ECONOMIC ANALYSIS OF USE OF CEMENT TREATED SUB BASE IN FLEXIBLE PAVEMENT

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ABSTRACT

Rapid infrastructure development in India has led to a significant increase in the demand for construction materials, particularly aggregates used in highway construction. This growing demand has resulted in material scarcity, increased costs, and the need for sustainable alternatives. The present study focuses on the design and analysis of flexible pavements using cement-treated sub-base (CTSB) as an alternative to conventional granular layers, following IRC: 37–2018 guidelines and utilizing IITPAVE software for mechanistic analysis. The study evaluates the structural performance of pavements by comparing untreated granular sub-base layers with cement-stabilized layers under similar traffic and loading conditions. Traffic analysis was conducted to estimate design traffic (25 MSA), and pavement layers were designed accordingly. The resilient modulus values of different pavement layers were determined, and critical strains such as vertical compressive strain on subgrade and horizontal tensile strain at the bituminous layer were analyzed. Results indicate that cement-treated sub-base significantly improves load distribution, reduces tensile and compressive strains, and enhances fatigue and rutting resistance. A comparative analysis revealed that the total pavement thickness can be reduced by approximately 30 mm when CTSB is used. Furthermore, cost analysis shows nearly 40% reduction in construction cost due to decreased aggregate consumption and optimized layer thickness. The study concludes that cement-treated sub-base is an economical, durable, and sustainable solution for flexible pavement design, particularly for roads with light to medium traffic. It also enhances pavement life and structural performance under varying environmental conditions.

Keywords: Flexible Pavement, Cement Treated Sub-Base (CTSB), IRC 37-2018, IITPAVE, Resilient Modulus, Pavement Design, Rutting, Fatigue Cracking, Cost Analysis, Sustainable Construction.

I. INTRODUCTION

In the modern era of rapid infrastructure growth, the demand for durable and economical road construction has increased significantly, especially in developing countries like India. Flexible pavements are widely used due to their ease of construction and maintenance; however, they require a large quantity of natural aggregates for base and sub-base layers. The excessive use of these materials has led to depletion of natural resources, increased construction costs, and environmental concerns. To overcome these challenges, engineers are exploring alternative techniques such as cement stabilization of granular layers. Cement-treated sub-base (CTSB) has emerged as an effective solution, as it enhances the strength, stiffness, and durability of pavement layers. By improving load distribution and reducing deformation, CTSB contributes to longer pavement life and better performance under traffic loading. The present project focuses on the design and analysis of flexible pavements using cement-treated sub-base in accordance with IRC: 37–2018 guidelines. A mechanistic-empirical design approach is adopted, which considers both theoretical analysis and field performance. Using IITPAVE software, critical parameters such as stresses, strains, and deflections are evaluated under various loading conditions. The design traffic is calculated in terms of million standard axles (MSA), and material properties such as resilient modulus are determined for each layer. The study aims to develop a cost-effective and sustainable pavement system. By comparing conventional pavements with cement-treated pavements, the research highlights improvements in strength, durability, and economy, making CTSB a promising alternative.

The increasing rate of urbanization and transportation demand has made the construction of efficient road networks a critical requirement. Flexible pavements are commonly adopted due to their adaptability and cost-effectiveness; however, their performance largely depends on the quality and quantity of materials used. Conventional granular layers often exhibit lower strength and higher susceptibility to moisture damage, leading to premature failures such as rutting and cracking. In this context, stabilization techniques using cement have gained attention as a reliable method to enhance the engineering properties of pavement materials. Cement-treated sub-base (CTSB) provides improved structural support by increasing stiffness and reducing deformation under repeated traffic loads. It also offers better resistance to environmental conditions, ensuring improved durability and performance over time. This project involves the design and analysis of flexible pavement structures using cement-treated sub-base based on IRC: 37–2018 guidelines. The mechanistic-empirical approach is utilized to analyze pavement performance by evaluating critical responses such as tensile and compressive strains. IITPAVE software is employed to simulate real-life loading conditions and assess the structural behavior of pavement layers. Parameters such as resilient modulus, layer thickness, and traffic intensity are carefully considered during the design process. The objective of this study is to compare conventional flexible pavement with cement-stabilized pavement in terms of performance and cost efficiency. The results demonstrate that CTSB significantly reduces pavement thickness, improves strength, and enhances resistance to fatigue and rutting, making it an economical and sustainable solution.

With the rapid expansion of road infrastructure, the need for innovative and sustainable pavement design techniques has become increasingly important. Traditional flexible pavements rely heavily on granular materials, which are becoming scarce due to extensive usage. This has led to the exploration of alternative construction methods that can reduce material consumption while maintaining structural integrity. Cement stabilization of sub-base layers is one such technique that has proven effective in enhancing pavement performance. Cement-treated sub-base (CTSB) increases the load-bearing capacity of the pavement, improves resistance to deformation, and provides a stable platform for upper layers. It also reduces the impact of moisture and temperature variations, thereby improving the overall durability of the pavement structure. In this study, flexible pavement design is carried out using IRC: 37–2018 guidelines, incorporating cement-treated sub-base layers. The analysis is performed using IITPAVE software, which applies a mechanistic-empirical approach to evaluate pavement behavior. Key parameters such as stresses, strains, and deflections are analyzed to ensure that the pavement meets performance criteria. The design traffic is estimated in terms of million standard axles (MSA), and appropriate layer thicknesses are determined accordingly. The findings of this study indicate that the use of CTSB leads to significant improvements in pavement performance. It reduces overall thickness, lowers construction costs, and enhances resistance to fatigue and rutting. Thus, cement-treated pavements offer a reliable, economical, and environmentally friendly solution for modern road construction.

Figure 1 Rolling of Cement Treated Granular Layer

II.LITRATURE REVIEW

[1] Varalakshmi V. et al. (2014) studied the design and analysis of multi-storey buildings using modern software tools and emphasized the importance of structural configuration and material selection. Their research highlighted that the performance of structural systems depends on proper load calculations and adherence to codal provisions. Though focused on buildings, the study demonstrates the importance of analytical tools in engineering design. Similarly, in pavement engineering, tools like IITPAVE help in accurate stress-strain analysis. Their findings stress that proper design methodology improves

safety, durability, and efficiency, which is also applicable in flexible pavement design using cement-treated layers.

[2] Chandrashekar et al. (2015) conducted analysis using advanced software under different loading conditions. Their study showed that computational tools reduce design time and improve accuracy. The research emphasized the importance of considering real-life loading scenarios such as wind and seismic effects. In pavement design, similar computational approaches are used to evaluate stresses and strains under traffic loads. Their work supports the use of software like IITPAVE for analyzing pavement performance and validating design assumptions based on IRC guidelines.

[3] Balaji U. and Selvarasan M.E. (2016) analyzed multi-storeyed structures under static and dynamic loading conditions. Their study concluded that dynamic analysis provides more accurate results compared to static analysis. This concept is relevant to pavement design, where repeated traffic loading behaves like dynamic loading. The study also highlighted the importance of evaluating displacement and stress distribution. Similarly, in flexible pavement design, analyzing strain responses helps in controlling fatigue and rutting failures, making mechanistic analysis essential.

[4] Happy Sharma et al. (2019) conducted an economic analysis of cement-treated base and sub-base in flexible pavements. Their study found that the use of cement stabilization significantly increases CBR values and reduces pavement thickness. The research concluded that cost savings of up to 9% can be achieved due to reduced aggregate usage. Additionally, cement-treated layers improve load distribution and durability. This study strongly supports the use of CTSB in pavement design as a sustainable and economical alternative.

[5] Aher D.D. et al. (2018) investigated the strength characteristics of cement-treated sub-base materials. They conducted experiments with varying cement and moisture content and found that 4% cement and 8% moisture provided optimum strength. The study reported improved compressive strength and density of stabilized layers. It also concluded that CTSB enhances pavement life and reduces construction cost. Their findings validate the effectiveness of cement stabilization in improving pavement performance.

[6] IRC: 37–2018 guidelines provide a mechanistic-empirical approach for the design of flexible pavements. The guidelines consider critical parameters such as vertical compressive strain on subgrade and horizontal tensile strain in bituminous layers. They also recommend the use of cement-treated layers for improved performance. The adoption of IITPAVE software for analysis ensures accurate evaluation of stresses and strains. These guidelines serve as the

foundation for modern pavement design, ensuring safety, durability, and cost-effectiveness.

III. WORKING METHODOLOGY

The methodology of this project begins with the collection and analysis of input data required for pavement design. Traffic data is obtained through traffic volume count surveys and converted into Commercial Vehicles Per Day (CVPD). Using IRC: 37–2018 guidelines, the design traffic is calculated in terms of Million Standard Axles (MSA) by considering factors such as traffic growth rate, vehicle damage factor, and design period. Soil investigation is carried out to determine subgrade properties, particularly the California Bearing Ratio (CBR). Based on CBR values, the resilient modulus of subgrade soil is calculated. Material properties of different pavement layers such as granular base, bituminous layer, and cement-treated sub-base are determined using standard relationships. These parameters form the foundation for the structural design of the pavement system.

The next stage involves the design of flexible pavement using both conventional granular sub-base and cement-treated sub-base (CTSB). Layer thicknesses are initially selected based on IRC guidelines. IITPAVE software is used to analyze the pavement as a multilayer elastic system. Input parameters such as wheel load, tyre pressure, layer thickness, Poisson's ratio, and resilient modulus are defined in the software. The analysis calculates critical responses such as vertical compressive strain on the subgrade and horizontal tensile strain at the bottom of the bituminous layer. Multiple trial sections are evaluated to ensure that the computed strains are within permissible limits for fatigue and rutting criteria. This iterative process helps in identifying the optimum pavement structure.

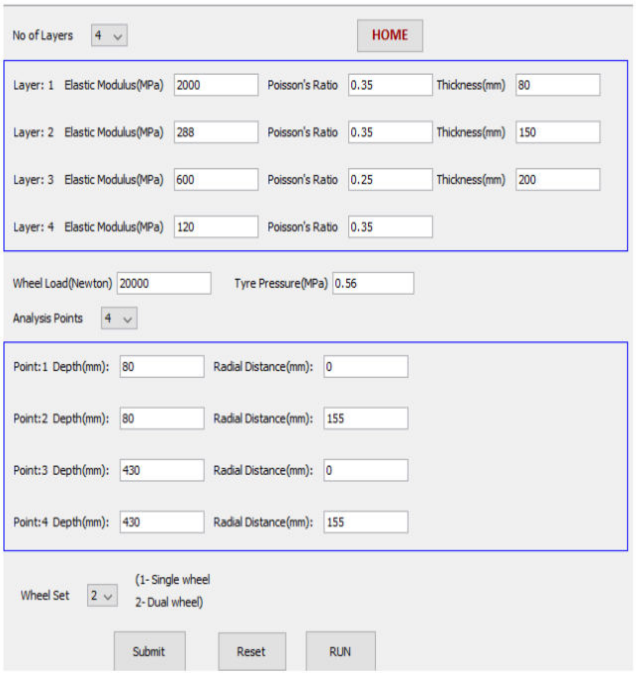

Figure 2: Trail 1 input

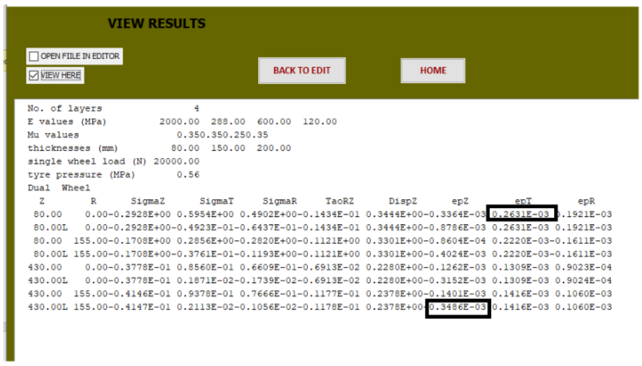

Figure 3: Trail 1 output

Finally, a comparative analysis is carried out between conventional flexible pavement and pavement with cement-treated sub-base. The comparison is based on parameters such as total pavement thickness, stress-strain behavior, and cost efficiency. The reduction in thickness due to CTSB is evaluated, along with savings in aggregate consumption. Cost analysis is performed by estimating the expenses associated with each pavement layer. The results are interpreted to assess the structural performance and economic feasibility of both systems. The methodology concludes by identifying the most efficient pavement design that satisfies strength, durability, and cost requirements, thereby supporting sustainable construction practices.

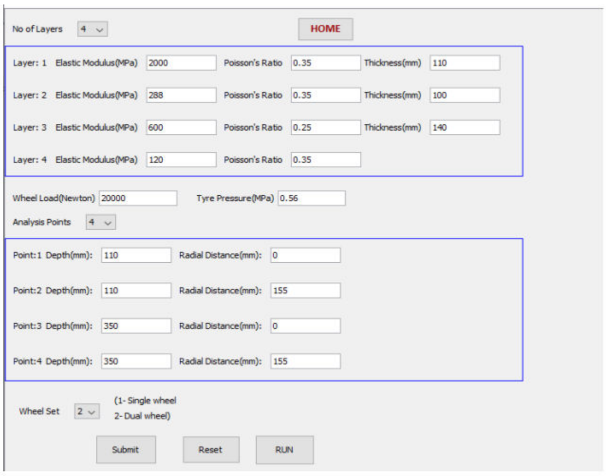

Figure4 : Trail 2 input

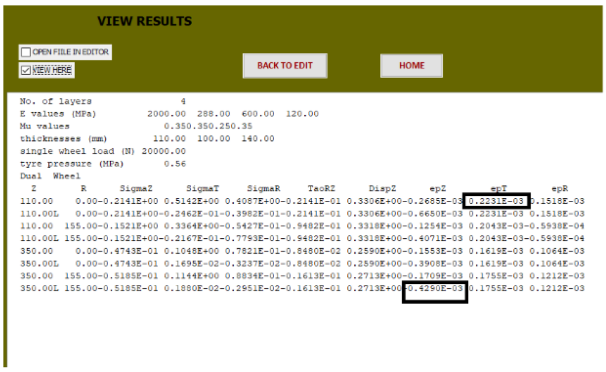

Figure : Trail 2 output

Generalized cost (for length - 1m)		
Item	**Thickness (m)**	**Cost (Rs.)**
Aggregate layer	0.1	1029
CT Sub-base	0.2	1200
Flexible pavement		
Aggregate layer	(150+150=300mm) = 0.3m	3087
Cement treated sub base based flexible pavement		
CT Sub-base & WMM	0.14m & 0.1m	840+1029 = 1869

Table 1 : Cost Comparison

IV.CONCLUSION

The present study focused on the design and analysis of flexible pavements using cement-treated sub-base (CTSB) in comparison with conventional granular pavements, based on IRC: 37–2018 guidelines and IITPAVE software. The results clearly indicate that the inclusion of cement stabilization significantly enhances the structural performance of pavement layers. The improved stiffness and strength of CTSB lead to better load distribution, reduced vertical compressive strain on the subgrade, and lower horizontal tensile strain in the bituminous layer. This directly contributes to minimizing common pavement failures such as rutting and fatigue cracking, thereby increasing the service life of the pavement. A comparative evaluation showed that the overall thickness of pavement can be reduced when cement-treated sub-base is used, without compromising safety and performance. This reduction in thickness results in decreased consumption of natural aggregates, making the construction process more sustainable and environmentally friendly. Additionally, the cost analysis revealed that CTSB-based pavement systems offer significant economic advantages, with considerable savings in material and construction costs. The reduction in transportation and material handling further adds to the overall efficiency of the project. In conclusion, cement-treated sub-base proves to be a reliable, economical, and durable alternative to conventional granular layers in flexible pavement design. It not only enhances pavement performance under varying traffic and environmental conditions but also supports sustainable construction practices. Therefore, CTSB can be effectively adopted in modern road construction, especially for light to medium traffic conditions, ensuring long-term benefits in terms of strength, durability, and cost efficiency.

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