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A Case Study on the Behavior of Flexible Pavement Subgrade Modified with Shredded Tyre Scrap

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ABSTRACT
This study aims to expand the scope of flexible pavement design by incorporating alternative materials, such as tyre scrap, into the subgrade.For this purpose a road has been selected which is Jibantala-Taldi road near Canning (Dist-South 24 Pgs, West Bengal, India), under PWD Govt. of west Bengal. Traffic studies and soil tests were conducted on this road, and IIT PAVE software was utilized to determine the pavement thickness, which was found to be 570mm.The same soil sample, which exhibited California Bearing Ratio (CBR) value of 3.36, was mixed with tyre scrap to examine the modified CBR value, which was found to be 8.90. Using the same traffic data and software, the pavement design was revised, and a thickness of 480mm was determined, representing a reduction of approximately 18.75%. Consequently, it is evident that the incorporation of tyre scrap in the subgrade led to a cost reduction of INR. 24,71,000.00 per Km. when compared to using normal soil.

Keywords- CBR, Cost analysis, IITPAVE, Pavement thickness, Subgrade,

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I. Introduction

Non-biodegradable waste materials like tyres and plastic pose significant challenges to human life and the environment. Exploring alternative uses, particularly in construction, can help address these issues. Waste tyres, with their unique properties of lightweight, insulation, water resistance, durability, and compressibility, can be utilized in road subgrades to enhance the California Bearing Ratio (CBR). Researchers are also investigating the potential of other waste materials like fly ash, fibre, rice husk ash, and recycled tyres as geomaterials. Waste tyre have been used for reinforcing soft soil in road construction [1]. India boasts to be one of the world's largest road networks, but the rapid growth in traffic has rendered the existing roads structurally inadequate. Traditional design and construction practices fall short of meeting construction standards. To overcome these limitations, researchers have sought alternatives, including sub-standard materials and innovative design practices. Waste tyre products have played a crucial role in helping designers solve various engineering problems.Mangi and Sarki [2] found that subgrade soil variability affects pavements. Strengthening the subgrade with scrap tyre aggregates improved California Bearing Ratio (CBR) by 5.1%, 10%, and 28.7% for 5%, 15%, and 30% replacements, respectively. Hussainbhi et al. [3] used IIT PAVE software and IRC: 37-2018 guidelines to design a safe flexible pavement for a 200 km road stretch in Andhra Pradesh, India. They considered various subgrade CBR values and traffic load. Two combinations, bituminous layer with granular base (WMM) and bituminous layer with foam bitumen stabilized RAP, were found to be suitable based on CBR and traffic data. The study offers insights for designing flexible pavements on similar roads. Juliana et al. [4] studied soil stabilization using crumb rubber to improve subgrade soil properties. Laboratory testing showed that mixtures with 4% crumb rubber achieved the highest CBR values, fulfilling subgrade requirements. This method reduces pavement thickness, increases pavement life. Pradeep et al. [5] studied soil strength with partial replacements of waste paper sludge ash (WPSA) and scrap tyre rubber. Optimum concentrations were found to be 6% WPSA and 8% scrap tyre rubber, resulting in increased strength properties. The combination showed potential as soil stabilizers, enhancing unconfined compressive strength and CBR ratio.

Flexible pavements provide great advantages as they can be strengthened and improved incrementally with the increase in traffic. The failure of bitumen pavement is often attributed to fatigue cracking and rutting deformation.This project aims to design flexible pavement for two different types of subgrade with same traffic data, following IRC:37-2018 guidelines [6] and utilizing IIT-PAVE software to determine stress and strain values at critical locations within different pavement layers [7]. The design process heavily relies on the strength of the subgrade soil and the magnitude of traffic load. Various procedures, including data acquisition on traffic, determination of VDF (vehicle damage factor) from axle load test [8] and subgrade soil CBR values, are employed in the design process.In the last few years, several studies have been conducted on the analysis of pavement thickness using IITPAVE software, following IRC:37-2018 guidelines [6]. Pandey et al. [9] studied to find the optimal design of flexible pavement using various method. From the values of the maximum tensile strain and maximum compressive strain obtained from the formulas mentioned in the IRC:37-2018.[6](the manual method) and the values of the tensile and compressive strains obtained by putting the values of thickness of different lyers, conclude the thickness of each layer is to be further reduced by some amount so that the strain differences obtained by both method is reduced. Banerji et al. [10] investigated the use of PET waste bottles to enhance clayey subgrade soil for pavement construction. Adding PET fibers improved soil properties, increasing CBR, UCS, and internal friction angle while reducing compaction characteristics. The addition of PET fibers also reduced pavement thickness and enhanced rutting performance under standard and overloading conditions. Goutami et al. [11] examined life cycle costs of various pavement compositions on the Solapur to Sangareddy section of NH-9. They collected data on traffic studies, axle loads, and sub-grade CBR values. Using IRC: 37-2012 guidelines, [12] they designed a flexible pavement. Comparing it with alternative materials in IRC: 37-2012 [12] and using IIT PAVE software, they found thinner alternate pavements to handle the same traffic, except for CTB and GSB pavements. Murana et al. [13] assessed overloaded trucks' impact on the Jebba-Mokwa-Bokani road in Nigeria State, Nigeria, determining axle load distribution and failure patterns. Results indicate the road was overstressed eight times beyond the standard load, necessitating axle load control systems to prevent pavement damage.One of the main objectives of the present study is to determine the pavement thickness and conduct a cost comparison study for the project road using original soil and shredded tyre scrap mixed soil as subgrade. The Road named Jibantala bazar to Taldi Bazar near Canning (Dist-South 24 Pgs, West Bengal, India) which starts from 0.00Km near Jibantala crossing market (Lat-22°20'37.7"N,Long.-88°36'29.6"E) and ends at Taldi bazar near Railway station (Lat-22°25'11.8"N, Long.-88°39'44.4"E) at 12.45km was taken from PWD Dept, Govt. of West Bengal for study.A random stretch of the road is shown in Fig.1. A comprehensive traffic study, including an axle load test, was conducted on the road to gather the necessary data. The analysis of flexible pavement design for two types of subgrade soil was performed using IITPAVE software, considering the same traffic data adhering to the guidelines specified in IRC:37-2018 [6] and two CBR values: one for normal soil and the other for tyre scrap mixed soil. Subgrade CBR values have been collected from the Soil Mechanics Research Division of Civil Engineering Department, Jadavpur University, Kolkata, India. Furthermore, a cost analysis was conducted for both pavement options to obtain an economic perspective, in accordance with the applicable PWD guidelines (PWD Roads Schedule of Rates, Govt of West Bengal ,India).

Fig. 1. Jibantala -Taldi Road

II. Methodology

2.1 General

The design of the flexible pavement follows the IRC: 37-2018 guidelines, which rely on the CBR value of the subgrade soil and design charts to determine the total pavement thickness. It is then analyzed using IIT PAVE software. Factors such as wheel load, subgrade soil properties, climate, stress distribution, and environmental conditions influence the pavement design. The project focuses on the Jibantala-Taldi road in South

24 Pgs, West Bengal, India, with a length of 11.45 km and width of 5.5m. The pavement is modelled as an elastic multilayer structure in the mechanistic empirical software, IITPAVE. The main objective is to compare the thickness and cost of flexible pavements for normal soil subgrade and tyre scrap mixed soil subgrade.

2.2 Data collection

Various traffic data are collected, including traffic volume counts, axle load surveys, and CBR values of the soil along the project road

2.2.1 Collection of traffic data

To design the pavement thickness, traffic study is an important parameter. The service life of a flexible pavement is generally considered for 15 to 20 years and the thickness of each layer of a flexible pavement varies with materials, traffic load repetitions and magnitude along with environmental conditions.To obtain the basic traffic study parameters for this work, traffic analysis and axle load survey have been conducted. Traffic analysis has been done by classified traffic count in the form of traffic census to find annual variation of traffic for consecutive Seven days carried out on Jibantala - Taldi Road section. This was done to find out total average commercial vehicles per day (CVPD) to assess traffic-flow rate. For this study, only commercial vehicles with a gross vehicle weight of 3 tonnes or more have been considered for the design of pavements, as per Clause :4.1.2 of IRC 37:2018 [6]. The vehicle details and a summary of the traffic census are presented in TABLE- 1

Table 1. Summary of Traffic census

Road: Jibantala bazar to Taldi bazar.Chainage:11.50 Km. Location: Taldi

Direction of traffic: Up- From Jibantala to Taldi, Down- From Taldi to Jibantala

Assumed year of traffic opening:2021

Motorized Vehicles				
Time Period	**Fast Goods**			**Slow Goods**
	Truck			**Agriculture Tractor withTrailer**
	2-Axle	**3-Axle**	**MAV**	
02.06.19	184	64	13	223
03.06.19	206	46	7	202
04.06.19	205	66	6	165
05.06.19	208	43	9	163
06.06.19	198	65	8	190
07.06.19	176	53	9	162
08.06.19	191	60	11	180
Average	195	57	9	184

Abbreviation used in TABLE 1: MAV-Multi axle vehicles.

Total average commercial vehicle per day (CVPD)= (195+57+9+184) =445

2.2.2 Axle Load Survey

An axle load survey was conducted at a location where sampling could be carried out easily and safely. A continuous 24-hour axle load survey was conducted on the project road during regular working days. The survey employed two portable weighing pads to measure the weight of all vehicle axles in both directions. In the pavement design process, vehicles with a gross weight of 3 tonnes or greater are taken into consideration. It is apparent that every vehicle in motion induces some level of damage to the road due to the tensile and compressive stresses generated by the dynamic wheel load, leading to deflection. For this study, an axle pad was utilised to measure the load applied by the axles, as illustrated in Fig.2.

Fig.2. Axle load test

The vehicles had been stopped on a random sample basis to measure the loads on each axle of the vehicle to obtain the loading pattern and Vehicle damage factor (VDF) as per clause 4.4 of IRC 37:2018 [6]. The results are shown in TABLE-2.

Table 2. Summary of Axle load test results

Road : Jibantala Taldi Road,Location:Taldi
Up : From Jibantala to Taldi,Down: From Taldi to Jibantala
Date : 08-06-2019 to 09-06-2019

Sl. No.	Type of Vehicle	UP				Down			
		No. of Samples	**VDF**	**ADT**	**Total Damaging Effect**	**No. of Samples**	**VDF**	**ADT**	**Total Damaging Effect**
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1	LCV	10	2.510	47	117.97	10	2.418	47	113.66
2	TRAILER	20	2.514	92	231.29	20	1.520	92	139.84
3	2 - Axle Truck	20	6.700	98	656.60	20	5.125	97	497.13
4	3 - Axle Truck	8	7.950	29	230.55	7	7.582	28	212.30
5	MAV	3	9.650	5	48.25	3	8.562	4	34.25
Total		61	29.324	271	1284.66	60	25.207	268	997.17
Combined VDF		4.74				3.72			
Adopted VDF		4.74							

Abbreviations used in table 6: ADT-Average daily traffic. LCV-Light commercial vehicles. MAV-Multi axle vehicles.

All the required traffic data had been collected from Jibantala -Taldi Road then by using these data along with effective CBR value, the pavement has been designed for a period of 15 years, using IRC 37:2018 [6]. Same traffic data has been considered for both proposed subgrade consisting of both original soil and modified soil.

2.2.3 Subgrade CBR value

Subgrade CBR values were collected from the Soil Mechanics Research Division of Civil Engineering Department, Jadavpur University, Kolkata, India. The soaked CBR for normal soil subgrade of Jibantala-Taldi road is 3.36, while the scrap tyre mixed soil yields a CBR value of 8.90. It is worth noting, according to information provided by the university, that incorporating 15mm × 15mm tyre scraps with a thickness of 2mm to 3mm into the normal subgrade soil at 10% of its dry weight produces a modified CBR value of 8.90.

III. Pavement design and analysis

To achieve the main goal of the study IIT PAVE software was used to determine the pavement thickness for both of proposed subgrade consisting of original soil and tyre scrap mixed soil sequentially. IIT PAVE is the multi-layer analysis programmer used for analysis of flexible pavement and to determine the stresses and strains at critical locations of the pavement [14]. To design a flexible pavement, the thickness of each layer needs to be determined based on the strength characteristics of the pavement materials. This can be done by using the CBR value as well as traffic data, and by using IIT PAVE software which computes the actual value of strains coming on the pavement due to wheel load. The software assumes the pavement as a linear elastic layered system and computes different functional parameters such as stresses, strains, and deflections. The vertical compressive strain and horizontal tensile strain are the essential mechanistic factors needed to check for sub-grade rutting and bottom-up cracking of bituminous layers, for which the software can be used to calculate these strains and stress parameters. Overall, the design process involves using the IIT-PAVE software to determine the thickness of component layers based on the strength characteristics of the pavement materials, as specified by IRC 37 :2018 [6].

3.1 Determination of pavement thickness by IIT PAVE using original soil as subgrade

The following steps have been utilized to ascertain the thickness of flexible pavement-

3.1.1 Calculation of Design Traffic

The traffic design has been calculated using equation 4.5 from IRC 37:2018 [6]. This equation estimates the traffic design by considering the projected number of standard axles that the pavement will encounter over its design life period. The equation is as follows:

N_{des} = 365 × [(1+r) n – 1] × A × D × F/ r (1)
Where,

N_{des} = Cumulative number of standard axles to be carried during the design period of 'n' years, A = Initial traffic (CPVD) in the year of completion of construction. D = Lateral distribution factor. F = Vehicle damage factor (VDF), n=Design period (years). r =Annual inflation rate of commercial vehicles in decimal. The input parameters for determining the design traffic of Jibantala-Taldi road in the present study have been provided in Table 3. The expected traffic in the completion year of a construction project can be calculated using the equation referenced in Equation 4.6 of IRC37:2018[6].

A = P(1+r)^x (2)

Where,

P = Count of commercial vehicles per day as per the previous record, x = difference in the number of years between the last record and the year of termination of construction, The input parameters required to determine the design traffic using the above equations have been tabulated in TABLE-3.

Table 3. Input Parameters for design traffic calculation of Jibantala-Taldi Road.

Sl. no.	Description of input parameters	Particulars	Reference
1	CVPD During Census (P)	445	TABLE 1
2	Year of Traffic Census	2019	TABLE 1
3	Assume the Year of Opening Traffic	2021	TABLE 1
4	Difference in the number of years (x)	2	2021-2019
5	Considered Rate Of Increment (r)	5%	Clause 4.2.2 of IRC37:2018
6	CVPD at Opening year of Traffic	490.61	From equationn 2
7	Lane Distribution Factor (D)	0.75	Clause 4.5.1.2 of IRC37:2018
8	VDF	4.74	TABLE 2
9	Design Life	15 Yrs	Clause 4.3.2 of IRC37:2018
10	Type of pavement considered	Flexible	According to the project

So, putting values in equation 2, we get A=445(1+0.05) ˆ2 =490.61 CVPD. Now, put these values into equation 1 and compute the design traffic by considering the increasing number of standard axles to be accommodated over a design period of 15 years-

$$N_{Des} = [365 \times \{(1 + 0.05)15 - 1\} \times 0.75 \times 490.61 \times 4.74] / 0.05 \times 10^{6} = 13.74 \text{ msa}$$

3.1.2 Analysis based on performance criteria of pavement

IRC: 37-2018 [6] guidelines for flexible pavement design suggest the following performance criteria -

3.1.2.1 Subgrade Rutting Performance Criteria

Critical rutting conditions are considered when the mean rut depth of 20 mm or more is observed across the wheel paths. To determine the sub-grade rutting life, empirical equations are discussed and provided in clause 3.6.1 of IRC 37:2018 [6]. The guidelines outlined in clause 3.7 of IRC 37:2018 [6] recommend using the performance equation for subgrade rutting (equation 3) with 80% reliability, particularly when designing for traffic volumes less than 20 msa.

$$N_R = 4.1656 \times 10^{-08} [1/\varepsilon_v]^{4.5337} \text{ (for 80 \% reliability)} \quad (3)$$

where, N_R = subgrade rutting life.ε_v = Maximum vertical compressive strain at the top of the sub grade.

3.1.2.2 Fatigue Cracking Criteria for Bituminous layer

The development of fatigue cracking, which encompasses 20% or more of the paved surface area in the segment of the pavement under consideration, is considered to be in a critical or failure condition. The fatigue life of the bituminous layer can be determined using clause 3.6.2 of IRC 37:2018[6]. The guidelines outlined in clause 3.7 of IRC 37:2018[6] recommend using the performance equation for fatigue (equation 4) with 80% reliability, especially when designing for traffic volumes less than 20 msa.

$N_f = 1.6064 \text{ x } C \text{ x } 10^{-04} [1/\varepsilon_t]^{3.89} \text{ x } [1/M_{Rm}] 0.854$
(for 80 % reliability) (4)

Where, C= adjustment Factor=10^M and $M=4.84((V_{be}/V_a+V_{be}) - 0.69))$, 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,N_f = fatigue life of bituminous layer, ε_t = max horizontal tensile strain at the bottom of the bituminous layer, M_{Rm} = resilient modulus (MPa) of the bituminous mix used in the bottom Bituminous layer,The input parameters required to analyse the bituminous pavement performance criteria of Jibantala-Taldi Road are presented in TABLE- 4

Table 4. Input parameters for the analysis of pavement performance criteria of Jibantala-Taldi Road.

Sl. No.	Description of input parameters	Particulars	Reference
1	Air voids(V_a)	3.50%	Clause 12.3 of IRC37:2018
2	Binder content(V_{be})	11.50%	Clause 12.3 of IRC37:2018
3	Resiliant Modulus of Bitumen (Mr)	3000 mpa	Table 9.2 of IRC37:2018
4	CBR of material under Subgrade	3.36%	Clause 12.3 of IRC37:2018
5	Sub Base - 1 (Separation layer)	GSB - Gr. - V	Clause 7.2.1 of IRC37:2018
6	Sub Base - 2 (Drainage layer)	GSB - Gr. -III	Clause 7.2.1 of IRC37:2018
7	Base - 1	WMM	Clause 7.2.1 of IRC37:2018
8	Binder Course	DBM	Clause 7.2.1 of IRC37:2018
9	Wearing Course	BC	Clause 7.2.1 of IRC37:2018
10	Ambient Temperature	35° C	Pavement Temparature
11	Design Traffic (Rutting life for granular layer)	13.74 msa	Equation 1
12	Design Traffic (Fatigue life for bituminous layer)	13.74 msa	Equation 1

By using the values from Table-4 the following starin values can be determined-

a) Maximum vertical compressive strain at the top of the sub grade (ε_v) = 0.0006276 (from equation 3).
b) Maximum horizontal tensile strain at the bottom of the bituminous layer(ε_t) = 0.0003325 (from equation 4)

3.1.3 Pavement thickness analysis trial by using IIT PAVE software

Assuming the pavement as a linear elastic layered system, various functional parameters such as stresses, strains, and deflections are computed. The IIT-PAVE software can be utilized to analyze linear elastic layered systems and is effective for designing and analyzing flexible pavements. As mentioned earlier, the vertical compressive strain and horizontal tensile strain are crucial mechanistic factors to assess the adequate performance of flexible pavements and evaluate subgrade rutting and bottom-up cracking of bituminous layers. These strains and stress parameters are calculated using the software. In the context of this present work, the initial parameters required for pavement design have been determined. The selection of a suitable pavement thickness is of utmost importance, and it can be achieved as per the IRC guidelines. Several catalogues are accessible to aid in selecting the appropriate thickness trial.Specifically, in the current scenario, Figure 12.1 of IRC 37:2018 [6] provides a range of trial pavement thicknesses for 5% CBR. In the present study Fig.3 represents the trial pavement thicknesses chart for 5% CBR by following IRC37:2018[6].

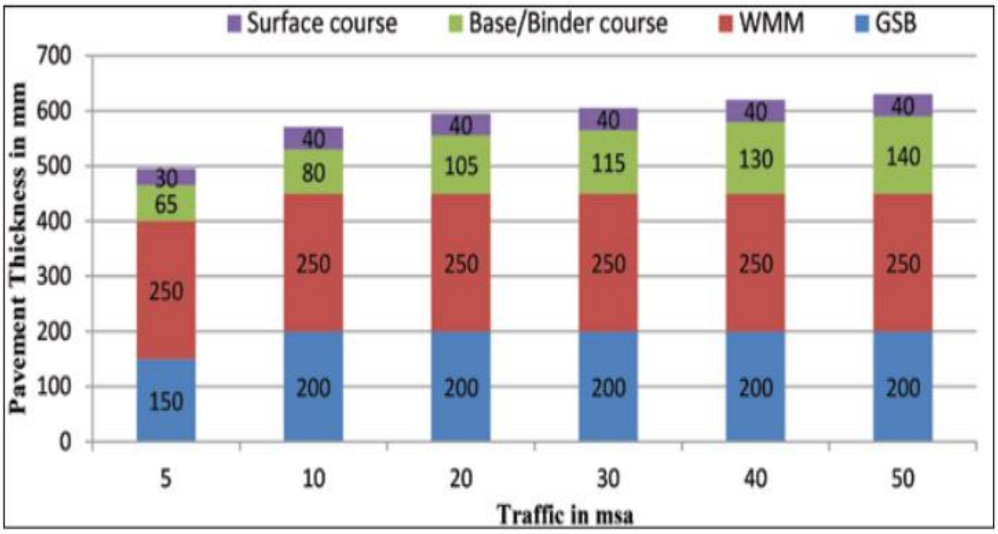

Fig.3. Trial pavement thickness for 5% CBR.

To evaluate the rutting strain in the subgrade and the tensile strain at the interface between the bituminous and granular layers with an 80 percent reliability, a trial pavement thickness analysis has been performed using IIT PAVE software. The results of this analysis are presented in TABLE-5.A typical input and output window of IITPAVE analysis for normal soil subgrade are shown in Figs. 4 and 5 respectively. The input for the software included all the parameters mentioned earlier.

Table-5. Trial pavement thickness analysis for normal soil subgrade by IITPAVE

Trial no	Thickness of bituminous layer	Thickness of granular layer	CBR Value	Resiliant modulus (Subgrade)	Resiliant modulus (Granular)	Resiliant modulus (Bituminus)	Calculated horizental tensile strain & vertical strain from IIT PAVE software		Calculated maximum allowable horizental tensile strain & vertical strain		Remarks
							Calculated tensile strain at bottom of bituminous	Calculeted vertical strain at subgrade	Maxiumum tensile strain at the bottom of bituminous layer	Maximum vertical strain on subgrade	
1	105	440	3.36%	33.60	103.97	3000	0.3476 x 10^-3	0.7007 x 10^-3	0.3325 x 10^-3	0.6276 x 10^-3	Design unsafe
2	110	450	3.36%	33.60	105.03	3000	0.3310 x 10^-3	0.6599 x 10^-3	0.3325 x 10^-3	0.6276 x 10^-3	Design unsafe
3	120	450	3.36%	33.60	105.03	3000	0.3048 x 10^-3	0.6168 x 10^-3	0.3325 x 10^-3	0.6276 x 10^-3	Design safe

After several trial runs, the safe thickness has been obtained from TABLE-5. Specifically, in trial 3, the bituminous layer has a thickness of 120mm, while the granular layer has a thickness of 450mm.

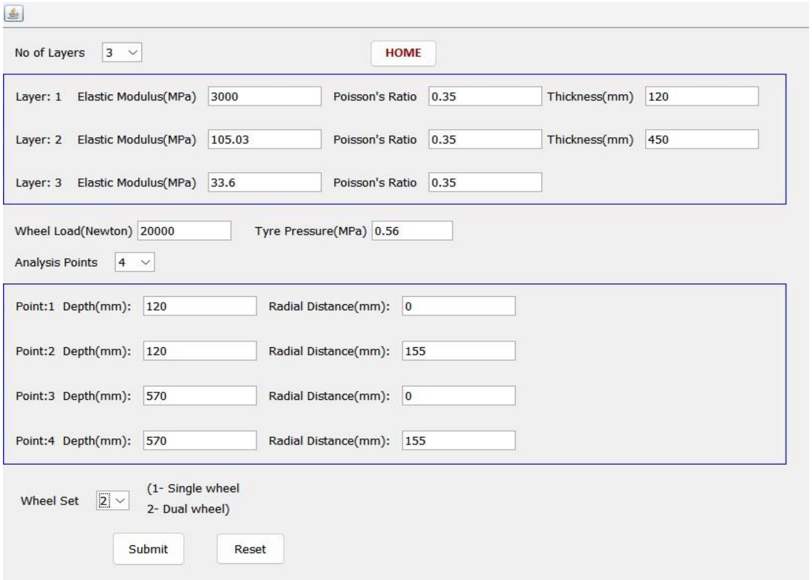

Fig.4. typical input window of IITPAVE analysis for normal soil subgrade


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No. of layers                   3
E values (MPa)          3000.00  105.03   33.60
Mu values                  0.350.350.35
thicknesses (mm)         120.00  450.00
single wheel load (N) 20000.00
tyre pressure (MPa)        0.56
Dual  Wheel
  Z         R       SigmaZ      SigmaT      SigmaR      TaoRZ      DispZ       epZ         epT         epR
120.00    0.00-0.9990E-01 0.1229E+01 0.9984E+00-0.1368E-01 0.7804E+00-0.2931E-03 0.3048E-03 0.2011E-03
120.00L   0.00-0.9990E-01-0.8891E-02-0.1695E-01-0.1368E-01 0.7804E+00-0.8650E-03 0.3048E-03 0.2011E-03
120.00  155.00-0.9139E-01 0.1080E+01 0.5582E+00-0.3994E-01 0.8028E+00-0.2216E-03 0.3055E-03 0.7073E-04
120.00L 155.00-0.9139E-01-0.9676E-02-0.2794E-01-0.3994E-01 0.8028E+00-0.7448E-03 0.3055E-03 0.7073E-04
570.00    0.00-0.1864E-01 0.2631E-01 0.2328E-01-0.2854E-02 0.5661E+00-0.3427E-03 0.2350E-03 0.1961E-03
570.00L   0.00-0.1863E-01 0.1602E-02 0.6488E-03-0.2852E-02 0.5661E+00-0.5779E-03 0.2350E-03 0.1967E-03
570.00  155.00-0.1978E-01 0.2785E-01 0.2589E-01-0.3623E-02 0.5792E+00-0.3674E-03 0.2448E-03 0.2196E-03
570.00L 155.00-0.1978E-01 0.1671E-02 0.1041E-02-0.3638E-02 0.5792E+00-0.6168E-03 0.2449E-03 0.2196E-03
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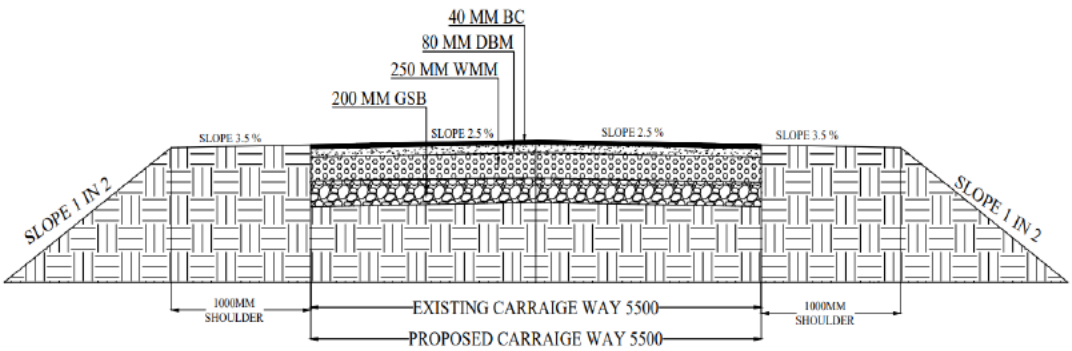
Fig.5. typical output window of IITPAVE analysis for normal soil subgrade

Based on the above design a typical pavement cross section has been given in Fig.6



Abbreviations used in Fig. 6: BC-Bituminous course. DBM-Dense bituminous macadam. WMM- Wet mix macadam. GSB-Granular sub base.

Fig. 6.Typical Cross Section of Normal Soil Subgrade with CBR 3.36

3.2 Determination of pavement thickness by IIT PAVE using shredded tyre scrap mixed soil as subgrade

To determine the safe thickness for shredded tyre scrap mixed soil as subgrade, the peak CBR value was considered in the study. The CBR value obtained was 8.90 for a mixture containing 10% tyre scrap with a size of 15mm X 15mm. The same equations and methods described earlier were utilized to determine the thickness using IIT PAVE trial method. All parameters, including traffic data, design traffic, and performance criteria, remained unchanged. For the IIT PAVE design, multiple trial runs were conducted to achieve a pavement design that is both safe and cost-effective. In this case, three trial runs were carried out, and the results are presented in TABLE-6.

Table-6. Trial pavement thickness analysis for shredded tyre scrap mixed soil subgrade by IITPAVE

After several trial runs, the safe thickness has been obtained from table-6. Specifically, in trial 3, the bituminous layer has a thickness of 80mm, while the granular layer has a thickness of 400mm.

Trial no	Thickness of bituminous layer	Thickness of granular layer	CBR Value	Resiliant modulus (Subgrade)	Resiliant modulus (Granular)	Resiliant modulus (Bituminus)	Calculated horizental tensile strain & vertical strain from IIT PAVE software		Calculated maximum allowable horizental tensile strain & vertical strain		Remarks
							Calculated tensile strain at bottom of bituminous	Calculeted vertical strain at subgrade	Maxiumum tensile strain at the bottom of bituminous layer	Maximum vertical strain on subgrade	
1	75	340	8.90%	71.31	196.48	3000	0.3235 x 10^-3	0.6194 x 10^-3	0.3325 x 10^-3	0.6276 x 10^-3	Design unsafe
2	80	340	8.90%	71.31	196.48	3000	0.3128 x 10^-3	0.5992 x 10^-3	0.3325 x 10^-3	0.6276 x 10^-3	Design unsafe
3	80	400	8.90%	71.31	211.39	3000	0.2963 x 10^-3	0.4915 x 10^-3	0.3325 x 10^-3	0.6276 x 10^-3	Design safe

Based on the above design a typical pavement cross section by using shredded tyre scrap mixed soil as subgrade has been illustrated in Fig-5.

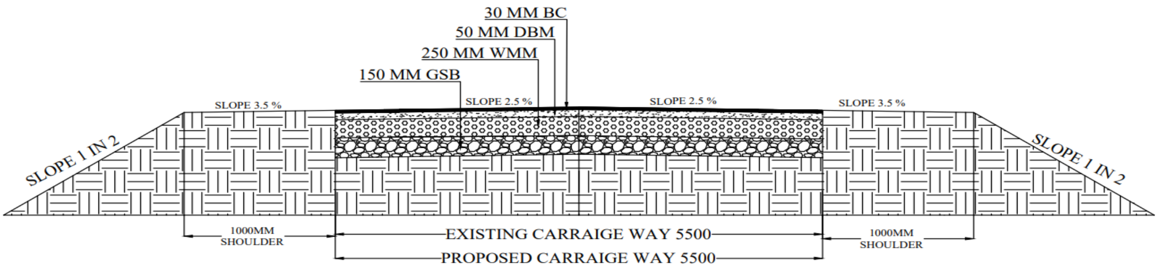


Fig. 7. Typical Cross Section of modified soil subgrade with CBR 8.90

IV. Observations from pavement thickness analysis

a) The CBR value has a significant influence on the design of pavement thickness. Higher CBR values indicate stronger subgrade materials that can withstand heavier loads without excessive deformation. In such cases, thinner pavement layers may be required as the subgrade provides better support to the overlying pavement structure.

b) By following IRC 37:2018, pavement design has been done for both normal soil subgrade and tyre mix soil subgrade using IIT PAVE software. Three (3) trial runs were conducted for both cases by utilizing the results of two parameters - Tensile Strain at Bottom of Bituminous and Vertical Strain at Subgrade.

c) TABLE-7 presenting thickness of different layer of pavement for both normal soil subgrade and tyre scrap mix soil subgrade is given below. A thickness reduction in Bituminous layer and granular layer was observed for tyre mix soil subgrade which is 90 mm. Subgrade layer thickness is 500mm for both pavement.

Table-7. Different layer pavement thickness for normal and tyre scrap mixed soil

Category	Layers	Thickness with untreated Soil Subgrade	Thickness with scrap tyre mixed Soil Subgrade
Bituminus Layer	BC	40 mm	30 mm
	DBM	80 mm	50 mm
Granular layer	WMM	250 mm	250 mm
	GSB	200 mm	150 mm
Total		570 mm	480 mm
Thickness differnence		90mm	

V. Cost comparison analysis

It has been observed from the thickness design that there had a thickness reduction in pavement of around 90mm. A cost study has been made and presented on Table 8 by following WB Govt PWD,India, Roads Schedule of rates -2018 with 10th Corrigendum.

Table-8. Thickness and cost analysis of treated and untreated Soil

Category (1)	Layers (2)	Thickness with untreated Soil Subgrade(mm) (3)	Thickness with scrap tyre mixed Soil Subgrade(mm) (4)	Per Km costs(INR) with untreated Soil Subgrade (5)	Per Km costs(INR) with scrap tyre mixed Soil Subgrade (6)	Cost Difference in per Km(INR) (7)=(5)-(6)
Bituminus Layer	BC	40	30	INR.1888893.60	INR.1416670.20	INR.472223.40
	DBM	80	50	INR.3454066.36	INR.2158791.23	INR.1295275.13
Granular layer	WMM	250	250	INR.3821620.00	INR.3821620.00	INR.0.00
	GSB	200	150	INR.2914021.59	INR.2185515.79	INR.728505.80

Total cost difference for per km road subgrade from column 7 of table-8=INR.2496004.33. Per km costs for procurement and preparation and mixing of tyre scrap of size 15mm X 15mm and mixing by manual and mechanical means=INR.25000.00 as per local market costs. Hence, net cost difference for per km road subgrade=INR(2496004.33–25000.00)=INR.2471004.33

VI. Conclusion

The following conclusions have been drawn based on the study –

1. It's important to note that the influence of CBR on pavement thickness is just one factor among several considerations in pavement design. The present study demonstrated that at 10% percentage of shredded rubber tyre with a size of 15mm × 15mm, the soaked CBR value of the subgrade soil exhibited a significant increase from 3.36% to 8.90%.

2. The study emphasizes both traffic analysis and subgrade soil assessment in pavement design. IRC method via IIT PAVE software determined thickness. Optimal 10% shredded rubber tyre (15mm × 15mm) reduced pavement thickness to 90mm or 18.75% compared to regular soil subgrade.

3. Evidently, incorporating shredded tyre scrap in the subgrade results in a cost reduction of approximately INR 24,71,000.00 per Km compared to using normal soil. Hence, it can be inferred that incorporating shredded tyre scrap is economically advantageous for flexible pavement design.

References

[1]. P.J Bosscher,T.B Edil, and S.Kuraoka,“Design of highway embankments using tire chips.”J.Geotech. Geoenviron.Eng.,10.1061/

(ASCE)10900241,1997,123:4(295), pp.295–304.

[2]. N.Mangi, and F.A Sarki,“Improvement of subgrade soil by blending tyre driven aggregate (TDA),” International Journal of Emerging Trends in Engineering Research,2021, Vol. 09, No: 06.

[3]. B.Hussainbhi, K.Sridhar, V.Naidu Mahalakshmi,“An Analytical study on flexible pavement and rigid pavement design of a Road”.International Journal of Research in Engineering and Science (IJRES),2021, Volume 09 Issue 10, PP. 81-88.

[4]. I.Juliana, A.R Fatin, R.Rozaini, M.N Masyitah, A.H Khairul, and A.N Shafieza,“Effectiveness of crumb rubber for subgrade soil stabilization” IOP Conference Series: Materials Science and Engineering,2019, Volume 849, 4th International Conference on Construction and Building Engineering & 12th Regional Conference in Civil Engineering (ICONBUILD & RCCE 2019) Langkawi, Malaysia.

[5]. A.Pradeep, S.Simon, K.Y Raneesh,“ Strength characteristics of soil partially replaced with waste paper sludge ash and scrap tyre rubber”International Journal Of Scientific Research, Volume : 5 Issue : 8.2016.

[6]. IRC: 37 2018., “Guidelines for the design of flexible pavements,” IRC, New Delhi, India, 2018.

[7]. M.Kumar, and P. Kumar, “Analysis of Flexible Pavement using IITPAVE Software and Economic Analysis of the Project using HDM-4 Software” .International Journal for Research in Applied Science & Engineering Technology (IJRASET) IC Value: 45.98; SJ Impact Factor: 7.429 Volume 8 Issue V.2020.

[8]. Y.KSingh, and D.S Ray,“Analysis of Vehicle Damage Factor in Overloading for Different Types of Loading”International Journal of Engineering Science and Computing, 2019 . Volume 9 Issue No. 5.

[9]. A.J Banerji, P.Topdar, and A.Datta,“Effect of Axle Overloading on Pavement Structural Behaviour with Improved Clayey Subgrade Using PET Fibres” Civil Engineering and Architecture,2022, 10(6): 2410-2425.

[10]. A.Pandey, K.Vanshaj, G.Singh, S.Yadav, and J.B.Srivastav,“Design of flexible pavement using experimental and software approach”International Research Journal of Engineering and Technology (IRJET)2022,Volume: 09 Issue: 06.

[11]. K. Goutami, KSR Murthy, and D. Sandhya Rani, “Flexible Pavement Design and Comparison of Alternative Pavements using IRC 37-2012 IITPAVE” International Journal for Scientific Research & Development, Vol. 5, Issue 06, 2017.

[12]. IRC: 37 2012., “Guidelines for the design of flexible pavements,” IRC, New Delhi, India, 2012.

[13]. A.Murana, C.D Uruaka, and O.Chukwuma,“Axle load distribution and failure pattern on highways in nigeria: a case study of the traffic analysis on jebba-mokwa-bokani road in Niger state, Nigeria.International Journal of Advances in Mechanical and Civil Engineering,2019, Volume-6, Issue-3.

[14]. G.R Harish, “Analysis of Flexible Pavements Design Using IIT PAVE”, Imperial Journal of Interdisciplinary Research (IJIR),2017, Vol-3, Issue-6, 2017, ISSN 2454-1362.