DESIGN OF BITUMEN MODIFIED FLEXIBLE PAVEMENT WITH THE APPLICATION OF IITPAVE SOFTWARE

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ABSTRACT

In recent years, rapid growth in traffic volume, especially due to heavy vehicles such as tandem, tridem, and multi-axle loads, has significantly increased the stress on conventional flexible pavements. These pavements often fail prematurely due to rutting and fatigue cracking caused by excessive vertical compressive strain on the subgrade and horizontal tensile strain in the bituminous layer. At the same time, environmental concerns arising from the accumulation of non-biodegradable plastic waste have created an urgent need for sustainable construction practices. This study focuses on the design and analysis of flexible pavement using plastic-modified bitumen as a partial replacement for conventional bitumen, aiming to improve pavement performance while addressing environmental issues. The project involves experimental investigation of subgrade soil properties through the California Bearing Ratio (CBR) test, which yielded a CBR value of 10.5%. Based on IRC:37-2018 guidelines, pavement design was carried out using both conventional bitumen and plastic-modified bitumen. The mechanistic-empirical analysis was performed using IITPAVE software to evaluate critical stresses and strains under varying layer thickness combinations. The results indicate that the incorporation of approximately 10% waste plastic in bitumen enhances the stiffness, strength, and durability of the pavement. It also improves resistance to moisture damage, rutting, and fatigue cracking. Comparative analysis shows that plastic roads can achieve similar or improved performance with optimized thickness and reduced material usage, leading to cost savings. Additionally, the use of waste plastic contributes to eco-friendly waste management and reduces environmental pollution. The findings demonstrate that plastic-modified pavements are a sustainable, economical, and high-performance alternative to conventional flexible pavements, particularly for low to medium traffic conditions.

Keywords: Plastic roads, Bitumen modification, IITPAVE, Flexible pavement design, CBR, Rutting, Fatigue cracking, Waste plastic utilization, IRC 37:2018, Sustainable construction

I. INTRODUCTION

In recent years, the rapid growth in traffic volume, especially due to heavy vehicles such as tandem, tridem, and multi-axle loads, has significantly increased stress on conventional flexible pavements. These pavements are typically designed based on standard assumptions, but the actual field conditions often differ due to variations in traffic intensity, environmental factors, and material properties. As a result, early failures such as rutting and fatigue cracking are commonly observed. Rutting occurs due to excessive vertical compressive strain on the subgrade, while fatigue cracking is caused by repeated tensile stress at the bottom of the bituminous layer. These issues reduce the service life of roads and increase maintenance costs. Therefore, there is a need to improve pavement performance by modifying traditional construction materials and design approaches. Additionally, scarcity of high-quality aggregates and rising construction costs further demand innovative solutions in pavement engineering. Engineers and researchers are now focusing on advanced materials and techniques that can enhance durability, strength, and cost-effectiveness. One such promising approach is the use of waste plastic in road construction. This not only improves the engineering properties of pavements but also helps in managing plastic waste effectively. Hence, adopting alternative materials like plastic-modified bitumen has become an important step toward sustainable and durable road infrastructure development in modern transportation systems.

Plastic is a widely used material due to its durability, flexibility, and resistance to degradation. However, these same properties make it a major environmental concern, as plastic waste is non-biodegradable and accumulates in landfills and surroundings for years. Improper disposal of plastic leads to pollution, blockage of drainage systems, and health hazards. To address this issue, researchers have explored the possibility of utilizing waste plastic in road construction as a value-added application. When waste plastic is processed and mixed with hot aggregates, it forms a thin coating over the aggregates, improving their binding characteristics with bitumen. This results in enhanced strength, stability, and resistance to water damage in pavements. Plastic-modified bitumen increases the softening point and reduces penetration, making the pavement more resistant to temperature variations and heavy traffic loads. The use of plastic in roads also reduces the quantity of bitumen required, thereby lowering construction costs. Studies have shown that adding around 8–10% plastic by weight of bitumen yields optimum performance. This method not only improves pavement quality but also provides an effective solution for plastic waste management. By converting waste into a useful construction material, this technology supports environmental sustainability and resource conservation. Therefore, plastic roads are gaining popularity as an innovative and eco-friendly alternative to conventional road construction techniques.

The present study focuses on the design and analysis of flexible pavement using plastic-modified bitumen in accordance with IRC:37-2018 guidelines and mechanistic-empirical principles. A specific road stretch was selected, and the engineering properties of the subgrade soil were determined through laboratory testing, particularly the California Bearing Ratio (CBR) test. The obtained CBR value of 10.5% was used as a key parameter in pavement design. The pavement structure was divided into different layers, including subgrade, granular sub-base (GSB), wet mix macadam (WMM), dense bituminous macadam (DBM), and bituminous concrete (BC). The design process involved selecting appropriate layer thicknesses based on traffic conditions and material properties. IITPAVE software was used to analyze the pavement structure by calculating critical stresses and strains at various layers. The main objective was to ensure that the actual strains are within permissible limits to prevent failure due to rutting and fatigue. Multiple trial thickness combinations were analyzed to identify the most efficient and economical design. The performance of plastic-modified pavement was compared with conventional pavement to evaluate improvements in strength, durability, and cost efficiency. The study demonstrates that plastic roads can provide better performance with reduced thickness and improved resistance to deformation. Thus, this approach offers a sustainable and effective solution for modern pavement design challenges.

II.LITRATURE REVIEW

[1] K. Venkatesh, A. Swarup, and U. Mishra, "Performance analysis of waste plastic modified bitumen for pavements," *Research Review International Journal of Multidisciplinary*, vol. 6, no. 3, pp. 90–98, 2021.

This study evaluates the effect of waste plastic on bitumen properties and pavement performance. Results show that adding plastic improves stiffness, reduces penetration, and enhances load-bearing capacity. The optimum plastic content was found between 5% and 7%, beyond which brittleness increases. The modified mix demonstrated better resistance to rutting and moisture damage compared to conventional bitumen. The research concludes that plastic-modified bitumen improves pavement durability and performance while providing an effective solution for plastic waste utilization in road construction.

[2] G. C. Dhanjode et al., "Plastic waste bituminous road using polythene," *International Journal of Innovative Research in Science, Engineering and Technology*, vol. 10, no. 5, 2021.

This study focuses on the use of plastic-coated aggregates in bituminous pavements. It highlights that plastic reduces voids and moisture absorption, improving pavement strength and durability. The research shows that plastic roads can withstand heavy traffic and reduce pothole formation. Additionally, the use of plastic reduces bitumen consumption by about 10%, making construction economical. The study concludes that plastic-modified roads offer better performance and serve as an eco-friendly method for managing plastic waste.

[3] R. Vasudevan, "Utilization of waste plastics for flexible pavement," *Indian Highways*, 2007.
This research demonstrates the effectiveness of coating aggregates with waste plastic for road construction. The study found that plastic coating reduces porosity and water absorption, thereby increasing strength and durability. The polymer-bitumen mix shows higher softening point and improved resistance to temperature variations. The pavement exhibits higher Marshall stability and better resistance to rutting and cracking. The study concludes that plastic roads are more durable and environmentally beneficial compared to conventional pavements.

[4] S. Rajasekaran, R. Vasudevan, and S. Paulraj, "Reuse of waste plastics coated aggregates–bitumen mix composite for road application," *American Journal of Engineering Research*, vol. 2, no. 11, pp. 1–13, 2013.
This paper studies the use of polymer-coated aggregates in flexible pavement. The results indicate improved bonding, reduced moisture susceptibility, and enhanced strength. The dry process method allows higher plastic usage and improves pavement life. The study also shows reduced bitumen consumption and better resistance to deformation. It concludes that plastic-modified pavements are economical and sustainable alternatives to conventional road construction.

[5] V. S. Punith, "Evaluation of plastic modified bituminous mixes," *Journal of Transportation Engineering*, 2001.
This study investigates the use of waste plastic as a binder modifier in pavement construction. The results show improved binding properties, increased strength, and better resistance to deformation. Plastic-modified mixes exhibit enhanced performance under heavy traffic conditions. The study concludes that using plastic in bituminous mixes improves pavement life and reduces construction costs while addressing environmental concerns related to plastic waste.

III. WORKING METHODOLOGY

The working methodology of this project begins with a comprehensive literature review to understand the behavior and advantages of plastic-modified bitumen in flexible pavement design. Based on previous research findings, an optimum plastic content of approximately 10% by weight of bitumen was selected for modification. The study area was identified near Kistapur, and soil samples were collected from the site to determine subgrade properties. Laboratory testing was conducted, with primary emphasis on the California Bearing Ratio (CBR) test, which is essential for evaluating subgrade strength. The obtained CBR value of 10.5% was used as a key input parameter in the pavement design process. Additionally, other basic soil properties such as moisture content and compaction characteristics were considered to ensure accuracy in analysis. The collected data helps in understanding the load-bearing capacity of the soil and its behavior under repeated traffic loading. This phase establishes a strong foundation for further design and analysis by providing reliable input values. The use of field-based data ensures that the design is realistic and suitable for actual site conditions. Thus, the initial stage focuses on data collection, laboratory investigation, and selection of appropriate material parameters for pavement design.

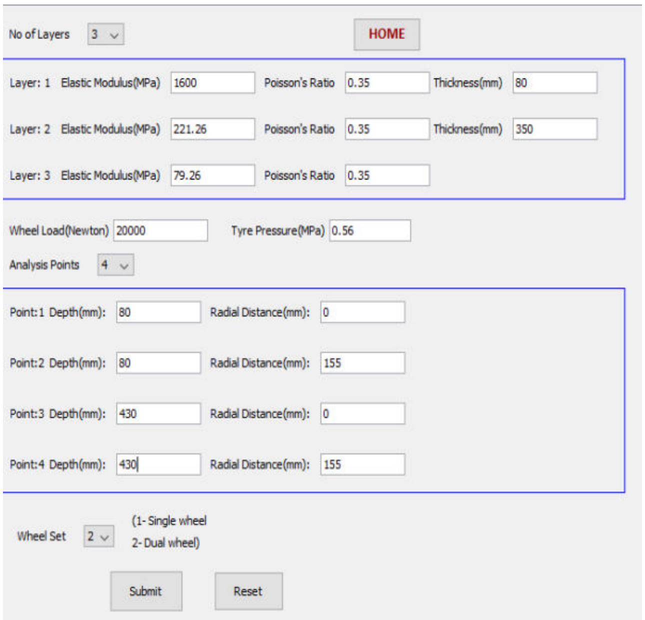

Figure 1: Trail 1 Input

The next stage of the methodology involves the design of flexible pavement using IRC:37-2018 guidelines based on a mechanistic-empirical approach. The pavement structure is divided into multiple layers, namely subgrade, granular sub-base (GSB), wet mix macadam (WMM), dense bituminous macadam (DBM), and bituminous concrete (BC). Each layer is assigned specific material properties such as elastic modulus and Poisson's ratio, obtained from standard IRC values and experimental results. The design traffic is estimated based on field conditions and assumed to be less than 5 million standard axles (MSA). Using this data, the permissible horizontal tensile strain at the bottom of the bituminous layer and vertical compressive strain at the top of the subgrade are calculated.

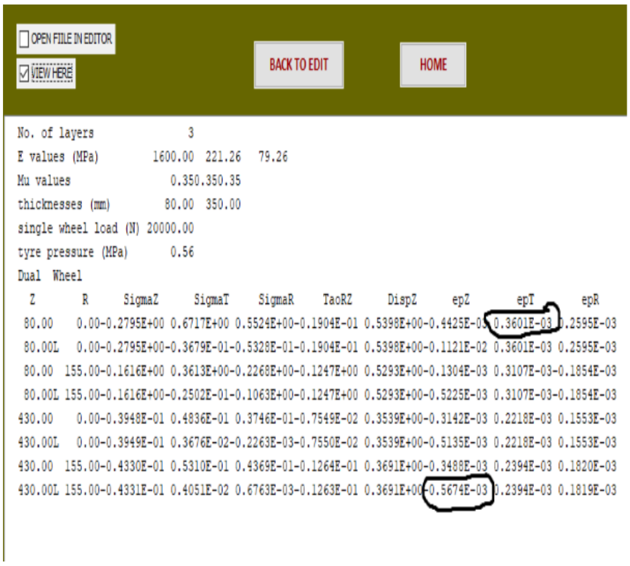

Figure 2: Trail 1 Output

These strain values are critical parameters used to evaluate pavement performance and prevent failures such as fatigue cracking and rutting. The design process involves selecting suitable layer thicknesses that can withstand expected traffic loads throughout the design life. The mechanistic-empirical approach ensures that both material behavior and real-world loading conditions are considered. This stage provides a theoretical framework for pavement design and establishes the criteria for evaluating the structural adequacy of the pavement. It ensures that the designed pavement is safe, durable, and economical under expected service conditions.

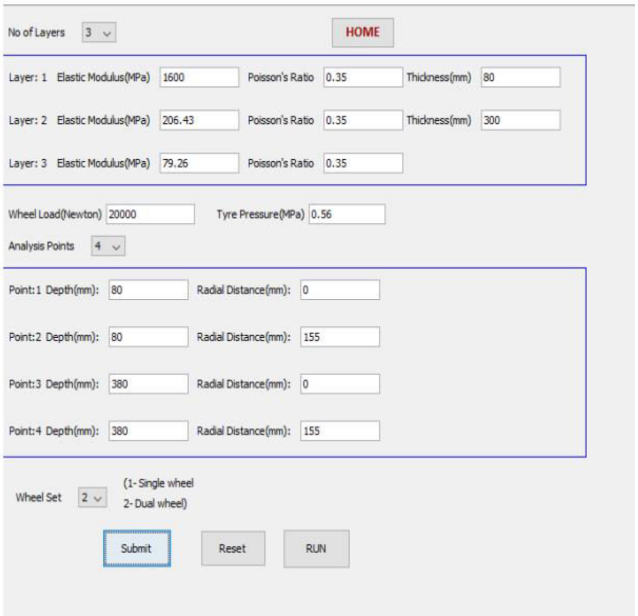

Figure 3: Trail 2 Input

In the final stage, IITPAVE software is used to perform detailed analysis of the pavement structure. The software is based on layered elastic theory and is used to compute actual stresses and strains at critical locations within the pavement. Input parameters such as layer thickness, elastic modulus, Poisson's ratio, wheel load, and tyre pressure are provided to the software. Multiple trial combinations of layer thickness are analyzed for both plastic-modified pavement and conventional pavement. The software calculates actual horizontal tensile strain in the bituminous layer and vertical compressive strain on the subgrade. These values are then compared with the previously calculated permissible strain limits. If the actual strain values are within permissible limits, the pavement section is considered safe; otherwise, modifications in layer thickness are made. Through iterative trials, the most efficient and economical pavement design is selected. A comparative analysis is then carried out between plastic roads and conventional roads in terms of strength, durability, and cost. The results demonstrate that plastic-modified pavements perform better and offer improved resistance to deformation and cracking. This stage validates the effectiveness of plastic roads and highlights their suitability as a sustainable solution in modern pavement engineering.

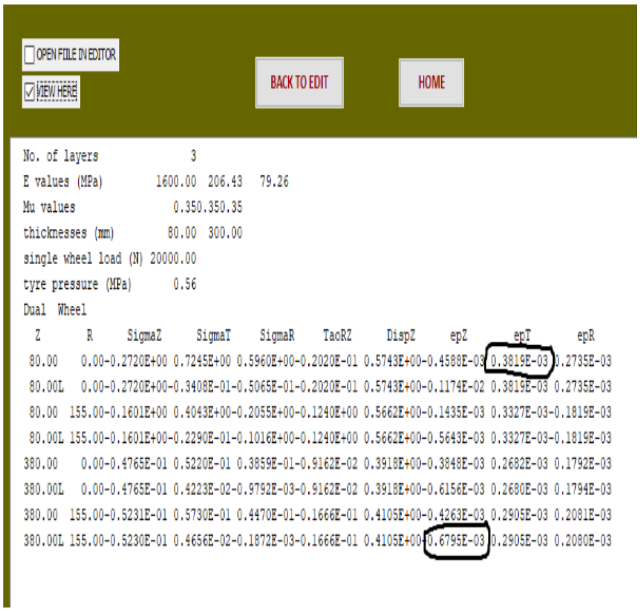

Figure 4 : Trail 2 Output

IV.CONCLUSION

The present study focuses on the design and analysis of flexible pavement using plastic-modified bitumen based on IRC:37-2018 guidelines and mechanistic-empirical principles. From the investigation, it is evident that traffic characteristics and subgrade soil properties play a crucial role in determining pavement performance. The CBR test conducted on the collected soil sample yielded a value of 10.5%, which was used for pavement design. Using this input, both conventional and plastic-modified pavements were designed and analyzed using IITPAVE software to evaluate critical stresses and strains.

The results clearly indicate that the incorporation of waste plastic in bitumen significantly improves the engineering properties of the pavement. Plastic-modified bitumen enhances stiffness, increases resistance to rutting and fatigue cracking, and reduces moisture susceptibility. It also improves the bonding between aggregates and bitumen, resulting in better durability and longer service life of roads. The analysis showed that plastic roads satisfy the permissible strain conditions and perform efficiently under given traffic loads.

Moreover, the use of plastic waste in road construction reduces the requirement of bitumen and aggregates, leading to cost savings. It also provides an eco-friendly solution for the disposal of non-biodegradable plastic waste, thereby reducing environmental pollution. The study concludes that plastic roads are a sustainable, economical, and high-performance alternative to conventional flexible pavements. Hence, adopting plastic-modified pavement technology can play a significant role in modern infrastructure development while addressing environmental concerns.

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