Construction and Building Materials 115 (2016) 153–162

Contents lists available at ScienceDirect

Construction and Building Materials

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

Slot stitching for longitudinal joint separation repairs

Dar Hao Chen [a,b,*], Pangil Choi [c], Kuan Yu Chen [d], Moon Won [c]

[a] College of Civil Engineering, Central South University of Forestry and Technology, ShaoShan South Road #498, ChangSha, Hunan Province, China
[b] Texas Department of Transportation, 4203 Bull Creek #39, Austin, TX 78731, United States
[c] Texas Tech University, Lubbock, TX 79409, United States
[d] Texas A&M Transportation Institute, Texas A&M University, College Station, TX 77843-3135, United States

HIGHLIGHTS

- Slot stitching is able to repair lane separations.
- Slot stitching provides 28% improvement in LTE after 4 years of service.
- The backfill materials should be low-shrinkage and low-CoTE.

ARTICLE INFO

Article history:
Received 13 January 2016
Received in revised form 27 March 2016
Accepted 29 March 2016
Available online 15 April 2016

Keywords:
Slot stitching
Longitudinal joint separation
Load transfer efficiency
Backfill materials

ABSTRACT

Lane separations at longitudinal joints not only allow water to infiltrate into layers under the concrete slabs and deteriorate slab support, but degrade load transfer efficiency (LTE) along longitudinal joints, resulting in an increase in load-related stresses in concrete slabs and poor performance of pavement. Slot stitching provides one of the more efficient methods to restore pavement structural capacity due to lane separations. In 2010, three slot stitching design configurations were implemented on US-75 in Sherman, Texas, which experienced lane separations as well as faulting along the longitudinal construction joint. After the dowel bars were installed, the ultra rapid repair method with the use of high early strength, low shrinkage, and low coefficient of thermal expansion (CoTE) backfill materials was utilized to minimize the traffic interruption and to restore the elevation. For measuring the effectiveness of the repair method, LTE at longitudinal joints was evaluated using Falling Weight Deflectometer (FWD). Testing results in this paper demonstrate the effect of slot stitching design, or more specifically the number of slot stitching in a slab and/or bar size, on improving LTE by providing before-and-after LTE measurements and detailed material information. In particular, the design configuration with 5 #8 bars (25.4-mm diameter) was the most cost-effective and efficient, with about 28% improvement in LTE after more than 4 years of service. Moreover, three design configurations with the use of low-shrinkage, low-CoTE backfill materials were demonstrated to improve LTE substantially, with an average increase from 45% to 74%.

1. Introduction

Designs for tie bars at longitudinal construction or warping joints in jointed concrete pavements (JCP) have been based on subgrade drag theory. A recent study proved that this theory is not valid [8], primarily because the assumptions made in the development of the subgrade theory, which are (1) there is no temperature gradient in the concrete though the slab depth and (2) there is full contact between concrete and the layer underneath, are not realistic. The study evaluated temperature variations through slab depth and slab displacements in several concrete pavement slabs. The field evaluations showed temperature variations through slab depth and lifting of the slab at slab edges, which make both assumptions invalid. However, almost all existing Portland cement concrete (PCC) pavements in the United States have been built with designs based on this theory. According to this theory, the amount of tie bars is proportional to the width of pavement tied together. When the number of lanes tied together is small, such as divided highways with 2 lanes in each direction, the amount of required tie bars or transverse steel is quite small, resulting in under-design of tie bars at longitudinal joints. The under-design

* Corresponding author at: Texas Department of Transportation, 4203 Bull Creek #39, Austin, TX 78731, United States.

E-mail addresses: darhao2008@gmail.com (D.H. Chen), Pangil.choi@ttu.edu (P. Choi), b97501055@gmail.com (K.Y. Chen), moon.won@ttu.edu (M. Won).

http://dx.doi.org/10.1016/j.conbuildmat.2016.03.222
0950-0618/© 2016 Published by Elsevier Ltd.

of tie bars subjected those bars to substantial stresses, especially when there are volume changes in base or subgrade layers, causing shear failures of those bars. Also, past construction practices of using L-shaped bars as tie bars to facilitate concrete placement, and bending those bars once concrete was hardened resulted in a higher frequency of shear failures of those bars. Deficient amount of tie bars and inadequate tie bar installation practices, along with volume changes or deteriorations in base or subgrade layers, resulted in lane separations. Once tie bars are broken at longitudinal joints, the probability of lane separations becomes high. Large openings at longitudinal joints are detrimental to pavement performance in two ways. One is letting water get into the pavement system, potentially degrading base or subgrade layer, especially if base layer is not stabilized. The other is the loss of load transfer efficiency (LTE) across joints. LTE at longitudinal joints is not as critical as LTE at transverse contraction joints; however, wandering of trucks could place concrete slabs with failed tie bars at edge loading condition, rather than at interior condition, increasing wheel load stresses substantially and thus reducing the fatigue life of the pavement. Moreover, loss of LTE due to failed tie bars could cause faulting at longitudinal joints as illustrated in Fig. 1a, which shows that a faulting as much as 51 mm (2 in.) occurred. A core was taken at this joint and, as expected, a tie bar was broken as shown in Fig. 1b. Fig. 1c shows the inside of the core hole, indicating that this is a longitudinal construction joint and there was a lane separation. Distresses observed in this pavement section included various types of cracking, including transverse, corner and diagonal cracking, as shown in Fig. 1d.

To restore the deteriorated structural condition of PCC pavement caused by poor load transfer between concrete slabs, the load transfer restoration (LTR) technique can be implemented. LTR is a rehabilitation technique for increasing the load transfer capacity of existing PCC pavement by placement of dowel bars or other mechanical devices across joints and/or cracks that exhibit poor load transfer (American Concrete Pavement Association, 1997). LTR helps to increase the transfer of loads across these discontinuities, there-by reducing pavement deflections and subsequent pumping and faulting. According to Stringer et al. [11], pavements with longitudinal cracks should be repaired as soon possible to prevent further deterioration and to save money in the long term. However, pavements that have little remaining life are not good candidates for LTR, since additional fatigue cracking will develop relatively soon, and the remaining life before the pavement will require a structural overlay may be so short that restoration is not a cost-effective rehabilitation option [2].

Fig. 1a. Faulting at longitudinal joint.

Fig. 1b. Shear failure of tie bar.

Fig. 1c. Lane separation at longitudinal construction joint.

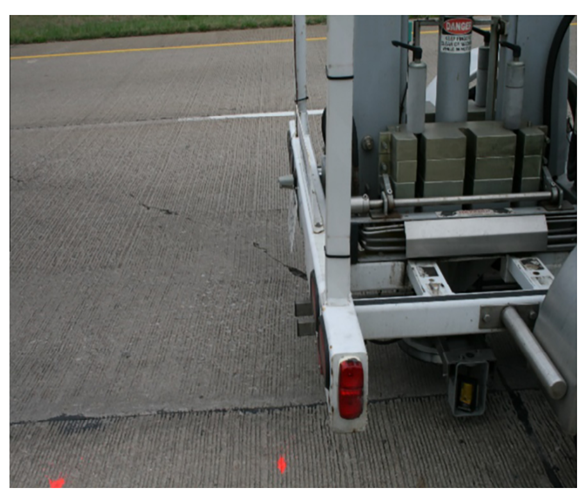

Fig. 1d. Diagonal cracking in the area of longitudinal joint with broken tie bars.

1.1. Slot stitching and cross stitching

Stitching, including cross stitching and slot stitching, is one of the most commonly used LTRs that is done at cracks and longitudinal joints to maintain aggregate interlock and provide added