“EFFECTS OF COPPER SLAG ON CONCRETE”

Project Report Submitted In Partial Fulfillment of Requirements for the Degree

Of

Masters of Technology

IN

CIVIL ENGINEERING

With specialization in

Structural Engineering

Under the Guidance of

Dr. Ashok kumar Gupta

(Professor and Head of Civil Department)

and

Mr. Abhilash Shukla

(Assistant Professor)

By:

Shashank Srivastava

Enrollment no: 142656

to

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY

WAKNAGHAT SOLAN – 173234

HIMACHAL PRADESH INDIA

June, 2016

CERTIFICATE

This is to certify that the work which is being presented in the project title **"EFFECTS OF COPPER SLAG ON CONCRETE"** in partial fulfillment of the requirements for the award of the degree of Bachelor of technology and submitted in Civil Engineering Department with specialization in "**Structural Engineering**" and submitted to the Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat is an authentic record of work carried out by **Shashank Srivastava (142656)** during a period from July 2015 to June 2016 under the supervision of **Mr. Abhilash Shukla**, Assistant Professor, Civil Engineering Department, Jaypee University of Information Technology, Waknaghat.

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

Date: -_________________

Dr. Ashok Kumar Gupta	Mr. Abhilash Shukla	External Examiner
Professor & Head of Department	Assistant Professor	
Civil Engineering Department	Civil Engineering Department	
JUIT Waknaghat	JUIT Waknaghat	

ACKNOWLEDGEMENT

"I have taken efforts in this project. However, it would not have been possible without the kind support and help of many individuals. I would like to extend my sincere thanks to all of them.

I am highly indebted to my guide Mr. Abhilash Shukla for their guidance and constant supervision as well as for providing necessary information regarding the project & also for his support in the project.

I would like to express my gratitude towards my head of department Dr. Ashok Kumar Gupta and JAYPEE UNIVERSITY of INFORMATION TECHNOLOGY for their kind co-operation and encouragement which help me in completion of this report.

My thanks and appreciations also go to Mr. Itesh Singh and civil department in developing the project and people who have willingly helped me out with their abilities.

My juniors were always very helpful to me. They were always there for me whenever I needed their support. I would like to thank my parents for their continuous support and motivation. Finally I would like to thank to all who directly or indirectly helped us in completing this project.

Shashank Srivastava

(142656)

TABLE OF CONTENTS

ABSTRACT....................vi

LIST OF SYMBOLS AND ABBREVIATIONS vii

LIST OF TABLES viii

LIST OF FIGURES....................ix

CHAPTER 1 1

1. INTRODUCTION....................1

1.1.COPPER SLAG 1

1.1.1 Physical Properties of copper slag 2

1.1.1. Chemical composition of copper slag 3

1.2 Cement 4

1.3 Chemical compostion of copper slag and cement....................5

CHAPTER 2 6

2.1 Literature review....................6

2.2 Research gap....................10

2.3 Objectives 11

CHAPTER 3 12

3.1 EXPERIMENTAL PROGRAMME....................12

3.2 MATERIAL USED 12

3.2.1 Cement....................12

3.2.2 Fine Aggregates....................13

3.2.3 Coarse Aggregate....................14

3.2.4 Water 15

3.2.5 Supplementary materials....................16

3.3 Mixture Proportioning- 17

3.3.1. For partial replacement of fine aggregates with copper slag....................17

3.3.2. For partial replacement of cement with copper slag 19

3.4 Batching, Mixing and Casting of Specimens 21

3.5 Tests Conducted....................23

3.5.1 Compression test (IS: 516 – 1959) 23

3.5.2. Strength Activity Test by A.S.T.M. (C311) 23

3.5.3. Workabiliy test by Slump 24
3.5.4. Compaction test- 24
3.5.5. Split tensile test 25
3.5.6. Flexural Bending Test (IS: 516 – 1959) 26
3.5.7. Durability tests 27
3.5.7.1 Sulphate Attack 27
3.5.7.2 Chloride Attack 28
Chapter 4 29
4.1. RESULTS AND DISCUSSION FOR PARTIAL REPLACEMENT OF SAND WITH COPPER SLAG 29
4.1.1. Compressive Strength test 29
4.1.2 Workability test by slump 33
4.1.3 Compaction factor test- 36
4.1.4 Flexural strength 37
4.1.5 Split tensile test 39
4.1.6 Durability Analysis- 41
4.2. RESULTS AND DISCUSSION FOR PARTIAL REPLACEMENT OF CEMENT WITH COPPER SLAG 44
4.2.1. Strength Activity Test by A.S.T.M. (C311) 44
4.2.2. Compressive Strength test 44
4.2.3. Workability test by slump 48
4.2.4 Compaction factor test 51
4.2.5 Flexural strength 53
4.2.6 Split tensile test 54
CHAPTER 5 56
5. Methodology 56
CHAPTER 6 57
Conclusion 57
CHAPTER 7 58
Recommendations 58
References
Annexure A
Annexure B

ABSTRACT

Cement and sand are major constituents of concrete. In manufacturing of concrete large quantity of the natural resources are used. There is great demand of material mainly from civil engineering industry for road and concrete constructions but now days it is very difficult problem in availability of material and also creates adverse effect on the environment. Unfortunately, production of cement involves emission of large amounts of carbon-dioxide gas into the atmosphere, a major contributor for greenhouse effect and the global warming, hence it is inevitable either to search for another material or partially replace it by some other material.

So researchers developed waste management strategies to apply for replacement of fine aggregates and cement for specific need. Natural resources are depleting worldwide while at the same time the generated wastes from the industry are increasing substantially. The waste management is trying to compensate the lack of natural resources and to find alternative ways conserving the environment.

Some of the industrial byproducts have been used in the construction industry for the production of concrete. Copper slag is one of the materials that is considered as a waste material which could have been used in construction industry as partial replacement of either cement or aggregates. For this thesis work, M40 grade concrete was used and the tests were conducted for various proportions of copper slag replacement with sand from 0% to 50 % in concrete and copper slag replacement with cement from 0% to 15%.

Key Words: *Copper Slag, Fine Aggregate, Compressive Strength, Workability, Slump, Durability, Flexural Strength and Partial Replacement.*

LIST OF SYMBOLS AND ABBREVIATIONS

SYMBOLS AND ABBREVIATIONS	Description
$\sum$	Summation
$\prod$	Pi
IS	Indian standard
d	Cross section dimension of specimen
p	Max. load applied
l	Length of the specimen
f_{ct}	Tensile strength
f_b	Flexure strength
f_{ck}	Characteristic compressive strength
f_t	Target mean strength
a	Distance between fracture line and the nearest support
Avg.	Average
U.T.M.	Universal testing machine
Mpa	Mega Pascal
w/c	Water cement ratio
M40	Concrete grade having strength of 40 N/mm^2 at 28 days
C10	M40 mix with 10% of copper slag replaced with fine aggregates
C20	M40 mix with 20% of copper slag replaced with fine aggregates
C30	M40 mix with 30% of copper slag replaced with fine aggregates
C40	M40 mix with 40% of copper slag replaced with fine aggregates
C50	M40 mix with 50% of copper slag replaced with fine aggregate
CC8	M40 mix with 8% of copper slag replaced with Cement
CC10	M40 mix with 10% of copper slag replaced with Cement
CC12	M40 mix with 12% of copper slag replaced with Cement
CC15	M40 mix with 15% of copper slag replaced with Cement

LIST OF TABLES

Sr.No.	Name Of Table	Page No.
1	Physical properties of copper slag	2
2	Chemical properties of copper slag	3
3	Chemical composition of cement and copper slag	5
4	Percentage of compound in cement	12
5	Properties of fine aggregates	13
6	Sieve analysis of fine aggregates	14
7	Sieve analysis of coarse aggregates	15
8	Sieve analysis of copper slag	16
9	Compressive strength at 7 and 28 days	30
10	Slump result	33
11	Standard value of slump	33
12	Compaction factor for different mixes	36
13	Flexure strength values	38
14	Split tensile values	40
15	Durability test for sulphate attack	41
16	Durability test for chloride attack	42
17	compressive strength of control mix cube at 7 days	44
18	compressive strength of test mix cube at 7 days	44
19 (a)	Compressive strength in N/mm^2 at 7 days	45
19 (b)	Compressive strength in N/mm^2 at 28 days	46
20	Slump result	48
21	Standard value of slump	48
22	Compaction factor for different mixes	51
23	Flexure strength values	53
24	Split tensile values	54
25	Table 1 of IS 10262:2009	65
26	Table 2 of IS 10262:2009	66
27	table 3 of IS 10262:2009	66

LIST OF FIGURES

Sr.No.	Name Of Figure	Page No.
1	Copper slag	1
2	Cement	4
3	Comparison of optimum content of copper slag by different authors	10
4	Casting of cubes	22
5	Graph of compressive strength at 7 days	30
6	Graph of compressive strength at 28 days	31
7	Compressive strength testing	32
8	Graph for slump values	34
9	Slump test for different proportions	34
10	Graph of compaction factor for different proportions	36
11	Compaction factor	37
12	Graph for flexure strength at 28 days	38
13	Split tensile testing	39
14	Flexure strength testing	39
15	Graph for split tensile strength at 7 and 28 days	40
16	Bar chart for compressive strength in different type curings	42
17	Suphate attack test	43
18	Chloride attack test	43
19	Graph for compressive strength at 7 days	45
20	Graph of compressive strength at 28 days	46
21	Compressive strength testing	47
22	Graph for slump values	49
23	Slump test for different proportions	49
24	Graph of compaction factor for different proportions	51
25	Compaction factor	52
26	Graph for flexure strength at 28 days	53
27	Split tensile testing	54
28	Graph for split tensile strength at 7 and 28 days	55

CHAPTER 1
1. INTRODUCTION
General

There is great demand of aggregates mainly from civil engineering industry for road and concrete constructions but now days it is very difficult problem for available of fine aggregates. So researchers developed waste management strategies to apply for replacement of fine aggregates for specific need. Natural resources are depleting worldwide while at the same time the generated wastes from the industry are increasing substantially. The sustainable development for construction involves the use of nonconventional and innovative materials, and recycling of waste materials in order to compensate the lack of natural resources and to find alternative ways conserving the environment. Copper slag is one of the materials that is considered as a waste material which could have a promising future in construction industry as partial or full substitute of either aggregates.

1.1.- COPPER SLAG

Fig1- Copper slag

Copper slag is one of the materials that is considered as a waste material which could have a promising future in construction industry as partial substitute of either aggregates and cement. It is a by product obtained during refining of copper. Production of concrete using copper slag (ground) in place of cement (partial replacement) gives strength. It has good pozzalonic properties.

1.1.1 Physical Properties of copper slag

Physical Properties	Copper Slag
Particle Shape	Angular
Appearance	Black & glassy
Type	Air cooled
Specific Gravity	3.5
Percentage of Voids	43.20%
Bulk Density	1770 Kg/m^3
Fineness Modulus of Copper Slag	3.61

Table 1- Physical properties of copper slag

1.1.1. Chemical composition of copper slag

S.No	Chemical Component	% Of Chemical Component
1	SiO_2	25-35
2	Fe_2O_3	53.45
3	Al_2O_3	2-9
4	CaO	2-9
6	K_2O	1-5
5	TiO_2	0-2
6	MgO	1-5
7	CuO	0.7
8	Free silica	<0.5

Table 2- Chemical composition of copper slag

1.2 Cement

Fig-2 Cement

Cements are adhesive materials which have the ability of bonding particles of solid matter into a compact whole. This broad definition encompasses a wide variety of adhesive materials. However, for engineering purposes it is restricted to calcareous cements that contain compounds of lime as their main principal constituent. The main raw materials used in producing Portland cement are the oxides: lime (CaO), produced by heating calcium carbonate; silica (SiO_2), found in natural rocks and minerals; alumina (Al_2O_3), found in clay minerals; and ferric oxide (Fe_2O_3), found in clays. Cement as a binder is a vital element in concrete and the quality of concrete depends on the cement or binder, the aggregate, the mix design and the handling involved in making, placing and subsequent curing. The performance of cement used in concrete is influenced by its chemical composition.

1.3 Chemical compostion of copper slag and cement

Compounds	Cement (%)	Copper slag (%)
CaO	63-68	2-9
SiO_2	19-24	25-35
Al_2O_3	4-7	2-9
Fe_2O_3	1-4	45-55
MgO	0.5-3.5	1-5
K2O	0.2-0.8	1-5
Mn_2O_3	0.05	-
CI	0.001	0.0
TiO_2	0.25	0-2%

Table 3- Chemical composition of cement and copper slag

CHAPTER 2

2.1 - Literature review

- T.Poovizhi et al. (2015)[1] - This paper present the optimization of partial replacement of natural sand and cement by copper slag. Concrete mixes of M25 grade were evaluated for compressive strength, flexural strength and split tensile strength. Natural sand was replaced with copper slag by five proportions (ie 10%, 20%, 30%, 40%,50%) and cement was replaced with copper slag by four proportions (ie 5%, 10%, 15%, 20%). Addition up to 40% of copper slag as sand, and 15% of copper slag as cement yielded comparable strength with that of the control mix.

- Binaya Patnaik et al. (2015)[2] - An experiment was conducted to investigate the strength and durability properties of concrete having copper slag as a partial replacement of sand (fine aggregate) . Two different types of Concrete Grade (M20 & M30) were used with different proportions of copper slag replacement (0 to 50%) in the concrete. Strength & Durability properties such as Compressive Strength, Flexural Strength were evaluated for both mixes of concrete. Test results shows that the strength properties of concrete has improved having copper slag as a partial replacement of Sand (up to 40%) in concrete however in terms of durability the concrete found to be low resistant to acid attack and higher resistance against Sulphate attack.

- Jagmeet Singh et al. (2015)[3] - This paper investigated the effect of copper slag as partial replacement of cement on the compressive strength of concrete .The reduction in compressive strength is minor up to 10% of CS but beyond 10% of CS, there is significant reduction in compressive strength due to the increase in free water content in mixes. The optimum content of copper slag as replacement of cement is recommended as 10%.

- Leema rose et al. (2015)[4] - The main focus of this study is to find out the strength and durability properties of M30 concrete in which fine aggregate is partially replaced with 10%, 20%, 30%, 40%. The results of compressive test show that the strength of the concrete increases with respect to the percentage of copper slag added by weight of fine aggregate up to 30% of replacement. Therefore, the recommended percentage replacement of fine aggregate by copper slag is 30%.

- M. V. PATIL (2015)[5] -This research work, M30 grade concrete was used and the tests were conducted for various proportions of copper slag replacement with sand of 0%, to100 % in concrete. Maximum Compressive strength of concrete increased by 34 % at 20% replacement of fine aggregate, and up to 80% replacement ,concrete gain more strength than normal concrete strength.. It is observed that up to 30% replacement of natural sand by copper slag, the flexural strength of concrete is increased by 14%. And all percentage replacement of fine aggregate by copper slag the flexural strength of concrete is more than normal mix.

- Harpreet Singh and Gurprit Singh Bath (2015)[6] - The present study encouraged the utilization of industrial waste copper slag as replacement of natural aggregates in M30 concrete. The results indicate that the use of copper slag in concrete increases the flexural strength of about 17% with that of control mixture. It is recommended that up to 40% of copper slag can be use as replacement of fine aggregates.

- Deepak Gowda et al. (2014)[7] - This research work mainly consist of substitution of natural sand partially by copper slag in M25 concrete is done with replacement of 0%, 35%, 40% and 45%. The optimum value obtained for 40% replacement of copper slag.

- V.M. Illayaraja Muthaiyaa et al. (2014)[8] – This paper investigated the optimum content of copper slag as replacement with fine aggregates and the result of compression test indicated that the strength of concrete increases with respect to the percentage of copper slag added by weight of fine aggregate up to 40% of additions.

- R R Chavan et. al. (2013)[9] - This paper reports on an experimental program to investigate the effect of using copper slag as a replacement of fine aggregate on the strength properties. For this research work, M25 grade concrete was used and tests were conducted for various proportions of copper slag replacement with sand of 0 to 100% in concrete. Maximum Compressive strength of concrete increased by 55% at 40% replacement of fine aggregate by copper slag, and up to 75% replacement, concrete gain more strength than control mix concrete strength.

- Amit S. Kharade et al. (2013)[10] - This paper presents the results of an experimental investigation carried out to evaluate the mechanical properties of concrete mixtures in which fine aggregate (sand) was replaced with Copper Slag. The fine aggregates (sand) was replaced with percentages 0% (for the control mixture), 10%, 20%, 30%, 40%, 50%, 60%, 80%, and 100% of Copper Slag by weight. Tests were performed for properties of fresh concrete and Hardened Concrete. Compressive strength and Flexural strength were determined at 7, 28 and 56days. The results indicate that workability increases with increase in Copper Slag percentage. Test results indicate significant improvement in the strength properties of plain concrete by the inclusion of up to 80% Copper slag as replacement of fine aggregate (sand), and can be effectively used in structural concrete.

- M. Najimi et al. (2011)[11] - In this paper the performance of copper slag contained concrete in sulfate solution is investigated. In this the concretes made by replacing 0%, 5%, 10% and 15% of cement with copper slag waste. The copper slag contained concretes showed better compressive strength performance in sulfate comparing with the control concrete specimens. Although the strength of copper slag contained concretes observed to be lower than control concerts in normal condition, they could develop their strength up to or even more than.

- D.Brindha et al. (2010)[12] - This paper presents the results of an experimental study on various corrosion and durability tests on concrete containing copper slag as partial replacement of sand and cement. For this research work , M20 grade concrete was used and the tests were conducted for various proportions of copper slag replacement with sand of 0%, 20%, 40%, and 60%, cement of 0%, 5%, 15%. The results of compressive have indicated that the strength of concrete increases with respect to the percentage of slag added by weight of fine aggregate up to 40% of additions and 15% of cement.

- Wei Wu et al. (2010)[13] - This study investigated the mechanical properties of high strength concrete incorporating copper slag as a fine aggregate and concluded that less than 40% copper slag as sand substitution can achieve a high strength concrete that comparable or better to the control mix, beyond which however its behaviors decreased significantly.

- C.H. Srinivas and S. M Muranal (2010)[14] - This paper presents the results of an experimental study on various durability tests on concrete containing copper slag as partial replacement of sand. In this report, M30 grade of concrete was designed and tests were conducted with different percentage of copper slag as fine aggregate in concrete. The result shows maximum compressive strength of concrete increases up to 8.63 % for 20 % percentage replacement of fine aggregate, but up to 40 % percentage of copper slag can be replaced which is greater than the target strength.

- Jardel Pereira Gonc et al. (2007)[15] - This paper presents the results of a study on the use of copper slag as pozzolanic supplementary cementing material for use in concrete. The results pointed out that there is a potential for the use of copper slag as a supplementary cementing material to concrete production. The concrete batches with copper slag addition presented greater mechanical and durability performance.

- Jagmeet Singh et al. (2014)[16] **-** This study investigated the mechanical properties of concrete incorporating copper slag as a cement (partially) and concluded that 8% copper slag as cement substitution can achieve a satisfactory strength that comparable to the control mix, beyond which however its behaviors decreased significantly.

2.2 Research gap

After analyzing these research papers I have concluded that the optimum copper slag content for replacing with fine aggregates is 40% in case of M25 and 30% and 20% in case of M30 . There is difference in optimum content of copper slag for different mix proportions. Now I will investigate the concrete properties by replacing fine aggregates and cement with copper slag for M40.

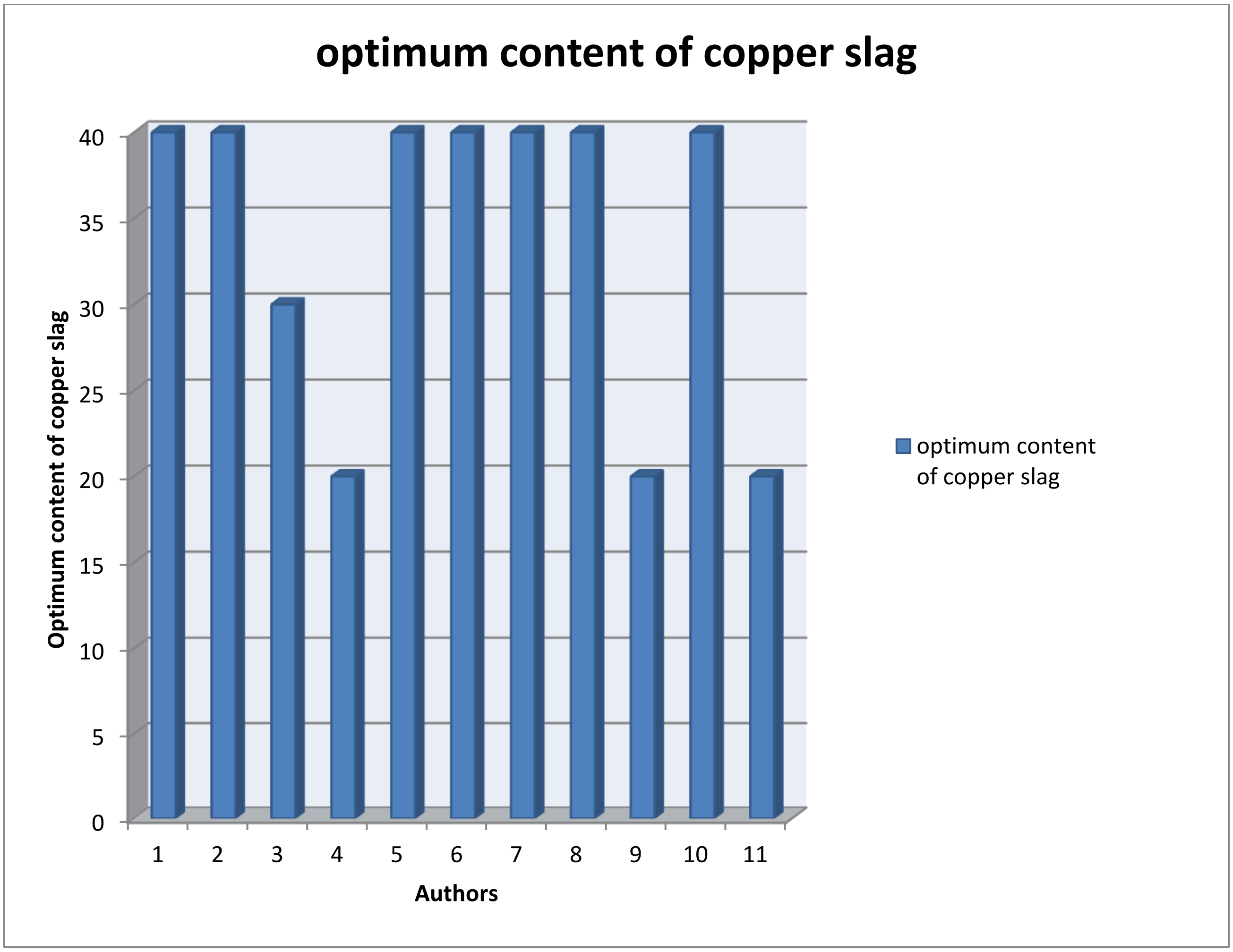


Fig3- Comparison of optimum content of copper slag by different authors

2.3 Objectives

1) To determine the optimum content of copper slag as replacement of fine aggregates in M40.

2) To determine the optimum content of copper slag as replacement of cement in M40.

To obtain the optimum content of the copper slag in both the cases, some of the test are conducted below on fresh and hardened concrete –

On Fresh Concrete

- Workability by Slump Test
- Workability by Compaction Factor

On Hardened Concrete'

- Compressive Strength Test
- Split Tensile Strength Test
- Flexural Strength Test
- Durability Test
    a. Sulphate Attack
    b. Chloride Attack

CHAPTER 3

3.1 EXPERIMENTAL PROGRAMME

GENERAL

The aim of this experimental program is to compare the behavior of copper slag in use as a supplementary material when subjected to different tests. All the tests carried out on concrete are mentioned here in this chapter followed by a brief description about mix design & aggregates .

3.2 MATERIAL USED

3.2.1 Cement

Cement is a fine, grey powder. It is mixed with water and sand, gravel and crushed stone to generate concrete. Cement and water form a paste that binds the other materials together as concrete hardens .

Compounds	Cement (%)
CaO	63-68
SiO_2	19-24
Al_2O_3	4-7
Fe_2O_3	1-4
MgO	0.5-3.5
K2O	0.2-0.8
Mn_2O_3	0.05
CI	0.001
TiO_2	0.25

Table 4- Percentage of different compound in cement

3.2.2 Fine Aggregates

Sand used was locally procured and was found to be conforming to Indian Standard specifications IS 383-1970. The sand was first sieved through 4.75 mm sieve to remove any particles larger than 4.75 mm and then was washed to remove the dust.

Sr. No.	**Characteristics**	**Value**
1	Specific gravity	2.46
2	Bulk density	1.4
3	Fineness modulus	2.56
4	Water absorption	0.85
5	Grading Zone (Based on percentage passing 0.60 mm)	Zone Ⅲ

Table 5 – Properties of fine aggregates

Properties of fine aggregates used have been presented in following table .the aggregates were sieved through a set of sieves to obtain sieve analysis presented in table 6. The aggregates was found to belong to zone Ⅲ.

Sr. No.	Sieve size	Mass retained	Percentage Retained	Cumulative percentage retained	Percentage passing
1	4.75 mm	4.0 g	0.4	0.4	99.6
2	2.36 mm	75.0 g	7.50	7.90	92.1
3	1.18 mm	178.0 g	17.80	25.70	74.3
4	600 µ	220.0 g	22.0	47.70	52.3
5	300 µ	274.0 g	27.4	75.10	24.9
6	150 µ	246.5 g	24.65	99.75	0.25
7				∑=256.55	

Table 6- Sieve analysis of fine aggregates

Total weight taken = 1000 gm

Fineness Modulus of Sand = 2.56

3.2.3 Coarse Aggregate

Coarse aggregate can be defined as any material Retained on IS no. 4.75 . The crushed stone is generally used as a coarse aggregate .The size of work decides the maximum size of coarse aggregate. 10 mm and 20 mm aggregate was used for this work which was locally available. The aggregate was washed to remove dust and dirt and were dried to surface dry condition . The aggregate were tested as per IS : 383-1970. The results of various tests conducted on coarse aggregate are mentioned in table given below shows the sieve analysis.

Sr. No.	Sieve size	Mass retained	Percentage Retained	Cumulative percentage retained	Percentage passing
1	20 mm	80 g	4	4	100
2	10 mm	1320g	66	70	16.13
3	4.75 mm	600 g	30	100	0.33
4	PAN	10 g	0.33	∑=174	

Table 7- Sieve analysis of coarse aggregates

Total weight taken = 3 Kg

FM of Coarse aggregate = [174 + 500] / 100 = 6.74

3.2.4 Water

Curing is a procedure that is adopted to promote the hardening of concrete under conditions of humidity and temperature which are conducive to the progressive and proper setting of the constituent cement. Curing has a major influence on the properties of hardened concrete such as durability, strength, water-tightness, wear resistance, volume stability, and resistance to freezing and thawing. Concrete that has been specified, batched, mixed, placed, and finished can still be a failure if improperly or inadequately cured. Curing is usually the last step in a concrete project and, unfortunately, is often neglected even by professionals. Water that is suitable for drinking should be used in concrete. Water from lakes and streams that contain marine life can also be used . No sampling is necessary when water is obtained from above mentioned source . If there is any suspicion that water may contain sewage, mine water or wastes from industrial plants or canneries , it should not be used until tests indicate them as satisfactory.

3.2.5 Supplementary materials

Copper slag - Copper slag is one of the materials that is considered as a waste material which could have a promising future in construction industry as partial substitute of either aggregates and cement. It is a by product obtained during refining of copper. Production of concrete using copper slag (ground) in place of cement (partial replacement) gives strength. It has good pozzalonic properties.

Sr. No.	Sieve size	Mass retained	Percentage Retained	Cumulative percentage retained	Percentage passing
1	4.75 mm	0 g	0	0	0
2	2.36 mm	12.8 g	2.56	2.56	97.44
3	1.18 mm	433.4 g	86.68	89.24	10.76
4	600 µ	52.8 g	10.56	99.8	0.2
5	300 µ	0.6 g	0.12	99.92	0.08
6	150 µ	0.4 g	0.08	100	00
7				$\sum$=361.52	

Table No.8- Sieve analysis of copper slag

Total weight taken = 1000 gm

Fineness Modulus of copper slag = 3.61

3.3 Mixture Proportioning

3.3.1. For partial replacement of fine aggregates with copper slag

- **Mix proportion (M40)–**

Cement = 450 kg/m^3

Water = 197 lit

Fine aggregates = 766.76 kg/m^3

Coarse aggregates = 1046 kg/m^3

Water-cement ratio = 0.4

- **M40 with partial replacement of sand by 10% of copper slag (C10) –**

Mix proportion –

Cement = 450 kg/m^3

Water = 197 lit

Fine aggregates = 690.09 kg/m^3

Coarse aggregates = 1046 kg/m^3

Water-cement ratio = 0.4

Copper slag = 76.67kg/m^3

- **M40 with partial replacement of sand by 20% of copper slag (C20) –**

Mix proportion –

Cement = 450 kg/m^3

Water = 197 lit

Fine aggregates = 613.41kg/m^3

Coarse aggregates = 1046 kg/m^3

Water-cement ratio = 0.4

Copper slag = 153.352 kg/m^3

- **M 40 with partial replacement of sand by 30% of copper slag (C30)–**

Mix proportion –

Cement = 450 kg/m^3

Water = 197 lit

Fine aggregates = 536.74kg/m^3

Coarse aggregates = 1046 kg/m^3

Water-cement ratio = 0.4

Copper slag = 230.02 kg/m^3

- **M 40 with partial replacement of sand by 40% of copper slag (C40) –**

Mix proportion –

Cement = 450 kg/m^3

Water = 197 lit

Fine aggregates = 460.056 kg/m^3

Coarse aggregates = 1140 kg/m^3

Water-cement ratio = 0.4

Copper slag = 306.704 kg/m^3

- **M 40 with partial replacement of sand by 50% of copper slag (C50) –**

Mix proportion –

Cement = 450 kg/m^3

Water = 197 lit

Fine aggregates = 383.38 kg/m^3

Coarse aggregates = 1046 kg/m^3

Water-cement ratio = 0.4

Copper slag = 383.38 kg/m^3

3.3.2. For partial replacement of cement with copper slag

- **Mix proportion (M40)–**

Cement = 450 kg/m^3

Water = 197 lit

Fine aggregates = 766.76 kg/m^3

Coarse aggregates = 1046 kg/m^3

Water-cement ratio = 0.4

- **M40 with partial replacement of cement by 8% of copper slag (C8) –**

Mix proportion –

Cement = 414 kg/m^3

Water = 197 lit

Fine aggregates = 766.76 kg/m^3

Coarse aggregates = 1046 kg/m^3

Water-cement ratio = 0.4

Copper slag = 36kg/m^3

- **M40 with partial replacement of cement by 10% of copper slag (C10) –**

Mix proportion –

Cement = 405 kg/m^3

Water = 197 lit

Fine aggregates = 766.76 kg/m^3

Coarse aggregates = 1046 kg/m^3

Water-cement ratio = 0.4

Copper slag = 45 kg/m^3

- **M 40 with partial replacement of cement by 12% of copper slag (C12)–**

Mix proportion –

Cement = 396 kg/m^3

Water = 197 lit

Fine aggregates = 766.76 kg/m^3

Coarse aggregates = 1046 kg/m^3

Water-cement ratio = 0.4

Copper slag = 54 kg/m^3

- **M 40 with partial replacement of cement by 15% of copper slag (C15) –**

Mix proportion –

Cement = 382.5 kg/m^3

Water = 197 lit

Fine aggregates = 766.76 kg/m^3

Coarse aggregates = 1140 kg/m^3

Water-cement ratio = 0.4

Copper slag = 67.5kg/m^3

3.4 Batching, Mixing and Casting of Specimens

Cubical moulds of size 150mm x 150mm x 150mm and 100mm*100mm*100mm were used to prepare the concrete specimens for the determination of compressive strength of concrete. Care was taken during casting . The moulds were placed upon the compaction table for proper compaction. Cylindrical moulds of size 100 mm x 200 mm were used to prepare the concrete specimens for the determination of split tensile strength concrete. Rectangular moulds of 100mm x 100mm x 500mm were used for flexural testing of beams. All the specimens were prepared in accordance with Indian Standard Specifications IS: 516-1959. All the moulds were cleaned and oiled properly. These were securely tightened to correct dimensions before casting. Care was taken that there is no gaps left from where there is any possibility of leakage of slurry. A careful procedure was adopted in the batching, mixing and casting operations. The coarse aggregates and fine aggregates were weighed first with an accuracy of 0.5 grams. The concrete mixture was sprepared by the concrete mixer. It was cleaned first by water and dried then , to ensure any impurities were not adhering to its surface form prior use . Dry fine aggregates are introduced first in the mixer & are thoroughly mixed. After that coarse aggregates are added to it. Sand is replaced by copper slag in different proportions. Then water was added carefully so that no water was lost during mixing. A total of 102 cubes, 33 beams and 66 cylinders were prepared which consists of cubes , beams , cylinders incorporated with copper slag. Proposed checks were made at 7, 14 and 28 days . The compaction machine was stopped as soon as the cement slurry appeared on the top surface of the mould. All the specimens were left in the steel mould for the first 24 hours at ambient condition. After that they were de-moulded with care upon requirement of aging so that no edges were broken and were placed in the curing tank at the room temperature for curing. The room temperature for curing was 27 ± 20 (IS: 10262-1982).

Fig 4- Casting of cubes

3.5 Tests Conducted

3.5.1 Compression test (IS: 516 – 1959)

The testing machine may be of any reliable type, of sufficient capacity for the tests and capable of applying the load a without shock and increased continuously at a rate of approximately 140 kg/cm2/min until the resistance of the specimen to the increasing load breaks down and no greater load can be sustained. The permissible error shall be not greater than ± 2 percent of the maximum load. The testing machine shall be equipped with two steel bearing platens with hardened faces. One of the platens (preferably the one 58 that normally will bear on the upper surface of the specimen) shall be fitted with a ball seating in the form of a portion of a sphere, the centre of which coincides with the central point of the face of the platen. The other compression platen shall be plain rigid bearing block. The bearing faces of both platens shall be at least as large as, and preferably larger than the nominal size of the specimen to which the load is applied. The bearing surface of the platens, when new, shall not depart from a plane by more than 0.01 mm at any point, and they shall be maintained with a permissible variation limit of 0.02 mm. The movable portion of the spherically seated compression platen shall be held on the spherical seat, but the design shall be such that the bearing face can be rotated freely and tilted through small angles in any direction. The measured compressive strength of the specimen shall be calculated by dividing the maximum load applied to the specimen during the test by the cross-sectional area, calculated from the mean dimensions of the section and shall be expressed to the nearest kg per sq cm. Average of three values shall be taken as the representative of the batch provided the individual variation is not more than ± 15 percent of the average. Otherwise repeat tests shall be made.

3.5.2. Strength Activity Test by A.S.T.M. (C311)

In the test mixture, replace 20 % of the mass of the amount of cement used in the control mixture by the same mass of the test sample. Make six-cube batches as follows:

Control Mixture:

500 g of portland cement
1375 g of graded standard sand
242 mL of water

Test Mixture:

400 g of portland cement
100 g of test sample
1375 g of graded standard sand

According to A.S.T.M. C311 Strength activity index with portland cement as follows:
Strength activity index with portland cement = (*A/B*) * 100

where:
A = average compressive strength of test mixture cubes, Pa , and
B = average compressive strength of control mix cubes, Pa .
.

3.5.3. Workabiliy test by Slump

The concrete slump test is an empirical test that measures workability of fresh concrete. The test measures consistency of concrete in that specific batch. It is performed to check consistency of freshly made concrete. Consistency refers to the ease with which concrete flows. It is used to indicate degree of wetness.

Work-ability is the ease with which the given concrete mix can be mixed together, transported to the application place and can be placed/applied/compacted their within the initial setting time of cement. This property depends largely on the amount of water added i.e. water cement ratio of the concrete mix and kind of aggregates used. Generally work-ability increases with the addition of the water, however it results in the less strength of concrete. So we have to settle for an intermediate value of water cement ratio at which it may have the sufficient work-ability as well as sufficient strength.

3.5.4. Compaction test

This is defined as the ease with which concrete can be compacted fully without Segregating and bleeding. It can also be defined as the amount of internal work required to fully compact the concrete to optimum density.

The workability depends upon the quantity of water, grading, shape and the percentage of the aggregates present in the concrete. To test the workably of freshly concrete, compaction factor test is carried out. This test works on the principal of determining the degree of compaction achieved by standard amount of work done by allowing the concrete to fall through a standard height. The degree of compaction factor is the ratio of weight partially compacted concrete to the weight of fully compacted concrete.

3.5.5. Split tensile test

A compression machine of sufficient capacity & reliability shall be used for the tests an should be capable of applying the load without shock and accelerated continuously at a nominal rate within the range 1.2 N/(mm^2/min) to 2.4 N/ (mm^2/min) should be used. It shall comply with the requirements given in IS 516 as far as applicable except that the bearing faces of both platens shall provide a minimum loading area of 12 mm multiplied by the length of the cylinder, as the case may be so that the load is applied over the entire length of the specimen. If necessary, a supplementary bearing bar or plate of machined steel may be used. A steel loading plate having minimum hardness value, when tested in accordance with IS 1500 shall be used between the platen of the machine and the hardboard packing strips. The piece shall not be shorter than the specimen.. Tests shall be made at the required ages of the test specimens, that is at 7 and 28 days. The ages shall be calculated from the time of the casting of the moulds.

Unless other conditions are required for specific laboratory investigation specimen shall be tested immediately on removal from the water whilst they are still wet . Surface water and grit shall be wiped off the specimens and any projecting fins removed from the surfaces if any. Central lines shall be drawn on the two opposite faces of the cube using any suitable procedure and a device that will ensure that they are in the same axial plane. The mass and dimensions of the specimen shall be noted before testing. The sides of the specimen, lying in the plane of the pre-marked lines, shall be measured near the ends and the middle of the specimen and the average taken to the nearest 0.2 mm. The length of the specimen shall be taken to the nearest 0.2 mm by averaging the two lengths measured in the plane containing the pre-marked lines. Before commencement of testing the bearing surfaces of the testing machine and of the loading strips have to be wiped clean and the test specimen shall be placed in the centering jig with packing strip and loading pieces carefully positioned along the top and bottom of the plane of loading of the specimen. The jig shall then be placed in the machine so as to locate the specimen centrally. For cylindrical specimen it shall be ensured that the upper platen is parallel with the lower platen. On manually controlled machines as failure is approached the loading rate decreases at this stage the controls shall be operated to follow possible the specified loading rate as far as.

The maximum load applied shall then be recorded. The appearance of concrete and any unusual features in the pattern of failure are to also be noted.

$$fct = 2P/ \pi ld \text{ ; where}$$

P = maximum load in Newtons applied to the noted before testing.

I = length of the specimen as shown in (in mm), and

d = cross sectional dimension of the specimen (in mm).

3.5.6. Flexural Bending Test (IS: 516 – 1959)

The testing machine may be of any reliable type of sufficient capacity for the tests and capable of applying the load at the rate such that the extreme fibre stress increases at approximately 7 kg/cm2/min, that is, 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 center-point loading method shall be used in the laboratory. The apparatus shall incorporate the following requirements. The load shall be applied at the center point of the span, normal to the loaded surface of the beam, employing bearing blocks designed to ensure that forces applied to the beam will be vertical only and applied without eccentricity. The direction of the reactions shall be parallel to the direction of the applied load at all times during the test. The load shall be applied at a uniform rate and in such a manner as to avoid shock. The edges of the load-applying block and of the supports shall not depart from a plane by more than .002 in. (0.051 mm).

Calculation — The flexural strength of the specimen shall be expressed as the modulus of rupture fb,

$$f_b = 3*p*l/2b*d^2$$

p = load applied on beam

b= effective width of beam

d=effective depth of beam

l=length of the specimen

3.5.7. Durability tests

A long service life is considered synonymous with durability. Since durability under one set of conditions does not necessarily mean durability under another, it is customary to include a general reference to the environment when defining durability. According to ACI Committee 201, durability of Portland cement concrete is defined as its ability to resist weathering action, chemical attack, abrasion, or any other process of deterioration; that is, durable concrete will retain its original form, quality, and serviceability when exposed to its environment. No material is inherently durable; as a result of environmental interactions the microstructure and, consequently, the properties of materials change with time. A material is assumed to reach the end of service life when its properties under given conditions of use have deteriorated to an extent that the continuing use of the material is ruled either unsafe or uneconomical.

3.5.7.1 Sulphate Attack

Most soils contain some sulphate in the form of calcium, sodium, potassium and magnesium. They occur in soil or ground water. Because of solubility of calcium sulphate is low, ground waters contain more of other sulphates and less of calcium sulphate. Ammonium sulphate is frequently present in agricultural soil and water from the use of fertilizers or from sewage and industrial effluents. Decay of organic matters in marshy land, shallow lakes often leads to the formation of H_2S, in which can be transformed in to sulphuric acid by bacterial action. Water used in concrete cooling towers can also be a potential source of sulphate attack on concrete. Therefore sulphate attack is a common occurrence in natural or industrial situations. Solid sulphates do not attack the concrete severely but when the chemicals are in solution, they find entry into porous concrete and react with the hydrated cement products. Of all the sulphates magnesium sulphate causes maximum damage to concrete. A Characteristic whitish appearance is the indication of sulphate attack. The term sulphate attack denote an increase in the volume of cement paste in concrete or mortar due to the chemical action between the products of hydration of cement and solution containing sulphates. In the hardened concrete, calcium sulphoaluminate, forming within the framework of hydrated cement paste. Because of the increase in volume of the solid phase which can go up to 227 percent, a gradual disintegration of concrete takes place. Another factor influencing the rate of attack is the speed in which the sulphate gone into the reaction is replenished. For this it can be seen that when the concrete is subjected to the pressure of sulphate bearing water on one side the rate of attack is highest.

3.5.7.2 Chloride Attack

The free chloride content in concrete has been found to be one of the major causes for corrosion of steel and it is one of the critical issues being dealt today by civil engineers globally. In fact, in the marine environment, a large number of concrete bridges, dams, and other mega structures have suffered from safety and serviceability problems due to the deterioration of concrete, can be directly attributed to the chloride penetration into the concrete. It is also understandable from the reported literature that, most of the concrete structures failed in the past are not necessarily due to inadequate design but due to failure of concrete to protect reinforcing steel from aggressive elements like chlorides. The chlorides that are penetrated through concrete pores depend upon the pore structure of concrete and the improvement in pore structure is mainly achieved by the use of mineral admixtures.. In addition, these admixtures reduce the mobility of chloride ions by changing the mineralogy of the cement hydrates. The chloride permeability depends on several factors like chemical composition of cement, water-to cement ratio, types and amounts of mineral admixtures etc. Therefore, in order to improve the resistance of concrete to chloride penetration, the mix proportions of concrete should be carefully selected considering the above parameters. Many studies have been carried out on the use of admixtures, however search for efficient alternative admixture is still continuing.

Curing in acid solution

Curing is adopted to promote the hardening of concrete under conditions of humidity and temperature which are conducive to the progressive and proper setting of the constituent cement. Curing has a major influence on the properties of hardened concrete such as durability, strength, water-tightness, wear resistance, volume stability, and resistance to freezing and thawing. Concrete that has been specified, batched, mixed, placed, and finished can still be a failure if improperly or inadequately cured. Curing is usually the last step in a concrete project and, unfortunately, is often neglected even by professionals. 6 cubes of five different mixes of M40 Grade namely referral M40, C10, C20, C30, C40, C50 by replacing (0%, 10%, 20%, 30%, 40%, 50%) of sand bycopper slag. . The cubes were demoulded after 1 day of casting and then kept in respective solutions of 5% H_2SO_4 for curing, at room temperature with a normal humidity. The cubes are taken out from curing after 30 days .The surface of specimen was cleaned and weights were measured. The mass loss and strength of specimen due to acid attack will be determined in 30 days.

Chapter 4

4.1. RESULTS AND DISCUSSION FOR PARTIAL REPLACEMENT OF SAND WITH COPPER SLAG

General

In this chapter, Compressive strength, slump , compaction factor ,Flexural Strength , Tensile strength and Sulphate resistance & Chloride resistance of M40 concrete mixe incorporating copper slag in varying percentages is discussed. All the tests conducted were in accordance with the methods described in chapter three. Results were compared and checked for compressive strength, split tensile strength, sulphate resistance and chloride resistance of concrete.

4.1.1. Compressive Strength test

Concrete was prepared under moderate exposure condition and quality control was good. It was poured into cubical moulds and placed on vibrating table to minimize air entrapped which would otherwise affect the compressive strength. After 24 hrs the moulds were removed and the specimens were kept for curing at room temperature until taken out for testing. Specimens were tested at different ages i.e. 7 days and 28 days compressive strength. The load is applied at a constant rate thus ensuring progressive increase in stress as failure approached.

Mix	Compressive strength in N/mm^2 at 7 days			Avg . Compressive strength in N/mm^2 at 7 days
M40	22	24	23	23
C10	24.1	25.4	24.2	24.5
C20	26.4	26	25.5	25.9
C30	29.8	30	28.2	29.33
C40	32.1	30.2	31	31.1
C50	29.9	30	29.4	29.7

Table 9 (a) - Compressive strength in N/mm^2 at 7 days

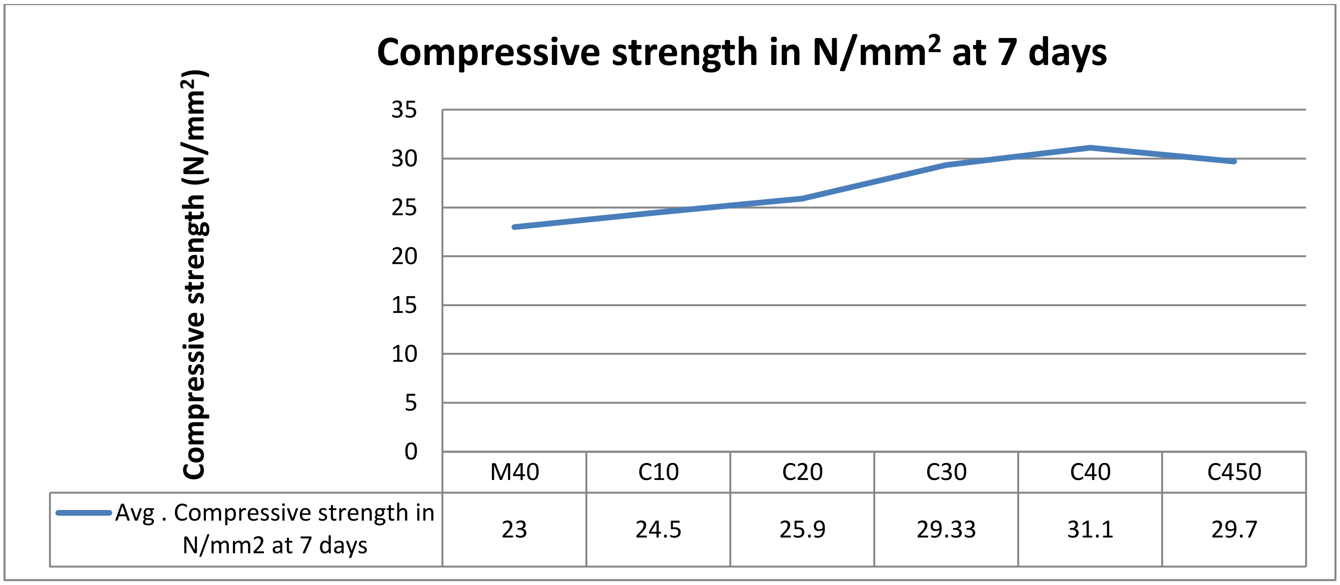


Fig -5 Graph for compressive strength at 7 days

Mix	Compressive strength in N/mm^2 at 28 days			Avg. Compressive strength in N/mm^2 at 28 days
M40	38	35	34	36.33
C10	40.12	41.02	40.2	40.44
C20	42.2	43	42.5	42.4
C30	44.5	45	43.9	44.4
C40	46.9	47.7	47.1	47.2
C50	43.2	44	44.2	43.8

Table 9 (b) - Compressive strength in N/mm^2 at 28 days

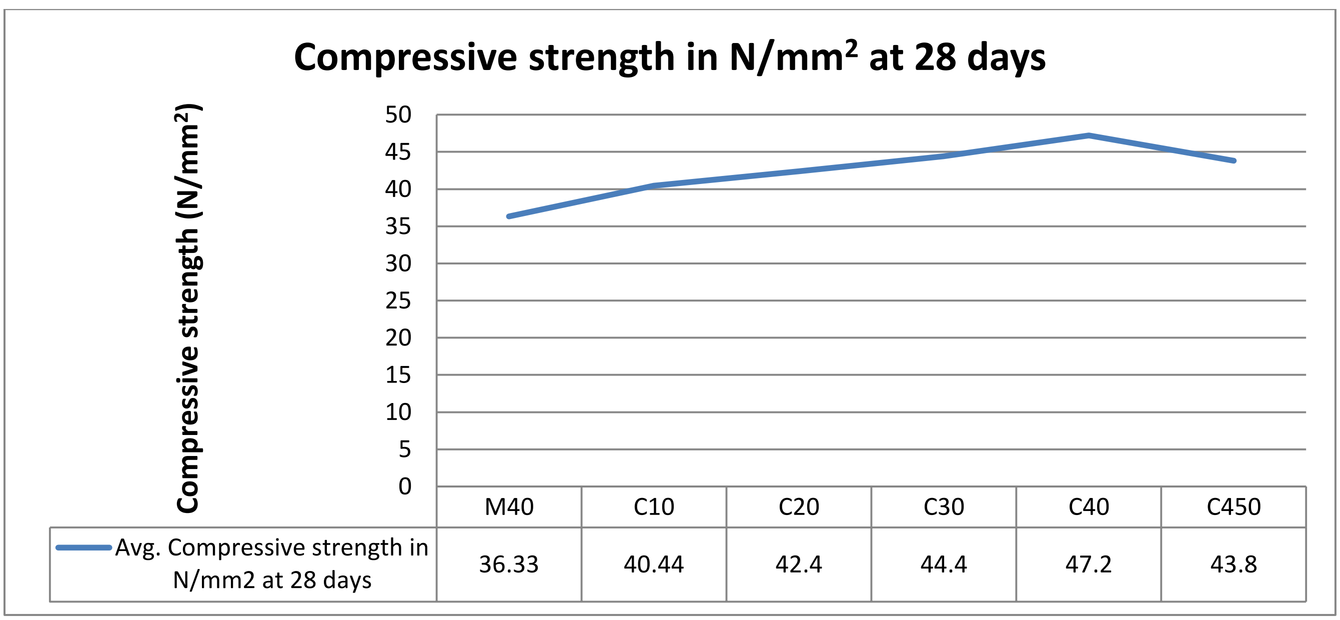


Fig 6-Graph for compressive strength at 28 days

Fig7 – Compressive strength testing

- Fig 7 showing the process of compression test, after completing the compression test i concluded that the Optimum content of copper slag is 40% by weight replacement of copper slag with sand in M40 mix. Maximum Compressive strength of concrete increased by 31.2% at 40% replacement of fine aggregate by copper slag at 7 days , and 29.9% at 40% replacement of fine aggregate by copper slag at 28 days.

4.1.2 Workability test by slump

In order to study slump of M40 mix containing different proportion of copper slag were prepared and checked for workability.

Results-

Mix	Slump (mm)
M40	65
C10	78
C20	84
C30	90
C40	105
C50	110

Table 10 -Slump values

Standard values of slump-

Workability	Slump (mm)
Very low	0-25
Low	25-50
High	50-100
Very high	100-175

Table 11 - Standard values of slump

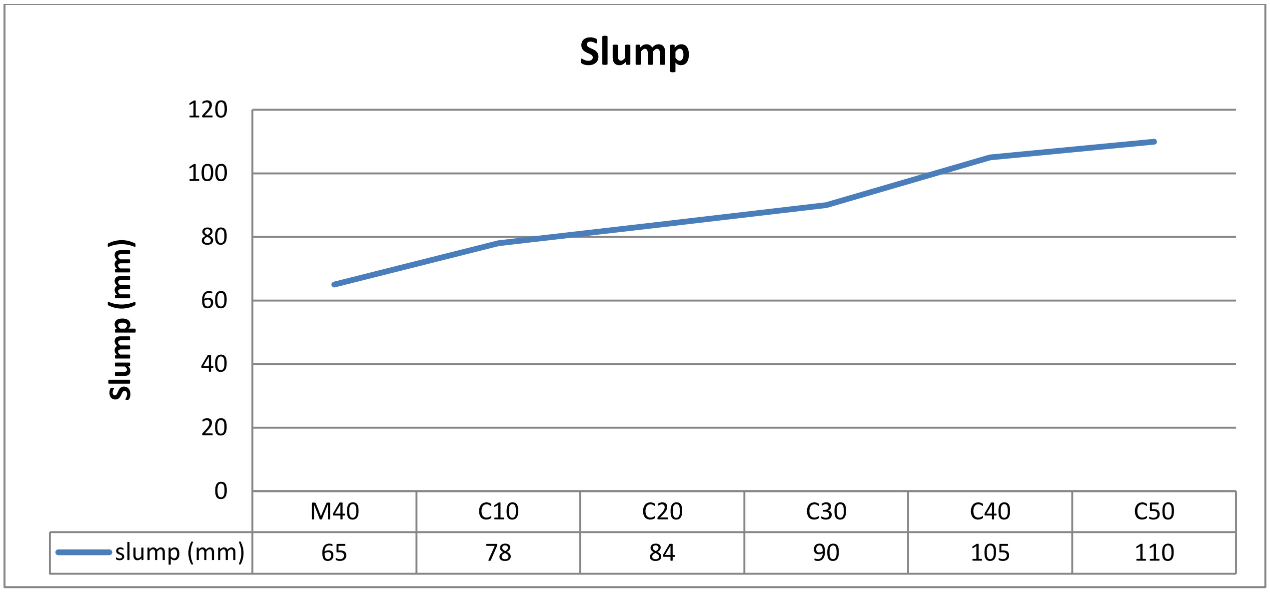


Fig8- Graph for slump values

Fig 9 (a)– slump test for different proportions

Fig 9 (b)– Slump test for different proportions

- Above fig 9 shows the decrement in the height of concrete (called as slump) for different proportions of copper slag in M40 grade of concrete and from fig 8 and table 10, it is observed that, the workability of concrete increases for all percentage replacements done in design mix.

4.1.3 Compaction factor test

In order to find the compaction factor of M40 mix containing different proportion of copper slag were prepared and checked for workability.

Results-

Mix	Compaction Factor
M40	0.75
C10	0.78
C20	0.82
C30	0.88
C40	0.90
C50	0.93

Table 12 - Compaction factor for different mixes

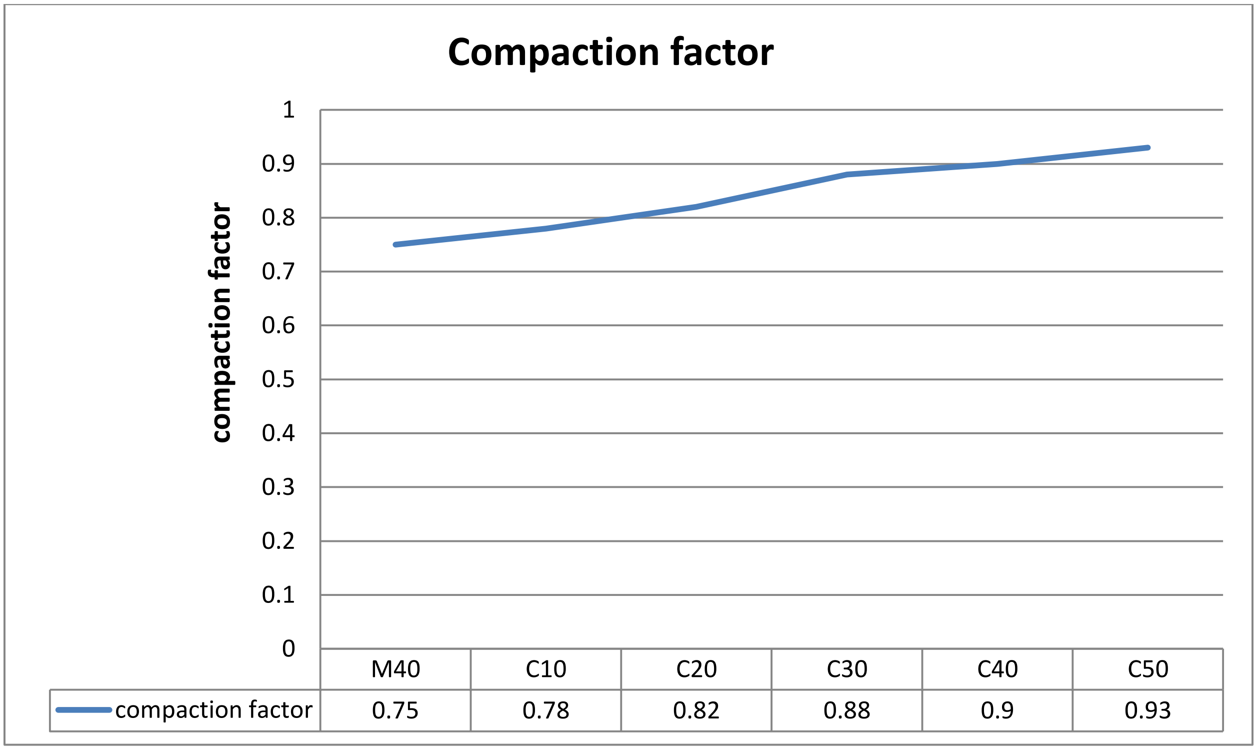


Fig 10 -Graph of compaction factor for different mixes

Fig11 – Compaction factor test

- Fig 11 shows the test procedure of compaction test of the concrete and from fig 10 and table 12, it is observed that, the compaction factor of concrete increases for all percentage replacements done in design mix.

4.1.4 Flexural strength

In order to study the effect on flexural strength, the beams containing different proportion of copper slag were prepared and kept for curing for 28 days. The test was conducted on U.T.M as per I.S.516-1959.

Results-

Mix	Flexure strength (N/mm^2) at 28 days			Average flexure strength (N/mm^2)
M40	4.35	4.4	4.39	4.38
C10	4.82	4.9	4.7	4.80
C20	5.12	5.2	4.98	5.1
C30	5.2	5.6	5.4	5.4
C40	5.32	5.4	5.41	5.37
C50	5.1	5.3	5.01	5.13

Table 13 – Flexure strength test

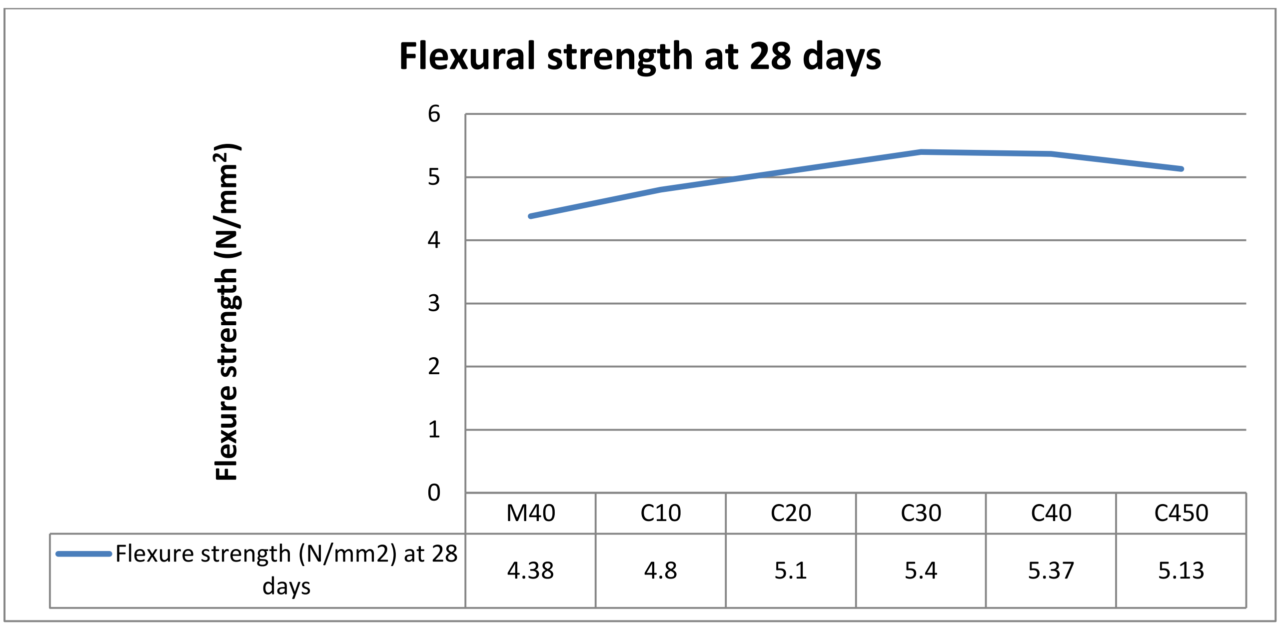


Fig 12 – Graph for flexural strength

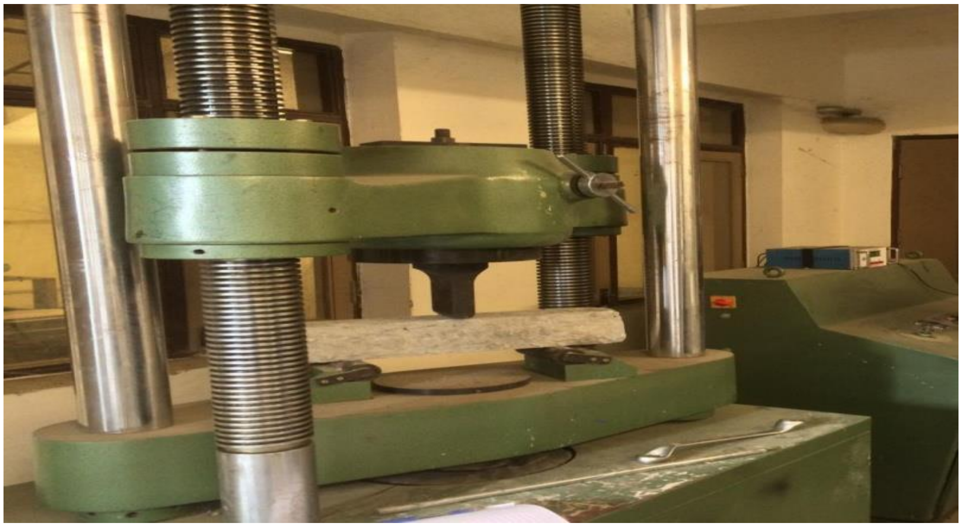


Fig 13- Flexural strength test

- Fig 13 showing the process of flexural strength test and table 13 showing maximum flexural strength of concrete increased by 23.2% at 30% replacement of fine aggregate by copper slag at 28 days.

4.1.5 Split tensile test

Concrete mixed with copper slag was prepared under moderate exposure condition and quality control was good. It was poured into cylindrical mould and was hand compacted by tamping rod to ensure homogenous distribution of copper slag. After 24 hrs the moulds were removed and the specimens were kept for curing at room temperature until taken out for testing. Specimens were tested at different ages i.e. 7 days and 28 days for split tensile test. The load is applied at a constant rate thus ensuring progressive increase in stress as failure approached.

Fig 14- Split tensile testing

Mix	Split tensile strength (N/mm^2) at 7 days			Avg. Split tensile strength (N/mm^2) at 7 days	Split tensile strength (N/mm^2) at 28 days			Avg. Split tensile strength (N/mm^2) at 28 days
M40	3.1	3.2	2.9	3.06	4.1	4.08	4.2	4.12
C10	3.4	3.2	3.05	3.21	4.3	4.2	4.2	4.23
C20	3.5	3.6	3.4	3.5	4.6	4.67	4.4	4.49
C30	3.9	3.8	4.0	3.9	4.98	5.0	5.04	5.00
C40	3.6	3.5	3.8	3.73	4.8	4.7	4.9	4.8
C50	3.4	3.3	3.2	3.3	4.6	4.45	4.35	4.46

Table 14 – Split tensile strength values

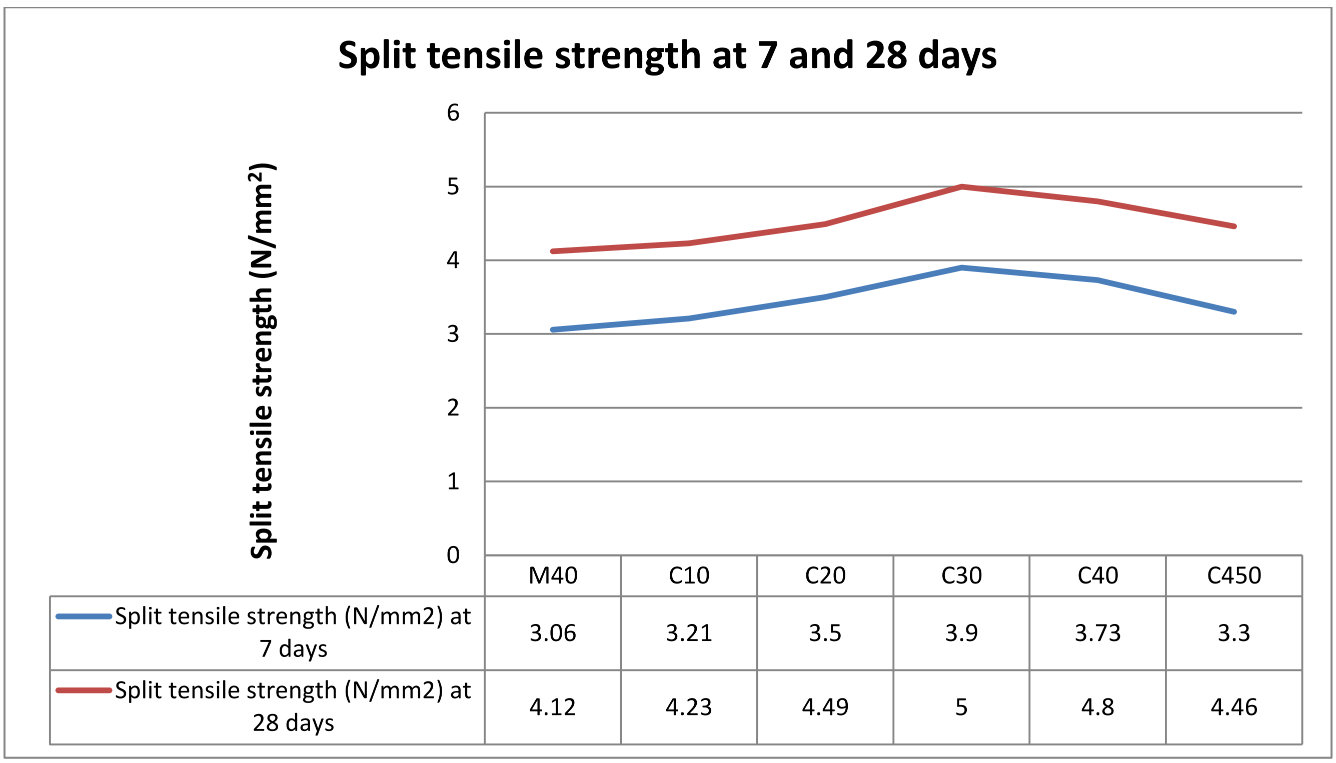


Fig 15 – Graph for split tensile strength for 7 and 28 days

- Fig 14 showing the process of split tensile test, maximum split tensile strength of concrete increased by 27.6% and 21.3% at 30% replacement of fine aggregate by copper slag at 7 and 28 days.

4.1.6 Durability Analysis

Casting-Initially the constituent materials were weighed and dry mixing was carried out for cement, sand and coarse aggregate and ultra fine slag. This was thoroughly mixed manually to get uniform colour of mix. The mixing duration was 2-5 minutes and then the water was added as per the mix proportion. The mixing was carried out for 3-5 minutes duration. Then the mix poured in to the cube moulds of size 100 x 100x 100 mm and then compacted by placing on compaction table. In this study we prepared 6 sets of six different mixes of M40 Grade namely referral as M40, C10, C20, C30, C40, C50 by replacing (0%, 10%, 20%, 30%, 40%, 50%) of sand by copper slag. The cubes were demoulded after 1 day of casting and then six cubes kept in respective solutions of, 5 % H_2SO_4 & in referral solution of 100 % H_2O and six other cube in 5% NaCl solution for curing, at room temperature with a normal humidity. After 30 days the specimens were taken out from respective solution. The surface of specimen was cleaned and weights were measured. The mass loss and strength of specimen due to acid attack will be determined.

Mix	Compressive strength (mpa)	Reduction in compressive strength in percentage	Weight of cube (kg)	weight of cube (kg) after curing in H_2SO_4
M40	33.6	8.1%	2.05	2.20
C10	37.9	6.7%	2.10	2.16
C20	40.26	5.1%	2.15	2.27
C30	43.5	2.1%	2.20	2.32
C40	46.27	2.0%	2.22	2.24
C50	43.2	1.3%	2.25	2.29

Table 15 - Durability test for sulphate attack

Mix	Compressive strength (mpa)	Reduction in compressive strength in percentage	Weight of cube (kg)	weight of cube (kg) after curing in NaCl
M40	30.7	18%	2.00	2.30
C10	35.16	15%	2.08	2.22
C20	37.8	12%	2.12	2.24
C30	40.4	10%	2.17	2.25
C40	43.7	8%	2.20	2.29
C50	40.7	7.6%	2.25	2.30

Table 16 - Durability test for chloride attack

Comparison of compressive strength of cubes in different curing -

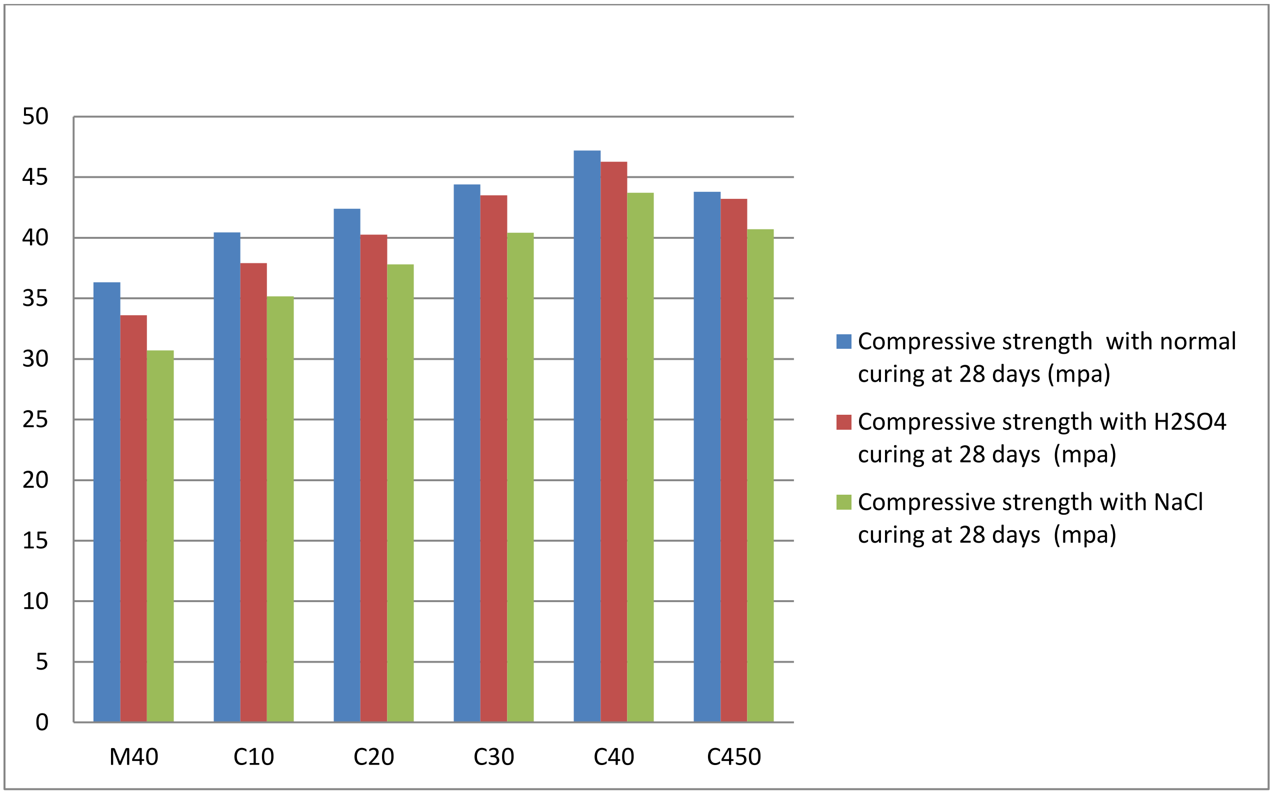


Fig 16- Bar chart for compressive strength in different type curings

Fig17 – Chloride attack test **Fig18– Sulphate attack test**

- From table 15,16 and fig 16 we can conclude that increament in weight and decreament in compressive strength of cubes is more in sulphate attack than chloride attack .

4.2. RESULTS AND DISCUSSION FOR PARTIAL REPLACEMENT OF CEMENT WITH COPPER SLAG

4.2.1. Strength Activity Test by A.S.T.M. (C311)

Strength Activity Test

According to A.S.T.M. C311 Strength activity index with portland cement as follows:
Strength activity index with portland cement = (*A/B*) * 100

where:
A = average compressive strength of test mixture cubes, Pa , and
B = average compressive strength of control mix cubes, Pa .

Mix	Strength at 7 days (N/mm^2)	Avg. Compressive strength (N/mm^2)
Control Mix	150	150
Control Mix	148	
Control Mix	152	

Table 17 – Compressive strength of control mix cube at 7 days

Mix	Strength at 7 days (N/mm^2)	Avg. Compressive strength (N/mm^2)
Test Mix	120	120
Test Mix	119	
Test Mix	121	

Table 18 – Compressive strength of test mix cube at 7 days

S.A.I. = (A/B) * 100 = (120/150)*100 = 80%

- It show that copper slag has pozzolanic activity and we can replace copper slag with cement in concrete.

4.2.2. Compressive Strength test

Concrete was prepared under moderate exposure condition and quality control was good. It was poured into cubical moulds and placed on vibrating table to minimize air entrapped which would otherwise affect the compressive strength. After 24 hrs the moulds were removed and the specimens were kept for curing at room temperature until taken out for testing. Specimens were tested at different ages i.e. 7 days and 28 days compressive strength. The load is applied at a constant rate thus ensuring progressive increase in stress as failure approached.

Mix	Compressive strength in N/mm^2 at 7 days			Avg . Compressive strength in N/mm^2 at 7 days
M40	28.8	30	30	29.6
CC8	27	27	27.8	27.26
CC10	26.5	26	26	26.1
CC12	24.2	24	24.5	24.2
CC15	22.3	22.5	22	22.266

Table 19 (a) - Compressive strength in N/mm^2 at 7 days

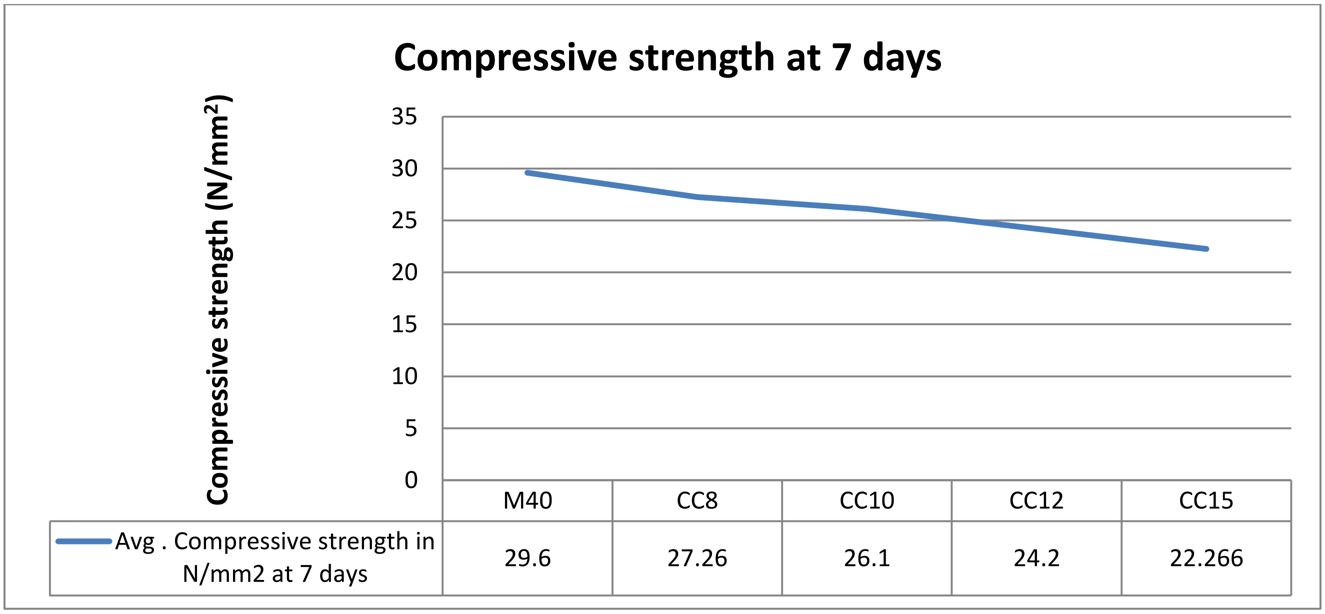


Fig -19 Graph for compressive strength at 7 days

Mix	Compressive strength in N/mm^2 at 28 days			Avg. Compressive strength in N/mm^2 at 28 days
M40	41	39	41	40.33
CC8	38	38.5	37	37.83
CC10	37.5	38	37	37.5
CC12	35	35.27	35	35.09
CC15	32	32	32.8	32.26

Table 19 (b) - Compressive strength in N/mm^2 at 28 days

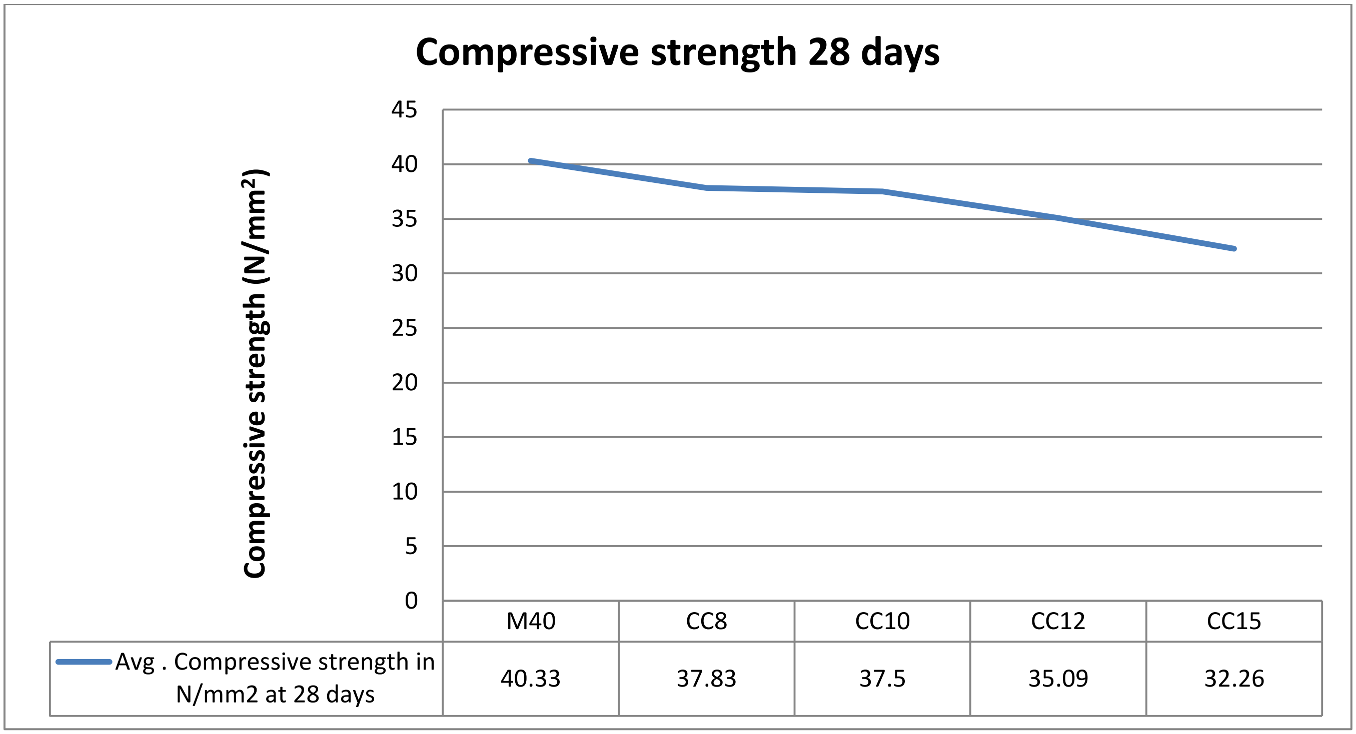


Fig 20-Graph for compressive strength at 28 days

Fig21 – Compressive strength testing

- Fig 21 showing the process of compression test, after completing the compression test i concluded that the Optimum content of copper slag is 8 % by weight replacement of copper slag with cement in M40 mix. Compressive strength of concrete decreased by 8% at 8 % replacement of cement by copper slag at 7 days , and 6% at 8% replacement of cement by copper slag at 28 days.

4.2.3. Workability test by slump

In order to study slump of M40 mix containing different proportion of copper slag were prepared and checked for workability.

Results-

Mix	Slump (mm)
M40	68
CC8	75
CC10	81
CC12	86
CC15	94

Table 20 -Slump values

Standard values of slump-

Workability	Slump (mm)
Very low	0-25
Low	25-50
High	50-100
Very high	100-175

Table 21 - Standard values of slump

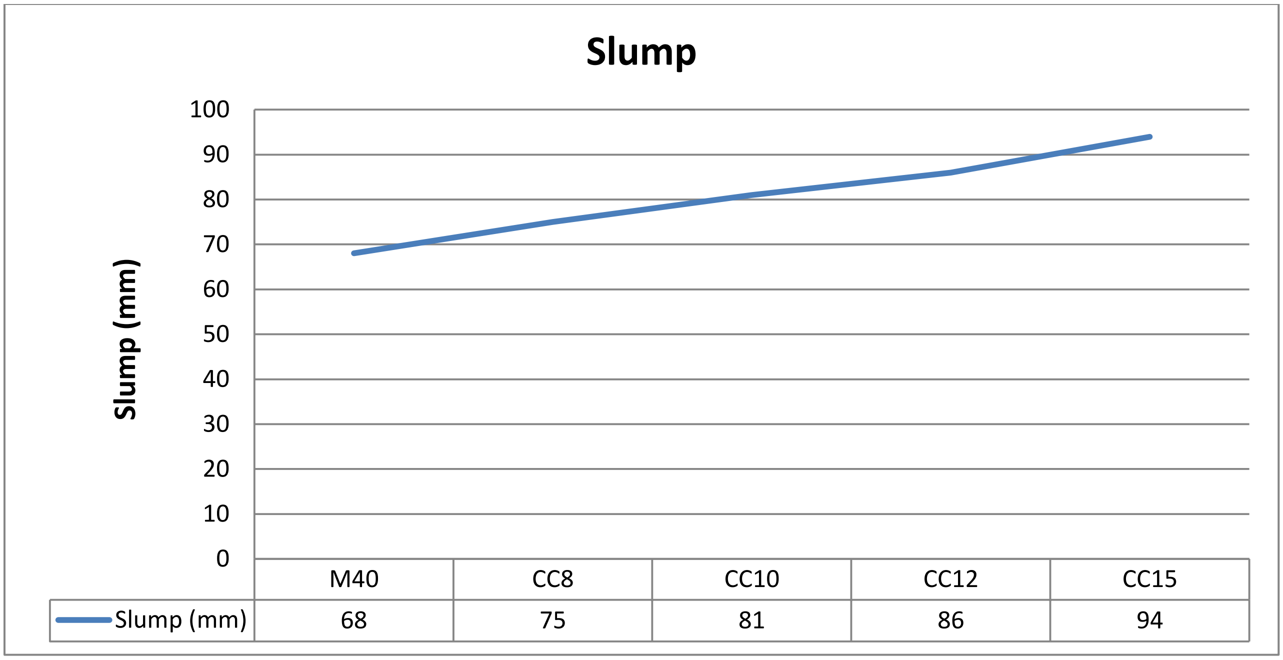


Fig22- Graph for slump values

Fig 23 (a)– Slump test for different proportions

Fig 23 (b)– slump test for different proportions

- Above fig 23 shows the decrement in the height of concrete (called as slump) for different proportions of copper slag in M40 grade of concrete and from fig 22 and table 21, it is observed that, the workability of concrete increases for all percentage replacements done in design mix.

4.2.4 Compaction factor test

In order to find the compaction factor of M40 mix containing different proportion of copper slag were prepared and checked for workability.

Results-

Mix	Compaction Factor
M40	0.75
CC8	0.78
CC10	0.87
CC12	0.90
CC15	0.92

Table 22 - Compaction factor for different mixes

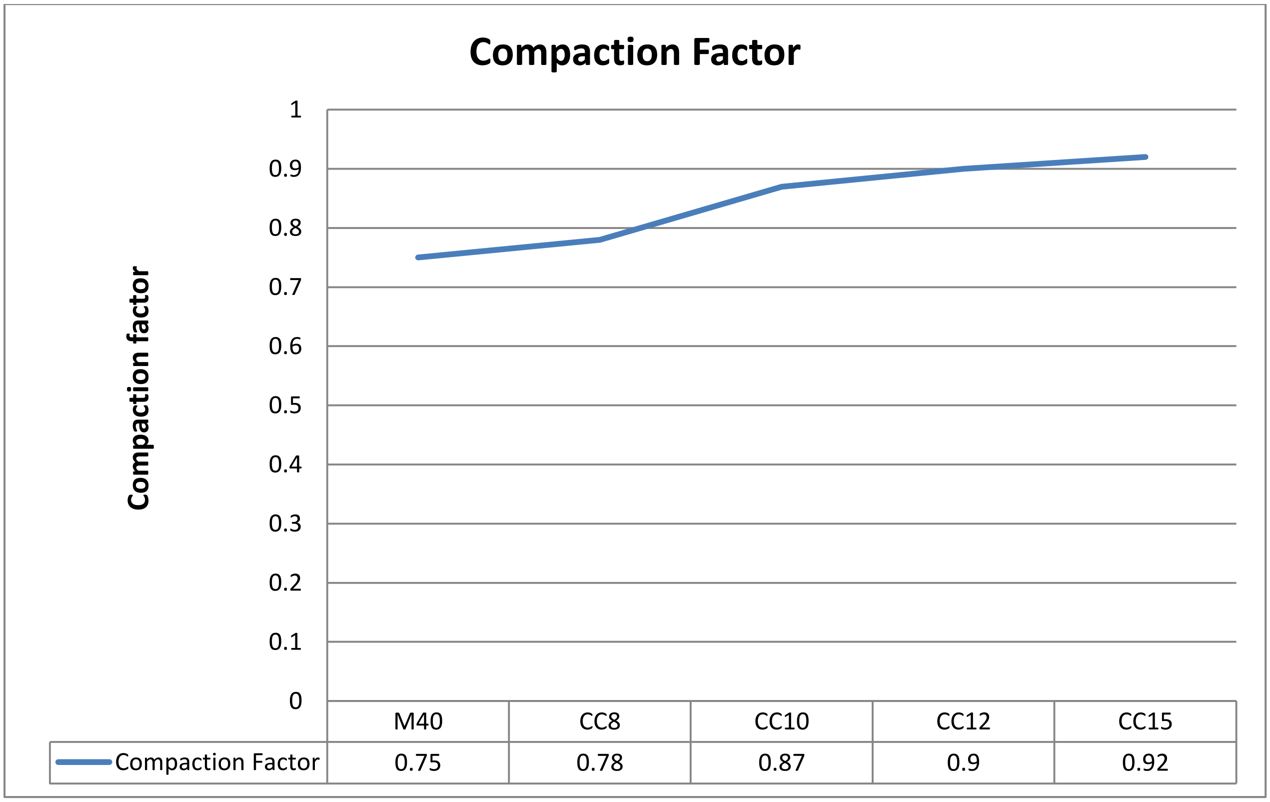


Fig 24 -Graph of compaction factor for different mixes

Fig25 – compaction factor test

- Fig 25 shows the test procedure of compaction test of the concrete and from fig 24 and table 22, it is observed that, the compaction factor of concrete increases for all percentage replacements done in design mix.

4.2.5 Flexural strength-

In order to study the effect on flexural strength, the beams containing different proportion of copper slag were prepared and kept for curing for 28 days. The test was conducted on U.T.M as per I.S.516-1959.

Results-

Mix	Flexure strength (N/mm^2) at 28 days			Average flexure strength (N/mm^2)
M40	4.2	4	4.3	4.16
CC8	4	4.12	3.98	4.03
CC10	3.8	3.85	3.78	3.75
CC12	3.62	3.72	3.69	3.67
CC15	3.5	3.45	3.5	3.48

Table 23 – flexure strength test

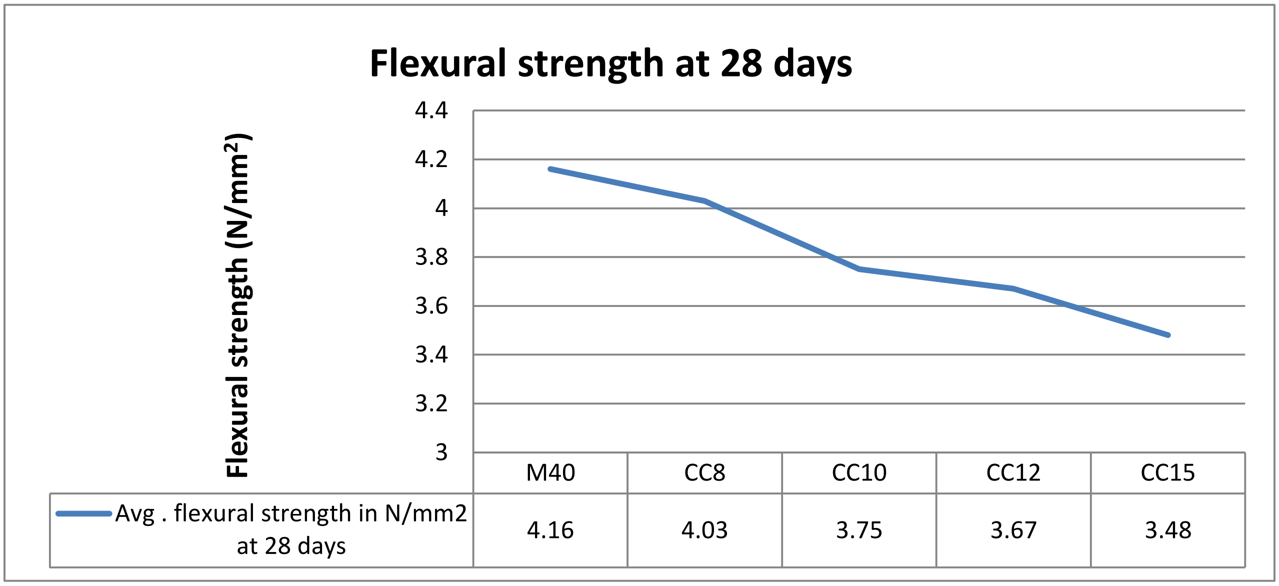


Fig 26 – Graph for flexure strength

- Fig 26 and table 23 showing flexural strength of concrete decreased by 3.1% at 8% replacement of cement by copper slag at 28 days.

4.2.6 Split tensile test

Concrete mixed with copper slag was prepared under moderate exposure condition and quality control was good. It was poured into cylindrical mould and was hand compacted by tamping rod to ensure homogenous distribution of copper slag to minimize air entrapped which would otherwise affect the compressive strength. After 24 hrs the moulds were removed and the specimens were kept for curing at room temperature until taken out for testing. Specimens were tested at different ages i.e. 7 days and 28 days for split tensile test. The load is applied at a constant rate thus ensuring progressive increase in stress as failure approached.

Mix	Split tensile strength (N/mm^2) at 7 days			Avg. Split tensile strength (N/mm^2) at 7 days	Split tensile strength (N/mm^2) at 28 days			Avg. Split tensile strength (N/mm^2) at 28 days
M40	3.3	3	3.2	3.16	4..3	4.23	4.24	4.21
CC8	3.1	2.89	2.9	2.96	4.1	4	3.9	4.00
CC10	2.7	2.8	2.85	2.783	3.8	3.7	3.78	3.76
CC12	2.45	2.54	2.5	2.49	3.4	3.45	3.5	3.45
CC15	2.05	2.12	2	2.05	3	2.98	3.12	3.03

Table 24 – Split tensile strength values

Fig 27- Split tensile testing

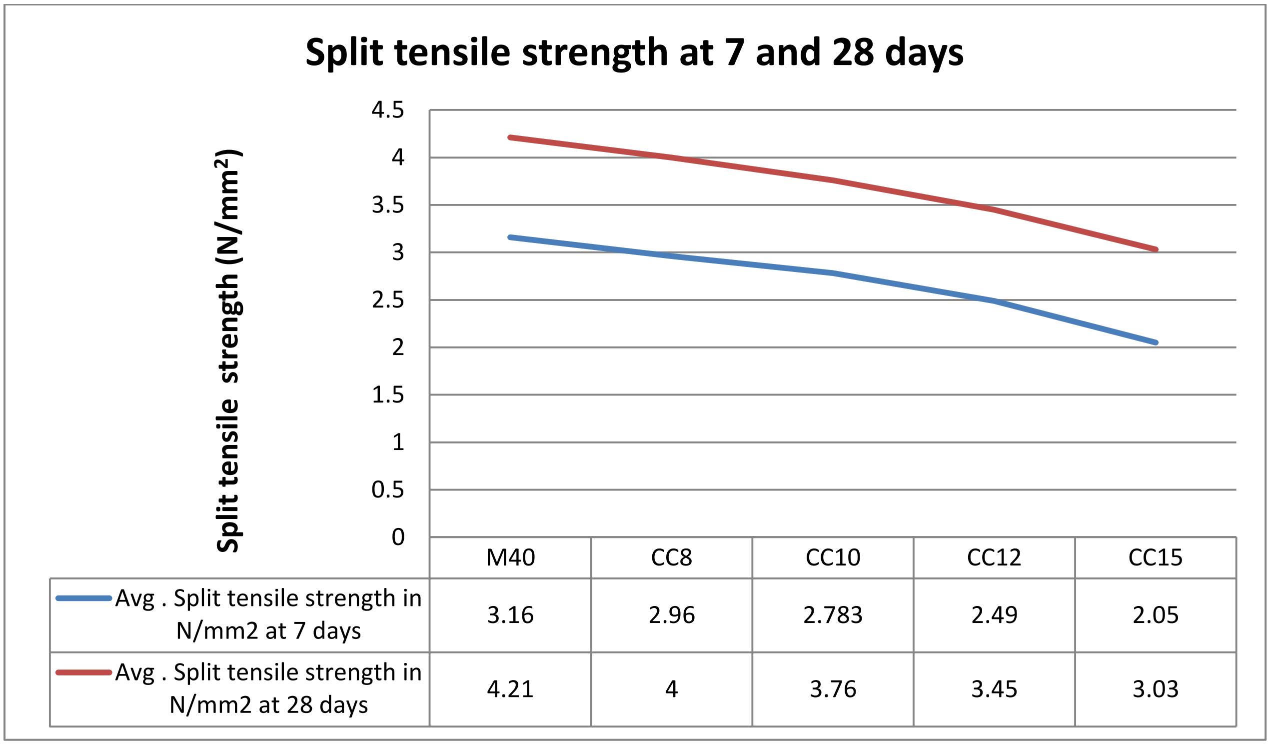
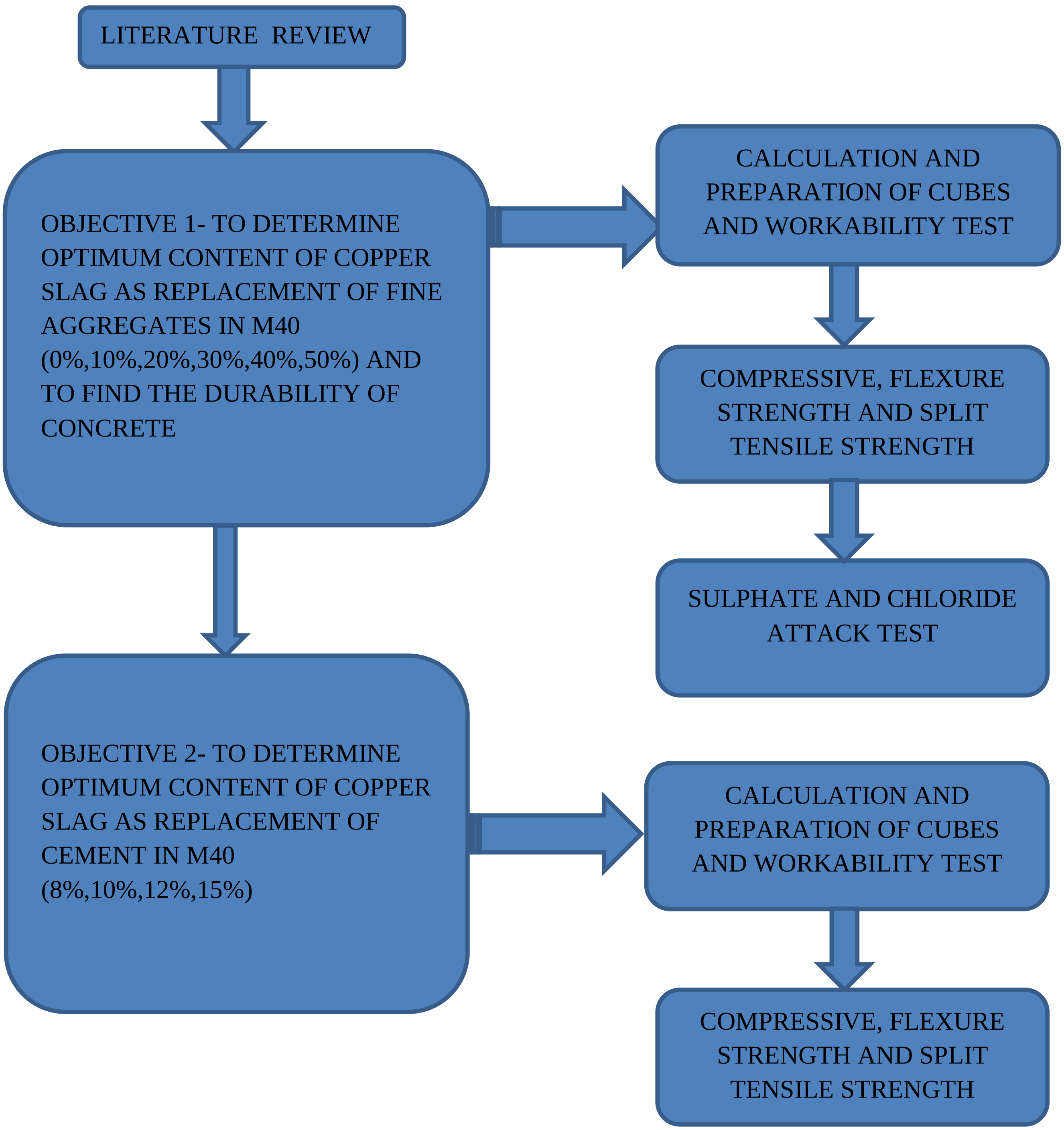


Fig 28 –Graph for split tensile strength for 7 and 28 days

- Fig 27 and fig 28 showing the process of split tensile test and split tensile strength of concrete deccreased by 5% and 6 % at 8% replacement of cement by copper slag at 7 and 28 days.

CHAPTER 5

5. Methodology



CHAPTER 6
Conclusion

- Maximum Compressive strength of concrete increased by 31.2% and 29.9% at 40% replacement of fine aggregate by copper slag at 7 and 28 days.
- Maximum split tensile strength of concrete increased by 27.6% and 21.3% at 30% replacement of fine aggregate by copper slag at 7 and 28 days.
- Maximum flexural strength of concrete increased by 23.2% at 30% replacement of fine aggregate by copper slag at 28 days.
- Compressive strength of concrete decreased by 8% and 6% at 8% replacement of cement by copper slag at 7 and 28 days.
- Split tensile strength of concrete decreased by 5% and 6% at 8% replacement of cement by copper slag at 7 and 28 days.
- Flexural strength of concrete decreased by 3.1% at 8% replacement of cement by copper slag at 28 days
- Optimum content of copper slag is 40% by weight replacement of copper slag with sand in M40 mix.
- Optimum content of copper slag is 8% by weight replacement of copper slag with cement in M40 mix.
- As the percentage of Copper slag in concrete mix increases, the workability of concrete increases. This is because copper slag is unable to absorb the water in large proportion.
- Addition of slag in concrete increases the density thereby the self-weight of the concrete.
- Compaction factor value also increases as the rate of percentage by weight of copper slag increases.
- Copper slag has good resistant from chloride and sulphate attack , because of its low permeability.
- Compressive strength is increased when it is partially replaced with fine aggregates due to high toughness of Copper slag.
- Use of copper slag helps in waste management and dumping industrial wastes.

CHAPTER 7
Recommendations

This report recommends that-

- The results of compressive test show that the strength of the concrete increases with respect to the percentage of copper slag added by weight of fine aggregate up to 40% of replacement. Therefore, the recommended percentage replacement of fine aggregate by copper slag is 40%. Compared to the control concrete, the copper slag based concrete showed increment in the workability. It is also concluded that the concrete with copper slag gains more strength than the control concrete.
- This report also shows that we can partially replace 8% of cement with copper slag as the compressive strength decreases very less about 8%. Compared to the control concrete, the copper slag based concrete showed increment in the workability. Therefore, the recommended percentage replacement of cement by copper slag is 8%.

References

1. T.Poovizhi and P.Kathirvel (2015) “Behaviour Of Concrete With Partial Replacement Of Copper Slag As Cement And Fine Aggregate” Transactions on Engineering and Sciences ISSN: 2347-1964 (Online) 2347-1875 Vol.3, Issue 2.

2. Binaya Patnaik ,Seshadri Sekhar.T and Srinivasa Rao (2015) “ Strength and durability properties of copper slag admixed concrete” IJRET: International Journal of Research in Engineering and Technology.

3. Jagmeet Singh, Jaspal Singh and Manpreet Kaur (2014) “ Use of copper slag in concrete” International Journal of Advanced Research in Engineering and Applied Sciences.

4. Leema rose andP. Suganya (2015) “ Performance of copper slag on strength and durability properties as partial replacement of fine aggregate in concrete” International Journal of Emerging Technology and Advanced Engineering -Volume 5, Issue 1, (January 2015).

5. M. V. PATIL “A STUDY ON PROPERTIES AND EFFECTS OF COPPER SLAG IN CONCRETE” IRF International Conference, 11th January 2015.

6. Harpreet Singh and Gurprit Singh Bath, “USE OF COPPER SLAG AS FINE AGGREGATE - A CASE STUDY”, INTERNATIONAL JOURNAL OF INNOVATIONS IN ENGINEERING RESEARCH AND TECHNOLOGY [IJIERT] ISSN: 2394-3696 VOLUME 2, ISSUE 5, MAY-2015.

7. Deepak Gowda. B and H. B. Balakrishna (2014) “ Experimental study on flexural behavior of reinforced concrete beams by replacing copper slag as fine aggregate” International Journal of Civil and Structural Engineering Research ISSN 2348-7607 (Online) Vol. 2, Issue 1, pp: (97-103).

8. V.M. Illayaraja Muthaiyaa , G. Elatharasan and A. Krishnamoorthy (2014) " copper slag" National Conference on Green Engineering and Technologies for Sustainable Future-2014.

9. R R Chavan and D B Kulkarni (2013) "Performance of copper slag on strength properties as partial replace of fine aggregate in concrete mix design" International Journal of Advanced Engineering Research and Studies.

10. Amit S. Kharade , Sandip V. Kapadiya and Ravindra Chavan (2013) "An Experimental Investigation Of Properties Of Concrete With Partial Or Full Replacement Of Fine Aggregates Through Copper Slag" International Journal of Engineering Research & Technology (IJERT).

11. M. Najimi, J. Sobhani, A.R. Pourkhorshidi, "Durability of copper slag contained concrete exposed to sulfate attack", Elsevier Construction and Building Materials 25 (2011) 1895–1905.

12. Brindha D, Baskaran T, Nagan S, "Assessment of Corrosion and Durability Characteristics of Copper Slag Admixed Concrete", International Journal of Civil and Structural Engineering, Vol. 1, No. 2, 2010, pp. 192 – 211.

13. Wei Wu, Weide Zhang, Guowei Ma "Optimum content of copper slag as a fine aggregate in high strength concrete" Materials and Design, Elsevier science Ltd, Vol. 31, 2010, pp. 2878–2883.

14. Srinivas C. H and S. M Muranal, " Study of the Properties of Concrete Containing Copper Slag as a Fine Aggregate", Construction and Building Materials, Vol. 23, December 2009, pp. 2132–2142.

15. Jardel Pereira Goncalves and Monica Batista Leite Lima, "Copper slag waste as a supplementary cementing material to concrete", Journal of Materials Science 42(7):2226-2230 · March 2007.

16. Jagmeet Singh, Jaspal Singh and Manpreet Kaur, " USE OF COPPER SLAG IN CONCRETE", International Journal of Advanced Research in Engineering and Applied Sciences Vol. 3, No. 12, December 2014.

17. IS:10262 (Guidelines for concrete mix proportioning).

Annexure A

Mix Design –

M 40 Design procedure

Conditions –

- Max. size of aggregates – 20 mm
- Min content of cement – 320 kg/m^3
- Slump – 120 mm
- Exposure – severe and for pumping purpose
- Max content of cement – 450 kg/m^3
- Max water cement ratio – 0.45
- Specific gravity of cement – 3.15
- Specific gravity of coarse aggregates – 2.74
- Specific gravity of fine aggregates – 2.74

Design –

Target mean strength –

$$F_t = F_{ck} + 1.65 * S$$

F_t – target mean strength

F_{ck} - characteristic compressive strength at 28-day

S – standard deviation

F_t = 40+1.65*5 (S from table 1 of IS 10262:2009)

= 48.75 N/m^2

Max water content = 186 lit (for 120 mm slump from table 2 of IS 10262:2009)

Estimated water content for 120mm slump = 186 + (6/10)*18 = 197 lit

Calculation of cement –

w/c =0.40

c=w/0.40

c= 197/.40 =492.50 kg/m^3 (more than 450 kg/m^3 hence we take 450 kg/m^3)

calculation of coarse and fine aggregates –

Proportion of volume of coarse and fine aggregate content

From Table 3 -volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate (zone 3) for water-cement ratio of 0.50 =0.62. (from table 3 of IS10262:2009)

In the present case water-cement ratio is 0.40. Therefore, volume of coarse aggregate is required to be increased to decrease the fine aggregate content. As the water-cement ratio is lower by 0.10. the proportion of volume of coarse aggregate is increased by 0.02 (at the rate of -/+ 0.01 for every ± 0.05 change in water-cement ratio).
Therefore corrected proportion of volume of coarse aggregate for the water-cement ratio of 0.40 = 0.64.

For pumpable concrete these values should be reduced by 10 percent.
Therefore, volume of coarse aggregate = 0.64 x 0.9 = 0.576.
Volume of fine aggregate content = 1 - 0.576 =0.424.

MIX CALCULATIONS –

Volume of concrete = 1 m^3

Volume of cement = (mass of cement / specific gravity of cement)* (1/1000)

=450/3.15 * 1/1000

=0.142 m^3

volume of water = mass of water/ s.g. of water * 1/1000

=197/1 *1/1000

=0.197m^3

Volume of all in aggregates =(a-(b+c)) =(1- (0.142+0.197)) = 0.66

Mass of coarse aggregates = e * volume of coarse aggregates * specific gravity of coarse aggreagates *1000

= 0.66*0.576*2.74*1000 =1046kg

Mass of fine aggregates = e * volume of coarse aggregates * specific gravity of fine aggreagates *1000

= 0.66*0.424*2.74*1000 =766.76kg

Mix proportion (M40)–

Cement = 450 kg/m^3

Water = 197 lit

Fine aggregates = 766.76 kg/m^3

Coarse aggregates = 1046 kg/m^3

Water-cement ratio = 0.4

Annexure B

- **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 25 – table 1 of IS 10262:2009

➢ **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 26 – table 2 of IS 10262:2009

➢ **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	Volume of Coarse Aggregate[1] per Unit Volume of Total Aggregate for Different Zones of Fine Aggregate			
	mm	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.

Table 27 – table 3 of IS 10262:2009