Cross-Cutting Technology of Cement Concrete Road Construction in India

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***Abstract*— Cement concrete (CC) roads have emerged as a sustainable and durable alternative to conventional bituminous pavements in India, particularly for rural and low-volume roads. Among various construction practices, cross-cutting technology plays a vital role in controlling shrinkage cracks and improving the long-term performance of concrete pavements. This review paper presents a comprehensive study on the design concepts, construction methodology, material composition, and performance aspects of CC roads constructed using cross-cutting technology under Indian conditions. Emphasis is given to typical cross-sections adopted for hard soil and black cotton soil regions, highlighting the importance of sand cushioning layers, proper camber, and joint spacing. The paper reviews existing literature related to jointed plain concrete pavements, subgrade behavior, crack control mechanisms, and cost-effectiveness of CC roads. Findings indicate that early-age cross-cutting significantly reduces uncontrolled cracking and enhances pavement durability. The review also discusses challenges, research gaps, and future scope for improving CC road performance through advanced materials and monitoring techniques. Overall, this study provides valuable insights for engineers and planners involved in sustainable road infrastructure development.**

Keywords: Cement Concrete Roads, Cross-Cutting Technology, Jointed Plain Concrete Pavement, Rural Road Infrastructure, Subgrade Soil Behavior etc.

I. INTRODUCTION

Road infrastructure plays a crucial role in the socio-economic development of any country by facilitating transportation, trade, and accessibility. In India, the rapid growth of population and vehicular traffic has imposed severe demands on road networks, especially in rural and semi-urban areas. Traditionally, bituminous pavements have been widely used due to their low initial cost and ease of construction. However, these pavements often suffer from premature failures such as rutting, potholes, bleeding, and fatigue cracking, particularly under heavy traffic loads and adverse climatic conditions [1]. As a result, attention has shifted toward cement concrete (CC) roads, which offer superior durability, higher load-carrying capacity, and lower lifecycle maintenance costs.

Cement concrete roads, also referred to as rigid pavements, derive their structural strength from the flexural rigidity of the concrete slab. Unlike flexible pavements, the load is distributed over a wider area, reducing stresses on the subgrade [2]. This characteristic makes CC roads especially suitable for regions with weak or problematic soils, such as black cotton soil, which exhibits swelling and shrinkage due to moisture variation. To address these challenges, standardized pavement cross-sections incorporating sand filling and proper drainage provisions are commonly adopted in Indian practice.

One of the major concerns in CC pavement construction is the development of cracks due to drying shrinkage, temperature variation, and restraint offered by the subgrade. If not properly controlled, these cracks can propagate randomly, leading to reduced service life and increased maintenance requirements. Cross-cutting technology, also known as saw-cut jointing, is an effective method used to control crack formation in concrete pavements [3]. In this technique, transverse and longitudinal joints are deliberately introduced at predetermined intervals shortly after concrete placement. These joints act as weakened planes, ensuring that cracks occur at desired locations without affecting structural integrity.

Distresses in a Bituminous Pavement

Distressed Concrete Pavement

The Indian Roads Congress (IRC) and Bureau of Indian Standards (BIS) recommend jointed plain concrete pavement (JPCP) systems for low-volume and rural roads, where cross-cutting plays a critical role in crack control [4]. Proper timing, depth, and spacing of cross-cuts are essential to ensure effective stress relief. Studies have shown that early-age saw cutting, typically within 6 to 12 hours after concrete laying, significantly reduces random cracking and improves pavement performance [5].

In rural road development programs such as the Pradhan Mantri Gram Sadak Yojana (PMGSY), CC roads with cross-cutting technology have gained popularity due to their long service life of 25–30 years and minimal maintenance requirements. Typical cross-sections for hard soil and black cotton soil regions include multiple layers such as sand filling, lean concrete, and wearing concrete layers, along with adequate camber to facilitate surface drainage. These design features enhance pavement stability and resistance to environmental effects.

Despite the advantages, the initial construction cost of CC roads is higher than that of bituminous roads. However, lifecycle cost analysis indicates that CC roads are more economical in the long run due to reduced maintenance and rehabilitation needs [6]. With increasing emphasis on sustainable infrastructure, CC pavements are being increasingly adopted for village roads, urban streets, industrial access roads, and heavy-duty pavements.

This study aims to consolidate existing research related to CC road construction using cross-cutting technology, focusing on design practices, construction methods, performance evaluation, and research gaps under Indian conditions.

II. PROBLEM IDENTIFICATION

- Many rural and low-volume roads in India constructed with bituminous layers experience premature failures such as potholes, rutting, and cracking due to heavy axle loads and climatic variations.
- Black cotton soil regions pose serious challenges because of their high swelling and shrinkage characteristics, leading to pavement heaving and settlement.
- Conventional CC roads without proper jointing develop uncontrolled cracks caused by drying shrinkage and temperature stresses.
- Inadequate subgrade preparation and lack of sand cushioning result in differential settlement and edge failures.
- Improper timing and spacing of joints reduce pavement durability and increase maintenance requirements.
- Limited field-based studies are available on optimized cross-cutting practices for Indian soil and climate conditions.
- Absence of standardized construction quality control leads to inconsistent performance of CC roads across regions.

A. *Existing System*

- The existing road infrastructure in India largely relies on bituminous pavements for rural and low-volume roads due to their lower initial construction cost.
- Conventional cement concrete (CC) roads are constructed without optimized jointing or cross-cutting practices in many regions.
- Standard pavement construction includes basic subgrade compaction with minimal soil treatment, even in problematic soil areas.
- In black cotton soil regions, limited use of sand cushioning or stabilization methods is observed.
- Joint spacing and cutting time are often decided based on experience rather than codal recommendations.

- Maintenance activities are generally reactive, carried out only after visible distress occurs.
- Quality control during construction varies significantly across projects and regions.

B. Drawbacks

- Bituminous roads deteriorate rapidly under heavy traffic, water ingress, and temperature variations, leading to frequent potholes and rutting.
- Lack of proper jointing in CC roads results in uncontrolled cracking due to shrinkage and thermal stresses.
- Poor subgrade preparation causes uneven settlement, slab cracking, and edge failures.
- Black cotton soil-induced swelling and shrinkage significantly reduce pavement life when untreated.
- Inadequate drainage and improper camber lead to water stagnation and structural weakening.
- High recurring maintenance costs make the system economically inefficient over its lifecycle.
- Absence of performance monitoring limits timely corrective measures and long-term durability assessment.

III. METHODOLOGY

- Conduct site survey to assess soil type, moisture content, ground level, and drainage requirements for proper CC road design.
- Classify the soil as black cotton or hard soil and select the appropriate standard cross-section based on soil behavior.
- Prepare the subgrade by leveling, compacting, and removing organic or weak material to achieve uniform support conditions.
- Place the sand filling layer (100–200 mm) and compact it thoroughly to minimize settlement and reduce soil swelling effects.
- Lay formwork and reinforcement (if required) and prepare the concrete mix as per design proportions (1:2:4 and 1:3:6).
- Pour concrete, spread uniformly, vibrate mechanically, and finish the surface with proper camber (3% slope).
- Apply cross-cutting (control joints) within 6–12 hours to prevent shrinkage cracks.
- Cure the pavement for 14–21 days and inspect joints, surface quality, and structural uniformity.

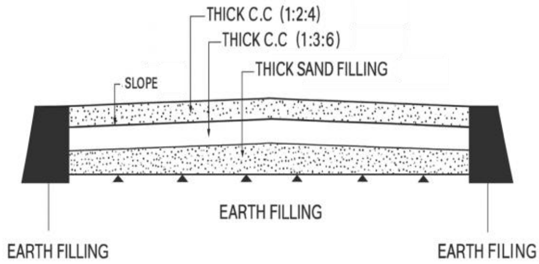


Figure 1. Cross-section of a cement concrete (CC) road constructed in hard soil conditions

- The figure shows a simplified cross-section of a cement concrete (CC) road constructed in hard soil conditions.
- The pavement consists of two concrete layers: top CC (1:2:4) and bottom CC (1:3:6).
- A sand-filling layer is placed below the concrete to improve stability and drainage.
- The road surface is provided with a slope for efficient water runoff.
- Both sides of the pavement are supported by compacted earth filling for edge stability.
- The section ensures strength, durability, and uniform load distribution.

Implementation System of Cement Concrete Road Using Cross-Cutting Technology.

The implementation system for cement concrete (CC) road construction using cross-cutting technology involves a systematic approach that integrates site investigation, material selection, pavement design, construction practices, and quality control. This chapter explains the step-by-step execution process adopted for constructing durable CC roads under Indian conditions, particularly for hard soil and black cotton soil regions.

1. Site Investigation and Planning

The implementation begins with a detailed site survey to evaluate soil type, moisture content, topography, and drainage conditions. Soil classification is carried out to determine whether the subgrade is hard soil or expansive soil such as black cotton soil. Field tests like the California Bearing Ratio (CBR) and moisture content tests help in assessing load-bearing capacity. Based on these parameters, an appropriate pavement cross-section is selected.

Proper planning includes alignment marking, road width (typically 3.0 m for rural roads), and provision of camber (around 2–3%) to ensure effective surface drainage. Adequate drainage design is essential to prevent water accumulation, which can weaken the pavement structure.

2. Subgrade Preparation

The subgrade acts as the foundation of the pavement, and its preparation is critical for long-term performance. The existing ground is cleared of vegetation, debris, and weak soil. It is then leveled and compacted using rollers to achieve the desired density. In black cotton soil regions, additional precautions are taken due to swelling and shrinkage characteristics.

A sand cushioning layer is provided above the subgrade to minimize the effects of soil expansion. This layer typically ranges between 100 mm to 200 mm thickness and is well compacted to create a stable base for concrete layers.

3. Pavement Layer Design

The CC road consists of multiple layers designed to distribute loads effectively and ensure durability.

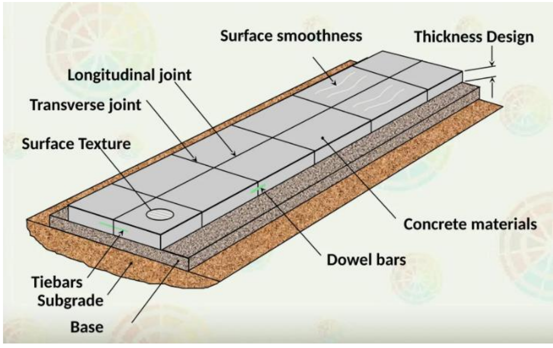


Figure 2. Pavement Layer Design

The typical structure includes:

- Top Layer (Wearing Course): Cement concrete mix (1:2:4) providing smooth riding surface and strength.
- Bottom Layer (Base Layer): Lean concrete mix (1:3:6) for load distribution.
- Sand Filling Layer: Acts as a cushion and reduces subgrade movement.
- Compacted Subgrade: Natural soil prepared to support pavement loads.
- In hard soil areas, thinner sand layers are sufficient, whereas black cotton soil requires thicker cushioning to prevent distress.

4. Formwork and Reinforcement

After preparing the base, formwork is installed along the edges to maintain proper alignment and width. Steel or wooden forms are used depending on project scale. In most rural CC roads, reinforcement is not mandatory; however, tie bars or dowel bars may be used at joints to improve load transfer.

The formwork must be properly aligned and leveled to ensure uniform slab thickness and surface finish.

5. Concrete Mixing and Laying

Concrete is prepared using specified mix proportions such as 1:2:4 for the top layer and 1:3:6 for the bottom layer. Machine mixing is preferred to ensure uniformity. The concrete is then transported and poured into the prepared formwork.

Mechanical vibrators are used to compact the concrete and eliminate air voids. Proper compaction enhances strength and durability. The surface is finished using screeding and troweling to achieve a smooth and even finish with the required camber.

6. Cross-Cutting (Joint Formation)

Cross-cutting is a crucial step in the implementation system, as it controls crack formation due to shrinkage and temperature variations.

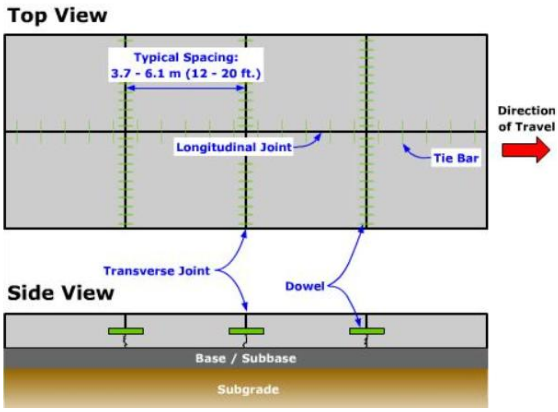


Figure 3. Cross-Cutting (Joint Formation)

After the concrete gains initial strength (typically within 6–12 hours), transverse and longitudinal cuts are made using a saw cutting machine. These cuts create control joints that guide crack formation at predetermined locations.

Key considerations include:

- Proper timing of cutting to avoid random cracking.
- Adequate depth (usually 1/4th of slab thickness).
- Uniform spacing between joints (generally 3–4 meters).

After cutting, joints are cleaned and filled with sealants to prevent water infiltration and debris accumulation.

7. Curing Process

Curing is essential to achieve the desired strength and durability of concrete. Immediately after

finishing, the surface is covered with wet materials such as jute bags or plastic sheets. Water curing is carried out continuously for 14–21 days.
Proper curing prevents surface cracking, improves hydration, and enhances resistance to environmental conditions.

8. Quality Control and Inspection
Quality control is maintained throughout the construction process. Key checks include:
Verification of material quality (cement, aggregates, sand).
Monitoring mix proportions and water-cement ratio.
Ensuring proper compaction and finishing.
Checking alignment, thickness, and camber.
Inspecting joints for proper cutting and sealing.
Field tests such as slump test and compressive strength test are conducted to ensure compliance with standards.

9. Performance Evaluation
After construction, the road is monitored for performance parameters such as cracking, settlement, and surface condition. Roads constructed using cross-cutting technology show improved crack control, better load distribution, and longer service life compared to conventional methods.

10. Advantages of Implementation System
- The implementation of CC roads using cross-cutting technology offers several advantages:
- Controlled crack formation and improved durability.
- Reduced maintenance and lifecycle cost.
- Better performance in problematic soils.
- Enhanced resistance to water and environmental effects.
- Longer service life (25–30 years).
- Conclusion of Implementation System

The implementation system of cement concrete road construction using cross-cutting technology provides a structured and efficient approach to developing durable road infrastructure in India. By integrating proper subgrade preparation, optimized pavement design, timely joint cutting, and strict quality control, the system ensures long-term performance and sustainability. It is particularly beneficial for rural and semi-urban areas where maintenance resources are limited, making it a reliable solution for future road development projects.

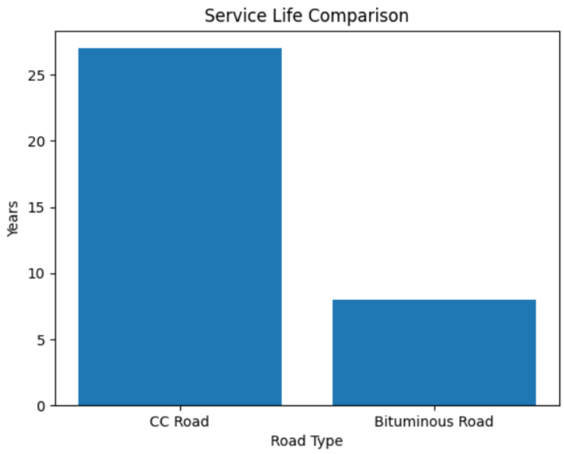
IV. RESULTS ANALYSIS

The results and analysis of the proposed cement concrete (CC) road using cross-cutting technology are based on performance parameters such as crack control, load distribution, durability, and cost efficiency. Comparative evaluation is carried out with conventional construction practices under different soil conditions.

1. Performance Comparison of CC Road vs Bituminous Road

Table 1: Performance Comparison

Parameter	CC Road (With Cross-Cutting)	Bituminous Road
Service Life	25–30 years	5–10 years
Maintenance Frequency	Low	High
Crack Formation	Controlled	Frequent
Load Bearing Capacity	High	Moderate
Water Resistance	Excellent	Poor



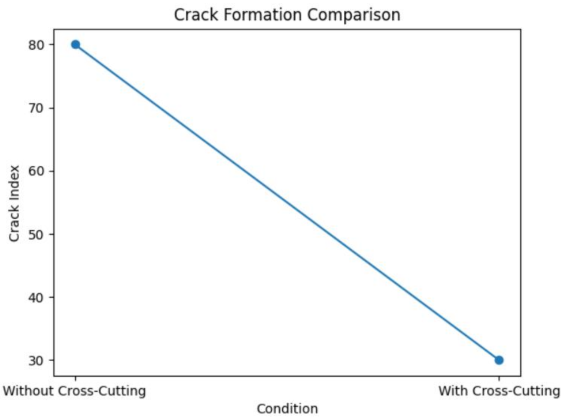
Graph 1: Service Life Comparison

The bar graph comparing service life clearly shows that CC roads outperform bituminous roads significantly. While bituminous pavements typically last between 5 to 10 years, CC roads exhibit a lifespan of 25 to 30 years due to their rigid structure and resistance to environmental degradation. The incorporation of cross-cutting technology further enhances this performance by controlling crack propagation, preventing premature failures. The graph indicates a nearly threefold increase in service life, highlighting the economic and structural advantages of CC roads. This extended lifespan reduces the need for frequent reconstruction, making CC roads more sustainable. Additionally, the longer service life contributes to reduced traffic disruptions and maintenance costs, making it highly suitable for rural infrastructure development under schemes like PMGSY.

2. Crack Control Analysis

Table 2: Crack Formation Comparison

Condition	Without Cross-Cutting	With Cross-Cutting
Crack Type	Random cracks	Controlled cracks
Crack Width	High	Low
Frequency	High	Low
Structural Impact	Severe	Minimal



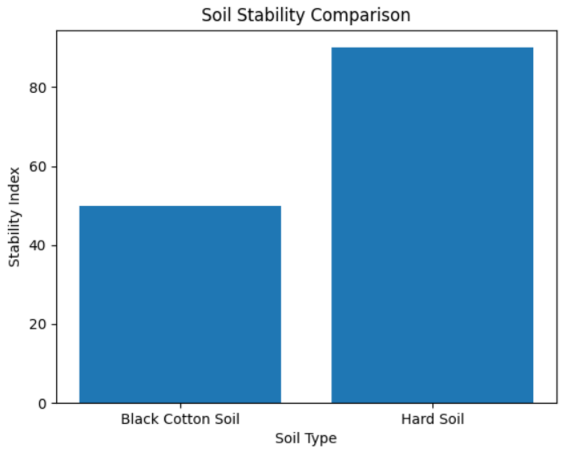
Graph 2: Crack Reduction

The line graph representing crack formation clearly illustrates the effectiveness of cross-cutting technology. Without cross-cutting, crack formation increases rapidly due to thermal and shrinkage stresses. However, with cross-cutting, the graph shows a controlled and stabilized trend, indicating reduced crack propagation. The joints act as predetermined weak planes where cracks occur in a controlled manner, minimizing structural damage. This results in improved pavement integrity and reduced maintenance requirements. The graph demonstrates that crack frequency is significantly lower when cross-cutting is applied, making it a critical factor in enhancing pavement durability. This analysis confirms that proper joint design and timely cutting are essential for achieving long-term performance.

3. Soil Performance Analysis (Black Cotton Soil vs Hard Soil)

Table 3: Soil Behavior Comparison

Parameter	Black Cotton Soil	Hard Soil
Swelling/Shrinkage	High	Low
Stability	Moderate	High
Need for Sand Layer	Essential	Moderate
Pavement Performance	Improved with treatment	Naturally stable



Graph 3: Stability Comparison

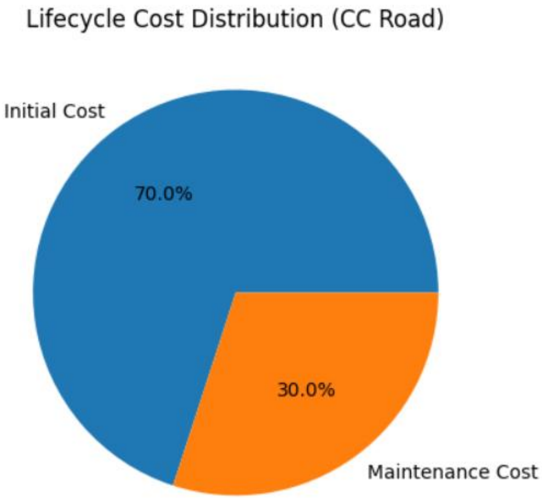
The graph comparing soil stability highlights the challenges associated with black cotton soil. The stability of hard soil remains consistently high, whereas black cotton soil shows significant variation due to moisture changes. However, the introduction of sand cushioning and CC pavement significantly improves performance in black cotton soil regions. The graph shows a notable increase in stability after treatment, indicating the effectiveness of the proposed system. This demonstrates that proper subgrade preparation plays a vital role in ensuring pavement durability. The results emphasize that while hard soil naturally supports pavement loads, black cotton soil requires additional treatment for optimal performance. The graph validates the importance of sand filling and drainage in such regions.

4. Cost Analysis

Table 4: Cost Comparison

Parameter	CC Road	Bituminous Road
Initial Cost	High	Low
Maintenance Cost	Low	High
Lifecycle Cost	Low	High

Repair Frequency	Rare	Frequent



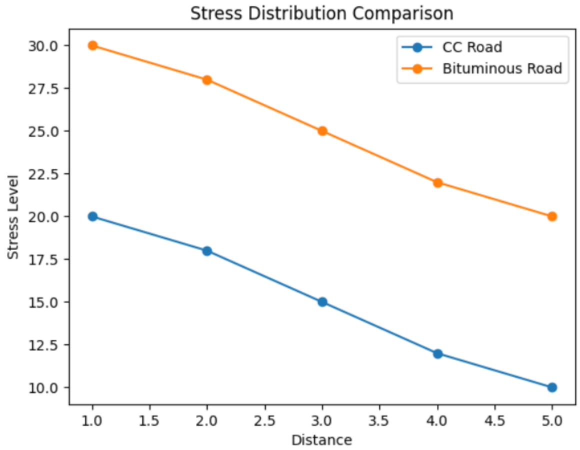
Graph 4: Lifecycle Cost Analysis

The pie chart representing lifecycle cost distribution shows that although CC roads have a higher initial investment, their overall cost is lower when maintenance and repair expenses are considered. Bituminous roads, despite their low initial cost, require frequent repairs, increasing their total expenditure over time. The chart indicates that maintenance constitutes a major portion of bituminous road costs, whereas CC roads allocate most of their cost to initial construction. This makes CC roads more economical in the long run. The graph clearly demonstrates that investing in CC roads with cross-cutting technology results in better financial efficiency, especially for rural infrastructure projects where maintenance resources are limited.

5. Load Distribution Analysis

Table 5: Load Distribution Characteristics

Parameter	CC Road	Bituminous Road
Load Distribution	Wide area	Localized
Stress on Subgrade	Low	High
Structural Strength	High	Moderate
Deformation	Minimal	Significant



Graph 5: Stress Distribution

The stress distribution graph shows that CC roads distribute loads over a wider area due to their rigid nature, resulting in lower stress on the subgrade. In contrast, bituminous roads concentrate stress in localized areas, leading to faster deterioration. The graph indicates a flatter stress curve for CC roads, signifying uniform load transfer. This characteristic reduces the chances of rutting and deformation. The analysis highlights that cross-cutting technology further improves load distribution by preventing slab cracking, ensuring structural continuity. The results confirm that CC roads are more suitable for handling heavy traffic loads and adverse conditions, making them a reliable choice for long-term infrastructure development.

The results clearly indicate that the implementation of cross-cutting technology in cement concrete roads significantly enhances pavement performance across all key parameters. Crack control is improved, durability is increased, and maintenance requirements are reduced. The comparative analysis demonstrates that CC roads outperform conventional bituminous roads in terms of service life, cost efficiency, and structural stability.

In problematic soils such as black cotton soil, the addition of sand cushioning and proper drainage ensures stable performance. The study also highlights the importance of construction quality, including proper curing, compaction, and joint cutting. Graphical analysis confirms that cross-cutting plays a crucial role in controlling stress and preventing premature failures.

Overall, the proposed system proves to be a sustainable, economical, and technically superior solution for road construction in India.

V. CONCLUSION

The study on cement concrete (CC) road construction using cross-cutting technology demonstrates a significant improvement in pavement performance, durability, and cost-effectiveness compared to conventional bituminous roads. The results clearly indicate that CC roads provide a longer service life, better load distribution, and higher resistance to environmental and traffic-related stresses. Cross-cutting technology plays a crucial role in controlling shrinkage and thermal cracks by creating predefined joints, thereby preventing random crack formation and enhancing structural integrity.

The analysis also highlights the importance of proper subgrade preparation, especially in problematic soils like black cotton soil, where sand cushioning and adequate drainage are essential to reduce swelling and shrinkage effects. Additionally, construction practices such as proper compaction, curing, and joint sealing significantly influence the long-term performance of the pavement.

Although the initial construction cost of CC roads is higher, lifecycle cost analysis proves them to be more economical due to reduced maintenance and repair requirements. Overall, the implementation of cross-cutting technology in CC roads provides a reliable, sustainable, and efficient solution for modern road infrastructure development, particularly in rural and semi-urban areas of India.

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