



Structural Design of Pre-stressed Reinforcement for Reinforced Concrete Electric Poles in Power Transmission and Transformation Networks

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Abstract. This paper utilizes anti-cracking pre-stressed reinforcement technology for the repair of reinforced concrete electric poles in power transmission and transformation networks. A specialized reinforcement structure is designed, and reinforcement is implemented using welding methods. By employing prescribed welding techniques, significant circumferential pre-stress is generated, further increasing the internal stress of the reinforcement steel pipes and steel hoops. This resolves the issue of lagging working stress in the reinforcement structure, effectively reinforcing the axial load-bearing capacity and flexural resistance of the cement pole. It enhances the effectiveness of the reinforcement structure's load-bearing capacity and the strength of the transmission pole, effectively limiting the formation and expansion of longitudinal cracks, thereby remarkably extending the service life of reinforced concrete electric poles.

Keywords: Concrete electric poles, reinforcement, welding, steel pipes

1 Introduction

Reinforced concrete electric poles are pivotal components in power transmission and transformation networks. Compared to steel structure pylons, these frameworks offer advantages such as lower investment and enhanced corrosion resistance. Consequently, they are extensively utilized in power transmission networks across China. Presently, reinforced concrete frameworks are widespread throughout the country, with many having been in use for over 20 years. With the passage of operational time, factors such as the aging of concrete poles, various disasters, and prolonged stress exposure lead to damage including concrete aging, cracking, steel reinforcement corrosion, and steel plate hoop degradation [1-6]. These issues pose safety risks to the operation of substations.

The prevalence of cracking and damage in reinforced concrete electric poles is considerable. Due to various constraints, a complete replacement of these poles is challenging. Therefore, research into repair technologies to enhance their load-bearing

capacity is crucial. However, research on damage repair technologies for reinforced concrete frameworks in power transmission and transformation networks remains limited [7]. Current repair methods typically involve cement grouting, adhesive bonding, or wrapping with carbon fiber cloth [8-13]. However, due to issues with stress transmission, these reinforcement methods exhibit problems related to stress and strain lag. Especially the corrosion rate of the steel plate ring increases due to residual stress in the welded structure. Once the anti-corrosion layer is damaged and the bearing capacity of the welded joint decreases due to rust, it is very easy to break at that location [14-16]. This paper utilizes anti-cracking pre-stressed reinforcement technology to design a reinforcement structure for reinforced concrete electric poles, aiming to enhance their load-bearing capacity using welding techniques, thereby addressing strength deficiencies resulting from corrosion damage and other factors affecting the poles.

2 Pre-stressed Steel Pipe Reinforcement Structure

To enhance the load-bearing capacity and flexural strength of the electric pole, a pre-stressed steel pipe is designed to secure pre-stress onto the reinforced concrete electric pole. The material for the pre-stressed steel pipe is Q345B, with a thickness of 8mm-10mm and an inner diameter matching the outer diameter of the electric pole. This steel pipe is processed along its central surface to form two nearly semi-circular pipes, as depicted in Figure 1. To apply pre-stress, a fastening block of 20mm thickness is welded onto the steel pipe, as shown in Figure 2.

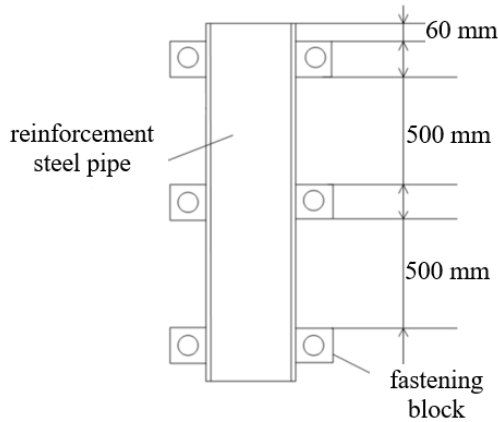


Fig. 1. Schematic of Pre-stressed Steel Pipe

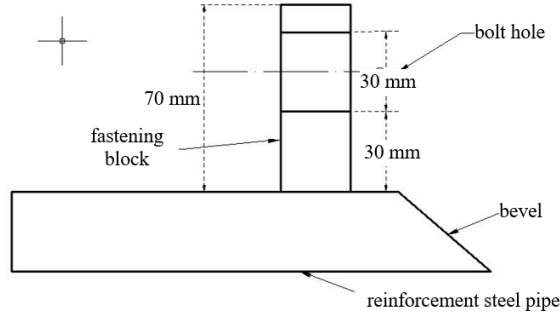


Fig. 2. Assembly Schematic of Fastening Block

The longitudinal junction of the two semi-circular pipes is processed into a "V"-shaped bevel, as illustrated in Figure 3. The groove angle ranges from 60° to 70° with a root face height of 0.5mm-1mm. The longitudinal length of the steel pipe exceeds the longitudinal height of the steel plate hoop on the cement pole by at least 100mm. By fastening and welding the two nearly semi-circular pipes onto the fastening block with bolts, a circular pre-stress is achieved. This design boasts high rigidity and transverse crack resistance, effectively reinforcing the axial load-bearing capacity and resistance to the bending of the cement pole.

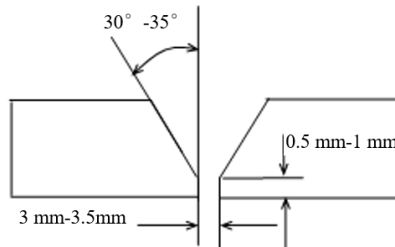


Fig. 3. Welding Bevel Schematic

When the electric pole is subjected to axial stress, it generates surface tension and may fracture. When the external surface is reinforced with steel pipes, it restrains the surface tension of the concrete pole, and the steel pipes experience not only pre-stress tension but also radial tension.

Based on the formula for steel pipe pressure:

$$P = \delta \times R / D \times \lambda \quad (1)$$

where P stands for pressure, δ represents wall thickness, R stands for tensile strength of the steel, D represents steel pipe inner diameter, and λ is the safety factor.

Under the action of axial stress on reinforced concrete electric poles, the lateral deformation of the concrete increases, causing an expansion in concrete volume. When the axial compressive stress reaches 0.5-0.7 times the design value of the concrete pole, the concrete volume increases notably. At this point, fine cracks start appearing in the pole, and as it approaches failure, internal steel reinforcements undergo buckling,

protruding outward. The concrete reaches its ultimate compressive strain, leading to its crushing. When the concrete pole is encased in steel pipes, the pipes constrain the concrete pole. When subjected to tri-axial compressive stress, the axial pressure resistance of the concrete pole is remarkably improved. The generation or expansion of fine cracks in the concrete pole only occurs at higher stress levels, and instability or fracture also occurs only at higher stress levels. Using the formula:

$$Nu = K_1 N_{co} + N_{sj} \tag{2}$$

where K_1 stands for coefficient greater than 1, N_u represents axial compressive load capacity of the pre-stressed steel pipe reinforced pole, N_{co} stands for load borne by the unrestrained concrete, and N_{sj} is the load the concrete strength improvement under steel pipe constraint can withstand. It can be calculated by:

$$N_{sj} = K \times 2\delta \times Re / D \tag{3}$$

where K stands for coefficient related to continuous constraint, section shape, steel pipe strength coefficient, and spacing, δ represents steel pipe wall thickness, Re stands for steel yield strength, and D is steel pipe inner diameter.

It's evident that N_{sj} is related to the maximum pressure the steel pipe can withstand. Since the steel pipe is a continuous constraint, the coefficient K approaches 1. Its compressive resistance can increase by nearly 30%. Considering the strength enhancement due to constrained concrete and steel reinforcements, the compressive strength increase could surpass 30%.

3 Pre-stressed Steel Hoop Reinforcement Structure

While the pre-stressed steel pipe reinforcement demonstrates excellent effectiveness, it comes with high costs and long construction periods. For lightly damaged concrete poles, a pre-stressed steel hoop reinforcement method can be employed. This method not only provides a certain level of constraint but also reduces costs and enhances efficiency. The pre-stressed steel hoop uses Q345B steel pipes with a thickness of 8mm-10mm. A 60mm-high ring is cut and split along the centerline to form two nearly semi-circular rings. A bevel is machined along the longitudinal section of the ring, and a pair of fastening blocks are welded at a distance from the bevel's edge. These hoops are then secured onto the pole using bolts, as shown in Figure 4.

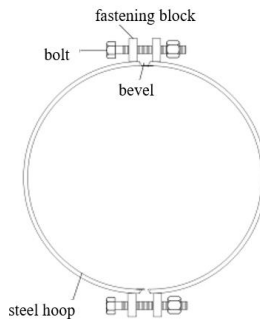


Fig. 4. Schematic of Pre-stressed Steel Hoop

The constraint and effect of pre-stressed steel hoops on the concrete pole are similar to Formula (2). However, the difference lies in the discontinuous constraint of the pre-stressed steel hoops. The value of K_{in} Formula (3) is related to the distribution spacing of the pre-stressed steel hoops. The larger the spacing is, the smaller the value is. To consider overall economic benefits, the spacing for sections with cracks is determined to be 500mm, whereas sections without cracks have a spacing of 1000mm. Additionally, there is an increase in the steel hoop's strength coefficient, achieved by increasing the height of the steel rings and the material strength.

4 Pre-stressed Steel Plate Hoop Reinforcement Structure

The most problematic area in aging transmission poles often lies at the steel platehoop section. The concrete at the steel plate hoop section typically exhibits damage and exposed reinforcement bars, leading to severe corrosion of the steel bars. Reinforced concrete electric poles are generally produced using centrifugal casting, resulting in poor density at the ends of cement poles, making them susceptible to water ingress. Corrosion of steel bars creates internal expanding forces, particularly at the ends, where the end section is subjected to multiple forces, causing concrete to fracture and spall during service. Additionally, the welding connections between the steel plate hoop and internal steel bars within the cement pole accelerate corrosion at the weld seams, posing considerable safety risks if damaged.

To reinforce this vulnerable point at the steel plate hoop, a pre-stressed steel pipe reinforcement structure is employed. Two nearly semi-circular steel pipes are fastened onto the cement pole using bolted fastening blocks. Subsequently, welding between the gaps of the two nearly semi-circular pipes forms a pre-stressed reinforcement structure for the cement pole steel plate hoop. Post-welding, the fastening blocks are ground away, forming the pre-stressed reinforcement structure, as depicted in Figure 5.

The specialized reinforcement structure designed for reinforced concrete electric poles allows for reinforcement without the need for prolonged power shutdowns. It even enables reinforcement procedures without requiring a power outage at all. Utilizing residual welding stresses further increases the internal stress of the reinforced steel pipes and steel hoops ^[17], remarkably enhancing

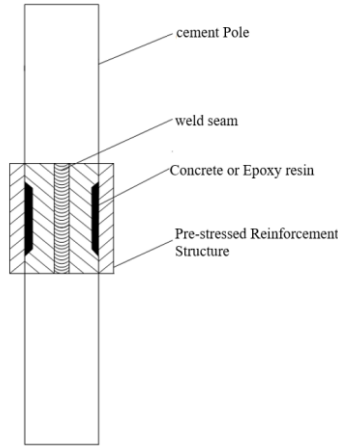


Fig. 5. Schematic of Pre-stressed Reinforcement Structure

the strength of the transmission and transformation of reinforced cement poles. This effectively restricts the circumferential tensile strain of pre-stressed poles after enduring axial loads, thereby limiting the expansion and formation of longitudinal cracks, substantially extending the lifespan of the poles.

Under the action of axial stress, the transverse deformation of concrete in transmission poles increases, and the volume of concrete increases. When the concrete reaches the transverse expansion deformation, micro cracks begin to appear in the poles. When the concrete pole is wrapped with a steel pipe, the steel pipe exerts a restraining effect on the concrete pole. The pole is subjected to a three-dimensional compressive stress state, and the axial compressive resistance of the concrete pole is significantly improved, which can prevent the generation and propagation of cracks in the concrete pole. When cracks or cracks, carbonization, weathering, etc. occur in the transmission poles, reducing the bearing capacity, the use of prestressed steel pipes for reinforcement is certainly the best, but the reinforcement cost is high and the construction period is long. Using prestressed steel hoops to reinforce concrete poles can not only achieve a certain constraint effect, but also reduce costs and improve efficiency.

5 Conclusions

(1) Through welding reinforcement methods, a substantial circumferential pre-stress has been generated, further increasing the internal stress of the reinforced steel pipes and steel hoops. This effectively reinforces the axial load-bearing capacity and flexural strength of the cement pole, significantly enhancing the strength of the reinforced concrete electric poles in power transmission networks.

(2) A specialized reinforcement structure for reinforced concrete electric poles has been designed, utilizing pre-stressed reinforcement techniques to repair damaged transmission cement poles. This resolves the issue of lagging working stress in the

reinforcement structure, enhancing the effectiveness of the structure's load-bearing capacity.

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