“Performance Evaluation of Concrete Containing Copper Slag as a Partial Substitute for Fine Aggregate”

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ABSTRACT: Advancements in concrete technology can help reduce the use of natural resources such as river sand and aggregates while minimizing environmental impacts. The steel manufacturing industry generates large quantities of copper slag as a by-product, which creates disposal problems and can negatively affect the environment.

This study investigates the suitability of using copper slag as a partial replacement for fine aggregate in concrete production. Recycling industrial waste materials like copper slag helps in effective waste management, reduces the dependency on natural resources, and promotes sustainable construction practices.

In this research, copper slag is incorporated into concrete mixes by replacing fine aggregate at different proportions while maintaining other mix parameters constant. The influence of copper slag addition on the mechanical properties of concrete is evaluated through compressive strength and split tensile strength tests. The study also examines the properties of locally available copper slag and its potential application as an alternative material for improving concrete performance without affecting strength and durability.

Keywords: Copper Slag, Fine Aggregate Replacement, M20 Concrete, M25 Concrete, Compressive Strength, Split Tensile Strength, Sustainable Construction.

INTODUCTION: The importance of cement concrete in present society can’t be thought little of. Solid Structures of Concrete Presents in all places, such as structures, streets, bridges, and dams. There is no avoidance the effect of concrete utilization makes on your regular day to day existence. Concrete is a combined substance which is consisting of filler and a fastener. Regular concrete is a combination of F.A., C.A, cement, and water. Cement and lime are usually utilized as fastening materials, while the sand binder is mixed as fine aggregates and crushed stones, gravel, broken bricks; clinker is employed as coarse aggregates. The concrete having cement, sand and coarse aggregates mix up in an appropriate percentage in addition to water is called cement concrete. In this kind of concrete, cement is mixed as a fastening substance, sand as fine aggregates and gravel, crushed stones as coarse aggregates.

STRENGTH OF CONCRETE

The concrete strength is very much dependent factor upon the hydration reaction. Water acting a vital function, particularly the amount used. The strength of concrete enlarges when a smaller amount of water is used to create concrete. The hydration effect itself graphs a specific amount of water. Concrete is essentially mixed with extra water than is wanted for the hydration responses. This additional water is mixed to provide concrete enough workability. Smooth concrete is preferred to attain suitable filling and the making of the shapes. The water not utilized in the hydration reaction will stay in the microstructure pore space. These holes formulate the concrete fragile because of the deficiency of strength-forming calcium silicate hydrate connections. A number of pairs will stay no substance how well the concrete has been compressed.

Concrete's strength may caused by the adding up of admixtures. Admixtures are materials extra than the key constituents or strengthening which are added during the mixing process. Some mixing contents add variability to concrete while involving a smaller amount of water to be used. An instance of an admixture which concerned strength is superplasticizer. This create concrete more practicable or fluid without addition of excess water. A list of any other admixtures and their functions is given below. Note that not all admixtures increase concrete strength. Stability is a very significant term in using concrete for a known function. Concrete offers good presentation during the service life of the organization when concrete is mix-up correctly and care is taken in curing it. High-quality concrete can have an unlimited life span under the right circumstances. Water, while significant for concrete hydration and hardening, can also contribute a purpose in reducing toughness when the formation is constructed. This is because water can convey dangerous chemicals to the internal of the concrete foremost to different shapes of deterioration. Such weakening eventually inserts costs because of maintenance and restore of the concrete organization. The service provider should be proficient to account for ecological issues and build a durable concrete organization if these aspects are considered when construction a concrete structures.

MATERIALS

Cement: Cement is by far the most important constituent of concrete, in that it forms the binding medium for the discrete ingredients. Made out of naturally occurring raw materials and sometimes blended or underground with industrial wastes. The cement used in this study was OPC 53 grades Ordinary Portland cement (OPC) conforming to IS12269-1987.

Fine Aggregate: Aggregates which occupy nearly 70 to 75 percent volume of concrete are sometimes viewed as inert ingredients in more than one sense. However, it is now well recognized that physical, chemical and thermal properties of aggregates substantially influence the properties w23mm and performance of concrete. The fine aggregate (sand) used was clean dry sand was sieved in 4.75 mm sieve to remove all pebbles.

Coarse Aggregate: Coarse aggregate is used for making concrete. They may be in the form of irregular broken stone or naturally occurring gravel. Material which is large to be retained on 4.75mm sieve size is called coarse aggregates. Its maximum size can be up to 40 mm.

Water: water plays an important role in the formation of concrete as it participates in a chemical reaction with cement. Due to the presence of water, the gel is formed which helps in increase of strength of concrete. Portable water is generally considered satisfactory for mixing. The pH value of water shall not be less than the following concentrations represent the maximum permissible values (of deleterious materials in water):

COPPER SLAG

Copper slag is a by-product of copper smelting and refining process. As refineries draw metal out of copper ore, they produce a large volume of non-metallic dust, soot, and rock. Copper slag which is an industrial waste obtained from smelting and refining process of copper from Sterlite Industry Ltd., Tuticorin, and Tamilnadu. Nearly 4 tons of copper is obtained as waste is disposed to lands cause's environmental impacts. So it can be reused as concreting materials. In refinery plants when copper metal produced by extraction process then copper slag is generated in a large amount in the production of copper metal. About 2-2.5 tons of

copper slag produced for each 1 ton of copper production. Production of concrete has many environmental benefits for example
waste recycling and resolve disposal problems. Concrete is wide utilized in the development of superior structures like high rise buildings, long-span bridges, etc. So, it must have higher workability, it has superior mechanical properties than those of typical concrete. In order to produce concrete with good mechanical properties, fly ash and silica fume that are assume as waste materials used one of the most constituent. Concrete production with that material gives upgrading in workability compared to traditional concrete.
OBJECTIVES OF THE STUDY: To compare the various properties like compressive strength and density of modified concrete with partial replacement of Copper slag with Conventional concrete.

- To investigate the effect of Copper Slag waste materials in concrete on its strength.
- To study the properties of fresh concrete prepared by Replacement of copper slag particle material
- By utilizing the knowledge about the different parameter working out on the better result and safe concrete production.
- To save the natural resource and cost optimization. Better consumption of resources and providing maximum servicea

LITERATURE REVIEW:

Sukhoon Pyo et. al. [2016] they conducted analysis using a recently developed impact testing system that uses suddenly released strain energy to generate an impact pulse. Three fiber categories were measured, a warped fiber and two extra types of straight fibers. Sample effect reply was estimated in terms of first cracking power, post-cracking strength, energy inclusion power and strain power. The test outcomes specify that samples with warped fibers normally show fairly better mechanical functions than samples with straight fibers for the series of strain rates measured. All UHP-FRC sequence experienced demonstrate extra rate sensitivities in energy inclusion power, normally made much more energy dissipative under increasing strain rates. [18]

Anju Ramesan et. al. [2015] they studied about suitability of functions of light weight concrete with plastic aggregate. the appropriateness of recycled fibers as coarse aggregate in concrete by performing different experiments similar to workability by slump test, compressive force of cube and cylinder, splitting tensile power analysis of cylinder, flexural strength of R.C.C Beams, to find out the function and performance in concrete. Cause of substitution of coarse aggregate with different percentages (0% to 40%) of plastic aggregate on behavior of concrete was investigational analysis and the finest particle replaced with of coarse aggregate was achieved. The outcome explained that the addition of plastic aggregate to the concrete combination enhanced the material goods of the resulting mixture. [2]

B. Patnaik et .al. [2015] The study demonstrated the compressive strength of concrete produced with selected recycled copper-enhanced fine aggregate that reduces the dumping of copper waste into the environment. Two different grades of concrete (M20 and M30) were used with different proportions of copper slag replacement (0 to 50 percent) in the concrete. The compressive strength, split tensile strength, flexural strength acid resistivity and sulphate resistivity of both mixes were evaluated for strength and durability properties. According to the findings acquired from the test results, concrete having copper slag as a partial substitute of sand gives better strength functions to concrete (up to 40%) but in the stability aspect, the concrete is found to have low resistance to acid attack and better resistance against sulfate attack.[3].

Pranshu Saxena et. al. [2015] they studied about scope of replacement of F.A. from C.S. in concrete. Copper slag represents an accepted substitute to sand as a blasting way in industrial cleaning. With explosion or aggressive spraying methods, companies are using C.S. to clean huge refining equipment or furnaces .Material like copper waste can be utilized as one which can decrease the cost of construction. Their effort has been completed to accumulate the different analyses completed on the substitution of copper waste in F.A. to observe the potency of concrete. [14]

M. A. Rasheed et. Al. [2015] they investigated to enlarge a high actions fiber reinforced concrete to offer a better substitute than aerated autoclaved concrete blocks for structural actions of masonry. Use of polymers augments pre-cracking actions of masonry by stunning cracks at micro-scale, whereas macro fibers induce ductile behavior in post-peak region by stunning the crack proliferation shortly when the crack initiation. Above all, the mechanical behavior of CLC cylinders beneath pure compression and CLC blocks below flexure with and while not polyolefin structural fiber reinforcement in addition as mixture fiber strengthening is investigated. Checkout comes designate that the accumulation of structural polymers enhanced the compressive force up to 66.8% for 0.55% volume portion. Hybrid fiber reinforcement improved the highest strength and ductility which indicated better crack bridging each at small and macro levels. [9]

S.W. Tang et. al. [2015] they analyzed about recent research activities on the durability of concrete, including major durability problems such as alkali aggregate reaction, sulfate attack, steel corrosion and freeze–thaw also analyzed durability of concrete in marine environment and coupling effects of mechanical load and environmental factors on durability of concrete. The study of natural green inhibitor for steel corrosion also opens a promising research direction in the near future. With respect to durability design codes, the mainstream codes or methods have more or less intrinsic drawbacks due to the failure to comprehensively consider various coupling effects of mechanical loading and multi environmental impacts. Therefore, it is necessary to develop a new approach of unified load-carrying capability and durability service life design theory for more accurate service life estimate. [15]

T. U. Ganiron et. al. [2014] they studied about the effects of thermoplastic when added to concrete cement and needs of the ecological sector in terms of recycling the waste plastic that harms not only the soil structure and the environment The plastic was grounded into pieces for concrete mixture, where it substitutes the 5% of the fine aggregate, which is the sand. It then undergoes to strength test that investigate whether it can pass or at least equal the standard specification of concrete mix for wall panel. The experimentation went through moisture content test, specific gravity test, slump test, sieve analysis, compressive test and flexural test. [18]

M.Chockalingam et. al. [2013] they studied about scope for reuse of copper slag in concrete and research works have been done to evaluate the suitability of copper slag for reuse. They give the solution that Reuse of copper slag has the dual benefit of safe disposal and judicial resource management. Application in concrete as an admixture, replacement of cement and as a fine aggregate has very good scope in the future. [12]

W.J. bullard et. al. [2011]they studied the current state of knowledge of cement hydration mechanisms including the origin of the period of slow reaction in alite and cement, the nature of the acceleration period, the role of calcium sulfate in modifying the reaction rate of tricalcium aluminate, the interactions of silicates and aluminates, and the kinetics of the deceleration period. In addition, several remaining controversies or gaps in understanding are identified, such as the nature and influence on kinetics of an early surface hydrate, the mechanistic origin of the beginning of the acceleration period, the manner in which microscopic growth processes lead to the characteristic morphologies of hydration products at larger length scales, and the role played by diffusion in the deceleration period. [5]

K. Sirijaroonchai et. Al. [2010] Analyze the behavior of strain hardening of high performance fiber reinforced cement composites (HPFRCC) under uniaxial, biaxial and triaxial compression. The parameters chosen for the experiment include type of fibre, fibre volume fraction, and loading path. For a 55-MPa mortar matrix, two types of commercially available fibers, high-strength hooked steel fiber and ultra high molecular weight polyethylene fiber, with volume fractions in the range of 1.0% and 2.0%. The test results indicate that the presence of short fibers can greatly increase the strength as well as ductility under uniaxial and biaxial loading paths, but the effect of volume fraction is rather small for the fiber volume content considered. The outcome further reveals that the confining effect imposed by the fibers is negligible in a triaxial compression test where there is a relatively large external confining pressure. The experimental data presented here can be used to develop multiaxial constitutive models for HPFRCCs. [8].

MATERIAL AND METHODOLOGY

Cement: Cement is by far the most important constituent of concrete, in that it forms the binding medium for the discrete ingredients. Made out of naturally occurring raw materials and sometimes blended or inter-ground with industrial wastes. The cement used in this study was OPC 53 grades Ordinary Portland cement (OPC) ultratech conforming to IS 10262.

Figure: Cement

Table : Properties of cement

Properties	Value
Grade of Cement	OPC(53 grade)
Specific gravity of cement	3.15
Initial setting time	35 min
Final setting time	330min
Normal Consistency	32%

Fine Aggregate: Aggregates which occupy nearly 70 to 75 percent volume of concrete are sometimes viewed as inert ingredients in more than one sense. However, it is now well recognized that physical, chemical and thermal properties of aggregates substantially influence the properties and performance of concrete. The fine aggregate (sand) used was clean dry sand was sieved in 4.75 mm sieve to remove all pebbles.

FIGURE: FINE AGGREGATE

Table: Properties of fine aggregate

Properties	Value
Specific Gravity	2.60
Fineness Modulus	3.75
Water absorption	0.6%

Coarse Aggregate: Coarse aggregate are used for making concrete. They may be in the form of irregular broken stone or naturally occurring gravel. Material which are large to be retained on 4.75mm sieve size are called coarse aggregates. Its maximum size can be up to 63mm.

FIGURE : COARSE AGGREGATE

Table : Properties of coarse aggregate

Properties	Values
Specific Gravity	2.94
Size of Aggregates	20mm
Fineness Modulus	7.07
Water absorption	0.219
Aggregate Impact value	15.2%
Aggregate Crushing value	22.5%

Methodology The aim of the experiment was to assess the properties of concrete made with Fine aggregates ,coarse aggregate, cement and copper slag to study the various important aspects such as compressive strength and split tensile strength of concrete Cube prepared by using Concrete materials and replacing copper slag with different percentage of replacements with fine aggregate. In fresh state; the workability parameters such as slump cone test was studied. In hardened state; the strength tests such as compressive strength and spilt tensile strength was studied. The study was carried out for mix design of concrete-M20 and M25 grade. In this study, concrete cubes casted for testing were of dimensions of 150150150 mm.and cylindrical beam 150mm dia. And 300mm length

The study of this project is fully based on the experimental work. In this section of the dissertation, following steps are adopted during experimental work:

- To build a structure first we need to build its base or foundations. Likewise first of all
- Mix design for M20 and M25 grade of concrete is prepared according to the "INDIAN STANDARDS CODE" IS 10262:2009.
- In the preparation of mix design for M20 and M25 grade of concrete various physical properties of the materials like specific gravity, nominal size, water absorption capacity, fineness Modulus etc. are required, also some other conditions like type of exposure to sun and water, material mixing technique etc. are to be assumed in accordance with INDIAN STANDARD CODE IS 456:2000.
- After working out the quality of different materials in an appropriate proportion, it's time for the selection of materials.
- Keeping in mind the "INDIAN STANDARDS" materials are selected i.e., aggregates Conforming/full filling the various conditions as per IS 383:1970 and cement 53 grade OPC conforming to IS 12269:1987 are taken.
- Selected materials are mixed in a fixed proportion as per mix design to acquire the desired strength. Sampling & analysis of concrete is done according to IS 1199:1959.
- IS 2386 (Part 1): 1963 is used for the methods of tests for aggregates for concrete
- Specifically for shape and size of aggregates.
- Two important tests are performed on concrete namely 1) slump cone test and 2) compaction factor test, after preparation of mix for physical properties of concrete.
- Standard moulds of size 150 mm x 150 mm x 150 mm are then cleaned and oiled Concrete is poured in the moulds and different shaped reinforcements are placed in the Moulds.

- After 24 hrs. Concrete cubes are unbolted from moulds and named with water resistant paint and placed in the curing tank filled with normal water at 27 ± 2 0C for 28 days.
- At the end of 28 days curing it's time for the final test which gives the actual strength of concrete i.e., compression strength test in accordance with the "INDIAN STANDARD CODE" IS 516:1959 for the test of concrete.

DESIGN MIX To study the effect of copper slag substitution as a replacement for fine aggregates on the strength of cement mortars, specimens were prepared with different Percentages of copper slag (by weight). Concrete mixtures with different proportions of copper slag used as a partial or full substitute for fine aggregates were prepared in order to investigate the effect of copper slag substitution on the strength normal concrete. Concrete mixtures were prepared with different proportions of copper slag. The proportions (by weight) of copper slag added to concrete mixtures were as follows: 0% (for the control mix), 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40%,45% and 50%.The mix proportion chosen for this study is M20 grade with water-cement ratio of 0.45. In this test total 99 Cubes of standard size 150x150x150mm and 99 Cylinders of standard diameter 150mm and height 300mm were casted and cured for 3rd day, 7th day & 28_{th} day and tested as per code IS: 516-1959. The main purpose for keeping the samples for longer curing periods of 28 is to observe any detrimental effect from the use of copper slag as fine aggregate on the compressive strength and split tensile strength of concrete. The mix proportion chosen for this study As per IS 10262-2009

Table 3.22: Details of Concrete Mix Proportions

Percentage copper slag	**Weight of Cement (kg/m^3)**	**Weight of copper slag(kg/m^3)**	**Weight of Water(kg/m^3)**	**Weight of C.A. (kg/m^3)**	**Weight of F.A. (kg/m^3)**
W	360	0	180	1277	693
5%	360	34.65	180	1277	658.35
10%	360	69.3	180	1277	623.7
15%	360	103.95	180	1277	589.05
20%	360	138.6	180	1277	554.4
25%	360	173.25	180	1277	519.75
30%	360	207.9	180	1277	485.1
35%	360	242.55	180	1277	450.45
40%	360	277.2	180	1277	415.8
45%	360	311.85	180	1277	381.15
50%	360	346.5	180	1277	346.5

RESULT AND DICUSSION

Compressive Strength Test

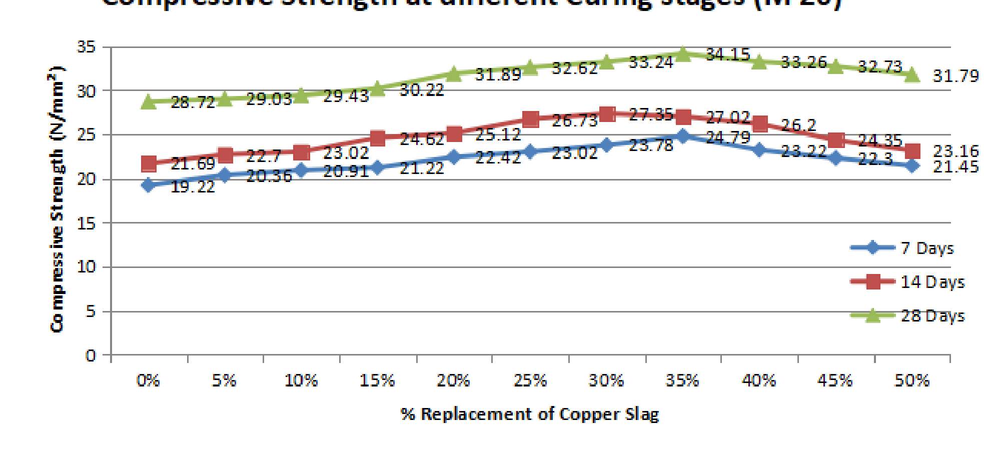
Concrete is weak in tension and strong in compression so the concrete should be strong to attain high compression. In this study for each mix 3-samples were tested and the average strength is compared with nominal mix of M20 & M 25 Mix. Compressive strength test finds out the high amount of compressive load a material can bear below facture limit. The results of compressive strength at the age 7^{th} day, 14^{th} day & 28^{th} day are shown in table

Table 4.1 Compressive Strength at different Curing stages (M 20)

Percentage Replacement of Copper Slag	Compressive Strength (N/mm²)		
	7 Days	14 Days	28 Days
0%	19.22	21.69	28.72
5%	20.36	22.70	29.03
10%	20.91	23.02	29.43
15%	21.22	24.62	30.22
20%	22.42	25.12	31.89
25%	23.02	26.73	32.62
30%	23.78	27.35	33.24
35%	24.73	27.02	34.15
40%	23.22	26.20	33.26
45%	22.30	24.35	32.73
50%	21.45	23.16	31.79

Table 4.2 Compressive Strength at different Curing stages (M 25)

Percentage Replacement of Copper Slag	Compressive Strength (N/mm²)		
	7 Days	14 Days	28 Days
0%	19.62	23.79	30.78
5%	19.83	25.12	31.43
10%	20.42	26.39	32.72
15%	20.97	27.39	33.63
20%	21.32	28.56	34.23
25%	22..37	29.13	34.93
30%	22.97	31.23	35.12
35%	24.82	32.73	35.43
40%	22.52	29.21	33.79
45%	21.73	26.37	32.87
50%	20.63	25.64	31.82



Compressive Strength at different Curing stages (M 20)

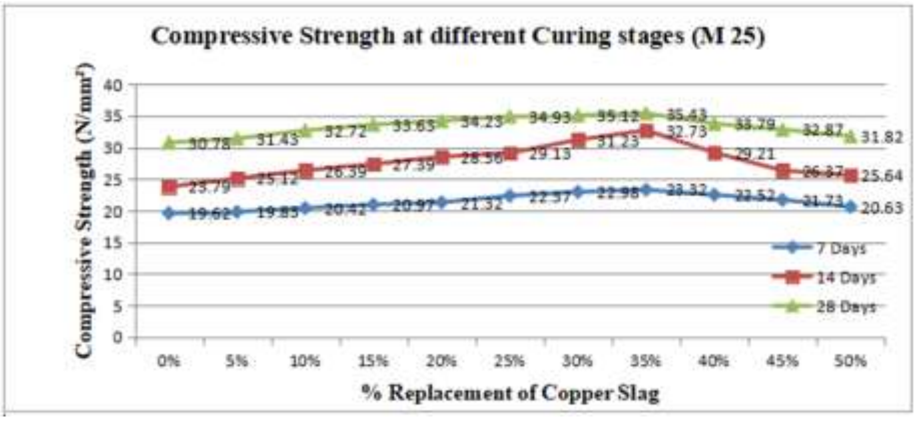
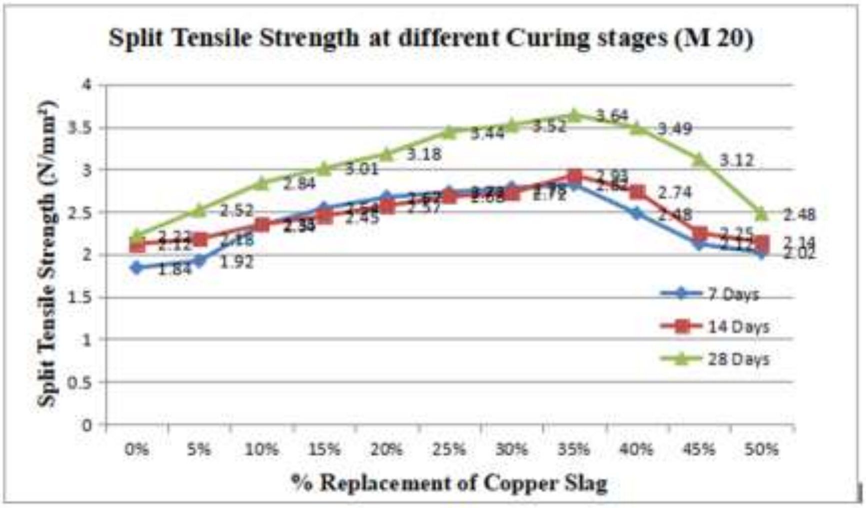


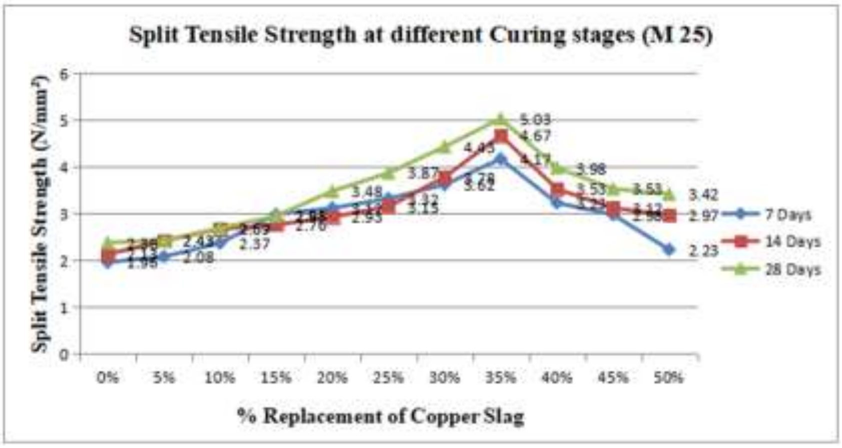
Table 4.3 Split tensile strength at different Curing stages (M 20)

Percentage Replacement of Copper Slag	Split tensile Strength (N/mm²)		
	7 Days	14 Days	28 Days
0%	1.84	2.12	2.22
5%	1.92	2.18	2.52
10%	2.34	2.35	2.84
15%	2.53	2.45	3.01
20%	2.67	2.57	3.18
25%	2.73	2.68	3.44
30%	2.77	2.72	3.52
35%	2.82	2.93	3.64
40%	2.48	2.74	3.49
45%	2.12	2.25	3.12
50%	2.02	2.14	2.48

Table 4.4 Split tensile Strength at different Curing stages (M 25)

Percentage Replacement of Copper Slag	Split tensile Strength (N/mm²)		
	7 Days	14 Days	28 Days
0%	1.96	2.13	2.38
5%	2.08	2.42	2.43
10%	2.37	2.67	2.69
15%	2.98	2.76	2.95
20%	3.12	2.93	3.48
25%	3.32	3.15	3.87
30%	3.62	3.78	4.43
35%	4.17	4.67	5.03
40%	3.23	3.53	3.98
45%	2.98	3.12	3.53
50%	2.23	2.97	3.42





CONCLUSION & FUTURE SCOPE

Introduction Based on the test results obtained from the experimental program of this work the following major calculations are arrived.Based on the experimental investigation following assumptions are as follows:

1. A Copper slag is a type of waste used as a substitute to Cement in concrete.
2. Cost of Concrete production reduces when Copper Slag is used as Cement in concrete.
3. After 7 days curing from the experimental test results, the compressive strength of concrete mix of cube having 15% of copper slag has the higher strength of 21.22Mpa(M20) and 23.45Mpa(M25).
4. After 14 days curing from the experimental test results, the compressive strength of concrete mix of cube having 15% of copper slag has the higher strength of 28.62Mpa(M20) and 33.14Mpa(M25).
5. After 28 days curing from the experimental test results, the compressive strength of concrete mix of cube having 15% of copper slag has the higher strength of 31.02Mpa(M20) and 36.26Mpa(M25).

Scope Of Future Work

1) This research was intended to examine the influence of copper slag additions in concrete for M20 & M 25 mixes. The same word can be extended to higher grades of concrete mixes with varying water/cement ratio.
2) Copper slag can be effectively replaced in making bricks, hollow blocks and pavement blocks.
3) Since copper slag has higher shear strength value it can be used for soil stabilization.
4) Copper slag can be replaced along with fly ash, silica fume and granulated blast furnace slag in concrete and RCC members which can be tested for mechanical performances.

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