Stiffer Bridges Result in Slower Bridge Deck DETERIORATION

by James M. Barker

For many years, bridge design engineers have been discussing and debating the benefits of stiff bridge superstructures. The issue involves the use of stiffer longitudinal girders relative to the cracking of bridge decks. The presence of cracks leads to accelerated deterioration caused by reinforcement corrosion from water and corrosive salts entering the cracks. A number of studies and research reports have been completed since the early 1990s. This article provides an update on some of the more recent studies.

The majority of this discussion is related to transverse cracks in bridge decks mostly near pier locations on continuous bridges. These cracks do not surprise any design engineer because, after all, the design theories assume that the slab is cracked when computing the areas of reinforcement required to carry the design loads.

Transverse cracks are also possible in longitudinal positive moment areas near midspans of bridges. This can be particularly true for older bridges where short end spans may be continuous with longer second and third spans. These cracks can be caused by permit loads or overloads, which may exceed the slab compression caused by the dead loads and provide sufficient tension to transversely crack the slabs. There is not usually sufficient residual compression in the slab due to dead load to cause the cracks to close afterwards. Rational thinking indicates that a stiffer heavier superstructure would result in larger dead load stresses and thus reduce the creation of transverse slab cracks in positive moment areas of the bridge spans due to overloads. The Portland Cement Association (PCA) Report SN 2936 titled *"Effect of Superstructure Properties on Concrete Bridge Deck Deterioration"* by Sanya Mackela Johnson, includes a discussion of the relationship of girder stiffness and deck cracking in the longitudinal direction parallel to the support girders. There seems to be a similar correspondence in the transverse direction as in the longitudinal direction due to load differentials and deformations associated with the transverse distribution of wheel loads.

Transverse Cracks due to Longitudinal Loads

Investigations have delivered a substantial amount of evidence that stiffer bridges exhibit less transverse cracking of bridge decks even where we expect to find those cracks. The work by Johnson is one of the latest studies that confirms this thinking.

Several states have invested in the belief that stiff bridges are longer-lasting bridges by the establishment of policies making every bridge deck composite with the longitudinal support girders no matter what material is used to fabricate the girders. Some states have even adopted a policy that composite action with the use of shear studs or extended reinforcement stirrups should be carried across the supports of continuous structures as well as in positive moment midspan regions. While most designers still assume the top slab is cracked over the pier supports, they do include the reinforcement in the moment of inertia computations thus resulting in a stiffer bridge in the longitudinal direction.

Deck Slab Cracks and Vibrations

The New York State Department of Transportation (NYSDOT) study titled *"A Qualitative Study of Correlations between Bridge Vibration and Bridge Deck Cracking"* by Sreenivas Alampalli, et al. and published at the TRB Annual Meeting, Washington, D.C., 2002, was also summarized by Johnson in the PCA report.

In the NYSDOT work, the cracking of the bridge deck was found to be related to the dynamic deflection component exhibited as bridge superstructures vibrate during the passage of live loads. A person standing on a bridge during the passage of a loaded concrete truck or semi-trailer can certainly feel the difference in vibrations that occur on a stiff bridge versus those occurring on a flexible bridge. The resulting oscillations can also be felt after the passage of the loads. The New York authors make the following statement: "In time, such a phenomenon can cause cracking or make the existing cracks, especially any transverse cracks, deeper and wider."

The NYSDOT report includes the following in their conclusions:

Vibration severity is the most significant parameter influencing bridge deck cracking. Higher severity equates to higher deck cracking. Decks with noticeable vibration cracked most severely.

Longer spans exhibit more deck cracking than shorter spans.

Bridges with noticeable vibration combined with longer span lengths exhibited significant bridge deck cracking.

NCHRP Report 297 reported on tests in the United Kingdom that showed that the most influential factor on the risk of cracking caused by traffic-induced dynamic deflection reversals is the amplitude of the deflection, not the frequency. The maximum dynamic deflection generally increased as the maximum static deflection increased.

Thus it seems that vibrations can play a very important role in bridge deck cracking. Stiffer bridges vibrate to smaller deflection amplitudes and exhibit less deck cracking.