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Effect of Copper slag and Egg Shells Powder by Partial Replacement of Fine Aggregate and Cement on Strength Properties of the M30 and M40 Concrete.

Pudi Vasudeva Acharyulu[1] and Tangellamudi Sri Vijaya Durga[2]

[1] M.tech in Structural Engineering, Department of Civil Engineering, DJR College of Engineering and Technology DJR nagar,NH-5,Velpur (V), Via Gudavalli, Vijayawada, Andhra Pradesh, 521104.

[2] Assistant professor , Department of Civil Engineering,Potti sriramulu chalavadi mallikharjuna Rao,college of Engineering, and technology ,Kothapeta,Vijayawada,520001

Abstract: Concrete is always expected to be stronger and more durable than in the past while being cost and energy efficient. Moreover the major advantages that concrete possesses over the construction materials have to be conserved. The possibility of being fabricated practically anywhere, the ability to make the form imposed by the shape of a mould and a low cost of components and manufacture. These factors have driven advances in improving the performance of concrete over years and continue to do so the need for improving the performance of concrete and concern for the environmental impact arising from the continually increasing demand for concrete has lead the growing use of alternative material components.

An experimental investigation will be conducted to study the properties of concrete containing copper slag as a partial replacement of fine aggregates in the concrete mix design. Various durability tests will be conducted on such concrete of M30 grade and M40 grade to know the compressive strength, split tensile strength, flexural strength by varying proportions of copper slag (CS) with fine aggregates by 0%, 5%, 10%, 15%, 20% and 25% and Egg shell powder (ESP) as cement by 0%, 5%, 10%, 15%, 20%, 25% by weight. The obtained results will be compared with the conventional concrete, there by knowing the changes in the properties of concrete containing copper slag as a partial replacement of fine aggregates.

Keywords: Copper Slag, Egg shells powder, compressive strength, M30, M40 etc.

1. Introduction

The utilization of industrial waste or secondary materials has encouraged the production of cement and concrete in construction field. New by-products and waste materials are being generated by various industries. Dumping or disposal of waste materials causes environmental and health problems. Therefore, recycling of waste materials is a great potential in concrete industry. For many years, by-products such as fly ash, silica fume and slag were considered as waste materials. Concrete prepared with such materials showed improvement in workability and durability compared to normal concrete and has been used in the construction of power, chemical plants and under-water structures.

Over recent decades, intensive research studies have been carried out to explore all possible reuse methods.

2. Copper Slag

Copper slag is a by-product of copper extraction by smelting. During smelting, impurities become slag which floats on the molten metal. Slag that is quenched in water produces angular granules which are disposed of as waste or utilized.

Uses of copper slag:

1. Copper slag has also gained popularity in the building industry for use as a fill material.

2. Contractors may also use copper slag in place of sand during concrete construction.

3. Copper slag can also be used as a building material, formed into blocks.

4. Copper slag is widely used in the sandblasting industry and it has been used in the manufacture of abrasive tools.

5. 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) and low free silica content.

3. Egg Shell Powder

Eggshell consists of several mutually growing layers of CaCO3, the innermost layer-maxillary 3 layer grows on the outermost egg membrane and creates the base on which palisade layer constitutes the thickest part of the eggshell. The top layer is a vertical layer covered by the organic cuticle. The eggshell primarily contains calcium, magnesium carbonate (lime) and protein. In many other countries, it is the accepted practice for eggshell to be dried and use as a source of calcium in animal feeds. The quality of lime in eggshell waste is influenced greatly by the extent of exposure to sunlight, raw water and harsh weather conditions. It is the fine grained powder with suitable proportion which is sieved to the required size before use with concrete/mortar.

Uses of egg shell powder

Eggshell contains calcium and trace amounts of other micro elements. Eggshell calcium is best natural source of calcium and it is about 90% absorbable, than limestone or coral sources. The whole medium eggshell makes about one teaspoon of powder. This can be used as fertilizer to treat blossom –end – root (BER) plants and also as calcium supplement tablet for human beings. These two applications would be studied here.

4. Scope & objective:

As the copper slag and egg shell power considered tobe a waste product and the land for its dumping increasing day by day showing a serious impact on environment, hence to reduce it we are making use of copper slag in construction field. Although copper slag has many uses but to a little percent when it compared to its use in construction.

The main objective is to study the feasibility of use of copper slag as fine aggregate in concrete. The scope of the work includes knowing the strength parameters of concrete such as compressive strength, split tensile strength, flexural strength in which copper slag and egg shell powder replaced with fine aggregates and cement by by 0%, (5%+5%), (10%+10%), (15%+15%), (20%+20%), (25%+25%), and (30%+30%) using M30 and M40 grades of concrete.

5. LITERATURE REVIEW

Al-Jabri et al (2009) He has investigated the performance of high strength concrete (HSC) made with copper slag as a fine aggregate at constant workability and studied the effect of super plasticizer addition on the properties of HSC made with copper slag. Two series of concrete mixtures were prepared with different proportions of copper slag. The first series consisted of six concrete mixtures prepared with different proportions of copper slag at constant workability. The water content was adjusted in each mixture in order to achieve the same workability as that of the control mixture. Twelve concrete mixtures were prepared in the second series. Only the first mixture was prepared using super plasticizer whereas the other eleven mixtures were prepared without using super plasticizer and with different proportions of copper slag used as sand replacement.

The results indicated that the water demand reduced by almost 22% at 100% copper slag replacement compared to the control mixture. The strength and durability of HSC were generally improved with the increase of copper slag content in the concrete mixture. However, the strength and durability characteristics of HSC were adversely affected by the absence of the super plasticizer from the concrete paste despite the improvement in the concrete strength with the increase of copper content.

Neves et al (1998) and Boron (2004) According to Neves (1998) and Boron (2004) the shell of an egg is a protective barrier, even against the penetration of microor-ganisms. The shell is a bioceramic composite material with an extracellularly assembled structure, whose function is to protect the contents of the egg and to ensure the calcium necessary for the formation of the chick's skeleton. The egg shell is composed of several porous layers, which are permeable to water and gases, allowing the embryo to breathe (Neves, 1998). During the industrial processing of egg shells the different components are separated. Egg shells are comprised of a network of protein fibers, associated with crystals of calcium carbonate (96% of shell weight), magnesium carbonate (1%) and calcium phosphate (1%), and also of organic substances and water. Calcium carbonate (CaCO3), the major constituent of the shell, is an amorphous crystal that occurs naturally in the form of calcite (hexagonal crystal), with low water solubility.

Okonkwo et al., (2012) Eggshell ash has been established to bç good accelerator for cement bound material because of extra calcium oxide by addition of eggshell ash. He concludes that the increase in the eggshell ash content will increase the strength of properties of the cement stabilized matrix up about 35% averagely. That show the usage of eggshell ash as an additive will increase the strength of the concrete.

Mtalib et al. (2009) said that the addition of eggshell ash to the Ordinary Portland Cement decrease the setting time of the cement. So they conclude that the eggshells ash as an accelerator in a concrete because the higher content of the faster rate of setting. But it is different the effect of eggshell to the soil.

Bipragorai et al (2003) He reviewed the characteristics of copper slag as well as various processes such as pyro, hydro and combination of pyro hydro metallurgical methods for metal recovery and preparation of value added products from copper slag. Copper slag, which is produced during pyro metallurgical production of copper from copper ores, contains materials like iron, alumina, calcium oxide, silica etc.

This paper discusses the favorable physic-mechanical characteristics of copper slag that can be utilized to make the products like cement, fill, ballast, abrasive, aggregate, roofing granules, glass, tiles etc. apart from recovering the valuable metals by various extractive metallurgical routes. The favorable physic-mechanical and chemical characteristics of copper slag lead to its utilization to prepare various value added products such as cement, fill, ballast, abrasive, cutting tools, aggregate, roofing granules, glass, tiles etc. The utilization of copper slag in such manners may reduce the cost of disposal. This may also leads to less environmental problems.

6. Experimental Programme

MATERIALS:

Cement:

Cement is a binder, a substance used in construction that sets and hardens and can bind other materials together. The most important types of cement are used as a component in the production of mortar in masonry, and of concrete- which is a combination of cement and an aggregate to form a strong building material.

The ordinary Portland cement of 53 grade is used in accordance with IS: 12269-1987.

Properties of this cement were tested and listed here.

1. Fineness of cement = 5%
2. Specific gravity if cement = 3.02
3. Standard Consistency of cement = 33%
4. Initial setting time = 50 minutes
5. Final setting time = Not more than 10 hours.

Aggregates:

Coarse Aggregate

Crushed stone aggregate of 20mm size is brought from nearby quarry. Aggregates of size more than 20mm size are separated by sieving. Tests are carried in order to find out the

•Specific gravity = 2.98

•Fineness modulus = 7.5

FINE AGGREGATE

Locally available fresh sand, free from organic matter is used. The result of sieve analysis confirms it to Zone-II (according to IS: 383-1970).The tests conducted and results plotted below.

· Specific gravity = 2.3

· Fineness modulus = 3.06

COPPER SLAG

The copper slag which we used had collected from a dealer of 'Hindustan copper limited' at Vishakhapatnam. The wholesale price of the copper slag is about ₹650/ton and is also economical to use copper slag at the places where it is available.

The effect of using copper slag as a fine aggregate on the properties of cement mortars and concrete. Various mortar and concrete mixtures were prepared with different proportions of copper slag ranging from 0% (for the control mixture) to 100% as fine aggregates replacement. Cement mortar mixtures were evaluated for compressive strength, whereas concrete mixtures were evaluated for workability, density, compressive strength, tensile strength, flexural strength and durability. The results obtained for cement mortars revealed that all mixtures with different copper slag proportions yielded comparable or higher compressive strength than that of the control mixture. Also, there was more than 70% improvement in the compressive strength of mortars with 50% copper slag substitution in comparison with the control mixture. The results obtained for concrete indicated that there is a slight increase in density of nearly 5% as copper slag content increases, whereas the workability increased significantly as copper slag percentage increased compared with the control mixture.

EGG SHELL POWDER

Eggshell consists of several mutually growing layers of CaCO3, the innermost layer-maxillary 3 layer grows on the outermost egg membrane and creates the base on which palisade layer constitutes the thickest part of the eggshell. The top layer is a vertical layer covered by the organic cuticle. The eggshell primarily contains calcium, magnesium carbonate (lime) and protein. In many other countries, it is the accepted practice for eggshell to be dried and use as a source of calcium in animal feeds. The quality of lime in eggshell waste is influenced greatly by the extent of exposure to sunlight, raw water and harsh weather conditions. It is the fine grained powder with suitable proportion which is

sieved to the required size before use with concrete/mortar.

Egg shell powder

WATER

Generally potable water should be used. This is to ensure that the water is reasonable free from such impurities as suspended solids, organic matter and dissolved salts, which may adversely affect the properties of the concrete, especially the setting, hardening, strength, durability, pit value, etc.

MIX DESIGN FOR M30 GRADE CONCRETE:

Target mean strength = 30+1.65x5

= 38.25Mpa

Selection of w/c ratio

From w/c ratio curves

30Mpa----------->0.52

40Mpa----------->0.43

38.25Mpa----------> ?

By using interpolation the w/c is 0.44 for 38.25Mpa

Selection of water content

From table 2 of IS 10262:2009

For 20mm size aggregates

Water content = 186 kg

Assuming slump is 75mm then 25mm slump correction is required

For every 25mm slump the water content is increased by 3%

So final water content = (3/100)x186+186

= 191.60 kg/m3

Calculation of cement content

w/c = 0.44

191.60/c=0.44

C=435.45 kg/m3

Cement=436kg/m3

calculation of coarse aggregates

From table 3 of IS10262-2009

For zone 2

Volume of coarse aggregates per unit volume of total aggregates = 0.62

For every +0.05 and -0.05 the coarse aggregate proportion is changed by 0.01

So final volume of coarse Aggregates = 0.63

For pump able concrete the volume of CA is reduced by 10%

---> 0.63x0.90

CA = 0.567

FA = 1-0.567

= 0.433

Estimation of mix ingredients

Volume of concrete = 1m3

Volume of cement = (mass of cement)/(sp.gravity of cement) x 1/1000

= 435.55/3.15 x 1/1000

= 0.138m3

Volume of water = (mass of water)/(sp.water) x 1/1000

=191.60/1 x 1/1000

= 0.19160m3

Volume of total aggregates = 1-0.19160-0.138

= 0.670m3

Mass of CA = 0.670X0.567X2.84X1000

= 1078.8876 kg

Mass of FA = 0.670X0.433X2.64X1000

= 765.90 kg

Calculation of mix proportion

Consider for 1 m3 of concrete ----------> 483.3kg/m3

(0.15x0.15x0.15)m3 of concrete----------> ?

?= 1.63kg

For CA 1m3----------->1078.88kg/m3

(0.15x0.15x0.15)m3 of concrete----------> ?

? = 3.64122kg

For FA 1m3----------->765.89kg/m3

(0.15x0.15x0.15)m3 of concrete----------> ?

? = 2.5848kg

C:FA: CA:=1:1.58:2.23 and w/c 0.45

Calculation of quantity of materials required:

1:1.58:2.23 at w/c 0.45.

Final quantities of materials for M30 grade

Sl.no	Cement	Coarse aggregates	Fine aggregates	Copper slag	ESP	water
quantities	195	313.77	182.42	26.5	21	59
Approximately	195	314	182.42	27	21	59
Addition of extra 10%	214.5	344.4	200.242	29.7	23.1	64.9

Mix design for M40 Grade concrete:

Target mean strength

= Fck+1.65xS

= 40+1.65x5

= 48.25Mpa

Selection of water-cement ratio

From water-cement ratio curves

For 40Mpa----------> 0.43

For 50Mpa---------->0.36

Then for 48.25Mpa----------> ?

From interpolation we get w/c is 0.37225

Approximately w/c is 0.4

Selection of water content

From table 2 of IS 10262

For 20mm----------> 186 kg/m3

Water = 186 kg/m3

Calculation of cement content

Since w/c = 0.4

Cement = 186/0.4

= 465kg/m3

Volume of coarse aggregates

From table 3 of IS 10262-2009

For Zone-II

Volume of coarse aggregate per unit volume of total aggregates=0.62

For every decrease in 0.05 w/c the volume of CA is increased by 0.01 for w/c<0.5

Since for 0.4 w/c

0.5-0.4=0.1

Here 0.1 is the decrease in the w/c so

0.05----------> 0.01

0.1----------> ?

=0.02

So the volume of coarse aggregate is =0.62+0.02=0.64

For pump able concrete the volume o0f CA is reduced by 10%

So the final volume of CA is 0.9x0.64=0.576

Now, volume of FA =1-CA

=1-0.576

=0.424

Estimation of ingredients

Volume of cement=(mass of cement)/(specific gravity of cement) x 1/1000

=490/3.15 x 1/1000

= 0.1476

Volume of water = (mass of water)/(specific gravity of water) x 1/1000

=186/1 x 1/1000

= 0.186

Volume of aggregates=1-(0.14776+0.186)

=0.66624

Calculation of mass of materials

Mass of CA = 0.66624X0.576X2.84X1000

= 1089.862 kg/m3

Mass of FA = 0.66624X0.424x2.64X1000

= 745.762 kg/m3

Calculation of proportions

Let us assume volume of 1 cube 1m3

For 1m3cement required is 490 kg/m

(But the volume of 1 cube is 0.15x.15x0.15=0.003375m3)

For 0.003375m3 volume cement is ?

Cement=1.66Kg

FA=745.762X0.0033758

= 2.52 kg

CA=1089.862X0.003375

=3.67 kg

So final proportion is 1.66:2.52:3.67 at w/c 0.4

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1:1.52:2.21 at w/c 0.4

Final quantities of materials for M40 grade

Sl.no	Cement	Coarse aggregates	Fine aggregates	Copper slag	ESP	water
quantities	121.9	320	231.4	33.6	23.1	62
Approximately	122	320	232	34	24	62
Addition of extra 10%	134.2	352	255.2	37.4	26.4	68.2

7. RESULTS AND ANALYSIS

Test results on the cement

Sl.no	Test	Results	IS code used	Acceptable limit
1	Specific gravity of cement	3.160	IS:2386:1963	3 to 3.2
2	Standard consistency of cement	6mm at 34% w/c	IS:4031:1996	w/c ratio 28%-35%
3	Initial and final setting time	45 mins and 10 hours	IS:4031:1988	Minimum 30mins and should not more than 10 hours
4	Fineness of cement	3.00%	IS:4031:1988	<10%

Test results on coarse aggregates

Sl.no	Test	Results	Is code used	Acceptable limit
1	Fineness modulus	6.5	IS:2386:1963	6.0 to 8.0mm
2	Specific gravity	2.90	IS:2386:1963	2 to 3.1mm
3	Porosity	46.83%	IS:2386:1963	Not greater than 100%
4	Voids ratio	0.8855	IS:2386:1963	Any value
5	Bulk density	1.50g/cc	IS:2386:1963	-
6	Aggregate impact value	37.5	IS:2386:1963	Less than 45%
7	Aggregate crushing value	26.6%	IS:2386:1963	Less than 45%

Test results on the fine aggregates

Sl.no	Test	Result	Is code used	Acceptable limits
1	Fineness modulus	4.305	IS:2386:1963	Not more than 3.2 mm
2	Specific gravity	2.43	IS:2386:1963	2.0 to 3.1
3	Porosity	36.6%	IS:2386:1963	Not greater than 100%
4	Voids ratio	0.577	IS:2386:1963	Any value
5	Bulk density	1.5424	IS:2386:1963	-
6	Bulking of sand	3.0%	IS:2386:1963	Less than 10%

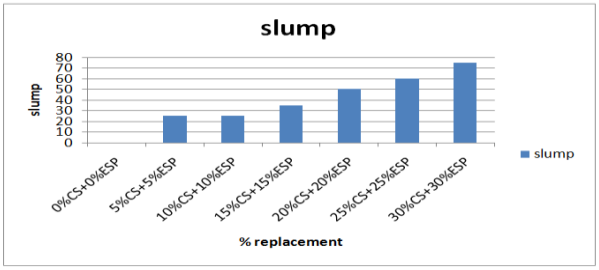
A. TESTS ON FRESH CONCRETE:

1. SLUMP CONE TEST:

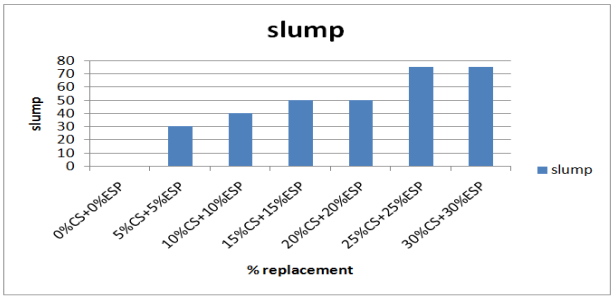
Slump values for M30and M40 Grade concrete .

S.NO	% Replacement	Slump for M30grade	Slump for M40 grade
1	0%CS+0%ESP	0	0
2	5%CS+5%ESP	25mm	30mm
3	10%CS+10%ESP	25mm	40mm
4	15%CS+15%ESP	35mm	50mm
5	20%CS+20%ESP	50mm	50mm
6	25%CS+25%ESP	60mm	75mm
7	30%CS+30%ESP	75mm	75mm

Slump for M30 grade concrete



Slump for M40 grade concrete



COMPACTION FACTOR TEST:

S.NO	% Replacement	Compaction factor for M30 grade concrete	Compaction factor for M40 grade concrete
1	0%CS+0%ESP	0.98	0.94
2	5%CS+5%ESP	0.95	0.90
3	10%CS+10%ESP	0.88	0.88
4	15%CS+15%ESP	0.88	0.84
5	20%CS+20%ESP	0.86	0.86
6	25%CS+25%ESP	0.82	0.80
7	30%CS+30%ESP	0.80	0.76

Compaction factor for M30 grade concrete

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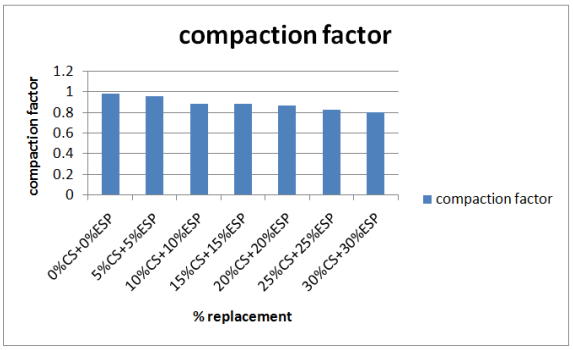
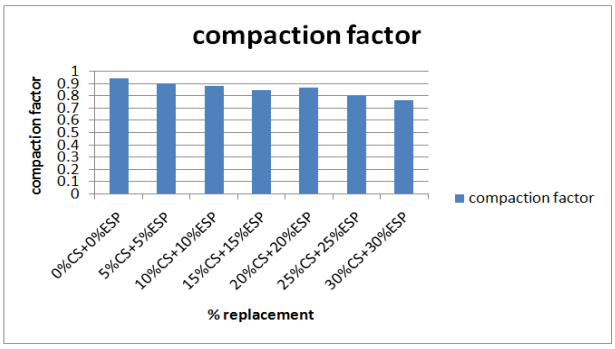


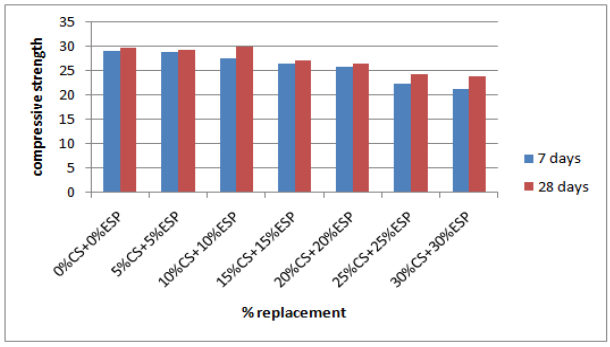
Compaction factor test for M40 grade concrete



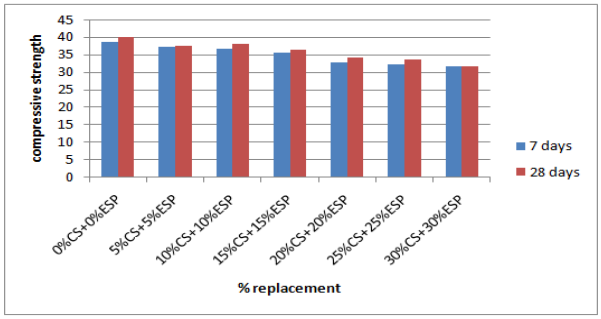
B. Tests on the hardened concrete

s.no	% replacement	Compressive strength of concrete			
		M30 grade concrete		M40 grade concrete	
		7 days	28 days	7 days	28 days
1	0%CS+0%ESP	28.84	29.60	38.60	39.86
2	5%CS+5%ESP	28.60	29.20	37.24	37.44
3	10%CS+10%ESP	27.40	29.80	36.60	37.90
4	15%CS+15%ESP	26.40	27.00	35.40	36.20
5	20%CS+20%ESP	25.60	26.40	32.80	34.22
6	25%CS+25%ESP	22.20	24.20	32.20	33.45
7	30%CS+30%ESP	21.00	23.60	31.60	31.62

Compressive strength for M30 grade concrete



Compressive strength for M40 grade concrete



8. CONCLUSIONS

From the above experimental program the following conclusions were made

1. The material properties of the cement, fine aggregates and coarse aggregates are within the acceptable limits as per IS code recommendations so we will use the materials for research.
2. Slump cone value for the copper slag concrete increases with increasing in the percentage of copper slag so the concrete was not workable.
3. Compaction factor value of copper slag concrete decreases with increase in the percentage of copper slag.
4. The compressive strength of concrete is maximum at 20% replacement of copper slag and is the optimum value for 7days curing and 28days curing.

So the replacement of 20% to 40% of copper slag is generally useful for better strength values in M30 and M40 grade of concrete.

FUTURE RECOMMENDATIONS

• Using Copper Slag with Fine aggregates and egg shell powder with cement checking out whether the minimum strength required for M50 and M60 grades of concrete can be achieved.

• Checking out the feasibility of utilization of Copper slag as Coarse aggregates and egg shell powder as fine aggregates finding the Strength characteristics of Concrete.

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