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Utilisation of E - Plastic Waste in Concrete

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***Abstract*— Efforts have been made in concrete to use non-biodegradable components of e-waste (e-plastic) as a partial replacement of coarse or fine aggregate. Recycling of e-plastic is a partial solution to environmental and ecological problems. Recycling of e-plastic not only helps in reducing in cost of cement concrete but also has numerous indirect benefits like reduction in land fill cost, reducing in air pollution due to incineration and many more. Electronic waste plastic abbreviated as e-plastic consists of discarded old keyboards, cabinets, smart phones, LCD's etc., basically any electrical or electronic appliance that has reached its end of life .In present study utilization of e-plastic as fine aggregate in concrete with 10% replacement on strength criteria of M20 grade. Hardened properties of concrete with and without e-plastic as a fine aggregate is observed which exhibits good strength. In present study hardened properties of concrete and durability is investigated for optimum cement content and 10% e-plastic content. It is observed that when e-plastic was replace with river sand, results comparable to control specimen were obtained. It is thereby suggested that utilization of this e-plastic in concrete will reduce the requirement for conventional fine aggregates thereby resulting in conservation of natural resources.**

Keywords—Concrete,Recycling,Electronic Waste,Utilization

I. INTRODUCTION

The rapid growth of technology, upgradation 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 which consist of end of life Electrical and Electronic Equipment(EEE) product known as E waste .Several tonnes of E waste need to be disposed per year. Traditional landfill or stockpile method is not an environmental friendly solution and the disposal process is also very difficult .According to United Nations report, India is the fifth biggest producer of e-waste in the world, discarding 1.7 million tonnes (Mt) of electronic and electrical equipment in 2014 and warned that the volume of global e-waste is likely to rise by 21 per cent in next three years. India generates 2.7 million tonnes of E-Waste annually. Of this, over 60 percent is generated by 65 cities. About 70 percent of the total Waste Electrical and Electronic Equipment (WEEE) come from ten states . Mumbai leads the country for generating the highest E-Waste, followed by Delhi and Bangalore. Among states in the country, Maharashtra is again among the leaders of E-Waste followed by Tamil Nadu .The other states sharing this dubious honour are Telangana, Uttar Pradesh, West Bengal, Delhi, Karnataka, Gujarat, Madhya Pradesh and Punjab. Plastics are a significant constituent of electrical and electronic equipment (EEE), about 30% by weight[1]. According to a study in 2004, four polymers, namely ABS, polypropylene, polystyrene and polyurethane represent more than 70% of the plastics contained in Waste Electrical and Electronic Equipment(WEEE) .There are other polymers also used in EEE. Although the proportion of plastics in the EEE has increased, the total weight of plastic contained in the EEE currently put on the market does not grow at the same rate because of the decrease in the average overall weight of equipment. Plastic, which is a major component of WEEE(Waste Electrical and Electronic Equipment), has become a major threat due to its non-biodegradability and high visibility in the waste stream. Its presence in the waste stream poses a serious problem when there is lack of efficient end of life management of plastic waste. Though there have been some focus on widespread littering of plastic bags, packaging and its impacts on the landscape, there has been little focus on plastic recycling in the informal sector, the possible threats and environmental impacts.

II. RECYCLING OF E-WASTE

E-waste contains material both toxic and valuable. It contains lot of harmful metals and waste plastics .Processing of e-waste causes to lot of serious problems in environment. This Paper deals with plastic material generated from obsolete keyboards, monitor,cpu,etc.This E-plastic contains plasticizerbisephenol-A(orBPA), as well DEHP (diethylhexyl phthalate) and DBP (Dibutyl phthalate) ,plastic compounds known as phthalates .Chlorinated plastics releases harmful chemicals into the surrounding soil, which seep into ground water or other surrounding water sources which cause serious harm to the species that drink this water, developing heart problems ,reproductive disease. Shredding and low temp melting of plastic leads to Emissions of brominated dioxins, heavy metals and hydrocarbons. Plastic is second largest component by weight in WEEE (Waste Electrical and Electronic Equipment) after electrical and electronic equipment. Objective of our task is reduce accumulation of e-

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plastic in environment and use of waste plastic in construction applications and making it durable[2].

III. ENVIRONMENT IMPACT OF E-PLASTIC RECYCLING

Plastics from printers , keyboards, monitors, etc .are recycled by Shredding and low Temperature melting to be reused this method of melting and shredding causes Emissions of brominated dioxins, heavy metals and hydrocarbons which causes effect to environment and human beings like respiratory problem , air pollution , heart problem .

IV METHODOLOGY

1. Properties of cement, aggregate, E-plastic is obtained by using standard IS methods and obtained values are considered.
2. Compressive strength of conventional and E-plastic for 7, 14 and 28 days are obtained using compressive testing machine (CTM). Different Percentages like 0% , 10% , 20% for coarse aggregate and 0% , 10% for fine aggregate replaced with E-plastic is tested to find out the compressive strength of the cube . Compressive strength will be the average of three sample for each percentage. First, taken sample from the mixture is used for slump test.
3. Flexural strength of E-plastic have obtained by using rectangular specimen. size of the specimen is (150mm x 150mm x 700mm). Percentage replacements of fine aggregate with E-plastic are 0%, 10%.
4. Split tensile strength of E-plastic have obtained by using Cylindrical specimen, size of the specimen is (300mm length and 150mm diameter). Percentage replacements of fine aggregate with E-plastic are 0%, 10%.
5. Durability tests like water absorption, density, chemical attack were conducted on conventional and E-plastic concrete cubes .

V EXPERIMENTAL DETAILS

1. MATERIALS USED

There are many potential applications of industrial byproducts or wastes in concrete. Depending upon type, nature and chemical composition of byproduct, its replacement for particular component is determined. Reuse of E-plastic as coarse or fine aggregate in concrete has many technical as well as economical advantages while the strength of the concrete remaining almost the same as compared to conventional concrete.

- *CEMENT*

The cement used in this experimental works are Ordinary Portland Cement (Bharathi cement 53 grade). All properties of cement are tested by referring IS specifications for OPC. Table 1 represents physical properties of cement.

Table 1: Physical properties of cement.

Properties	Cement
Fineness	2.433%
Initial setting time	135 min.
Final setting time	245 min.
Normal Consistency	35%
Specific Gravity	3.07

- *FINE AGGREGATE*

The fine aggregate used was river sand confirming to zone 1 and maximum size was 4.75mm.The testing of sand was done as per Indian Standard Specifications IS:383-1970.

- *COARSE AGGREGATE*

Two types of aggregates was used for this investigation viz. 10mm and 20mm.Sieve analysis was performed according to IS 383:1970-specification for C.A. and F.A. and IS 2386:1977-Methods of tests for aggregate of concrete.

- *E-PLASTIC*

This study ensures that reusing of E-plastic as substitute in concrete gives technical as well as economical advantages and also the problem of E-plastic disposal can be solved. This investigation was carried out in two stages, stage 1 including replacement of coarse aggregates and the latter stage included replacement of fine aggregate. The E-plastic used was of discarded monitors, keyboards, mouse and C.P.U. of computers. Table 2 represents physical properties of coarse aggregate ,fine aggregate and E-plastic.

Table 2: Physical properties of E-plastic and conventional aggregates.

Properties	Coarse Aggregate	Fine Aggregate	E-plastic
Specific Gravity	2.65	2.6	0.84
Absorption	0.5	1.2	Nil
Colour	Dark	Dark	Black
Shape	Angular	---	Angular
Abrasion Value		---	97.65%
Impact Value	24.73%	----	4.33%
Crushing Value	27.2%	----	2.83%

- *GGBS (Ground Granulated Blast Furnace Slag)*

The main components of blast furnace slag are CaO (30-50%), SiO_2 (28-38%), Al_2O_3 (8-24%), and MgO (1-18%).The GGBS of JSW cement was used. It is off-white colour and substantially lighter than Portland cement. The advantage of GGBS when used with Portland cement ensures higher durability of concrete avoids thermal cracking and improves workability. 50% by weight of cement was replaced by GGBS.

- *WATER*

Bore water was used for mixing and curing. Water cement ratio of 0.5 was adopted for this study.

- *CONCRETE MIXES*

The mixes were designated with the grade of concrete and the type of aggregate used. IS 10262:2009 and IS 456:2000 were used for design of concrete mixes as per the properties of the material found from the tests conducted. The E-plastic content was calculated on volumetric basis as fine aggregate in conventional mixes . Assuming the use of E-plastic particles as substitute of Coarse aggregate and Fine aggregate and remaining mix ratio as the same with conventional mix in concrete mixes as much as possible and achieve suitable compressive strength and workability is attempted and strength criteria of Grade M20 concrete mix is analyzed . Conventional mix concrete and modified mix concretes with varying percentage of E-plastic are presented in

International Journal of Engineering Research & Technology (IJERT)
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For Conventional Mix

cement	Coarse aggregate	Fine aggregate
1	2.78	1.86

W/c ratio: 0.5

Replacement of Fine aggregate with E-plastic on volumetric basis

For 6 cubes, use 0.682 kg of E-plastic replacing 1.903 Kg of fine aggregate.

Replacement criteria for Coarse Aggregate and fine aggregate are listed in Table 3 and Table 4 respectively.

Table 3: Replacement criteria for Coarse Aggregate:

Mix Specification	Conventional Mix	EP1	EP2
Proportion Of E-Plastic	0%	10%	20%

Table 4: Replacement criteria for fine Aggregate:

Mix Specification	Conventional Mix	EP01
Proportion Of E-Plastic	0%	10%

Table 5: Workability of concrete:

Mix	Slump (mm)
Conventional Mix	55
E-plastic Mix (EP01)	145

2. TESTS

Compressive strength test was conducted to evaluate the strength development of concrete containing various E-plastic contents at the age of 7, 14, 28 days respectively. Cylindrical specimens were also cast for finding the Tensile strength of specimens on 28 days also Beam Specimen were Cast for Flexure Strength of specimen at 28 days for each mix specification following the standard test procedures.

2.1 Compressive strength test on cubes

A cube compression test was performed on standard cubes of conventional and E-plastic of size 150mm x 150mm x 150mm at 7 , 14 and 28 days of immersion in water for curing

Results are shown in Table 6 and 7. The Compressive strength of the specimen was calculated by using the formula:

$$f_{ck} = P_c/A$$

where ,

P_c = Failure load in compression, in KN

A = Loaded area of the specimen, in mm^2

For Coarse aggregate:

Table 6: Compressive strength of specimen in N/mm^2

Mix Specification	Conventional Mix	EP1	EP2
Proportion Of E-Plastic	0%	10%	20%
7 Days	14.10	14.07	8.67
14 Days	17.08	16.59	10.74
28 Days	18.55	17.80	10.72

For Fine Aggregate:

Table 7: Compressive strength of specimen in N/mm^2

Mix Specification	Conventional Mix	EP01
Proportion Of E-Plastic	0%	10%
7 Days	11.86	13.79
14 Days	17.85	16.6
28 Days	19.08	20.82

Fig. 1 Compressive testing machine

2.2 Flexure strength test

Standard beams of size 150 x 150 x 700 mm were supported symmetrically over the span of 600 mm subjected to centre point loading till the failure of the specimen.

Maximum experimental flexural strength or Modulus of Rupture of beam specimen was computed by the equation using theory of strength of materials. Results are shown in Table 8. The flexure strength of the beam specimen was calculated as:

$$F_b = Pl/bd^2 \quad \text{, if a > 20.0 cm for 15cm Specimen}$$

where ,

b = Width of specimen (cm)

d = Failure point depth (cm)

l = Supported length (cm)

P= maximum Load (KN)

Table 8: Flexural strength of specimen in N/mm^2

Mix Specification	Conventional Mix	EP01
Proportion Of E-Plastic	0%	10%
28 Days	3.41	2.74

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 02, February-2016

Fig. 2 Setup for centre point loading for flexure testing

Fig. 3 crack pattern after loading of beam under point load

2.3 Split Tensile test

Standard cylinder of 15cm Diameter and 30 cm length were supported with the observation made that the upper pate is parallel to the lower plate and the specimen was tested out in accordance with IS : 5816:1999. The diametrical compressive load along the height of the cylinder was applied and the ultimate load at failure or rupture was noted for calculations. . Results are shown in Table 9.

The split Tensile strength of the specimen was calculated as :

$$F_{ct} = 2P / \pi l D$$

Where ,

P = Maximum load in Newton applied to the specimen

l = Length of the specimen, in mm

D = Cross sectional dimension of the specimen, in mm

Table 9: Split tensile strength of specimen in N/mm^2

Mix Specification	Conventional Mix	EP01
Proportion Of E-Plastic	0%	10%
28 Days	2.137	1.91

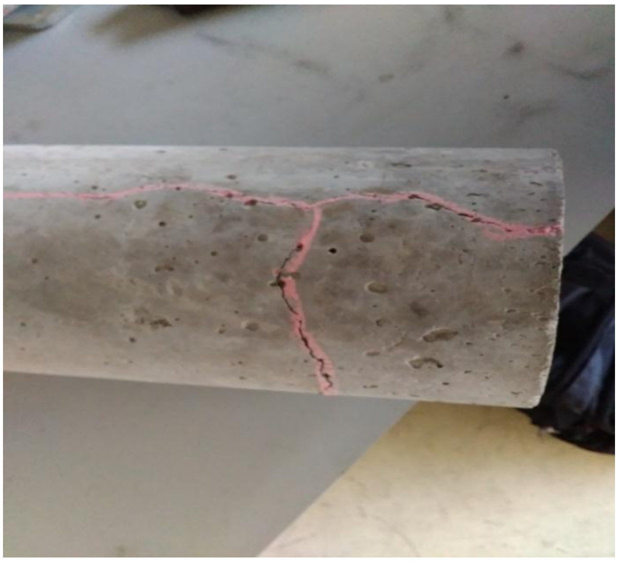

Fig. 4 Crack pattern of cylinder specimen after split tensile test

2.4 Durability tests on cubes

Both Conventional and E-plastic cubes of size 100mm x 100mm x 100mm were cast to test durability against Sulphate , acid , water absorption and density. Observation was recorded on first and fourth week after immersion into the solutions for sulphate and acid attack. Similarly , the water absorption and density were recorded on fourth week after immersion into the curing tank[3].

2.4.1 Test on sulphate Resistance

The concrete cubes of conventional and E-plastic were immersed in the sodium sulphate solution of 5% concentration in accordance to the procedure given in ASTM C 642 . The cubes were immersed in solution after the normal curing of the concrete cubes. The cubes were fully immersed in the solution kept in plastic containers. The containers were covered in order to minimize the evaporation rate and to avoid falling of the dust in the containers. The p^H of the solution was maintained throughout the study period. The compressive strength and change in mass of the concrete cubes were observed on first and fourth week after immersion into the solution and reading were noted. The surfaces were cleaned and oven dried at 100^0 c for 24 hours. The oven dried cubes were weighed and tested under Compression testing machine. The cubes inside the containers are shown in the figure[3]. Results are shown in Table 10.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 02, February-2016

Fig. 5 cubes immersed in Na_2So_4 Solution

Table 10: Compressive strength of specimen in N/mm^2

Mix Specification	Conventional Mix	EP01
Proportion of E-plastic	0%	10%
7 days	27.72	27.94
28 days	21.14	25.34

2.4.2 Test on acid resistance

As per the procedure in ASTM C 642, concrete conventional and E-plastic cubes were immersed in 5% concentration of sulphuric acid solution kept in plastic containers. The specimen were weighed, recorded as W_1 and submerged so that there was a minimum of 30mm depth of acid above the top surface of the specimens. The P^H of the solution was maintained and specimens were observed on first and fourth week. Observation was made on visual appearance, compressive strength and change in weight on first and fourth week after immersion of specimen and readings were noted. The surfaces were cleaned and oven dried at 100^0 c for 24 hours .The oven dried cubes were weighed and tested under Compression testing machine. The cubes inside the containers are shown in the figure[3]. Results are shown in Table 11.

Fig. 6 cubes immersed in H_2SO_4 Solution

Table 11: Compressive strength of specimen in N/mm^2

Mix Specification	Conventional Mix	EP01
Proportion of E-plastic	0%	10%
7 days	27.13	26.29
28 days	21.67	16.67

Fig. 7 cubes taken out of Na_2SO_4 and H_2SO_4 solution after first week

2.4.3 Test on Water Absorption and Density

The water absorption values of conventional and E-plastic cubes were conducted as per procedure given in ASTM C 642. The Specimens were taken out after fourth week to record the water saturated weight (W_S). The drying was carried in an oven at a temperature of 105^0c. The drying process was continued for 24 hours. The oven dried specimens were cooled to the room temperature and were weighed (W_d)[3]. Results are shown in Table 12 and 13.

From this the saturated water absorption was calculated by using,

$$SWA= (W_S-W_d)/W_d*100$$

Fig. 8 Cubes immersed in curing tank

Table 12: Water Absorption

Mix Specification	Conventional Mix	EP01
Proportion Of E-Plastic	0%	10%
28 Days	0.7	2.91

Table 13: Density (Kg/m^3)

Mix Specification	Conventional Mix	EP01
Proportion Of E-Plastic	0%	10%
28 Days	2222.959	2175.75

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 02, February-2016

III DISCUSSION

This experimental study shows that E-plastic can be recycled as a construction material in concrete industry. By performing and comparing various tests on e-plastic and conventional aggregates, we conclude that e-plastic can be used as a partial replacement to conventional aggregate. We complete our study in 2 groups. First we replaced e-plastic as a coarse aggregate 0%, 10%, and 20% in mix proportion. Then we perform compression testing to compare results. We observed that up to 10% replacement we get comparable results but as we goes for higher replacement strength was decreased rapidly. [4]

Series CM- Conventional mix (0% replacement)
Series EP1- E-plastic concrete (10% replacement)
Series EP2- E-plastic concrete (20% replacement)

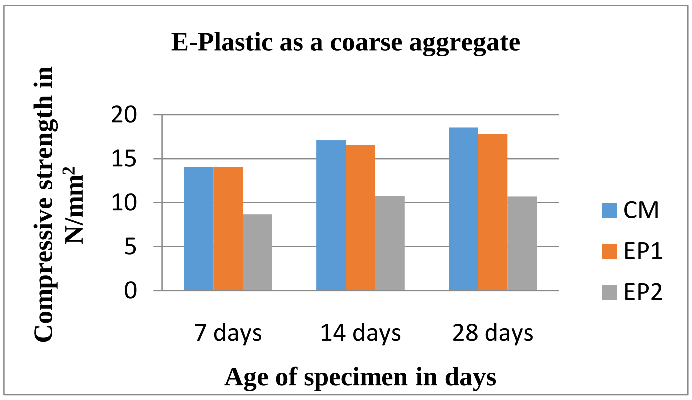

Fig. 9 Comparision between compressive strength of Conventional and E plastic mix concrete

Then second we replaced e-plastic as a fine aggregate 0%, 10% in mix proportion. We perform compressive test, split tensile test, flexure test to check harden properties of concrete. We calculate compressive strength at 7, 14, 28 days.

Series CM- Conventional mix (0% replacement)
Series EP01- E-plastic concrete (10% replacement)

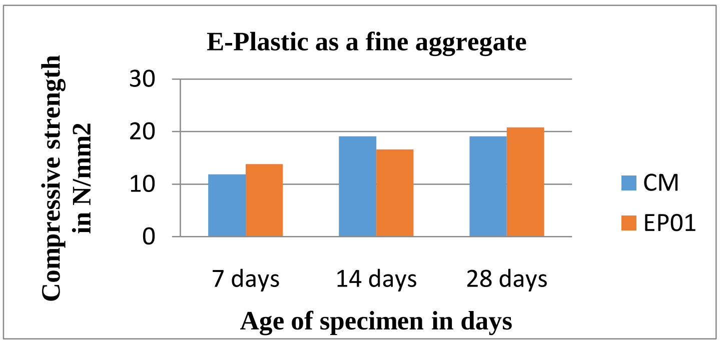

Fig. 10 Comparision between compressive strength of Conventional and E plastic mix concrete

We calculate split tensile strength and flexural strength at 28 days. We found comparable results hence we precede for further

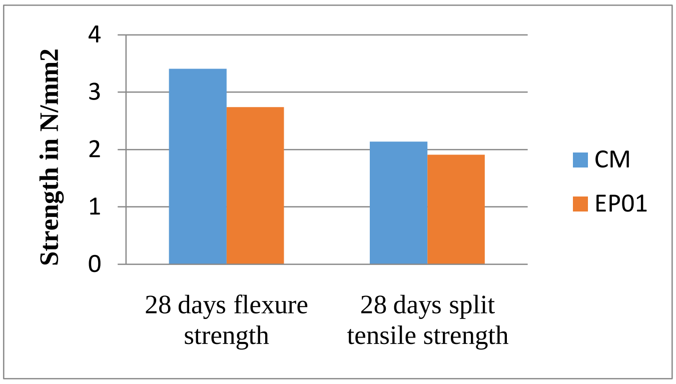

Fig. 11 Comparision between Flexure and Split tensile of Conventional and E plastic mix concrete

Then we perform durability test to check performance of this concrete in aggressive environment. We immersed samples in 5% conc. H_2SO_4 solution and 5% conc. Na_2SO_4 solution to check acid attack and sulphate attack.

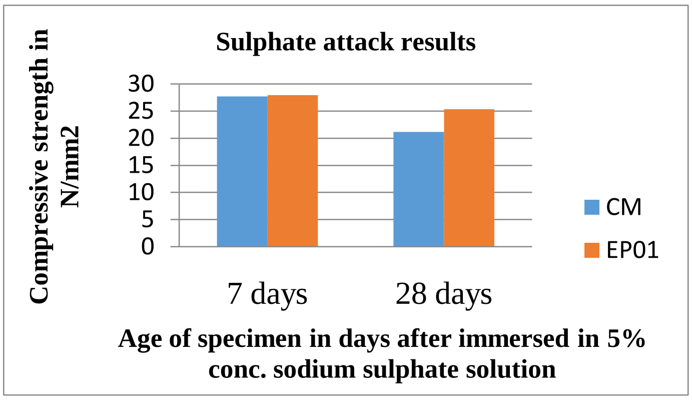

Fig. 12 Comparision between compressive strength of Conventional and E plastic mix concrete

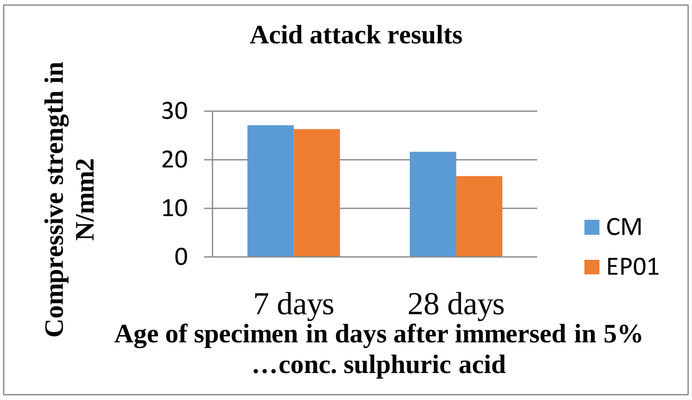

Fig. 13 Comparision between compressive strength of Conventional and E plastic mix concrete

We calculate compressive strength at 1st week and 4th week after immersing specimen in solution. We found that, E-plastic concrete having comparable durability with conventional mix concrete. Also we perform water absorption and density test on specimen after 28 days. We observe that e-plastic concrete have a less density than conventional mix concrete; hence we can produce light weight concrete as compare to conventional mix concrete.

International Journal of Engineering Research & Technology (IJERT)
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Vol. 5 Issue 02, February-2016

IV APPLICATIONS

1. The concrete embedded with E-Plastic can be used as a light weight material for constructing structures like storage room , office chamber , also for the load bearing structure etc
2. The E-Plastic concrete can be successfully used as a pavement material in areas of low traffic like parking pavements in various school , colleges , hospital etc
3. Also can be used to construct paver blocks , concrete bricks , kerbs ,etc
4. Abrasive strength of E-Plastic material is very high , hence , can be used in construction works of gutter , manhole , manhole cover , pipes of low pressure flow , etc
5. Impact strength is very good thereby can be used in workshop and colleges as a pedestal for machine to absorb shock caused by impact .
6. As E-Plastic gives substitute for fine Aggregate (river sand) the absorption of water in E-plastic concrete is less than that of conventional concrete thus providing a high workable concrete than conventional concrete thereby can be used as a self compacting concrete

V ADVANTAGES OF USING E-PLASTIC

1. E-Plastic concrete produce high workable concrete than conventional concrete for same W/C ratio thus reduces the high cost of admixture required to produce workable concrete
2. They have high impact strength and also good abrasion strength
3. Can be used as a substitute for high cost river sand and also reduces the problem which are been causesd by E-waste material
4. The E-waste now a days is nothing but a scrap material but by using of E-pastic in concrete and remaining material like copper , gold and silver material obtained from plates can be used by Government and can help Government to make a little contribution towards the economy of the country and also reducing the problem of E-waste.
5. The Concrete with E-plastic are comparatively light in weight than the conventional one.
6. After the utility period of the Structure constructed using E-plastic , it can be again used as a recycled aggregate .

VI DISADVANTAGE OF USING E-PLASTIC

1. The E-plastic when used as a coarse Aggregate does not bonds with the mixture properly hence it is difficult to obtained a homogenous mixture .
2. When used as a replacement for Coarse aggregate , the Concrete starts to segregate as the Water Absorption of E-plastic is nearly zero.
3. The E-plastic in concrete can be replaced upto certain percentage of fine aggregate and coarse aggregate (i.e. 10%) after this there is considerable decrease in the strength of the E-plastic concrete .

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VIII CONCLUSION

From this experimental study we concluded that,

1. E-plastic can be disposed by using them as a construction material. This results in reduction of environmental pollution as well as reduction in burden on landfill disposing.
2. E-plastic can be used as a coarse and fine aggregate to partial replacement for conventional aggregates, these results in saving of natural aggregates as well as producing eco friendly structure.
3. E-plastic can be replaced up to 10% as a coarse and fine aggregate.
4. For 10% replacement, comparable results are found for both coarse aggregate as well as fine aggregate.
5. Harden properties of conventional concrete and e-plastic concrete are comparable with less strength variation for 7, 14, 28days results.
6. E-plastic containing concrete shows comparable performance in aggressive chemical attack condition.
7. Density of e-plastic concrete is less as compare to conventional concrete hence light weight concrete structure can be produced.
8. By comparing slump value for same W/C ratio, we concluded that e-plastic concrete had a higher workability than conventional mix concrete; it saves cost of admixture results in economical concrete.
9. Results proved that e-plastic containing concrete exhibits better resistance to sulphate attack.

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