Concrete is strong in compression, but weak in tension, its tensile strength varies from 8 to 14 percent of its compressive strength. Due to such a low tensile capacity, flexural cracks develop at early stages of loading. In order to reduce or prevent such cracks from developing, a concentric or eccentric force is imposed in the longitudinal direction of the structural element. This force prevents the cracks from developing by eliminating or considerably reducing the tensile stresses at the critical midspan and support sections at service load, thereby raising the bending, shear, and torsional capacities of the sections. The sections are then able to behave elastically, and almost the full capacity of the concrete in compression can be efficiently utilized across the entire depth of the concrete sections when all loads act on the structure. Such an imposed longitudinal force is called a prestressing force, i.e., a compressive force that prestresses the sections along the span of the structural element prior to the application of the transverse gravity dead and live loads or transient horizontal live loads. The type of prestressing force involved, together with its magnitude, is determined mainly on the basis of the type of system to be constructed and the span length and slenderness desired. Prestressed concrete uses much less materials than reinforced concrete: savings can reach 40% of the overall mass! Longer spans, thinner and lighter elements allow a reduction in number of piles, height of buildings, consumption of energy in freight and handling, therefore CO2 emissions. Refer Figure 1 for post tensioning strands placement in the beam before concreting. Refer Figure 2 for tensioning process after concreting. Refer Figure 3 for post tensioned I Girder.
Economics of Prestressed Concrete

Prestressed members are shallower in depth than their reinforced concrete counterparts for the same span and loading conditions. In general, the depth of a prestressed concrete member is usually about 65 to 80 percent of the depth of the equivalent reinforced concrete member. Hence, the prestressed member requires less concrete, and about 20 to 35 percent of the amount of reinforcement. Unfortunately, this saving in material weight is balanced by the higher cost of the higher quality materials needed in prestressing. Also, regardless of the system used, prestressing operations themselves result in an added cost: Formwork is more complex, since the geometry of prestressed sections is usually composed of flanged sections with thin webs. In spite of these additional costs, if a large enough number of precast units are manufactured, the difference between at least the initial costs of prestressed and reinforced concrete systems is usually not very large. And the indirect long-term savings are quite substantial, because less maintenance is needed, a longer working life is possible due to better quality control of the concrete, and lighter foundations are achieved due to the smaller cumulative weight of the superstructure. Once the beam span of reinforced concrete exceeds 70 to 90 feet, the dead weight of the beam becomes excessive, resulting in heavier members and, consequently, greater long-term deflection and cracking. Thus, for larger spans, prestressed concrete becomes mandatory since arches are expensive to construct and do not perform as well due to the severe long-term shrinkage and creep they undergo. Very large spans such as segmental bridges or cable-stayed bridges can only be constructed through the use of prestressing.

“Steel wires and strands are the backbone of this magical concrete technology. There has been significant advancement in this industry over the years. In this paper high strength steel details and properties of steel strands and wires are being discussed.”

High Tensile Steel Strands for Prestressed Concrete (Low Relaxation)

Reason for Low Relaxation Strands: A steel member that is prestressed and embedded in concrete loses the initially applied stress exponentially with the passage of time. The utmost important factor attributing to this loss in stress is the stress relaxation property of the steel itself. By treating the steel through a thermo mechanical process known as stabilising, the propensity of the steel to “relax” under a stressed condition is controlled to a great extent. Some of the main advantages that our customers derive by using low relaxation strands are listed below:

- Upto 10% reduction in steel requirement is possible.
- Saving in number of anchorages, ducts, sheathings, wedges and labour resulting in overall reduction of project cost.
- Reduction in concrete requirement due to reduced size of structural members.
- Thermo-mechanical processing during manufacture of LRPC Strands produces a nearly straight strand, thereby eliminating necessity for extra post straightening treatment.

Refer Figure 4 below for high tensile steel strands.
Standard properties of Strands and Wires: As per BS 5896:2010, the following are the standards for prestressing strands and wires.

**Geometrical properties**

The geometrical properties shall be defined by a nominal diameter, a nominal cross-sectional area and a nominal mass per metre. For indented wire the nominal dimensions of indentations and for strands the lay length. Refer Figure 5, 6, 7 for various geometry of strands.

For 7-wire strands, the diameter of the straight central wire shall be at least 3.0% greater than the diameter of the outer helical wires.

For 7-wire compacted strands, the diameter of the straight central wire shall be at least equal to the diameter of the outer helical wires.

For 7-wire indented strands, the diameter of the straight central wire shall be at least 3.0% greater than the diameter of the outer helical wires and is normally plain.

The requirements for the surface configuration of the product and the product straightness shall be as given in sections 2 and 3 of this specification

**Mechanical properties**

The standard mechanical properties are:

- The maximum force;
- The 0.1% proof force;
- The total percentage elongation at maximum force;
- The ductility properties appropriate to the product type (i.e. percentage reduction of area, resistance to reverse bending and/or bending);
- The force ratio.

The specified values of the standard mechanical properties

**The Special Properties of Pre-Stressing Steels**

**Mandatory:**
- Isothermal relaxation and stress corrosion resistance.

Figure 4: Prestressing Strands / Wires

Figure 5: Wire: Plain, indented, for pipes

Figure 6: Strands: 2 or 3 wires, plain or indented

Figure 7: Strands: 7 wires, plain or indented

Figure 8: Strand Packs

Figure 9: Dirt Free prestressing strand
Optional: fatigue behavior and deflected tensile test for strands 12.5mm 15.7mm nominal diameter.

Isothermal stress relaxation

The losses by relaxation of force shall be established at a nominal temperature of 20 °C, for a period of 1000 hr from an initial force of 70% of the actual maximum force, in the tensile test, determined by a tensile test on an adjacent test piece.

Fatigue behavior

Products shall withstand without failure two million load cycles under conditions of stable upper force and frequency where the stable upper force is defined by 70% of the actual maximum force determined in a tensile test on an adjacent test piece.

Deflected tensile behaviour

The maximum permitted deflection percentage reduction value (D) for strands with nominal diameter 12.5mm ≤≤d 15.7mm shall be in accordance with the value specified in BS 5896:2010.

Stress corrosion resistance

The minimum individual and median values of life-time to failure shall be determined using a solution of ammonium thiocyanate specified in BS EN ISO 15630-3. These values may be in accordance with the values specified in BS 5896:2010.

Packaging and Handling of Strands And Wires

If the product is supplied in a coil form then these coils shall be formed in such a way that the material is held firmly by restraining bands or ties. In case of reopening the coils special caution shall be taken to contain the energy contained to avoid personal injuries. Incase the product is supplied in straight lengths then the material shall be held firmly by retaining ties and supported to avoid any degradation of straightness. Packaging for all products shall be selected to ensure no damage or collapse occurs during transportation. Agreements between producers and purchasers, at the time of order may be made to define particular conditions of packaging consistent with the likely conditions to be encountered by the products before application (i.e. core, packing paper, paperboard, protection by water soluble oil film etc.).

Transport and Storage

Prestressing steels in transport and storage shall be protected against damage and contamination, particularly from substances or liquids, which are likely to produce or facilitate corrosion.

Installation of Strands

Following Figures demonstrates the strand installation process in a bridge.

Conclusion

Prestressing is a combination of high strength steel with concrete. Prestressed Concrete is no longer a strange type of design. It is rather an extension and modification of the applications of reinforced concrete to include steels of higher strength. Strands and wires are the backbones in the prestressed concrete and the evolution of prestressed concrete is in directly related to the evolution and advancement of prestressed concrete.

Reference

- [standardsproposals.bsigroup.com/Home/getPDF/161](standardsproposals.bsigroup.com/Home/getPDF/161)
- [BS 5896:2010](BS 5896:2010)