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Research Article

EXPERIMENTAL STUDY ON THE DUCTILITY BEHAVIOUR OF E-WASTE CONCRETE

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ABSTRACT

The utilisation of the waste generated from the electronic devices adds sustainability for the environment. This study generates a path to find the efficient methods to reutilize the electronic waste in place of the conventional building materials. This paper reports the ductile behaviour of the concrete with E-waste as a partial replacement of fine aggregate due to its compatibility. The percentage of E-waste replacement is 5%, 10%, 15% 20% of the fine aggregate. Polychlorinated Biphenyl (PCB), a powder derived from the waste product from E-waste recycling plants has been utilised to conduct this experiment. Slab panels of size 600 mm × 600 mm × 100 mm were cast and subjected to the concentric load to test the ductile character of the slab specimen. With the incremental load, the deflections were recorded, and the variations among different percentile replacement of E-Waste are depicted graphically. The variation of ductility factor is also found for the different replacement level of E-waste. Reutilization of electronic waste is relatively a boon to the advancements and research over finding alternatives for building materials.

INTRODUCTION

Globally, technological advancements have been occurring every day making the predecessor obsolete with latest upgrades thereby taking the level of competition among the market to a higher level. Indirectly this advancement has also added to the increment in pollution content impacting the environment to a greater extent. The sustainability of the future generation is at stake as this rate of pollution grows from time to time rather decreasing. Discarded materials of the components such as computers, mobile phones, televisions, refrigerators, etc. constitute the E-waste or Electronic waste (RaghatateAtul, 2012). Rapid changes in technology fall in prices and obsolescence has paved the way in the rate of growth in the quantity of electronic waste. With growing concerns over the handling of e-waste all over the world, many countries have taken effective measures in developing an optimum method of dismantling the obsolete electronic devices. Utilisation of E-Waste along the building materials and research are in its embryonic stages, and this study adds to the credibility in using so (Lakshmi and Nagan, 2011).

This study investigates the behaviour of the concrete specimen with partial replacement of fine aggregates with E-Waste materials. E-Waste in a powdered form was replaced for fine aggregates in concrete at various percentiles starting from 5%, 10%, 15% and 20% for M40 concrete and the preliminary strength criterion were recorded (Chen and Hwang, 2006). The results showed the replacement of E-waste showed an effective gain in overall strength of the concrete. The ductility behaviour of the concrete with E-Waste replacement was monitored over corresponding slab panels. Slab panels of size 600 mm × 600 mm were cast and subjected to incremental load after a considerable amount of curing. The reutilisation of E-waste particles in place of fine aggregates of M40 concrete showcased an increment in strength over the conventional specimen (Chen and Hwang, 2006). Investigations were carried out

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to understand the effects of E-waste being utilised to increase the yield strength and ductile behaviour of concrete.

Research significance

The research investigated the feasibility of utilising E-waste plastic particles as partial replacement of fine aggregate. The E-plastic is having very good yielded stability and compressive strength. For the designers, it provides information about the relationship between the deformation capacity and ultimate load for the E-waste replaced concrete mixes.

EXPERIMENTAL INVESTIGATION

The tests were carried out on conventional concrete, and concrete specimens with E-waste as a replacement at 5%, 10%, 15%, 20% and the results were graphically plotted to monitor the behaviour under various strengths at 7.14 and 28 days.

Materials used

The test was carried with the M40 grade of concrete (IS 10262, 2009) at a ratio of 1:1.73:2.13. The following Table 1 shows the proportions of M40 design mix. The tests were carried out by Ordinary Portland cement of 53-grade investigation which is conforming to IS: 12269 (1987) (IS 12269, 2013). The Fineness of cement is 5%. The maximum nominal size of coarse aggregate is 10 mm which is having the specific gravity of 2.74 (IS 383, 1970).

Table 1. Proportions of constituents of the M40 design mix

Constituent Materials	Quantity
Cement	465 kg/m^3
Water	186 kg/m^3
Fine aggregate	805.15 kg/m^3
Coarse aggregate	991.32 kg/m^3

The E-Waste being used is characterized as a loosely discarded, crushed and ground into the powdered form shown in Fig. 1, making it a suitable replacement for fine aggregate among all the building materials used. The specific gravity of the E-Waste is 1.70.

Fig. 1 Electronic wastes crushed as fine aggregate.

Specimen details

Slab size: 600 mm × 600 mm × 100 mm

Grade of concrete: M40

Diameter of reinforcement bar: 10 mm (Table 2)

Table 2. Specimen details

S. No.	Replacement level of FA	No. of specimens
1	0	1
2	5%	1
3	10%	1
4	15%	1
5	20%	1

Casting and testing

The Fig. 2 shows the casting of slab panels of size 600 mm × 600 mm × 100 mm to study the ductile characteristics of the E-waste replaced concrete. Before concreting, the Electronic waste was crushed to the size of 4.75 mm. The preliminary test of fine aggregate was conducted for the crushed E-waste. At the time of concreting, the dry fine aggregate was mixed thoroughly with the crushed E-waste aggregate. The concrete was vibrated with the needle vibrator to avoid honey combing (Seung-Bum and Bong-Chun, 2004). The curing period for the test specimens is 28 days. The specimens were tested under concentric loading and the deflections observed were plotted graphically.

Fig. 2 (a) Casting of slab panels. **(b)** Variations in compressive strength of concrete.

The above Fig. 3 shows the test setup for the slab panel. The centre concentric load was applied on the slab.

The load cell was fixed over the slab, and through hydraulic jack the load was applied. The load was increased successively for every 4 kN till it reaches the ultimate value (IS: 14858, 2000). The dial gauge was fixed beneath the slab to read the deflection.

Fig. 3 Testing of slab panel.

THEORETICAL STUDY

Data

Slab size = 600 mm × 600 mm × 100 mm

Effective depth d =100-20=80 mm

Area of steel = 2 × Π (10^2)/4 = 942.47 mm^2

Ratio of steel =942.47/(600×80) = 0.01963

Calculation of M_r and φ

$f_{cr}=0.7\sqrt{fck}$ = 6.324 N/mm^2

$E_s = 5700 \frac{fcr}{Es}$ = 36.049 N/mm^2

Strain = $\frac{fcr}{Es}$ = 1.754 × 10^{-4}

Assuming depth of neutral axis, x= d/2 =40 mm

Φ = strain / x = 4.3855 × 10^{-6} mm^{-1}

$M_{cr} = f_{cr}$ × D/6 = 6.324 kNm

Finding neutral axis depth after cracking

m = $\frac{280}{fck}$ = 11.2

mρ = 0.056

$$x/d = \sqrt{mp(\text{mp}+2)} - \text{mp} = 0.28$$

x = 22.4 mm

Determining lever arm, M_y and φ on yielding of steel

d-x = 57.6 mm

Yield strain in steel = f_y / E = 1.25 × 10^{-3}

Strain in concrete = yield strain × x / d-x =4.861× 10^{-4}

Z =d-(x/3) = 72.53 mm

$M_y = A_s f_y Z$ = 17.08 kNm

$\phi = \frac{E}{d-x}$ = 21.701 × 10^{-6} mm^{-1}

Determining x, M_u and φ at ultimate condition

From IS 456, Assuming the value of ε_c = 0.0035

$$X = \frac{f_y A_s}{0.36 fckb} = 27.27mm$$

x/d = 0.3408

Lever arm = d- 0.42 x = 68.54 mm

Mu = $A_s f_y Z$ = 16.236 kNm

Φ = concrete strain / x = 1.28 × 10^{-4} mm^{-1}

Ductility factor = φ_u/φ_y = 5.912

RESULTS AND DISCUSSION

The ductility behaviour of the concrete slab panel with E-waste as a replacement of fine aggregate was tested and the results were monitored. The slab panels of size 600 mm × 600 mm × 100 mm was cast and the same being studied for ductility under concentric loading condition. The deflection, stiffness and the variation in the ductile character of the slab panel are discussed as follows Table 3 and Fig. 4.

Table 3. Load vs. deflection of slab panel for various replacement level E-waste

Load (kN)	Deflection (mm)				
	CC	5%	10%	15%	20%
4	0.38	0.23	0.36	0.37	0.34
8	0.60	0.41	0.67	0.51	0.65
12	0.78	0.56	0.94	0.67	0.92
16	1.01	0.75	1.25	0.86	1.17
20	1.29	1.23	1.53	1.02	1.41
24	1.50	1.42	1.79	1.19	1.59
28	1.72	1.56	2.21	1.37	1.80
32	1.90	1.69	2.45	1.57	2.01
36	2.05	1.80	2.75	1.76	2.19
40	2.18	1.73	2.96	1.97	2.37
44	2.36	2.13	3.22	2.15	2.51
48	2.55	2.23	3.44	2.32	2.67

The above Fig. 5 shows the variation of stiffness for different mixes of E-waste concrete slab. The stiffness is increased 15.71% for the 5% E-waste replaced mix compared to the conventional slab. Due to the higher percentage of the replacement levels, the stiffness of the slab is getting reduced. The ductility factor of the E-waste replaced slab specimen is increased by 34.48% compared to the conventional slab specimen. The ductility factor calculated from theoretical study is 5.912 (Jiranggui and Forssberg, 2003; Hai-yong and Schoenung, 2005; Shetty, 2006).

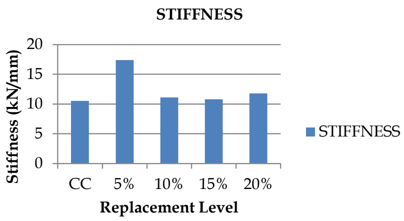

Fig. 4 Variation of stiffness for different mixes of E-waste concrete slab.

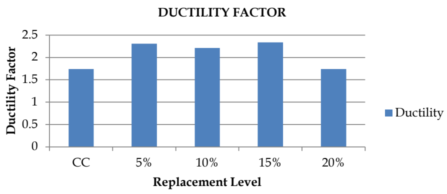

Fig. 5 Ductility factor for different mixes of E-waste concrete slab.

CONCLUSION

1. The load carrying capacity of slab panel with E-waste concrete is increased compared to conventional slab panel

2. The ultimate load of 20% replacement level is 120 kN with the deflection of 8.11 mm. The ultimate load is 15.38% increased over that of conventional concrete. E-waste can be replaced for fine aggregate up to 20%, and the replacement will not affect the capacity of the structural components.

3. The stiffness is increased 15.71% for the 5% E-waste replaced mix compared to the conventional slab. Due to the higher percentage of the replacement levels, the stiffness of the slab is getting reduced.

4. The ductility factor of the E-waste replaced slab specimen is increased by 34.48% compared to the conventional slab specimen. The ductility factor calculated from the theoretical study is 5.912.

5. For the 15% of E-waste replacement having the maximum ductility factor of 2.34 and the maximum displacement of 10.58 mm. More ductile specimen experiences larger deformation.

6. From the present study, it is concluded that the ductility of E-waste replaced concrete is increased compared to conventional concrete.

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