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STRENGTH ENHANCEMENT OF RECYCLED CONCRETE INCORPORATING COPPER SLAG

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ABSTRACT:

Concrete occupies unique position among the modern construction materials. Concrete is a material used in building construction, consisting of a hard, chemically inert particulate substance, known as aggregate (usually made for different types of sand and gravel), that is bond by cement and water. Now a days utilization of industrial soil waste or secondary materials has encouraged in construction field for the production of cement and concrete because it contribute to reducing the consumption of natural resources. Copper slag is obtained as waste product from the sterlite industries. Experiments are carried out to explore the possibility of using copper slag as a replacement of sand in concrete mixtures. 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. The main focus of this study is to find out the strength and durability properties of concrete in which fine aggregate is partially replaced with 10%, 20%, 30%, 40%.

Keywords— copper slag, fine aggregate, compressive strength, durability, concrete.

INTRODUCTION

1.1 GENERAL

One of the major challenges for construction industries is the concern for protection of our environment. Some of the important elements here, are the reduction of the consumption of energy and natural raw materials and waste utilization. These topics are getting considerable attention under sustainable development nowadays. The use of recycled aggregates from Construction and Demolition (C&D) wastes is showing prospective application in construction as alternative to primary (natural) aggregates. It conserves natural resources and reduces the space required for landfill disposal. Many countries are witnessing a rapid growth in the construction industry which involves the use of natural resources for infrastructure development. This growth is jeopardized by the lack of natural resources that are available. Natural resources are depleting world-wide while at the same time the generated un-utilized 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 depleting natural resources, with a focus on conserving the environment.

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1.2 RECYCLED AGGREGATE CONCRETE

Recycled material use is an attractive alternative to landfill disposal of waste, as it reduces the depletion of natural resources, limits the high energetic/environmental impacts in traditional concrete production, and increases the life-cycle of recycled aggregate. In civil constructions, the use of recycled aggregates (RA) in the manufacture of concrete is growing. This increase is a result of the environmental benefits, rather than the advantages in mechanical and durability behaviors presented by recycled waste. Thus, it is partially accepted that there are losses in the mechanical and durability properties for these recycled concretes.

Aggregates are considered one of the main constituents of concrete since they occupy more than 70% of the concrete matrix. In many countries there is scarcity of natural aggregates that are suitable for construction while in other countries there is an increase in the consumption of aggregates due to the greater demand by the construction industry. In order to reduce dependence on natural aggregates as the main source of aggregate in concrete, artificially manufactured aggregates and artificial aggregates generated from industrial wastes provide as an alternative for the construction industry. Therefore, utilization of aggregates from industrial wastes can be alternative to the natural and artificial aggregates.

1.2.1 Properties of Recycled Aggregates

The crushing characteristics of hardened concrete are similar to those of natural rock and are not significantly affected by the grade or quality of the original concrete. Recycled concrete aggregates produced from all but the poorest quality original concrete can be expected to pass the same tests required of conventional aggregates.

Recycled concrete aggregates contain not only the original aggregates, but also hydrated cement paste. This paste reduces the specific gravity and increases the porosity compared to similar virgin aggregates. Higher porosity of RCA leads to a higher absorption.

1.3 COPPER SLAG

Copper slag is one of the materials 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. In Oman approximately 60,000 tons of copper slag is produced every year. Also, the production of approximately 0.36, 0.244, 2.0, and 4.0 million tons of copper slag is reported in Iran, Brazil, Japan and the United States, respectively. Utilization of copper slag in applications such as Portland cement substitution and/or as aggregates has threefold advantages of eliminating the costs of dumping, reducing the cost of concrete, and minimizing air pollution problems.

LITERATURE REVIEW

Khalifa S. Al-Jabri et al., (2009) have presented an experimental program to investigate the effect of using copper slag as a replacement of sand on the properties of high performance concrete (HPC). Eight concrete mixtures were prepared with different proportions of copper slag ranging from 0% (for the control mix) to 100%. Concrete mixes were evaluated for workability, density, compressive strength, tensile strength, flexural strength and durability. The results indicate that there is a slight increase in the HPC density of nearly 5%

with the increase of copper slag content, whereas the workability increased rapidly with increases in copper slag percentage. Addition of up to 50% of copper slag as sand replacement yielded comparable strength with that of the control mix. However, further additions of copper slag caused reduction in the strength due to an increase of the free water content in the mix. Mixes with 80% and 100% copper slag replacement gave the lowest compressive strength value of approximately 80 MPa, which is almost 16% lower than the strength of the control mix. The results also demonstrated that the surface water absorption decreased as copper slag quantity increases up to 40% replacement; beyond that level of replacement, the absorption rate increases rapidly. Therefore, it is recommended that 40% of copper slag can used as replacement of sand in order to obtain HPC with good strength and durability properties.

D. Brindha et al., (2010) have studied the potential use of granulated copper slag from Sterlite Industries as a replacement for sand in concrete mixes. The effect of replacing fine aggregate by copper slag on the compressive strength and split tensile strength are attempted in this work. The percentage replacement of sand by granulated copper slag were 0%, 5%, 10%, 15%, 20%, 30%, 40% and 50%. The compressive strength was observed to increase by about 35-40% and split tensile strength by 30-35%. The experimental investigation showed that percentage replacement of sand by copper slag shall be upto 40%.

Jayapal Naganur et al., (2014) have performed studies on experimental investigation on the properties of concrete using copper slag as partial replacement of fine aggregate. For this research work, M20 grade concrete was used and tests were conducted. Various concrete mixtures were prepared with different proportions of copper slag as fine aggregates replacement. Concrete mixtures were evaluated for workability, compressive strength, splitting tensile strength, corrosion, acid resistivity and microstructural analysis. The results for concrete indicated that workability increased significantly as copper slag percentage increase compared with the control mixture. A substitution of up to 40 to 50% copper slag as a fine aggregate yielded comparable strength to that of the control mixture. However addition of copper slag more than 50% resulted in strength reduction compared to conventional concrete.

MATERIALS AND METHODOLOGY

Materials to be used are available from different sources based on the location of work. This chapter deals with the type of materials used, their source and the method adopted.

CEMENT

The word „cement‟ usually means Portland cement used in civil engineering works which sets well under water, hardens quickly and attains strength. The main functions of cement are

- To fill voids between aggregate particles providing lubrication of the fresh concrete and water tightness and durable structure in the hardened concrete

- To give strength to the hardened concrete

In the present work, Bagalkot cement is used. It is ordinary Portland cement of 43 grade. Various tests are conducted on this cement to evaluate its properties.

Fine Aggregates

River sand conforming to Zone I (IS 383-1970 grading requirements) with specific gravity 2.62 is used. The aggregate which pass through 4.75 mm IS sieve and entirely retain on 75 micron IS sieve is called fine aggregate. The tests are conducted to find the properties of fine aggregate and the results are tabulated as below in Table 3.2. Table 3.3 presents the results of sieve analysis of sand.

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Table 3.1 Properties of fine aggregates

Sl. No.	Property	Results
1	Specific gravity	2.62
2	Bulk density i) Loose ii) Compact	1463 Kg/m3 1661 Kg/m3
3	Moisture content	Nil
4	Fineness modulus	2.47

METHODOLOGY

- To cast 80 Nos of 150mm concrete cubes of nominal mix (1:1.5:3) and to crush them to failure after 28 days water curing, to later process this concrete to obtain recycled corase aggregates.

- Concrete fragments are broken using a hammer into small pieces of size compatible to that of processing.

- Parameters to be adopted in processing of recycled aggregates using rod mill machine is decided based on different sets of experiments

Table 3.2 Sieve analysis of fine aggregates

IS sieve size	Percentage passing	IS 383-1970 Sieve analysis of fine aggregate				Remarks
		Zone 1	**Zone 2**	**Zone 3**	**Zone 4**	Satisfies Zone –I grading requirements
10 mm	100	100	100	100	100	
4.75 mm	99.5	90-100	90-100	90-100	95-100	
2.36 mm	95.7	60-95	75-100	85-100	95-100	
1.18 mm	69.0	30-70	55-90	75-100	90-100	
600 μ	29.3	15-34	35-59	60-79	80-100	
300 μ	5.3	5-20	8-30	12-40	15-50	
150 μ	2.8	0-10	0-10	0-10	0-10	

- ✓ Concrete cubes with same water cement ratio and different proportions of copper slag as 25%, 50%, 75%, 100% were cast as 3 cubes for each mix and compressive strength is obtained after 28 days of curing.

- ✓ Cubes are cast with different proportions of recycled aggregate as 25%, 50%, 75%, 100% as 3 cubes for each mix and compressive strength of this cubes is obtained after 28 days of curing.

- ✓ Cubes are cast keeping the recycled aggregate constant as 50% and varying copper slag in proportions of 0%, 25%, 50%, 75%, 100% with 3 cubes for each mix.

- ✓ Cement is replaced by 4% silica fume and cubes are cast keeping the recycled aggregate constant as 50% and varying copper slag in proportions of 0%, 25%, 50%, 75%, 100% with 3 cubes for each mix.

- ✓ These cubes are kept for 28 days curing and are tested for compressive strength.
- ✓ Based on analysis of results obtained, important conclusions are to be drawn.

Figure shows Testing of cubes for compressive strength

RESULTS AND DISCUSSION

In this chapter, the results of tests performed on recycled concrete, copper slag, silica fume and combination of these materials are discussed. The variation in compressive strength is discussed in detail.

PROCESSING OF RECYCLED AGGREGATE

The quality of recycled aggregate from Construction & Demolished waste essentially depends on the technique of processing of the processing methodology involved in obtaining recycled aggregate. As mentioned in previous chapter, for processing recycled aggregate a rod mill has been used, preliminary experiments were undertaken to optimize on working parameters such as amount of C&D waste for each run to be used, variation in the nature of charge such as only rods, only steel balls & a combination of the two, and also the time of run. Water absorption of processed recycled aggregate was the basis to decide on the quality of processing.

4.2.1 Experiment 1

To determine the quantity of material to be used for each run, Construction & Demolished material as multiples of weight of charge is considered. Optimum quantity of raw C&D material is decided based on the values of water absorption of the recycled aggregates being processed. Table 4.1 presents the results obtained

3.3 Properties of coarse aggregates

Sl. No.	Property	Results
1	Specific gravity	2.73
2	Bulk density (i) Loose (ii) Compact	1360 Kg/m3 1527 Kg/m3
3	Water absorption	0.2%
4	Fineness modulus	6.95

Virgin aggregates

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Broken concrete

Recycled aggregate

Variation in water absorption with material weight being processed

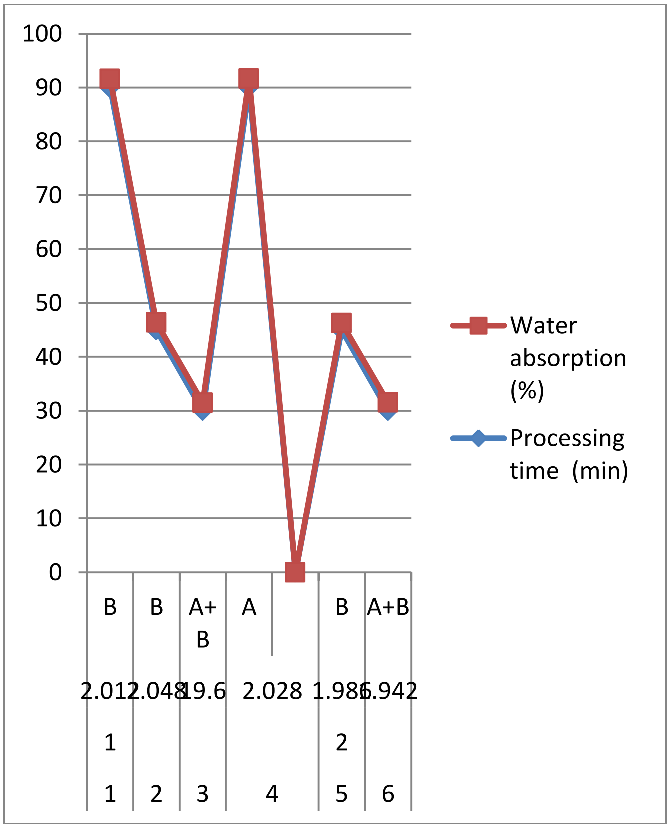
Figure 4.1 shows the quality of aggregates before and after processing. Figure 4.2 shows the water absorption variation with amount of C&D waste being processed. From Table 4.1 & Fig. 4.2, it is clear that best processing occurs for 5kg of C&D waste.

Experiment 2

To find the charge to be used in each cycle, charge is divided into three sets as A,B and A+B. The available materials are steel balls each weighing 65g and steel rod each weighing 75g.
Charge A- 11 balls – 825g
Charge B- 13 rods - 845g
Charge A+B – 6 balls+ 6 rods – 840g

Table 4.1 Water absorption results for various types of charges tried

SL. NO	Set	Material weight (kg)	Charge	Processing time (min)	Water absorption (%)
1	1	2.012	B	90	1.60
2		2.048	B	**45**	1.40
3		**19.60**	A+ B	**30**	1.50
4		**2.028**	A	**90**	1.71
5	**2**	**1.986**	B	**45**	**1.32**
6		**1.942**	A+B	**30**	**1.55**



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Virgin agreegate

Recycled aggregate

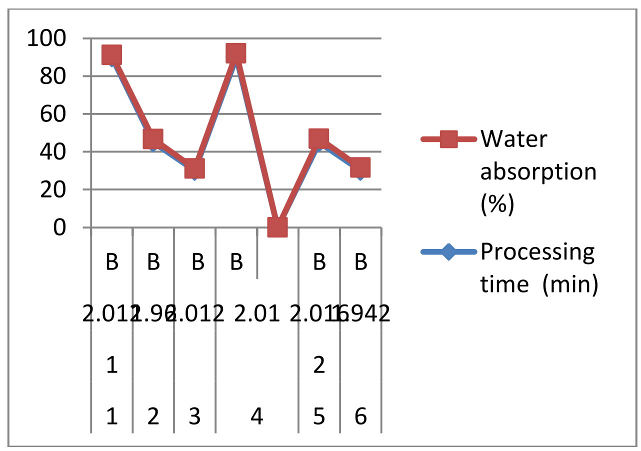
Aggregates before and after processing

COMPRESSIVE STRENGTH

Compressive strength testing of all specimen were carried out as per IS: 516-1959. The load was applied without shock at a rate of 140 kg/cm2/min. A set of three cubes were tested for each mix, for each percentage of replacement. The maximum load resisted divided by cross sectional area of specimen, gave the compressive strength. Average of three specimen were taken, provided the individual variation in strength was not more than ±15% of the average, and the results were tabulated and interpreted

Table 4.2 Compressive strength results for different proportions of RCA

SL. NO	Set	Material weight (kg)	Charge	Processing time (min)	Water absorption (%)
1	1	2.012	B	90	1.2
2		1.960	B	**45**	1.7
3		**2.012**	B	**30**	1.1
4		**2.010**	B	**90**	2.0
5	**2**	**2.016**	B	**45**	**1.9**
6		**1.942**	B	**30**	**1.6**



CONCLUSIONS

5.1 INTRODUCTION

As elaborated in the previous chapters, studies were undertaken to explore the RCA processing techniques & optimize the working conditions. The strength variation with RCA is studied. Further attempts were made to propose guidelines to recover the strength lost due to RCA by adding Copper slag & Silica fume. The test results obtained were analyzed and discussed in the previous chapters. Based upon the detailed analysis important conclusions are summarized in this chapter.

5.2 CONCLUSIONS

 As the degree of processing gets higher the recycled aggregate tends to be more closer to virgin aggregate by way of its surface texture. Hence recycled aggregate after processing shows better results than unprocessed recycled aggregate

 Quality of recycled aggregate plays vital role in the production of high strength RCA concrete.

 RCA exhibits similar behavior to fresh aggregate; therefore, RCA could be incorporated into many concrete structures. However, RCA that has an unknown origin should be tested to ensure that the RCA was not from a structure that was suffering from alkali-silica reaction, alkali-aggregate reaction, sulphate attack, or some other harmful reaction. Such RCA could affect the strength and durability of the concrete and may be harmful.

 A maximum reduction of about 22% was noticed in compressive strength when the entire natural aggregate was replaced with RA. Moreover, environmental benefits may be able to compensate to some extents the negative effect due to the use recycled coarse aggregate concrete and can lead us significantly closer toward green infrastructure.
 with increase in processed recycled aggregate content the compressive strength of concrete were lower. Based on the results, replacement of up to 50% is advisable.
 a maximum increase of 10% was observed when 50% copper slag replaces fine aggregate.

 the strength was further increased when silica fume is used as 4% replacement ofcement in the same experiment done with that of RCA and Copper slag.

 This values of strength obtained by addition of silica fume are found to be equal to that of the control mix when RCA is 50%, Copper slag is 25% and Silica fume is 4%. Thus recycled aggregate can be used successfully with copper slag and silica fume at optimum proportions as a solution to the depleting natural resources.

5.3 CLOSURE

Key findings in compression strength, absorption and replacement with Recycled aggregate, Copper slag, Silica fume with the concrete are summarized. In addition, scope for the further research is briefly discussed.

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