# "EFFECT OF MARBLE DUST AND RICE HUSK ASH ON PROPERTIES OF CONCRETE"

## A Thesis

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

**MASTER OF TECHNOLOGY**

**IN**

**CIVIL ENGINEERING**

**With specialization in**

**STRUCTURAL ENGINEERING**

Under the supervision of

**Mr. Chandra Pal Gautam**

**(Assistant Professor)**

***By***

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**to**

**JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY**

**WAKNAGHAT SOLAN – 173 234**

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# CERTIFICATE

This is to certify that the work which is being presented in the project title **"EFFECT OF MARBLE DUST AND RICE HUSK ASH ON PROPERTIES OF CONCRETE"** in partial fulfillment of the requirements for the award of the degree of Master of technology in civil engineering with specialization in "**structural engineering**" and submitted in Civil Engineering Department, Jaypee University of Information Technology, Waknaghat is an authentic record of work carried out by ABHISHEK SINGH KSHATRIYA during a period from July 2015 to June 2016 under the supervision of **Mr. Chandra Pal Gautam** Assistant Professor, Civil Engineering Department, Jaypee University of Information Technology, Waknaghat.

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

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# ABSTRACT

The objective of this research was to examine the behavior of concrete when the cement is duly replaced by two different materials viz. Rice Husk Ash and Marble Dust Powder. This project presents the study of concrete mix design (M40 mix) using rice husk ash and marble Dust. The problems of disposal of the rice husk ash & Marble Dust also seemed feasible by the results obtained. RHA-MD causes significant increase in the compressive strength of concrete. Compressive strength, Flexural strength test as well as Split tensile Strength were conducted on RHA-MD concrete mix.

The Marble Dust Powder used in experiment was obtained from marble processing factory in Makrana Tehsil of Nagaur district in Rajasthan. Rice Husk Ash was obtained from KGR Agro Fusions Pvt. Ltd. Ludhiana, Punjab. The concrete is mixed with RHA and MD in varying percentage of 5-35% with both the materials varying, then properties like compressive strength, flexural strength and split tensile strength are studied. There has been a linear increase in the strength properties of concrete mix up to 25% of RHA-MD thereafter gradual decrease is observed in the strength properties of the mix. The optimum value of RHA-MD in concrete is 25% with the proportion of RHA being 15% and MD being 10%. The investigation concluded that the concrete containing RHA-MD has better strength characteristics than the normal concrete.

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# LIST OF ABBREVIATIONS AND SYMBOLS

| SYMBOLS AND ABBREVIATIONS | DESCRIPTION |
|---|---|
| SCC | Self Compacting Concrete |
| MD | Marble Dust |
| RHA | Rice Husk Ash |
| OPC | Ordinary Pozzolona Cement |
| UTM | Universal Testing Machine |
| IS | Indian Standard |
| $f'_{ck}$ | Target average compressive strength |
| $f_{ck}$ | Characteristic compressive strength |
| w/c | Water Cement Ratio |
| Π | Pi |
| MPa | Mega Pascal |

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# CHAPTER 1

# INTRODUCTION

## 1.1 GENERAL

Concrete is a composite material containing hydraulic cement, water, coarse aggregate and fine aggregate. The resulting material is a stone like structure which is formed by the chemical reaction of the cement and water. The concrete demand has increased rapidly in the past decades which has led to increased cement consumption, as a result of which it is difficult for the production in large scale which requires energy and use of natural resources. Now-a-days the cost of material is increasing so if we use waste materials in the production of the concrete so we can reduce the price and preserve the natural resources. The advancement of concrete technology can reduce the consumption of natural resources and energy sources and limit the burden of pollutants on environment. The production of ordinary Portland cement produces approximately 7% of the total greenhouse gas emitted to the atmosphere.

Thus further advancements have been made in the field of concrete technology and came complex structures which required heavy reinforcements. When large quantity of heavy reinforcement is to be placed in a reinforced concrete (RC) member, it is difficult to ensure that the formwork gets completely filled with concrete that is, fully compacted without voids or honeycombs. Compaction by manual or by mechanical vibrators is very difficult in this situation. The typical method of compaction, vibration, generates delays and additional cost in the projects. Underwater concreting always required fresh concrete, which could be placed without the need to compaction; in such circumstances vibration had been simply impossible. This problem can now be solved with self-compacting concrete. This type of concrete flows easily around the reinforcement and into all corners of the formwork.

## 1.2 SELF COMPACTING CONCRETE

Concrete technology has made tremendous strides in the past decade. The development of specifying a concrete according to its performance requirements, rather than the constituents and ingredients has opened innumerable opportunities for producers of concrete and users to design concrete to suit their specific requirements. One of the most outstanding advances in the concrete technology over the last decade is “self compacting concrete” (SCC). Self-compacting concrete is a highly flowable, stable concrete which flows readily into places around congested reinforcement, filling formwork without any consolidation and significant segregation. The hardened concrete is dense, homogeneous and has the same engineering properties and durability as that of traditional vibrated concrete. The use of SCC eliminates the need for compaction thereby saves time, reduces labor costs and conserves energy. Furthermore use of SCC enhances surface finish characteristics.

## 1.3 HISTORY

The introduction of the “modern” self-compacting concrete (SCC) is associated with the drive towards better quality of concrete pursued in Japan in late 1980’s, where the lack of uniform and complete compaction had been identified as the primary factor responsible for poor performance of concrete structures. There were no practical means by which full compaction of concrete on a site was ever to be fully guaranteed, instead, the focus therefore turned onto the elimination of the need to compact, by vibration or any other means. This led to the development of the first practicable SCC by researchers (Okamura, Ozawa et al.) at the University of Tokyo and the large Japanese contractors (e.g. Kajima, Maeda, Taisei etc.) quickly took up the idea. The contractors used their large in-house R&D facilities to develop their own SCC technologies. Each company developed their own mix designs, trained their own staff to act as technicians for testing on sites, and tailor made their SCC mixes for large projects they tendered for. Importantly, each of the large contractors also developed their own testing devices and test methods

Current Indian scenario in construction shows increased construction of large and complex structures, which often leads to difficult concreting conditions. Vibrating concrete in congested locations may cause some risk to labour in addition to noise stress. There are always doubts about the strength and durability placed in such locations. So it is worthwhile to eliminate vibration in practice, if possible. In countries like Japan, Sweden, Thailand, UK etc., the knowledge of SCC has moved from domain of research to application. But in India, this knowledge is to be widespread.

## 1.4 PROPERTIES OF SELF COMPACTING CONCRETE

### 1.4.1 HARDENED PROPERTIES OF SCC

The compressive strength, as one of the most important properties of hardened concrete, in general is the characteristic material value for the classification of concrete in national and international codes. For this reason, it is of interest whether the differences in the mixture composition and positive dissimilarities in the microstructure, as mentioned before, affect the short and long term load-bearing behavior. Accordingly, clarification is still necessary to determine whether the hardening process and the ultimate strengths of SCC and conventional concrete differ. After 28 days the reached compressive strength of SCC and normal vibrated concrete of similar composition does not differ significantly in the majority of the published test results. Isolated cases, however, showed that at the same water cement ratios slightly higher compressive strengths were reached for SCC. At the current time there is insufficient research to result in generalized conclusions with this fact. The comparison of hardening processes shows that the strength development of SCC and conventional concrete is similar. Some of the published test results show that an increase of the cement content and a reduction of filler content at the same time increases the initial concrete strength and the ultimate concrete strength. For example if limestone powder is used higher compressive strengths are noticeable at the beginning of the hardening process.

Splitting tensile strength: All parameters which influence the characteristics of the microstructure of the cement matrix and of the interfacial transition zone (ITZ) are of decisive importance in respect of the tensile load bearing behavior. By evaluating the created database it could be shown, that most results of the measured splitting tensile strength values are in the range of valid regulations for normal vibrated concrete with the same compressive strength. However, in about 30% of all data points a higher splitting tensile strength was stated,

**Fig 1.4 – Self Compacting Concrete**

### 1.4.2 ADVANTAGES OF SELF-COMPACTING CONCRETE

- Simple inclusion even in complicated formwork and tight reinforcement
- Higher installation performance since no compaction work is necessary which leads to reduced construction times, especially at large construction sites
- Reduced noise pollution since vibrators are not necessary
- Higher and more homogenous concrete quality across the entire concrete cross-section, especially around the reinforcement
- Improved concrete surfaces (visible concrete quality)
- Typically higher early strength of the concrete so that formwork removal can be performed more quickly.

## 1.5 RICE HUSK ASH (RHA)

Rice milling generates a byproduct know as husk. This surrounds the paddy grain. During milling of paddy about 78 % of weight is received as rice, broken rice and bran. Rest 22 % of the weight of paddy is received as husk. This husk is used as fuel in the rice mills to generate steam for the parboiling process. This husk contains about 75 % organic volatile matter and the balance 25 % of the weight of this husk is converted into ash during the firing process, is known as rice husk ash (RHA). This RHA in turn contains around 85% - 90% amorphous silica. So for every 1000 kgs of paddy milled, about 220 kgs (22%) of husk is produced, and when this husk is burnt in the boilers, about 55 kgs (25%) of RHA is generated.

India is a major rice producing country, and the husk generated during milling is mostly used as a fuel in the boilers for processing paddy, producing energy through direct combustion and/or by gasification. About 20 million tons of RHA is produced annually. This RHA is a great environment threat causing damage to the land and the surrounding area in which it is dumped. Lots of ways are being thought of for disposing them by making commercial use of this RHA. The particle size of the cement is about 35 microns. There may be formation of void in the concrete mixes, if curing is not done in properly. This reduces the strength and quality of the concrete.

Silpozz – which is made out of this RHA is finer than cement having very small particle size of 25 microns, so much so that it fills the interstices in between the cement in the aggregate.  That is where the strength and density comes from.  And that is why it can reduce the amount of cement in the concrete mix. RHA is a good super-pozzolans .Silpozz can be used in a big way to make special concrete mixes. There is a growing demand for fine amorphous silica in the production of special cement and concrete mixes, high performance concrete, high strength, low permeability concrete, for use in bridges, marine environments, nuclear power plants etc. This market is currently filled by silica fume or micro silica, being imported from Norway, China and also from Burma. Due to limited supply of silica fumes in India and the demand being high the price of silica fume has risen to as much as US$ 500 / ton in India.

**Fig 1.5 - Rice Husk Ash**

## 1.6 MARBLE DUST

Marble is one of the most important materials used in buildings since ancient times, especially for decorative purposes. However its powder has bad effects on the environment, soil, water and health problems. Marble powder is produced from processing plants sawing and polishing of marble blocks. Some factories have water recycling plants containing flocculation tank and filter press unit. About 25% of the processed marble is turn into dust or powder form. About 7,000,000 tons of marble have been produced in the world. Disposal of the marble powder material of the marble industry is one of the environmental problems worldwide today.

Typical properties of Marble Dust

- less reactive
- better acid resistance
- increases flow rates because of its higher bulk density and sp. Gravity

**Fig 1.6 - Marble Dust Powder**

## 1.7 SUPERPLASTICISER

Normal water reducers are well established admixtures called plasticizers in concrete technology. A normal water reducer is capable of reducing water requirements by 10 to 15%. Higher water reductions, by incorporating larger amounts of these admixtures, result in undesirable effects on concrete like bleeding, segregation and hardening. So, a new class of water reducers, chemically different from the normal water reducer and capable of reducing water content by about 30% has been developed. The admixtures belonging to this class are known as super plasticizers. Superplasticiser are in fact the extended version of plasticisers. At a given water /cement ratio and water content in the mix, the dispersing action of superplasticiser increases the workability of concrete, typically by raising the slump from 75mm to 200 mm, the mix remaining cohesive. The resulting concrete can be placed with little or no compaction and is not subject to excessive bleeding or segregation. Such concrete is termed as flowing concrete and is useful for placing in very heavily reinforced sections, in inaccessible areas, in floor or road slabs, and also where very rapid placing is desired. The principal mode of action of superplastcisers is their ability to disperse cement particles very efficiently. As they do not entrain air, they can be used at high dosage rates without affecting strength.


**Fig 1.7 Superplasticiser**

### 1.7.1 TYPES OF SUPERPLASTICISER

There exist four main categories of superplastcisers based on their chemical composition:

(i) Sulfonated melamine formaldehyde condensates

(ii) Sulfonated naphthalene formaldehyde condensates

(iii) Modified lignosulfonates

(iv) Others such as sulfonic acid esters and carbohydrate esters

### 1.7.2 ADVANTAGES OF USING SUPERPLASTICISERS

i) Cement content can be reduced to a greater extent keeping the same water/cement ratio. This will lead to economy.

ii) Water-cement ratio can be reduced significantly keeping same cement content and workability. This will lead to increase in strength.

iii) Higher workability at very low water cement ratio like casting concrete with heavy reinforcement.

iv) Reduction in permeability.

# CHAPTER 2

## 2.1 LITERATURE REVIEW

**2.1.1** Study on properties of RHA and its use as cement replacement material
Authors: *Ghassan Abood Habeeb, Hilmi Bin Mahmud*

Summary: The compressive strength of the blended concrete with 10% RHA has been increased significantly, and for up to 20% replacement could be valuably replaced by cement without adversely affecting the strength. Increasing RHA fineness enhances the strength of blended concrete.

**2.1.2** Influence of marble powder/granules in concrete mix
Authors: *Baboo Rai, Khan Naushad H, Abhishek Kr, Tabin Rushad S, Duggal*

Summary: When marble powder is partially replaced in cement by weight, there is a marked reduction in compressive strength values of mortar mix with increasing marble powder content when compared with control sample at each curing age. The flexural strength of waste marble mix concrete increases with the increase of the waste marble ratio

**2.1.3** Partial replacement of cement with marble dust powders
Authors: *Prof. P.A. Shirulea, Ataur Rahman, Rakesh D. Gupta*

Summary: The Compressive strength of Cubes are increased with addition of waste marble powder up to 10% replace by weight of cement and further any addition of waste marble powder the compressive strength decreases. The optimum percentage for replacement of marble powder with cement and it is almost 10% cement for both cubes and cylinders.

**2.1.4** Rice husk ash – an ideal admixture for concrete in aggressive environments

Author: *R.N. Krishna*

Summary: Considerable study needs to be done on applications of RHA as repair mortars, coatings and soil Stabilization.

**2.1.5** Study of concrete properties using rice husk ash and marble powder

Authors: *Piyush Raikwar, Vandana Tare*

Summary: Addition of RHA and MP in concrete improves the properties of concrete on addition of RHA-MP in concrete the concrete is durable. When 21 % of cement is replaced by 10% Rice husk ash and 5% Marble Powder, flexural strength of RHA-MP concrete is more than the normal concrete

**2.1.6** A study on use of rice husk ash in concrete

Authors: *P.Padma Rao, P.Pradhan Kumar, B.Bhaskar Singh*

Summary: At all the cement replacement levels of Rice husk ash there is gradual increase in compressive strength from 3 days to 7 days. However there is significant increase in compressive strength from 7 days to 28 days followed by gradual increase from 28 days to 56 days. At the initial ages, with the increase in the percentage replacement of both Rice husk ash, the flexural strength of Rice husk ash concrete is found to be decrease gradually till 7.5% replacement.

**2.1.7** Experimental study on use of waste marble dust in concrete

Authors : *Aalok D. Sakalkale, G. D. Dhawale, R. S. Kedar*

Summary :The compressive strength of concrete is increased with addition of waste marble powder up to 50% by weight in place of sand and further any addition of waste marble powder the compressive strength decreases.

**2.1.8** Use of rice husk ash as partial replacement for cement in concrete

Authors : *Obilade, I.O*

Summary : The optimum addition of RHA as partial replacement for cement is in the range 0-20%. The compacting factor values of the concrete reduces as the percentage of RHA increases. The Bulk Densities of concrete reduced as the percentage RHA replacement increased. The Compressive Strengths of concrete reduced as the percentage RHA replacement increased.

**2.1.9** Study on properties of concrete using marble dust and rise husk ash

Authors: *Jayesh Patel Prof. M.A.Jamnu*

Summary: Use of marble dust up to 10% uses of concrete make the maximum strength for the normal concrete. Maximum strength for 10% replacement of marble dust in concrete. Maximum compressive and tensile strength about 10% replacement of rise husk ash for cement content so both materials are use up to 10% replacement of cement content in maximum strength.

**2.1.10** Effect of using MP in concrete mixes on the behavior and strength of R.C slabs

Author: *Noha M. Soliman*

Summary: Workability was increased by using small amount of marble powder ratio as a replacement of cement and leads to increase the compaction and the strength of concrete.
Increasing the marble powder ratio replacement of cement led to the increasing as the compressive strength by about (25% and 8%) for the marble powder replacement ratios (5% and 7.5%) compared to the control mix.

## 2.2 RESEARCH GAP

After studying and analyzing the research papers it was concluded that there has been significant study been carried out with both RHA and MD mixed separately in concrete but not much research work has been carried out with mix of RHA and MD.in SCC. Thereby to obtain a definite mix ratio of Rice Husk Ash and Marble Dust to obtain a concrete with better strength characteristics than the normal concrete.

## 2.3 OBJECTIVES

- To Compare the properties of SCC with normal concrete
- To investigate the behavior of SCC on addition of RHA and MD.
- To analyze the difference in strength characteristics of SCC by adding different proportions of RHA and MD (5%, 10%, 15%, 20%, 25%, 30% and 35%)
- To recommend the best possible mix ratio for better strength, more load bearing conditions.

Addition of RHA and MD to concrete and to study the strength properties of concrete with the variation in RHA and MD content by Cement Replacement in concrete i.e., to study the strength properties of M40 concrete mix by performing various tests on the design mix concrete. .

The strength properties being studied in our thesis are as follows:

1. Compressive strength
2. Split tensile Strength
3. Flexural strength

# CHAPTER 3

# EXPERIMENTAL INVESTIGATION

## 3.1 EXPERIMENTAL PROGRAM

In order to study the interaction of Marble Dust and Rice Husk Ash with concrete as cement replacement under compression, flexure and split tension various cubes, beams and cylinders were casted to perform various experiments

The experimental program was divided into following groups.
Each group consists of cubes, cylinders and beams

Dimensions:

| | |
|---|---|
| Cube | 15 x 15 x 15 cm, |
| Cylinder | 10 x 20 cm |
| Beam | 10 x 10 x 50 cm |

• The first group is the control concrete with 0% RHA and MD

0% - 0% MD + 0% RHA

• Then the following groups will be casted with the following ratio distributions:

| | | | | | | |
|---|---|---|---|---|---|---|
| 5% | - | 2% MD | + | 3% | RHA | as cement replacement |
| 10% | - | 4% MD | + | 6% | RHA | as cement replacement |
| 15% | - | 6% MD | + | 9% | RHA | as cement replacement |
| 20% | - | 8% MD | + | 12% | RHA | as cement replacement |

25% - 10% MD + 15% RHA as cement replacement

30% - 12% MD + 18% RHA as cement replacement

35% - 14% MD + 21% RHA as cement replacement

• One additional group consisting of 10% of Marble Dust as cement replacement is casted to determine the properties and behavior of SCC under loading because no adequate data is present for MD.

## 3.2 MATERIALS

### 3.2.1 CEMENT

Cement acts as a binding agent for materials. Cement as applied in Civil Engineering Industry is produced by calcining at high temperature. It is a mixture of calcareous, siliceous, aluminous substances and crushing the clinkers to a fine powder. Cement is the most expensive materials in concrete and it is available in different forms. When cement is mixed with water, a chemical reaction takes place as a result of which the cement paste sets and hardens to a stone mass. Depending upon the chemical compositions, setting and hardening properties, cement can be broadly divided into following categories.

- Portland cement
- Special Cement

Cement used in the project was provided by the university itself. The cement used in the experiment is Ambuja Cement 53 grade, the cement obtained was pre hydrated as lump formation was observed. Storage of cement requires extra special care to preserve its quality and fitness for use. To prevent its deterioration it is necessary to protect it from rain, winds and moisture.

**Fig 3.2.1 - Cement**

| Oxide | % content |
|---|---|
| CaO | 60-67 |
| $SiO_2$ | 17-25 |
| $Al_2O_3$ | 3-8 |
| $Fe_2O_2$ | 0.5-6.0 |
| MgO | 0.1-0.4 |
| Alkalies | 0.1-1.3 |
| $SO_3$ | 1.0-3.0 |

Table 3.2.1 Chemical composition of Cement as per IS 12269 (1987)

### 3.2.2 FINE AGGREGATES

Fine aggregates was procured from JUIT campus itself. Initial observations showed the presence of various impurities and moisture. The impurities were removed by sieve analysis. It had cubical or rounded shape with smooth surface texture. Being cubical, rounded and smooth texture it give good workability. Sieve analysis was done to find out fineness modulus which comes out to be 3.14% which is under limit as per IS 383-1970. The specific gravity of Fine aggregate was 2.65

### 3.2.3 COARSE AGGREGATES

The Corse Aggregates were taken from JUIT campus, Initial observations showed the presence of dust particles and leaves. The material whose particles are of size as are retained on I.S Sieve No.480 (4.75mm) is termed as coarse aggregate. The size of coarse aggregate depends upon the nature of work. The coarse aggregate used in this experimental investigation are of 20mm and below. The aggregates are free from dust before used in the concrete.

### 3.2.4 WATER

Water to be used in the concrete work should have following properties:

- It should be free from injurious amount of soils
- It should be free from injurious amount of acids, alkalis or other organic or inorganic impurities.
- It should be free from iron, vegetable matter or any other type of substances, which are likely to have adverse effect on concrete or reinforcement.
- It should be fit for drinking purposes.

The function of water in concrete

• It acts as lubricant

• It acts as a chemically with cement to form the binding paste for coarse aggregate and reinforcement

• It enables the concrete mix to flow into formwork.

### 3.2.5 RICE HUSK ASH

Rice Husk Ash was obtained from KGR Agro Fusions Pvt. Ltd. Ludhiana, Punjab. Rice Husk Ash was burnt for approximately 72hours in air in an uncontrolled burning process. The temperature was in the range of 400-600 degree C .The ash collected was grey in colour.

Technical Specifications:
Silica : 85%
minimum Humidity: 2%
maximum Particle size: 25 -45 microns
Colour : Grey
Loss on ignition at 800 C : 4 %
maximum pH value: 8

### 3.2.6 MARBLE DUST

Marble powder is produced from the marble processing plants during the cutting, shaping and polishing. During this process, about 20-25% of the process marble is turn into the powder form. India being the topmost exporter of marble, every year million tons of marble waste form processing plants are released. The disposal of this waste marble on soils causes reduction in permeability and contaminates the over ground water when deposited along catchment area.

Thus, utilizing these marble waste in construction industry itself would help to protect the environment from dumpsites of marble and also limit the excessive mining of natural resources of sand.

The Marble Dust Powder used in experiment was obtained from marble processing factory in Makrana Tehsil of Nagaur district in Rajasthan.

Physical properties

Colour - White

Form – Fine Powder

Odour - Odourless

Specific gravity - 2.68 gm/cm3

| | |
|---|---|
| $Sio_2$ | 25-30 |
| $Al_2o_3$ | 0.3-0.5 |
| $Fe_2o_3$ | 8-10 |
| Cao | 38-45 |
| Mgo | 15-18 |
| Specific gravity | 2.55 |

Table 3.2.6 Chemical Composition of Marble Dust Powder (as provided by the supplier)

### 3.2.7 SUPERPLASTICSER

In the experimental program two different types of superplastcisers were used due to the failure of various test samples by the use of first superplasticiser.
The superplasticiser used initially was Sikament® 280/1(ITD)

Technical Data:
Aspect: Dark Brown Liquid
Type: Modified Napthalene Formaldehyde Sulphonate
Specific Gravity: Around 1.24

Weakness: Setting time increased, effect of temperature observed, in the given conditions.

The main superplasticiser used for the Experimental Program is Conplast® SP430(G) by FOSROC.

Properties:
Specific gravity 1.20 to 1.22 at 300C
Chloride content Nil. as per IS:9103-1999 and BS:5075
Air entrainment Approx. 1% additional air over control

Conplast SP430 G is based on Sulphonated Napthalene Polymers and supplied as a brown liquid instantly dispersible in water. Conplast SP430 G has been specially formulated to give high water reductions up to 25% without loss of workability or to produce high quality concrete of reduced permeability.

**Fig 3.2.7 – Use of Superplasticiser**

## 3.3 MIX DESIGN FOR M40 GRADE CONCRETE

a) Grade designation: M40

b) Type of cement: OPC 53 grade confirming to IS 8112

c) Maximum nominal size of aggregates: 20 mm

d) Minimum cement content: 320 kg/m3

e) Maximum water cement ratio: 0.45

f) Workability: 100 mm (slump)

g) Exposure condition: Moderate

h) Method of concrete placing: Pumping

i) Degree of supervision: Good

j) Type of aggregate: Crushed angular aggregate

k) Maximum cement content: 450 kg/m3

l) Chemical admixture: Superplasticiser Fosroc Conplast SP 430 G8

TEST DATA FOR MATERIALS

a) Cement used: OPC 53 grade confirming to IS 8112

b) Specific gravity of cement: 3.15

c) Chemical admixture: Superplasticiser Fosroc Conplast SP 430 G8 conforming to IS 9103

d) Specific gravity of

Coarse aggregate: 2.74

Fine aggregate: 2.74

e) Water absorption

Coarse aggregate: 0.5 percent

Fine aggregate: 1.0 percent

f) Free (surface) moisture

Coarse aggregate: Nil (absorbed moisture also nil)

Fine aggregate: Nil (very less observed)

g) Sieve analysis

Coarse aggregate: Conforming to Table 2 of IS: 383

Fine aggregate: Conforming to Zone I of IS: 383

TARGET STRENGTH FOR MIX PROPORTIONING

$f'ck = fck + 1.65\ s$

Where

f'ck = Target average compressive strength at 28 days,

fck = Characteristic compressive strength at 28 days,

s= Standard deviation

Standard deviation, s = 5 N/mm2

Therefore target strength = 40 + 1.65 x 5 = 48.25 N/mm2

SELECTION OF WATER CEMENT RATIO

From Table 5 of IS: 456-2000, maximum water cement ratio = 0.45

Based on experience adopt water cement ratio as 0.40

0.40 < 0.45, hence ok

SELECTION OF WATER CONTENT

Maximum water content = 186 liters (for 25mm – 50mm slump range and for 20 mm aggregates)

Estimated water content for 100 mm slump = 186 + 6/100 x186 = 197 liters

As superplasticiser is used, the water content can be reduced up to 20 percent and above

Based on trials with SP water content reduction of 25 percent has been achieved.

Hence the water content arrived = 197 x 0.75 =147.75 liters

CALCULATION OF CEMENT CONTENT

Water cement ratio = 0.40

Cement content = 147.75/0.40 = 370 kg/m3

From Table 5 of IS: 456, minimum cement content for severe exposure condition = 320 kg/m3

370 kg/m3 > 320 kg/m3, hence OK

PROPORTION OF VOLUME OF COARSE AGGREGATE AND FINE AGGREGATE CONTENT

From Table 3 IS 456, volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate (Zone IV) for water-cement ratio of 0.50 =0.66

In the present case w/c= 0.40. The volume of coarse aggregate is required to be increased to decrease the fine aggregate content. As w/c ratio is lower by 0.10, increase the coarse aggregate volume by 0.02 (at the rate of -/+ 0.01 for every +/- 0.05 change in water cement ratio). Therefore corrected volume of coarse aggregate for w/c of 0.40 =0.68

Note: In case the coarse aggregate is not angular, then also the volume of CA may be required to be increased suitably based on experience

For pumpable concrete these values should be reduced by 10 percent

Therefore volume of coarse aggregate = 0.68 x 0.9 = 0.61

Volume of fine aggregate content = 1- 0.62 = 0.39

MIX CALCULATIONS

The mix calculations per unit volume of concrete shall be as follows

a) Volume of concrete = 1 $m^3$

b) Volume of cement = [370/3.15] x [1/1000] = 0.117 m3

c) Volume of water = [148/1] x [1/1000] = 0.148 m3

d) Volume of chemical admixture = [7.4/1.195] x [1/1000] = 0.006 m3 (SP 2%by mass of cement)

e) Volume of all in aggregates (e) =a – (b + c + d) = 1 – (0.117 + 0.148 + 0.006) = 0.729 m3

f) Volume of coarse aggregates = e x Volume of CA x specific gravity of CA

= 0.729 x 0.61 x 2.74 x 1000 = 1222.89 kg

g) Volume of fine aggregates = e x Volume of FA x specific gravity of FA

= 0.729 x 0.39 x 2.74 x 1000 = 779 kg

**MIX PROPORTIONS**

Cement = 370 kg/m3

Water = 148 kg/m3

Fine aggregate = 779 kg/m3

Coarse aggregates = 1222 kg/m3

Chemical admixture = 7.4 kg/m3

Water cement ratio = 0.40

The slump shall be measured and the water content and dosages of admixture shall be adjusted for achieving the required slump based on trials, if required. The mix proportions shall be reworked for the actual water content and checked for durability requirements.

Two more trials having variation of ± 10 percent of water cement ratio shall be carried out keeping water content constant, and a graph between three water cement ratios and their corresponding strengths shall be plotted to work out the mix proportions for the given target strength for field trials. However, durability requirements shall be met.

## 3.4 FOR 1 Kg Cement M40 GRADE CONCRETE Batch will Contain

Cement = 1 kg

Water = 0.42 ltr

F.A = 2.10 kg

C.A = 3.30 kg

Chemical Admixture = 0.02

## 3.5 MIXING OF SPECIMEN:

Hand mixing is adopted throughout the experimental work. First the materials cement, fine aggregate, coarse aggregate, superplasticiser, RHA and Marble Dust are weighed accurately as per the previously mentioned calculations.

The sand is laid in a layer of approximately 10cm thick. Then cement is added to the sand and mixed thoroughly to get a uniform colour. The coarse aggregate is spread on the ground and then the cement-sand mixture is mixed with it to get a uniform matrix. The superplasticiser is mixed with 20% water which is procured off the total water content and added simultaneously after adding water. The additives MD and RHA are added with cement to produce a uniform blend. After mixing the fresh concrete is tested for the workability using slump test.

**Fig 3.5 a - Batching**

**Fig 3.5 b – Mixing**

**Fig 3.5 c – Final Mix**

## 3.6 TESTS ON FRESH CONCRETE

### 3.6.1 SLUMP TEST

Slump test is the most commonly used method for measuring consistency of concrete which can be employed either in laboratory or at site of work. It is not a suitable method for very wet or very dry concrete. It is used conveniently as a control test and gives an indication of the uniformity of concrete from batch to batch.

Slump cone - a mould of 1.6 mm thick galvanized metal in the form of the lateral surface of the frustum of a cone with the base 200 mm in diameter, the top 100 mm in diameter and the height 300 mm. The base and the top shall be open and parallel to each other and at right angles to the axis of the cone. The mould shall be provided with a foot piece on each side for holding the mould in place, and with handles for lifting the mould from the sample. Tamping Rod - A round, straight steel rod 16 mm in diameter and approximately 600 mm in length. The tamping end shall be a hemisphere 16 mm in diameter.

**Procedure:**

1. Dampen the slump test mould and place it on a flat, moist, nonabsorbent, rigid surface, like steel rod.
2. Fill the mould to 1/3 full by volume and rod the bottom layer with 25 evenly spaced strokes.
3. Fill the mould to 2/3 full and rod the second layer with 25 strokes penetrating the top of the bottom layer.
4. Heap the concrete on top of the mould, and rod the top layer with 25 strokes penetrating the top of the second layer.
5. Strike off the top surface of the concrete even to the top of the mould.
6. Remove the mould carefully in the vertical direction (take about five seconds).
7. Immediately invert and place the mould beside the slumped concrete and place the rod horizontally across the mould, and measure the slump, in mm.

### 3.6.2 COMPACTION FACTOR TEST

It is one of the most efficient tests for measuring the workability of concrete. This test works on the principle of determining the degree of compaction achieved by a standard amount of work done by allowing the concrete to fall through a standard height. The degree of compaction called the compaction factor is measured by the ratio of density of actually achieved in the test to the density of the same concrete fully compacted.

The sample of concrete to be tested is placed in the upper hopper up to the brim. The trap door of the lower hopper is opened so that the concrete falls into the lower hopper. The trap door of the lower hopper is opened so that the concrete falls into the cylinder. In case of dry mix it is likely that the concrete may not fall in opening the trap door. In such case a slight poking by a rod may be required to see the concrete in motion. The excess concrete remaining above the top level of the cylinder is then cut-off with help of plain blades. The outside of cylinder is wiped clean. The concrete is filled up exactly up to the top level of the cylinder. It is weighed to the lowest 10gm. This is known as the weight of partially compacted concrete. The cylinder is emptied and then refilled with the concrete from the same sample in three layers approximately. The layers are heavily rammed 25blows) to obtain full compaction. The top surface of the fully compacted concrete is carefully struck of level with the top of the cylinder and weighed to the nearest 10gm. This weight is known as the weight of fully compacted concrete.

Compaction factor = weight of partially compacted concrete/weight of fully compacted concrete

The compacting factor is calculated for various percentages of RHA and MD. Workability is the property of concrete which determines the amount useful internal work necessary to produce full compaction. As per IS 6461-1972, workability is defined as “the ease which it can be mixed, transported, placed and compacted easily.”

**Fig 3.6.2 Compaction factor Test Apparatus**

## 3.7 CASTING OF SPECIMEN

For casting the cubes, beam specimens, standard cast iron metal moulds of size 150x150 cubes, 100x100x50mm beam moulds are used. The moulds have been cleaned of dust particles and applied with mineral oil on all sides, before the concrete is poured into the moulds. Thoroughly mixed concrete is filled into the mould in three layers of equal heights followed by tamping. Then the mould is placed on the table vibrator for a small period. Excess concrete is removed with trowel and top surface is finished to smooth level.

**Fig 3.7 a – Moulded Specimen**

**Fig 3.7 b – Demoulded Specimen**

## 3.8 CURING

Curing is the process of preventing the loss of moisture from concrete while maintaining a satisfactory temperature. More elaborately curing is defined as process of maintaining satisfactory moisture content and favorable temperature in concrete during the period immediately following placement, so that hydration of cement may continue until the desired properties are developed to a sufficient degree to meet the requirement at service.

After casting the molded specimens are stored in the laboratory and at a room temperature for 24 hours from the time at addition of water to dry ingredients.

After this period the specimens are removed from the moulds immediately submerged in clean and fresh water. The specimens are cured for 7 days and 28days in the present work.

## 3.9 TESTS ON HARDENED CONCRETE:

### 3.9.1 CUBE COMPRESION TEST

This test was conducted as per IS 516-1959. The cubes of standard size 150x150x150mm were used to find the compressive strength of concrete. Specimens were placed on the bearing surface of UTM, of capacity 100tones without eccentricity and a uniform rate of loading of 550 Kg/cm2 per minute was applied till the failure of the cube. The maximum load was noted and the compressive strength was calculated.

Cube compressive strength (fck) in MPa = P/A

Where,

P= cube compression load

A= area of the cube on which load is applied (= 150 x 150= 22500 $mm^2$ )


**Fig 3.9.1 a – Finished cube**

**Fig 3.9.1 b - Compression testing Machine**

### 3.9.2 FLEXURAL TEST

Beams of size 100x100x500mm are tested using a flexure testing machine. The specimen is simply supported on the two rollers of the machine which are 600mm apart, with a bearing of 50mm from each support. The load shall be applied on the beam from two rollers which are placed above the beam with a spacing of 200mm. The load is applied at a uniform rate such that the extreme fibres stress increases at 0.7N/mm2/min i.e., the rate of loading shall be 4 KN/min. The load is increased till the specimen fails. The maximum value of the load applied is noted down. The appearance of the fracture faces of concrete and any unique features are noted.

The modulus of rupture is calculated using the formula.

$\sigma_s = 3Pl/2bd^2$, where,

P = load in N applied to the specimen

l = length in mm of the span on which the specimen is supported (600)

b = measured width in mm of the specimen

d = measured depth in mm of the specimen at point of failure.

**Fig 3.9.2 Flexure Testing machine**

### 3.9.3 SPLIT TENSILE TEST

Cylinders of size 15cm (dia) x 20cm (height) are casted. The test is carried out by placing a cylindrical specimen horizontally between the loading surface of a compression testing machine and the load is applied until the failure of the cylinder, along the vertical diameter. When the load is applied along the generatrix, an element on the vertical diameter of the cylinder is subjected to Horizontal stress of $2P/\pi ld$.

Where, P is the compressive load on the cylinder

l is the length of the cylinder

d is diameter of the cylinder.

The main advantage of this method is that the same type of specimen and the same testing machine as used for the compression test can be employed for this test. This is why this test is gaining popularity. The splitting test is simple to perform and gives more uniform results than the other tension tests. Strength determined in the splitting test is believed to be closer to the true tensile strength of concrete, than the modulus of rupture.


**Fig 3.9.3 Split Tensile Strength Testing in progress**

## 3.10 PRACTICAL DIFFICULTIES ENCOUNTERED

The various practical difficulties encountered can be summarized as below:

**1**. Various adjustments had to be made in the mix design due to hand mixing process.

**2**. Temperature variations were observed in H.P extreme cold climate delayed the setting time due to the low heat of hydration

**3**. Failure of various Test Specimens were observed due to the addition of Sikament® 280/1(ITD) Due to the delayed setting time. The setting time was adversely affected. After the delayed demoulding too the specimen were subject to failure further during the curing process the disintegration was observed.

As a result of the above mentioned difficulties the mix design, w/c ratio as well as the superplasticiser was replaced. The new superplasticiser (FOSROC Conplast SP 430G) showed more stable properties the setting time was reduced with better strength characteristics.

**4**. These Difficulties caused little delay in the completion of objective but was later rectified as per the guidance of my project Guide.

**Fig 3.10 Failed Sample at the time of demoulding**

# CHAPTER 4

# RESULTS

## 4.1 COMPRESSION TEST

**Fig 4.1 a Compression Test**

### 4.1.1 COMPRESSION TEST VALUES OF M40 GRADE SCC AFTER 7 DAYS CURING

| S.No | Percentage Distribution | | Load in N/mm$^2$ | | | Avg. Compressive Strength (N/mm$^2$ ) |
|---|---|---|---|---|---|---|
| | **MD** | **RHA** | **Trial 1** | **Trial 2** | **Trial 3** | |
| **1** | **0** | **0** | **25.22** | **25.41** | **25.38** | **25.33** |
| **2** | **10** | **0** | **26.79** | **26.72** | **26.76** | **26.75** |
| **3** | **2** | **3** | **26.98** | **26.93** | **26.95** | **26.96** |
| **4** | **4** | **6** | **28.64** | **28.79** | **29.02** | **28.81** |
| **5** | **6** | **9** | **29.64** | **30.08** | **30.10** | **29.94** |
| **6** | **8** | **12** | **30.89** | **30.96** | **31.10** | **30.98** |
| **7** | **10** | **15** | **31.74** | **31.80** | **31.84** | **31.79** |
| **8** | **12** | **18** | **31.04** | **30.87** | **30.72** | **30.87** |
| **9** | **14** | **21** | **29.68** | **29.54** | **29.63** | **29.61** |

### 4.1.2 COMPRESSION TEST VALUES OF M40 GRADE SCC AFTER 28 DAYS CURING

| S.No | Percentage Distribution | | Load in $N/mm^2$ | | | Avg. Compressive Strength ($N/mm^2$) |
|---|---|---|---|---|---|---|
| | **MD** | **RHA** | **Trial 1** | **Trial 2** | **Trial 3** | |
| **1** | **0** | **0** | **36.62** | **36.74** | **36.68** | **36.68** |
| **2** | **10** | **0** | **37.41** | **37.60** | **37.55** | **37.52** |
| **3** | **2** | **3** | **37.84** | **37.78** | **37.75** | **37.79** |
| **4** | **4** | **6** | **39.91** | **40.12** | **40.45** | **40.16** |
| **5** | **6** | **9** | **41.34** | **42.33** | **42.45** | **41.96** |
| **6** | **8** | **12** | **43.12** | **43.34** | **43.41** | **43.23** |
| **7** | **10** | **15** | **44.34** | **44.42** | **44.51** | **44.48** |
| **8** | **12** | **18** | **43.30** | **42.74** | **42.88** | **42.96** |
| **9** | **14** | **21** | **41.82** | **41.94** | **41.77** | **41.84** |

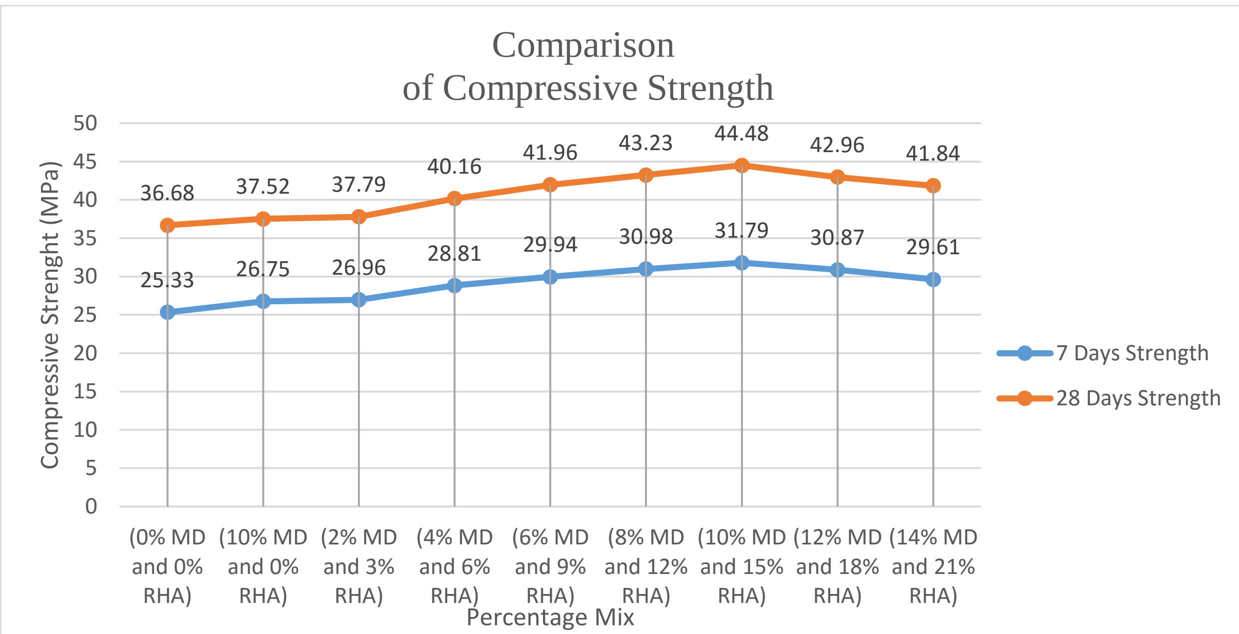


**Fig 4.1 b Graph for 7 & 28 days of Compressive strength**

## 4.2 SPLIT TENSILE TEST

**Fig 4.2 a – Split Tensile Strength Test**

### 4.2.1 SPLIT TENSILE TEST VALUES OF M40 GRADE SCC AT 7 DAYS CURING

| S.No | Percentage Distribution | | Load in N/mm$^2$ | | | Avg. Split Tensile Strength (N/mm$^2$ ) |
|---|---|---|---|---|---|---|
| | **MD** | **RHA** | **Trial 1** | **Trial 2** | **Trial 3** | |
| **1** | **0** | **0** | **3.09** | **3.11** | **2.96** | **3.11** |
| **2** | **10** | **0** | **3.23** | **3.12** | **3.19** | **3.18** |
| **3** | **2** | **3** | **3.14** | **3.11** | **3.24** | **3.16** |
| **4** | **4** | **6** | **3.26** | **3.31** | **3.35** | **3.30** |
| **5** | **6** | **9** | **3.52** | **3.59** | **3.68** | **3.59** |
| **6** | **8** | **12** | **3.89** | **3.81** | **3.93** | **3.88** |
| **7** | **10** | **15** | **4.11** | **3.94** | **3.99** | **4.01** |
| **8** | **12** | **18** | **3.84** | **3.71** | **3.73** | **3.76** |
| **9** | **14** | **21** | **3.54** | **3.49** | **3.61** | **3.54** |

### 4.2.2 SPLIT TENSILE TEST VALUES OF M40 GRADE SCC AT 28 DAYS CURING

| S.No | Percentage Distribution | | Load in $N/mm^2$ | | | Avg. Split Tensile Strength ($N/mm^2$) |
|---|---|---|---|---|---|---|
| | **MD** | **RHA** | **Trial 1** | **Trial 2** | **Trial 3** | |
| **1** | **0** | **0** | **4.06** | **4.02** | **4.00** | **4.02** |
| **2** | **10** | **0** | **4.30** | **4.16** | **4.25** | **4.23** |
| **3** | **2** | **3** | **4.18** | **4.11** | **4.28** | **4.20** |
| **4** | **4** | **6** | **4.29** | **4.38** | **4.42** | **4.36** |
| **5** | **6** | **9** | **4.61** | **4.63** | **4.74** | **4.66** |
| **6** | **8** | **12** | **4.98** | **4.90** | **4.93** | **4.92** |
| **7** | **10** | **15** | **5.20** | **5.06** | **5.11** | **5.09** |
| **8** | **12** | **18** | **4.82** | **4.75** | **4.73** | **4.76** |
| **9** | **14** | **21** | **4.56** | **4.48** | **4.62** | **4.55** |

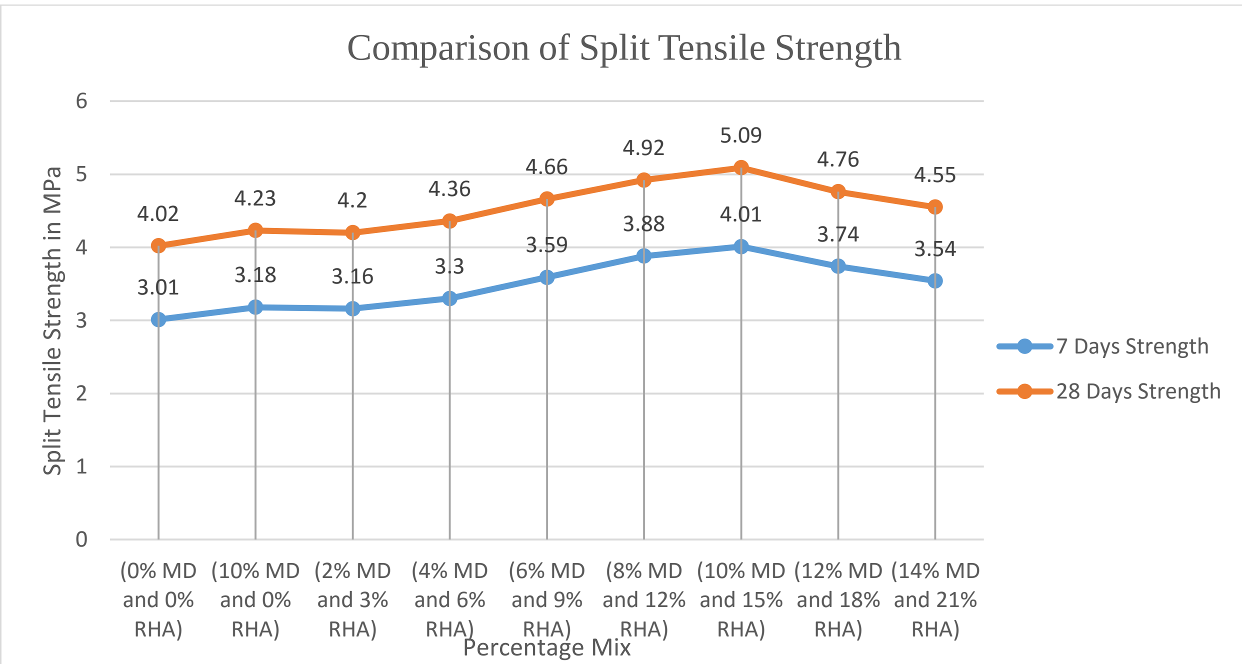


**Fig 4.2 b Graph for 7 & 28 days of Split Tensile strength**

## 4.3 FLEXURAL TEST

**Fig 4.3 a – Flexure Test**

### 4.3.1 FLEXURAL TEST VALUES OF M40 GRADE SCC AT 28 DAYS CURING

| S.No | Percentage Distribution | | Load in N/mm$^2$ | | | Avg. Flexural Strength (N/mm$^2$ ) |
|---|---|---|---|---|---|---|
| | **MD** | **RHA** | **Trial 1** | **Trial 2** | **Trial 3** | |
| **1** | **0** | **0** | **3.89** | **3.91** | **3.86** | **3.88** |
| **2** | **10** | **0** | **3.95** | **3.98** | **3.94** | **3.96** |
| **3** | **2** | **3** | **4.04** | **4.01** | **3.95** | **4.01** |
| **4** | **4** | **6** | **4.24** | **4.21** | **4.10** | **4.18** |
| **5** | **6** | **9** | **4.36** | **4.39** | **4.32** | **4.35** |
| **6** | **8** | **12** | **4.49** | **4.38** | **4.42** | **4.43** |
| **7** | **10** | **15** | **4.52** | **4.59** | **4.57** | **4.56** |
| **8** | **12** | **18** | **4.38** | **4.40** | **4.32** | **4.36** |
| **9** | **14** | **21** | **4.20** | **4.31** | **3.98** | **4.16** |

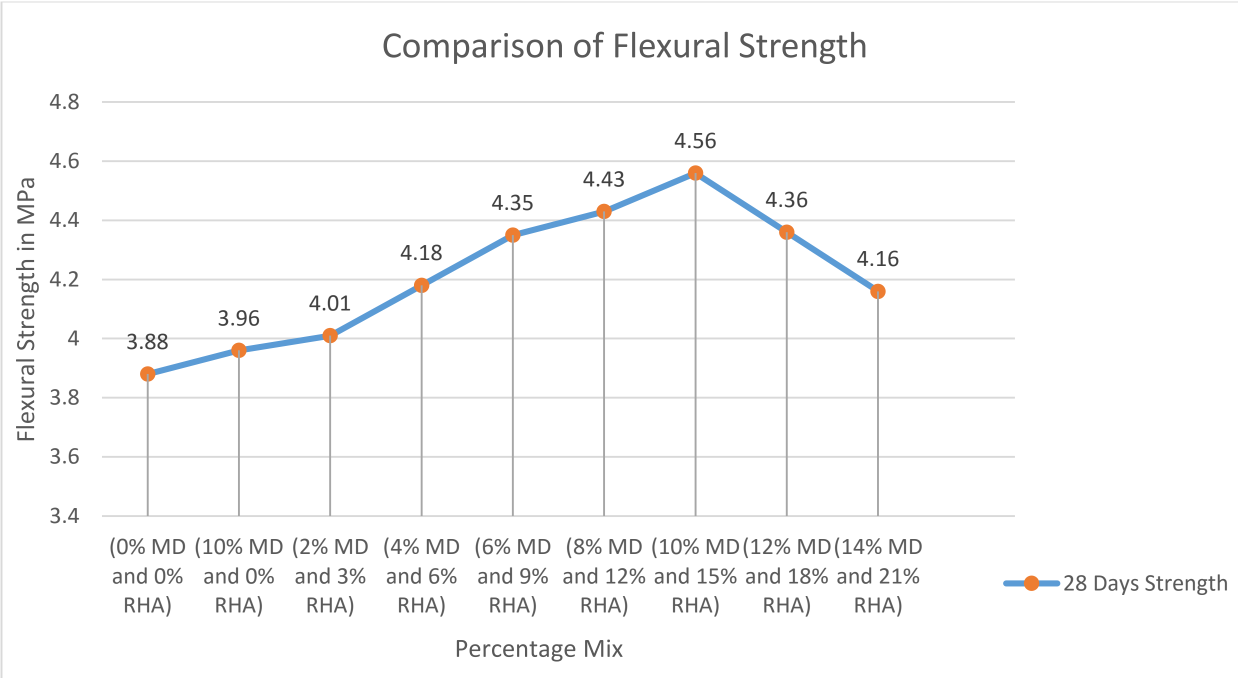


**Fig 4.3 b – Graph of Flexure Strength**

## 4.4 SLUMP TEST

| Percentage | Slump (in mm) |
|---|---|
| 0% Mix | 61 |
| 5% Mix | 64.3 |
| 10% MD Mix | 66 |
| 10% Mix | 68 |
| 15% Mix | 72 |
| 20% Mix | 75 |
| 25% Mix | 78 |
| 30% Mix | 81 |
| 35% Mix | 84 |

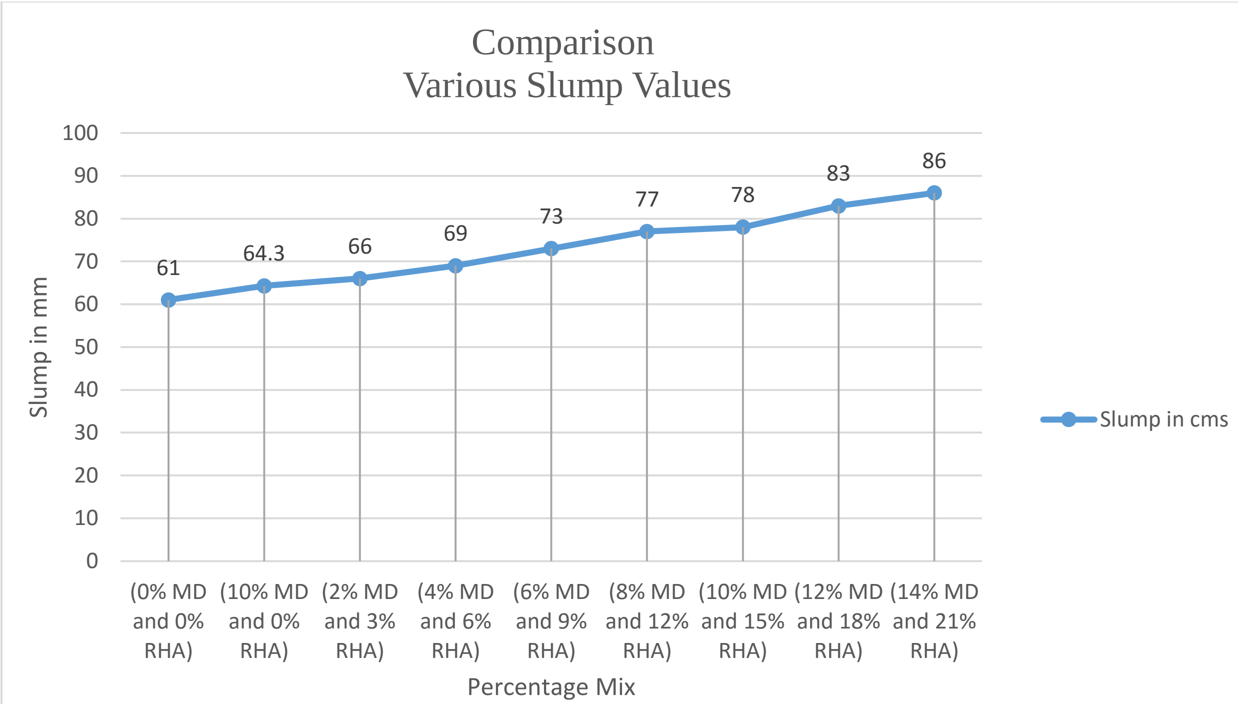


**Fig 4.4 Graph of Slump Test**

## 4.5 COMPACTION FACTOR TEST

| Percentage | Compaction Factor |
|---|---|
| 0% Mix | 0.73 |
| 5% Mix | 0.76 |
| 10%  MD Mix | 0.75 |
| 10% Mix | 0.79 |
| 15% Mix | 0.82 |
| 20% Mix | 0.87 |
| 25% Mix | 0.90 |
| 30% Mix | 0.94 |
| 35% Mix | 0.98 |

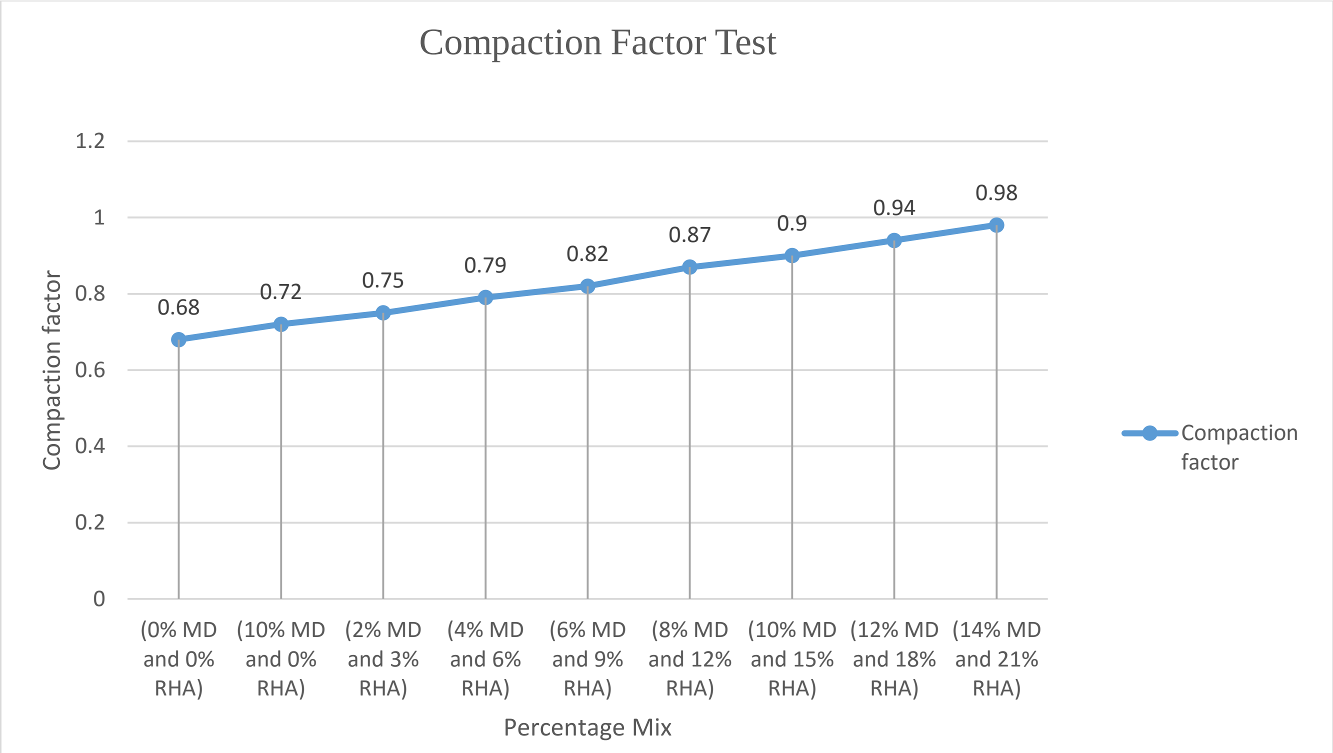


**Fig. 4.5 – Graph of Compaction Factor Test**

## 4.6 OBSERVATIONS

- Maximum Compressive strength of concrete increased by 25.45 % and 26.88 % at 25% replacement of cement by MD and RHA at 7 and 28 days.
- Maximum split tensile strength of concrete increased by 27.6% and 24.5% at 30% replacement of cement by MD and RHA at 7 and 28 days.
- Optimum content of MD and RHA is 25% (10+15 %) by weight replacement of Cement with MD and RHA in M40 mix.
- It is observed that, the workability of concrete increases for all percentage replacements done in design mix.
- It is observed that, the compaction factor of concrete increases for all percentage replacements done in design mix.

# CHAPTER 5

# CONCLUSION

- Compressive strength is increased due to the presence of pozzolonic material and the fine filler material.

- With further increase in the ratio of RHA and MD from 10% and 15% there has been a gradual decrease in strength properties.

- The optimum content of RHA-MD based concrete M40 design mix is 25%.

- It is depicted from this study that the marble dust is very low cost and waste material and improves the strength compare the normal concrete and rise husk ash is agro waste so his cost is low and improve the workability and increase compressive strength.
- Use of RHA and MP solves the problem of disposal of these materials.
- Workability was increased by using small amount of marble powder and rice husk ash ratio as a replacement of cement and leads to increase the compaction and the strength of concrete.
- The pozzolonic activity of RHA is not only effective in enhance the concrete strength, but also in improving the impermeability characteristics of concrete.
- Due to addition of rice Husk ash, concrete becomes cohesive and more plastic and thus permits easier placing and finishing of concrete. It also increases workability of concrete.
- The usage of waste marble dust in concrete show as a filler effect as it is an inert addition and it can be assumed as ultrafine aggregates filling voids in concrete. The usage of waste marble dust reduces the porosity in concrete matrix physically, and has an important binding property which is developed by hydration of calcite and $C_3A$ chemically

# CHAPTER 6

# FUTURE WORK

- Various tests on the durability can be carried out with the mix ratios studying the behavioral properties of the mix.

- Study on the properties of concrete with different mix ratios of concrete.

- Cost analysis can be carried out to check for the comparative study between the cost of normal concrete and the concrete with RHA and MD.

# CHAPTER 7

# RECOMMENDATIONS

The tests conducted on M40 design mix concrete indicates that there has been a constant increase in the strength characteristics and properties of hardened concrete upto 25% addition of RHA-MD (10 % MD and 15% RHA) as replacement of cement by weight. Therefore recommended percentage of RHA-MD is 25% when replaced with cement by weight in the design mix of M40. Further conclusion made are the hardened concrete has better surface finish due to the presence of very fine particles ie. marble dust which is used as a filler material.

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# Annexure A

**Table 1 of IS 10262:2009**

**Table 1 Assumed Standard Deviation**

(*Clauses* 3.2.1.2, A-3 *and* B-3)

| Sl No. (1) | Grade of Concrete (2) | Assumed Standard Deviation $N/mm^2$ (3) |
|---|---|---|
| i) | M 10 | 3.5 |
| ii) | M 15 | |
| iii) | M 20 | 4.0 |
| iv) | M 25 | |
| v) | M 30 | 5.0 |
| vi) | M 35 | |
| vii) | M 40 | |
| viii) | M 45 | |
| ix) | M 50 | |
| x) | M 55 | |

NOTE — The above values correspond to the site control having proper storage of cement; weigh batching of all materials; controlled addition of water; regular checking of all materials, aggregate grading and moisture content; and periodical checking of workability and strength. Where there is deviation from the above, values given in the above table shall be increased by 1 $N/mm^2$.

**Table 2 of Is 10262:2009**

**Table 2 Maximum Water Content per Cubic Metre of Concrete for Nominal Maximum Size of Aggregate**

(*Clauses* 4.2, A-5 *and* B-5)

| Sl No. | Nominal Maximum Size of Aggregate mm | Maximum Water Content [1] kg |
|---|---|---|
| (1) | (2) | (3) |
| i) | 10 | 208 |
| ii) | 20 | 186 |
| iii) | 40 | 165 |

NOTE — These quantities of mixing water are for use in computing cementitious material contents for trial batches.

[1] Water}content corresponding to saturated surface dry aggregate.

**Table 3 of IS 10262:2009**

**Table 3 Volume of Coarse Aggregate per Unit Volume of Total Aggregate for Different Zones of Fine Aggregate**

(*Clauses* 4.4, A-7 *and* B-7)

| Sl No. | Nominal Maximum Size of Aggregate mm | Volume of Coarse Aggregate[1] per Unit Volume of Total Aggregate for Different Zones of Fine Aggregate | | | |
|---|---|---|---|---|---|
| | | Zone IV | Zone III | Zone II | Zone I |
| (1) | (2) | (3) | (4) | (5) | (6) |
| i) | 10 | 0.50 | 0.48 | 0.46 | 0.44 |
| ii) | 20 | 0.66 | 0.64 | 0.62 | 0.60 |
| iii) | 40 | 0.75 | 0.73 | 0.71 | 0.69 |

[1] Volumes are based on aggregates in saturated surface dry condition.

# Annexure B

## Photographs Taken During Course of Experiment


Compression Testing
Machine


Compression Testing
Machine


Compression Testing
Machine