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Pre-Stressed Concrete over Reinforced Concrete

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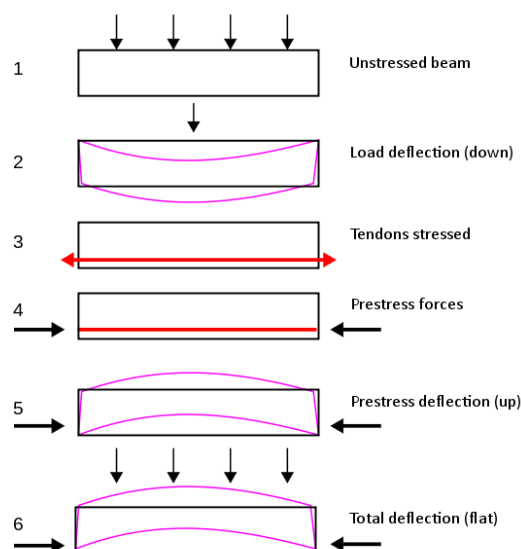
ABSTRACT: Most of the concrete construction in the world is cast-in-place reinforced concrete. In reinforced concrete structures, steel reinforcement is placed into the concrete to provide the tensile resistance to flexural loads or to assist the concrete in carrying compressive loads. Reinforced concrete must crack before the steel can significantly contribute to the strength and stiffness. This behavior led to develop prestressed concrete, which uses high-strength steel tendons that are stretched to apply a compensating compressive load to the concrete before to the application of the service loads. The prestressing force creates a compressive stress in the concrete to counteract the tensile stresses induced by the service loads. While this prestressing force does not result in an intrinsically higher member strength than reinforced concrete, it does delay cracking so that the service loads are carried primarily by uncracked concrete. This allows for the use of longer spans without increasing the member depth, or shallower members for the same span as can be designed with reinforced concrete.

KEYWORDS: Tendons, Solite, Dyform

I. INTRODUCTION

According to ACI Committee of Pre-stressed concrete, it is defined as “*Pre-stressed concrete is the one in which there have been introduced internal stresses of such magnitude and distribution that the stresses resulting from the external loading are counter balanced to a desired degree*”.

In Pre-stressed concrete, stresses are made to develop internally in a predetermined manner such that the stresses developed from the external loading gets balanced with these internal stresses of concrete. This whole process is achieved by tensioning the reinforced steel.



The principle of Prestressing of concrete is reflected by the fact that stresses are induced in a member of concrete in a proper and planned manner so that when the member is subjected to the external loading, the stresses due to the external load gets modified by the stresses induced by the prestressing of the member.

II. PRESTRESSED CONCRETE

Concrete being strong in compression, can take compressive stresses upto 50N/mm^2 or more (taking standard 150mm cubes), but when it comes to tension, it being very weak and it is very difficult to have concrete of tensile strength greater than 2.5N/mm^2 . This is the reason why the usual reinforced concrete is provided with steel bars in the tension zone to increase the tensile strength of concrete in the region. Taking the assumption of perfect bond between concrete and steel into the account, cracks get developed in concrete with the yielding of steel (undergoes strain). So, under these usual conditions of working loads, minute cracks are developed in concrete in the tension zone.

To reduce these defects in concrete, Prestressing of concrete plays an important role. A prestressed concrete member being a usual concrete member but tendons are to be provided to supply the necessary prestressing force. To overcome the disadvantages of reinforced concrete by Prestressed concrete at maximum, it is beneficial to use high strength concrete along with high tensile steel tendons.



III. NEED OF HIGH STRENGTH CONCRETE

The need of high strength concrete for prestressing is desired as:

1. High strength concrete being used in a member reduces the size of the concrete member thereby resulting in reduction of self-weight.
2. The presence of large prestressing force due to tendons results in the development of large bearing stresses in concrete at the ends by anchoring devices.
3. Bursting stresses developed at the ends cannot be effectively resisted by the concrete with low strength.
4. The transfer of shear from tendons to concrete takes place due to the bond between steel and concrete. So, high bond strength can be achieved by high strength concrete.
5. Shrinkage cracks are low when high strength concrete is used.
6. High strength concrete having high modulus of elasticity of concrete ($=5000\sqrt{f_{ck}}$). So, elastic and crack strains are low resulting in smaller loss of prestressing force.

IV. NEED OF HIGH TENSILE STEEL

High tensile steel is used in prestressed concrete because of the following reasons:

If the steel with low tensile strength is used, due to creep and shrinkage of concrete, the loss of prestress is large. Thus, the net tensile stress which is offering the required prestressing force will be very small.

Losses due to creep and shrinkage is in the range of 0.0008, i.e., 0.08%.

Therefore,

Strain lost = 0.0008

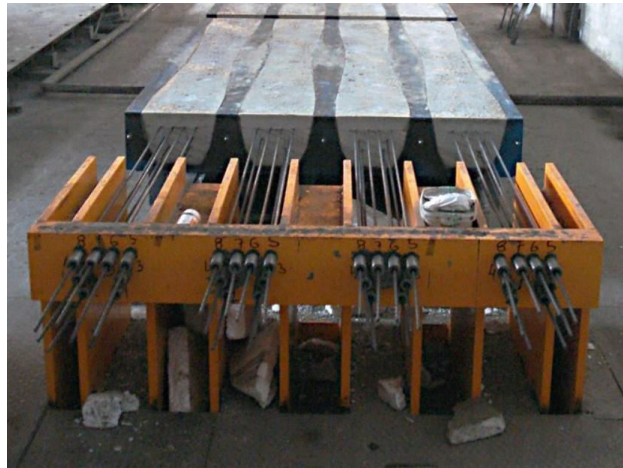
So,

Stress lost = $0.0008 \times 2 \times 10^5 = 160 \text{ N/mm}^2$

Total loss being in the range of about 200 to 300 N/mm^2 .

But losses ∇ 10 – 20%

So initial prestress in steel should be in the range of 1000 to 2000 N/mm^2 .



V. WHY PRE-STRESSED CONCRETE IS MORE ADVANTAGEOUS?

- [1] If a member is fully Pre-stressed, being free from tensile stresses under working loads, the cross-section is utilized more efficiently as compared to reinforced concrete which gets cracked.
- [2] Pre-stressed concrete offers improved resistance against shear forces due to the compressive pre-stressing force. The use of curved tendons especially in longer span members helps to decrease the shearing forces at the supports.
- [3] For the depth being the same in concrete member, a Pre-stressed concrete member is stiffer than RCC member under working loads.
- [4] In longer span structures, pre-stressed concrete is more economical than the RCC.
- [5] The permanent dead load can be nullified by increasing the eccentricity of the pre-stressing tendon.
- [6] If the cracks get appeared (pre-stress is lost) in a pre-stressed member, then the member behaves similar to RCC member.

VI. EXPERIMENTAL DATA

The aim of this testing programme was to study the flexural behaviour and to establish the serviceability characteristics of reinforced and prestressed concrete beams made of Solite lightweight aggregate. Altogether 13 beams were tested and their details are given below.

a. DETAILS OF REINFORCED BEAMS

Five reinforced beams were tested. Three beams were of all Solite concrete (mix S1) having steel ratios of 1.14, 2.03 and 3.16%. The other two beams having a steel ratio of 3.16% were made from Solite with sand concrete (mix S2) and normal gravel concrete respectively. All the beams had the same width and effective depth and adequately reinforced for shear. The details of these beams are shown in Table 1.



b. DETAILS OF PRESTRESSED BEAMS

Eight prestressed beams were tested—four at 28 days and one at three months (series P). The other three beams (PS1, PS2 and PS3 of series PS) were tested after they had been subjected to a sustained design load corresponding to an extreme fibre concrete compressive stress of 26.0 N/mm^2 for four days, and then left unloaded for one year exposed to the outside environment covered with polythene sheet. These latter beams were exploratory tests, tested particularly to study their ultimate load and deflection characteristics under permissible concrete compressive stresses of 26.0 N/mm^2 . All the

beams were prestressed such that the stress at the top fibre was zero. Beams P1, P2 and P4 were identical—P1 and P4 being from all Solite concrete, and beam P2 from Solite with sand concrete. These beams were stressed with wires with a concrete stress at transfer of 17.3 N/mm^2 . Beam P3 made from all Solite concrete was also stressed with wires but with a concrete stress at transfer of 26.0 N/mm^2 . All the other four beams were prestressed with Dyform strands. Beam PS had a stress at transfer of 17.3 N/mm^2 while the three beams of the PS series, retested after sustained loading, had a stress at transfer of 26.0 N/mm^2 . Details of these beams are shown in Table 1.

Table 1. Details of Solite concrete reinforced and prestressed beams

Beam No.	Mix* type	Cube strength (N/mm ²)	Cylinder strength (N/mm ²)	Flexural strength (N/mm ²)	Y-modulus E (kn/mm ²)	B × d (mm)	Reinforcement No. and size (mm)	Yield stress† (N/mm ²)	Area of steel As (mm ²)	Steel ratio As/bd (%)	Prestress‡ at bottom fibre (N/mm ²)
Reinforced beams											
R3	S1	44.4	36.3	2.5	17.40	127 × 156	2-12	410	226.3	1.14	—
R2	S1	42.5	36.0	2.9	17.60	127 × 156	2-16	410	402.3	2.03	—
R1	S1	44.5	37.6	2.9	16.80	127 × 156	2-16 } 2-12 } 2-16 }	410	628.6	3.16	—
RS1	S2	51.0	44.0	2.9	17.93	127 × 156	2-16 } 2-12 } 2-16 }	410	628.6	3.16	—
O1	O.C.	59.6	—	—	35.36	127 × 156	2-16 } 2-12 }	410	628.6	3.16	—
Prestressed beams											
P1	S1	42.5	36.0	2.9	17.61	127 × 135	5-7	1730	192.5	1.122	17.3
P2	S2	48.5	41.2	3.0	19.50	127 × 135	5-7	1730	192.5	1.122	17.3
P4§	S1	51.2	39.5	2.9	17.00	127 × 135	5-7	1730	192.5	1.122	17.3
P3	S1	50.9	40.4	2.9	16.50	127 × 135	8-7	1730	308.0	1.795	26.0
PS	S1	48.3	40.5	2.8	18.06	152 × 135	2-12.7	1960	224	1.09	17.3
PS1	S1	47.0	—	—	—	127 × 135	2-12.7	1960	224	1.308	26.0
PS2	S1	48.0	—	—	—	127 × 135	2-12.7	1960	224	1.308	26.0
PS3	S2	54.5	—	—	—	127 × 135	2-12.7	1960	224	1.308	26.0

*S1 = All Solite mix.

S2 = Solite with sand mix.

O.C. = Ordinary concrete.

†Ultimate tensile strength for prestressed steel.

‡Zero stress at Top Fibre.

§Tested at 3 months.

||Tested at one year.

All other beams tested at 28 days.

VII. CONCLUSION

Hence, pre-stressing can reduce the volume of concrete as the members are significantly thinner than the RCC members, therefore lowering the use and transportation of materials. There is also a definite saving in Stirrups, since shear in post-tensioned concrete is reduced in the inclination of the tendons. Also the pre-stressed members have better quality control and promote rapid construction.



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