Concept of Prestressed Concrete

Refer to

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1.1 Development of PC

- Reinforced concrete combines concrete and steel bars by simply putting them together.
- PC combines high strength concrete with high strength steel in an active “manner”.
- This is achieved by tensioning the steel and holding it against the concrete, thus putting the concrete into compression.

Cont.

- Concrete is a brittle material with its tensile capacity now improved by being compressed.
- The basic principle of prestressing was applied to construction perhaps centuries ago when ropes or metal bands were wound around wooden staves to form barrels (Fig.1-2).
- Also lifting up 麻雀 (mahjong) 牌 tiles

Cont.

- The bands and the staves were both prestressed before they were subjected any service loads.
- Around 1890, some obtained patents.
- These first patented methods were not successful, because low tensile prestress then produced in the steel was soon lost as a result of the shrinkage and creep of concrete.

Why not succeeded (Fig.1-3)

- Consider an ordinary structural steel bar prestressed to a stress of 124MPa.
- If the modulus of elasticity of steel is approximately 200x10E3 MPa, the strain of the bar is
- Strain= 124/200,000=0.00062
- Since eventual shrinkage and creep often induce this strain, the initial unit lengthening of steel could be entirely lost.

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- In 1928, he started using high strength steel wires for prestressing.
- Such wires, with an ultimate strength as high as 1725MPa and a yield point over 1240MPa, are prestressed to about 1,000MPa, create a unit strain of (Fig.1-4)
- δ = 1,000/200,000 =0.005

Cont.

- Assuming a total loss of 0.0008 due to shrinkage and creep, a net strain of 0.005-0.0008=0.0042 would still be left, which is equivalent to a stress of 0.0042x200,000=840MPa.
- Though it did not actually come to fore until 1945.
- Perhaps the shortage of steel in Europe during the war had given it some impetus.

Cont.

- The basic concept of prestressing is not limited to structures in concrete. It has been applied to steel construction as well.

1-2 General principles PC

- One of the best definitions:
- PC: concrete in which there have been introduced internal stresses of such magnitude and distribution that the stress resulting from given external loadings are encountered to a desired degree. In RC members the prestress is commonly introduced by tensioning the steel reinforcement.

Three different concept

First concept

- Prestressing to transform concrete into an elastic material.
- From this concept, the criterion of no tensile stresses was born. It is generally believed that if there are no tensile stresses in the concrete, there can be no cracks, and the concrete is no longer a brittle material but becomes an elastic material.

Cont.

- From this standpoint concrete is visualized as being subject to two systems of forces: internal prestress and external load.

- In its simplest form, let us consider a simple rectangular beam prestressed by a tendon through its centroidal axis (Fig.1-13).

Stress distribution

- Due to prestress F: F/A
- Due to external moment : My/I
- f =F/A ± My/I
- I: moment of inertia of the section 断面2次モーメント

Due to an eccentric pre-stress 12/2 Fig.1-13

- The moment produced by the prestress is Fe
- $f = F/A \pm Fey/I \pm My/I$
- Try example 1-1 by yourself.

Second concept

- Prestressing for combination of high strength steel with concrete
- This concept is to consider PC as a combination of steel and concrete similar to RC.
- Two materials form a resisting couple against external moment.
- (So, after cracking this concept works.)

Cont.

- From this point , PC 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.
- (Fig.1-21) The following example illustrates a simple application.
- Note: if no crack, the tensile force of prestressed steel has no change. Not so much difference.
- After cracking, this concept can be used.

Third concept

- Prestressing to achieve load balancing
- This concept is not familiar in Japan.

1-3 Classification and types (Be classified in a number of ways)

- Externally or internally prestressed (almost internally)
- Linear or circular prestressing
- Pre-tensioning or post-tensioning
- End-anchored or Non-end-anchored

1.4 Stages of loading

- Initial stage : before pre-stressing, during pre-stressing– this is a critical test for the strength of PC tendons and for concrete, the pre-stressing operation impose a severe test on the bearing strength at the anchorages. : at transfer of pre-stress
- Intermediate stage: this is the stage during transportation and erection for pre-cast members.

- Final stage: sustained load, working load, cracking load, ultimate load
- Also, fatigue loadings or dynamic loads. Sometimes, ductility is required.