Experimental Study on Mechanical and Durability Properties of Concrete Influenced By Waste Materials

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***Abstract*—Concrete is a composite material composed mainly of water, aggregate, and cement. It is an indispensable material of today's construction world has gone through stages of development. It is difficult to find another material of choice to concrete owing to its versatility. The sustainable development in construction involves use of waste materials and by-products. The concrete produced with cement contain pores, in order to squeeze the pores, use of industrial by product like Marble Sludge Powder as a filler material and Copper Slag as partial replacement of sand. For this research work M30 grade of concrete were prepared in various proportions. Copper slag was used constant replacement of sand. The copper slag is replaced by 20 % of total weight of sand and MSP were used in different proportions 15%, 25%, 35%, 45% as filler. The strength properties was determined such as compressive split tensile, flexural strength test and also the durability properties was determined such as impact resistance and sorptivity test. The benefits of using MSP in cement concrete as mineral filler 25% gave the optimum results compared to the other proportions.**

Keywords*—Copper Slag, Marble Sludge powder, Partial Replacement, Compressive Strength, Split Tensile Strength, Flexural Strength and Durability

I. INTRODUCTION

Concrete is the most widely used material in the world next to water. It is strong, gives flexibility in design and comes with a low cost. But the concrete industry is not sustainable due to environmental concerns with the production of cement and aggregates. Sand is an important material for the preparation of concrete. Now days, the demand of natural sand is very high in the developing countries like India, due to the large usage of concrete to satisfy the rapid infrastructure growth. Concrete is widely used for making architectural structures, foundations, brick or block walls, pavements, bridges or overpasses, highways, runways, parking structures, dams, pools/reservoirs, pipes, footings for gates, fences and poles and even boats. Concrete is used in large quantities almost everywhere mankind has a need for infrastructure Copper slag was brought from Sterlite Industries India Ltd (SIIL), Tuticorin, Tamil Nadu, India. SIIL is producing CS during the manufacture of copper metal. Copper slag is one of the materials that can be considered as a waste material which could have a promising future in construction industry as partial or full substitute of any two either cement or aggregates. It can be used for a surprising number of applications in the building and industrial fields.

Marble is a non-foliated metamorphic rock composed of re-crystallized carbonate minerals, most commonly calcite or dolomite. A rheological study was carried out on various cement pastes prepared with marble sludge powder in combination with cement. Marble as a building material especially in palaces and monuments has been in use for ages. However the use is limited as stone bricks in wall or arches or as lining slabs in walls, roofs or floors, leaving its wastage at quarry or at the sizing industry generally unattended for use in the building industry itself as filler or plasticizer in mortar or concrete. This huge unattended mass of marble waste consisting of very fine particles is today one of the environmental problems around the world.

II. MATERIALS USED

A. Cement

Ordinary Portland cement (OPC) is the basic Portland cement and is best suited for use in general concrete construction. The OPC confirming to IS 4031 was used for the preparation of specimens. OPC 53 grade was used.

B. Water

Water is the most important constituent of a concrete mass which enables bonding between cementitious materials and the aggregates. A part of mixing water is utilized in the hydration of cement to form binding matrix in which the inert aggregates are held in suspension until the matrix has harden. The remaining water serves as a lubricant between the fine and coarse aggregate and makes concrete workable.

C. Coarse Aggregate

The coarse aggregate particles passing through 20mm and retained on 12.5 mm I.S Sieve used as the natural aggregate which met the grading requirement of IS 383-1970.

D. Fine Aggregate

Those fractions from 4.75 mm to 150 micron are termed as fine aggregate. The river sand is used as fine aggregate conforming to the requirements of IS: 383-1970. Sieve analysis was done using standard sieve analysis procedure and the sand conforms to Zone II.

E. Copper Slag

Copper slag is a by-product obtained during the matte smelting and refining of copper. Copper slag used in the present studies was procured from Sterlite Industries India Limited (SIIL), Tuticorin, Tamil Nadu, India. SIIL is producing Copper slag during the manufacture of copper metal. The use of copper slag in the concrete as a replacement for fine aggregate, reduces the costs of disposal, lowers the cost of the concrete and also helps in protecting the environment

TABLE 1 CHARACTERISTICS OF CS

Properties	UOM	Value
Shape	Nil	Angular
Hardness	Moh	6.75
Specific Gravity	Nil	3.65
Bulk Density	g/cc	2.25
Unit Weight	kg/m^3	2250
pH	Nil	6.6
Sio_2	%	30
Fe_2O_3	%	57.5
Al_2O_3	%	3
CaO	%	2.25

F. Marble Sludge Powder

Marble sludge powder is one of the waste produces in marble Industry. Marble sludge powder is produced from processing plant during the sawing, shaping and polishing of marble blocks. Disposal of the marble sludge powder material from the marble industry is one of the environmental problems worldwide today.

TABLE 2 CHEMICAL PROPERTIES OF MSP

S.NO	Characteristics	MSP
1	Sio_2	69.21%
2	Fe_2O_3	4.40%
3	Al_2O_3	13.48%
4	CaO	8.40%
5	Mgo	0.81%
6	Mno	0.02%
7	Na_2O_3	0.26%
8	K_2O	0.11%
9	Loss of ignition	3.33%

III. PRELIMINARY TEST

A. Test On Cement

Grade of cement: OPC 53 Grade
The followings tests were conducted on cement.

- Fineness test
- Consistency test
- Initial and final setting time of test
- Specific gravity test

1) Properties Of Cement And Result

a) Fineness Modulus = 3.6%
b) Consistency = 32%
c) Initial setting time = 30 min
d) Final setting time = 630 min
e) Specific gravity = 3.14

B. Test On Fine Aggregate

Properties of fine aggregate and result
Specific Gravity = 2.58
Fineness modulus = 4.21
Bulk density

1) Loose state = 1661.614kg/m³
2) Rodded state =1843.09 kg/m³

C. Test On Coarse Aggregate

Specific Gravity = 2.69
Fineness modulus = 8.4
Bulk density

1) Loose state =1553.46 kg/m3
2) Rodded state =1693.15 kg/m3

D. Tests For Copper Slag

Specific gravity of Copper Slag = 3.61
Bulk density of Copper Slag

1) Loose State = 2140.516 kg/m^3
2) Rodded State = 2386.317 kg/m^3

Fineness of Copper Slag =3.97
Zone conformation for CS (as per IS 383: 1997) is Zone II

E. Tests For Marble Sludge Powder

Specific gravity of MSP = 2.975
Fineness of MSP =2.64

IV. MIX DESIGN

Mix Design for M30- IS 10262-2009 (Conventional Concrete)
Characteristic compressive strength required= 30Mpa
Maximum size of aggregate= 20mm (angular)
Degree of workability = 0.9 (compacting factor)
Degree of quality control = Good
Type of exposure = Mild
Specific gravity of cement = 3.14
Specific gravity of F.A = 2.58

Specific gravity of C.A = 2.69
Water absorption of coarse aggregate = 0.5%
Free (surface) moisture of F.A = 2%
Sand confirming to zone II

A. *Target Mean Strength of Concrete:*

Fck = fck + 1.65 S {M30 'S' value = 6}
= 30 + (1.65 × 6)
= 39.9 N/mm^2

B. *Selection of water cement ratio:*

The free water cement ratio required for the target strength 39.9 N/mm^2 is 0.37 from IS 10262-2009

C. *The Selection of Water and Sand Content:*

For 20 mm nominal size of aggregate and sand confirming to grading zone II.
Water content per m^3 of concrete = 186 kg.
Sand content as percentage of total aggregate by absolute volume = 35%

Adjustment is made according to IS code.

Change in Condition	Adjustment Required in	
	Water Content Percent	*% of Sand in Total Aggregate*
For sand confirming to zone II	0	0
For increase in value of compacting factor (0.9-0.8) that is 0.1	3	0
For decrease in water cement ratio (0.6-0.37) that is 0.23	0	-4.6
Total	3	-4.6

Required sand content as percentage of total aggregate by absolute volume = 35 – 4.6
= 30.4%

Required water content = 186 + (186 × 3) / 100
= 191.6 l/m^3

D. *Determination of Water Content*

Water cement ratio = 0.37
Water content = 191.6 l/m^3
Cement content = (191.6/0.37)
= 518 kg/m^3

E. *Determination Of Coarse Aggregate & Fine Aggregate*

Air content for concrete mix having nominal maximum size of aggregate 20mm is taken as 2%

$$V = \left[W + \frac{C}{S_c} + \frac{1}{p} \times \frac{fa}{S_{fa}}\right] \times \frac{1}{1000}$$

$$V = \left[W + \frac{C}{S_c} + \frac{1}{1-p} \times \frac{ca}{S_{ca}}\right] \times \frac{1}{1000}$$

Where,
V=Absolute volume of fresh concrete, which is equal to gross volume (m^3 the volume of entrapped air.
W=Mass of water (kg) per m^3 of concrete.
C=Mass of cement (kg) per m^3 of concrete.
S.c=Specific gravity of cement
p=Ratio of fine aggregate to total aggregate by absolute volume.
Fa, Ca=Total mass of fine aggregate and coarse aggregate (kg) per m^3 of concrete respectively.
S.fa, S.ca=Specific gravity of saturated surface dry fine aggregate and coarse aggregate respectively.

$0.98\ m^3$ = [191.6 + (518/ 3.14) + (1/ 0.304) × (fa /2.58)] × (1/1000)
Fa = 489 kg/m^3
$0.98\ m^3$= [191.6 + (518/ 3.16) + (1/ 1-0.304) × (ca/2.69)] × (1/1000)
Ca = 1167 kg/m^3

The mix proportion is,

Water	Cement	Fine Aggregate	Coarse Aggregate
191.6 l/m^3	518 kg/m^3	489 kg/m^3	1169 kg/m^3
0.37	1	0.94	2.25

V. RESULTS AND DISCUSSION

A. *Compressive Strength Test*

The compression test is used to determine the hardness of cubical and cylindrical specimens of concrete. The strength of a concrete specimen is depends upon cement, aggregate, bond, w/c ratio, curing temperature, and age and size of specimen. Mix design is the major factor controlling the strength of concrete.

Compressive strength = Ultimate load / Contact area of the cube

TABLE 3 TEST RESULTS FOR COMPRESSIVE STRENGTH

S.no	Mix ID	Compressive Strength (N/mm^2)	
		7 days	*28 days*
1	Mix 1- CC	21.60	32.4
2	Mix 2- CM	23.84	36.69
3	Mix 3	25.80	39.70
4	**Mix 4**	**26.84**	**41.30**
5	Mix 5	24.92	38.45
6	Mix 6	23.01	35.40

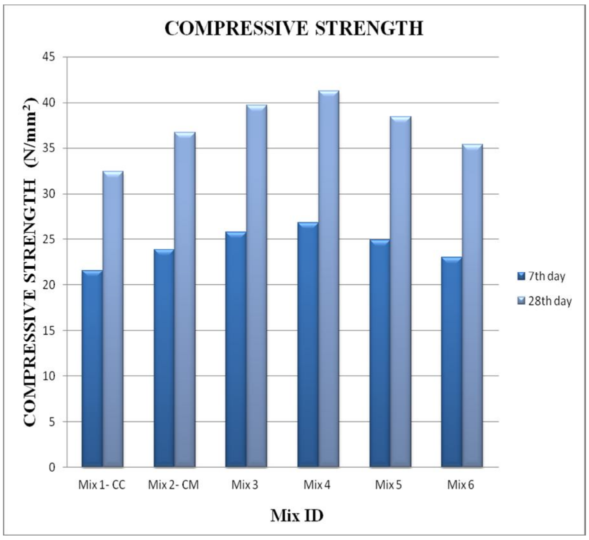

Fig 1 Compressive Strength

B. *Split Tensile Strength Test*

The objective of this is to find the Splitting tensile strength of concrete cylinders. To investigate Split tensile strength, standard cylinder (150mm dia X 300mm height) are cast and tested as per IS 5816-1970 this is indirect test on finding the tensile strength of concrete. This is also sometimes referred as "Brazilian Test". Specimens are kept in rest condition for 24 hours before testing in ordinary compression testing machine.

The wet cylinder specimen is placed on the strip horizontally with its axis perpendicular to the loading direction. The second steel rod is then placed lengthwise on the cylindrical centrally. The load is then applied without shock and increased continuously at a rate to produce approximately a splitting tensile strength of 14 to 21 $Kg/cm^2/min$ until failure. The maximum load is applied to the specimen is noted ad the splitting tensile strength is calculated as follows.

Split Tensile Strength = 2P/ (ΠLD)

TABLE 4 TEST RESULTS FOR SPLIT STRENGTH

S.no	Mix ID	Split Strength (N/mm^2)	
		7 days	28 days
1	Mix 1- CC	2.30	3.54
2	Mix 2- CM	2.50	3.84
3	Mix 3	2.77	4.26
4	**Mix 4**	**3.12**	**4.58**
5	Mix 5	2.73	4.19
6	Mix 6	2.43	3.75

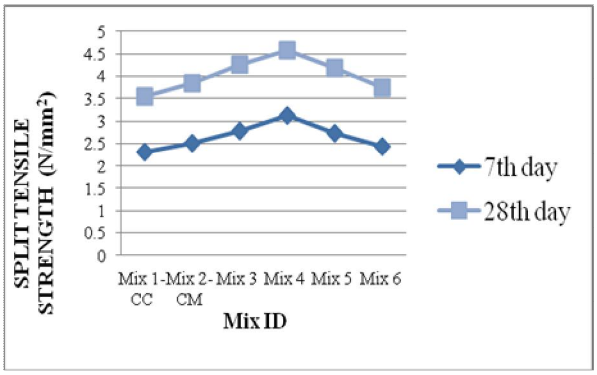

Fig 2 Split Strength

C. *Flexural Strength Test*

Automatic universal testing machine was used for this test according to IS 519-1959. Beam samples measuring 100×100×500mm were moulded and stored in water for 28days before test for flexural strength. Three similar samples were prepared for each mix proportion. The casting was made by filling each mould with freshly mixed concrete in three layers. Each layer was compacted manually using a 25mm diameter steel tamping rod to give 150 strokes on a layer. The hardened beam was placed on the universal testing machine simply supported over a span 3times the beam depth on a pair of supporting rollers. Two additional loading rollers were placed on top the beam. The load was applied without shock at a rate of 200m/s. The flexural strength was then calculated using the formula below:

Flexural strength = $3pl/bd^2$

TABLE 5 TEST RESULTS FOR FLEXURAL STRENGTH

S.no	Mix ID	Flexural Strength (N/mm^2)
1	Mix 1- CC	5.87
2	Mix 2- CM	6.29
3	Mix 3	6.46
4	**Mix 4**	**6.82**
5	Mix 5	6.35
6	Mix 6	5.93

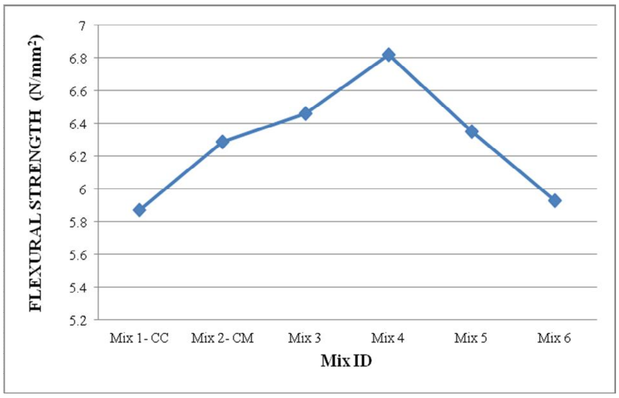

Fig 3 Flexural Strength

D. *Impact Resistance Test*

The impact strength of concrete is important when it is subjected to sudden load or repeated impact load as witnessed in forge hammer foundations. Thy cylindrical moulds size is 150 x 200 mm. The discs were then subjected to drop weight. The test consisted of repeated application of impact load in the form of blows, using a 44.5N hammer falling from 457 mm height on the steel ball of 63.5 mm diameter, placed at the centre of the top surface of disc. Number of blows (N_1) and (N_2) that caused the first visible crack and failure respectively was noted as first crack strength and the failure strength of the sample. The impact energy was calculated for each concrete specimen using below equation:

Impact energy U = (n. m. V^2 / 2)

Fig 4 Impact resistance

TABLE 6 IMPACT RESISTANCE TEST

S.no	Mix ID	First crack	Final crack	Impact Energy In 10^3 J or N-m	
				First crack	*Final crack*
1	Mix 1- CC	77	80	15.63	16.24
2	Mix 2 -CM	84	89	17.05	18.07
3	Mix 3	90	96	18.27	19.49
4	Mix 4	94	101	19.08	20.51
5	Mix 5	88	91	17.87	18.47
6	Mix 6	83	85	16.85	17.26

E. Sorptivity Test

The sorptivity can be determined by the measurement of the capillary rise absorption rate on reasonably homogeneous material. Water was used of the test fluid. The cylinders after casting were cured in heat curing chamber at 70°C for 24 hours. The specimen size 100mm dia x 50 mm height after drying in oven at temperature of 100 + 10 °C were drowned with water level not more than 5 mm above the base of specimen and the flow from the peripheral surface is prevented by sealing it properly with non-absorbent coating. The quantity of water absorbed in time period of 60 minutes was measured by weighting the specimen on a top pan balance weighting up to 0.1 mg. The surface water on the specimen was wiped off with a dampened tissue and each weighting operation was completed within 30 seconds. Sorptivity (S) is a material property which characterizes the tendency of a porous material to absorb and transmit water by capillarity. The cumulative water absorption (per unit area of the inflow surface) increases as the square root of elapsed time (t).

$$S=I/ t^{1/2}$$

TABLE 7 TEST RESULTS FOR SORPTIVITY

S.no	**Mix ID**	**Dry Weight In Grams (W_1)**	**Wet Weight In Grams (W_2)**	**Sorptivity Value In 10^{-5} mm/min$^{0.5}$**
1	Mix 1-CC	1454	1455.5	2.46
2	Mix 2 -CM	1460.5	1462.5	3.27
3	Mix 3	1442.5	1444	2.23
4	Mix 4	1449	1450	1.64
5	Mix 5	1451	1452.5	1.87
6	Mix 6	1452.5	1453.5	1.96

VI. CONCLUSION

Based on the study, Copper slag was used constant replacement of sand. The copper slag is replaced by 20 % of total weight of sand and MSP were used in different proportions 15%, 25%, 35%, 45% as filler material in concrete manufacturing. The following conclusions are drawn the experimental investigation.

- The properties values are increased up to 20 % replacement of Copper Slag and 25 % filler material of Marble Sludge Powder.
- The maximum value of Mechanical properties are obtained for the Mix 4, to enhance the compressive, split tensile and flexural strength test of 41.30, 4.58 and 6.82 MPa respectively.
- The impact resistance of Copper slag and MSP is higher than cement concrete
- The sorptivity of the concrete shows lower water penetration for Mix 4 specimen than the others
- Use of industrial waste products saves the environment and minimizes the pollution problems.

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