Study on foundation selection and economy of 220kV four circuit narrow base steel tube tower

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Abstract:  Through the practice of a certain urban line project in Hebei Province, the common forms of steel tube tower foundation with narrow base are introduced, and make a comparison from the basic form, technical economy and other aspects, and recommend the foundation form suitable for the corresponding situation. It is expected to be a reference for the foundation design of steel tube tower with narrow foundation.

1. Foreword
Urban lines are characterized by narrow corridors and many shared circuits, the steel tube tower with narrow base occupies a small area and has large overall rigidity, so narrow base steel tube tower is more and more used in transmission line engineering design[1]. However, the external load of the multi circuit narrow base steel tube tower is large and the foundation root opening is small, therefore, the foundation force of multi circuit narrow base steel tube tower is large. The construction period of transmission line foundation project accounts for about 50% of the whole construction period, the transportation volume accounts for about 60% of the whole project, and the cost accounts for about 35% of the whole project[2]. Therefore, the reasonable selection of the foundation form is the key factor affecting the project investment.

In this paper, through the line engineering practice of a certain urban development zone in Hebei Province, the foundation selection and practical application of steel tube tower with narrow base are introduced, the selection of narrow base tower foundation and its economy are analyzed, summarize the key points of design, and provide the basis for the design of narrow base steel tube tower foundation.

2. Project overview
A 220kV line project in Cangzhou, design wind speed 31m / S (10m reference), icing 5mm (conductor). The route is located in Huanghua Port Economic and Technological, the route is located in the port economic and Technological Development Zone of Huanghua City, and the route is located in the green belt under planning. The urban planning department requires that the tower root opening be strictly controlled within 6m, according to the construction scale of the project and the actual situation of the line corridor, the project adopts four circuit narrow base steel tube tower design (including two 220kV lines and two 110kV lines).

The route was originally salt pond with slight relief, the whole terrain is relatively flat after manual back filling in the near future, it belongs to alluvial and marine sedimentary plain accumulation landform; The geological conditions at the tower base are mainly plain fill, silty clay and silty fine sand. The upper plain fill and silty clay are in the flow plastic soft plastic state, and the bearing capacity of the
foundation is about 80kPa; Silt and silty clay in other strata are medium dense and plastic, and the bearing capacity of foundation is about 130kpa.

The buried depth of groundwater in the project is 1.1m-1.5m, and the variation amplitude of groundwater is generally 0.5m-1.0m, the design can be considered as 0m underground water. Groundwater and topsoil are moderately corrosive to concrete structures, It has strong corrosiveness to steel bars in reinforced concrete structure.

3. Study on foundation selection of steel tube tower with narrow Foundation

Study on foundation selection of steel tube tower with narrow Foundation, according to the tower load size, geological and hydrological conditions of the project itself, summarize and absorb the previous experience of transmission line foundation design, select and plan the foundation selection according to local conditions.

3.1. Flexible beam slab foundation

For geological conditions with deep groundwater and good bearing capacity of foundation, flexible beam slab foundation can be used, as shown in Figure 1, this kind of foundation is to connect the main columns through beams to form a whole. The uplift resistance of this kind of foundation is mainly determined by the weight of the foundation and the weight of the soil within the uplift angle of the foundation slab, the calculation principle is simple.

Although the flexible beam slab foundation can meet the engineering load conditions, however, it belongs to the large excavation foundation, on the basis of the original size of the foundation slab and the sloping, the excavation face is large, in consideration of economic and environmental protection requirements, it is not recommended to adopt.

3.2. Cast in place pile cap foundation (multiple columns)

The foundation of cast-in-place pile cap is composed of the foundation pile and the pile cap connected to the pile top[3]. In the transmission line engineering, it is mainly used for the weak foundation or the tower location where deep foundation is needed, and the concrete cast-in-place pile foundation is often used. The foundation form belongs to integral foundation, it is suitable for narrow foundation of steel tube tower with the distance between pile centers less than 3 times of its design diameter. As shown in Figure 2.

However, this type of foundation requires the connection of pile foundation and bearing platform, Generally, the bearing platform size is large, moreover, the cushion cap part needs foundation pit excavation and form work support, so the construction period is relatively long.
3.3. Cast in place pile foundation (single pile)

The single pile foundation of cast-in-place pile is generally applicable to the tension tower or linear tower with the soil condition of flow plastic, deep foundation bearing layer and large foundation force, convenient construction, safe and reliable[4]. As shown in Figure 3. The cast-in-place pile foundation is a kind of undisturbed soil foundation, in line with the principles of safety, reliability, advanced technology, economic applicability, adaptation to local conditions, environmental protection and convenient construction, when the foundation root opening of narrow foundation tower can meet the requirement of 3 times of pile diameter, the foundation type is preferred.

4. Economic comparison of typical narrow base steel tube tower foundation

Through different basic forms, in this paper, the economic comparison of flexible beam slab foundation, cast-in-place pile cap foundation (multi column) and cast-in-place pile foundation (single pile) is made, for typical tower types (2/I2-SSZZG2B-30, 2/I2-SSJZG2B-24), three kinds of foundations are designed and calculated, and the schemes are compared.

4.1. Load size

This paper takes the four circuit narrow base steel tube tower used in the 220kV line project of west industry as an example, carry out basic selection and economic research, a linear tower
2/112-SSZZG2B-30 and a strain tower 2/112-SSJZG2B-24 were selected for analysis. See Table 1 for the two tower foundation forces and root opening.

Table 1. Root opening and foundation force of four circuit narrow base steel tube tower

| Tower type         | Call high (m) | root span (m) | Foundation force |
|--------------------|---------------|---------------|-----------------|
|                    |               |               | Pull up force   |
|                    |               |               | Tmax (kN)       |
|                    |               |               | downward pressure |
|                    |               |               | Nmax (kN)       |
| 2/112-SSZZG2B      | 30            | 4.25          | 2145.3          |
|                    |               |               | 2378.51         |
| 2/112-SSJZG2B      | 24            | 4.389         | 2898.85         |
|                    |               |               | 3183.01         |

According to table 1, the foundation force of steel tube tower with narrow base is larger and the root opening is smaller. According to <the code for design of overhead transmission line foundation>, the center distance of cast-in-place pile should not be less than 3 times of its design diameter, therefore, the maximum diameter of single pile foundation for two typical tower types is 1.4m.

4.2. Comparison of typical narrow base steel tube tower foundation

Tower foundation design needs to be based on engineering geological conditions and hydrological characteristics. ①Flexible beam and slab foundation: the foundation is simple in construction and easy to guarantee in quality. It is suitable for the case of deep groundwater level, but its earthwork excavation volume is large.②Cast in place pile cap foundation (multi column): the foundation is suitable for the tower with underground water and small foundation root opening, which can not meet the requirements of single pile foundation. ③Single pile foundation of cast-in-place pile: it is applicable to the tower with shallow groundwater, thick sand layer and foundation root opening meeting the requirement of 3 times or more pile diameter. According to the calculation, the design dimensions and material consumption of the two tower types are shown in Table 2 and table 3.

Table 2. Comparison of two tower foundation materials without underground water

| Tower type         | Basic form                  | Pile diameter × pile length(m) | Size of bearing platform and base plate(m) | Concrete dosage(m³) | Steel consumption (t) | Body cost (10000 yuan) |
|--------------------|-----------------------------|-------------------------------|------------------------------------------|---------------------|-----------------------|------------------------|
| 2/112-SSZZG2B-30   | Flexible beam slab foundation | ——                           | 9.8×9.8×6.2                             | 186.90              | 14.68                 | 12.77                  |
|                    | Cast in place pile cap foundation (multiple columns) | 4×1×20                       | 6.0×6.0×1.2                             | 107.28              | 21.55                 | 12.32                  |
|                    | Single pile foundation of cast-in-place pile | 1×15.5                       | ——                                      | 49.33               | 5.54                  | 2.85                   |
| 2/112-SSJZG2B-24   | Flexible beam slab foundation | ——                           | 17×17×6.2                               | 384.47              | 39.84                 | 29.94                  |
|                    | Cast in place pile cap foundation (multiple columns) | 4×1.2×37.5                   | 6.6×6.6×1.2                             | 223.69              | 25.74                 | 18.39                  |
|                    | Single pile foundation of cast-in-place pile | 1.2×40                       | ——                                      | 196.63              | 14.74                 | 13.17                  |
Table 3. Comparison of two tower foundation materials with underground water

| Tower type | Basic form | Pile diameter × pile length (m) | Size of bearing platform and base plate (m) | Concrete dosage (m³) | Steel consumption (t) | Body cost (10000 yuan) |
|------------|------------|--------------------------------|---------------------------------------------|----------------------|----------------------|------------------------|
| 2/112-SSZZ G2B-30 | Flexible beam slab foundation | — — | 13×13×6.2 | 262.1 | 24.32 | 19.33 |
| | Cast in place pile cap foundation (multiple columns) | 4×1×20 | 6.6×6.6×1.2 | 114.78 | 22.29 | 12.89 |
| | Single pile foundation of cast-in-place pile | 1×20 | — — | 63.47 | 7.11 | 5.15 |
| 2/112-SSIZ G2B-24 | Flexible beam slab foundation | — — | 20×20×6.2 | 430.56 | 44.96 | 33.66 |
| | Cast in place pile cap foundation (multiple columns) | 4×1.2×37.5 | 6.6×6.6×1.2 | 223.69 | 25.74 | 18.39 |
| | Single pile foundation of cast-in-place pile | 1.2×43 | — — | 209.6 | 15.59 | 13.99 |

It can be concluded from tables 2 and 3, The quantity of concrete and reinforcement for the foundation of cast-in-place pile cap and single pile foundation of cast-in-place pile is smaller than that of combined raft foundation, however, the pile cap foundation of the cast-in-place pile cap has a large amount of concrete, and the construction is more difficult than the single pile foundation of the cast-in-place pile. Therefore, the single pile foundation of the cast-in-place pile should be the first choice for the narrow foundation steel tube tower.

5. Conclusion
In this paper, the common forms of steel tube tower foundation with narrow base are introduced in detail, according to the geological conditions of the West Industrial line project, using century Lily basic design software, the optimization calculation of flexible plate beam foundation, cast-in-place pile cap foundation (multi column) and single pile foundation of cast-in-place pile is carried out. The single pile foundation of cast-in-place pile belongs to undisturbed soil foundation, without earth excavation and with good mechanical performance, compared with the whole foundation, the bending moment is smaller, and the engineering quantity is smaller, and the cost is lower than the other two foundation forms, therefore, in order to meet the design conditions, the single pile foundation of cast-in-place pile should be selected as much as possible.

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