Experimental Study on The Bearing Capacity of Super High Strength Concrete Pole

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Abstract. In order to study the ultimate bearing capacity of super high strength concrete pole, the pole type planning and structural design of super high strength concrete pole are carried out. Under the design condition, the ultimate bearing capacity of super high strength concrete pole is tested. By using the finite element software ABAQUS, the finite element model of super high strength concrete pole is established, and the same external load as the test is applied to fit the true type test. The ultimate bearing capacity of super high strength concrete pole is obtained by true type test and finite element numerical simulation.

1. Introduction
With the development of economy and society in our country, the transmission line erection is developing to larger diameter and more circuits, and the requirement of tower structure and load is also higher and higher. The common concrete pole used in transmission line can not meet the requirements of transmission line bearing capacity and transportation and installation.

In recent years, the research and application of super high strength concrete in the field of building are developing, and more and more attention has been paid to the bridge, high-rise building and power industry. In the design and production of electric pole, super high strength concrete is used instead of ordinary concrete, which can lighten the electric pole and improve the corrosion resistance of electric pole, such as salt resistance, alkali resistance and carbonation resistance. Super high strength concrete can be widely used in electric power industry in China, especially in coastal areas, saline alkali areas and other areas with strong soil corrosion. Compared with steel tube pole, the design horizontal span of super high strength concrete pole is increased by about 50%, and the price of single base is reduced by about 25%, which can reduce the floor area of pole and tower and project investment, and has good economic and social benefits.

2. Structural Design of Super High Strength Concrete Pole

2.1. Design conditions
In this test, 35CG-SZ1-21 straight pole and 35CG-SJ1-15 corner pole are selected for true type test, and the design conditions of the two pole types are as follows. Voltage grade: 35kV; circuit number: double circuit; maximum design wind speed:30m/S; icing thickness: 5mm; horizontal span: 220m; vertical span: 270m(35CG-SZ1-21), 250m(35CG-SJ1-15); angle degree: 0-3 (35CG-SZ1-21) and 0-10 (35CG-SJ1-15).

2.2. Structural Design of Pole
The pole concrete selected in this test is C100 super high strength concrete. As there is no relevant
specification for super high strength concrete at present, the material parameters of super high strength concrete are derived by the calculation method according to the code for design of concrete structures. The layout of reinforcement adopts partial prestressed reinforcement, the prestressed reinforcement adopts high-strength reinforcement with tensile strength of 1470MPa, the spiral reinforcement adopts cold drawn wire with tensile strength of 650MPa, and the non prestressed reinforcement adopts HRB400 reinforcement [1]-[3].

In the technical code for design of tower structure of overhead transmission line, the section bearing capacity, deformation of pole body and width of concrete crack of super high strength concrete pole under tension, compression and bending are checked [4]-[5]. The design results of pole structure are shown in Fig. 1-1 and Fig. 1-2.

3. Bearing Capacity Test of Pole

According to the code for design of 66kV and below overhead power lines, the load condition combination of tower is long-term load condition, installation condition, disconnection condition, icing condition and gale condition, and the load value of each test condition is calculated.

3.1. Test Conditions of Pole

The loading point of the test wire is arranged at the end of the cross arm, the wind load of the ground wire is arranged at the hanging point on the top of the pole, the wind load of the tower body is simplified as the concentrated force, and the loading point is shown in Fig.3. The test is carried out in the sequence of 0~50%~75%~90%~95%~100%~0, and the test is carried out in the sequence of the working conditions given in the test project.
3.2. Loading test of pole

In this test, 35CG-SZ1-21 pole has passed the 100% design load test under 8 working conditions, of which 90° gale, balanced tension and 3° line angle are the control working conditions. After the working condition is loaded to 100%, no abnormality is found in each pole. The test site is shown in Fig.4-a. The control working condition of this true type test is gale working condition. In the process of gale working condition loading, when loading to 100% according to the established loading steps of the test, the concrete of each part of the pole body does not appear collapse and tensile damage, and the pole does not appear the phenomenon of sudden increase of lateral displacement. The test results show that the straight pole can meet the requirements of bearing capacity. The total height of the straight pole in this test is 30m. According to the technical code for design of overhead transmission line tower structure, the control deformation of pole top deflection under long-term load is 150mm. When the test is loaded to 100% load value of long-term load, the observed pole top deflection is 14mm. The test results show that the straight pole can meet the deformation requirements. At the same time, the observation shows that the lateral displacement is 975mm when the wind load is 100%.
In this test, 35CG-SJ1-15 double circuit angle rod has passed the 100% design load test under 10 working conditions established in the test, of which the installation and hanging of conductor in the installation working condition is the control working condition, and the working condition is loaded to 100%, no abnormality is found in each member of the rod, and the test site is shown in Fig.4-b.

The control working condition of this loading test is that of installing the lowest conducting wire. During the loading process of the control working condition, when the loading is 100% according to the loading steps established in the test, the concrete of each part of the pole body does not appear compression and tension damage, and the pole does not appear the phenomenon of sudden increase of lateral displacement. The test results show that the angle pole can meet the requirements of bearing capacity. According to the technical code for design of overhead transmission line tower structure, the control deformation of pole top deflection under long-term load is 168mm. When the test is loaded to 100% load value of long-term load, it is observed that the deflection of pole top is 10mm. The test results show that the angle pole can meet the deformation requirements. At the same time, it can be seen from the observation that the lateral displacement is 348mm when the conductor is installed under 100% load.

4. Finite element numerical analysis of the loading test

4.1 Establishment of the finite element model

The finite element model of the pole is established by using abquq software. The main structure of the model includes super high strength concrete, prestressed reinforcement, non prestressed reinforcement and stirrup. The solid element is used for super high strength concrete and truss element is used for reinforcement. In the process of finite element analysis, taking concrete and reinforcement as the research object, the maximum transverse displacement of pole, the maximum tensile stress of pole concrete and the maximum tensile stress of prestressed reinforcement in the model are extracted.

4.2 Finite element analysis of the electric poles

The transverse displacement, concrete tensile stress and prestressed reinforcement tensile stress of the two pole finite element models are shown in Fig.5-7. It can be seen from the figure that the maximum lateral displacement of the pole of 35CG-SZ1-21 type is located at the top of pole under long-term load condition and strong wind condition, with the size of 19mm and 938mm, which is consistent with the test results of 14mm and 975mm. The maximum lateral displacement of the pole of 35CG-SJ1-15 type is located at the top of the pole. The lateral displacement of the pole top is 14mm and 317mm respectively under the long-term load condition and the wire installation condition, which is in good agreement with the test results of 10mm and 348mm.
The maximum tensile stress of the super high strength concrete of the pole body is located at the bottom of the pole, with the size of 3.416MPa, less than the design value of C100 tensile strength of 4.47MPa, and the maximum compressive stress of the pole concrete is 54.81MPa, less than the design value of the axial compressive strength of 63.8MPa, meeting the specification requirements; the maximum tensile stress of the prestressed steel bar is located at the bottom of the first section of the pole, with the size of 951.7MPa, less than the design value of tensile strength of prestressed reinforcement 1040MPa, meeting the design requirements.

Fig. 5 Lateral displacement nephograms of the poles

Fig. 6 Stress nephograms of concrete of the poles

Fig. 7 Stress nephograms of reinforcement of the poles

5. Conclusion
(1) The pole type planning of super high strength concrete pole is carried out, and the design and use
conditions, reinforcement type, cross arm arrangement, pole taper, overall dimension and cross arm
dimension of super high strength concrete pole are determined.

(2) Through the test, it is proved that the super high strength concrete pole can meet the bearing
capacity and deformation requirements of the code, and can ensure the safe operation of the project,
which provides a new idea for the construction of the transmission line project in the future.

(3) Through the finite element numerical simulation, the true type test is fitted. Through the
analysis, it can be seen that the finite element numerical simulation and the true type test fit well.
Under the limit load, the concrete and steel bar of the super high strength concrete pole are not
damaged, which can meet the requirements of the code and the operation of the line, and provide a
reliable basis for the design of the super high strength concrete pole in the future.

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