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Material development for a sustainable precast concrete block pavement

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ABSTRACT

Portland cement concrete (PCC) and asphalt concrete (AC) are the most common roadway and highway construction materials which are more suitable for continuous slab pavements. The durability of these materials is highly dependent on construction quality and techniques, and both materials are difficult to repair. Heavy rain storms in India have recently revealed several roadway pavement failures and resulted in significant repair costs. Interlocking block type pavements are simpler to construct and maintain than both PCC and AC pavements but, have only been used for slower traffic roads due to weak interlocking at the joints. To improve the quality of block pavements, blocks made of PCC with waste tire crumb rubber partially replacing river sand (fine aggregate) are suggested. The joint interlocks can be further improved by modifying the block geometry. The material is completely recycled and is deemed more superior than concrete pavements when repair and construction techniques and costs are concerned. This paper presents the material characterization of Rubberized Concrete Blocks (RCBs) using crumb rubber particle size ranging from 0.075 mm to 4.75 mm to partially replace the fine aggregates. It also discusses the advantages of RCB over continuous material pavements.

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1. Introduction

Conventional modes of roadway and highway pavement construction utilize predominantly in-situ, large dimension and slab-based techniques with either Portland cement concrete or hot mixed asphalt concrete (AC). Due to the wear, tear and abuses of daily traffic, paved roads experience usage damages and require constant maintenance. For example, based on the 2010 capital spending estimate, the US spends $65.3–$86.3 billion annually for highway condition maintenance (US DOT, 2013). Furthermore, the maintenance of roadways require extended traffic closure periods to complete the patching, overlaying, cutting and curing of materials involved, all resulting in additional financial

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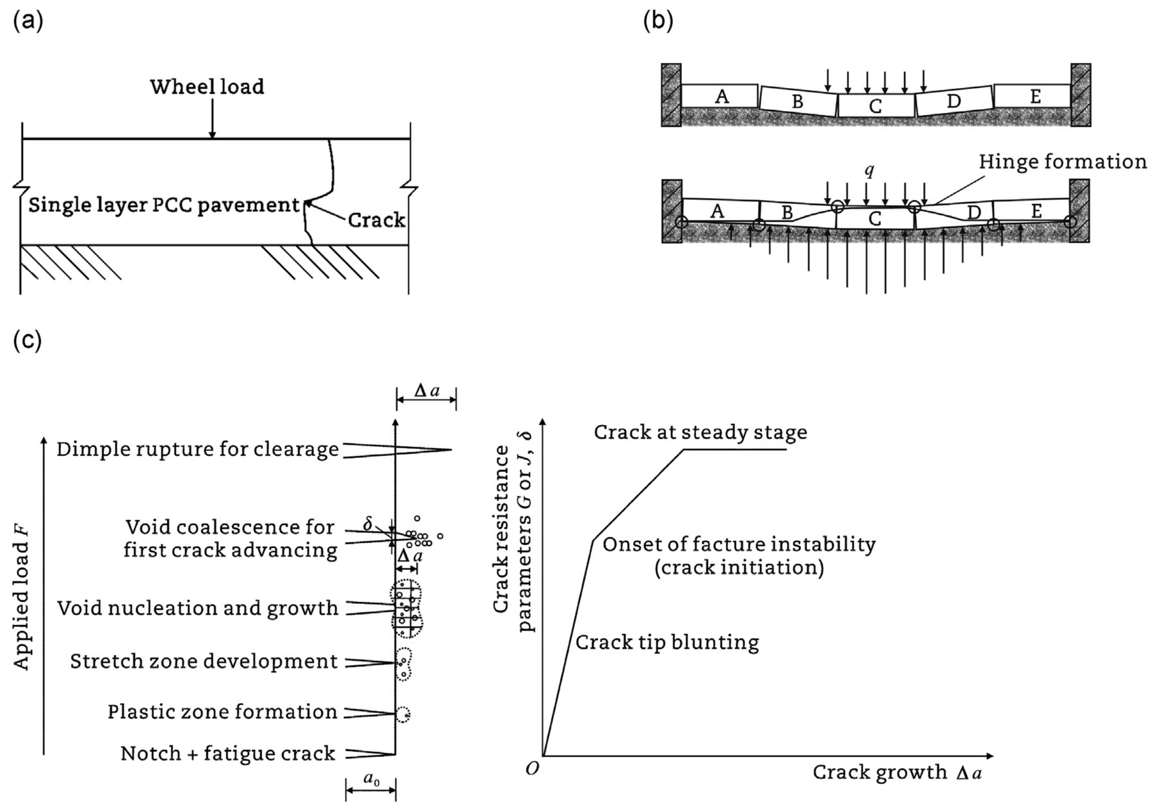

Fig. 1 – Failure modes of different pavements. (a) PCC pavement. (b) Concrete block pavement (Soutsos et al., 2011). (c) AC pavement (Tang, 2014).

losses. The key disadvantages of conventional roadway in-situ construction and maintenance are inconveniences to drivers and additional costs associated with extensive site operations. In addition, there is also the seasonal constraint to on-site constructions such as concrete curing or hot mix asphalt placement during low temperatures, that can result in sub-standard products. An alternative pavement technology is the use of block pavements. Despite advances in concrete block pavement technologies, the use of concrete block pavement (CBP) remains limited and must be promoted.

State-of-the-art reviews of CBP technologies indicate that modern CBPs' have excellent engineering properties and low life cycle costs. They are easy to construct and maintain, and have a very good esthetic appearance as compared to conventional pavements (i.e., concrete and asphalt). Additionally CPB's can be easily replaced, thus minimizing the waste of materials and time for construction. This last advantage makes CPB's more sustainable than conventional pavements.

The durability of CPB is mainly dependent on the quality and strength of the paving block. However, the block–block interface conditions are also critical to the overall performance of the pavement. The paving blocks can be produced in different grades of concrete, shapes and sizes (Shackel, 1990). Several standards and specifications, such as the Indian Standards (Bureau of Indian Standards, 2006), the British Standards (BS EN 1338:2003) (British Standards Institution, 2003), the ASTM C936/C936M (ASTM, 2015), are available for the detailed definition and basic requirements of the paving blocks. In earlier global standardization efforts, Houben et al. (1984) gave a comprehensive review of all published standards, which documented block thickness of 140 mm in some cases.

For typical applications, the small element of precast paving unit is used as a surface course and the bedding sand provides a more flexible response compared to conventional pavements (Singh et al., 2012). Thus, the following factors can influence the structural performance of CBP: (1) paving blocks (i.e., shape, size, thickness and laying pattern); (2) bedding sand (i.e., thickness, grading, angularity and moisture content); (3) base and sub-base (i.e., material type and thickness); and (4) sub-grade (i.e., material type and strength) (Soutsos et al., 2011). Joints can be filled with sand to enhance the interface friction. Polymer filler material can be used to stabilize the joint sand and reduce water infiltration.

Loading frequency and scenarios are also critical to the durability of block pavements. The standard IS 15658:2006 clearly indicates that the strength and thickness of paving blocks are decided based on the traffic volume. For high volume traffic roads, there is a need to carry large amounts of load, thus requiring stronger and thicker paving blocks. The sub-base and bedding sand thickness are selected based on required bearing capacity of the base course design. For base course with lower bearing capacity, the required sub-base and bedding sand materials would be more.

Manufactured paving blocks have a high compressive strength, but they can still fail during heavy traffic loads due to

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