Strengtheing Of Recycled Concrete Incorporating Copper Slag

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I. 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.

Any construction activity requires several materials such as concrete, steel, brick, stone, glass, clay, mud, wood, and so on. However, the cement concrete remains the main construction material used in construction industries. For its suitability and adaptability with respect to the changing environment, the concrete must be such that it can conserve resources, protect the environment, economize and lead to proper utilization of energy. To achieve this, major emphasis must be laid on the use of wastes and byproducts in cement and concrete used for new constructions. The utilization of recycled aggregate is particularly very promising as 75 per

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.

1.3.1 Uses of copper slag

- Copper slag has also gained popularity in the building industry for use as a fill material.
- Contractors may also use copper slag in place of sand during concrete constructions.
- Copper slag is widely used in the sand blasting industry and it has been used in the manufacture of abrasive tools.
- Copper slag is widely used as an abrasive media to remove rust, old coating and other impurities in dry abrasive blasting due to its high hardness (6-7 Mohs), high density (2.8-3.8 g/cm^3) and low free silica content.Table 1.1 presents the chemical properties of copper slag

Table 1.1 Chemical Properties of Copper Slag

Chemical Component	Weight (%)
SiO_2	32.74
Fe_2O_3	49.30
Al_2O_3	6.06
CaO	0.84
Na_2O	0.14
K_2O	0.03
Loss on Ignition	0.25

1.4 SILICA FUME

Silica fume is a by-product of producing silicon metal or ferrosilicon alloy. Because of its chemical and physical properties, it is a very reactive pozzolan.

1.4.1Properties of silica fume

A. Physical properties

More than 95% of silica fume particles are finer than 1 micrometer. Its typical physical properties are given in table 1.2.

Table 1.2 Typical physical properties of Silica fume

Property	Value
Particle size (typical)	<1µm
Bulk density	
(as-produced)	130-430 kg/m^3
(Slurry)	1320-1440 kg/m^3
(Densified)	480-720 kg/m^3
Specific Gravity	2.22
Surface area (BET)	13000-30000 m^2/kg

B. Chemical properties

Silica fume has a very high content of amorphous silicon dioxide and consists of very fine spherical particles. Small amounts of iron, magnesium, and alkali oxides are also found. Table 1.3 presents the chemical properties of silica fume.

Table 1.3 Chemical composition of silica fume samples

Oxides	Sandvik andGjorv(1992)	Titherington and Hooton(2004)	Yazici (2008)
SiO_2	92.1	96.65	92.26
Al_2O_3	0.5	0.23	0.89
Fe_2O_3	1.4	0.07	1.97
CaO	0.5	0.31	0.49
MgO	0.3	0.04	0.96
K_2O	0.7	0.56	1.31
Na_2O	0.3	0.15	0.42
SO_3	0.0	0.17	0.33
LOI	2.8	2.27	0.0

1.4.2 Advantages of using silica fume

• High early compressive strength
• High tensile, flexural strength and modulus of elasticity
• Increased toughness
• High bond strength
• Enhanced durability

1.5 CLOSURE

In this chapter, importance and scope for utilization of construction & demolished waste in concrete is discussed. Importance of part replacement of fine aggregate by Copper Slag in concrete is also introduced

II. LITERATURE REVIEW

2.1 INTRODUCTION

Several works have been carried on different materials used in this experiment. All these works give a brief idea of procedure to be adopted and the ratio of materials to be used.

2.2 SOME PERTINENT LITERATURE

SILICA FUME

Hooton (1993) determined the compressive strengths of concretes containing 0, 10, 15, and 20% silica fume up to the age of 5years. While strengths of the concretes containing silica fume were higher at ages between 7 and 91 days, the Portland cement concrete continued to gain strength at later ages; with a 55% increase between 28 days and 5 years. In contrast, the long-term strength gain of silica fume concretes was very low and 5-year strengths were ±12% of the day strengths. Reductions in strengths were noted to be within the normal variation of strengths observed in long-term studies with Portland cement concretes. Also, the influence of silica fume on the splitting tensile strength of concretes up to the age of 182 days was investigated. It was concluded that except at 28 days, the splitting tensile strength was not improved for silica fume concrete mixes. Also it was observed that with increasing replacement of silica fume split tensile strength decreased. Modulus of elasticity of silica fume was also determined in this work for concretes up to the age of 365 days . It was seen that elastic modulus of the Portland cement concrete was approximately equal to silica fume concretes at 28 days but continued to increase at later ages.

Mazloom et al., (2004) investigated the influence of silica fume (0, 6, 10, and 15%) on the compressive strength of high performanceconcrete up the age of 400 days. He concluded that at 28 days, the silica fume concrete was 21% stronger than control concrete and compressive stren-gth development of concrete mixtures containing silica fume was negligible after the age of 90 days; however, there was 26% and 14% strength increase in the control concrete after one year compared to its 28 and 90 days strength, respectively. He also investigated the effect of silica fume on the secant modulus of elasticity. It was observed that increasing the silica fume replacement level increased the secant modulus of concrete. Tests were also conducted for total, autogenous and drying shrinkage of high performance concrete having silica fume. The percentages of silica fume were: 0, 6, 10 and 15% with w/c ratio being 0.35. The results showed that silica fume did not have much effect on drying specimens (total shrinkage)and also that it (silica fume) considerably affected the shrinkage of sealed specimens. Thus it was made clear that the general effect of increasing the silica fume inclusion is to increase autogenous shrinkage; and there were significant increase in autogenous shrinkage at high levels of silica fume. Inclusion of 10 and 15% silica fume increased the autogenousshrinkage of concrete by 33 and 50%, respectively. The effect of silica fume on autogenous shrinkage was explained by its influence on the pore structure and pore size distribution of concrete as well as its pozzolanic reaction.

COPPER SLAG

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%.

R RChavan et al., (2013)have investigated the effect of using copper slag as a replacement of fine aggregate on the strength properties. For this research work, M25 grade concrete was used and tests were conducted for various proportions of copper slag replacement with sand of 0 to 100% in concrete. The obtained results were compared with those of control concrete made with ordinary Portland cement and sand. Maximum Compressive strength of concrete was increased by 55% at 40% replacement of fine aggregate by copper slag, and up to 75% replacement, concrete gain more strength than control mix concrete strength. It was observed that for all percentage replacement of fine aggregate by Copper slag the flexural strength of concrete was more than control mix. Also, the flexural strength of concrete at 28 days was higher than design mix (without replacement) for 20% replacement of fine aggregate by Copper slag, the flexural strength of concrete was increased by 14%. This also indicates flexural strength was more for all percentage replacements than design mix. Compressive strength and flexural Strength were increased due to high toughness of Copper slag.

T.Ch. Madhavi (2014)has studied the application of copper slag as an alternative replacement material of sand. This paper also studies the effect of replacement of Fine aggregate with copper slag on mechanical properties of concrete. Copper slag can be used up to 30% but when used beyond 50% results in decrease in strength.

C. K. Madheswaran et al., (2014) have studied the use of copper slag, as a partial replacement of sand for use in cement concrete and building construction. Cement mortar mixtures prepared with fine aggregate made up of different proportions of copper slag and sand were tested for use as masonry mortars and plastering. Three masonry wall panels of dimensions 1×1 m were plastered. The studies showed that although copper slag based mortar is suitable for plastering, with the increase in copper slag content, the wastage due to material rebounding from the plastered surfaces increases. It is therefore suggested that the copper slag can be used for plastering of floorings and horizontal up to 50% by mass of the fine aggregate, and for vertical surfaces, such as, brick/block walls it can be used up to 25%. In this study on concrete mixtures were prepared with two water cement ratios and different proportions of copper slag ranging from 0% (for the control mix) to 100% of fine aggregate. The Concrete mixes were evaluated for workability, density, and compressive strength.

JayapalNaganur 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**.**

Syed MoizuddinMahmood et al., (2014)have conducted studies where in fine aggregates (sand) was replaced with percentages 0% (for the control mixture), 10%, 20%, 30%, 40%, 50%, 60%, 80%, and 100% of Copper Slag by weight. Tests were performed for properties of fresh concrete and Hardened Concrete. Compressive strength test was conducted for 7 and 28 days. Tensile strength and Flexural strength were determined at 28 days. RCC beams Flexural strength tested @ 28 days. The results indicate that workability increases with increase in Copper Slag percentage. Test results indicate significant improvement in the strength properties of plain concrete by the inclusion of up to 100% Copper slag as replacement of fine aggregate (sand), and can be effectively used in structural concrete.

P.S. Ambily et al., (2014)have investigated on the technical feasibility of using copper slag as fine aggregate replacement in Ultra High Performance Concrete (UHPC). The studies demonstrated that it is possible to produce UHPC having compressive strength greater than 150 MPa by incorporation of copper slag. The complete replacement of standard sand by copper slag resulted in a maximum decrease in 28-day compressive strength of about 15–25% whereas, the flexural strength, fracture energy recorded was of the similar order. It can be concluded from the results that use of copper slag as fine aggregate in UHPC is technically viable.

RECYCLED AGGREGATE

Jianzhuang Xiao et al., (2004)presented a study where the compressive strength and the stress–strain curve (SSC) of recycled aggregate concrete (RAC) with different replacementpercentages of recycled coarse aggregate (RCA) were investigated experimentally. Concrete specimens were fabricated and tested withdifferent RCA replacement percentages of 0%, 30%, 50%, 70% and 100%, respectively. Uniaxial compression loading was applied in theexperiments. Special attention of the analysis was devoted to the failure behavior and the influences of the RCA contents on the compressivestrength, the elastic modulus, the peak and the ultimate strains of RAC. Analytical expressions for the peak strain and the stress–strainrelationship of RAC are given, which can be directly used in theoretical and numerical analysis as well as practical engineering design ofRAC structures.The compressive strengths including the prism and thecube compressive strengths of RAC were observed to decreasewith increasing RCA contents. But the ratio of theprism compressive strength and the cube compressive strength was higher than that of the normal concrete.The elastic modulus of RAC was lower than that of thenormal concrete. It was observed to decrease as the RCA contentincreases. For a RCA replacement percentage equals 100%, the elastic modulus was reduced by 45%.The peak strain of RAC was higher than that of normalconcrete. It was increasing with the increase of RCAcontents. For a RCA replacement percentage equals100%, the peak strain was increased by 20%.The use of high percentages of recycled aggregates in concrete would usually worsen the concrete properties.

JayeshkumarPitroda et al., (2013) proposed a study of recycled aggregate concretewith an approach for use of recycled concrete aggregate without compromising the strength in view for better economic growth to pave way for new construction as the old structures brought down. Here, M65 concrete mixtures was prepared with water-to-binder W/B ratios of 0.45 and the recycled aggregate was used as 0%, 20%, 50% and 100% by weight replacements of natural aggregate. A concrete mixture was prepared in the laboratory with a water-tobinder W/B ratio and a cement content of 0.45 and 400 kg / m^3, respectively. For each concrete mixture, 100 mm cubes were casted to determine the compressive strength of concrete. Three cubes were immediately used after demoulding to measure the 1 day compressive strengths. The rest of the specimens were cured in a water-curing tank at 27 ±1°C until the age of testing. The compressive strength of concrete was determined using a Denison compression machine with a loading capacity of 3,000 KN. The loading rate applied in the compressive test was 200 KN/min. The compressive strengths were measured at the ages of 1, 4, 7, 28, and 90 days. It was observed that up to 20% replacement RCAs can be utilized for economical and sustainable development of concrete.

Job Thomas et al (2013) proposed a study regarding the scenario of construction and demolition waste management system practiced in various countries. The infrastructure development sector and real estate sector were bulk generators of waste. Thus, to account for the increasing global waste they proposed 3R concept which had three strategies of reduce, reuse and recycle. Also, green building concept was introduced which refers to a structure that uses process which were environmentally responsible and resource efficient throughout their life cycle. By using such concepts it was possible to achieve comfort, utility, durability and economy with minimum harm to the environment. Green buildings were certified based on certain rating program by different agencies such as the United States Green Building Council (USGBC), Leadership in Energy and Environmental Design (LEED) whereas in India they were certified by Green Rating for Integrated Habitat Assessment (GRIHA). They indicated that a widespread adoption of proper waste management technique could save huge amount of money which would otherwise go to landfills and also it can conserve non-renewable mineral resources offering intangible benefits towards sustainable development and definitely mitigate the issues that were arousing from C&D wastes.

2.3 CLOSURE

Literature review was carried out on the use of recycled coarse aggregates, copper slag and silica fume. The factors regarding the absorption, workability and mixing were also noted. Based on these literature reviews the objectives of the current investigation were

III. MATERIALS AND METHODOLOGY

3.1 INTRODUCTION

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.

3.2 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. Table 3.1 presents these properties.

3.3AGGREGATES

Aggregate comprise 70-80% of the volume of concrete and exert a significant influence on concrete properties. Hence quality of aggregate is of primary importance to produce good strength and durability to the concrete.The functions of aggregates are,

- To provide a relatively cheap filler for the cementing material
- To provide a mass of particles which are suitable for resisting the action of applied loads, abrasion, the percolation of moisture and the action of weather

To reduce the volume changes resulting from the setting and hardening process and from

3.3.2Coarse Aggregates

Coarse aggregates with specific gravity 2.73 satisfying IS 383-1970 grading requirements for single sized aggregates are used. The coarse aggregate used here was of size 20 mm down and holding 12.5 mm. The tests are conducted to find the properties of coarse aggregate and the results are tabulated as below in table 3.4.

Table 3.5 gives the results of sieve analysis

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

3.3.3 Recycled CoarseAggregates

The recycled coarse aggregates were obtained from the concrete after attaining the 28 day strength.They are extracted from the concrete matrix by using the hydraulic machine to break it into smaller pieces of 20mm to 40mm. These pieces will be having a high content of old mortar attached to it which is not desirable to be used as aggregates. Separation of this adhered mortar was the main challenge in obtaining the RCA which should have similar properties of fresh aggregates after processing.

Fig.3.1 Rod Mill Machine

All the cubes were broken into small pieces using a hammer.A new method is adopted to get RCA in this work. Rod mill machine, available in the department of Mining Engineering, Osmania university was used to process the broken concrete. Figure 3.1 shows the experimental setup. This machine consists of a cylindrical can of 23cm dia and a length of 22cm. It is placed on two parallel shafts which are separated by a small distance. One of this shaft is connected to motor. Can is placed in such a way that longitudinal axis of the can is parallel to that of shafts. When power is supplied single shaft starts rotating which inturn rotates the can and the second shaft starts rotating automatically. This resembles the gear mechanism in a analog watch. This explains the mechanism of the machine.

Fig.3.2 Rod Mill Machine

This can consists of steel rods of different desired dimensions which can process the material placed in it once it starts rotating. This can has a capacity of only 5 kg in terms of material to be used in each cycle. Thus, in addition to rods some steel balls were also used to increase the efficiency of processing in the available space inside the can. As this machine was being used for the first time to process recycled aggregate, it was necessaryto decideon the charge to be used in terms of number of steel rods and its dimensions. Also the amount of broken concrete to be used for each cycle was to be evaluated. If the charge used is more than optimum it results in wear and tear of aggregates. Thus there were many aspects to be taken care of and optimized before processing concrete. Three different sets of experiments were conducted to decide the charge to be used, amount of aggregate to be used, the processing time for each cycle.Water absorption test was the basis for deciding the quality of processed recycled aggregates. These results shall be presented in the next chapter.

Thus recycled aggregate is obtained using rod mill machine with the above parameters

Table 3.7Properties of recycled coarse aggregates

Sl. No.	Property	Results
1	Specific gravity	2.53
2	Water absorption	1.25%
3	Fineness modulus	5.75

3.4WATER

Water is an important ingredient of concrete as it actively participates in chemical reaction with cement. The quantity of water used should be just sufficient for hydration and suitable workability of concrete. In present investigation the potable water is used.

3.5COPPER SLAG

Copper slag is a by-product created during the 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. Collectively, these materials make up slag.One of the primary advantages to copper slag is the low risk it poses to health and the environment.Copper slag is bought from a local supplier which was in excess of what is brought for the blasting of pipes. Various tests are conducted on this material and the values obtained are listed as below.Copper slag used was passing through 4.75mm sieve and retained on 75 micron sieve which is same as that of fine aggregate.

Table 3.8 Sieve analysis of copper slag

IS sieve size	Percentage passing	IS 383-1970 Sieve analysis of fine	Remarks

3.6SILICA FUME

Silica fume used in this study belongs to CORNICHE SF brand. It is recommended to be used with any compatible high range water reducing admixture to provide maximum workability maintaining the desired low water/cement ratio.

Specifications of this brand complies to the following standards:
ASTM C 1240 : 2005
IS 15388 : 2003

3.6.1 Properties of CORNICHE SF

CORNICHE SF typically has the following properties:
SiO_2 : 85.0% Min
Loss on Ignition : 6.0%Max
Moisture : 3.0% Max
Bulk Density : 550 to 700 Kg/m^3

Design mix adopted

Nominal mix design of 1:1.5:3 was adopted in the present study. Water cement ratio is found to be 0.46 after trial and error experiments with different w/c ratios so as to achieve slump in the range of 60 to 80 mm.

3.7 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.
- 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 isobtained 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.

3.8TEST MATRIX

Table 3.9 Concrete mix proportions per cubic meter of concrete

Mix	RCA (%)	C (kg)	FA (kg)	CA (kg)	RCA (kg)	W (kg)
Mix 1	0	404	606	1212	-	198
Mix 2	25	404	606	909	303	201
Mix 3	50	404	606	606	606	203
Mix 4	75	404	606	303	909	205
Mix 5	100	404	606	-	1212	205

Mix	RCA (%)	COPPER SLAG		C (kg)	FA (kg)	CA (kg)	RCA (kg)	W (kg)
		(%)	(kg)					

Mix 1	50	0	-	404	606	606	606	203
Mix 2	50	25	152	404	454	606	606	204
Mix 3	50	50	303	404	303	606	606	205
Mix 4	50	75	454	404	152	606	606	206
Mix 5	50	100	606	404	-	606	606	207

3.9SLUMP TESTS

Initial experiments are conducted to get a slump of at least 50-75mm without super plasticizers. Standard slump cone apparatus is used for measuring the value of slump. Sump test is done for virgin concrete to decide the water cement ratio to be adopted. As the water cement ratio is constant, chemical admixtures are used in the later experiments done with different proportions of recycled aggregate, copper slag and silica fume to attain the desired workability.

3.10COMPRESSIVE STRENGTH

Strength of concrete is the most important, although other characteristic may also be critical and cannot be neglected. Strength is an important indicator of quality because strength is directly related to the structure of hardened cement paste. Even though strength is not a direct measure of durability or dimensional stability, it has a strong relationship with the water to cement ratio of the concrete, which in turn influences durability, dimensional stability and other properties of concrete.

The strength measured in concrete depends on some factors including the age, degree of hydration, rate of loading, method of testing, specimen geometry, and the properties and proportions of the constituent materials. Mostly, concrete strength improves with the increase of age. The strength of saturated specimen may have lower strength than dry specimen. Compressive strength measured in impact loading will be higher than that in a normal rate of loading. Cube specimen may result higher strength than cylinder specimen. The properties of constituent materials such as the quality of aggregate, the quality of cement paste, and the bond between aggregate and cement paste, influence the strength of concrete.

The testing of the cubes was done in a 200T capacity compression testing machine. Fig 3.3 shows the compression testing facility.

Fig. 3.3Testing of cubes for compressive strength

3.11 CLOSURE

The materials used and concrete mixes with different context of RCA along with copper slag and silica fume are briefly discussed. Detailed methodology used for concrete mixing, casting, curing and testing is also elaborated, in this chapter. Also, the method adopted to obtain recycled aggregate has been explained

IV. RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

4.1 INTRODUCTION

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.

4.2 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.

Fig. 4.2 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.

4.2.2 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 4.2 Water absorption results for various types of charges tried

SL.NO	SET	MATERIAL (kg)	CHARGE	WATER ABSORPTION (%)
1	1	2.012	A	1.60
2		2.048	B	1.40
3		1.960	A+B	1.50
4	2	2.028	A	1.71
5		1.986	B	1.32
6		1.942	A+B	1.55

(a)virgin aggregate
(b) broken concrete

Fig. 4.3 Aggregates before and after processing

(c) processed concrete
(d) recycled

Fig. 4.4 Variation in water absorption for different types of charge tried

Figure 4.3 shows the quality of aggregates before and after processing. Figure 4.4 shows water absorption variation for different types of charges tried. From Table 4.2 and Fig. 4.4, it is clear that best processing is possible by use of 13 Nos of rods, each weighing 65g.

4.2.3 Experiment 3

Time required for processing is decided based on the water absorption values of aggregates obtained after three different time intervals.

Time intervals for study are decided as 30 min, 45 min, 90 min.

(a) 30 minutes

(b) 45 minutes

(c) 90 minutes

slag

Figure 4.8 presents the strength variation with different proportions of Copper slag replacing river sand. It is observed that strength increases upto 50% replacement level and thereafter it decreases

Table 4.6 presents the results in a non-dimensionalized form called strength factors for various levels of RCA replacements and Copper slag.

4.3.4 Strength Variation of RCA concrete adopting Copper slag and Silica fume

Silica fume is introduced in this set of experiments in order to achieve more strength than the previous set of experiments. Silica fume is maintained constant at 4% replacement of cement along with recycled aggregate constant at 50% and copper slag is varied to find out the optimum percentage of replacement. Table 4.8 presents the results obtained. The strength is achievable with 4% Silica fume, 50% RCA & 25% Copper slag

4.4 CLOSURE

Important results pertaining to the technique of RCA processes have been worked out and processed. Results attempting to achieve the strengths of control concrete by variation in RCA, Copper slag & Silica fume have been discussed.

V. 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 of cement 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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