MECHANICAL PROPERTIES OF E-WASTE COMPOSITES: A LITERATURE REVIEW

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ABSTRACT

The proliferation of electronic waste (e-waste) has become a global concern due to its environmental impact and potential health hazards. As a sustainable approach, the utilization of e-waste in composite materials has gained attention in recent years. This literature review explores the mechanical properties of e-waste composites, aiming to provide a comprehensive understanding of the current state of research in this field. A systematic search of academic databases was conducted to identify studies published in the last decade. Keyword searches encompassed "e-waste," "composite materials," and "mechanical properties." Selection criteria prioritized experimental studies and reviews focused on the mechanical behaviours of e-waste composites. Analysis of the literature revealed a spectrum of e-waste constituents integrated into composite matrices. Tensile strength, flexural strength, impact resistance, and hardness were examined, showcasing the influence of e-waste particle size, composition, and processing techniques. The synthesis of findings emphasizes both advantageous and detrimental effects on mechanical performance, underscoring the nuanced considerations required for the successful implementation of e-waste composites.

Keywords: *e-waste, composite materials, mechanical properties*

INTRODUCTION

Electronic waste is also known as e-waste which is obtained from discarded electrical and electronic components or devices such as Mobile phones, Refrigerator, Computers, Compact disk, Printed circuit boards etc. E-waste is one of the fastest growing wastes in the world. In Malaysia, e-waste generated more than 365,000 tonnes per annum. Most of the developed countries pull their e-waste into the developing waste like Malaysia due to the availability of cheap labour, absence of strict law and also due to the abrupt increase in the volume of e-waste. Because of this, the developing countries are facing critical issues like disposing of these wastes and also health hazardous to the human beings. To overcome this disposal problem, we are in need to reuse and recycle this waste into useful composite materials with various compositions.

E-waste accumulation has become a major concern for most of the environmental problems. The E-waste accumulation becomes an immediate environmental issue which can develop the human health hazards such as inflammation and oxidative stress precursor to cardiovascular diseases, cancer, skin diseases, and DNA damage etc. Recycling is the major way to dispose E-waste materials. Replacing the E-waste into the useful products is the major challenging process. Printed Circuit Board (PCB) which holds a majority share in E-waste is most hazardous when dumped into water, air and land. So we are in need to reuse or recycle the e-waste into some useful materials.

Plastic waste from electrical and electronic equipment (WEEE) grows up exponentially fast in the last two decades. Either consumption increase of technological products, like cell phones or computers, or the short lifetime of this products contributes to this rise generating an accumulation of specific plastic materials such ABS (Acrylonitrile-Butadiene-Styrene), HIPS (High impact Polystyrene), PC (Polycarbonate), among others. All of they can be recycled by themselves. However, to separate them by type is neither easy nor economically viable, then an alternative is recycling them together as a blend. Taking into account that could be a deterioration in final properties, to enhance phase adhesion and add value to a new plastic WEEE blend a compatibilization is needed

LITERATURE REVIEW

Composites were prepared by melt blending PP with varying amounts of PCB waste ranging from 0 to 25 wt. %. Mechanical and rheological properties of PP composites were investigated. The incorporation of PCB waste increased the tensile modulus, the flexural strength and the flexural modulus of composites by 38, 31 and 93% respectively; however the tensile strength was found to decrease by 12%. PP/PCB waste composites showed good resistance to impact as the notched impact strength of composites showed a marginal decrease of 19% for up to 15 wt. % loading and became constant for higher waste loadings. An optimum in mechanical properties was achieved at 25 wt. % PCB waste loading. Glass fibers pull out from the PP matrix was found to act as an effective energy dissipation mechanism during impact. Elastic and viscous moduli of the composites increased approximately by 6 and 2 times respectively than PP alone. The complex viscosity modulus value increased by around 7 times at high shear rate as compared to pure PP, while still remaining well within the acceptable limits for moulding processes (Kumar et al. 2017).

(Lokesh K. S 2019) discussed about his work aims to prepare and test samples prepared by the E-waste scrap glass mixed with polymer matrix material proportioned with glass fibre. Composites with different filler ratio (0%, 3%, 6%, 9%) are prepared. Tests were performed to calculate tensile properties, flexural strength of the composites. Based on the tensile and flexural test it is depicted that composite with 6% filler material exhibits enhanced properties due to the strong bonding between filler and the matrix material.

(Samat et al. 2021) studied on composites by combining recycled high-density-polyethylene (rHDPE) with ground butylrubber (bR); which is a material commonly used in the production of tubed-tyres. The bR-rHDPE composites of different bR content with or without the addition of bitumen were produced via melt-mixing in an internal mixer. The impact resistance and mechanical properties of each composite were evaluated using (i) Charpy impact, (ii) drop-weight and (iii) tensile testing. Impact tests show a significant improvement in impact resistance. However, the addition of bR and bitumen adversely affected the tensile properties of the composites. The results indicate that the bR-rHDPE composites performed better with a higher content of bR, and the impact resistance further improved with the addition of bitumen. The obtained property suggests that this composite could be used to manufacture playground tiles, vehicles wheel chocks, door stops and wedges, rubber speed bumpers, etc. The promising impact resistance of bR-rHDPE+bitumen composites coupled with viable processing methods have provided a sustainable solution for the disposal of tubed tyre.

(Hu et al. 2023) studied how to achieve the high value-added reutilization of WPCB non-metals in sustainable polymer composites. In his review, recent progress in developing sustainable polymer composites based on WPCB non-metallic components was systematically summarized. It has been demonstrated that the WPCB non-metals can serve as a promising reinforcing and functional fillers to significantly ameliorate some of the physical and chemical properties of polymer composites, such as excellent mechanical properties, enhanced thermal stability, and flame retardancy. The recovery strategies and composition of WPCB non-metals were also briefly discussed. Finally, the future potentials and remaining challenges regarding the reutilization of WPCB non-metallic components are outlined. His work provides readers with a comprehensive understanding of the preparation, structure, and properties of the polymer composites based on WPCB non-metals, providing significant insights regarding the high value-added reutilization of WPCB non-metals of electronic wastes.

(Senthil Kumar and Baskar 2015) invested on concrete with partial replacement of coarse aggregate using electronic plastic waste (E-plastic). The E-plastic from computer plastics was considered as coarse aggregate. Coarse aggregate was replaced with different percentages (10, 20, 30, 40 and 50 %) of E-plastic by volume. Tests were performed for properties of fresh and hardened concrete at different ages such as 7 and 28 days. From the investigation, it was noted that the workability of the mix was reduced against the increase in percentage of E-plastic. The compressive strength, split tensile strength, flexural strength of partially replaced concrete was comparatively less than that of the control concrete. The effect of adding the E-plastic in concrete reduced the dry density of the concrete and showed the high deformability behaviour before failure. The lesser dry density may be having advantage in self-weight reduction in structural elements which leads to lesser attraction of pseudo inertia forces in the seismic prone area.

Melt-processing of blended plastics from waste electrical and electronic equipment (WEEE) is a method to facilitate mechanical recycling, and this might improve the recycling conditions and increase the amounts of plastics being recycled. To ensure the quality of melt- blended plastic waste, it is essential to know the composition of the incoming material and then possibly improve the compatibility between the different polymer phases. WEEE plastic compositions as well as the mechanical and thermal properties obtainable from a model material of a recyclable WEEE plastics blend have been studied in this work. A real collected and recyclable WEEE plastics fraction was found to contain mainly high impact polystyrene (HIPS, 42 weight% (wt%)), acrylonitrile-butadiene-styrene copolymer (ABS, 38 wt%) and polypropylene (PP, 10 wt%). The remaining part (10 wt%) consisted primarily of other styrene-based thermoplastics and polyolefins. 1-2 wt% were found to be non-thermoplastic contaminants including wood, polyurethane foam, and silicone rubber. The number of merged HIPS and ABS was relatively stable at 80 ± 4 wt% (95% confidence interval) in the sampled waste volume of 600 kg. Virgin and recycled (containing collected and sorted WEEE plastics) ternary blends, with the same relative composition of HIPS, ABS and PP as presented above, were blended to model the studied WEEE plastics fraction. Melt-processing by extrusion was compared with injection moulding. An intermediate degree of orientation corresponding to 400-500 % melt- elongation, obtained by extrusion, resulted in the highest ductility while the ductility of the injection-moulded material was significantly lower, but exhibited less variation. The stiffness and yield stress of the recycled ternary blend were found to be higher, while the elongation at break was lower than the values for the virgin blend. It was also seen that the stiffness and the yield stress of the virgin and recycled blends mainly followed the rule of mixtures, but that blending had an adverse impact on the elongation at break, indicating incompatibility between HIPS, ABS and PP. The thermal analysis of the blends indicated relatively low thermo- oxidative stability, with an onset temperature of exothermic oxidation at 187 C for the recycled blend and 200 C for the virgin blend. The low thermo-oxidative stability indicated that it is necessary to increase the amount of active thermo-oxidative stabilisers. The low ductility of the blends implied the need of improving the compatibility between the plastic phases (Stenvall 2013).

(Wang et al. 2022) investigated on how carbon nanotubes (CNTs) nanofillers can enhance the mechanical performance of polymers. In his work, CNTs produced from plastics, named pCNTs, were applied as fillers to epoxy resin (EP), while commercial CNTs (cCNTs) were used as a reference. The carboxyl groups were effectively inserted on the CNT skeleton by a facile purification and modification. After ultrasonic dispersion, the modified pCNTs (M-pCNTs) were uniformly dispersed and loaded in the EP matrix. Better mechanical properties than EP were attained with a Young's modulus of 3776.9 MPa, a tensile strength of 37.3 MPa, a fracture strain of 6.32%, and a fracture strength of 111.7 MPa with 2 wt % M-pCNT loading. Thus, pCNTs enhanced the toughness of the EP composites and simultaneously retained the stiffness.

Two different nanosized mineral fillers (nano calcium carbonate and nano clay) were used in the high-density poly(ethylene) (HDPE) composites pilot plant production. Structural and mechanical properties of the prepared composites were examined by (Murtaja et al. 2022) The homogenous filler distribution was confirmed in the tested samples by scanning electron microscopy, transmission electron microscopy, and energy dispersive spectroscopy analyses. The fillers' fortifying effect on polymer composites' mechanical performance was confirmed as indicated by the increased elastic modulus and indentation modulus. Additionally, the possible modulation of the plastic-elastic mechanical behaviours was confirmed by the type of the filler as well as its concentration used in the final composites testing articles.

(Sinha et al. 2021) analysed on electronic waste plastic materials including recycled PCB's and other PVC components of e-waste has been used for filler in asphalt mix for pavement. A significant increase of Marshall Stability and Flow Value has been observed as percentage of e-waste plastic increases. The plastic content of mix varies 0 %, 4 %, 8 % and 12 % by weight of aggregate. Plots of various Marshall Parameters such as Marshall Stability, Flow value, voids filled with bitumen, voids in mineral aggregates and unit weight against the bitumen content shows an improving trend of parameters with increasing the plastic replacement. Comparison with earlier published result shows that increasing the plastic replacement beyond 12% will have a negative influence on stability value. The recycling of e-waste plastic and marble dust in asphalt mix design for pavements provide us a better way of resource utilization in a cost-effective manner.

(Omondi 2023) studied and evaluated the challenges and opportunities around e-plastic management practices such as recycling, pyrolysis, incineration, land filling, bioremediation and use in aggregates while analysing sustainability of the techniques. His study highlights the toxicity associated with e-plastic waste and its imposed challenge to general e-waste handling. The study recommends up scaling of regulatory framework and policies for efficient management of e-plastic waste to avert the looming health and environmental impacts.

Two major types of electronic waste plastics were used in this investigation: acrylonitrile butadiene styrene (ABS) and high impact polystyrene (HIPS) by (Colbert 2012) . This research investigation utilized two approaches for incorporating electronic waste plastics into asphalt pavement materials. The first approach was blending and integrating recycled and processed electronic waste powders directly into asphalt mixtures and binders; and the second approach was to chemically treat recycled and processed electronic waste powders with hydro-peroxide before blending into asphalt mixtures and binders. The chemical treatment of electronic waste (e-waste) powders was intended to strengthen molecular bonding between e-waste plastics and asphalt binders for improved low and high temperature performance. Superpave asphalt binder and mixture testing techniques were conducted to determine the rheological and mechanical performance of the e-waste modified asphalt binders and mixtures. This investigation included a limited emissions-performance assessment to compare electronic waste modified asphalt pavement mixture emissions using SimaPro and performance using MEPDG software. Carbon dioxide emissions for e-waste modified pavement mixtures were compared with conventional asphalt pavement mixtures using SimaPro. MEPDG analysis was used to determine rutting potential between the various e-waste modified pavement mixtures and the control asphalt mixture. The results from this investigation showed the following: treating the electronic waste plastics delayed the onset of tertiary flow for electronic waste mixtures, electronic waste mixtures showed some improvement in dynamic modulus results at low temperatures versus the control mixture, and tensile strength ratio values for treated e-waste asphalt mixtures were improved versus the control mixture.

(U. Kumar 2019) discussed the development of several novel processes to recycle e-waste plastics. It demonstrates how their secondary use may potentially divert them from landfills and contribute to many high-end value-added applications such as energy storage. Styrene acrylonitrile type plastics from end-of-life printers (provided by an e-waste recycler in Sydney) were selected for this work. Firstly, the plastics were used as carbon source/reductant to extract iron from another low-value and Fe_3O_4-rich component of e-waste i.e. toner powder. A qualitative mechanism was proposed for the reduction of iron-oxide to metallic iron. Next, hydrocarbon oils with high calorific values (38.27 MJ/kg) were generated via non-catalytic thermal transformation of plastics. These oils were characterised using gas chromatography-mass spectrometry and nuclear magnetic resonance spectroscopy followed by detailed qualitative mechanism for the formation of major oil components such as styrene, toluene, and naphthalene. The solid carbonaceous residues obtained from thermal transformation process were activated at 700-900 oC to produce porous activated carbons. Supercapacitor electrodes prepared from these carbons exhibited remarkable specific capacitance values of ~220 F/g at 5 mV/s. The same activated carbons when used as anodes in sodium-ion batteries, demonstrated superior rate capability and delivered capacities ~190 mAh/g at 3 mA/g after 25 cycles. An in-depth ex-situ analysis of electrodes was performed to get an insight into the sodium storage mechanism. These notable results pave the way for various other plastic types to be used in similar high-end applications. Plastics are inexpensive, lightweight, and durable materials, which can readily be moulded into a variety of products that find use in a wide range of applications. Consequently, the production of plastics has increased markedly over the last 60 years.

(Hopewell, Dvorak, and Kosior 2009) set recycling into context against other waste-reduction strategies, namely reduction in material use through downgauging or product reuse, the use of alternative biodegradable materials and energy recovery as fuel. While plastics have been recycled since the 1970s, the quantities that are recycled vary geographically, according to plastic type and application. Recycling of packaging materials has seen rapid expansion over the last decades in several countries. Advances in technologies and systems for the collection, sorting and reprocessing of recyclable plastics are creating new opportunities for recycling, and with the combined actions of the public, industry, and governments it may be possible to divert most of the plastic waste from landfills to recycling over the next decades.

(Tarantili, Mitsakaki, and Petoussi 2010) aimed to establish a procedure for recycling the same engineering plastics deriving from waste of electrical and electronic equipment (WEEE), which offers the additional advantage of using the as-received waste stream as a recyclable mixture, i.e. without sorting and classification of its components. The experimental results showed that blends of PC with ABS or ABS/HIPS can be prepared by direct mixing and this, would allow easy handling of the engineering plastics coming from WEEE, i.e. blending without the need of sorting. These mixtures can be easily processed and display acceptable mechanical properties with reasonable cost. Therefore, the processing characteristics and properties of the systems studied in this work could be the key for the design of an interesting approach for handling solid plastic waste from electrical and electronic devices. © 2009 Elsevier Ltd. All rights reserved.

CONCLUSION

From the research discussed, e-waste composites and filler are suitable for various engineering applications. The e-waste materials from domestic applications like Refrigerators, Televisions, Mobile phones, IT products like Computers, PVC cables, LED's etc. Based on the study of various research papers, the e-waste composites have various physical and mechanical properties in various combinations. Depending upon the properties of fillers, we can reuse that material for various applications. As disposal of waste is a major problem in the today's world due to limited landfill space as well as hazardous to human health by utilization of waste in various engineering applications.

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