

# **An Experimental Study to Analyze the Strength and Thermal Insulation Properties of E-Waste (FR-4) Concrete with Partial Replacement of Fine Aggregate**

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**ABSTRACT:** Electronic waste or waste electronic and electrical equipment is an emerging issue posing serious pollution problems to the human and the environment. New effective waste management options need to be considered especially on recycling concepts. This research presents the results of an investigation to study the performance of M30 concrete prepared with E-plastic waste (PCB cutting waste) as part of fine aggregate. A detailed experimental study has been done to analyze the durability characteristics of conventional concrete by casting the specimen such as Cubes, Cylinder and Beams and to analyze the steady state condition in a concrete slab. Also the tested were conducted such as Compressive strength test, Split tensile test and Flexural test. From the results we had found that the E-waste aggregate up to 5% weight of the fine aggregate and replacement of cement with fly ash (10% by weight) can be used effectively in concrete and thus results in waste reduction and resources conservation. In this paper, the investigation was made by the partial replacement in the coarse aggregate with E-waste (PCB cutting waste) (FR-4) in the conventional concrete. The durability test such as compressive strength test, split tensile and flexure strength were made and the results analyzed. The investigation is made by casting slab panels of various thickness (1' x 1' x 0'-2", 1' x 1' x 0'-4", 1' x 1' x 0'-6", 1' x 1' x 0'-8" & 1' x 1' x 0'-10") with same area and different temperature. These panels were allowed for curing of 28 days and tested in a closed chamber. The heat was transferred from one part of chamber to another chamber through the slab element. Then the heat transformation and U-factor will be calculated and the insulation properties of the e-waste concrete with conventional concrete

## **I. INTRODUCTION**

Electronic and Electrical waste, popularly known as e-waste products, do not decompose or rot away. The information and communication technology (ICT) sector in the last twenty years or so in India has revolutionized life of one and all, ratcheting a viral effect on electronic manufacturing industries leading to phenomenal growth in terms of both, volume and applications. Digital development has become the new mantra having its all engulfing footprints everywhere. The booming usage of electronic and electrical equipment has created a new but very dangerous stream of waste, called "electronic-waste", or simply known as e-waste.

## **II. E-WASTE AN OVERALL VIEW**

According to a report of Confederation of Indian Industries, the total waste generated by obsolete or broken down electronic and electrical equipment in India has been estimated to be 1,46,000 tons per year (CII, 2006). The results of a

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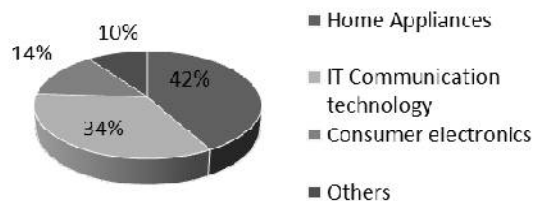
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field survey conducted in the Chennai, a metropolitan city of India to assess the average usage and life of the personal computers (PCs), television (TV) and mobile phone showed that the average household usage of the PC ranges from 0.39 to 1.70 depending on the income class (Shobbana Ramesh and Kurian Joseph, 2006). In the case of TV it varied from 1.07 to 1.78 and for mobile phones it varied from 0.88 to 1.70. The low-income households use the PC for 5.94 years, TV for 8.16 years and the mobile phones for 2.34 years while, the upper income class uses the PC for 3.21 years, TV for 5.13 years and mobile phones for 1.63 years. Although the per-capita waste production in India is still relatively small, the total absolute Volume of wastes generated will be huge. Further, it is growing at a faster rate. The growth rate of the mobile phones (80%) is very high compared to that of PC (20%) and TV (18%).

## Overall view of e-waste in india



### III. THERMAL INSULATION OVERVIEW

The thermal insulation varies inversely with density, light weight concrete has better thermal insulation properties than the normal conductivity for conventional Concrete. The thermal conductivity for conventional concrete is  $20.8 \text{ w/m}^\circ \text{C}$ . Lightweight Concrete is generally lesser than the conventional concrete. The power supply for the heat application a micro processor board is used which is the board function of (Programmed). The heat energy is applied at the one side and it is measured by the sensors. While on the other side, the thermal observed (overall heat transfer coefficient) measured by the sensor using the steady state measurement technology, the thermal transfer is calculated. Thermal Conductivity for FR-4 is  $0.29 \text{ w/m}^\circ \text{K}$  to  $1.059 \text{ w/m}^\circ \text{K}$ .

### IV. METHODOLOGY & FORMULA

The concrete state module are casted for the sizes of 300mm X 260mm with the variation in the thickness 2'', 3'', 4'' and 5''. The thickness variation of the state module represents the density of the concrete. After the curing, the state module is being kept in the middle of the closed chamber. The occupancy sensors are fixed in the sides of the state module to measure thermal energy liberation.

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Fig.1. (a) Setup



Fig.1. (b) Display unit

An incandescent lamp is an extremely inefficient light source. A 100 watt bulb is 2.1% efficient. In other words, it produces about 2 watts of light and 98 watts of heat make ESU 200 incandescent 'Bright light'. The heat mass pass through the medium (Slab of conventional concrete and e-waste concrete with the size of 0.3m X 0.3m area) with various thickness Fig. 1 (a) and (b) shows the experimental setup and display unit. The calculation part is carried out by the following equation.

## ENERGY

Energy = power x time.

Unit: watt sec

In purpose, energy unit is KWH. 1 joule= one watt sec

$Q = KA\Delta T / l$

## V. EXPERIMENTAL DETAILS

### MATERIALS

#### 1. CEMENT:

43 grade of Ordinary Portland cement was used. The property of the Cement is as show in table 1.

Table 1: Properties of 43 grade Cement

Physical Properties	Obtained values
Compressive strength	43 Mpa
Fineness	5%
Initial setting time	30 minutes
Final setting time	600 minutes
Standard consistency	29 %

#### 2. FINE AGGREGATE:

#### RIVER SAND:

River sand was used as fine aggregate. The size of the aggregate is 4.75 mm and lower. The property of the river sand is as show in table 2.

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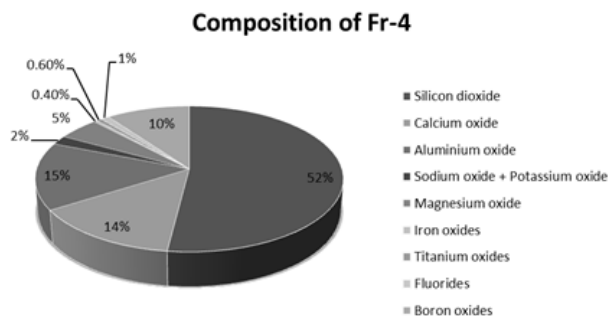
**Figure 2:** Fine Aggregate

**Table 2:** Properties of Fine aggregate

Physical Properties	Obtained values
Size	Passing through 4.75mm
Bulk density	1721 kg/ m <sup>3</sup>
Fineness modulus	2.9
Specific gravity	2.65

### 3. E-WASTE:

In our experimental study we have decided to use PCB cutting waste (FR-4) as a fine aggregate (partial replacement). FR4 is a grade designation assigned to glass-reinforced epoxy laminate sheets, tubes, rods and printed circuit boards (PCB). FR-4 is a composite material composed of woven fiberglass cloth with an epoxy resin binder that is flame resistant (self-extinguishing). "FR" stands for flame retardant, and denotes that safety of flammability of FR-4 is in compliance with the standard UL94V-0. FR-4 is created from the constituent materials (epoxy resin, woven glass fabric reinforcement, brominated flame retardant, etc.) by NEMA in 1968. FR-4 glass epoxy is a popular and versatile high-pressure thermoset plastic laminate grade with good strength to weight ratios.



**Figure 3:** Composition of Fr-4

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Figure 4: FR-4

Table 3: Properties of e-waste (FR-4)

Parameter	Value
Specific gravity/density	1,850 kg/m <sup>3</sup> (3,120 lb/cu yd)
Water absorption	-0.125 in < 0.10%
Temperature index	140 °C (284 °F)
Rockwell hardness	110 M scale
Compressive strength – flatwise	> 415 MPa (60,200 psi)

#### 4. COARSE AGGREGATE:

Crushed Blue metals obtained from a local quarry were used as Coarse aggregate. The properties of the coarse aggregate are shown in table 4.

Table 4: Properties of Coarse aggregate

Physical Properties	Obtained values
Size	Passing through
Water absorption	0.45
Fineness modulus	7.6
Specific gravity	2.68
Impact value	14.5
Crushing value	19

#### CONTROL MIX AND MIX PROPORTION

Mix design for M30 grade concrete according to BIS method (IS 10262:2009). The mix proportion for concrete is shown in the table 5.

Table 5: Control mix

Cement kg	Fine Aggregate kg	Coarse Aggregate kg	Water
380	711	1283	160
1	1.87	3.37	0.42

#### MIX SPECIFICATION

The control mix were prepared for the M30 grade of concrete and E- waste is added in various percentage of combination along with the fine aggregate and it is tabulated in table 6.

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**Table 6: Mix Specification**

Mix proportion	Control mix					
	A	B	C	D	E	F
Proportion of E-waste + 10% of fly ash	0%	5%	10%	15%	20%	25%
Mix proportion	Control mix					
	G	H	I	J	K	-
Proportion of E-waste + 10% of fly ash	30%	35%	10%	15%	20%	-

## VII. TESTS ON CONCRETE

From the above observation and results of materials such as cement, Fine aggregate, e-waste, coarse aggregate and water the required design mix was prepared and the final ratio was 1:1.71:2.70 with the water cement ratio of 0.44. Then the specimens such as Cubes ( 150mm x 150mm x150mm), Cylinder (150mm diameter & 300mm length) and Beam (100mm x 100mm x 500mm) was casted to evaluate the Compressive strength , Split tensile strength and Flexural strength of the concrete.



**Figure 5: Casted Specimen**

### Compressive Strength

To evaluate the Compressive strength of the concrete we have casted 9 cubes for each percentage of e-waste with aggregate. Therefore totally 66 cubes was caste and allowed for curing process.. Then the cubes are tested for the compressive strength using CTM machines. The average values of samples from 7 days, 14 days and 28 day are tabulated in table

### Split Tensile Test

To determine the Split tensile of the concrete we have casted 33 numbers of cylinders of 300mm length and 150mm diameter

### Flexural Strength Test

To evaluate the flexural strength we have casted 33 numbers of beams of size 100mm x 100mm x 500mm and allowed for curing of 7 days, 14 days and 28 days.

## IX. RESULT AND DISCUSSION

- Table7 and Figure 6 represent the compressive strength of the respective specimens. The maximum strength of the specimen was identified and it was 10% of E-waste in Fine aggregate when compared to the 0% E-waste. And also we have observed that when increasing the FR-4 in fine aggregate upto 25% the overall concrete mixture absorbs



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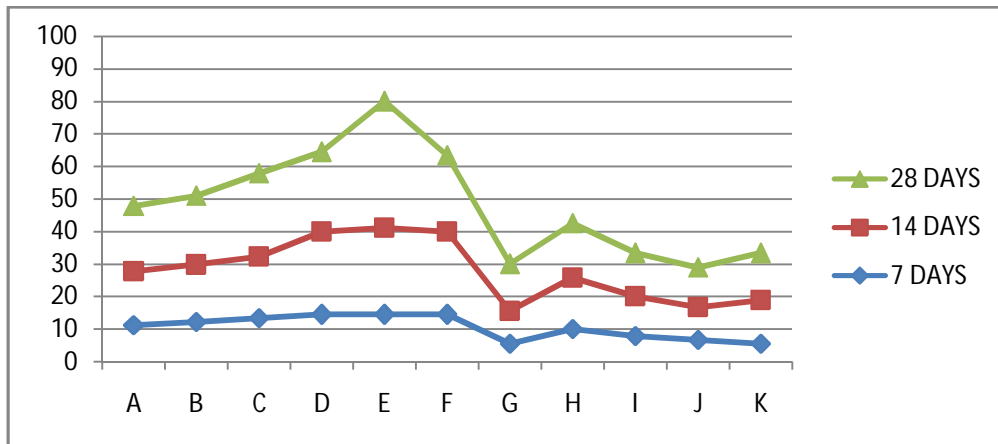
excess than the calculated value. An important thing is the gradual increase of FR-4 in fine aggregate decrease weight of the Concrete i.e. Light weight concrete.

**Table 7:** Compressive Strength of The Control Mix M30 Grade Concrete Specimen

MIX PROPORTION	CONTROL MIX					
	A	B	C	D	E	F
Proportion of E-waste + 10% Fly ash	0%	5%	10%	15%	20%	25%
7 DAYS	11.21	12.22	13.33	14.44	14.44	14.44
14 DAYS	16.46	17.56	18.89	25.56	26.67	25.56
28 DAYS	20.10	21.11	25.56	24.44	38.87	23.33

MIX PROPORTION	CONTROL MIX				
	G	H	I	J	K
Proportion of E-waste + 10% Fly ash	30%	35%	40%	45%	50%
7 DAYS	5.56	10	7.78	6.67	5.56
14 DAYS	10	15.78	12.22	10	13.11
28 DAYS	14.44	16.67	13.33	12.22	14.44

Compressive strength in N/m<sup>2</sup>



**Figure 6:** Compressive strength chart

- The casted panels of slab are tested in well closed container be the length of 1.5m, the medium (slab) are placed centrally and the heat energy produced by 200watts incandescent bulb. The observation were shown below in Table 8 and Table 9 for various thickness and Fig. 7. (a) and (b) shows the graph plot.

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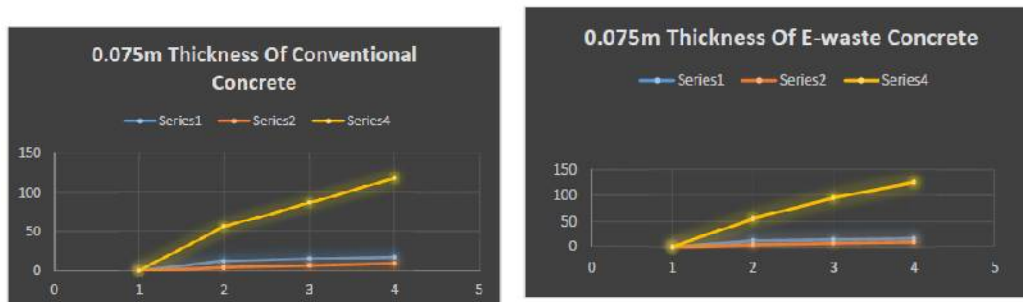
**Table 8.** For Conventional Concrete

S.No.	Area (m <sup>2</sup> )	Thick-ness (m)	Time (min-utes)	Q/3600 (kj)	ΔT (°C)	Thermal Conductivity K Value	U values	Ave- rage K	Ave- rage U
1.	0.09	0.050	5	60	11	3.032	60.64	4.933	98.30
			10	120	13	5.127	102.54		
			15	180	15	6.667	133.30		
2.	0.09	0.075	5	60	12	4.170	55.58	6.942	91.93
			10	120	14	7.290	95.21		
			15	180	16	9.380	125.00		
3.	0.09	0.100	5	60	14	4.760	47.64	8.068	80.68
			10	120	16	8.330	83.30		
			15	180	18	11.110	111.10		
4.	0.09	0.125	5	60	20	4.170	33.35	7.372	59.08
			10	120	22	7.570	60.59		
			15	180	24	10.410	83.30		
<b>Overall Average</b>								<b>6.829</b>	<b>82.50</b>

**Table 9.** E-Waste Concrete

S.No.	Area (m <sup>2</sup> )	Thickness (m)	Time (min-utes)	Q/3600 (kj)	ΔT (°C)	Thermal Conductivity K Value	U values	Ave- rage K	Ave- rage U
1.	0.09	0.050	5	60	10	3.340	66.70	5.045	100.85
			10	120	13	5.130	102.54		
			15	180	15	6.665	133.30		
2.	0.09	0.075	5	60	12	4.168	55.58	6.502	86.63
			10	120	15	6.515	86.87		
			15	180	17	8.824	117.65		
3.	0.09	0.100	5	60	14	4.764	47.64	7.710	77.10
			10	120	17	7.841	78.41		
			15	180	19	10.526	105.26		
4	0.09	0.125	5	60	21	3.970	31.76	6.723	53.79
			10	120	24	6.942	55.54		
			15	180	27	9.259	74.07		
<b>Overall Average</b>								<b>6.495</b>	<b>79.59</b>





**Fig. 7. (a)** 0.075m thickness of conventional concrete **Fig. 7. (b)** 0.075m thickness of e-waste concrete

## X. CONCLUSION

E-waste concrete U factor values are more than the conventional concrete slab with the same area and different thickness. It shows that the R value (heat resistance) for e-waste concrete is lesser than the conventional concrete and the energy stored in the body of e-waste concrete is also lesser than the conventional concrete. So we can prefer e-waste by replacing with fine aggregation portion by 20 %.By adding FR-4 to the fine aggregate, it decrease the weight of the concrete and it can provide fine strength and durability like conventional concrete.

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