DESIGN AND STRUCTURAL ANALYSIS OF A FOUR-LANE FLEXIBLE PAVEMENT USING IITPAVE AND IRC 37

[1]NANDHINI, [2]Mrs.V.KAVITHA, [3]K. ARUN NAYAK, [4]K. BALAJI

[1,3,4]Students, Department of Civil Engineering, Siddhartha Institute Of Technology & Sciences, Narapally, Telangana-501301, 24TQ5A0103@siddhartha.co.in, **24TQ5A0117@siddhartha.co.in, 24TQ5A0125@siddhartha.co.in**

[2]Associate Professor , Department of Civil Engineering, Siddhartha Institute Of Technology & Sciences, Narapally, Telangana-501301, vavilakavitha.civil@siddhartha.co.in

ABSTRACT

Road transportation plays a significant role in the economic development of a country by facilitating the efficient movement of people and goods. The increasing traffic volume, higher axle loads, and rapid urbanization have created the need for durable and cost-effective pavement systems capable of providing long-term serviceability under varying environmental and traffic conditions. Flexible pavements are widely adopted due to their ease of construction, lower initial cost, and efficient load distribution characteristics. However, improper pavement thickness design may result in premature failures such as rutting, fatigue cracking, surface deformation, and excessive maintenance costs. Therefore, accurate pavement design using advanced analytical tools has become essential for ensuring pavement performance and durability. This project presents the Design of a 4-Lane Flexible Pavement Using IIT PAVE Software and IRC 37. The study focuses on designing a flexible pavement structure based on the guidelines specified in IRC:37-2018 by considering design traffic, axle load repetitions, subgrade strength, climatic conditions, and pavement material properties. The pavement structure is analysed using IIT PAVE, a mechanistic–empirical pavement analysis software developed by the Indian Institute of Technology. The software computes critical pavement responses including horizontal tensile strain at the bottom of the bituminous layer, vertical compressive strain on the top of the subgrade, surface deflection, and stress distribution under wheel loading. These responses are evaluated to determine the required thickness of bituminous layers, granular base, granular sub-base, and subgrade. The results demonstrate that the designed pavement satisfies the fatigue and rutting criteria recommended by IRC standards while ensuring structural stability, durability, and long service life. The proposed methodology provides highway engineers with an accurate and economical approach for designing four-lane flexible pavements capable of accommodating increasing traffic demand while minimizing maintenance requirements and improving pavement performance.

Keywords : Flexible Pavement, IIT PAVE, IRC 37:2018, Mechanistic-Empirical Design, Four-Lane Highway, Pavement Thickness Design, Bituminous Pavement, Fatigue Analysis, Rutting Analysis, Highway Engineering, Pavement Performance, Transportation Engineering.

I. INTRODUCTION

Road transportation is one of the most important components of a nation's infrastructure, contributing significantly to economic growth, industrial development, and regional connectivity. The continuous increase in traffic volume, vehicle ownership, and axle loads has placed greater demand on highway pavements to provide safe, comfortable, and durable transportation facilities. Among the different pavement types, flexible pavements are widely adopted because of their lower initial construction cost, ease of maintenance, and ability to distribute wheel loads through multiple pavement layers. A properly designed flexible pavement ensures adequate load transfer from the surface to the subgrade while minimizing pavement distress such as fatigue cracking, rutting, and excessive deformation. However, conventional empirical design methods often fail to accurately predict pavement performance under modern traffic conditions. Therefore, mechanistic–empirical pavement design approaches have become increasingly popular because they combine theoretical stress–strain analysis with field performance observations to achieve more reliable pavement designs. In India, the design of flexible pavements is primarily governed by IRC:37-2018, which provides comprehensive guidelines for pavement thickness design based on design traffic, subgrade strength, climatic conditions, and material properties. Modern pavement analysis software such as IIT PAVE enables engineers to perform accurate stress, strain, and deflection analysis, thereby improving pavement performance and service life.

Recent developments in pavement engineering have significantly improved the accuracy and efficiency of flexible pavement design. IIT PAVE, developed by the Indian Institute of Technology, is a mechanistic pavement analysis software widely used for evaluating multilayer flexible pavement systems under wheel loading. The software computes critical pavement responses including horizontal tensile strain at the bottom of the bituminous layer, vertical compressive strain at the top of the subgrade, surface deflection, and stress distribution. These parameters play an essential role in predicting fatigue failure and rutting, which are the two major modes of pavement deterioration. IIT PAVE allows engineers to define pavement layer thicknesses, elastic moduli, Poisson's ratios, wheel load, tyre pressure, and contact area before performing structural analysis. The generated results assist engineers in selecting appropriate pavement thickness and material properties capable of satisfying the fatigue and rutting criteria specified in IRC:37-2018. Compared with traditional empirical methods, mechanistic–empirical pavement design provides improved reliability, optimized material utilization, and enhanced pavement durability. Consequently, IIT PAVE has become one of the preferred software tools for flexible pavement analysis and design in highway engineering projects.

This project presents the Design of a 4-Lane Flexible Pavement Using IIT PAVE Software and IRC:37-2018. The objective is to design a durable and economical pavement structure capable of safely carrying projected traffic loads throughout the design life of the highway. The pavement structure consists of bituminous concrete (BC), dense bituminous macadam (DBM), wet mix macadam (WMM), granular sub-base (GSB), and prepared subgrade. The pavement is designed by considering important parameters including design traffic, commercial vehicle growth rate, cumulative standard axles (MSA), California Bearing Ratio (CBR), wheel load, tyre pressure, and material properties according to IRC:37-2018. The complete pavement model is analysed using IIT PAVE to determine the critical stress, strain, and deflection values generated under wheel loading. The computed tensile strain and compressive strain are compared with the permissible fatigue and rutting criteria recommended by IRC standards to verify the adequacy of the pavement thickness. The study demonstrates that mechanistic–empirical pavement design using IIT PAVE provides accurate structural analysis, optimized pavement layer thickness, improved load distribution, enhanced pavement durability, and reduced maintenance costs. The proposed methodology assists highway engineers in developing safe, economical, and long-lasting four-lane flexible pavements capable of accommodating increasing traffic demand while ensuring efficient transportation infrastructure.

II. SURVEY OF RESEARCH

1. Flexible Pavement Design Using Mechanistic–Empirical Approach

Flexible pavement design has evolved significantly with the adoption of mechanistic–empirical methods that combine theoretical stress–strain analysis with field performance observations. Researchers have reported that conventional empirical design methods often fail to accurately predict pavement performance under increasing traffic loads and changing environmental conditions. Mechanistic–empirical pavement design enables engineers to determine critical pavement responses such as tensile strain, compressive strain, and surface deflection under wheel loading. These parameters are directly related to fatigue cracking and rutting, which are the two major failure mechanisms in flexible pavements. Several studies have demonstrated that mechanistic analysis improves pavement reliability, enhances service life, and optimizes pavement layer thickness while reducing construction and maintenance costs. The adoption of mechanistic–empirical design has therefore become an essential practice in modern highway engineering for developing durable and economical pavement structures capable of supporting increasing traffic demand.

2. Flexible Pavement Analysis Using IIT PAVE Software

IIT PAVE is one of the most widely used pavement analysis software packages for mechanistic evaluation of multilayer flexible pavements. Developed by the Indian Institute of Technology, the software calculates stresses, strains, and deflections developed within different pavement layers under wheel loading. Researchers have extensively used IIT PAVE to analyse bituminous pavements by defining pavement layer thicknesses, elastic modulus, Poisson's ratio, wheel load, tyre pressure, and contact radius. The software computes horizontal tensile strain at the bottom of the bituminous layer and vertical compressive strain at the top of the subgrade, which are critical parameters governing fatigue and rutting failures. Comparative investigations have demonstrated that IIT PAVE provides highly accurate analytical results while minimizing manual calculations. The software also assists engineers in optimizing pavement layer thicknesses according to IRC guidelines, thereby improving pavement durability, structural stability, and long-term performance under varying traffic conditions.

3. IRC 37 Guidelines for Flexible Pavement Design

The Indian Roads Congress (IRC:37-2018) provides comprehensive guidelines for the mechanistic–empirical design of flexible pavements in India. Researchers widely follow these recommendations for designing national highways, state highways, and urban roads. The design procedure considers important parameters including design traffic, cumulative standard axles (MSA), subgrade strength, California Bearing Ratio (CBR), climatic conditions, material properties, and pavement layer characteristics. Several studies have shown that pavement structures designed according to IRC:37 exhibit improved structural performance and longer service life compared with traditional empirical designs. The guidelines also recommend fatigue and rutting criteria based on computed tensile and compressive strains obtained from mechanistic analysis software such as IIT PAVE. Proper implementation of IRC recommendations ensures adequate load distribution, minimizes pavement distress, reduces maintenance frequency, and enhances the overall efficiency of highway infrastructure.

4. Influence of Traffic Loading on Flexible Pavement Performance

Traffic loading is one of the most important factors affecting the structural performance and service life of flexible pavements. Researchers have investigated the influence of axle loads, wheel configurations, traffic growth, tyre pressure, and cumulative traffic repetitions on pavement deterioration. Experimental and numerical studies indicate that increasing traffic volume produces higher stresses and strains within pavement layers, accelerating fatigue cracking, rutting, and permanent deformation. The design traffic is generally expressed in terms of Million Standard Axles (MSA), which represents the cumulative traffic expected during the pavement design life. Comparative investigations have shown that pavements carrying higher traffic volumes require thicker bituminous layers and stronger granular bases to safely distribute wheel loads. Accurate estimation of traffic loading therefore plays a vital role in achieving economical pavement thickness and long-term structural performance.

5. Pavement Layer Behaviour Under Wheel Loading

Flexible pavements consist of multiple structural layers, including the bituminous surface course, base course, sub-base, and prepared subgrade. Each layer performs a specific function in distributing traffic loads and protecting the underlying soil. Researchers have analysed the stress and strain distribution within these layers using mechanistic models and finite element techniques. Studies indicate that the highest horizontal tensile strain generally occurs at the bottom of the bituminous layer, whereas the maximum vertical compressive strain develops at the top of the subgrade. These critical strains directly influence fatigue cracking and rutting performance. Proper selection of pavement materials, layer thickness, and elastic properties significantly improves load distribution and reduces pavement distress. Mechanistic analysis enables engineers to optimize pavement composition while ensuring compliance with design standards and improving structural reliability.

6. Future Trends in Flexible Pavement Engineering

Recent advancements in pavement engineering focus on integrating Artificial Intelligence (AI), Machine Learning (ML), Geographic Information Systems (GIS), Building Information Modelling (BIM), and Internet of Things (IoT) with traditional pavement design methods. Researchers are developing intelligent pavement management systems capable of predicting pavement deterioration using traffic, environmental, and structural data. Advanced numerical techniques and finite element modelling are being used to improve the accuracy of pavement response prediction. Smart sensors embedded within pavement layers enable continuous monitoring of stress, strain, temperature, and moisture conditions, facilitating preventive maintenance and extending pavement service life. Future pavement design is expected to combine mechanistic–empirical analysis, cloud computing, digital twin technology, and AI-based optimization with software such as IIT PAVE to develop more sustainable, economical, and resilient highway infrastructure capable of accommodating future transportation demands.

III. PROPOSED SYSTEM

The proposed Design of 4-Lane Flexible Pavement Using IIT PAVE Software and IRC:37-2018 aims to develop a safe, economical, and durable flexible pavement structure capable of carrying projected traffic loads throughout its design life. The proposed methodology integrates traffic analysis, subgrade evaluation, pavement material characterization, mechanistic pavement analysis, pavement thickness design, and structural performance evaluation using IIT PAVE in accordance with the recommendations of IRC:37-2018. The primary objective is to determine the optimum thickness of each pavement layer while satisfying the fatigue and rutting criteria specified by the Indian Roads Congress. The proposed pavement design ensures adequate load distribution, improved structural stability, enhanced riding quality, and longer pavement service life under varying traffic and environmental conditions.

Initially, the required design parameters are collected from field investigations and design specifications. These parameters include design traffic (Million Standard Axles - MSA), California Bearing Ratio (CBR) of the subgrade, annual traffic growth rate, design life, wheel load, tyre pressure, climatic conditions, and pavement material properties. The quality of subgrade soil is evaluated through laboratory testing to determine its bearing capacity and suitability for supporting pavement layers. Material properties including elastic modulus, Poisson's ratio, and layer thicknesses for the Bituminous Concrete (BC), Dense Bituminous Macadam (DBM), Wet Mix Macadam (WMM), Granular Sub-Base (GSB), and prepared subgrade are selected according to IRC specifications. The collected design data are verified before performing pavement analysis to ensure accurate computational results. After completing the input preparation, the multilayer pavement structure is developed in IIT PAVE. The software models the pavement as a layered elastic system consisting of the bituminous surface layer, granular base, granular sub-base, and subgrade soil. Each pavement layer is assigned its corresponding thickness, elastic modulus, and Poisson's ratio. Standard wheel load and tyre contact pressure are then applied to the pavement surface. IIT PAVE performs mechanistic analysis by computing the stress, strain, and deflection developed within different pavement layers due to traffic loading. The software automatically determines horizontal tensile strain at the bottom of the bituminous layer, vertical compressive strain at the top of the subgrade, surface deflection, and stress distribution, which are the critical parameters governing pavement performance.

The computed pavement responses are compared with the permissible fatigue and rutting criteria specified in IRC:37-2018. The horizontal tensile strain is used to evaluate the fatigue life of the bituminous layer, whereas the vertical compressive strain is used to predict rutting performance of the pavement. If the calculated strains exceed the allowable design limits, the thickness of the pavement layers is modified and the analysis is repeated until the pavement satisfies all structural performance requirements. This iterative design procedure ensures that the pavement structure possesses adequate fatigue resistance, rutting resistance, structural stability, and long-term durability while minimizing material consumption and construction cost. Finally, the effectiveness of the proposed pavement design is evaluated using engineering parameters including horizontal tensile strain, vertical compressive strain, surface deflection, fatigue life, rutting life, stress distribution, pavement layer thickness, and overall structural performance. The obtained results verify that the designed four-lane flexible pavement satisfies the mechanistic–empirical design criteria recommended by IRC:37-2018. The proposed IIT PAVE-based methodology provides highway engineers with an efficient and reliable approach for designing flexible pavements capable of safely carrying increasing traffic volumes while ensuring improved durability, reduced maintenance requirements, enhanced riding quality, and economical pavement construction.

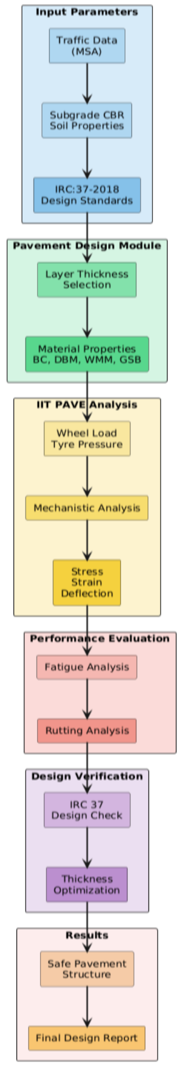

Fig1: Proposed workflow

III. WORKING METHODOLOGY

The proposed Design of 4-Lane Flexible Pavement Using IIT PAVE Software and IRC:37-2018 follows a systematic mechanistic–empirical pavement design methodology to develop a durable, economical, and structurally stable flexible pavement. The methodology integrates traffic analysis, subgrade evaluation, pavement material selection, multilayer pavement modelling, mechanistic analysis, pavement thickness optimization, and performance evaluation using IIT PAVE. The complete pavement design is carried out in accordance with the recommendations of IRC:37-2018, ensuring that the pavement satisfies the fatigue and rutting criteria required for long-term serviceability. Initially, the required design parameters are collected from traffic surveys, soil investigations, and laboratory testing. The primary input parameters include Average Daily Traffic (ADT), traffic growth rate, design life, vehicle damage factor (VDF), lane distribution factor, California Bearing Ratio (CBR) of the subgrade soil, wheel load, tyre pressure, and climatic conditions. The cumulative traffic expected during the design life is calculated in terms of Million Standard Axles (MSA) according to IRC:37-2018. Simultaneously, laboratory tests are conducted to determine the engineering properties of the subgrade soil, including CBR value, moisture content, and density. These parameters are essential for selecting suitable pavement layer thicknesses and material properties.

After completing the input preparation, the pavement structure is developed using IIT PAVE. The pavement is modelled as a multilayer elastic system consisting of Bituminous Concrete (BC), Dense Bituminous Macadam (DBM), Wet Mix Macadam (WMM), Granular Sub-Base (GSB), and prepared subgrade. Each pavement layer is assigned its respective thickness, elastic modulus, and Poisson's ratio according to IRC recommendations. Standard wheel load and tyre pressure are then applied on the pavement surface to simulate the actual traffic loading conditions. IIT PAVE performs mechanistic analysis by computing stresses, strains, and deflections generated within each pavement layer due to repeated wheel loading. The software automatically calculates important pavement response parameters including horizontal tensile strain at the bottom of the bituminous layer, vertical compressive strain at the top of the subgrade, surface deflection, and stress distribution. These responses are considered the governing parameters for predicting fatigue cracking and rutting failure. The calculated strains are compared with the allowable design limits specified in IRC:37-2018. If the obtained values exceed the permissible limits, the thickness of one or more pavement layers is modified and the mechanistic analysis is repeated. This iterative procedure continues until the pavement structure satisfies all fatigue and rutting requirements while maintaining an economical design.

Following mechanistic analysis, the structural adequacy of the pavement is verified by evaluating the fatigue life and rutting life of the designed pavement. The optimized pavement structure is then assessed for stress distribution, load transfer efficiency, structural stability, and long-term performance. Comparative analysis of different pavement layer combinations is performed to determine the most suitable configuration capable of safely carrying the projected traffic throughout the design period. The final pavement structure provides adequate resistance against permanent deformation, fatigue cracking, moisture damage, and excessive deflection.

Finally, the effectiveness of the proposed pavement design is evaluated using engineering performance parameters including horizontal tensile strain, vertical compressive strain, surface deflection, fatigue life, rutting life, pavement thickness, stress distribution, and overall structural performance. The results obtained from IIT PAVE confirm that the designed four-lane flexible pavement satisfies the mechanistic–empirical design criteria recommended by IRC:37-2018. The proposed methodology provides highway engineers with an efficient and reliable approach for designing flexible pavements that ensure improved structural stability, enhanced riding quality, reduced maintenance cost, and longer service life under increasing traffic demand.

Engineering Formulae

Equation (1): Design Traffic

$$N = \frac{365 \times A\left[(1+r)^n - 1\right] \times D \times F}{r}$$

Where:

(N) = Design traffic (Million Standard Axles, MSA)

(A) = Initial commercial vehicles per day (CVPD)

(r) = Annual traffic growth rate

(n) = Design life (years)

(D) = Lane distribution factor

(F) = Vehicle damage factor

Equation (2): Wheel Load Stress

$$\sigma = \frac{P}{A}$$

Where:

(\sigma) = Contact stress (MPa)

(P) = Wheel load (N)

(A) = Contact area (mm²)

Equation (3): Horizontal Tensile Strain

$$\varepsilon_t = \frac{\sigma_t}{E_b}$$

Where:

(\varepsilon_t) = Horizontal tensile strain

(\sigma_t) = Tensile stress

(E) = Elastic modulus of bituminous layer

Equation (4): Vertical Compressive Strain

$$N_f = 2.21 \times 10^{-4} \left(\frac{1}{\varepsilon_t}\right)^{3.89} \left(\frac{1}{E_b}\right)^{0.854}$$

These equations are based on the mechanistic–empirical pavement design approach adopted in IRC:37-2018 and are directly applicable to the design of a 4-lane flexible pavement using IIT PAVE software.

IV. IMPLEMENTATION

The implementation of the proposed Design of 4-Lane Flexible Pavement Using IIT PAVE Software and IRC:37-2018 was carried out using the IIT PAVE mechanistic pavement analysis software to develop a structurally safe, economical, and durable flexible pavement. The implementation involved traffic data collection, subgrade evaluation, pavement layer design, mechanistic analysis, fatigue and rutting verification, and pavement thickness optimization. The complete design procedure followed the recommendations specified in IRC:37-2018, ensuring that the pavement satisfies the required structural and performance criteria throughout its design life.

Initially, the design parameters required for pavement analysis were collected through traffic surveys, field investigations, and laboratory testing. The collected information included Average Daily Traffic (ADT), commercial vehicle traffic, annual traffic growth rate, design life, Vehicle Damage Factor (VDF), lane distribution factor, and California Bearing Ratio (CBR) of the subgrade soil. The cumulative traffic expected during the design life was calculated in terms of Million Standard Axles (MSA) using IRC design procedures. Simultaneously, laboratory tests were performed to determine the engineering properties of pavement materials and subgrade soil, including density, moisture content, elastic modulus, and Poisson's ratio. These properties formed the basis for developing the multilayer pavement structure in IIT PAVE.

After completing the data collection process, the pavement structure was modelled in IIT PAVE. The pavement consisted of multiple structural layers including Bituminous Concrete (BC) as the wearing course, Dense Bituminous Macadam (DBM) as the binder course, Wet Mix Macadam (WMM) as the base course, Granular Sub-Base (GSB), and the prepared subgrade. Each pavement layer was assigned its corresponding thickness, elastic modulus, and Poisson's ratio according to IRC:37-2018 recommendations. Standard axle load, wheel load, tyre pressure, and contact radius were specified in the software to simulate the actual loading conditions experienced by a four-lane highway. The completed pavement model was verified before initiating mechanistic analysis to ensure that all input parameters were correctly assigned.

The IIT PAVE software then performed mechanistic analysis of the multilayer pavement system. The program automatically calculated the critical pavement responses including horizontal tensile strain at the bottom of the bituminous layer, vertical compressive strain at the top of the subgrade, surface deflection, stress distribution, and strain distribution under wheel loading. These parameters are directly associated with pavement fatigue and rutting failures. The software generated numerical results and graphical outputs representing stress and strain variations within each pavement layer. The obtained responses were carefully examined to determine whether the designed pavement satisfied the fatigue and rutting requirements prescribed by IRC:37-2018.

Following mechanistic analysis, the pavement structure was verified by comparing the calculated strains with the allowable design limits. If the computed horizontal tensile strain exceeded the permissible fatigue limit, the thickness of the bituminous layers was increased. Similarly, if the vertical compressive strain exceeded the rutting criterion, the thickness of the granular layers or subgrade improvement measures were modified. The pavement model was repeatedly analysed until both fatigue life and rutting life satisfied the required design standards. This iterative optimization process ensured that the final pavement structure provided sufficient load-carrying capacity while minimizing unnecessary material usage and construction cost.

Finally, the optimized pavement design was evaluated using engineering performance parameters including horizontal tensile strain, vertical compressive strain, surface deflection, fatigue life, rutting life, stress distribution, pavement layer thickness, and overall structural stability. Comparative analysis confirmed that the proposed four-lane flexible pavement satisfied all mechanistic–empirical design criteria specified in IRC:37-2018. The designed pavement structure exhibited adequate resistance against fatigue cracking, rutting, excessive deformation, and repeated traffic loading. The implementation demonstrated that IIT PAVE provides an accurate, reliable, and efficient platform for flexible pavement analysis and thickness design. The developed framework assists highway engineers in optimizing pavement layer configuration, improving structural durability, reducing maintenance requirements, and ensuring economical construction of modern four-lane highway pavements capable of accommodating increasing traffic demand.

VI. RESULTS EXPLANATIONS

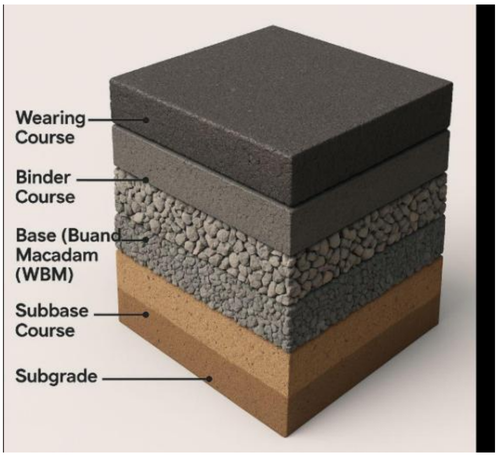

Figure 2. Multilayer Flexible Pavement Structure Designed Using IIT PAVE

Figure 2 illustrates the multilayer flexible pavement structure adopted for the proposed four-lane highway. The pavement consists of Bituminous Concrete (BC) as the wearing course, Dense Bituminous Macadam (DBM) as the binder course, Wet Mix Macadam (WMM) as the base course, Granular Sub-Base (GSB), and the prepared subgrade. Each layer performs a specific structural function in distributing wheel loads from the pavement surface to the underlying soil. The bituminous layers provide riding quality, waterproofing, and resistance against traffic abrasion, whereas the granular layers improve load distribution and reduce stresses transmitted to the subgrade. The pavement thicknesses were selected according to the recommendations of IRC:37-2018 and verified using IIT PAVE software. Proper layer configuration improves fatigue resistance, rutting resistance, and overall structural stability while reducing maintenance requirements throughout the design life of the pavement.

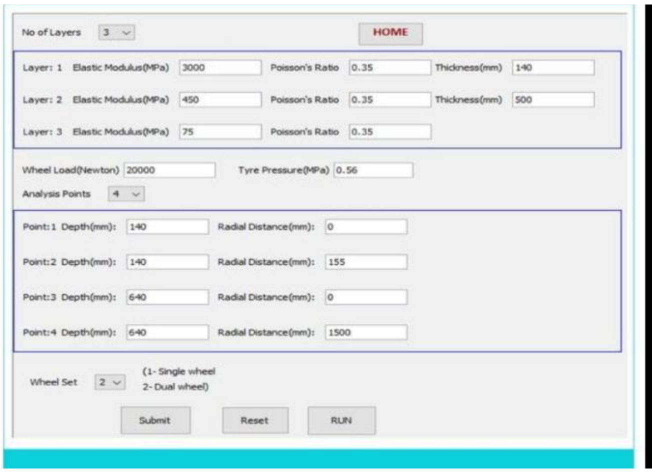

Figure 3. Input Parameters Entered in IIT PAVE Software

Figure 3 presents the input parameters used for mechanistic pavement analysis in IIT PAVE. The software requires information such as pavement layer thickness, elastic modulus, Poisson's ratio, wheel load, tyre pressure, contact radius, and subgrade properties before initiating analysis. These parameters were selected according to the recommendations of IRC:37-2018 and laboratory test results. The multilayer pavement system was modelled by assigning the engineering properties of each pavement layer. Accurate input data are essential because the computed stresses, strains, and deflections directly depend on these parameters. Proper selection of material properties ensures realistic simulation of field conditions and improves the accuracy of pavement thickness design. The input interface also enables engineers to modify pavement parameters and evaluate alternative pavement configurations for achieving optimum structural performance.

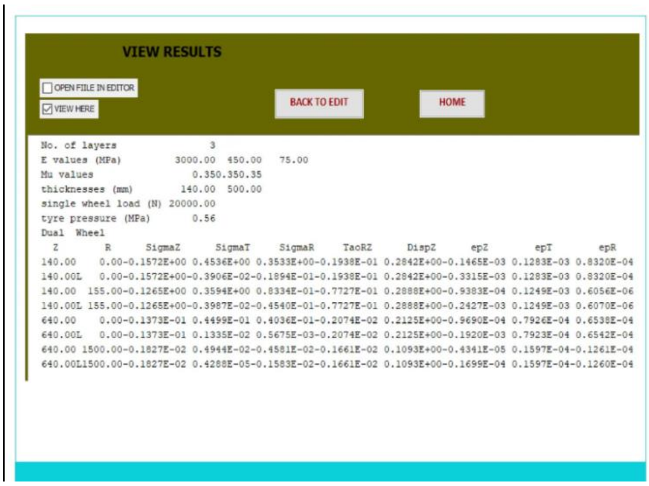

Figure 4. Horizontal Tensile Strain at the Bottom of the Bituminous Layer

Figure 4 illustrates the horizontal tensile strain developed at the bottom of the bituminous layer under wheel loading. This strain is one of the most important mechanistic parameters because it governs the fatigue life of the pavement. Repeated traffic loading causes tensile stresses within the bituminous layer, eventually leading to fatigue cracking if the strain exceeds the allowable design limit. IIT PAVE calculates the maximum tensile strain using multilayer elastic theory and compares the obtained value with the fatigue criterion specified in IRC:37-2018. The results indicate that the designed pavement structure maintains tensile strain within the permissible range, confirming adequate fatigue resistance throughout the design life. The analysis demonstrates that the selected bituminous layer thickness effectively distributes wheel loads and minimizes the possibility of premature cracking.

VII. CONCLUSION

The present study successfully designed a 4-Lane Flexible Pavement Using IIT PAVE Software and IRC:37-2018 by adopting the mechanistic–empirical pavement design approach. The pavement structure was developed considering important design parameters such as design traffic (MSA), California Bearing Ratio (CBR) of the subgrade, traffic growth rate, vehicle damage factor, wheel load, and material properties in accordance with the recommendations of IRC:37-2018. The multilayer pavement system consisting of Bituminous Concrete (BC), Dense Bituminous Macadam (DBM), Wet Mix Macadam (WMM), Granular Sub-Base (GSB), and prepared subgrade was analysed using IIT PAVE to determine the structural response under repeated wheel loading. Critical engineering parameters including horizontal tensile strain, vertical compressive strain, surface deflection, stress distribution, fatigue life, and rutting life were evaluated to verify the structural adequacy of the proposed pavement.

The mechanistic analysis demonstrated that the selected pavement layer configuration effectively distributes wheel loads through successive pavement layers while minimizing the stresses transmitted to the subgrade. The calculated horizontal tensile strain remained within the allowable fatigue limits prescribed by IRC:37-2018, indicating adequate resistance against fatigue cracking of the bituminous layers. Similarly, the vertical compressive strain at the top of the subgrade satisfied the rutting criteria, confirming that the designed pavement possesses sufficient resistance against permanent deformation under repeated traffic loading. The obtained surface deflection values also remained within acceptable limits, indicating satisfactory structural stability and serviceability throughout the design life of the pavement.

The implementation of IIT PAVE significantly improved the accuracy and reliability of pavement thickness design compared with conventional empirical methods. The software efficiently analysed the multilayer pavement structure, generated detailed stress–strain responses, and enabled optimization of pavement layer thicknesses while minimizing material consumption and construction cost. The mechanistic–empirical approach ensured better prediction of pavement performance under increasing traffic loads and enhanced the overall durability of the pavement structure.

Overall, the proposed methodology provides an efficient, economical, and scientifically validated approach for designing four-lane flexible pavements capable of supporting heavy traffic under varying field conditions. The study demonstrates that IIT PAVE, together with IRC:37-2018, provides an effective framework for pavement design, resulting in improved structural performance, longer service life, reduced maintenance requirements, and enhanced riding quality. Future research may focus on incorporating reclaimed asphalt pavement (RAP), geosynthetics, industrial waste materials, warm mix asphalt technologies, Artificial Intelligence-based pavement optimization, and life-cycle cost analysis to further improve the sustainability and long-term performance of flexible pavement systems.

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