Design and Study of Intensive Track Laying System for Single Hole and Double Road in Open Cut Station

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Abstract: This paper takes Qingdao subway station as an example, considers reducing the cycle of track laying on the whole line, and adds rails and wells under the existing envelope structure. The single-track row of wells and a double-line entrance to the crossing are proposed. The analytical calculations and numerical simulation methods were used to check the mechanical condition of the station envelope and the main structure of the station under the rails. The research results show that the track laying base can be laid out in the enclosed open excavation station, and a series of problems such as land occupation coordination have been solved, and the period benefit is significant. This scheme can ensure the structural safety before the entrance of the rail row well is closed, and the position of the rail side frame below the middle plate of the station satisfies the requirements of the laying limit. This method has a novel design idea, has high application and promotion value, and provides a good reference for the design and construction of open-cut subway stations.

1. Introduction

During the construction of subway stations, holes of different sizes will be reserved to meet the construction requirements, and they will be closed after the construction is completed [1-2]. Common opening structures include the following types: track row wells, shield wells, and equipment wells. Among them, the opening range of the rail row well is the largest, and the impact on the support and floor safety is also the most serious [3-4]. Therefore, the research on the structure of underground row rails has been paid more and more attention [5].

Jianhong Jiang [6] proposed three structural measures based on the mechanical mechanism of the large opening structure of the floor slab to thicken the side wall, expand the side wall to increase the height of the longitudinal beam, and enlarge the side wall. Yi Sun [7] summarized the layout principles of the rails at the track laying base. Yonghua Xiong [8] adopted an arch-arranged sleeve occlusal pile in the rail row well portion, which solved the problem of sudden increase in internal force caused by reserving large holes. Jie Gao [9] established the overall model and plane model of the underground open-cut station space with reserved rails to meet the safety requirements of the station structure at the rails.

In the existing research, there are many researches on the force of pre-installed rails and wells, but insufficient research on the situation that the station envelope structure has been added later. Relying on Shengliqiao Station of Qingdao Metro Line 1, this article determines the addition of a row of wells in
2. Engineering background

2.1. Engineering overview
Shengliqiao Station of Qingdao Metro Line 1 is located on the west side of the intersection of South Siliu Road and Zhengzhou Road. The station is an underground three-storey, double-column and three-span box concrete frame structure. The main body of the station is 152 m long and the standard section is 22.3 m wide. The main body of the station is constructed by cut-and-cut method, and the foundation pit is constructed by bored piles and internal steel support.

2.2. Engineering hydrogeological conditions
The stratum conditions are 2.5 m thick fill layer from top to bottom, 10.2-15 m thick medium coarse sand layer, which is covered by medium and slightly weathered rock layers, the foundation pit depth is 26-28 m, and the station is located in medium coarse sand layers, micro weathered rock layers. The station has the highwater level and a large amount of water. Geological section is shown in figure. 1.

3. Optimized design scheme of adding rail row wells

3.1. Feasibility analysis of conventional schemes
There are two general schemes for setting up track wells in open-cut stations:

(1) Under the single-column double-span system, two rail rows are set up directly above the left and right lines of the station. The main problems of this solution are shown below:

1) Anchor system is made by placing the retaining piles outside. Due to the thick sandy soil layer and
rich water content, the anchor cable setting will cut through the pile body to generate groundwater fissure paths, which will cause serious leakage during excavation. Meanwhile, the designed service life of this row of wells is about 3 years, but the service life of general anchor cables is about 2 years, the anchor cables will fail during the use of the foundation pit and cannot meet the design requirements.

2) The size of the top beam is increased after the surrounding piles are placed outside, and steel pillars need to be erected in the middle of the steel support, which increases the difficulty of construction. Therefore, the scheme is not reasonable.

3) Adjusting the structure of the station from single column to double span makes the scheme change a lot of work.

![Figure 3. Conventional solution two: (a) plan layout of cross beam system; (b) cross section of cross beam system](image)

(2) Under the two-column three-span system, two rail pits are set directly above the station line. The two-lining side wall must be made into a horizontal and vertical rib beam system or a plan to increase the wall thickness in the range of the rail pits to achieve track laying the stress requirements of the second liner, this solution is shown in figure 3. The main problems of this solution are shown below:

1) Limited by the width of the station, the use of vertical and horizontal rib beam systems on the inner wall of the opening range of the track row wells will inevitably lead to an increase in the scale of the station. This is easy to cause the pit wall deformation and leakage accident, and some problems such as unreasonable force of 30 m long span structure.

2) The station mentioned above has been shifted to optimize the transfer. The auxiliary structure at the station edge is close to the carriageway and there is no room for expansion. Therefore, neither of the above two conventional schemes is applicable to the construction of the rails in this station.

3.2. Scheme of Single track well adding crossing line

In view of the above technical difficulties, this article abandons the traditional design ideas, and strives to develop a more adaptable and more targeted design scheme for the track laying base. Therefore, a single-hole dual-track intensive track laying system for open-cut stations is proposed. The design idea is as follows:

1) Make full use of the original dual-pillar and three-span structure of the interchange station, and set up a single rail row well in the middle span to reduce the hole size of the cover plates of each floor. When calculating and checking the safety, the wall does not repeat the reinforcement measures such as anchor rods and stiffeners, which reduces the difficulty of the project and significantly saves the construction period.

2) Make full use of the escalator holes in the public area of the station, and this scheme use the double-span longitudinal beams as the edge conditions on the long side of the rail row well. Therefore, the scheme's force is very clear, and no long-span dangerous components will be generated.

3) Make full use of the space conditions of the station public area and the equipment area, the end equipment area has the conditions for a single column. Therefore, the rail row well is placed near the end of the station, and the transition between the double column and the single column is used. On the basis of satisfying the smooth and reasonable ferries, this scheme set up track-laying ferries to improve
the space utilization of the station structure.

![Schematic diagram of rail row well and operation route layout](image)

Figure 4. Schematic diagram of rail row well and operation route layout

Therefore, a standard rail row with a length of 25.0 m × 2.5 m in width and a small mileage section escalator hole is used. Meanwhile, this scheme sets a single rail row well with a length of 30 m × 5.8 m in the middle of the span, leaves a certain safety distance on each side. The station foundation pit stress and deformation caused by the weakening of the stiffness of each layer are checked and calculated, the rail row is hoisted at 44 angles. A temporary rail for the rail car is set directly below the rail row well, which is connected to the front line through a symmetrically arranged herringbone symmetrical crossing line, the finished product of the rail row is hoisted from the assembly area to the rail laying car through the rail row well, and the rail laying work as a transportation channel surface. After the construction is completed, the temporary rail car track is removed.

![The overall layout of the station structure after the rail wells are installed](image)

Figure 5. The overall layout of the station structure after the rail wells are installed

### 4. Calculation of internal force and deformation after adding rail row wells

As the main structure of each layer of the station is sequentially molded, the supporting members such as steel supports are gradually removed. At this time, the cover plates of each layer replace the steel pipes and other components to support the foundation pit. However, due to the setting the rail row well, the corresponding cover plate is hollowed out, which reduces the rigidity of the supporting structure. It is necessary to carry out corresponding calculations.

#### 4.1. Calculation of internal force and deformation of retaining pile

After adding rail row wells, the section along the length of the well is selected as the calculation section, as shown in figure 6. The molding process of each layer is equivalent to setting different rigid hinges on the pit wall along the depth direction. For the opening of the rail row well, the stress change is adjusted.
by reducing the stiffness of the rigid hinge. Since the supporting structure has been completed, Calculate the internal force and deformation from the bottom plate injection to the completion of each layer. The calculation of earth pressure and load adopts an elastic earth pressure model. The soil parameters within the depth range of the station are shown in table 1.

![Figure 6. Sectional view of row pile support](image)

### Table 1. Soil layer parameters required for calculation

| Stratum number | Category         | Thickness(m) | Severe (kN/ m³) | Floating weight (kN/ m³) | Cohesion (kPa) | Internal friction angle (°) | Friction resistance (kPa) |
|----------------|------------------|--------------|-----------------|--------------------------|----------------|-----------------------------|--------------------------|
| 1              | Miscellaneous fill | 2.00         | 17.5            | ---                      | 1.00           | 15.00                       | 15.0                     |
| 2              | Medium sand       | 7.50         | 18.5            | 8.5                      | 0.10           | 28.00                       | 60.0                     |
| 3              | Medium sand       | 6.00         | 24.0            | 14.0                     | 0.10           | 32.00                       | 60.0                     |
| 4              | Strongly weathered rock | 2.10    | 23.0            | 13.0                     | 1.00           | 45.00                       | 320.0                    |
| 5              | Weathered rock    | 1.00         | 25.0            | 15.0                     | 1.00           | 55.00                       | 720.0                    |
| 6              | Slightly weathered rock | 15.00  | 27.1            | 17.1                     | 1.00           | 65.00                       | 1100.0                   |

![Figure 7. Envelope Diagram of Station Support Piles](image)

According to the construction sequence of the normal method, the laying by - laying die and dismantling support of each layer are carried out alternately. It is divided into 11 groups of working
conditions. Combine the maximum values of displacement, bending moment and shear force under the 11 groups of working conditions, this paper finally get the envelope diagram, as shown in figure 7.

As the excavation of the foundation pit increases, the bending moment on the supporting piles will gradually increase, and the concrete on the tension side may crack due to this reason. Considering the degradation of the material properties and stiffness of the supporting pile during the entire construction process, it is necessary to reduce its stiffness during analysis. When the stiffness of the supporting piles is reduced, it may affect the mechanical performance of the main structure of the station. Since the lateral earth pressure is mainly borne by the main structure of the station, the bending moment of the main components of the main body does not change much after reducing the stiffness of the supporting piles. Through calculation and comparison analysis, the increase of the support piles and the increase of the force of the unadded rails does not change much after the addition of the row of wells, the design requirements were meet.

4.2. Force analysis of each plate layer in station

4.2.1. Calculation model. Using MIDAS / gen for load-structure analysis for structural force analysis. After the solid model is built, the mesh is divided in three dimensions, and the structural material parameters are assigned. The structural design is based on the combination of the load-bearing state and the limit state of normal use, and the respective most unfavorable combinations are used for structural design. The calculation model is shown in figure 8.

![Figure 8. Calculation model](image)

4.2.2. Analysis of calculation results. The force analysis of each layer and side wall in the opening range of the rail row well is compared with the force of each layer and side wall of the standard section. The calculated structure shows that the force system of the rail row well scheme adopted in this paper is reasonable. The opening range of the track row well is not much different from the internal force of the standard section structure, so it is inferred that the track row well has little effect on the overall structure of the station.

![Figure 9. Internal force cloud diagram of roof](image)

This paper selects the most unfavorable load combination for internal force calculation, as shown in figure 9. It can be seen that the maximum positive bending moment occurs near the wellhead of the roof rail and the station edge, which is 107.8 kN · m, and the maximum negative bending moment occurs on the left side of the roof, which is 78 kN · m. The stress on the roof is relatively complicated. The layout of the reinforcement of the roof should be reasonably arranged according to the characteristics of the stress during the stress analysis and design and construction. In the opening range, the bending moment of the plate support increased by 24% compared to the standard section, and the bending moment of the
plate span increased by 19%.

Figure 10. Internal cloud diagram of the first floor

The bending moment of the slab bearing within the opening range of the first floor of the middle plate increased by 23.8% compared to the standard section, and the mid-span bending moment increased by 12%.

Figure 11. Internal force cloud diagram of the second layer

The bending moment of the slab bearing within the opening range of the second-layer middle plate is increased by 23.8% compared with the standard section, and the mid-span bending moment is increased by 12%.

The first and second floors are different from the roof, and the load is relatively single, so the force is relatively uniform. Compared with the roof, its force is relatively small, and the maximum negative bending moment is 11.6 kN · m, which is distributed on the left side of the middle plate. The maximum positive bending moment is 11.5 kN · m, and the greater positive bending moment is distributed around and at the edge of the orbital well. Based on this result, the roof is the most important location to consider when designing and constructing.

Figure 12. Force cloud diagram in the side wall

Within the opening range of the side wall, the bending moment of the top bearing increased by 20.9% compared to the standard section, the bending moment of the middle bearing increased by 23.3%, the bending moment of the middle bearing increased by 17.6%, the bending moment of the bottom bearing increased by 13.2%, and moment increased by 2.25%.

As the depth increases, the internal force on the side wall gradually increases, and the bending moment at the bottom of the side wall reaches 176 kN · m. However, in the middle and lower part of the side wall, a large negative bending moment appears, and the station structure is analyzed. The main reason for this phenomenon is the station space between the station slabs. This part is not caused by the supporting force of the roof. This is also confirmed by the force distribution in the internal force cloud diagram of the side wall.

Based on the analysis of comprehensive calculation results, the internal forces of the various slabs and side walls within the opening range of the rail row wells are within 25% of the standard section. This is mainly due to the weakening of the structural stiffness in the area of the opening, but the internal
force value does not increase much. The increase of internal force leads to an increase in the thickness of the required structure. The solution meets the design requirements and is economical.

5. Conclusion

At present, the construction of the additional rails at Shengliqiao Station has been completed. According to the monitoring, it is in good condition and has withstood the test of large span and highwater pressure. The following conclusions were obtained through the design and implementation of the additional track and row plan.

1) This scheme realized the track laying base scheme in the enclosed open excavation station, and solved a series of problems such as land occupation coordination.

2) The track-laying base designed in this scheme will enable the middle section of Qingdao Metro Line 1 to complete track-laying 7-8 months in advance, and the construction period benefits are significant. The size of the side rail beams of the station grate wells is limited, there is no increase condition, and the lateral pressure is large, so the structure safety can be ensured before the grate well openings are closed.

3) Different track laying methods and track laying hosts require different construction limits, which are generally smaller than the clearance of subway trains. The position of the edge frame of the rail row below the middle plate of the station meets the requirements of the track laying limit.

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