

DETENSIONING AN EXTERNAL PRESTRESSING TENDON

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On August 28, 2000 a routine inspection of the seven year old, Mid - Bay Bridge over the Choctawhatchee Bay located in Okaloosa County, Florida revealed severe corrosion of two prestressing tendons. In order to replace one tendon it became necessary to detension its remaining force, estimated to be 500 kips. This report provides information relative to the detensioning operation and how it was safely carried out on September 12, 2000.

BRIDGE DESCRIPTION

This bridge is a 19,265 foot long precast segmental box girder bridge, built by the span by span method of construction with 6-136 foot spans per typical continuous superstructure unit. There are six external prestressing tendons, each composed of 19 - .6" diameter 270 ksi strands. These are anchored at each end of each 136 foot span. The box superstructure, designed for three AASHTO HS20-44 live load lanes, is 42.75 ft. wide by 8.0 ft. deep.

The bridge was designed in 1989 for the Mid - Bay Bridge Toll Authority and construction was completed in 1993. The average daily traffic is approximately 11,400 vehicles with 4% trucks. The bridge is located in what the Florida Department of Transportation (FDOT) terms a severely aggressive environment, in that it spans a body of tidally influenced salt water.

THE CORROSION PROBLEM FOUND AND IMMEDIATE ACTIONS TAKEN



PHOTO 1

The routine maintenance inspection of the Mid - Bay Bridge revealed that one tendon in span 57 was completely slack, as evidenced by its geometry, which allowed it to drape, making contact with the floor of the box superstructure (See Photo 1). It was later found that corrosion had taken place in the top tendon anchor at the expansion joint end of this span. At this time it is presumed that the existence of a void space within the anchor region and 'grout bleed water' created the corrosive condition.



PHOTO 2



PHOTO 3

(See photo 2) Photo 3 shows that all strands broke in the trumpet region or at the trumpet to steel pipe transition.

The toll bridge was immediately closed to all traffic, resulting in a 30 mile detour for those who normally used the bridge. A further detailed inspection revealed that in span 28, 6 of 19 strands in one tendon were severed due to corrosion. This was detected because several ruptured strands had split the protective grout and polyethelene pipe and were thus partially protruding at a location 13 feet from the anchor head at the expansion end of the span. (See photo 4)

The original bridge designer performed an analysis utilizing the original design file, but modified it to account for the loss of prestress encountered. Reviewing these calculations the FDOT determined it was safe to allow 2 axle vehicles on the bridge and the bridge was again opened to traffic after 12 hours of closure.

A contractor was hired, under an emergency contract, within 2 days after initial disclosure of the corrosion problem, to make the necessary

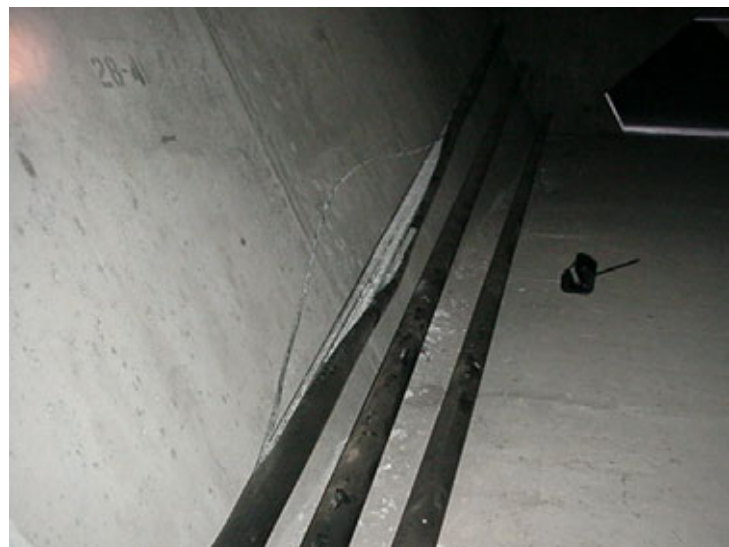


PHOTO 4

repairs to restore the bridge to full design capacity.

A consulting engineering firm was also hired to oversee the repair work as well as perform a more detailed inspection which included a vibration testing technique developed by Dr. Sagues, University of South Florida. An extensive inspection was begun by removing the pour-back cover from all post-tensioning anchorages, drilling into the post-tensioning anchorage trumpet areas through the grout ports and utilizing a flexible borescope to check for voids behind anchorages.

The FDOT Materials and Testing Office gathered samples of grout and prestressing strand for chemical testing to help determine the cause of the corrosion and to help evaluate the current condition with respect to possible future corrosion.

BASIC CONSIDERATIONS FOR TENDON REMOVAL

Significant corrosion of the tendon in span 28 was observed once the PE pipe and visible grout were removed (see photo 5). Although only 6 of 19 strands were ruptured the degree of corrosion on other strands indicated that other strands in this tendon might rupture. It was thus decided to proceed quickly with slackening and removal of this partially corroded tendon in span 28, the removal of the slack tendon in span 57 and then to replace both tendons during the same contract.



PHOTO 5

There are two tendon deviators per web located at about the third points of each span (see figure 1). These deviation blocks, located at the box floor, are designed to carry the vertical component of the deviated tendons. We knew from observations at this bridge and another similar occurrence that a sudden rupture of a tendon would cause unbalanced forces at the nearest deviation block, causing cracking in the block and sliding of the embedded deviation pipe within the deviation block. Damage to the deviation blocks had to be avoided so as not to compromise the integrity of the bridge.

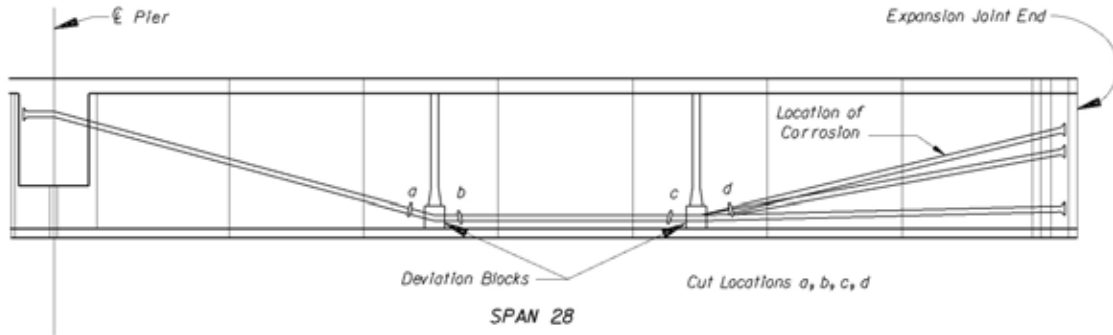


FIGURE 1

The tendon force would have to be gradually slackened along its length so as to keep sudden shock loading and unbalanced forces at the deviation blocks to a minimum.

The safety of workers was a primary concern in deciding how to slacken the tendon, which still held an estimated tension force of 500 kips!

SOME METHODS CONSIDERED FOR TENDON SLACKENING

The possibility of removing the PE pipe and grout and then heating the tendon along its entire length to relieve its force and then 'burning through' was a consideration. Although at first this seemed reasonable this method was dismissed for various reasons. The heat required to significantly change the steel modulus and to relax the tendon force through elongation is above 900 deg Fahrenheit. It was estimated that at 900 degrees the steel yield strength would be reduced to about 60 ksi and the remaining stress in the tendon would be about 20 ksi. Although the entire tendon would be heated to 900 degrees it would not be fully slackened.

For this reason, the practicality of heating the tendon inside the enclosed space of the box girder, ventilation concerns and other unknowns surrounding this method, it was dropped from further consideration.

Consideration was given to removing the P.E. pipe and grout over a one foot length between each anchorage/deviation point. One strand would be cut at each location until all the strands were cut (see figure 2). However due to bond transfer within the P.E.

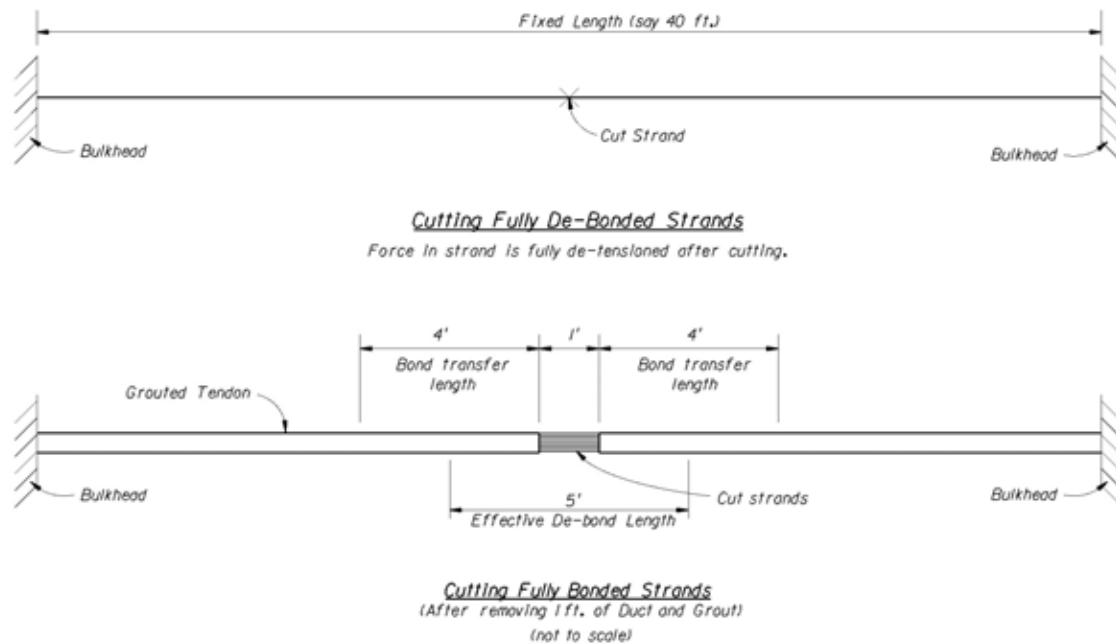


FIGURE 2

pipe/grout system, the tendon force from each cut strand would be transferred to the remaining strands. These strands will elongate, due to the increase stress and corresponding strain, over approximately 5 feet of tendon. This elongation will be distributed over the remaining tendon length (~35 feet) resulting in a reduced tendon force. However this reduction will only be about 1/7 (5 feet/35 feet) of the increase stress in the cut area. Since the increase to ultimate stress in the cut area will be approximately $(1.0-0.63)f^{\prime}s$, the reduction in stress for the over all tendon will only be $(0.37/7) = 0.053 f^{\prime}s$; which is about 8% of the initial tendon force. After cutting just 7 of the 19 strands, the stress in the remaining 12 strands would begin yielding. This yielding would continue until 15 strands had been cut, at which time the strain in the remaining 4 strands would exceed the 3.5% elongation guaranteed by the ASTM Specifications. The force in these remaining strands would be at their ultimate (58.6 kips/strand). Any further cutting could result in sudden rupture of the remaining strands, which was deemed to be unsafe for the workers.

Based upon this theory, but with more cut locations it was felt that the tendon could be removed with minimum risk of sudden rupture. However this method was dropped from further consideration in favor of the method selected and presented later.

The contractor proposed removing the anchorages by burning out the wedges, but this was considered to be entirely too dangerous for several reasons. The condition of bond within the trumpet areas was unknown. If through load transfer from one strand to another a partially corroded strand suddenly fractured, the released energy could propel the strand and wedge directly out the back of the anchor where the worker is positioned. This phenomenon has actually been observed in pretensioning operations where a strand

is cut and the cut strand is actually propelled, through the released energy, back out through the stressing bulkhead.

If the grout in the steel pipe and trumpet area, embedded in the pier diaphragms, was in good condition, the tendon force might not release, even with the wedges cut. This would then require entering the critical span and cutting the tendons a second time. As the strands adjacent to the anchorage area would be cut, the release of energy and resulting vibrations would damage the good grout in the embedded steel pipe and trumpet which could result in a sudden slippage of the tendon causing an unsafe condition. Also a sudden release of force at the anchorage could damage or fail a deviation block.

SLAKENING AND REMOVAL OF THE TENDON

It was reported to us that simply grinding through a stressed tendon had been successfully accomplished on a project, where during construction, the tendon had been mislocated and had to be removed. Although few details were available we confirmed that it was indeed practical and feasible to cut the prestressing strand with standard hand held tools. This was a big plus considering that access to this area was difficult with only a 3 ft by 3 ft opening in the bottom of the box girder located 2700 ft from span 28.

After reviewing our options we recommended the following method to slacken the tendon in span 28, which the contractor seemed to like and accept:

- a) Remove the PE pipe from the entire length of the tendon.
- b) Remove as much grout as practical throughout the entire length of the tendon.
- c) Install, on the tendon, 4-inch diameter heavy-duty U – bolt clamps (see photo 6) every 4 ft. to control the possible strand ‘whip-lash’ as each strand is cut.
- d) Attempt to cut a path through the grout in the lower section of the deviation pipe by means of a high-pressure waterpower sprayer (to decrease bond at the deviation blocks). If not successful the subsequent steps will continue as outlined.
- e) The cutting of strands will be performed with an electric powered cut-off saw using metal abrasive blades (see photo 6). Torch cutting will not be allowed.
- f) For the purposes of this procedure, the tendon sections to be cut are labeled a,b,c and d in figure 1.
- g) Cut one strand at location a. (leaving enough strand length so that a mono-strand jack can be used to grip the strands and remove them later)
- h) Cut one strand at location b.
- i) Steps g and h continue sequentially until the same number of strands have been cut as are currently broken at the opposite end. (to equalize the forces in the tendon with respect to the deviation saddles).
- j) Check that cut strands are shortening by the appropriate amount to relieve their stress (see photo 7). If not, loosen U-bolt clamps to allow cut strands to slide along their length.
- k) Now it is required to cut the tendon in an alternating pattern at locations a, b, c and d, with never more than one cut strand out of balance on any side of a deviation block until all strands are cut.



PHOTO 6



PHOTO 7

This procedure was followed with the exception of step d). The pressure sprayer available, on short notice, did not deliver the required pressure. However it was found that even with full bond at the deviation blocks the slacking procedure worked very well, and as intended. The contractor did complete step d) on other tendons that were removed and found the release of the force was better controlled as the strands were cut. The contractor commented on the fact that the U - bolt clamps obviously restrained the strands as they were cut and their energy was released.

To remove the tendon sections now still embedded in the anchor blocks and at the deviation blocks a 20,000 psi water jet was used to remove grout as needed to then allow the final removal with a mono-strand jack. As strand sections are removed the remaining grout simply crumbles allowing relatively easy removal of the remaining strands. The individual strands were carried out by hand.