Installation of Post-Tensioning Tendons

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Chapter 1 - Introduction

1.1 Objective

One of the major advancements in bridge construction in the United States in the second half of the twentieth century was the development and use of prestressed concrete. Prestressed concrete bridges offer a broad range of engineering solutions and a variety of aesthetic opportunities. The objective of This course is to provide guidance to individuals involved in the design, installation, grouting and inspection of post-tensioning tendons for prestressed concrete bridges.

1.1.1 Benefits of Post-Tensioning

The tensile strength of concrete is only about 10% of its compressive strength. As a result, plain concrete members are likely to crack when loaded. Reinforcing steel can be embedded in the concrete members to accept tensile stresses which plain concrete cannot resist. Reinforcing is selected assuming that the tensile zone of the concrete carries no load and that tensile stresses are resisted only by tensile forces in the reinforcing bars. The resulting reinforced concrete members may crack, but it can effectively carry the design loads (Figure 1.1).

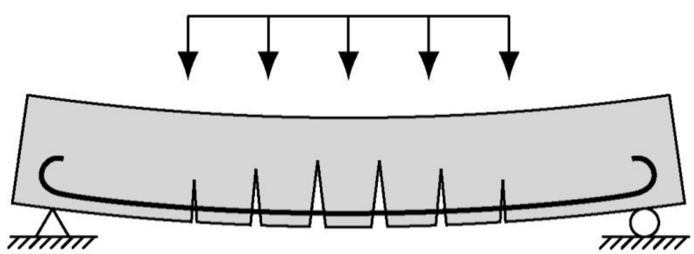

Figure 1.1 - Reinforced Concrete Beam Under Load

Although cracks occur in reinforced concrete, the cracks are normally very small and well distributed. Cracks in reinforced concrete can reduce long-term durability. Introducing a means of precompressing the tensile zones of concrete members to offset anticipated tensile stresses, reduces or eliminates cracking to produce more durable concrete bridges.

1.1.2 Principle of Prestressing

The function of prestressing is to place the concrete structure under compression in those regions where load causes tensile stress. Tension caused by applied loads will first have to cancel the compression induced by the prestressing before it can crack the concrete. Figure 1.2 (a) shows a plainly reinforced concrete simple span beam and fixed cantilever beam cracked under applied load. Figure 1.2(b) shows the same unloaded beams with prestressing forces applied by stressing post-tensioning tendons. By placing the prestressing low in the simple-span beam and high in the cantilever beam, compression is induced in the tension zones; creating upward camber.

Figure 1.2(c) shows the two prestressed beams under the action of post-tensioning and applied loads. The loads cause both the simple-span beam and cantilever beam to deflect down, creating tensile stresses in the bottom of the simple-span beam and top of the cantilever beam. The designer balances the effects of load and prestressing in such a way that tension from the loading is compensated by compression induced by the prestressing. Tension is eliminated under the combination of the two and tension cracks are prevented. As a result, durability is increased and more efficient, cost effective construction is realized.

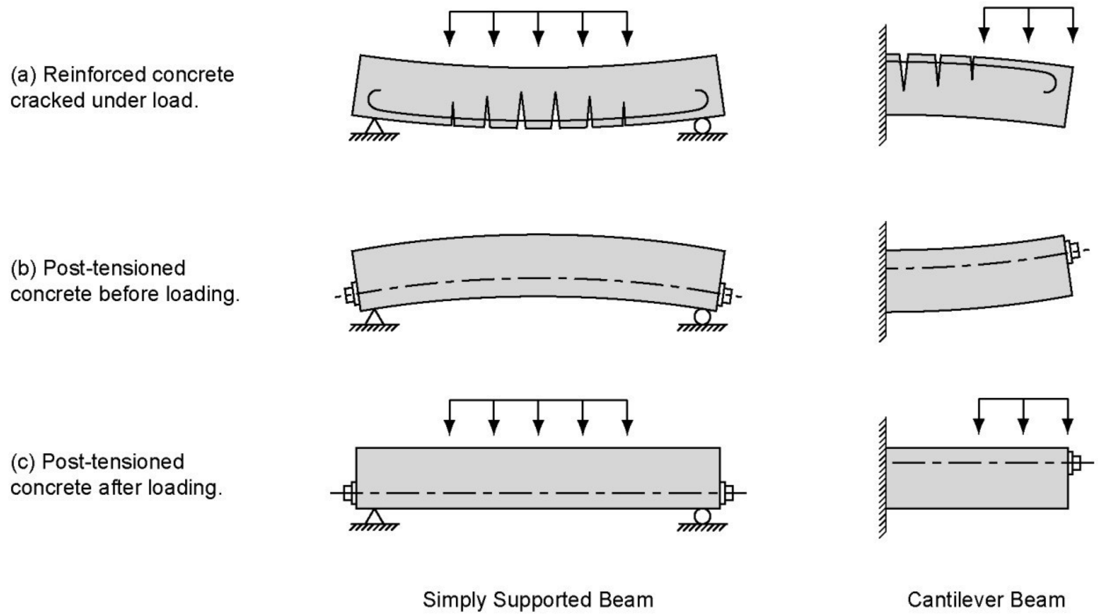

Figure 1.2 - Comparison of Reinforced and Prestressed Concrete Beams

Prestressing can be applied to concrete members in two ways, by pretensioning or post-tensioning. In pretensioned members the prestressing strands are tensioned against restraining bulkheads before the concrete is cast. After the concrete has been placed, allowed to harden and attain sufficient strength, the strands are released and their force is transferred to the concrete member. Prestressing by post-tensioning involves installing and stressing prestressing strand or bar tendons after the concrete has been placed, hardened and attained a minimum compressive strength for that transfer.

1.1.3 Post-Tensioning Operations

Compressive forces are induced in a concrete structure by tensioning steel tendons comprised of strands or bars placed in ducts embedded in the concrete. The tendons are installed after the concrete has been placed and sufficiently cured to a prescribed initial compressive strength. A hydraulic jack is attached to one or both ends of the tendon and pressurized to a predetermined value while bearing against the end of the concrete beam. This induces a predetermined force in the tendon and the tendon elongates elastically under this force. After jacking to the full required force, the force in the tendon is transferred from the jack to the end anchorage.

Tendons made up of strands are secured by steel wedges that grip each strand and seat firmly in a wedge plate. The wedge plate itself carries all the strands and bears on a steel anchorage. The anchorage may be a simple steel bearing plate or may be a special casting with two or three concentric bearing surfaces that transfer the tendon force to the concrete. Bar tendons are usually threaded and anchored by means of spherical nuts that bear against a square or rectangular bearing plate cast into the concrete. For an explanation of post-tensioning terminology and acronyms, see Appendix A.

The protruding "tails" of strands or bars of permanent tendons are cut off using an abrasive disc saw or plasma cutting after stressing. Flame cutting should not be used as it negatively affects the characteristics of the prestressing steel. Tendons are then grouted using a cementitious based grout. This grout is pumped through a grout inlet into the duct by means of a grout pump. Grouting is done carefully under controlled conditions using grout outlets to ensure that the duct anchorage and grout caps are completely filled. After grouting, anchorages are protected by multiple levels of protection appropriate to the environmental demand on the structure. See Chapter 5 for details regarding corrosion protection of tendons.

Materials other than cementitious grout, such as wax, have been used to fill ducts after the installation and stressing of tendons. These materials are not commonly used in the United States and are not addressed in This course. Post-tensioning and grouting operations require certain levels of experience and certification, as outlined in Appendix B.

1.1.4 Post-Tensioning Systems

Many proprietary post-tensioning systems are available. Several suppliers produce systems for tendons made of wires, strands or bars. The most common systems found in bridge construction are multi-strand systems for permanent post-tensioning tendons and bar systems for both temporary and permanent situations. Refer to manufacturers' and suppliers' literature for details of available systems. Key features of three common systems (multiple-strand and bar tendons) are illustrated in Figures 1.3, 1.4 and 1.5.

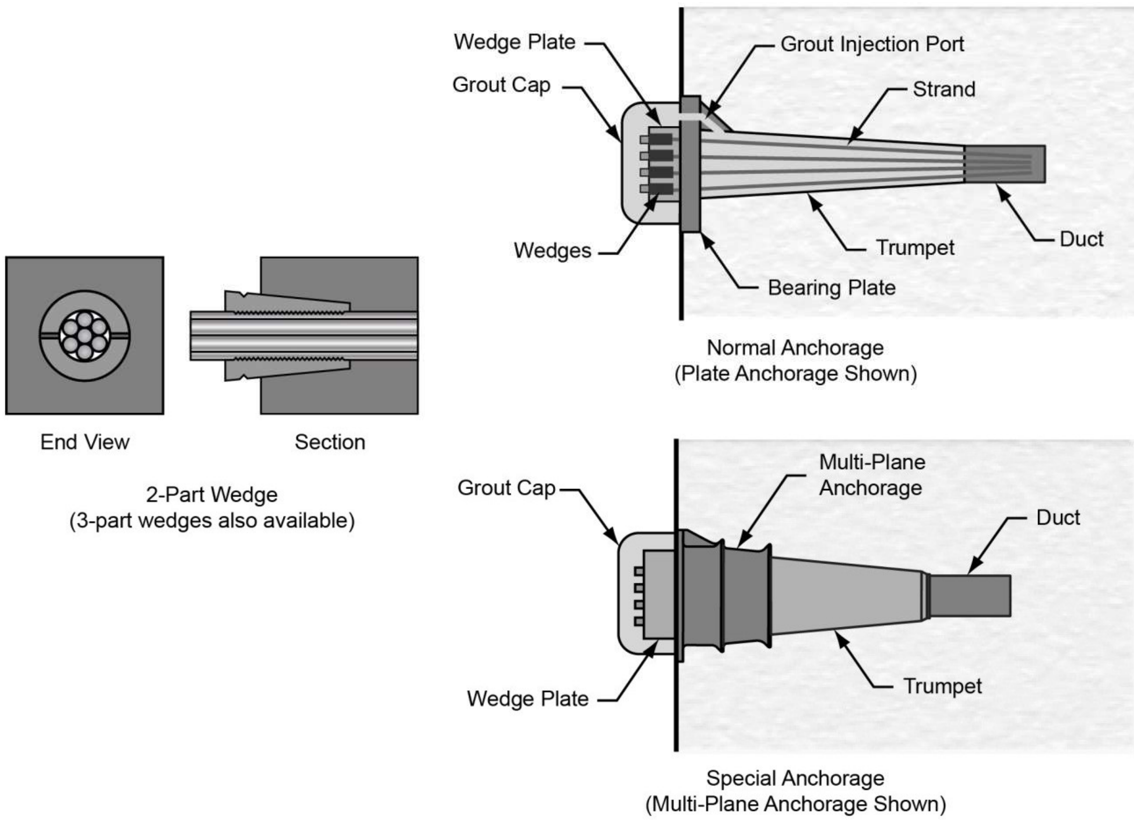

Figure 1.3 - Typical Post-Tensioning Anchorage Hardware for Strand Tendons

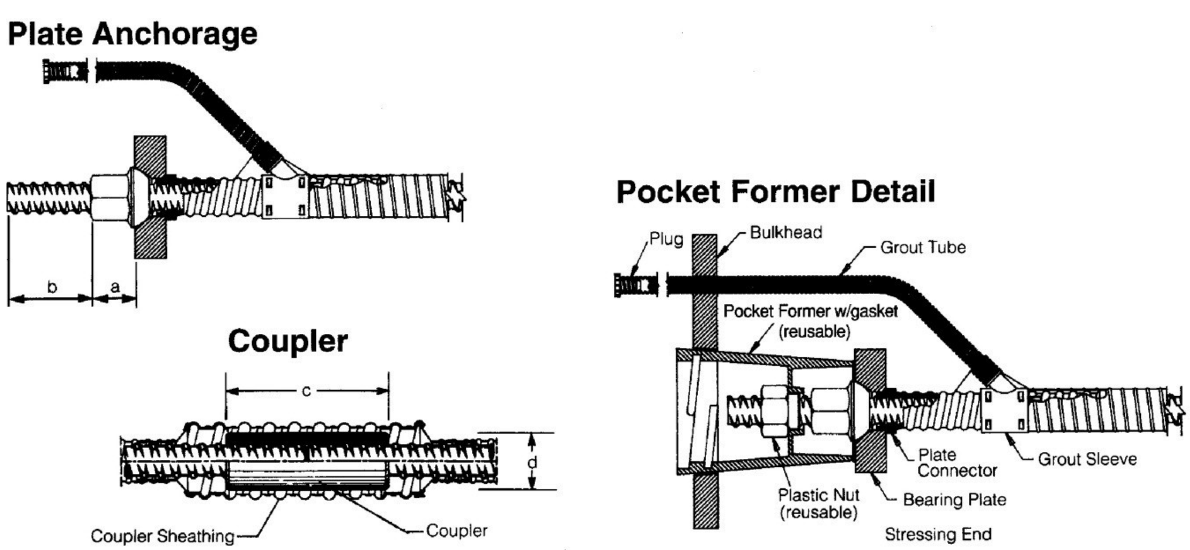

Figure 1.4 - Typical Post-Tensioning Bar System Hardware
(Courtesy of Dywidag Systems International)