

Sustainable Highway Pavement Design Using Waste Tyre Reinforced Subgrade Materials

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Abstract- — The rapid growth of transportation infrastructure has increased the demand for sustainable pavement materials and environmentally friendly construction practices. The disposal of waste tyres has become a major environmental concern due to their non-biodegradable nature and increasing accumulation in landfills. This research investigates the application of waste tyre reinforced subgrade materials in sustainable highway pavement design. The study focuses on improving subgrade strength, load-bearing capacity, and pavement performance through the use of waste tyre rubber as reinforcement. Laboratory tests such as Atterberg limits, compaction test, California Bearing Ratio (CBR), plate load test, and settlement analysis were conducted to evaluate the performance of reinforced subgrade soil. The results indicate that the inclusion of waste tyre materials significantly improves subgrade strength, reduces settlement, and enhances pavement durability. Sustainable pavement design using waste tyre reinforcement also reduces construction cost and environmental pollution. The study concludes that waste tyre reinforced subgrade materials can be effectively used in highway pavement construction to promote sustainable infrastructure development and waste management.

Keywords: Highway engineering, sustainable pavement, waste tyre, subgrade reinforcement, plate load test, CBR, flexible pavement.

I. INTRODUCTION

Highway pavement plays a crucial role in the development of transportation infrastructure by providing a smooth, durable, and safe surface for vehicular movement and economic connectivity between regions. The increasing demand for road networks due to rapid urbanization, industrialization, and population growth has significantly increased the need for sustainable and high-performance pavement materials. Conventional highway construction relies heavily on natural resources such as aggregates, soil, and cement, which leads to depletion of natural materials and environmental degradation. Moreover, the rising traffic load and climatic variations require pavement systems that can sustain heavy loading conditions and provide long-term durability with minimal maintenance requirements [1]. Sustainable pavement design has therefore become an essential aspect of modern highway engineering to ensure environmental protection, economic efficiency, and structural stability of roads [2].

In recent years, the disposal of waste materials has become a serious environmental concern worldwide, particularly the accumulation of waste tyres generated from the automobile industry. Millions of waste tyres are discarded every year, creating environmental hazards such as land pollution, fire

risks, and mosquito breeding in stagnant water stored in tyres. Waste tyres are non-biodegradable and occupy large landfill space, making their disposal a major challenge for environmental agencies and governments [3]. Recycling and reusing waste tyres in civil engineering applications has emerged as a sustainable solution to minimize environmental impact and promote circular economy in infrastructure development. The use of waste tyre materials in highway pavement construction provides an effective approach to reduce landfill waste while improving the engineering properties of pavement layers [4].

Subgrade soil is one of the most important components of highway pavement, as it supports the entire pavement structure and transfers load to the ground. Weak subgrade soil leads to excessive settlement, cracking, and pavement failure, resulting in high maintenance cost and reduced pavement life. Traditional soil stabilization methods such as lime, cement, and chemical additives are widely used, but they increase construction cost and carbon emissions. Therefore, researchers are exploring alternative sustainable materials such as waste tyre rubber, industrial by-products, and recycled materials to enhance subgrade strength and improve pavement performance [5]. Waste tyre rubber has shown promising results in

improving soil stability, reducing settlement, and increasing bearing capacity due to its elastic and flexible properties [6].

The use of shredded tyre rubber in subgrade and sub-base layers enhances load distribution and reduces stress concentration under traffic loads. Rubber particles improve soil compaction characteristics and increase resilience, leading to better performance under repeated loading conditions. Several experimental studies have reported that waste tyre reinforcement significantly increases California Bearing Ratio (CBR) values and reduces deformation in flexible pavement systems [7]. Additionally, waste tyre materials improve drainage and reduce moisture sensitivity in subgrade soil, which contributes to improved durability and long-term pavement stability [8]. These properties make waste tyre reinforced subgrade materials a suitable option for sustainable highway construction.

Plate load testing and CBR testing are commonly used methods to evaluate the strength and bearing capacity of subgrade soil in highway engineering. These tests provide reliable data for pavement thickness design and performance evaluation under field loading conditions. The integration of waste tyre materials with subgrade soil can enhance load-bearing capacity and reduce settlement, leading to optimized pavement thickness and reduced construction cost [9]. Sustainable pavement design using waste tyre reinforcement also contributes to reduced greenhouse gas emissions and energy consumption in road construction, supporting global sustainability goals and environmental protection policies [10].

Therefore, this study focuses on the sustainable highway pavement design using waste tyre reinforced subgrade materials by conducting laboratory and experimental investigations such as Atterberg limits, compaction test, California Bearing Ratio test, and plate load test. The main aim of this research is to evaluate the mechanical performance and environmental benefits of waste tyre reinforced subgrade materials and develop an eco-friendly pavement design approach for modern highway engineering applications. The findings of this study will contribute to sustainable infrastructure development and provide a practical solution for waste tyre management in highway construction [11–15].

II. OBJECTIVES OF THE STUDY

- To study the properties of subgrade soil and waste tyre materials
- To evaluate the strength of waste tyre reinforced subgrade

- To conduct CBR and plate load test on reinforced soil
- To analyze pavement performance using sustainable materials
- To develop an eco-friendly highway pavement design

III. LITERATURE REVIEW

1. Shen et al. (2025)

Shen et al. (2025) investigated the application of unprocessed waste tyres in pavement base structures using finite element simulation techniques. The study analyzed deformation and stress distribution in tyre-reinforced pavement layers and found that the hyperelastic properties of rubber significantly improved deformation resistance and load recovery. The research concluded that waste tyre reinforcement enhances structural performance and reduces settlement in flexible pavement systems, making it a sustainable solution for highway construction.

2. Sarkar et al. (2024)

Sarkar et al. (2024) conducted an experimental study on subgrade modification using waste tyre scrap in flexible pavements. The researchers evaluated deflection and elastic modulus of clayey soil using Falling Weight Deflectometer and laboratory testing. Results showed improved subgrade stiffness and reduced deformation with tyre reinforcement, indicating that waste tyre materials can enhance pavement durability and load-bearing capacity.

3. Gücek et al. (2024)

Gücek et al. (2024) studied soil stabilization using waste tyre rubber, lignin, and glass waste materials. The research focused on mechanical behavior and environmental sustainability of hybrid waste stabilization techniques. The study reported significant improvement in soil strength, compaction characteristics, and durability, demonstrating the effectiveness of waste tyre rubber in sustainable pavement construction.

4. Wangmo et al. (2021)

Wangmo et al. (2021) investigated the improvement of road subgrade using waste tyre crumbs through laboratory testing such as CBR and compaction tests. The results showed that 6% tyre content provided optimum strength and reduced pavement thickness, resulting in cost savings and improved environmental sustainability. The study recommended using waste tyres in subgrade and sub-base layers for highway construction.

5. Zutting and Naktode (2020)

Zutting and Naktode (2020) examined soil stabilization using scrap tyre rubber to improve engineering properties of subgrade soil. The study highlighted that waste tyre rubber increases flexibility, reduces plasticity, and improves load-bearing capacity of soil. The research emphasized the environmental benefits of recycling waste tyres in pavement construction.

6. Materials Today Proceedings Study (2021)

A study published in Materials Today Proceedings (2021) focused on the development of subgrade layers using scrap tyre and expansive soil stabilization. The research demonstrated that waste tyre materials improve soil stability and reduce swelling behavior in black cotton soil, making it suitable for highway pavement construction.

7. Sarkar et al. (2023)

Sarkar et al. (2023) evaluated in-situ CBR of flexible pavement subgrade mixed with waste tyre scrap. The results indicated a significant increase in CBR value and improved subgrade strength with tyre reinforcement. The study confirmed that waste tyre materials provide sustainable and economical solutions for highway pavement design.

8. Review by Construction and Building Materials (2023)

A comprehensive review in Construction and Building Materials (2023) analyzed waste material stabilization techniques for pavement subgrade. The study emphasized that waste tyre rubber and industrial by-products can reduce environmental impact and improve soil engineering properties in flexible pavement systems.

9. Firoozi et al. (2017)

Firoozi et al. (2017) presented fundamental concepts of soil stabilization and ground improvement techniques. The study highlighted the importance of sustainable materials in highway construction and recommended the use of recycled materials such as waste tyres for environmental protection and improved pavement performance.

10. Terashi and Juran (2000)

Terashi and Juran (2000) discussed ground improvement techniques and stabilization methods for weak soils. The research emphasized the role of reinforcement materials in enhancing subgrade strength and improving pavement durability.

11. Huang et al. (2019)

Huang et al. (2019) studied rubber-modified asphalt and tyre rubber in pavement materials. The research showed improved fatigue resistance and durability in rubberized pavement layers.

12. Ahmed and Lovell (1993)

Ahmed and Lovell (1993) conducted early research on scrap tyre applications in geotechnical engineering and found that tyre chips improve drainage and reduce settlement in pavement subgrades.

13. Edil and Bosscher (1994)

Edil and Bosscher (1994) conducted a detailed experimental investigation on the engineering properties of tyre chips and their application in soil reinforcement and geotechnical structures. The study focused on evaluating the mechanical behavior of tyre chips when mixed with soil and used as a lightweight geomaterial in pavement and embankment construction. Laboratory tests such as compaction, shear strength, and compressibility analysis were performed to determine the effectiveness of tyre chips in improving soil performance. The results indicated that tyre chips significantly reduce the unit weight of soil and increase flexibility, making them suitable for lightweight fill and subgrade reinforcement applications. The research also highlighted that tyre chip-soil mixtures exhibit improved drainage characteristics and reduced settlement under loading conditions. Furthermore, the study concluded that waste tyres can be effectively used as a reinforcing material in pavement subgrade and embankment structures due to their elastic nature and durability. The environmental benefits of using tyre chips were also emphasized, as they reduce landfill waste and promote sustainable construction practices. Therefore, the research recommended the use of waste tyre chips in highway engineering to enhance soil stability and improve long-term pavement performance [4].

14. Foose et al. (1996)

Foose et al. (1996) investigated the use of shredded waste tyres as reinforcement material in sand and soil mixtures for geotechnical and pavement engineering applications. The study primarily focused on analyzing shear strength, compressibility, and stress-strain behavior of sand reinforced with tyre shreds through laboratory testing and analytical evaluation. Direct shear tests and compression tests were conducted to understand the interaction between tyre shreds and soil particles under loading conditions. The results showed that the inclusion of tyre shreds significantly improved shear strength and reduced compressibility of the soil, leading to better load-bearing capacity and reduced settlement in pavement subgrades. The researchers observed that tyre shreds provide additional friction and interlocking within the soil matrix, which enhances structural stability and deformation resistance. The study also highlighted that tyre-reinforced soil exhibits higher energy absorption capacity and resilience under repeated loading, making it suitable for highway and embankment construction.

Additionally, the environmental advantage of recycling waste tyres was emphasized as it reduces disposal problems and promotes sustainable infrastructure development. The research concluded that tyre shreds can be effectively used in flexible pavement subgrade and foundation layers to improve mechanical performance and durability [6].

15. Humphrey (1999)

Humphrey (1999) presented a comprehensive review of civil engineering applications of scrap tyres with a focus on their use in highway construction, embankments, and pavement subgrade reinforcement. The study discussed various engineering properties of scrap tyres, including lightweight characteristics, high permeability, flexibility, and durability, which make them suitable for geotechnical and pavement applications. The research highlighted that scrap tyres can be used as drainage layers, lightweight fill material, and subgrade reinforcement to improve pavement performance and reduce settlement. Field and laboratory investigations showed that tyre-derived materials enhance load distribution and reduce stress concentration in pavement layers, thereby increasing the service life of highway structures. The study also emphasized the environmental benefits of using scrap tyres, such as reduction in landfill waste, conservation of natural resources, and promotion of sustainable construction practices. Furthermore, the research identified cost-effectiveness and ease of construction as major advantages of tyre-based materials in highway engineering. The study concluded that scrap tyres offer a practical and eco-friendly solution for pavement construction and recommended their wider adoption in sustainable highway infrastructure projects [9].

16. Yoon et al. (2004)

Yoon et al. (2004) conducted an experimental investigation on the use of tyre chips in embankment and pavement construction with a focus on evaluating settlement characteristics and load distribution behavior of reinforced soil systems. The study examined the engineering properties of tyre chip–sand mixtures through laboratory testing and field observations to understand their suitability in highway and embankment applications. Various parameters such as compressibility, shear strength, permeability, and stress–strain response were analyzed to determine the effectiveness of tyre chips in improving soil performance. The results showed that tyre chips significantly reduced settlement and improved load distribution due to their lightweight and flexible nature. The researchers observed that tyre chip reinforcement increases the resilience of soil and enhances energy absorption under repeated loading conditions, making it suitable for pavement subgrade and embankment construction. The study also highlighted that tyre chips improve drainage and reduce pore water pressure, which contributes to

long-term stability of pavement structures. Furthermore, the research emphasized the environmental and economic benefits of recycling waste tyres in highway engineering by reducing landfill disposal and conserving natural resources. The authors concluded that tyre chips can be effectively used in pavement subgrade and embankment layers to enhance structural stability, reduce deformation, and improve sustainability in highway infrastructure development [20].

17. Kim and Santamarina (2008)

Kim and Santamarina (2008) investigated the mechanical behavior of rubber–sand mixtures to understand their performance in geotechnical and pavement engineering applications. The study focused on evaluating stress–strain behavior, compressibility, and stiffness characteristics of sand mixed with rubber particles through laboratory testing and theoretical analysis. The researchers found that the inclusion of rubber particles significantly improved flexibility and resilience of the soil, leading to enhanced energy absorption and reduced stiffness degradation under cyclic loading. The rubber–sand mixtures exhibited better deformation resistance and increased damping capacity, which are important for pavement subgrade subjected to heavy traffic loads. The study also reported that rubber reinforcement reduces brittleness and increases ductility of soil, resulting in improved long-term performance and reduced cracking in pavement layers. Additionally, the research highlighted that rubber–sand mixtures provide lightweight and eco-friendly alternatives to conventional soil stabilization materials. The environmental advantage of using waste tyre rubber was emphasized as it promotes recycling and reduces environmental pollution. The authors concluded that rubber–sand mixtures can be effectively used in highway pavement subgrade and foundation layers to improve mechanical performance, flexibility, and durability of pavement systems [11].

18. Li et al. (2010)

Li et al. (2010) evaluated the performance of rubber-modified subgrade materials by analyzing compaction characteristics, California Bearing Ratio (CBR), and strength behavior of soil mixed with waste tyre rubber. The study focused on determining the optimum rubber content that provides maximum strength and stability in pavement subgrade layers. Laboratory tests such as compaction test, CBR test, and shear strength analysis were conducted to evaluate the engineering properties of rubber-soil mixtures. The results showed that the inclusion of rubber particles improved compaction behavior by increasing optimum moisture content and reducing maximum dry density, which contributes to better soil stability and flexibility. The CBR values increased significantly with the addition of rubber, indicating improved load-bearing capacity

and reduced pavement thickness requirement. The study also highlighted that rubber-modified subgrade materials exhibit improved resistance to cracking and deformation under traffic loading conditions. Furthermore, the environmental benefits of using waste tyre rubber in pavement construction were emphasized as it reduces landfill waste and promotes sustainable infrastructure development. The research concluded that rubber-modified subgrade materials can be effectively used in flexible pavement design to enhance strength, durability, and sustainability of highway pavements [12].

19. Kalantar (2012)

Kalantar (2012) investigated the use of crumb rubber in asphalt pavement and evaluated its effect on durability, fatigue resistance, and overall pavement performance. The study focused on analyzing mechanical properties of rubberized asphalt mixtures through laboratory testing such as Marshall stability, fatigue testing, and rutting resistance analysis. The results indicated that the addition of crumb rubber significantly improved durability and fatigue resistance of asphalt pavement by enhancing elasticity and reducing crack propagation. The rubber-modified asphalt mixtures showed better resistance to rutting and deformation under heavy traffic loads, leading to longer pavement service life and reduced maintenance cost. The study also highlighted that crumb rubber improves temperature susceptibility and enhances flexibility of asphalt pavement, making it suitable for varying climatic conditions. Additionally, the environmental and economic benefits of recycling waste tyres in asphalt pavement were emphasized, as it reduces waste disposal problems and promotes sustainable highway construction. The research concluded that crumb rubber asphalt technology is an effective and eco-friendly solution for improving pavement durability and supporting sustainable transportation infrastructure development [10].

20. Rahman et al. (2014)

Rahman et al. (2014) conducted an experimental study on the application of waste tyre rubber in flexible pavement systems with the objective of improving load-bearing capacity and reducing cracking in pavement layers. The research focused on evaluating the mechanical and durability properties of rubber-modified pavement materials through laboratory testing and performance analysis. Tests such as Marshall stability, CBR, and fatigue resistance were carried out to understand the effect of tyre rubber on pavement strength and deformation characteristics. The results indicated that the inclusion of waste tyre rubber significantly increased load-bearing capacity and reduced crack propagation in flexible pavement structures. The study also reported improved elasticity and flexibility in pavement layers, which helps in resisting thermal stresses and

traffic-induced deformation. Furthermore, the use of waste tyre rubber improved resistance to rutting and moisture damage, thereby enhancing the overall durability of pavement systems. The research emphasized that waste tyre rubber not only improves engineering properties but also contributes to environmental sustainability by reducing landfill waste and promoting recycling of non-biodegradable materials. The authors concluded that waste tyre rubber can be effectively used in flexible pavement design to enhance structural performance, durability, and sustainability of highway infrastructure [13].

21. Sol-Sanchez et al. (2015)

Sol-Sanchez et al. (2015) analyzed the performance of rubberized asphalt mixtures in sustainable pavement construction with a focus on environmental and mechanical benefits. The study investigated the effect of crumb rubber on asphalt mixture properties such as stiffness, fatigue resistance, and durability under different loading and environmental conditions. Laboratory tests were conducted to evaluate resistance to cracking, rutting, and temperature variations in rubberized asphalt mixtures. The results showed that the incorporation of crumb rubber significantly improved flexibility and resistance to deformation, leading to enhanced pavement life and reduced maintenance requirements. The study also highlighted the environmental advantages of using waste tyre rubber, including reduction in greenhouse gas emissions, conservation of natural resources, and lower energy consumption in pavement construction. Additionally, the research demonstrated that rubberized asphalt mixtures provide better performance in extreme weather conditions and heavy traffic loading. The authors concluded that rubberized asphalt technology is a sustainable and eco-friendly approach for highway pavement construction and recommended its wider implementation in infrastructure projects [16].

22. Arabani and Pedram (2016)

Arabani and Pedram (2016) evaluated the performance of crumb rubber asphalt mixtures by conducting laboratory experiments to analyze rutting resistance, fatigue behavior, and pavement durability. The study focused on understanding the effect of crumb rubber on asphalt mixture stability and long-term performance in flexible pavement systems. Marshall stability tests, rutting analysis, and fatigue testing were conducted to assess the mechanical properties of rubber-modified asphalt mixtures. The results indicated that crumb rubber significantly improved rutting resistance and increased pavement service life by enhancing elasticity and deformation resistance. The study also reported that rubberized asphalt mixtures exhibit better adhesion between aggregates and binder, which improves structural stability and reduces

cracking under repeated loading. Furthermore, the environmental benefits of using waste tyre rubber were emphasized, including reduction in waste disposal problems and promotion of sustainable construction practices. The authors concluded that crumb rubber asphalt is a reliable and efficient solution for improving pavement performance and ensuring long-term durability in highway engineering applications [2].

23. Thomas et al. (2018)

Thomas et al. (2018) studied the use of sustainable pavement materials with a focus on waste tyre rubber as an eco-friendly reinforcement material in civil engineering applications. The research evaluated durability, mechanical strength, and environmental impact of rubber-based construction materials through experimental and analytical methods. The study highlighted that waste tyre rubber improves flexibility, toughness, and crack resistance in pavement and concrete structures. Laboratory tests showed that rubber-modified materials exhibit better energy absorption capacity and reduced brittleness, which enhances structural performance under dynamic loading conditions. The research also emphasized the importance of recycling waste tyres to reduce environmental pollution and conserve natural resources in highway construction. Additionally, the study discussed the economic advantages of using waste tyre rubber, such as reduced construction cost and lower maintenance requirements. The authors concluded that waste tyre rubber is a sustainable and eco-friendly reinforcement material that can significantly improve pavement performance and contribute to green infrastructure development [18].

24. Guo et al. (2020)

Guo et al. (2020) investigated the application of recycled tyre materials in pavement construction with a focus on improving mechanical performance and reducing environmental impact. The study analyzed the use of tyre rubber in subgrade, sub-base, and asphalt layers through laboratory testing and performance evaluation. The results showed that recycled tyre materials enhance strength, flexibility, and durability of pavement structures by improving load distribution and reducing stress concentration. The research also reported that tyre rubber improves resistance to rutting, cracking, and moisture damage, leading to longer pavement life and reduced maintenance cost. Furthermore, the environmental benefits of using recycled tyre materials were highlighted, including reduction in landfill waste, conservation of natural resources, and lower carbon emissions in highway construction. The study concluded that recycled tyre materials provide a sustainable and cost-effective solution for modern pavement engineering and recommended

their large-scale implementation in highway infrastructure projects [7].

25. Chen et al. (2022)

Chen et al. (2022) studied waste tyre reinforced pavement systems and evaluated their structural performance and sustainability in highway engineering applications. The research focused on analyzing mechanical properties, durability, and environmental impact of tyre rubber in pavement layers through laboratory testing and numerical modeling. The results indicated that waste tyre rubber significantly improves structural performance by enhancing flexibility, load-bearing capacity, and resistance to cracking in pavement systems. The study also reported that tyre rubber reduces pavement deformation and improves long-term durability under heavy traffic loads and varying climatic conditions. Additionally, the environmental advantages of using waste tyre reinforcement were emphasized, including reduction in waste disposal, energy savings, and promotion of sustainable construction practices. The authors concluded that waste tyre reinforced pavement systems are an effective solution for sustainable highway infrastructure and recommended further research on large-scale field implementation and performance evaluation [3].

IV. MATERIALS USED

Table 1 Materials used

Material	Specification	Purpose
Subgrade Soil	Clayey soil	Base material
Waste Tyre Rubber	Shredded tyre pieces	Reinforcement
Cement	OPC 53 Grade	Stabilization
Sand	River sand	Filler material
Water	Potable water	Hydration
Aggregate	Crushed stone	Pavement layer

V. METHODOLOGY

The methodology adopted in this study focuses on evaluating the performance of waste tyre reinforced subgrade materials for sustainable highway pavement design through systematic laboratory and analytical procedures. Initially, subgrade soil samples were collected from an active highway construction site to ensure realistic field conditions and representative soil

properties. The collected soil was air-dried, sieved, and prepared for laboratory testing to determine its engineering characteristics. In the second stage, waste tyres were collected from local automobile workshops and scrap yards, and they were thoroughly cleaned and shredded into small pieces of uniform size to be used as reinforcement material in the subgrade soil. The shredded tyre pieces were selected carefully to ensure proper mixing and uniform distribution within the soil matrix.

In the third stage, laboratory testing was conducted to determine the physical and mechanical properties of both natural soil and tyre-reinforced soil. Standard tests such as Atterberg limits test were carried out to evaluate the plasticity characteristics of soil, while the compaction test was performed to determine optimum moisture content and maximum dry density. The California Bearing Ratio (CBR) test was conducted to evaluate load-bearing capacity of the reinforced soil, and plate load test was performed to determine bearing capacity and settlement behavior under loading conditions. Settlement analysis was also carried out to understand deformation characteristics of the reinforced subgrade under different load intensities.

In the fourth stage, waste tyre pieces were mixed with subgrade soil in different percentages such as 5%, 10%, 15%, and 20% by weight to determine the optimum reinforcement content that provides maximum strength and stability. Each mix proportion was thoroughly blended and tested to analyze the variation in compaction characteristics, CBR value, and bearing capacity. The results obtained from laboratory testing were then used in the fifth stage to design flexible pavement based on standard pavement design guidelines, where CBR and plate load test values were considered for determining pavement thickness and structural layers. Finally, in the sixth stage, performance evaluation was carried out by analyzing strength, settlement, and load-bearing behavior of reinforced subgrade soil, and the optimum percentage of waste tyre reinforcement was identified for sustainable and economical highway pavement design.

Step 1: Collection of Subgrade Soil
 Soil samples were collected from highway construction site.

Step 2: Collection of Waste Tyres
 Waste tyres were collected and shredded into small pieces.

Step 3: Laboratory Testing

- Atterberg limits
- Compaction test
- CBR test
- Plate load test

- Settlement test

Step 4: Reinforcement of Soil
 Waste tyre pieces were mixed in different percentages:

- 5%
- 10%
- 15%
- 20%

Step 5: Pavement Design
 Flexible pavement was designed based on CBR and plate load test results.

Step 6: Performance Evaluation
 Strength and settlement were analyzed.

VI. EXPERIMENTAL TESTS

6.1 Atterberg Limits Test

Determines plasticity and soil behavior.

6.2 Compaction Test

Determines optimum moisture content and maximum dry density.

6.3 California Bearing Ratio Test

Determines load-bearing capacity.

6.4 Plate Load Test

Evaluates subgrade strength and settlement.

VII. RESULTS AND DISCUSSION

CBR Results

Table 2 CBR Results

Mix	CBR Value (%)
Soil	4.2
Soil + 5% Tyre	6.8
Soil + 10% Tyre	8.5
Soil + 15% Tyre	10.2
Soil + 20% Tyre	9.6

Observation:

- CBR increases up to 15% tyre
- Strength improves significantly

- Optimum mix = 15%
Plate Load Test Results

Table 3 Plate Load test results

Mix	Bearing Capacity (kN/m ²)
Soil	120
5% Tyre	160
10% Tyre	185
15% Tyre	210
20% Tyre	205

Observation:

- Bearing capacity increases
- Settlement reduces
- Sustainable performance achieved

VIII. SUSTAINABLE BENEFITS

Waste tyre reinforced subgrade materials provide significant environmental and economic benefits in highway construction. The use of waste tyres reduces landfill disposal and promotes recycling of non-biodegradable materials. Sustainable pavement design also reduces the use of natural aggregates and improves durability of pavement layers. Waste tyre materials enhance flexibility, reduce cracking, and increase load-bearing capacity of subgrade soil, leading to longer pavement life and reduced maintenance cost. The approach supports circular economy and green highway development.

IX. CONCLUSION

- Waste tyre reinforced subgrade improves pavement strength.
- CBR and bearing capacity increase significantly.
- Settlement is reduced under load conditions.
- Sustainable pavement design reduces environmental pollution.
- Optimum waste tyre content is around 15%.
- Waste tyre materials can be effectively used in highway engineering.

The study concludes that sustainable highway pavement design using waste tyre reinforced subgrade materials is an eco-friendly and cost-effective solution for modern road construction.

X. FUTURE SCOPE

- Field implementation on highways
- Use of geogrid with waste tyres
- Life cycle cost analysis
- AI-based pavement design
- Long-term durability studies

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