TECHBRIEF

LTPP Data Analysis: Frequently Asked Questions About Joint Faulting With Answers From LTPP

The Long-Term Pavement Performance (LTPP) program is a 20-year study of inservice pavements across North America. Its goal is to extend the life of highway pavements through various designs of new and rehabilitated pavement structures, using different materials and under different loads, environments, subgrade soil, and maintenance practices. LTPP was established under the Strategic Highway Research Program, and is now managed by the Federal Highway Administration.

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Background

Transverse joint faulting is considered an important type of deterioration of jointed concrete pavements (JCP) because it affects ride quality, which is very important to the traveling public. If significant joint faulting occurs, there will be a major impact on the life-cycle costs of the pavement in terms of rehabilitation and vehicle operating costs.

Objectives

This Long-Term Pavement Performance (LTPP) data analysis was intended to examine, in a practical way, the LTPP data base and to identify the site conditions and design features that significantly affect transverse joint faulting. In other words, the emphasis was to identify what works and what does not work to control the development of joint faulting.

Key Products of This Research

The following key products were developed as part of this research:

- Answers to frequently asked questions regarding design features and site conditions that lead to "good" (better than expected) and "poor" (worse than expected) performance of jointed concrete pavements relative to joint faulting.
- Guidelines to assist highway agencies on what works and what does not work in the design of transverse joints to control joint faulting.

Currently, faulting is not directly considered in the pavement design process, but it is considered indirectly through joint design standards that are set by policy. This approach is far from adequate as many pavements have required early rehabilitation due to excessive faulting; this causes a significant impact on life-cycle costs.

Research Approach

Based on the recommendation of an expert panel consisting of State highway agency engineers, all LTPP JCP sections were divided into good performing, normal performing, and poor performing sections with respect to faulting. A section was considered to be good performing if it did not show more than 2 mm of faulting after 20 years of service. A section was considered to be poor performing if its faulting after 20 years of service exceeded 4 mm. Figures 1 and 2 present plots of all doweled and non-doweled jointed plain concrete pavements (JPCP) from GPS-3 and jointed reinforced concrete pavements (JRCP) from GPS-4 sections with respect to faulting and age, and show the designation of those sections by their performance. Different statistical methods, such as hypothesis analyses, survival analysis, and the t-test, were applied to investigate what site conditions contribute most toward the development of faulting and which are the most effective in the prevention of faulting.

Key Findings

■ How much does faulting of transverse joints affect the ride quality of JCP?

LTPP data show that faulting of transverse joints dramatically affects ride quality. Sections with higher faulting, on average, have a higher IRI. Therefore, good design practice must prevent significant faulting development to maintain good ride quality for the public.

■ Are dowels really effective in controlling faulting?

The presence of dowels was found to be the most effective design feature for controlling joint faulting. Figure 1 (non-doweled) shows much more early faulting than figure 2 (doweled). Figure 3 presents two faulting frequency curves for JPCP sections—doweled and non-doweled. It shows that more than 90 percent of the doweled sections do not exhibit faulting greater than 2 mm. This shows that doweled sections exhibited good performance with respect to faulting. On the other hand, faulting for 40 percent of the non-doweled sections exceeded 2 mm, and almost 20 percent of the sections exceeded 4 mm. The mean Equivalent Single-Axle Loads (ESAL's) carried and the mean age of all the doweled and non-doweled pavement sections were approximately the same (6 million ESAL's and 14 years, respectively).

■ Does dowel bar diameter affect faulting?

Very much so. A plot of the mean joint faulting for doweled JPCP/JRCP vs. dowel diameter clearly shows that the larger dowel bars reduce faulting. This phenomenon has been modeled mechanistically and is related to the bearing stress between the dowel and concrete. The steel/concrete bearing stress for a 25-mm-diameter dowel is more than 2.5 times that of a 38-mm-diameter dowel bar.

■ Does subdrainage affect faulting?

Subdrainage has been cited many times as an important design feature. The overall subdrainage condition was characterized using the drainage coefficient (C_d), which is based on the 1986 American Association of State Highway and Transportation Officials (AASHTO) drainage coefficient.[2] This factor is a reflection of the pavement's ability to drain excessive moisture from within the structure, as well as the pavement's potential for being exposed to near-saturated conditions. The C_d varies from 0.7 for poor drainage to 1.3 for excellent drainage. Figure 4 illustrates the effect of drainage on non-doweled JPCP sections. Good drainage reduces faulting for all types of pavements and designs, but especially for non-doweled sections. The mean ESAL's carried and the mean age of all the well-drained non-doweled JPCP are 7.0 million and 14 years, respectively. Similar values were also obtained for the non-drained, non-doweled JPCP (5 million ESAL's and 15 years).

■ Does joint spacing affect faulting?

Yes, somewhat. Joint spacing affects the amount of horizontal movement at pavement joints and, therefore, load transfer efficiency at the joints. Several previous studies demonstrated the importance of reducing joint spacing for improving JPCP performance in general and faulting in particular.[1] Comparison of average joint spacing for good JRCP sections, approximately 13 m, and poor/normal JRCP sections, approximately 18 m, from the LTPP data base shows that the joint spacing of good sections is significantly shorter.

■ Does widening of portland cement concrete (PCC) slabs reduce faulting?

Yes, dramatically. Widened (by 0.6 m) PCC slabs (as opposed to conventional width slabs) improve faulting performance of concrete pavements by reducing the critical deflections at the corner of the slab. It is achieved by moving the critical corner further away from the wheel path, thereby reducing the frequency of traffic encroachment to the pavement edge. A previous limited field study showed that a widened slab reduced the amount of faulting by approximately 50 percent.(1) The LTPP data base contains information on only a few JPCP sections with widened slabs. The mean faulting for non-doweled sections both with and without widened slabs shows about 50 percent less faulting with a widened slab. There was no difference in faulting between doweled widened slab sections and doweled conventional slab width JPCP.

■ Does base type affect faulting?

Yes. Adequate stabilization of the pavement base reduces its erodibility (note there must be an adequate amount of stabilizer to control erodibility). This leads to lower erodibility and, therefore, lower faulting. From distribution plots of good and poor/normal faulted sections for stabilized and non-stabilized bases for LTPP non-doweled JPCP sections, it can be observed that although sections with a stabilized base account for 60 percent of all good JPCP sections, they represent less than 40 percent of poor/normal sections. A similar trend is observed for JRCP pavements, although the effect is not as pronounced as for JPCP pavements.

■ Does joint orientation affect faulting?

Although the practice of skewed joints has been standard for many years, there exists little evidence of its benefits. A previous side-by-side comparison of pavement sections with non-doweled skewed and non-skewed joints conducted in a Federal Highway Administration study demonstrated (albeit with very limited data) that skewed joints have approximately 50 percent lower faulting than non-skewed joints.(1) This can be explained by the reduction of impact of the wheel load from vehicles crossing the joint. The LTPP data base supports these findings. Whereas only half of the sections with non-skewed joints have shown good performance, the fraction of the good performing sections with skewed joints is about two-thirds of the total number of the sections with skewed joints. However, LTPP results also show that perpendicular doweled joints with reasonable subdrainage will not fault; thus, it is not necessary to skew a doweled joint.

Design Guidelines

Non-Doweled JPCP: Specific guidelines to minimize faulting include good subdrainage (C_d >1), adequately stabilized base (designed to resist erosion), widened slabs in the outer lane, relatively short joint spacing, and skewed joints.

Doweled JPCP/JRCP: In general, doweled JPCP and JRCP were found to have very low amounts of joint faulting. However, the diameter of the dowel bar was found to significantly affect faulting. Pavements having 38-mm-diameter dowels had very little faulting, regardless of other design features. Other design features significantly affected joint faulting, including subdrainage, stabilized base, and shorter joint spacings. Results showed that doweled joints do not need to be skewed to control faulting.

Engineering Design Against Faulting: This LTPP data analysis has shown that several design features must be considered simultaneously in controlling faulting to achieve an economical life-cycle design. These design features should be selected to fit the given site conditions (traffic, climate, and subgrade), as is done for slab thickness design, not just set by a general policy. A more customized, comprehensive engineering design of transverse joints will lead to a much more reliable and cost-effective pavement design and will avoid early failures from excessive faulting. Future LTPP analyses will lead to mechanistic-based models that will produce the required analytical procedures for design.

References

1. Yu, T.H., M.I. Darter, K.D. Smith, J. Jiang, and L. Khazanovich. *Performance of Concrete Pavements: Volume III - Improving Concrete Pavement Performance*, Report No. FHWA-RD-95-111, Federal Highway Administration, Washington, DC, 1996.

2. *AASHTO Guide for Design of Pavement Structures*, American Association of State Highway and Transportation Officials, Washington, DC, 1993.

FIGURE 1

Transverse joint faulting for non-doweled JPCP

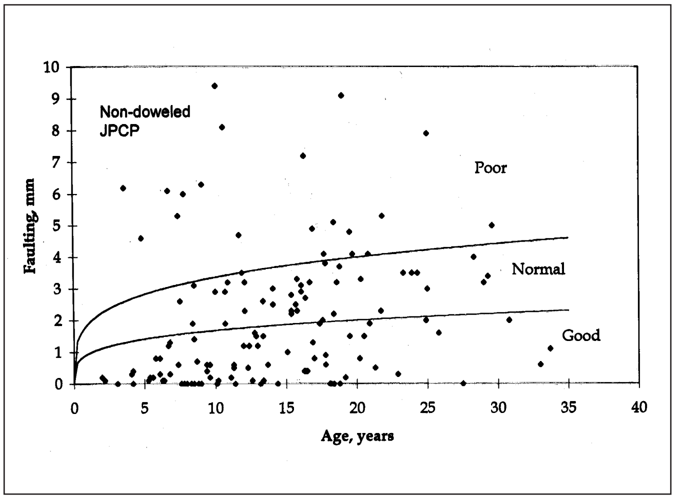


FIGURE 2

Transverse joint faulting for doweled JPCP and JRCP

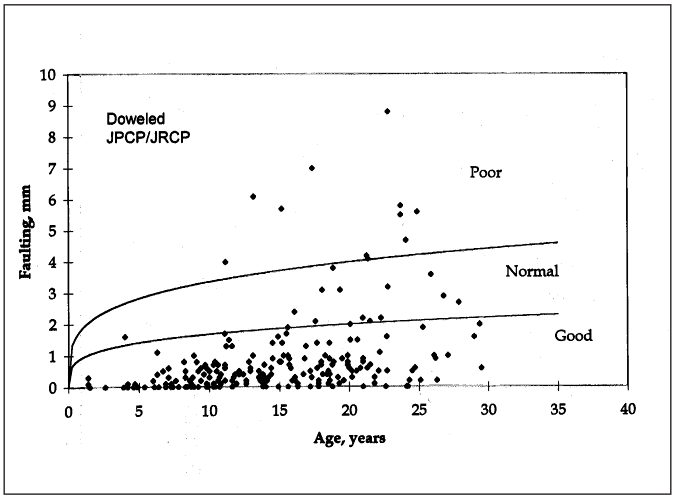


FIGURE 3

Cumulative frequency curves for JPCP sections

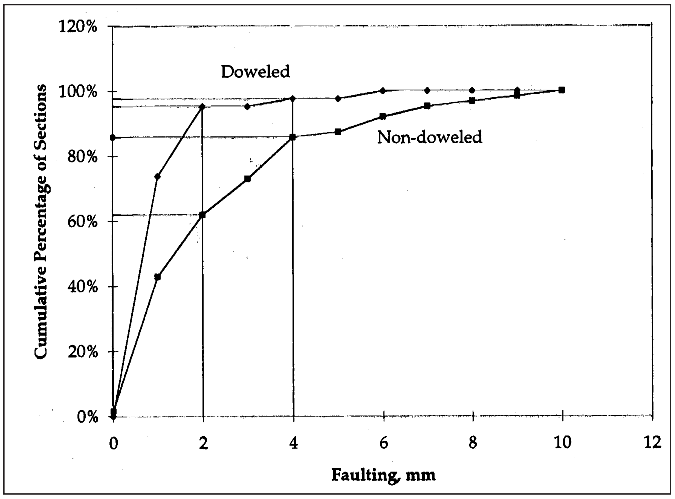
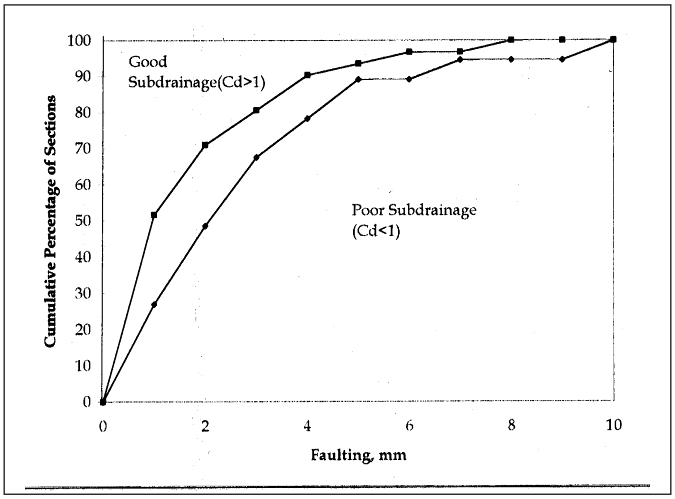


FIGURE 4

Cumulative frequency curves for JPCP non-doweled sections



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Availability: The publication from which this TechBrief was developed—*Common Characteristics of Good and Poorly Performing PCC Pavements*—will be published in 1988.

Key Words: Pavement performance, faulting, dowel, drainage, joint spacing.