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Analysis of compressive strength of concrete by effective replacement of coarse aggregate with ceramic waste

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ABSTRACT--In both developed and undeveloped countries it has become a technical challenge to design low cost, durable and sustainable concrete. The main focus of this research work is to study the strength of concrete by effectively replacing coarse aggregate with ceramic wastes. According to a statistical record tiles industry of the world, India stands in second position with7.97% contribution in tile manufacturing. These industries produce an average of 20-30% waste during its process and thus pose a threat to waste disposal. In order to make an effort towards its waste disposal this research study intends replacing coarse aggregate with ceramic waste in a range of 0%, 5%, 10%, 15% and 20% by weight in M_{20} grade concrete. Compressive strength tests were conducted on hardened concrete cubes after 3rd, 7th, 14th and 28th day of curing in water. This experiment shows an improvement in concrete compressive properties. The compressive strength after 3rd, 7th ,14th and 28th day was determined by taking 3 cubes for each percentage.

Keywords — sustainable, ceramic waste, compressive strength, durable

I. INTRODUCTION

Concrete can be considered a composite material with composition of crushed stones, fine aggregate and cement as binding material. In an age of rapid growing technology, the demand construction industries have risen. It required to meet the functional, economical and durability stability of any organisation. Ceramic industries are another booming sector and also generate huge amount of waste. During 2012-2017 a growth rate of 4% was registered which results to a value of 13.27 billion sqauremetre volume of ceramic consumption. During 2017 it was mainly buoyed by countries like Africa, Europe and US where there was recovery in construction work. Asia continues to be the largest consumer with 8.98sqm about 68% of total consumption. India standing second to ceramic manufacturing next to China. China being the highest producer of ceramic is currently facing dumping issues. Also, according to an estimate by Indian tile and ceramic industries the global consumption will grow by 3-5% between 2018-2022. The wastes generated by ceramic industries do contribute to environmental problems. One sanitary cluster in India carries out production around 7.2 lakh tonnes of clay per year out of which 21600 tonnes of fired pieces goes to waste due to manufacturing defects.

The need of time has urged us to pay attention to conserve natural resources and to reduce energy used in production. These ceramic wastes can be used in effective replacement of coarse aggregate. These ceramic wastes collected from industries in Bargarh Locality used for the experiment were manually crushed using a tamping rod and passed through IS sieve conforming the size of coarse aggregate.

II. MATERIALS REQUIRED

A. MATERIALS

a) Cement

The cement used in this experiment is pozzolana Portland cement (PPC) of Local brand. Fresh cement of grade 53 conforming to IS 269 was used in this experiment.

TABLE-1
PHYSICAL PROPERTIES OF (PPC) CEMENT

PROPERTY	IS 269-1989
Specific Gravity	2.90

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Consistency	33
Initial setting time (mins)	30
Final Setting time (mins)	600 specified

b) Ceramic Waste

The ceramic waste coming out of the industries are generally in powder form. The waste generated during the finishing process is estimated to be around 15-30% of the total raw material used. Although this waste is utilised in backfilling but the amount of waste produced is much more than what is used for backfilling process. The disposal of these wastes is a major concern as it requires large areas and it also spoils the aesthetics of the region. Ceramic wastes can be used in concrete for improving the strength and durability. Effectively replacing ceramic to concrete could impart different properties of concrete.

TABLE-2
CHEMICAL COMPOSITION OF CERAMIC WASTE

Compound Composition	Percentage
SiO2	63.29
Al2O3	18.29
Fe2O3	4.32
CaO	4.46
MgO	0.72
P2O5	0.16
K2O	2.18
Na2O	0.75
SO3	0.10
Cl-	0.005
TiO2	0.61
SrO2	0.02
Mn2O3	0.05
L.O. I	1.61

c) Aggregates

Fine aggregates-

In this study river sand was used as fine aggregate conforming to IS:383. Sieves were arranged as 4.75 to 150 Micron and fractions were taken.

TABLE-3
PROPERTIES OF FINE AGGREGATE

Property	Fine Aggregate
Fineness Modulus	3.28
Specific Gravity	2.65
Bulk Density kg/m3	1.73

Coarse Aggregate-

Crushed Basalt rock was used conforming IS:383. Sieving through arranged sieves of 20mm to 4.75mm, fractions were considered. The flakiness and elongation were considered well below 15%.

TABLE-4
PROPERTIES OF COARSE AGGREGATE

Property	Passing 20mm
Fineness Modulus	7.28
Specific Gravity	2.75
Bulk Density kg/m^3	1.74

d) Water-

It is the most essential component for initialising the chemical reaction. The sample of water taken for this experiment is potable and free from any organic impurities.

III. MIX DESIGN

According to IS 10262-2009, a mix design of M20 was considered for this experiment. The samples taken were of the same design mix.

TABLE-5
MIX DESIGN PROPORTION FOR M20

	Water (L)	Cement Kg/m^3	F.A Kg/m^3	C.A (Kg/m^3)
By Wt.	162.75	375.50	555.25	1120.00
By Vol	0.50	1	1.47	2.98

W= WATER, F. A= FINE AGGREGATE, C.A= COARSE AGGREGATE

TABLE-6
CONCRETE DESIGN PROPORTION

Sl no.	Concrete type	Concrete design proportion				
		W/C	C (KG)	F.A (KG)	C.A (KG)	C.W (KG)
1	C0	0.50	1.5	2.25	4.5	0
2	C5	0.50	1.5	2.25	4.275	0.225
3	C10	0.50	1.5	2.25	4.05	0.45
4	C15	0.50	1.5	2.25	3.825	0.675
5	C20	0.50	1.5	2.25	3.6	0.9

IV EXPERIMENTAL SET UP METHODOLOGY-

The process of assessment of ceramic waste to be used as an alternative to coarse aggregates started with the concrete testings. The control concrete contained cement, sand, aggregate and water to a specified content. The replacement has been done in order of 5%, 10%, 15%, 20% with the coarse aggregate proportion. Three cube samples with each of different percentage replacement was compared with standard concrete cube in a controlled environment. The size of the mould was 15 x 15 x 15 cm. The standard and replaced concrete cube were removed from there mould after 24hrs and immersed in water for curing. The samples were tested for 7,14,28 days for their compressive strength.

Compressive Strength-

The strength of the samples was calculated using a power operated compressive testing machine with a load drop of 35N/mm^2. Three samples from each batch were tested and the results were noted. A comparative assessment on the properties of design mix concrete and concrete cube with replaced ceramic waste was done at 5%, 10%, 15%, 20% replacements.

TABLE -7
COMPRESSIVE STRENGTH OF CUBES M20 (7,14,28 DAYS)

Concrete type	Average compressive strength (kN/mm^2)		
	7 days	14 days	28 days
C0	16.14	22.54	27.89
C5	16.87	23.06	28.16
C10	17.52	23.73	29.46
C15	17.23	23.47	28.70
C20	16.32	22.91	27.60

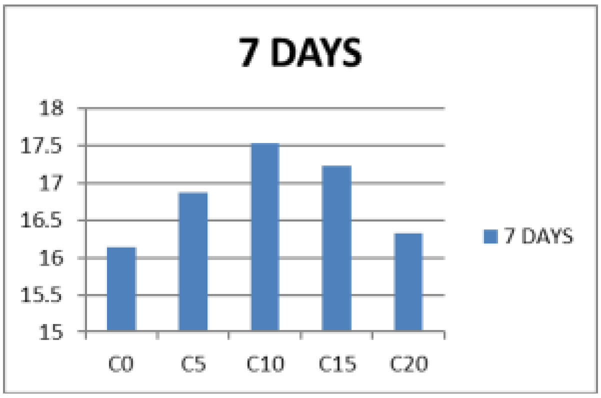

Chart 1: Compressive strength values(in MPa) after 7 days

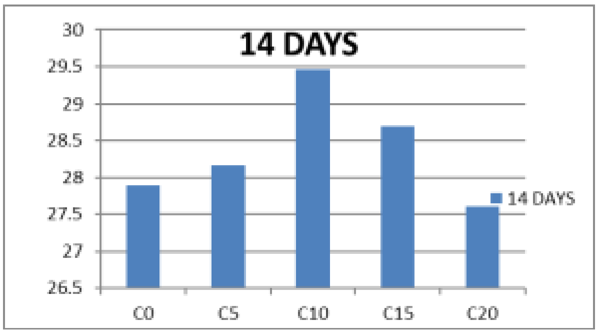

Chart 2: Compressive strength values(in MPa) after 14 days

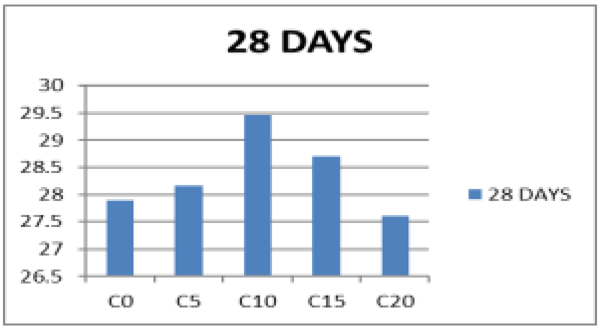

Chart 3: Compressive strength values(in MPa) after28 days

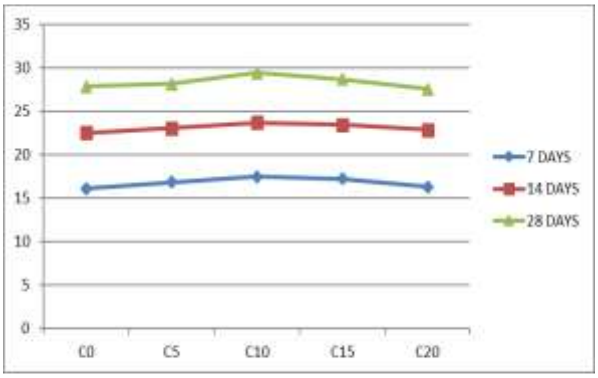

Chart 4: Compressive strength values comparison

V. COST FEASABILITY

TABLE- 8
COSTS OF MATERIALS

SL NO.	MATERIAL	RATE RS/KG
1	CEMENT (LOCAL)	6.60
2	SAND (LOCAL)	0.30
3	AGGREGATE (LOCAL)	2.00
4	CERAMIC WASTE (LOCAL)	0.20

TABLE – 9
TOTAL COST OF MATERIALS FOR M20 (1:1.47:2.98) PER m^3

Sl no	Concrete type	Concrete design proportion				Total	Profit
		C (KG)	F.A. (KG)	C.A (KG)	C.W (KG)	□/m^3	%
1	C0	375.50	555.25	1120.00	0	4996	-
2	C5	375.50	555.25	1064	56	4895	2.00
3	C10	375.50	555.25	1008	112	4794	4.02
4	C15	375.50	555.25	952	168	4693	6.04
5	C20	375.50	555.25	896	224	4615	7.60

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VI. CONCLUSION

Our study has demonstrated that there is a significant correlation between the addition of ceramic waste to the strength of concrete. The compressive strength of concrete with 10% replacement of coarse aggregate with ceramic waste has been found to have maximum compressive strength. Further replacement of ceramic waste powder to concrete reduces the compressive strength significantly. It has also been observed that concrete with 10% replacement has reduced the cost of coarse aggregate by 4%. Through our analysis of the literature and data we have shown that ceramic waste has a potential of being a replacement material for cement in concrete.

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