Materials for Prestressed Concrete
1. Concrete, Strength Requirement

- In practice, 28-day cylinder strength of 28 to 55 MPa are required for PC.
- Higher strength is necessary for PC for several reasons.
- First: Commercial anchorages for prestressing steel are always designed on the basis of high strength concrete. Weaker concrete either will require special anchorages or may fail under the application of pre-stress.
Second: High strength concrete offers high resistance in tension and shear, as well as bond and bearing.

Third: High strength concrete is less liable to the shrinkage cracks. If very good curing in a factory

Fourth: It also has a higher modulus of elasticity and smaller creep strain, resulting in smaller loss of prestress.
Concrete strength of 28 to 41 MPa can be obtained without excessive labor or cement.

It is a general practice to specify a lower strength of concrete at transfer than its 28 day strength. This is desirable in order to permit early transfer of pre-stress to the concrete.
2. Concrete, Strain characteristics

- In PC, the strains are produced as well as stresses. This is necessary to estimate the loss of prestress in steel.
- Such strains can be classified into 4 types: elastic strains, lateral strains, creep strains, and shrinkage strains.
Elastic strains – just, take a look

- **Review**
- The stress-strain curve for concrete is seldom a straight line even at normal levels of stresses (Fig.2.1). The lower portion of the instantaneous s-s curve, being relatively straight may be called elastic.
- It is then possible to obtain the values for the modulus of elasticity.
- The modulus varies with several factors: the strength, the age, the properties of aggregate and cement and the definition of modulus.
Elastic strains cont.

- Tangent, initial, or secant modulus.
- The modulus may vary with the speed of load application and type of specimen (a cylinder or a beam).
- Hence it is almost impossible to predict it with accuracy.
Elastic strain  Cont.

- As an average value for concrete at 28 days old, and compressive stress up to 40% strength, the secant modulus has been approximated by the following formula.
  - A. ACI code (2-1). \( Ec = w1.5 \times 0.043 \sqrt{f} \)
  - B. By Jansen
  - C. By Hognestad
  - D. JSCE. Given by a Table based on the strength

- The modulus in tension is same as in compression before cracking.
Lateral strains

- Lateral strains are computed by Poisson’s ratio. The loss of prestress is slightly decreased in biaxial prestressing.
- Poisson’s ratio varies from 0.15 to 0.22, averaging about 0.17.
Creep strains- just take a look

- Defined as its time-dependent deformation resulting from the presence of stress.
- A brief summary of an investigation carried out at the UC extending over 30 years.
- Creep continued over the entire period. Of the total creep in 20 years,
  - 18-35% (ave: 25) occurred in the first 2 weeks of loading,
  - 40-70% (ave. 55), within 3 months
  - 60-83% (ave 76), within 1 year (Fig.2-3)
Creep strains  Cont.

2. Creep increased with a higher W/C ratio and with a lower aggregate cement ratio, but was not directly proportional to the total water content.

3. Creep of concrete with type IV (low heat) shows greater.

4. Creep of concrete was greater for crushed sandstone.
Creep strains Esp. from 28 to 90 days at time of loading, from 2-8 MPa, 50%RH

1. Those loaded at 90 days had less creep than those at 28 days, by roughly 10%.

2.

3. The total amount of creep strain at the end of 20 years ranged from 1 to 5 (averaging 3 in Japanese definition 2).

4. The creep at 50% RH was about 1.4 times that in air at 70% RH and about 3 times that for storage in water.

5. Creep decreased as the size of specimen increased.
Shrinkage strain

- As distinguished from creep, shrinkage in concrete is its contraction due to drying and chemical changes dependent on time and moisture conditions, but not on stresses.

- It may ranges from 0.0000 to 0.0010 and beyond. Stored under very dry condition, 0.0010 can be expected.
Shrinkage Cont.

- Shrinkage of concrete is somewhat proportional to the amount of water.
- Hence, the water cement ratio and the cement paste should be kept to minimum.
- Thus aggregate of larger size, well graded for minimum void, will need a smaller amount of cement paste, and shrinkage will be smaller.
- Cement: shrinkage is small for cements high in C3S and low in the alkalis and the oxides of sodium and potassium.
The amount of shrinkage varies, depending on the individual conditions.

For the purpose of PC design, shrinkage strain would be 0.0002 to 0.0006.

The rate of shrinkage depends chiefly on the weather conditions—swelling during rainy seasons and shrinking during dry ones.
3. Concrete, special manufacturing techniques

- Most of the techniques for good concrete can be applied to PC.
- There is a few factors peculiar to PC.
  1. They must not decrease the high strength required.
  2. They must not appreciably increase the shrinkage and creep.
  3. They must not produce adverse effects, such as inducing corrosion in the wires.
Compacting

- Compacting the concrete by vibration is usually desirable and necessary.
- Usually, without using an excessive amount of mortar, a low water cement ratio and a low slump concrete must be chosen.
- There are only a few isolated applications in which concrete of high slump is employed.
Too early drying of concrete may result in shrinkage cracks before applying prestress.

**Only by the careful curing can the specified high strength can be attained.**

(As I explained, high strength concrete is easier to be cracked.)

Steam curing and also auto-clave curing is often resorted to in the pre-casting factory.
Early hardening

- To speed plant production or to hasten field construction.
- High-early strength cement or steam curing is commonly employed.

**Accelerators should be employed with caution. For example, calcium chloride will cause corrosion.**
Pre-cast segmental construction for prestressed bridges (cantilever)

- Breaking up a bridge superstructures into segments reduces the individual weight and facilitates casting and handling.
- They are used for longer spans, thus enabling them to compete with structural steel on these larger spans.
- The joints are very thin epoxy-filled space with the surfaces being match cast.
- Prestressing tendons are threaded through.
4. Lightweight aggregate concrete

- This content will be explained later.
5. Self-stressing cement

- Types of cements that expand chemically after setting and during hardening are known as expansive or self-stressing cement.
- If used, the steel is prestressed in tension, concrete is in compression, known as chemical or self-stressed concrete.
- When concrete made with expanding cement is unrestrained, the amount will be 3-5%, and the concrete will disintegrate by itself.
When restrained, the amount of expansion can be controlled but not so much.

- By applying restraint in one direction, the growth in the other two directions can be limited because of the crystalline nature of hardened paste. (maybe, not well understood)

- When high-strength steel is used to produce the prestress, say 1035 MPa and an Es of 186x103 MPa, an expansion of 1035/186x103 = 0.55% (5500 μ) will be required (very difficult to achieve).

- 普通は、ひび割れ制御
Because of the expansion in all three directions,

- It seems difficult to use the cement for complicated structures.
- Expanding cement has been successfully for many interesting projects. In Japan, sewage structures, crack control or even destroying concrete.
- While many problems are remained, esp. about long term stability.
Steels for prestressing

High strength steel.
The production of high-tensile steel is by alloying. Carbon is an economical element for alloying.
Beneficial results have been obtained by quenching from the rolling heat.
The most common method is by cold drawing.
The process of cold drawing tends to realign the crystals.
High strength steel for PC takes one of three forms: wires, strands or bars.