REVIEW ON 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.

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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.

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 review paper 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 [1].
- Black cotton soil regions pose serious challenges because of their high swelling and shrinkage characteristics, leading to pavement heaving and settlement [2].
- Conventional CC roads without proper jointing develop uncontrolled cracks caused by drying shrinkage and temperature stresses [3].
- Inadequate subgrade preparation and lack of sand cushioning result in differential settlement and edge failures [4].
- Improper timing and spacing of joints reduce pavement durability and increase maintenance requirements [5].
- Limited field-based studies are available on optimized cross-cutting practices for Indian soil and climate conditions [6].
- 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 [1].
- Conventional cement concrete (CC) roads are constructed without optimized jointing or cross-cutting practices in many regions [2].
- Standard pavement construction includes basic subgrade compaction with minimal soil treatment, even in problematic soil areas [3].
- In black cotton soil regions, limited use of sand cushioning or stabilization methods is observed [4].
- Joint spacing and cutting time are often decided based on experience rather than codal recommendations [5].
- Maintenance activities are generally reactive, carried out only after visible distress occurs [6].
- Quality control during construction varies significantly across projects and regions.

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B. Drawbacks

- Bituminous roads deteriorate rapidly under heavy traffic, water ingress, and temperature variations, leading to frequent potholes and rutting [1].
- Lack of proper jointing in CC roads results in uncontrolled cracking due to shrinkage and thermal stresses [2].
- Poor subgrade preparation causes uneven settlement, slab cracking, and edge failures [3].
- Black cotton soil-induced swelling and shrinkage significantly reduce pavement life when untreated [4].
- Inadequate drainage and improper camber lead to water stagnation and structural weakening [5].
- High recurring maintenance costs make the system economically inefficient over its lifecycle [6].
- Absence of performance monitoring limits timely corrective measures and long-term durability assessment.

III. Literature Reviews

A) Literature Survey:

R. K. Sharma et. al. (2021), studied the structural behavior and performance of jointed plain cement concrete pavements under Indian traffic and climatic conditions. Their research emphasized the importance of proper joint spacing, joint depth, and load transfer mechanisms in controlling cracking. The authors highlighted that early-age saw cutting significantly reduces random shrinkage cracks and improves pavement life. Field observations revealed that pavements with timely cross-cutting exhibited lower maintenance requirements and better riding quality. The study concluded that adherence to IRC guidelines for joint design and construction practices is essential for ensuring durability and cost-effectiveness of CC roads, especially in rural and low-volume traffic conditions.

A. S. Kulkarni et. al. (2020), investigated the effect of black cotton soil on pavement performance. Their study focused on swelling and shrinkage behavior due to seasonal moisture variation. The authors reported that untreated black cotton soil leads to pavement heaving, cracking, and differential settlement. They recommended the use of sand cushioning layers, proper drainage, and moisture barriers to reduce subgrade movement. The research highlighted that CC pavements perform better than bituminous pavements over expansive soils when appropriate subgrade treatment is adopted. The study concluded that soil stabilization and sand layers are critical for extending pavement service life in black cotton soil regions.

N. Gupta, S. Reddy et. al. (2019), reviewed cross-cutting and saw-cutting techniques used in concrete pavements. The study compared early and delayed cutting practices and their influence on crack control. The authors observed that cutting within 6–12 hours after concrete placement is optimal for preventing uncontrolled cracking. Diamond blade saw cutting was found to provide clean and effective joints. The paper emphasized that improper timing or insufficient depth of cuts can lead to random cracks, reducing pavement durability. The study concluded that standardized cutting procedures and skilled workmanship are essential for effective implementation of cross-cutting technology.

L. Menon, T. Desai et. al. (2022), analyzed the role of sub-base materials in enhancing the durability of cement concrete pavements. Their research compared sand, granular sub-base, and stabilized layers. The authors found that well-compacted sand filling provides uniform support and reduces stress concentration in concrete slabs. Poorly prepared sub-base layers were linked to slab cracking and settlement. The study emphasized the importance of compaction control and material gradation. The authors concluded that sub-base quality plays a crucial role in load distribution and long-term pavement performance, particularly in rural road construction.

Authors: P. Kumar et. al. (2020) examined the performance of different joint sealants used in cement concrete pavements. The study evaluated hot-pour sealants, polysulfide sealants, and bituminous fillers. Results indicated that flexible sealants significantly reduce water infiltration and prevent subgrade weakening. The authors stressed that improper sealing leads to joint failure and accelerated pavement deterioration. The study highlighted that joint sealing is often neglected in rural road projects, affecting pavement life. The authors concluded that proper selection and installation of joint sealants are essential for maintaining joint integrity and long-term pavement durability.

S. Rao et. al. (2018) conducted a lifecycle cost analysis comparing cement concrete and bituminous pavements in India. Their findings showed that although CC roads have higher initial construction costs, they offer lower maintenance and rehabilitation expenses over time. The authors observed that CC pavements are more economical for roads carrying moderate to heavy traffic. The study highlighted that frequent repairs in bituminous roads increase overall costs. The authors concluded that lifecycle cost analysis should be prioritized in pavement selection, especially for rural roads with limited maintenance resources.

M. P. Joshi et. al. (2021) focused on load transfer mechanisms in jointed concrete pavements. The study examined the effectiveness of dowel bars and tie bars in reducing joint faulting and slab deflection. Experimental results showed that proper dowel alignment improves load transfer efficiency and minimizes edge stresses. The authors emphasized corrosion protection and accurate placement of dowels. The study concluded that effective load transfer systems significantly enhance pavement performance and extend service life under repeated traffic loading.

R. L. Bansal, et. al. (2019), studied the influence of curing and compaction on the strength development of cement concrete pavements. The research demonstrated that inadequate curing leads to surface cracking and reduced durability. Proper curing for 14–21 days improved compressive strength and resistance to abrasion. Mechanical compaction using vibrators ensured uniform density and reduced voids. The authors concluded that curing and compaction are critical construction stages that directly affect pavement performance and service life.

V. K. Mishra et. al.(2022), investigated the effectiveness of sand cushion layers in mitigating subgrade movement in expansive soils. Their study showed that sand layers act as a buffer between the concrete slab and active soil zone. Properly compacted sand reduced differential movement and slab cracking. The authors emphasized drainage provision to prevent moisture accumulation. The study concluded that sand cushioning is a cost-effective solution for improving pavement stability in black cotton soil regions.

D. S. Nair et. al. (2020) evaluated the field performance of PMGSY cement concrete roads across various Indian states. Their findings indicated that roads constructed with proper jointing, curing, and subgrade preparation performed well over time. Common failures were linked to poor workmanship and lack of quality control. The authors recommended strict supervision and adherence to specifications. The study concluded that CC roads are a reliable solution for rural connectivity when constructed using standard practices.

B) Literature Summary

- Literature highlights cement concrete (CC) roads as durable and cost-effective alternatives to bituminous pavements in Indian conditions.
- Proper jointed plain concrete pavement design significantly improves crack control and service life.
- Cross-cutting or saw-cutting at early ages is essential to prevent uncontrolled shrinkage cracking.
- Sand cushioning layers are effective in mitigating subgrade movement, especially in black cotton soil regions.
- Adequate sub-base preparation and compaction enhance load distribution and pavement stability.
- Proper curing and compaction improve strength and durability of concrete pavements.
- Lifecycle cost studies favor CC roads over bituminous pavements despite higher initial costs.
- Performance of CC roads depends strongly on construction quality and adherence to standards.

C) Research Gap

- Limited field-based studies quantify optimal cross-cutting spacing and depth for rural CC roads in Indian climates.
- Insufficient comparative analysis exists between CC road performance on black cotton soil and hard soil using standardized sections.
- Long-term monitoring data on joint performance, crack propagation, and maintenance needs are scarce.
- Lack of integrated studies combining soil behavior, joint design, and traffic loading effects.
- Minimal research on mechanized versus manual cross-cutting practices in rural projects.
- Limited adoption of modern monitoring tools such as sensors for crack detection and joint distress.
- Absence of region-specific guidelines addressing varying moisture and temperature conditions across India.

IV. Research Methodology

A) Criteria for selecting this study

This study on cement concrete road construction using cross-cutting technology was selected due to the increasing demand for durable and low-maintenance road infrastructure in India, particularly in rural and semi-urban areas. Frequent failures of bituminous pavements under heavy traffic loads, monsoon conditions, and poor subgrade soils highlight the need for alternative solutions. Cement concrete roads offer longer service life, better load distribution, and reduced lifecycle costs. However, uncontrolled cracking remains a major concern, which can be effectively addressed through cross-cutting technology. Additionally, the widespread presence of problematic soils such as black cotton soil necessitates a detailed evaluation of appropriate pavement cross-sections and construction practices. This study is also aligned with current government initiatives like PMGSY, which emphasize sustainable and long-lasting rural road development. The availability of established standards, growing field implementation, and identified research gaps further justify the selection of this study.

*B) **Method of analysis:***

- Collection of site-specific data including soil type, moisture condition, and existing ground profile.
- Classification of subgrade soil as hard soil or black cotton soil based on laboratory and field tests.
- Selection of suitable cement concrete road cross-sections as per IRC and BIS guidelines.
- Analytical evaluation of pavement layers to assess load distribution and stress behavior.
- Comparison of structural performance parameters such as crack control, slab stability, and settlement tendency.
- Review of joint spacing, depth, and timing of cross-cutting based on literature and standards.
- Assessment of construction practices including compaction, curing, and joint sealing.
- Interpretation of results to identify performance improvements and durability benefits of cross-cutting technology.

C) Comparison and Analysis

Authors (Year)	Subgrade / Soil Consideration	Jointing / Cross-Cutting Practice	Performance & Durability	Cost / Maintenance Aspect
Sharma & Verma (2021)	General Indian subgrades	Emphasized proper joint spacing and depth	Significant reduction in cracking and improved service life	Lower maintenance due to controlled cracking
Kulkarni & Patil (2020)	Black cotton soil	Indirect focus on joint necessity	CC roads perform better with treated subgrade	Reduced repair cost with proper soil treatment
Gupta & Reddy (2019)	Not soil-specific	Early-age cross-cutting (6–12 hrs)	Effective control of shrinkage cracks	Prevents costly rehabilitation
Menon & Desai (2022)	Hard soil and weak subgrades	Conventional jointing	Improved slab stability with good sub-base	Economical with proper compaction
Kumar & Singh (2020)	General subgrades	Joint sealing emphasized	Prevents water ingress and joint failure	Reduces long-term maintenance
Rao & Iyer (2018)	Various Indian soil conditions	Standard JPCP joints	Long service life (25–30 years)	Lifecycle cost lower than bituminous roads
Joshi & Narayan (2021)	Stable subgrades	Dowel bars at joints	Improved load transfer and reduced faulting	Higher initial cost, lower distress cost
Bansal & Thomas (2019)	Not soil-specific	Joint performance linked to curing	Enhanced strength and surface durability	Proper curing reduces repair frequency
Mishra & Prakash (2022)	Expansive (BC soil)	Jointing with sand cushion	Reduced slab movement and cracking	Cost-effective soil mitigation
Nair & Bose (2020)	Rural Indian soils	Jointing as per IRC	Better field performance under PMGSY	Reduced maintenance in rural roads

V. Discussion

A) Synthesis of findings from literature

The reviewed literature collectively emphasizes that cement concrete (CC) roads offer superior durability, structural stability, and long-term economic benefits compared to conventional bituminous pavements, particularly under Indian climatic and traffic conditions. Studies consistently highlight the critical role of cross-cutting technology in controlling shrinkage and thermal cracks, thereby enhancing pavement performance and service life. Proper joint spacing, depth, and early-age cutting are identified as key factors in preventing uncontrolled cracking. The literature also underscores the importance of subgrade preparation, especially in black cotton soil regions, where sand cushioning and drainage significantly reduce soil-induced distress. Adequate compaction, curing, and joint sealing are shown to directly influence strength development and durability. Lifecycle cost analyses further confirm that despite higher initial costs, CC roads are more economical over time due to reduced maintenance needs. Overall, adherence to standard design and construction practices emerges as essential for achieving reliable and sustainable CC road infrastructure.

B) Methodology for future research directions

- 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.

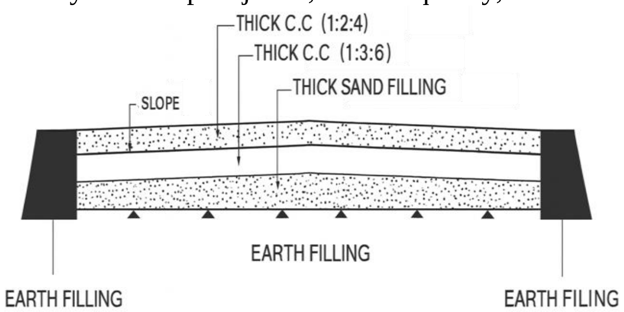

Figure 1. Cross-section of a cement concrete (CC) road constructed in hard soil conditions

- 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.

VI. Conclusion

This review paper highlights the growing importance of cement concrete (CC) roads as a durable and sustainable alternative to conventional bituminous pavements in India. The synthesis of literature confirms that CC roads provide superior structural performance, longer service life, and lower lifecycle maintenance costs, particularly for rural and low-volume roads. Cross-cutting technology emerges as a critical construction practice for controlling shrinkage and temperature-induced cracking, thereby enhancing pavement durability and functional performance. Studies emphasize that timely execution of cross-cutting, along with proper joint spacing and depth, is essential to prevent uncontrolled crack development. The review also demonstrates that subgrade conditions significantly influence pavement behavior, especially in black cotton soil regions where sand cushioning and drainage play a vital role in mitigating soil movement. Furthermore, adequate compaction, curing, and joint sealing are consistently identified as key factors governing long-term pavement performance. Despite higher initial construction costs, CC roads prove to be more economical over their service life due to reduced maintenance requirements. Overall, the findings underline the need for strict adherence to codal provisions, quality construction practices, and further field-based research to optimize cross-cutting techniques under diverse Indian conditions.

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