Improving The Strength of Highway Pavement By Using The Electronic Waste: A Review

Ravish Kumar[1], Mr. Ushendra Kumar[2]

[1]*Master of Technology, Civil Engineering, Lucknow Institute of Technology, Lucknow, India*
[2]*Head of Department, Department of Civil Engineering, Lucknow Institute of Technology, Lucknow, India*

***

Abstract - *The infrastructure of highways, particularly the pavement, is crucial for efficient transportation systems and economic progress. However, conventional pavement materials often have limitations in terms of strength, durability, and sustainability. Recently, there has been a growing interest in exploring alternative materials to improve pavement performance and lessen environmental impact. One promising approach is the use of electronic waste (e-waste) in pavement construction. This review critically evaluates the potential of integrating e-waste materials into highway pavement to enhance its strength and durability. It consolidates existing literature on the characteristics, composition, and properties of e-waste, as well as various techniques for its integration into pavement materials. The review underscores the advantages and challenges of utilizing e-waste, including its capacity to bolster pavement strength, diminish environmental pollution through waste diversion, and alleviate the depletion of natural resources.*

The paper discusses the effects of incorporating e-waste on pavement performance, encompassing its influence on structural integrity, stiffness, fatigue resistance, and rutting behavior. Environmental aspects such as leachability, toxicity, and long-term sustainability are also addressed. By conducting a comprehensive analysis of current research findings and case studies, this review offers insights into the feasibility and potential benefits of employing e-waste in highway pavement construction. It identifies knowledge gaps and proposes areas for future research to optimize the utilization of e-waste in pavement engineering. This review underscores the importance of integrating innovative materials like e-waste into pavement construction practices, thereby contributing to the development of sustainable and resilient transportation infrastructure systems.

Key Words: Highway Pavement, Electronic Waste, Strength, Polymer, Compressive Strength

1.HISTORY

The history of bolstering highway pavement strength using electronic waste (e-waste) finds its roots in recognizing the limitations of traditional pavement materials and the growing call for sustainable infrastructure solutions. In the late 20th century, rapid technological advancements coincided with a notable increase in electronic device production, leading to a significant surge in e-waste generation. This surge raised environmental concerns due to the hazardous materials present in electronic products, such as heavy metals and toxic chemicals. As environmental awareness grew and waste management efforts intensified, researchers and engineers began exploring alternative applications for e-waste. One promising area that emerged was its potential utilization in civil engineering, notably in pavement construction. The notion of integrating e-waste into pavement materials gained traction in the early 21st century as the need for sustainable infrastructure solutions became more apparent. Early studies focused on understanding the characteristics and properties of e-waste and its suitability for pavement applications. Researchers explored various methods for processing and integrating e-waste into pavement mixtures, including shredding, grinding, and blending with traditional aggregates and binders. Through laboratory experiments and pilot projects, they evaluated the mechanical, chemical, and environmental performance of e-waste-modified pavements.

Advancements in materials science and pavement engineering techniques facilitated the development of innovative approaches for integrating e-waste into pavement designs. Researchers investigated using e-waste as a partial replacement for conventional aggregates, fillers, or additives to enhance pavement strength, durability, and sustainability. As research progressed, numerous studies demonstrated the potential benefits of incorporating e-waste in highway pavement construction, including improved mechanical properties such as increased compressive strength, enhanced resistance to fatigue and rutting, and reduced susceptibility to environmental degradation. The incorporation of e-waste into pavement construction also provided environmental benefits by diverting hazardous waste from landfills and reducing the depletion of natural resources, aligning with broader efforts towards circular economy principles and sustainable development goals. In recent years, there has been growing interest from governments, transportation agencies, and industry stakeholders in promoting the adoption of e-waste-modified pavements as part of sustainable infrastructure strategies.

Pilot projects and real-world applications have been initiated to assess the performance and feasibility of these innovative pavement designs in various geographical and environmental conditions. Looking ahead, ongoing research aims to address remaining challenges, such as optimizing processing techniques, evaluating long-term performance, and addressing concerns related to leachability and environmental impact. Through collaborative efforts among researchers, policymakers, and practitioners, the integration of e-waste into highway pavement construction continues to evolve as a promising approach for achieving resilient, resource-efficient transportation infrastructure systems.

2.INTRODUCTION

Highway pavement infrastructure plays a crucial role in supporting transportation networks, facilitating the movement of goods and people vital for economic prosperity and societal welfare. However, traditional pavement materials often encounter issues regarding strength, durability, and sustainability, prompting the exploration of innovative solutions to tackle these challenges. In recent times, there has been a growing interest in leveraging electronic waste (e-waste) as a novel resource to enhance the performance of highway pavements. The widespread use of electronic devices and rapid technological progress has resulted in a corresponding increase in e-waste generation. This poses significant environmental concerns due to the presence of hazardous substances like heavy metals, brominated flame retardants, and other toxic compounds in electronic products. Managing and disposing of e-waste has become a pressing global issue, leading to endeavors to explore alternative approaches for its reuse and recycling. One promising approach is integrating e-waste into highway pavement construction. E-waste comprises various materials with potential engineering properties suitable for pavement applications, including metals, plastics, glass, and ceramics. By incorporating e-waste into pavement materials, we can address waste management challenges and enhance the performance and sustainability of highway pavements. This paper offers a comprehensive review of research and developments in using e-waste to bolster the strength of highway pavements.

It consolidates existing literature on characterizing e-waste materials, methodologies for integrating e-waste into pavement mixtures, and the impact of e-waste addition on pavement properties and performance. Moreover, it discusses environmental considerations concerning the utilization of e-waste in pavement construction, such as leachability, toxicity, and long-term sustainability. Through an exploration of the potential benefits, challenges, and opportunities associated with employing e-waste in highway pavement construction, this review aims to contribute to the advancement of sustainable infrastructure practices. By harnessing e-waste as a resource for pavement engineering, we can not only enhance the strength and durability of highway pavements but also contribute to environmental preservation and the circular economy.

3.HIGHWAY PAVEMENT

Highway pavement denotes the uppermost layer of a road constructed to endure vehicle loads and furnish a durable, even driving surface. It typically comprises multiple layers, each fulfilling a distinct role to guarantee the road's durability and functionality. These layers commonly encompass the subgrade, subbase, base course, and surface course. The subgrade refers to the natural soil or prepared earth beneath the pavement layers, furnishing support and stability. Above the subgrade, the subbase layer is incorporated to further distribute loads and facilitate drainage. Following the subbase, the base course is installed to offer additional structural support and aid in load distribution. Lastly, the surface course, also recognized as the wearing course, constitutes the topmost visible layer to drivers. It's engineered to withstand traffic wear and environmental factors while delivering a smooth, skid-resistant driving surface. Highway pavement construction employs various materials, including asphalt concrete (commonly known as asphalt), concrete, and composite materials. Material selection hinges on factors such as traffic volume, climate conditions, and budgetary constraints. Regular maintenance and periodic resurfacing are imperative for extending the lifespan of highway pavements and ensuring the safety and efficiency of road transportation systems.

Figure-01: Highways Pavement.

3.1.Type of the Highway Pavement

Highway pavement can be classified into several types based on the materials used in construction and the design specifications. The main types of highway pavement include:

- Flexible Pavement
- Rigid Pavement
- Composite Pavement

3.1.1.Flexible Pavement

Asphalt concrete, often referred to as asphalt, serves as the principal material in flexible pavements. These pavements are comprised of layers of asphalt mixtures laid atop a compacted base and subbase. Flexible pavements possess the ability to tolerate minor movements and deformations without developing cracks, rendering them suitable for diverse traffic loads and climates.

Figure-02: Flexible Pavement

3.1.2.Rigid Pavement

Concrete is the primary material used in rigid pavements. Rigid pavements are constructed with reinforced or unreinforced concrete slabs, typically supported directly by the subgrade or a thin base layer. They offer excellent load-bearing capacity and durability but are less flexible than asphalt pavements, making them more susceptible to cracking under certain conditions.

Figure-03: Rigid Pavement.

3.1.3. Composite Pavement

Composite pavements blend features from both flexible and rigid pavement designs, often incorporating a flexible asphalt concrete surface layer atop a rigid concrete base layer. The aim of composite pavements is to harness the advantages of both flexible and rigid pavements, resulting in enhanced durability, load-bearing capacity, and resistance to cracking. In highway construction, composite pavement presents a versatile solution comprising multiple layers tailored to optimize performance and longevity. At the surface lies the wearing course, typically made from asphalt concrete, providing a resilient and skid-resistant driving surface capable of withstanding traffic and weather challenges. Below this, the base layer adds structural integrity and facilitates load distribution, often crafted from compacted aggregate materials to resist deformation. Further down, the subbase layer aids in load distribution and drainage, commonly composed of granular materials compacted to establish a stable foundation. In certain designs, a concrete base layer reinforces the structure, especially under heavy loads. Finally, the subgrade, the natural soil or prepared earth below, serves as the foundation, requiring appropriate preparation and compaction for stability and support over the pavement's lifespan. Together, these layers create a cohesive system, balancing flexibility, durability, and load-bearing capacity to meet the demands of modern transportation infrastructure.

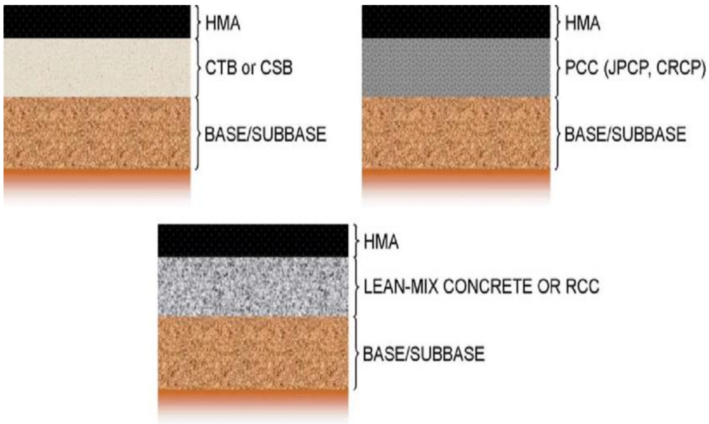

Figure-04: Composite Pavement.

4.LITERATURE REVIEW

In the literature review, we have studied the previuos research paper related to the improvement of the highways pavement by using the different materials. The summary of the previous research paper is given below in details:

Imtiaz, Lovell (2012): An assessment considering technical, environmental, and economic aspects highlighted the substantial potential of reclaimed paving materials, coal fly ash, blast furnace slag, bottom ash, boiler slag, steel slag, and rubber tires to substitute conventional materials in various highway construction applications. It is recommended that these materials be considered for future construction projects. However, it's essential to address technical, economic, and environmental challenges associated with their usage before widespread adoption in highway construction. These challenges must be carefully identified and discussed for each waste material to ensure their effective integration into highway construction practices.

Anoop, Vikas (2015): The compressive strength of E-waste concrete, with up to a twenty percent replacement level as fine aggregate, is comparable to the reference concrete at both 7 and 28 days. Additionally, the compressive strength of E-waste concrete, with a five percent replacement as coarse aggregate, surpasses that of the reference concrete. Moreover, E-waste concrete, with up to a twenty percent replacement level as coarse aggregate, exhibits compressive strength similar to the reference concrete at both seven and twenty-eight days. This suggests that E-waste can be effectively utilized as construction materials.

Vikram et.al (2017): The tests conducted on bitumen were carried out with precision, and successful results were obtained for replacements of 5% and 10%. Bitumen with a 10% replacement rate can be utilized for road paving. Although tests were also conducted with a 15% replacement rate, the results did not meet the standards and were thus excluded from the report. Further research on 15% replacement may lead to successful outcomes. E-Waste management is a novel concept. If the procedures outlined in the report are implemented, environmental issues associated with electronic waste could be addressed. Implementation of these procedures in every city has the potential to minimize electronic waste production.

Anupam, Nitin (2018): Our thorough examination of Electronic Waste (PCB) as a Coarse Aggregate replacement has yielded valuable insights. The specific gravity of the utilized PCB averages at 2, with a minimal water absorption rate not exceeding 0.3% of its own weight. Notably, the average Impact Value for the PCBs used in Fine Aggregate reaches 17%. As for the fine aggregate, its average specific gravity is 2.67, with a water absorption rate not surpassing 1.21% of its own weight. The fineness modulus stands at 3.16, and the bulk density records 1577 N/mm3, indicating that the fine aggregates conform to standard grade requirements.

In the testing of Cement grade 43, we observed an average specific gravity of 3.15, a fineness of 3%, a Normal consistency of 31.5%, and initial and final setting times of 19 minutes and 625 minutes, respectively. The compressive strength of the cement cube after 28 days registered at 43.33 N/mm2, with an expansion of 3.33 mm in the cement mixture. Moving to the compressive strength of the concrete mixture, it ranged from 45.35 N/mm2 to 35.33 N/mm2. Intriguingly, up to a 10% replacement of coarse aggregate with Electronic Waste (PCB) did not result in a significant difference in compressive strength, beyond which a decline was observed, particularly noticeable after a 5% replacement. These findings underscore the potential of judiciously using Electronic Waste (PCB) in construction, but careful consideration is essential to balance the benefits and maintain structural integrity.

Manjula, Chore (2019): From the few experimental investigations conducted on the reclaimed rubber cell reinforced model pavement, it is evident that incorporating reclaimed rubber cells within the sub-base enhances the pavement's load carrying capacity and reduces settlement. Integrating such waste materials into pavements not only offers a practical solution to their disposal, thus addressing environmental concerns, but also promotes their effective utilization as sustainable construction materials in road development. Additionally, constructing pavements in this manner proves to be cost-effective. This holds particular significance for developing countries like ours.

Malleswara, Khadar (2020): The polymer-coated aggregate, containing a higher percentage of polymers, is compacted into a block exhibiting commendable compressive and bending strength, showcasing the adhesive prowess of the polymers. This characteristic significantly enhances the stability of the PCA bituminous mix. During the mixing process of bitumen with PCA, conducted at temperatures around 140-150º C, both polymers and bitumen are in a fluid state. They amalgamate at the surface, facilitating thorough bitumen spread and thereby augmenting bonding between aggregate and bitumen. The removal of bitumen occurs at a sluggish pace, with only approximately 85% being extracted, while the remaining portion adheres to the aggregate surface due to the presence of the coated polymers. Further washing with a polymer solvent, termed "decline," eliminates both bitumen and polymer residues. The molten polymer serves as an effective binder, making it a suitable substitute in flexible pavement mix preparation. Notably, the quantity of bitumen required is reduced proportionally to the amount of polymer utilized in the mix preparation.

Aniket et.al (2020): The approach to proportioning discussed throughout this paper allows for the utilization of a wide range of E-waste ash variations. It has been observed that the quality of E-waste ash isn't the sole determining factor, but rather the variation in that quality plays a crucial role. Smart concrete is typically proportioned to include occasional quality ash until the quality remains consistent. The significant advantage of using E-waste ash in concrete lies in the flexibility it offers in selecting blend proportions. By incorporating the ash, a diverse range of potential blends can be explored for any given specification. In each scenario, it becomes possible to decide on the most cost-effective blend, the most efficient placement, or the most durable option. E-waste ash has a lower unit weight, meaning that a higher proportion of ash within the paste results in better lubricated aggregates, leading to improved concrete flow and enhanced binding with lime over time. This accelerates the attainment of maximum strength for the concrete mix.

Thus, E-waste ash can effectively serve as a material in concrete road pavement construction.

Sahebagouda et.al (2022): Based on all the experiments conducted, it is concluded that e-waste enhances the strength of the pavement. At an optimum bitumen content of 5%, replacing 5%, 10%, and 15% of e-waste plastic powder with bitumen results in improved strength, with the 10% replacement deemed suitable for pavements. Utilizing e-waste for pavement construction not only improves e-waste management in the environment but also reduces costs. Furthermore, properties of bitumen such as penetration value, ductility, flash and fire point, specific gravity, and softening point are altered. Additionally, the use of aggregates can be minimized.

Firdous et.al (2022): This process is environmentally friendly and holds significance in terms of economics, environment, and social aspects. Utilizing e-waste in road development serves two purposes: reducing construction costs and contributing to effective waste management of this unwanted material. The bulk density surpasses that of the mix prepared with plain bitumen. Incorporating modified bitumen with approximately 6% processed e-waste by weight of bitumen significantly enhances Marshall Stability, strength, fatigue life, and other desirable properties of bitumen while also leading to minor savings in bitumen usage. The recommended ratio of E-Waste plastic for modification is up to 6% by the weight of bitumen content, suitable for road construction in hot climates where low penetration grade bitumen is utilized. Stability increases by 9% with an increase in e-waste percentage.

Shadab , Ankit (2023): The development of sustainable pavement materials to enhance road performance and minimize environmental impact is a crucial research focus in modern transportation infrastructure. This thesis concentrates on the process of material selection and characterization to assess the viability of recycled concrete aggregate (RCA) as a sustainable pavement material. Favorable physical and mechanical properties, including relatively high specific gravity and satisfactory strengths, suggest RCA's potential to meet pavement performance requirements. Moreover, environmental impact assessment highlights RCA's lower embodied energy, reduced carbon footprint, decreased water consumption, and minimized waste generation, underscoring its sustainability advantages.

Pramod et.al (2023): Utilizing e-waste in road construction can yield several environmental advantages. E-waste typically harbors hazardous substances like lead, mercury, and cadmium. Disposal of e-waste in landfills poses the risk of these substances leaching into the soil and groundwater, thereby contaminating the environment. By incorporating e-waste into road construction, the potential for these hazardous materials to enter the environment is mitigated. In essence, leveraging e-waste in road construction presents a promising solution that not only aids in cost reduction and durability improvement but also safeguards the environment.

Zahoor, Ashish (2023): All results obtained regarding densities and compressive strengths for the control test demonstrate consistency, meeting the standard requirements for grade 30 (G30) concrete as specified in BS 1881, 1978 method of testing concrete. Additional findings concerning the percentage replacements of fine aggregate with ore waste at 10%, 20%, and 30% were also established across various curing ages. Upon analyzing these results, variations in compressive strengths among concrete cubes produced under these replacement conditions are evident. The flexural strength of reinforced concrete beams remains unaffected by the replacement of sand with iron ore tailing (IOT). Conversely, there is an enhancement of flexural strength for all percentages of sand replacement. Although the increase in flexural strength is not substantial, the mixes with 10%, 20%, and 30% IOT performed better in terms of flexural strength compared to the control mixes, respectively. This suggests the feasibility of producing cost-effective concrete with acceptable 7 days and 28 days strength through partial replacement of IOT.

5.CONCLUSION

In summary, this review has delved into the potential of using electronic waste (e-waste) to bolster the strength and durability of highway pavement. Through an in-depth analysis of existing literature, it is evident that integrating e-waste materials, such as electronic components and printed circuit boards, offers a promising solution to address both environmental concerns linked to e-waste disposal and the imperative for sustainable infrastructure development. The incorporation of e-waste in pavement construction brings forth numerous advantages, including enhanced mechanical properties, increased resistance to environmental degradation, and reduced dependency on traditional construction materials. Nevertheless, further research is needed to refine incorporation techniques, assess long-term performance, and evaluate potential environmental impacts. Overall, the findings underscore that integrating e-waste into highway pavement holds significant potential for advancing sustainable infrastructure practices while concurrently mitigating the adverse effects of e-waste accumulation.

REFERENCE

1. IMTIAZ AHMED AND C. W. LOVELL "Use of Waste Materials in Highway Construction: State of the Practice and Evaluation of the Selected Waste Products " 2012, TRANSPORTATION RESEARCH RECORD 1345.

2. Anoop Singh, Vikas Srivastava "Utilisation of E-waste in Concrete - An Experimental Investigation" 2015, International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181 Published by, www.ijert.org ISNCESR-2015 Conference Proceedings.

3. Vikram J. Patel1 , Hemraj R. Kumavat2 , Ganesh V. Tapkire3 “An Experimental Study of Bituminous Pavement adding Electronic-Waste to Increase the Strength Economically” 2017, International Journal of Innovative Research in Science, Engineering and Technology (An ISO 3297: 2007 Certified Organization) Website: www.ijirset.com.Vol. 6, Issue 1, January 2017.

4. Anupam Kumar Sharma1 , Nitin Dutt Sharma2 “An Experimental Study on Use of E-Waste Materials in Concrete for Rigid Pavements” 2018, International Journal of Science and Research (IJSR) ISSN: 2319-7064 ResearchGate Impact Factor (2018): 0.28 | SJIF (2018): 7.426.

5. B. Manjula Devi, H.S. Chore “Use of Reclaimed Rubber Cell in Highway Pavement: An Experimental Research” 2019, International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278-3075, Volume-8, Issue- 6S4, April 2019.

6. P.Naga Malleswara Rao1, B Khadar Mohammed2 “UTILIZATION OF WASTE POLYMERS FOR FLEXIBLE PAVEMENT FOR LOW VOLUME RURAL ROADS ” 2020, International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056 Volume: 07 Issue: 07 | July 2020 www.irjet.net p-ISSN: 2395-0072.

7. Aniket Ravindra Ingole, Shweta Kailashrao Gulhane, Shivani Sanjay Shirbhate, Mayur Pandit Chavhan, Toshini Narendra Makde “Use of Electronic Waste Concrete for Road Construction ” 2020, International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249 – 8958 (Online), Volume-9 Issue-5, June 2020.

8. Sahebagouda R Patil*1, Ushe Y Neeralakeri*2, Kishan Neelkhant Nagannavar*3, Krishna*4, Vinay A *5 “Experimental Investigation on Replacement of Bitumen with PCB Powder (E-Waste)” 2022, International Journal of Research Publication and Reviews Journal homepage: www.ijrpr.com ISSN 2582-7421.

9. Firdous Ahmed Parray, 2Aman Bathla, 3Dr. Gurcharan Singh “Study on use of E-Waste in Flexible Pavements” 2022, 2022 IJRTI | Volume 7, Issue 5 | ISSN: 2456-3315.

10. Shadab Akhtar*1, Ankit Sethi*2 “SUSTAINABLE PAVEMENT MATERIAL FOR ENHANCED ROAD PERFORMANCE AND ENVIRONMENTAL IMPACT REDUCTION” 2023, International Research Journal of Modernization in Engineering Technology and Science (Peer-Reviewed, Open Access, Fully Refereed International Journal) Volume:05/Issue:07/July-2023 Impact Factor- 7.868 www.irjmets.com.

11. Mr. Pramod Banne1 , Mr. Shantanu Mane2 , Mr. Yash Mane3 , Mr. Pratik Padwal4 , Mr.D.W.Gawatre5 “Utilization of E-Waste in Flexible Pavement: A Sustainable Solution to Waste Management ” 2023, June 2023| IJIRT | Volume 10 Issue 1 | ISSN: 2349-6002.

12. Zahoor Ahmad Bhat1 , and Mr. Ashish Kumar2 “Pavement Stabilization Using Iron Ore Waste ” 2023, International Journal of Innovative Research in Engineering & Management (IJIREM) ISSN: 2350-0557, Volume-10, Issue-2, April 2023 https://doi.org/10.55524/ijirem.2023.10.2.1 Article ID IJIR2334, Pages 1-4 www.ijirem.org