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Application of Recycled Coarse Aggregates and E-Waste for Pavements with Low Traffic

Rajiv Gupta[a], Harish Puppala[b], Nakka Rajesh[c]
[q]*Senior Professor, Civil Engineering Department, Birla Institute of Technology and Science Pilani, India-333031*
[b,c] *Post graduate student, Civil Engineering Department, Birla Institute of Technology and Science Pilani, India-333031*

Abstract: *Huge quantities of construction wastes, demolition, and electronic wastes are being generated these days in many of the countries and the disposal of them has become a serious problem. This study is an integrated experiment in which different combinations of e-wastes and recycled coarse aggregate together are used as a substitute of conventional aggregate. Recycled aggregates from site-tested concrete specimens were collected and are integrated with the e-waste by altering the proportions of these wastes. The compressive strength of M20 mix designed is assessed by casting cubes and the flexural strength by prisms. This study is carried out to ensure the usage of integrated- waste and the recycled coarse aggregate as a replacement of coarse aggregate. Experimental study is carried out to find if the e-waste strips can be used as the reinforcement instead of steel. Results are checked against the standards of IRC to use for the sub-grade of the pavement.*
Keywords: *e-waste (electronic waste), Conventional aggregate (CA), Recycled coarse aggregate (RCA), compressive strength, IERA (Integrated e-waste and recycled coarse aggregate), Indian road congress IRC.*

I. Introduction

Due to the unprecedented growth in the industries all over the world there is a depletion of natural aggregates and during this process enormous amount of waste material from construction and demolition activities is being generated. The disposal of this waste is a significant problem as it requires huge space for its disposal and pollutes the environment. The utilization of recycled coarse aggregate in the production of concrete is one of the ways to diminish this problem. Due to the continuous use of natural resources, like river sand for construction the depth of river bed is increasing which results in drafts and also change in the climatic conditions. The need of hour is to protect and preserve the natural resources like sand and stones.

Several research activities were carried out to prove that recycled concrete aggregate could be a reliable alternative for aggregates in production of concrete. The concrete produced by using RCA should be used only for the non-structural applications [1].Since the strength of concrete is dependent on the type of coarse aggregate used there is a great need to know the characteristics of RCA. As the properties of RCA used in several research works are not same the optimum dosage of the RCA is still a fuzzy number. For the applications of medians, sidewalks, curbs and bridge foundations processed RCA can be used [2].Recycled coarse aggregate normally has higher water absorption and lower specific gravity [3]. The workability of RCA is less as the water absorption of the aggregate is more when compared with the conventional aggregate [3].The density of recycled coarse aggregate used is lower than the density of normal aggregate. Porosity of recycled coarse aggregates is also much higher than those of natural aggregate [4]. The flexural strength drops by 13% with the 100% replacement of coarse aggregate [5].The strength of RCA is reported to be less by about 10% compared to normal concrete [6].

The second type of waste used in this study is e-waste whose production is being increased due to the growth in population, which leads to the upswing of e-waste production. The electrical appliances after use are treated as waste. Every year million tons of electronic waste from obsolete computers and other electronic articles are being generated. Characterization of e-waste is of paramount importance for developing a cost effective and environmental friendly recycling system.

The European community directive has classified the electrical appliances into large household appliances, Small household appliances, Toys, leisure and sports equipment, Electrical and electronic tools, IT and telecommunication equipment, Medical devices, Consumer equipment, Monitoring and control instruments, Lighting equipment, Automatic dispensers [7].E-waste contains numerous types (more than 1000 different) of substances and chemicals creating serious human health and environment problems if disposed in the open environment[8].It was estimated that the e-waste inventory based on this obsolescence rate and installed base in India for the year 2005 as 146180.00 tones. That was expected to exceed 8, 00,000 tons by 2012. Mega cities like Delhi, Mumbai and Bangalore contribute most of the e-waste generate in India. A tradition of recycling the electronic waste has started in these cities. Sixty five cities in India generate more than 60% of the total e-waste generated in India. Ten states generate 70% of the total e-waste generated in India. Maharashtra ranks first followed by Tamil Nadu, Andhra Pradesh, Uttar Pradesh, West Bengal, Delhi, Karnataka, Gujarat, Madhya Pradesh and Punjab in the list of e-waste generating states in India [9].The compressive strength of M20 mix concrete prepared by replacing 20% of coarse aggregate reduces by 23.6% when compared with the standard mix [10].To avoid long term detrimental effects concrete can be prepared with 12% replacement of coarse aggregate [10].On the addition of plastic fibers the compressive strength of the mix increases[11]. Compressive strength of nearly twice the strength of the standard mix is achieved upon addition of 2.5% of e-waste which are in the form of fibers [11].Upon 20% replacement of coarse aggregates by e-waste the compressive strength of the mix dropped by 33.7% [12].

The objective of this study is to show that the integration of recycled coarse aggregates with e-waste in concrete is both economically viable & technically feasible.

II. Methodology

Among the several available varieties of e-waste Printed Circuit Boards (PCB) are selected to be used as aggregate in this research. The e-waste thus collected is cut into pieces by using machinery. The use of recycled materials in construction applications the most attractive option because of the large availability. Since many research works were carried out using Recycled coarse aggregate as a partial replacement of coarse aggregate .In this study an attempt is made to show the integrated e-waste and the recycled coarse aggregates 100% replacement of conventional aggregate is a viable solution to the problem of recycling costs and high disposal costs.

Environment Impact Of E-Waste Recycling:

E-waste contains lead, mercury, cadmium and many toxic substances which leach into soil and water polluting the water bodies. If this happens in a large scale the water body will become unfit for consumption.

Environmental Impact Of Recycled Coarse Aggregate:

The processing of recycled coarse aggregate on a large scale produces dust and noise. Few indirect pollution activities such as smoke from the transit used to transfer the recycled coarse aggregate may also take place.

Scope Of Investigation:

Due to the increase in the generation of the e-waste and the recycled coarse aggregate the landfill has become a serious problem as the disposal at random places causes pollution. Therefore the waste management technique has to be adopted to dispose the wastes. Several factors such as economic sustainability, technical feasibility and a realistic level of social support for the disposal are to be considered for the development of such management system. One aspect of the strategy should include recycling and reuse of EOL (End of Life) electronic products in construction field.

The current study is aimed to compare compressive strength of M20 grade of conventional concrete with IERA concrete in which different proportions of e-waste particles and RCA are used as 100% replacement of coarse aggregate. Based on the results obtained, the optimum composition is considered to be as best for the application.

III. Materials Used In This Study:

Cement: PPC cement (ULTRA TECH) is used throughout the experimental study. 8% as fineness, initial setting time of 28 min, final setting time of 550 min, Normal consistency of 36%, specific gravity of 3.15

Fine aggregate: Natural sand conforming to Zone I with a specific gravity 2.416 was used. The maximum size of fine aggregate was taken to be 4.75 mm. The testing of sand was done as per Indian Standard Specifications IS: 383-1970.

Coarse aggregate: In this study two types of aggregates are used viz. e-waste and the recycled coarse aggregate .The combination is termed as IERA for the convenience.
(Integrated e- waste and the recycled coarse aggregate)

Recycled coarse aggregate: Site tested concrete cubes are collected and they are broken manually. The aggregates thus broken are passed through the 20mm sieve and the aggregates thus retained on the 10mm sieve are used as recycled coarse aggregates .Conventional aggregates used in the preparation of the 0 % replacement has a specific gravity of 2.70 and the recycled coarse aggregate has a specific gravity of 2.103 .

E-waste: Generally the electrical components whose life is over are considered as the e-waste but in this study only PCB boards are used as e-waste. Since the e-waste collected was of irregular shape and irregular size they are cut by using marble cutter and the processed e-waste is then passed through the 20 mm sieve and the e-waste retained on the 10mm sieve is collected and using in the preparation of concrete mix. E-waste thus used in the study has specific gravity of 2.056

Water: Potable water is used for mixing and curing. Water cement ratio of 0.5 is adopted in this study.

Concrete Mix Design:
All the calculations are done per meter cubic.M20 mix design is done as per the standards of IS 456.As the mix prepared contains an integrated coarse aggregate the corresponding weights per meter cubic of concrete for different proportions are represented in table 1.

Proportions Of Materials For Different Combinations: The coarse aggregate used in this study is the combination of e-waste and the recycled coarse aggregate. In this study different combinations of e-waste + recycled coarse aggregate are prepared and are tested for compression and flexural. The proportions of materials in Kgs for 1 m^3 of concrete used for different combinations are shown in the table 1

Combination 1 (C1): Conventional aggregate; Standard mix
Combination 2 (C2): 5% e-waste + 95% recycled coarse aggregate as replacement of conventional aggregate.
Combination 3(C3): 10% e-waste +90 % recycled coarse aggregate as replacement of aggregate.
Combination 4 (C4):15% e-waste + 85 % recycled coarse aggregate as replacement of aggregate.
Combination 5 (C5): 20% e-waste +80% recycled coarse aggregate as replacement of aggregate.

Table 1: Proportions of material for different combinations

Combination	Cement	Water	RCA	e -waste	CA	Fine aggregate
C1	394	197	0.00	0.00	988.52	753.50
C2	394	197	731.45	37.64	0.00	753.50
C3	394	197	692.96	75.27	0.00	753.50
C4	394	197	654.46	112.91	0.00	753.50
C5	394	197	615.96	150.55	0.00	753.50

Results Of Compressive Strength: The compressive strength tests for the specimens were performed at 28-days in accordance with the provisions of the Indian Standard Specification IS: 516-1959

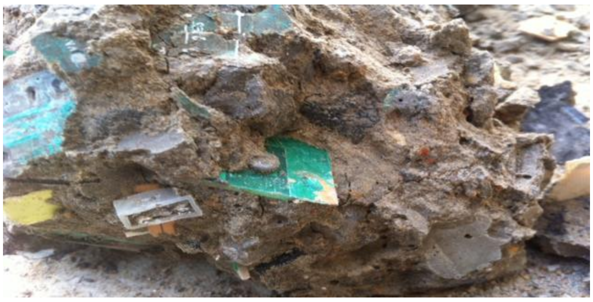
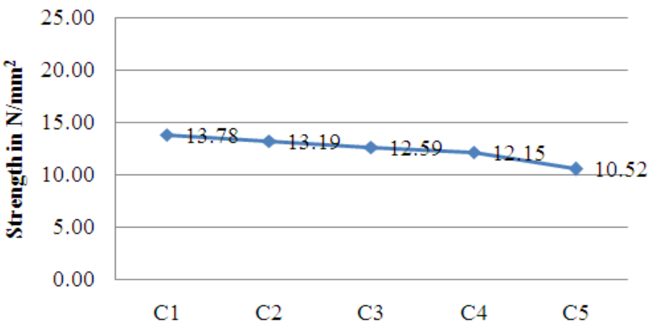


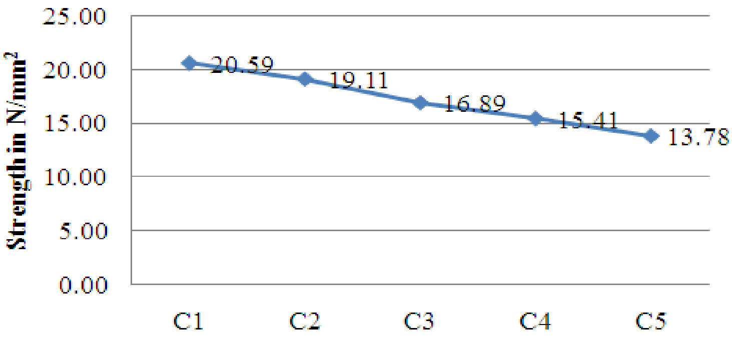
Fig.1: Tested cube sample

7 Day Compressive Strength: The compressive strength of the specimens are evaluated in N/$mm^2$for 7 days and is represented in Graph-1.



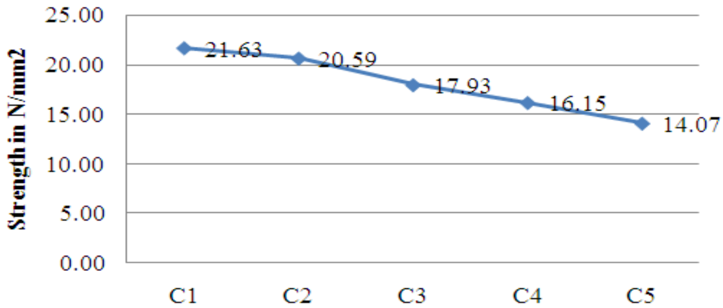
Graph-1:7 Day compressive strength for different proportions

14day Compressive Strength: The compressive strength of the specimens is evaluated after 14days of curing. The results of 14day compressive strength in N/mm^{2}are as shown as in graph 2.



Graph-2: 14 Day compressive strength for different proportions

28day Compressive Strength: The compressive strength of the specimens is evaluated after 28days of curing and the results are shown as in the Graph-3. The tested specimen after 28 days of curing is shown in the figure 1.

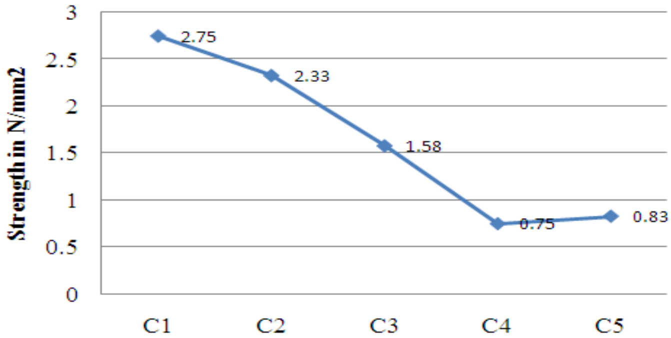


Graph-3: 7 Day compressive strength for different proportions

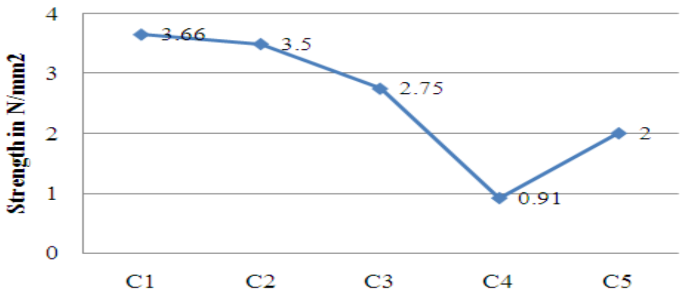
Flexure Strength: Modulus of rupture, which is the measure of flexural strength of concrete, is measured for the Prisms of dimensions 500mm x 100 mm x 100 mm are casted and are tested for 7 days and 28 days and the results are represented in the Graph-8.The specimens before and after the application of load are shown in the figure2 and figure 3 respectively.

Fig.2: Specimen before application load

Fig. 3: Specimen after the application of load



Graph-4:7 Day Flexural Strength



Graph 5:28 Day Flexural Strength

E-waste as reinforcement: In this study an attempt is made to use the e-waste as the replacement of steel. To compare the properties such as deflection and the maximum load carried by them beam is designed to take load of 51kN**.** Beams were casted with dimensions of 230x300mm and of 1.3meter in length. A trail area of the e-waste with the total area of e-waste as 1.5 times the area of steel in random and the beams are casted and are cured for 28 days. To compare the results another beam is designed with steel as reinforcement.

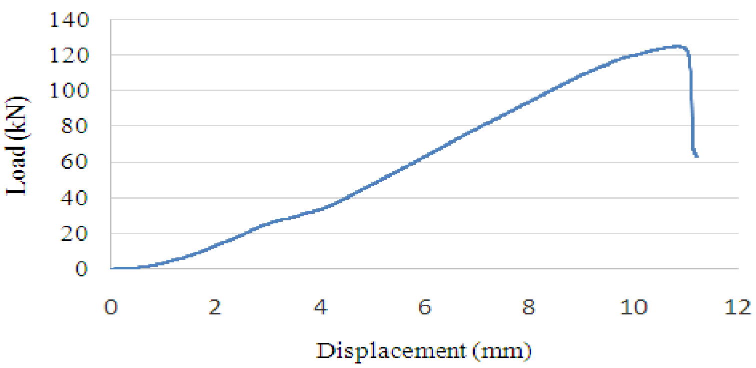
Beam 1: Beam with steel as reinforcement
Beam 2: Beam with e-waste as reinforcement
Properties Of Beams: The properties of the beams with e-waste and steel as reinforcement are shown in the table 2

Table 2 Dimensions of the beams

Dimensions of beam (mm)	Area of reinforcement (mm^2)	Number Of Reinforcement Members
230 x 300 x 1300	525.35 mm^2	3 bars
230 x 300 x 1300	824.6 mm^2	10 strips

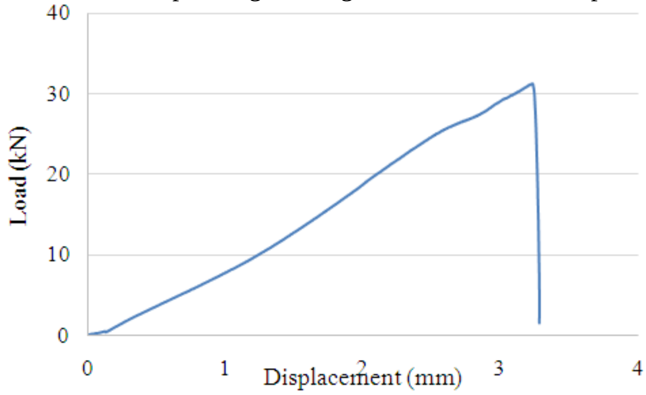
The orientation of the e-waste strips should be in such a way that the tensile strength of the strips is utilized. The beams thus casted are cured for 28 days and are tested to determine the maximum load carried by the beams.

Results Of Beams:
The response of the beam with steel as a reinforcement on the application is represented in the graph 6.



Graph-6: Load vs deflection for steel as reinforcement

The response of the beam with e-waste strips along the length as reinforcement is presented in the graph 7



Graph-7Load Vs deflection (e-waste as a reinforcement)

Comparison Of Results:
Maximum load taken by the beam with steel as reinforcement =126.01 kN
Maximum load taken by the beam with steel as reinforcement =33.02758 kN
The load bearing capacity drops by 73%

Crack Patterns: Casted beams after 28 days of curing are subjected to three point loading and the crack patterns in the Fig. 4 and Fig. 5 reveals that the beam casted with e-waste along the length as a reinforcement fails in flexure.

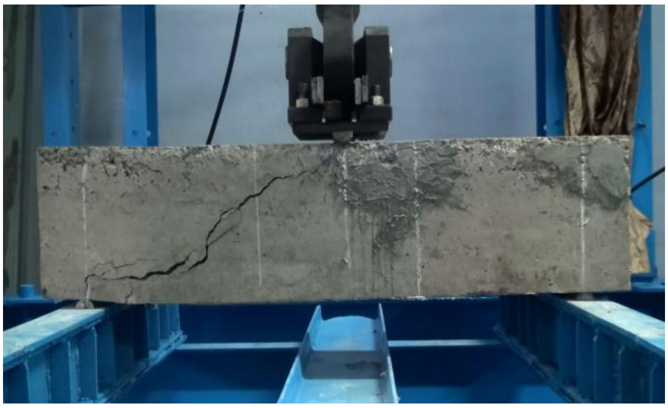


Fig.4: Crack pattern for beam with steel as reinforcement

The crack pattern for the beam with e-waste as reinforcement along the length is shown in the figure 5.

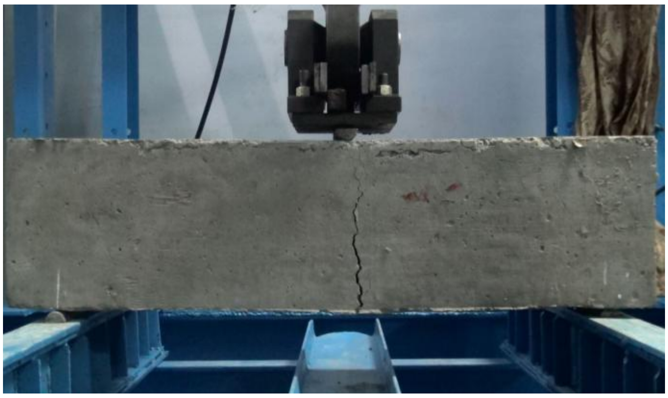


Fig. 5: Crack pattern for beam with e-waste as reinforcement

Applications:

According to IRC SP49 the compressive strength of the concrete at 7 days should not be less than 10 Mpa. And the compressive strength of each cube should not be less than 7.5 Mpa. So the combination 2 in which conventional aggregates are replaced completely is the optimum mix and can be used for as a sub grade material in the pavements.

IV. Conclusion

1. This study intended to find the effective ways to reutilize the e-waste and the recycled coarse aggregate. Different combinations of e-waste+ recycled coarse aggregate are prepared and the combination 2 is found to be efficient for the application in sub grade for pavements.
2. The optimum mix can be effectively used for the preparation of sub base in the rigid pavements.
3. This mix can also be used for the construction of low volume concrete pavements.
4. E-waste alone can also be used as the reinforcements especially for the non-structural applications.
5. For the designed load of 51 kN ,load carrying capacity of the beams drops by 73% when the e-waste is replaced with 1.5 times the area of steel.
6. When the combination of e-waste is used along with the recycled aggregate it is advisable to use the admixtures as the recycled coarse aggregates will have a coating of cement which is in dry state absorbs water.
7. Few deviations were observed in the trails while testing the aggregates (e-waste) because of change in the properties of e-waste. While collecting the e-waste care should be taken to segregate them before using them as aggregate.
8. The orientation of e-waste should be perpendicular to the width while using it as a reinforcement because to use the tensile property of the e-waste.
9. Instead of using the e-waste pieces and joining those with binding wire if they are made into some small sheet which is continuous the results may be effective. As while working with the small pieces which are joined the probability of change in orientation may take place.
10. While testing the e-waste for its tensile strength, care should be taken to choose a strip of e-waste whose surfaces are smooth so that the grip should be to the sheet not to the soldering's .

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