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A REVIEW PAPER ON PROPERTIES OF E-WASTE CONCRETE

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ABSTRACT - *Nowadays researchers are working on different material to get high strength and high-performance concrete. The aim is to reduce the cost of construction and enhance the properties of the concrete. Also, e-waste is a global problem for both developing and developed nations. The reason is, there is no method of disposal of e-waste other than some traditional ones. Landfill and incineration are commonly used for disposal of e-waste but, landfill needs a wide landmass and also pollute the groundwater by leaching. On the other hand, incineration cause air pollution. So, using e-waste in concrete is the better idea as compared to these traditional methods. Different researchers worked over the utilization of e-waste in concrete. In their research, they use e-waste as coarse aggregate, fine aggregate, admixture and so on, and perform both strength and durability test over them. The researches show the possibility of substitution of raw materials with e-waste.*

***Key Words*: chloride attack, compressive strength, durability properties, e-waste, flexural strength, shear strength, strength properties, sulphate attack, tensile strength**

1. INTRODUCTION

In today's era, E-waste is emerging as a major problem. Not only India but all the countries of the world, whether developing countries or developed ones are facing this problem. As the information technology and communication sector is increasing, so is the increase in electrical and electronic equipment, as a result of which e-waste is also increasing. About 3 MT of e-waste is generated in India every year. India ranked third in e-waste generation in the world, following China and the united states at first and second position in the list.

To be more specific, our problem is not e-waste, our problem is its proper administration and disposal. There is a saying that "today's electronic gadgets, tomorrow's e-waste", but if we use these electronic gadgets properly and think about the methods of its administration, then it can also be resolved.

Traditionally we use four methods to dispose of e-waste, Landfill, Incineration, Reuse, and Recycle. In the landfill, all the e-waste is dumped over the land or buried under the soil which will cause leaching of waste with groundwater and leads to contamination of groundwater. Incineration is burning e-waste which releases toxic gases and harms the environment, while close incineration is somehow effective and less harmful for the environment. Reusing e-waste is also an option through which we can use second-hand products either directly or after some modifications. Recycling of e-waste refers to recycle the raw material present in the particular plastic and manufacture a new product. Reuse and recycle are the best and environment-friendly methods for the disposal of e-waste.

One such method is to use e-waste in concrete. Many researchers are working on this subject and have been successful to a great extent. There will be many benefits from using e-waste. Since we are adding e-waste to concrete, the material cost will be reduced and at the same time, a waste product will be used efficiently, which will also be better for the environment. As we know the density of e plastic will be less than the density of aggregate, as a result, the density of concrete made from e plastic will also be less than the conventional concrete, consequently, we will get lightweight concrete. Many researchers use e-waste in concrete in different forms and got different results. Some of them replace Fine aggregate with e-waste, while some others replace Coarse aggregate, sometimes e-waste is also used as an admixture thus, different researchers adopt the different methods for proper utilization of e-waste in concrete effectively. In this paper, we are going through different methods and approaches adopted by researchers to use e-waste in concrete.

2. LITERATURE REVIEW

The literature is based on the strength properties of the concrete. This includes compressive strength, flexure strength, split tensile strength and shear strength.

2.1 COMPRESSIVE STRENGTH

Compressive strength test is important for concrete because all the concrete structures are designed to resist compressive stresses. Even, the grading of concrete also depends on its compressive strength. Many researchers worked on this property of e-waste concrete.

(Gavhane, et al. 2016), in their paper "Utilization of e-waste in concrete", replaced e-waste by coarse as well as fine aggregate 0%, 10%, and 20% by volume. This e-waste was collected from broken computer parts such as mouse, keyboard, CPU, etc with a specific gravity of 0.84. For 10% replacement of both the aggregates separately.

The testing was done at 7, 14 and 28 days. comparable results are found in the compressive strength test while on moving to 20% the compressive strength starts decreasing. Through the study they concluded that the E-waste concrete has higher workability than the control concrete mix thus, it saves the cost of construction and due to less density of e-waste particles the concrete prepared was lightweight concrete.

(Colina Martínez, et al. 2018), replace sand with irradiated recycled polycarbonate of specific gravity 1.2 at 3%, 6%, and 15% by volume. The size of the polycarbonate particle is 1mm X 3mm. The gamma irradiation was done on polycarbonate particles at doses 600, 800, 1000 and 1200 kGy through, industrial Cobalt-60 source. By using gamma rays the texture becomes rough and the irradiated particles make a strong bond with cement concrete thus the strength increases up to 12% as compared to a controlled mix. But, as the percentage of the particle increases up to 15% it gives similar strength as the controlled mix. They have also done morphological characterization of gamma-irradiated particles through Scanning Electron Microscopy (SEM).

(Arora and Dave 2013), use e-waste and plastic bottle waste as fine aggregate and replace at 0%, 2%, and 4% by weight of fine aggregate with e-waste specific gravity 1.2. The specimens were tested at 7, 14 and 28 days. Reduction in strength was observed because of the flaky nature of grinded bottle waste and lack of Cementous property in the grinded waste. In the case of crushed e-waste strength increases up to 4% but on increasing the percentage further the strength starts decreasing. The very slight decrease in strength shows that it can be used as fine aggregate in concrete. The cost analysis was also done on tiles made by e-waste and concluded that the tiles with e-waste and white cement are 20% cheaper than vitrified tiles.

(Kurup and Kumar 2016), used e-waste fibres taken from waste electrical cables (PVC) with an aspect ratio of 35 and specific gravity of 1.45. The test was conducted in two groups one was fibre reinforced concrete and another was silica fibre reinforced concrete. E-waste fibres replaced with cement by 0.6%, 0.8% and 1%. The testing was done in 7 and 28 days. As e-waste increases the workability decreases but was in the permissible range. The increase in strength observed up to replacement of 0.8%. However, at 1% replacement, the strength decreases. The maximum increase in strength was observed to be 30.89% with respect to the control mix, and the optimum percentage was found to be 0.8% with respect to cement.

(Manjunath 2016), use e-plastic of specific gravity 1.1 as a replacement of coarse aggregate, the replacements are done at 0%, 10%, 20% and 30% by weight and the maximum size of aggregates were 20mm. The specimens are tested at 7, 14 and 28 days. Workability decreases as the percentage of e-waste increases. However, compressive strength decreases with an increase in % e-waste. At 10% replacement, the compressive strength is somehow equivalent to that of the control mix. The conclusions show that the effect of the water-cement ratio on the strength of concrete is not useful for plastic e-waste concrete due to a reduction in bond strength because of plastic aggregates.

(Dawande, Jain and Singh 2015), Replace coarse aggregate partially with e-waste which was collected from local area contains a TV, Radio, CD, etc. with specific gravity 1.17. The research was done in two parts. At first using e-plastic with 0%, 5%, 10%, 15% and 20% and then e-plastic along with 10% fly ash. The testing was done at 7, 14 and 28 days. Workability increases as the percentage of e-waste increases and even more when fly ash replaced by cement. Here, compressive strength decreases as % e-waste increases when compared with the control mix. On the other hand, the compressive strength increases when e-waste along with fly ash concrete compared with e-waste concrete. This shows that the replacement of cement with fly ash is more desirable than using the e-waste solely.

(Gull and Balasubramanian 2014), use PVC wires of 4mm diameter with sizes 3cm, 4cm and 5cm as admixture in concrete by 0.4%, 0.6%, 0.8% and 1%. Concrete cubes were cast and tested at 7, 14, and 28 days. In addition to 4cm wires by 0.8%, the strength increases maximum up to 5.9% while by adding 3cm wire by 1% the strength increases maximum up to 10.6% concerning control mix.

(Alagusankareswari, et al. 2016), used Printed Circuit Boards (PCBs) as fine aggregate. The replacement was done by 0%, 10%, 20% and 30% by volume. The testing was done at 7, 14 and 28 days. Compressive strength decreases as the % of sand increases, as for 10% the percentage decrease was 7.6%, for 20% the percentage decrease was 21.47% and for 30% the percentage decrease was 26.11%. But, due to less density of replacement particles the concrete prepared was lightweight concrete.

(Kumar and Baskar, Response Surfaces for Fresh and Hardened Properties of Concrete with E-Waste (HIPS) 2014), High Impact Polystyrene (HIPS) plastic was used which is taken from the computer and its accessories with size 6-12mm and specific gravity 1.29. Partial substitution of coarse aggregate is done as 10%, 20%, 30%, 40% and 50%. Three different grades of concrete were prepared i.e., M20, M25 and M30 with water-cement ratio of 0.45, 0.49 and 0.53. 7 and 28days of testing were done. The observations show a decrease in slump with a percentage increase in HIPS content. Compressive strength decreases as the percentage of HIPS increases. Quadratic models were employed through face centred composite surface design and found reliable by testing some standard results.

(Sabău and Vargas 2018), used Acrylonitrile Butadiene Styrene (ABS) plastic for partial replacement of coarse aggregate. Computer accessories and other electronic devices consist of ABS i.e., because of its mechanical behaviour and resistance against chemical attacks. Coarse aggregate was replaced by ABS plastic with specific gravity 0.93 by 40%, 50% and 60%. An increase in workability and a decrease in compressive strength was observed. The maximum reduction in compressive strength was 44% corresponds to 60% replacement. The outcomes also elucidate that the concrete prepared was lightweight concrete because of a 22% reduction in weight by employing 60% of e-plastic waste.

(Santhanam and Anbuarasu 2019), Reported that High strength concrete can be prepared using e-plastic waste. They used PCBs as a partial replacement of coarse aggregate with a specific gravity of 0.8. A concrete of M60 grade was prepared. Admixture "Polycarboxylate Ether" was used. Aggregates replaced by 0%, 8%, 12% and 16% by volume. The samples are tested at 7, 14, and 28 days. The result shows an increase in compressive strength as the percentage of e-waste increases. Through the results, it can be concluded that even High strength concrete can be prepared by using e-waste as a replacement for coarse aggregate, it increases the mechanical strength of concrete and was an environment-friendly approach.

(Nagajothi and Felixkala 2014), e-fibre waste is used as an admixture taken from PCB cutting units in the form of long chips, with a specific gravity of 1.09. E-fibres added in the proportion of 0%, 0.5%, 1.5%, and 2.5%. The samples are cast taking the water-cement ratio of 0.5. Testing was done at 7, 21, and 28 days. Concrete strength increases as the percentage of e-waste increases. By adding 2.5% of e-fibre the 28 days compressive strength was nearly twice that of conventional concrete.

(Manatkar and Deshmukh 2015), e-waste was collected from various local bodies. Worked on two grades of concrete M20 and M25. Coarse aggregate was partially replaced by e-waste by percentage 0%, 5%, 10%, 15% and 20%. The testing was done on 7, 14 and 28days. The result shows that the replacement of 5 to 10% gives strength very close to the control mix. While, at 20% replacement, the decrease in strength was about 37.84% for the M20 grade of concrete. The conclusions carried out says that 5-6% replacement of e-waste was suitable for roads and (G+2) building constructions, but, over 10% was not desirable for use in construction because of reduction in strength.

(Kumar and Malik 2016), added PVC wires of 3cm, 4cm and 5cm. For 5cm and 1%, PVC wire has added the reduction in strength by about 2.59% was reported. Adding 3cm and 4cm at the same percentage gives an increase in strength concerning the control mix.

(Needhidasan and Sai 2019), reported an increase in strength up to a certain percentage by using circuit boards chips of size 20mm. The replacement is done by 0%, 8%, 12% and 16% of coarse aggregate. The testing was done at 7, 14, and 28days. Workability decreases as the percentage of e-waste increases. Up to 12% replacement compressive strength increases about 3.73% while decreases at 16% replacement. The result also shows that the replacement of fly ash with cement along with coarse aggregate replacement is more effective than replacing coarse aggregate solely.

(Raut, Dhapudkar and Mandaokar 2018), perform replacement of coarse aggregate by 5%, 10%, 15% and 20% by e-waste. The samples are tested at 7, 14 and 28days of the time interval. The results show a decrease in workability as the percentage of e-waste increases. Up to 15% replacement compressive strength increases then start decreasing, the maximum increase was noted about 10.64% to the control mix.

(Kale and Pathan 2015), e-waste used as PCBs with specific gravity 2.85 with partial replacement of fine aggregate by 5%, 10%, 15% and 20% by weight. M25 mix was prepared with a water-cement ratio of 0.5 and tested at 7days and 28days of the time interval. E-waste concrete by replacement of sand shows an increase in strength up to 10% replacement. The maximum strength increase is 13.93% compared to conventional concrete. In PCBs copper and silica are present at 36.44% and 63.55%, due to this reason the strength increases. They also concluded that the water-cement ratio must be monitored while preparing the mix due to the negligible water absorption of plastic aggregates.

(Ahirwar, et al. 2016), Crushed plastic waste as e-waste is used which pass through 20mm sieve and retained over 4.75mm sieve with specific gravity 1.20, The workability increases as the percentage of e-waste increases. E-waste with fly ash is also added at 10, 20 and 30%. The cubes were tested at intervals of 7, 14, and 28days. By adding fly ash workability increases even more than e-waste solely. Compressive strength decreases as e-waste increases by comparing with control mix while comparing e-waste along with fly ash the strength increases as compare to the e-waste solely. 30% of replacement of cement with fly ash gives the best result along with e-waste. They concluded that the optimum percentage replacement of coarse aggregate was 10-20% by e-waste while replacing coarse aggregate 30% by e-waste along with 30% fly ash is also admissible.

2.2 FLEXURE AND SPLIT TENSILE STRENGTH

Both the test Flexure strength test and Split tensile strength test are important. These tests give the indirect tensile strength of concrete. As we know that the concrete is weak in tension so, it makes this important to know and work on these properties of concrete.

(Gavhane, et al. 2016), Replaced both coarse and fine aggregate with discarded monitors, keyboards, mouse, etc. in concrete. The testing was done at 7, 14, and 28days. The split tensile strength and flexure strength were recorded at 0% and 10% replacement of fine and coarse aggregate. The water-cement ratio was 0.5 and the specific gravity of e-waste is reported 0.84. Both flexure and split tensile strength are reduced when compared with the conventional mix. The reduction in flexural strength was about 19.65% while, in split tensile strength, the reduction was 10.62%.

(Kurup and Kumar 2016), in their paper they use waste plastic from PVC cables with an aspect ratio of 35 and specific gravity of 1.45. The percentages added are 0.6%, 0.8% and 1% and tested at intervals of 7 and 28days. The result shows an increase in flexure and split tensile strength up to 0.8%, but at 1% decrease in strength was observed, in both fibre reinforced concrete and silica fibre reinforced concrete.

(Manjunath 2016)**,** replaced coarse aggregate with e-plastic of specific gravity 1.1 at percentages 0, 10, 20, and 30%. The specimens were tested at 7, 14, and 28days. Reported an increase in flexure strength and split tensile strength up to 10% replacement of coarse aggregate with e-plastic waste aggregate in concrete. Although, on replacement with 20% of the same gives almost same strength as the conventional concrete. But on 30% replacement, the result shows a decrease in strength as compared to the conventional mix. So, replacement of coarse aggregate with e-plastic waste is desirable up to 20%.

(Dawande, Jain and Singh 2015), collected e-waste from tv, radio, etc. with specific gravity 1.17. Replacement of coarse aggregate is done with e-waste plastic. 10% fly ash was also added in replacement of cement. E-waste replaced as 0%, 5%, 10%, 15% and 20%. The testing was done on 7, 14, and 28days. Both split tensile strength and flexure strength decreases as % of e-waste increases. But it is to be noted that the increase in these strengths was observed when fly ash was added by replacement of cement. So, it was concluded that using e-waste aggregate solely in concrete and with fly ash, the desirable percentage should be 10% and 25%.

(Gull and Balasubramanian 2014), use different sizes of PVC wires plastic in different proportions. The sizes are 3cm, 4cm and 5cm at percentage 0%, 0.4%, 0.6%, 0.8%, and 1% and testing was done in 7, 14, and 28days. Flexure strength increases when e-plastic of 5cm is added up to 0.8%, although when the size decreases i.e., 4cm and 3cm the strength increases up to 0.8% of e-waste and 1% of e-waste. Split tensile strength gives compatible results concerning conventional concrete. Overall, both the split tensile strength and flexural strength increases concerning control mix, when used as an admixture.

(Alagusankareswari, et al. 2016), used e-waste as a partial replacement of sand. The percentage replacement is 10%, 20%, and 30%. In the study, the PCBs are used as e-waste. The testing was done at 7, 14, and 28days. By replacing fine aggregate the split tensile strength decreased progressively by 1.67%, 20.98% and 38.98% at the percentages 10%, 20% and 30%. Flexural strength also decreases by 16.67%, 40.5% and 42.86% at the same percentage replacement.

(Kumar and Baskar, Response Surfaces for Fresh and Hardened Properties of Concrete with E-Waste (HIPS) 2014), here the coarse aggregate is partially replaced with HIPS plastic of size 6-12mm and specific gravity 1.29. The percentage replacement was 10%, 20%, 30%, 40% and 50%. Three different mixes are prepared i.e., M20, M25 and M30. 7 and 28days testing was done. Both flexure strength and split tensile strength decreases as the HIPS content increases. They have also done response surface analysis through design expert software and predicted a model by 25% HIPS replacement and the water-cement ratio of 0.49. The results are very close to the experimental data.

(Needhidasan and Sai 2019), used PCB as e-waste, replaced by volume replacement of coarse aggregate at percentages 0%, 8%, 12% and 16%. M60 grade of concrete was prepared and tested at 7, 14, and 28days. The flexural strength increases as the percentage of e-waste increases. The maximum increase in flexural strength was observed as 19.51%. Similarly, the split tensile strength also increases as e-waste increases. The maximum increase was observed as 48.48% as compared to the controlled mix.

(Raut, Dhapudkar and Mandaokar 2018), Replacement of coarse aggregate was done by percentages, 5, 10, 15, and 20%. The specimens were tested on 7, 14, and 28days. Not much change was observed in Split tensile strength, though strength increases up to 15% replacement of coarse aggregate.

(Kale and Pathan 2015), replaced e-waste as fine aggregate with a specific gravity of 2.85. The replacement was done at percentages 5, 10, 15 and 20% by weight of fine aggregate and tested at the duration of 7 and 28 days. Split tensile strength of e-waste concrete increases up to 10% and the maximum increment was observed to be 23.38% concerning control mix. Flexural strength increases up to 5% replacement by e-waste and the maximum increment was 6.52% concerning control mix.

2.3 SHEAR STRENGTH

There are several methods to determine the shear strength of concrete. But, the method with two shear planes will not be practical. Some researchers bring new approaches to determine shear strength.

(Kumar and Baskar 2014), Replaced coarse aggregate with "high-impact polystyrene" by volume at percentages 10, 20, 30, 40, and 50%. HIPS aggregate has a size of 6 to 12mm and specific gravity of 1.29. An M25 grade was prepared with a water-cement ratio of 0.49. They prepared an L-shape mould which is a mould of a cube, partially covered with 90x60x150mm of a wooden block. The test was done by using the compressive testing machine. The specimens were tested on 7 and 28days. The observation shows that the shear strength decreases with an increase in HIPS content. The HIPS plastic shows similar results as fibre. At the ultimate loads, it enhances the shear behaviour. So, the ultimate load at which the control concrete specimens broken into pieces, the HIPS delayed the failure and thus considered good for resisting seismic loads and earthquakes. At 50% replacement, the percentage decrease in shear strength at 7 and 28days was 58.14% and 52.63%.

(Kurup and Kumar 2016), used e-waste fibres of aspect ratio 35 as admixture. The addition of fibres was at percentages 0.6, 0.8, and 1%. Silica powder was also added to this concrete by 10% of the volume of the cement. The shear strength was calculated using the approach applied by Bairagi and Modhera in their paper "shear strength reinforced concrete" in 2001. The same procedure was followed by Kalyavardhan Senthil Kumar in 2014. The silica powder used has a specific gravity of 2.2. M30 mix was prepared and tested for 7 and 28 days. An L-shaped specimen is used and tested for shear strength. The results show that fibre concrete and silica fibre concrete have very close results to that of the conventional mix at the addition of 0.6% of e-waste fibres. Although, the strength was reduced when e-waste fibre increases. While the strength of silica fibre reinforced concrete is slightly more than that of fibre reinforced concrete.

2.4 DURABILITY TEST

some researchers carried out durability test in e-waste concrete. They have performed several tests like temperature susceptibility, Resistance to thermal shock, Acid attack, etc which are given below:

(Kumar and Baskar, Effect of Temperature and Thermal Shock on Concrete Containing Hazardous Electronic Waste 2018), prepared M25 mix. The coarse aggregate was replaced by HIPS plastic by volume using percentages 10, 20, 30, 40, and 50%. "High-temperature test" and "Thermal insulation property of concrete", were tested. In a high-temperature test 100mm cubes were cast and heated at 100^0, 200^0 and 300^0C in a muffle furnace for 1 hour. The test was done simulating the field conditions. The results were also noted while heating the specimens which shows, at 100^0C no change in colour and no cracks were observed, at 200^0C colour changes but no cracks were observed but at 300^0C plastic close to the surface starts burning and visible hairline cracks were observed. After heating, the specimens cool down for 24 hours and then a compressive strength test was carried out. The test shows a decrease in strength with an increase in temperature and HIPS content. Thus, it was concluded that this concrete can be used as a non-structural member. Thermal insulation property was also checked by thermocouple test setup using a voltmeter, ice bath and copper and Constantine wires. The result shows that using HIPS will keep the interior cooler when comparing with control concrete.

(Lakshmi and Nagan 2011), The cubes of 150mm were cast with percentage replacement of coarse aggregate as 0, 4, 8, 12, 16, 20, and 24% with and without fly ash. The fly ash used was 10% of the weight of cement. "Chloride attack test" was done after 28days of curing. The specimen after 28 days of curing kept in the solution of 5% H_2SO_4 and 5% HCL. They are taken out after curing for 105 days and tested for weight loss and compressive strength. Results were positive, as it shows less loss of weight and strength as compared to the control mix which shows that the particles of e-waste were not influenced by the chloride.

"Sulphate attack test" was also carried out after the same duration of 105days in the sodium sulphate solution i.e Na_2SO_4. Similar results were seen in sulphate attack also and the result concluded that the e-waste particles have no influence of sulphate. Thus, gives comparable results in sulphate attack as control concrete.

"Permeability test" was carried out in conventional and modified concrete. saturated water absorption, porosity and sorptivity are checked for the permeability test. The test result shows that E-waste concrete gives a slightly higher value as compared to conventional concrete. This is due to intermolecular voids in e-waste plastic. Overall the e-waste concrete is durable and can be used in low-cost construction and also as non-structural members in some structures.

3. CONCLUSIONS:-

The literature shows that e-waste in concrete plays a major role in the construction sector. Some important points are given below-

- The use of e-waste in concrete reduces environmental pollution and unriddle the problem of disposal. which indirectly protect our natural resources like groundwater and air.
- Both coarse and fine aggregates can be replaced through e-waste up to a certain percentage,

depends on the quality and properties of e-waste material. Which leads to an eco-friendly structure.

- Lightweight concrete can be prepared through e-waste. Due to the fact that the density of e-waste is less as compared to conventional aggregates.
- It was seen that, by using e-waste the workability of concrete increases, which concludes that using e-waste decreases the cost of admixture.
- E-waste can also be used as an admixture in concrete. By using it as an admixture the hardened properties show an increasing trend up to a certain percentage.
- E-waste is a potentially viable material used in low-cost construction as structural and non-structural members.
- It can also be used as a replacement of cement up to certain percentages.
- Using e-waste in concrete gives better resistance to sulphate attack and chloride attack.
- Due to less density of concrete and intermolecular voids, e-waste concrete is more permeable than conventional concrete.
- By infusion of e-waste plastic in concrete, the ductility of concrete increases. Due to which the concrete deforms before failure. So, can be used in harsh weather conditions.

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