PERFORMANCE AND EVALUATION OF E-WASTE & CERAMIC WASTE AS COARSE AGGREGATE IN CONCRETE

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Abstract

Durability, workability and sustainability have been achieved in concrete and mortar by replacing the coarse aggregate by e-waste and ceramic waste in M20 grade concrete. In this study an attempt has been made to find the suitability of the ceramic industrial wastes as a possible substitute for conventional crushed stone coarse aggregate. Experiments were carried out to determine the compressive, splitting tensile and flexural strength of concrete with ceramic waste coarse aggregate and to compare them with those of conventional concrete made with crushed stone coarse aggregate. The properties of the aggregate were also compared test result indicate that the workability of ceramic & e-waste coarse aggregate concrete is good and the strength characteristics are comparable to those of the conventional concrete. An experimental study is made by preparing specimens by utilizing ceramic & e- waste particles as coarse aggregates in concrete with a percentage replacement by 10% (2% of e-waste & 8% of ceramic waste), 15% (4% of e-waste & 11% of ceramic waste) and 20% (6% of e-waste & 14% of ceramic waste) of e-waste and ceramic waste.

1. Introduction

Concrete is the most widely used man-made construction material in the world. It is obtained by mixing cementitious materials, aggregates and water, and sometimes admixtures, in required proportions. The hardening is caused by chemical reaction between water and cement and it continues for a long time, and consequently the concrete grows stronger with age. The hardened concrete may also be considered as an artificial stone in which the voids of the larger particles are filled by the smaller particles and the voids of fine aggregates are filed with cement and voids are removed by adding water, with the addition of water, cement and water results in the formation of a paste called water cement paste which coats the surface of fine and coarse aggregates and binds them together.

The strength, durability and other characteristics of concrete depend upon the properties of its ingredients, proportion of mix, the

method of compaction and other controls during placing, compaction and curing. Concrete making is not just a matter of mixing ingredients to produce a plastic mass, but good concrete has to satisfy performance requirements in the plastic or green state and also the hardened state. In the plastic state the concrete should be workable and free from segregation and bleeding. Segregation is the separation of coarse aggregate and bleeding is the separation of cement paste from the main mass. In its hardened state concrete should be strong, durable, and impermeable and it should have minimum dimensional changes.

2. Experimental

2.1. Materials Used

Portland Pozzolanic cement of ‘Dalmia’ brand conforming to IS 1489, 53 grade was used. The fine aggregate was screened washed river sand of fineness modulus 2.73.Hard granite broken stones are used as coarse aggregate. The maximum size of aggregate is generally limited to 20mm. Aggregate size of 10 - 12mm is desirable for structures having congested reinforcement. Potable water available in laboratory with P_H value of 7.0 and confirming to the requirement of IS 456- 2000 was used for mixing concrete and curing the specimen as well. The water to cement ratio was 0.5.Following alternative material of coarse aggregate were used.

2.1.1.Ceramic Waste

Ceramic waste from ceramic and industries is one of the most important parts in the global volume of construction and demolition waste (CDW). Ceramic waste has several uses, one of which as coarse aggregate for concrete artifacts. Within a research campaign in coarse at Institute Superior Techniques, concerning the recycling of CDW, the viability of replacing primary lime stone aggregate with ceramic waste on the production of concrete pavements slabs have been studied.The big ceramic waste such as flowerpot, tiles, and sanitary ware are to be broken into small pieces about 5-40 mm size by a hammer. These small pieces are then fed into vibrator sieved to get required 14- 20 mm size.

Figure 1. Ceramic waste

2.1.2E-Waste

"Electronic waste" may be defined as discarded computers, office electronic equipment, entertainment device electronics, mobile phones, television sets and refrigerators. This definition includes used electronics which are destined for reuse, resale, salvage, recycling or disposal. The following electrical and electronic components that are considered as e-waste. They are air conditioning, computer, refrigerator, washing machine, video recorder, telephone, radio, mobile phones, mother board, hard disk drive, circuit board, waste metal contaminated with heavy metals cadmium, ferrous metal, aluminium, mercury, lead, nickel, copper, chromium, silver, lithium, integrated circuit board, Indium, glass, lead glass, brominated plastics, palladium and others.

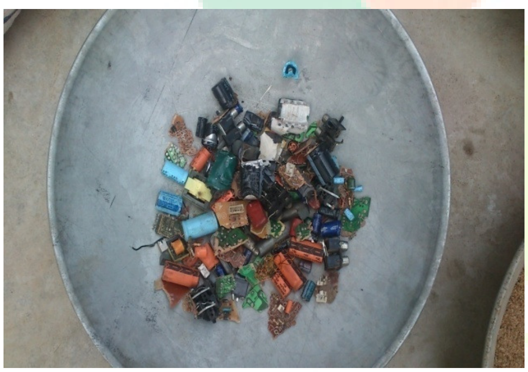

Figure 2. E-waste aggregate

2.2. Experimental Part

2.2.1.Mix design

Cement = 383.16 kg/m^3

Fine aggregate = 720.36 kg/m^3

Coarse aggregate =1188.18kg/m^3

Water cement ratio = 0.50

Therefore the ratio obtained: **1:1.5:3**

2.2.2.Choice of Mixes

The percentage replacements of coarse aggregates by electronic waste were 0%, 2%, 4%, 6% and ceramic waste 0%, 8%, 11%, 14%.This was done to determine the proportion that would give the most favorable result. The 0% replacement was to serve as control for other sample which is finally used for the comparison.

Table 1. Mix proportions

Sample	Coarse aggregate	Ceramic waste	Electronic waste	Total Replacement
1	100%	0%	0%	0%
2	90%	8%	2%	10%
3	85%	11%	4%	15%
4	80%	14%	6%	20%

2.2.3.Compressive Strength Test

It is the resistance of concrete to crushing cement concrete has substantial compressive strength and forms a very important property for structural concrete. As per Indian standards the crushing strength is measured as axial load per unit area at failure on cubes of 150 mm size at the age of 28 days and is specified in N/mm^2. This strength this used to specify the grade of concrete. Using Portland cements, concrete can be manufactured with compressive strength ranging from 10 N/mm^2 and 40 N/mm^2. By using specially selected cement, admixtures and other materials, concrete of 60 N/mm^2 or even more can be obtained.

Sometimes very clean concretes needed for mass concreting and base of foundations may have compressive strength as low as 4 N/mm^2. In building construction concrete having compressive strength of 15 N/mm^2 (M_{15} grade) is normally specified. For roads and bridges structural concrete of compressive strengths ranging from 20 to 40 N/mm^2 (M_{20} to M_{40} grades) is generally specified. Higher grades of concrete (M_{30} to M_{40}) are especially suitable for pre-stressed structures while concrete grade of M_{20} to M_{25} are commonly used for R.C.C structure. Compressive strength of concrete is important because other strength such as flexure, bond, and abrasion resistance improve with increase in its compressive strength and it is also comparatively easier to measure compressive strength of concrete.

From the quality control point of view, the compressive strength of concrete is accepted as the main criterion for the acceptance of the quality of structural concrete.

Compressive Strength = P/A (N/mm^2)

Where,

P = Load in N

A = Area in mm^2

Figure3. Compressive Strength Test

2.2.4.Split Tensile Strength Test

This test is used to determine the tensile strength of concrete. Split tensile strength test was carried out on cylindrical specimens of size 150 mm dia and 300 mm long at the age of 7 and 28 days after curing using CTM. To avoid the direct load on the specimen the cylindrical specimens were kept between two wooden pieces and the readings were noted.

The split tensile strength of concrete was found using the relation:

Split tensile strength = (2P/πLD)

Where,

P is the maximum load on the cylinder.
L is the length of cylinder.
D is the diameter of the cylinder.

2.2.5.Flexural Strength Test

The resistance of concrete offered to tension under flexural loading is called its flexural strength. Cement concrete is comparatively weak in tension. Generally the flexural tensile strength of cement concrete is about one eighth to one tenth of its compressive strength. It is difficult to measure direct tensile strength and hence flexure tensile strength is commonly measured. The flexure tensile strength is slightly higher than the direct tensile strength because in the latter case there is no surrounding adjacent under-stressed material to stop the fracture. In fact the strength of the concrete is to be considered is to be considered as the strength of its weakest element. Hence the flexure strength is considered as the resistance to cracking under flexural loading. This flexure stress in concrete at the time of cracking is also called modulus of rupture. It is observed that there exists a relationship between tensile stresses at cracking in direct compression specimen.

Flexural tensile strength of concrete is affected greatly by the shape and texture of the aggregates. The concrete with angular crushed aggregate offers more flexural strength in comparison to rounded smooth gravel due to better mechanical bonds in the former. The ratio of the tensile strength to its compressive strength decreases with age of concrete and also increase in its grade.

Flexural strength of concrete (fck) = PL/ BD^2 (N/mm^2)

Where,
P = maximum load applied to the specimen in (N)
L = length between the two support in (mm)
B = breath of the specimen in (mm)
D = depth of the specimen in (mm)

Figure 4. Flexural Strength Test

3. Results and Discussion

3.1.Compressive Strength Test

Breadth of the specimen (B) = 150mm
Depth of the Specimen (D) = 150mm

Table 2. Conventional concrete test results for compressive strength

Test	7 days (N/mm^2)	28 days (N/mm^2)

Compressive strength	14.5	19.8

Table 3.Average compressive strength test results

Mix Identification	Days	2% of e-waste + 8% of ceramic waste	4% of e-waste + 11% of ceramic waste	6% of e-waste + 14% of ceramic waste
Average compressive strength(N/mm^2)	7	19.50	18.95	18.07
	28	26.42	25.75	23.84

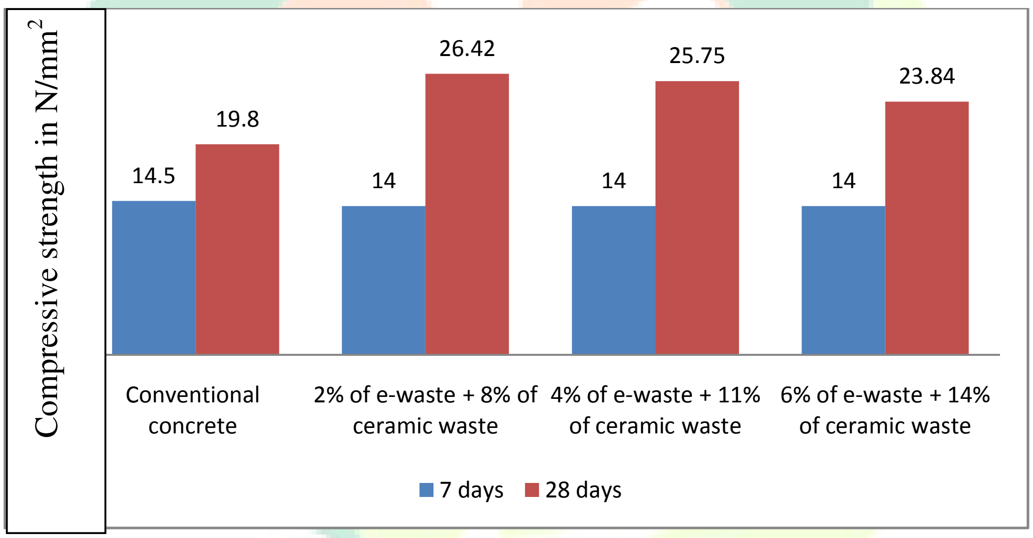

Figure 5. Comparison of compressive strength

3.2.Split Tensile Strength Test

Length of the specimen (B) = 300mm
Diameter of the Specimen (D) = 150mm

Table 4. Conventional concrete test results for split tensile strength

Test	7 days (N/mm^2)	28 days (N/mm^2)
Split tensile strength	1.71	2.14

Table 5.Average split tensile strength test results

Mix Identification	Days	2% of e-waste + 8% of ceramic waste	4% of e-waste + 11% of ceramic waste	6% of e-waste + 14% of ceramic waste
Average split tensile strength(N/mm^2)	7	2.81	2.57	2.5
	28	3.46	3.14	2.98

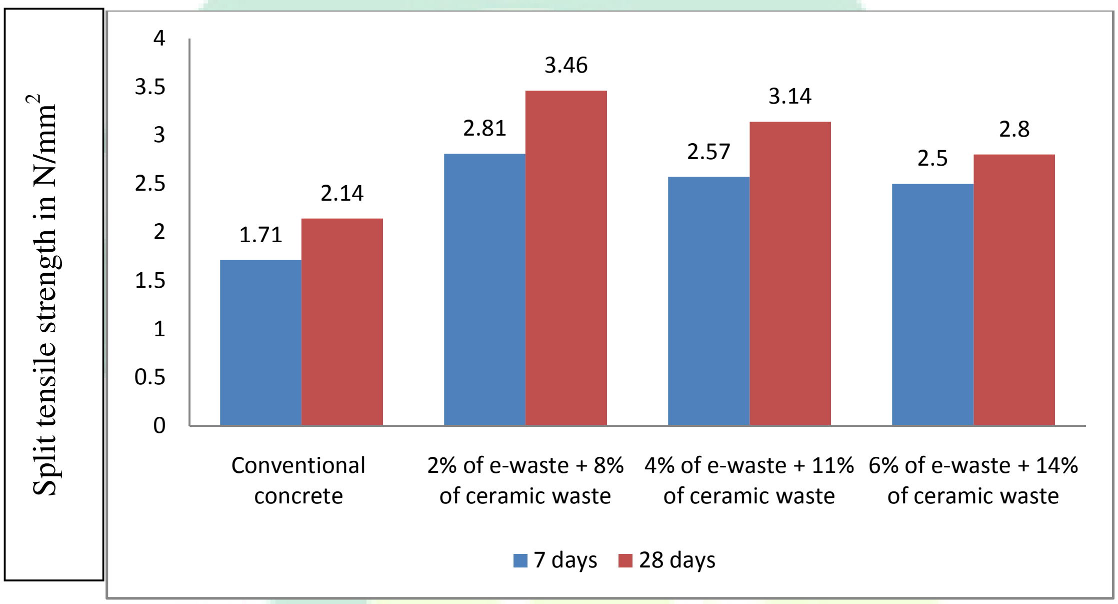

Figure 6. Comparison of split tensile strength

Discussion

- The compressive strength at 7 days for addition of electronic waste & ceramic waste increase at 12.56% for 10% replacement, decrease at 1.60% for 15% replacement, decrease at 6.17% for 20% replacement.
- The compressive strength at 28 days for addition of electronic waste & ceramic waste decrease at 2.09% for 10% replacement, decrease at 14.30% for 15% replacement, decrease at 20.66% for 20% replacement.
- The split tensile strength at 7 days for addition of electronic waste & ceramic waste decrease at 20.39% for 10% replacement, decrease at 27.19% for 15% replacement, decrease at 29.17% for 20% replacement.
- The split tensile strength at 28 days for addition of electronic waste & ceramic waste decrease at 38.76% for 10% replacement, decrease at 44.42% for 15% replacement, decrease at 47.25 for 20% replacement.

4. Conclusion

- Based on the studies conducted on strength characteristics of concrete made with utilizing waste materials, it was found that the concrete made of waste ceramic waste aggregate and e-waste aggregate produced similar strength in compression as conventional concrete.
- The compressive strength of the cubes increases to certain extent when the coarse aggregate is replaced by ceramic waste & e-waste and the optimum percentage of replacement is determined as **10%**
- The split tensile strength of the cylinder increases to certain extent when the coarse aggregate is replaced

by ceramic waste & e-waste and the optimum percentage of replacement is determined as **10%**

- Besides economical and strength criteria, concrete made from waste materials as aggregates, solves the disposal problem of these waste materials.

5. References

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