TECH**BRIEF**

Relating Ride Quality and Structural Adequacy for Pavement Rehabilitation and Management Decisions

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This document is a technical summary of the Federal Highway Administration (FHWA) report, *Relating Ride Quality and Structural Adequacy for Pavement Rehabilitation/Design Decisions* (FHWA-HRT-12-035).[1]

This TechBrief discusses the relationship between pavement ride quality and structural adequacy. It presents highlights from a literature search and findings from the analysis and comparison of ride quality and structural adequacy data from the Long-Term Pavement Performance (LTPP) program. Although a viable relationship between the two parameters could not be established, the lack of correlation is considered of value to pavement management system (PMS) practitioners, as it indicates that good ride quality does not mean good structural support or vice-versa. This becomes an important consideration for those who want to base performance measures on ride quality indicators.

Background

State highway agencies spend billions of dollars each year on transportation infrastructure assets to meet legislative, agency, and public expectations. Pavements are a major component of those assets, and pavement rehabilitation is one of the most critical, costly, and complex elements because it preserves pavements to extend their service life and, more importantly, to improve motorist safety and satisfaction and save public tax dollars.

PMSs are at the heart of the rehabilitation decisionmaking process. Earlier PMS generations considered ride quality and distress as direct results of the American Association of State Highway Officials Road Test. With advances in technology, PMSs started to use distress (cracking, rutting, etc.) and longitudinal roughness (typically the International Roughness Index (IRI)) as key performance indicators in the decisionmaking process. Both are important indicators that merit emphasis within the PMS process, but they are not the only ones. Structural adequacy, for example, is another important indicator for making rational pavement investment decisions, and many State highway agencies are incorporating deflection testing as part of their routine PMS activities.

Although ride quality and structural adequacy are key performance indicators, the relationship between them has been a topic of frequent and continuing discussion in the pavement community. To date, an accepted and widely used relationship has not been identified.

The Long-Term Pavement Performance (LTPP) program is a large research project for the study of in-service 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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Recognizing the benefits of such a relationship, FHWA sponsored a study to identify the relationship between ride quality and structural adequacy (if any) using the LTPP data. This was done to develop a mechanism to include both ride and structural adequacy values within the context of current network-level PMS practices. This TechBrief presents the major findings and conclusions from the study.

Literature Search

The purpose of the literature search was to collect, review, and synthesize available information related to ride quality and structural adequacy in support of pavement rehabilitation and design decisions. A total of 62 references were identified, but only 16 of them were considered relevant to the study. The majority (62 percent) of these references were from LTPP-related studies, and the remainder (38 percent) were from universities or highway agencies. In addition, the majority (69 percent) of these references were articles, and the remainder (31 percent) were reports. Table 1 shows the distribution of the 16 references by topic area.

Although a couple of studies indicated a potential relationship between structural response and pavement performance, neither of them established a direct relationship. Several studies were successful in relating ride quality to pavement condition or distress. In fact, the roughness models in the American Association of State Highway and Transportation Officials (AASHTO) *Mechanistic-Empirical Pavement Design Guide* use distress as an input to predict roughness.[2] Similarly, structural response has been used to predict certain distresses. While it is evident that many factors influence pavement performance in different ways, a strong correlation between the three different performance measures (i.e., ride quality, pavement distress, and structural adequacy) has yet to be established such that measurement of any one performance indicator is adequate for understanding the structural and functional condition of the pavement.

Data Review and Analysis

The best source of data to accomplish the study objective was the LTPP program, which was established to explain how pavements perform and why they perform as they do. In particular, the use of data associated with Specific Pavement Studies (SPS)-1 (new hot mix asphalt (HMA) pavements), SPS-2 (new jointed concrete pavements), and SPS-5 (rehabilitation of existing HMA pavements) project sections were considered particularly relevant, as they capture performance and the factors influencing it throughout the entire pavement life cycle. The pavement sections selected for use in the study were grouped into the following categories:

- **Group 1:** Seven SPS-1 sections included pavements with a wide range in IRI values changing over time.
- **Group 2:** Four SPS-1 sections exhibited significant decreases in structural adequacy over time.
- **Group 3:** Four SPS-1 sections included different base types exhibiting structural differences.
- **Group 4:** Three SPS-5 sections exhibited significant increases in IRI since overlay.
- **Group 5:** Three SPS-2 sections exhibited significant increases in IRI over time.

A number of parameters were investigated to select an appropriate ride quality indicator, but IRI was identified as the best one for the study. More specifically, continuous IRI plots using a 25-ft base length were used to look at how IRI varied with distance along the section. Such plots showed the distribution of roughness along the section, with any point on a 25-ft base length continuous IRI plot showing the average IRI of a 25-ft-long segment centered at that point. Only the right wheel path was considered in the study as it matched the falling weight deflectometer (FWD) test path. Similarly, many parameters were considered to select an appropriate structural adequacy indicator. Of these,

Table 1. Distribution of literature search references by type and topic.

Type/Topic	Relationship Between Ride and Structural Adequacy	Factors Influencing Pavement Performance	Structural- and Functional-Based Approaches for Pavement Evaluations	Relationship Between Ride and Distress	Total (Percent)
Report/guideline	2	1	0	2	5 (31 percent)
Article/ presentation	0	6	1	4	11 (69 percent)
Total	2 (13 percent)	7 (43 percent)	1 (6 percent)	6 (38 percent)	16 (100 percent)

the AASHTO effective pavement structural number (SN) for flexible pavements and effective concrete slab thickness (D_{eff}) for rigid pavements were selected. FWD deflection data were used to estimate both SN and D_{eff}.

Continuous IRI and SN or D_{eff} plots were developed to evaluate and compare the relationship between changes in ride quality and structural adequacy. These changes were evaluated using the initial and latest profile survey and FWD test data available in the LTPP database for each section.[3] The resulting plots were then normalized to visualize the percent changes in IRI and SN or D_{eff}. Figure 1 illustrates these plots for section 010102 in Alabama, which is one of the group 1 sections. As shown, there was a significant increase in IRI over the last 300 ft of the section when compared to the first 200 ft of the section. The decrease in SN for the last 300 ft of the section was also greater, but the decrease was only slightly higher than that for the first 200 ft. Also, a slight decrease in SN was noted at the 300-ft station, which was within the limits that showed the highest increase in IRI for this section.

Figure 2 shows the relationship between average percent change in IRI and SN observed in the sections of groups 1 through 4. While significant IRI changes were noticed at localized areas within most sections, the observed changes in SN at these localized areas were not significantly different than those over the remainder of the section. Consequently, an IRI to SN relationship was not apparent and/or did not exist. For the group 5 sections, D_{eff} was used as the structural adequacy parameter. Similar to the flexible pavement sections, no relationship was observed between changes in IRI and changes in effective slab thickness.

Supplemental analyses were conducted to validate the study findings. The evaluation of maintenance and repair activities indicated that limited maintenance had been performed on the sections, and, with few exceptions, this did not affect the findings. The review of IRI and FWD time history data confirmed that the use of the initial and latest survey/test dates to characterize the change in IRI and SN or D_{eff} over time appeared reasonable. Also, an assessment of concrete pavement warping and curling showed that significant changes in IRI can occur with changes in slab shape, which has no relationship with the structural adequacy of the pavement.

Summary

This TechBrief summarizes the major findings from a study to identify the relationship (if any) between ride quality and structural adequacy or ride deterioration and structural adequacy using the LTPP pavement performance data. Major conclusions from the study are as follows:

- Continuous IRI and SN or D_{eff} plots were generated to see if a viable relationship between ride quality and structural capacity relationship could be identified. Such a relationship was not observed in the sections and data investigated. It is possible that other researchers will pursue alternate approaches that will yield a reliable relationship.
- The lack of correlation found in the study is considered of value to PMS practitioners, as it indicates that good ride quality does not mean good structural adequacy or vice-versa. This is an important consideration for those who want to base performance measures on ride quality indicators.
- While a relationship would be expedient for PMS applications, a fundamental understanding of the differences in factors causing structural deterioration and roughness makes it unlikely to find a simple relationship, particularly one excluding most other factors.

Figure 1. Normalized SN and IRI plot for section 010102 in Alabama.

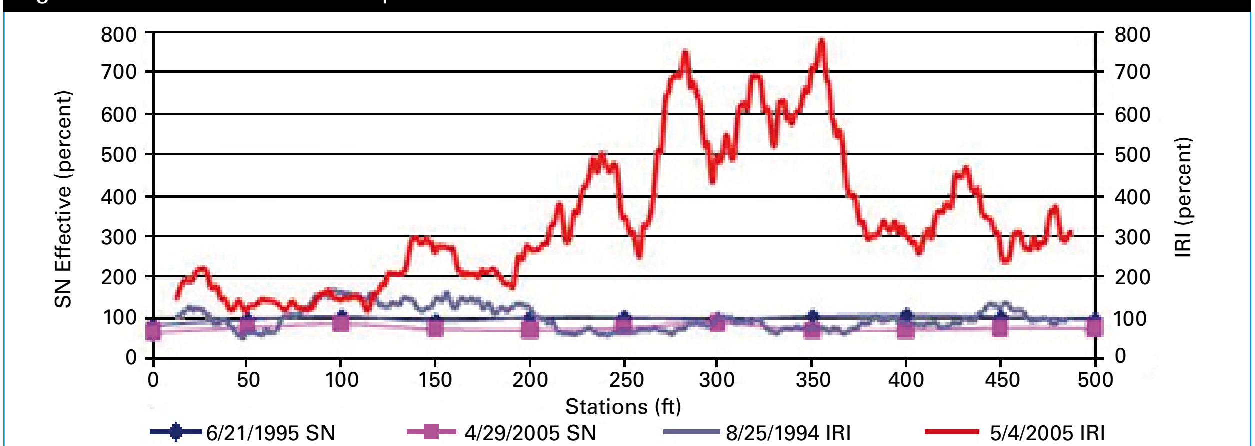
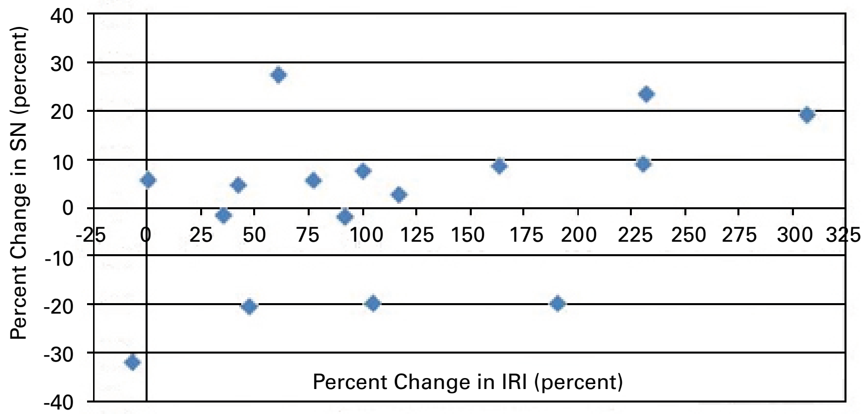


Figure 2. Relationship between percent change in IRI and SN.



- Although pavement functional and structural performances are not independent of each other, they are not related in a one-to-one manner that can easily be implemented within a network-level PMS. It is hypothesized that a strong relationship between these two performance indicators will require the inclusion of many other variables, potentially undoing its usefulness for PMS.

References

1. Rada, G.R., Perera, R., and Prabhakar, V. (2012). *Relating Ride Quality and Structural Adequacy for Pavement Rehabilitation/Design Decisions*, Report No. FHWA-HRT-12-035, Federal Highway Administration, Washington, DC.
2. American Association of State Highway and Transportation Officials. (2008). *Mechanistic-Empirical Pavement Design Guide, A Manual of Practice*, Interim Edition, Washington, DC.
3. Turner-Fairbank Highway Research Center. *How to Get LTPP Data*, Federal Highway Administration, Washington, DC. Obtained from: http://www.fhwa.dot.gov/research/tfhrc/programs/infrastructure/pavements/ltpp/getdata.cfm.

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