EXPERIMENTAL STUDIES ON THE USE OF MINERAL ADMIXTURE IN CONCRETE STRUCTURES

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Abstract - *In view of global warming, efforts have to be taken to minimise the emission of CO_2 to the environment. Cement industry is a major contributor in the emission of CO_2 and the use of high level of energy resources in the production of cement leads to depletion of natural resources. In addition to the above problem, new by-products and waste materials are being generated by various industries. Dumping and disposal of waste materials causes environmental and health problems. So it is preferable to recycle the waste materials and implement them in the concrete industry to minimise the use of natural resources. In this present study, an attempt has been made to utilise one of the industrial by-product "copper slag" for making of concrete there by reducing the CO_2 emission. In this study the effect of copper slag as partial replacement of cement in various percentages ranging from 0% to 15%, on physical properties such as consistency, initial setting time, final setting time, slump, compressive and tensile strength are investigated. The durability properties were determined by conducting water absorption test and deterioration test on control, acid and sulphate medium whereas the corrosion behaviour of the admixed concrete has also been studied using time to cracking and potential test. The results obtained have been compared with those of control concrete made with Ordinary portland cement.*

Key Words: **Mineral admixture, copper slag, durability studies**

1. INTRODUCTION

Many countries are witnessing a rapid growth in the construction industry, involving the use of natural resources for the development of infrastructures. This growth is jeopardized by the lack of natural resources that are available. Natural resources are depleting worldwide, while at the same time the generated wastes from the industry are increasing substantially. So it is preferable to recycle the waste materials and implement them in the concrete industry to minimise the use of natural resource.

Mineral admixtures are the fine ground solid materials i.e. Fly ash, slag and silica fume. Normally mineral admixtures have an ability to enhance workability as well as mechanical properties of concrete. Generally mineral admixtures are utilized as a replacement of cement, which leads in lower usage of cement in the concrete contributes to reducing the consumption of natural resources and CO_2 emission. In this present study copper slag has been partially replaced the cement.

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 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. Extensive studies have already done on fly ash, rice husk ash, slag and very little work has been done in the copper waste product. Utilization of copper slag in concrete has the dual benefit of eliminating the costs of disposal and lowering the cost of the concrete production in construction. Therefore, to generate specific experimental data on durability characteristics of copper slag as cement replacement in concrete, this research was performed.

2. MATERIALS USED

Cement - Cement used for test specimens was Ordinary Portland cement (OPC) confirming to IS 12269: 1987.

Fine aggregate- Natural river sand confirming to Zone III was used as fine aggregate for casting test specimen.

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. The maximum size of coarse aggregate used was 20mm.

Copper slag- Copper slag is a by-product during copper smelting and refining process.

3. EXPERIMENTAL DETAILS

3.1 Consistency of cement

Standard consistency of a cement paste is defined as that consistency which will permit a vicat plunger having 10 mm diameter and 50 mm length to penetrate to a depth of 33-35 mm from top of the mould. The vicat mould was placed on the non-porous plate, fill mould with cement paste by mixing 500g of cement and 28% of water by weight of dry cement. Smooth the surface of the plate making thick level with the top of the mould. Shake the mould slightly to remove the air bubbles in cement paste. The paste block together with non-porous plate was placed under the required plunger of 10 mm diameter. The plunger was gently touched the surface of the paste block and quickly released allowing it sink into the cement paste. The penetration of the needle from the bottom of the mould indicate on the scale was noted. Same procedure was repeated with varying percentage of water until the amount of water necessary for making standard consistency, which permits plunger to penetrate to a point 5 mm to 7 mm from bottom of the mould was determined.

Calculate percentage of water (P) by weight of dry cement required to prepare cement paste of standard consistency by following formula,

$$P = \frac{W}{C} \times 100$$

Where, W = Quantity of water for 33-35mm penetration
C = Weight of cement

3.2 Initial and final setting time

Initial setting time of cement is defined as period elapsing between the time water added to the cement and the time when the 1mm sq section needle fails to penetrate cement this block to depth of about 5mm form the bottom of the mould. Generally the initial setting time of cement is not less than 30min and not more than 600min. Initial setting time test is important for transportation, placing and compaction of cement concrete.

Final setting time of cement is defined as the time elapsed between the moment the water is added to the cement and the time when the paste has completely lost its plasticity and has attained sufficient firmness to resist certain definite pressure. Final setting time of cement should not be more than 10 hours. Determination of final setting time period facilitates safe removal of scaffolding or form.

The Vicat mould was placed on the non-porous plate, filling mould with cement paste by mixing 500g of cement and 0.85P of water by weight of dry cement. Smooth the surface of the plate making thick level with the top of the mould. Shake the mould slightly to remove the air bubbles in cement paste. The 1mm diameter needle is attached to the movable rod of Vicat apparatus, then the needle is quickly released and allowed to penetrate in the cement paste. In initial stage, the needle penetrates completely. It is then taken out and dropped at a fresh place. The test procedure is repeated at regular intervals till the needle does not penetrate completely. The needle should penetrate up to about 5 mm measured from bottom.

The initial test procedure for final setting time of cement is same that of initial setting time test. Instead of 1mm diameter needle, annular needle is used, which is attached to the movable rod of Vicat apparatus. Place the test block under the Vicat needle with the annular attachment and quickly release the needle allowing it to penetrate into the test block. The cement is said to be finally set when the needle makes an impression on the test block and the attachment fails to do so. The time elapsed between this stage and the instant when the water was added to the cement is noted as the final setting time.

3.3 Slump test

Slump test is used to determine the workability of fresh concrete. Slump test is carried out as per IS: 1199–1959. Workability is important because, if the concrete mixture is too wet, coarse aggregates settle at the bottom of concrete mass and as a result concrete becomes non-uniform composition and so if the concrete mixture is too dry, it will be difficult to handle and place it in position.

This test is carried out with a mould called slump cone whose top diameter is 10cm, bottom diameter is 20 cm and height is 30 cm. Placing the slump mould on a smooth flat and non-absorbent surface, mix the dry ingredients of the concrete thoroughly till a uniform colour is obtained and then add the required quantity of water. Fill the mixed concrete in the mould to about one-fourth of its height and Compact the concrete 25 times with the help of a tamping rod uniformly all over the area. After compacting fill the concrete in the mould about half of its height and compact it again and then the concrete is filled up to its three fourth height and then up to its top. Compact each layer 25 times with the help of tamping rod uniformly. After the top layer is tamped, the concrete is struck off the level with a trowel. The mould is removed from the concrete immediately by raising it slowly in the vertical direction. Remove the mould immediately, ensuring its movement in vertical direction. When the settlement of concrete stops, measure the subsidence of the concrete in millimeters which is the required slump of the concrete.

3.4 Compressive strength test

Compressive strength is the maximum compressive stress that, under a gradually applied load, a given solid material can sustain without fracture. For compressive strength test two types of specimens are used either cubes of 15 × 15 × 15 cm or 10 × 10× 10 cm depending upon the size of aggregate. The concrete is poured in the mould and tampered properly so as not to have any voids. After 24 hours these moulds are removed and test specimens are put in water for curing. The top surface of these specimen should be made even and smooth. This is done by putting cement paste and spreading smoothly on whole area of specimen. These specimens are tested by compression testing machine after 7 days curing or 28 days curing. Load should be applied gradually at the rate of 140 kg/cm^2 per minute till the Specimens fails. Load at the failure divided by area of specimen gives the compressive strength of concrete as follows,

Compressive strength = load in N/ area in mm^2

3.5 Deterioration study

The deterioration study is carried out in the following three mediums,

Control medium

Cubes of sizes 50 × 50 × 50 mm are cast and cured for 28 days. After 28 days curing cubes have been taken out and allowed for drying for 24 hours and weights were taken. For control medium normal tap water is used. The cubes were to be immersed in water for a period of 30 days. After 30 days the specimens were taken from control medium and he surface of specimen is cleaned. Then, the weight and the compressive strength of the specimens were found out and the average percentage of loss of weight and compressive strength were calculated.

Acid medium - 5% HCl

Cubes of sizes 50 × 50 × 50 mm are caste and cured for 28 days. After 28 days curing cubes were taken out and allowed for drying for 24 hours and weights were taken. For chloride attack test 5% HCl is used. The cubes are immersed in solution for a period of 30 days. The concentration is to be maintained throughout this period. After 30 days the specimens were taken from acid solution and the surface of specimen is cleaned. Then, the weight and the compressive strength of the specimens were found out and the average percentage of loss of weight and compressive strength were calculated.

Sulphate medium - 5% Na_2SO_4

Cubes of sizes 50 × 50 × 50 mm are caste and cured for 28 days. After 28 days curing cubes were taken out and allowed for drying for 24 hours and weights were taken. For sulphate attack test 5% Na_2SO_4 is used. The cubes are immersed in solution for a period of 30 days. The concentration is to be maintained throughout this period. After 30 days the specimens were taken from sulphate solution and the surface of specimen is cleaned. Then, the weight and the compressive strength of the specimens were found out and the average percentage of loss of weight and compressive strength were calculated.

3.6 Potential time study

The corrosion performance can be studied by using potential time measurement study. For this study, concrete specimen of size 50 x 100 mm have been cast with TMT rebar. Before embedding the respective rebar specimens in concrete, the initial rust products have been thoroughly cleaned by pickling solution. After curing period was over, the specimens were subjected to alternate wetting and drying in 5% sodium chloride (NaCl) and distilled water. The potential measurement was carried out using digital multimeter and a standard saturated calomel electrode (SCE). One terminal of the multimeter was connected to the respective rebar and other terminal was connected to the reference electrode which was kept just above the rebar embedded in concrete and the potential reading was noted.

4. RESULTS AND DISCUSSION

4.1 Consistency of cement

The results of consistency of cement are presented in Table 1. From the consistency test, it was found that the minimum water required was around 128 ml in the 5 % replacement of copper slag.

Table 1 Consistency of cement

SL.NO	% OF COPPER SLAG	CONSISTENCY	
		%	ml
1	0	31	155
2	5	30	150
3	10	31	155
4	15	31	155

4.2 Initial and final setting time

The Results of Initial Setting and Final Setting Time are presented in Table 2 and Table 3. In all percentage of replacement, the initial setting time is more than the required setting time given in standards. In the final setting time, all the replacements were set within the stipulated maximum setting time of 10 hours. From the above results, it is clear that the addition of copper slag does not affect both initial and final setting time.

Table 2 Initial setting time

SL.NO	% OF COPPER SLAG	INITIAL SETTING TIME	
		WATER ADDED (ml)	TIME (min)
1	0	132	32
2	5	128	20
3	10	132	34
4	15	132	37

Table 3 Final setting time

SL.NO	% OF COPPER SLAG	FINAL SETTING TIME	
		WATER ADDED (ml)	TIME (min)
1	0	132	508
2	5	128	530
3	10	132	550
4	15	132	585

4.3 Slump test

The results of slump test are presented in Table 4. The slump values increases with the percentage increase of mineral admixture. The slump of concrete has not affected by the addition of mineral admixture.

Table 4 Slump test

SL.NO	% OF COPPER SLAG	SLUMP (mm)
1	0	6
2	5	6
3	10	2
4	15	1

4.4 Compressive strength test

The variation of compressive strength for concrete for all percentage of copper slag is shown in Fig. 1 after 28 days curing period. From the Figure it can be seen that in all the replacement of copper slag the strength was higher than the control specimen for 28 days of curing.

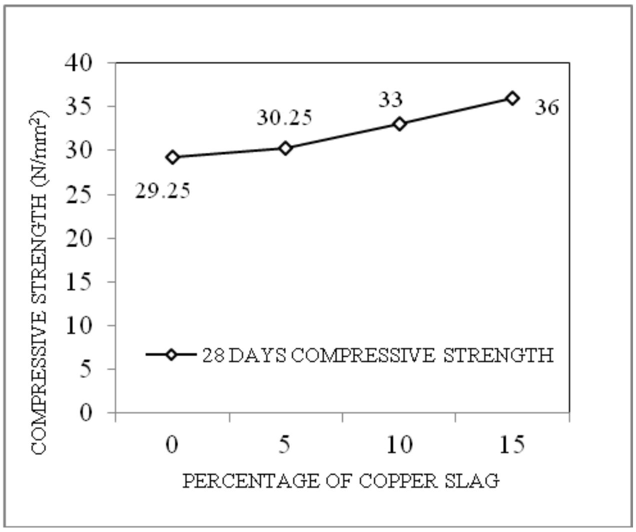

Fig 1 Compressive strength after 28 days

4.5 Deterioration test

The average percentage loss of compressive strength in acid medium after 28 days is shown in Fig. 2. comparing with the control medium. From the figure it can be seen that the percentage loss of compressive strength is less in 10 % replacement whereas in 15% replacement percentage loss is higher compared to control specimens.

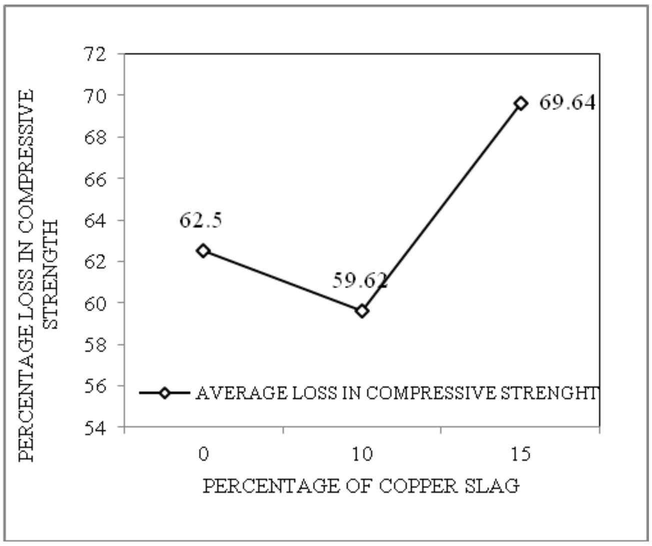

Fig 2 Average percentage loss of compressive strength in acid medium

The average percentage weight loss on sulphate medium after 28 days is shown in Fig 3 comparing with the control medium. From the figure it can be seen that the percentage loss of compressive strength is less in 10 % replacement whereas in 15% replacement percentage loss is higher than control specimens.

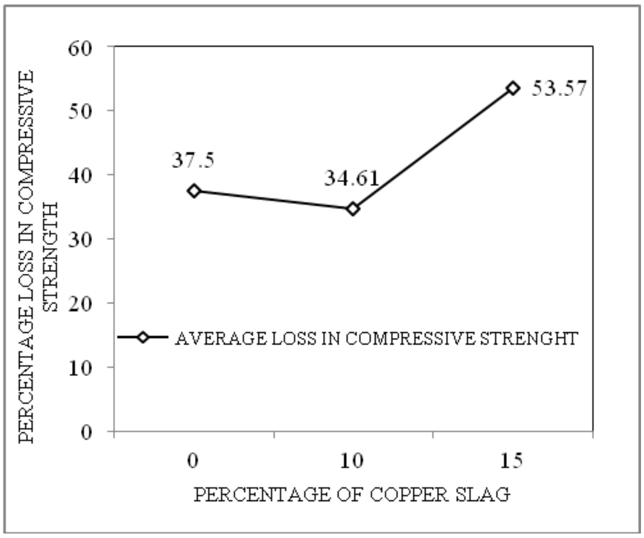

Fig 3 Average percentage loss of compressive strength in sulphate medium

4.6 Potential time studies

The potential time behaviour of rebar embedded in all percentage of replacement exposed in distilled water is shown in Fig 4. It can be seen that the potential values was less than -220mV throughout the study period for rebars embedded in both the concretes. This indicates the rebar was quite safe even at different replacements of copper slag under normal exposure.

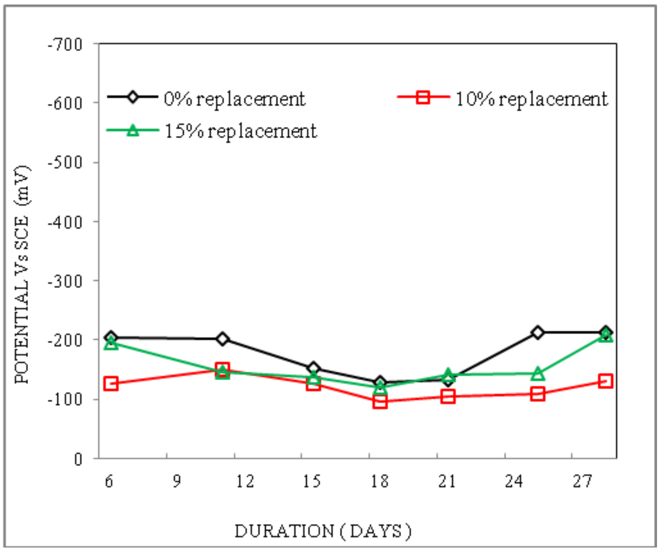

Fig 4 Potential time behaviour of rebar exposed to normal environment

The potential time behaviour of rebar embedded in all percentage of replacement exposed in 5% NaCl is shown in Fig 5. It can be seen that the potential values was numerically more negative throughout the study period for rebars embedded in concretes. This indicates the rebar was exposed to passive corrosion in aggressive environmental condition of 5% NaCl solution

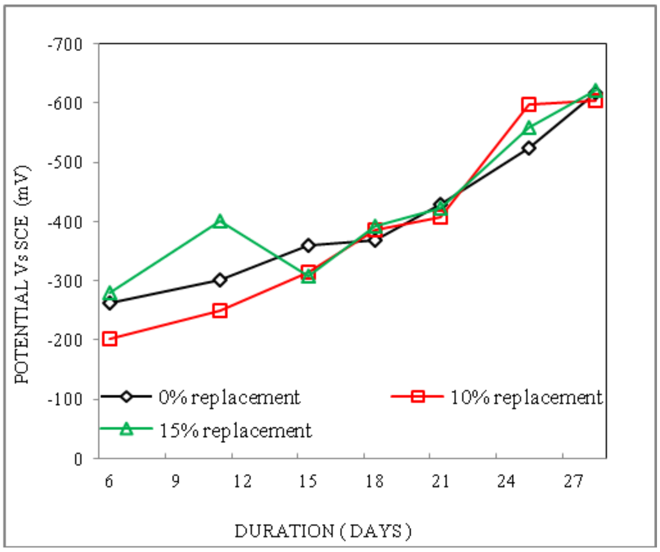

Fig 5 Potential time behaviour of rebar exposed to aggressive environment

3. CONCLUSIONS

From the results of the experimental investigations carried out in this study, the following conclusions can be drawn,

1. Except 5% replacement of copper slag, all other replacements show same consistency as that of control specimens.
2. In all percentage of replacement, the initial setting time is more than the required initial setting time of 30 min given in standards.
3. Final setting time is also less than 600 min irrespective of percentage of replacement and it is also within the maximum time limit given in standards.
4. The slump of concrete has not affected by the addition of mineral admixture.
5. At the end of 28 days curing period, the compressive strength for all replacements are higher than control.
6. Irrespective of acid and sulphate medium, the percentage weight loss and loss of compressive strength is lower in 10 % replacement whereas in 15% replacement percentage loss is higher when compared to control specimens.
7. In potential time behaviour of both normal and aggressive environment conditions, the potential of the replaced concretes rebar exhibit slightly lower potential value than control concrete.
8. From the above studies it can be concluded that 10% replacement of waste material does not affect the durability of concrete.

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