Flexible Pavement Design Report
Group F

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1 Introduction

This report presents a comprehensive flexible pavement design for Group F, based on IRC 37-2012 guidelines and analyzed using IITPAVE software. The design aims to optimize material usage while ensuring durability, safety, and cost-efficiency.

1.1 Group F Conditions

- **Traffic Load**: 125 msa
- **Reliability**: 90%
- **Subgrade**: Fly Ash Stabilized Subgrade, CBR = 15%, Poisson's Ratio (μ) = 0.30
- **Sub-base**: Cemented Sub-base Layer
- **Base Layer**: Unbound Base Layer
- **Bituminous Layer**: $M_R = 3000$ MPa, $\mu = 0.35$

2 Pavement Model and Layer Configuration

The main design criteria involve:

- **Fatigue Cracking**: Evaluated based on tensile strain at the bottom of the bituminous layer.
- **Rutting**: Evaluated based on vertical strain at the top of the subgrade.

3 Design Calculations

3.1 Determining Subgrade Resilient Modulus

The resilient modulus (M_R) of the subgrade is calculated based on the subgrade CBR value using the formula from IRC 37: 2012 (Section 5.3). For CBR greater than 5%, the resilient modulus (M_R) is given by:

$$M_R = 17.6 \times (\text{CBR})^{0.64}$$

Given CBR value for the subgrade is 15%. Thus,

$$M_R = 17.6 \times (15)^{0.64} = 99.58\,\text{MPa}$$

3.2 Layer Thickness Determination

The layer thicknesses are selected from the IRC 37: 2012 design catalogues based on the traffic load (125 msa) and the subgrade CBR (15%). The thickness of each layer is interpolated between the values for 100 MSA and 150 MSA for traffic and for reliability between 5% to 10%. Using the provided data:

3.3 Maximum Strain Calculation

3.3.1 Tensile Strain Calculation

For 90% reliability, the fatigue life equation is given by:

$$N_f = 0.5161 \times C \times 10^{-4} \left(\frac{1}{\epsilon_t}\right)^{3.89} \left(\frac{1}{M_R}\right)^{0.854}$$

Given $N_f = 125 \times 10^6$ and $M_R = 3000$ MPa, we solve for ϵ_t:

$$125 \times 10^6 = 2.21 \times 3.16 \times 10^{-4} \left(\frac{1}{\epsilon_t}\right)^{3.89} \left(\frac{1}{3000 \times 10^6}\right)^{0.854}$$

Where:

$$C = 10^M$$

$$M = 4.84(\frac{V_{bc}}{V_a + V_{bc}} - 0.69)$$

$$M = 0.5$$

$$C = 10^{0.5} = 3.16$$

Where:

- **Design traffic** = 125 msa (Million Standard Axles)
- V_a = Air void content = 3%
- V_{bc} = Effective binder volume = 11.5%

Rearranging and solving for ϵ_t:

$$\left(\frac{1}{\epsilon_t}\right)^{3.89} = \frac{125 \times 10^6 \times (3000 \times 10^6)^{0.854}}{2.21 \times 3.16 \times 10^{-4}}$$

Solving the equation for ϵ_t, we get:

$$\epsilon_t = 472 \times 10^{-6} \quad \text{(approx.)}$$

3.3.2 Vertical Strain Calculation

The rutting fatigue life for 90% reliability is determined using the formula:

$$N_r = 1.41 \times 10^{-8} \left(\frac{1}{\epsilon_v}\right)^{4.5337}$$

Where:

- N_r = Rutting fatigue life in terms of the number of standard axles
- ϵ_v = Maximum vertical strain at the top of the subgrade layer

To determine the allowable vertical strain ϵ_v, we rearrange the equation:

$$\epsilon_v = \left(\frac{1.41 \times 10^{-8}}{N_r}\right)^{\frac{1}{4.5337}}$$

For $N_r = 125\,\text{million}$ (as per the given MSA value), we substitute to find ϵ_v:

$$\epsilon_v = \left(\frac{1.41 \times 10^{-8}}{125 \times 10^{6}}\right)^{\frac{1}{4.5337}}$$

Solving the equation for ϵ_v, we get:

$$\epsilon_v = 300 \times 10^{-6} \quad \text{(approx.)}$$

4 Use of IITPAVE Software for an Economical Pavement Design

4.1 Assumptions used in the Design Approach

In accordance with IRC guidelines, the following assumptions were used for the pavement design:

- **Pavement Design Life**: The pavement design life is assumed to be 15 years.
- **Subgrade Modulus**: Based on Table 1 of the IRC guidelines, the subgrade modulus is assumed to be 70 MPa.
- **Traffic Growth Rate**: A traffic growth rate of 7.5% per annum is considered.
- **Vehicle Load Distribution**: The vehicle load distribution is considered as per IRC-37 guidelines, which takes into account the expected traffic and load patterns.

- The material properties and thicknesses for each layer are as defined in the original design.
- No modification in material properties to maintain consistency with the original design.
- Traffic Load and environmental conditions are assumed constant throughout the service period.

Table 3.1 Standard Conditions for Pavement Analysis using IITPAVE

Analysis Conditions	
Material response model	Linear elastic model
Layer interface condition	Fully bonded (all layers)
No. of Wheels	Dual wheel
Wheel loads	20 kN on each single wheel (two wheels)
Contact stress for critical parameter analysis	0.56 MPa for tensile strain in bituminous layer and vertical compressive strain on subgrade; 0.80 MPa for Cement treated base
Critical Mechanistic Parameters	
Bituminous layer	Tensile strain at the bottom
Cement treated base	Tensile stress and tensile strain at the bottom
Subgrade	Compressive strain at the top
Note: (a) Only the absolute values of strains/stresses (without the + or – sign) should be used in the performance equations (b) For pavements with strong bases and/or thin bituminous layers, it is possible that the strain at the bottom of the bituminous layer may be compressive instead of tensile.	

Figure 1: Sectional Drawing of IRC Design

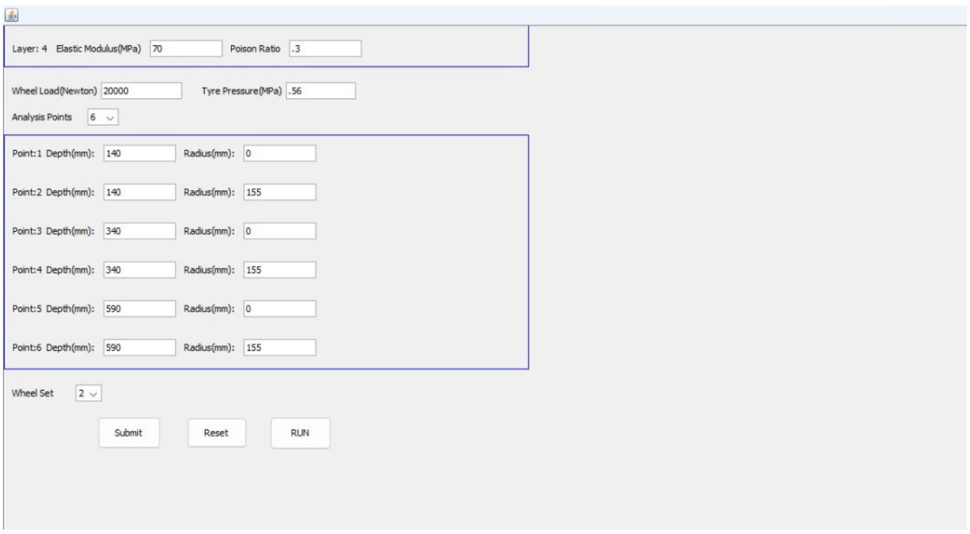

Figure 2: IITPAVE Run 1

4.2 Strain Comparison and Safety Analysis

The strains obtained from IITPAVE are within the allowable limits, so this is a safe design.

4.3 Comparison and Evaluation of IRC and IITPAVE Designs

The IITPAVE design approach results in lower strain values than the IRC design due to its ability to incorporate detailed, site-specific parameters, advanced material characterization, realistic load models, and environmental factors. Consequently, IITPAVE tends to yield designs that are both safer and potentially more cost-effective.

Table 1: Strain Comparison and Safety Analysis

Strains	**Allowable Strains** ($\mu\varepsilon$)	**Actual Strains (IITPAVE)** ($\mu\varepsilon$)	**Remark**
Horizontal Tensile Strain at Bottom of Bituminous Layers (ε_{Ht})	472	409	Safe
Vertical Compressive Strain at Top of Subgrade (ε_v)	300	247	Safe

Table 2: Strain Comparison and Safety Analysis

4.4 Sectional Drawing of Modified Design Using IITPAVE

There is no modification done in this design. However, suggestions can be made for optimizing CTSB thickness since the difference between allowable strain and actual IITPAVE strain is significant.

4.5 Bituminous Pavement Design Chart Based on IITPAVE Data

Starting with a full-depth bituminous pavement, we have prepared fatigue and rutting curves where the pavement is safe in both aspects by adjusting the thickness of the base layer (h_1 with respect to changes in h_2). Subgrade and subbase properties remain as in Table 1. The chart includes five data points each for fatigue and rutting curves.

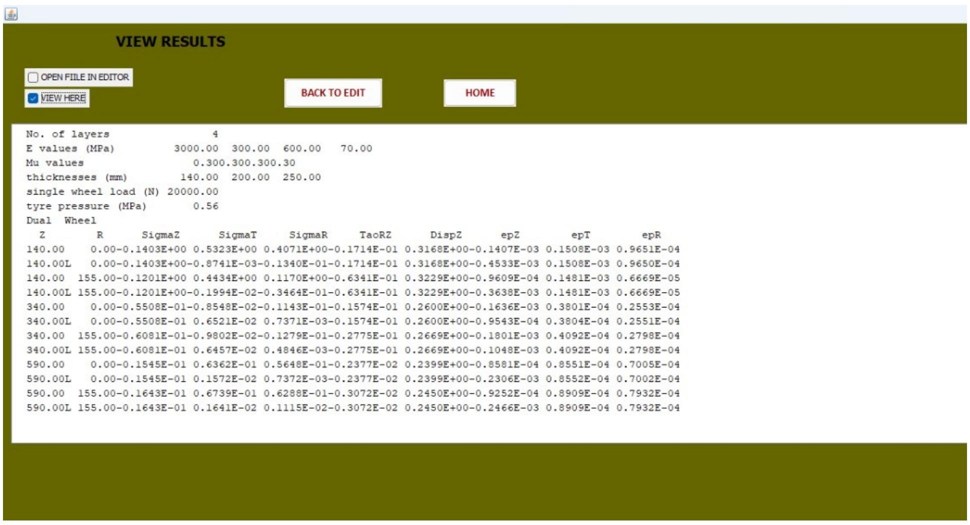

Figure 3: Screenshots of IITPave Runs Supporting the Design Modifications