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Design of Flexible Pavement by Group Index Method

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A B S T R A C T

The design of flexible pavements plays a crucial role in ensuring the longevity, safety, and cost-effectiveness of transportation infrastructure. Among the various methodologies available for pavement design, the Group Index method stands out as a widely used approach due to its simplicity and practicality. This research aims to provide a comprehensive analysis of the design process of flexible pavements utilizing the Group Index method. This study explores the use of the Group Index (GI) method for determining flexible pavement thickness. The GI method considers soil properties, traffic loading, and environmental factors to estimate pavement structural adequacy. Modern technologies like GIS and pavement performance models enhance the accuracy of this approach. Case studies or simulations illustrate the method's effectiveness in optimizing pavement thickness. The findings contribute to pavement engineering by offering a reliable method for designing flexible pavements suited to local conditions. Adoption of the GI method supports the construction of resilient transportation infrastructure, promoting socio-economic development and safer mobility.

Keywords: GI, CBR, pavement, soil, properties

1. Introduction

1.1 Overview

Flexible pavement design is essential for constructing durable and safe road networks. One crucial aspect of this design process is determining the appropriate pavement thickness to ensure structural integrity and longevity. In this context, the Group Index (GI) method emerges as a fundamental approach for assessing the structural adequacy of flexible pavements.

1.2 Necessity of Study

The necessity of studying the application of the Group Index method lies in the critical need to develop reliable and cost-effective pavement design techniques. With increasing demands on transportation infrastructure, particularly in rapidly growing urban and suburban areas, there is a pressing need for methods that can efficiently accommodate diverse soil conditions and traffic loads.

1.3 Objectives of Study

The objectives of this study encompass evaluating the suitability and accuracy of the Group Index method for determining flexible pavement thickness. Through comprehensive analysis and empirical investigations, the study aims to assess the method's performance across various soil types, traffic volumes, and environmental factors. Additionally, the research endeavors to identify any limitations or areas for refinement to enhance the method's applicability and reliability in practical engineering applications.

1.4 Advantages

Advantages inherent in utilizing the Group Index method for pavement thickness design include its ability to integrate multiple factors influencing pavement performance into a cohesive framework. By considering soil characteristics, traffic loading, and environmental conditions, the method offers a holistic approach to pavement design, optimizing material usage and construction costs. Moreover, its simplicity and adaptability make it accessible to engineers and practitioners, facilitating informed decision-making in pavement engineering projects.

1.5 Significance of Study

The significance of this study extends beyond technical considerations to encompass broader socio-economic implications. By establishing a robust methodology for flexible pavement thickness design, the research contributes to the development of resilient transportation infrastructure. Enhanced pavement performance ensures safer travel for road users and supports economic growth by facilitating efficient movement of goods and services. Thus, the study's findings hold potential to positively impact infrastructure development initiatives and promote sustainable mobility solutions in diverse geographical contexts.

2. Literature Review

Flexible pavements are widely used for roads due to their cost-effectiveness and adaptability to various traffic volumes. However, ensuring their long-term performance necessitates a well-designed structure. This review explores the literature on design methods for flexible pavements, focusing on the Group Index method.

2.1 Indian Standards and IRC Guidelines:

- **IS 2720 (Part 4 & 5):1985:** These Indian Standards (IS) likely provided specifications for materials used in flexible pavement construction (Part 4) and methods of test for soil and aggregates used in pavement construction (Part 5). While valuable for understanding historical practices, they might be superseded by more recent standards.
- **IRC 37 Series:** This series of IRC guidelines chronicles the evolution of flexible pavement design practices in India. It's crucial to note the following:
- **IRC 37-1970, 1984, 2001, and 2012:** These older versions of IRC 37 might have outlined design procedures using methods like the Group Index method. However, their relevance for current design practices in India is limited.

2.2 Research Articles:

- **"Designing of Flexible Pavement for IET Lucknow, Using Group Index Method" (International Journal of Research Publication & Reviews):** This article might present a case study of flexible pavement design using the Group Index method. While the Group Index method offers a quicker approach, it's important to compare its accuracy and limitations with the CBR method as per current IRC recommendations. [1], [2]

3. Group Index Method

The Group Index (GI) method offers a few advantages that make it usable for determining the thickness of flexible pavement, especially for preliminary designs or in situations with limited resources.

Here's why:

- Simple and Quick: The GI method relies on basic soil properties like sieve analysis, Atterberg Limits (liquid limit and plasticity index), and dry density. These tests are relatively simple and inexpensive to conduct compared to more complex methods.
- Focuses on Subgrade Strength: The GI incorporates factors that influence the subgrade's ability to support traffic loads. Factors like fines content, plasticity, and liquid limit all contribute to a soil's susceptibility to deformation under load.
- Empirical Relationship: The GI method establishes an empirical relationship between these soil properties and the required pavement thickness. This relationship is based on historical data and field observations, offering a quick way to estimate pavement thickness for various subgrade conditions.
- However, it's important to remember some limitations of the GI method:
- Limited Scope: The GI method primarily focuses on subgrade characteristics and doesn't account for factors like traffic volume, tire pressure, or environmental conditions. These can significantly impact pavement design.
- Empirical Nature: The GI method relies on past observations, and its accuracy can be affected by variations in local soil behavior and materials used in the pavement structure.
- Conservative Approach: The GI method often leads to conservative pavement designs, meaning the recommended thickness might be more than strictly necessary. This can result in increased construction costs.

In conclusion, the GI method provides a usable approach for initial pavement thickness estimation due to its simplicity and focus on subgrade strength. However, it's crucial to consider its limitations and combine it with other design methods or engineering judgment for a more comprehensive pavement design.

4. Test Procedure

The Group Index method itself doesn't involve a specific test procedure. It relies on data obtained from standard geotechnical tests performed on subgrade soil samples. Here's a breakdown of the steps involved in using the GI method:

4. 1. Subgrade Soil Sampling:

Collect representative soil samples from the intended pavement subgrade location following standard procedures. This may involve obtaining samples from different depths depending on the anticipated pavement depth.

4.2. Laboratory Testing:

Conduct the following laboratory tests on the collected soil samples:

- **Sieve Analysis:** Determine the grain size distribution of the soil by separating it into different size fractions using a series of sieves. This helps determine the percentage of fines (material passing a specific sieve size) which is included in the GI calculation.
- **Atterberg Limits:** Perform Atterberg Limits tests to determine the Liquid Limit (LL) and Plasticity Index (PI) of the soil. These tests measure the soil's water content at different plasticity states.

4.3. Group Index (GI) Calculation:

Once you have the results from the sieve analysis and Atterberg Limits tests, use the following formula to calculate the Group Index (GI):

$GI = 0.2a + 0.005ac + 0.01bd$ ------(1)

where:

a = Percentage of soil passing a 0.074 mm sieve (No. 200 sieve) in excess of 35%, not exceeding 75%

b = Percentage of soil passing a 0.074 mm sieve (No. 200 sieve) in excess of 15%, not exceeding 55%

c = Liquid Limit (%) in excess of 40% (not exceeding a value of 60%)

d = Plasticity Index (%) in excess of 10% (not exceeding a value of 30%)

4.4. Determine Pavement Thickness:

With the calculated GI value, refer to established charts or tables that relate the GI to the recommended total pavement thickness (including surface, base, and sub-base layers) for various traffic volumes. These charts are typically provided by national or regional transportation authorities or industry standards.

Remember: The GI method provides a preliminary estimate. For a complete and reliable pavement design, consider factors like traffic volume, environmental conditions, and specific material properties in conjunction with the GI method or other established design procedures.

Samples are collected from different patches of existing road and different suggestions were made to enhance the quality of existing pavement.

1. Collection of samples: 3 samples of soil had been collected in the location of the site.
2. Types of test:
3. Plastic limit
4. Liquid limit
5. Sieve analysis

In urban areas, designing flexible pavements must address fluctuating traffic patterns and diverse soil conditions. The Group Index (GI) method is ideal for this, considering traffic loading and soil properties.

Traffic Variation:

Urban traffic varies greatly, from heavy congestion to intermittent flows. The GI method adjusts pavement thickness based on traffic surveys, accommodating different vehicle types, loads, and volumes.

Soil Variability:

Urban soils differ due to past land use and geological factors. The GI method assesses soil properties like texture and moisture content, vital for pavement design adjustments.

Methodology:

This case study employs field investigations, laboratory tests, and GIS analysis to understand traffic and soil conditions. It then applies the GI method to optimize pavement thickness designs.

Outcome:

Using the GI method results in tailored pavement designs, considering urban traffic and soil variability. Recommendations include regular monitoring and maintenance to sustain pavement performance amidst urban dynamics. , [11]–[16],

5. Calculations

a) Sieve Analysis (IS 2720 (Part 4):1985)

Weight of dry soil sample – 1000gm

Table 1 – Sieve analysis for soil sample

Sieve Size	**Mass Retained**	**Cumulative mass retained (gm)**	**Percentage Cumulative mass retained**	**Percentage finer or Percentage passing**
10mm	200	200	20	80
4.75mm	75	275	27.5	72.5
2mm	130	405	40.5	59.5
1mm	50	455	45.5	54.5
600mic	75	530	53	47
425mic	25	555	55.5	44.5
300mic	50	605	60.5	39.5
150mic	25	630	63	37
75mic	15	645	64.5	35.5
PAN	355	1000	100	0

b) Plastic Limit (IS 2720 (Part 5):1985)

PL = 34.443

Table 2 – Plastic Limit analysis for soil sample

Container No.	**06**	**14**	**01**
Mass of empty container (M1), (g)	10	10	10
Mass of container + wet soil (M2), (g)	18	16	16

Mass of Container + dry soil (M3), (g)	16	15	14
Mass of wet soil (M2-M1), (g)	8	6	6
Mass of dry soil (M3-M1), (g)	6	5	4
Mass of water (M2-M3), (g)	2	1	2
Moisture Content = (M2-M3) / (M3-M1) x 100 %	33.33	20	50

c) Liquid Limit (IS 2720 (Part 5):1985)

LL = (M2-M3/M3-M1) *100

= 51.85

Table 3 – Liquid Limit analysis for soil sample

Sample No.	**1**	**2**	**3**
No. of blows	48	24	09
Container no.	23	03	09
Mass of empty contained with Lid (M1) (g)	10	10	10
Mass of container with lid and wet soil (M2) (g)	21	23	24
Mass of container with lid and dry soil (M3) (g)	18	18	19
Mass of dry soil, Md = (M3-M1) (g)	08	08	09
Mass of Water, Mw = (M2-M3) (g)	03	05	05
Water Content (g)	37.50	62.50	55.55

Plasticity Index = PI = LL – PL

= 51.85 – 34.43

PI = 17.42

1st Step:- Group index value:

GI = 0.2a+ 0.005ac +0.01bd

a = Percentage Passing Sieve 0.075 – 35

= 35.5 – 35

= 0.5

b = Percentage Passing Sieve 0.075 – 15

= 35.5 – 15

= 20.5

c = Liquid Limit - 40

= 51.85 – 40

= 11.85

d = Plasticity Index – 10

= 17.42 – 10

= 7.42

GI = (0.2 x 0.5) + (0.005 x 0.5 x 11.85) + (0.01 x 20.5 x 7.42)

GI = 1.65 = ~2.0

2nd Step:- Traffic Volume:

- Light traffic:- 50 commercial vehicles/day
- Medium traffic:- 50-300 commercial vehicles/day
- Heavy Traffic:- ≥300 commercial vehicles/day

Assuming, Traffic Intensity is High (500 commercial vehicles/day)

3rd Step:- Flexible Pavement Thickness Design:

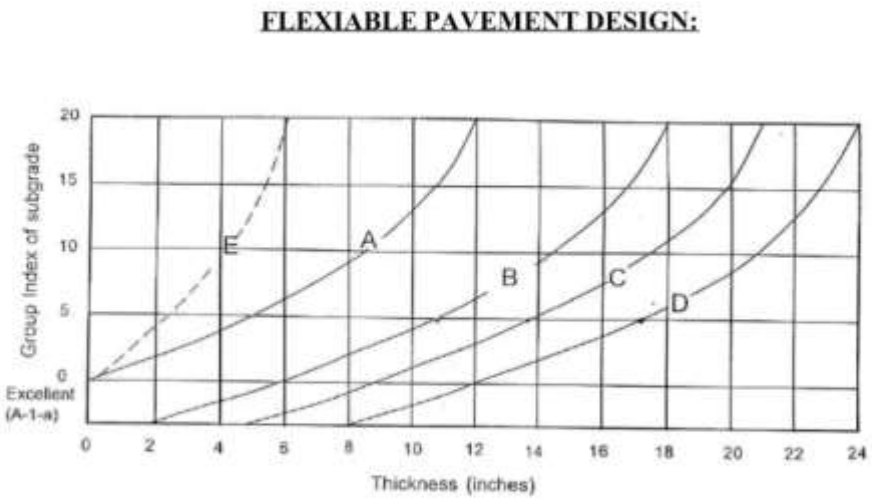

Fig. 1 -.Thickness design as per to IRC

According to IRC 37 we can select the thickness of pavement (surface course, base course, sub-base course) by using this chart.

Table 4 - An example of a table.

Traffic Intensity	**Total Thickness (T) (Inch)**	**Thickness of surface Course (Ts) (Inch)**	**Thickness of Base Course (Tb) (Inch)**	**Thickness of Sub-base Course (Tsb) (Inch)**
High Intensity 500 VPD	14.0	2.0	6.0	6.0

Surface Course 2inch Thickness
Base Course 6inch Thickness

Sub Base Course 6inch Thickness
Subgrade

Fig. 2 -. Pavement Thickness Diagram

6. Result & Conclusion

The design of the flexible pavement, employing the Group Index (GI) method, has been tailored considering key soil properties and traffic characteristics. The plastic limit, liquid limit, and plasticity index of the soil serve as crucial parameters in determining its suitability for pavement construction.

The soil's plastic limit of 34.443, liquid limit of 51.85, and plasticity index of 17.42 provide insights into its behavior and potential for deformation under traffic loading. These properties aid in classifying the soil and assessing its engineering properties, which are essential for pavement design.

The type of traffic, identified as heavy traffic with a traffic intensity of 500 vehicles per day, underscores the importance of selecting appropriate pavement thickness and materials to withstand the anticipated loadings and minimize distresses over time.

The calculated Group Index (GI) value of 2.0 reflects the overall quality of the subgrade soil and its suitability for pavement construction. This value guides the determination of pavement thickness and structural design requirements.

With a pavement thickness of 35 cm obtained through the design process, the proposed flexible pavement structure is expected to provide adequate support, load distribution, and resistance to deformation under heavy traffic loading conditions.

In conclusion, the design of the flexible pavement using the Group Index (GI) method takes into account the soil properties, traffic characteristics, and structural requirements to ensure the development of a resilient and durable pavement system capable of withstanding the rigors of heavy traffic and environmental conditions. [3]–[10]

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