Project Management Institute. Kingdom of Saudi Arabia

Digital Insights:

Construction of Concrete Roads

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ABSTRACT

Concrete pavements / roads have been evolved significantly by the use of advancement in materials, technologies, and detailed design methods & practices.

This technical paper explores current trends in concrete pavements design and construction, showing their advanced practices, sustainable approaches, and the integration of advanced materials. It discusses life-cycle cost benefits, resilience improvements.

INTRODUCTION:

Concrete roads also known as rigid pavements, often preferred for their quick construction with high durability for long time with low maintenance costs and so have gained importance with the development of advanced concrete technologies and good site practices. Conventional methods are being replaced by innovations to addressing cost, environmental impact as well as efficiency with long time usage.

Concrete pavements are utilized in various applications, including local roads, streets, highways, airport runways, parking lots, industrial facilities, and other infrastructure types. Over decades of construction and utilization of rigid pavements, it has become evident that their extended service life positively influences environmental sustainability when compared to flexible pavements, such as those made of asphalt.

Furthermore, the construction of concrete pavements leads to fewer traffic delays, as they can be reopened within a few hours, unlike flexible pavements, thereby decreasing fuel consumption and exhaust emissions.

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OBJECTIVE:

This paper objective is to present an overview of the latest Engineering design trends construction of concrete roadways by use of working practices, the failure mechanisms associated with and the design methodologies frequently employed in various projects and technology-driven advancements, challenges and their solutions in rigid pavements with various types of rigid pavements.

Consequently, errors in design or construction, as well as the improper selection of materials, can significantly diminish the service life of the rigid pavements.

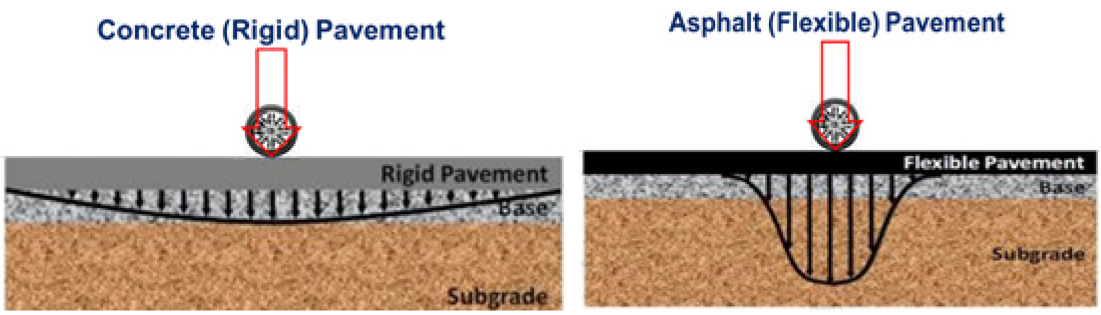
The paper also highlights that the long working life of concrete /rigid pavements is influenced not only by the quality of the concrete but also by utilizing effective construction practices, which incorporate placement, compaction, and curing processes. Also addresses the challenges and solutions with concrete type, applications and key benefits for the construction of the rigid roads.

Therefore, it is essential for pavements engineers to comprehend and tackle issues related to the selection of suitable materials, mix design, detailing, prevailing drainage conditions, construction methodologies, and overall pavement performances.

Additionally, a thorough understanding of the theoretical principles that underpin commonly utilized design procedures, along with awareness of their limitations, is crucial.

ENGINEERING DESIGN OF RIGID ROADS

Concrete pavements are engineered to withstand flexural stresses caused by vehicular traffic and to manage cracking resulting from various factors, including drying shrinkage, curling, and warping (ACPA, 1992; Delatte, 2008). The flexural strength of concrete can exceed its tensile strength, although it tends to be lower in uniform materials. Enhanced flexural strength occurs when the concrete under load incorporates stronger materials at its edges, as the extreme fibers experience the highest levels of stress, allowing for deformation under greater stress. Additionally, concrete pavements effectively distribute stress across a broad area, which results in reduced pressure on the base layers from axle loads, as illustrated in (figure 1 below).



Concrete functions more as a bridge over the subgrade. When comparing inch for inch, it exerts significantly less pressure on the underlying materials than asphalt pavements do.

FIGURE 1: LOAD DISTRIBUTION SYSTEM.

SPECIFIC INSTRUCTION TO BIDDERS:

A) Sustainable Design Practices

A. Use of supplementary cementitious materials (SCMs) such as fly/slag ashes and to reduce carbon emissions.
B. Application of permeable concrete for enhanced drainage.
C. Implementation of reflective concrete pavements to combat urban heat islands.

B) Physical Improvements

A. Concrete pavements without joints with shrinkage control concrete.
B. Roller compacted concrete (RCC) for cost-effective heavy load applications.
C. Pre-stressed concrete pavements to minimize cracking and extend lifetime.

C) Digitalized Design Approaches

a. Using of Building Information Modeling (BIM) for roads design.
b. Use of other software such as (FEA) in pavement stress-strain design works.

CURRENT TRENDS IN CONSTRUCITON OF CONCRETE / RIGID ROADS

A) Automation in Construction

A. Slip-forming for faster pavement construction.
B. Cameras/drones check in system for safety and progress of works.

B) Construction Practices

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CURRENT TRENDS IN MATERIAL OF CONCRETE ROADS

A) Ultra-performance Concrete

a. Using high/ultra-performance concrete with high strength, good workability and environmentally friendly.

B) Fiber Reinforced Concrete

a. Adding of fibers, synthetic materials would reduce cracking.

CURRENT TRENDS IN MATERIAL OF CONCRETE ROADS

A) High Preliminary Costs

Initially the concrete pavements costs are very high but by Implementation of government sectors to divide the monetary issues between government and firms.

B) Extended Construction Time

As the construction of concrete pavement take long time as it involves formworks, casting and curing as well, so chemicals may introduce to reduce curing time in construction.

C) Ecological Apprehensions

Conventional method for concrete construction evolves carbon in atmosphere so need to focus on carbon free concrete production technologies.

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PAVEMENT TYPES

There are four major common types of pavements namely;

1. PRECAST PRE-STRESSED PAVEMENTS

Precast concrete pavement systems are constructed or assembled off-site, then transported to the project location for installation on a prepared foundation, which may consist of existing pavement or a re-graded base. These systems eliminate the need for field curing of the precast concrete panels and require only a short duration for the components to gain sufficient strength. This approach minimizes traffic disruption and extends the lifespan of the repaired or rehabilitated pavement sections. The implementation of precast concrete pavement technologies should lead to fewer lane closures or more effectively managed closures, resulting in reduced traffic interruptions and enhanced safety in construction zones. This technology is also suitable for the repair and rehabilitation of rural roadways, where traditional methods may be impractical due to accessibility issues or cost considerations.

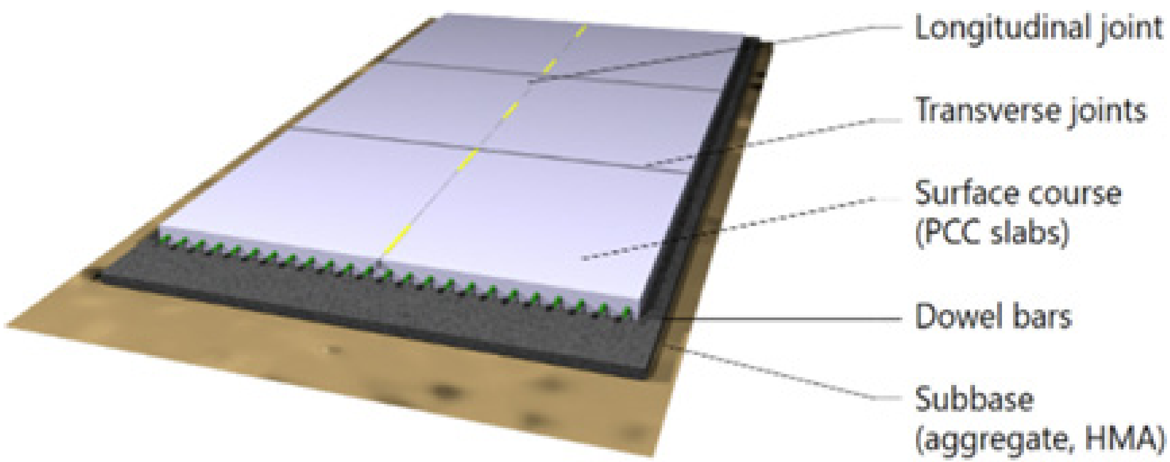

FIGURE 2: POSITIONING PRECAST SEGMENTS ON POLYETHYLENE (FHWA, 2009) (ADOPTED FROM WWW.ARTOPRECAST.IN)

2. CONVENTIONAL CONCRETE PAVEMENTS

2.2.1 Joint Plain Concrete Pavement

Joint plain concrete pavements (JPCP) are characterized by the absence of reinforcement, as suggested by their designation. They feature a controlled joint spacing ranging from 3.5 to 6.0 meters, which is designed to mitigate the occurrence of shrinkage cracks (Delatte, 2008). JPCP is the most commonly constructed form of concrete pavement due to its cost-effectiveness, primarily attributed to the lack of reinforcing steel. The mechanism for load transfer at the joints of plain concrete pavements relies on aggregate interlock (Fuchs & Jasienski, 2001).

2.2.2 Joint Reinforced Concrete Pavement

Joint plain concrete pavements (JPCP) are characterized by the absence of reinforcement, as suggested by their designation. They feature a controlled joint spacing ranging from 3.5 to 6.0 meters, which is designed to mitigate the occurrence of shrinkage cracks (Delatte, 2008). JPCP is the most commonly constructed form of concrete pavement due to its cost-effectiveness, primarily attributed to the lack of reinforcing steel. The mechanism for load transfer at the joints of plain concrete pavements relies on aggregate interlock (Fuchs & Jasienski, 2001).

FIGURE 3: REINFORCED CONCRETE PAVEMENT WITH JOINTS. (ADOPTED FROM WWW.PAVEMENTINTERACTIVE.ORG)

3. CONTINUOUSLY REINFORCED CONCRETE PAVEMENT

Continuously reinforced concrete pavements (CRCP) are distinguished by their lack of transverse joints. These pavements incorporate longitudinal steel reinforcement, as illustrated in figure 5. The diameter of the reinforcing bars is determined to effectively manage cracking, ensuring that any cracks that do occur are evenly spaced at intervals of 1 to 3 meters. It is essential that the width of these cracks remains minimal, specifically less than 0.3 mm, to prevent the entry of harmful substances. A notable example of continuously reinforced concrete pavement can be found in the bus rapid transit (BRT) route in Cape Town. This concrete roadway system is constructed without joints, with the exception of intersections where it interfaces with asphalt, and is engineered to support heavy loads. A significant application of ultra-thin continuously reinforced concrete pavement in South Africa is observed in the Huguenot Tunnel on the N1 (Ebels et al., 2007) and within the Tshwane municipality, as depicted in figure 4.

FIGURE 4: ULTRA-THIN RC PAVEMENT IN TSHWANE, (ADOPTED FROM PRETORIA WWW.B2BCENTRAL.CO.ZA)

FIGURE 5: CRCP (ADOPTED FROM WWW.RACHANAINFRA.COM AND WWW.WORLDHIGHWAYS.COM)

4. ROLLER COMPACTED CONCRETE PAVEMENTS

Roller compacted concrete (RCC) is characterized by its very dry composition, which can be manufactured as ready-mixed concrete, although it is frequently produced using a pug mill. This mixture exhibits low to negligible slump, making it more akin to cement-treated aggregate base than to traditional flowing concrete (Delatte, 2008). The construction methodology is similar to that employed for hot-mix asphalt pavements. The material is transported via dump trucks, placed into an asphalt paver, and subsequently compacted using steel wheel rollers. Following this, the RCC undergoes a curing process. The pavement may be permitted to crack naturally, or intentional joints may be introduced. Due to RCC's reduced shrinkage compared to conventional concrete, the resulting joints or cracks are spaced further apart than those found in jointed plain concrete pavements (JPCP). RCC serves as an effective solution for the construction of pavements on local streets and roads. It is particularly advantageous in urban settings, as it facilitates the rapid reopening of roads to vehicular traffic. In the process of constructing an RCC pavement, several critical factors must be considered to ensure high-quality results. These factors include the design of the mix, the production of the mix, the methods of placement, compaction techniques, the configuration of joints (whether longitudinal or transverse), and the curing process.

Concrete Types and Applications

Concrete Forms	Principal Application	Key Benefits
Regular Concrete	General Roads	Affordable
Ultra-Performance Concrete	High-traffic Roads	Durability
Fiber-Reinforced Concrete	Heavy-load Roads	Crack Resistance

CONCLUSION

The design and construction of rigid pavements / concrete roads are experiencing a growing time and focusing on strength, quickness and advanced technologies integration. These roads also useful to construct at water logged areas with proper water drainage system.

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