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 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.

Cont.

- 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.

Cont.

- 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). $E_c = w^{1.5} \times 0.043 \sqrt{f}$
- 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.
- 1.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.

Shrinkage Cont.

- 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.

Curing 12・9

- 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 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.

Cont.

- High strength steel for PC takes one of three forms: wires, strands or bars.