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DEPARTMENTAL
INFORMATION
EXCHANGE

FRETTING FATIGUE IN EXTERNAL POST-TENSIONED TENDONS

PROBLEM STATEMENT

For the past 50 years, engineers have successfully constructed moderately long span bridges using box-girder segments reinforced by internal cables. Often these cables—called tendons—are post-tensioned, meaning that once the concrete has been placed and cured (or after the precast segments have been assembled), the tendons are pulled through ducts within the girder and stressed. The ducts are then cement-grouted for better bonding and corrosion protection.

A recent refinement of this technology has been the development of a system of *external* post-tensioning cables or tendons, in which the tendons are attached outside the concrete cross section (i.e., inside the void of the box girder) (Figure 1). The Long Key Bridge, constructed in 1980 as part of the series of bridges connecting the Florida Keys, was the first externally post-tensioned box-girder bridge built in the U.S. In Texas, this innovative system was used by the Texas Department of Transportation in the late 1980s to construct several miles of elevated highway in San Antonio.

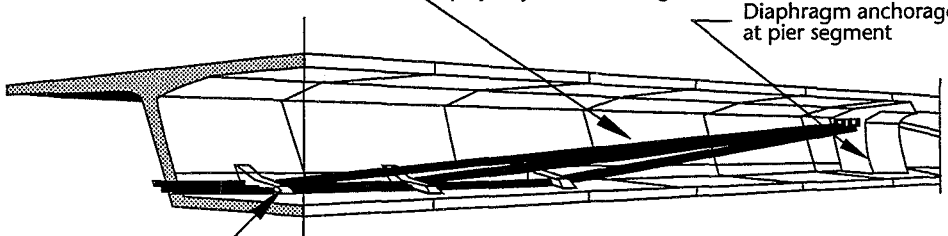

Figure 1. Cross-section of box-girder segment showing draping of external tendons.

The tendons of an external post-tensioned concrete box girder are draped along the inside of the girder, where they are held in position at discrete points by blocks known as "deviators" (Figure 2). These deviators, containing metal or rigid plastic ducts through which the tendons pass, are reinforced concrete projections cast as part of the one-piece girder section. The exposed tendons, typically enclosed in polyethylene tubing, are usually grouted along their entire length for protection against corrosion. (Engineers consider these tendons unbonded, since most of the tendon is not bonded to the concrete section, and because the strains in the tendon are independent of the strains in the adjacent concrete section.)

There are several advantages to using box girders having post-tensioned external tendons (as opposed to the more classical internal post-tensioning): The tendons themselves are easier to install and replace; and the thinner construction of the sections, made possible by the lack of internal cables, makes the sections easier and less expensive to construct. They are, in addition, less susceptible to stress-related failure. According to most studies, the lower stress fluctuation (under live loads) associated with the unbonded tendon reduces the risk of fatigue failure.

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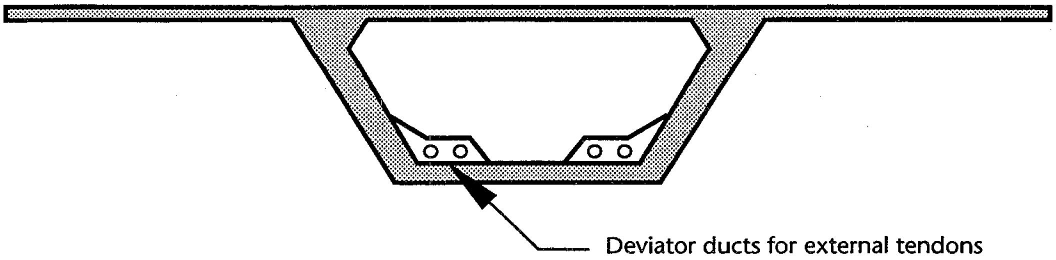

Figure 2. Concrete box-girder segment showing deviation points for external tendons.

At the same time, however, there are two main disadvantages. Long, unbonded tendons are subject to vibration problems, which can cause structural damage. More serious is the unbonded tendons' susceptibility to "fretting," a kind of corrosion occurring between two materials in contact under high pressure. This action can lead to failure—fretting failure—at the critical deviators.

The potential for fretting failure in the deviators of external post-tensioned tendons—commonly used in segmental box-girder bridges erected by the span-by-span construction method—was the subject of a recent Center for Transportation Research report prepared by K. K. Ryals, J. E. Breen, and M. E. Kreger, all of The University of Texas at Austin.

OBJECTIVES

The report, "Fretting Fatigue in External Post-Tensioned Tendons," documents the findings of Project 1211, conducted by the Center for Transportation Research (CTR) of The University of Texas at Austin for the Texas Department of Transportation (TxDOT) and the Federal Highway Administration (FHWA). The objective of the research was to determine whether changes in the angle of the tendons—in relation to the deviators—promotes fretting failure, which, if present, has the potential to shorten the life of the system. The particular focus of this study was the three-way interaction of the tendon, the deviator, and the deviator duct. According to the report's authors, it is precisely this interrelationship that determines the system's susceptibility to failure.

FINDINGS

In studying the effects of fretting fatigue on external post-tensioned tendons, the researchers lab-tested three deviator specimens. In the first specimen test, the deviator duct was set up to represent an "ideal" field condition. A load was then applied to simulate an unrealistically high 24,000-pounds-per-square-inch (24 ksi) stress range in the tendon. (Such an extreme load was thought capable of inducing immediate fretting fatigue.) Because the first ideal specimen performed surprisingly well, the researchers concluded that another such test of an ideal specimen at a lower, more realistic stress range was unnecessary. Accordingly, the last two specimens were tested for evidence of fretting fatigue by varying only the degrees of misalignment of the deviator ducts (variations that ranged from "bad" to "worst case"). A post-test examination of the specimens revealed the following:

1. Fretting occurred in all three specimens.
2. Fretting was more severe in the deviator specimens having misaligned ducts.
3. Fretting was most often characterized by strand-to-strand fretting or fretting between wires of the same strand, rather than by strand-to-duct fretting.
4. The "test termination fatigue life" of all of the deviator specimens was surprisingly long, an indication that fretting fatigue "is not a major issue in externally post-tensioned girders."

CONCLUSIONS

The central conclusion drawn from this study is that current design and construction procedures relating to external tendons in post-tensioned systems are, according to the report's authors, "generally acceptable and safe." The study team found that, even in the worst-case scenarios recreated in their testing, the potential for fretting fatigue in external tendons in post-tensioned construction was no greater than that normally associated with internal tendons.

Citing the absence of current code provisions relating to the fatigue design of externally post-tensioned girders, the CTR study team crafted a design procedure based on "values typically used in fatigue design of structural steel under the AASHTO Bridge Design Specifications." According to the authors, this more rational and flexible design approach should improve both safety and economy. Specifically, the excessive prestressing prescribed by current design approaches (to preclude cracking at service-load levels) could, say the authors, be substantially reduced for such secondary structures as rural overpasses and bridges on low-volume roads. And the consequent reduction in the number of required strands could, in turn, lower both construction and congestion-related costs.

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The information provided in this summary is reported in detail in Research Report 1211-1F, "Fretting Fatigue in External Post-Tensioned Tendons," by K. K. Ryals, J. E. Breen, and M. E. Kreger (December 1992). The contents of the summary report do not necessarily reflect the official views of the FHWA or TxDOT.