Analysis on the Key Points of Architectural Design of Underground Totally Buried Sewage Treatment Plant

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Abstract. With the continuous improvement of urbanization level and people's living environment requirements in China, especially in some large-scale urban built-up areas, traditional surface sewage treatment plants occupy a large area, and the problem of environmental pollution around the plant area is becoming increasingly prominent, which seriously affects the production and living environment of the surrounding land market and residents. Therefore, the construction of underground sewage treatment plants that occupy less space, save land resources, and treat parts with little odor spillage, while beautifying the city appearance and increasing the area of urban green space will become the new development trend and direction of large-scale urban sewage treatment projects.

1. Introduction
In our country, environmental protection has been regarded as a basic national policy, which has been paid attention by the whole society and people's governments at all levels. The Central People's Government and relevant administrative departments have promulgated a series of laws, regulations and technical standards to ensure the implementation of this basic national policy. With the development of human civilization and social economy, human beings have gradually realized the importance of environmental protection and pollution control to the prosperity of economy and stability of society. With the rapid development of city construction and social economy, the amount of sewage entering Qilihe and Anning sewage main pipes has increased, and the capacity of some pipe diameters is insufficient. The first phase of the sewage treatment plant was planned and constructed in 2000, and the sewage discharge was implemented in the “Urban Wastewater Treatment Plant Pollutant Emission Standard” GB18918-2002 Level 1 B standard, according to the existing towns and cities required by the State's “Water 10” issued in April 2015. Sewage treatment facilities should be modified according to local conditions, and the corresponding emission standards or recycling requirements should be met before the end of 2020. At the beginning of the construction, the development of surrounding land was limited. With the rapid progress of urbanization and ecological civilization construction, the surrounding area has been surrounded by residential areas. The impact of environmental pollution such as odor and noise generated by current sewage plants on the environment of surrounding residential areas has attracted great attention. The incongruity between the landscape of the south side and the Yellow River's amorous feelings line greatly restricts the enhancement of the value of surrounding land. After in-depth comparison and demonstration of various schemes, the final decision is to build the Qilihe Anning Sewage Treatment Plant in Lanzhou into a fully buried underground sewage treatment plant with the advantages of saving land resources, good vision, improving the environment and coordinating with the surrounding environment. However, through many years of practice, although there have been a number of underground sewage plants
successfully constructed and operated in China, targeted design standards and operation management standards for underground sewage plants have not yet been formed, and the current operation status of existing underground sewage plants still needs to be evaluated and summarized through continuous practice. According to the characteristics of underground sewage plants, there are three prominent problems in the design process of the building major: fire protection design, waterproof design and ground landscape design.

2. Project Overview
Lanzhou Anning Qilihe Sewage Plant is located in the north of the west section of Beibinhe Road. The underground productive structure (building) is an underground two-story (local three-story) buried steel concrete box. The civil work of the box is reserved at 400,000 m$^3$/d, and the equipment is configured at 300,000 m. The buried steel concrete box includes: Coarse grille and lifting pump room, fine grille and aeration sand sink, membrane grille, primary sedimentation tank, MBR biological tank, MBR membrane tank, membrane equipment workshop, blower room, recycling water tank and recycling water pump room, UV disinfection room, sludge treatment workshop, mud storage tank, as well as auxiliary deodorization room, distribution room, carbon source feeding room, fire fighting pool and pump room, etc. The total land area of the plant is 108211.00 ㎡, the cabinet covers an area of 86,000 ㎡ (281m×306m); the total construction area is about 187428.97 ㎡.

The ground is mainly composed of green landscape, and the thickness of the covering soil is about 1.5m. It is divided into two areas: the front area of the plant and the open ecological park. The front area of the plant is mainly equipped with a five-storey comprehensive office building (local six floors) and a 10KV distribution room, covering an area of 23,000 ㎡, and an ecological park open to the outside world of 63,000 ㎡.

![Figure 1 Lanzhou Anning Qilihe Wastewater Treatment Plant](image)

3. Fire Protection Design

3.1 Building Fire Hazard
The project mainly adopts the improved A2O + MBR membrane process in the sewage plant for the urban sewage collected through the pipeline, and the effluent is discharged after ultraviolet disinfection or reused after sodium hypochlorite disinfection, with the production fire risk of class E. The underground sewage plant is a reinforced concrete tank with less combustible materials and is normally unattended. Only the operation and management personnel conduct regular inspections. Most of the underground floors are sewage treatment structures (the total surface area of the underground floor is about 60000 ㎡), such as coarse and fine grid aeration grit chamber, membrane grid, primary sedimentation tank, biochemical tank, membrane tank, recycling tank, etc. which contain
water and occupy about 70% of the building area of the lower floor. The underground floor (part of the interlayer) is the auxiliary equipment room of the sewage plant. The fire risk of the distribution room is C, and the others are E.

The front area of the above-ground plant includes the comprehensive production management building and 10KV transformer and distribution room. The comprehensive building is a multi-storey public building, mainly including production office, laboratory test, staff canteen, duty rest, etc. The building height is 21m, which is a multi-storey public building, and the fire risk of 10KV transformer and distribution room is a two-storey class C workshop.

3.2 General Layout Fire Protection Design

According to the provisions of clauses 3.4.1, 7.1 and 7.2 of GB 50016-2014 (2018 edition) Code for Fire Protection Design of Buildings, the fire protection spacing between buildings and structures on the ground meets the requirements of Class C factory buildings and civil buildings ≥10m. A hardened site is set up around the integrated production management building and power distribution room in the front of the plant to meet the needs of fire lanes and rescue sites. At the same time, in the open park area, a circular fire lane with a width of 5 meters is set, and the radius of the road flat curve is not less than 12m.

3.3 Building Fire Protection Design

3.3.1 Interpretation of Current Norms and Standards

(1) Fire prevention zoning

Articles 3.3.1 and 3.3.3 of the current code GB50016-2014 (2018 edition) stipulate that the maximum allowable building area of each fire compartment of underground Class E factory building is 1000 m². When an automatic fire extinguishing system is installed in the factory building, the building area of each fire compartment can be doubled, i.e. the maximum allowable building area of each fire compartment is 2000 m² (when an automatic fire extinguishing system is locally installed, the increased area of its fire compartment can be calculated as twice the local area). If this project is strictly carried out in accordance with this regulation, each floor underground of the box body has a construction area of about 86000 m², the first floor underground needs to be provided with not less than 43 fire prevention zones, and the second floor underground needs to have a construction area of about 26000 m², excluding the parts of sewage treatment structures such as coarse and fine grid aeration grit chamber, membrane grid, primary sedimentation tank, biochemical tank, membrane tank, reuse tank, etc. that contain water, and requires not less than 13 fire prevention zones, and the construction area of local underground three floors and interlayer is about 11600 m², requiring not less than 6 fire prevention zones. According to the “Building Design Fire Protection Code” GB50016-2014 (2018 version) 3.7.3, when the underground powerhouse has multiple fire zones arranged adjacent to each other and separated by a firewall, each fire zone can be opened to the adjacent wall by using a firewall. Class A fire doors in the fire zone are used as the second safety exit, but each fire zone must have at least one independent safety exit through the outdoor. According to this regulation, the project needs to set up no less than 43 independent safety exits for direct outdoor use.

(2) Evacuation distance and width

In the design of this project, the evacuation distance is strictly in accordance with the regulations. The straight distance from any point in the Class E factory building to the nearest safety exit is not more than 60m, and the straight distance from any point in the local Class C part (power distribution room) factory building to the nearest safety exit is not more than 30m. Due to the gradual improvement of modernization and intellectualization of the sewage treatment plant, the personnel quota of the sewage treatment plant is 50. The minimum width of the evacuation staircase, the evacuation aisle and the door in the workshop can meet the minimum specified in the code.

(3) Evacuation staircase installation
Smoke-proof staircases are installed in the sandwiches with buried depth greater than 10m and in the second and third floors of the underground. The upper space of biochemical pools and membrane pools is buried depth of 7m and enclosed staircases are installed. On the first floor of the staircase shared by underground and above ground parts, fire partition walls with fire resistance limit of not less than 2h and Class B fire doors are used to completely separate the underground and above ground connecting parts.

(4) Fire elevator installation

Articles 7.3.2 and GB50016-2014(2018 edition) of the current code “Code for Fire Protection in Architectural Design” stipulate that underground or semi-underground buildings (rooms) with a buried depth of more than 10m and a total construction area of more than 3000 ㎡ shall be equipped with fire elevators, which shall be set in different fire zones respectively, and each fire zone shall not be less than one. According to the actual situation of the project, the buried depth of the second floor and interlayer of the project is more than 10m. There are 19 fire-fighting zones, and no less than 19 fire-fighting elevators need to be installed.

3.3.2 Interpretation of Similar Norms and Standards

Referring to the requirements of other underground space in China, such as “Code for Metro Design” (GB50157-2013), the platform and Hall of underground station should be divided into a fire protection zone. When underground transfer station shares a fire protection zone, the public area of the hall should not be greater than 5000. “Code for Fire Protection Design of Garage, Repair Garage and Parking lot” (GB50067-2014): Underground parking garages equipped with automatic sprinkler fire extinguishing systems with fire resistance rating of Class I and Class II have a maximum construction area of 4000 ㎡ in each partition. According to the Code for Fire Protection Design of Hydropower Projects, the maximum allowable building area of fire protection zones for non-ground auxiliary workshops and closed auxiliary workshops is 2,000 ㎡. With reference to the Code for Fire Protection Design of Buildings, the building area of each fire protection zone can be doubled, that is, the maximum allowable building area of each fire protection zone is 4,000 ㎡. Compared with the subway station hall and the underground parking garage, the underground sewage treatment plant has less combustibles and is unattended under normal conditions. The combustibles and people flow are much less than the subway station hall and underground parking lot. In addition, due to modernization, the sewage plant has a high degree of automation and few operation and management personnel. Each operator has received strict training before going to work. He is very familiar with the working environment and can quickly reach the evacuation port when a fire occurs. Therefore, the underground sewage plant is divided into fire zones. The area requirements should not be higher than the subway station hall and underground parking lot. According to the operation and maintenance requirements of underground sewage plant and hydropower plant, there are many similar places, all of which have the characteristics of large plant space, few combustible materials, and production technology requiring space connectivity. At the same time, the production fire risk category of the auxiliary powerhouse of the hydropower project is Category D, which refers to the terminal auxiliary powerhouse with the central control room and other personnel on duty uninterruptedly. The fire risk category and the personnel on duty of the auxiliary powerhouse are higher than that of the underground sewage plant for fire protection design. Therefore, the requirement of the fire protection zoning area of the underground sewage plant should not be higher than that of the non-ground auxiliary powerhouse and the closed auxiliary powerhouse in the hydropower project.

3.3.3 Case Analysis of Similar Projects At Home and Abroad

At present, the sewage treatment plant with a scale of 100,000 m³/d and above has been built in the domestic underground sewage treatment plant, Qingdao High-tech Zone Wastewater Treatment Plant (180,000 m³/d), and the area of a single fire protection zone is not more than 4000. ㎡; Taiyuan Jinyang Sewage Plant (320,000 m³/d) has a single fire prevention zone area of not more than 3,000 ㎡;
The total underground sewage plant in Zhengding New District of Hebei Province (100,000 m³/d) has an area of no more than 4,000 m², and the area of individual fire zones of other large-scale sewage plants has basically broken through the requirements of “Code for Fire Protection Design of Buildings” for underground plants.

3.3.4 The Actual Practice of Building Fire Protection Design in This Project

As compared with other production workshops, the underground sewage plant has less combustible materials and is unattended under normal conditions. Only the operation and management personnel conduct regular inspections and adopt MBR membrane new materials, new processes, new technologies and other characteristics. Referring to similar cases, the design of this project partially breaks through the provisions of the current codes and standards, mainly including the area of some fire zones exceeding the standard limits, the safety exits of some fire zones being shared, and the setting of fire elevators being appropriately deleted. Relevant strengthening measures have been taken for those parts that break through the code. Common fire prevention zones are directly connected to outdoor safety exits. Class A fire doors are used for fire doors in front rooms or stairwells installed on firewalls. Fire zones where fire elevators need to be installed but no fire elevators need to be installed are all miniature fire stations near the evacuation stairwell. If strictly according to the current norms, 43 independent outdoor safety exits, 19 fire-fighting elevators and corresponding elevator rooms, plus fan rooms, deodorizing towers, air supply and exhaust shafts, equipment hoisting holes, etc., need to be set up. There are too many small structures on the ground, which seriously affects the shaping of the landscape of the ground ecological park.

According to Article 16 of the Regulations on Fire Supervision and Management of Construction Projects (Decree No. 119 of the Ministry of Public Security), new materials, processes and technologies to be used in the design documents may affect the fire safety of the construction project and do not conform to the national standards. Referring to the application examples of similar projects that have been implemented at present, and entrusting departments with relevant qualifications to carry out fire safety assessment of fire protection design documents, the fire control institutions of the provincial people's government, together with the administrative departments of housing and urban and rural construction at the same level, can hold a special fire protection demonstration meeting to discuss and pass the meeting before putting it into use.

4. Waterproof Design

As the project is a fully buried underground sewage plant and is designed to face the Yellow River, most of the structures are of two underground layers (partial three layers) and the elevation of the foundation bottom surface is 1509.3m. According to geological exploration, the proposed site is adjacent to the Yellow River and the groundwater is closely connected with the water power of the Yellow River. The exposed groundwater level elevation is 1519.27~1521.24m. The groundwater in the site mainly exists in the pebble layer. It belongs to the Quaternary loose rock type pore diving. The groundwater flow direction is from northwest to southeast. The groundwater recharge mode is mainly the atmospheric recharge and runoff recharge of groundwater. The excretion method is mainly atmospheric evaporation and underground run-off. According to regional hydrological data, the groundwater level varies with the season, with a maximum variation of about 1.0 to 1.5 m. As a large-scale underground concealed project, and to avoid pollution of groundwater caused by leakage of sewage from the pool, underground waterproof design is particularly important.

1) Waterproof grade: considering the importance of the project, six power transformation and distribution rooms of different sizes are arranged in the box, and the upper part is a landscape park, so the underground waterproof grade is designed as grade I.

2) Waterproof and defense measures: the depth of burial of underground box is 18.6m, waterproof concrete is used in the main structure of water-facing surface, and the anti-seepage grade of waterproof concrete is P8. At the same time, the use function, service life, hydrogeology, structural form, environmental conditions and construction methods are considered comprehensively. For the
main structure, a pre-laid anti-sticking polymer waterproof material is selected outside the self-waterproof structure (the top plate is provided with a root puncture resistant waterproof material with a root blocking agent on the upper part of the common waterproof layer). The construction joints shall be equipped with buried waterstop+external waterproof coating. The post-cast strip shall be made of shrinkage compensating concrete+externally attached waterstop+waterproof sealing material. The deformation joint adopts buried waterstop+waterproof sealing material+external waterproof coiled material.

5. Ground Landscape Design

Sewage treatment itself is an environmental protection project, so environmental design is of vital importance. In the landscape design, efforts are made to integrate the ground production management buildings (structures), greening arrangements and architectural sketches of the whole plant area with the landscape greening of the Yellow River amorous feelings line to form a pleasant, fresh and elegant external landscape with unique style.

![Surface landscape design sewage treatment engineering drawing](image)

Figure 2  Surface landscape design sewage treatment engineering drawing

The project aims to transform the landscape of the sewage plant and embody the design concept of ecological green. The upper green landscape design is based on the principle of combining rest, swimming and playing, with leisure entertainment and ecological recreation as its main functions, supplemented by appropriate display and education functions, which is conducive to enhancing citizens' awareness of environmental protection. Combined with the upgrading and reconstruction of the sewage plant, the existing beautiful landscape of the Yellow River Customs Line will be fully utilized to plan in a scientific and systematic way, creating a harmonious and vibrant living environment that conforms to the local humanistic characteristics and specific ecological relationships. The public provides an ecological open-plan event venue with reasonable layout, beautiful environment and leisure and entertainment functions.

According to the technological process, the top of the box body is covered with different thickness of soil. According to the specific situation, tree species are reasonably selected, and ground cover, flowering shrubs, trees, etc. are arranged in combination to form an ecological landscape with green in the four seasons and flowers in the three seasons. At the same time, the use of purified water from sewage plants to create surface waterscape can intuitively show Lanzhou citizens the changes from sewage to reclaimed water.

5.1 Landscape Concept

The project is conceived as the concept of “Peach Blossom Stream, Shuiyun” of Silk Road Flower. Sewage treatment plant will be built as a demonstration site of garden factory to create a green ecological factory environment. Unlike the fast-paced urban life in the central urban area, the ground ecological park offers another possibility of life, that is, a quiet green life. Convenient transportation can be at arm's length from the city center, providing healthy life choices for the surrounding
population. At the same time, the base uses the local characteristic element “peach blossom” in Anning of Lanzhou city as its composing method, combining water, forest, cloud and flower, giving the plot more social significance and humanistic care, and the plot will also carry more local cultural context and land use efficiency, which has a great demonstration effect on the construction of multi-level compound urban green space in this area.

5.2 Main Entrance Landscape
The landscape of the main entrance uses the particularity of the terrain to treat the elevation difference as a degraded green landscape. At the same time, the facade of six large suction towers is modified to strengthen the functional publicity, weaken its volume and integrate into the landscape. The entrance gate adopts the architectural creativity of “door” shape, which organically connects the rigid building of the ground entrance and exit, integrates the landscape and highlights the theme. Slowly up the steps, let the entrance landscape enhance the sense of ritual, hierarchy, publicity and display, so that the pedestrian traffic on Beibinhe Road can feel the overall simple and green level of the entrance image.

5.3 Pedestrian Entrance and Exit Design
There are many pedestrian entrances and exits in the site. In the design, weatherproof steel is used to decorate the exterior facade. Each entrance corresponds to a treatment workshop in the underground plant area, such as coarse grille, primary sedimentation tank, membrane tank, sludge dewatering room, etc. Therefore, in the design of the facade, the sewage treatment process is reflected, and corresponding to each entrance and exit, so that visitors can understand the relevant knowledge of sewage treatment when having a rest and sightseeing, combine teaching with pleasure, and highlight the participation of the landscape.

5.4 Landscape Avenue
The landscape avenue in the park meanders and occupies, showing the graceful curve in combination with the terrain. Landscape avenue combines design of strolling road and riding system. A pedestrian slow-moving system is designed on the right side of the road, which is distinguished by the paving color of the road. The design of the slow-moving system and the fast-moving system better combed the traffic flow in the park, facilitating visitors and improving the safety factor in the park.

Walking on the avenue, peach blossoms burning on both sides, as if in the modern “Peach Blossom Source”.

5.5 The Leisure Platform of the 100-Meter Flower Path
The height of the top plates of the two rectangular sites on the south side of the site is 3.5m different from the height of the top plates of the underground box body, and the earth covering is relatively shallow. The design uses the elevation difference to design the step-down greening. The platform is designed with the “100-meter flower path leisure platform” taking “peach blossom” as an element. On this basis, we can see the flower energy landscape can move, make use of the platform, strengthen the
functionality, and facilitate people to experience the landscape space from different perspectives.

6. Conclusion
Underground sewage treatment plants are widely used in foreign countries, and many cities in China have begun to implement them. Because the underground sewage treatment plant is totally enclosed, it has little influence on the surrounding environment and has strong coordination with the surrounding environment. It can save land resources and stimulate the land market around the plant area. It is especially suitable for construction in economically developed areas where land resources are highly tense and environmental requirements are high. In the long run, it also meets the requirements of the scientific development concept of resource conservation and harmonious development between human and nature. At present, there are no professional codes and standards for its fire protection design, but there is no trivial matter in the fire protection responsibility. Great attention should be paid in the design. It is necessary to ensure the premise of safe operation of the sewage treatment plant, but excessive fire protection is not recommended at the same time. It is recommended to simplify the design appropriately and save investment.

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