Construction and Building Materials 75 (2015) 368–374

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Evaluation of reflective cracking in pavements using a new procedure that combine loads with different frequencies

Irene Gonzalez-Torre [a], Miguel A. Calzada-Perez [b], Angel Vega-Zamanillo [b], Daniel Castro-Fresno [a,*]

[a] Construction Technology Applied Research Group (Giteco), University of Cantabria, Avda de Los Castros s/n, 39005 Santander, Spain
[b] Group of Roads (GCS), University of Cantabria, Avda de Los Castros s/n, 39005 Santander, Spain

HIGHLIGHTS

- A new procedure to study crack propagation in pavements is carried out.
- The test combines two loads with different frequencies and amplitudes.
- The test is easy to perform since it only applies vertical loads.
- The effect of a geosynthetic in crack propagation is included.

ARTICLE INFO

Article history:
Received 27 June 2014
Received in revised form 7 October 2014
Accepted 12 November 2014
Available online 5 December 2014

Keywords:
Fatigue test
Bituminous mixture
Reflective cracking
Combined load
Geosynthetic

ABSTRACT

Reflective cracking is one of the most common failure modes of roads and it is mainly caused by traffic loading and thermal variations. In this paper, a new laboratory procedure has been developed. The study has been carried out applying a combined cyclic load that overlaps two loads with different frequencies and amplitudes. The aim of the test was to study crack propagation in asphalt mixtures and to evaluate the effectiveness of geosynthetics as anti-reflective cracking systems. Results indicate that low frequency loads produce more damage than high frequency loads and that the presence of a geosynthetic retards the propagation of cracks.

1. Introduction

Cracking is one of the main forms of pavement deterioration. When an overlay layer is installed on a cracked pavement as rehabilitation, the cracks usually propagate to the surface in a short time. This is very common in semi rigid pavements and it is known as reflective cracking [1]. The origin and propagation of cracks is mainly due to two reasons: the passing of vehicles and the horizontal movements due to temperature variations in cement-treated layers [2].

Many authors have stated that the effect produced by temperature variations is more important than that produced by traffic loads (the main cause of cracking in semi-rigid pavements is the horizontal movement caused by temperature variations) [3,4]. There are numerous tests to study the propagation of cracks in pavements, and most of them were designed to evaluate the effectiveness of anti-reflective cracking systems, using bi-layer specimens with an induced crack and with these systems placed in the interface. These tests can be distinguished depending on the type of load that they apply.

On the one hand, there are tests that study the effects of traffic and temperature variations separately. Generally the tests used to evaluate the effectiveness of the anti-reflective cracking systems are of this type.

First, there are two types of tests that apply loads to simulate the effect of traffic: those that apply a passing wheel over the surface, and those that apply a vertical load in a fixed position. The first type is based on the Wheel Tracking Test, evaluating the propagation of cracks in a pavement caused by the repeated passing of a wheel. Livneh et al. [5] developed in 1993 the Wheel Tracking Device. After that, other authors have employed the same concept by varying the support and boundary conditions of the specimens [6,7]. In the second category there are tests which apply vertical loads. Some authors [8] have studied both static and dynamic loads to study the effectiveness of various geosynthetics and to determine the optimal position within the pavement. Other authors [9–11] have applied only dynamic loads centred over the

* Corresponding author. Tel.: +34 942 20 20 53; fax: +34 942 20 17 03.
E-mail address: castrod@unican.es (D. Castro-Fresno).

http://dx.doi.org/10.1016/j.conbuildmat.2014.11.030
0950-0618/

specimen, in order to reproduce the horizontal deformation that occurs in the lower part of the rehabilitation layer. Within this type of tests there are others which consider the effect of shear that the traffic load would produce employing non-centred loads [12].

Second, there are those that simulate the effect of temperature variations. The tests simulate this kind of loads through horizontal movements employing mechanisms that open and close an induced crack. This is the case of the tests performed in the Belgium Laboratory of Roads (BRRC test) [13], the ENTPE test [14], the test of the University of Illinois [15] and the TTI Overlay Test [16].

On the other hand, there are some laboratory tests that combine the effects of traffic and temperature variations, by applying vertical loads and horizontal opening displacements. Some as the Reflective Cracking Device [17] and the test from the Autun Laboratory [18,4], simultaneously apply a slow horizontal displacement and a vertical cyclic load at a higher frequency. Other tests such as Reflective Wheel Cracking, developed in 2007 by Prieto et al. [19] reproduce simultaneously bending, tensile and shear stresses with the help of a mobile support in which the test specimen is placed. The thermal effect is simulated by an opening and closing movement and the traffic load through the repeated passing of a wheel on the specimen surface. Among the most recent studies, Moreno-Navarro and Rubio-Gámez in 2013 [20] have developed the UGR-FACT test. Using a new laboratory device they have studied the effect of tensile and shear stress caused by traffic loads and of tensile strains that simulate thermal contractions, but in this case they simulate both effects using a single frequency. They have also studied the behaviour of different anti-reflective cracking systems employing this methodology [21].

In this paper an experimental study to evaluate the behaviour of geosynthetics as anti-reflective cracking system is carried out. The test device is based on previous tests that study the effect of traffic loads, but it tries to consider simultaneously traffic and thermal effects by applying high and low frequency loads. In this case only vertical loads are applied to simulate both effects. Unlike the tests carried out in other researches, this is done by the superposition of two loads with different frequencies and amplitudes, which is an advantage since a special device is not required.

2. Test description

2.1. Previous considerations

The traffic and thermal loads are very different but they both produce tensile stresses at the bottom of the bituminous overlay layer (Fig. 1). Stress concentration on the existing cracks is the reason of their origin and subsequent propagation [22].

One of the differences between the loads is the application rate. The traffic load is applied almost instantaneously, while thermal variations occur in a longer period of time. Bituminous mixtures present a different modulus depending on the load frequency and the temperature, due to their visco-elastic behaviour. The higher the load frequency and the lower the temperature, the greater is the modulus of the bituminous mixture [23,24].

The first load can be associated with a frequency of 10 Hz, which is commonly used in the fatigue tests of these materials. The second loads are slower. They should have a cycle time that varies from one day (daily variations) to three months (seasonal variations). From a practical point of view, the latter frequencies are not applicable in the laboratory tests, so we need to apply shorter cycles.

With the objective to set the loads to apply in the laboratory test, a preliminary study using the finite element method (employing the commercial software ANSYS®) has been carried out. It studies the influence of the modulus of the bituminous mixture in the response of the material to loads with high and low frequencies. The aim was to establish a relation between the loads amplitudes, taking into account the different deformations that they produce in the bituminous mixture. The 2D linear elastic model simulates a semi-rigid pavement with a crack on which an overlay layer is placed. This model considers a thermal load and a traffic load independently. The thermal load corresponds to a temperature decrease of 10 °C, simulating the thermal shrinkage of the cement-treated layer, and the traffic load is that corresponding to a 13t axle when the wheel is passing over the existing crack (0.662 MPa). The numerical model consists of approximately 22,000 plane elements and 88,000 nodes. All displacements are restricted in the bottom side while only horizontal displacements

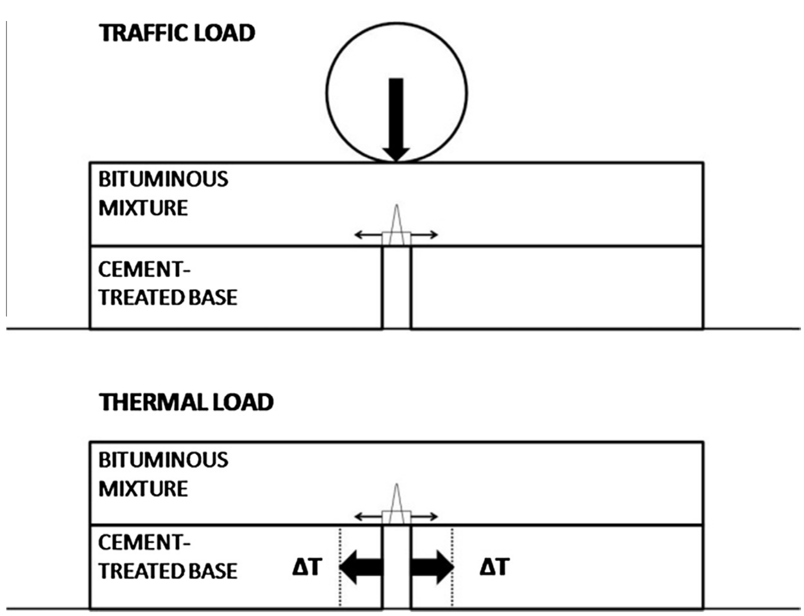

Fig. 1. Effect of loads over the crack.