Application of temporary reinforcement technology in insufficient construction of the understructure bearing capacity of viaduct

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Abstract: The complex three-dimensional traffic construction often occur when the lower structure cannot bear the construction load and other special cases, indicating the need for temporary reinforcement of the lower structure. In this paper, combined with a project construction example, various temporary reinforcement technologies are adopted to solve the insufficient bearing capacity during understructure construction, which poses a serious danger, to ensure synchronous construction of the understructure and viaduct. Compared with the traditional construction technology, the temporary reinforcement technology proposed in this paper features the advantages of saving project cost and time and has achieved better economic and social benefits.

1 Project overview

The complex three-dimensional traffic construction often occur when the lower structure cannot bear the construction load and other special cases, indicating the need for temporary reinforcement of the lower structure [1-7]. In this paper, combined with a project construction example, application of temporary reinforcement technology in insufficient construction of the understructure bearing capacity of viaduct.

Guangzhou Bai yun International Airport consists of a departure viaduct, T2 terminal, and GTC traffic center, forming a three-dimensional transportation hub

integrating aviation, ground, and underground, respectively. The fourth and sixth links of the outbound viaduct feature a total length of 360 m and 10 spans. The bridge deck measures 52.45 m across. The north side of the bridge is 5.3 m away from the terminal, whereas the south side is connected to the GTC traffic center. Most structures, including LED tunnel, bridge set port bus under wear in tunnel, GTC traffic center of the basement, and the upper structure; and the utility tunnel, subway, city rail, transfer channels, and transfer hall, feature the problem of insufficient bearing load bearing capacity of the viaduct construction. Thus, viaduct construction presents a major security danger in the lower structure, as shown by the clearance viaduct layout in Figure 1.

Figure 1. Floor plan

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2 Temporary reinforcement technology

2.1 In situ fulcrum reinforcement technology

When the lower beam and plate structure cannot bear the construction load of the viaduct, the in-situ fulcrum reinforcement technology is considered. This temporary reinforcement technology adopts a double-layer section steel to transfer the load of viaduct to the in-situ fulcrum (structural column) without contacting the beam and plate structure with insufficient bearing capacity to protect the safety of the beam and plate structure without affecting its function. As shown in Figure 2, the concrete method involves padding a 10 cm×10 cm wood beam at the fulcrum (structural column). Thus, the position of the fulcrum is higher than that of the beam and plate structure. The longitudinal I-beam is set on the wooden

beam as the beam structure between the fulcrum points. Horizontal I-beams with 600 mm spacing are arranged on the longitudinal I-beams to serve as construction platforms.

Conventional reinforcement methods, such as the increase fulcrum reinforcement, beam and plate, and paste steel plate methods, can also solve the problem of insufficient bearing capacity of the beam and plate structure. However, it affect the service space or function of the original structure and increases the size of the structure, cost, and reinforcement time. Conventional reinforcement methods cause no effect on the use of substructure function, require no pasting of the steel plate, and can be dismantled and recycled in the viaduct after construction. The construction period shows no effect on the construction of the substructure floor and normal use.

Figure 2. Temporary reinforcement technology

2.2 Combined reinforcement technology of steel pipe rack and section steel indirect crossing

For the roof structure with insufficient capacity to bear the construction load of the viaduct, the load is transmitted to the next floor through the steel tube support roof (Figure 3). If a large-size reserved hole

exists in the floor, the steel section is set on the roof structure relative to the plane position of the reserved hole in the floor to cross the reserved hole indirectly. The reinforcement technology of adding dense steel pipe as fulcrum at the hole edge reduces the number of layers of the reserved hole position and the difficulty of section steel installation on the lower structure plate.

Figure 3. Combined reinforcement technology of steel pipe rack and section steel indirect crossing

2.3 Combined reinforcement technology of adding fulcrum and section steel

The elevation of civil roofing plate from the bottom of the viaduct cannot meet the space requirements for the installation and removal of the formwork of the viaduct

and the insufficient bearing capacity of the roofing plate and lower floor. Evenly distributed fulcrum is used to transfer the load of the viaduct supported by the second floor to the cantilever section on the first floor (Figure 4). Then, a fulcrum is added to support the section under the extension section to form the structure. By increasing the

fulcrum and section steel cantilever, the load can be transferred to the shear wall with sufficient bearing capacity. In load transfer, the load will not pass through

each layer of beam structure with insufficient bearing capacity to protect the safety of beam and plate structure and exert no effect on its function.

Figure 4. Combined reinforcement technology of adding fulcrum and section steel

2.4 Load reduction reinforcement technology

reduction reinforcement technology is adopted to solve the problem of insufficient bearing capacity of viaduct surface caused by construction load due to backfill of large area long-span structure. After the equivalent construction load of viaduct is converted into backfill

thickness, the backfill thickness on the substructure is correspondingly reduced (Figure 5). The high-support mold is removed after viaduct construction. After completion of construction, backfill the soil to the design elevation. The total load within the allowable range of the design must be controlled to ensure the safety of the substructure.

Figure 5. Load reduction reinforcement technology

Given the actual situation, the substructures under the departure viaduct, such as subway, city rail, transfer passage, GTC traffic center, pipe corridor, bus tunnel, and taxi tunnel, which feature insufficient bearing capacity, in-situ reinforcement, load reduction reinforcement, increasing fulcrum, and section steel joint reinforcement are adopted. Compared with the conventional reinforcement method, these technologies solve important safety problems that may occur in the high-support die and its substructure. Compared with the traditional methods, such as back jacking and bonding steel plate method, which are commonly used in China, the technologies adopted in this project exhibit a better reinforcement effect. The adopted methods save

considerable amount of materials, shorten the construction period, and cause no effect on the construction and use of the space under the beam and plate structure.

3 Verification of calculated reinforcement effect

Considering the sixth in-situ reinforcement technology as an example, G-3-G-4/ G-Z-G-1/Z section steel in Figure 6 is selected for verification of force calculation. The calculations of other reinforcement technologies and reinforcement positions are similar.

Sectional area $A(\text{cm}^2)$	309.8	Moment of inertia $I_x(\text{cm}^4)$	187832.4
Sectional resistance moment $W_x(\text{cm}^3)$	5962.94	Dead weight standard value $g_k(\text{kN/m})$	3.384
Design value of bending strength $[f](\text{N/mm}^2)$	215	Maximum normal stress $\sigma(\text{N/mm}^2)$	125
Design value of shear strength $\tau(\text{N/mm}^2)$	125	Maximum shear stress $\tau(\text{N/mm}^2)$	163
Allowable deflection $[v](\text{mm})$	22.5	Actual deflection $v(\text{mm})$	18.4
Design value of support strength (N/mm^2)	20.1	Maximum normal stress of support (N/mm^2)	3.2

method also saves construction time and features good economic and social benefits.

4 Reinforcement effect

4.1 Influence of settlement

The reinforcement technology was implemented from the sixth construction in December 2016 until the viaduct closed on August 2017. The superstructure concrete was poured six times in three stages, during which the deformation of the high-support model and the substructure was monitored by a third-party monitoring unit in real time. The maximum settlement value of the high-support model of the strengthened part is $5 \text{ mm} < 8 \text{ mm}$ (alarm value), and the maximum horizontal displacement value is $4.6 \text{ mm} < 8 \text{ mm}$ (alarm value). The settlement value of the substructure of the strengthened part is $0.5 \text{ mm} < 1 \text{ mm}$ (design allowable value). A good reinforcement effect is observed, which ensures the safety of the high-support die and the substructure. No cracks that affect the function form in the substructure.

4.2 Economic benefits

The technology of in-situ fulcrum reinforcement, steel pipe rack and section steel indirect cross reinforcement, increasing fulcrum, and section steel joint reinforcement are adopted. These methods solve the problem of insufficient bearing capacity of substructure caused by construction load and ensure the synchronous construction of the substructure and viaduct. The steel can be dismantled and recycled, resulting in savings of 2.228 million yuan in project cost and 60-day construction period. The construction area of 2993.63 m² with load reduction reinforcement technology can save 4.807 million yuan in project cost and 90 days of construction period.

Given the two items above, the temporary reinforcement technology saves a total of 7.035 million yuan savings in project cost and construction period of 90 days. This technology eliminates the serious hidden danger of insufficient understructure bearing capacity during construction and ensures the simultaneous construction of the understructure and viaduct. This

5 Conclusion

The project is complicated in structure and presents construction difficulties and the problems of insufficient bearing capacity of the substructure caused by construction load. Adopting a variety of temporary reinforcement techniques effectively strengthens the understructure, guarantees the safety of the high-support model and understructure, eliminates the over-limit crack, and ensures that the deformation value of the high-support model and understructure is within the allowable range of the design. These methods reduce the project cost and time limit, offer good economic and social benefits, and provide reference for similar project constructions.

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