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Engineering Failure Analysis 13 (2006) 898–913
ENGINEERING FAILURE ANALYSIS
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Failure prediction of skewed jointed plain concrete pavements using 3D FE analysis

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Received 20 April 2005; accepted 14 July 2005
Available online 6 September 2005

Abstract

A section of skewed jointed plain concrete pavements (JPCPs) that was constructed in the northern part of Indiana failed with premature transverse cracks. The cracks were observed within 3–4 years of construction. This research was performed to determine if the failure of the skewed JPCPs could have been predicted using a 3D finite element (FE) analysis. A representative 3D FE model was developed and analyzed using three different subgrade materials under traffic and nonlinear thermal loads. The dowel bars and aggregate interlock action were modelled at the skewed joints between adjacent concrete slabs. The effects of linear and nonlinear temperature gradients were compared with regard to the predicted failure of the pavements. The finite element analysis predicted not only the failure of the pavement, but also the correct orientation of the cracks.

Keywords: Skewed jointed pavement; Concrete pavement; Finite element; Temperature curling

1. Introduction

A section of State Route 49 in Valparaiso, Indiana had to be reconstructed due to premature failure. The pavement was a skewed jointed plain concrete pavement (JPCP) from the reference post 29 + 73 north of US-30 to the interstate 80/90 interchange. This section of JPCP was constructed in 1987 with four lanes and functions as a rural major collector (RMC) road. The weighted average annual average daily traffic (AADT)

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doi:10.1016/j.engfailanal.2005.07.001

in 1999 was 23,000 with 14% truck traffic. The 1999 pavement condition rating (PCR) was 86 (fair condition) but the pavement quality index (PQI) was 69 (poor condition). The low PQI was mostly from the mid-slab cracks and joint faulting with lane drop-off almost in the whole length of the pavement section. These skewed JPCPs failed prematurely – within the 3–4 years of construction. Interestingly, the pavements generally cracked perpendicularly to the direction of traffic, not parallel to the joints. This research was performed in order to ascertain if the failure could have been predicted using modern 3D finite element (FE) analysis techniques.

2. Skewed JPC pavements under consideration

2.1. Problem data

The studied skewed jointed pavements were located on SR-49 in the state of Indiana, from 1.29 km north of US-30 to I-80/90. The 1.65 km portion of the southbound lanes from E400N to E500N has been investigated in this work. Soil borings taken in the vicinity indicate the native subsoils range from medium-stiff clay to stiff clay. In this work, the subgrade material for the representative model was assumed to be medium-stiff clay. The thickness of the concrete slab and the granular subbase are 25.4 cm (10 in.) and 15.2 cm (6 in.), respectively.

For the SR-49 project, askew angle of approximately 15° was used at the pavement joints. A repeating cycle of four joint spacing of 3.66 m (12 ft), 3.96 m (13 ft), 5.79 m (19 ft), and 5.49 m (18 ft) were used. A visual inspection of the cracks in the existing slabs indicated that the longer concrete slabs (5.49 and 5.79 m) were more likely to have cracks than the shorter slabs (3.66 and 3.96 m). In the current study, three slabs, with emphasis on the middle slab, were considered. A 5.79 m slab was chosen as the middle slab and 3.96 and 5.49 m slabs are located on both of its sides. The basic dimensions of the studied section are given in Fig. 1.

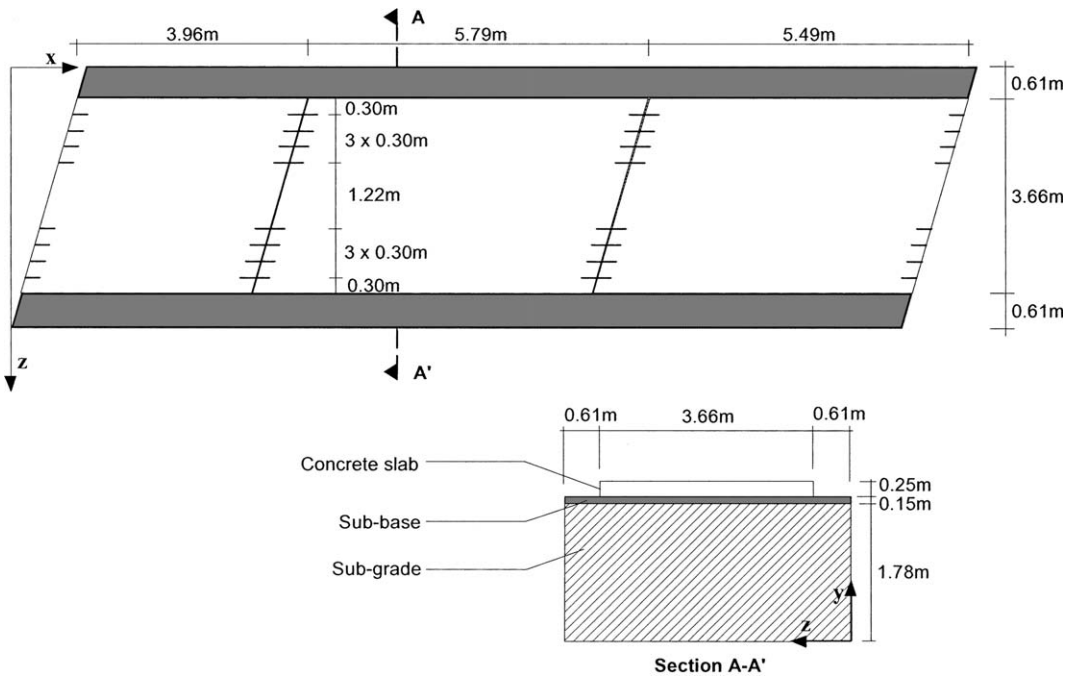

Fig. 1. Representative model and dimensions.