Civil Engineering Construction I
(CBE5031)
Prestressed Concrete
1. **Principles of Prestressed Concrete**

- The well known properties of concrete are that it has high compressive strength and low tensile strength.
- Consider a beam of plain concrete carrying a load, the beam deflects slightly and then fails abruptly as the load increases.
- We can expect this happen at a relatively small load.
1. **Principles of Prestressed Concrete**

- In a reinforced concrete beam, reinforcement in the form of steel bars is placed in tensile zones to resist the induced tension.
- Since the tensile strength of steel reinforcement is much higher than the concrete, this enables the R.C. beam to resist a greater load than a plain concrete beam.
1. Principles of Prestressed Concrete

- Prestressing is a method for overcoming the concrete's natural weakness in tension.
- In a prestressed concrete beam, steel tendons (generally of very high tensile strength alloy steel) are stretched to introduce a pre-compressive force into the member.

- The prestressing force offsets the tensile stress and eliminates the tensile strain allowing the beam to resist further higher loading or to span longer distance.
1. Principles of Prestressed Concrete

(Source: R. Chudley)
1. Principles of Prestressed Concrete

(Source: R. Chudley)

Prestress Principle II

Further moment can be accommodated.
1. **Principles of Prestressed Concrete**

Prestressing also improves the properties of concrete in the different ways:

- Concrete is a brittle material because it has a low tensile strength.
  - By prestressing, concrete behaves as if it has a high elastic properties and has a higher resistance to dynamic loadings such as vibration and impact.

- Prestressing eliminates or reduces tensile stresses hence the concrete is less liable to crack.
  - Prestressed concrete is more durable and particularly suitable for structures in severe conditions, such as marine structures.
2. **Tendons for Prestressing**

- ‘Tendon’ is a stretched element used in a concrete member to impart prestress to the concrete.
- Tendons may consist of individual hard-drawn wires, bars or strands.

2.1 **Single Wire**

- Single wires have diameters ranging from 3 to 7 mm, and are in coils up to 500 m.
2.2 Strand

- Strands are made up of several small diameter wires, twisted around a straight central wire.
- The most commonly used strand is seven-wire strand and is available in sizes from 8 mm to 18 mm nominal diameter.
2.3 Compacted Strand

- To reduce the percentage of voids in the cross-section of normal strand, the strand can be drawn through a die which compresses it.
- for the same ‘nominal’ diameter, the amount of steel is higher, thus enabling a larger force to be exerted.
2.4 High-tensile alloy-steel bar

- High-tensile alloy-steel bars vary in diameter from 20 mm to 50 mm and can be smooth or ribbed.
- With the smooth bars, threads are rolled on at the ends which can be used for anchorage purposes or coupling together.
- The ribbed bars have rolled-on ribs for the entire length and these ribs act as threads for anchorage purposes.
### 2.4 High-tensile alloy-steel bar

<table>
<thead>
<tr>
<th>Type</th>
<th>Nominal diameter (mm)</th>
<th>Specified characteristic breaking load (kN)</th>
<th>Nominal tensile strength (N/mm²)</th>
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<tr>
<td>Wire</td>
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<td>60.4</td>
<td>1570</td>
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<tr>
<td>Strand</td>
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<tr>
<td>‘Standard’</td>
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<td>164</td>
<td>1770</td>
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<tr>
<td></td>
<td>15.2</td>
<td>232</td>
<td>1670</td>
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<tr>
<td>‘Super’</td>
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<td>1860</td>
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<td>15.7</td>
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<td>‘Drawn’</td>
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<td>1230</td>
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<td></td>
<td>32</td>
<td>990</td>
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</table>

(Source: A.H. Allen)
3. Pre-tensioning

- In pre-tensioning, the steel tendons are tensioned before concreting.
- The tendons are embedded and bonded to the concrete.
3.1 Equipment for Pre-tensioning

- The equipment used for pre-tensioning consists of abutments, barrels and wedges, and hydraulic prestressing jack.
- Abutments provide reaction points for the hydraulic prestressing jack to stress the tendons and anchorage points of the tendons.
- A barrel has a tapered hole into which two or three pieces of steel wedges are fitted.
- The wedges have serrated teeth to grip the tendon.
3.1 Equipment for Pre-tensioning

Typical pre-tensioning arrangement

Barrels and Wedges

(Source: R. Chudley)
3.2 Procedure of Pre-tensioning

1. Stressing (Tensioning)
   – The concrete mould with the reinforcement cage, if any, is placed between the abutments.
   – The tendons are threaded through the mould and anchored to one of the abutments with barrels and wedges.
   – At the opposite abutment, the tendons are stressed with a hydraulic jack to the predetermined tension and then securely anchored them on the abutment.

2. Concreting
   – Concrete is placed in the moulds and the tendons are embedded by the concrete.
3.2 Procedure of Pre-tensioning

3. Curing
   – The casting is then usually steam-cured for 24 hours to obtain the desired characteristic strength.

4. De-tensioning
   – When the concrete has achieved sufficient strength, the tendons are released from the abutments gradually;
   – the prestressing force is transferred to the concrete through the bond that now exists between the tendons and the concrete.
3.2 Procedure of Pre-tensioning

Prestressing Bed
3.3 Applications of Pre-tensioning

- Pre-tensioning is only used in precast concrete production.
- It is particularly suitable for the manufacture of a large number of identical units.
- Some examples are shown below:

3.3.1 Precast Beam and Slab

- The sections can be of rectangular, inverted T-shape, U-shape, box shape or double T-shape.
3.3.2 Precast Bridge Beam

Precast Building Beams

Precast Bridge Beam
(Source: Jufri & Wellman)
3.3.3 Railway slipper - Precast Prestressed Tubular Concrete Pile

- This type of pile is produced by using the steel mould to provide reaction for prestressing instead of abutments; e.g. Daido SS Pile and Nippon Hume SS Pile.

(Source: B.C. Gerwick)
4. Post-tensioning

- In post-tensioning the concrete is cast around ducts in which the steel tendons can be housed.
- Stressing is carried out after the concrete has hardened.

4.1 Materials and Equipment for Post-tensioning

4.1.1 Tendon Ducts
4.1.1 Tendon Ducts

- Tendon ducts can be made of corrugated steel or plastic.
- Plastic ducts offer better corrosion protection, and provide reduced duct friction.
- However, they are more expensive.
- Although the ducts can be made to very long length, normally they are supplied in standard lengths.
- Special care should be taken when joining ducts to ensure that no mortar can get into the duct during concreting.
4.1.1 Tendon Ducts

Anchor Casting

Tendon ducts
4.1.2 Anchorage

- Anchorages are units used in post-tensioning for the transfer of the prestressing forces to the concrete.
- They can be further subdivided into stressing anchorages and dead-end anchorages.
4.1.2 Anchorage

Stressing Anchorage

Dead-end Anchorage
4.1.2 Anchorage

- In most cases an stressing anchorage is installed at one end of the concrete member while at the opposite end a dead end anchorage is used.

- In very long structures especially with ducts with multiple curvatures stressing anchorages are installed at both ends of the concrete member.
4.1.2 Anchorage

Post-tensioning Arrangements
4.1.3 Grout Pipes and Vent Pipes

- As the cables are usually grouted when stressing has been completed, grout pipes or air vents have to be provided at suitable intervals.
4.2 Procedure of Post-tensioning
4.2.1 Placing tendons

- Tendons are housed in tendon ducts and the ducts are fixed in their predetermined alignment, level and profile. (Sometimes the tendons are threaded through the ducts after concreting.)
- The tendon ducts shall be securely tied to the reinforcement to prevent dislodgment during concreting.
4.2.2 Concreting

- Insitu concrete is cast. It is then cured as normal reinforced concrete

4.2.3 Stressing (Tensioning)

- Stressing can be carried out when the concrete has achieved sufficient strength. Stressing is performed by using a hydraulic jack.
4.2.3 Stressing (Tensioning)

• During stressing, the readings of load and extension are recorded.
  – When about one-half of the designed stressing load has been reached, a graph of load against extension is plotted.
  – An extension correction is obtained from the plot by extrapolation method.
4.2.3 Stressing (Tensioning)

- Stressing is continued until the designed load has been reached.
  
  - Check if the corrected extension matches with the theoretical value.
  
  - If it does, the tendon can be wedged to the anchorage.
  
  - Otherwise, remedial action shall be taken.
4.2.4 Grouting

- The ducts are grouted with cement grout through the grout holes/tubes to protect the tendons from corrosion.
4.5 Application of Post-tensioning

Post-tensioning has wide range of applications. It is particular suitable in the following situations:

• stressing is to be carried out on site,
• curved tendons are required, and
• jointing a series of precast concrete units.
4.5.1 Positioning in Buildings

**Post-tensioned Slab**

**Post-tensioned Raft Foundation**
4.5.2 Post-tensioning in Bridges

Segmental Launching Method

Source: B.C. Genwick
4.5.3 Ground anchor

Ground Anchor

(Source: R. Chudley)
4.5.3 Ground anchor
Reference:

- VSL Construction Systems, VSL
- Civil Engineering Construction IV Vol. 4, S.A.R Jufri & R.J. Wellman (1992), Hong Kong Polytechnic.