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Compressive Strength of Concrete Incorporated with E-fiber Waste

P. Gomathi Nagajothi[1], Dr. T. Felixkala[2]

[1]*Research Scholar, Dept of Civil Engg., St. Peter's University, Chennai, India*
[2]*Professor and Head, Dept of Civil Engg., Dr. MGR Educational and Research Institute, University, Chennai, India*

gomathinagajothi@yahoo.co.in
kalastrut@yahoo.co.in

***Abstract*--** **Rapid growth of technology, up gradation of technical innovations and a high rate of obsolescence in the electronics industry have led to one of the fastest growing waste streams in the world, simply called as E-waste. Improper disposal of E-waste can cause serious threats to human health and environment. This paper examines the possibility of reusing the non metallic portions of E-waste in concrete to increase its mechanical properties compressive strength test result shows concrete containing E-fiber exhibits a good strength gain than the control mix concrete.**

***Keywords*--** **E-fiber waste, PCBs, environmental issues, concrete and compressive strength**

I. INTRODUCTION

New electrical and electronic products have become an integral part of our daily lives providing us with more comfort, security, easy and faster acquisition. Due to technological growth, there is a high rate of obsolescence in the electronic equipments which leads to one of the fastest growing waste streams in the world. This waste stream consists of end of life electrical and electronic equipment products. The European Union (EU) defines this new waste stream as 'Waste Electrical and Electronic Equipment' (WEEE). Since there is no definition of the WEEE in the environmental regulations in India, it is simply called 'E-waste'. According to Gui et al (2003),"WEEE is diverse and complex in terms of materials and components as well as the manufacturing process. Characterization of this waste stream is of paramount importance for developing a cost effective and environmental friendly recycling system**"**.

Kang et al (2005), discussed the various possibilities of recycling the plastic such as coke oven process, thermal recycling, mechanical recycling etc.

They concluded that the major challenge for the plastic waste recycling is the need for a continuous and stable supply of materials to be recycled and lack of cost effective technologies for recycling. Lakshmi and Nagan(2011) suggested the use of E-Plastic particles as partial replacement of coarse aggregates in M20 concrete with and without fly ash. The results revealed that 20% replacement of e-waste as coarse aggregate in concrete shows improvement in compressive and tensile strength. Atul (2012) suggested the use of plastic (polyethylene) bags in concrete to improve its mechanical properties. He found experimentally that up to 0.8% addition of polyethylene pieces to concrete shows improvement in tensile strength. Taha et al(2009) and park et al.(2004) carried out works to examine the possibility of reusing waste recycled glass in concrete and construction applications, as an alternative solution to the growing quantity of waste recycled glass as well as to meet the demand of natural aggregates. Tung-chai Ling and chi-sun Poon suggested the feasibility of using treated CRT glass as 100% substitution of fine aggregate in making heavy weight concrete, and untreated glass should be limited to below 25% due to its potential lead leaching. Huang et al (2006) assessed the feasibility of utilizing resin powder and glass fibers recycled from PCB waste as a partial replacement of fine aggregates in cement mortar. They suggested PCB resin powder replacement to less than 10% and addition level of glass fiber to less than 2% to achieve the needed strength. Numerous researches are being conducted to find the use of e-waste in concrete not only to improve its properties but also to find solution for a safer and economical e-waste disposal method.

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II. Research Significance

Globally about 20-50 million tones of e-wastes are disposed off each year, which accounts for 5% of all municipal solid waste. When this waste ends up in landfill, it creates leaching problem which in turn contributes to the pollution of ground water resources. According to Central Pollution Control Board (CPCB), the total e-waste production in India was about 400,000 tons in 2009 which has reached 800,000 tons in 2012, Out of which only 19,000 tons was recycled officially in 2009. A report of the United Nations predicted that by 2020, e-waste from old computers would jump by 500 per cent on 2007 levels in India. Additionally, e-waste from discarded mobile phones would be higher about 18 times in India than 2007 levels. Such predictions highlight the urgent need to address the problem of e-waste in developing countries like India, where the collection and management of e-waste and the recycling process is yet to be properly regulated. Printed circuit board (PCB) is a very usual part of almost every electronic product. The vast annual production of PCB waste creates environmental concerns because of the leaching of toxic chemicals into landfills when it is dumped and incineration produces dioxins and furans which persist in the environment for a longer period. Due to the task of dealing with the disposal of non cyclable parts and the expense incurred in dealing the toxic waste, recycling is not willingly done. Hence it is necessary to arrive at a cost effective and environmental friendly solution for the disposal of PCB waste. Accordingly, this paper examines the feasibility of utilizing the non metallic portion of printed circuit boards in concrete making. In particular, waste strips from the cutting of printed circuit boards are taken for the work.

III. E-Waste An Overview

E-waste encompasses ever growing range of obsolete electronic devices, such as computers, servers, main frames, monitors, TVs and display devices, cellular phones, calculators, audio and video devices, printers, scanners, copiers, refrigerators, air conditioners, washing machines, microwave ovens, electronic chips, processors, mother boards, printed circuit boards (PCBs), industrial electronics such as sensors, alarms etc..,Electronic and electrical equipments are made up of several components, many of which contains toxic substance, like lead, chromium, mercury, beryllium, cadmium, acids and plastics etc.

These toxic substances can have highly adverse impacts on human health and environment, if not handled properly. Often these hazards arise due to improper recycling and rudimentary processes used for disposal of E-waste. For example, improper breaking or burning of printed circuit boards (PCBs) and switches may lead to the release of mercury, cadmium and beryllium which are highly toxic to human health. Another dangerous process is the recycling of components containing hazardous compounds such as halogenated chlorides and bromides used as flame-retardants in plastic, which form persistent dioxins and furans on combustion at low temperatures. A study on burning printed wiring boards in India showed alarming concentrations of dioxins in the surroundings of open burning places reaching 30 times the Swiss guidance level. About 70% of the heavy metals especially mercury and cadmium, in landfills come from electronic waste. Consumer electronics is the root cause for the presence of about 40% of the lead in landfills. These toxins can cause brain damage, allergic reactions and cancer.

IV. Scope Of Investigation

New waste management options are needed to divert End-Of-Life (EOL) electronics from landfills and incineration. Increasing the need for landfills is a burden to our environment. Also with the storage of landfill capacity and an increased concern about environmental quality, newer waste treatment methods are desired. While developing a successful diversion strategy, it must be based on its economic sustainability, technical feasibility and a realistic level of social support from the society. Reuse of EOL electronic product in construction industry is one of the environmentally friendly aspects. Hence the current study is aimed at utilize E-waste in concrete for understanding some of the mechanical properties of E-waste added concrete. Especially to compare the compressive strength of M20 grade of conventional concrete with E-fiber waste added concrete.

V. Materials And Methods

The most commonly available Portland cement of 43 grades confirming to IS 8112-1989 was selected for the investigation. The cement used was dry, powdery and free from lumps. All possible contact with moisture was avoided while storing cement. Concrete mixes were prepared using locally available river sand.

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Physical properties like specific gravity, water absorption, and fineness modulus were conducted. Sieve analysis was carried out for fine aggregate and the results are presented in Table.1

Table 1
Sieve analysis results of coarse aggregates

Sieve Size (mm)	% Passing
25	100
20	98.1
16	89.2
12.5	64
10	14.23
6.3	1.47
4.75	00

Table 2
Sieve analysis results of fine aggregates

Sieve Size	% Passing
4.75 mm	97.2
2.36 mm	90.0
1.18 mm	69.0
600µm	40.6
300 µm	14.6
150 µm	4.2

Ordinary blue metal was used as coarse aggregate in concrete mixes. Stones are generally coarse to medium grained, holocrystalline and equigranular rocks. They generally posses all the essential qualities of a good building stone showing very high crushing strength, low absorption value and least porosity. Sieve analysis for coarse aggregate was done and percentage passing at different sieves is given in Table.2. In general, water fit for drinking is suitable for mixing concrete. Impurities in the water may affect concrete setting time, strength, shrinkage or promote corrosion of reinforcement. Hence locally available purified drinking water was used for the present work. E-fiber waste was collected locally from a PCB cutting unit in the form of long chips. Copper strips present at the bottom of PCB were removed manually and broken in to half inch length pieces. Specific gravity, water absorption, crushing value and impact value were tested for E-fibers and the results are given in Table 3.

Superplasticiser was added to 1% of cement mass according to supplier prescription. With higher dosage, delay in hydration and hardening may occur together with apparent early setting of the fresh mix.

Table 3
Physical Properties of Natural Aggregates and E-fiber Waste.

Properties	Fine aggregate	Coarse aggregate	E-fiber waste
Specific gravity	2.65	2.7	1.09
Water Absorption (%)	1.2	0.65	0.2
Color	Dark	Dark	White and Ivory
Shape	-	Angular	Angular
Crushing value (%)	-	26.8	<2
Impact value (%)	-	24.9	<2

VI. Details Of Concrete Mix

The mixes were designated with the grade of concrete and the type of fine aggregates used. IS method of concrete mix (shetty, 1986) was used to achieve a mix with cube strength of 20 MPa. Mix proportions were arrived and E-fibers were added to the concrete mix with a w/c ratio 0.5. The percentage of E fibers added by weight was 0, 0.5, 1.5and 2.5. Control mix concrete and modified concretes with varying percentage of E-fiber waste are presented in Table.4

Table 4
Details of Concrete Mix

Mix Specification	Control Mix	Modified Mix 1(A)	Modified Mix 2 (B)	Modified Mix 3 (C)
Proportion of E-fiber waste added by weight (%)	0	0.5	1.5	2.5

Water curing is the most effective method of curing. It produces the highest level of compressive strength (Kala, 2012). If a concrete is not well cured, it cannot gain the properties and durability to endure long life service. A proper curing greatly contributes to reduce the porosity and dry shrinkage of concrete and thus achieves higher strength and greater resistance to physical and chemical attacks in aggressive environments. With these results in mind, proper curing was done for specified days after the specimens are removed from the moulds.

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VII. Experimental Procedure

A. Preparation of test specimens

The aggregates were soaked in part of the mixing water for about 5 min, prior to the start of the mixing operations. Coarse aggregate was placed in the drum first and batch water was increased to account for the adsorption of the aggregates during rotation. After mixing for 10 to 15 sec, the fine aggregates with correct proportions were introduced and mixed in for a period of 15 to 20 sec. This was followed by E-fiber waste chips and water. Finally cement was added. The mixture was allowed to mix for a total time of 60 sec from the placing of coarse aggregate. Superplasticiser was added 30 secs after addition of all the other materials during the mixing. Cube specimens were cast for studying the variation in strength properties due to the addition of E-fiber waste to the concrete. After one day the demoulded specimens were cured in water. The dimensions and the number of specimens used for the present study are listed in Table. 5

Table 5
Details of Test Specimens

Test Details	Shape and Dimensions of the Specimens	No: of Specimens Tested
Compressive strength	Cube: 150mm X 150 mm X 150 mm	12

B. Testing of specimens

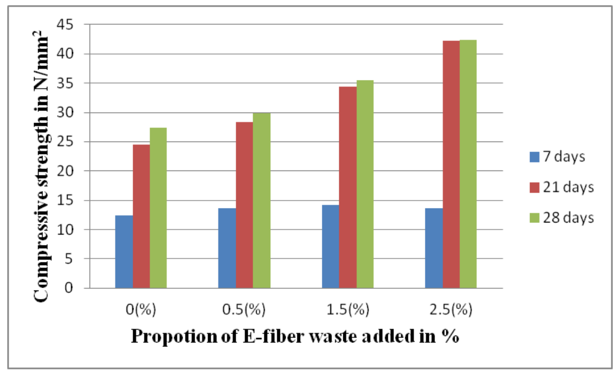
Compressive strength was determined using compression testing machine (CTM) of 600 kN capacity. Compressive strength test was carried out on 150mm X 150 mm X 150 mm cube specimen for which three cubes were prepared for each mix. Strength of each cube was evaluated after 7, 21 and 28 days respectively. Results of compressive strength test are presented in the Table.6

Table 6
Compressive Strength Test Results

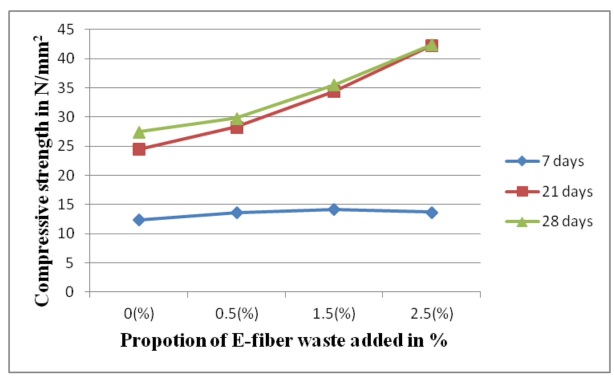
Compressive Strength in N/mm^2				
% of E fiber waste added	0(%)	0.5(%)	1.5(%)	2.5(%)
7 days	12.36	13.6	14.2	13.7
21 days	24.5	28.3	34.4	42.2
28 days	27.43	29.8	35.5	42.4

VIII. Result And Discussion

According to the compressive strength result presented in Table 6, it is clear that the compressive strength of concrete goes on increasing with increase in percentage of E-fiber waste.



The addition of E-fiber waste shows increase in compressive strength gradually. Hence higher percentage of E-fiber waste can be utilized in the construction field without compromising strength. And also this may be one of the economical ways for the disposal of E-waste without creating any environmental issues.



IX. Conclusion

A study on the effect of addition of E-fiber waste to concrete in different percentages for 0.5 water-cement ratio subjected to water curing is conducted to determine the characteristic compressive strength of the concrete cubes.

Based on the experimental result the following points are summarized with regard to the effect of E-fiber waste on the properties of concrete.

- Compressive strength of concrete is increased with the addition of E-fiber waste constantly.
- E-fiber waste concrete with 2.5% addition has achieved a characteristic compressive strength nearly twice that of the conventional concrete after 28 days curing.

Thus it is concluded that the use of E-fiber waste in concrete can be possible to increase the compressive strength of concrete. From the above discussion it is identified that the use of E-waste in concrete is possible to improve its mechanical properties and can also be one of the economical ways for their disposal in an environment friendly manner.

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