Design of Pre-Stressed R.C.C. Electric Pole

Deepkumar G. Patel[1], Karm R. Patel[2], Vinit P. Oza[3], Jimmy A. Patel[4]

[1-4] Graduate Student, Dept. of Civil Engineering, Gujarat Power Engineering & Research Institute, Gujarat, India

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Abstract - *Prestressing of concrete is defined as the application of compressive stresses to concrete members. Prestressed concrete works on the idea that compressive stresses produced in a concrete member by high-strength steel tendons before loads are applied balance the tensile stresses produced in the member during service. Prestressed can be applied in two ways – Pre-tensioning and Post-tensioning. We visited a casting unit of prestressed electric pole then analysis of prestressed and understand concept of prestressed electric pole. We have provided design for some shapes and size of electric pole then we have compared present and future electric pole. The objective of this project is to analysis provide suitable shape, size and economical design of electric pole and also provide easy installation procedure.*

Key Words: Pre-Stressed concrete, Pre-Tensioning, Post-Tensioning, Electric Pole, Casting

1. INTRODUCTION

Early cracks in reinforced concrete caused by incompatibility in the strains of steel and concrete could have been the catalyst for the formation of a new material known as "Prestressed concrete". Based on the exhaustive studies of properties of concrete and steel, Freyssinet demonstrated, in 1928 the advantages of using high strength steel and concrete to account for the various losses of prestress due to creep and shrinkage of concrete.

1.1 Need for Prestressing Concrete

Concrete has a poor tensile strength and a great compressive strength. This is a concrete weakness that causes early flexural cracks in flexural components such as beams and slabs. Compressive stress is induced in the concrete to prevent this. Prestressing is a stress that counteracts the tensile stress that the structure is subjected to while in service. Hence the chances of flexural cracks are reduced.

1.2 History of Electric Pole

For many years throughout the world, Poles made of wood, steel and concrete have been used to support power transmission, telephone and telegraph lines, street lighting, overhead power lines for rail-roads and other many purpose used pole. The application of permanent compressive stress to a material like concrete, which is strong in compression but weak in tension, increases the tensile strength of that material. In 1904, French engineer Freyssinet attempted to introduce permanently acting forces in concrete to resist the elastic forces developed under loads and this idea was later developed under the name of "Prestressing". The current status of prestressed concrete development is the result of ongoing study by engineers and scientists in the area over the last 90 years.

1.3 Pre Tensioning

The application of a tensile force to high tensile steel tendons around which the concrete is to be cast is known as pre-tensioning. When the poured concrete has gained sufficient compressive strength, it is given a compressive force by releasing the tendons, resulting in the concrete member remaining prestressed permanently.

1.4 Post Tensioning

Post-tensioning is the process of applying a compressive force to concrete after it has been cast. Prestressing is achieved by tensioning steel tendons passed via ducts cast into the concrete and clamping the stressed tendons with mechanical anchors once the concrete has developed strength. The tendons are usually grouted in place after that.

1.5 Advantages of Prestressing

1. Prestressing reduces the chance of cracks in concrete components by compressing the concrete.
2. Prestressing allows for lesser beam depths while maintaining the same design strength.
3. Prestressed concrete is more durable than any other structural material, recovering from the effects of a greater degree of loading.

4. The ability to control deflections in prestressed beams and slabs permits longer spans to be achieved.
5. Prestressing allows for more efficient steel utilization as well as the cost-effective use of high-tensile steels and high-strength concrete.

2. METHODOLOGY

Three methods are generally used to manufacturing of prestressed concrete pole and they are…

2.1 Centrifugal Casting Method

Centrifugal casting, commonly known as spin casting, is a process of producing hollow and tapered prestressed concrete poles. This approach involves partially filling steel Moulds with concrete and placing them in a spinning machine. The centrifugal force provided by the spinning machine, which will rotate for many minutes, consolidates the concrete in the Moulds. The concrete squeezes out water as it spins, and the surplus water is emptied out of the hollow hole made in the pole's core. Finally, the form is steam-cured for a period of time until the concrete strength reaches 3500 psi (Pound per square inch). The prestressed wire is then released and allowed to cure for 28 days in the open air. Finally, we have a hollow prestressed concrete pole.

Fig-1: Centrifugal Casting Method

2.2 Long Line Method

The most frequent way for producing solid prestressed concrete poles is the long line method. In this method, molding forms are positioned end to end on casting bed. These forms are placed up to a length of 400 feet. The molding forms contains bulkheads at its ends and holes are provided to these bulkheads using which Prestressing wires are threaded. At each end of the line of forms, these wires are pretensioned against abutments. For several poles, this pretensioning is done once. Molding shapes are now filled with concrete that has been vibrated from the outside. Many other forms of solid poles, such as square, rectangular, I-shaped, Y-shaped, and so on, may be made using this approach. Any precast site or yard can use this method.

Fig-2: Long Line Method

2.3 Mensel's Method

Mensel's method of prestressed poles making is more mechanized process. In this, poles are made on a production line which consists of horizontal light weight molds. In the production process, these Moulds will be moved from one station to the next. To produce hollow concrete poles, concrete is poured into these moulds and a block out is supplied in the center of the mould when pouring concrete. Vibration consolidates the concrete in the moulds. After the concrete starts to firm, the central block is turned and removed when it is entirely solid. These poles are heated to a temperature of 73ºC for 24 hours and cooled down to room temperature.

Fig-3: Mensel's Method

3 ADVANTAGES OF PRESTRESSING POLE

1. Less in weight and easy to handle.
2. It is quicker and more convenient to install prestressed concrete poles in drilled holes.
3. They are less porous and provide high corrosion resistance for Prestressing wire, especially in hot climates.
4. In arid areas, it is very resistant to erosion.
5. Good fire resistance which is useful when bush fires or grass fires occur near the ground line.
6. Good resistance against freezing and thawing occurred in colder regions.

4. DESIGN OF PSC CIRCULAR SPUN POLE OF 8 METER LONG

4.1 Data

Working Load	200 kg
Factor of Safety	2.5
Ultimate Load	500 kg
Planting Depth	1.5 meter (as per is:1678-1998,pg:2,cl:6.3,t-1)
Point of Application of Load	600 mm below top of pole
Tapper (Max)	1 in 72
Cube Crushing Strength of Concrete at 28 Days	48 MPA
Allowable Max Compressive Strength in Concrete at Working Load	20 MPA
Ultimate Tensile Strength of Tensile Steel	1860 N/ mm^2
Initial Tension in Steel	1302 N/ mm^2

4.2 Calculation for Wind Pressure as per IS: 875 Part-3

→ Basic wind speed (vb) (IS 875, Part 3, Page 53, Appendix A)

vb = 39 m/sec (for Ahmedabad)

→ Design wind speed (vz) (IS 875, Part 3, Page 8, cl. 5.2)

$k1$ (Risk coefficient)	1.0
$k2$ (Terrain category)	1.03
$k3$ (Topography factor)	1.0

$$vz = vb \times k1 \times k2 \times k3$$

$$= 39 \times 1 \times 1.03 \times 1$$

$$= 40.17 \text{ m/sec}$$

→ Design wind pressure (pz) (IS 875, Part 3, Page 12, cl. 5.3.3.1)

$$pz = 0.6 \times vz2$$

$$= 0.6 \times 40.17^2$$

$$= 968.17 \text{ N/m}^2$$

→ Wind force (F) (IS 875, Part 36, Page 8, cl.6.3)

cf (force coefficient of building)	0.933(IS 875, Part 3, pg.40, T-23)
Ae (Effective frontal Area)	3 [(a+b) (h/2)]
Pd (Design wind pressure)	968.17

$$F = cf \times Ae \times Pd$$

$$= 0.933 \times 3 \times 968.17$$

$$= 2701.19 \text{ N}$$

$$= 2.7 \text{ KN}$$

→ Critical B.M. will be at a section 2.73m above ground level are the equivalent working load would be acting at 600mm from top.

Equivalent working load 600mm below top	2 kN
B.M. for which pole to be designed	2 × 5.9 = 11.8 KN.m

→ Assumption

1. The effect of shear, which in beam structure transferred by the web, is here obtain by the local B.M. introduce by cross diaphragm connecting the two principal member.
2. The strength of the pole in the direction of line shall not be less than one quarter of the required strength in the direction transverse to the line.
3. Cover 30mm (I S: 1678-1998, c.l.7.5, pg. – 3)

4.3 Stress in Direction of Line

$$I_{XX} = I_{YY} = \frac{\pi}{64}(D^4 - d^4)$$

$$= \frac{\pi}{64}(295^4 - 154^4) = 3.44 \times 10^8 mm^4$$

$Z_{ex} = Z_{ey} = \frac{Ixx}{4}$

$= \frac{3.44 \times 10^8 mm^4}{4000} = 8.6 \times 10^4 mm^3$

Axial pull or push in leg = $\frac{B.M.}{Dia.\ at\ G.L.}$

$= \frac{11.8}{0.295} = 40$ KN

Horizontal component = $\frac{40}{72}$

= 0.55 KN = 555 N

Effective shear force at mid span of each pole =

$\frac{1}{2}$ external pole – H.L.

$= \frac{2000}{2} - 555 = 445$ N

If the tapper were increased so way that the center line of the leg meet at the top, the local B.M., both in the leg end in the diaphragm disappear together.

(Assume d = 0.9m)

Local B.M. at joint with diaphragm = $\frac{1}{2} \times SL \times d$

$= \frac{1}{2} \times 445 \times 0.9$

= 200.25 N.m

= 200250 N.mm

Where, Section area= $\frac{\pi}{4} \times (D^2 - d^2) = \frac{\pi}{4} \times (295^2 - 154^2)$

f_a = axial stress in pole

$= \frac{\text{Axial pull or push in leg}}{\text{Section area}}$

$= \frac{40000}{49723}$

$= 0.8\ N/mm^2$

f_s = Secondary stress in leg

$= \frac{\text{Local B.M.}}{Z_{ex}}$

$= \frac{200250}{8.6 \times 10^4}$

$= 2.32\ N/mm^2$

Total external stresses = $f_a + f_s$

= 0.8 + 2.32

$= 2.4\ N/mm^2$

Total pre-stressing forces

Provide 12 Nos bar of 4mm dia. (As per UGVCL's guideline)

Pre-stressing work = no. of bar × area of bar × ultimate tensile strength of tensile steel

$= 12 \times (\frac{\pi}{4} \times 4^2) \times 1860$

= 280339.2 N

= 280.33 KN

Pre-compression = $\frac{\text{pre-stressing work}}{\text{Section area}}$

$= \frac{280339.2}{49723} = 5.63$ N/mm

Point	Circular spun pole
Volume of concrete	$0.20\ m^3$
Weight of tension wire 4mm Dia. Main HT steel wire	9.504 kg
Weight of stirrups 4mm Dia. HT wire	1.365 kg

4.4 Drawing of PSC Circular Spun Pole of 8 Meter Long

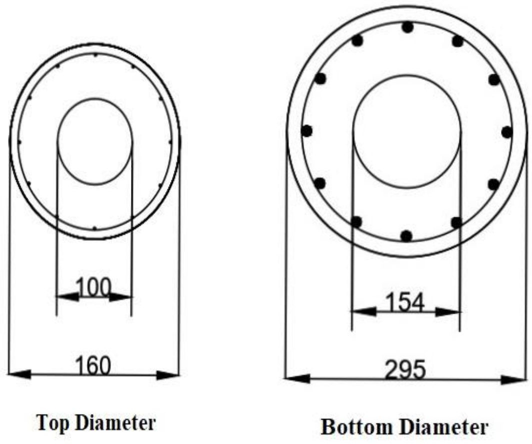

Fig-4: Top and Bottom View

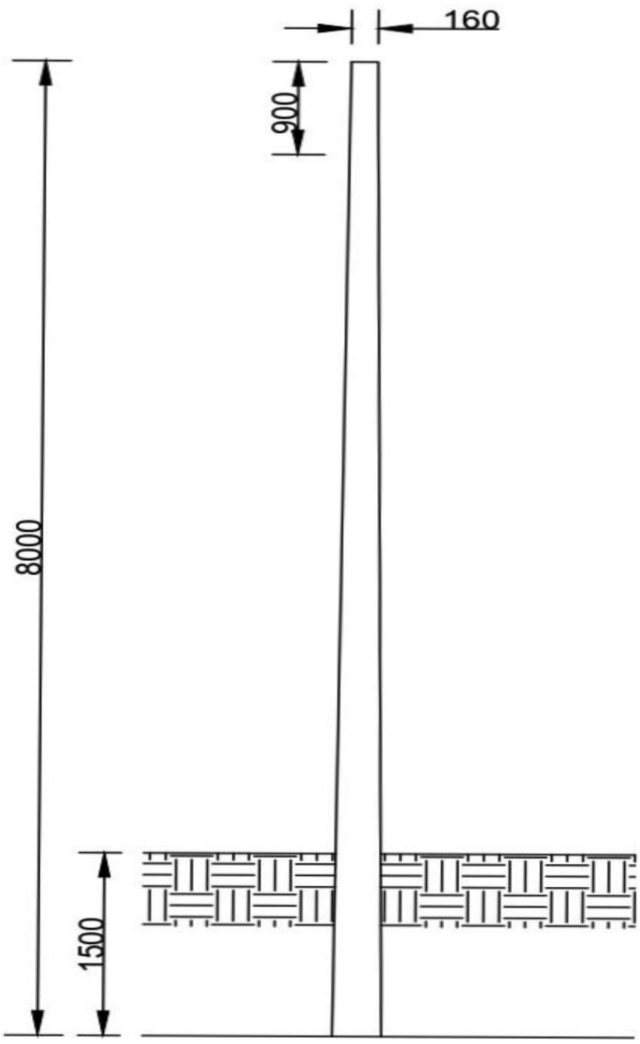

Fig-5: Side View

*All Dimension in Millimeter.

5. CONCLUSION

1. There is no gap in a circular spun pole, thus no one can climb up and the possibilities of an accident are reduced.
2. As the surface of a circular spun pole is uniform in all directions, wind force is reduced.
3. The circular spun pole eliminates a window, the possibilities of a defect are reduced.
4. The circular pole has a more elegant look than conventional electric poles.
5. Circular poles are simple to transport and erect.

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BIOGRAPHIES

Deepkumar G. Patel
Graduate Student, Dept. of Civil Engineering, Gujarat Power Engineering & Research Institute, Gujarat, India

Karm R. Patel
Graduate Student, Dept. of Civil Engineering, Gujarat Power Engineering & Research Institute, Gujarat, India

Vinit P. Oza
Graduate Student, Dept. of Civil Engineering, Gujarat Power Engineering & Research Institute, Gujarat, India

Jimmy A. Patel
Graduate Student, Dept. of Civil Engineering, Gujarat Power Engineering & Research Institute, Gujarat, India