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Evaluating life cycle costs of perpetual pavements in China using operational pavement management system

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ABSTRACT

Highway transportation is considered as vital factor in China's economic growth; many high grade highways have been constructed in China during the last decades. The research and application of perpetual asphalt pavement (PP) technology have been deployed in China since 2000. The semi-rigid pavement has been normally considered as typical pavement of high class highways in the design according to the Chinese experience. The objective of this research is to evaluate the performance of different Chinese perpetual pavements using operational pavement management system and to examine its suitability for use in the design and construction of more economical and durable pavements. It has been found that the use of thin asphalt layers over semi-rigid pavement foundation in PP structure will create more sustainable, economical, and durable PP structures in comparison with typical thick asphalt layers PP structures.

Introduction

General

The Romans built their empire roads network more than 2000 years ago to last for long time using thick layers of durable rock materials, their remaining road pavement layers can be seen intact till now without maintenance or rehabilitation (Steiger, 1995). The building of road networks is important for the growth and prosperity of any nation and for the evolving of economic and social developments. During the last twenty years, the road pavements have been subjected to increasing number and weight of trucks beyond the capacity of their original design limits due to the growing demand on road transport. The increasing cost of maintenance and rehabilitation of roads is a heavy burden on governments, road agencies and road users. This problem has focused the light on the need for building road pavements that survive for long time under heavy and increasing traffic loads with minimum maintenance and rehabilitation costs taking into consideration the recent developments in improving the durability and performance of asphalt concrete materials.

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Perpetual pavement

The perpetual pavement (PP) is defined by Asphalt Pavement Alliance (APA) (2002) as "An asphalt pavement designed and built to last longer than 50 years without requiring major structural rehabilitation or reconstruction, and needing only periodic surface renewal in response to distresses confined to the top of the pavement". This longevity in PP is attributed to the use of special formulated asphalt concrete mixes for the construction of asphalt concrete layers. The upper surface layer is designed to resist wear and top-down cracking, the intermediate asphalt binder layer is designed to resist the rutting and fatigue, and the lower asphalt base layer is designed to resist bottom-up cracking. In PP, the possibility of traditional fatigue cracking is reduced, and pavement distress is limited to the upper layer of the structure. Thus, when surface distress reaches unacceptable level, the economical solution is to mill and replace the top layer. The PP concept can be used for any pavement structure where it is required to minimize rehabilitation and reconstruction costs as well as reducing closures to traffic. These factors are especially necessary on high traffic volume freeways where user delay costs may be very high. The conventional asphalt pavements are usually designed for a 20-year service life, while PP is expected to be in use for 50 years or more. The main problem with the current PP design method is the absence of optimum design of pavement structure and/or layers because of the interaction of many variables as will be highlighted in Section 'Pavement management system' later. The thickness of asphalt layers in PP is usually thick (from 20 to 50 cm). The thickness of PP is determined by limiting the tensile strain at the bottom of asphalt layer (fatigue criterion), while the total thickness of PP structure is determined by limiting the compressive strain on the surface of sub grade (rutting criterion). Increasing the thickness of asphalt layers increases the total stiffness of the pavement structure and decreases the stresses transmitted to the sub grade layer (Asphalt Pavement Alliance (APA), 2002). Due to the large thickness of asphalt layers, higher resistance to bottom-up fatigue cracking, structural rutting, and thinner granular base/sub base layers are expected in comparison with the conventional pavement designs. Since the evolving AASHO pavement design method in the late 1950s, many examples of conventional road pavements which last for more than its design period are reported around the world with only suitable maintenance and rehabilitation of surface layers (Tarefder and Bateman, 2009). The full depth asphalt pavements are well known everywhere since early 1970s (Yoder and Witczak, 1975). The only difference which characterized PP is the design for long time period more than 50 years and for high number of equivalent single axle wheel loads (ESAL) up to 100 millions, which requires thorough analysis of life cycle performance.

Perpetual pavements in China

Semi-rigid base asphalt pavement is the main pavement structure in China since 1997 and it comprises about 90% of total pavement structures. China started to design, construct, and test PP expressway sections such as Yan Jiang expressway in Jiangsu province in 2004, Xu Wei expressway in Henan province in 2005, and Binzhou test road in Shandong province in 2005 as reported by Wang (2013). Three PP test sections with fatigue strain of 70 and 125 micro strains as shown in Fig. 1, along with two control sections as shown in Fig. 2, were built during the summer of 2005 as part of a perpetual

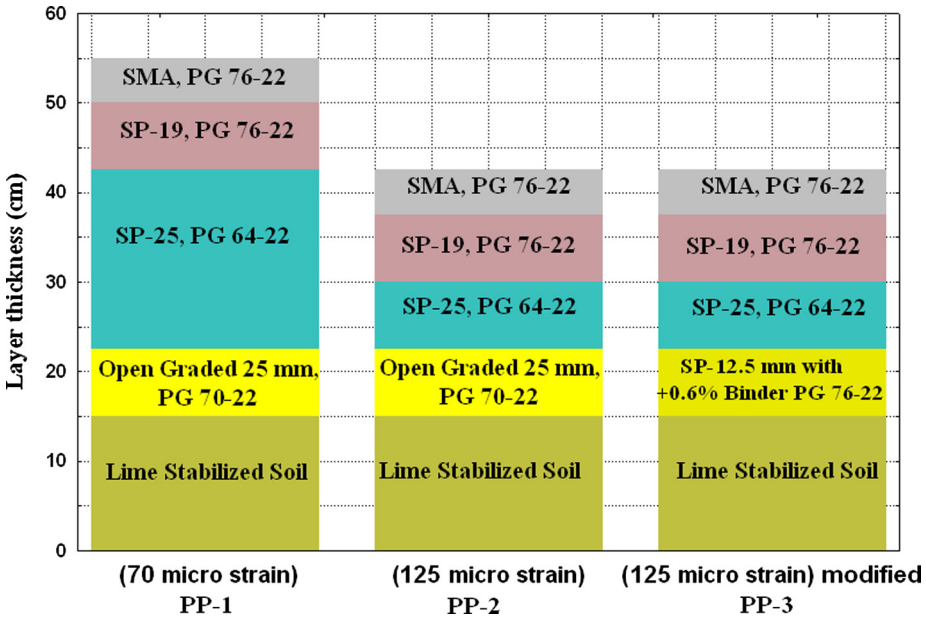

Fig. 1. Perpetual pavement test sections on Shanghai to Tianjin motorway near Binzhou, Shandong Province (Yang and et al., 2006).