PRESTRESSED CONCRETE STRUCTURES

Pre-stressing is the application of an initial load on the structure so as to enable the structure to counteract the stresses arising during its service period

Applying tensioning technique in design can take care/enhance the following properties of concrete:

a) Compressive strength
b) Character of the Stress-strain relationship
c) Modulus of elasticity (E), the higher the value, the stiffer the material
d) Creep and shrinkage
e) Tensile strength

$$E \equiv \frac{\text{tensile stress}}{\text{extensional strain}} = \frac{\sigma}{\varepsilon} = \frac{F/A_0}{\Delta L/L_0} = \frac{FL_0}{A_0 \Delta L}$$

Compressive strength:

The compressive strength of concrete is given in terms of the characteristic Compressive strength of 150 mm size cubes tested at 28 days . The characteristic strength is defined as the strength of the concrete below which not more than 5% of the test results are expected to fall. This concept assumes a normal distribution of the strengths of the samples of concrete.

Points to recall about reinforced concrete:

- Concrete is strong in compression but weak in tension
- Steel is strong in tension (as well as compression)
- Reinforced concrete uses concrete to resist compression and to hold the steel bars in place, and uses steel to resist all of the tension
- Tensile strength of concrete is neglected (i.e. zero)
- RC beam *always* crack under service load

Defects in concrete:

Shrinkage

- associated with the loss of moisture from gel particles of the paste.

creep

- Time dependent increase in deformation due to sustained loading. This can occur in all types of loading- compression , tension and torsion . The earlier the age at which loading is applied larger the creep . Creep is higher in wet conditions than in dry conditions.

Steel:

Forms of Prestressing Steel

<u>Wires</u>
Prestressing wire is a single unit made of steel.

<u>Strands</u>
Two, three or seven wires are wound to form a prestressing strand.

Tendon

A group of strands or wires are wound to form a prestressing tendon.

Cable

A group of tendons form a prestressing cable.

Bars

A tendon can be made up of a single steel bar. The diameter of a bar is much larger than that of a wire.

- Reinforced concrete is concrete in which reinforcement bars , reinforcement grids, plates or fibers have been incorporated to strengthen the concrete in tension.
- The failure strain of concrete in tension is so low that the reinforcement has to hold the cracked sections together.
- For a strong, ductile and durable construction the reinforcement shall have the following properties.

➢ High strength, High tensile strain

➢ Good bond to the concrete

➢ Thermal compatibility

➢ Durability in the concrete environment

Common failures modes of steel reinforced concrete

- Reinforced concrete can fail due to inadequate strength, leading to mechanical failure.
- reduction in its durability
- Corrosion and freeze/thaw cycles may damage poorly designed or constructed reinforced concrete.

Prestressed concrete

Pre-stressed concrete is a technique that greatly increases the load-bearing strength of concrete (beam).

Pre-tensioned concrete:

Pre-tensioned concrete is cast around already tensioned tendons.

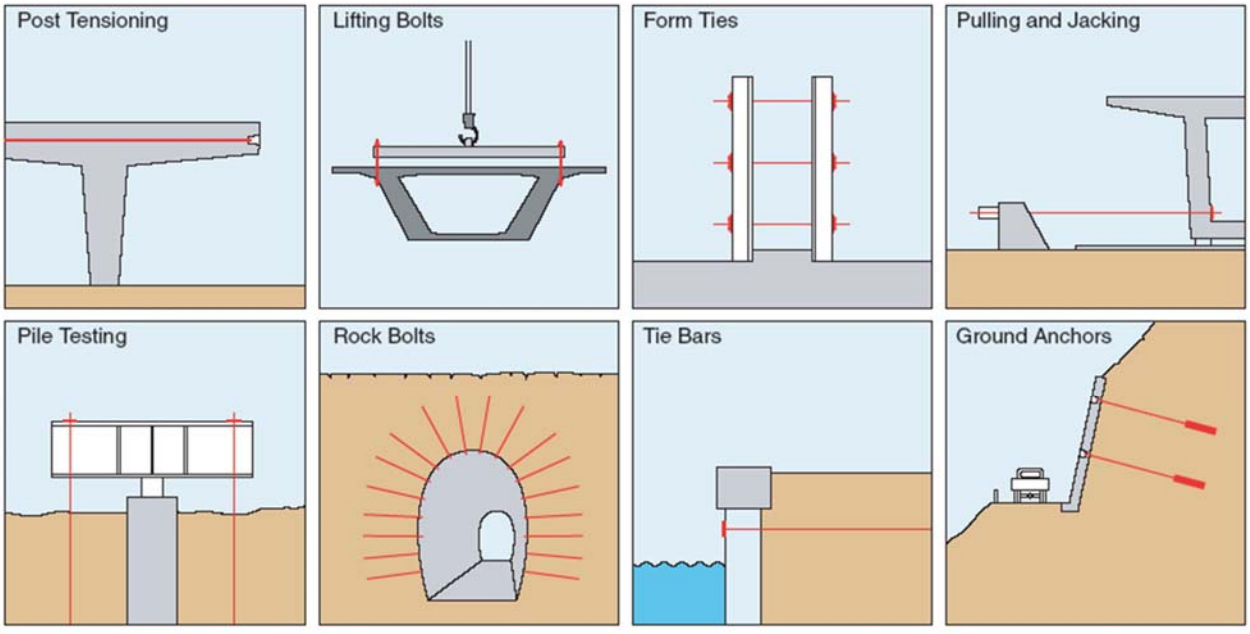
This method produces a good bond between the tendon and concrete, which both protects the tendon from corrosion and allows for direct transfer of tension.

- The cured concrete adheres and bonds to the bars and when the tension is released it is transferred to the concrete as compression by static friction.
- It requires anchoring points between which the tendon is to be stretched. The tendons are usually in a straight line. Sometimes it can run in curve to control the distribution of bending.
- Once the concrete has hardened, the tension on the reinforcing steel is released, placing a built-in compressive force on the concrete.
- When loads are applied, the reinforcing steel takes on more stress and the compressive force in the concrete is reduced.
- Since the concrete is always under compression, it is less subject to cracking and failure.

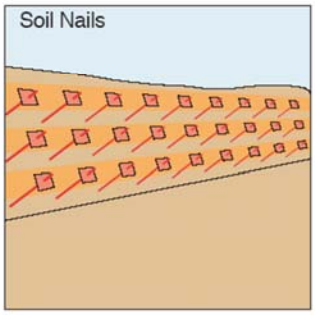
Advantages of PC over RC:

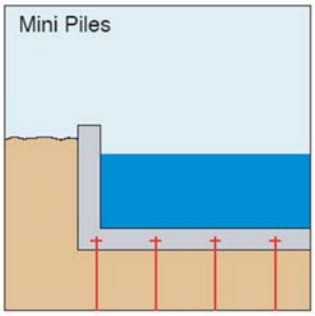
- Take full advantages of high strength concrete and high strength steel
- Need less materials
- Smaller and lighter structure
- No cracks
- Use the entire section to resist the load
- Better corrosion resistance
- Good for water tanks and nuclear plant
- Very effective for deflection control
- Better shear resistance

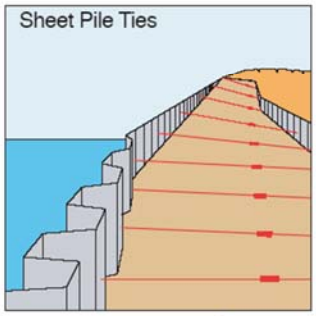
Applications of the concept of pre-stressing

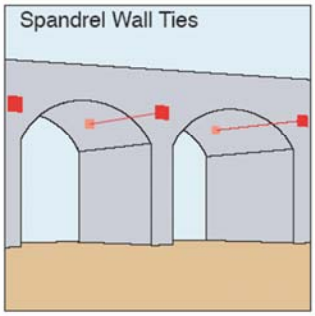


Applications





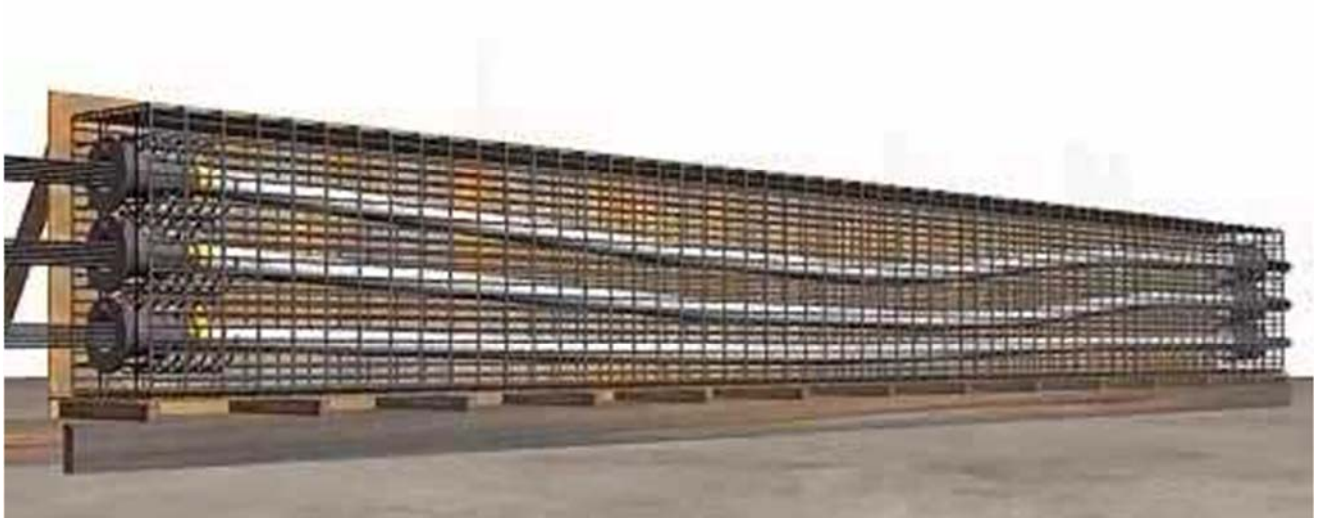




Other use in building works
- Tensioning to flat slab
- Tensioning to long-span beam
- Strengthening of rigidity in building structures

Principle of post-tensioned concrete slab

Floor slab using tensioning technique (usually for flat slab)



Use tensioning cable to tie down a pier head for a bridge.

The formwork for the precast beam

The tension cable and the hydraulic jack for applying the tension

Forming pre-stressing beam

Using tensioning technique to tie individual precast beams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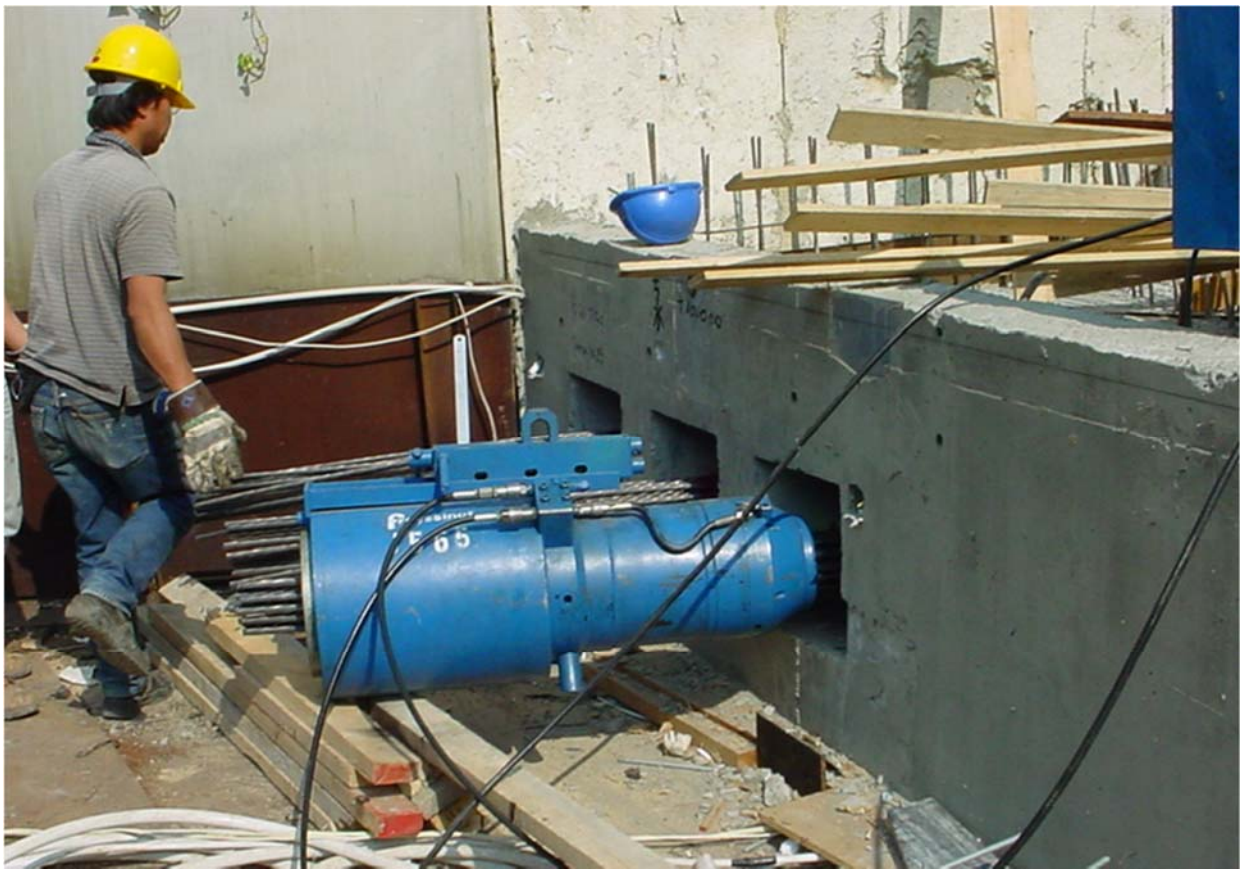

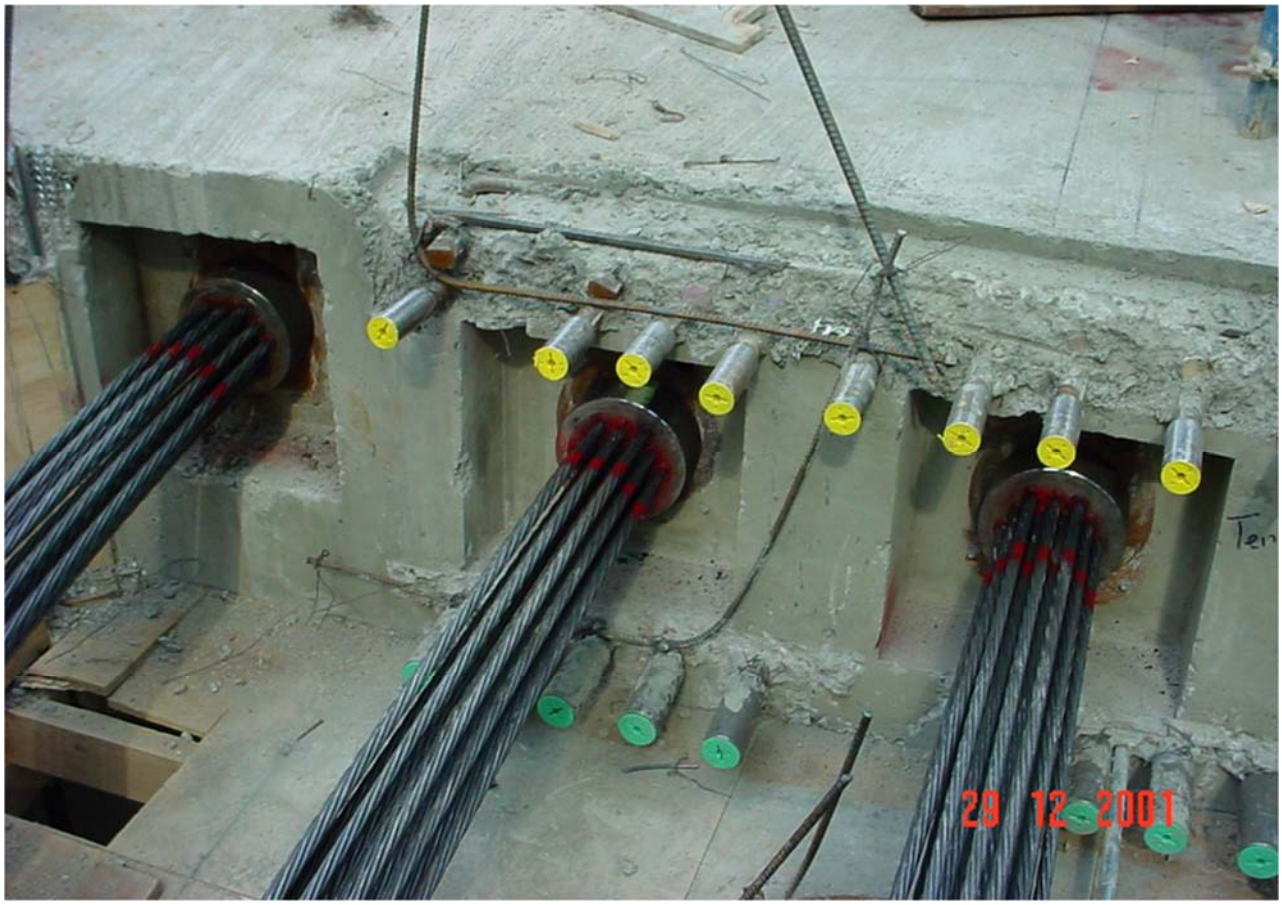
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Basic principle of tensioning technique and application

https://www.youtube.com/watch?v=YXBJuGztPSs

Record video showing the process of applying tensioning to a bridge deck

https://www.youtube.com/watch?v=STW2FCWhfPM

Record video showing the process of applying tensioning to floor slab

https://www.youtube.com/watch?v=ehQPLdSE_Gc

https://www.youtube.com/watch?v=EFBSV5y-fEg

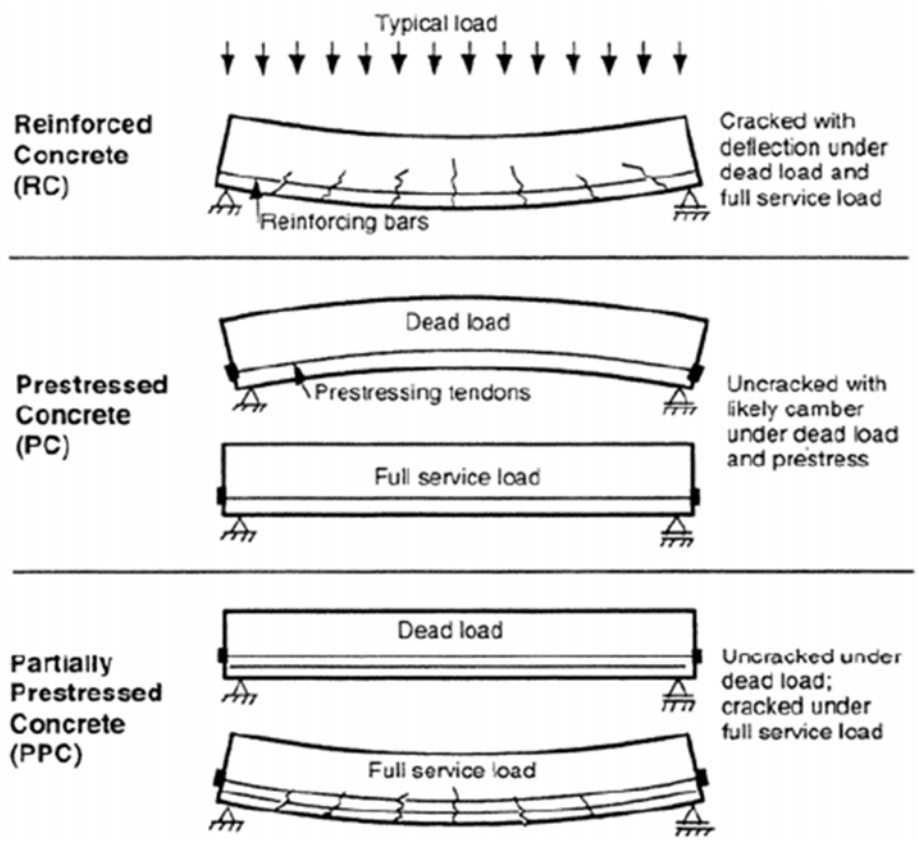
Record video showing the process of casting of pre-stressed concrete

https://www.youtube.com/watch?v=2QQsaPYssVU

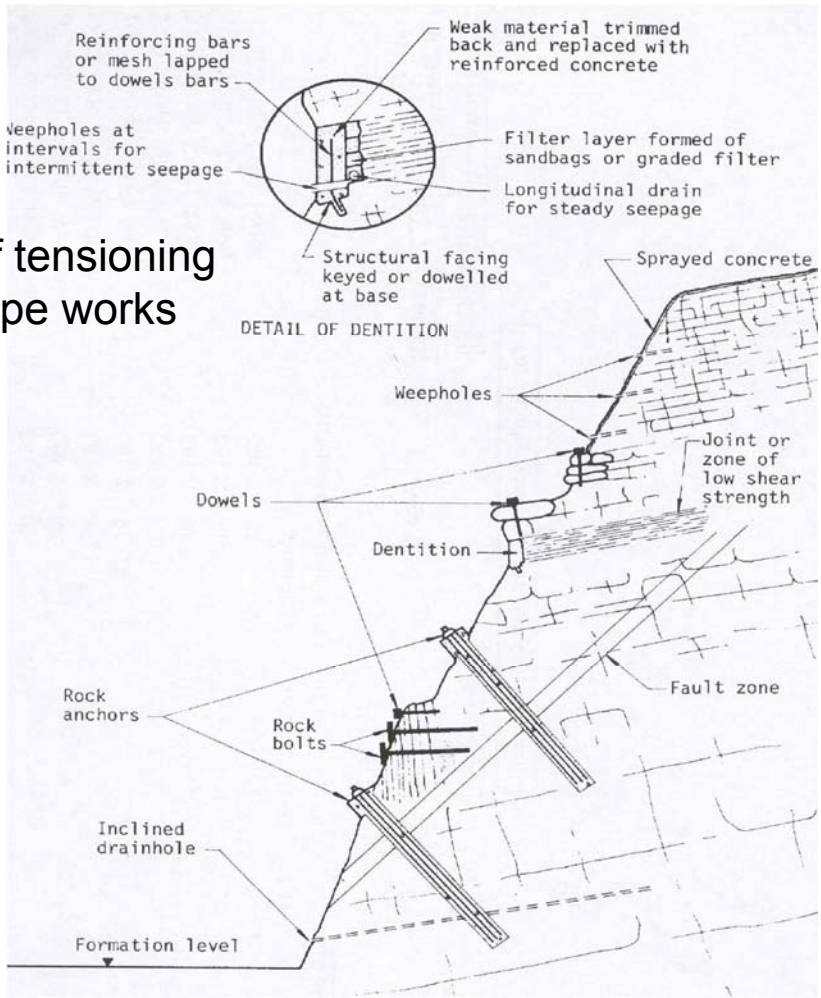
Temporary tying of precast segment for bridge

precast segment

RC vs. PPC vs. PC



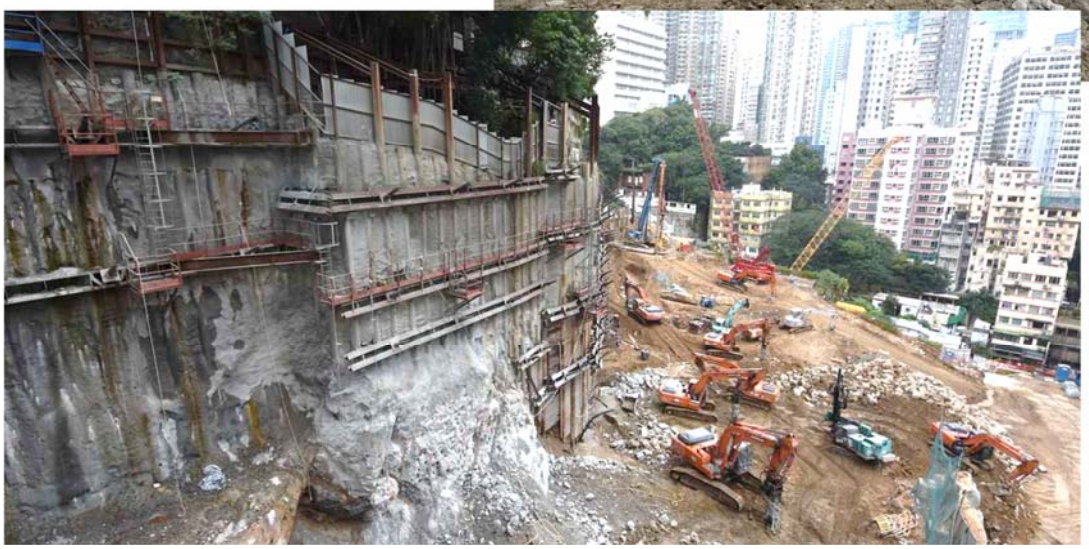
Concept of tensioning used in slope works



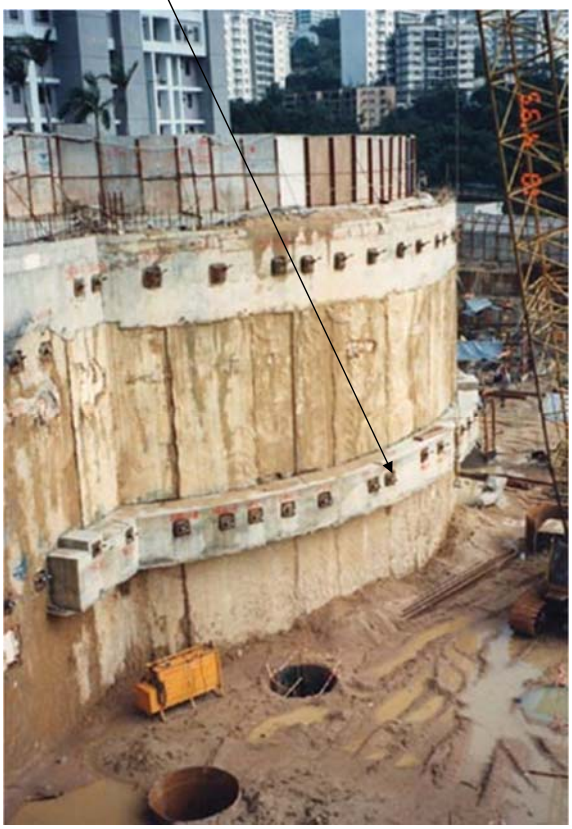



Forming soil nail and rock bolts

Rock anchor to stabilize a slope cutting



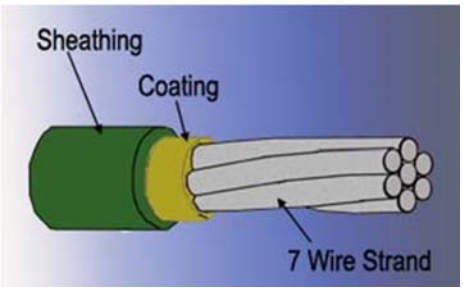
Diaphragm wall panel tie back using ground anchor



Materials and Hardwares for prestressing:

Prestressing tendons:

- Prestressing tendon may be in the form of stands , wires , round bar , or threaded rods

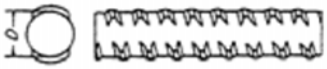


Prestressing steel

- Materials
  - ➢ High strength steel
  - ➢ Fiber-reinforced composite (glass or carbon fibers)

Common shapes of prestressing tendons.

Type	Size (Diameter)		Shape
	mm	in.	
Plain round wire	2.0 ~ 9.0	0.06 ~ 0.360	
Indented wire	5.0 ~ 7.0	0.200 ~ 0.276	
Sumi - Twist	7.3 ~ 13.0	0.276 ~ 0.512	
Two-wire strand	2.9 x 2	0.114 x 2	

Seven-wire strand	6.2 ~ 15.2	0.250 ~ 0.600	
Nineteen-wire strand	17.8 ~ 21.8	0.700 ~ 0.860	
Round bar	9.2 ~ 32.0	0.362 ~ 1.260	
Threaded bar (Dywidag)	23.0 ~ 32.0	0.906 ~ 1.260	

Advanages of Prestressing

- Prestressing minimises the effect of cracks in concrete elements by holding the concrete in compression.
- Prestressing allows reduced beam depths to be achieved for equivalent design strengths.
- Prestressed concrete is resilient and will recover from the effects of a greater degree of overload than any other structural material.
- If the member is subject to overload, cracks, which may develop, will close up on removal of the overload.
- Prestressing enables both entire structural elements and structures to be formed from a number of precast units, e.g. Segmented and Modular Construction.
- Lighter elements permit the use of longer spanning members with a high strength to weight characteristic.

The ability to control deflections in prestressed beams and slabs permits longer spans to be achieved.

Prestressing permits a more efficient usage of steel and enables the economic use of high tensile steels and high strength concrete.

Cost advantages of Prestressing

• Prestressed concrete can provide significant cost advantages over structural steel sections or ordinary reinforced concrete.

Limitations of Prestressing

• Prestressing needs skilled technology. Hence, it is not as common as reinforced concrete.
• The use of high strength materials is costly.
• There is additional cost in auxiliary equipments.
• There is need for quality control and inspection.