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Research Paper

DESIGN AND STRUCTURAL ANALYSIS OF RIGID PAVEMENT USING KENPAVE AND IRC 58

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ABSTRACT

Road infrastructure plays a vital role in supporting economic development by providing efficient transportation for passengers and freight. Among various pavement systems, rigid pavements are widely preferred for highways carrying heavy traffic because of their high load-carrying capacity, longer service life, lower maintenance requirements, and superior structural performance. Unlike flexible pavements, rigid pavements distribute wheel loads through the flexural strength of cement concrete slabs, making accurate structural analysis essential for ensuring durability and safety. Improper pavement thickness or inadequate joint design may lead to cracking, faulting, pumping, and excessive deflection, resulting in reduced pavement performance and increased maintenance costs. Therefore, modern mechanistic pavement analysis techniques are increasingly adopted for designing rigid pavements capable of withstanding repeated traffic loading and environmental effects. This project presents the Analysis and Design of Rigid Pavement Using KENPAVE and IRC:58-2015 Methods. The study focuses on analysing a rigid pavement structure using KENPAVE, a mechanistic pavement analysis software, and designing the pavement according to the recommendations of IRC:58-2015. Important design parameters including design traffic, wheel load, modulus of subgrade reaction (k-value), modulus of elasticity of concrete, Poisson's ratio, load transfer efficiency, and temperature gradients are considered during the analysis. The software evaluates critical pavement responses such as wheel load stress, edge stress, corner stress, interior stress, slab deflection, and load transfer characteristics. The computed stresses are compared with the permissible flexural strength of concrete to determine the required pavement thickness. The results demonstrate that the designed rigid pavement satisfies the structural and serviceability requirements specified in IRC:58-2015, ensuring improved durability, load distribution, and long-term pavement performance. The proposed methodology provides highway engineers with an efficient and reliable approach for designing economical, durable, and heavy-duty rigid pavements suitable for modern transportation infrastructure.

Keywords : Rigid Pavement, KENPAVE, IRC:58-2015, Cement Concrete Pavement, Pavement Thickness Design, Highway Engineering, Wheel Load Stress, Slab Deflection, Modulus of Subgrade Reaction, Mechanistic Analysis, Transportation Engineering, Pavement Design.

I. INTRODUCTION

The rapid growth of transportation infrastructure and the continuous increase in commercial vehicle traffic have significantly increased the demand for durable and high-performance pavement systems. Highways carrying heavy axle loads require pavement structures capable of withstanding repeated traffic loading while maintaining structural integrity and riding quality throughout their design life. Among the different types of pavements, rigid pavements have gained widespread acceptance because of their superior load distribution capability, longer service life, lower maintenance requirements, and higher structural strength compared with flexible pavements. Rigid pavements primarily consist of Portland Cement Concrete (PCC) slabs that distribute wheel loads through flexural action over a wider area of the subgrade. Unlike flexible pavements, the structural behaviour of rigid pavements depends on slab thickness, modulus of elasticity of concrete, modulus of subgrade reaction, load transfer efficiency, temperature stresses, and joint performance. Improper pavement design may result in fatigue cracking, corner breaks, faulting, pumping, excessive slab deflection, and premature pavement failure. Therefore, accurate pavement analysis and structural design are essential for ensuring long-term durability and economical highway construction. In India, the design of rigid pavements is governed by IRC:58-2015, which provides comprehensive guidelines for pavement thickness design based on mechanistic principles and field performance observations.

Recent advancements in pavement engineering have introduced mechanistic analysis software that significantly improves the accuracy of rigid pavement design. KENPAVE is one of the most widely used pavement analysis programs for evaluating the structural response of concrete pavements under wheel loading. The software performs multilayer elastic and finite element analysis to determine important engineering parameters including interior stress, edge stress, corner stress, slab deflection, load transfer efficiency, and stress distribution within the concrete slab. Engineers can define pavement thickness, wheel load, axle configuration, modulus of elasticity of concrete, Poisson's ratio, modulus of subgrade reaction (k-value), and joint characteristics before performing structural analysis. The obtained analytical results enable engineers to determine the optimum slab thickness capable of resisting repeated traffic loading without exceeding the allowable flexural strength of concrete. Compared with conventional empirical design methods, mechanistic analysis using KENPAVE provides greater accuracy, improved structural reliability, optimized material utilization, and enhanced pavement performance. Consequently, KENPAVE has become an important software tool for the structural analysis and design of rigid pavements used in highways, airports, industrial roads, and heavy-duty transportation facilities.

This project presents the Analysis and Design of Rigid Pavement Using KENPAVE and IRC:58-2015 Methods. The primary objective is to analyse the structural behaviour of a rigid pavement subjected to heavy traffic loading and determine the optimum pavement thickness according to the recommendations of IRC:58-2015. The pavement design considers important parameters including design traffic, wheel load, modulus of subgrade reaction (k-value), modulus of elasticity of concrete, Poisson's ratio, load transfer efficiency, temperature gradient, and concrete flexural strength. The complete pavement structure is modelled using KENPAVE, where mechanistic analysis is performed to compute interior stress, edge stress, corner stress, slab deflection, and load transfer characteristics under wheel loading. The obtained responses are compared with the permissible stress limits specified by IRC standards to verify the adequacy of the pavement thickness. The study demonstrates that the combined use of KENPAVE and IRC:58-2015 provides an efficient and scientifically validated approach for designing durable rigid pavements capable of supporting heavy traffic while minimizing structural failures and maintenance costs. The proposed methodology assists highway engineers in developing economical, reliable, and long-lasting concrete pavements suitable for modern transportation infrastructure.

II. SURVEY OF RESEARCH

1. Rigid Pavement Design Using Mechanistic Approach

Rigid pavements have become an essential component of modern highway infrastructure because of their superior load-carrying capacity, longer service life, and lower maintenance requirements. Researchers have extensively investigated the structural behaviour of cement concrete pavements under varying traffic and environmental conditions using mechanistic analysis methods. Unlike conventional empirical approaches, mechanistic pavement design evaluates the actual stresses, strains, and deflections developed within the concrete slab due to wheel loading. Several studies have demonstrated that mechanistic analysis significantly improves the accuracy of pavement thickness design and enables engineers to predict pavement failures such as fatigue cracking, corner breaks, pumping, and faulting. Comparative investigations indicate that rigid pavements designed using mechanistic–empirical principles exhibit improved durability, structural reliability, and serviceability while reducing maintenance costs. These studies emphasize that accurate stress analysis plays a crucial role in determining optimum slab thickness and ensuring long-term pavement performance under heavy traffic conditions.

2. Structural Analysis Using KENPAVE Software

KENPAVE is one of the most widely used mechanistic pavement analysis software packages for evaluating the structural response of rigid and flexible pavements. Researchers have successfully utilized KENPAVE to analyse concrete pavements subjected to different wheel loads, axle configurations, and subgrade conditions. The software performs multilayer elastic analysis to calculate important engineering parameters such as interior stress, edge stress, corner stress, slab deflection, load transfer efficiency, and stress distribution within the pavement. The computed stresses are compared with the allowable flexural strength of concrete to determine the required pavement thickness. Numerous investigations have shown that KENPAVE provides accurate numerical results while significantly reducing manual calculations. The software also enables engineers to evaluate different pavement configurations and optimize slab thickness according to design standards, thereby improving structural safety, durability, and construction economy.

3. IRC:58 Guidelines for Rigid Pavement Design

The Indian Roads Congress (IRC:58-2015) provides comprehensive guidelines for the analysis and design of rigid pavements in India. Researchers widely adopt these recommendations for designing cement concrete pavements used in national highways, expressways, industrial roads, and airport pavements. The design procedure considers important parameters including design traffic, wheel load, modulus of subgrade reaction (k-value), modulus of elasticity of concrete, Poisson's ratio, temperature stresses, load transfer efficiency, and flexural strength of concrete. Several studies have confirmed that pavements designed according to IRC:58 exhibit improved structural stability, reduced cracking, and enhanced service life. The guidelines also recommend evaluating critical stress conditions such as interior loading, edge loading, and corner loading before selecting the final pavement thickness. Proper implementation of IRC provisions ensures safe, durable, and economical rigid pavement construction.

4. Influence of Wheel Load and Subgrade Support

Wheel load magnitude and subgrade support significantly influence the structural behaviour of rigid pavements. Researchers have investigated the effect of axle loads, tyre pressure, concrete slab thickness, and modulus of subgrade reaction on pavement performance. Experimental and numerical studies indicate that increasing wheel loads produce higher bending stresses and slab deflections, whereas stronger subgrade support reduces pavement deformation and improves load distribution. Comparative analyses have shown that pavements constructed over stronger subgrade soils require comparatively thinner concrete slabs than those constructed over weaker foundations. Accurate estimation of subgrade characteristics and wheel loading conditions therefore plays a vital role in achieving economical pavement thickness while maintaining structural safety and long-term durability.

5. Performance Evaluation of Cement Concrete Pavements

Performance evaluation is an essential stage in rigid pavement design because it determines the structural adequacy of the pavement under repeated traffic loading. Researchers have analysed pavement performance using parameters such as wheel load stress, corner stress, edge stress, interior stress, slab deflection, load transfer efficiency, and fatigue life. Studies have shown that excessive stress concentrations near slab edges and corners may lead to cracking and structural deterioration if not properly considered during design. Proper joint spacing, dowel bars, tie bars, and slab thickness significantly improve pavement performance and reduce maintenance requirements. Comparative investigations have demonstrated that mechanistically designed rigid pavements exhibit improved structural efficiency and longer service life than pavements designed using conventional empirical methods.

6. Future Trends in Rigid Pavement Engineering

Recent developments in rigid pavement engineering focus on integrating Finite Element Analysis (FEA), Artificial Intelligence (AI), Machine Learning (ML), Building Information Modelling (BIM), Geographic Information Systems (GIS), and Internet of Things (IoT) with pavement analysis software. Researchers are developing intelligent pavement management systems capable of predicting pavement deterioration using traffic, environmental, and structural monitoring data. Smart sensors embedded within concrete pavements continuously measure stress, strain, temperature, moisture, and slab movement to support preventive maintenance and improve pavement performance. Future pavement engineering is expected to combine mechanistic analysis using software such as KENPAVE, digital twin technology, cloud computing, and AI-based optimization techniques to design more durable, economical, sustainable, and resilient rigid pavements capable of accommodating future transportation demands.

III. PROPOSED SYSTEM

The proposed Analysis and Design of Rigid Pavement Using KENPAVE and IRC:58-2015 Methods aims to develop a durable, economical, and structurally efficient cement concrete pavement capable of carrying heavy traffic loads throughout its design life. The proposed methodology integrates traffic analysis, subgrade evaluation, pavement material characterization, mechanistic pavement analysis, slab thickness design, and structural performance evaluation using KENPAVE in accordance with the recommendations of IRC:58-2015. The primary objective is to determine the optimum concrete slab thickness capable of resisting wheel load stresses, temperature stresses, and environmental effects while ensuring long-term structural performance, safety, and serviceability.

Initially, the required design parameters are collected through field investigations, traffic surveys, and laboratory testing. Important input parameters include design traffic (Million Standard Axles – MSA), wheel load, axle configuration, traffic growth rate, design life, modulus of subgrade reaction (k-value), flexural strength of concrete, modulus of elasticity, Poisson's ratio, and temperature differential. The engineering properties of the subgrade soil are evaluated through laboratory tests to determine its load-supporting capacity. Similarly, the properties of cement concrete including compressive strength, flexural strength, elastic modulus, and density are determined according to Indian Standard specifications. The collected data are verified before pavement analysis to ensure accurate and reliable computational results. After completing the input preparation, the rigid pavement structure is developed using KENPAVE. The pavement model consists of a Portland Cement Concrete (PCC) slab, Dry Lean Concrete (DLC) base, Granular Sub-Base (GSB), and the prepared subgrade. The required material properties such as slab thickness, modulus of elasticity, Poisson's ratio, and modulus of subgrade reaction are assigned to each pavement layer. Standard wheel loads, tyre pressure, and loading positions are defined in the software according to IRC recommendations. The pavement is then analysed under interior loading, edge loading, and corner loading, which represent the most critical loading conditions experienced by rigid pavements during service.

The KENPAVE software performs mechanistic analysis to determine the critical pavement responses under repeated traffic loading. The software automatically computes interior stress, edge stress, corner stress, wheel load stress, slab deflection, load transfer efficiency, and stress distribution throughout the concrete slab. These engineering parameters are compared with the permissible flexural strength of concrete specified in IRC:58-2015. If the computed stresses exceed the allowable design limits, the slab thickness or pavement layer configuration is modified and the analysis is repeated. This iterative design process continues until the pavement satisfies all structural safety and serviceability requirements while maintaining an economical design. Following mechanistic analysis, the designed rigid pavement is evaluated for fatigue performance, load transfer efficiency, structural stability, joint behaviour, and temperature stress resistance. The optimized pavement structure is verified to ensure adequate resistance against cracking, pumping, faulting, and excessive slab deflection. Comparative evaluation of different slab thicknesses and subgrade support conditions enables engineers to determine the most suitable pavement configuration capable of safely carrying projected traffic throughout the design life. The final pavement structure satisfies the fatigue and structural requirements prescribed by IRC:58-2015. Finally, the effectiveness of the proposed methodology is evaluated using engineering performance parameters including wheel load stress, interior stress, edge stress, corner stress, slab deflection, load transfer efficiency, fatigue life, concrete slab thickness, and overall structural stability. The results obtained from KENPAVE confirm that the designed rigid pavement satisfies the mechanistic design requirements specified by IRC:58-2015. The proposed framework provides highway engineers with an efficient, reliable, and scientifically validated approach for designing rigid pavements capable of supporting heavy traffic while ensuring improved durability, reduced maintenance requirements, enhanced riding quality, and long-term structural performance.

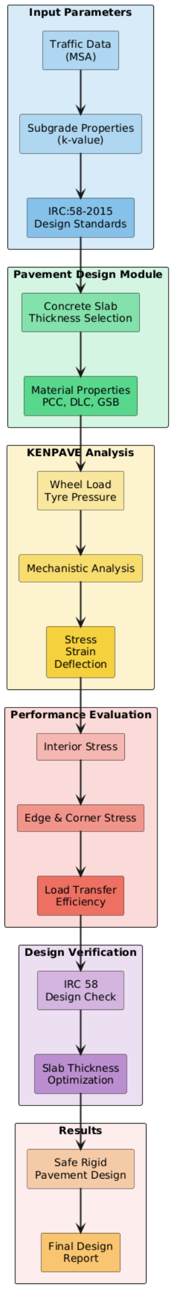

Fig1: Proposed workflow

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 Analysis and Design of Rigid Pavement Using KENPAVE and IRC:58-2015 Methods was carried out using the KENPAVE mechanistic pavement analysis software to develop a structurally safe, durable, and economical rigid pavement capable of carrying heavy traffic loads. The implementation involved traffic data collection, subgrade investigation, pavement material selection, rigid pavement modelling, mechanistic stress analysis, slab thickness optimization, and structural performance evaluation. The complete design process was performed in accordance with the recommendations of IRC:58-2015, ensuring that the designed pavement satisfies the structural and serviceability requirements 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), wheel load, axle configuration, modulus of subgrade reaction (k-value), and climatic conditions. Laboratory tests were conducted to determine the engineering properties of pavement materials, including the compressive strength, flexural strength, modulus of elasticity, Poisson's ratio, and density of Portland Cement Concrete (PCC). The properties of the Dry Lean Concrete (DLC) layer, Granular Sub-Base (GSB), and prepared subgrade were also evaluated to ensure accurate pavement modelling. These design parameters formed the basis for mechanistic analysis in KENPAVE.

After completing the data collection process, the rigid pavement structure was modelled in KENPAVE. The pavement system consisted of a Portland Cement Concrete (PCC) slab, Dry Lean Concrete (DLC) base, Granular Sub-Base (GSB), and the prepared subgrade. Each pavement layer was assigned its corresponding thickness, elastic modulus, Poisson's ratio, and material properties according to IRC:58-2015 recommendations. Wheel load magnitude, tyre pressure, contact radius, and loading position were specified before initiating the analysis. The pavement model was then analysed under interior loading, edge loading, and corner loading, representing the most critical loading conditions encountered during the service life of rigid pavements. The completed pavement model was verified to ensure correct assignment of all design parameters before commencing structural analysis.

The KENPAVE software performed mechanistic analysis by evaluating the stress and deflection characteristics of the rigid pavement under repeated wheel loading. The software automatically calculated interior stress, edge stress, corner stress, wheel load stress, slab deflection, stress distribution, and load transfer efficiency within the concrete slab. These parameters are essential for evaluating the structural behaviour of rigid pavements and determining their resistance to fatigue cracking and structural deterioration. The analytical results were generated in both numerical and graphical forms, enabling engineers to identify critical stress regions and evaluate the adequacy of the selected pavement thickness.

Following mechanistic analysis, the computed stresses were compared with the allowable flexural strength of concrete specified by IRC:58-2015. If the calculated interior, edge, or corner stress exceeded the permissible limit, the concrete slab thickness was increased and the pavement model was analysed again. Similarly, if excessive slab deflection or poor load transfer efficiency was observed, modifications were made to the pavement configuration, joint design, or supporting layers. This iterative optimization process continued until all structural parameters satisfied the design requirements prescribed by IRC standards. Proper joint spacing, dowel bars, and tie bars were incorporated to improve load transfer between adjacent concrete slabs and minimize differential settlement and joint distress.

Finally, the optimized rigid pavement structure was evaluated using important engineering performance parameters including wheel load stress, interior stress, edge stress, corner stress, slab deflection, load transfer efficiency, fatigue resistance, concrete slab thickness, and overall structural stability. Comparative analysis confirmed that the designed rigid pavement satisfied all structural requirements specified in IRC:58-2015. The obtained stress values remained within the allowable flexural strength of concrete, while slab deflections were maintained within acceptable serviceability limits. The implementation demonstrated that KENPAVE provides an accurate and reliable platform for analysing rigid pavements subjected to heavy traffic loading. The developed methodology enables highway engineers to optimize slab thickness, improve structural durability, reduce maintenance costs, and achieve economical pavement construction while ensuring long-term serviceability and safe highway operation.

VI. RESULTS EXPLANATIONS

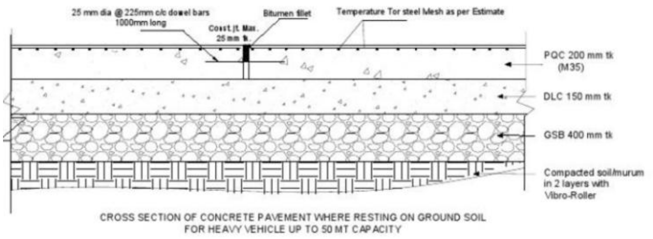

Figure 2. Structural Model of the Rigid Pavement

Figure 2 illustrates the multilayer rigid pavement structure developed for analysis using KENPAVE according to IRC:58-2015 recommendations. The pavement consists of a Portland Cement Concrete (PCC) slab, Dry Lean Concrete (DLC) base, Granular Sub-Base (GSB), and the prepared subgrade. Each layer performs a specific structural function in distributing wheel loads and protecting the underlying foundation. The PCC slab acts as the primary load-carrying layer due to its high flexural strength, while the DLC and GSB layers provide uniform support and improve load distribution. The subgrade acts as the foundation supporting the entire pavement structure. Appropriate layer thicknesses and material properties were assigned based on IRC standards before initiating mechanistic analysis. The developed pavement model accurately represents actual field conditions and forms the basis for evaluating slab stresses, deflections, and load transfer efficiency under repeated traffic loading. The structural configuration ensures improved durability, reduced maintenance requirements, and enhanced service life for heavy-duty highway applications.

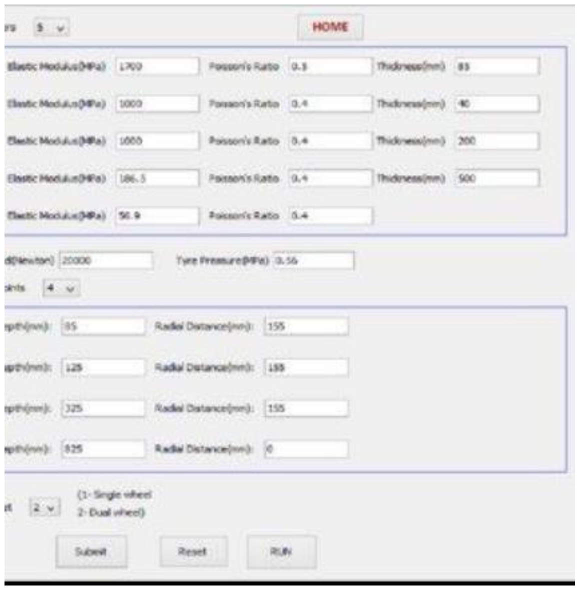

Figure 3. Input Parameters Used in KENPAVE Analysis

Figure 3 presents the input parameters entered into KENPAVE before performing rigid pavement analysis. The software requires engineering parameters including wheel load, tyre pressure, concrete slab thickness, modulus of elasticity, Poisson's ratio, modulus of subgrade reaction (k-value), and pavement layer properties. These values were selected according to IRC:58-2015 recommendations and laboratory test results. Accurate input data are essential because the computed stresses and slab deflections directly depend on these material and loading properties. The software interface allows engineers to modify pavement thickness, loading conditions, and support characteristics to evaluate alternative design configurations. Proper definition of these parameters improves the accuracy of stress prediction and facilitates optimization of pavement thickness while ensuring compliance with IRC design requirements. The validated input model provides reliable numerical results for structural analysis and pavement performance evaluation.

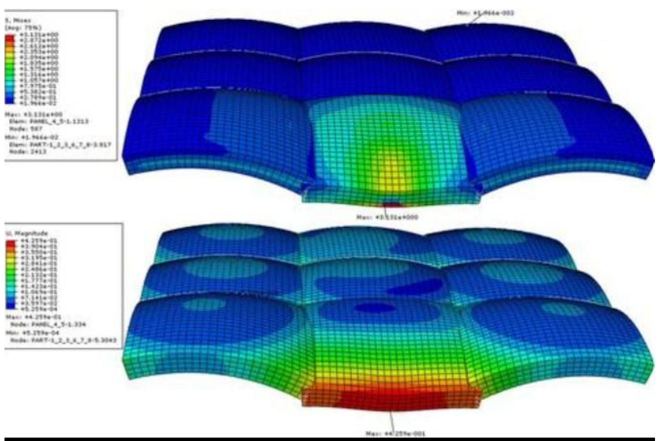

Figure 4. Interior Stress Distribution in the Concrete Slab

Figure 4 illustrates the interior stress distribution obtained from the mechanistic analysis performed using KENPAVE. Interior loading represents the condition where the wheel load acts near the centre of the concrete slab. Under this loading condition, bending stresses are distributed uniformly within the slab because the surrounding concrete provides adequate structural support. The software computes the interior stress based on the slab thickness, modulus of elasticity, modulus of subgrade reaction, and applied wheel load. The calculated stress values remained below the allowable flexural strength of the concrete specified in IRC:58-2015, indicating that the proposed slab thickness is structurally adequate. The stress contour also demonstrates effective load distribution across the pavement layers, reducing localized stress concentrations and improving fatigue resistance. These results confirm that the designed rigid pavement possesses sufficient structural capacity to safely support repeated traffic loading while maintaining long-term durability and serviceability.

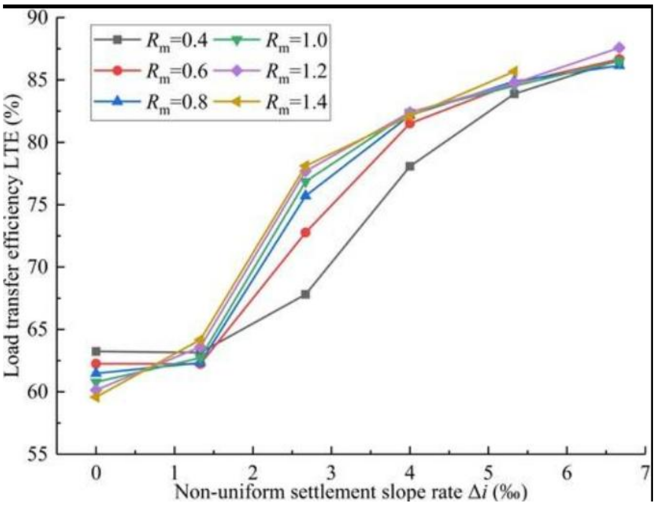

Figure 5. Slab Deflection and Load Transfer Performance

Figure 5 illustrates the slab deflection profile and load transfer performance obtained from KENPAVE. The software evaluates vertical displacement of the concrete slab under wheel loading and determines the effectiveness of load transfer between adjacent slabs through joints. The maximum deflection occurs directly beneath the applied wheel load and gradually decreases away from the loading point due to the stiffness of the concrete slab and the supporting pavement layers. The calculated deflection values remained within the permissible limits specified by IRC:58-2015, indicating satisfactory structural behaviour and serviceability. Efficient load transfer across pavement joints minimizes differential settlement, reduces edge stresses, and prevents premature failures such as pumping and faulting. The results demonstrate that the selected slab thickness, joint design, and supporting layers provide adequate structural stability and ensure the long-term performance of the rigid pavement under repeated heavy traffic loading.

VII. CONCLUSION

The present study successfully analysed and designed a Rigid Pavement Using KENPAVE and IRC:58-2015 Methods by adopting the mechanistic–empirical pavement design approach. The pavement structure was designed considering important engineering parameters including design traffic, wheel load, modulus of subgrade reaction (k-value), modulus of elasticity of concrete, Poisson's ratio, flexural strength of concrete, and temperature effects in accordance with the recommendations of IRC:58-2015. A multilayer rigid pavement consisting of a Portland Cement Concrete (PCC) slab, Dry Lean Concrete (DLC) base, Granular Sub-Base (GSB), and prepared subgrade was modelled and analysed using KENPAVE. Critical pavement responses such as interior stress, edge stress, corner stress, wheel load stress, slab deflection, and load transfer efficiency were evaluated to verify the structural adequacy of the proposed pavement.

The mechanistic analysis demonstrated that the selected concrete slab thickness effectively distributed wheel loads through the pavement structure while minimizing stress concentrations within the concrete slab. The calculated interior, edge, and corner stresses remained below the allowable flexural strength specified by IRC:58-2015, confirming that the pavement possesses sufficient structural capacity to resist repeated traffic loading. The obtained slab deflection values were also within the permissible serviceability limits, indicating satisfactory structural behaviour under heavy axle loads. Proper joint design, together with the use of dowel bars and tie bars, significantly improved load transfer efficiency and reduced the possibility of pavement distress such as cracking, pumping, and faulting.

The implementation of KENPAVE significantly enhanced the accuracy and efficiency of rigid pavement analysis by providing detailed stress, strain, and deflection responses under different loading conditions. The software enabled rapid evaluation of multiple pavement configurations, allowing optimization of slab thickness while reducing unnecessary material consumption and construction costs. The mechanistic approach adopted in this study provides a more reliable prediction of pavement performance compared with conventional empirical methods and supports economical pavement design without compromising structural safety.

Overall, the proposed methodology offers a scientifically validated and practical approach for the design of rigid pavements carrying heavy traffic. The combined use of KENPAVE and IRC:58-2015 ensures improved structural performance, enhanced durability, lower maintenance requirements, and extended pavement service life. The study demonstrates that mechanistic pavement analysis is an effective tool for modern highway engineering and assists engineers in developing safe, reliable, and cost-effective rigid pavements. Future research may focus on incorporating Fiber-Reinforced Concrete (FRC), Roller Compacted Concrete (RCC), recycled construction materials, Finite Element Analysis (FEA), Artificial Intelligence-based pavement optimization, and real-time pavement health monitoring to further improve the sustainability and long-term performance of rigid pavement systems.

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