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Copper Slag Admixed Fibre Reinforced Concrete Subjected to Thermal Cyclic Loads

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ABSTRACT

In the current arena, infrastructure development holds the key for the development of every nation. Concrete is one of the most utilized material by the construction industry which is a homogeneous material prepared of heterogeneous materials like Cement, sand and aggregate. However rapid urbanization has created a huge demand for natural sand hence made it even more expensive. This led the researchers to find other materials which could be used as a replacement of sand whose main chemical composition is Silica (SiO_2). After a great extent of research, researchers found that materials like Stone dust, Copper Slag, Coal Fly Ash, Carbonate Sand etc. having silica composition could be used as a replacement of sand. This paper studies on the effect of thermal cycles fibre reinforced copper slag admixed concrete. The experiments were carried out on concrete cubes of size 100 mm x 100 mm x 100 mm. The concrete cubes were subjected up to 56 thermal cycles of constant temperature of 100°C.

Keywords: Thermal Cycle, Copper Slag, Crimped Steel fibres

INTRODUCTION

In India, 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 non conventional 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 cement or aggregates. Copper slag is a by-product obtained during smelting and refining of copper. The waste copper slag can be used as abrasive tools, road construction, and ballast. Despite increasing rate of reusing copper slag, the huge amount of its annual production is disposed in dumps or stockpiles to date. One of the greatest potential applications for reusing copper slag is in cement and concrete production. Many researchers have investigated the use of copper slag in the production of cement, mortar, and concrete as mixed with lime stone powder, dust, cement replacement, use as partial replacement of coarse, and fine aggregates. The use of copper slag in cement and concrete provides potential environmental as well as economic benefits for all related industries, particularly in areas where a considerable amount of copper slag is produced. Many researchers have been carried out experimentally to study the strength and durability properties of concrete by using copper slag as a replacement of sand and the results have been encouraging. However there are no studies available on the effect of thermal cycles on fibre reinforced copper slag concrete. Hence to gain the confidence of the builders and engineers, it is highly important to study the effect of thermal cycles on strength properties of fibre reinforced copper concrete. Taking into account the gap in the existing literature an effort has been made to study the effect of thermal cycles on the fibre reinforced copper slag concrete.

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EXPERIMENTAL INVESTIGATION

Cement

Ordinary Portland cement of 53 grade with normal consistency of 32%, specific gravity of 3.094 and fineness modulus of 4.62% was used. The cement was tested in accordance to IS 4031-1988 standards.

Fine Aggregate

River sand having Bulk Density in compacted state of 1700kg/m^3 and in loose state of 1597 kg/m^3, fineness modulus of 2.4, specific gravity of 2.6 and water absorption of 1.20% was used. Various properties of sand were tested as per IS 2386-1963. It was also ensured that the sand used was free from salt, organic impurities and clayey matter.

Coarse Aggregate

Angular crushed granite metal of 20 mm size having fineness modulus of 7.1, water absorption of 1.1%, Bulk Density in compacted state of 1550 kg/m^3 and in loose state of 1414 kg/m^3 and specific gravity of 2.6 was used. It was ensured that the coarse aggregate was free from impurities such as organic matter, dust and clay particle etc. Various physical properties of the coarse aggregate according to IS 2386-1963 were also tested.

Copper Slag

Copper slag is an industrial by-product produced during the metal smelting process of copper manufacturing process. Air cooled, glassy, irregular and black copper slag with fineness modulus of 3.3 and specific gravity of 3.47 was used. Water absorption was 0.24%. Bulk Density in loose state was found to be 1898 kg/m^3 and in compacted stage of 2024 kg/m^3.

Crimped Steel Fibre

Rounded crimped steel fibres of diameter 0.5 mm X length 30 mm (Aspect ratio = 60) with various volume fractions (0%, 0.5%, 1% & 1.5%) have been used for this study. The Ultimate Tensile Strength of the crimped steel fibres was found to be 1020 MPa.

MIXES

The optimum percentage of copper slag has been established as 40% for partially replacing sand in preparation of M20 grade concrete. In this study, various mixes were prepared by adding crimped steel fibres of different volume fraction (0%, 0.5%, 1% & 1.5%) to this optimized copper slag concrete and plain cement concrete.

The following notions are used for various proportions of copper slag with sand and crimped steel fibre.

- C_0S_0 – 0 % of copper slag and 0% crimped steel fibre
- $C_0S_{0.5}$ – 0 % of copper slag and 0.5% crimped steel fibre
- C_0S_1 – 0 % of copper slag and 1% crimped steel fibre
- $C_0S_{1.5}$ – 0 % of copper slag and 1.5% crimped steel fibre
- $C_{40}S_0$ – 40 % of copper slag and 0% crimped steel fibre
- $C_{40}S_{0.5}$ – 40 % of copper slag and 0.5% crimped steel fibre
- $C_{40}S_1$ – 40 % of copper slag and 1% crimped steel fibre
- $C_{40}S_{1.5}$ – 40 % of copper slag and 1.5% crimped steel fibre

THERMAL CYCLE PROCEDURE

One thermal cycle constitute a heating period of 8 hours and subsequent cooling (in air room temperature) period of 16 hours. The standard specimens after curing period of 28 days were placed in electric ovens at 100ºC for 0 to 56 thermal cycles. The specimens were removed from ovens and then allowed to cool in air for 2 hours after specified time. Then the specimens were tested for weight, ultrasonic pulse velocity, compressive strength and split tensile strength.

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EXPERIMENTAL RESULTS AND DISCUSSION

The variation in weight, UPV of various mixes of M20 OPCC (Ordinary Portland Cement Concrete), SFRC (Steel Fibre Reinforced Concrete), CSC (Copper Slag Concrete) and CS-SFRC (Copper Slag- Steel Fibre Reinforced Concrete) when subjected to a thermal cycle of 100°C are presented in fig 1.The percentage of loss in weight, UPV are presented in fig 2 .

Impact on Weight

It can be observed from the fig 1 that the weight of all types of concrete mixes is continuously decreasing with the increase in the number of thermal cycles. It can also be observed that with the increase in fibre content from 0% to 1.5%, the percentage of loss in weight continuously decreasing and the minimum percentage weight loss is observed at 1.5% steel content for both normal and copper slag concrete. The percentage of loss in weight in case of copper slag concrete mixes is found to be lower than that of corresponding normal concrete mixes.

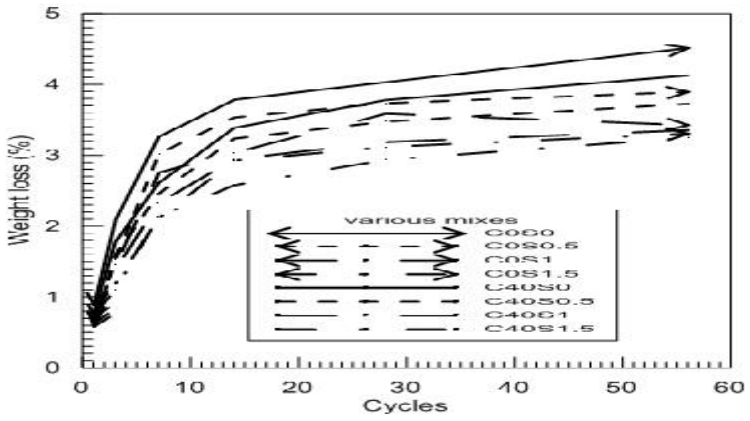

fig-1. Percentage loss of weight (M20 grade)

Impact on Ultrasonic Pulse Velocity

It can be observed from the fig 2 that the UPV of all types of concrete mixes is continuously decreasing with the increase in the number of thermal cycles. It can also be observed that with the increase in fibre content from 0% to 1.5%, the percentage of loss in UPV in case of normal concrete mixes continuously decreasing and the minimum percentage loss of UPV is observed at 1.5% steel content while for copper slag concrete the minimum percentage loss of UPV is observed at 1% of steel fibre and with further increase in the steel fibre the percentage loss of UPV is increasing.

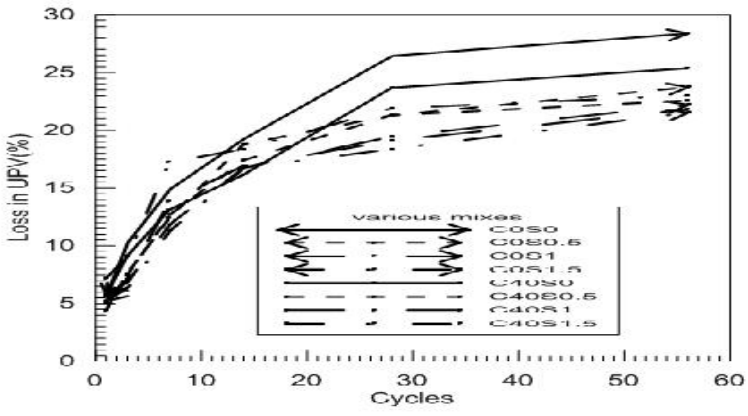

fig-2. Percentage loss of UPV (M20 grade)

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CONCLUSIONS

Fibre reinforced copper slag concrete has a better performance when subjected to a thermal cycle (100°C) when compared to normal concrete. The percentage of loss in weight decreasing with increase in fibre content from 0% to 1.5% and the minimum percentage loss is observed at 1.5% steel fibre content for both normal and copper slag concrete. The percentage of loss in UPV in case of normal concrete is continuously decreasing with the increase in fibre content from 0% to 1.5% and the minimum percentage loss is observed at 1.5% steel content while for copper slag concrete the minimum percentage loss is observed at 1% of steel fibre and with further increase in the steel fibre the percentage loss is increasing. Copper slag concrete found to have good resistance to weight loss when subjected to thermal cycles. The loss of weight takes place due to the evaporation of the moisture from the concrete when subjected to thermal cycle.

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