STUDY TO PERFORMANCE OF BITUMEN MIX USING E-WASTE FOR FLEXIBLE PAVEMENT

Er.Nittin kumar[1], Er.Neeraj garg [2]

[1]M.tech scholar, civil Engineering deptt. ; SRIEMT, Bhurewala, Ambala, Haryana, India
[2]Assistant professor, civil Engineering deptt. ; SRIEMT, Bhurewala, Ambala, Haryana, India

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Abstract - The fast acceleration of urbanization has resulted in a rise in the production of waste materials such as electronic garbage and waste made of plastic, both of which are contributing to the detriment of the natural environment. To lessen the negative effects that these wastes have on the environment, one eco-friendly solution is to use the waste materials in the building of roads. The purpose of this work is to provide the findings of an investigation into the functionality of a polymer and e-waste modified bituminous mix in flexible pavement. The purpose of the research is to analyze the performance of bitumen mixes using e-waste in a cost-effective manner. Investigating the characteristics of the modified bituminous mix and contrasting those findings with those of the traditional bituminous mix are the primary goals of this study.

***Key Words*: E-waste, bitumen, Plastic, Marshall apparatus, kumar, eco-friendly**

1. INTRODUCTION

One of the most significant uses of bitumen composite materials is the use of bitumen as a binder in the production of pavement. Bitumen is often used in asphalt. The process of fractional distillation of crude oil from petroleum yields bitumen as a byproduct. Bitumen may be used in a variety of applications. Bitumen was used back in the day for a wide variety of purposes, including the production of jewelry and ceramics, amongst other things. For advancement to be made in the field of transportation, an appropriate surface to move on is required. In the past, people often made extensive use of bitumen for these sorts of things. They built the pavement using bitumen, which is a flexible substance; hence, they referred to the surfaces as flexible pavement. Bitumen was employed in the creation of the pavement. As a result, using bitumen as a material in the building of the pavement is something that must be avoided. The transportable paving surface may be broken up into two large portions that can be utilized alone or together.

1. Rigid pavements
2. Flexible pavements

Rigid pavements are concrete pavements that employ cement or a cement-like substance as a binding ingredient together with stone aggregate and sand. Sand is also used in rigid pavements. After being stretched out and rolled, the resulting layer is referred to as stiff pavements. When compared to the expense of constructing flexible pavements, the cost of constructing stiff pavements is much higher. As a result, the building of rigid pavements in an area with a lower budgetary allocation is a challenge that is difficult to overcome. As a result, the pavement industry has transitioned to the construction of flexible pavements, which are able to sustain enormous loads and continue to function effectively for a number of years with only minimal deformations as a result of their high load-bearing capacities.

Bitumen is used as a binder with stone while building flexible pavements. The bitumen used to create the flexible pavement is crucial to its functionality. Bitumen is used for creating flexible pavement because to its visco-elastic properties, which allow it to act both like a viscous liquid and an elastic solid. Bitumen's properties change with both temperature and strain rate. In the past, flexible pavements were made using the readily available ordinary bitumen. This has been used for years with no issues. Increased traffic and variations in weather and other factors, such as temperature and rainfall, mean that traditional bitumen is no longer suitable for usage. The usage of bitumen brought about the need of enhancing its qualities. Because of this, modified bitumen is necessary.

Bitumen is composed of carbon hydrogen bonds and is a homogenous collection of complicated molecules. Bitumen may be thought of as a combination of polar and non-polar molecules, with the non-polar molecules acting as a kind of "matrix" within which the polar molecules are dispersed. Bitumen has a fragile dispersed structure, and its behavior is temperature and load rate dependent. Bitumen's structure also determines the material's viscous elasticity. Bitumen's non-polar molecules are responsible for its viscosity, while its polar molecules provide its flexibility.

1.1Bitumen

The term "bitumen" refers to a substance that, depending on the temperature, may be an elastic solid, a viscous liquid, or a visco elastic material at room temperature (or all three). Bitumen is a thick fluid that may be extracted from crude oil using fractional distillation. Hydrocarbons of varying molecular weights and boiling points are all present in crude oil, making it a complex oil. An example of a hydrocarbon compound created in the fractional distillation unit's bottom section is bitumen. Bitumen comes in several varieties that are categorized by its penetration grade. Crude oil, which in turn comes from the decayed remnants of marine animals including phytoplankton, algae, and other vegetative materials, is the source of bitumen. Over billions of years, this biomaterial accumulates, and under the influence of massive heat and the immense weight of the higher layers of earth, it is transformed into crude oil. Large subsurface reservoirs are formed when this crude oil is trapped in impervious rock. There are instances when the crude oil may make its way up to the surface, via cracks in the higher strata. Hydrocarbons make up the bulk of crude oil, with other, smaller components including non-hydrocarbons and trace metals. These days, drilling is the primary method for retrieving crude oil from the ground

The bitumen is a substance composed of several elements, including carbon, hydrogen, sulphur, oxygen, and nitrogen.

In addition to that, it has trace amounts of several elements, such as magnesium, calcium, and iron. The composition that is listed in Table 1.1

Table 1.1 Composition of bitumen

Component	Percentage
Carbon	80-100
Hydrogen	8-11
Oxygen	0-1.5
Nitrogen	0-1

1.1 E-waste

The fast pace of technological advancement and modernization has led to a rise in the production of electronic waste. Because of the surge in urbanization, sectors such as electronics and electrical work have seen significant growth in recent years. Because of this fast expansion, the management of electronic trash is becoming a global concern. To put it more simply, the technological equipment that have reached the end of their useful lives. The vast majority of the elements that make up electronic trash are both repairable and recyclable; nonetheless, such waste is often thrown away because to the greater processing costs associated with processing useless items. The disposal of untreated electronic trash in landfills raises concerns owing to the potential for heavy metals to seep into the groundwater and for the combustion of the garbage to emit harmful compounds into the atmosphere. Therefore, a system for the recovery and reuse of electronic waste that is both well-designed and monitored is necessary.

The disposal of e-waste components in a manner that is less harmful to the environment is now the primary focus of current research. With an annual creation rate of between 3 and 5%, it is anticipated that the total volume of electronic waste would reach 65.3 million metric tons by the year 2025 over the whole world as shown in Figure 1.2

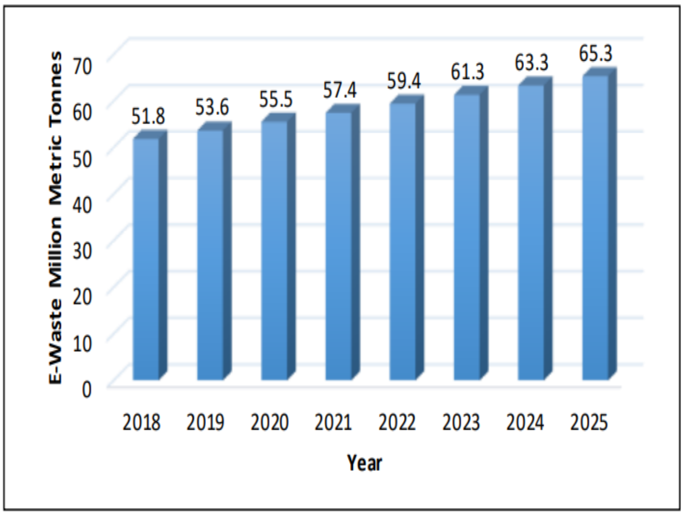

Figure 1.2 Total e-waste generated and expected

The use of E-waste products as an alternative to conventional material for the creation of roads will not only help in lowering the production cost of asphalt, but will also aid in lowering the harmful effects and pollution in the environment, lower the cost of landfill space, and lead to significant savings in our natural resources. Multiple studies demonstrate that electronic trash may be successfully included into bitumen and bituminous mixes for the construction of flexible pavements

2. REVIEW OF LITERATURE

Janani. et al., (2023)[1] analyzed every year, India is responsible for producing around 10 percent of the world's electronic waste. The purpose of this research is to investigate the possibility of using E-waste, also known as electronic waste, in place of coarse aggregate (CA) and fine aggregate (FA) in construction projects. Examples of E-Waste include waste from circuit boards, wires, and cables. As a result of the large amount of garbage that is deposited into the soil on the grounds, the ground water becomes contaminated, which in turn disrupts the natural development cycle of plants and the human health cycle. In order to create an environment that is profitable, the trash should be used to the greatest feasible extent. Many different mixtures of around 5, 10, and 20% of the waste were used as a replacement for FA, while 10% of the trash was used as a substitute for CA. The samples are put through a series of tests, including those to determine their specific gravity and consistency, as well as tests to determine their flexural strength and split tensile strength. The findings that were acquired provide a solution that is practicable for the problem of e-management waste. Once you go over 10% replacement of both coarse and fine aggregate, the strength starts to drop below the needed strength.

Tauseef. et al., (2023)[2] examined that the plastic cell-filled concrete pavement (rigid pavement) consists of a framework of plastic cells over the compacted subgrade/sub-base, filled with concrete which has proved to be a very promising solution for overloaded vehicles, inadequate drainage facilities, and water logging problems. The technology also helps to achieve the sustainability goals in road construction. The study develops a methodology to assess the Ecological Footprint of a plastic (waste) cell-filled concrete pavement construction. The enviro -economic assessment of the plastic cell-filled concrete pavement indicated that the plastic cell-filled concrete pavement is eco-friendly and cost-effective compared with the conventional pavements (for low traffic volumes).

Bhandari. et al., (2023)[3] examined that heavy loads cause quick deterioration of roads. While many things contribute to pavement degradation over time, traffic loads is particularly crucial. Poor road conditions are exacerbated by large vehicle loads and the inadequate structural capability of pavements. Distresses including alligator cracking, rutting, and roughness are used as indicators of road quality and are the major subject of this research. This study evaluates the impact of various structural variables, traffic loads, and environmental conditions on pavement performance with the goal of better comprehending pavement degradation in terms of these distresses. Regression models (GLM, BLR) are compared to RF using the cross-validation method. In comparison to previous models, RF has been shown to be more accurate and better at identifying influential factors by a wide range of performance measures. According to the findings, the base thickness and base type are two crucial design characteristics that have a major impact on rutting, roughness, and alligator cracking. Significant influences on pavement performance may be attributed to traffic loads, pavement age, and weather conditions. This research introduces a novel concept by using statistical techniques to the investigation of the impact of structural elements and loads on flexible pavements.

Bayat. et al., (2023)[4] studied that it is largely the responsibility of transportation authorities to construct new roads and to keep existing roads in good repair. The primary goals of these institutions are to establish maintenance priorities and come to substantial repair choices in order to address the severe difficulties that are being faced by road authorities. In order to understand the nature of pavements, their processes, test techniques, and measurement standards for the purpose of preserving and improving highways, a substantial amount of work and research have been conducted. In the research that is being presented, a state-of-the-art evaluation on current advancements in the use of artificial intelligence in different phases of flexible pavement is being reported. These steps include the building of flexible pavement, as well as its performance, cost, and maintenance. The difficulties associated with collecting vast volumes of data, parameter optimization, portability, and inexpensive data annotation are covered in this study. According to the results, it is advised that more emphasis should be devoted to integrating multidisciplinary highway engineering methodologies in order to meet present difficulties and possibilities in the future.

Ayasrah. et al., (2023)[5] created a temperature prediction model for the flexible pavement construction by using an analytical strategy that is based on the specific environmental variables of the study area. For the purpose of analyzing the qualities of the pavement layer, few samples of the flexible pavement layer were obtained. These depths included 6 centimeters, 11 centimeters, 20 centimeters, and 40 centimeters. The temperature profiles were figured out for the previously determined depths of the pavement. This assumption was used to build the model. The temperature readings that were taken allowed for the establishment of the beginning circumstances. The temperature readings taken from the field were analyzed and utilized to make necessary adjustments to the model's input parameters. In order to construct the temperature profiles, the MATLAB program was used. According to the findings of the research, the prediction model was successful in accurately predicting the temperature profiles of the field for the pavement construction. At a depth of 11 cm, the greatest relative error was 7.02% (0.83 °C), whereas at a depth of 6 cm, the maximum relative error was 6.68% (1.92 °C).

Nakhaei. et al., (2023)[6] analyzed that flexible pavements with stabilized foundations are often employed as an alternative in areas of the United States where the subgrade and aggregate base materials are less than ideal. Despite their prevalence, there is a paucity of empirical and mechanistic data as well as a restricted number of research that focus on various kinds of pavement. This work was conducted with the purpose of finding a solution to the difficulties associated with backcalculating the layer moduli of a flexible pavement that had a stable basis. The backcalculation procedure, which used standard methodologies, produced findings that were unrealistic and had a significant degree of unpredictability. This program included additional characteristics such as partial friction for layer interfaces, which demonstrated a considerable improvement in comparison to conventional complete bonding circumstances. Despite this, the issue of high variability was not totally resolved by the software. An innovative approach for analyzing the real-world deflection basins was created in order to reduce the amount of variation in the obtained data. In order to eliminate deflection basins that led to an inaccurate calculation of layer moduli, the "x-intercept" approach examined readings from the four sensors that were located at the very edge of the system. According to the findings of this research, integrating the partial friction approach and the x-intercept analysis is required in order to produce moduli of stabilized foundation sections that are acceptable.

Jelusic. et al., (2023)[7] examined that the suggestions for a pavement design that works best are presented in this study.

In order to accomplish this goal, eight separate optimization models, each one corresponding to a particular kind of pavement, were devised. The optimization models were used in order to get the best possible designs for each unique set of design data. These findings were put to use in the execution of a multi-parametric study, and it was from that investigation that the design suggestions for the best possible design were extracted. The manual execution of the optimization procedure was not an option since it needed to be conducted for such a huge number of different design-parameter combinations. Consequently, a loop was included into the optimization model so that it could carry out the process of optimizing each of the possible combinations. The project data that demonstrate how geosynthetically reinforced flexible pavements perform better than traditional flexible pavements are discussed.

3. RESEARCH METHODOLOGY

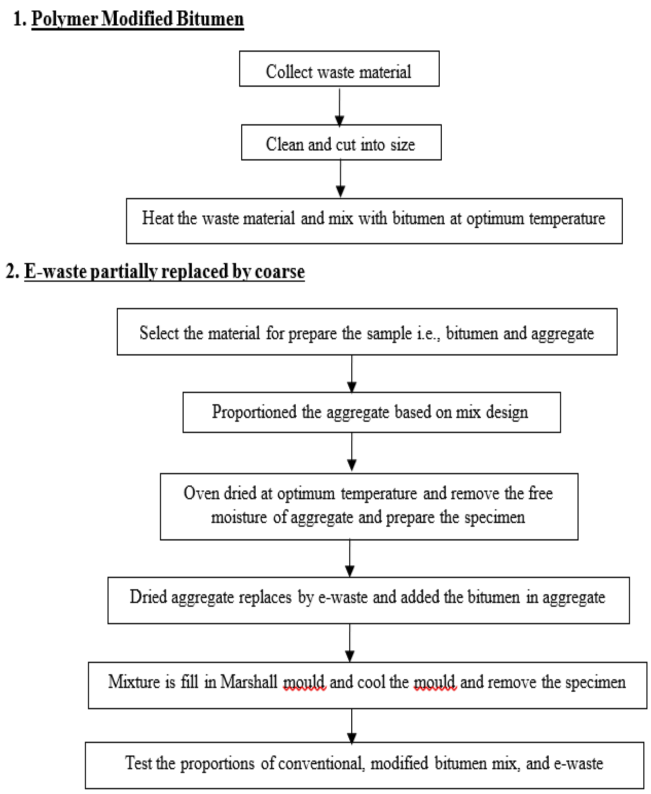

Figure : Process of methodology

The wet technique is used to create polymer modified bitumen. The wet method involves combining shredded waste plastic with bitumen in a predetermined ratio. Initially, LDPE and HDPE waste must be gathered for recycling. The waste plastic is sorted, cleaned, and afterwards sized to a range from 2.36 mm to 4.75 mm. Bitumen is then heated to a temperature of about 160 degrees Celsius. Bitumen and the shredded plastic are combined at the ideal melting temperature.

The initial stage in using electronic waste as a partial coarse aggregate replacement is sample preparation, which includes the selection of material (bitumen and aggregate). The mix design then dictates the aggregate ratios. They are dried in an oven for 4 hours at 102–110 degrees Celsius to get rid of any remaining free moisture in the aggregate

4. RESULT AND DISCUSSION

This chapter serves to analyze, interpret, and contextualize the data collected during the research process. We discuss the implications of these findings, highlighting how the use of e-waste can potentially enhance the performance and ductility of flexible pavements.

Penetration test: The penetration of bituminous material is the distance in mm that a standard needle would penetrate vertically, through a sample of the material under standard circumstances of temperature, load, and time. The value of IS code is 1203–1978. The objective of this study is to perform a penetration test on both regular and modified bitumen samples, in order to determine their respective values when combined with E-waste powder. The modified bitumen is produced by substituting a certain proportion of bitumen with E-waste powder, namely 0%, 5%, 10%, 15% and 20% as shown in Figure 4.1.

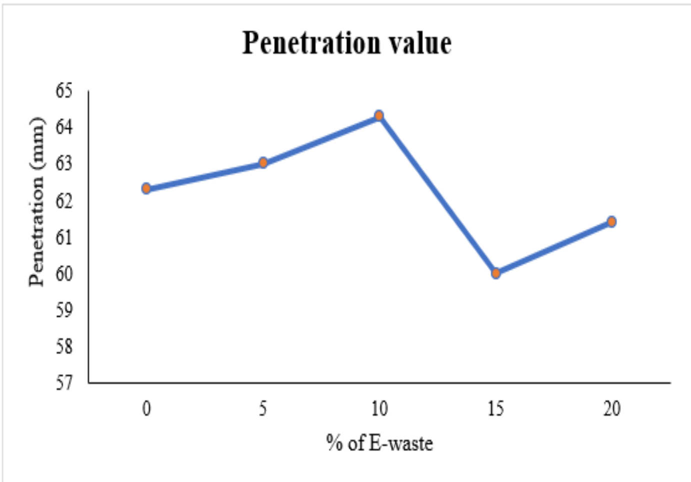

Figure 4.1 Penetration value of bitumen

Ductility test:

The measurement of ductility in bituminous materials involves determining the extent of elongation, in centimeters, prior to fracture. This is achieved by subjecting a standardized briquette specimen of the material to a specific pulling force at a predetermined temperature and speed. The ductility value of IS code range is 1203–1978. The evaluation of the ductility property of bitumen is carried out using traditional methods. Additionally, modified bitumen samples are prepared by substituting a certain proportion of bitumen with E-waste powder, namely 0%, 5%, 10%, 15% and 20% as seen in Figure 4.2. The ductility value has a negative correlation with the quantity of E-waste powder, as an increase in the latter leads to a reduction in the former.

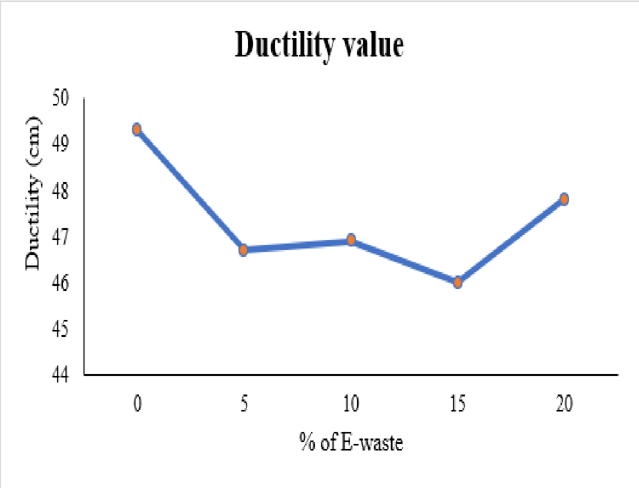

Figure 4.2 Ductility value of bitumen

Softening point test:

The softening point refers to the temperature at which a material undergoes a transition into a softened state beyond a certain level of softness. The modified bitumen is produced by substituting a certain proportion of bitumen with E-waste powder, namely 0%, 5%, 10%, 15% and 20%, as seen in Figure 4.3. The softening point test value of IS code range is 1203–1978. The data shown in Figure 4.3 demonstrates a positive correlation between the quantity of E-waste plastic powder and the corresponding rise in softening temperature.

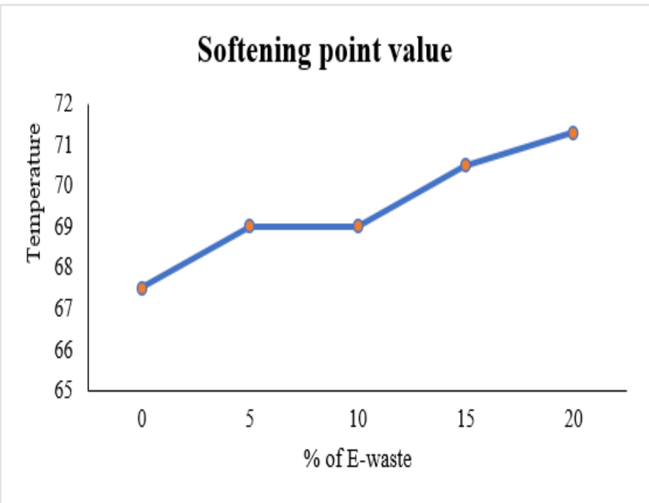

Figure 4.3Softening point value of bitumen

Marshall stability test:

The Marshall Stability test result for the standard bituminous mix with 5% optimal bitumen concentration was found to be 1460 kg, which is within the limitations provided by MORTH, which is 917.74 kg (min).

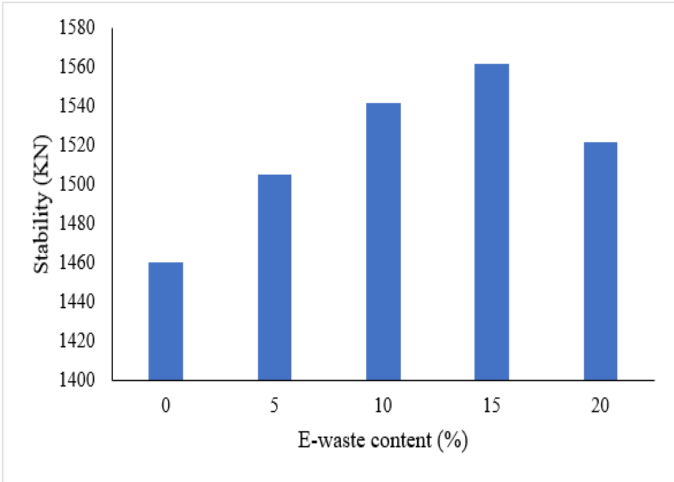

Figure 4.5 Marshall Stability vs. E-waste

Flow value:

The graph makes it quite clear that there is a rise in stability with an increase in the amount of e-waste. However, the steadiness falls once 20% of e-waste has been added to the mix. According to MORTH IS-6927, the flow index value for typical bituminous mix was determined to be 3.47 millimeters, which is in line with the requirements. The MORTH value is between 2.5-4mm. It was discovered that the flow index value for 1% plastic and 15% e-waste was 3.6mm, which was the highest possible value. The values of e-waste content are plotted along the x-axis of the graph shown in Fig. 4.7, and the values of flow index are displayed along the y-axis.

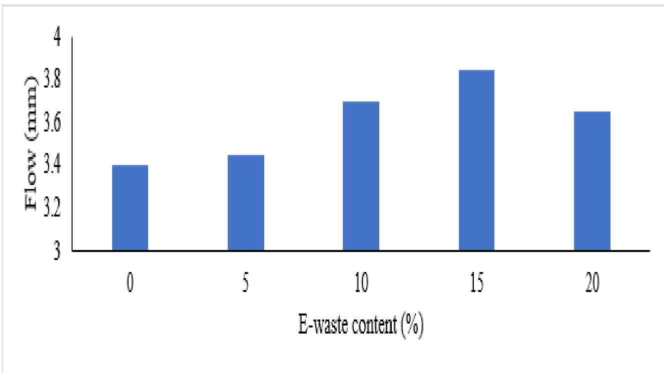

Figure 4.6 Flow value vs. E-waste

5. CONCLUSIONS

Plastics have the potential to maintain their original form for up to 4,500 years if stored properly. Plastic garbage is being produced at a higher rate as a direct result of the quick pace at which urbanization and development are occurring. The finding of our study is described given below.

Based on the findings presented, one may draw the conclusion that an improvement in stability can be shown at an optimal bitumen level of 5% when 1% of the bitumen is replaced by waste plastic and 15% of the aggregate is replaced by e-waste. This was demonstrated in the results presented. The combination becomes stronger because to the addition of e-waste, while the addition of plastic makes it more flexible and long-lasting. When the percentage of e-waste added reaches 15%, there is a progressive decline in stability. The flow value climbs to a maximum of 15% more e-waste before beginning a downward trend. When compared to the density of traditional bituminous mix, the modified bituminous mix has the lowest possible density. This is because there has been a rise in the amount of content found in e-waste. Based on the results of the experiments, it is crystal clear that the traditional bituminous mix cannot compare to the performance of the modified bituminous mix. It is obvious that there is a disparity between the values of the mix and the conventional values when compared to each other. The research determined that the ideal proportion of E-waste chips in the Bituminous mix is 10% of the aggregate's weight, when combined with 12% Modified Bitumen and 5% optimal bitumen content. The present experimental study demonstrates the cost-effectiveness of the proposed approach, which effectively mitigates the consumption of bitumen and aggregates, hence promoting sustainable practices. Therefore, the modified bituminous mix has the potential to be employed for practical applications, which will result in a reduction of the negative impacts that waste plastic and electronic waste have on the environment. There is more room for improvement in this sector due to the fact that the amount of bitumen and waste may vary in a greater number of ways.

Research can focus on developing more advanced material compositions by blending different types of e-waste plastics. This may lead to improved pavement properties and performance. In future research, it is recommended to enhance the proportion of E-waste material in bituminous mixes and propose more investigations.

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