Experimental Study on High Strength Self - Compaction Concrete by using Fly Ash as a Partial Replacement of Cement and Copper Slag with Fine Aggregate

M. Veerraju, S. Arunchaitanya

Abstract**:** ***In recent years, many of the structures are in complicated Architectural design, it is very difficult to compact the concrete in congested reinforcement. Self-Compacting Concrete (SCC) is a new kind of high performance concrete with excellent deformability and segregation resistance and that can flow through the gaps, corners and joints of reinforcement, without any vibrations or compaction. It was first developed in japan, 1986. But in our country usage of SCC is very less when compared with other countries like japan, European countries etc. Construction industry is facing a lot of problem with availability of natural resources. To overcome this, we need to go for alternative material in place of conventional aggregate. The attention for the environmental aspects moves the research towards recycling industrial by-products, as Fly ash and Copper slag. In this experimental study M60 grade of concrete is to be adopted. The cement and fine aggregate is partially replaced with fly ash and Copper slag respectively. Fly Ash will be replaced 5%, 10%, 15%, 20%, 25% by weight of cement And Copper slag by weight of fine Aggregates in various percentages such as 10%, 20%, 30%, 40%, 50% .The Compressive strength, Flexural strength, Split tensile strength on hardened concrete with various replacements is to be investigated. Slump cone, V-funnel, L-box, J-box, T-50 will also be conducted***

Index Terms**:** ***Fly Ash, Copper Slag, T50 test, L-box, J-box, V-funnel, Compressive Strength, Split Tensile Strength, Flexural Strength, high water reducer (HWR).***

I. INTRODUCTION

Self-consolidating concrete is a highly flowable type of concrete that spreads into the form without the need for mechanical vibration. Self-Compacting Concrete is a non-segregating concrete that is placed by means of its own weight. The importance of self-compacting concrete is that maintains all concrete's durability and characteristics, meeting expected performance requirements. In certain instances the addition of super plasticizers and viscosity modifier are added to the mix, reducing bleeding and segregation.

Concrete that segregates loses strength and results in honeycombed areas next to the formwork. A well designed SCC mix does not segregate, has high deformability and excellent stability characteristics. Self-consolidating concrete (SCC) owns over three key characteristics those are Filling Ability, Passing Ability and Segregation resistance. These characteristics were made possible by the development of highly effective water reducing agents (super plasticizers), those usually based on poly-carboxylate ethers. The mixture composition of SCC deviates from conventional concrete. The powder contents of SCC are normally lying above those of conventional concrete.

In India, there is great demand of aggregates mainly from civil engineering industry for road and concrete constructions, mainly coarse aggregate occupied place is 70% of aggregate. But now–a-days we are facing a problem due to scarcity of fine aggregate. 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 are considered as a waste material which could have a promising future in construction industry as partial or full replacement of either cement or aggregates. It is a by- product obtained during the matte smelting and refining of copper. To produce every ton of copper, approximately 2.2–3.0 tons copper slag is generated as a by-product material. In India, one of the copper slag is produced by Satellite Industries Ltd (SIL), Tuticorin Tamil Nadu.

It is producing Copper slag during the manufacture of copper metal. Currently, about 2600 tons of Copper slag is produced per day and a total accumulation of around 1.5 million tons. If we are able to use the copper slag in place of natural sand then we can successively obtain a material to replace the sand, which is eco-friendly and cost effective. Hence there is a growing need to find the alternative solution for the slag management. In the present study, it is proposed to study the effect of addition of copper slag mixed with natural sand in concrete.

II. LITERATURE SURVEY

1. Khalifa S. Al-Jabri, et. Al. (2009): The effect of using copper slag as a replacement of sand on the properties of high performance concrete (HPC).

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Concrete mixtures were prepared with different proportions of copper slag ranging from 0% to 100%. There is a slight increase in the HPC density of nearly 5% with the increase of copper slag content, workability increased rapidly. Recommended that 40% to 50% of copper slag can be used as re-placement of fine aggregate in order to obtain high performance concrete with good strength and durability properties

2. Dinesh (2016): concluded that cement replacement with fly ash and copper slag studies M50 grade of concrete. The cement and fine aggregate is partially and fully replaced with fly ash and copper slag. Replacement of copper slag by weight of fine Aggregates in various percentages such as 10%, 20%, 30%, 40% up to 100% does not have any adverse effect on strength. Water consumed by the copper slag when compared with river sand is very less . Use of copper slag and fly ash in construction is very cheap and gives good result.

The 30% replacement of sand with copper slag and 40% replacement of weight of cement with fly ash significantly increase the compressive strength of concrete mixtures.

3. Mostafa Khanzadi, Ali Behnood (2009): In this study the effects of replacing limestone coarse aggregate by copper slag coarse aggregate. The compressive strength, splitting tensile strength, and rebound hammer values of high-strength concretes are evaluated in the work. Concrete mixtures containing different levels of silica fume were prepared with water to cementations materials ratios of 0.40, 0.35, and 0.30. The percentages of the cement replacements by silica fume were 0%, 6%, and 10%. The use of copper slag aggregate compared to limestone aggregate resulted in a 28-day compressive strength increase of about 10–15%, and a splitting tensile strength increase of 10–18%, Increased the rebound hammer measurements from 2.6% to 9.3%, because of the higher hardness of copper slag aggregates.

III. RESEARCH OBJECTIVES

In the present investigation, a self-compacting concrete mix, proportioned for a characteristic strength of 60 MPa had been studied with different proportions. Super plasticizer and viscosity modifying agent were used to obtain the SCC characters at fresh state. Compressive, tensile and flexural strength and modulus of elasticity of the SCC mix were investigated to determine the optimum proportion of HSSCC.

The main objective of this study was to investigate the use of copper slag as partial and/or full replacement for fine aggregate in normal and high strength self-compacting concrete mixtures. The following were specific tasks:

(1) Evaluate the effect of copper slag addition on the workability and density of normal and high strength self-compacting concretes.

(2) Conduct compressive, tensile and flexural strength testing on concrete mixtures.

IV. SELF-COMPACTING CONCRETE

Self-Compacting Concrete (SCC) is a type of special concrete that has high workability and self-compacting property, i.e. the compaction occurs due to its high flowing property and the need for external vibrators are not required. The concrete is cohesive enough to avoid bleeding or segregation. he making of self-compacting concrete for high strength purpose the water cement ration should be kept to the minimum. In order to increase the flow property and high workability, chemical admixtures are used in order to increase the workability of the concrete without compromising on the water cement ratio and strength of the concrete.

The following properties shown in Table-I should satisfy the SCC

Table-I Tests to Determine the Workability

Property	Test Method
Filling Ability	Slump Flow, T50 cm slump flow, V-Funnel
Passing Ability	L-Box, U-Box
Segregation Resistance	V-Funnel at T5 min

Self-Compacting Concrete should contain some limitation as shown Table- II.

Table – II SSC Properties

Test method	Property	Permissible range of values	
		Min	Max
Slump flow	Filling Ability	650mm	800mm
T50 cm slump flow	Filling Ability	2sec	5sec
V-Funnel	Filling Ability	8sec	12sec
J-Ring	Passing Ability	0	10mm
L-Box	Passing Ability	0.8	1.0
U-Box	Passing Ability	0	30
V-Funnel at T5 min	Segregation Ability	0	3sec

SCC must meet the required levels of properties filling and passing ability whilst its compaction remains uniform throughout the process of transport and placing. Many tests have been used in successful applications of SCC. However, in all the projects the SCC was produced and placed by an experienced contractor whose staff has been trained and acquired experience with interpretation of a different group of tests. Slump flow test, L – Box test, U – Box test, V funnel test were used to evaluate the fresh concrete properties of SSC.

A) SLUMP FLOW TEST: It is the most commonly used test and gives a good assessment of filling ability. The slump cone is held down firmly. The cone is then filled with concrete. No tamping is done. Any surplus concrete is removed from around the base of the concrete. After this, the cone is raised vertically and the concrete is allowed to flow out freely. The diameter of the Concrete in two perpendicular directions is measured the slump board was shown in Fig - I. The average of the two measured diameters is calculated. This is the slump flow in mm, the higher the slump `under its own weight. The range is from 600 mm to 800 mm.

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B) L -BOX TEST: It assesses filling and passing ability of SCC. The vertical section is filled with concrete, and then gate lifted to let the concrete flow into the horizontal section. When the flow has stopped, the heights 'H_1' and 'H_2' are measured. Closer to unit value of ratio 'H_2/ H_1' indicates better flow of concrete as shown in Fig – II.

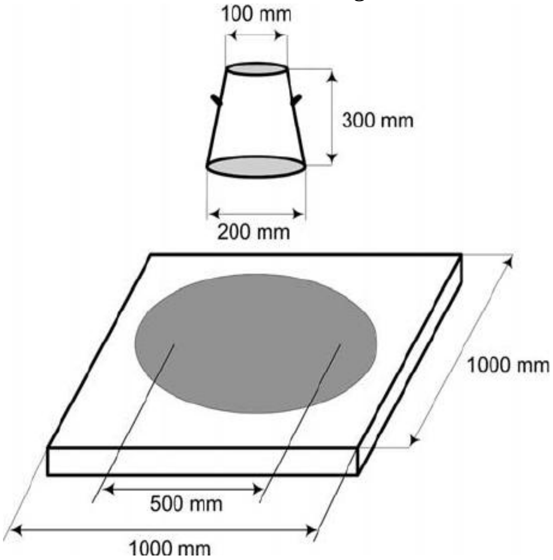

Fig –I Slump Cone

C) V-FUNNEL TEST: The test measures flow ability and segregation resistance of concrete. The test assembly is set firmly on the ground and the inside surfaces are moistened. The trap door is closed and a bucket is placed underneath. Then the apparatus is completely filled with concrete without compacting. After filling the concrete, the trap door is opened and the time for the discharge is recorded. This V-funnel determines the filling ability of concrete. This is taken to be when light is seen from above through the funnel. To measure the flow time at T 5minutes, the trap door is closed and V-funnel is refilled immediately. The trap door is opened after 5 Minutes and the time for the discharge is recorded. This is the flow time at T 5 minutes. Shorter flow time indicates greater flow ability. V- Funnel at T 5mm indicates the resistance to segregation. It should be 0-3 sec. if concrete segregates, time increases as shown in Fig – III.

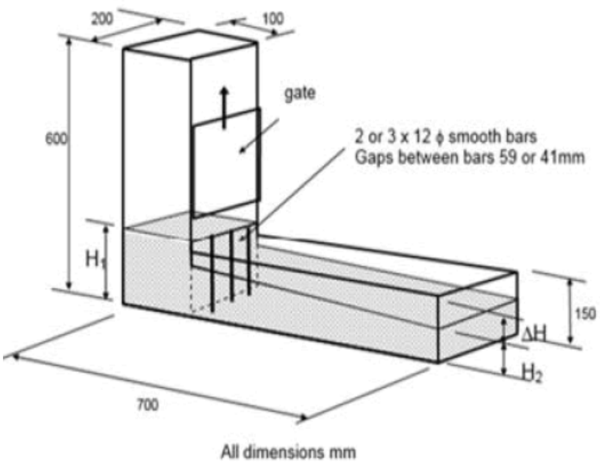

Fig – II L-Box

D) U-BOX TEST: This method used for evaluating Self-Compatibility, the U-type test proposed by the Taisei group is the most appropriate, due to the small amount of concrete used, compared to others as shown in Fig- IV. In this test, the degree of compatibility can be indicated by the height that the concrete reaches after flowing through obstacles. Concrete with the filling height of over 300mm can be judged as Self-Compacting. Some companies consider the concrete Self-Compacting if the filling height is more than 85% of the maximum height possible.

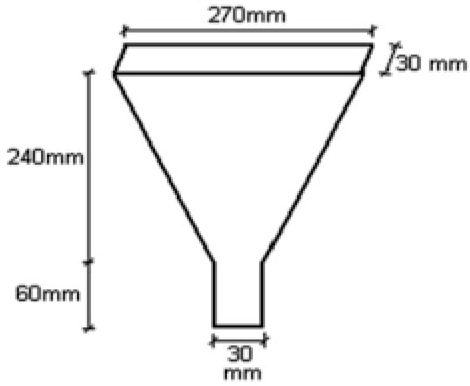

Fig – III V- Funnel

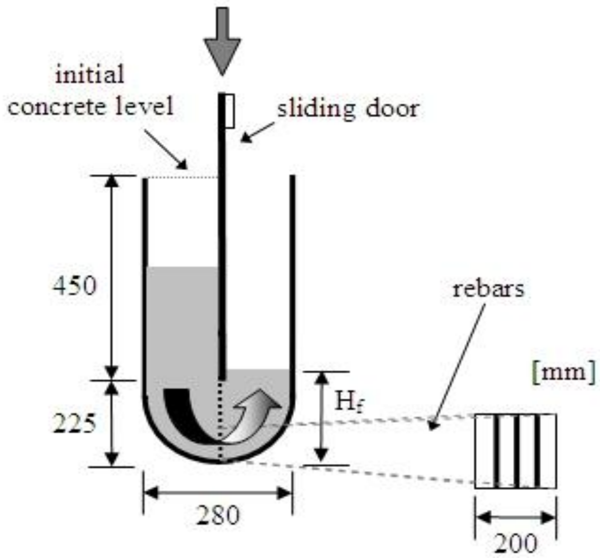

Fig – IV U-Box Test

V. MATERIALS

For this research project the following materials are used for preparation of the Self-Compacting Concrete.

A) CEMENT: Ultra tech 53 grade ordinary Portland cement is used for this study. This cement is the most widely used in the construction industry in India. The different property of cement is shown in Table - III. It conforms to various standard test as per IS recommendation.

B) FLYASH: Fly ash is a finely divided powder obtained from the combustion of bituminous coal or sub-bituminous coal (lignite). It is also known as Flue Ash. It is available in large quantities in the country as a waste material which is obtained at the thermal power plants. Fly Ash is used as a partial replacement of cement for cement concrete.

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The properties of Fly-Ash are Fineness – 4% and Specific Gravity – 2.625.

C) FINE AGGREGATE: The sand particles should be free from any clay or inorganic materials and found to be hard and durable. Aggregates of size ranges between 0.075mm – 4.75mm are generally considered as fine aggregate. The Fine aggregate are selected as per IS-383 specifications.

The Fine aggregate to be used in the SCC has the following properties.

- Natural river sand
- Specific Gravity 2.66
- Fineness Modulus 2.81
- Fine aggregate zone –II

Table – III Cement Properties

Property	Average value for OPC used in investigation	As per code Standard value for OPC
Fineness	4.33%	Less than 10 % as per IS 4013 part- I
Specific Gravity	3.15	3-3.15 as per IS 4013 part-XI
Consistency	31%	IS 4013 part- IV OPC ranges from **26 to 33%**
Initial setting time	37min	Not Less than **30** minutes as per IS 4013 part- V
Final setting time	395 minutes	Less than **600** minutes as per IS 4013 part-V
Compressive strength (N/mm^2)		
3 days	28.7	>27
7days	39.63	>37
28days	55.94	>53

D) COPPER SLAG: Copper slag is by-product of the manufacture of copper. Large amount of copper slag are generated as waste Worldwide during the copper smelting process. To produce every ton of copper, approximately 2.2–3.0 tons copper slag is generated as a by-product material. The properties of Copper Slag are shown in Table-IV.

Table – IV Copper Slag Properties

Particulars	Values
Particle shape	Irregular
Appearance	Black and glassy
Fineness modulus	3.58
Specific gravity	3.218

E) COARSE AGGREGATE: Sizes of aggregates above 4.75mm are generally considered as coarse aggregate. The maximum size of coarse aggregate used in this experimental work is 12 mm and 10 mm, and chips also have used 20% that is size of 12mm passing and 10mm retaining. A good quality of Coarse aggregate is obtained from nearest crusher unit. The Coarse aggregate are selected as per IS-383 specifications.

The Coarse aggregate to be used in the SCC has the following properties.

- Crushed blue granite
- 12 and 10 mm size
- Angular shape
- Specific Gravity 2.925 and 2.915
- Fineness modulus 7.29

F) WATER: Water gives strength to cement and workability to the concrete. Drinking water is used for casting and curing of the concrete blocks.

G) SUPER PLASTICIZER: Chemical Admixture - Glenium B233 is an admixture of new generation based on modified poly carboxylic ether. The addition of super plasticizer to dry aggregate or cement is not recommended and forced action for 60 seconds in mixers is recommended as shown in Table – V.

This is based on a unique carboxylic ether polymer with long lateral chains. This greatly improves cement dispersion. At the start of mixing process the electrostatic dispersion occurs but the presence of lateral chains, linked to the polymer backbone, generate a steric hindrance which stabilizes the cement particle to separate and disperse.

Table – V Properties of GLENIUM B233

Properties	Limits
Colour	Light Brown liquid
Relative density	1.09 ± 0.01
pH	>6
Chloride ion content	<0.2%

Dosage – GLENIUM B233 dosage ranges from 500ml to 1500ml per 100 kg of cementitious material is normally recommended. Figure 1 shows the manufacture pack of GLENIUM B233 from BASF Chemicals

Fig- V GLENIUM B233

VI. MIX PROPORTIONS

Mix design can be defined as the process of selecting suitable ingredients of concrete and determining with the object of producing concrete of certain minimum strength and durability as economically as possible. To achieve the desired combination of properties in fresh SCC mixes:

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- The fluidity and viscosity of the concrete paste is adjusted and balanced by careful selection and proportioning of the cement and additions, by preventive the water to powder ratio and then by adding a super plasticizer (SP). Perfectly controlling these elements of SCC, their compatibility and interaction is that the key to achieving good quality filling ability, passing ability and segregation resistance.
- The coarse to fine aggregate ratio in the concrete mix is reduced so that individual coarse aggregate particles are fully surrounded by a layer of mortar. This may reduce and weak aggregate interconnect and bridging when the concrete mix passes through slender openings or gaps between reinforcing bars and shows increase in the passing ability of the self-compacting concrete.

For the present work SCC of grade M60 is adopted. The mix design of SCC is obtained as per standard procedure as out lined in IS: 10262-2009 was followed. The mix proportion for one cubic meter for M60 designed for SCC was shown in Table –VI and the total concrete mixes considered are shown in Table – VII.

Table – VI. Mix Proportion for M60 SCC

S no	MATERIALS		WEIGHTES
1	Cement content		550 kg/m^3
2	Fine aggregate		649.94 kg/m^3
3	Coarse aggregate	10 mm size	464.83 kg/m^3
		12 mm size	699.64 kg/m^3
4	Water content		165 liters
5	Super plasticizer		8.25 liters

Mix proportion = 1:1.18:2.11

Table – VII Mix Types

S. No	Mix Notations	Fly ash (%)	Copper Slag (%)
1	A	Conventional	
2	B	5	0
3	C	10	
4	D	15	
5	E	20	
6	F	25	
7	G	15 (OPTIMUM)	10
8	H		20
9	I		30
10	J		40
11	K		50

VII. RESULTS AND DISCUSSION

A. Results for Fresh Concrete

Workability test are carried out for fresh concrete the results are shown in Table – VIII & IX .

Table – VIII Fly ash Proportional Fresh Concrete Mix Results

Mix	Slump Flow(sec)	T50(mm)	L – Box (mm)	V – Funnel (sec)	J – box (mm)
A	4.5	762	0.83	9.2	33
B	4.3	758	0.84	8.9	29
C	4.1	755	0.86	8.5	27
D	3.9	751	0.87	8.2	25
E	3.7	748	0.92	8.1	24
F	3.5	746	0.95	7.9	22

Table – IX Copper Slag Proportional Fresh Concrete Mix Results

Mix	Slump Flow(sec)	T50(mm)	L – Box (mm)	V – Funnel (sec)	J – box (mm)
G	4.4	756	0.83	9.0	31
H	4.2	752	0.85	8.7	29
I	4.0	749	0.87	8.5	27
J	3.8	743	0.91	8.2	23
K	3.6	738	0.94	7.8	20

B. Results for Hardened Concrete

COMPRESSION TEST

Compressive strength is obtained by applying crushing load on the cube surface. So it is also called as Crushing strength. Compressive strength of concrete is calculated by casting 150mm x 150mm x 150mm cubes. The test results are presented here for the Compressive strength of 7 days, 28 days of testing shown in Table – X & XI and Fig – VI & VII.

Table – X Compressive Strength for Fly ash

Mix	Compressive strength	
	7 days	28 days
A	48.33	69.23
B	49.81	70.02
C	51.12	72.25
D	53.72	74.95
E	52.02	73.40
F	50.43	71.08

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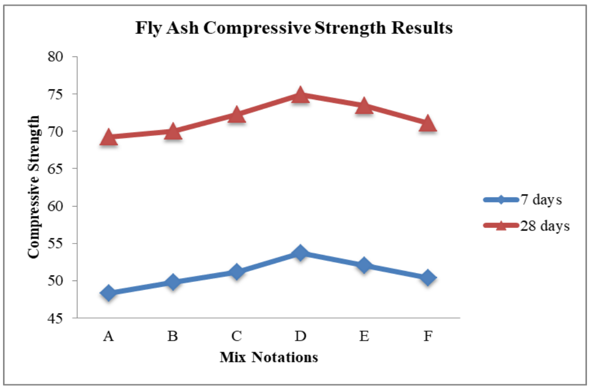

Fig – VI Fly Ash Compressive Strength Results

Table – XI Compressive Strength for Copper Slag

Mix	Compressive strength	
	7 days	28 days
G	50.11	71.12
H	52.23	73.33
I	54.15	75.85
J	53.15	74.41
K	51.53	73.23

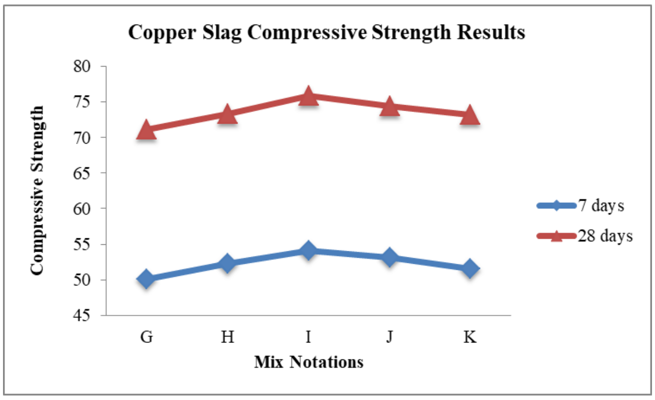

Fig – VII Copper slag Compressive Strength Results

SPLIT TENSILE TEST: Split Tensile strength is obtained by applying crushing load on the cylinder surface. Split Tensile strength of concrete is calculated by casting 150mm diameter and 300mm cylinders. The test results are presented here for the split tensile strength of 7days and 28 days of testing as shown in Table XII & XIII and Fig VIII & IX.

Table – XII Split Tensile Strength for Fly Ash

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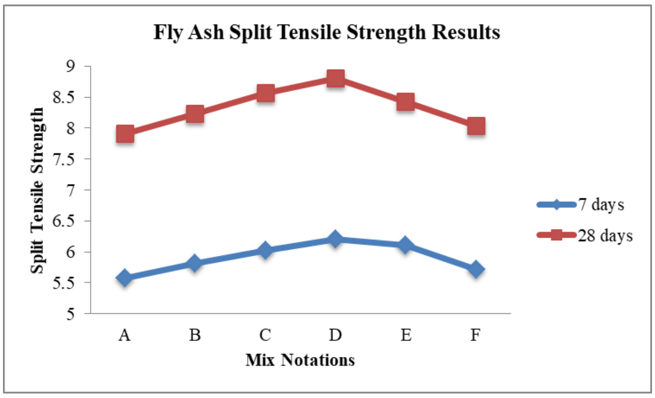

Fig – VIII Fly Ash Split Tensile Strength Results

Table – XIII Split Tensile Strength for Copper Slag

Mix	Split tensile strength	
	7 days	28 days
G	5.33	7.63
H	5.56	7.85
I	5.68	7.91
J	5.53	7.62
K	5.31	7.53

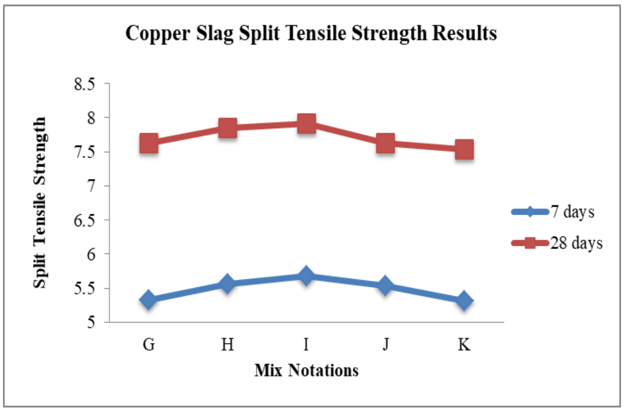

Fig – IX Fly Ash Split Tensile Strength Results

FLEXURAL TEST: Flexural test was performed on beams size of 500mm ×100mm ×100mm size by placing them on universal testing machine find out the flexural strength. The test results are presented here for the flexural strength test of 28 days of testing the results are shown in Table – XIV & XV and Fig – X & XI.

Table – XIV Flexural Strength for Fly ash

Mix Type	Flexure Strength
	28 days
A	4.63
B	4.71
C	4.82
D	4.89
E	4.76
F	4.57

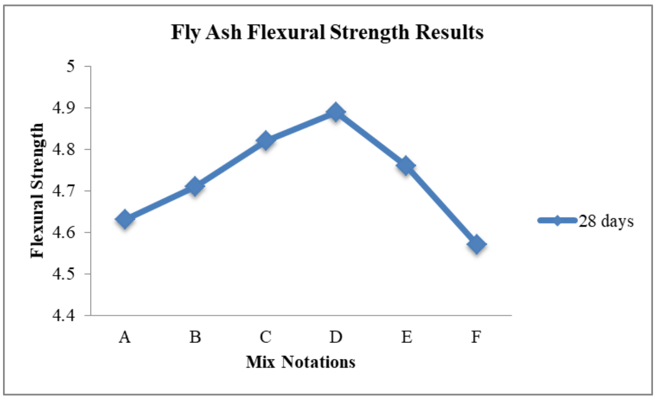

Fig – X Fly Ash Flexural Strength Results

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Table – XV Flexural Strength for Copper Slag

Mix Type	Flexure Strength
	28 days
G	4.15
H	4.33
I	4.65
J	4.5
K	4.38

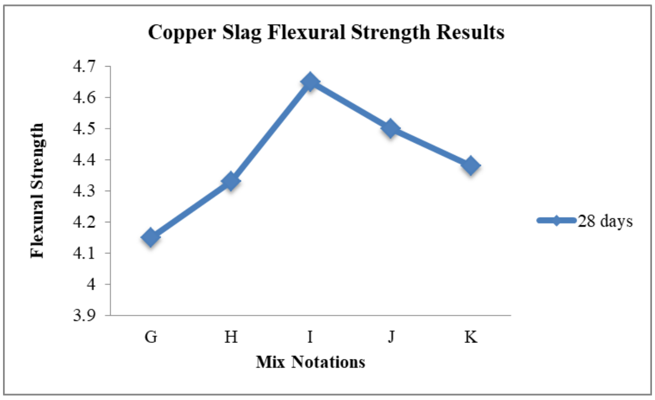

Fig – XI Copper Slag Flexural Strength Results

VIII. CONCLUSION

- The test result on fresh concrete are within the limits of follows EFNARC-2005 guide lines decrease of water to powder (W/P) ratio increase compressive strength.
- Self-compacting concrete is a relatively new form of concrete which is used for general applications. The main advantages that scc has over standard concrete is its high compressive strength and self-compacting properties, inched high flowability ,workability and passing ability.
- In this super plasticizer is water reducing agent in the range of (0 to 40%) of water. The optimum dosage of chemical admixture is 1.5% of super plasticizer (GLENIUM B223)chemical composition is poly-carboxylic ether dosage of super plasticizer require painting of the self-compatibility of concrete.
- It is recommended that 15 wt% of fly ash can be used as replacement of cement, and 30 wt% of copper slag can be used as replacement of sand in order to obtain high strength self-compacting concrete with good property.
- Use of copper slag and fly ash in construction is possible to work and it is very cheap and gives good result.
- This study points out the beneficial aspects of using copper slag as a replacement material of fine aggregate.
- So compared to conventional concrete, self-compacting concrete (SCC) gained higher compressive strength.

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