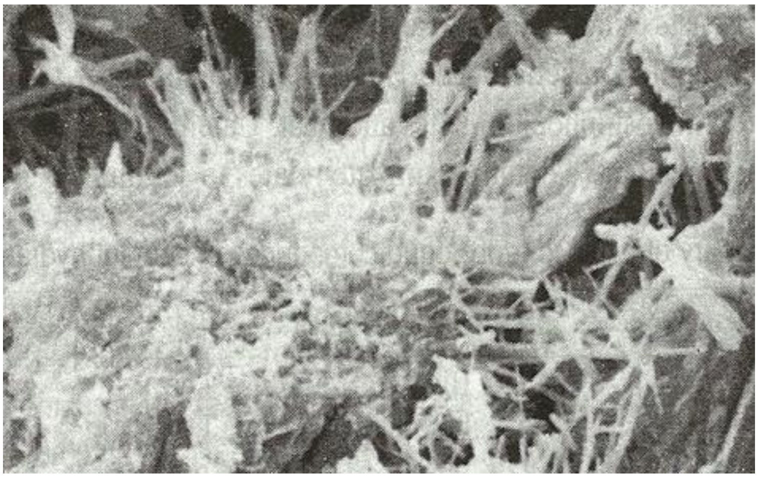

**Fig 1.2: Ettringite Crystals**

The aluminate monosulpahate has a plate like structure which is irregular in shape as shown in figure 1.3 whereas ettringite has a very crystalline and needle like structure as shown in the figure 1.2 which constitutes about 10-20% of solid content.The ettringitre has prismatic long and slender crystals which are stable only gypsum is still there and has not depleted in the solution. This substance has diminished role in the strength development but it affects durability. If formed in early stages its good for concrete matrix as it is filling up the pores inside the concrete matrix but if delayed Ettengrite formation takes place due to the sulphate attack this compound would make concrete less durable as it is expansive in nature.

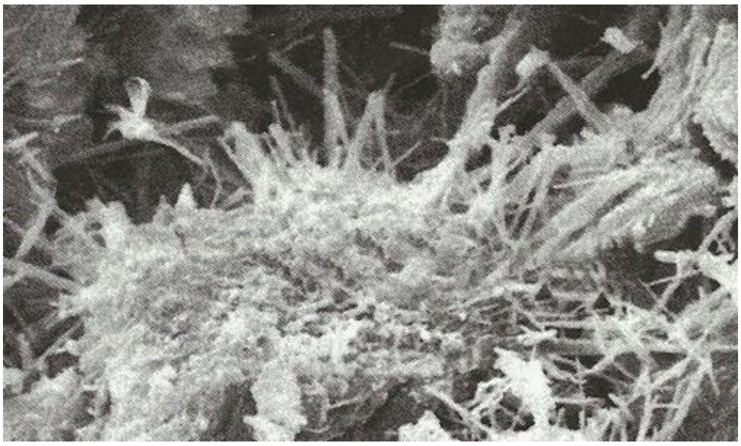

**Fig 1.3: Aluminatemonosulphate crystals**

**Tetra-calcium alumino ferrite-$C_4AF$** :

Hydration of Tetra-calcium alumino ferrite ($C_4AF$) similar to Tricalcium aluminate ($C_3A$) and same products are formed that are ettingreite and aluminatemonosulphate. The only difference in the hydration of Tetra-calcium alumino ferrite and Reacts slowly and generates less heat and the combination of Tetra-calcium alumino ferrite ($C_4AF$) with gypsum is better than the Tricalcium Aluminate.

## 1.4 POZZOLANS:

Pozzolans are siliceous or aluminous materials, which possess by themselves little or no cementitious properties, but in finely divided form react with calcium hydroxide in the presence of moisture at ordinary temperatures to form compounds possessing cementitious properties.

***Pozzolonic Reaction***:

The pozzolonic reaction is given below:

$$CH + \text{Reactive } SiO_2 + H_2O \rightarrow C\text{-}S\text{-}H$$

The calcium hydroxide which is a cement hydration product in presence of water reacts with amorphous silica to give calcium silicate hydrate which is the main hydration product of cement. This product is the main binding agent of the concrete matrix and results in the overall strength of the concrete. It is not only present in the concrete as a hydration product but its quantity is also enhanced by the use of highly reactive pozzolonic material such as rice husk ash as used in this project.

$$CH + \text{Reactive } Al_2O_3 + H_2O \rightarrow C\text{-}A\text{-}H$$

The calcium hydroxide from the cement can undergo a similar reaction with reactive aluminium oxide leading to the formation of calcium aluminate hydrate. This calcium aluminate hydrate can react with sulphate to form ettringite which may cause expansion but the quantity of reactive $Al_2O_3$ is very less as compared to reactive silica.

The Pozzolonic reaction which occurs due to the addition of pozzolans has following advantages which are listed below:

1. The reaction is lime consuming which is the main contributor to the deterioration of the concrete. Thus, the durability of the concrete increases.
2. The puzzolonic reaction leads to the pore refinement of both the concrete matrix leading to the durable concrete.
3. Interfacial transition zone is also refined which is the weakest link in the concrete matrix this implies a substantial increase in the strength and durability.
4. Due to the addition of puzzolons the heat of hydration evolved in the hydration process due to the slow rate of reaction.

## 1.5 CLASSIFICATION OF MINERAL ADMIXTURES:

Different admixtures can produce different performances broadly speaking some are pozzolanic (e.g., low-calcium fly ash), some are cementitious (e.g., granulated iron blast-furnace slag), whereas others are both cementitious and pozzolanic (e.g., high-calcium fly ash).

Mehta classifies mineral admixtures into four categories:

*Cementitious and Pozzolanic* containing mostly Silicate glass and mainly calcium, magnesium ,aluminium and alkalies (e.g., High-calcium fly ash)

*Highly active Pozzolans* having essentially pure Silica in non-crystalline form (e.g., condensed silica fume and rice husk ash)

*Normal Pozzolans* containing mostly silicate glass and mainly aluminium, iron , alkalies and quartz, feldspar etc. (e.g., Low-calcium fly ash and natural pozzolans)

*Weak Pozzolans* constituting crystalline Silica and negligible amount of non- crystalline Silica (e.g., Slowly cooled blast furnace slag boiler slag, field burnt rice husk ash)

The mineral admixtures can also be broadly divided into two groups namely natural pozzolans and by products. These are described in the paragraphs given below:

*Natural materials* are those materials which are processed for the sole purpose of producing a pozzolan. Various processes are involved which includes crushing, grinding, size separation and thermal activation.(e.g., Volcanic glass, volcanic tuff , diatomaceous earth etc.)

*By-product materials* are those materials that are not the primary products of the industry producing them. Industrial by-products may or may not require any processing (e.g., drying and pulverization) before use as mineral admixtures.(e.g., Rice husk ash, fly ash , tile powder etc.)

## 1.6 RICE HUSK ASH:

Rice husk are the shells which are removed from the paddy during dehusking of paddy. Rice husk is useless from domestic and agricultural point of view. It cannot be even used for feeding animals as its nutritional value is negligible. When burnt an ash is produced which is known as rice husk ash which has been found pozzolanic in nature by researchers. One tonne of paddy can produce up to 200 kg of husk, which when burnt gives about 40 Kg of ash. Rice husk and rice husk ash are shown in the figure 1.4.

The temperature and duration for which the husk is burnt is of very important. When temperature is kept in range of 500 to 600$^{o}$C for duration of about 2 hours, Rice husk ash with low un-burnt carbon and amorphous silica is produced. If burnt without any temperature control, crystalline silica is produced which is less reactive.

A crystalline solid is one in which there is a there is long-range order or in other words, regular repeating pattern in the structure for example diamond, table salt. An amorphous solid is one which does not have long-range order. In other words, there is no repeat unit for example glass, wax and plastics. So due to the lack of long ranged order of the amorphous silica the reactivity of that silica will be considerably higher than the crystalline silica. Rice husk ash produced generally has silica above 85%, a small particle size less than 45 microns and has high specific surface area 40-100m$^2$/g. Its constituents are given in table 1.2:

**Table 1.2: Constituents of Rice Husk Ash**

| Constituent | Percentage |
|---|---|
| $SiO_2$ | 87.20 |
| $Al_2O_3$ | 0.15 |
| $Fe_2O_3$ | 0.16 |
| $CaO$ | 0.55 |
| $MgO$ | 0.35 |
| $SO_3$ | 0.24 |
| C | 5.91 |

The values in the above table 1.2 are taken from CK Singh et al for an amorphous rice husk ash show that the Silica content is very high in the rice husk ash and it can act as a very good pozzolan.

**Fig 1.4 Rice Husk and Rice Husk Ash**

## 1.7 SUPERPLASTICIZER:

Superplasticizers are chemical admixtures which produce plasticizing effect in wet concrete. They improve workability at a given water-cement ratio and at same level of workability, water content can be reduced up 30 % to 40 % also known as High range water reducers.

For high performance concrete superplasticizer dosage in the range of 0.5% to 3.0% by weight of cement.

Examples of superplasticizer that are mainly used in the construction industry are given below :

- Sulphonated Melamine Formaldehyde Condensate (SMF)
- Sulphonated Napthalene Formaldehyde Condensate (SNF)
- Modified Lignosulphates

We have used Sulphonated Napthalene Formaldehyde Condensate (SNF) in this work.

Superplasticizers mainly works by two mechanisms which are illustrated in figure 1.5 and are described below:

***Electrostatic repulsion* (due to Zeta Potential):**

To understand electrostatic repulsion first of all we need to define zeta potential. It is defined as the difference of voltage between the medium where particles are scattered and the stationary layer of air or water attached to the particle which is getting scattered. The zeta potential can also be defined as the the total charge a particle obtains in a specific medium. If all the particles obtain a large similar zeta potential that is negative or positive they will repel each other as similar charges repel each other which would cause  dispersion stability. If the particles have low zeta potential values then there is no force to prevent the particles coming together and there is dispersion instability. A dividing line between stable and unstable aqueous dispersions is generally taken at either +30 or -30mV.

The negative charges imparted by the Water reducers impart negative charges to the cement grains and they repel each other (as like charges repel each other) known as Electrostatic repulsion. Lignosulphonates (normal and sugar-refined), SMF, and SNF based superplasticizers work on the mechanism of zeta potential that leads to electrostatic repulsion. Electrostatic repulsion depends on the composition of the solution phase and the adsorbed amount of the SP (greater the adsorption, better the repulsion.)

***Steric repulsion***:

Polymers with backbone and graft chains, such as Poly Carboxylic Ether (PCE) based, acrylic esters, and cross-linked acrylic polymers, cause dispersion of cement grains by steric hindrance. The presence of the bulky polymer side chains prevents the particles physically from agglomeration. Thus, the slump can be retained for longer time.Steric repulsion depends on the length of main chain, length and number of side chains.PCE based admixtures is effective in low w/c ratio, with SNF steric hindrance is secondary.

Steric hindrance is a more effective mechanism than electrostatic repulsion. The side chains, primarily of extending on the surface of cement particles, migrate in water and the cement particles are dispersed by the steric hindrance of the side chains.

Apart from Electrostatic repulsion and Steric hindrance, Super plasticizer action is based on dispersion of cement particles by reduction in surface tension of surrounding mixing water and a decrease in frictional resistance because of the line-up of linear polymers along the concrete flow direction and lubrication properties produced by low molecular weight polymers.

**Uses of Super plasticizers**:

1. The workability of the concrete mix can be easily enhanced by use of a super plasticizer without changing anything in the mix proportions and composition.
2. The water cement ratio is decreased by the use of a super plasticizer as the super plasticizer reduces the mixing water requirement resulting in increased strength of concrete.
3. As they can reduce the amount of mixing water so thus they increase the impermeability of the concrete and thus making the concrete more durable.
4. They can also be applied to reduce both water and cement in order to cut cost and which indirectly reduces creep, shrinkage, and heat of hydration.

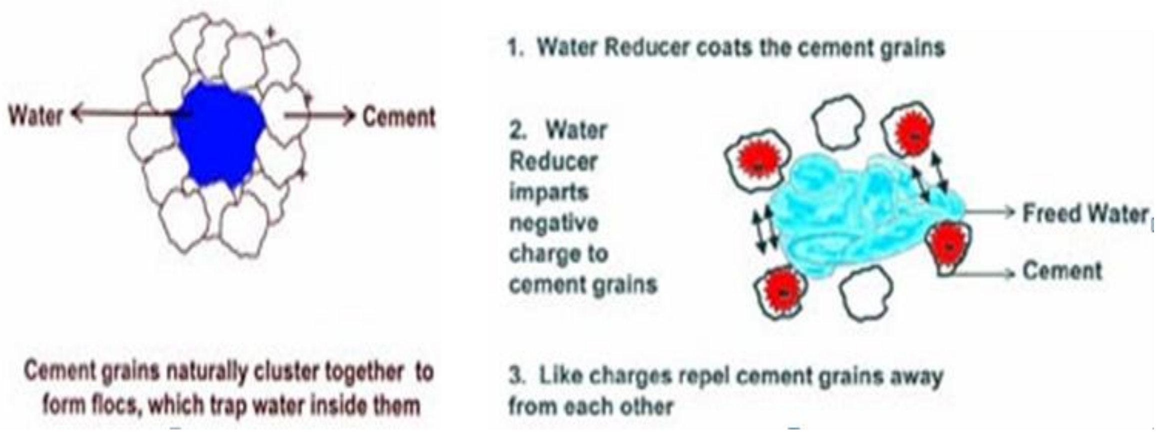


**Fig 1.5: Mechanism of super plasticizers.**

# CHAPTER 2
# LITERATURE REVIEW

Many research papers were studied during this whole project for carrying out our own studies on one type of commercially available rice husk ash. Various journals studied and their findings have been given below:

**Ghassan Abood Habeeb et al [5]** first investigated the effect of grinding on the particle size and the surface area and then they performed XRD analysis and found out the presence of amorphous silica in the rice husk ash. Also, the effect of RHA average particle size and percentage on concrete workability, fresh density, superplasticizer (SP) content and the compressive strength was seen.
Although grinding RHA would reduce its average particle size (APS), it was not the main factor controlling the surface area and it is thus resulted from RHA's multilayered, angular and microporous surface. Incorporation of RHA in concrete increased water demand. It was found out that the concrete which had Rice husk ash in it improved the concrete in strength at 10% replacement (30.8% increase in the strength), and results also show that 20% of cement can be effectively replaced with RHA without affecting the strength. They also found that finer the RHA better the strength.

**P.chandan Kumar et al [16]** performed experimental work with Rice Husk Ash as a replacement to Portland Pozzoloana cement in concrete, and measured the strength parameters of concrete by conducting Compressive strength and flexural strength test at 3, 7, 28 and 56 days. All these tests were conducted according to the Indian standards. It was concluded that the concrete in which 7.5% replacement with RHA was made came to be optimum in both the compressive and flexural strength at 28 days.

**Abhilash Shukla et al [27]** carried out this investigation to determine the optimum percentage of RHA (0, 5, 10, 15 & 20%) as a partial replacement of OPC cement for M30 and M60 grade of concrete with super plasticizer. Significant amount of improvement in Compressive strength and flexural strength of the Concrete with rice husk ash content of 10% for different grades namely M30 and M60 and at different ages i.e. 7 days and 28 days was seen.There was also significant improvement in Flexural strength of the Concrete with rice husk ash content of 10% for different grades namely M30 and M60 and at the age of 28 days. Split tensile strength reduced for 28 days at every percentage. With increase in the percentage of rice husk ash, the split tensile strength decreased.

**K. Kartini [11]** reported that increase in the amount of RHA in the mix resulted in a dry and unworkable mix without super plasticizer. Use of super plasticizer while maintaining the water to binder ratio increased the slump and improved the workability. At 28 days it was found out that the optimum replacement of OPC with RHA with different grades namely Grade 30 and Grade 40 was 30%, while for Grade 50 was 20%. Reduction in the water permeability of the concrete was found out with replacement of OPC with RHA. This suggested that the use of RHA in the mix and with concrete of higher grade, the coefficient of permeability reduces, thus durability of concrete is improved. The water absorption values of RHA concrete are lower than the OPC control concrete. The results in this journal clearly show that using RHA as an admixture can increase the durability properties of concrete in any concrete grade. The average percentage of water absorption was found out to be 3% to 5% for all the grades (30, 40 and 50). The resistance to chloride ion penetration of concrete was observed by the incorporation of RHA which clearly indicated that the durability and permeability are being improved.

**Giri Prasad et al [23]** showed that the Rice husk ash Self Compacting Concrete satisfied all the criteria of the Self compacting concrete. Incorporation of Rice Husk Ash (RHA) had shown significant reduction in flow ability of SCC (self compacting concrete).An improvement in the strengths in SCC mix was observed. Stress–strain behaviour has been observed and an empirical equation is made to predict the behaviour of such concrete under compression.

**Deepa G Nair et al [21]** reported improvement in compressive and flexural strength of concrete by use of RHA in concrete. It was observed that for a particular water to binder ratio (0.4) the compressive strength of concrete at 7 day and 28 day was maximum when the replacement of OPC with RHA is kept at 25percent. RHA- High strength concrete showed a reduction in density compared with conventional concrete. Slump cone test was carried out on all the mixes. It was found out that that the dosage of super plasticizer increased with the increase of RHA content. This was attributed to the porosity of the RHA sample.

**Rishabh Kashyap et al [2]** carried out the investigation of partial replacement of OPC cement by the incorporation of RHA by 5%, 10% & 15% & 20% by weight of cement in concrete to find out the maximum compressive strength and compare it with the strength of normal concrete by using the grade of M30 at the days of 7days,14days &28 days. The optimum strength was found out at the level of 10 % of OPC replaced by RHA.

**Sonali K. Gadpalliwar et al [3]** reported that Partial replacement of natural sand with Quarry sand and partial replacement of cement with GGBS and RHA can be an economic alternative. The ordinary Portland cement was replaced with RHA and GGBS to find out the optimum percentage of both. The composition of 22.5% GGBS + 7.5% RHA with 60% of quarry sand gives the best strength results.Acid attack tests and chlorine attack tests were carried out to determine the durability characteristics of the mixes. The concrete with RHA performed better.

**K. G. Vinothan et al [1]** reported that the concrete in which RHA requires higher dosages of super plasticizer than the control Portland cement.The water requirement is greater than for OPC but Addition of RHA speeds up setting time.The increase in compressive strength for 5% and 10% of cement replacement by RHA was found out to be 4.1% and 5% at 28 days respectively for M30 grade concrete. The optimum replacement of cement by RHA is 10%. The performance of concrete in term of strength, modulus of elasticity, permeability, acid resistance and sulfate attack has been improved with RHA as an pozzolanic material.

**Satish Sathawane et al [12]** studied combine effect of rice husk ash and fly ash for M30 with 30% replacement of cement in concrete. Combine proportion started with 0% rice husk ash and 30% fly ash and with increment of 5% in RHA and decrement in fly ash by 5% in each step. Compressive strength test, flexural strength tests and split tensile strength were conducted at 28 days. Flexural strength increased by 4.57%, split tensile strength decreased by 9.58% as compared with control concrete at 28 days, at a percentage of 22.5% fly ash and 7.5% rice husk ash which came to be the optimum combined percentage.

**Harshit Varshey [28]** prepared M20 concrete with ordinary Portland cement and partially replaced OPC with an increasing percentage step of 5% from 0% to 20% for M20. Six (three at 7 days and three at 28 days ) cubes were casted for each percentage of rice husk ash that is 0%, 5%, 10%, 15% and 20% for compressive strength test and also six (three at 7 days and three at 28 days ) cylinders were casted for split tensile strength test. These two tests were conducted at 7 days and 28 days and results were noted down. These results were compared with the normal concrete and it was found out that the compressive strength increased and split tensile strength decreased both at 7 and 28 days.

**M.V. Tatikonda et al [13]** partially replaced OPC with RHA and made High strength concrete M60, M80 and M100. Compressive and flexural strength tests were done on the three grades. Conclusions include that rice husk ash can be used as an admixture for concrete with use of super plasticizer for high strengths, the compressive strength, flexural strength increased with the incorporation of rice husk ash in reference to 0% concrete mix. It was found out that compressive strength of cylindrical specimen came 0.92 times the cube compressive strength. The strength gain is slow in 10% and 15% RHA replacements than 0% replacement and 5% RHA replacements for M60, M80 and M100.

**Piyush Raikwar et al [24]** mixed rice husk ash with percentages in between of 10% to 30%, with constant 5% of marble powder and then tests for compressive strength, flexural strength, durability and water absorption were studied. The optimum value of replacement in concrete was found out to be 21%.With 21% of cement as replacement by 16% Rice husk ash and 5% Marble Powder, compressive strength and flexural strength of rice husk ash and marble powder concrete is more than the normal concrete. Water absorption of replaced concrete decreased for 16% RHA and 5% MP and there after increased. Durability increased with the replacement.

**Sourav Ghosal et al [19]** concluded that rice husk ash is one of the most active research areas that include many disciplines of civil engineering. Rice husk ash which is an agricultural waste product is produced in large quantities globally every year and is difficult to dispose so the rice husk ash is posing as an environmental hazard in rice producing countries. India alone produces around 120 million tons of paddies per year, giving around 24 million tons rice husk per year and 6 million tons of rice husk ash per year.

As rice husk piles up day by day, there is a pressure on rice industries for its disposal. It is very important to develop eco-friendly concrete from rice husk ash. Rice husk ash can be certainly used in concrete to improve its strength and other durability factors. From the review of literatures of the various researchers, it was found out that rice husk ash can be used in lightweight structural concrete preparation. Sustainable utilization would preserve conventional materials for future. For green construction, rice husk ash is one of the most suitable choices, as it does not produce pollution and also speed of construction is accelerated by its incorporation.

**Padma -Rao et al [17]** replaced Portland Pozzolona Cement which is fly ash based by Rice husk ash. They made replacements to cement (Portland Pozzolona Cement based on fly ash ) with percentages 5, 7.5, 10, 12.5 & 15 and carried out many tests such as compressive strength test and flexural strength test and compared the results achieved in these tests with the results of the control mix which means the normal concrete with no rice husk ash. Compressive strength test and flexural strength test were conducted at 3, 7, 28 and 56 days. The compressive strength and the flexural strengths of rice husk ash concrete were increased up to much extent at 28 and 56 days Significant increase was found in compressive strength from 7 days to 28. The optimum percentage of rice husk ash was found at 10 %.

**Makarand Kulkarni et al [15]** replaced cement (Ordinary Portland Cement) with Rice Husk Ash and did various tests of workability and strengths such as Compaction Factor test, compressive strength test, tensile strength of concrete, flexural strength of the concrete. They came to know that the workability of the concrete mix was decreasing as the content of RHA (Rice Husk Ash) was increasing and it was also came into their knowledge that as the content of rice husk ash increasing the strengths (compressive at 14 days and 28 days, flexural at 14 days and 28 days of the concrete) first increased up to some extent and there after decreased giving an optimum at 20% replacement of rice husk ash.

**Sunil Tushir et al [29]** made M30 and M60 grade RHA concrete with rice husk ash percentages as 0%, 5%, 10%, 15% and 20%. The mix design was prepared according to Indian Standards. They performed split tensile strength test and compressive strength test for these various percentages of rice husk ash in concrete. They also performed flexural strength test. It was found out in their study that flexural and compressive strengths at 28 days were increased both for M30 and M60 grade of concrete but the split tensile strength reduced for both the grades at 28 days. They came to the conclusion that the split tensile strength test at 28 days is not a very good parameter to assess rice husk ash addition in the ordinary Portland cement.

**Naveen et al [22]** concluded in their research that the rice husk ash was an excellent pozzolanic material as the compressive strength of the concrete increased substantially both at 7 days and 28 days for M30 and M60 grade of the concrete. It was found out in their study that the compressive strength at 28 days increased more in comparison to the strength at 7 days. This is attributed to the fact that the pozzolonic reaction starts to take place at later ages.

# CHAPTER 3

# OBJECTIVES

By reading the journals we came on the following specific objectives to carry out our own study on the Rice Husk Ash Concrete. These objectives have been listed below in the following points:

1. To determine the optimum replacement content of Rice Husk Ash in PPC cement that is the content at which maximum compressive strength at 14, 28 days in concrete.
2. To determine the Compressive Strength, Split Tensile Strength and Flexure Strength of concrete.
3. To prepare mix design for M60 concrete as per IRC 44: 2008 and achieve the high strength of 60 MPA.
4. Durability studies are done to determine the capability of RHA in concrete to resist aggressive environment.

# CHAPTER 4

# EXPERIMENTAL WORK

## 4.1 MATERIALS:

Various materials were used in the project namely, rice husk ash, super plasticizer, cement, fine aggregates, coarse aggregates, sulphuric acid and hydrochloric acid. In the next few lines the nature and sources of these materials have been described:

### 4.1.1 Rice Husk Ash:

Rice husk ash was collected from a rice mill at **KGR AGRO FUSIONS PVT LTD, Ludhiana**, Punjab, India who are the commercial suppliers of Rice Husk Ash. The Rice husk ash is amorphous in nature.

### 4.1.2 Superplasticizer:

The super plasticizer used was **Conplast-SP-430**.Conplast SP430 is Sulphonated Naphthalene Polymer (SNF type) which is brown in colour. It can give up to 25 percent water reduction without loss of workability to produce high quality concrete which can reduce permeability.

### 4.1.3 Cement:

Cement used was **Jaypee cement** provided by the Jaypee University of information and Technology. The cement was Portland Pozzolona Cement (fly ash based) conforming to Part 1 of IS 1489:1991.

### 4.1.4 Fine aggregate:

Locally available sand which is conforming to the **zone 4 of IRC 44: 2008** has been utilised in this project work.

### 4.1.5 Coarse aggregate:

Locally available coarse aggregates were used which have the **maximum nominal aggregate size of 20mm**.

### 4.1.6 Sulphuric acid:

Sulphuric acid has been purchased from **Quali-tech chemicals** and was used in acid attack test.

### 4.1.7 Hydrochloric acid:

Hydrochloric acid has been purchased from **Quali-tech chemicals** and was used in chloride attack test.

## 4.2 TESTS FOR MIX DESIGN:

Following tests are mandatory for mix design according to IRC 44:2008 and these tests were performed by keeping in mind the various recommendations of the code and the mix design for M60 concrete was prepared**:**

### 4.2.1 Specific Gravity of Cement/RHA:

The specific gravity is normally defined as the ratio between the weight of a given volume of material and weight of an equal volume of water.

**OBSERVATIONS:**

(i) Weight of empty specific gravity bottle =$M_1$ g

(ii) Weight of empty specific gravity bottle + 50 g cement/RHA = $M_2$ g

(iii) Weight of empty specific gravity bottle + 50 g cement/RHA + Kerosene Oil = $M_3$ g

(iv) Weight of empty specific gravity bottle + kerosene oil = $M_4$ g

Specific gravity of cement/RHA = $(M_2-M_1)/ 0.79((M_2-M_1)-(M_3-M_4))$

### 4.2.2 Specific gravity Test for Coarse Aggregates:

The specific gravity of an aggregate is a measure of its strength. Aggregates which have low specific gravity are normally weaker than those having higher specific gravity values.

**OBSERVATIONS :**

Weight of saturated aggregate in water with basket = $M_1$ g

Weight of basket suspended in water = $M_2$ g

Weight of saturated aggregate in water = $M_1 – M_2$ g

Weight of saturated surface dry aggregate in air = $M_3$ g

Weight of water equal to the volume of the aggregate = $M_3–(M_1–M_2)$g

Weight of oven dry aggregate = $M_4$ g

(1) Specific gravity = $M_3 / (M_3– (M_1– M_2))$

(2) Apparent specific gravity = $M_4 / (M_4– (M_1– M_2))$

(3) Water Absorption = $((M_3 – M_4) / M_4)$ X 100

**4.2.3 Specific Gravity of Fine Aggregate:**

**OBSERVATIONS:**

Mass of density bottle= $M_1$ g

Mass of bottle + sand= $M_2$ g

Mass of bottle + sand + water= $M_3$ g

Mass of bottle + water =$M_4$ g

Specific Gravity= $(M_2-M_1)/(M_4-M_1)-(M_3-M_2)$


**Fig 4.1: Specific Gravity Determination**

The figure 4.1 shows the specific gravity determination of the cement which is carried out with the help of specific gravity bottle and kerosene oil.

**4.2.4 Sieve Analysis of Fine Aggregate:**

Sieve analysis is used to determine the particle size distribution of fine and coarse aggregates. Sieving of aggregates is to be done conforming to IS: 2386 (Part I) – 1963. In this we have used different sieves as standardized by the IS code and then aggregates are passed through them and then collected over different sized particles left over different IS sieves of sizes – 80mm, 63mm, 50mm, 40mm,31.5mm, 25mm, 20mm, 16mm, 12.5mm, 10mm, 6.3mm,4.75mm, 3.35mm, 2.36mm, 1.18mm, 600μm, 300μm, 150μm and 75μm.The procedure for sieve analysis is as given below:

1. Sample is dried to a stable weight at a temperature of 110 + 5$^{o}$C and weighed.
2. The test sample is then sieved accordingly with IS Sieves as shown in the figure 4.1.
3. The weight material retained on each sieve is recorded.
4. At last calculate cumulative weight passing through each sieve as a percentage of total weight.

**Fig 4.2: Sieve Analysis performed by student Mohit Thakur**

## 4.3 MIX DESIGN:

**Mix design by IRC 44:2008, IS 10262:2009, IS 456:2000**

**4.3.1 Characteristic Strength of concrete**:

$f_{ck}' = f_{ck} + 1.65s$

From table 3, s= 5 for M60

= 60+1.65×5

= **68.25 MPA**

**4.3.2 Selection of water/cement or cementitious ratio:**

From table 4,

**w/c= 0.28**

**4.3.3 Selection of water content:**

From table 5,

At w/c = 0.50 and angular aggregates having maximum nominal size of 20mm:

**Suggestive water content= 186 kg/m$^3$**

2% superplasticizer by weight of cement is used.

=>30% reduction in water content.

So, Final water content= 186×0.30

= **130.2 kg/m$^3$**

### 4.3.4 Selection of cement content:

**Cement content** = water content/water to cement ratio

=130.2/0.28

=**465 kg/m$^3$**

### 4.3.5 Estimation of Coarse Aggregate Proportion in Total Aggregate:

From table 6 of the IRC 44 2008 we came to know that:

For w/c=0.50 and zone IV and max nominal size of aggregate=20mm:

**Coarse aggregate proportion in total aggregate= 0.66**

Since there is an decrease in the w/c ratio (0.50-0.28=0.22) this proportion is increased according to the code recommendation by (0.22/0.05=4.4%)

=> **Corrected coarse aggregate proportion in total aggregate=** 0.66+4.4/10 **= 0.70=CA**

**Fine aggregate proportion in total aggregate=** 1-0.704 **= 0.30=FA**

### 4.3.6 Mix calculations:

The mix calculations have been shown below:

**(a)** Volume of concrete = 1m$^3$
**(b)** Volume of cement = (Mass of cement/Specific gravity of cement)×(1/1000)

= (465/3.11)×(1/1000)

= 0.1495m$^3$

**(c)** Volume of water = (Mass of water/Specific gravity of water)×(1/1000)

= (130/1)×(1/1000)

= 0.130 $m^3$

**(d)** Volume of super plasticizer = (Mass of super plasticizer/Specific gravity of water)×(1/1000)

= (2×465/1.1×100)×(1/1000)

=8.4545×$10^{-3}$ $m^3$

**(e)** Volume of all-in- aggregate = 1-(b+c+d)

= 1-(0.1495+0.130+8.4545×$10^{-3}$)

= **0.712 $m^3$**

**(f)** Mass of coarse aggregate = e×CA×specific gravity of coarse aggregate×1000

= 0.712×0.70×2.57×1000

= 1280.88 kg/$m^3$

**(g)** Mass of fine aggregate = e×FA×specific gravity of fine aggregate×1000

= 0.712×0.30×2.63×1000

= 561.768 kg/$m^3$

**4.3.7 Final result:**

The final result for the mix design done for the control mix is given below:

Cement : 465 kg/$m^3$

Water: 130 kg/$m^3$

Fine aggregate : 562 kg/$m^3$

Coarse aggregate : 1281 kg/$m^3$

Superplasticizer : 9.3 kg/$m^3$

**4.3.8 Final Ratio:**

The final ratio from the calculations is given below:

**C:W:FA:CA:SP**

**1:0.28:0.83:2.75:0.02**

**Where, C is for cement, W for water , FA for fine aggregate , CA for coarse aggregate , SP for super Plasticizer**

*After this replacements for 0,2.5,5,7.5&10 of cement by RHA by weight is done. First volume of all in aggregate has been calculated then the whole mix design is tabulated:*

**Table 4.1: Volume of all in aggregate for different Percentage of RHA**

| Replacement | Volume of cement($m^3$) | Volume of RHA($m^3$) | Volume of all in aggregate($m^3$) |
|---|---|---|---|
| **2.5** | 0.1458 | 0.005 | 0.710 |
| **5** | 0.1420 | 0.011 | 0.709 |
| **7.5** | 0.1383 | 0.017 | 0.706 |
| **10** | 0.1346 | 0.022 | 0.705 |

The calculation in the table 4.1 has been done in the following manner:

Volume of Rice Husk Ash

= (Mass of Rice Husk Ash/Specific gravity of Rice Husk Ash)×(1/1000)

Specific gravity of Rice Husk Ash as calculated = 2.1

Volume of all-in- aggregate

= 1-(volume of cement+volume of RHA+volume of water+volume of superplasticizer)

Mass of coarse aggregate = e×CA×specific gravity of coarse aggregate×1000

Mass of fine aggregate = e×FA×specific gravity of fine aggregate×1000

***Note:** volume of water, cement and superplasticizer will be same as for the control mix*

On the basis of volume of all in aggregate the final mix proportions for different percentages of the rice husk ash that is 0%, 2.5%, 5%, 7.5% and 10%. These mix designations with their mix proportions have been put together and tabulated in the Table 4.2 (Mix Proportions) which is given below:

**Table 4.2: Mix Proportions**

| **Mix Designation** | M1 | M2 | M3 | M4 | M5 |
|---|---|---|---|---|---|
| **Rice Husk Ash Present %** | 0 | 2.5 | 5 | 7.5 | 10 |
| **w/c ratio** | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 |
| **Cement(Kg/m$^3$)** | 465 | 453.38 | 441.75 | 430.3 | 418.5 |
| **Rice Husk Ash (Kg/m$^3$)** | 0 | 11.63 | 23.25 | 34.88 | 46.5 |
| **Sand(Kg/m$^3$)** | 561.76 | 560.19 | 559.40 | 557.40 | 556.24 |
| **Coarse Aggregate(Kg/m$^3$)** | 1280.88 | 1277.29 | 1275.49 | 1270 | 1268.30 |
| **Water (Kg/m$^3$)** | 130 | 130 | 130 | 130 | 130 |

***Note: M1-Control Mix(0% RHA),M2-2.5 % RHA,M3-5% RHA,M4- 7.5% RHA,M5-10%RHA***

## 4.4 MIXING:

Mixing of constituents of concrete is either done by hand for small quantities or in a laboratory batch mixer for large quantities. We used a Laboratory batch mixer for mixing as shown in the figure 4.3 and following steps have been followed: Before adding the mix make sure that the mixer has been washed well and is soaked with water.Wait for 10-15 minutes.

1. Start the mixer, add coarse aggregates and 3/4$^{th}$ of water.
2. Add fine aggregates along with cement and remaining water until the mix has become workable.
3. Mix for about 5 minutes and pour the ingredients in a tray.
4. The optimum revolution for a ideal laboratory mixer is 20 revolutions.

**Fig 4.3: Concrete Mixing using laboratory mixer**

## 4.5 FRESH CONCRETE PROPERTIES:

### 4.5.1 Workability:

Workability is a fresh concrete property and in simple terms it means the ease of placing, transporting and working with concrete. Other definition of workability is that it is the amount of internal work done for the compaction of concrete.

#### 4.5.1.1 Requirements of Workability:

From mixing until it is transported, placed and compacted, fresh concrete must fulfill the following requirements;

1. The concrete mix which has been prepared must be stable and cohesive.
2. It must have good flowability so that it can easily fill up the forms around the reinforcements.
3. It must be susceptible to proper compaction and should be such that the concrete mix can be lifted by the pump.
4. The concrete mix must be able to get a sufficiently good finish on the surface of the concrete mix.

These different requirements of stability, flow ability, compactibility, place ability, pump ability and finish ability together are called Workability. In other words it can also be defined as useful amount of internal work done to produce full compaction.

#### 4.5.1.2 Factors affecting Workability:

The factors that have an impact on the workability of concrete have been described briefly as follows:

**Materials and Mix Proportions:**

The workability depends upon the materials used and mix proportions used to make the concrete mix. The various things to be considered from the perspective of workability are

Water content, shape and size of aggregates, fineness of sand, and use of admixtures such as super plasticizers, air entrainers, mineral admixtures etc. These factors are as described below:

**Water Content:**

As water in the mix is increased, the workability is also increased but it affects the strength of the concrete in adverse way because as water cement ratio increases the strength of the concrete decreases. So we cannot add more water to increase the workability of concrete mix.

**Shape and size of Aggregates:**

Smaller the maximum nominal size of the aggregates, better is the workability. Also the workability depends on the shape of the aggregates. Angular aggregates which have a rough surface tend to be difficult to work while rounded aggregates which are smooth textured are easier to handle, thus the workability for rounded aggregates having smooth texture would be better. Workability can be increased by the use of non porous and saturated aggregates.

**Fineness of sand:**

The fineness of sand also affects workability. The fine aggregate that is sand if having high fineness decreases the workability while the sand which has low fineness increase the workability. This is due to the fact the more finer sand would have high specific area which implies that this sand would adsorb more water than the less fine sand.

**Use of admixtures:**

Admixtures such as super plasticizers, air entrainers, viscosity modifiers can enhance the workability of the concrete but using mineral admixtures such as rice husk ash are very fine and thus have high specific surface area adsorbing a great amount of water and highly reducing the workability of the mix.

**High Temperaure, Humidity and Delay in placement:**

These three factors also have a significant effect on the workability of the concrete mix which is explained here:

**Elevation in Temperature:**

The workability of the concrete decreases with the elevation of the temperature. This is because elevation in the temperature causes evaporation of the water molecules present inside the freshly prepared concrete mix. We know that reduction in the water content of the cement leads to decrease in the workability of the concrete thus temperature affects workability.

**Humidity:**

Humidity means the presence of moisture in the environment. If the environment is humid then the moisture is readily available. This means that the fresh concrete would not undergo any reduction in its moisture and even may get water from the outside moisture of the environment implying an increase in workability. On the other hand in case of dry environment workability would decrease.

**Delay in Placement:**

Freshly prepared concrete has a particular time period after it becomes stiff and loses its plasticity which is termed as initial setting time (IST). This time period starts when water is firstly mixed with other ingredients of concrete. When this particular time period is over the concrete becomes unworkable e.g. 30 minutes in case of ordinary Portland cement (OPC). So we have to be careful that we place the concrete as soon as it is prepared or otherwise with increase in time the concrete would become more and more unworkable.

### 4.5.2 Compaction Factor Test:

Compaction factor test is generally done to measure the workability of concrete. Workability is a fresh concrete property and in simple terms it means the ease of placing, transporting and working with concrete. Other definition of workability is that it is the amount of internal work done for the compaction of concrete.

Compaction Factor determines the amount of compaction done for a given amount of compacting effort. Compaction factor test is done for medium to low workable mixes. Workability is measured in the terms of compaction factor. Compaction factor is defined as the ratio of weight of partially compacted concrete to the weight of fully compacted concrete. For concrete it is always less than unity. The dimensions of compaction factor apparatus which are as listed below:

- **Upper hopper:** 250mm is the larger diameter of the hopper, 125mm is the smaller diameter of the hopper and 275 mm is the height the hopper.
- **Lower hopper:** 250mm is the larger diameter of the hopper, 125mm is the smaller diameter of the hopper and 275 mm is the height the hopper.
- **Cylinder** : 150mm in diameter and 300 mm in height.
- **Spacing**: 200mm between the cylinder and lower hopper and also 200mm between the lower and the upper hopper.

These dimensions are shown in the figure 4.4 below:

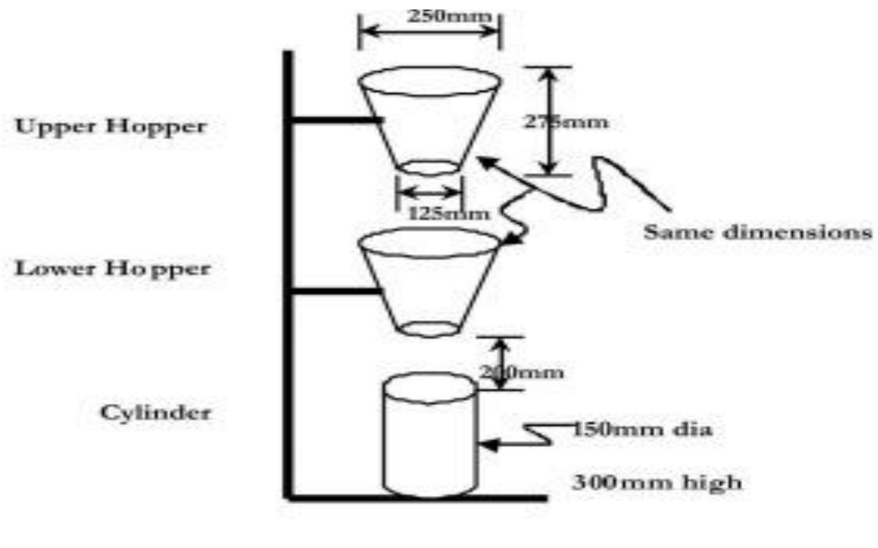


**Fig 4.4: Compaction Factor Apparatus**

**Fig 4.5: Students performing Compaction Factor Test.**

**Apparatus**:

Compaction factor test apparatus, cylinder, trowel, tray and tamping rods.

**Procedure:**

1. The desired concrete mix is prepared and all the trap doors of the apparatus are closed.
2. In its fresh state the prepared concrete mix is poured in the upper hopper to fill it completely.
3. The concrete mix is allowed to fall in the lower hopper from the upper hopper.
4. Now, concrete mix is allowed to fall into the cylinder from the lower hopper and excess of concrete is removed.
5. Thus, partial compaction of concrete is completed.
6. The weight of cylinder is now noted down.
7. The next step is to fully compact the concrete in the cylinder. This can be achieved by either tamping rods or vibration table.
8. The weights of cylinder are again noted down.
9. Ratio of these weights in step number 6 to that of step number 7 is calculated. This ratio is the compaction factor.

## 4.6 CASTING:

In this project cubes, beams and cylinders were casted. Casting of the concrete is done in following manner:

1. Cleaning of the moulds is done.
2. The moulds required for the casting are nuts are bolted with the help of keys.
3. The moulds are lubricated with oil.

4. The concrete is filled inside the moulds in appropriate layers.
5. The concrete is compacted using a tamping rod(steel bar 16mm diameter and 60cm long, bullet pointed at lower end) or by vibration table.
6. The top surface is smoothened with the help of a trowel to get good finishing.

**Fig 4.6: Casting of cubes by student Kshitij Tandon**

## 4.7 DEMOULDING:

Demoulding of the specimens (cubes, beams and cylinders) is done with the help of hammer and keys as shown in the figure 4.7.The demoulding is done after casting and then the specimens are kept for curing for a particular specific period of time for example 7 days or 14 days or 28 days or 56 days or 90 days as desired.

While demoulding following things should be kept in mind:

1. Test specimens should be demoulded after 24 hours of casting.
2. If still the specimens have not achieved sufficient strength , they must be delayed for some time.
3. When removing the cubes from the mould care should be taken to remove it completely, a chisel and a hammer may be used for proper demoulding.
4. No damage should be caused to the cube as it may reduce the compressive strength of the specimen.
5. After demoulding, each cube should be marked on the surface using ink to identify. The mould must be cleaned after demoulding.
6. It should be ensured that dirt does not collect between the faces of the flanges as the two halves will not fit together properly and there will be leakage through the joint and an irregularly shaped cube may result.
7. After demoulding the cubes, they are marked for identification with a marker as shown in the figure 4.8 so that after curing is completed we can easily identify a particular set of specimens.


**Fig 4.7: Demoulding of cubes**

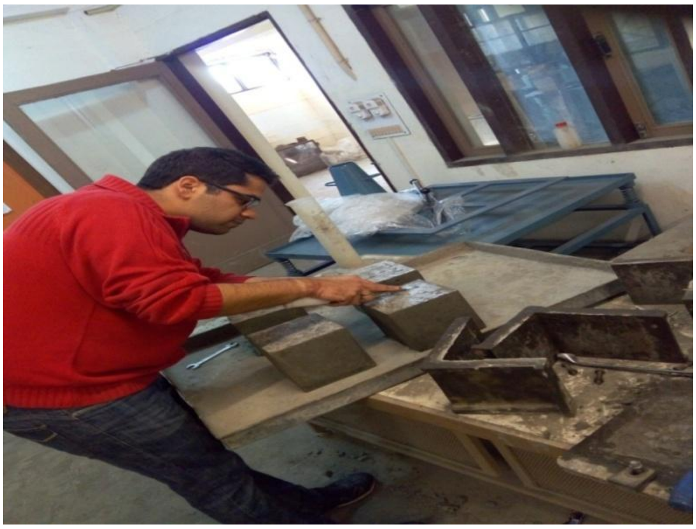

**Fig 4.8: Marking cubes for identification**

## 4.8 CURING:

Curing is done after demoulding to maintain proper moisture in concrete..It is the very basic requirement for proper hydration of the cement. Cement when properly cured results in better strength development and durability. Curing is done in the following manner:

1. A batch of 3 test specimens is stored in moist air for 24hours and after this they are demoulded and marked for identification.
2. The next step is to put the specimens into a clean water tank and submerged in water at normal temperature ranging between 25 to 27 ° C for the appropriate period (7days or14 days or 28days) .
3. The specimens are taken out after the period of curing for the test.
4. In this way cubes,cylinders and beams were cured. The figure 4.9 shows cubes taken after the completion of curing period i.e 28 days.

**Fig 4.9: Student showing cubes taken out of curing tank**

## 4.9 HARDENED PROPERTIES TESTS (STRENGTH TESTS):

Hardened properties of concrete include its properties in its hard state mainly strengths: compressive, flexural and split tensile. Tests were performed to determine these strengths namely compressive strength test, flexural strength test and split tensile strength test according to the Indian standards.

### 4.9.1 Compressive Strength Test:

The compressive strength test is done to calculate the compressive strength of the concrete. The compressive strength is the property of concrete to resist compressive forces acting on it. It is the most important characteristic property of the concrete as the concrete is designated on the basis of this property e.g. M30, M40, M60 etc. The cubes were casted according to the calculated mix design which is given in section 4.3 of this report and compressive strength was checked on 14 and 28 days in compression testing machine (as shown in figure 4.11) and universal testing machine (which is shown in figure 4.10) in accordance with IS 516 (1959).

**Fig 4.10: Compressive Strength Test on Universal Testing Machine.**

**Apparatus:**

Cube moulds having side 15cm, tamping rods, curing tank, compression testing machine.

**Procedure:**

1. First of all the cubes are casted and then demoulded and cured for the appropriate amount of time that was 14 days or 28 days in our case.
2. Cubes are then taken out of the water tank and wiped with a cloth.
3. The dimensions of the cubes are then noted down. The standard dimensions for cubes according to IS 519 is 15cmX15cmX15cm.
4. The machine is thoroughly cleaned.
5. The cubes are placed in such a manner that the load to be applied will act on the two oppostite faces of the cube.
6. The cube is alligned centrally to the base plate of compression testing machine.
7. The movable portion is roatated so that it touches the top surface .
8. Now, apply the load on the cube at a rate of 140 kg/cm$^2$/minute until the specimen fails.
9. The load at which the specimen fails is noted down.
10. The above steps are repeated for every mix at a particular time period (e.g 14days,28 days) for 3 cubes and average load(P) is calculated.
11. This load is divided by the crosssectional area to get the compressive strength $\mathbf{C=P/L^2}$ where L is the side of the cube.

**Fig 4.11: Compression Strength Testing**

### 4.9.2 <u>Split Tensile Strength Test</u>:

The concrete is brittle in nature and is very weak in tension. Splitting tensile strength test was don on cylindrical concrete specimens is an indirect method to determine the tensile strength of concrete as the concrete is unable to resist direct tension. The cylinders were casted and cured for 28 days at which the test was conducted.

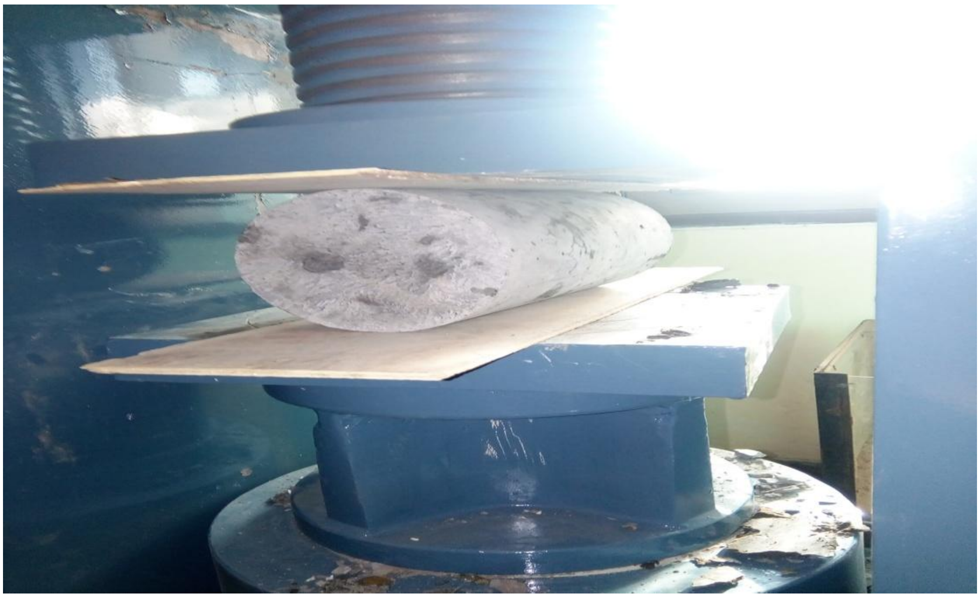

**Fig 4.12: Split Tensile Strength Test.**

**Apparatus:**

Cylinders having dimensions 20 cm X 10 cm, compression testing machine, tamping rods, curing tank, and vibration table.

**Procedure:**

1. Cylinders are casted as shown in figure 4.13, demoulded and cured for a period of 28 days.
2. The cylinders are taken out from the curing tank and are wiped.
3. The dimensions of the cylinders are noted down.
4. The standard dimensions of the cylinders according to IS 5816 is 10cmX20cm.
5. The plywood strip is kept on the lower and upper plate respectively and then the specimen is placed in the compression testing machine.
6. The specimen is aligned in such a way that the lines marked at the ends are centered at the top and bottom plate respectively.
7. Now, load is applied without shock at a rate of 14-21kg/cm$^2$/minute (9900kg/minute to 14850kg/minute) till the specimen fails.
8. Note down the failure load.
9. This procedure is repeated for at least 3 cylinders for each mix and average load is calculated (P).
10. Split tensile strength is calculated from the equation**:**

$$\mathbf{T = 2P/ \pi DL}$$

In this equation D is the diameter of the cylinder casted which was 100mm and L is the length of the cylinder casted which was 200mm.

The figure 4.12 shows the split tensile strength test being conducted on compression testing machine.

**Fig 4.13: Casting and display of Cylinders.**

### 4.9.3 Flexural Strength Test:

Flexural strength is a way to measure the tensile strength of concrete. It can be defined as the strength which is required by a concrete beam to resist failure in bending. The concrete beams should have a span length three times the depth at least. Flexural strength test was carried out after a curing period of 28 days according to IS 516 (1959).

**Fig 4.14: Beams casted for Flexural Strength Test**

The formula for the flexural strength calculation of 10cmX10cmX50cm specimen:

When'‘s’ > 13.3: **$f= (3ps)/bd^2$**

When 10 >‘s’ > 13.3: **$f= (pl)/bd^2$**

Where ‘f’ is the flexural strength in MPa

‘b’ and ‘d’ are the breadth and depth of the beam in mm

‘l’ is the length of specimen in mm

‘p’ is the load in N

‘s’ equals the distance between the line of fracture and the nearest support, measured on the centre line of the tensile side of the specimen, in mm

**Procedure:**

1. The beam specimen is prepared by filling the concrete in three layers of approximate equal thickness and tamping is done 35 times for each layer uniformly.
2. This specimen is demoulded and cured for a period of 28 days.
3. The beam is taken out of the curing tank and excess water is wiped out as shown in figure 4.14.
4. The bearing surfaces of support and load rollers are cleaned.
5. The casted beam is now placed in the machine centred with the longitudinal axis of the specimen making a right angle to the rollers. The figure 4.15 shows the casting of beam and flexural strength test being carried out on that beam by students.
6. Now, at a rate of loading of 400 kg/min for the 15.0 cm specimens and at a rate of 180 kg/min for the 10.0 cm specimens the load is applied on the beam until the beam fails.
7. The load of failure is noted down.
8. The above procedure is repeated at least for three beams for each mix and average load is calculated.
9. Now the flexural strength is calculated by these formula:
   When‘s’ > 13.3: **$f= (3ps)/bd^2$**
   When 10 >‘s’ > 13.3: **$f= (pl)/bd^2$**

**Fig 4.15: Casting of Beam and Flexural Strength Test**

## 4.10 DURABILITY TESTS:

Durability is the property which holds utmost importance for the concrete. Durability can be defined as the capability of the concrete to resist the various conditions for a long period of time. The concrete which has been casted should at least perform for its service life or design life. Durability can also be defined as the ability of the concrete to perform in harsh environment i.e to resist various kinds of chemical actions (such as acid attack, chloride attack etc.) weathering action, abrasion, freeze thaw cycle etc.

**Fig 4.16: Testing of Durability Specimens**

To check the performance of RHA concrete the following two tests were conducted:

1. Acid attack test
2. Chloride attack test

### 4.10.1 Acid Attack Test:

Sulphate Attack in concrete is a major problem and we need to minimize it as much as possible.

It is of two types:

**External sulphate attack**:

From ground water or seawater, Oxidation of sulfide minerals in clay adjacent to the concrete, Bacterial action in sewers, sulfates present in bricks

**Internal sulphate attack**:

Occurs when a late release of sulphates within concrete takes place. In this case, the formation of ettringite occurs after the concrete has hardened, and this results in distress.

Sulphate solutions attack most of the normal hydration products of cement in an aqueous medium.Thaumasite (calcium-carbonate-silicate-sulphate-hydrate):C-S-H reacting with appropriate carbonate, sulfate, $Ca^{2+}$ ions and excess water forms Thaumasite causes softening and loss of integrity of the concrete. Sulphate solution attacks most of the normal hydration products of cement in an aqueous medium. Each individual hydration product can give rise to a new compound as a result of the sulphate attack. Primary products formed are gypsum and ettringite. Also other reactions can occur resulting in the deterioration of the calcium silicate hydrate (CSH), which is the main binding agent and strength giver in the concrete matrix. Loss of calcium hydroxide during the reaction leads to reduction in the pH which is harmful for the the concrete.

**Procedure:**

Acid attack test is carried out in the following manner:

1. The cubes were casted and cured for a period of 28 days for 0% Rice husk content and 7.5% Rice husk ash mix (optimum value).
2. Then, these cubes were submerged inside diluted 1% of sulphuric acid solution for a time period of 30 days so that acid attack could take place. These cubes are shown in figure 4.17.
3. After this time period the cubes were taken out and compressive strength test was conducted on these cubes and the readings were noted.
4. These readings were then compared with the already noted readings of 0% Rice husk content mix and 7.5% Rice husk ash content at 28 days.
5. The comparison is done in respect of percentage reduction of the compressive strength.
6. Thus, it can be known whether the addition of the Rice Husk Ash was beneficial or not.

**Fig 4.17: Acid Attack Test (Sulphuric acid)**

**4.10.2 Chloride Attack Test:**

Solutions having chloride ions like sulphate ions also react with hydration product, although the products that form as a result do not cause any expansions like with the sulphate solutions. The reaction with hydration products can lead to, reduction of pH, etc. The primary issue with chloride attack is the corrosion of reinforcement so it is desirable that the concrete performs better against this attack.

**Procedure:**

Chloride attack test is carried out in the following manner:

1. The cubes were casted and cured for a period of 28 days for 0% Rice husk content and 7.5% Rice husk ash mix (optimum value).
2. Then, these cubes were submerged inside diluted 3% of hydrochloric acid solution for a time period of 30 days so that acid attack could take place. These cubes are shown in figure 4.18.
3. After this time period the cubes were taken out and compressive strength test was conducted on these cubes and the readings were noted.
4. These readings were then compared with the already noted readings of 0% Rice husk content mix and 7.5% Rice husk ash content at 28 days.
5. The comparison is done in respect of percentage reduction of the compressive strength.
6. Thus, it can be known whether the addition of the Rice Husk Ash was beneficial or not.

**Fig 4.18: Chloride Attack Test (Hydrochloric Acid)**

# CHAPTER 5

# RESULTS AND DISCUSSIONS

**5.1 Specific Gravity of Cement and RHA:**

The calculations for the specific gravity of cement and rice husk ash are shown in the following section:

**5.1.1 Specific Gravity of Cement:**

(i) Weight of empty specific gravity bottle =30.2 g

(ii) Weight of empty specific gravity bottle + 50 gm cement = 80.2 g

(iii) Weight of empty specific gravity bottle + 50 gm cement + Kerosene oil = 135g

(iv) Weight of empty specific gravity bottle + Kerosene oil = 92.05 g

Specific gravity of cement = $(M_2-M_1)/\ 0.79((M_2-M_1)-(M_3-M_4)) = 3.11$

**5.1.2 Specific Gravity of RHA:**

(i) Weight of empty specific gravity bottle = 30.2 g

(ii) Weight of empty specific gravity bottle + RHA = 80.2 g

(iii) Weight of empty specific gravity bottle + 50 gm RHA + Kerosene Oil = 125.25 g

(iv) Weight of empty specific gravity bottle + kerosene oil = 92.05 g

Specific gravity of cement/RHA = $(M_2-M_1)/\ 0.79((M_2-M_1)-(M_3-M_4)) = 2.10$

**5.2 SPECIFIC GRAVITY OF FINE AGGREGATES:**

The calculations for the specific gravity of fine aggregates are shown in this section:

Mass of density bottle=30.4 g

Mass of bottle + sand=80.4 g

Mass of bottle + sand + water=110.4 g

Mass of bottle + water =79.4 g

Specific Gravity= $(M_2-M_1)/(M_4-M_1)-(M_3-M_2) = 2.63$

### 5.3 SPECIFIC GRAVITY OF COARSE AGGREGATE:

The calculations for the specific gravity of cement and rice husk ash are shown in this section:

Weight of saturated aggregate suspended in water with basket = 2.18Kg

Weight of basket suspended in water = 0.57 Kg

Weight of saturated aggregate in water = 0.78Kg

Weight of saturated surface dry aggregate in air = 2.64Kg

Weight of water equal to the volume of the aggregate = 1.46Kg

Weight of oven dry aggregate = 2.596Kg

(1) Specific gravity = $M_4 / (M_3 – (M_1 – M_2))$

$= 2.596 / ((2.62 – (1.61))$

$= 2.57$

(2) Water Absorption = $((2.62 – 2.596) / 2.596)) \text{ X } 100$

$=1$

In the table 5.1 we have tabulated the specific gravity of cement, rice husk ash, fine aggregates and coarse aggregates. These values have been taken from the calculations shown in 5.1, 5.2 and 5.3. Also, the water absorption for the coarse aggregates is given in the table 5.1.

**Table 5.1: Materials with their respective Specific Gravity**

| Material | Specific Gravity |
|---|---|
| Cement | 3.11 |
| Rice Husk Ash | 2.10 |
| Fine Aggregates | 2.63 |
| Coarse Aggregates | 2.57 |
| Water Absorption by coarse aggregates = 1 | |

## 5.4 SIEVE ANALYSIS OF FINE AGGREGATES:

To determine the zone of the sand sieve analysis was performed. One kilogram of sand was taken and the sieves were shaken in Sieve shaker for 15 minutes.

**Table 5.2: Sieve Analysis of Fine Aggregates**.

| I S Sieve | Wt retained(g) | %age passed | **Zone IV** |
|---|---|---|---|
| 10 | 4.9 | 99.51=100 | 100 |
| 4.75 | 2.3 | 99.28 | 95-100 |
| 2.36 | 5.3 | 98.75 | 95-100 |
| 1.18 | 6.8 | 98.07 | 90-100 |
| 600um | 10.9 | 96.98 | 80-100 |
| 300um | 646 | 32.33 | 15-50 |
| 150um | 304.3 | 0.205 | 0-15 |
| Pan | 19.5 | - | - |

From table 5.2 we came to know that the zone of the sand according to the IRC 44: 2008 was zone IV.

## 5.5 COMPACTION FACTOR:

As our water cement ratio was 0.28 so we performed compaction factor test on different percentages of replacement of rice husk ash in concrete**.** The compaction factor values are tabulated in table 5.3:

**Table 5.3: Mix with their respective Compaction Factor values**.

| Mix Designation | M1 | M2 | M3 | M4 | M5 |
|---|---|---|---|---|---|
| Compaction Factor | 0.78 | 0.71 | 0.67 | 0.65 | 0.63 |

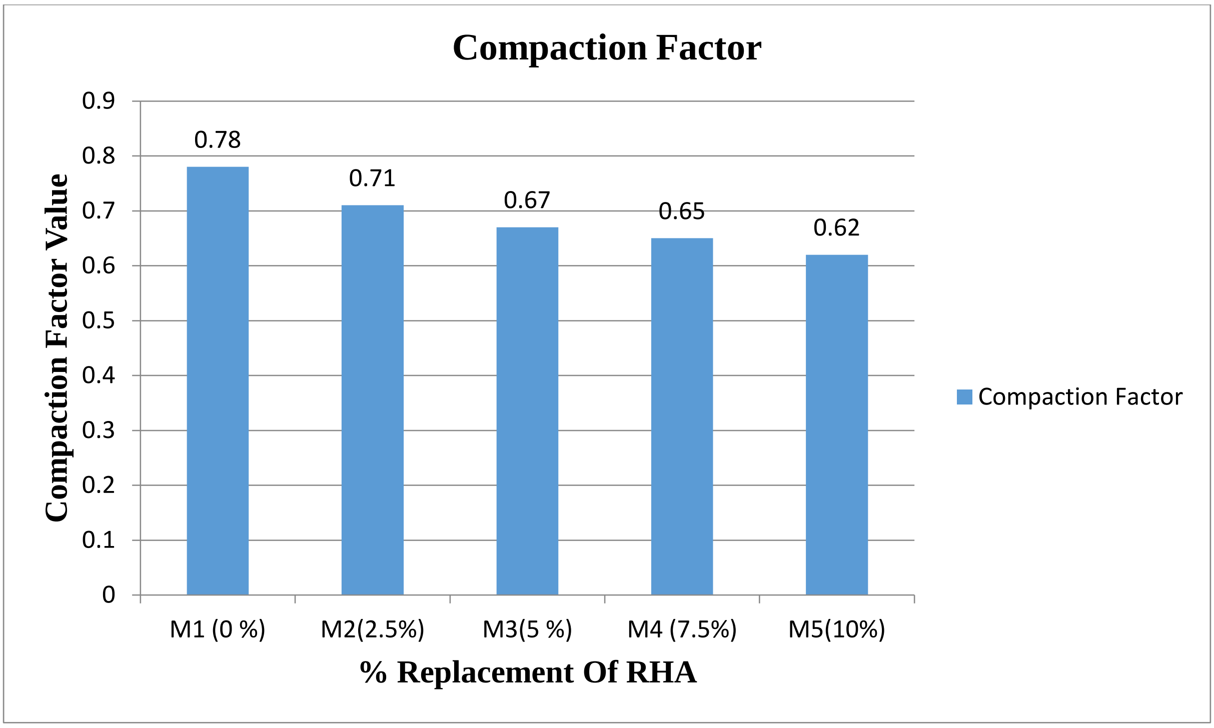


**Fig 5.1: Bar Graph Showing Compaction Factor.**

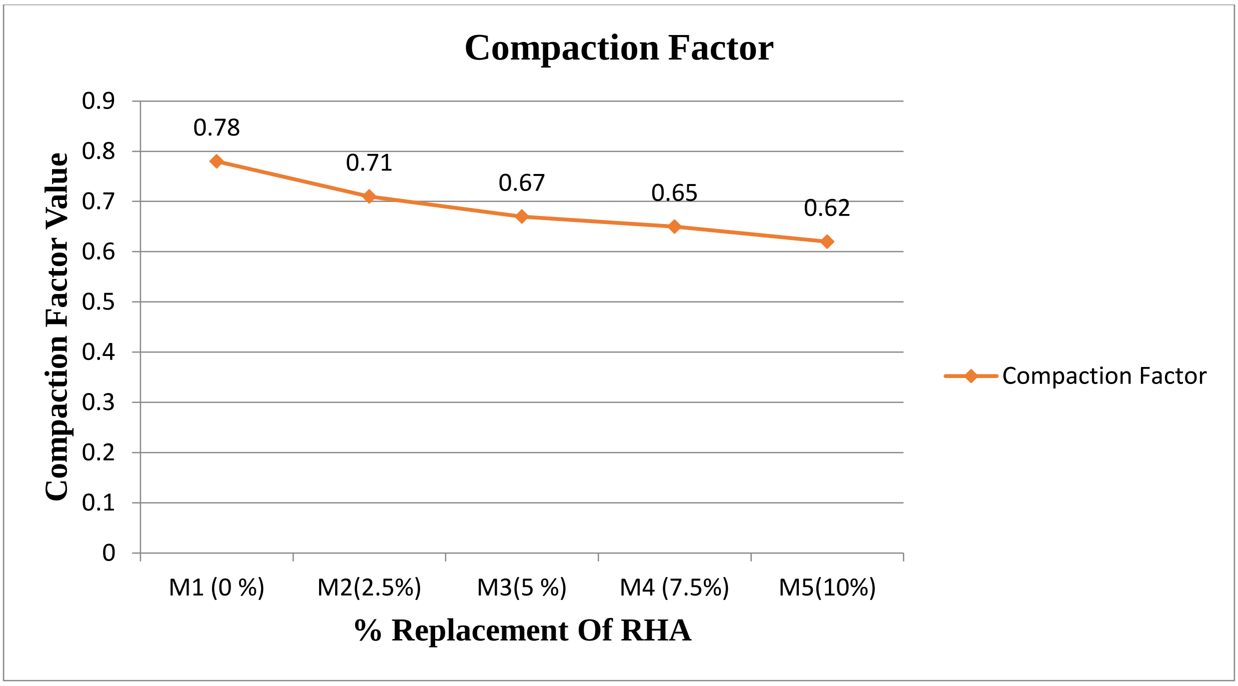


**Fig 5.2: Line Chart Showing Compaction Factor.**

***Note:*** *M1*-Control Mix(0% RHA),M2-2.5 % RHA,M3-5% RHA,M4- 7.5% RHA,M5-10%RHA

## DISCUSSION:

- As the mix was hard to work with and negligible slump was present even with the use of super plasticizer. Therefore we performed compaction factor test.
- Compaction Factor Test was carried out at different percentages of rice husk ash that are (0,2.5,5,7.5,10) and Compaction Factor came out to be (0.78,0.71,0.67,0.65,0.62) respectively as shown in figure 5.1 and 5.2.
- The Compaction Factor Test shows that the workability of the mixes were low. The highest workability was found at 0% i.e Control Mix and minimum workability was found at 10% rice husk ash content.
- The graph is decreasing which shows that the workability is decreasing as the content of rice husk ash is increasing in the concrete.

## 5.6 COMPRESSIVE STRENGTH TEST:

30 cubes were casted with 6 cubes for each percentage (0, 2.5, 5, 7.5, 10) and 3 cubes of each percentage were checked for 14 and 28 days compressive strength.

### 5.6.1 Compressive Strength after 14 days:

**Table 5.4: Compressive Load corresponding to each sample after 14 days.**

| Sample (3 each) | Load (KN) | Avg Load(KN) |
|---|---|---|
| M1 | 1041<br>1033<br>1051 | 1040 |
| M2 | 1096<br>1093<br>1106 | 1098 |
| M3 | 1113<br>1110<br>1118 | 1114 |
| M4 | 1184<br>1190<br>1179 | 1184 |
| M5 | 1066<br>1073<br>1054 | 1062 |

***Note:*** *M1-Control Mix(0% RHA),M2-2.5 % RHA,M3-5% RHA,M4- 7.5% RHA,M5-10%RHA*

**Table 5.5: Compressive Strength corresponding to average load of each Mix after 14 days.**

| Compressive Strength test on cubes 15cmX15cmX15cm after 14 days | | |
|---|---|---|
| Sample | Average load(kN) | Compressive Strength(MPa) |
| M1 | 1040 | 46.2 |
| M2 | 1098 | 48.8 |
| M3 | 1114 | 49.5 |
| M4 | 1184 | 52.6 |
| M5 | 1062 | 47.2 |

***Note:*** *M1-Control Mix(0% RHA),M2-2.5 % RHA,M3-5% RHA,M4- 7.5% RHA,M5-10%RHA*

**Table 5.6: Percentage increase in the compressive strength at 14 days due to the rice husk ash addition.**

| Concrete Mix | Compressive Strength at 14 days (MPa) | Percentage increase in Strength due to RHA addition.(%) |
|---|---|---|
| M1 | 46.2 | - |
| M2 | 48.8 | 5.23 |
| M3 | 49.5 | 7.14 |
| M4 | 52.6 | 13.85 |
| M5 | 47.2 | 2.16 |

***Note:*** *M1-Control Mix(0% RHA),M2-2.5 % RHA,M3-5% RHA,M4- 7.5% RHA,M5-10%RHA*

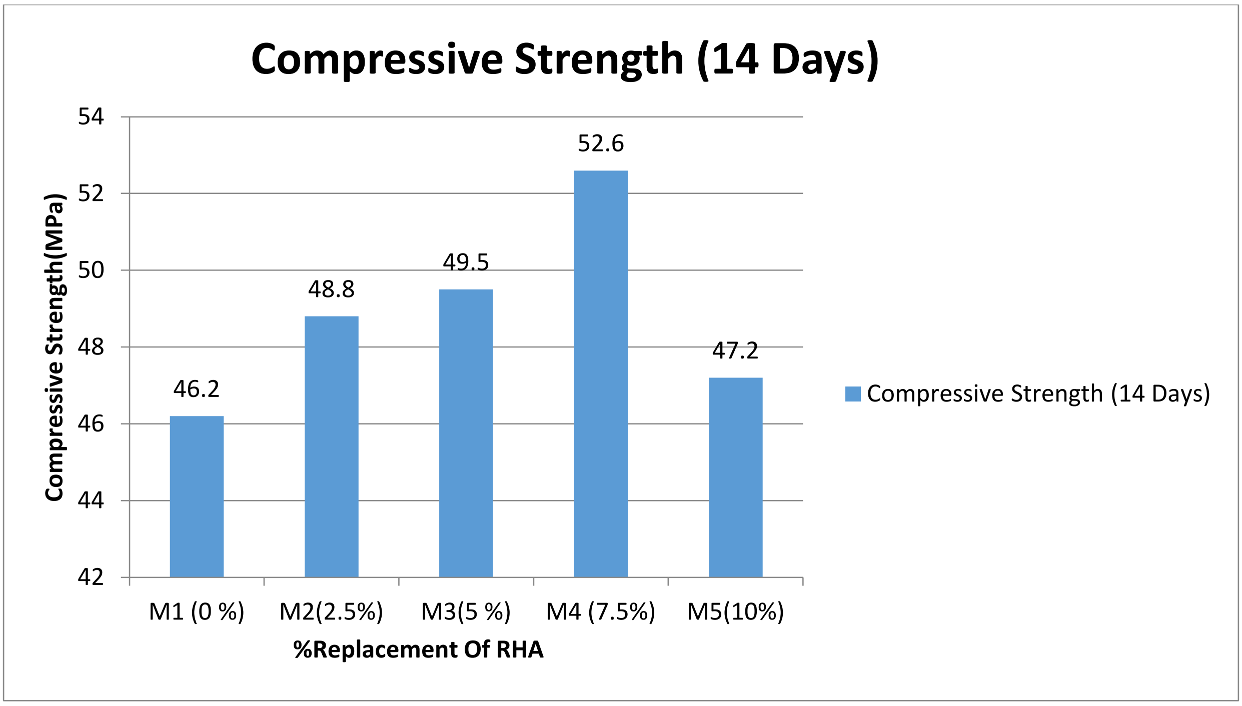


**Fig 5.3: Bar Graph showing Compressive Strength after 14 days.**

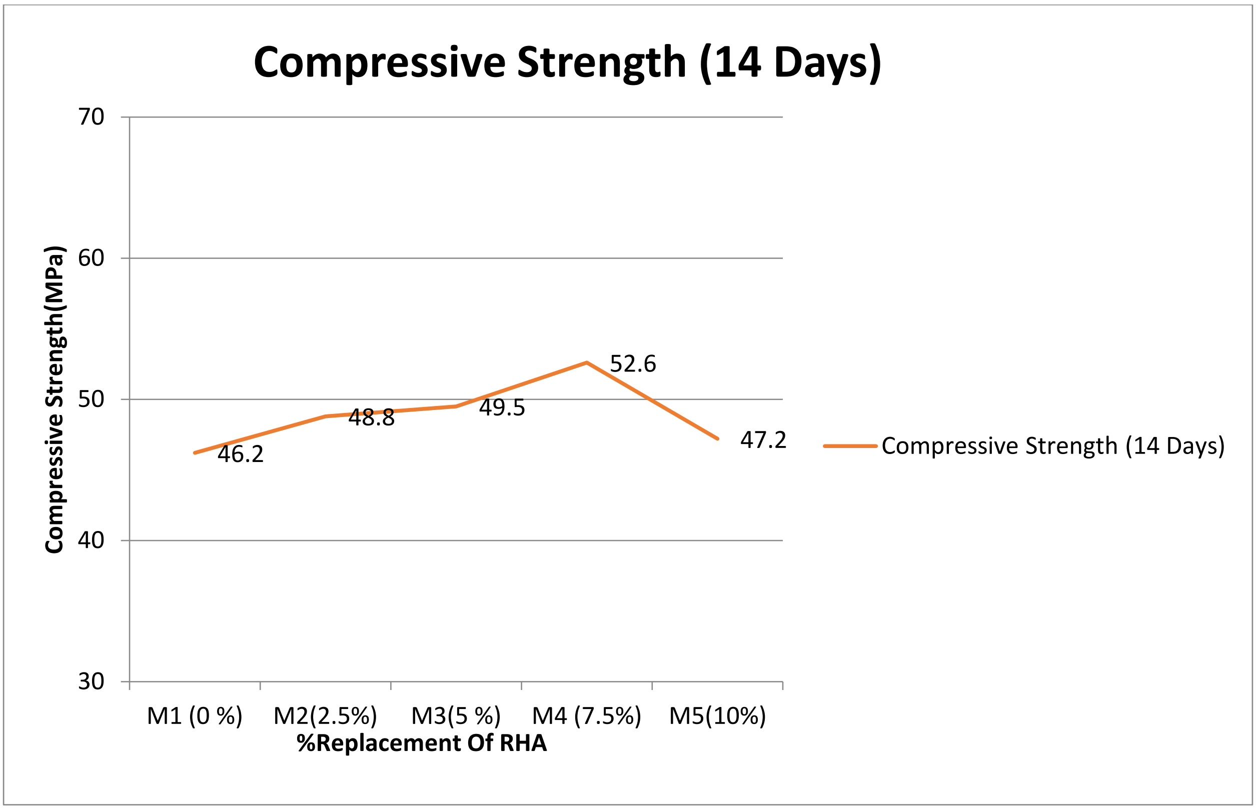


**Fig 5.4: Line Chart showing Compressive Strength after 14 days**

## DISCUSSION:

- Compressive Strength Test is of utmost importance and it is what we use to grade concrete (i.e. M30, M40, M60 etc).
- It is necessary to conduct this test in 14 days because first of all we get an idea if our mix design correct or not and secondly as we have used rice husk ash with PPC, the pozzolonic reactivity show its effect (increase in strength) in the later ages so that is the reason we went for 14 days testing instead of 7 days testing.
- 15 cubes were casted with 3 cubes for each percentage i.e (0,2.5,5,7.5,10) and each were tested at 14 days and the compressive strength came out to be (46.2,48.8,49.5,52.6,47.2) respectively.
- The graph is increasing upto 7.5 % and then decreasing upto 10 %, so we found out that 7.5 % is the optimum value of rice husk ash at 14 days as shown in the figures 5.3 and 5.4.

## 5.6.2 Compressive Strength After 28 days:

**Table 5.7: Compressive Load corresponding to each sample after 28 days.**

| Sample(3 each) | Load(KN) | Avg Load(KN) |
|---|---|---|
| M1 | 1275<br>1287<br>1293 | 1289 |
| M2 | 1350<br>1363<br>1368 | 1359 |
| M3 | 1424<br>1415<br>1428 | 1422 |
| M4 | 1492<br>1198<br>1504 | 1498 |
| M5 | 1351<br>1349<br>1356 | 1352 |

***Note:*** *M1-Control Mix(0% RHA),M2-2.5 % RHA,M3-5% RHA,M4- 7.5% RHA,M5-10%RHA*

**Table 5.8: Compressive Strength corresponding to average load of each Mix as after 28 days.**

| **Compressive Strength Test On Cubes 15cmX15cmX15cm after 28 days** | | |
|---|---|---|
| Sample | Average load(kN) | Compressive Strength(MPa) |
| M1 | 1289 | 57.3 |
| M2 | 1359 | 60.4 |
| M3 | 1422 | 63.2 |
| M4 | 1498 | 66.6 |
| M5 | 1352 | 60.1 |

***Note:*** *M1-Control Mix(0% RHA),M2-2.5 % RHA,M3-5% RHA,M4- 7.5% RHA,M5-10%RHA*

**Table 5.9: Percentage increase in the compressive strength at 28 days due to the rice husk ash addition.**

| **Concrete Mix** | **Compressive Strength at 28 days (MPa)** | **Percentage increase in Strength due to RHA addition.(%)** |
|---|---|---|
| M1 | 57.3 | - |
| M2 | 60.4 | 5.41 |
| M3 | 63.2 | 10.3 |
| M4 | 66.6 | 16.23 |
| M5 | 60.1 | 4.89 |

***Note:*** *M1-Control Mix(0% RHA),M2-2.5 % RHA,M3-5% RHA,M4- 7.5% RHA,M5-10%RHA*

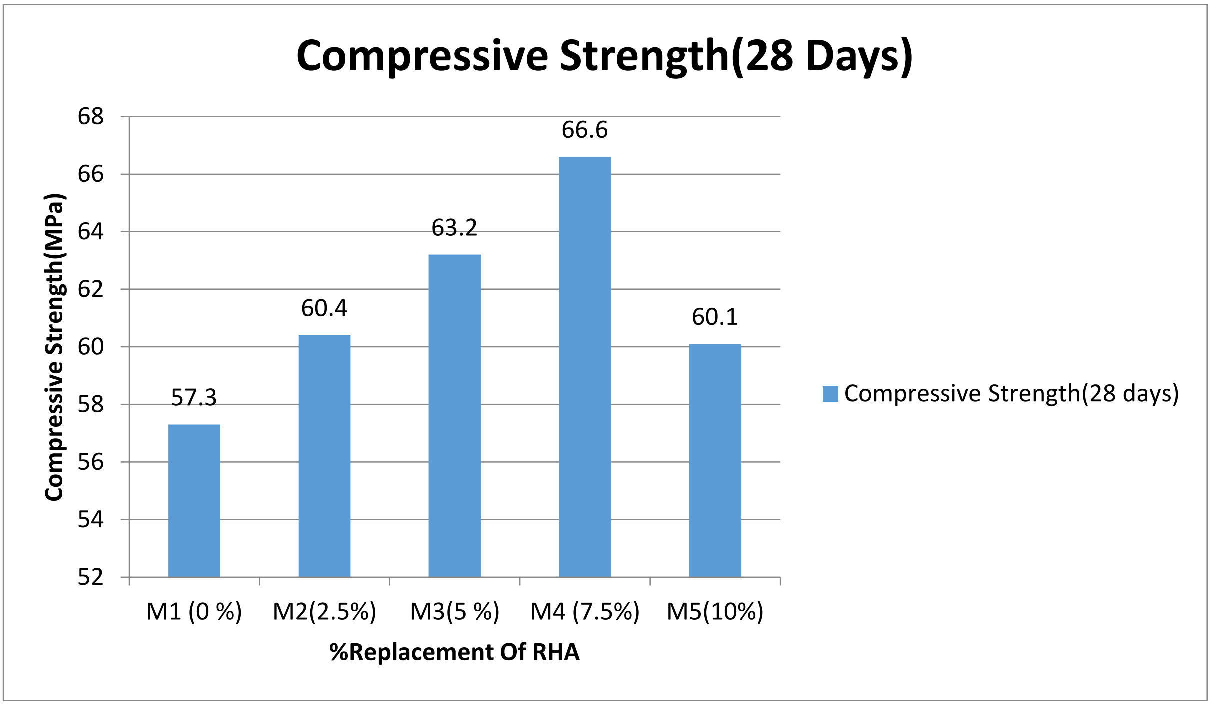


**Fig 5.5: Bar Graph showing Compressive Strength after 28 days.**

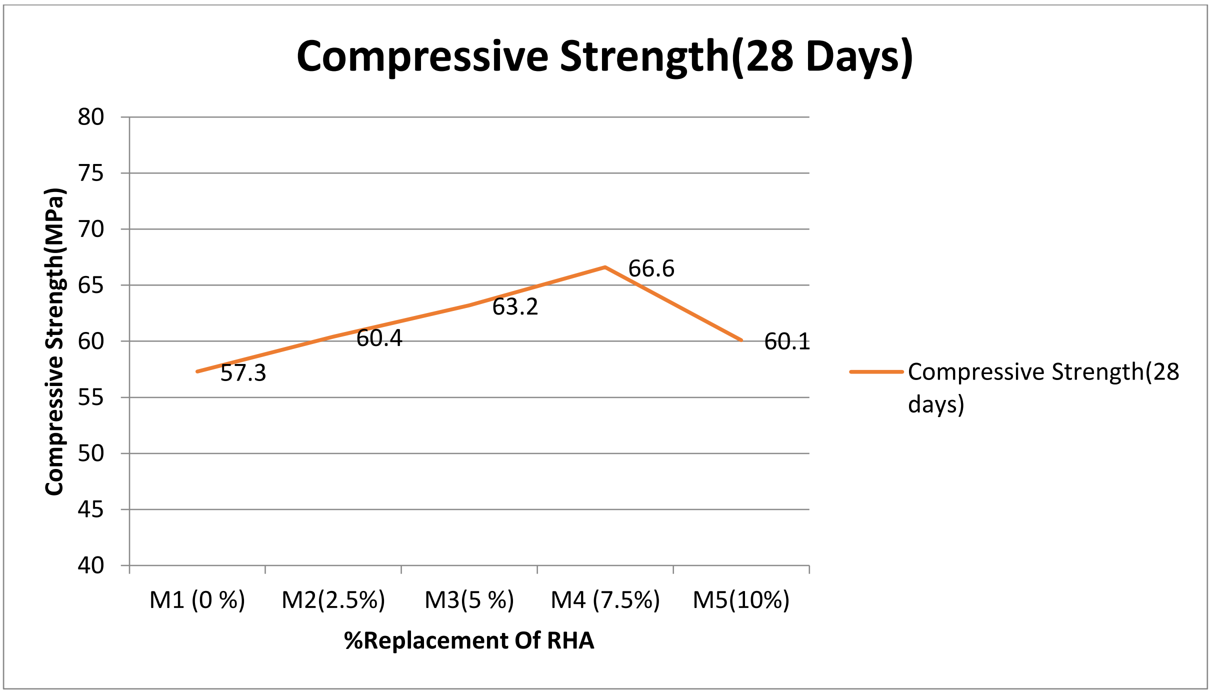


**Fig 5.6: Line Chart showing Compressive Strength after 28 days.**

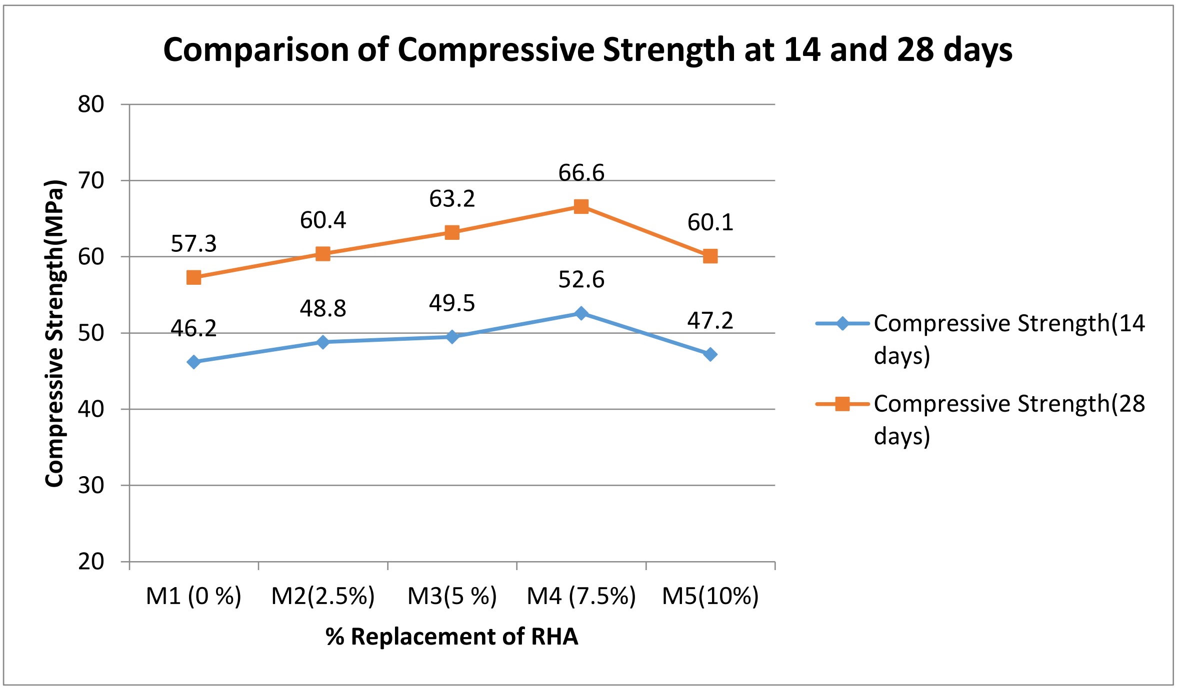


**Fig 5.7: Line Chart showing comparison between Compressive Strength at 14days and 28 days.**

## DISCUSSION:

- Compressive Strength Test is of utmost importance and it is what we use to identify concrete(i.e M30,M40,M60 etc).
- It is standard to conduct this test at 28 days and also we have used rice husk ash with PPC, the pozzolonic reactivity show its effect (increase in strength) in the later ages.
- 15 cubes were casted with 3 cubes for each percentage i.e (0,2.5,5,7.5,10) and each were tested at 28 days and the compressive strength came out to be (57.3,60.4,63.2,66.6,60.1) respectively.
- Hence high strength of 60 MPa was achieved.
- The graph is increasing upto 7.5 % and then decreasing upto 10 %, so we found out that 7.5 % is the optimum value of rice husk ash at 28 days.
- If we compare the graphs of the 14 days and 28 days compressive strength we can clearly see that the slope of graph of the latter is greater than the former. This can be attributed to the pozzolonic reaction due to the rice husk ash as shown in the figure 5.7.

## 5.7 SPLIT TENSILE STRENGTH TEST:

15 cylinders were casted with 3 cylinders for each percentage and were tested after 28 days. The cylinders had following dimensions:

- Height: 200 mm
- Diameter: 100mm

## Split Tensile Strength after 28 days:

**Table 5.10: Split Tensile Load corresponding to each sample after 28 days**

| Sample (3 each) | Load (KN) | Avg Load(KN) |
|---|---|---|
| M1 | 165<br>163<br>167 | 165 |
| M2 | 156<br>158<br>160 | 158 |
| `M3 | 153<br>147<br>151 | 150 |
| M4 | 147<br>144<br>146 | 146 |
| M5 | 143<br>146<br>141 | 143 |

**Table 5.11: Split Tensile Strength of each Mix after 28 days.**

| **Split Tensile Strength test on cylinders 20cmX10cm after 28 days** | | |
|---|---|---|
| Sample | Average load(kN) | Split Tensile Strength(MPa) |
| M1 | 165 | 5.25 |
| M2 | 158 | 5.03 |
| M3 | 150 | 4.77 |
| M4 | 146 | 4.65 |
| M5 | 143 | 4.55 |

***Note:*** *M1-Control Mix(0% RHA),M2-2.5 % RHA,M3-5% RHA,M4- 7.5% RHA,M5-10%RHA*

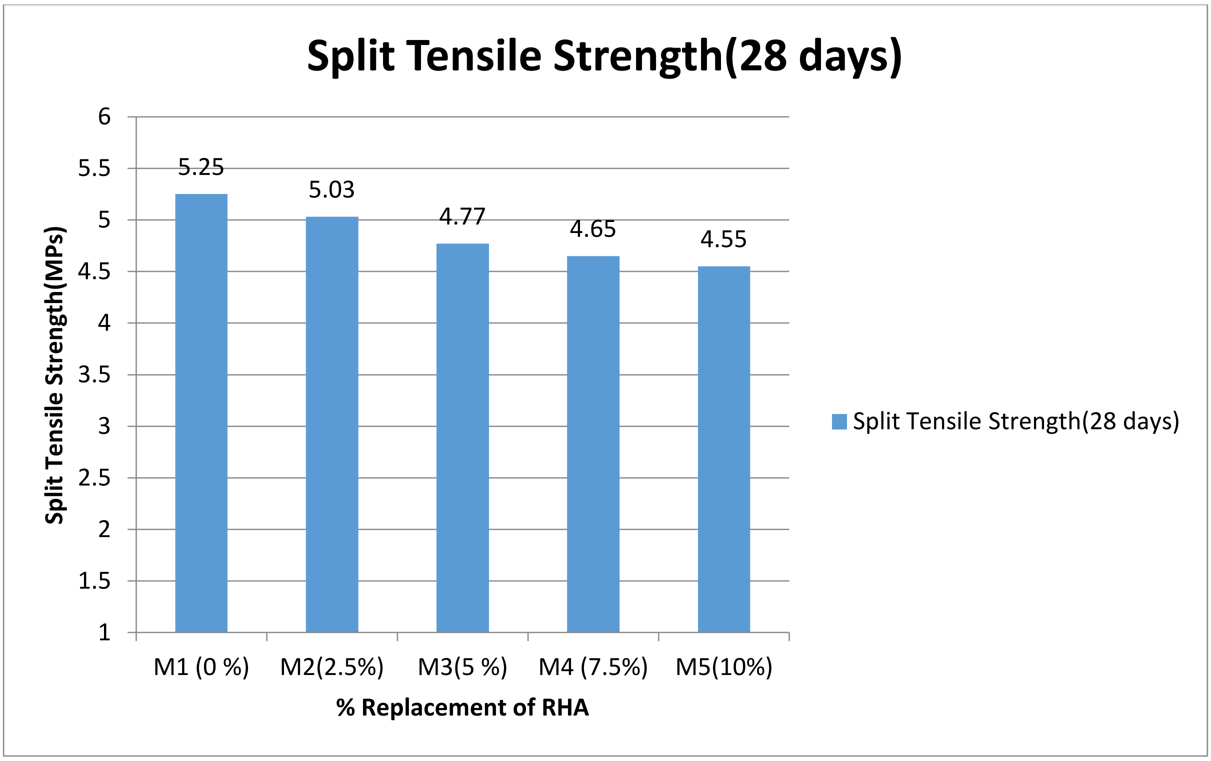


**Fig 5.8: Bar Graph showing split tensile strength after 28 days.**

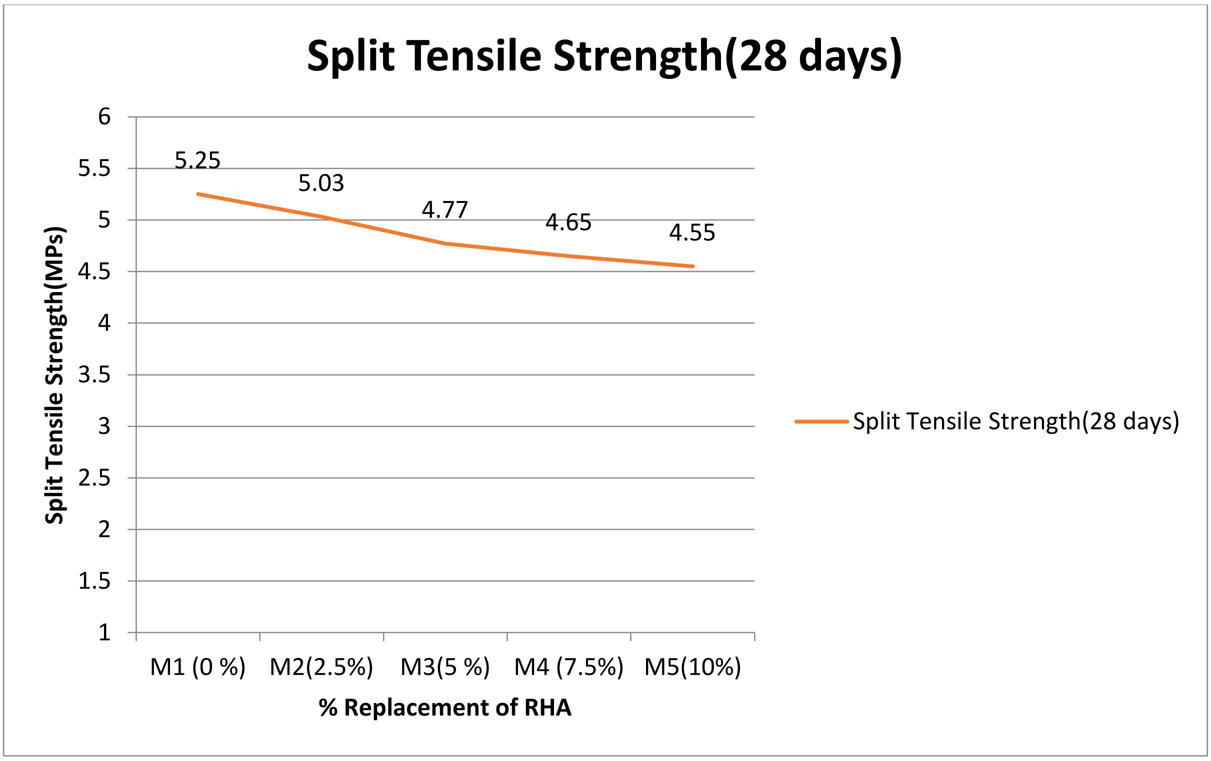


**Fig 5.9: Line chart showing split tensile strength after 28 days.**

**Table 5.12: percentage decrease in split tensile strength due to the addition of rice husk ash.**

| Concrete Mix | Split Tensile Strength at 28 days (MPa) | Percentage decrease in Split Tensile Strength due to RHA addition.(%) |
|---|---|---|
| M1 | 5.25 | - |
| M2 | 5.03 | -4.19 |
| M3 | 4.77 | -9.14 |
| M4 | 4.65 | -11.43 |
| M5 | 5.55 | -13.33 |

***Note:*** *M1-Control Mix(0% RHA),M2-2.5 % RHA,M3-5% RHA,M4- 7.5% RHA,M5-10%RHA*

## DISCUSSION:

- Split Tensile Strength Test was conducted to measure the tensile strength of concrete in an indirect way.
- 15 cylinders were casted with 3 cylinders for each percentage i.e (0,2.5,5,7.5,10) and each were tested at 28 days and the split tensile strength came out to be (5.25,5.03,4.77,4.65,4.55) respectively.
- With increase in the rice husk ash content it was found out that the split tensile strength is decreasing.
- The maximum split tensile strength was observed for the sample having no rice husk ash content and the minimum strength was observed for the maximum rice husk ash content i.e. 10% RHA content.
- In the work of some researchers we came to know that the split tensile strength is decreasing at 28 days with increase in rice husk ash content and it has been found out by them that at later ages such as 90 days, the strength increases upto some percentage of replacement with rice husk ash and then decreases thereafter.
- Split tensile strength test at 28 days is not a good parameter to assess the benefits of rice husk ash

### 5.8 FLEXURAL STRENGTH TEST:

15 Beams were casted with 3 beams for each percentage and were tested after 28 days.

**Flexural Strength after 28 days:**

**Table 5.13: Flexuaral load corresponding to each sample after 28 days**

| **Sample (3 each)** | **Load (KN)** | **Avg Load(KN)** |
|---|---|---|
| M1 | 11.6<br>11.9<br>11.7 | 11.73 |
| M2 | 11.9<br>11.9<br>11.8 | 11.86 |
| M3 | 12.1<br>11.9<br>12.1 | 12.03 |
| M4 | 12.2<br>12.3<br>12.3 | 12.26 |
| M5 | 11.8<br>11.9<br>11.8 | 11.83 |

**Table 5.14: Flexural Strength of each Mix at 28 days.**

| **Flexural Strength Test On Beams 10cmX10cmX50cm after 28 days** | | |
|---|---|---|
| Sample | Average load(kN) | Flexural Strength(MPa) |
| M1 | 11.73 | 5.87 |
| M2 | 11.86 | 5.93 |
| M3 | 12.03 | 6.02 |
| M4 | 12.26 | 6.13 |
| M5 | 11.83 | 5.92 |

***Note:*** *M1-Control Mix(0% RHA),M2-2.5 % RHA,M3-5% RHA,M4- 7.5% RHA,M5-10%RHA*

**Table 5.15: Percentage increase in Flexural Strength due to RHA addition**

| Concrete Mix | Flexural Strength at 28 days (MPa) | Percentage increase in Strength due to RHA addition.(%) |
|---|---|---|
| M1 | 5.87 | - |
| M2 | 5.93 | 1.02 |
| M3 | 6.02 | 2.56 |
| M4 | 6.13 | 4.43 |
| M5 | 5.92 | 0.85 |

***Note:*** *M1-Control Mix(0% RHA),M2-2.5 % RHA,M3-5% RHA,M4- 7.5% RHA,M5-10%RHA*

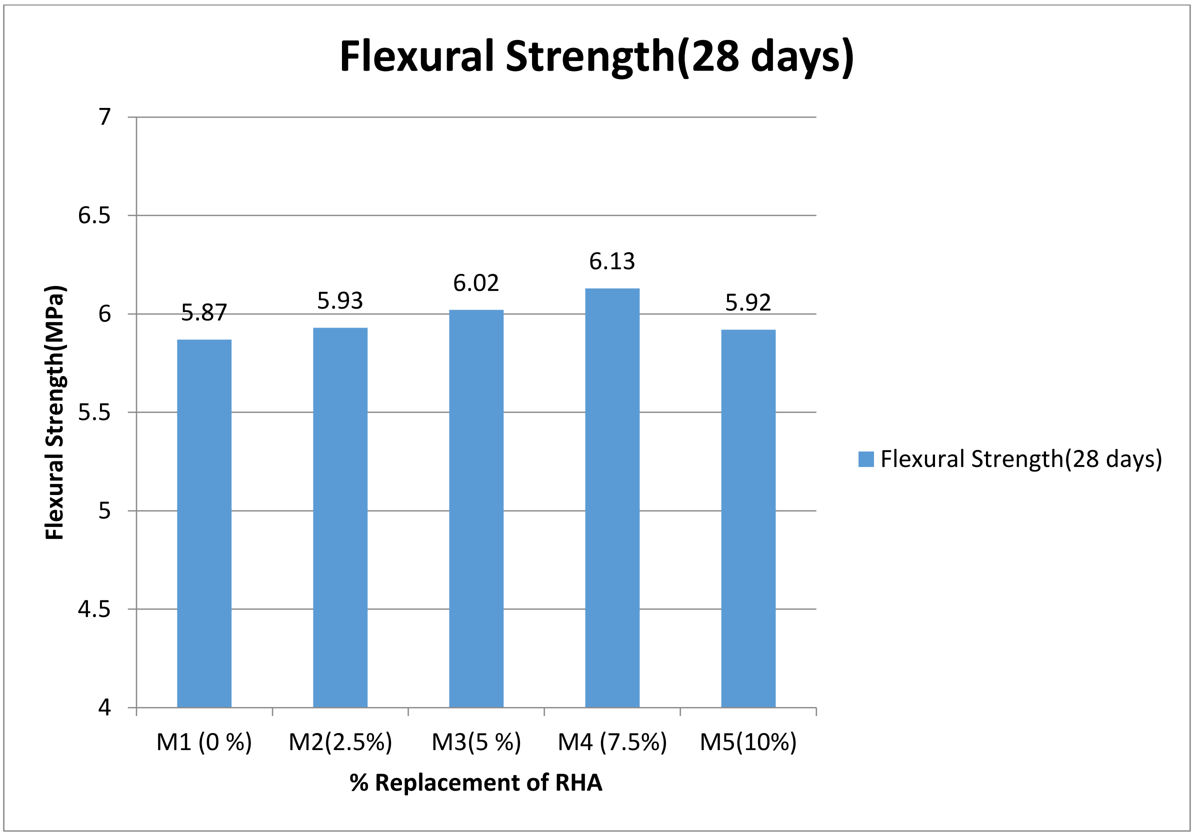


**Fig 5.10: Bar Graph showing Flexural Strength after 28 days.**

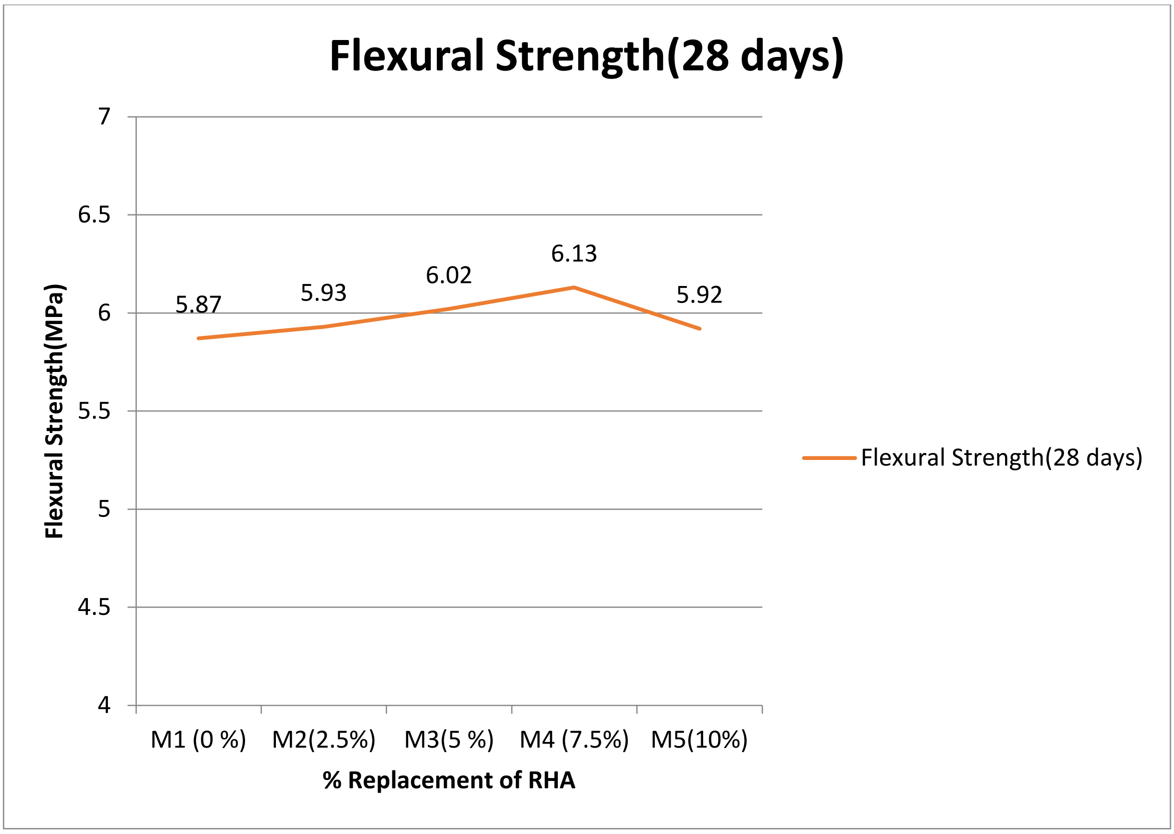


**Fig 5.11: Line Chart showing Flexural Strength after 28 days.**

## DISCUSSION:

- Flexural strength in simple words is the resistance of a beam to bending and it is also the way to assess the tensile strength of concrete.
- 15 beams were casted with 3 beams for each percentage i.e (0,2.5,5,7.5,10) and each were tested at 28 days and the flexural strength came out to be (5.87,5.93,6.02,6.13,5.92) respectively.
- The graph is increasing upto 7.5 % and then decreasing upto 10 %, so we found out that 7.5 % is the optimum value of rice husk ash at 28 days as shown in figure 5.10 and 5.11.
- As the strength is increasing, this confirms that the rice husk ash used in this project is amorphous in nature meaning it lacks order and thus it is reactive. So as a result of pozzolonic reaction we are seeing increase in the flexural strength of concrete which has rice husk ash in it as compared to normal concrete.
- This shows that with the incorporation of rice husk ash in concrete the flexural strength is increasing that is there is significant improvement in tensile strength of concrete.

## 5.9 Durability Tests:

### 5.9.1 Acid Attack Test:

The results of acid attack test are given below:

**Table 5.16: Average Compressive load corresponding to the specimens undergone acid attack**

| Sample(3 each) | Load(KN) | Avg Load(KN) |
|---|---|---|
| M1 | 1135<br>1136<br>1137 | 1137 |
| M4 | 1403<br>1400<br>1402 | 1402 |

**Note:** *M1-Control Mix (0% RHA), M4- 7.5% RHA*

**Table 5.17: Compressive Strength at 28 days of cubes placed in acid for 30 days**

| **Compressive Strength Test on cubes placed in acid after 28 days** | | |
|---|---|---|
| Sample | Average load(kN) | Compressive Strength(MPa) |
| M1 | 1137 | 50.5 |
| M4 | 1402 | 62.3 |

**Table 5.18: Comparison of Compressive Strength at 28 days of RHA concrete with control mix when placed in acid for 30 days**

| **Change in Compressive Strength of cubes at 28 days after placing them in acid for 30 days** | | | |
|---|---|---|---|
| Sample | Compressive Strength(MPa) | Compressive Strength after acid attack(MPa) | Reduction in Compressive Strength(%) |
| M1 | 57.3 | 50.5 | 11.87 |
| M4 | 66.6 | 62.3 | 6.45 |

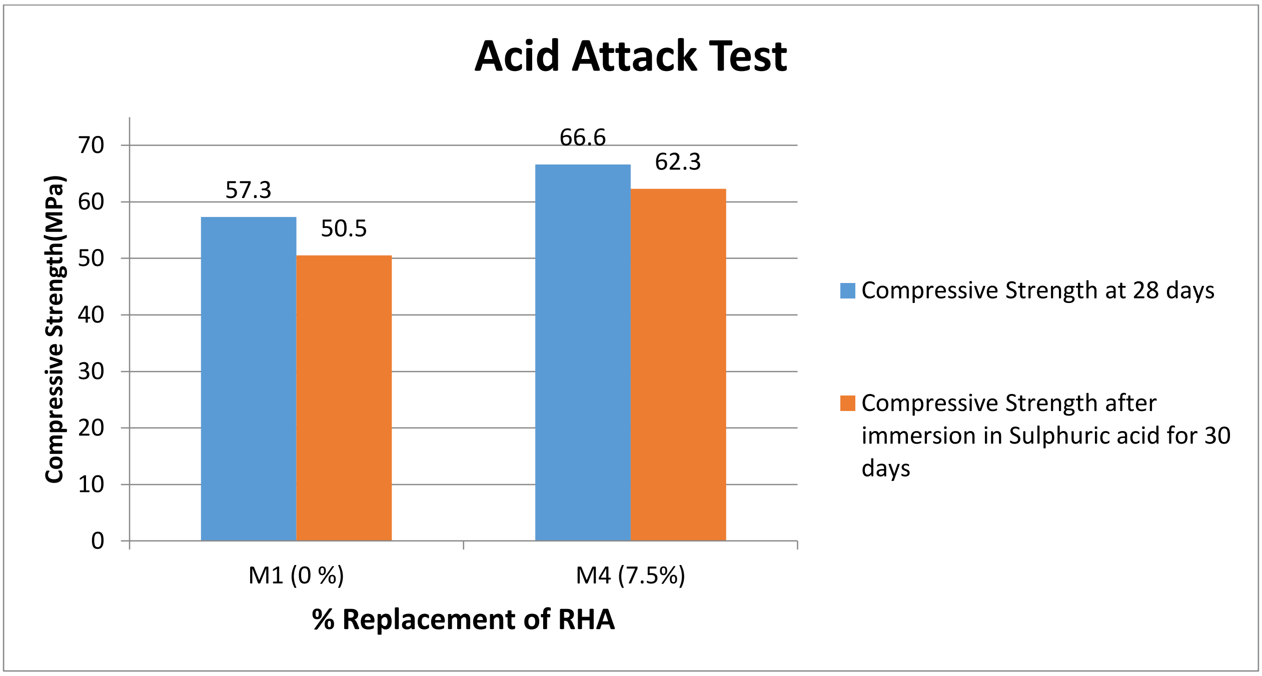


**Fig 5.12: Bar Graph showing Compressive Strength after Acid Attack Test**

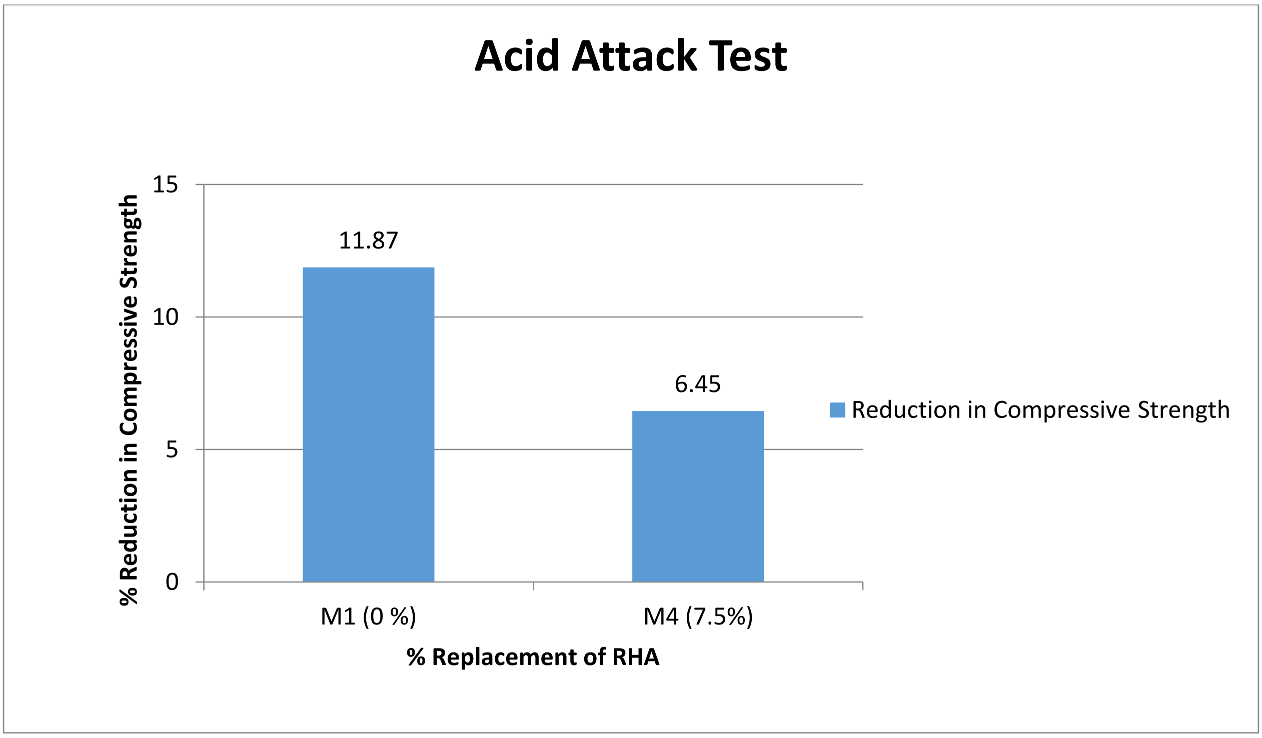


**Fig 5.13: Bar Graph showing Reduction in Compressive Strength after acid attack**

## DISCUSSION:

- Acid attack test was carried out to see the performance of rice husk ash concrete in acidic environment rich in sulphate ions for eg. Groundwater.

- A total of 6 cubes were casted, 3 cubes for 0% Rice husk content and another 3 for 7.5% Rice husk ash mix (optimum value).
- Then, these cubes were submerged inside diluted 1% of sulphuric acid solution for a time period of 30 days so that acid attack could take place and then their compressive strength was evaluated and compared with the compressive strength at 28 days.
- The strength reduction in percentage for RHA concrete came to be less than (6.45% < 11.87%) the control mix. Thus addition of RHA made concrete more durable.

### 5.9.2 CHLORIDE ATTACK TEST:

The results of chloride attack test are given below:

**Table 5.19: Average Compressive load corresponding to the specimens undergone chloride attack**

| **Sample(3 each)** | **Load(KN)** | **Avg Load(KN)** |
|---|---|---|
| M1 | 1192<br>1193<br>1195 | 1193 |
| M4 | 1434<br>1433<br>1433 | 1434 |

**Table 5.20: Compressive Strength at 28 days of cubes placed in chloride for 30 days**

| **Compressive Strength Test on cubes placed in HCL after 28 days** | | |
|---|---|---|
| Sample | Average load(kN) | Compressive Strength(MPa) |
| M1 | 1193 | 53 |
| M4 | 1434 | 63.7 |

**Table 5.21: Comparison of Compressive Strength at 28 days of RHA concrete with control mix when placed in chloride for 30 days**

| **Change in Compressive Strength of cubes after placing them in HCL for 28 days** | | | |
|---|---|---|---|
| Sample | Compressive Strength(MPa) | Compressive Strength after chloride attack(MPa) | Reduction in Compressive Strength(%) |
| M1 | 57.3 | 53 | 7.50 |
| M4 | 66.6 | 63.7 | 4.35 |

**Note:** *M1-Control Mix(0% RHA),M4- 7.5% RHA*

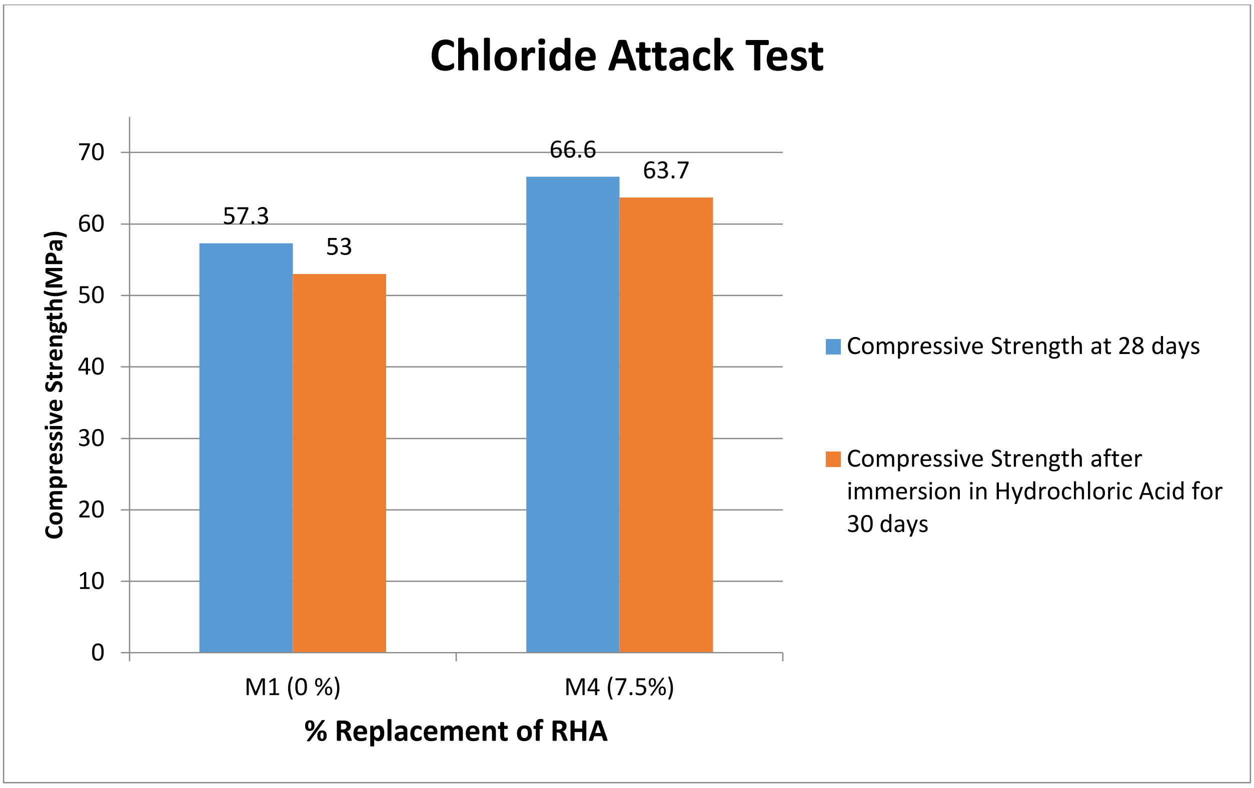


**Fig 5.14: Bar Graph showing Compressive Strength after Chlroide Attack Test**

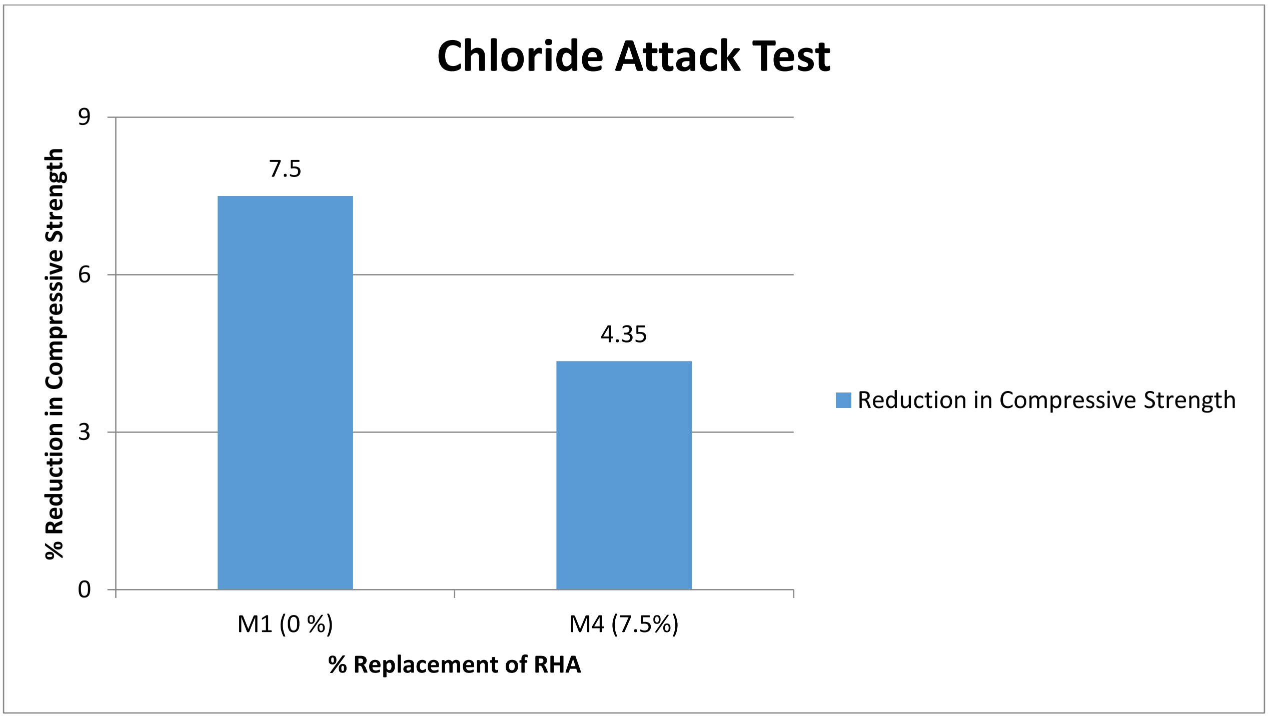


**Fig 5.15: Bar Graph showing reducitom Compressive Strength after Chlroide Attack Test**

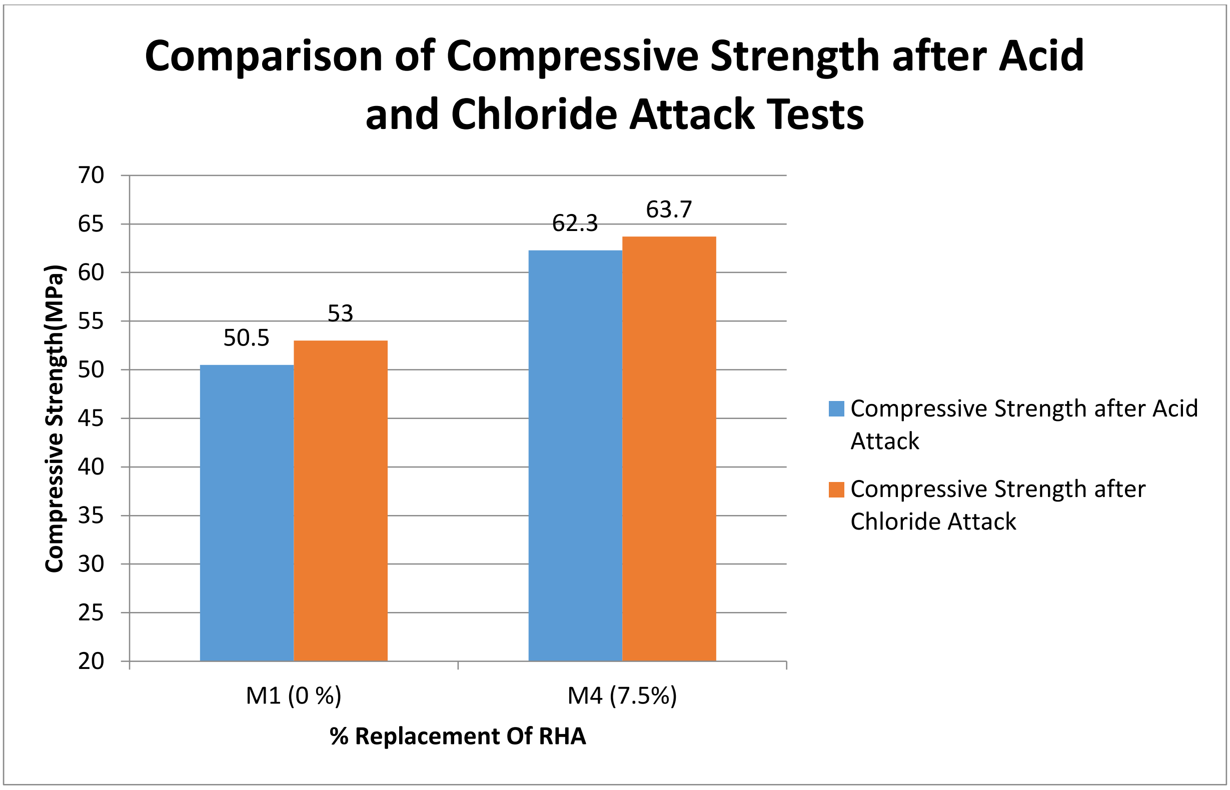


**Fig 5.16: Comparison of Compressive Strength after Acid and Chloride attack Tests.**

## DISCUSSION:

- Chloride attack test was carried out to see the performance of rice husk ash concrete in acidic environment rich in chloride ions (from sea water) which cause corrosion of reinforcements. This test is a way to assess the durability of RHA concrete especially resistance to chemical action.
- A total of 6 cubes were casted, 3 cubes for 0% Rice husk content and another 3 for 7.5% Rice husk ash mix (optimum value).
- Then, these cubes were submerged inside diluted 3% of hydrochloric acid solution for a time period of 30 days so that chloride attack could take place and then their compressive strength was evaluated and compared with the compressive strength at 28 days.
- The strength reduction in percentage for RHA concrete was found out to be less than (4.35% < 7.50%) the control mix.
- Hence the durability of RHA concrete is better than the normal concrete.

## 5.10 Cost Benefit Analysis:

The cost benefit analysis of using rice husk ash in the concrete is done here:
Cement in kilograms in one bag = 50
Price of cement per bag = Rs 320
Price of cement every kilogram = Rs 6.4
No. Of kilograms in one tonne = 1000

Price of one tonne rice husk ash = Rs 1000
Price of one Kilogram of rice husk ash = 1000/1000 = Rs 1

Let us assume 1000 bags of cement was utilized in a project,
Therefore, cement consumption = 50000 Kg
Total cost of cement = Rs 320000

Cost of 10% rice husk ash in the project = Rs 5000
Cost of 7.5 % rice husk ash in the project = Rs 3750
Cost of 5 % rice husk ash in the project = Rs 2500
Cost of 2.5 % rice husk ash in the project = Rs 1250

Cost of 90 % cement in the project = Rs 288000
Cost of 92.5 % cement in the project = Rs 296000
Cost of 95 % cement in the project = Rs 304000
Cost of 97.5 % cement in the project = Rs 312000

Total cost savings:
If 10 % rice husk ash is used = 320000-(288000 + 5000) = Rs 27000
If 7.5 % rice husk ash is used = 320000-(296000 + 3750) = Rs 20250
If 5 % rice husk ash is used = 320000-(304000 + 2500) = Rs 13500
If 10 % rice husk ash is used = 320000-(312000 + 1250) = Rs 6750

Therefore, total percentage savings:
If 10 % rice husk ash is used = 8.44 %
If 7.5 % rice husk ash is used = 6.33 %
If 5 % rice husk ash is used = 4.22 %
If 2.5 % rice husk ash is used = 2.11 %

The results of cost benefit analysis of use of Rice Husk Ash in concrete are given in Table 5.22.

**Table 5.22: Cost savings in percentage.**

| Rice Husk Ash | Percentage cost savings |
|---|---|
| 2.5 % | 2.11 |
| 5 % | 4.22 |
| 7.5 % | 6.33 |
| 10 % | 8.44 |

So, by the use of rice husk ash the compressive strength of concrete is increasing as discussed earlier but also the cost of the concrete is decreasing as shown by the cost benefit analysis.

# CHAPTER 6
# CONCLUSION

The following conclusions were drawn from the study of rice husk ash in concrete:

1. Compaction factor decreased on same water to cement ratio and same amount of super plasticizer with increase in rice husk ash content as shown in the figure 5.1 and 5.2.This shows that the workability is decreasing on same amount of super plasticizer and water cement ratio with the increase in rice husk content.
2. Optimum content of RHA was found to be 7.5 % for Portland Pozzolana Cement from the Compressive Strength and Percentage Replacement of RHA and both at 14 and 28 days as shown in the figures 5.4 and 5.6.
3. High Strength of 60 MPa was achieved at 28 days as shown in the table 5.8
4. Split Tensile Strength at 28 days decreases with replacement with RHA as shown in the figure 5.8 and 5.9.
5. Flexural Stength at 28 days increases with increase in RHA content and the optimum content of RHA was found to be 7.5 % as shown in the figures 5.10 and 5.11.
6. With the use of Rice husk Ash (7.5% optimum mix) in the concrete it was found out that Rice Husk Ash performed better than the control mix both in the case of acid attack and chloride attack as shown in the figures 5.12 and 5.14.
7. The concrete performed better in case of chloride attack test than the acid attack test as shown in the Figure 5.16.
8. The cost benefit analysis carried out for Rice Husk Ash shows that replacing cement with rice husk ash is economical as shown in the table 5.22.

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