Analysis of Flexible Pavement using IIT-PAVE Software

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ABSTRACT

The improvement of a country's infrastructure is essential to its economic, social, and industrial growth. These connect people and goods throughout communities and regions, serving as the backbone of our economy and society. These help a variety of industries, from agriculture to manufacturing to tourism, grow by attracting new consumers, suppliers, and staff. This paper's goal is to examine how well and for how long a flexible pavement holds up under different loads and climates. This project entails gathering field data for traffic studies, determining the CBR of the subgrade soil, and creating a flexible pavement in accordance with the requirements of IRC: 37-2012. IITPAVE software is used to analyze the structural behavior of the pavement and predict its performance over time. The article describes the research techniques and conclusions that were utilized to evaluate the initiative. From the findings, it is clear that IITPAVE software can accurately predict pavement behavior and provide insight on the structural response to different loads and environmental circumstances. The study concludes with software-based recommendations for enhanced pavement design and upkeep. This study delves further into how IITPAVE software may be used to examine flexible pavement, and is easiness for the future of sustainable road design.

Keywords: - Flexible Pavement, IIT-PAVE, CBR Value, Fatigue Cracking, Rutting.

1. Introduction

The primary objective of this project is to make extensive use of the cutting-edge features offered by the IIT-PAVE Software in order to carry out an investigation of flexible pavement. Our objective is to determine how well flexible pavements operate and how long they last under a wide range of situations and loads. We are able to successfully simulate and analyse the behaviour of flexible pavements by utilising the cutting-edge capabilities of the IIT Pave software. This provides us with the ability to make well-informed decisions on the design, building, and maintenance strategies for flexible pavements. This research project is of major significance since it will help improve our understanding of the performance of flexible pavement, which will, in the end, contribute to the development of road infrastructure that is more resilient and cost-effective.

Pavements are the backbone of every road network. Even though they are meant to last for 15-20 years, pavements are failing in their first few years of use due to severe weather and early distresses. Poor quality control during construction, excessive axle loads, harsh weather, and a lack of maintenance money all contribute to early pavement failure. In order to make the right choice when it comes to reinforcing the flexible pavement, knowing the degradation pattern is essential. Extreme distresses in flexible pavement are brought on by premature failures such rutting and fatigue. Instead of using the traditional empirical design method, modern pavement designers have shifted to using the Mechanistic-Empirical (M-E) pavement design technique. The M-E design approach's performance prediction is heavily influenced by the pavement stress and strain responses provided by KENPAVE and IITPAVE. This research provides a literature evaluation of KENPAVE and IITPAVE response analysis for flexible pavement. With the use of KENPAVE and IITPAVE, paving materials and paving performance may be analysed more precisely.

Visual inspections, pavement condition index (PCI) surveys, and deflection testing (Benkelman Beam) are some of the ways that the performance of flexible pavement can be evaluated. Other approaches include the use of the Benkelman Beam. There is a theoretical and practical ceiling to the level of precision and efficacy that can be achieved with these methods. The IIT PAVE software was developed to deliver correct stress and strain values at crucial nodes in the architecture of the pavement. Additionally, the programme analyses the pavement's reactivity to various loading situations in order to remedy these issues.

1.1 IIT PAVE Software

IIT PAVE, a programme developed by the Indian Institute of Technology KHARGPUR as an enhanced version of FPAVE under the MoRTH Research Scheme R-56 "Analytical design of Flexible Pavement" [3] was used to conduct the pavement study. Flexible pavement may be examined and evaluated with the use of the IIT PAVE programme. This software is essential in the field of transportation engineering for the design and study of flexible pavement. The IIT PAVE project uses the finite element technique (FEM) to analyse how flexible pavement reacts to different loads. The tool gives a comprehensive analysis of pavement behaviour by taking into account a variety of factors including traffic volumes, weather, and material quality.

The software can simulate different loading conditions, give complete stress and strain data at critical sections of the pavement structure, and analyse pavement performance over time. The IIT PAVE program's user-friendly interface makes it easy to input data, make changes to the pavement's structure, and see the resultant output. IIT PAVE software has revolutionised the field of pavement engineering by providing a more accurate and time-saving method of pavement design and analysis. The strategy has been widely adopted by transportation authorities and specialists across the world because of its effectiveness in constructing sustainable, long-lasting roads. Using the IIT PAVE programme may help you save money and make roads safer for drivers.

Traditional Approaches

Mill and Overlay is a method that involves milling away a certain depth of the surface of the old pavement and then replacing it with a fresh layer of asphalt or concrete. This method is also known as "milling and repaving." It is frequently employed in situations in which the existing pavement has a good structural foundation but needs to have its surface rehabilitated.

Inlay is a technique for repairing localised regions of distress or deterioration in the pavement. This technique, which is also known as partial-depth repair, is referred to as inlay. It entails removing the section of the pavement that is damaged and replacing it with fresh asphalt or concrete in its place.

Full-depth Replacement: A full-depth replacement is utilised in situations in which the current pavement is either structurally deficient or substantially deteriorated. It entails removing the entire piece of the existing pavement that is there, including the subbase and the subgrade, and then replacing it with a new framework for the pavement.

strategies of Rehabilitation There are many different strategies of rehabilitation that can be utilised to restore the usefulness of the pavement as well as its structural integrity. Techniques such as crack sealing, joint resealing, patching, and surface treatments like as slurry sealants and microsurfacing are included in these methods.

Overlay with Interlayer: An interlayer can be placed between the existing pavement and the overlay to improve bond strength, prevent reflective cracking, and enhance the overall performance of the overlay. An example of an interlayer would be a geotextile or a geosynthetic material.

Surface Treatment: Surface treatments, such as chip seals or asphalt emulsion slurry seals, are applied to the existing pavement surface in order to create a protective layer and improve skid resistance. These surface treatments can also be referred to simply as surface coatings. It is usual practise to employ them for the purpose of preventative maintenance and elongating the pavement's service life.

In projects involving pavement overlay, these tried-and-true methods are consistently employed since they have been demonstrated to be beneficial. The state of the existing pavement, the traffic loads, the available budget, and the requirements of the project all play a role in the choice of the method that is going to be the most appropriate.

2. Literature Reviews

A. Harish, (2017) In this the examination of the International Road Congress (IRC): 37-2012 codebook's guidelines for the design of a flexible pavement using a cementitious foundation and sub-base with a stress-absorbing membrane interface (SAMI) is carried out. Engineers use the multi-layer analysis programme IIT PAVE to determine the stresses and strains in critical sections of a flexible pavement. Here, the subgrade soil's engineering properties are examined on a section of road in the Bangalore region. Compared to conventional paving materials, cementitious base and sub-base with SAMI have improved serviceability and cheaper costs owing to considerable reductions in stresses and thickness, as discovered by the study team.

C. Mohan Kumar A N and Praveen Kumar (2020), The objectives of the study is to collect data relating to traffic studies and subgrade soil CBR values from the field, and to design the flexible pavement in compliance with the guidelines established by IRC: 37-2012. The data is then analyzed using the IITPAVE software to determine whether it is up to par. In addition, the HDM-4 assessment of the 56.53-kilometer long National Highway NH-234 is summarized in this project. The HDM-4 programme gathers data on current road conditions, traffic volumes, axle counts, and other criteria to predict the deterioration of roads in the future.

J. Praghna Blessy, Y. Pushpanjali, D. V. Swathy padmaja1, & Praghna Blessy (2019), Plans, designs, and analyses of flexible pavements for the municipal building in Amravati, India, are laid forth here. The asphalt was designed with 2050 traffic forecasts in mind. The design is analyzed using IIT's Pave programme. Fatigue cracking in the bituminous surface to 20% of the pavement's surface area or rutting in the pavement reaching the terminal rutting of 20mm are considered in the mechanistic-empirical data analysis used.

3. Methodology

1. Mechanistic-Empirical (ME) Method

To forecast how a pavement would fare in a variety of traffic and weather scenarios, engineers might use the Mechanistic-Empirical (ME) method, which blends empirical models with mechanistic analytic approaches. The pavement structure is represented in ME as a stack of layers, each of which has its own set of characteristics and dimensions. Consideration is also given to the volumes of traffic, the weather (including temperature and humidity), and the processes of pavement distress (including cracking and rutting). The effect of these variables on pavement performance is estimated using empirical models calibrated with information gathered from prior research and on-the-ground observations. The features of the pavement layers and the loads they receive are then employed in a mechanistic analysis model to predict the stresses and strains inside the pavement structure. The ME technique integrates these two strategies to provide more reliable forecasts of pavement performance and aid in the choice of materials and design elements. The ME technique is extensively utilised in the transportation industry for pavement design and analysis, and has been accepted by several organisations.

2. Pavement is modelled as multilayer System

The "linear elastic layered theory," which models the pavement as a multi-layer system, has been chosen as the theory for the analysis of pavements. All of the top levels are supposed to be infinite in horizontal extent and finite in thickness, with the exception of the bottommost layer (foundation or subgrade), which is semi-infinite. The many layers of the flexible pavement are depicted in Figure 1.

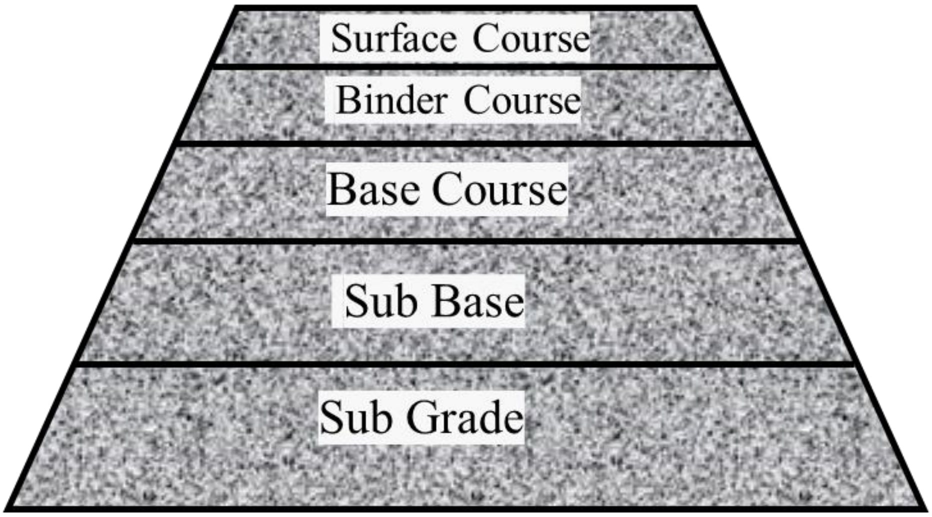


Figure 1. Different layers of flexible pavement

finite element method- As a form of numerical analysis, the finite element method (FEM) may be used to find approximations to a wide range of engineering issue solutions. Continuum mechanics is a large subject that has benefited from the theory, which was initially created to examine stresses in complex aircraft structures (Huebner et al., 2001[1]). Since the relevant variables in a continuum issue (such as one involving a continuous surface or volume) are functions of each generic point in the continuum, they can take on an unlimited number of values. Because the functions describing the stresses in a given piece of pavement are site-specific, there is no universal equation that can be used to solve for those stresses. In contrast to a precise closed-form solution for the whole pavement volume, an approximate numerical solution may be obtained for each of a large number of tiny discrete volumes using the finite element approach. Fifty years ago, the calculations required to achieve this were extremely time-consuming; now, computers can execute them with relative ease.

Wheel loads are located at the top of the region of interest in a flexible pavement's FEM analysis, which is why the pavement and subgrade are discretized into a number of elements (Figure 3). All regions of interest under the wheel's sway are represented by finite components that radiate outward in all directions from the centre of the wheel.

When compared to the layered elastic technique, the FEM method requires fewer assumptions since it employs a more complicated mathematical model. As a rule, FEM has to make certain assumptions about the values at the edges of the study area. For instance, the Winkler Foundation is modelled in the computer programme EverFlex created by Hongyu Wu and George Turkiyyah of the University of Washington (Wu, 2001[2]). Each of the four sides of the flexible pavement model in this programme is delimited by free bounds. The total performance of the model will also be affected by the interpolation functions and element geometry (size and shape) that are used.

Layered elastic model

When a surface load is applied to a pavement, a layered elastic model can determine the stresses, strains, and deflections at every location along the pavement. In layered elastic models, the underlying pavement layers are assumed to be identical in composition, isotropic in nature, and linearly elastic. That is to say, it behaves consistently regardless of location, and it recovers its initial shape when pressure is released. V.J. Boussinesq, in his seminal work from 1885, is widely regarded as the creator of layered elastic theory. The field of soil mechanics and foundation design continues to rely heavily on Boussinesq impact charts. In this part, we will go through the usual inputs, assumptions, and outputs of a layered elastic model.

The layered elastic method relies on simplifying assumptions since it is applicable to less complex mathematical models. The presumptions here are:

The horizontal extent of the paving layers is unlimited.

The subgrade, which is the base stratum, goes on forever.

Elastic limits of the materials are not exceeded.

Defects in Pavements

Alligator Cracking

Alligator cracking occurs when a load is applied to a structure. Weakness in the surface, base, or sub grade; too little surface or base; inadequate drainage; or some combination of these can cause failure. Alligator cracking is the last stage of what begins as longitudinal cracking in the wheel path and generally results from extreme stress.

Block Cracking

Large, overlapping rectangles best describe the appearance of block fractures. In most cases, asphalt pavement has block cracking because the asphalt binder is unable to expand and contract in response to changes in temperature. Too little water was used during mixing and placement, too much asphalt binder was used in the mix design, fine particles were used, asphalt penetration was limited, absorptive aggregates were used, asphalt binder choice was poor, or the asphalt had aged and dried out.

Longitudinal (Linear) Cracking

Parallel to the pavement's centerline or laydown direction is what we call longitudinal cracking. Pavement fatigue, reflective cracking, and inadequate joint structure are all potential causes. In most pavements, joints have the lowest density.

Transverse Cracking

Single cracks that run perpendicular to the pavement's centerline or laydown direction are called transverse cracks. Poor construction owing to incorrect operation of the paver, daily temperature fluctuations, and reflecting fissures from an underlying layer are all potential causes of transverse cracks.

Edge Cracks

The length of an edge crack on a paved area is typically between one and two feet. Poor drainage and a lack of edge support are the most prevalent causes of this sort of fracture in pavement. The outcome is a weakening and eventual settlement of the underlying foundation materials. Intense traffic and the presence of thick hedges or trees at the pavement's edge can also cause cracking.

Joint Reflection Cracks

The pavement in question is an asphalt overlay over concrete, and it has developed fractures. As a result, they appear just atop the stiff pavement joints below. Reflection cracks that do not appear near an underlying joint or any other sort of base (such as cement or lime stabilised) are not considered joint reflection cracking.

Slippage Cracks

When fresh asphalt slides over an older course, it can cause crescent-shaped fissures or rips in the surface layers. A breakdown in interlayer adhesion is to blame for this issue. It usually happens when a prime coat isn't utilised to attach the asphalt to the underlying stone base course or when a tack coat isn't used to form a link between the asphalt layers. Contaminants like dirt, grease, or dust can also play a role in preventing the layers from sticking together.

Pot Holes

Potholes are divots or craters in the pavement that are deeper than the asphalt layer and extend into the base course. Near the opening's apex, they often have sharp corners and straight sides. Water seepage causes potholes, which are the ultimate outcome of alligator cracking that has gone untreated. When alligator cracking gets severe, little pieces of pavement are formed as a result of the interconnecting fissures. A pothole is the crater left in the road when a section of pavement has been broken loose.

Depressions (bird baths)

Small, localised sections of pavement having a lower height than the surrounding pavement are called depressions. After a downpour, puddles and depressions become striking features.

3.1 Traffic Data Collection – For a period of 7 days, the traffic volume on the project road was assessed by conducting manual counts of the vehicles moving in both directions.

TRAFFIC CENSUS																				
From 22-06-2021 To 23-06-2021							WEEKLY TAFFIC SUMMARY						Road Classification :: Other District Road							
Name Of Work	Kamasin - Oran Road , Strengthening of Kamasin – Oran Road from 0.00 Kmp to 6.00 Kmp under PWD BANDA																			
Count Dates	Fast Vehicles											Slow Vehicles								
	Cars, Jeeps, Vans, Three Wheelers etc.		Buses		Trucks		Motor cycles & Scooters		Total Fast			Animal Drawn Vehicles		Cycles		Rickshaw Others (Specify)		Total Slow		
	Up	Down	Up	Down	Up	Down	Up	Down	Up	Down	Total col. 10 & 11	Up	Down	Up	Down	Up	Down	Up	Down	Total col. 19 & 20
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
DAY : 1	124	122	343	338	408	434	154	175	1029	1069	2098	0	0	123	142	92	100	215	242	457
DAY : 2	121	121	490	378	359	287	146	185	1116	971	2087	0	0	167	166	138	134	305	300	605
DAY : 3	124	125	338	309	435	438	164	172	1061	1044	2105	0	0	132	101	96	106	228	207	435
DAY : 4	132	114	418	412	367	337	120	142	1037	1005	2042	0	0	122	109	101	114	223	223	446
DAY : 5	109	110	434	408	364	332	121	141	1028	991	2019	0	0	153	146	112	149	265	295	560
DAY : 6	107	101	418	380	373	346	124	144	1022	971	1993	0	0	146	145	86	208	232	353	585
DAY : 7	96	86	426	405	362	367	124	134	1008	992	2000	0	0	125	126	112	143	237	269	506
Total	813	779	2867	2630	2668	2541	953	1093	7301	7043	14344	0	0	968	935	737	954	1705	1889	3594
7 days average	116	111	410	376	381	363	136	156	1043	1006	2049	0	0	138	134	105	136	244	270	513
Total Up & Down for Vehicle Type	227		785		744		292		2049			0		272		242		513		

Table 1.

Total Numbers of commercial vehicles

P = [Total no. of Buses in Both Direction + Total no. of Truck (including Agricultural Tractor) in Both Direction]

= 785 + 744

= 1529 CV/Day

A = Initial traffic (commercial vehicles per day) in the year of completion of construction

r = Annual growth rate of commercial vehicles in decimal (5% = 0.05)

x = No. of years between the last count and the year of completion of construction = 2

$$\mathbf{A} = \boldsymbol{P(1+r)^{x}}$$

$$= 1529(1+0.05)^{2}$$

$$= 1686\ CV/Day$$

3.2 Computation of Design Traffic

$$\textbf{NDes} = \frac{365\,x\,[(1+r)^n - 1]}{r} \textbf{ x A X D X F}$$

NDes = Cumulative number of standard axles to be catered for during the design period of 'n' years

A = Initial traffic (CV/Day) in the year of completion of construction = 1686 CV/Day

D = Lateral distribution factor (as explained in IRC 37-2018 para 4.5) = 0.5

F = Vehicle damage factor (VDF) = 5

r = Annual growth rate of commercial vehicles in decimal

n = Design period in years = 20 Years

$$N = \frac{365\,x\,[(1+0.05)^{25} - 1]}{0.05} \text{ x } 1686 \text{ X } 0.5 \text{ x } 5$$

N = 73426948.35 Standard Axel (sa)

N = 73.42694835 million Standard Axel (msa)

N = 74 msa

3.3 Performance Criteria

Subgrade Rutting Criteria

The term "subgrade rutting criteria" describes the maximum amount of rutting or deformation permitted in a pavement structure's subgrade layer prior to the pavement being deemed to have failed or reached the end of its useful life. The rules define a critical or failure rutting condition as an average rut depth of 20 mm or greater along the wheel tracks.

$\mathbf{N_R = 4.1656 \times 10^{-8}\, [1/\varepsilon_V]^{4.5337}}$ (for 80 % reliability IRC:37-2018 Eq – 3.1)

$\mathbf{N_R = 1.4100 \times 10^{-8}\, [1/\varepsilon_V]^{4.5337}}$ (for 90 % reliability IRC:37-2018 Eq – 3.2)

Where,

N_R = Subgrade rutting life is the total amount of 80 KN standard axle loads that the pavement can support before reaching a critical rut depth of 20 mm or more.

ε_v = By applying a normal axle load to the surface of the chosen pavement system, vertical compressive strain at the top of the subgrade is computed using the linear elastic layered theory.

Use models with a 90% dependability for bituminous layer cracking and subgrade rutting (design traffic > 20 msa).

$\mathbf{N_R = 1.4100 \times 10^{-8}\, [1/\varepsilon_V]^{4.5337}}$ (for 90 % reliability)

$$74 \times 10^6 = 1.4100 \times 10^{-8} [1/\varepsilon_V]^{4.5337}$$

ε_v = **0.0003409**

Allowable vertical compressive strain on subgrade for a design traffic of 74 msa and for 90 % reliability (using equation 3.2) = **0.0003409 (0.301 X 10^{-3})**

3.4 Fatigue cracking criteria for bituminous layer

According to the guidelines, the critical or failure condition for fatigue cracking is when the total area of interconnected cracks in the section of the road under consideration is 20% or more than the paved surface area of the section.

To determine the number of standard axle load repetitions (80 KN) that the pavement can serve before reaching the critical condition of a cracked surface area of 20% or more, IRC: 37-2018 equations 3.3 and 3.4 are used. These equations provide the equivalent number of repetitions for 80% and 90% reliability levels, respectively.

$$N_f = 1.6064 \times C \times 10^{-4} \times \left[\frac{1}{\varepsilon_t}\right]^{3.89} \times \left[\frac{1}{M_{RM}}\right]^{0.854} \quad \text{(For 80 % reliability Eq – 3.3)}$$

$$N_f = 0.5162 \times C \times 10^{-4} \times \left[\frac{1}{\varepsilon_t}\right]^{3.89} \times \left[\frac{1}{M_{RM}}\right]^{0.854} \quad \text{(For 90 % reliability Eq – 3.4)}$$

N_f = Fatigue life of bituminous layer (cumulative equivalent number of 80 KN standard axle loads That can be served by the pavement before the critical cracked area of 20 % or more of paved surface area occurs)

ε_t = Standard axle load applied to the pavement surface yields the maximum horizontal tensile strain in the bottom bituminous layer (DBM) as determined by linear elastic layered theory.

M_{Rm} = Resilient modulus (MPa) of the bituminous mix used in the bottom bituminous layer, selected as per the recommendations made in these guidelines.

Mix design considerations were integrated into the fatigue performance model by including an adjustment factor (denoted by the letter 'C') in the fatigue models to account for the effect of variation in the mix volumetric parameters (effective binder volume and air void content) on the fatigue life of bituminous mixes.

$$C = 10^M, \quad M = 4.84 \left[\frac{V_{be}}{V_{be}+V_a} - 0.69\right]$$

V_a = Per cent volume of air void in the mix used in the bottom bituminous layer

V_{be} = Per cent volume of effective bitumen in the mix used in the bottom bituminous layer

$$M = 4.84 \left[\frac{11.5}{11.53+3} - 0.69\right] = 0.499$$

$$C = 10^{0.499}$$

Use 90 % reliability performance models for subgrade rutting and bituminous layer cracking (design traffic > 20 msa)

$$N_f = 0.5162 \times C \times 10^{-4} \times \left[\frac{1}{\varepsilon_t}\right]^{3.89} \times \left[\frac{1}{M_{RM}}\right]^{.0.854} \quad \text{(for 90 \% reliability)}$$

$$74 \times 10^6 = 0.5162 \times 10^{0.499} \times 10^{-4} \times \left[\frac{1}{\varepsilon_t}\right]^{3.89} \times \left[\frac{1}{3000}\right]^{.0.854}$$

$$\varepsilon_t = 0.000172799$$

Design traffic of 74 msa, 90% dependability, air void content of 3%, effective binder volume of 11.5%, and resilient modulus of 3000 MPa for bottom rich bottom DBM layer (DBM-I) (using Equation 3.4) allowable horizontal tensile strain at the bottom of bituminous layer. = **0.0001728 (0.1728 X 10^{-3})**

4.Data Required for Analysis by IIT Pave Software

Number of Layer: The current IITPAVE software version can evaluate pavements with up to ten layers, including the subgrade. When there are more than 10 layers in a pavement, layers with similar properties, like granular or bituminous, can be combined and treated as a single layer. In my analysis, there are three pavement layers total (bituminous layer, granular layer, and subgrade). All bituminous layers are treated as one layer, and all granular levels are treated as one layer.

CBR Value: The CBR (California Bearing Ratio) test measures the ratio of the force per unit area needed to penetrate a standard circular plunger with a 50 mm diameter at a constant rate of 1.25 mm/min into a soil sample to the force needed to achieve the same penetration in a standard material. For this test, the typical penetration depths are 2.5 mm and 5 mm. The ratio at 5 mm is used if the CBR ratio there is consistently higher than the ratio at 2.5 mm.

$$\text{CBR Value} = \frac{\text{Load Sustained by Sample at 2.5 MM Penetration}}{\text{Standard Load}} \times 100$$

$$= \frac{110}{1370} \times 100$$

$$= 8\%$$

Resilient modulus/Elastic modulus: The capacity of a flexible pavement to resist deformation when subjected to an applied load is known as its elastic modulus. It gauges the pavement's stiffness, or its capacity to disperse stresses and strains brought on by loads. The elastic modulus based on the recoverable strain under repeated loads is called the resilient modulus (Mrs). The repeated tri-axial test described in AASHTO T307-99[19] can be used to measure the resilient modulus of soils in a laboratory setting. The following relationships can be used to calculate the resilient modulus of subgrade soil (MRS) from its CBR value because this equipment is typically pricey.

A. Elastic Modulus of Subgrade (M_{RS})-

$$M_{RS} = 17.6 * (\text{CBR})^{0.64} \qquad \text{for CBR} > 5\ \% \ (6.2)$$

$$= 17.6 * (8)^{0.64}$$

$$= 66.60 \text{ MPa} \qquad \text{(less than 100 MPa, the upper limit, OK)}$$

Road Section	**Bituminous Layer**			**Granular Layer**		**Subgrade Layer**
Kamasin to Oran Road	Surface layer	DBM-I	DBM-II	Granular Base	Granular Sub Base	Sub-Grade
	50	60	80	250	230	Semi-Infinite
Total	**190**			**480**		

Table 2. Composition of Road

B. Elastic modulus of the granular layer

$$\mathbf{M_{RGRAN} = 0.2.(H)^{0.45}.M_{RSUPPORT}}$$

Where,

H = Thickness of granular layer in mm
MRGRAN = Resilient modulus of the granular layer (MPa)
MRSUPPORT = (Effective) resilient modulus of the supporting layer (MPa)

$$\mathbf{M_{RGRAN} = 0.2.(H)^{0.45}.M_{RSUPPORT}}$$

$$= 0.2.X(480)^{0.45}X66.60$$

$$= 214.32$$

$$= 215 \text{ Mpa}$$

C. Elastic/Resilient Modulus of **Bituminous layer:** We use VG40 Bitumen according to IRC 37-2018 elastic modulus is taken 3000.

Poisson's Ratio: The Poisson's ratio is a material property that relates the lateral strain to the longitudinal strain when a material is subjected to an applied load. In the context of flexible pavement, the Poisson's ratio refers to the ratio of the transverse strain to the longitudinal strain. According to IRC: 37-2018 **Poisson’s Ratio** = 0.35 (For all layers).

Tyre Pressure: Tyre pressure refers to the amount of air pressure that is inside a vehicle's tyres. The contact pressure of **0.56 MPa** is typically used for calculating the vertical compressive strain on top of the subgrade and the horizontal tensile strain at the bottom of the bituminous layer. This value represents the average contact pressure between the tire and pavement surface under normal operating conditions.

Wheel load & Wheel Set: The force that a vehicle wheel applies to the pavement surface is referred to as the wheel load. The pavement's responsiveness to traffic loads is determined by this crucial input element. A single wheel load is used in the IITPAVE software's examination of flexible pavement.

A set of wheels that are installed on the same axle is referred to as a wheelset. A wheelset is an essential part of numerous modes of transportation, such as trains, buses, trucks, and trailers. For analysis, a dual wheel set is used, with each wheel carrying a force of 20,000

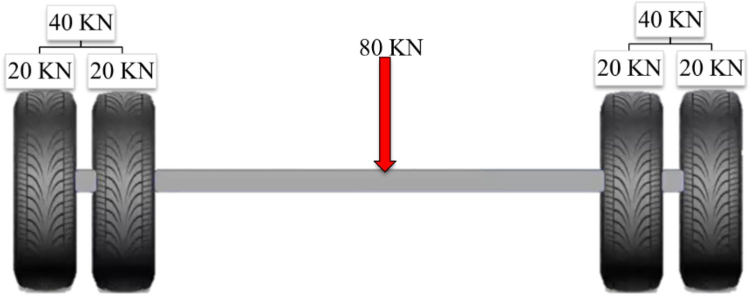


Figure 2. Wheel load assembly of single axle dual wheel load

Newton. The wheel load assembly for a single axle twin wheel load is shown in Figure 2.

Analysis Point: When analysing flexible pavement with IITPAVE software, a specific place inside the pavement structure is usually chosen, usually the key area where the greatest stresses or strains are anticipated to occur. The sort of study being done and the design criteria being taken into account usually decide this location.Permanent deformation in the subgrade is thought to be caused by vertical strain on top of the subgrade ((ε_V).An indication of fatigue cracking in the bituminous layer is the horizontal tensile strain (ε_t) near the bottom of the bituminous bound layer.

Analysis point depth is computed horizontally from the dual wheel's centre line, and radial distance is calculated vertically from the top layer.

Analysis Point = 4

Point 1 : 190 mm (From Top) Radial Distance = 0
Point 1 : 190 mm (From Top) Radial Distance = 155
Point 1 : 660 mm (From Top) Radial Distance = 0
Point 1 : 660 mm (From Top) Radial Distance = 155

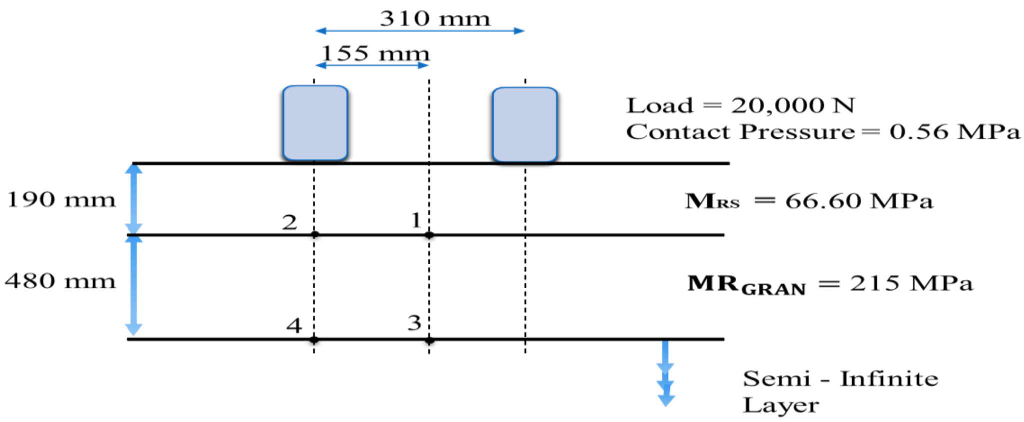
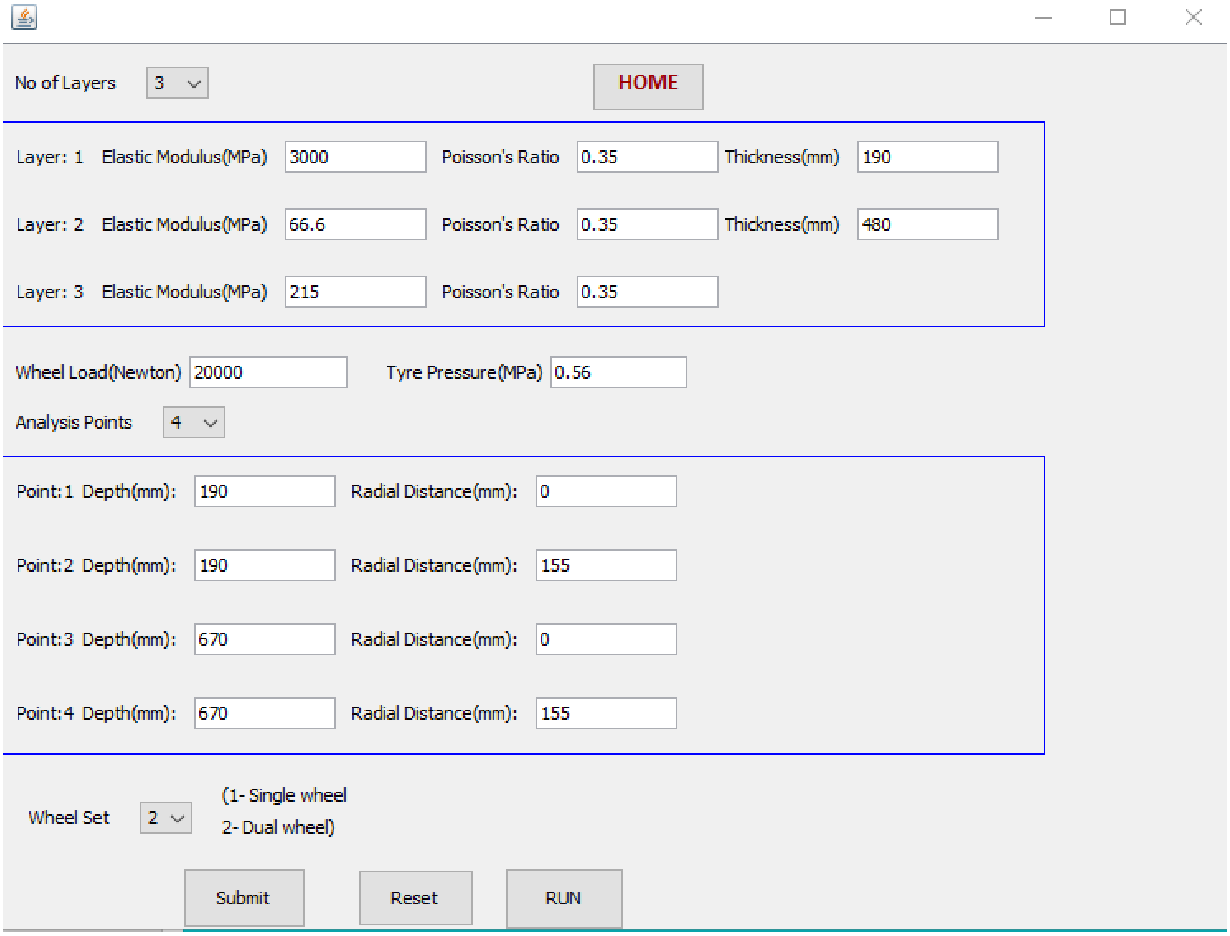
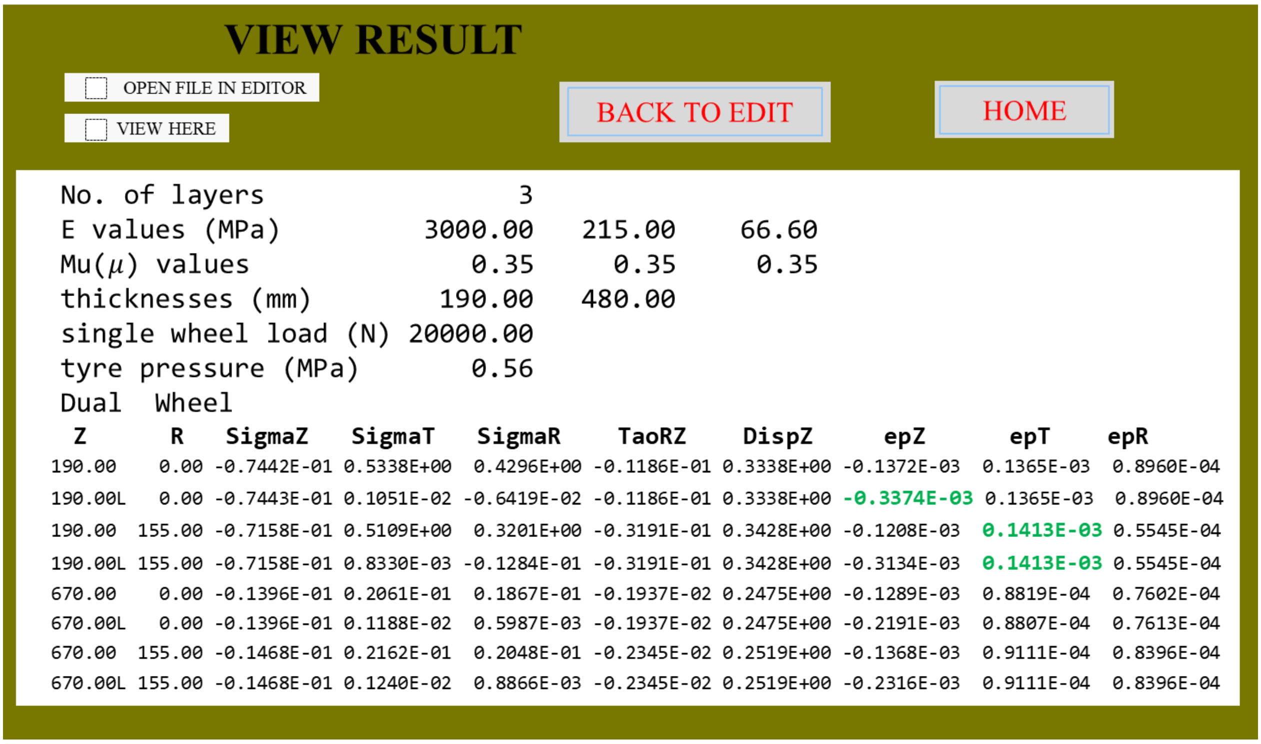


Figure 3.

INPUT IN IIT PAVE





No. of layers	3		
E values (MPa)	3000.00	215.00	66.60
Mu(μ) values	0.35	0.35	0.35
thicknesses (mm)	190.00	480.00	
single wheel load (N)	20000.00		
tyre pressure (MPa)	0.56		

Dual Wheel

Z	R	SigmaZ	SigmaT	SigmaR	TaoRZ	DispZ	epZ	epT	epR
190.00	0.00	-0.7442E-01	0.5338E+00	0.4296E+00	-0.1186E-01	0.3338E+00	-0.1372E-03	0.1365E-03	0.8960E-04
190.00L	0.00	-0.7443E-01	0.1051E-02	-0.6419E-02	-0.1186E-01	0.3338E+00	**-0.3374E-03**	0.1365E-03	0.8960E-04
190.00	155.00	-0.7158E-01	0.5109E+00	0.3201E+00	-0.3191E-01	0.3428E+00	-0.1208E-03	**0.1413E-03**	0.5545E-04
190.00L	155.00	-0.7158E-01	0.8330E-03	-0.1284E-01	-0.3191E-01	0.3428E+00	-0.3134E-03	**0.1413E-03**	0.5545E-04
670.00	0.00	-0.1396E-01	0.2061E-01	0.1867E-01	-0.1937E-02	0.2475E+00	-0.1289E-03	0.8819E-04	0.7602E-04
670.00L	0.00	-0.1396E-01	0.1188E-02	0.5987E-03	-0.1937E-02	0.2475E+00	-0.2191E-03	0.8807E-04	0.7613E-04
670.00	155.00	-0.1468E-01	0.2162E-01	0.2048E-01	-0.2345E-02	0.2519E+00	-0.1368E-03	0.9111E-04	0.8396E-04
670.00L	155.00	-0.1468E-01	0.1240E-02	0.8866E-03	-0.2345E-02	0.2519E+00	-0.2316E-03	0.9111E-04	0.8396E-04

Design and analysis of Kamasin – Oran Road from 0.00 Km to 6.00 Km under PWD BANDA	
MSA	**74**
Effective CBR Of Subgrade (%)	**8**
Resilient Modulus of Subgrade	**66.6**
Resilient Modulus of Granular Layer	**215**
Trial Thickness	
Bituminous (BC+DBM)	**190**
Granular Layer (WMM+GSB)	**480**
Modulus Of Bituminous Mix (MPa)	**3000**
Allowable Horizontal Tensile Strain	**0.000173725**
Allowable Vertical Compressive Strain	**0.000340903**
Computed Horizontal Tensile Strain (Ept) From IIT	**0.0001413**

PAVE		
Computed Vertical Compressive Strain (Epz) From IIT PAVE	**0.0003374**	
RESULTS -		
Computed Horizontal Tensile Strain from IIT PAVE < Allowable Horizontal Tensile Strain	**0.0001413 < 0.0001737**	**SAFE**
Computed Vertical Compressive Strain from IIT PAVE < Allowable Vertical Compressive Strain	**0.0003374 < 0.0003409**	**SAFE**

Table 3. Outcome from IITPAVE

Conclusion

IITPAVE is a cutting-edge strategy for paving design and upkeep that makes use of modern technology and data analysis. IITPave's objectives and advantages above conventional approaches are as follows:

IITPave's objectives:

1. Enhanced Performance: IITPave's main goal is to improve pavement performance by incorporating real-time data, sophisticated modelling methods, and clever decision-making algorithms.

2. Cost Optimisation: IITPave uses predictive models and analysis to make well-informed judgements about materials, maintenance schedules, and rehabilitation procedures in order to reduce costs related with pavement design, construction, and maintenance.
3. Longevity and Sustainability: By taking into account elements like environmental effect, durability, and the utilisation of recycled materials, IITPave focuses on extending the longevity and sustainability of pavements.

Advantages of IITPave:

1. Enhanced Accuracy: IITPave uses cutting-edge data collection techniques including remote sensing, LiDAR, and ground-penetrating radar to acquire accurate data on the subgrade characteristics, traffic loadings, and pavement conditions. Decisions about design and maintenance become more accurate as a result.
2. Real-Time Monitoring: Using sensor networks and IoT devices, IITPave offers real-time monitoring of pavement conditions. This lowers the likelihood of catastrophic failures by enabling prompt identification of distresses, prompt intervention, and proactive maintenance.
3. Predictive Maintenance: IITPave can forecast the performance of pavements in the future and suggest suitable maintenance approaches by analysing data gathered from diverse sources. This helps to minimise delays brought on by unforeseen breakdowns and optimise maintenance costs.
4. Customised Solutions: IITPave enables customised project needs, traffic patterns, environmental variables, and material considerations in pavement design and maintenance solutions. As a result, approaches are customised to better suit the requirements of certain projects.
5. Better Decision-Making: IITPave offers extensive data analysis, visualisation tools, and simulation capabilities to decision-makers. As a result, stakeholders are better able to make decisions about the design, construction, and maintenance of pavement.

In comparison to conventional approaches, IITPave provides a more sophisticated and data-driven approach to pavement management, resulting in increased performance, cost optimisation, and sustainability.

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