

Methodology & Materials for Prestressed Concrete

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Abstract— The working of any structure made up of concrete or steel depends upon its strength. Therefore to enhance the strength of the structure reinforced concrete or prestressed steel is often used. Prestressed concrete offers the great technical advantages in comparison to other forms of construction. As they possess resistance to shear reinforcement, the use of prestressed concrete as well as high strength steel has revolutionized the entire building industry globally. The different type of materials used for prestressed concrete is concrete with high compressive strength and high tensile strength. The permissible stresses in concrete vary with materials used and the strength required. Also, it is important to work out the shrinkage of concrete over a period of time which is due to gradual loss of moisture resulting into change in volume. Also the progressive inelastic strain due to creep in a concrete structure are likely to occur under the smallest sustained stresses at ambient temperature. Therefore simulation of creep of concrete is important to determine the life span of the structure. The prevalent temperature, ambient wetness, pressure of the underground water flow should also be given due consideration. The economy of prestressed concrete structure will determine its applications and uses, the ideal being that if easily available raw material at affordable price is used in mixture to yield the highest strength of prestressed concrete; the prestressed concrete is ideally suitable for long span bridge construction. This needs several experimentation to utilize available materials from nearby vicinities as far as possible to form concrete.

Index Terms— Ambient stress, creep of concrete, prestress concrete, simulation.

I. INTRODUCTION

Prestressed concrete is construction material in which external pre-stressing force is applied on the concrete to reduce the tensile stresses which results in the prevention of cracking. It also makes the prestressed concrete section stiffer than reinforced concrete section. The downward moment of prestressed section is eliminated due to upward force which is imposed on the concrete in curved tendons. Prestressed concrete structures have become extremely useful in the construction of leakage free structures. It is also being used for many years for structures under gravitational loading. The applications of the material like high strength concrete and high strength steel are increasing rapidly, encouraged as the suitability of prestressed concrete to modern prefabricated construction. One of the major problems with prestressed

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concrete structures is that the prestress forces will decrease with time due to long-term effects in both the concrete and the prestressing steel. All the review traces the approach of the use of methods and materials to the design and construction of bridges, beam, slab, earthquake resistance structures etc.

II. PRESTRESSED CONCRETE MATERIALS

In the prestressed concrete structures, high strength concrete and high strength steel are used to improve the load bearing capacity and crack control.

A. Constituents of Concrete

The sand obtained from river beds or quarries is used as fine aggregate. The fine aggregate all along with the hydrated cement paste fill the space amid the coarse aggregate. The important properties of aggregate are as follows. [2]

- 1) Shape and texture
- 2) Size gradation
- 3) Moisture content
- 4) Specific gravity
- 5) Unit weight
- 6) Durability and absence of deadly materials.

The nominal maximum coarse aggregate size is restricted by the lowest of the following quantities.

- 1/4 times the least thickness of the member
- Spacing between the tendons/strands less 5 mm
- 40 mm.

B. Cement

In present day concrete, cement is a mixture of lime stone and clay heated in a kiln at 1400 to 1600°C. The types of cement permitted by **IS: 1343 - 1980 (Clause 4.1)** for prestressed applications are the following. The information is revise as per **IS: 456 - 2000**, Plain and Reinforced – Concrete Code of Practice.

- a) Ordinary Portland cement confirming to **IS: 269 - 1989**, Ordinary Portland Cement, 33 Grade – Specification.
- b) Portland slag cement confirming to **IS: 455 - 1989**, Portland Slag Cement – Specification, but with not more than 50% slag content.
- c) Rapid-hardening Portland cement confirming to **IS: 8041 - 1990**, Rapid Hardening Portland Cement – Specification.

C. Water

The water should satisfy the necessities of **Section 5.4** of **IS: 456 - 2000**. “Water use for mixing and curing shall be clean and free from injurious amounts of oils, salts, acids, alkalis, sugar, organic materials or other substances that may be venomous to concrete and steel”.

D. Admixtures

The admixtures can be broadly divided into two types: chemical admixtures and mineral admixtures. The general chemical admixtures are as follows.

- 1) Air-entraining admixtures
- 2) Water reducing admixtures
- 3) Set retarding admixtures
- 4) Set accelerating admixtures
- 5) Water reducing and set retard admixtures
- 6) Water reducing and set accelerate admixtures.

The common mineral admixtures are as follow.

- a) Fly ash
- b) Ground granulated blast-furnace slag
- c) Silica fumes
- d) Rice husk ash
- e) Metakoline

E. Prestressing Steel

1) Forms of Prestressing Steel

The development of prestressed concrete was influenced by the invention of high strength steel. It is an alloy of iron, carbon(1.5%), manganese, silicon(.3-.4%), and optional materials. The following material describes the types and properties of prestressing steel:-

a) Wires

A prestressing wire is a single unit ready of steel. The nominal diameters of the wires are 2.5, 3.0, 4.0, 5.0, 7.0 and 8.0 mm.

b) Strands

A few wires are spun together in a helical form to form a prestressing strand. The central wire is larger than the other wires.

c) Tendons

A group of strands or wires are placed together to form a prestressing tendon. The tendons are using in post-tensioned members.

d) Cables

A group of tendons form a prestressing cable. The cables are using in bridges.

e) Bars

A tendon can be made up of a single steel bar. The diameter of a bar is much more than that of a wire. Bars are accessible in the following sizes: 10, 12, 16, 20, 22, 25, 28 and 32 mm

2) Types of Prestressing Steel

The steel is treated to achieve the desired properties. The following are the healing processes.

a. Cold working (cold drawing)

The cold working is done by rolling the bars through a cycle of dyes. It re-aligns the crystals and increases the strength.

b. Stress relieving

The stress relieving is done by heating the strand to on 350° C and cooling bit by bit. This reduces the plastic deformation of the steel after the onset of yielding.

c. Strain tempering for low relaxation

This process is done by heating the strand to on 350° C while it is under tension. This also improves the stress-strain behaviour of the steel by dipping the plastic deformation following the onset of yielding. In addition, the relaxation is reduced.

3) Properties of Prestressing Steel

The steel in prestressed applications has to be of good quality. It requires the following attributes.

- High strength

- Adequate ductility
- Bendability, which is required at the harping points and near the anchorage
- High bond, required for pre-tensioned members
- Low relaxation to reduce losses
- Minimum corrosion.

III. PRESTRESS LOSSES

i. Introduction

The major disadvantage with the prestressing systems is that the tendon forces will decrease with time due to various long term mechanisms in both the concrete and the tendons. The long term prestress losses are due to contraction of the concrete, i.e. creep and shrinkage, and relaxation of the steel tendons. In addition, initial losses occur during the post tensioning process, these are the elastic shortening of the concrete, friction between tendon and duct and slip in the anchor head.

ii. Initial losses

1) Elastic shortening

The initial elastic shortening is the elastic response of the concrete during the post-tensioning process. Since the deformation is elastic it depends on the modulus of elasticity of the concrete and the contraction of the concrete. The contribution from the elastic shortening to the total prestress losses for a single tendon can be estimated according to equation 3.1.

$$\varepsilon = \frac{(N - n) \cdot \sigma}{(N - 1) \cdot E}$$

Where

ε = strain due to elastic shortening

σ = concrete stress, MPa

E = modulus of elasticity of concrete, GPa

N = number of tendons

n = the order in which the tendon was tensioned (for the initially tensioned tendon)

n is equal to 1

2) Friction

The friction generated at the interface of concrete and steel during the stretching of a warped tendon in a post-tensioned member, leads to a drop in the prestress along the member from the stretch end. The loss due to friction does not occur in pre-tensioned members because there is no concrete during the stretching of the tendons. The friction generate due to the twist of the tendon and the vertical component of the prestressing force. In addition to friction, the stretching has to overcome the **wobble** of the tendon. The wobble implies to the change in position of the tendon along the duct. The losses due to friction and wobble are grouped together under friction.

3) Anchorage Slip

In a post-tensioned member, when the prestress is transfer to the concrete, the wedges slip through a small distance before they get properly seated in the conical space. The anchorage block also moves before it settles on the concrete. There is loss of prestress due to the consequent reduction in the length of the tendon

iii. Long term losses

1. Creep of Concrete

Creep of concrete is defined as the increase in deformation with time under constant load. Due to the creep of concrete, the prestress in the tendon is reduced with time. The ratio of the ultimate creep strain to the elastic strain is defined as the ultimate creep coefficient or simply creep coefficient (θ). The following considerations are applicable for calculating the loss of prestress due to creep:-

- The creep is due to the sustained (permanently applied) loads only. Temporary loads are not considered in the calculation of creep.
- Since the prestress may vary along the length of the member, an average value of the prestress can be considered.
- The prestress changes due to creep and the creep is related to the instantaneous prestress. To consider this interaction, the calculation of creep can be iterated over small time steps.

2. Shrinkage of Concrete

Shrinkage of concrete is defined as the contraction due to loss of moisture. Due to the shrinkage of concrete, the prestress in the tendon is reduced with time.

3. Relaxation of Steel

Relaxation of steel is defined as the decrease in stress with time under constant strain. Due to the relaxation of steel, the prestress in the tendon is reduced with time. The relaxation depends on the type of steel, initial prestress (f_{pi}) and the temperature.

IV. CONCLUSION

From the above study it can be concluded that by changing the constituent of carbon in steel, results increase in strength of steel, which can be utilized to increase the load bearing capacity of the and reduces the self weight of the concrete structure. It nearly doubles the life span of structure and gives indication before collapse of the structure.

REFERENCES

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