

Design of Flexible Pavement Using IRC: 37-2018 A Case Study of TB Road, Raturaj-Mehsana, Gujarat, India

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Abstract - Accurate characterization of subgrade strength and estimation of traffic loading are essential for reliable structural performance prediction of flexible pavements. This study presents the structural design of flexible pavement for TB Road in accordance with IRC: 37-2018 guidelines. The pavement thickness was determined based on projected traffic growth and representative soil parameters of the Mehana region. The initial commercial traffic was considered as 450 CVPD with an annual growth rate of 7.5%, lane distribution factor of 0.75, and vehicle damage factor (VDF) of 3.5, for a design life of 15 years. The cumulative design traffic was calculated as 11.26 MSA. A subgrade strength of 6% CBR was adopted based on local soil conditions. Using IRC design charts for traffic category 10-20 MSA and CBR of 6%, the total pavement thickness was determined as 620 mm, comprising 40 mm BC, 100 mm DBM, 250 mm WMM, and 230 mm GSB. The proposed pavement structure satisfies IRC requirements and is expected to perform adequately over the design life.

Key Words: Flexible Pavement Design, IRC: 37-2018, Subgrade Strength, CBR, Traffic Loading, MSA, And Pavement Thickness.

1. INTRODUCTION

Flexible pavements possess a multi-layer structure where the loads imposed by vehicles are gradually transferred to the subgrade through layered load transferring systems. In contrast to rigid pavements that get their strength mainly from slab action, the flexible pavement comes from the combined structural interaction of bituminous and granular layers. The maximum stress occurs at the wheel loading surface, becoming smaller as it penetrates each layer.

There are two critical responses, which control the structural performance of flexible pavements; tensile strain at the bottom of the bituminous layer governs fatigue cracking and vertical compressive strain at the top of subgrade controls rutting. Careful selection of layer thickness ensures that these strains do not exceed allowable limits over the design life.

1.1 Importance of Proper Pavement

Pavement design is vital for ensuring the longevity, safety, ride quality, and cost-effectiveness of road systems. Failure to correctly predict traffic growth or to accurately assess subgrade strength can result in early failures like fatigue cracking, rutting, potholes, and surface deformation. These issues not only elevate maintenance expenses but also shorten service life and diminish user comfort.

Precise traffic forecasting is especially crucial since pavement damage increases in a nonlinear manner with axle loads. A minor rise in axle load can greatly shorten the lifespan of the pavement. Likewise, poor subgrade conditions necessitate thicker structural layers to avoid excessive deformation. As a result, a rational design that adheres to standardized guidelines is critical for the long-term performance of pavements.

1.2 IRC Guidelines and Indian Context

The Indian Roads Congress (IRC) serves as the primary technical authority for establishing standards and specifications for road infrastructure in India. IRC: 37-2018 offers detailed guidelines for designing flexible pavements through a

Mechanistic-empirical approach tailored to Indian traffic and climatic conditions.

The guideline incorporates:

- Modelling of traffic growth
- Vehicle Damage Factor (VDF)
- Considerations for lane distribution
- Classification of subgrades using CBR
- Criteria for fatigue and rutting performance

By merging mechanistic concepts with empirically derived relationships that are calibrated to field data, IRC: 37-2018 guarantees that pavement designs are both structurally sound and cost-effective for the conditions in India.

1.3 Site Context – TB Road, Ruturaj– Mehsana

TB Road is situated in the Ruturaj–Mehsana district of Gujarat and acts as a vital connection between agricultural areas and urban commercial hubs. The road accommodates a variety of traffic, including cars, buses, light commercial vehicles, and heavy trucks. The rise in commercial activities and regional growth has led to increased traffic loads in recent years.

The Mehsana area experiences semi-arid climate conditions, marked by high temperatures in summer and moderate rainfall during the monsoon season. These environmental factors affect the performance of the bituminous layer and variations in subgrade moisture. The predominant local soil types are sandy loam and clay, featuring a moderate bearing capacity. Given the traffic volume and local soil conditions, it is essential to implement a structured pavement design based on IRC: 37–2018 to ensure structural integrity and durability.

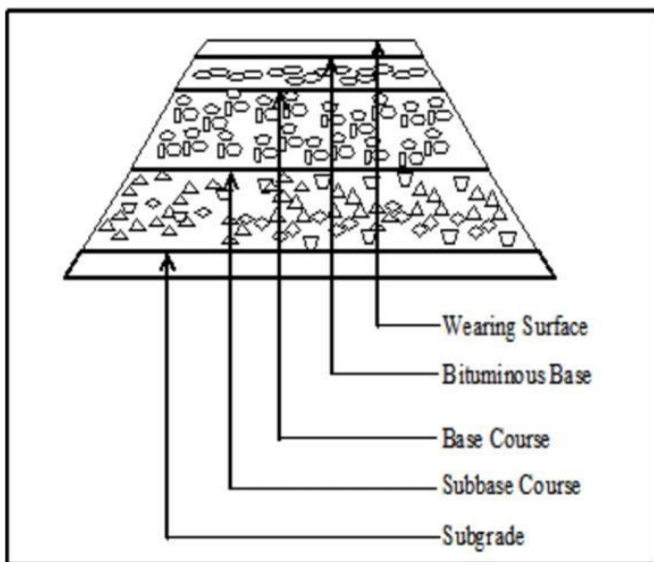


Fig -1: Typical flexible pavement layered system

2. LITERATURE REVIEW

The design of flexible pavements in India has experienced significant changes over the last few decades. Earlier design methods were primarily empirical and based on observations from the field, along with correlations derived from the California Bearing Ratio (CBR). The original IRC guidelines focused on thickness design mainly related to subgrade strength and projected traffic volumes.

2.1 Designs in India

The IRC: 37–1970 represented the first thorough standard for flexible pavement design in India. Later updates in 1984 and 2001 gradually introduced improved techniques for traffic estimation and more refined specifications for

materials. Nevertheless, these versions remained predominantly empirical in character.

The launch of IRC: 37–2012 and subsequently IRC: 37–2018 marked a significant change toward a mechanistic–empirical approach in design methodology. The revised guidelines take into account the stress–strain behavior of pavement layers and associate them with performance standards such as fatigue cracking and rutting. This shift enhanced reliability and guaranteed that pavement structures are more accurately adjusted to the traffic loading conditions in India.

2.2 Research Contributions to Pavement Design

Substantial advancements in research have influenced contemporary flexible pavement design theories. The mechanistic methodology introduced by Yoder and Witczak [6] revealed the connection between pavement layer characteristics and critical stress responses during repeated loading. Their research established that fatigue failure is predominantly determined by tensile strain at the bottom of the bituminous layer, while rutting is influenced by compressive strain at the subgrade level.

In the context of India, Khanna and Justo highlighted the importance of precisely assessing traffic growth and correctly choosing vehicle damage factors. Their research pointed out that pavement deterioration often stems from the incorrect estimation of total traffic load. Studies have demonstrated that the lifespan of pavement declines nonlinearly with higher axle loads, in accordance with the fourth power damage law. As a result, an accurate estimation of the Vehicle Damage Factor (VDF) is essential for ensuring precision in structural design.

2.3 Studies on Gujarat Highway Conditions

Pavement performance in Gujarat is affected by the local climate and soil conditions. The northern region of Gujarat, including the Mehsana district, has a semi-arid climate that features high temperatures during summer and moderate rainfall. Higher surface temperatures of the pavement influence the stiffness and aging properties of the bituminous layer.

Geotechnical studies in the area show that sandy loam and clayey soils are prevalent, with California Bearing Ratio (CBR) values generally falling between 4% and 8%. There are also areas with black cotton soil, which are prone to changes in volume due to variations in moisture content.

Research on highways in Gujarat has indicated that early pavement deterioration is frequently linked to insufficient drainage and increased traffic from commercial vehicles. These results emphasize the necessity of appropriate selection of structural thickness and assessment of the subgrade.

2.4 IRC: 37–2018 Guidelines

IRC: 37–2018 serves as the latest guideline for the design of flexible pavements in India. This guideline employs a mechanistic–empirical approach that merges theoretical stress analysis with empirical performance models refined using field data from India. The design process involves:

- Assessing cumulative traffic in terms of Million Standard Axles (MSA)
- Determining subgrade strength through CBR
- Analyzing critical strains in the pavement layers
- Choosing layer thickness based on design charts

Fatigue cracking is addressed by controlling the horizontal tensile strain at the base of the bituminous layer, while rutting is reduced by capping the vertical compressive strain at the topmost layer of the subgrade. The design charts provided in IRC: 37–2018 aid in selecting the appropriate thickness for various traffic categories and subgrade conditions.

2.5 International Design Practices

Globally, methods for pavement design differ according to local conditions and the data that is accessible. In the United States, the AASHTO Guide for Design of Pavement Structures relies on empirical relationships established from the AASHO Road Test.

The more recent Mechanistic–Empirical Pavement Design Guide (MEPDG) integrates layered elastic theory and material characterization to enhance prediction accuracy. European pavement design techniques often employ analytical models to calculate stresses and strains using layered elastic analysis.

In comparison to purely empirical approaches, mechanistic empirical frameworks offer greater flexibility in adapting to variations in traffic patterns and material properties. The IRC: 37–2018 aligns well with international mechanistic–empirical practices while being calibrated specifically to the traffic loading characteristics and environmental conditions of India.

2.6 Gap Identification

Despite the existence of standardized design protocols, numerous regional road initiatives continue to use generalized or presumed traffic metrics. Poor traffic growth predictions and insufficient evaluations of subgrade conditions often result in inadequately designed pavement structures.

There is still a requirement for the site-specific application of the IRC: 37–2018 methodology, incorporating realistic traffic parameters and representative soil properties. This research aims to fill that void by applying IRC procedures to TB Road

in Raturaj–Mehsana and providing a structured calculation based pavement design.

3. OBJECTIVES

- To compute cumulative design traffic (MSA) using IRC: 37–2018 methodology.
- To classify subgrade strength based on CBR value.
- To determine pavement layer thickness using IRC design charts.

4. SCOPE OF STUDY

The study focuses on structural design of flexible pavement for TB Road using IRC: 37–2018. It includes traffic estimation, subgrade evaluation, thickness determination, and design verification. Detailed material testing and economic analysis are beyond the scope of this study.

5. METHODOLOGY

The pavement design procedure follows these steps:

- Collection of traffic parameters
- Determination of design life
- Calculation of growth factor
- Estimation of cumulative MSA
- Subgrade classification
- Thickness selection from IRC design charts
- Verification of minimum layer requirements

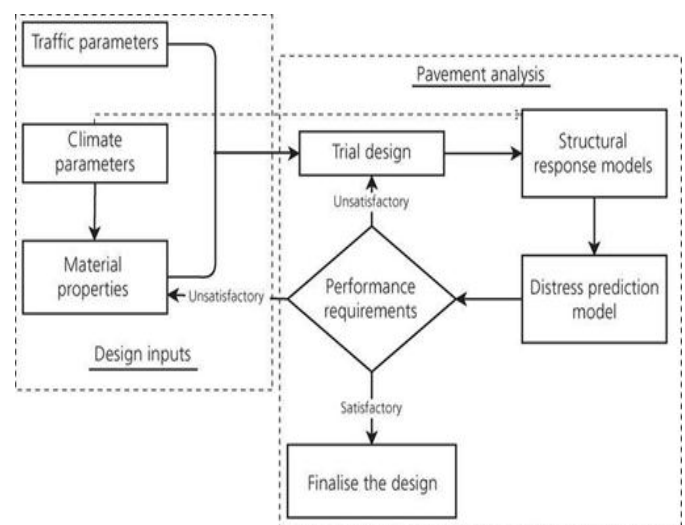


Fig. -2: Flexible pavement design procedure

6. SITE DESCRIPTION

TB Road serves as a district-level route linking agricultural zones to the city of Mehsana. It accommodates a variety of traffic, such as passenger cars, buses, light commercial vehicles, and heavy trucks. The area has a semi-arid climate characterized by elevated temperatures and moderate precipitation.

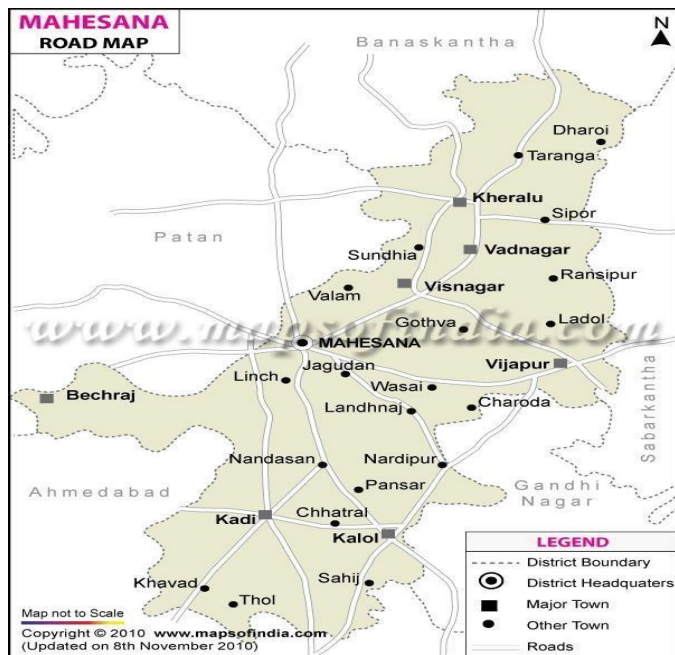


Fig. -3: Location map of TB Road in Ruturaj-Mehsana

7. DESIGN INPUT PARAMETERS

Table -1: Design Input Parameters

Parameter	Value
Initial CVPD (A)	450
Growth Rate (r)	7.5%
Design Life (n)	15 years
Lane Distribution Factor (D)	0.75
Vehicle Damage Factor (F)	3.5
Subgrade CBR	6%

8. DESIGN TRAFFIC CALCULATION

Design traffic is calculated using IRC formula

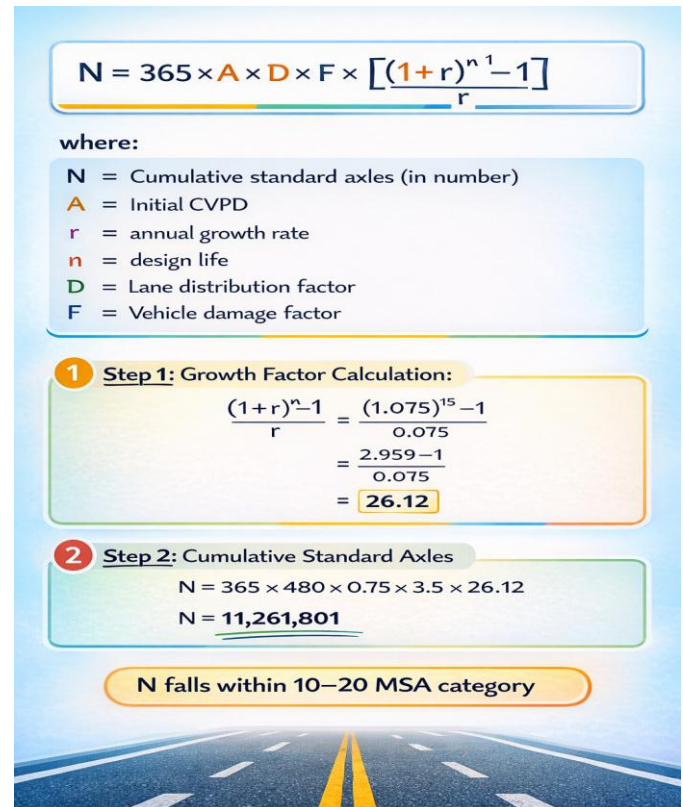


Fig. -4: Traffic calculation

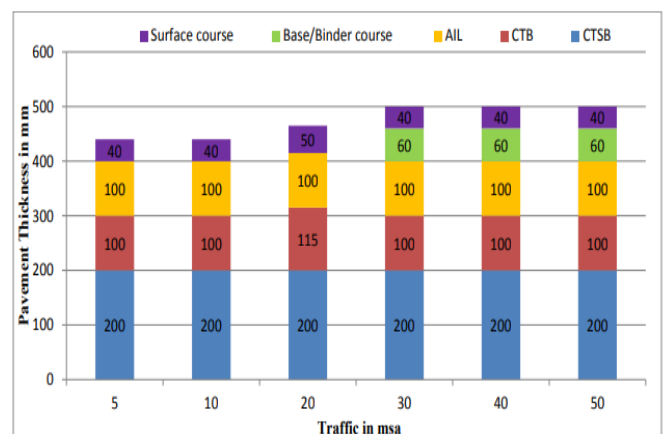


Fig. -5: IRC Design chart for 10-20 msa

9. FINAL PAVEMENT COMPOSITION

Traffic Category: 10-20 MSA Subgrade CBR: 6%

Required thickness ≈ 620 mm.

Table -2: Recommended Pavement Structure

Layer	Material	Course Type	Thickness (mm)
Wearing Course	Bituminous Concrete	Surface Layer	40
Binder Course	Dense Bituminous Macadam	Intermediate Bituminous Layer	—
Base Course	Wet Mix Macadam	Base Layer	100
Sub-base	Granular Subbase	Sub-base Layer	250
Total	—	—	620

Minimum bituminous thickness required ≥ 140 mm provided = 140 mm

Base thickness required ≥ 250 mm provided = 250 mm

Total thickness = 620 mm Adequate for 11.26 MSA and CBR 6%.

The design traffic of 11.26 MSA places TB Road under moderate commercial loading. The thickness of 620 mm ensures stresses transmitted to the subgrade remain within permissible limits. The design balances structural safety and cost efficiency.

10. COMPARISON WITH TYPICAL DESIGNS

Typical flexible pavement designs for similar traffic conditions in Gujarat often range from 550 mm to 700 mm total thickness. The designed 620 mm falls within this range, validating the reasonableness of the design.

Table -3: Comparison with Typical Designs

Traffic Range (MSA)	CBR (%)	Typical Thickness Range (mm)	Design (mm)
10-20	6	580-650	620

From comparison, if subgrade CBR were lower (e.g., 4%), the required total thickness would increase to approximately 700-750 mm. Conversely, if traffic were lower (e.g., 5 MSA), thickness could be reduced to 550-600 mm. This demonstrates the sensitivity of pavement design to input parameters and the importance of accurate site-specific data.

11. FACTORS AFFECTING PAVEMENT PERFORMANCE

Several factors beyond design thickness influence pavement performance:

Construction Quality:

Achieving design performance relies heavily on effective compaction, monitoring layer thickness, ensuring uniformity of materials, and maintaining strong bonding between layers. One of the primary reasons for early pavement failure is insufficient compaction. It is essential that each layer is compacted to the specified density with optimal moisture content.

Drainage:

Inadequate drainage leads to moisture accumulation in granular layers and subgrade, reducing strength and causing premature failure. For TB Road, side drains should be provided and maintained. Cross-drainage structures must be adequate for the catchment area. The pavement surface should have proper camber (2.5-3.0%) for effective surface drainage.

Material Quality:

Aggregates must meet gradation, strength, and durability requirements. Poor quality aggregates can break down under traffic, leading to loss of structural integrity. Bitumen should conform to specified grades and properties. Contaminated materials must be rejected.

Traffic Loading:

Vehicles that are overloaded can greatly shorten the lifespan of pavement. A 10% rise in axle load can lead to a 30-40% decrease in pavement longevity due to the fourth-power relationship between load and damage. Enforcing weight restrictions is crucial for meeting the intended lifespan of the pavement.

Environmental Conditions:

Elevated temperatures in Mehsana (40-45°C during summer) can soften bitumen, which may result in rutting. Rainfall during the monsoon season affects the moisture levels in the subgrade, making proper drainage necessary. Variations in temperature induce thermal stresses within the bituminous layers.

Maintenance:

Consistent maintenance, such as sealing cracks, repairing potholes, and periodically renewing the wearing surface, prolongs the lifespan of the pavement. Postponing maintenance allows wear and tear to worsen, resulting in more extensive and expensive repairs.

12. SENSITIVITY ANALYSIS

The design is sensitive to variations in input parameters:

Traffic Growth Rate:

If growth rate increases to 8.0%: $N = 12.48$ MSA (10.8% increase)

If growth rate decreases to 7.0%: $N = 10.18$ MSA (9.6% decrease)

Vehicle Damage Factor:

If VDF increases to 4.0: $N = 12.87$ MSA (14.3% increase)

If VDF decreases to 3.0: $N = 9.65$ MSA (14.3% decrease)

Initial CVPD:

If CVPD increases to 500: $N = 12.51$ MSA (11.1% increase)

If CVPD decreases to 400: $N = 10.01$ MSA (11.1% decrease)

Subgrade CBR:

If CBR is 5%: Required thickness increases to ~660 mm

If CBR is 8%: Required thickness decreases to ~560 mm

this sensitivity analysis underscores the importance of accurate input data and the need for conservative assumptions in the absence of site-specific data.

13. LIMITATIONS OF THE STUDY

This study has several limitations that should be acknowledged:

Traffic Data: Traffic information relies on standard figures instead of thorough traffic assessments. Conducting an extensive traffic analysis, which includes classified volume counts, axle load assessments, and origin-destination research, would yield more precise data.

Subgrade CBR: CBR relies on standard values instead of being established through lab tests. It is advisable to conduct site-specific testing for real construction, which should involve sampling at regular intervals along the route.

No Mechanistic Analysis: Although the approach of using a design catalogue has been confirmed, a comprehensive mechanistic analysis could offer further confirmation of how pavements respond, specifically regarding tensile strains in bituminous layers and compressive strains in the subgrade.

Material Properties: The material properties were derived from standard values instead of being established through lab testing. Creating a mix design and characterizing the actual materials would enhance the design.

No Economic Analysis: A life-cycle cost analysis to compare different options was not conducted. This type of analysis would aid in optimizing the design by taking into account initial costs, maintenance expenses, and user costs.

Environmental Factors: The environmental factors of temperature and moisture were not quantitatively analyzed. These elements affect the behavior of materials and the performance of pavement.

Drainage Design: In-depth drainage design, which encompasses hydrological analysis and cross-drainage structures, was not included in the project scope.

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