Lessons Learned

problems and solutions encountered by practicing structural engineers

Repairs to Prestressed Strands in Double-Tee Stems

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A new repair method was implemented to restore the structural integrity of precast double-tee stems that have lost their prestressing strands due to physical damage or corrosion. The repair method is intended for strands that are closely spaced, where currently available strand splices cannot be used without modification. Pressure jackets are used to splay the wire strands apart and align them with splices in order to re-stress the strand to the original pre-load.

Background

Prestressed concrete double-tee beams are pre-compressed with wire strands embedded in their stems. The size and number of strands in each stem varies depending on the original design requirements, and are often harped to make more efficient use of the strands and concrete cross-section. Harping consists of sloping the strands so that they start at each end of a stem at a vertical spacing of 2 inches (or more), and are brought closer together at harp points. During manufacturing, hold-downs in the stressing beds are used to react against the vertical component of the force created by the change in strand angle.

In service, the prestressed strands can be damaged physically or by corrosion. Typically, significant flexural cracking and deflections are signs that the strands are damaged and the structural capacity of the member has been compromised. Several repair methods have been used to restore the structural capacity of damaged stems. These include external post-tensioning and installation of steel channels. External post-tensioning typically requires the installation of a pair of steel or concrete brackets (across the stem) on both sides of the crack, and tendons or rods that are subsequently post-tensioned at the brackets. For the steel channel method, a pair of steel channels is bolted across the stem. Each method has structural design and construction challenges that would be unique to the particular structural repair.

Investigation and Findings

Over the past few years, the author investigated two precast parking garages in which each had developed a flexural crack in a stem of a double-tee at the harped point. The first garage was a 1974 structure with normal weight concrete double-tees. The bolted steel channel option, installed in 2009, worked well for this particular stem. The second garage was a 1971 structure with lightweight concrete double-tees.

In the 1971 structure, the main findings at the damaged stem included a crack that developed near midspan of an 86-foot long, 24 LDT double-tee. The crack measured about ¼ inches wide at the bottom and gradually narrowed to zero near the stem-to-flange intersection. Deflections were not noticeable, most likely because the loads of the damaged stem were being distributed to its sister stem and adjacent double-tees. The damaged stem still had its bottom strand, as described below.

Figure 1.

An exploratory opening at the crack was made (*Figure 1*). It revealed that: 1) the crack developed at the harped point, 2) six strands were used, the top five strands were harped, and the bottom was straight, 3) the top five strands were positioned adjacent to each other vertically, 4) stress corrosion had caused total loss of steel area of the top five strands and the bottom strand developed minor surface corrosion, 5) the vertical steel strut used to maintain the position of the stretched strands at the harped point during manufacturing had been removed and mortar grout placed in the void, 6) no supplemental steel was present in this region of the stem, and 7) signs of cracking and corrosion were not observed beyond the crack.

The prestressed strands were ½-inch diameter strands with a likely 270-ksi ultimate tensile strength. Thus, each strand can carry tension loads in the order of about 30 kips. The concrete stems were nominal 4 inches wide and 22 inches tall.

Pressure Jacket

A stressing device was designed to restore the prestressing forces directly to the original strands. It is intended for situations where the prestressed strands are so close to each other that available re-stressing splices cannot be used without some modification. The stressing device uses two pressure jackets such that strand splices can be used.

For this case, Grabb-It strand splices (G-I strand splice) were used to re-stress the strands. A G-I strand splice is a specialty "come-along" device, manufactured specifically for prestressing strands (refer to manufacturer literature). It grabs the

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ends of strands with anchors and standard prestressing wedges, and then pulls the strands together by torqueing on a long, double-handed threaded nut. A torque wrench is used to torque the nut, thus tensioning the strands. Concrete has to be excavated to expose the free ends of the strand, install the splice, and apply the proper torque. The manufacture's calibration table is used to determine the torque-tension relationship. The splice is intended to be installed in line with the strand (aligned, not offset). These splices have been tried in repairs of bundled post-tensioned tendons where the splices were not aligned with the tendons. Difficulties were experienced achieving torque values, most likely because the splice deformed at high torque values. Thus, it was determined for this case that the splices should be aligned with the tendons.

The challenge in this project was that the failed strands were close together, and the G-I splices could not be installed properly to apply high tension loads. In order to install the splices, have room for the torque wrench, and align the splices, the strands needed to be separated (splayed). The pressure jacket shown in *Figure 2* does that. At one end it receives the strands at their original position and at the other end it separates them enough to install the splices in line with the strands, and have room for the torque wrench. Within the pressure jacket, the strands need to have smooth transition curves (no kinks). A mirror pressure jacket is needed on the opposite side of the strand splices.

If the strands were to be tensioned, they would straighten and would be damaged due to the sharp angles caused by separating the strands in this fashion. To avoid this, the jackets are filled with flowable concrete mortar by pumping grout into the jackets and letting it cure. As the strands are tensioned, internal pressures are developed because the strands still want to straighten, but the grout resists these forces. The internal pressures are resisted by the steel pressure jacket – hence the name. The internal pressures can be calculated using equations for curved tendons.

Figure 3.

The pressure jacket consists of a carbon steel tube with injection and breathing ports, two end plates with holes to match the strands at one end and separate them at the other end, and grout. The end plate holes include stainless steel protection sleeves to: 1) isolate the prestressing steel from the carbon steel and thus inhibit galvanic corrosion, and 2) inhibit damage between the strands and end plates. Grabb-It strand splices are used to tension the strands.

Stressing Sequence

The installation of the pressure jackets and the strand splices required excavating the lower portion of the stem (*Figure 3*). Re-stressing five strands to a total load of 150 kips required that the bottom section of the augmented stem be cast and cured while the strand splices were still accessible (*Figure 2*). After the strands were tensioned, the splice pocket was filled with grout.

Other Applications

Modifications to the pressure jacket described here can be made for repairing post-tensioned tendons that are bundled together and need to be separated in order to install re-stressing devices, and other conditions.

Conclusion

A repair option is presented to address damaged prestressed strands and post-tensioned tendons in concrete. The main concept was the development of a pressure jacket able to splay strands so that they are aligned for the proper use of strand splices. The repair procedure restores the tension forces directly back to the original strands.■

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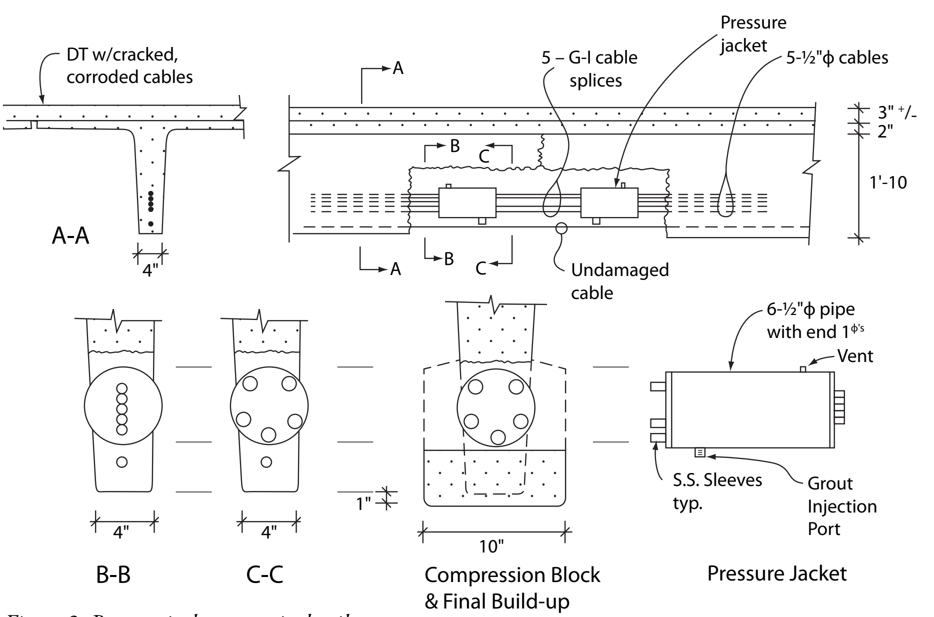

Figure 2: Pressure jacket – repair details.