The Application of New Material In The Tower Foundation

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Abstract: During transmission line construction, the tower foundation needs high cost and long operating time. So far, the main tower foundation is reinforced concrete, and the concrete is made of natural gravel, but the natural gravel is growing scarcity with the development of construction; as well, the production of industrial waste and solid waste is growing fastly, if it is not treated, it will brake up habitat. The recycling utilization of wasted concrete and mineral admixture concrete have been used widely in other building areas, however, they are not used in transmission line construction. This paper will take them in transmission line as raw materials, comparing their construction technology, technological advantages and economic benefit with general material. Through the analysis and demonstration, the two types of tower foundation material realize the renewable resources and utilization efficiently and economically, environmental protection.

Chinese Library Classification Number TU528.41; Document code A

1. Introduction
Transmission line is the most important lifeline in power grid engineering. Among them, the length of high-pressure transmission line is generally relatively long, at least tens of kilometers, and even hundreds of kilometers longer. In recent years, with the continuous improvement of the transmission voltage level, the external force on the transmission tower foundation also gradually increases, thus increasing the volume of the foundation and the consumption of structural materials. Therefore, it also increases the demand for engineering quantity and the difficulty of construction. According to relevant materials, the material transportation volume of tower foundation project is close to 2/3 of the whole project, and the construction time needs to take up about 1/2 of the whole time. In addition, the cost also accounts for 20%-25% of the whole line. Therefore, aiming at the problems of long construction period, large consumption and high cost, it is imperative to study more scientific, reasonable and economical tower foundation types.

At present, the tower foundation is mainly reinforced concrete. However, in the concrete raw materials, its aggregate accounts for 75% of the total amount. The source of aggregate is mainly to cut mountains and take stones to process them into sandstone, or to take sand, gravel and pebble from rivers [1]. In the past, people did not attach importance to the awareness of protecting the natural environment, believing that this natural material is inexhaustible and can be harvested at will. Therefore, it has caused very serious damage to the ecological environment. At the same time, with the rapid economic development, the output of industrial waste residue and construction solid waste have increased dramatically [2]. These industrial waste residues and construction wastes are transported to the suburbs and disposed of by open-air stacking or burying, which will definitely cause...
some damage to the ecological environment. At the same time, it will also bring great pressure to the ecological environment. The strategy of recycling construction waste and industrial waste residue is an effective way to solve a series of problems such as shortage of building materials resources, land occupation and environmental pollution. Moreover, this strategy can also be an important way to achieve sustainable development [4]. Based on the above factors, this paper will propose two new tower foundation materials, namely, new Rock-filled concrete and mineral cement concrete.

2. New Rock-filled concrete
Rock-filled concrete[5] (RFC) technology is a new type of mass concrete developed from self-compacting concrete (SCC) technology (as shown in Figure 1 [6]). Rock-filled concrete technology has obtained a series of national invention patents. Not only that, it has also been applied to mass concrete construction in many fields of hydraulic engineering [7]. However, this technology has not been used in the transmission line, so, based on the Rock-filled concrete construction technology, this paper proposes to treat the waste concrete, and simply crush it into aggregate with a diameter greater than 150 mm to form a pile body, and replace the block stone in it. Moreover, the self-compacting concrete that does not need to be vibrating is poured and then introduced into the transmission line tower foundation construction. He Shiqin [2] and Yuan Qitao [3] research on the recycling of construction waste concrete shows that while saving natural sand and gravel, self-compacting concrete can be enriched in waste concrete to form a dense structure. In addition, the hardened new Rock-filled concrete also has good mechanical properties and durability.

2.1 Economic comparison of new Rock-filled concrete tower foundation.
In the new Rock-filled concrete foundation, as the use of waste concrete is increased, the concrete consumption can be saved by 40%-50% compared with the conventional concrete construction method. Taking tower 2E5-SJ4-18 as an example, the economic acute analysis is made on common cast-in-place pile foundation and new Rock-filled concrete pile foundation. The angle of rotation of the tower is 80-90 degrees, and its basic acting force and geological and hydrological reports are as follows.

Table 1  Fundamental force （kN）

| Degree of rotation | Tmax | Tx | Ty | Nmax | Nx | Ny |
|-------------------|------|----|----|------|----|----|
| 80-90             | 1624.73 | 267.32 | 212.11 | -1954.28 | 307.00 | 252.59 |

Table 2  Engineering geological report

| Depth (m) | Lithology | State | Water content (%) | Mass density ρ (g/cm³) | Void ratio e | Limit side resistance standard value qsk(kPa) | Ultimate end resistance qsk(kPa) | Characteristic value of foundation bearing capacity fak(kPa) |
|-----------|-----------|-------|-------------------|-------------------------|--------------|--------------------------------|-----------------------------|----------------------------------|
| 0.00-0.75 | Silty soil | Medium density | 25.0 | 17.9 | 1.80 | 0.850 | 45 | - | 130 |
## Table 3: The cast-in-situ pile (single leg)

| Depth (m) | Lithology    | State     | Depth of groundwater level (m) | Water content (g/cm³) | Density ρ (g/cm³) | Void ratio e | Limit side resistance standard value qstk (kPa) | Standard value of ultimate end resistance qsk (kPa) | Characteristic value of foundation bearing capacity fak (kPa) |
|-----------|--------------|-----------|--------------------------------|-----------------------|-------------------|-------------|-----------------------------------------------|--------------------------------------------------|--------------------------------------------------|
| 7.00-10.00 | Powdery clay | Waxiness  | 21.6                           | 1.97                  | 0.611             | 55          | 400                                          | 130                                              |                                                   |
| 10.00-19.10 | Fine sand   | Medium density | -                              | 1.84                 | -                 | 40          | 1000                                         | 150                                              |                                                   |
| 19.10-21.50 | Silty soil  | Thick     | 21.7                           | 1.94                  | 0.720             | 65          | 900                                          | 160                                              |                                                   |
| 21.50-25.00 | Fine sand   | Thick     | -                              | 1.98                  | 0.656             | 70          | 1100                                         | 180                                              |                                                   |

## Table 4: The comparison of quantities

| Tower type         | Base size | Concrete (m³) | Steel consumption (t) | Cost (Yuan) |
|--------------------|-----------|---------------|-----------------------|-------------|
| Tension tower      | Buried depth | Pile diameter |                       | 18          | 1.4 | 28.8 | 2.3 | 54 117 |

## Section 2.2: New Rock-filled concrete tower foundation construction technology

Compared with the traditional cast-in-situ foundation, the foundation construction of the new Rock-filled concrete has certainly2 technological differences, which can be roughly summarized as follows:

1. Forming holes. Large excavation foundations can be excavated by excavators and the like, and cast-in-place pile foundations can be constructed by machines such as rotary drilling rigs and the like.
2. Steel frame. After the steel bars of flexible foundation and large plate foundation are erected, formwork shall be supported first, and then erect steel shall be applied.
3. Pour the waste concrete particles with particle size meeting the requirements into the pile hole to allow them to accumulate naturally.
4. Pour the self-compacting concrete that does not need to be vibrating.
5. Due to the long foundation of main column and pile length, reasonable arrangement is required, and the 3 and 4 steps shall be circularly operated until the whole foundation casting construction is completed.

Here, it should be noted that the coarse aggregate particle size should be broken according to the actual situation. Under normal circumstances, the maximum particle size shall not exceed 1/4 of the minimum size of the structural interface, and shall not be greater than 3/4 of the minimum net spacing between reinforcement bars. Self-Mixing Concrete shall be tested in advance according to local materials, water reducing agent and strength grade, and the mixture ratio shall be confirmed.

## Section 2.3: Advantages of new Rock-filled concrete tower foundation

This new material can effectively reduce energy consumption and environmental load in the construction process, and can achieve environmental protection. At the same time, the process of
concrete vibration. Thick is avoided, therefore, the artificial unfavorable interference is eliminated, and the construction quality and stability are more guaranteed. A large amount of building waste concrete is used as raw materials, the filling rate can reach about 50%, and the waste concrete can be used efficiently and economically. In addition, the construction technology is simple, which can reduce the comprehensive cost of foundation, greatly improve the construction efficiency, and shorten the construction time. Compared with the traditional Rock-filled concrete foundation, it can reduce or eliminate the roughening process and further improve the construction speed.

3. Mineral concrete

Mineral admixture refers to an additional admixture that can replace part of cement or reduce the amount of cement directly before or during concrete mixing. Mineral admixture mainly includes fly ash, slagpowder and silica fume. Among them, fly ash is waste residue generated in the power generation process of coal-fired thermal power plants. Slagpowder is the waste residue produced in the iron-making process. Silica fume, on the other hand, is dust collected from flue gas emitted from the production of ferro silicon and silicon steel. A large number of studies have shown that the volcanic ash of mineral admixture and the effect of aggregate can reduce the probability of void formation in concrete, and have certain effect on the improvement of pore structure, thus improving the durability of concrete [8-16]. This paper will introduce the new material into the transmission line tower foundation construction based on the best mix proportion proposed by Luo bidan [17] and others. Similarly, the technical and economic advantages of the 2E5-SJ4-18 tower and its geological conditions are compared with those of conventional concrete.

3.1 Technical and Economic Advantages of Mineral admixture Concrete

This material reduces a large amount of cement consumption, uses a large amount of industrial waste residue, achieves environmental protection, effectively reduces energy consumption and reduces construction cost. Several minerals admixture are mixed together, so that the continuous gradation of concrete is more reasonable, the mixing material and its particularity are improved, the porosity of concrete is reduced, and the thickness of concrete is increased. The strength and durability of concrete are improved.

3.2 Economic Benefit Analysis of Mineral admixture Concrete Tower Foundation

Compared with the traditional C25 concrete for foundation, the mineral admixture concrete adopted in this technology has excellently mechanical properties, obviously improves the compressive strength, at the same time, also obviously improves the Thick degree, and has excellent durability.

Regarding the mix proportion of concrete materials that affect the mechanical properties of the foundation, the height of the foundation steps and the Buried depth of the foundation are carefully optimized. Compared with the conventional foundation under the same load condition and geological condition, the concrete usage is reduced by about 8% on average.

Based on the optimized foundation of mineral admixture concrete, the cost of cementing materials is reduced by about 69 yuan per cubic meter compared with that of conventional cement materials, and the saving percentage is about 45%. Compared with the traditional foundation, each foundation can save 3,614 yuan for installation and 893 yuan for materials, with a total amount of 4,507 yuan, reducing the overall cost by 13.5%.

Optimizing the foundation size can also reduce the excavation of land and save land resources. At the same time, the comprehensive utilization of large industrial waste residue has also made great contributions to energy conservation and emission reduction. According to the adopted mix proportion and actual engineering calculation, a single foundation can save about 6t of cement consumption, i.e. it could reduce the emission of 4.86 tons of CO².

4. Conclusion

(1) In the tower foundation, the new Rock-filled concrete can efficiently and economically use waste
concrete. The construction technology is very simple, which can reduce the comprehensive cost of the foundation, greatly improve the construction efficiency and shorten the construction period. At the same time, the process of concrete vibrating thick is avoided, and the artificial unfavorable interference is eliminated. In addition, CO\textsubscript{2} emissions have been reduced by more than 50%. It plays an environmental role in ecology and meets the requirements of sustainable development.

(2) In the construction of transmission line foundation, several minerals admixture are mixed together to make the continuous gradation of concrete more reasonable. Mixing material and its particularity are relatively improved, reducing the probability of forming pores in concrete and increasing the thickness of concrete. The strength and durability of the concrete are improved, the size of the concrete foundation is reduced, the earth excavation is reduced, and the land area is saved. In addition, a large amount of industrial waste residue has been utilized, making great contributions to energy conservation and emission reduction.

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