TECHBRIEF

What Makes Portland Cement Concrete (PCC) Pavements Rough?

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FHWA Contact: Cheryl Richter, HNR-30, (703) 285-2183

Introduction

Roughness is widely regarded as the most important measure of pavement performance. To better understand how and why roughness occurs in pavements, the Long-Term Pavement Performance (LTPP) program recently completed a study entitled, "The Investigation of Development of Pavement Roughness." A component of the study investigated the changes in three types—Jointed Plain Concrete Pavement (JPCP), Jointed Reinforced Concrete Pavement (JRCP), and Continuously Reinforced Concrete Pavement (CRCP)—of PCC pavement roughness over time and its relationship to design factors, subgrade conditions, and climatic conditions.

Key Findings

- A strong relationship exists between roughness and faulting in undoweled JPCP pavements. Lower roughness values were noted for undoweled JPCP pavements that had high modulus of subgrade reaction values.

- JRCP pavements with higher roughness values were associated with high precipitation, higher moisture content in subgrade, thicker slabs, longer joint spacing, and higher modulus values for PCC. Exponential growth appears to be the overall trend in roughness for JRCP pavements.

- CRCP pavements appear to maintain relatively constant roughness values over time. CRCP pavements with higher roughness values were associated with higher values of PCC elastic modulus. Also, in non-freezing areas, higher roughness values were noted in areas that had a higher number of days above 32°C.

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

U.S. Department of Transportation
Federal Highway Administration

Research and Development
Turner-Fairbank Highway
Research Center
6300 Georgetown Pike
McLean, VA 22101-2296

Roughness Trends

JPCP

Figures 1 and 2 show roughness versus pavement age plots for JPCP pavement sections in wet freeze and wet no-freeze zones. As you will note, the majority of the sections show little change in roughness over the monitored period, while some sections appear to show an increase in roughness and then have a relatively constant roughness.

Figure 3 shows the relationship between faulting and roughness for undoweled JPCP pavements. In this figure, the total faulting is the sum of faulting at all joints and cracks. This relationship was not seen for doweled JPCP pavements.

Figure 1. Roughness vs. pavement age JPCPs in wet freeze areas.

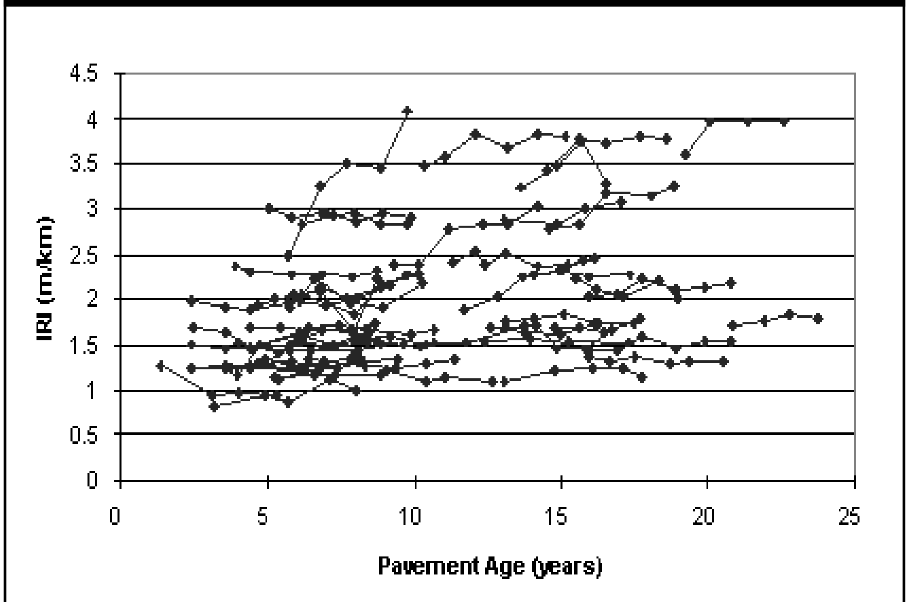
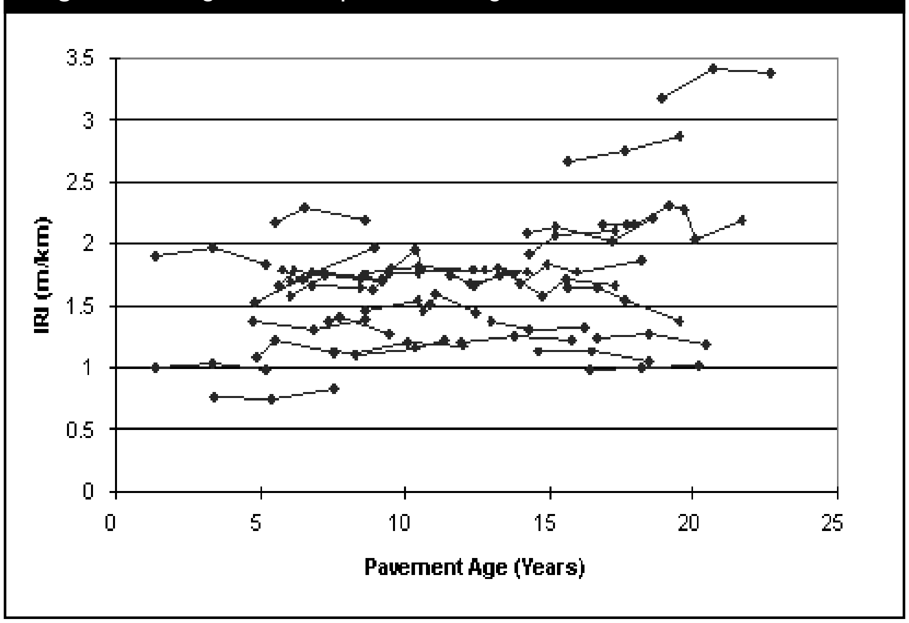


Figure 2. Roughness vs. pavement age JPCPs in wet no-freeze areas.



Better performance can be achieved for undoweled JPCP pavements by designing them to minimize faulting. For example, undoweled pavements that had higher values for modulus of subgrade reaction had lower roughness values.

Both doweled and undoweled JPCP pavement roughness values were generally higher for pavements located in areas that received high precipitation, had higher freezing indices, and had a high content of fines in the subgrade. In non-freeze regions, doweled and undoweled JPCP pavements located in areas that had a high number of days above 32°C had lower roughness values. This factor is likely to be related to the higher load transfer that occurs at higher temperatures.

JPCP pavements that had higher modulus values had higher roughness values. This indicates that mix design factors and the type of aggregate used may influence the performance of the pavement from a roughness perspective.

JRCP

Figure 4 shows roughness versus pavement age plots for JRCP pavement sections in wet freeze regions. The overall trend in roughness at these sections appears to be an exponential increase in roughness.

JRCP pavements in areas having high precipitation, higher moisture content in the subgrade, thicker slabs, longer joint spacing, and higher modulus values for PCC had higher roughness values. The higher roughness values for thicker slabs may be construction-related. Increased joint spacing would likely result in a greater proportion of transverse cracks, and may result in spalling and faulting at these locations, which would contribute to higher roughness.

JRCP pavements with the following characteristics—higher values for modulus of subgrade reaction, higher PCC compressive strength, and higher water and cement content in the PCC mix—had lower roughness values. Lower roughness for JRCP pavements with higher water-cement ratios in the PCC mix may be explained by the fact that a mix with a higher water-cement ratio would be more workable compared to a mix with a lower water-cement ratio; however, a mix that has a lower water-cement ratio is expected to be more durable over the long term.

CRCP

Figure 5 (see back page) shows roughness versus pavement age plots for CRCP pavement sections in wet no-freeze regions. As seen from this plot, most of the sections appear to maintain a relatively constant roughness. Similar behavior patterns were observed for sections in the wet freeze zone. The roughness patterns appear to be similar for new as well as old pavements. In fact, there are many sections that are more than 15 years old, but are still very smooth. This observation indicates that CRCP pavements appear to maintain their initial roughness over a long period.

CRCP pavements that had a higher percentage of longitudinal steel and higher water-cement ratios had lower roughness values. Whereas CRCP pavements that had higher values of PCC elastic modulus had higher roughness values. This indicates that mix design factors such as coarse aggregate content and type of coarse aggregate may affect the roughness behavior. In non-freezing areas, sections located in areas that had a higher number of days above 32°C had higher roughness values.

Summary

The overall analysis of PCC pavements from "The Investigation of

Figure 3. Faulting vs. roughness for undoweled JPCPs.

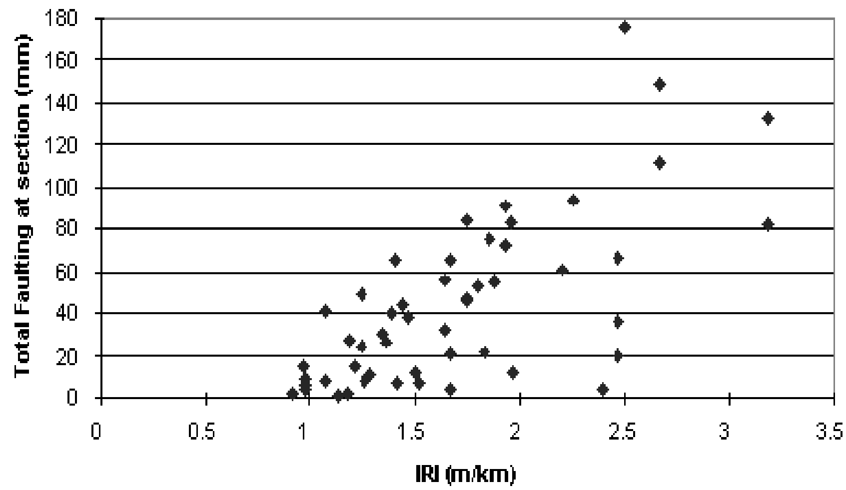


Figure 4. Roughness vs. pavement age JRCPs in wet freeze areas.

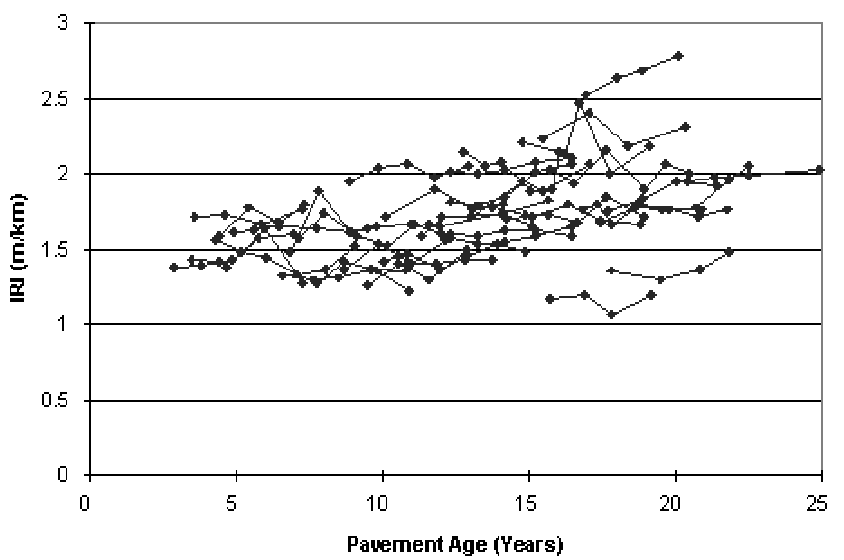
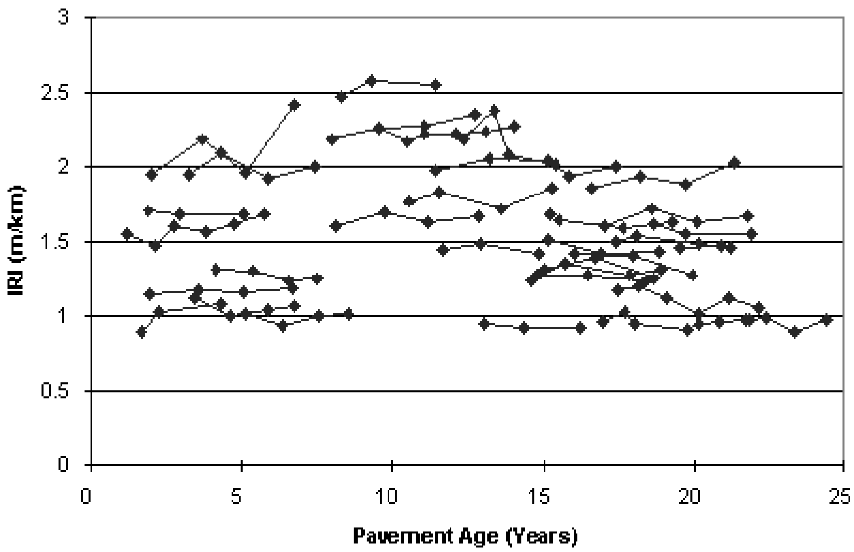


Figure 5. Roughness vs. pavement age for CRCPs in wet freeze areas.



Development of Pavement Roughness" (the study from which these key findings are excerpted) showed that faulting (transverse joints and cracks) has a great influence on the measured roughness of PCC pavements. In addition, PCC pavements with a higher PCC modulus were associated with higher roughness values. Lastly, there were indications that PCC pavements that have higher strength (split tensile) while maintaining a relatively low modulus will provide better performance.

Researcher: This study was performed by Soil and Materials Engineers, Inc., 43980 Plymouth Oaks Blvd., Plymouth, MI 48170-2854, Telephone: (734) 454-9900, Fax: (734) 454-0629. Contract No. DTFH61-95-C-00124.

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Availability: Copies of Report No. FHWA-RD-97-147, *Investigation of Development of Pavement Roughness*, are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161. A limited number of copies are available from the R&T Report Center, HRD-11, FHWA, 9701 Philadelphia Court, Unit Q, Lanham, MD 20706, Telephone: (301) 577-0818, Fax: (301) 577-1421.

Key Words: Concrete pavement, pavement roughness, pavement design.

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