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To cite this article: Ding Yongqiang *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **242** 062085

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Discussion on the design of integrated node of urban integrated pipe gallery

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Abstract. With the progress of urbanization in China, the urban comprehensive pipe corridor has been rapidly developed. The section forms of the composite pipe gallery generally include rectangular section, circular section and elliptic section. Circular section is generally applicable to trenchless construction (such as pipe jacking, shield) of the project. Combined with the design example, this paper summarizes the design of the integrated node of the comprehensive pipe gallery of the circular shield, analyzes the principle of determining the spacing of the comprehensive well, and hopes to contribute to the construction and improvement of the comprehensive pipe gallery of the city.

1. Overview of the integrated node of the comprehensive pipe gallery of the circular shield

Urban underground pipeline corridor is an underground urban pipeline corridor. A tunnel space built under the ground of the city integrates power, communication, gas, heating, water supply and drainage and other engineering pipelines into a building facility, and is equipped with a special access, lifting access and corresponding monitoring system to implement unified planning and design. Unified construction and management is the "lifeline" of urban operation[1].

Due to the current construction of shield pipe gallery, many technologies and design solutions are still being explored. There are integrated nodes in the shield pipe gallery which is an intensive and efficient node design, combines the air vent, the hoisting mouth, the escape port, the vent, the substation and so on. It not only preserves the original function of each node, but also shares facilities to save the engineering quantity.

The integrated node is mainly used in the shield integrated pipe gallery. The purpose of the integrated node is to consider that shield integrated pipe gallery is usually deep and the difficulty in construction caused by frequent openings is very large. Secondly, the design of circular integrated pipe gallery adopts the way of piece splicing, which is different from the construction method of the open-cut pipe gallery. Meanwhile frequent opening will cause the overall and local stability even the danger of the integrated pipe gallery. Third, analogous to the subway, the phenomenon of water seepage often occurs. And the opening on the tube sheet will inevitably increase the probability of water seepage, which is not conducive to the stability and use level of the pipe gallery. Since shield construction is usually deep, frequent openings mean an increase in the design of shafts or foundation pits, which greatly increases the cost of design and construction.



2. Determination of the spacing of integrated nodes

The setting of integrated nodes should be combined with the spacing of each node and the fire compartment requirements. Shield integrated pipe galleries are usually used in areas where underground structures and complex old towns are not suitable for open excavation. This means that integrated nodes are also designed in the old city, which is certain when meeting the requirements of integrated node spacing. Within the scope of the distance, considering the cost of construction and the aesthetic appearance of the city, it is more difficult to locate the integrated node.

"Code for Design of Power Engineering Cables" (GB 50217 - 2007) 7.0.2.2 stipulates[3]: A firewall should be installed at a distance of about 200 meters or a ventilation section in a long distance channel in the cable trench of a tunnel or important circuit. The basis of the fire prevention zone of 200 meters can be found. At present, the fire prevention zone of the open-cut integrated pipe gallery is set within 200 meters.

Refer to the general building fire prevention regulations from the relevant provisions of the "Fire Protection Code for Building Design", "Code for Fire Protection Design of Civil Air Defense Engineering", "Code for Design of Power Engineering Cables", and draw lessons from other underground integrated pipe trenches, the area of the fire protection zone is controlled at about 2000 m². So its length should not exceed 200 m. The integrated pipe gallery can be considered to be the structure in the "Exploration of fire protection problems in large-scale airport integrated pipe gallery". Refer to the requirements of "Code for Fire Protection of Building Design" and "Code for Design of Fire Extinguisher for Buildings", the area of the fire protection zone is controlled to be around 2,000 to 2,500 m², so that it can be about 300 m for a general pipe gallery with a width of about 7 m.

3. Example of integrated node design

At present, the construction and the experience of the shield pipe gallery is still relatively lacking. Chengdu Chengluo Avenue Integrated Pipe Gallery combined with road reconstruction project was built in 2016, with a total length of about 4.4 kilometers; it is constructed with a shield with an outer diameter of 9 meters and an inner diameter of 8.1 meters. There are 21 integrated shafts in the whole pipe gallery: 12 of them are used for releasing material, ventilation, escape and exit, 9 comprehensive shafts for ventilation and escape and exit; the maximum depth of the integrated shaft is 36.2 meters and the minimum depth is 18 meters. It can be judged that the spacing of the integrated nodes is about 200 meters, which is in line with the regulations of various process node spacing.

The Shenyang South Canal Integrated Pipe Gallery [5] is the first integrated pipe gallery in China that uses shield tunneling in the old city. According to the on-site field survey and underground structure risk analysis, it is difficult to meet the requirements of frequent ground openings (personnel entrances and exits, escape ports, hoisting ports, air inlets, exhaust vents, pipeline branch ports). Secondly, the construction method of the integrated pipe gallery adopts the shield construction method with an average depth of 20m. Compared with the open cut integrated pipe gallery, the construction is difficult because of deep depth, which takes time and effort. Meanwhile in order to avoid the frequent opening on the segment that is not conducive to the stability and safety of the integrated pipe gallery to resulting in the structural risk source of the integrated pipe gallery, and consider reducing the construction cost of the entire integrated pipe gallery, it is set to set up a comprehensive node every 400~600m. The pipe gallery adopts a ventilation system with mechanical air inlet and mechanical exhaust and the ventilation shaft cannot be installed in the middle section combined with the fire compartment. A total of 29 integrated nodes are installed across the line in the Shenyang South Canal Pipe Gallery including 20 process nodes, 1 escape node (single function), 1 outlet node (single function) and 7 shield nodes.

Setting the spacing of the integrated nodes to 400~600m in the Shenyang South Canal Integrated Pipe Gallery is not in accordance with the provisions of emergency escape port not greater than 200m in "Technical code for urban utility tunnel engineering". However, considering the difficulty of opening in the old city, the risk increase caused by the construction of the shield method and the increase of the cost, the spacing of the integrated nodes is set to 400~600m through special argumentation, which is in line with the actual design and construction requirements of the shield circular integrated pipe gallery.

4. Thoughts on increasing the spacing of integrated nodes

In the case of increasing the spacing of the integrated nodes, we can consider whether other process node spacing meets the spacing requirements of the integrated nodes of 400 m. If not, whether the process node can be added between the integrated nodes and the integrated nodes. In addition, combined with the actual situation of the engineering example and the shield integrated pipe gallery, the specific node spacing of the integrated nodes can be combined with theoretical proof, and other favorable auxiliary measures to reduce or offset the negative impact caused by the increase of the spacing.

The following mainly analyzes the escape modes of several shield pipe corridors.

4.1. *Escape cabin:*

The escape cabin is a compartment with a separate cabin structure dedicated to emergency escape routes. When the spacing of integrated nodes is large (400m~600m), it does not meet the requirements of the escape port spacing. As an independent emergency escape route, the escape cabin is separated from other potentially dangerous compartments to effectively prevent the fireworks from further harming human life.

Although the escape cabin makes the escape of the corridor safer and more reasonable, it is obvious for that the space of the pipe gallery is sacrificed. The escape cabin designed by the shield tunnel of Shenyang South Canal Integrated Pipe Gallery is based on the design of two single-circle shield construction methods. So the underground space is large and can meet the design size requirements of the escape cabin.

In the design of the escape hall of the Shenyang South Canal Integrated Pipe Gallery[4], it has set up an independent emergency escape channel in each of the two single round pipe corridors. When the integrated node spacing is about 400m for two single-circle shield pipe porches, the power cable and the natural gas pipeline can be placed in the same single round pipe gallery, and an escape cabin is designed at the same time; other pipes can be set at another single-circle pipeline, when the integrated node spacing is 400m, no emergency escape route is set. Optimizing the design of the shield pipe gallery saves the use of limited space.

4.2. *Integrated pipe gallery - subway (underground structure)*

Considering that the integrated pipe gallery and the subway are underground projects, the same depth and they have the same construction method, which makes the design and construction of integrated pipe gallery and subway synchronous in theory feasible. The construction method of the subway section is the same as that of the shield pipe gallery, so they can not only share the construction site in the subway section, but also share the shield equipment and prefabricated segment die, which could save construction costs. When the integrated pipe gallery is synchronized with the subway, emergency escape routes such as fire corridors (pipeline and subway parallel design) and vertical passages (pipe gallery, subway longitudinal design) can be set up between the pipe gallery and the subway as an escape mode. The design spacing can be determined based on the integrated node spacing and the required spacing of the laying pipeline. In addition to the subway, when the integrated pipe gallery is roughly equal to the buried depth of underground buildings such as underground plazas, parking lots, underground air-raid shelters, etc., comprehensive consideration is given to designing the escape mode of the integrated pipe gallery.

4.3. *Optimization of integrated node function*

The spacing requirements of the integrated nodes must meet the spacing requirements of various types of process nodes. The integrated node spacing is maintained at around 200m, but the construction scale and functional requirements of the integrated nodes are different. The integrated nodes are divided into two categories: The first category named full-function integrated node including all process node functions of personnel entrances and exits, escape ports, hoisting ports, air inlets, exhaust vents, and pipeline branch ports is set at intervals of about 400 m; The other type of integrated nodes mainly consists of escape and ventilation functions, and the spacing is also about 400m. The two types of

integrated nodes are separated by a 200m crossover arrangement, which can meet the requirements of the hoisting port and meet the requirements of escape and fire protection. The integrated node size of the escape function is smaller than the full-function integrated node, which makes the cost less. Due to the small volume, the impact on the underground structure and the floor space, the layout position is relatively easy to select.

According to the Chengdu Chengluo Avenue Integrated Pipe Gallery, there are 21 integrated nodes in the whole pipe gallery: 12 for releasing material, ventilation, escape and exit, and 9 integrated nodes for ventilation and escape and exit.

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