Design Considerations for Traffic and Pavement thickness Layer

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***Abstract*—This paper presents an analytical approach to the interpretation of pavement layers and the design considerations required for traffic and pavement layer thickness. The study focuses on the role of subgrade strength (CBR values) in determining the required pavement thickness and evaluates how different contamination levels affect pavement performance. The research highlights how the granular base, sub-base, and bituminous layers are designed to accommodate varying traffic loads while maintaining long-term durability. The findings emphasize the importance of engineering interventions in pavement design to enhance road longevity and performance.**

***Index Terms*—Pavement layers, CBR value, Traffic design, Bituminous macadam, Granular base.**

I. INTRODUCTION

Pavement design plays a crucial role in ensuring the long-term durability and functionality of road infrastructure. The interpretation of pavement layers is essential for understanding how different components contribute to load distribution and stability. The strength of the subgrade, typically determined by the California Bearing Ratio (CBR), significantly influences the required pavement thickness. This study examines the impact of subgrade strength variations on pavement layer design, particularly in the context of acidic and basic contamination.

In road transportation, the main objective of CBR analysis is to ensure that the pavement can withstand the cumulative traffic loads over its design life without premature failures like rutting, cracking, or heaving. The test result helps classify the subgrade soil and optimize the pavement layers to enhance durability, performance, and cost-efficiency.

CBR values are crucial for determining pavement thickness. The higher the CBR value, the stronger the soil and the thinner the pavement layers required. Typical CBR ranges are as follows:

- High Strength Soil: CBR > 10% (requires thinner pavement).
- Medium Strength Soil: CBR between 5% and 10% (moderate pavement thickness).
- Low Strength Soil: CBR < 5% (requires thicker pavement to distribute the load effectively).

CBR analysis is integrated with traffic data, including the number of commercial vehicles per day (cvpd), growth rate, lane distribution factor, and vehicle damage factor, to calculate the cumulative standard axles (MSA) over the design life of the pavement. This value helps engineers design pavements that can endure increasing traffic loads while minimizing maintenance costs.

CBR analysis is a foundational tool in the design of flexible pavements for road transportation. By accurately determining subgrade strength and optimizing layer thickness, CBR testing ensures long-term pavement performance, cost efficiency, and road safety. Soil stabilization techniques, like lime or cement treatment, may also be applied to enhance subgrade CBR, further improving pavement durability.

II. INTERPRETATION OF PAVEMENT LAYERS

Pavement structures comprise multiple layers designed to distribute traffic loads efficiently while resisting environmental and mechanical stresses. The key layers include:

A. Bituminous Concrete (BC) (Top Layer)

- Acts as the wearing course, providing a smooth and durable surface.

- Maintains a constant thickness of 40 mm across all CBR values.
- Resists traffic loads and environmental conditions.

B. Dense Bituminous Macadam (DBM) (Binder Course)
- Functions as a load-distributing layer beneath the bituminous concrete.
- Thickness varies based on CBR values: 60 mm (CBR 7.0), 80 mm (CBR 4.5), and 90 mm (CBR 3.0).
- Lower CBR values require thicker DBM layers to maintain structural integrity.

C. Granular Base (GB)
- Provides fundamental structural support and load distribution.
- Maintains a constant thickness of 250 mm, ensuring adequate load-bearing capacity.

D. Granular Sub-Base (GSB)
- Functions as a drainage layer and additional load distributor.
- Thickness varies with CBR: 230 mm (CBR 7.0), 330 mm (CBR 4.5), and 380 mm (CBR 3.0).
- Weaker soils necessitate increased thickness to improve stability.

E. Layer of Good Earth Soil (Subgrade Improvement Layer)
- Provides foundational support to the pavement system.
- Remains constant at 500 mm for all cases to ensure soil strength.

F. Total Pavement Thickness
- Increases as CBR decreases to compensate for weaker subgrade:
  - 580 mm for CBR 7.0.
  - 700 mm for CBR 4.5.
  - 760 mm for CBR 3.0.
- This ensures the pavement can withstand the anticipated traffic loads.

III. DESIGN CONSIDERATIONS FOR TRAFFIC & PAVEMENT THICKNESS

A. Traffic Growth Impact on Pavement Performance
- Urban expansion and commercial vehicle traffic contribute to increasing loads on pavements annually.
- Reduction in subgrade strength due to contamination can accelerate pavement deterioration.
- Regular reassessment of traffic loads ensures that pavements remain structurally sound.

B. Design Parameters for Flexible Pavement

The following factors are considered while designing a flexible pavement:
1. Two-lane single carriageway.
2. Commercial vehicle growth rate of 7.5% per annum.
3. Initial traffic at construction completion: 500 cvpd.
4. Lane distribution factor: 0.75 (as per IRC-37: 2001).
5. Vehicle damage factor: 3.5 for 150-1500 cvpd.
6. Design life: 15 years.
7. Subgrade CBR: 7.0%.

C. Pavement Layer Thickness Based on CBR Values

CBR Value (%)	BC Thickness (mm)	DBM Thickness (mm)	Granular Base (mm)	Granular Sub-Base (mm)	Total Thickness (mm)
7.0	40	60	250	230	580
4.5	40	80	250	330	700
3.0	40	90	250	380	760

D. Key Observations
- Lower CBR values necessitate thicker pavement layers to ensure durability and performance.
- Granular Sub-Base and DBM layers are variable and adjusted to maintain stability.
- Bituminous Concrete and Granular Base remain constant, indicating their standardized function in pavement design.

E. Design Calculations

Design Traffic Calculations for Flexible Pavement

In the design of flexible pavements, calculating the design traffic in terms of **cumulative standard axles (msa)** is crucial to ensure adequate load-bearing capacity over the pavement's design life. The following equation, as per IRC guidelines, is used to determine the cumulative traffic load:

$$N = 365 \times A \times \frac{(1+r)^n - 1}{r} \times D \times F$$

Where:
- **N** = Cumulative standard axles (msa)

- **A** = Initial traffic in the year of construction (500 commercial vehicles per day)
- **r** = Annual traffic growth rate (7.5% or 0.075)
- **n** = Design life (15 years)
- **D** = Lane distribution factor (0.75)
- **F** = Vehicle damage factor (3.5, applicable for 150-1500 cvpd on rolling/plain terrain)

Substituting the given values:

1. $(1+r)^n = (1+0.075)^{15} = 2.948$
2. $\frac{2.948-1}{0.075} = 25.973$
3. Calculate N:

$N = 365 \times 500 \times 25.973 \times 0.75 \times 3.5N = 12{,}426{,}212.5 \approx 12.4$ msa

Result

The design traffic load is approximately 12.4 msa, and for practical purposes, it is rounded off to 12.0 msa. This value will be used to determine the appropriate thickness of the pavement layers to ensure durability and performance over the specified design life.

IV. PRACTICAL IMPLICATIONS & ENGINEERING RECOMMENDATIONS

1. Enhanced Layer Thickness for Contaminated Subgrades
   - Acidic contamination weakens soil strength, requiring thicker pavement layers.
   - Basic contamination slightly increases strength but still requires design modifications.
2. Material Selection
   - Use of chemically stabilized subgrades or geosynthetics is recommended.
   - Lime or cement stabilization may enhance subgrade performance.
3. Drainage Considerations
   - Sub-surface drains should be incorporated to mitigate moisture-related weakening of contaminated soils.
4. Regular Monitoring & Maintenance

Long-term performance assessment is necessary to adjust pavement rehabilitation strategies.

V. CONCLUSION

This study highlights the significance of interpreting pavement layers in designing roads with varying subgrade strengths. Lower CBR values demand thicker pavement layers to compensate for reduced soil strength. Acidic contamination severely weakens the subgrade, whereas basic contamination offers slight improvements. Proper material selection, layer thickness adjustments, and regular traffic load reassessments are essential to maintaining pavement durability. Future research should focus on optimizing stabilization techniques to enhance road longevity while minimizing construction costs.

VI. ACKNOWLEDGMENT

I am profoundly grateful to Almighty God for His grace and mercy, which guided me throughout the completion of this dissertation. I express my heartfelt gratitude to my parents for their constant blessings and unwavering support, which have been a source of strength throughout this journey.

I extend my sincere appreciation to Prof. Jash Kansara, Assistant Professor, Faculty of Engineering and Technology, Sankalchand Patel College of Engineering, Visnagar, and Prof. Apoorva Patel, my external guide, for their invaluable guidance, insightful suggestions, and encouragement, which greatly contributed to the successful completion of this work. I am also deeply thankful to Mr. Srinath Karli, Lead Penetration Tester, Cipher Legion Pvt. Ltd., Pune, Maharashtra, for his support and valuable insights.

My sincere thanks go to Dr. P.J. Patel, Principal, and Dr. P.J. Patel, Head of Department (H.O.D.), for their moral support and cooperation throughout the course of this work. I am equally appreciative of the faculty members of the Civil Engineering Department for their academic guidance and continuous encouragement.

Finally, I wish to express my deepest gratitude to my family and friends, whose constant encouragement and unwavering belief in me have been instrumental in the successful completion of this dissertation.

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