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Review on Utilizing E-Waste Plastic in Bitumen for Better Strength and Sustainable Environment

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Abstract. E-Waste or Electronic waste is the broken pieces or junk or which is not used in present that is thrown out at the end of their lives. Generation of Electronic Waste is rising year by year due to the demand for newer electronic products which made the public to upgrade their technologies. The composition of plastics in Electronic Waste is high which is non degradable may cause consequential reaction. These wastes would contaminate in water, air, soil and also severely affect the humans and environment. Managing the Electronic Waste with tactical approach may create a way for sustainable waste management. For effective waste management process it is essential to adopt the 4R methods of Reduce, Recovery, Reuse and Recycle. Because it is significant to contemplate the health of the people and also by generating jobs in e-recycling field. In recent times the research is underway to examine the possibilities of using E-Waste in construction field. By adding the Electronic Waste as an alternative material to conventional material in bitumen for various percentages like 5%, 10%, 15%, 20% and 25%. Reusing the E-Waste plastic in aggregate form as certain or diverse forms probably low-budget and it is feasible in technical manner for disposing the huge E-waste. Replacing Electronic Waste in various forms in bitumen gives better strength than conventional bitumen.

Introduction

In recent times, Electrical and electronic industries are burgeoning towards a greater step. E-Waste or Electronic waste is the broken pieces or not useable at now or junk that is produced at the end of their lives. The plastic waste dismantled by E-Waste is rising at a greater pace around the earth. Every year, lot tones of Electronic Wastes are needed to discard in lands contribute to pollution in the surroundings. [1]. Managing of these wastes with tactical approach requires a systematic effort to create a method for reaching sustainable waste management. E-Waste Management is a booming global issue, which showcase the consequence of such E-Wastes on humans and environment. For effective waste management it is quite essential to execute the recycling options. The origination of E-Waste and the pollution possibilities relates the problems with electrical and electronic industries. [2]. Electronic products contains dangerous and harmful toxins in the components that leads to environmental problems when they are throw away in the lands. Owing to fast development, the duration of computers have been draw back to small period of time. Every latest unearthing have potential of twice the antiquation wage, also by advertising and giving offers to find its affordable and agreeable to get a newer one rather upgrading the older appliances. Cathode ray tubes (CRT's) are present in computer monitors and TV's that contains more amount of lead oxide. In inclusion most of the electronic components have batteries that consists of toxic materials like cadmium (Cd),

nickel and many ferrous metals. These toxic materials might affect the workers staff and people who are living on that side. [3]. The Electrical and electronic appliances will pursue to be manufactured, reused, recycled, recovered and disposed because it is significant to contemplate the health of the people and also by generating jobs in e-recycling field owing to the huge chemicals are intrinsic in the E-Waste flow. In e-recycling, the formal type offers services to civilization and propose limitless offers to the people. If we done recycling in applicable method it will be the best method and it will recover the materials from E-Waste and also reduces the wastes from landfills [4]. The disposing of E-Waste plastic is contemplated to exist as huge problem because of its little bit of biodegradability and large quantities in generation. In recent times the research is underway to examine the possibilities of using E-Waste in construction field. Reusing the E-Waste plastic in aggregate form as certain or diverse forms probably low-budget and it is feasible in technical manner for disposing the huge E-waste. Contingent on size of particle and chemical composition, E-waste practiced as fine aggregate, coarse aggregate and fine filler in field of construction. [5].

Classification of e-waste

E-Waste is enlarging epidemically in proportions by reason of more demand of newer versions in all equipment. Diverse government sectors, private sectors, hospitals and public are fast feeding the old appliances [3]. The Electronic items considered as E-Waste:Large domestic appliances (clothes dryer, air coolers, refrigerator, Dish washers), Small domestic appliances (blender, electric fry pan), Information Technology devices (Monitors, keyboards, computers, telephones, mobile phones, laptops), User electronics (Flat screen TV's, MP3 players, DVD players), Lighting devices (LED downlights, track light, floor lamp), Electrical tools and equipment (electric drills, saws, screwdrivers), Toys, sports equipment (Tennis baseball automatic server), Medical equipment in hospitals (ventilator, ECG machines) Control and monitoring instruments (Thermostats, smoke detectors) [3, 6]. The figure 1 shows the sources of E-Waste.

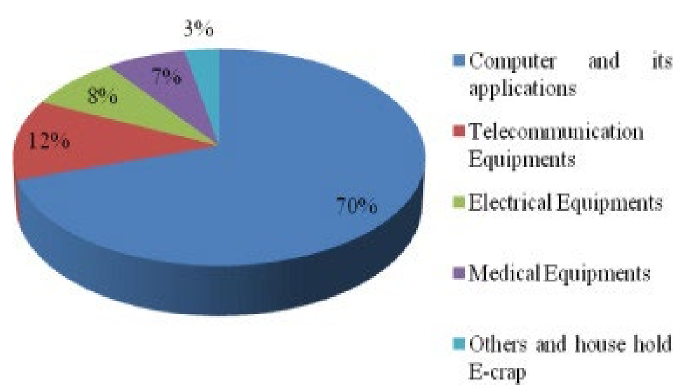

Fig. 1, Source of E-Waste
(SOURCE: ASSOCHAM-KPMG Report, 2018)

Generation of e-waste

Electrical and electronic waste is enlarging towards a fast and unmanageable allowance and also rapidest increasing proportion in MSW. It can be presumed that the disposal of outdated electronic products is mainly driven by the production of new electronic products. This signifies that the growth in the global production will result in alike growth in E-Waste generation [7]. Nowadays, human beings coming with technological development that each second they attached with the

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electronic equipment like mobile phones, laptops, computers etc., but the life span of these electronic products is 3-5 years. The lesser life duration of equipment, the higher its proportion. For example, computers have shorter life span up-to three years so it comprises greater proportion than other electronic waste products like ovens and refrigerators these have duration of life up-to 10-12 years [8]. In 1990 after the Economic liberalisation of first phase, the difficulties in E-Waste have found exhibiting. As stated in TRAI, In 2008, 113.26 million newer consumers have been added by India with 9.5 million average consumers of every month. The growth market of cellular from (2007-2008) is 168.11 million to 261.97 million [9]. In 2007 A GIZ-MAIT study had put the approximate of 333,000 tonnes and other different estimates to 420,000 tonnes.

As per approximation UNEP report 2010, the generation of E-Waste in equipment wise are: Refrigerators of 100,000 tonnes; Mobile phones of 1700 tonnes; Personal computer of 56,300 tonnes ; Televisions of 275,000 tonnes ; of 4700 tonnes [10].

In 2014, the overall electronic waste generated by the world is 41.8 million tonnes and it is anticipated to increase averagely by 2018 is 50 million tonnes. 3-5% is the approximated growth rate of E-Waste stream. The rate will be thrice rapidest rather than the all wastes [11]. The components of electronic wastes are categorized as lighting equipment, large household equipment, small equipment, Computer monitors and screens, temperature exchange equipment, Information Technology and telecommunication equipment. [12]. The below table 1 shows the different categories of E-Waste.

Table 1. DIFFERENT CATEGORIES OF E-WASTE
(SOURCE: AMIT KUMAR et al, E-WASTE [12])

CATEGORIES	AMOUNT (in million tonnes)
Lighting equipment	1.0
Large household Equipment	11.80
Small household Equipment	12.80
Information Technology and Telecommunication equipment	3.0
Cooling and freezing equipment	7.0
Computer monitors and screens	6.3

In sequence of tallest allowance to electrical and electronic equipment of the top states involve Tamil Nadu, Madhya Pradesh, Uttar Pradesh, Maharashtra, West Bengal, Andhra Pradesh, Delhi, Punjab, Karnataka and Gujarat [13]. The table 2 gives the quantity of WEEE generated in Indian states.

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Table2. QUANTITY OF WEEE GENERATED IN INDIAN STATES
(SOURCE: E-WASTE SCENARIO IN INDIA [13])

SI.NO	INDIAN STATES	WEEE (TONNES)
1	Andhra Pradesh	12,780.3
2	Andaman and Nicobar Islands	92.2
3	Nagaland	145.1
4	Maharashtra	20,270.6
5	Kerala	6,171.8
6	Jammu and Kashmir	1,521.5
7	Gujarat	8,994.3
8	Daman and Diu	40.8
9	Chandigarh	359.7
10	Assam	2176.7
11	West Bengal	10,059.4
12	Uttar Pradesh	10,381.1
13	Tamil Nadu	13,486.2
14	Rajasthan	6,326.9
15	Puducherry	284.2
16	Utarakhand	1,641.1
17	Tripura	378.3
18	Sikkim	78.1
19	Punjab	6,958.5
20	Orissa	2,937.8
21	Chhattisgarh	2149.9
22	Goa	427.4
23	Himachal Pradesh	1,595.1
24	Bihar	3055.6
25	Dadra and Nagar Haveli	29.4
26	Haryana	4,506.9
27	Delhi	9,729.2
28	Meghalaya	211.6
29	Madhya Pradesh	7,800.6
30	Jharkhand	2,021.6
31	Mizoram	79.6
32	Karnataka	9,118.7
33	Lakshadweep	7.4
34	Manipur	231.7
35	Arunachal Pradesh	131.7
	TOTAL	146,180.7

In 2014, as stated in United Nations Environment Program 62 million tons of electronic wastes are produced around the world. Out of that 8 lakhs tones have been produced by India. Three equipment is taken for this report that is cellular phone, computers and television [14]. As reported by Global E-Waste Monitor 2017. In 2016 India produced 2 million metric tonnes of Electronic waste, flows next to China, United States and Japan as 7.2, 6.3 and 2.1 million metric tonnes respectively in the top 10 countries which produces more E-waste among the global nations [15]. The figure 2 shows the total E-Waste generated up-to year 2021.

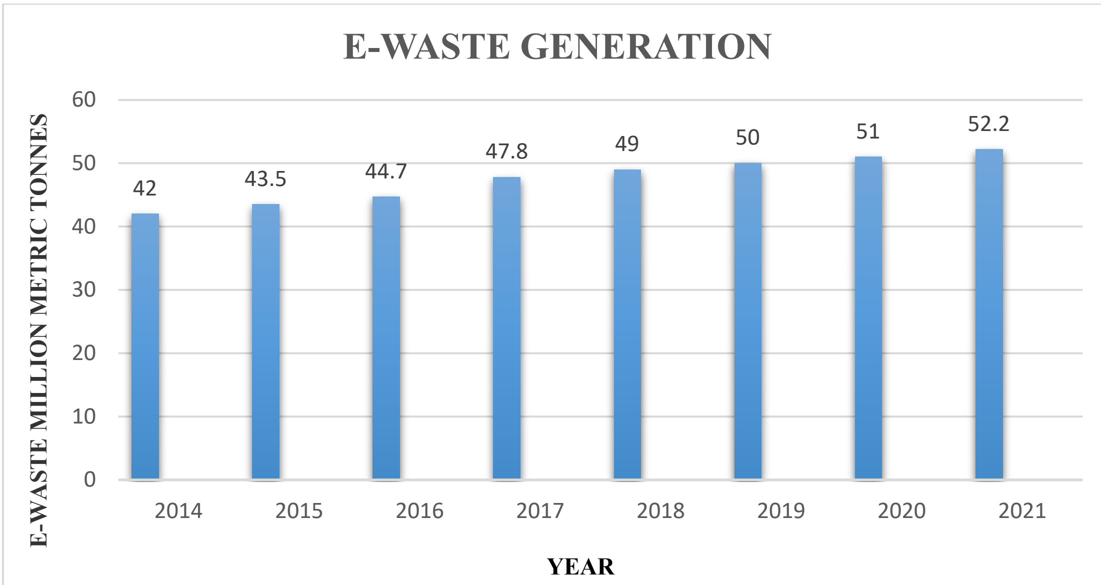

Fig. 2, TOTAL E-WASTE GENERATED
(SOURCE: THE GLOBAL E-WASTE MONITOR 2017 [15])

Resultant to the requirement of new appliances, more performance and effectual technology leads to the more generation of electronic waste. [16]

Composition of e-waste

At the end of life electronic waste provides a precious raw material for the production of new electronic products. In E-Waste boundless substances are found, there are number of batteries, thermostats, condenser comprising elements namely mercury, Aluminum, lead, Poly chlorinated biphenyls, Tin, PVC (Poly Vinyl Chlorides), Copper, thermosetting plastics, fibreglass, Carbon, Silicon, Beryllium, and Iron [17]. Large domestic equipment like machines for dish washers, washing machines, for vegetable and fruit storage refrigerants, air conditioners etc., devices using in homes viz., mobile phones, MP3 players, FM's, personal computer etc., Lighting equipment like bulbs, Compact Fluorescent Lamp (CFL), tube light, fluorescent lamps, entertainment equipment, toys etc., Equipment used in medical applications like machines for sonography, MRI, Blood pressure monitor all these equipment are abundant in Mercury (Hg), Barium (Ba), Cadmium (Cd) [18]. Information Technology and Telecommunication Equipment like telephones, computer, laptops, tablets etc., and the systems used for calling services at Business Process Outsourcing having more toxic composition viz., Ni, Cd, Copper (Cu) [19]. E-Waste consists of abundant number of toxic substances there are broadly categorized into hazardous material, non-hazardous, ferrous metals, non-ferrous metals, glass, plastic, , precious metals, printed circuit boards etc. [20]. The figure 3 shows the material fractions in E-Waste.

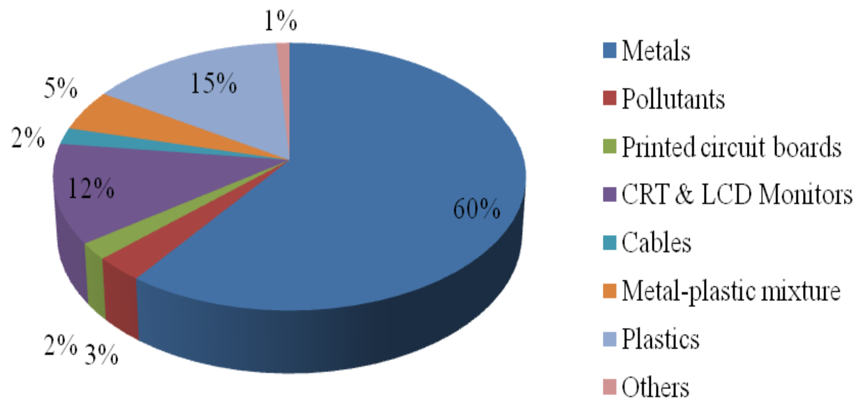

Fig. 3, MATERIAL FRACTIONS IN E-WASTE
(SOURCE : The Generation, Composition, Collection, Treatment and Disposal system and Impact of E-Waste)

In the last decades, Electrical and Electronic Equipment was the main waste flows and also it will be pursue in coming generation. E-Waste contains 10%-30% of plastics which makes it more valuable to recycle the plastic in the value point of view and also as WEEE target. The percentage of plastics in WEEE is generally high it is very dependent on WEEE category. Control instruments, toys and monitoring equipment have more than 50% of plastics while medical devices and lighting equipment have less than 5% weight of plastics [21]. Electrical and Electronic Equipment are categorized under 15 various types of engineering plastic including high-impact polystyrene (HIPS), polystyrene (PS), polyamide (PA), polypropylene (PP), styrene-acrylonitrile (SAN), acrylonitrile–butadiene–styrene (ABS), blends of polycarbonate (PC)/ABS, polyurethane (PU), blends of HIPS/poly (Poly Phenylene oxide) (PPO) and polyesters.[22]

The elements of E-Waste are Americium (AM), Barium (BA), Cobalt (CO), Manganese (MN), Palladium (PD), Sb, Pt, Gallium (Ga), Bi, Eu, Au, Nickel (Ni), Se, Ta, Ti,Yttrium(Y),Tb, Arsenic (As), B, Indium (In), Ru, Li, Th, Vanadium (V), Rh, Nb, Silver (Ag) [23]. The figure 4 shows the composition of E-Waste.

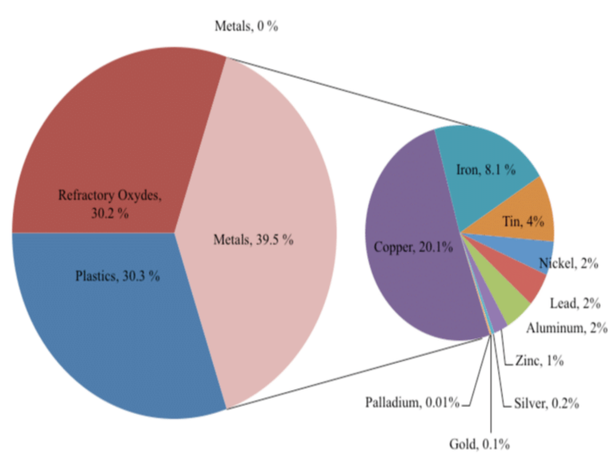

Fig. 4, COMPOSITION OF E-WASTE
(SOURCE: PERCENTAGE OF CHEMICAL CONSTITUTES IN THE TOTAL E-WASTE [23])

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Table 3. COMPONENTS AND COMPOSITION OF EEE (SOURCE: ELECTRONIC WASTE, AN OVERVIEW OF TREATMENT TECHNOLOGIES OF E-WASTE [24, 25, 26])

COMPOSITION	COMPONENTS OF ELECTRICAL AND ELECTRONIC EQUIPMENT
Aluminum (Al)	Mobile phones, connectors, cathode ray tubes, computer chips, hard drives
Barium (Ba)	Getters in cathode ray tubes, fluorescent lambs, phones
Cadmium (Cd)	Solder, SMD chip resistor, detectors, batteries, toners, printed circuit boards
Copper (Cu)	Cathode ray tubes, heat sinks, computer chips, cables, central processing unit, Wirings
Polychlorinated Biphenyls (PCB)	Condenser, transformers, coolants in generators, dielectric fluids, ceiling fans, capacitor and transformer, dish washers
Mercury (Hg)	Gas discharge lamps, fluorescent lamps, thermostats, monitors, sensors, cells, housing
Tin (Sn)	Liquid crystal display screens, computer chips, solder, printed wiring board
Scandium(Sc)	Aerospace, laser and lightings
Nickel (Ni)	printed wiring board, mobile phones, housing, batteries
Chromium (Cr)	Data tapes, anticorrosion coatings, floppy disks, decorative hardener
Indium (In)	LCD displays, Printed wiring board
Beryllium (Be)	Power supply boxes, silicon controlled rectifiers, x-ray machines
Tantalum (Ta)	capacitors, Printed wiring board and power supply

Effects of e-waste

Many cities in India doesn't consider the effects of Electronic waste problems. Mostly the electronic wastes are collected, handled, disassembled and recycled by nonunionized or non-formal sections they are shortage of knowledge in the systematic process. Environmental problem and human health correlated with electronic wastes be hypercritical and contemplative within nature foremost to pollution and degradation of natural resources and causes a dreadful diseases like cancer, skin disease etc., in human beings [27]. In disposing the electronic wastes there are two types, i.e. incineration and landfill, both of these methods will produce substantial pollution problems. Even the recycling of electronic waste hand over the poisonous substances to the environment and perhaps influence the health of human [28]. There are two ways that affect the health of human while disposal of electronic wastes: a)OBSTACLE IN FOOD CYCLE:

defilement by hazardous matters beginning with process of recycling and disposal wastes leads to infiltrate in food web and it shifting to the human health. b) UNMEDIATED CONSEQUENCES ON LABOUR: labor who are working in the elementary of recycling process will lead to the hazardous matters exposure to their health. [29]. The figure 5 shows the effects of E-Waste on Human and Environment.

Fig. 5, EFFECTS OF E-WASTE ON HUMAN AND ENVIRONMENT
(SOURCE: MANAGE AND RECYCLE E-WASTE IN INDIA)

In the course of divergent steps of recycling operations (mincing, extracting and diverge process) have a chance of toxic substances to enhance as airborne having the form of aerosol matters that size ranges from nanoparticles to tens of microns. Among the most important, industry is mainly responsible for the health hazards of humans in form of aerosol nanoparticles which may travel and deeply stay into the tract of respiratory and lungs [30]. Electronic components contains dreadful toxic which may intense exertion on environment and human health. Polyvinyl Chloride (PVC), Computer monitors, Brominated flame retardants (BFRs) contains more quantity of lead. Repeated exposure of this component affect the internal organs like reproductive system, kidney, endocrine, nervous system. Due to this affects, electronic goods are differentiated into three:BROWN GOODS: radios, computers, WHITE GOODS: washing machine, refrigerators, GREY GOODS: color printer, scanners

During recycling process, brown goods and white goods have fewer toxics rather grey goods [31]. Nowadays mobile phones production are more due to the new innovative in technology makes them to use only 2 years but duration of devices is 7 years. So discarding those plastic from mobile phones require an incineration burning process to remove priceless metal. The burning of electronic waste plastic leads to the pollution of environment and also affects human health [32]. In innovation of new technology the metals usage are in long term so production and demand for toxic goods also raised. Electronic appliances are supplied mainly by the mining can't be disregard. Large scale lands are needed for mining activities also that toxic substances may end up in air, land and water. Utilization of natural resources leads to the release of radioactive substances and it may affect the environment and human health. Also the extraction of priceless components from electronic waste will release carbon-dioxide. Production of valuable components in tons like silver, gold will emit 10,000 tons of carbon-dioxide (CO2) [33]. Main origin for groundwater is from water bodies and it transfers to voids in underground soil. The water which is moving is in upper surface will contaminate with toxics present in soil and also contaminate with water. These contamination in water will affect the health of human being by drinking and using of these toxic water cause a chronic diseases [34]. One of the components in electrical and waste i.e. exposure of mercury have more chances to affect the pregnant women and also influence the health of fetal. The contiguity of mercury with water interchange them into furthermore poisonous form methyl mercury and corrupt the food cycle. The human beings who are interlinked with recycling operations will definitely exposure to poisonous chemicals. Among human beings, kids and female are hugely affected to the electronic waste contamination [35]. In an electronic waste, the second hugest component is plastics it have a weight description to come near to 20-35% of total weight. Part of the plastic are summed with many poisonous substances like flame retardant, if it doesn't disposed in sequence manner it will affect the environment leads to pollution [36]. Some other poisonous substances in electronic waste comprises of polychlorinated Biphenyls (PCBs), hydro chlorofluorocarbons (HCFCs), arsenic, asbestos, chlorofluorocarbons (CFCs). Presence of few quantity of these chemicals may cause huge pollution problem, further evaporation of di methylene mercury and metallic components cause dangerous to environment [37]. Plastic which disposing in lands guide to biotic and abiotic downgrade of plastic and supplements present in plastic (EXAMPLE: plasticizers, stabilizers, heavy metals) could discharge into the environment. During downgrade the plastics release methane leads to global warming [38, 39]. Pollution in environment and human health problems will be reduced when the process of landfills are performed well [40].

Management of e-waste

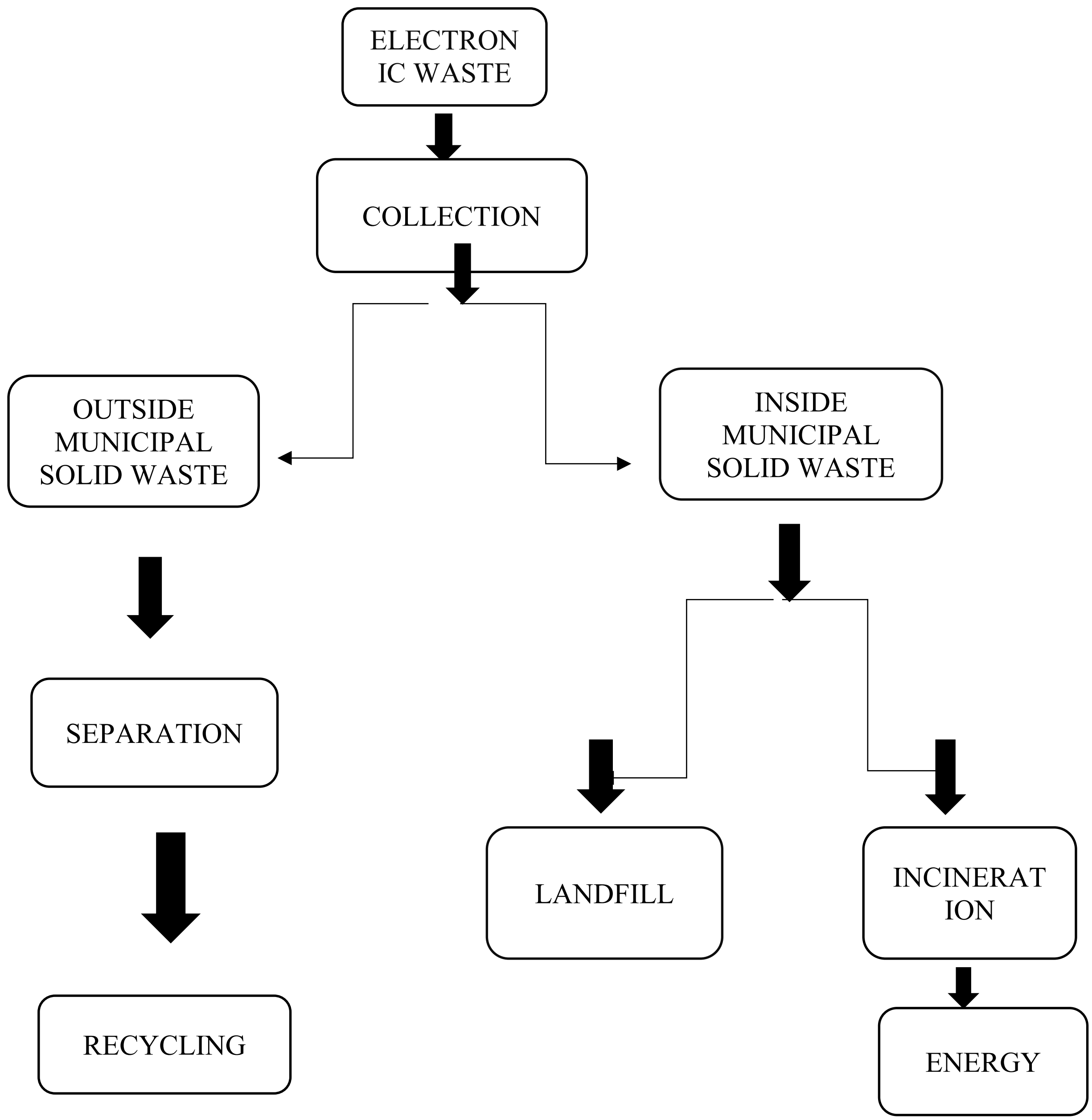
In India, conventional managing of electronic waste should have Centre of attention about collecting, extraction and also upraise having knowledge of health problems and environmental affect due to the inappropriate management methods. Have to gather the details about the chemical components added in the electronic waste from zonal research so it will be easy to find the fault existed and also to bring a standard solution for environmental problems and health issues [41, 42]. Ministry of Environment, Forest and Climate Change (MOEF) have formatted specification for managing electronic waste in eco-friendly manner. The specification consists recommendation for disposing and treating electronic waste and also codification of electronic waste [43]. Reasonable procedure for managing electronic waste is coming from various ways to solve the problems by creating stable policies, requisition for systematic approaches of discarding and extracting components from electronic waste [44]. For ecological management of electronic waste, variance modifying technique is to be implemented like the amount and standard component of electronic waste to be improved. From profitable countries, producers could adopt a greatest method for managing electronic waste [45]. Systematic recycling process is important one so the profitable countries must enhance their way of managing electronic waste rather by transporting to emerging countries. By the fundamental idea of Extended Producer Responsibility (EPR), the creators must ensure the extended lifespan of component till they are fully recycled [46].

Primarily, the substantial working of managing electronic waste comprises: Collecting electronic waste plastics, Disposing of plastics, Rehabilitate its energy, Reprocessing it to newer products [47].

Collecting electronic waste plastics

For recouping the electronic waste plastic it have two methods. Firstly, collection of waste plastic later they go in for Municipal solid waste and Secondly, collecting it prior to go in for Municipal solid waste. Electronic waste plastics are the type of 'non-visual' plastics. They are collected outer of the Municipal solid waste for the further process recycling operations in ecological manner [48].

The flow diagram of electronic waste plastic management process is given below:



(SOURCE: PLASTIC WASTE MANAGEMENT IN CONSTRUCTION: TECHNOLOGICAL AND INSTITUTIONAL ISSUES [49])

Disposing of plastics

Demeaning of electronic waste plastics and further more waste plastics didn't have a disposing problems on lands. Even though it has slight effect of disposing problems it won't develop more problems in landfilling process and also won't grant harmful leachate on lands. Using the following two techniques in disposing makes environment more better i.e. Photo degradation (by

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integrating photo sensitive supplement in plastic) and bio-degradable plastic (by integrating starch supplement in plastics). Degradation of plastic would enhance their preferable characteristics in diverse approach [50, 51]

Rehabilitate its energy
Heat of electronic waste plastic could be retrieved beside incineration process. Electronic waste plastics are great combustible origin due to the presence of more resins. It have a warming desirability just equivalent to the coal value. It also gives more benefit by conserving natural etymology, lowering the dependence of energy from foreign and contributing fascinating etymology for replacement of vivacity. 90-95% mass of electronic waste plastic is reduced by incineration method. Many researches are going on to implement these wastes in construction sites [52, 53]

Recycling
Recycling operation is one of the best method to manage the electronic waste plastics because it saves the energy, reduces the major plastics in landfills and also by conserving the natural petrochemical by- products. Various newer technologies makes the electronic waste plastic convert to newer products in many ways. The method which is used in recycling must workable to various composition. Further growing of recycling method is enhanced by giving more knowledge about health and environmental problems [54, 55]

TABLE 4. TECHNIQUES FOR SEPARATION PROCESS

S.NO	METHODS	SEGREGATION TESTS	CONCEPT OF SEPARATION	CATEGORISATION PROCESS
1.	Cleansing, Grating, Screening	**Screening:** Mechanical forces **Grating:** Vibratory	**Cleaning:** To pull out adhering contamination **Grating**: Utilizing graters combined to vibratory revolutionary	**Cleansing:** Segregating contamination out of beneficial component [56] **Grating:** Pulverizing and powdering [57] **Screening:** Fragment dimension segregation [58]

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2.	Magnetic Separation	Magnetic field	Utilizing magnets to segregate components from wastes	Segregating non-magnetic and non-ferrous materials from ferromagnetic metals [59, 60]
3.	Eddy current Separation	Electrical density and electrical conduction	Utilizing a strong field of magnet to segregate magnetic composition from components	Separating non-metal and non-ferrous metals [61, 62]
4.	Electrostatic Separation	Electrical conduction	Molecules interconnecting gives various charges molecules repercussion in various intensity	Separating metals and non-metals from components [63, 64]
5.	Triboelectrostatic separation	Dielectric constant	Categorizing positive and negative ions downward an field of electric depending on plan levying features	Separating plastics [65, 66]

Materials

Coarse aggregate

Aggregates are the most vital segment in road construction. They are worn for sub base, granular base in mix proportion of bitumen. It is also used as chief substance in comparatively low-cost roads i.e. water bound macadam. Various sizes like 20mm, 10mm, 4.75mm, 2.36 mm are used. Being a construction material for pavement it must be assessed in consonance with recommendations of Ministry of Road Transport & Highways (MORTH) [67, 68, 69]. The table 5 gives the properties of coarse aggregate.

TABLE 5. PROPERTIES OF COARSE AGGREGATE

S.NO	NAME OF TEST	MORTH ACCEPTABLE VALUE
1	Flakiness Index	30% maximum
2	Water Absorption	2% maximum
3	Specific Gravity	2.0-3.0
4	Impact Test	24% maximum
5	Crushing Test	30% maximum
6	Elongation Index	30% maximum

Bitumen

Bitumen is one of the material in road construction which obtained along with fractional distillation of petroleum products. It consists of 11% hydrogen, 87% carbon, 2% oxygen. The bitumen 60/70 is used. The color is black and it holds adhesive and water resistant properties. It also has a great binding property and holds the aggregate together [70, 71, 72]. The table 6 gives the properties of bitumen.

TABLE 6. PROPERTIES OF BITUMEN

S.NO	NAME OF TEST	MORTH ACCEPTABLE VALUE
1	Ductility	75cm minimum
2	Softening Point	40-50 c
3	Penetration	60/70

E-waste

Using E-Waste as an alternative for conventional is an effectual method for disposing wastes in road construction because it has impact resistance, high tensile strength and stiffness. Polyethylene plastic is used. Here toxics are removed from components and made into e-waste powder [73, 74, 75].

Test analysis

Ductility test

Here the elastic nature of bitumen is compared with conventional and alternative mix design. E-Waste powder is added to bitumen in various proportions like 5%, 10%, 15%, 20% and 25%. From the test results, it exhibits that the value of ductility is reduced when Electronic Waste powder is included supplementary. But the mix design of alternative method of 5% E-Waste powder and 95% bitumen gives more ductility. [76, 77]

Penetration test

In this test, the foremost aim is to notice the distance in mm. For the trials, firstly heating the bitumen at 160°C then permitting the bitumen to dry for 1 hour and keeping it in water for 30 minutes. Obtaining the values by popping the needle into bitumen for thrice times. From the trial mix, when there is no adding of E-Waste powder, there is low penetration. By slightly adding E-Waste powder makes it to have high value of penetration [78, 79].

Softening point

The objective is to examine at which temperature the material melts and enhance soften. This test is to managing the various softening point of bitumen which is used in national highways, village roads and state highways. By using ring ball apparatus the bitumen is heated for 15 min and keeping it in water for 10 min to know at which temperature the bitumen softens and falls from ring. From trial mix, when there is no adding of E-Waste powder, there is minimum of temperature but gradually adding E-Waste powder the temperature is maximum [80, 81]

Viscosity test

The goal of this test is to examine the bitumen smoothness. Smoothness of bitumen is determined by examining the capacity of bitumen flow at required temperature. By adding E-Waste in various percentages like 5%, 10%, 15%, 20%, 25%. From the test results, when there is no adding of E-Waste, there is minimum viscosity value but gradual adding increases the value of viscosity [82, 83].

Marshall stability test

Marshall Test is to determine the extreme load fetched by material at a quality temperature of 60°C. When the specimen is fetching to extreme load there is deformation of flow value. This method is of low amount and simple, it is used to characterize the bitumen mixes in India. This test is practical in nature. The load bear on specimen is perpendicular to the cylinder axis having deformation rate of 51mm per minute. Flow value and Stability is low when no E-Waste powder is added but gradual increase of E-Waste increases the flow value and stability [84, 85].

Conclusion

Based on the study, the Electronic Waste contamination leads to a major problems in humans and environment. By adopting 4R methods of Recycle, Reduce, Recovery, Reuse, the Electronic wastes are utilized in a great manner. Because it saves the energy, reduces the major plastics in landfills and also by conserving the natural petrochemical by- products. Using Electronic waste plastic as an alternative material to conventional bitumen increases the properties of bitumen by adding it in various percentages. It is also cost effective and minimizes the usage of natural resources like bitumen and aggregate. Managing the Electronic Waste is the new technique, if the same method is followed the impacts on environment and humans can be minimized.

References

[1] L. Salmabanu., L. Ismail, Potential application of E-wastes in construction industry, Construction and Building Materials, 203 (2019) 222-240. https://doi.org/10.1016/j.conbuildmat.2019.01.080

[2] M. Lakshmi, Use of e-plastic waste in bituminous pavements, Gradevinar, 70,7 (2018) 607-615. https://doi.org/10.14256/JCE.1375.2015

[3] M. N. Mundada, K. Sunil, A. V. Shekdar, E - waste: a new challenge for waste management in India, International Journal of Environmental Studies, 61,4 (2001) 265-279. https://doi.org/10.1080/0020723042000176060

[4] C. Diana Maria, D. Zhao, The formal electronic recycling industry: Challenges and opportunities in occupational and environmental health research, Environment International, 95 (2016) 157-166. https://doi.org/10.1016/j.envint.2016.07.010

[5] S. Needhidasan, B. Ramesh, S. Gorab Agarwal, Experimental investigation of bituminous pavement (VG30) using E-waste plastics for better strength and sustainable environment, Materials Today: Proceedings, 2214-7853.

[6] S. Sivakumaran, E-Waste Management, Disposal and Its Impacts on the Environment, Universal Journal of Environmental Research and Technology, 3,5 (2013) 531-537.

[7] Y.Richardson, J.B. Walker, A.K. Youn, TCLP heavy metal leaching of personal computer components, Journal of Environmental Engineering, 132,4 (2006) 497-504. https://doi.org/10.1061/(ASCE)0733-9372(2006)132:4(497)

[8] S.k. Ajim Ali, E-Waste Generation and Its possible Impacts on Environment and Human Health: A Study on Kolkata, Asian Profile, 45,1 (2017) 78-94.

[9] Sushant B. Wath, P. S. Dutt, T. Chakrabarti, E-waste scenario in India, its management and implications, Environmental Monitoring and Assessment, 2010.

[10] C. Hicks, R. Dietmar, M. Eugster, The recycling and disposal of electrical and electronic waste in China- legislative and market responses, Environ. Monit. Assess. Journal of Environmental Impact Assessment Review, 25 (2005) 459-471. https://doi.org/10.1016/j.eiar.2005.04.007

[11] K. Amit, H. Maria, Denise Crocce Romano Espinosa, E-waste: An overview on generation, collection, legislation and recycling practices, Resources, Conservation and Recycling, 122 (2017) 32-42. https://doi.org/10.1016/j.resconrec.2017.01.018

[12] G. Cucchiella, D. Adamo, I. Lenny Koh, S.C. Rosa, Recycling of WEEEs: An economic assessment of present and future e-waste streams. Renew, Sustain. Energy Rev, 51 (2015) 263-272. https://doi.org/10.1016/j.rser.2015.06.010

[13] M. Turner, D. Callaghan, Waste electrical and electronic equipment directive, UK to finally implementthe WEE directive, Computer Law and Security Report, 23 (2017) 73-76. https://doi.org/10.1016/j.clsr.2006.11.007

[14] J. Senophiyah Mary, T. Meenambal, Inventorisation of E-Waste and Developing a Policy - Bulk Consumer Perspective,. Procedia Environmental Sciences, 35 (2016) 643 - 655. https://doi.org/10.1016/j.proenv.2016.07.058

[15] Dwivedi, Amrita, V. K. Kumar, Solid Waste Management and Sanitation in Varanasi City, National Geographical Journal of India, 55,3 (2009) 1-12.

[16] J. Ladou, S. Lovegrove, Export of Electronics Equipment Waste, International Journal of Occupation and Environmental Health, 14,1 (2008) 1-10. https://doi.org/10.1179/oeh.2008.14.1.1

[17] S. Badur., R. Chaudhary., 2008. Utilization of hazardous wastes and by-products as agreen concrete material through S/S process: a review, Rev. Adv. Mater. Sci 17 (1-2), 42-61. https://doi.org/10.1002/prs.680170112

[18] W. Rolf, K. Heidi Oswald, K. Deepali Sinha, Max Schnellmann, Heinz Bo, Global Perspectives on E-Waste, Environmental Impact Assessment Review, 25 (2005) 436-458. https://doi.org/10.1016/j.eiar.2005.04.001

[19] P. Vanegas, J. R. Peeters, D. Cattrysse, W. Dewulf, J. R. Duflou, Improvement potential of today's WEEE recycling performance: the case of LCD TVs in Belgium Front. Environ. Sci. Eng., 11,5 (2017) 13. https://doi.org/10.1007/s11783-017-1000-0

[20] Y. Abdollahi, S. B. M. Said, N. A. Sairi, Enhancement of electronic protection to reduce e-waste, J. Indust. Eng. Chem., 29 (2015) 400-407. https://doi.org/10.1016/j.jiec.2015.04.021

[21] M. Grano, P. Ana, S. Luanha, R. Rita, Composition of plastics from waste electrical and electronic equipment (WEEE) by direct sampling, Waste Management, 32 (2012) 1213-1217. https://doi.org/10.1016/j.wasman.2012.02.010

[22] F. Vilaplana, S. Karlson, Quality concept of the improved use of recycled polymeric materials, Macromal Materials Engineering, 293 (2008) 274-297. https://doi.org/10.1002/mame.200700393

[23] A. Pariatamby, D. Victor, Policy trends of e-waste management in Asia, J. Mater. Cycles Waste Manage., 15,4 (2013) 411-419. https://doi.org/10.1007/s10163-013-0136-7

[24] V. Dissanayake, Electronic Waste, Encyclopedia of Toxicology, 2 (2014) 568-572. https://doi.org/10.1016/B978-0-12-386454-3.00565-0

[25] C. Jirang, R. Hans Hogen, Electronic Waste, Management of Electronic Waste, (2011) 281-296. https://doi.org/10.1016/B978-0-12-381475-3.10020-8

[26] K. Peeranart, P. Jatindra Kumar, M. Sanchita, B. Jayanta Kumar, S. Binoy, An overview of treatment technologies of E-waste, Waste Management, 57 (2016) 113-120. https://doi.org/10.1016/j.wasman.2016.01.043

[27] J. Gregory, A. Kirchain, A comparison of North American electronic recycling systems, In Proceedings of the 2007 IEEE international symposium on electronics and the environment, (2007) 227-232. https://doi.org/10.1109/ISEE.2007.369399

[28] S. Zhang, E. Forssberg, Mechanical separation-oriented characterization of electronic scrap. Resources, Conservation and Recycling, 21 (1997) 247-269. https://doi.org/10.1016/S0921-3449(97)00039-6

[29] J. P. Wang, X. K. Guo, Impact of electronic wastes recycling on environmental quality, Biomedical and Environmental Sciences, 19 (2006) 137-142.

[30] T. Ourania, L. Michael, Environmental Risks Associated with Waste Electrical and Electronic Equipment Recycling Plants, Encyclopedia of Environmental Health, (2018) 1-10.

[31] F. J. Barbosa, J. E. Tanus-Santos, R. F. Gerlach, P. J. Parsons, A critical review of biomarkers used for monitoring human exposure to lead: advantages, limitations, and future needs, Environmental Health Perspect, 113 (2005) 1669-1674. https://doi.org/10.1289/ehp.7917

[32] O. Tsydenova, M. Bengtsson, Chemical hazards associated with treatment of waste electrical and electronic equipment, Waste Management, 31,1 (2011) 45-58. https://doi.org/10.1016/j.wasman.2010.08.014

[33] J. H. Rademaker, R. Kleijn, Y. Yang, Recycling as a strategy against rare earth element criticality: a systemic evaluation of the potentialyield of NdFeB magnet recycling, Environmental Science Technology, 47 (2013) 10129-10136. https://doi.org/10.1021/es305007w

[34] S. Fahad, S. Hussain, S. Saud, F.Khan, S. Hassan, W. Nasim, M. Arif, F. Wang, J. Huang, Exogenously applied plant growth regulators affect heat-stressed rice pollens, J Agron Crop Science, 202 (2016) 139-150. https://doi.org/10.1111/jac.12148

[35] P. Hennebert, M. Filella, WEEE plastic sorting for bromine essential to enforce EU regulation, Waste Management, 71 (2018) 390-399. https://doi.org/10.1016/j.wasman.2017.09.031

[36] H. Alter, Environmentally sound management of the recycling of hazardous wastes in the context of the Basel Convention, Resources, Conservation and Recycling, 29 (2011) 111-129. https://doi.org/10.1016/S0921-3449(99)00061-0

[37] S. Zhang, E. Forssberg, Intelligent liberation and classification of electronic scrap, Powder Technology, 105 (1999) 295-301. https://doi.org/10.1016/S0032-5910(99)00151-5

[38] S. M. Ogilvie, WEEE and Hazardous Waste, AEA Technology Environmental, (2004).

[39] R. Hischier, P. Waüger, J. Gauglhofer, Does WEEE recycling make sense from an environmental perspective? The environmental impacts of the Swiss take-back and recycling systems for waste electrical and Electronic Equipment, Environmental Impact Assessment, 25 (2005) 525-539. https://doi.org/10.1016/j.eiar.2005.04.003

[40] T. Puckett, T. Smith, Exporting harm: the high-tech trashing of Asia, The Basel Action Network, Silicon Valley Toxics Coalition, Seattle, (2002).

[41] M. Dwidwey, R. K. Mittal, An investigation into E-Waste flows in India, J.clean production 37 (2012) 229-242. https://doi.org/10.1016/j.jclepro.2012.07.017

[42] A. Borthakur, P. Singh, Electronic waste in India: problems and policies, Int. J. Environmental Science 3,1 (2012) 353-362.

[43] D. Sinha-Khetriwal, P. Kraeuchi, M. Schwaninger, A comparison of electronic waste recycling in Switzerland and in India, Environmental Impact Assessment Rev 25,5 (2005) 492-504. https://doi.org/10.1016/j.eiar.2005.04.006

[44] P. Agamuthu, D.Victor, Policy trends of extended producer responsibility in Malaysia, Waste Manage Res 29,9 (2011) 945-953. https://doi.org/10.1177/0734242X11413332

[45] R. Afroz, M. M. Masud, R.Akhta, J. B. Duasa, Survey and analysis of public knowledge, awareness and willingness to pay in Kuala Lumpur, Malaysia-a case study on household waste management, J. Clean Production. 53(2013) 185-193. https://doi.org/10.1016/j.jclepro.2013.02.004

[46] V. N. Pinto, E-waste hazard: the impending challenge, Indian J. Occup. Environmental Med. 12,2 (2008) 65. https://doi.org/10.4103/0019-5278.43263

[47] V. S. Rotter, P. Chancerel, W. P. Schill, Practicalities of individual producer responsibility under the WEEE directive, Waste Management Resources 29,9 (2011) 931-944. https://doi.org/10.1177/0734242X11415753

[48] T.R. Carlee, The Economic Feasibility of Recycling: A Case Study of Plastic Wastes, Prager, New York, 1986.

[49] H. Alter., The origins of municipal solid waste: II. Policy Options for plastics waste management, Waste Management Resources. 11 (1993) 319-332. https://doi.org/10.1006/wmre.1993.1034

[50] F. P. Boettcher, Environmental Compatibility of Polymers, Emerging Technologies in Plastics Recycling, ACS Symposium Series 513, American Chemical Society (1992) 16-25. https://doi.org/10.1021/bk-1992-0513.ch002

[51] H. Mankowitz, Incineration of municipal solid waste: Scientific and technical evaluation of the state of- the art by an expert panel, Resources, Conservation and Recycling, 4 (1990) 241-252. https://doi.org/10.1016/0921-3449(90)90005-O

[52] J. Gourmands, H. van der Slot, T. Alberts, Waste Materials in Construction. Studies in Environmental Science, 48, Elsevier Science Publishing Company Inc., New York, 1991.

[53] J. W. Barlow, D. R. Paul, The Compatibility of Mixed Plastic Scrap. Secondary Reclamation of Plastic Waste; Research Report-Phase I, Plastics Institute of America (1987) 137-148.

[54] R. S. Stein, Miscibility in Polymer Recycling, Emerging Technologies in Plastics Recycling. American Chemical Society, (1992) 39-48. https://doi.org/10.1021/bk-1992-0513.ch004

[55] Bennett, R.A, Recycled Plastics: Product Applications and Potential, Emerging Technologies in Plastics Recycling. American Chemical Society (1992) 26-38. https://doi.org/10.1021/bk-1992-0513.ch003

[56] F. Fenella, I. de Michalis, A. Scorcher, M. Pelion, F. Velia, Extraction of metals from automotive shredder residue: Preliminary results of deferent leaching systems, Chin. J. Chemical Engineering 23 (2015) 417-424. https://doi.org/10.1016/j.cjche.2014.11.014

[57] J. Cui, E. Forsberg, Mechanical Recycling of Waste Electric and Electronic Equipment: A Review, Hazardous Materials, 99 (2015) 243-263. https://doi.org/10.1016/S0304-3894(03)00061-X

[58] A. Gung, S. M. Gupta, Disassembly Sequence Planning for Products with Defective Parts in Product Recovery,Computer Engineering 35 (1998) 161-164. https://doi.org/10.1016/S0360-8352(98)00047-3

[59] M. Sethuraman, E. D. van Hullebusch, D. Fontana., A.Akcil, H. Devec., B. Batinic, J. P. Leal, T. A. Gasche, M. A. Kucuker, K. Kuchta, Recent advances on hydrometallurgical recovery of critical and precious elements from end of life electronic wastes-A review, Crit. Rev. Environmental Science Technology. 49 (2019) 212-275. https://doi.org/10.1080/10643389.2018.1540760

[60] X. N. Zhu, C. C. Nie, S.S. Wang, Y. Xie, H. Zhang, X. J. Lyu, J. Qiu, Cleaner approach to the recycling of metals in waste printed circuit boards by magnetic and gravity separation, J. Cleaner production (2019). https://doi.org/10.1016/j.jclepro.2019.119235

[61] F. Settimo, P. Bevilacqua, P. Rem, Eddy Current Separation of Fine Non-Ferrous Particles from Bulk Streams, Physical Separation Science Engineering. 13 (2009)15-23. https://doi.org/10.1080/00207390410001710726

[62] Z. Schlett, F. Claici, I. Mihalca, M. Lungu, A New Static Separator for Metallic Particles from Metal-Plastic Mixtures, Using Eddy Currents, Mineral Engineering 15 (2002) 111-113. https://doi.org/10.1016/S0892-6875(01)00215-1

[63] F. Hamersk, A. Krummenauer, A. M. Bernardes, H. M. Veit, Improved settings of a corona-electrostatic separator for copper concentration from waste printed circuit boards. J, Environmental Chemical Engineering. 7 (2019). https://doi.org/10.1016/j.jece.2019.102896

[64] J. Cui, E. Forssberg, Mechanical Recycling of Waste Electric and Electronic Equipment: A Review, J. Hazardous Materials. 99 (2003) 243-263. https://doi.org/10.1016/S0304-3894(03)00061-X

[65] Y. Higashiyama, K. Asano, Recent Progress in Electrostatic Separation Technology, Partical Science Technology 16 (1998) 77-90. https://doi.org/10.1080/02726359808906786

[66] C. W. Kiewiet, M. A. Bergougnou, J. D. Brown, I. I. Inculet, Electrostatic Separation of Fine Particles in Vibrated Fluidized Beds, IEEE Transport appliance IA-14 (1978) 526-530. https://doi.org/10.1109/TIA.1978.4503586

[67] R. Chinapu, R. Aswani kumar, M. Jarupala, The study on use of recycled materials on highway construction, International Journal of Advance Research in Science and Engineering, 5,10 (2016) 331-338.

[68] M. Surya, O. K. C. Bavithran, A. R. Nandhagopal, Stability study on eco-friendly Flexible pavement using E-waste and Hips, International Journal of Civil Engineering and Technology (IJCIET), 8,10 (2017) 956-965.

[69] K. Rajat, C. Rajesh, Use of e-waste and fly ash as a filler replacement in the bituminous concrete pavement, International Journal of Advance Research, Ideas and Innovations in Technology. 4,2(2018) 1283-1288.

[70] M. S. Ranadive, S. Maheshkumar Krishna, Performance Evaluation of E-Waste In Flexible Pavement an Experimental Approach, International Journal of Civil, Structural, Environmental And Infrastructure Engineering Research And Development. 2,3 (2012) 1-11.

[71] S. Prashant, K. Abishek, S. Sushanth, R. Raajev, Use of Plastic waste in flexible pavement, International Journal Of Engineering Research And Technology, 9,9 (2020). https://doi.org/10.17577/IJERTV9IS090423

[72] S. Amit Kumar, R. K. Singh, Application of waste materials in road construction, Non-Conventional Energy Sources for Sustainable Development of Rural areas, (2016) 1-5.

[73] D. Javiya, A. Yogesh, G. Himanshu, A Review on Performance of Bituminous Mix using E-waste and Fly-ash for the Flexible pavement, International Journal of Advance Engineering Research and Development, 4,2 (2017) 11-15. https://doi.org/10.21090/IJAERD.41658

[74] R. Himani, J. Rajesh, Utilization of Mobile Waste in Construction Industry in Preparation of Flexible Pavement, International Journal of Scientific Research in Civil Engineering, 2,6 (2018) 6-10.

[75] C. Vaidevi, D. Sahana, E. Sripriya, T. Tamilselvi, D. S. Vijayanand, Utilization of e-waste in flexible pavement, International Conference on Mechanical, (2020) 030001-030006. https://doi.org/10.1063/5.0024752

[76] P. Pankaj, H. Nikhil, Experimental Study of Bituminous Concrete Containing Plastic Waste, Journal of Mechanical and Civil Engineering, 11,3 (2014) 47-54. https://doi.org/10.9790/1684-11323745

[77] Dr. R. Vasudevan, S.K. Nigam, R. Velkennedy, A. Ramalinga Chandra Sekar, B. Sundarakannan, Utilization of Waste Polymers coated aggregates for flexible pavement and easy disposal of waste Polymers, Proceedings of the International conference on sustainable solid waste management, 5 (2007) 105-111.

[78] S. Needhidasan, S. Gorab Agarwal, A review on properties evaluation of bituminous addition with E-waste plastic powder, Materials Today: Proceedings, (2019). https://doi.org/10.1016/j.matpr.2019.12.127

[79] Sangita, Tabrez Alam Khan, Sabina, D. K. Sharma, Effect of waste polymer modifier on the properties of bituminous concrete mixes, Construction and Building Materials, 25 (2011) 3841-3848. https://doi.org/10.1016/j.conbuildmat.2011.04.003

[80] R. L. Schroder, The use of recycled materials in highway construction, Transportation Research Board, 58,2 (1994) 32-41.

[81] A. Shankar, K. Koushik, G. Sarang, Performance studies on bituminous concrete mixes using waste plastics, Highway Research Journal, 6,1 (2013).

[82] M. Brajesh, Use of Plastic Waste in Bituminous Mixes of Flexible Pavements by Wet and Dry Methods: A Comparative Study, International Journal of Modern Engineering Research, 6,3 (2016) 41-45.

[83] S. E. Zoorab, I. B. Superma, Laboratory design and Performance of Improved Bituminous Composites Utilizing Recycled Plastic Packaging Waste, 5,6 (2006) 203-209.

[84] W. Baron, Y. Zaping, Properties of Modified Asphalt Binders Blended with Electronic Waste Powders, Journal of Materials in civil Engineering, 24,10 (2012) 1261-1267. https://doi.org/10.1061/(ASCE)MT.1943-5533.0000504

[85] S. Manjay kumar, M. Prathiksha, An Experimental Study on Partial Replacement of Aggregate by E-Waste for bitumen Pavement, International journal of trend in scientific research and development, 3,3 (2019) 382-384. https://doi.org/10.31142/ijtsrd22865