ADVANCEMENT OF COMPOSITES IN CONSTRUCTION MATERIALS: A REVIEW

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ABSTRACT

Waste management is the major problem to the environment in the current scenario. Of the various waste materials, plastic, agro and e-wastes are of great concern. Plastics are not eco-friendly as they are non-biodegradable. On the other side, the traffic intensity is increasing. The load bearing capacities of the road are to be increased. This paper sheds light on the concept of utilization of waste materials in the construction field in an eco-friendly manner The population growth, industrialization, consumerism and technological development have led to the uncontrollable accumulation of waste. Proper waste disposal is of great importance in both rural and urban areas. This study discussed the suitability of plastic waste materials, agro waste e-waste for construction purposes. This paper shows use of various waste materials in construction and their effect on properties of concrete, aggregates, roof tiles, and effective use of waste.

Keywords-Composites, Agro waste, E-waste, Plastic waste, Waste Management

1. INTRODUCTION

In the recent years, there has been a dynamic change in the surrounding environment. Lots of environmental detrimental activities are taking place, which is day by day deteriorating condition of our mother earth. Nowadays the world is a global village every day millions of people are moving from villages to urban areas, leading to increased construction activities production of building material causes significant air pollution due to the release of CO_2 gas. There is a need of an eco-friendly substitute for these materials. Using some eco-friendly or green materials in the major material one can harvest promising result. Combination of some waste product from different sectors to building materials to give a superior recital and hence reduce the damaging effect on the environment. This task is accomplished by using composite materials Sustainable, eco-friendly road construction is increasingly receiving more attention globally in both developed and developing countries and among various stakeholders such as private and public sectors and governments.

It is driven largely in part by the increase in demand and opportunities to green our infrastructures and reduce environmental impacts of road construction, tightening budget for road infrastructures, and innovative practices that are continuously churned out across the globe. It is also spurred by the increase in demand for eco-cities and eco-developments that are more environmentally friendly than before (Flynn, Yu, Feindt, & Chen, 2015). Eco-friendly construction can also be viewed as a response of stakeholders to the calls for sustainable development which arose from growing awareness of the negative impact of construction on our environment. De

Rezende, Camapum-de-Carvalho, and Palmeira (2015) and Safiuddin, Jumaat, Salam, Islam, and Hashim (2010) attributed the birth of eco-friendly construction to increasing cost of construction materials due to high demand, scarcity of raw materials, and high price of energy, which led to the search for alternative construction globally, while Wahlstrom et al. (2014) cited increasing costs and new restrictions for landfilling.

The authors classified recycled materials into five categories, namely: organic agricultural industrial wastes, inorganic industrial wastes, mining/mineral wastes, non-hazardous wastes, and hazardous wastes. Obstacles to recycling in construction include concerns about quality variations in the wastes, inadequate information on the properties of the products manufactured with the recycled wastes, lack of technical standards for use of recycled materials as input materials in new construction products, and poor awareness about the important elements and necessary actions in promoting recycling of wastes (Vieira & Pereira, 2015; Wahlstrom et al., 2014).The composite material can provide properties superior to the properties of the individual components. Advanced composites have found their application in varied fields including aerospace, marine, automobile etc. due to their superior engineering properties. The increasing awareness towards the environment has tremendously contributed to the concern related to effective waste disposal. Some of the major waste contributors to environmental contamination in India is due to disposal of e-waste, agro left outs, plastic waste etc. With the scarcity of space for landfilling and seeing its damaging effect on groundwater and soil waste utilization has become an attractive alternative to its disposal.

Using electronic, plastic and agro wastes waste materials the cost of the final product can be reduced to a considerable amount. In a nutshell, e-waste, plastic waste, and agro waste have a potential to be utilized in construction materials. There is an urgent need for the development of its management sector. There are 178 number of e-waste sorting and shredding plants in India according to central pollution control board (CPCB). These waste products are in something. According to CAG (comptroller and auditor general), report 4 lakh tons of the e-waste is produced annually in India. Efforts have been made in the concrete industry to use e-waste as a potential replacement as coarse aggregate in concrete, though its hazardous nature is still a problem that needs to be resolved. The agricultural sector contributes about 70% to Indian gross domestic product (GDP). Hence a considerable amount of waste is also produced which need to be managed efficiently. Agro-waste is byproducts of agricultural produce they include – husk straw, rice husk, millet husk etc. though there is a limited number of research works on millet husk and rice husk.

Electronic, agro and plastic waste materials have great potential to be utilized on concrete plastic waste are non-biodegradable and its disposal is a major problem faced by every country in the word hence if this can be utilized efficiently in concrete it can bring huge change. The plastic is the most used man-made material in the world through their specific characteristics such as easy manufacturing and shaping, cheaper cost and low density. According to central pollution control board(CPCB), India produces about 5.6

million tons of plastic waste annually in which 40% of waste remains untreated and undisposed [3]. It is very useful in different areas such as medicine, architecture, construction, and transport. Unfortunately, after the use are thrown in nature. Their accumulation poses an environmental problem. Due to its the non- biodegradable. The consumption of waste plastic in the manufacturing of another material is a partial solution that will ease the proportion of waste plastic incineration or landfill. In the present study, an attempt has been made to review the work carried out by various authors and investigators in the field of advancement of composites in construction.

1. Use of agro waste in concrete

Agro-waste is readily available in India but till now it has not been recognized as a potential source for replacement in concrete. Bagasse, straw cereals, corn starch, corn cob, cotton, stalk, knead, rice husks, rice straw, sunflower hulls and stalks, banana stalks, coconut coir, bamboo, durian peel, oil palm leaves, Particleboards, hardboards and fiber boards are some of the examples of agricultural waste that can be used as building products. Several analytical and experimental studies have been performed by investigators around the globe for using agro waste in concrete. Multitudinous studies pertaining to agro waste conducted by different researchers. A perusal of the data summarized in the table indicates the present scenario of use of agro waste as a construction material.

1.1 Oil Palm Shell as coarse aggregate

Oil palm shell which is a variant of agro waste can also be utilized in concrete. Oil palm shell (OPS) is a waste lightweight aggregate originating from the palm oil industry, which is approximately 50% lighter than the conventional aggregate. Several investigators have studied pertaining to its use in concrete. Shafigh et al., (2014) carried out a study by replacing coarse aggregates with the agricultural waste. Oil Palm shell (OPS), Coconut shell and crushed granite were used as waste materials and he found that bulk density increased from 510-550 kg/m^3 compact form to 590-600 kg/m3 compacted form and that of crushed granite increased from 1300 kg/m3 compact form to 1420-1470 kg/m^3 compacted form. However, it was observed that void ratio decreases from 63% compact form to 57% compacted form and that of crushed granite 52% compact form to 47% compacted form. The same has been summarized in table no.1. Mo hung et. al., (2015) carried out an experimental investigation on the properties of lightweight concrete containing waste oil palm shell aggregate. He replaced OPSC as coarse aggregate on concrete. In the production of the OPSC, total binder content of 520 kg/m^3 was adopted in the mix design which consisted of 80% ordinary Portland cement and 20% GGBS (ground granulated blast furnace slag). OPS (sizes between 2.36 – 9 mm) was used as coarse aggregate while manufactured sand (sizes between 0.3 – 5 mm) was used as fine aggregate in the OPSC mix. The compressive strength of OPSC exceeds the compressive strength of normal weight concrete by 2 MPa. While tensile strength value of OPSC is slightly less than of NWC. The same has been summarized in table no.2.

However, another study conducted by Shafigh et. al., (2012) represents the use of crushed oil palm shell for making lightweight concrete. In this study, crushed old OPS was used as coarse aggregate. Compressive strength under different curing conditions and the splitting tensile and flexural strengths were compared with those of the normal weight granite concrete. The test results showed that OPS concrete with a compressive strength in the range of 34–53 MPa has a splitting tensile strength range of 2.8–3.5 MPa and flexural strength range of 4.4–7.0 MPa. The sensitivity of compressive strength of OPS concrete in this study is significantly lower than uncrushed OPS concrete reported in the literature. The sensitivity of OPS concrete, under the poor curing regime, can be reduced by decreasing the water/cement ratio, increasing the OPS content or reducing the cement content. It was found that there was no substantial difference in 28-day compressive strength for OPS concretes cured initially for 3, 5 and 7 days. The 28-day compressive, splitting tensile and flexural strengths of OPS concrete was found to be 38%, 28% and 17%, lower than that of granite concrete, respectively. The same has been summarized in table no.3.

Mannan and Ganapathy investigated that the oil palm shell concrete showed 14 times more slump value by adding super plasticizer than without super plasticizer. Alengaram et al. conducted the slump test by taking different aggregate size and concluded that particle size and mix proportion of oil palm shell did not cause any variation in workability. Olusela and Babafemi reported that slump value varies with the size of the oil palm shell and percentage of replacement. The authors also concluded that superplasticizer can be used to make the oil palm shell concrete workable. Another researcher Apeksha Kanojia and Sarvesh K. Jain, (2017) conducted a study for replacement of oil palm shell as coarse aggregates. Mix design was carried out for M20 grade control concrete (i.e. without coconut shell). Cubes of control concrete were prepared according to this mix design. In order to investigate the effect of replacing partially the conventional aggregate (CA) by coconut shell (CS), 150 mm cubes of coconut shell concrete were also cast. The same proportion of ingredients was maintained for coconut shell concrete also except replacing partially (by volume) the CA with CS. Total coarse aggregate comprised of respectively five different ratios of CA and CS viz (100:0); (90:10); (80:20); (70:30) and (60:40). Further, for increasing replacement of CA by CS, in steps of 5%, proportioning of ingredients was carried out for M20 grade concrete (i.e. concrete of 20 N/mm2 characteristic strength).

The effect of quantity of coconut shell was observed in respect of parameters like density; 7 & 28 days' compressive strength; and cement requirement. Effect of coconut shell on compressive strength of concrete presents 7 days and 28 days' compressive strength of 150 mm cube for different ratios of CA and CS; taking the number of ingredients (except coarse aggregate) corresponding to the M20 grade of control concrete. The compressive strength of coconut shell concrete is decreasing gradually with increase in the quantity of coconut shell. Gain in strength after 7 days is significantly higher for coconut shell concrete than that for control concrete shows the decrement in compressive strength due to increasing percentage of coconut shell. It can be observed that the decrement in the 28 days' compressive strength of coconut shell concrete is lesser than the decrement in compressive strength at 7 days. Results also indicate that coconut shell concrete gain less strength initially (7 days) but shows rapid strength gain at later stage. The same has been summarized in table no.4.

1.2 Sawdust Ash as fine aggregate

However, another study conducted by Elinwa et. al., (2002) assessed the properties of the ash and evaluated the performance of sawdust ash/ ordinary Portland cement. The researcher experimentally observed that as the percentage of content of ash is increased from 0% - 30% the soundness of the sample increased from 0.70 to 1.45. While the initial setting time increases from 116 -190 min and final setting time increase to 241 – 337 min. he also observed as the percentage of ash increases the slump value and the compacting factor decreases hence the workability decreases. The same has been summarized in table no.5. Some researchers have also carried out a study about another type of alternative agro wastes in concrete like bagasse ash, groundnut shell ash, and rice husk ash.

1.3 Sugarcane Bagasse Ash as fine aggregate

Modani and Vyawahare (2013) studied the property of bagasse ash and their suitability as binders in concrete. He observed that the compressive strength decreases for 7 days with the increase in the sugarcane bagasse ash content but 28-day compressive strength increases up to M10 and then decreases. Also, the average tensile strength decreases with the increases in the replacement of fine aggregate in sugarcane bagasse ash. whereas the percentage content of SCBA (sugar cane bagasse ash) increases the sorptivity value increases. The same has been summarized in table no.6.

1.4 Groundnut Shell as partial replacement of cement

Mahmoud et al., (2012) studied the properties of the ground shell ash and their use in the partial replacement of cement in the concrete block production. He found that as the percentage content of the groundnut shell increases the slump value first increases up to 10% and then decreases by 50%. The initial and the final setting time increases from 95min with 0% replacement to 436 min with 50% replacement. However, the percentage replacement of GSA increases the as compressive strength decreases. The same has been summarized in table no.7.

1.5 Rice Husk Ash as fine aggregate

The potential of rice husk can't be ignored as a replacement of fine aggregates in concrete. Muhammad Shoaib Ismail and A. M. Waliuddin (1996) reported that RHA is a by-product of paddy industry. Rice husk ash is a highly reactive pozzolanic material produced by the controlled burning of rice husk. FA is finely divided produced by the coal-fired power station. Fly ash possesses pozzolanic properties similar to the naturally occurring pozzolanic material. The unburnt rice husk contains about 50% cellulose, 25-30% lignin and 15-20% of silica. The former two components are removed by burning, leaving behind silica ash. Completely burnt husk is grey or whitish in color, while partially burnt husk is blackish. India is the second largest rice paddy cultivating country in the world. Both the technical advantages offered by structural concrete containing rice husk ash and the social benefits related to the decrease in a number of problems of ash disposal in the environment have simulated the development of research into the potentialities of this material. A large amount of agricultural waste was disposed of in most of the tropical countries especially in Asia for countries like India, Thailand, Philippine and Malaysia. Hence observing the problem related to the disposal of rice husk, it can be used as a partial replacement in concrete.

Multitudinous researchers have conducted studies pertaining to the study of replacement of rice husk ash in concrete. Madanoust et. al., (2011) carried out the study in the context for replacing cement in the concrete by using a different mixture with 0-30% of RHA by weight of cement and found that air content percentage increases from 3.6 to 4.1. Similarly, tensile strength increases with increase in curing age. However, the workability decreases from 65% to 45% a similar trend was observed with compressive strength with a decrease from 35.4 to 26.6 MPa. The same has been summarized in table no.8. H. Sathawane et. al., (2013) studied on compressive strength on a cube of 150 x 150 x 150mm for an M25 grade concrete. The strength was tested for 0, 5, 10, 15% replacement of cement by RHA after curing for 7, 14, 28, 56, 90 days on a digital compression testing machine. It was observed that the optimum value of replacement of RHA is 7.5% and has a maximum value of 46.67 MPa after 90 days of curing and after 7.5% replacement, its compressive strength decreases by 19.04% and then decreases to 15% replacement. Hence 7.5% replacement of RHA gives the optimal value of replacement. The same has been summarized in table no.9.

Another investigator Ganesan et al., (2007) carried out a study concerning the use of rice husk ash in concrete as a partial replacement of cement. RHA blended cement was prepared by replacing OPC (0, 15 and 30 %). Compressive strength test of blended cement mortar cube was performed and it was observed that 7 days' compressive strength remains constant till 15% replacement of OPC by RHA. While 28- days compressive strength show optimum value at 15% replacement of OPC by RHA. Replacement with 30% of re-burnt rice hush ash leads to substantial improvement in the permeability properties of blended concrete when compared to that of unblended OPC concrete.

Researchers V. Saraswathy and Ha-Won Song (2007) carried out a study on the corrosion performance of rice ash blended concrete. Compressive strength and Split tensile strength were tested on the specimen of size 100mm x 100mm x 100mm with a mix of 1:1.5:3 with W\C ratio of 0.53. Here concrete blocks were prepared by replacing OPC with Rice Husk at 5%, 10%, 15%, 20%, 25% and 30% replacement levels. Compressive strength after 7 days, 14 days, and 28 days were observed. After 7 days, 14 Days, and 28 Days the compressive strength increases but the compressive strength after 28 days of curing is almost constant. The results prove that it is possible to obtain RHA concrete with comparable or better properties than those of the control specimen (without RHA) with a lower consumption of cement, thus reducing the CO_2 emissions during the production of cement. Numerous conclusion has been made till now relating to the use of rice husk in concrete. One notable work has been done by Christopher et. al., (2017). Who came to a general conclusion that RHA containing a considerable amount of SiO_2 will react with $Ca(OH)_2$ to produce the CSH gel; and that due to the fact that the pozzolanic reaction is a time-consuming reaction, the paste containing RHA has a lower $Ca(OH)_2$

content than the pure Portland cement paste.

There is, however, a conflicting conclusion as to the effect of RHA on the early rate of hydration. The investigation conducted by Feng et al. (2004) showed that the addition of RHA stimulates the hydration of cement at the early age, and hence more heat and more CH in the RHA-blended cement paste are produced. Studies pertaining to the compressive and shrinkage properties obtained after mixing of rice husk in concrete portrays that Replacing OPC by RHA shows an increase in compressive strength up to a specified replacement level. From the analysis of the results of some of these researchers, the factors affecting the compressive strength of concrete incorporating RHA are a water-cement ratio, the curing duration, and RHA replacement level. Bui et al. (2005), De Sensale, 2006, Chindaprasirta et al. (2007), and Babaiefar (2007) suggested that at the water-cement ratios of 0.30, 0.32, and 0.34 compressive strength increased (relative to the control) with RHA up to 20% at the curing ranges of 7, 28 and 90 days. At the water-cement ratio of 0.35, there seemed to be a contradiction. While Isaia et al. (2003) and Hwang et al. (2011) concluded that the compressive strength decreased with RHA up to 30%.

According to CCA (2002), proper mix design of concrete is one of the measures that will produce concrete of low shrinkage characteristics. According to (Wu and Peng, 2003; Habeeb and Fayyadh, 2009; Mahmud et al., 2009; Chatveera and Lertwattanaruk, 2011; Khassaf et al., 2014) there is a drastic change in the drying shrinkage when RHA is used as a partial replacement of cement in concrete. The reduction in drying shrinkage was progressive when the percentage replacement of RHA is increased. Thus when shrinkage is a concern, the use of RHA can serve as part of the strategy to mitigate its effect.

1.6 Corn Cob as coarse aggregate in concrete

Among the above-identified agricultural products, corn cob belongs to the set which has the additional advantage of not colliding with the worldwide food stock and of being generally considered as agricultural waste. Corn cob is obtained from maize and has a similar chemical elementary composition and microstructure to that of extruded polystyrene. It is the most important cereal crop in sub-Saharan Africa. According to food and agricultural organization (FAO) data 589 million of tons of maize were produced worldwide in the year 2000 and by 2009 it is 998 million tons. South Africa and Nigeria are the first and the second largest producer of maize. As the corn cob is considered as the agricultural waste therefore by using sustainable and economic benefits may be achieved through technological solutions. D.A. Adesanya, A.A. Raheem used it as a partial replacement for Clinker during cement production in the factory. Researchers investigated on the durability of corn cob ash (CCA) blended cement. Permeability and chemical attack were the key parameters. A 100 mm cube with 1:1½:3, 1:2:4 and 1:3:6 mix proportion with 0.5, 0.6 and 0.7 water-to-binder ratios was used for water absorption test. The result indicated that the use of CCA blended cement reduces the water absorption of concrete specimens. The optimal reduction occurred at 10% CCA replacement for 1:1½:3 and 1:2:4 mix proportions and at 15% CCA replacement for 1:3:6 mix proportion. The same has been summarized in table no. 10.

D.A. Adesanya, A.A. Raheem (2009) performed the compressive strength on a cube of using 100 mm x 100 mm x 100mm with a mix proportion of cement: sand: granite is 1:1½:3, 1:2:4 and 1:3:6 with 0.5, 0.6 and 0.7 water-to-cement ratios, respectively. A total of nine batches were prepared for each mix proportion corresponding to each of the nine percentage CCA replacement of 0%, 2%, 4%, 6%, 8%, 10%, 15%, 20% and 25% in the blended cement used. The result indicated from the slump value test that the slump value decreases with increase in the CCA content. The slump value decreases as the CCA content increases. For 1:1½:3 mix proportion, revealed that the slump decreases from 35 mm to 12 mm as the percentage CCA substitution increases from 0% to 25%. Similarly, the compacting factor decreases from 0.89 to 0.67 as the percentage CCA substitution increases from 0% to 25%. The same trend was observed for 1:2:4 and 1:3:6 mix proportions. Here the optimal value for the cement replacement by the CCA is 6% and it also indicates that more water is needed to make the concrete more workable. The same has been summarized in table no. 11.

2. Use of e-waste in construction

The waste generated due to the discarded, obsolete, end of life electrical and electronics equipment is known as E-waste world over. It is well known by acronym WEEE (Waste from Electrical and Electronics Equipment's). Developing countries mostly face the problems related to the disposal of E-waste. Conventional disposal techniques include landfill, incineration which leads to hazardous environmental problem hence an alternative for disposal is necessary. India is generating e-waste more than 8,00,000 tons annually [MoEF, Guidelines, 2008]. The 70% e-waste is being generated by ten states in the country Rajya Sabha Report]. The obsolete, short-lived, damaged, End of life EEEs (Electrical and Electronic Equipments) all together made e-waste a fast growing waste in the country. In India, IT industry has promoted both software and hardware segment and become a leader in the world. The growth rate of IT [Information Technology] industry was 42.4% between 1995 to 2000[EMPA, 2006].

2.1 E-waste as coarse or fine aggregates in concrete

Many researchers carried out studies for the effective use of E-waste by replacing it in concrete as fine and coarse aggregates. The research done by M. Suchithra et. al. (July –August 2015) focus on the replacement of the coarse aggregate with the e-waste. The addition of E-waste shows increases in compressive strength up to 15% replacement, after 15% it shows a slight decrease. The tests conducted on reinforced e-waste beam also show an increase in flexural strength and optimum at 15% replacement of coarse aggregate as e-waste. Another investigator Dave et al., (2013) effectuated an experimental study on the utilization of E-waste and plastic waste particles as aggregates in mortar cubes with a percentage replacement ranging from 0% to 4%. Results show an increase of compressive strength till 4% replacement. The same has been summarized in table1.

Although Manjunath et al. (2016) investigated the properties obtained when e-waste is used as coarse aggregate in cement. The slump of concrete decrease with an increase in %e waste mix Concrete. Also, flexural strength decreases as e-waste

% is increased above 20%. The same has been summarized in table 3. E-waste can be utilized in ground form as fine aggregates pertaining to this Vignesh et. al., (2016) conducted a study on concrete using ground e-waste as a replacement for fine aggregate. The main aim of the study is to detect an alternative material for river sand (fine aggregate) in the production of cement concrete. The compressive strength also shows a slight decrease with decrease with increase in E-waste %. Split tensile strength of concrete pertaining to E-waste aggregate decreases from 2.5 – 3 N/mm^2 and Flexural strength decrease from 4 – 3.5 N/mm^2. As the %control mix of e-waste is increased strength decreases. The yield of concrete reduces when E-waste is used as a replacement material for sand. It is coherent that E-waste can be biased by using them as constructional material. The same has been summarized in table 4.

However, Ahirwar et al. (2015) experimentally determined the compressive strength for 7 days, 14 days, and 28 days using different proportions of E-Waste. Results indicate that there is an increasing trend of compressive strength with increase in the age of the concrete specimens. However, it shows that the compressive strength of E-Waste specimens is lower than normal aggregate specimens. The same has been summarized in table 5.

Hence, numerous studies have discussed possible aspects for use of E-waste to be used in various forms. Another researcher Balasubramanian et al., (2016) has done a study to conclude the compressive strength, tensile strength and flexural strength of concrete by using E-Waste as a partial replacement material for coarse aggregate. He used e-waste obtained from printed circuit boards(PCB). Results obtained show an increase in compressive strength from 20 to 24 N/mm2 when replacement is done from 5 to 15% but increasing e-waste proportion above 15% show decrease in compressive strength. Results of flexural strength at 28 days also show increase till 15% replacement of e-waste as coarse aggregates. The same has been summarized in table 6. Mathur et al., (2017) studied related to replacement of e-waste with plastic waste as coarse aggregates. The proportion of e and plastic waste was from 2.5 – 10% in the M25 concrete mix. Tensile and flexural strength tests were performed on the mix. It is observed that the compressive strength initially increases from 19 to 21 N/mm2 with 2.5 to 5% E and plastic waste replacement. Flexural strength shows a similar increase from 7 to 8 N/mm2 with a maximum value of 5% replacement. Hence we get that optimum percentage up to which we can introduce a mix of e-waste and plastic waste in concrete as coarse aggregate is 0%-5% (increase in strength) to 5%-7.5%. The same has been summarized in table 7.

Newer approaches are required to make the process feasible. Gupta R. et al. (2015) carried out a study pertaining to the utilization of different combinations of e-wastes and recycled coarse aggregate together as a substitute for conventional aggregates. The site-tested concrete specimens which would contain recycled aggregates were collected and were combined with the e-waste (PCBs) as a complete replacement of coarse aggregates by altering the proportions of these wastes. The M20 grade of concrete was made. He used recycled and e-waste in coarse aggregates. The e-waste PCBs strips were also used as reinforcement in concrete to enhance the tensile properties. Flexural strength shows a sharp decrease from 3.5 to below 2.5 N/mm2 with an increase in mix proportion. Optimum results are obtained at 5% e-waste mix and 90% recycled coarse aggregate. The results show that optimum mix of recycled aggregates and e-waste as coarse aggregates can be effectively used in the sub-base preparation for the rigid pavements, also in the construction of low volume concrete pavements. The same has been summarized in table 7.

Damal et al., (2015) studied on replacement of e-waste in concrete. He used e-waste as a replacement for fine aggregates. Mix formed were of e waste% 5, 7.5 and 15%. The specimen was tested for 7, 14, 28 days' compressive strength. It is also observed that the compressive strength of concrete is found to be optimum when the fine aggregates are replaced by 7.5% with Electronic waste. Beyond it, the compressive strength of concrete goes on decreasing. The compressive strength of concrete will gradually decrease when the fine aggregate is replaced beyond 15% with E-waste. The same has been summarized in table 8.

Another researcher Shamili et al., (2017) also performed study pertaining to replacement of different forms of e-waste as fine aggregates in concrete. She analyzed workability and strength characteristics of e-waste replaced as fine aggregates in concrete. Slump value decrease from 50 to 36 mm on increasing e-waste proportion from 5 to 20%. Compressive strength also shows a similar drop from 42 to 35 with an increase in E-waste proportion in concrete. Workability of concrete decreases when the percentage of the E-Waste is increased. Mechanical properties of concrete with E-Waste as aggregate shows slightly lesser than the controlled mix. Workability of concrete decreases when the percentage of the E-Waste is increased. Mechanical properties of concrete with E-Waste as aggregate shows slightly lesser than the controlled mix. The same has been summarized in table 9.

Other notable works related to replacement of E-waste in concrete include Manatkar and Deshmukh (2015) investigated the use of non-metallic e-waste as coarse aggregates in concrete. They used 4.75 mm of e-waste in M20 grade of concrete and performed compressive strength test at 7,14 and 28 days. It was observed from the results that compressive strength almost remains same till 5% replacement of e-waste in the mix. But the further increasing proportion of e-waste strength decreases sharply. Hence, up to 5-6% replacement of e-waste is suitable to use up to (G+2) building construction, road construction. The same has been summarized in table 10.

Roy et al., (2015) conducted experimental work for partial replacement of e-waste as coarse aggregates in concrete. Compressive and slump test was performed. E-waste was replaced with 10, 20 and 30% of fly ash. When fly ash content added to electronic waste concrete, it has been observed that workability increased. Workability of fly ash with electronic waste concrete is even more than conventional and electronic waste concrete. The compressive strength of electronic waste concrete decreases with increase in the percentage of e-waste. It was concluded in the study that cement replacement of 30% by fly ash along with electronic waste gives the best result. The same has been summarized in table 11.

2.2 E- waste with fly ash and m- sand in concrete

Several investigators have also used admixtures with e-waste to get enhanced properties. Another form of E-waste is studied by Lakshmi and Nagan, (2016). They replaced e-waste and 10% fly ash as fine aggregates. Compressive strength and split tensile strength were analyzed by preparing M20 grade of concrete from the mix. It was observed that compressive strength remains constant till 12% replacement of e-waste and fly ash but the starts to decrease. While split tensile strength decrease from 6 – 5 N/mm2 with 4 – 12% mix. It attains optimum value at 16% mix proportion (e-waste and 10% fly ash). Addition of fly ash in the mix considerably improves strength index of control mix as well as e-waste concrete. The strength development of fly ash based e plastic concrete in early days found to be less but 28 days compressive and split tensile strength has proven results in comparison with controlled concrete up to 25% e plastic replacement. The same has been summarized in table12.

Harish More performed analysis of e-waste in concrete as fine aggregates with m- sand (manufactured sand). Results show a maximum value of compressive strength, split tensile strength and flexural strength at 95% m sand and 5% e-waste in fine aggregates. While slump value also shows a linear increase with an increase in the content of both e-waste and m- sand. Considering both strength and durability aspect it can be said that the 10 % EWFA (e-waste fine aggregates) replacement satisfies to be the optimum percentage of e-waste as a partial replacement in fine aggregate that can be utilized in concrete mixes. The collection, treatment, recovery, and disposal of e-waste is needed at a national and regional level for reducing the adverse effects. The same has been summarized in table 13. Similarly, Prasanna and Rao, (2014) also tried to replace e-waste with fly ash to obtain enriched properties. They replaced e-waste as coarse aggregates with 10% fly ash. It is observed that the compressive strength of concrete is found to be optimum when coarse aggregate is replaced by 15% with E-Waste. Beyond it, the compressive strength is decreasing. The compressive strength will gradually decrease when fly ash is added by 10% in addition with different proportions replacement of E-waste with Coarse aggregate. The same has been summarized in table14.

2.3 E-waste in construction of roads and pavements

E-waste also has the potential to be utilized in the construction of roads and pavements. Efforts are being made by CRRI to use discarded e-waste for road construction. As 25,586 cubic meters of hazardous black powder, or e-waste, has been lying along the banks of Rāmgangā river at Moradabad, Central Pollution Control Board (CPCB) wrote to Central Road Research Institute (CRRI) to test it and see if it can be used to build roads. After National Green Tribunal (NGT) had directed CPCB to submit an action plan for disposal of black powder lying dumped along the river, CPCB had approached National Highways Authority of India (NHAI) for using black powder in road construction and filling of over bridges and embankments. Ranadive and Shinde (2012) investigated the effects of E-waste and fly ash as a filler replacement in bituminous roads. Ductility, softening point, impact value, Marshall stability was analyzed and all the results were up to permissible value. Experimental results proved that partial replacement of aggregates by e-waste is technically feasible; at 10% e-waste and 5.5% bitumen content, which attains 11.28 % higher stability than control mix. The use of e-waste saves bitumen consumption by 5.33% and 10% aggregate by total volume. The bituminous concrete mix having 10% e-waste was found to be the optimal mix. The fly ash along with e-waste as filler replacement cannot improve strength; it is found that 14.78% decrease in stability is seen as compared with control mix.

Anand T. et al. (2015) studied pertaining to the use of e-waste in flexible pavements. It was concluded that 5.5% bitumen content in which 7.5% of bitumen replaced by waste plastic and 7.5% aggregate replaced by Electronic waste showed increased stability keeping all the other parameters within limits. From the experimental work, it was cleared that the properties of the designed bituminous mix for bituminous concrete were much more superior to those of the control mixes entirely composed of mineral aggregates and effectively used in practical applications. The same has been summarized in table15.

Selvam and Krishna (2015) studied pertaining to the replacement of e-waste as coarse aggregates. They used 10 -30% of e-waste in concrete for preparing molds and using them for comparison with the conventional mix. It was observed that compressive strength (7 days) increase to 23 N/mm2 but it shows a steady decrease in 20 and 30% e-waste. Also 14 and 28-day compressive strength decrease with the introduction of e-waste. Tensile strength test conducted on cylindrical specimen shows that with an increase at 10% e-waste in 7 days. But comparable to compressive strength it also shows a decrease in tensile strength at 20 -30% e-waste replacement in 14 and 28 days. The same has been summarized in table16.

Kadam Digvijay et al. (2015) in this study it was found that 7.5 % of aggregate was volumetrically replaced by Electronic waste in DBM layer with 5.5 % optimum bitumen content (OBC). As, the e-waste percentage was increased beyond 7.5% the stability was decreased which clearly indicates negative results due to excess use of e-waste. The outcomes from the laboratory investigation proved that the use of Electronic waste is suitable in the construction of flexible pavement which also helps in cost saving. Also the disposal of Hazardous electronic waste in the flexible pavement and it was proved that e-waste was one of the alternatives to make the earth greener and pavements more durable.

Further a different scholar Gull and Balasubramanian investigated for replacement of e-waste wires (5,4 and 3 mm diameter) in concrete for insulation. E-waste wires were replaced from 0.4 – 1% and then compressive strength and tensile strength was observed. After performing tests, it was observed that when 1% of the E-plastic for 5cm is added, the compressive strength gets reduced by 2.59 % when compared to control mix. With the addition of the E-waste 4cm and E-waste 3cm, the compressive strength gets increased up to a maximum of 5.9 % and 10.6% respectively when compared to control mix. The tensile strength of concrete with the presence of E-waste when 1% of the E-plastic for 5cm is added, the tensile strength gets increased by 2.3% and for 1% of 4cm, the strength increase observed is 4.6% when compared to control mix at 28 days of curing. However, when 1% of the E-plastic for 3cm is added, the tensile strength initially gets increased by 4.6% and then gets decreased with increase in percentage.

R. Kajal and R. Chauhan, (2018) carried out study for use of e waste in bituminous concrete pavement. Research includes various tests on materials to be used as well as on nominal mix and design mix. This research includes the tests on coarse aggregates, fine aggregates, bitumen, e-waste and fly ash also. For strength the Marshall Stability tests are performed with the different percentage of e-waste as a coarse aggregate i.e. 5%, 10%, 15% and making filler constant which is fly ash. The percentage of filler in the design mix is 7% which meet the requirement standard of gradation. The grade of bitumen which is used i.e. VG30. Coarse aggregates were replaced by e waste from 5-15% with 7% fly ash in each specimen. Marshall stability, bulk density, percentage air voids tests were performed in specimens prepared. Maximum stability found at 5.5% bitumen content with 10% e-waste as a coarse aggregates and 7% fly ash as a filler in design mix, which is more as compare to nominal mix and all other readings are at under MORT&H specifications. The filler helps in attaining the value equivalent to the nominal mix which help in the cost saving of the material.

2.4 Optimum Proportion on E- waste in Concrete

It is important to know the amount or proportion of e-waste at which can be desired properties can be achieved. Pertaining to this a group of researchers studied to the determine the optimum dosage of e-waste that could be replaced in concrete. Rajkumar and Nithya (2016) made an attempt to determine the optimum dosage of e-waste that could be replaced as coarse aggregates in the M25 grade of concrete. It is observed that compressive strength of M25 grade concrete with the mix proportion shows an increase in strength for up to 10% replacement of coarse aggregate by e-waste. It is observed that 28days compressive strength of M25 grade concrete containing 10% replacement of coarse aggregate by E-waste exceeded the strength of control mix by 8.51%. Also, the tensile strength is achieved for10% replacement. There is a slight reduction in flexural strength for 10% replacement. The optimum percentage of E-waste that can be used as a replacement for coarse aggregate in M25 grade concrete was found to be 10%. The same has been summarized in table17.

Senthil and Baskar (2014) studied related to use of mixed electronic waste in concrete. In this study, mixed electronic plastic chips (referred in this study as E-plastic) were used as partial replacement of coarse aggregates in concrete. The experimental study has been conducted to assess the benchmark properties of E- plastic aggregates to the concrete. 5, 10, 15 and 20 % weight of coarse aggregates have been replaced by E-plastic waste. It was observed that the slump has shown a significant decrease upon increasing the E plastic quantity. The concrete specimens were tested on 7, 14 and 28 days. E-plastic concrete has low unit weight and considerable ductility. The Compressive, splitting tensile and flexural strength were found to be decreased by 42.35%, 36.33%, and 40.98%, respectively, for 20% replacement of E-plastic compared to control concrete. The same has been summarized in table18.

2.5 E- waste as an admixture in concrete

E-waste can also be utilized in powdered form as an admixture in cement mortar. Ru Wang et al. (2012) considered the use of waste PCB in powdered form in cement mortar. The waste PCBs nonmetallic powder used in this research consists of about 60% cured thermosetting epoxy resins, 38% glass fiber. The waste PCBs nonmetallic powder was added in cement mortar as an admixture with powder to cement ratio by mass (mp/mc) of 0, 5, 10, 15, 20 and 25%. The dimensions of the mortar specimens are 40 mm * 40 mm * 160 mm. it was observed that as mp/mc increases from 0 to 15%, the compressive strength changes from 23.2 to 16.9 MPa, from 34.9 to 28.8 MPa and from 53.8 to 40.0 MPa for the mortars cured for 3 days, 7 days and 28 days, respectively. It can be seen that the compressive strength of mortar with the waste PCBs nonmetallic powder addition less than 15% doesnt decline rapidly. But after that, the compressive strength decreases gradually. When the mp/ mc increases from 0 to 15%, the flexural strength varies from 4.7 to 4.1 MPa, from 6.4 to 5.5 MPa and from 8.6 to 6.6 MPa for the mortars cured for 3 days, 7 days and 28 days, respectively, indicating that adding no more than 15% nonmetallic powder has no significant effect on the flexural strength. It is easily observed that the water-retention rate goes up evidently as the mp/mc increases and the growth rate in the whole mp/mc range from 0 to 25% is steady, from 91 to 97.5%. The same has been summarized in table19.

2.6 E- waste plastic in concrete

Several researchers have also utilized plastic in e-waste for replacement in concrete with fly ash. Bharat Dawande, Devansh Jain and Dr. Gyanendra Singh 2016 The author of this paper used e-plastic waste material and replaces with coarse aggregate up to 25% with a regular interval of 5% whereas cement is partially replaced with fly ash. Workability of fly ash with electronic plastic waste concrete is even more than conventional and e-plastic waste concrete. In his paper, it can be concluded that e-plastic waste could be used in concrete as course substitution up to 10% alone and up to 25% with fly ash. Workability of fly ash with e-plastic waste concrete has even more than conventional and plastic waste concrete. The author recorded decrement in strength for 7 days from 1.78% to 13.05% and same for 28 days' compressive strength the decrease in strength from 3.37%, to 20.29%.

Amiya Akram et al. 2015. Their experiment' s attention is on the utilization of e-plastic in concrete and their possibility of using shredded plastic as substitution of coarse aggregate. It was noticed that when only E Plastic was used in the concrete mix, its strength decreases but the addition of 10% fly ash in same concrete mix shows comparable strength to conventional concrete. Through this experimental study author concluded an assumption that e-plastic has viability to be utilized as construction material and hence lowers the necessity of natural coarse aggregate, resulting in the preservation of coarse aggregate. In their research work they used the e-plastic with a difference of 5% by their weight with every change in coarse aggregate with 0 to 5%, from 5 to 10%, 10 to 15%, and 15 to 20 % for the M20 grade. There is a decrease of 18.18%, 24.24% and 24% with an increase of every 5% at the age of 7 days curing. And after 28 days the decrease in compressive strength is 35%, 37.5%, and 43%.

An analysis was made on the strength characteristics by Dave and Arora, 2013 conducting the tests on e-waste mortar cubes with grinded e-waste and plastic bottle waste. Figure 4 shows the reduction in the strength of the cubes. It was because of the grinded waste does not possess cementitious property. It does not bind well with the cement and thus the strength was subsequently reduced. Figure 5 shows the strength versus percentage of grinded plastic bottle waste. Due to the flaky nature of the grinded bottle waste the strength was reduced with the increase in proportion of the waste. In the case of crushed e-waste which was pulverized by friction rolling machine strength in figure 6, increases till 4% and subsequent reduction was observed in the strength after that. This fall in strength was because of the decrease in the packing density. Making of tiles out of white cement and e-waste. The same has been summarized in table 2.

Another investigator Aditya, et al., 2016 carried out the experimental work has used non–biodegradable components of E-waste (plastic) as a partial replacement of coarse aggregate. The efforts of work exhibit that good strength in the concrete with 10% replacement of M20 grade. Also, it was replacing with the river sand as compared with the control specimen will reduce the essential for conventional coarse aggregates. Nadhim, et al., 2016 investigated the comparative study on E–plastic waste and fly ash concrete with conventional concrete. This study shows that E– plastic waste as coarse aggregate which is compared with the fly ash as the cement that improves the strength and durability. Also reduces the bleeding, segregation and lower the heat of hydration (Nadhim, et al., 2016). The literature study shows that 0–20% replacement of E-waste in concrete is giving an improvement in compressive and flexural strength. However, strength decreases when E-waste content is more than 20%. Hence, concluding from the above-discussed studies we cannot underrate the potential of E-waste to be utilized in concrete.

2.7 E-waste with corn cob in concrete

R.N. Patil et al., (2017) studied pertaining to the replacement of coarse aggregates by e waste and corn cob in concrete. The concrete is poured into the moulds in 3 layers by poking with tamping rod for cubes of 150×150×150 mm Size, cylinders of 150×300 mm size and beams of 500×100×100 mm size was tested for compression split tensile and flexural strengths. The cast specimens are removed after 24 hours and these are immersed in a water tank. After a curing period of 7 and 28 days the specimens are removed and these are tested for compression, split tensile and flexural strengths tests. The results are compared with conventional concrete. By considering the use E-waste and corn cob in the mixes as much as possible and achieve suitable workability was attempted and strength criteria of Grade M30 concrete mix was analyzed. E waste and corn cob was replaced upto 40% in concrete. Various tests conducted on E-waste & corn cob and results compared with coarse aggregates are satisfactory as per IS 2386. Due to use of E-waste & corn cob as partial replacement of coarse aggregate in construction, energy & cost of coarse aggregates is significantly saved. It is identified that e-waste can be disposed by using them as construction materials. E-waste and corn cob can be used effectively up to 10% replacement of coarse aggregates. This in turn directly reduces the impact of waste material on environment. The experimental results show that the flexural strength and split tensile strength of normal concrete and modified concrete is approximately same up to 10-20% replacement by e-waste and corn cob

3. plastic Waste In Concrete

Plastics have become an inseparable and integral part of our lives. The amount of plastics consumed annually has been growing steadily. Its low density, strength, user-friendly designs, fabrication capabilities, long life, lightweight, and low cost are the factors behind such phenomenal growth. Plastics have been used in packaging, automotive and industrial applications, medical delivery systems, artificial implants, other healthcare applications. Disposal of waste materials including waste plastic has become a serious problem and waste plastic are burnt for deceptive disposal which causes environmental pollution. Plastic waste can find its use in road construction process, this can help in solving the problem of pollution and disposal. The better binding property of waste plastic in the molten state has helped in finding out a method of safe disposal of waste plastic. Due to its low cost, easy manufacturing and impervious to water plastic is used in an excessive and manufacturing wide range of products.

3.1 Use of plastic waste material in polymer modified bitumen

Several investigators had carried out studies related to the use of waste plastic in road construction, roof tiles. Appiah et. al. (2016) investigated on the use of plastic waste material polymer modified bitumen HDPE and PP for road construction and studied penetration, softening point, viscosity. Penetration shows a sharp decrease of 5% in concentration of polymer from unmodified bitumen. However, a linear increase in softening temperature for HDPE up to 3% concentration has been observed. Bitumen with viscosity 360 CSR at 1315 centigrade shows an increase in viscosity with a decrease in polymer concentration and shear rate. Sabina et al., (2009) evaluated the performance of waste plastic/polymer modified bituminous mix and observed that the results of marshal stability and retained stability of polythene modified bituminous concrete mix increases 1.21 and 1.18 times higher than that of conventional mix by using 8% and 15% (by weight of bitumen) polythene with respect to 60/70 penetration grade of bitumen. But modified mix with 15% polyethylene showed slightly decreased values for Marshall Stability than that of the mix with 8% modifier in their results.

3.2 Use of plastic in bitumen road construction

Anuj Dhiman (2016) carried out an experimental study and focused on the use of recycled polythene carry bags in road construction and found that penetration value decrease with increase in use of plastic, 5% plastic decrease it from 70mm to 6.8mm. Ductility also tends to decrease with the use of plastic from 83mm to 57mm. According to Verma et al., (2008) while a normal “highway quality” road lasts four to five years, plastic-bitumen roads can last up to 10 years and it would be a boon for India’s hot and extremely humid climate, where temperatures frequently cross 50°C and torrential rains create havoc, leaving most of the roads with big potholes.

The researchers Kashiyani et al., (2013) carried out a study on Comparison Between Properties of Ordinary Bituminous Roads and Waste Plastic Bituminous Roads and found out that the porosity is reduced to less than 2%, resulting in very less stripping of bitumen thereby improving the aggregate quality. The ability of the aggregate to resist weather conditions is improved., the moisture absorption ability of the aggregates decreases, resulting in better resistance to rain. Rebound deflection is minimized while higher resistance to rain and waterlogging. Reduced the need for bitumen by around 10%. Reduce the cost of bitumen to around Rs. 5000/Km. Plastic waste can also be utilized as coated aggregates. Another research carried out by Rokdey et al. (2015) shows that with the use of plastic waste coated aggregate in road construction the compressive strength increases from 250-320Mpa as well as there is the similar trend in case of binding properties which increases from 325-390 Mpa.

3.3 Replacement of asphalt with plastic waste

Yakub et. al. (2017) carried out a study on the replacement of asphalt with waste polythene in bitumen road and found that aggregate impact value improves with use of waste polythene from 13gm to 10gm as well as stability increase from 300kg to 367 kg. Water absorption has decreased from 2.77 to 1.7 also cost decreases from Rs 1134 to Rs1008.The same has been summarized in table no. 3. However, Yocef et. al. (2014) carried out a study on the use of plastic bag waste as fine aggregate and conducted tests on fresh and hardened properties and found that fluidity of concrete increase with an increase in the use of plastic from 5cm to 11cm. Whereas bulk density decrease with increase in plastic as 40% plastic waste decrease to 11.5%.Compressive strength tends to decrease with the use of plastic, 10-20% plastic waste its value reduces to 10-24 %.Also, ultrasonic pulse velocity is much higher for concrete which contains low % of waste.

Sui and Chen et al., (2011) studied application and performance of polyethylene as modifying additive in the asphalt mixture. They added polyethylene as an additive to hot mineral aggregate for few minutes and then added the asphalt mixing together which simplifies the construction process and reduces the cost of construction. They concluded that there is an improvement in high-temperature stability, low temperature cracking resistance and water resistance on modification and evaluate polyethylene as an additive in the technical, economic and environmental aspects. M. Elzafraney et al. (2005) this study has incorporated use of recycled plastic aggregate in concrete material for a building to work out its performance with regards to thermal attributes and efficient energy performance in comparison with normal aggregate concrete. They have suggested the use of recycle plastic aggregate concrete being economical and light weights are having high resistance to heat.

3.4 Use of plastic waste as coated aggregates

Plastic shows promising results in bitumen and asphalt mix. Plastic in roads can enhance its properties. Several notable works for plastic in road construction are discussed here. The study carried out by Barad M. shows that with the use of plastic waste as coated aggregates the moisture content decreases from 4- 0%, also soundness gets completely reduced from 5% to 0%. The research carried out by Priya et al., (2017) shows that with the use of plastic waste from 0% to 15% there has a variation in the properties, penetration value increases from 87-89mm, softening value increases from 57^0C to 73^0C whereas ductility and viscosity shows a similar trend they increase up to 10% from 75 -79cm and 1200 poise -1600pise and then decreases for 15% use plastic to 68cm and 1500 poise. The research carried out by Azmat et al. show that there has been a great variation in the properties of aggregates as well as on bitumen with the use of plastic waste. Some of them are aggregated impact value (10.7-9.27), water absorption (3.2-2), abrasion value (12.8-11.7) shows a decrease in their values when plastic coated aggregates were used. Bitumen properties also show variation marshal stability increases with the use of plastic from 950-1980 kg, Marshal flow value also decreases with use of polythene from 3.1-5.0. The researcher R. Manju et al., (2017) carried out the study and found that the crushing value reduces from 23.32 to 14.22 for normal and plastic coated aggregate. The aggregate impact value of plastic coated aggregate was reduced by 9% than the normal aggregate The abrasion value plastic coated aggregates were 21% less than the normal aggregates. The penetration value of bitumen is higher than the bitumen mixed with the plastic. The stability of modified bitumen (10% bitumen replaced by plastic) is higher than the normal bitumen.

R. Atul studied based on experimental results of concrete sample casted with use of plastic bags pieces to study the compressive and split tensile strength. He used concrete mix by using Ordinary Portland Cement, Natural River sand as fine aggregate and crushed granite stones as coarse aggregate, portable water free from impurities and containing varying percentage of waste plastic bags (0%, 0.2%, 0.4%, 0.6% 0.8% and 1.0%). Increase in tensile strength of concrete was observed by adding up to 0.8% of plastic bag pieces in the concrete mix afterward it starts decreasing when adding more than 0.8% of plastic bags pieces.

Also, A. Bhogayata et al., (2012) they have studied the environment friendly disposal of shredded plastic bags in concrete mix to be use in construction industry which have dire need for alternative material to be use in lieu of conventional materials. Different test results were analyzed after testing on 48 x concrete cubes (150mm x 150mm x150mm) prepared from varying percentage of polyethylene fibers (0.3, 0.6, and 0.9 to 1.2% of volume of concrete) with conventional concrete material to prepare mixes. Two type of plastic bag fibers were used, one cut manually (60mm x 3mm) and another shredded into a very fine random palette. Cubes were tested for 7&28 days' compressive strength and compaction. They concluded that good workability was shown by the mix added with shredded fibers due to its uniform and higher aspect ratio evenly sprayed in the mix

3.5 Replacement of plastic waste and polymer in flexible pavement

Several investigators have studied in relation to the replacement of plastic waste and polymers in flexible pavements. R. Vasudevan et al., (2015) infers that addition of natural or synthetic polymers to bitumen is known to impart enhanced service properties. By adding small amounts of polymers to bitumen, the lifespan of the road pavement is considerably increased and the purpose is to achieve desired engineering properties such as increased shear modulus and reduced plastic flow at high temperatures and/or increased resistance to thermal fracture at low temperatures. Saiyed Farhana et al., (2015) concluded that the specific gravity of these aggregates ranges from 1.5 to 2.7 and the marble chips are extremely durable. They also reported that replacement of marble chips to aggregates had a beneficial effect on the mechanical properties such as crushing strength and stripping value.

3.6 Use of plastic in as lightweight material

The plastic waste also has capabilities to be used as lightweight materials such as roof tiles the same study has been carried out by Seghiri et.al., (2017) on the possibility of making composite materials from waste plastic and conducted tests on density, breaking load by flexure and impermeability. He found that density tends to decrease with increase in plastic waste ratio, breaking load value of all polymers tend to increase below the value of roof tile reference with an increased amount of HDPE, Impermeability tends to increase in the ratio of HDPE. 70% HDPE with 30% sand dunes gives best quality tiles. The above-discussed literature has depicted the use of plastic waste in various states for diverse applications. Aggregates impact value shows a drastic change from 25-17%, similar is the case with aggregate crushing value 26-18.%. the voids also decrease from 4-0%.

3.7 Plastic waste as a partial replacement of inorganic aggregates in concrete

Plastic wastes may also be used with some effectiveness as a partial replacement of inorganic aggregates in concrete applications to decrease the dead weight of structures. Similarly, recycled rubber can be used in asphaltic concrete mixes (McQuillen et al., 1998) or as a fill material in road construction (Eldin and Senouci, 1992). The advantages of adding recycled rubber to the asphalt mix include increased skid resistance under icy conditions, improved flexibility and crack resistance, and reduced traffic noise. Many researchers have reported the use of scrap tire/rubber in cement mortar and concrete, and Siddique and Naik (2004) have published a review paper, detailing the research on the use of scrap tire/rubber in concrete.

In this section, research findings related to the effects of recycled and waste plastics on the fresh and hardened concrete are presented. Properties of concrete covered are bulk density, air content, slump, compressive strength, splitting tensile strength, modulus of elasticity, impact resistance, permeability, and abrasion resistance.

3.8 Mechanical properties

Byung-Wan et al. (2006) studied the mechanical properties such as the compressive strength, the splitting tensile strength, and the flexural strength of polymer concrete using an unsaturated polyester resin based on the recycled PET. They concluded that at the age of 7 days, polymer concrete using a resin based on recycled PET achieved compressive strength of 73.7 Mpa, flexural strength of 22.4 Mpa, splitting tensile strength of 7.85 Mpa, and elastic modulus of 27.9 Gpa.

Some relationships exist between the compressive strength of polymer concrete and other properties (elastic modulus, flexural strength, and splitting tensile strength). The use of recycled PET in polymer concrete helps in reducing the cost of the material, solving some of the solid waste problems posed by plastics, and saving energy. Another investigator Al-Manaseer and Dalal (1997) investigated the effects of inclusion of plastic aggregates on the compressive strength of concrete. Concrete mixtures were made with different w/cm and varying percentages of plastic aggregates. Compressive strength decreased with increase in aggregates content. At any given plastic aggregates content, the compressive strength was found to decrease when the w/cm was increased.

3.8.1 Bulk Density

Al-Manaseer and Dalal (1997) investigated the effect of plastic aggregates on the bulk density of concrete. For this purpose, they made 12 concrete mixes with different w/cm containing varying percentages (0%, 10%, 30%, and 50%) of plastic aggregates. Angular post-consumer plastic aggregates having a maximum size of 13 mm were used. They concluded that: (i) bulk density of concrete decreased with the increase in plastic aggregates content; (ii) reduction in bulk density was directly proportional to the plastic aggregates content; and (iii) density of concrete was reduced by 2.5%, 6%, and 13% for concrete containing 10%, 30%, and 50% plastic aggregates, respectively. Reduction in density was attributed to the lower unit weight of the plastics.

3.8.2 Air content

Bayasi and Zeng (1993) studied the effect of polypropylene fibers on the air content of concrete. For the purpose, seven mixtures of polypropylene fibers reinforced concrete were made. Mixture proportions and details (length and percentages) of polypropylene fibers. They reported that air content increased with the inclusion of polypropylene fibers, and there was no detectable effect on air content of fresh concrete at a volume below 0.3%.

3.8.3 Slump test

Slump test, K-test, and inverted slump cone are tests used for measuring the workability of concrete. Workability of concrete is defined as the ease with concrete can be mixed, transported, placed and finished easily without segregation. Soroushian et al. (2003) reported a reduction in the slump with the use of recycled plastic in concrete. It is evident that the addition of any discrete reinforcement caused slump loss. While non-slender plastic particles, automobile shredder residue, and flakes were used at dosages that were in the order of magnitude of those of slender fibers, their effects on fresh mixture properties were comparable. This could be attributed to the pronounced adverse effects of highly slender fibers on fresh mixture workability. Mehta and Monteiro (1993) concluded that slump loss reduced the efficiency of air entrainment in the fresh concrete.

3.9 Plastic Aggregates and Plastic Fiber in Concrete Mix

Concrete is made up from coarse and fine aggregates, cement and water. Accordng to Yin, S., et al., (2015) Concrete is the most prevalent construction materials due to the fact that the raw materials are easily available and relatively low cost. It also provides better fire resistance than any other building materials. Traditionally, concrete contains numerous weakness and flaws if no appropriate preconditioner is in place. Briefly, there are two forms of plastics waste which are plastic aggregate (PA) and plastic fibre (PF) commonly employed for building materials as described by Gu and Ozbakkaloglu (2016). PAs are employed to replace coarse aggregates (CA) and fine aggregates (FA). Normally, the PA possess lower bulk density than granite, limestone or basalt. Therefore, they are preferably being employed for lightweight concrete. PAs can be obtained by applying mechanical recycling method. In contrast, plastic fiber (PF) are used as reinforcement which can replace common steel fibre that can improve mechanical and strength durability.

Conclusion

This review study presented different possible potential uses of e-waste, agro waste and plastic waste in construction materials. It discussed that agro waste including rice husk, corn cob can be effectively utilized in concrete and bitumen and asphalt mixes. It also discussed that e-waste can also serve as a replacement in concrete and bitumen mixes. Optimum replacement level of e-waste in different mixes to get enhanced properties is also discussed. Furthermore, it discusses regarding the use of plastic waste from different sources as a partial replacement as coated aggregates, filler materials in polymer modified bitumen, asphalt, lightweight concrete. The literature surveyed also discusses gain in different properties of the specimen at various replacement levels of waste. Consequently, use of above-discussed waste products in construction materials will aid to sound waste management. it gave changes in activity, stability, renewability, recoverability, and selectivity in particular in some of these production methods. Financial constraints, manpower, and technology challenges facing this sector were equally outlined hence trying to proffer suggestions on the way forward. Drawing from the discussions and ideas presented, the whole notion is that the use of above-discussed waste materials in construction materials will serve as a greater good for the environment and will help in effective waste management to some extent.

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S. No	Author	Type of composites	Parameters						Remarks
			Bulk density (uncompact) (kg/m3)	Bulk density (compacted) (kg/m3)	Void ratio (uncompact) (%)	Void ratio (compacted) (%)	Aggregate impact value (%)	Aggregate crushing value (%)	
1.	Shafigh et. al., (2014)	Oil palm shell	510-550	590-600	63	57	4-8	5-10	Bulk density increase (63%) with oil palm shell and with crushed granite (510-1300). Void ratio decreases with the use of oil palm shell and crushed granite. Aggregate crushing value increases with oil palm shell and crushed granite.
		Coconut shell	-	650	-	-	8.15	2.58	
		Crushed granite	1300	1420-1470	52	47	13-17	20	
			Compressive strength (MPa)	Splitting tensile strength (MPa)	Modulus of elasticity (GPa)				
2.	Hung Mo et. al.,(2015)	OPSC	34.2	2.36	7.4				Here we can observe that the Oil palm shell has higher compressive strength than the normal weight cement and the tensile strength of Oil palm Shell has a lower value than the normal weight and the modulus of elasticity of OPSC is less than NWC. From here we can see that when we use the crushed oil palm shell the compressive strength ranges between 34-53MPa, tensile strength ranges from 2.8 -3.5 MPa and flexure strength ranges from 4.4-7 MPa.
		NWC	32.3	2.77	30.4				
			Compressive strength (MPa)	Splitting tensile strength	Flexural strength				
3.	Shafigh et. al., (2012)	Crushed oil palm shell	34–53 MPa	2.8–3.5 MPa	4.4–7.0 MPa				
				Compressive strength (MPa)					
4.	Apeksha Kanojia, Sarvesh K. Jain	Performance of coconut shell as coarse aggregate in concrete	Mix proportion	7 days	28 days				Here the compressive strength decreases with the increase in the percentage of coconut shell in 7 days but the compressive strength become nearly equal to the 28 days compressive strength.
			CA:CS (100:0)	24.6	28.3				
			CA:CS (90:10)	15.7	25.6				
			CA:CS (80:20)	14.2	25.3				
			CA:CS (70:30)	11.4	24.2				
			CA:CS (60:40)	9.2	22.				

5.	Elinwa et. al.,(2002)	Ash from timber waste as cement replacement material	Ash (%)	0 -30					Soundness increase with an increase in the percent ash content and the initial and the final setting time also increases. Slump value increases with the increase in the percentage of Ash is increased, means its workability increases. The compacting factor also increases.
			Soundness	0.70 -1.45					
			Initial setting time(min)	116 -190					
			Final setting (min) time	241 – 337					
			Slump(cm)	58 -80					
			Compacting factor	241 - 337					
			Sample (grade of concrete)	Average compressive strength, N/mm^2 (28 days)	Average tensile strength, N/mm^2	Sorptivity cm/s1/2			
6.	Modani and Vyawahare (2013)	Utilization of Bagasse Ash as a Partial Replacement of Fine Aggregate in Concrete	M0-M30	22.36-14.7	4.31-3.12	1.53-3.78			Here the average compressive strength and the average tensile strength decreases with the increase in the SCBA from M0-M30. The sorpitivity value increases from 1.53 to 3.78 with the increase in SCBA.
			Percentage of ground shell ash	Water/binder ratio	Slump(mm)	Intial setting time (min)	Final setting time (min)	Compressive strength	
7.	Mahmoud et. al., (2012)	Groundnut shell ash as a partial replacement of cement in sand Crete blocks production.	0% - 50%	0.52 – 0.59	15 - 20	95-436	155-821	1.60 – 0.63	Slump (15 -20) and intial setting time increases from (95-436) and final setting time increases from (155-821) with the increase in the ground shell ash. Compressive strength decreases with the increase in the ground shell ash concentration from 0% GSA to 50% GSA

			Mix	Air content (%)	Density (kg m^{-3})	Slump (mm)	28 days comp.st. (MPa)	
8.	Madanoust et. al. ,(2011)	Rice husk in the concrete =	NC	3.6	2346	65	35.4	With the increase in the rice husk content, the 28-day compressive strength (30 – 33) decreases.
			CR 5 – CR 20	3.6 – 3.8	2342 - 2345	56 - 60	30.8 -33.6	And also the workability decreases with the increase in the percentage of RHA content
			Mix Proportion		Compressive Strength after No. of Days of curing in N/mm^2			
9.	Sathawane et. al., (2013)	Rice husk and fly ash	FA by% of cement	RHA by% of cement	7 Days	14 Days	28 Days	Here as we increase the percentage of RHA from 0-15% by the Fly Ash the compressive strength decreases. The optimal value of replacement of RHA is found to be 7.5% as it gives the maximum compressive strength.
			30-15%	0-15%	32.89-17.78	33.33-24.00	39.11-28.89	
					Weight before immersion (g)	Weight after immersion (g)	Weight absorbed (g)	
10.	D.A.Adesanya, A.A. Raheem	Corn cob ash	(mix proportion 1:1½:3)	0% 10% 25%	2321 2311 2309	2397 2370 2396	76 60 87	Here the water absorbed decreases from76g to 60 gram for 10% replacement and then it increases to 87 for 25% replacement.
			mix proportion 1:2:4	0% 10% 25%	2360 2352 2337	2457 2416 2438	97 64 101	Here the water absorbed decreases from 97g to 64g for 10% replacement and then it increases to 101g for 25% replacement.
			mix proportion 1:3:6	0% 10% 25%	2380 2401 2368	2482 2470 2476	102 69 108	Here the water absorbed decreases from 102g to 69g for 10% replacement and then it increases to 108g for 25% replacement.
			Percentage replacement (0%-25%)	Slump (mm)	Compacting factor			
11.	D.A. Adesanya, A.A. Raheem (2009)	**Corn cob ash**	(mix proportion 1:1½:3)	35-12	0.89-0.67			With the increase in the percentage of corn cob and with different mix proportion, the slump value decreases mean the workability decreases.
			(mix proportion 1:2:4)	45-10	0.93-0.68			

S No.	Author	Material used	Parameters						Remarks
			E- waste %	Compressive strength (7days)	Compressive strength(14days)	Compressive strength(28days)	Slump value(mm)	Flexure strength (N/mm^2)	
1.	Suchitra.et.al. (2015)		0 - 15	21 - 25	_	_	_	3- 6	By replacing 15 % e-waste by coarse aggregate maximum compressive strength (7 days). Obtained comparable compressive strength the flexure strength also maximum at 15% e-waste.
2.	Dave et.al., (2013)	E-waste converted by scrap grinder machine	0-4	18 -22	28 -33	49-55	_	_	Concrete show considerable improvement in strength using 4% replacement of e-waste by fine aggregates.
3.	Manjunath, (2016)	E-waste as coarse aggregate. Coarse grinder in roller	0-30				75-128	0.75-1.2	The maximum slump can be observed at minimum e mix concrete. Use of e-waste as coarse aggregate lowers the flexure strength.
4.	Vignesh et. al., (2016)	E-waste converted by scrap grinder machine	10 – 30	18 – 23	20 – 25	20 – 30	_	3 – 4.5	Concrete show considerable improvement in Strength hence it can be replaced by aggregate (4% replacement). Flexural and split tensile strength decrease with increase in e-waste % in concrete.
5.	Ahirwar et al.,(2015)	Ground E-waste							When cement is replaced with fly ash and e-waste as coarse aggregates then compressive strength shows increase but show optimum value only till 15% E-waste mix.
6.	Balasubramanian et al., (2016)	E-waste (ground printed circuit boards)	0 – 15%	_	_	20 – 25	_	3.5 – 5	The compressive strength of concrete is found to be 27% higher when coarse aggregate is replaced by 15% with E-Waste. Flexural strength tests show the good result of 15% replacement of E-waste.

7.	Gupta R. et al. (2015)	E-waste with recycled coarse aggregates	0 – 15%	_	_	20 – 16	_	2 – 3	
8.	Damal et al., (2015)	E-waste as fine aggregates	7.5 – 21.5%	30 – 15	40 -20	45 – 25	_	_	The compressive strength of concrete it is observed that the compressive strength of concrete is reduced by 52.98% when fine aggregates are replaced by 21.5% of E-waste.
9.	Shamili et al.,(2017)	E-waste as lightweight aggregates	5 – 20%	36 – 42	_	_	30 – 50	_	
10.	Manatkar and Deshmukh (2015)	E-waste as coarse aggregates	0 – 15%	12 – 14	12 – 18	15 – 20	_	_	It is observed that compressive strength decrease with increasing e-waste percentage for both grades. Up to 5%, it is nearly same to normal concrete but after 15%, it reduces maximally.
11.	Roy et al., (2015)	E-waste with fly ash as coarse aggregates	5 – 15%						
			Fly ash 10%	47 – 48	_	_	43 – 54	_	
			Fly ash 20%	45 – 46	_	_		_	
			Fly ash 30%	48 - 49	_	_	65 - 81	_	
12.	Lakshmi and Nagan, (2010)	E-waste with 10% fly ash	4 – 25%	12 – 18	21 – 27	22 – 29	_	4 – 6	

13.	More H.	EWFA (e-waste fine aggregates) and M- sand	0 – 15%	_	_	35 – 45	120 - 135	6 – 6.5	The compressive strength of E-waste concrete having 5% E-waste as a partial replacement to fine aggregates shows a significant increase in comparison to conventional concrete. Considering both strength and durability aspect it can be said that the 10 % EWFA (e-waste fine aggregates) replacement satisfies to be the optimum percentage of e-waste as a partial replacement in fine aggregate that can be utilized in concrete mixes. Slump value linearly increases with an increase in e-waste proportion.
14.	Prasanna and Rao, (2014)	E-waste as coarse aggregates with 10% fly ash.	5 – 20%	23 – 27	33 – 40	37 – 41		5 – 8	
				Increase in stability					
15.	Anand et al., (2015)	E-waste in bitumen with modified polymer	Bitumen content	4.5 – 6%					It is concluded that at 5.5% bitumen content in which 7.5% of bitumen replaced by waste plastic and 7.5% aggregate replaced by e-waste shows increased stability keeping all the other parameters within limits.
			Control mix	2.18 – 2.34					
			7.5% e- waste	2.34 – 2.40					
			10% e-waste	2.18 – 2.34					
			12.5% e-waste	2.25 – 2.35					
16.	Selvam and Krishna G. , (2015)	E- waste as coarse aggregates	10 – 30%	12 – 23	13 – 26	14 – 29	_	1.91 – 3	Results revealed that up to 20% replacement e-waste for coarse aggregate in concrete shows improvement in compressive & Tensile strength.
17.	Raj Kumar and Nithya, (2016)	E-waste as coarse aggregates	10 – 20%	19 – 27	20 - 35	20 - 35	_	3 - 5	

18.	Senthil and Baskar (2014)	Mixed plastic electronic waste in concrete	5- 20	20 - 30	20 - 35	30 - 45	_	2 - 3	
19.	Ru Wang et al. (2012)	Waste printed circuit board nonmetallic powder	5 -25%	10 - 2	20 - 35	25 - 55	_	4.5 – 8.5	The waste PCBs nonmetallic powder improves the water-retention property of cement mortar evidently. The water-retention rate rises to about 97.5% with the increase of the mp/mc up to 25%. The compressive strength and flexural strength of cement mortar change slightly with the mp/mc below 15% and starts to decrease gradually as the mp/mc is higher than 15%.
			Water retention 90 – 96%						
20.	R.N. Patil et al., (2017)	E-waste with corn cob in concrete	0-40%	0.42- 2.07	-	0.43- 2.78	-	0.17- 1.82	The experimental results show that the flexural strength and split tensile strength of normal concrete and modified concrete is approximately same up to 10-20% replacement by e-waste and corn cob.

S No	Author	Type of material		Parameters				Remarks
1	Dhiman (2016)	Recycled polythene carry bags		Penetration	Ductility	Marshal stability		With the use of plastic, the penetration value, ductility and marshal stability increases within the within standard range.
			Standard value	(20 -225mm)	-	-		
			15% polymer	, 64mm	52 cm elongated before breaking	1181.31kg		
2	Yakub et al.,(2017)	Replacement of asphalt with waste polythene		Aggregate impact value	Water absorption value	Marshal stability	Cost benefit for 10sq.meter	The aggregate impact value decreases with the use of plastic waste. Water absorption also decreases with the use of plastic waste. Marshal stability increases with increase in percentage of plastic. Cost for 10.sq.meter decreases with the use of plastic waste.
			Without plastic coated	13gm	2.7	245 kg	Rs.1225	
			Plastic coated	10gm	1.7	(40%) coated 367 kg	Rs.756	
3	Yosef et al., (2014)	Use of recycled plastic bag waste in concrete [plastic bag waste as fine aggregate in concrete]		Fluidity of concrete	Bulk density	Compressive strength	Ultraso11nic pulse velocity	More waste increase fluidity waste decrease fluidity of concrete. [40% waste decrease it to 11.5% Reduction in bulk density to the considerable amount of the use of waste Reduction in compressive strength with use plastic (10-24% reduction with use of 10-20% waste) The speed of sound is much higher for concrete which contain low % of waste plastic.
4	Appiah et al., [2016]	Polymer modified bitumen HDPE and PP(plastic waste)		Penetration	Softening point	Viscosity		Penetration values decreases sharply for 0.5% concentration of polymer from unmodified bitumen. A linear increase in softening temperature for HDPE up to 3% concentration. Bitumen with viscosity 360csr at 1315^0c shows a increase in viscosity with decrease in polymer concentration and shear rate

5	Mehdi Seghiri et al., (2017)	The possibility of making composite material from waste plastic [sand dunes+ high density polyethene(recycled)	Prop-1	HDPE (%)	HDPEr(g)	Breaking load by flexure(N)	Impermeability	Breaking load by flexure shows a decreasing rate with the use of recycled high density polythene. Impermeability also decreases with the increment in in the use of high density polythene recycled.	
			Prop-2	30	.023	1200	.0085		
			Prop-3	40	.030	400	.005		
			Prop -4	50	.038	400	.001		
			Prop-5	60	.045	450	.001		
			Prop-6	70	.053	600	.001		
				80	.060	-	-		
6	Mahesh M Barad et al., (2015)	Plastic waste as coated aggregates		Moisture Absorption	Soundness	Aggregate Impact Value	Aggregate crushing value	Los Angeles Abrasion Value	Moisture absorption reduces the use of plastic waste. Soundness decreases with the use of plastic Aggregate impact value shows a decreasing trend with the use of plastic waste. Aggregate crushing value also decreases while compared to without plastic coated aggregates Los Angeles Abrasion value decreases with the use of plastic waste.
			Without plastic coating	4%	5% - 1%	5% - 1%	26%	37%	
			With plastic coating 1-3%	Traces- 2%	-	17%-21%	18%-21%	26%-32%	
7	Rockdey et al., (2015)	Plastic waste as coarse aggregates	% Plastic coated aggregates	Compressive strength (MPa)	Binding strength(MPa)				The compressive strength increase with the use of %plastic waste. The binding strength also increases with the use of %plastic waste.
			10-20%	250-270	3325-335				
			30-40%	290-320	350-390				

8	Devi et al.,()	Partial Replacement of Bitumen by using Plastic Waste in Bitumen Concrete		Bitumen%	Plastic added %	Stability(Kg)			The marshal stability increases with the use of plastic waste u[to 7% then tends to decrease
				6	5-12.5	1010-1898			
				5	5-12.5	903-1773			
				5.5	5-12.5	879-1656			
				4.5	5-12.5	756-1428			
9	Priya et al., (2017)	plastic waste utilization in flexible pavement with marble chip as aggregate		Penetration value(mm)	Softening value (^{0}c)	Ductility value (cm)	Viscosity(poise)	Specific gravity	There is an increasing trend in penetration value . Softening value increases for 5-10% use of plastic and thereafter remains same for 15% . Ductility value increases up to 10% and then decreases Viscosity increases up to 10% and then decreases Specific gravity increases with the use of plastic.
			Bitumen	87	57	75	1200	1.36	
			Bitumen+5% plastic	78	62	76	1500	1.38	
			Bitumen +10% plastic	72	73	79	1600	1.40	
			Bitumen +15% plastic	89	73	68	1500	1.39	
10	Bayasi and Zeng, 1993	Plastic in road construction		Fiber length (cm)	Air content (%)	Slump (mm)			
				12.7	2	216			
				12.7	1.5	241			
				12.7	2.5	203			
				19	4.5	191			
11	Manju.et.al,2017	Plastic waste as coated aggregates		Aggregate crushing value	Los Angeles abrasion value	Aggregate impact value	Penetration value(mm)		The crushing value shows a decrease in the value with the use of plastic waste. The abrasion value decreases with the use of plastic waste Aggregate impact value decreases with the use of plastic waste Penetration value decreases with the use of plastic waste.
			Normal aggregates	0-25%	0-5.5%	5.4-6.4%	63-79		
			Plastic coated aggregates	0-15%	0-4.5%	5.4-5.8%	49-67		