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Accelerated pavement testing of thin RCC over soil cement pavements

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Abstract

Three full-scale roller compacted concrete (RCC) pavement sections built over a soil cement base were tested under accelerated pavement testing (APT). The RCC thicknesses varied from 102 mm (4 in.) to 152 mm (6 in.) and to 203 mm (8 in.), respectively. A bi-directional loading device with a dual-tire load assembly was used for this experiment. Each test section was instrumented with multiple pressure cells and strain gages. The objective was to evaluate the structural performance and load carrying capacity of thin RCC-surfaced pavements under accelerated loading. The APT results generally indicated that all three RCC pavement sections tested in this study possessed very high load carrying capacity; an estimated pavement life in terms of equivalent single axle load (ESAL) for the thinnest RCC section (i.e., RCC thickness of 102 mm) evaluated was approximately 19.2 million. It was observed that a fatigue failure would be the primary pavement distress type for a thin RCC pavement under trafficking. Specifically, the development of fatigue cracking was found to originate from a longitudinal crack at the edge or in the center of a tire print, then extended and propagated, and eventually merged with cracks of other directions. Instrumentation results were used to characterize the fatigue damage under different load magnitudes. Finally, based on the APT performance of this experiment, two fatigue models for predicting the fatigue life of thin RCC pavements were developed.

Keywords: Roller compacted concrete; APT; Pavement performance; Non-destructive testing; Fatigue analysis

1. Introduction

The Louisiana Department of Transportation and Development (LADOTD) is seeking alternate use of roller compacted concrete (RCC) for low volume roadways in the oil and gas exploration areas in the northwest region of the state. RCC is a zero-slump concrete mixture placed with modified asphalt paving equipment and compacted by vibratory rollers [1]. RCC is an economical, fast and durable candidate for many pavement applications. Properly designed RCC mixes can achieve outstanding compressive strengths similar to those of conventional concrete. Due to its relatively coarse surface, RCC has traditionally been used for pavements carrying heavy loads in low-speed areas, such as parking, storage areas, port, airport service areas, intermodal and military facilities [1]. With improved paving and compaction methods as well as surface texturing techniques, recent applications of RCC can be found for interstate highway shoulders, city streets, and rural highways [2–6]. In addition, due to low water content RCC pavements have reduced shrinkage and low maintenance costs [7].

Thickness design for RCC pavements may follow the same design strategy as for conventional concrete pavements, i.e., keeping the pavement's flexural stress and fatigue damage caused by wheel loads within an allowable limit [1]. By flexural stress is meant the tensile stress at the bottom of a RCC slab under traffic loading. The critical (maximum) flexural stress under wheel load divided by

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flexural strength of the concrete slab is defined as Stress Ratio (*SR*). A fatigue curve (so called fatigue model) between different allowable load limits and *SR*s is needed in the thickness design, which can be determined from laboratory beam fatigue tests. The design thickness is then estimated based on the allowable loads to failure at a certain design *SR*. Both the Portland Cement Association (PCA) and the U.S. Army of Corps Engineering (USACE) developed the thickness design procedures for RCC industrial pavements, and the PCA procedure was later incorporated into a computer program called RCC-PAVE [1]. However, both the USACE and PCA design procedures were developed for the thickness design of RCC pavements for heavy industrial applications (such as ports and multimodal terminals) with a minimum design RCC thickness of 203 mm (8 in.) [1]. The following fatigue model is used in RCC-PAVE [8]:

$$\log N_f = 10.25476 - 11.1872\,(SR) \quad \text{for} \quad SR > 0.38 \tag{1}$$

where N_f is the allowable number of load repetitions.

Meanwhile, Eq. (2) shows the fatigue model used for PCC pavement thickness design developed by American Concrete Institute (ACI) [9]:

$$\begin{aligned} N_f &= (4.2577/(SR - 0.4325))^{3.268} \quad \text{for} \quad 0.45 < SR < 0.55 \\ \log N_f &= 11.737 - 12.077\,(SR) \quad \text{for} \quad SR \geqslant 0.55 \end{aligned} \tag{2}$$

The main objective of this study was to evaluate the structural performance and load carrying capacity of thin RCC pavements constructed over typical Louisiana base materials through the accelerated pavement testing (APT). The ultimate goal is to come up with a design alternative (a thin RCC surfaced pavement structure) suitable to be used for low volume roads under heavy truck trafficking in Louisiana.

2. Description of APT experiment

2.1. RCC test sections

Three RCC pavement test sections were constructed for this study. Fig. 1 presents the pavement structures of the test sections. Each section is about 4 m (13 ft.) wide and 21.8 m (71.5 ft.) long. As shown in Fig. 1, each section has a similar 216-mm (8.5-in.) soil cement base and a 254-mm (10-in.) cement treated subgrade layer built over an existing embankment subgrade. The only difference among these sections is the thickness of RCC layers. The RCC thicknesses for Section 1, 2 and 3 are 102 mm (4 in.), 152 mm (6 in.) and 203 mm (8 in.), respectively, Fig. 1. Normal highway construction procedures were followed in construction of the subgrade and base layers. A modified asphalt paver was used in the RCC placement and a special-designed pug mill was used in the production and mixing of RCC mixtures [10].

2.2. Materials

The RCC mixtures used in this experiment include a type I Portland cement, a #67 crushed limestone, and a No. 89 crushed limestone manufactured sand. The designed RCC mix contains a well-graded aggregate blend of 57 percent coarse and 43 percent fine aggregate by weight and 11.4 percent cement with an optimum moisture content of 6.5 percent. More details of RCC mix design may be found elsewhere [10].

Silty-clay embankment soil (A-6) was used for both soil cement and cement treated soil layers. To meet the Louisiana roadway design specification, a 8 percent cement by volume was applied to the 216 mm (8.5-in.) soil cement base, and a 4 percent cement by volume was used in the 254 mm (10-in.) treated subgrade layer.

Cylindrical samples of RCC were prepared on site during the construction. RCC cores and saw-cut beams were prepared after the construction for the laboratory strength tests. Test results indicated that, for the RCC mixtures used in the test sections, the average compressive strength at 28 days and average flexural strength were 37,232 kPa (5400 psi) and 4558 kPa (661 psi), respectively. More details on the laboratory test results may be referred to elsewhere [10].

2.3. Instrumentation

Fig. 2 shows the instrumentation layout of this experiment. Each test section was instrumented with three earth pressure cells (Geokon 3500), two H-type asphalt strain gages (Tokyo Sokki KM-100HAS), and two concrete

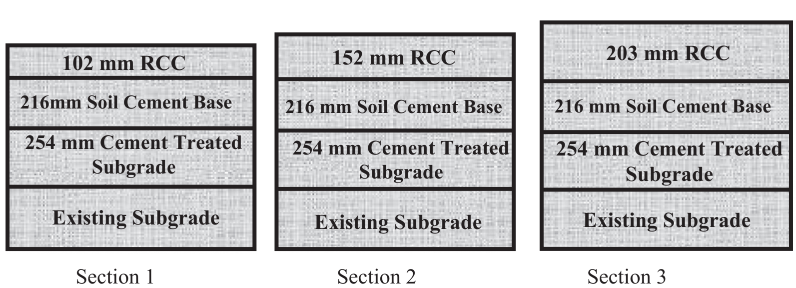

Fig. 1. Pavement structures of APT test sections.