



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

## Roughness Trends of Flexible Pavements

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

### Background

Roughness is widely regarded as the most important measure of pavement performance because it is the measure most evident to the traveling public. It greatly affects ride quality, safety, and vehicle operating costs. Therefore, understanding how and why roughness occurs in pavements is of major concern to highway agencies. To this end, the Long Term Pavement Performance (LTPP) program recently completed a study to investigate the changes in roughness of flexible pavements over time and their relationship to design factors, subgrade conditions, and climatic conditions. The results of this study were published in Report No. FHWA-RD-97-147, *Investigation of Development of Pavement Roughness*.

### Key Findings

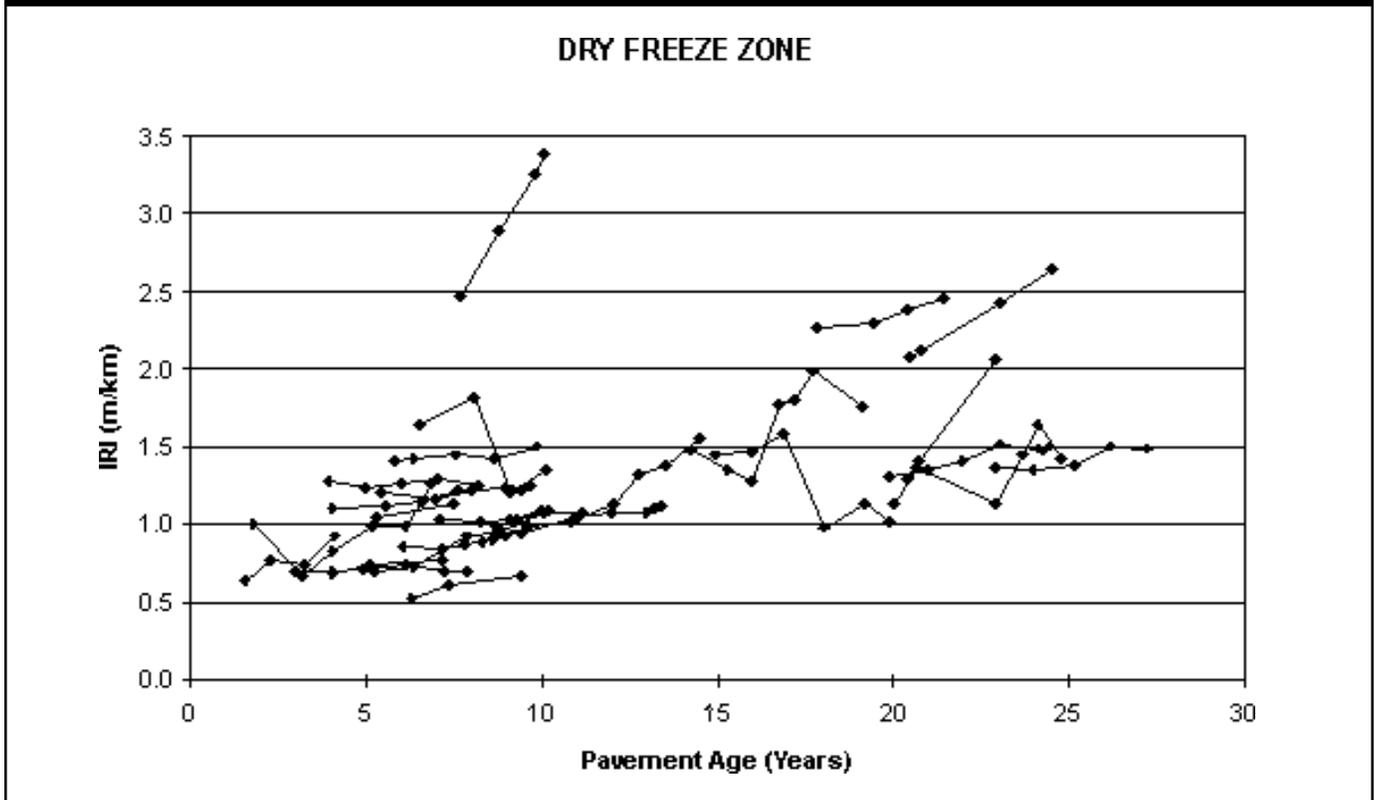
- Flexible pavement roughness remains relatively constant over the initial life of the pavement. Then, after a certain point, it shows a rapid increase.
- Roughness of pavements located over fine-grained soils was related to the plasticity index and the percentage of subgrade passing the 75- $\mu$ m sieve. Pavements on fine-grained soils having higher plasticity indices and a higher percentage passing the 75- $\mu$ m sieve have higher International Roughness Index (IRI) values.
- Pavements in areas that have a high freezing index or a high number of freeze/thaw cycles had higher roughness values. This would suggest that adequate frost protection is an important factor for good pavement performance in freezing regions.

### Roughness Trends

- Most of the flexible pavement sections studied showed little change in roughness over time.

Several test sections studied were more than 15 years old, but had low roughness values. A preliminary analysis of these sections indicated

Figure 1. Roughness trends for GPS sections in dry freeze environmental zone.



that they had carried a low cumulative traffic volume when compared to the theoretical cumulative traffic volume that can be supported by the pavement structure. Furthermore, most of the sections that were showing a high increase in roughness over the years were close to or had exceeded their design life based on equivalent single-axle loads and the 1993 American Association of State Highway and Transportation Officials (AASHTO) pavement design equation.

A closer examination of the data indicated that the changes in roughness for flexible pavements could be classified into the following three categories: (1) roughness shows an increase with time; (2) roughness remains relatively stable over time; (3) roughness values are variable between the years, with no clear overall trend for the

test sections studied. It was noted that pavements with roughness in excess of 2 m/km generally exhibited larger increases in roughness over time when compared to the other test sections.

- Climatic and subgrade conditions showed a strong relationship with roughness in flexible pavements.

Analysis of data from each of the LTPP program's environmental zones indicated that roughness of pavements located over fine-grained soils was related to the plasticity index and the percentage of subgrade passing the 75- $\mu$ m sieve. Pavements on fine-grained soils having higher plasticity indices and a higher percentage passing the 75- $\mu$ m sieve had higher roughness values. In freezing environments, test sections located in areas that had a high freezing index

or a high number of freeze/thaw cycles generally had higher roughness. This observation suggests that adequate frost protection is an important factor for good pavement performance. (Figures 1 through 4 show pavement age vs. roughness for each environmental zone.)

- Variability in roughness values is due to several factors.

Variability in the time-sequence roughness values at a test section can occur due to the following factors: (1) variations in the profiled path, (2) seasonal effects, and (3) maintenance activities. Variations in the profiled wheelpath for different years can cause changes in the measured profile and, therefore, the computed roughness. In some pavements, there is considerable transverse variability, which can cause considerable variations in

Figure 2. Roughness trends for GPS-1 sections in dry no-freeze environmental zone.

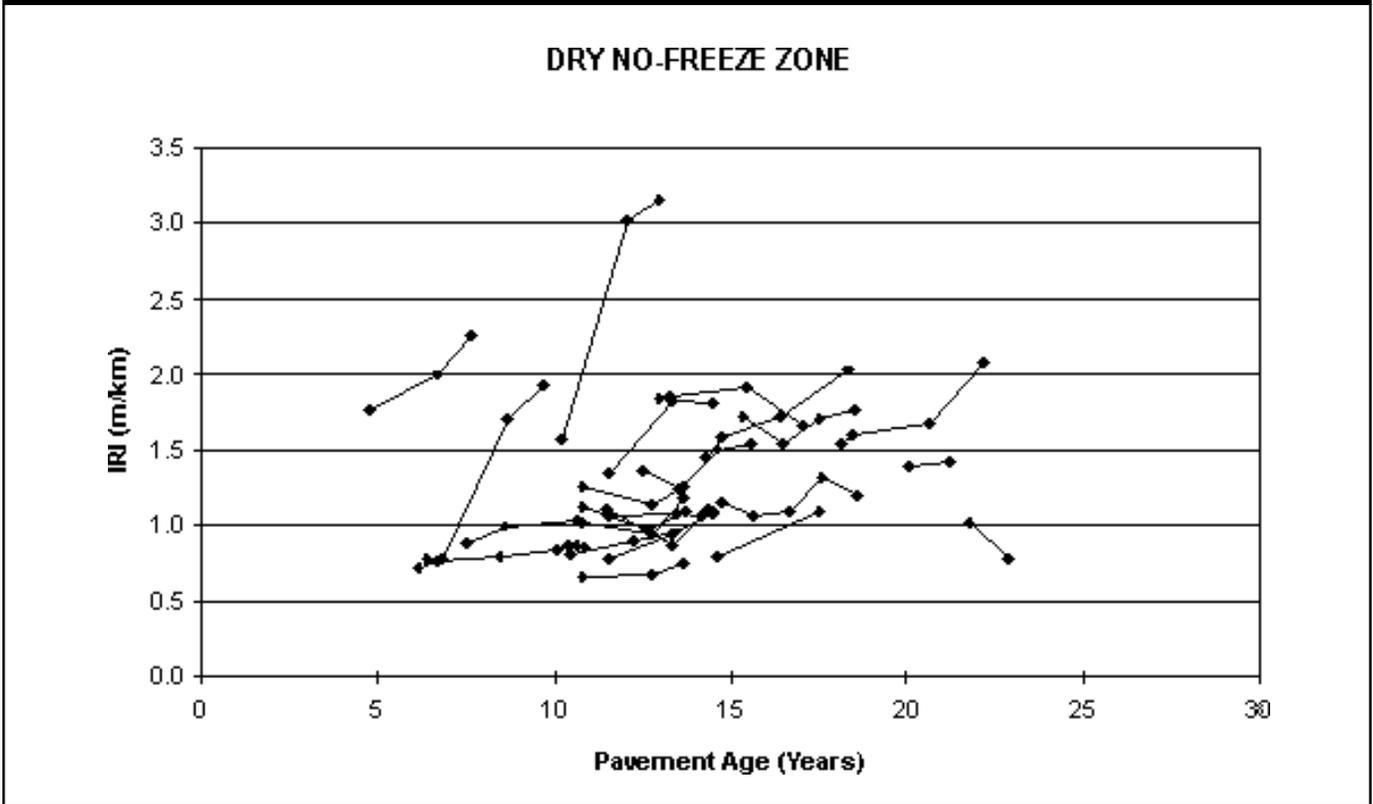


Figure 3. Roughness trends for GPS-1 sections in wet no-freeze environmental zone.

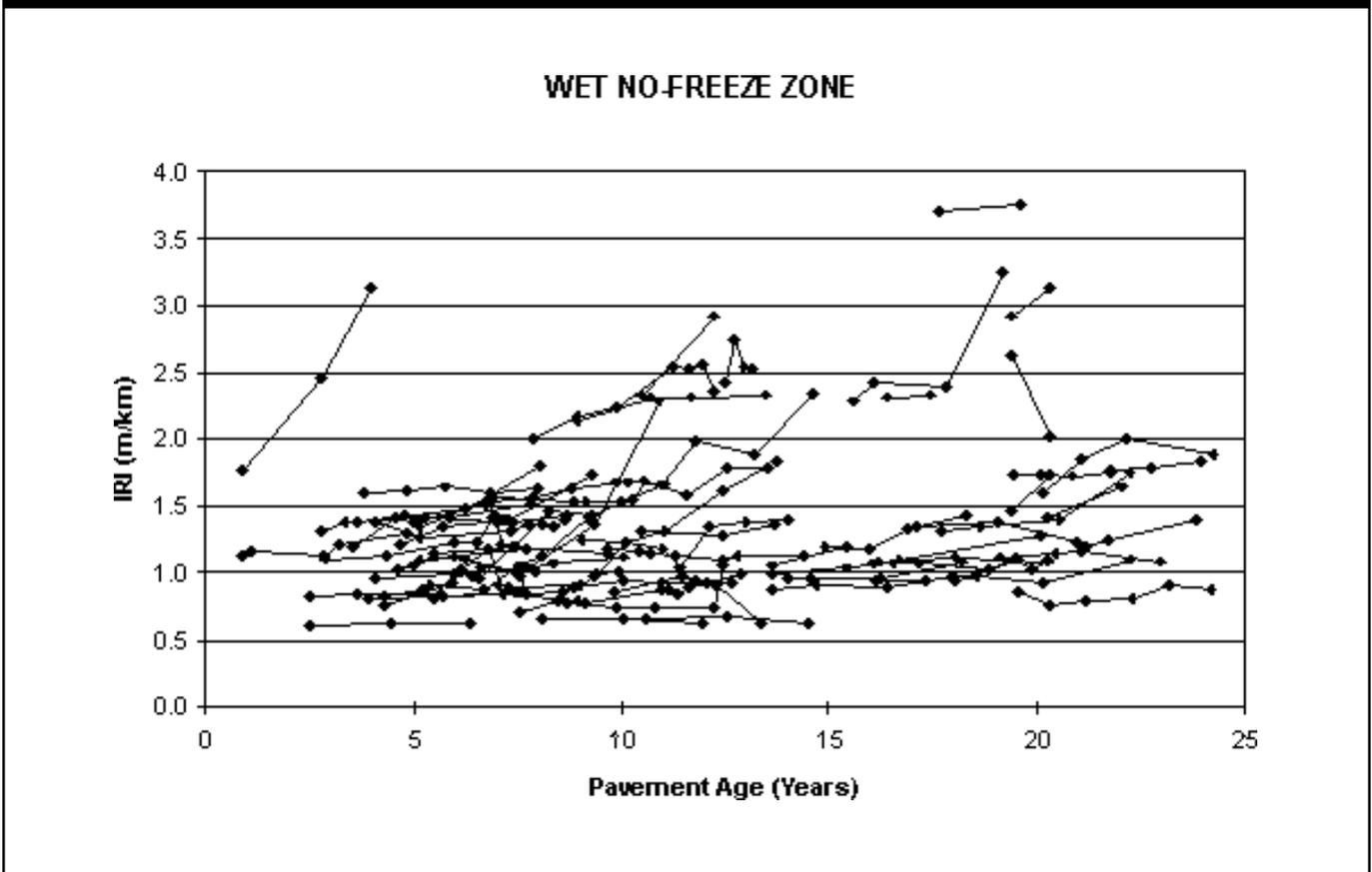
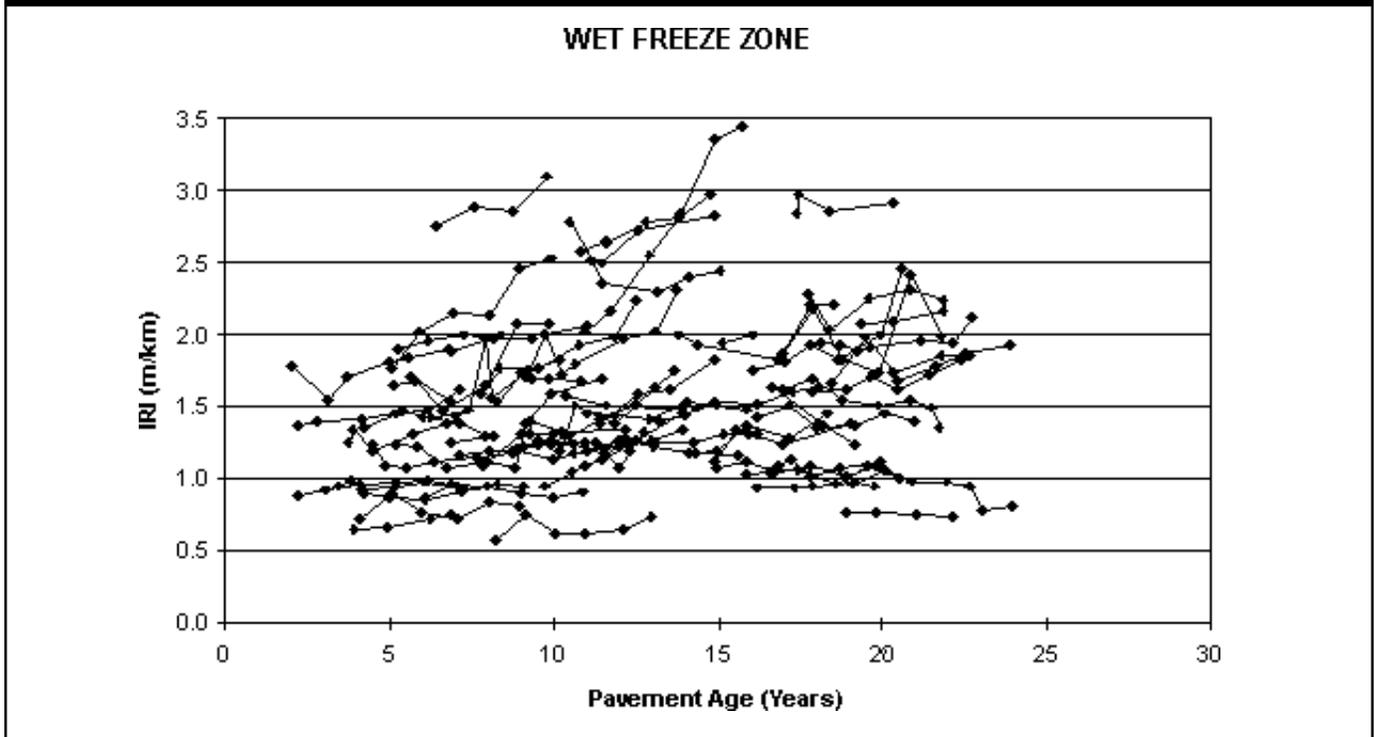


Figure 4. Roughness trends for GPS-1 sections in wet freeze environmental zone.



roughness, depending on the wheelpath that is followed.

Changes in roughness can also occur in pavements due to changes in profile caused by seasonal effects. Although the General Pavement Studies (GPS) sections are profiled annually, differences of several months can occur between subsequent profiling

dates. This can result in the section being profiled during different seasons of the year. For example, the profile of a pavement can change due to moisture effects on a subgrade that cause the subgrade to swell or shrink. During the winter months, frost heave of the subgrade and base layers can cause variations in the pavement profile. Both of these effects

will contribute to variations in roughness.

Maintenance activities on a section can also change the roughness of a section. Repair of distressed areas can lead to a reduction of pavement roughness. The variable roughness patterns that were observed at some of the test sections are attributed to these causes.

**Researcher:** This study was performed by Soil and Materials Engineers, Inc., 43980 Plymouth Oaks Boulevard, Plymouth, MI 48170-2584, Telephone: (313) 454-9900, Fax: (313) 454-0629. Contract No. DTFH61-95-C-00124.

**Distribution:** This TechBrief is being distributed according to a standard distribution. Direct distribution is being made to the regions and divisions.

**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:** Roughness, pavement performance, pavement profile, IRI, LTPP, flexible pavements.

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