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Experimental investigation on effect of copper slag in alccofine based self compacting concrete.

Investigación experimental sobre el efecto de la escoria de cobre en hormigones autocompactantes a base de alcofina.

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ABSTRACT

Self-compacting concrete (SCC) is widely used in the development of infrastructure due to various benefits such as high-speed construction, less man power, better surface finish and effortless placing. Aggregates perform significant character in enhancing the strength and workability of concrete. The global consumption of an enormous number of aggregates will cause exhaustion of instinctive resources. For suitable alternative materials, either by-product generated from industries or artificial source of aggregates can be utilized in the production of concrete. Copper slag is an industrial by-product. The Management and disposal of copper slag poses a major challenge for the environment. For the generation of greener concrete, the content of cement in concrete need to be reduced. This can be done by using supplementary cementitious materials. The main aim of the project work is to investigate the properties of alccofine based self-compacting concrete with partial replacement fine aggregate by copper slag. The Alccofine replacement was carried out at different percentages of 5%, 10%, and 15%, and the optimal replacement percentage was determined. Once the optimal Alccofine replacement was established, the replacement of fine aggregate by copper slag was done at varying percentages ranging from 0% to 60% to determine the ideal combination. The compression and split tensile strength test were conducted to find the mechanical properties and slump flow test and J ring were conducted to find the fresh properties. According to the findings, 10% alccofine replacement gives improved concrete properties and the incorporation of 40% copper slag as a partial replacement for fine aggregate in self-compacting concrete resulted in improved workability and strength properties.By utilizing an optimal mixture of Alccofine and copper slag, there is an observed enhancement in the compressive strength by 11% and the split tensile strength by 15%.

Keywords: Self-compacting concrete, alccofine, copper slag pozzolanic character, compression test

RESUMEN

El hormigón autocompactante (SCC) se utiliza ampliamente en el desarrollo de infraestructura debido a diversos beneficios, como una construcción de alta velocidad, menos mano de obra, mejor acabado superficial y colocación sin esfuerzo. Los agregados desempeñan un papel importante a la hora de mejorar la resistencia y trabajabilidad del hormigón. El consumo global de una enorme cantidad de agregados provocará el agotamiento de los recursos

instintivos. Para materiales alternativos adecuados, en la producción de hormigón se pueden utilizar subproductos generados por industrias o fuentes artificiales de agregados. La escoria de cobre es un subproducto industrial. La gestión y eliminación de escorias de cobre supone un gran desafío para el medio ambiente. Para generar un hormigón más ecológico, es necesario reducir el contenido de cemento en el hormigón. Esto se puede hacer utilizando materiales cementosos suplementarios. El objetivo principal del trabajo del proyecto es investigar las propiedades del hormigón autocompactante a base de alcofino con sustitución parcial de árido fino por escoria de cobre. La reposición de Alccofine se realizó a diferentes porcentajes de 5%, 10% y 15% y se determinó el porcentaje de reposición óptimo. Una vez establecido el reemplazo óptimo de Alccofine, el reemplazo del agregado fino por escoria de cobre se realizó en porcentajes variables que van del 0% al 60% para determinar la combinación ideal. Se realizaron pruebas de compresión y resistencia a la tracción dividida para encontrar las propiedades mecánicas y se realizaron pruebas de asentamiento y anillo J para encontrar las propiedades en estado fresco. Según los hallazgos, el reemplazo del 10% de Alccofine brinda propiedades mejoradas del concreto y la incorporación de un 40% de escoria de cobre como reemplazo parcial del agregado fino en el concreto autocompactante resultó en mejores propiedades de trabajabilidad y resistencia. Al utilizar una mezcla óptima de Alccofine y cobre escoria, se observa una mejora en la resistencia a la compresión en un 11% y en la resistencia a la tracción dividida en un 15%.

Palabras clave: Hormigón autocompactante, alcofino, escoria de cobre de carácter puzolánico, ensayo de compresión.

INTRODUCTION

Self-compacting concrete (SCC) is a modern innovation in the construction industry that can be effortlessly placed and compacted without the need for excessive vibration. It has the remarkable ability to fill heavily reinforced structural members effectively while preventing issues like segregation or bleeding. One of the advantages of SCC is its ability to provide excellent structural performance. However, it is important to note that the utilization of a significant amount of cement in SCC can lead to increased costs and higher levels of exothermic heat.The use of additions such as fly ash, blast furnace slag, limestone filler, rice husk ash, Alccofineetc. could decrease the temperature of the mix without increasing the cost of SCC [4]. The addition of SCM (Supplementary Cementitious Materials) in SCC can upgrade the strength, durability, economic aspect, and the effects due to inadequate compaction [2]. Alccofine (AL) is a new generation, micro fine material of particle size is much lesser than other cementitious materials like fly ash, GGBS, the use of aggregates is crucial in improving the strength and workability of concrete, as they make up a considerable portion (about 60-70%) of the concrete's volume. However, the extensive worldwide demand for aggregates is depleting natural resources and compromising environmental sustainability. Copper slag (CS) is a by-product of copper manufacturing, and it has properties such as low water absorption and comparable fine aggregate gradation [3]. Moreover, due to its chemical composition, copper slag produces a pozzolanic effect in concrete matrix when incorporated. These features make copper slag a viable

alternative to conventional fine aggregate without affecting the workability, strength, and durability of concrete. Reusing industrial by-products is an economically and environmentally sustainable practice. In the present paper an investigation was carried out to develop a self-compacting concrete by partially replacing cement with Alccofine and fine aggregate by copper slag.

MATERIALS AND METHODS

A. Materials and properties

The materials used in the experimental work are, cement (OPC), fine aggregate, coarse aggregate, Alccofine, copper slag, water and super plasticizer.

1. Cement

In present work, OPC 53 grade was used. It contains very high content of Tri-Calcium Silicate providing long lasting durability to concrete structures.

2. Fine aggregate

M-sand was used as the fine aggregate in the present study. M-sand used was conforming to Zone II of IS 383:1963. collected from Royal Rock products Peppathy, Arakkunnam

3. Coarse aggregate

Coarse aggregates of size 12mm is used for casting. The coarse aggregate was collected from Ultratech RMC yard, Eranakulam

4. Alccofine

The waste material generated from the iron ore industries Collected sample is Alccofine- 1203 from Ambuja cements, Ernakulam

5. Copper slag

An industrial waste material generated from copper manufacturing industry. The copper slag collected is black granular type from Santhana Lakshmi Metals, Aluva

6. Super plasticizer

It is an admixture of a new generation based on modified polycarboxylate ether.

Table 1 Properties of cement and aggregates

Material	Property	Result	Allowable Limit
Cement	Fineness	9.8%	10%
	Specific Gravity	3.12	Not specified
	Consistency	28%	Not specified
Fine aggregate	Specific Gravity	2.64	2.5-3.0
	Water Absorption	2.3%	<3%
Coarse aggregate	Specific Gravity	2.7	2.6-2.8
	Water Absorption	0.2%	<2%

B. *Mix Proportion and Preparation of Specimen*

Mix design was done as per IS 10262: 2019. Mix design of M40 equivalent Alccofine based self - compacting concrete with trial mix was found. Total of 5 mixes are formed by using different percentage of substitution by AL. The water- cement ratio is 0.36 and the in the mix ratio of 1: 2: 1.414

Note: *S - Self Compacting Concrete

*AL - Alccofine

*CS – Copper slag

SAL0 - Control mix of SCC without any AL& CS content

SAL5 - M40 grade SCC containing 5% AL

SAL10 - M40 grade SCC containing 10% AL

SAL15 - M40 grade SCC containing 15% AL

SA10C20 -M40 grade SCC containing 10% AL and 20% CS

SA10C40 -M40 grade SCC containing 10% AL and 40% CS

SA10C60 - M40 grade SCC containing 10% AL and 60% CS

RESULTS AND DISCUSSION

The test conducted on self-compacting concrete were slump flow test and J ring test to determine the workability of concrete mix. The mechanical properties of self-compacting concrete were evaluated by conducting compressive strength test, split tensile strength

A. Workability

Table 3 Workability results obtained for all the mixes

Mix	Slump flow (mm)	J-ring (mm)	Passing ability (mm)	Remarks (as per ASTM 1621/C 1621M)
SAL0(CM)	785	771	14	
SAL5	790	780	10	
SAL10	807	800	7	
SAL15	802	791	16	No visible blocking since passing ability values are between 0 and 25 mm
SAL10C20	815	806	9	
SAL10C40	824	817	6	
SAL10C60	820	809	11	

The obtained result fall under the range of 760 to 850 mm recommended by IS 10262: 2019.The visual observation shows the SCC possess good cohesion. So, from the workability results and visual observation, the mixes can be said to be an SCC with SF3 class. Among the alccofine replacement, the 10% gives maximum

workability values. The incorporation of copper slag increases the workability up to 40% replacement, beyond that the slump flow value gets decreases. the low water absorption nature copper slag helps to increase the workability. From the overall workability study, it was observed that the mix contains 10% alccofine along with 40% copper slag gives better values for both slump flow and passing ability values

Fig. 1 Slump flow test

Fig.2 J ring test

B. Compressive strength

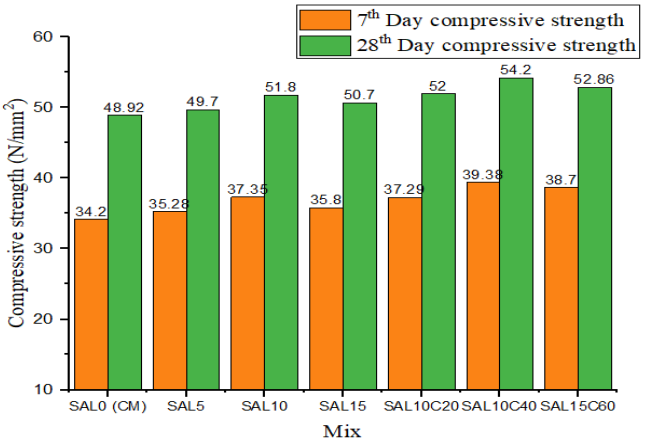

Fig.3 Variation in compressive strength of all the mixes

Figure 4.2 shows the variation in compressive strength with the replacement of AL and CS. After conducting tests, it was determined that the optimum replacement percentage for Alccofine is 10%. Various percentages of copper slag were then added to the 10 % Alccofine-containing SCC to determine the most effective combination. It was observed that, the compressive strength of AL based SCC increases with the incorporation of copper slag up to 40%.It is mainly due to high toughness and provision of good interlocking of copper slag leading to better volumetric and mechanical quality. Beyond 40% the compressive strength gets decreases because of the accumulated water in the concrete. The SCC mix with 10% AL and 40%CS substitution gives the maximum

compressive strength of 54.2N/mm^2, which is about 11% more with respect to that of control mix (in 28 days).

B. Split tensile strength

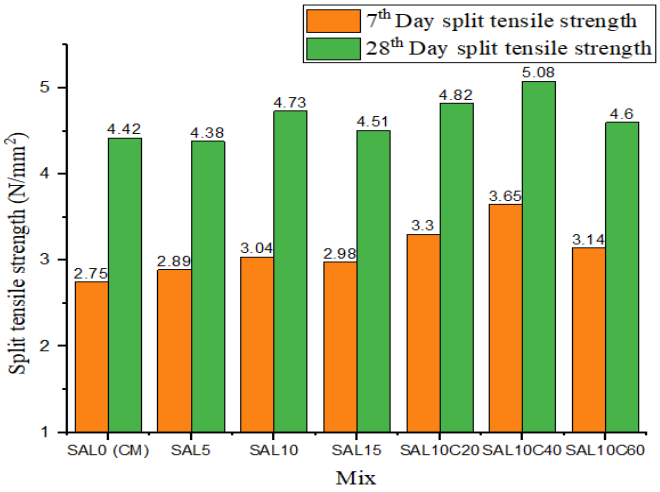

Fig. 4 Variation in split tensile strength of all the mixes

From the results, we can understand that, split tensile strength of SCC increases with the addition Alccofine. 10% Alccofine replacement with cement shows the maximum split tensile strength. 20%, 40% and 60% percentages of copper slag were then added as the fine aggregate replacement to the 10 % Alccofine-containing SCC to determine the most effective combination. According to the results it was observed that, the split tensile strength of AL based SCC increases with the incorporation of copper slag up to 40%. Beyond 40% substitution the tensile strength value gets decreases. The maximum split tensile value obtained is 5.08 N/mm^2 for the mix containing 10% alccofine and 40% copper slag and it is about 15% more than that of the control mix

In this study, an experimental investigation was performed to evaluate the combined effect of both alccofine and copper slag in self-compacting concrete. Based on the results of presented work, the following main concluding remarks are made:

- Slump flow test results of self-compacting concrete with both Alccofine and copper slag were categorized as class SF3, which is suitable for vertical application in every congested structure, structures with complex shapes, etc.
- Compared to control mix, the workability of self-compacting concrete increases with replacement of cement by 10% alccofine. This is mainly due to the glass content and water repelling properties of alccofine material.
- Both flowing and passing ability of SCC increases with replacement of fine aggregate by copper slag up to 40%. The low water absorption nature of copper slag helps to increase the workability.
- The replacement of cement by alccofine and fine aggregate by copper slag enhances the strength properties of SCC. The mix with 10% AL and 40% CS gives the maximum compressive strength value of 54.2N/mm^2, which is 11% more than that of the control mix.
- Split tensile strength values are also increased with alccofine and copper slag. The maximum value of

5.08N/mm^2 is obtained at 10% AL and 40% CS substitution and it is 15% more than that of the control mix.

- Due to the pozzolanic nature and microfilling effect alccofine- 1203 along with the angular edges of copper slag particles, helps in improving cohesion of the concrete matrix and there by increases the strength of the concrete.
- Because of the low water absorption property, the over usage of copper slag material increases the free water content in the concrete. This causes bleeding and reduction in strength values.
- Thus, incorporation of combination of AL & CS in a self-compacting concrete enhanced fresh and mechanical behaviour of the SCC and resulted in the production of environmentally friendly type concrete.

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