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An analysis of the durability features and strength of the E-waste concrete

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ABSTRACT

This study examines the effects of using crushed Printed Circuit Board (PCB) (also known as E-waste aggregate) in concrete as a partial substitute for regular coarse aggregate (NCA). M25 grade concrete was utilized. After substituting 0%, 10%, and 15% of the natural coarse aggregates with E-waste aggregate, three combinations were still complete. Verified examples continue to focus on strength attributes, after which long-lasting characteristics such as aquatic concentration, thermal expansion, and abrasion encounter tests were carried out. Test results proved that when the replacement percentage of Electronic waste aggregate was higher significant reduction in strength properties was noticed. It is container remains credited to the reality that incorporation of E-waste aggregate slows down the hydration process that would lead to a significant loss in strength. However, it was observed that mix made with 10% and 15% E-waste aggregate shows better resistance against durability properties than control mix concrete. It was also observed that utmost care should be taken for maintaining proper workability and removal of toxic substances in E-waste aggregate for better forte and toughness properties.

Keywords: Thermal expansion; hydration; mechanical Properties; durability; E-waste aggregate.

1. INTRODUCTION

Concrete is the most extensively utilized building material in the biosphere. It was mostly made of water, natural coarse aggregate, fine aggregate, and cement. Inherent properties such as high durability and strength property observed in concrete make it to use construction material around the globe next to water [1–3]. Concrete strength mainly depends on the water-cement ratio and its strength can also be affected by environmental factors. The material, which has major occupancy in concrete is aggregate. The main source of aggregate is river beds, crushing of rocks and stones, etc. Due to infrastructure development, there is a need to find an alternative source for aggregates. Many materials are used as replacements for coarse aggregates [4–6]. Among the wasted electronic items, or “E-waste,” are computers, televisions, laptops, printers, scanners, keyboards, screens, cables, and circuit boards. The rapid expansion of the electronic industry is leading to the disposal of many electrical and electronic devices. Only 17.4% of the 53.6 million tons of electronic garbage produced in 2019 were recovered, according to “Global E-waste Monitor 2020.” [7, 8]. The environment and human health may be seriously threatened by the disposal of E-waste. Numerous hazardous materials, including cadmium, beryllium, arsenic, mercury, nickel, silver, and zinc, are included in these E-wastes.

E-waste can be found in various forms, such as broken or loosely discarded electrical and electronic items. It can be collected from recyclers and crushed to a specific size depending on whether coarse or fine aggregate is needed. These days, getting rid of this E-waste is becoming a difficult issue. Recycling E-waste is thought to be the most flexible application as opposed to disposing of it [9, 10]. Recycling electronic waste is a good way to safeguard people and the environment from the hazards associated with it. Compared to ordinary concrete, the density of electronic waste substituted for coarse aggregate is somewhat lower. Additionally, when the durability and compressive strength grows, it was proposed that replacement of up to 15% of the original value might be justified [11–14]. The utilization of E-waste particles can be effectively used for spare of well and rough aggregate in concrete. The replacement ranges from 0% to 30% for M20 score tangible is used and originates that the concrete has better strength values when compared to conventional concrete [15]. E-waste aggregate as an alternative material for coarse aggregate showed that there is a rise in strength when match up to conventional concrete [16]. The used PCB boards are crushed in a jaw crusher to make E-waste aggregate.

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During the process, metals present in the E-waste are removed and the recovered metals can be used. The process for making E-waste aggregate is represented as a flowchart in Figure 1 [17–19]. The strength and durability characteristics of concrete built from crushed PCB board (also known as E-waste aggregate) are thoroughly discussed in the current study.

2. MATERIALS

The study employed Portland Cement of grade 53, which was acquired from Mahalakshmi Agencies in Coimbatore. Table 1 shows the various properties studied on OPC. Blue granite metal and M-sand were purchased from the quarry. Printed Circuit Board (PCB) an E-waste aggregate 12 mm size was gathered from Green Era Recyclers, Coimbatore.

3. MIX PROPORTION

The M25 grade was the one employed in this investigation [20, 21] and E-waste aggregate is replaced partially by 0%, 10% and 15% for natural coarse aggregate. Mix proportions were identified and tabulated in Table 2. Mix ID M0 denotes a mix made with 0% E-waste aggregate. Mix M1 and M2 denotes, a mix containing 10% and 15% E-waste aggregate.

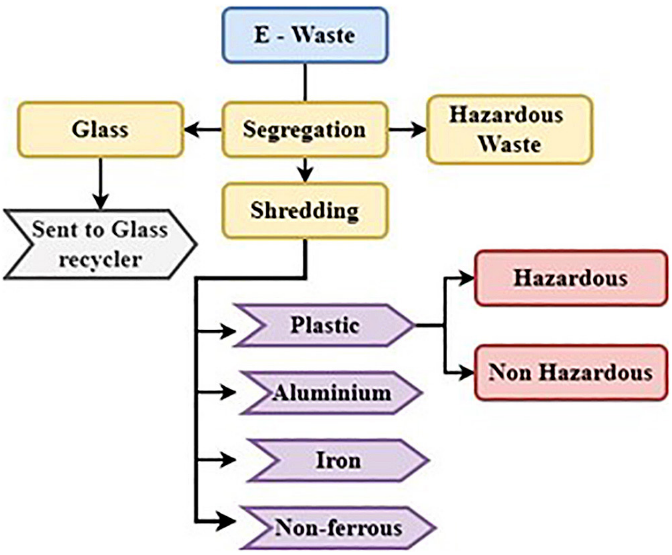

Figure 1: E-waste recycling – schematic representation.

Table 1: Ordinary Portland Cement's physical properties (OPC).

S.NO	TESTS	EXPERIMENTAL RESULTS
1	Particular gravity	3.14
2	Persistence (%)	29.15%
3	first-time setting	185 mins
4	Last-minute setup time	241 mins
5	Strength in Compression	46.56 MPa

Table 2: Mix proportions.

MIX ID	CEMENT (kg/m^3)	FINE AGGREGATE (kg/m^3)	COARSE AGGREGATE (kg/m^3)	WATER (kg/m^3)	E-WASTE AGGREGATE (kg/m^3)
M0	383.16	690.20	1211.43	191.58	0
M1	383.16	690.20	1158.95	191.58	52.47
M2	383.16	690.20	1132.73	191.58	78.70

4. EXPERIMENTAL INVESTIGATION

In total, 24 cubes measuring 150 × 150 × 150 mm, 18 cylinders measuring 150 mm in diameter and 300 mm in height, 18 beams measuring 100 × 100 × 500 mm, and 6 cylinders measuring 150 mm in diameter and 101.6 mm in height were created to investigate the durability of the concrete containing electronic waste. Temperature fluctuations can cause concrete to expand or contract. Thermal changes may be caused due to environmental effects and sometimes because of exothermic effects. Initially, at the time of casting, two steel pins were inserted at a predetermined distance. The specimens are demoulded and soaked in water for 28 days of curing. Then, the initial distance between the two pins was noted using an vernier caliper and the specimens were exposed to ambient air temperature for 28 days. After the exposing period, the expansion length between the two steel pins (δl) was observed by the vernier caliper to study the thermal expansion property of previous concrete. Cantabro test was conducted by using Los angels abrasion testing machine. Initially, the weight was measured and the cylindrical specimens (150 mm diameter, 101.6 mm height) were subjected to rotations without a steel ball inside the machine. The sample was removed after 100 spins to calculate the weight change. The proportion of Cantabria loss in previous concrete was calculated by ASTM C 13 recommendations [22, 23].

5. RESULTS AND DISCUSSION

5.1. Mechanical properties

Various strength tests have been performed (Table 3) and the test results are discussed elaborately.

5.2. Compressive strength test

Table 3 represents the compressive strength properties of E-waste concrete with replacement ranging from 0%, 10%, and 15%. The Test results observed at the 7 and 28 days were discussed. Test results exhibited that when the replacement percentage of E-waste aggregate was increased, a significant reduction in compressive strength was observed. At the age of 28 days, mix M1 has a 9.43% decreases compressive strength property to control mix M0. Similarly mix M2, exhibits, a 17% decrease in compressive strength compared to mix M0. This is because E-waste replacement in concrete The compressive strength characteristics of E-waste concrete with replacement varying from 0% to 15% are shown in Table 3. There was a discussion of the test results at 7 and 28 days. According to test results, compressive strength significantly decreased as the replacement % of E-waste aggregate increased. After 28 days, mix M1's compressive strength property is 9.43% lower than that of control mix M0. Comparatively speaking, mix M2 shows a 17% drop in compressive strength over mix M0. This is because the substitution of E-waste in concrete causes weak bonding at the aggregate interface, which obliquely indicates severe declines in the parameters of compressive strength. Figure 2 illustrates the outcome.

5.3. Split tensile strength

The results demonstrated that there was a progressive decline in split tensile strength properties as the replacement percentage of E-waste aggregate increased. Split tensile strength was calculated and is displayed in Table 3. Properties related to compressive strength showed the same pattern. The parameters of split tensile strength are visually represented in Figure 3.

5.4. Flexural strength

Table 3 shows the flexural strength of various mixes. At the age of 28 days, mix M1 possesses, a 5.14% decrease in flexural strength when compared to conventional Control mix M0. M2 mix shows 11% lesser in flexural strength property when matched up with mix M0. The same trend was observed in compressive strength and split tensile strength properties. The same is graphically shown in Figure 4.

Table 3: Properties of strength for different mixes.

MIX ID	COMPRESSIVE STRENGTH (MPa)		SPLIT TENSILE STRENGTH (MPa)		FLEXURAL STRENGTH (MPa)	
	7 DAYS	28 DAYS	7 DAYS	28 DAYS	7 DAYS	28 DAYS
M0	15.2	26.5	1.45	2.50	2.65	3.5
M1	14.5	24	1.30	2.32	2.50	3.3
M2	13.0	22	1.22	2.15	2.40	3.1

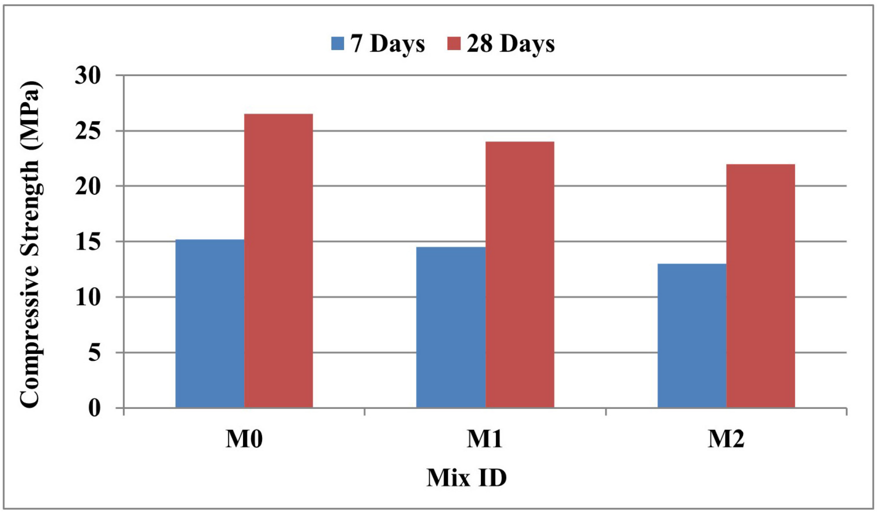

Figure 2: Differential mixes' compressive strengths.

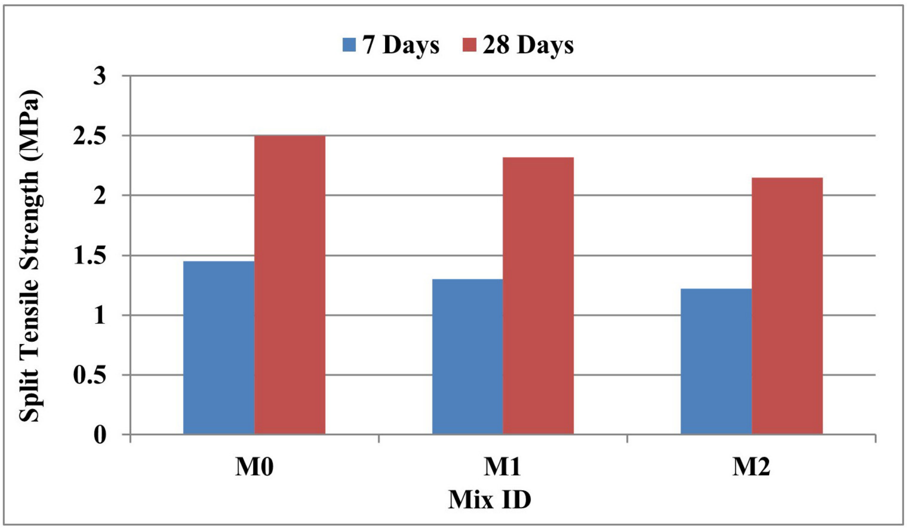

Figure 3: Test of split tensile strength for different mixes.

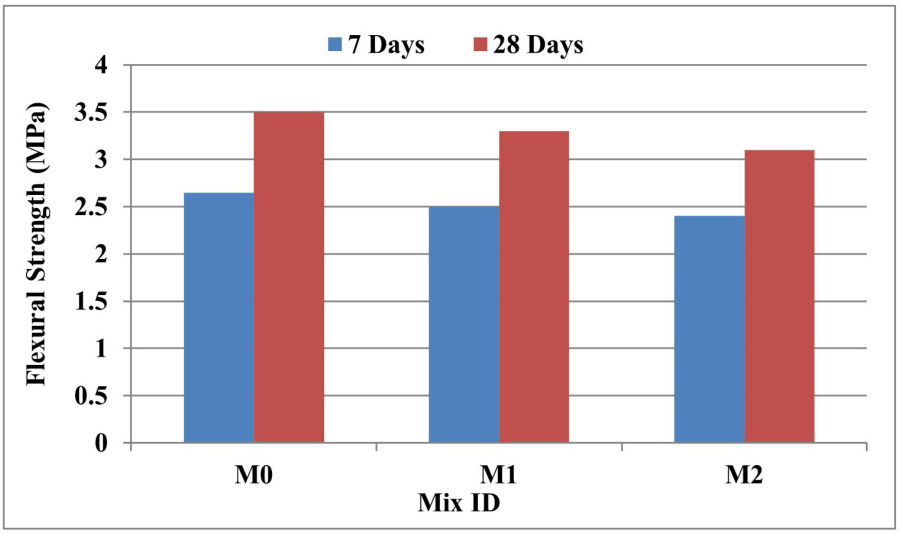

Figure 4: Flexural strength test for various mixes.

6. DURABILITY PROPERTIES

Durability properties such as water absorption, thermal expansion and cantabro loss abrasion tests have been performed and results are explained the results of the durability property tests are shown in Table 4.

6.1. Water absorption

M2 mix shows higher water absorption when matchup with control mix M0 and M1 at 28 days as represented in Table 4. The absorption percentage is increased due to excess void content observed in the specimens. However, water absorption can be reduced by doing proper compaction. The results are graphically represented in Figure 5.

6.2. Thermal expansion

It was observed that, at the age of 28 days, a mix made with 10% E-waste aggregate (M1) shows a 20% increase in expansion than conventional control mix M0. Similarly, the M2 mix shows a 50% expansion than the control mix M0. The expansion in concrete is observed due to poor bonds between aggregate phases. The results are graphically represented in Figure 6.

6.3. Cantabro loss abrasion test

Table 4 shows, abrasion percentage loss due to Cantabria test. Due to abrasion, it was observed that mix M1 had 10% increase in abrasion loss than the control mix M0, 25% increase in abrasion loss was found in mix M2 when compared to mix M0. The results are graphically represented in Figure 7.

7. CONCLUSION

The strength and long lasting properties of Electronic waste concrete are studied and the following conclusions are drawn.

1. A thorough assessment of relevant literature was conducted to ascertain the durability and strength of electronic waste concrete that uses PCBs as coarse aggregate.

Table 4: Durability characteristics of different mixes.

MIX ID	WATER ABSORPTION (%)	THERMAL EXPANSION (mm)	ABRASION LOSS (%)
M0	2.0	1.0	2.0
M1	2.5	1.2	2.2
M2	2.9	1.5	2.5

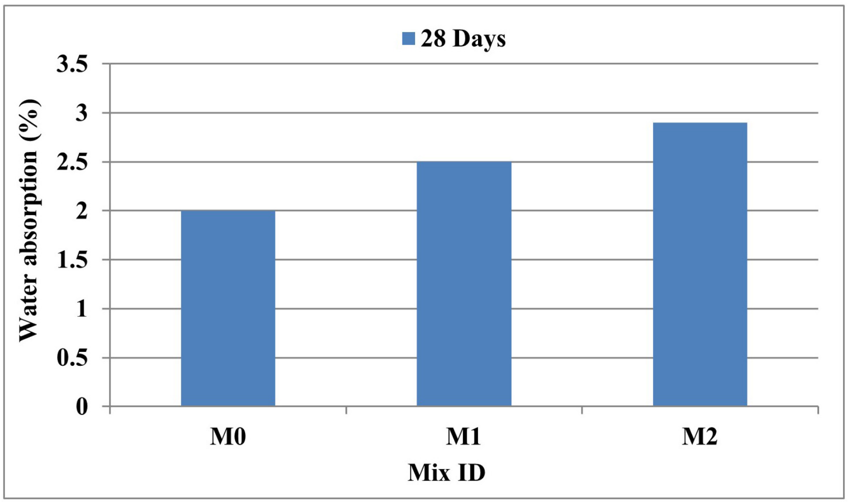

Figure 5: Water absorption of various mixes.

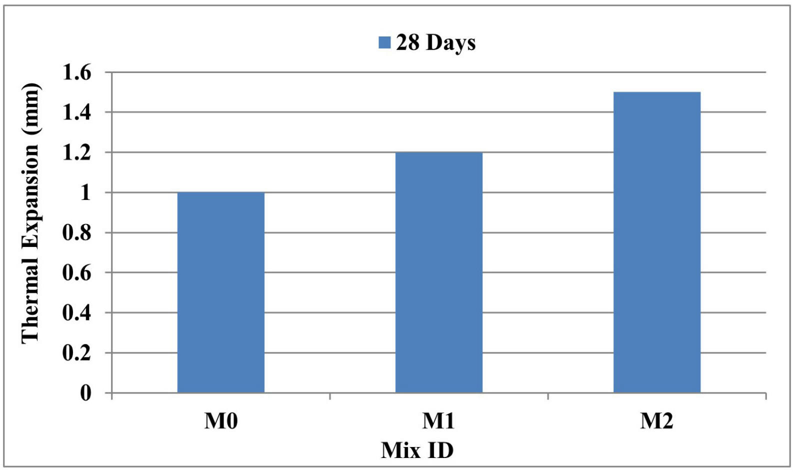

Figure 6: Thermal expansion of various mixes.

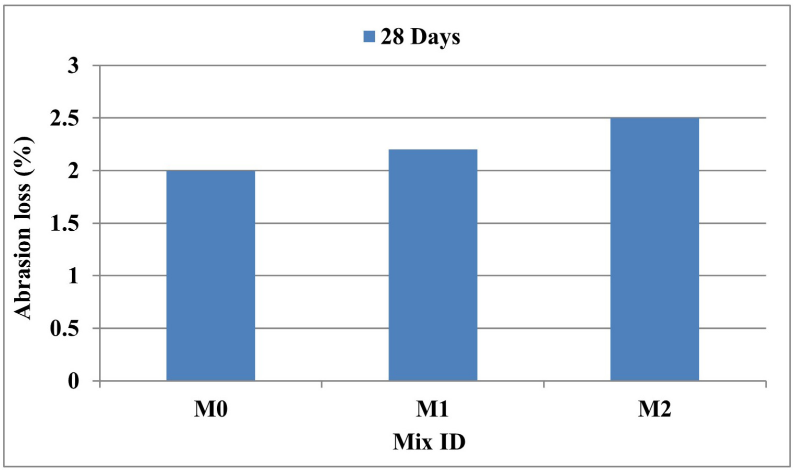

Figure 7: Abrasion loss of various mixes.

2. The mechanical property results indicated a progressive deterioration in strength qualities as the fraction of E-waste used to replace coarse aggregate increased.
3. It can be explained by the fact that adding E trash material to the mix causes less bonding than adding natural coarse aggregate, which significantly reduces the mix's strength characteristics.
4. Whatever the durability characteristics, mixes including up to 15% electronic waste aggregate demonstrated exceptional durability.

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