Research on Application of Environmental Protection Dredging Construction Technology in Environmentally Sensitive Areas

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Abstract. At present, there are few cases about the implementation of environmental protection dredging project in China's environmentally sensitive areas, and there is a serious lack of relevant project implementation experience. This paper combines the basic characteristics of environmental dredging in environmentally sensitive areas, and takes Xiangyang City's moat dredging project as an example to analyze the difficulties in the implementation of the project, mainly including the control of construction impact, compliance with schedule, prevention of secondary pollution, and sludge. In order to solve these problems, the project mainly adopts targeted measures to minimize the impact of project construction; in order to realize the scheduled implementation of the sludge disposal mode using 6000m³ of daily dredging and dredging combined with the industrialization mode; The project successfully prevented potential secondary pollution risks during construction through the use of environmentally friendly cutter heads, integrated ultra-magnetic separation equipment and specialized sludge conditioning agents; finally, the combined use of soil improvement soil outside the mud cake and landfill for external transportation successfully solved the silt digestion problem of the project. At the same time, through the pilot test of sludge resource utilization, two major soils for mud cake production engineering and landscaping were developed Process products lay a solid foundation for the multi-channel comprehensive utilization of sludge.

1. Introduction

Dredging is mainly divided into engineering dredging and environmental dredging according to its purpose. The former is mainly used for capacity expansion and cross-section expansion. It is mostly used for channel dredging and reservoir expansion. The latter is mainly used to eliminate internal pollution and is mostly used for water environment treatment of landscape water bodies, rivers, lakes, etc.

Environmental protection dredging is one of the effective methods for water environment improvement projects in environmentally sensitive areas, and it is also one of the pre-engineering projects. However, due to the particularity of environmentally sensitive areas in terms of geographical
Based on the special situation of environmentally sensitive areas, this paper combined with the actual case-Xiangyang City Moat Desilting Project, studied the environmentally friendly dredging construction technology in environmentally sensitive areas, with a view to providing reference and reference for similar projects.

2. Project Introduction

The Xiangyang City Moat Desilting Project is one of the key livelihood projects in Xiangyang City, and it is a typical internal source river treatment project in environmentally sensitive areas.

The moat of Xiangyang City is located in Xiangcheng District of Xiangyang City. It has a long history and is an important scenic spot in Xiangyang. The moat of Xiangyang City is 4700m long and has an average width of 130m. It is the widest moat in Asia with a total water area of $61.1 \times 10^4 \text{m}^2$.

The dredging scope of this project is Xiangyang Park to Nanmen Bridge (pile numbers 0+000~2+266, that is, areas B1 and B2 in Figure 2 with a bridge between B1 and B2), Minzhu Road Bridge to Madam City (3+360~4+700, that is, there are bridges between A1, A2, and A3 in Figure 2, between A1 and A2, and between A2 and A3), the total length is 3606m, the thickness of silt is 0.33~0.95m, and the dredging area is $547864 \text{m}^2$. The total dredging capacity is $35.48 \times 10^4 \text{m}^2$. The total construction period of this project is 120 calendar days, and it is implemented by EPC mode.
3. Analysis of Difficulties in Implementation of the Project
The Xiangyang City Moat Desilting Project involves environmentally sensitive areas and needs to complete the dredging, silt treatment and digestion of $35.48 \times 10^4 \text{ m}^2$ within 120 days. It is difficult to implement. The implementation difficulties are summarized as follows:

1. Minimize the impact of dredging on the surrounding area
   The inner bank of the moat of Xiangyang City is close to the ancient city wall, the other bank is close to the houses and shops, etc., and the northern side is close to the Han River. There are many leisure people and tourists in the surrounding area. Minimizing the impact on the surrounding area during the dredging construction is the problem of this project.

2. Ensure compliance
   The construction period is only 120 calendar days, and there are many projects to be completed, including environmental impact assessment, survey and design of the project, civil installation of the sludge disposal center, dredging of $35.48 \times 10^4 \text{ m}^2$ silt, silt treatment, silt digestion, completion acceptance, etc., considering that the preliminary procedures and temporary construction will take about 45 days, and the actual construction time is only about 70 days. According to calculation, the daily dredging amount and the daily sludge treatment amount are up to 5068 underwater natural side. and the moat is an environmentally sensitive area and the lack of surrounding construction land is not conducive to the large-scale construction. Therefore, whether the contract can be fulfilled on time is problem of this project.

3. Prevent secondary pollution during construction
   There are three main areas that are likely to cause secondary pollution in this project: First, during the dredging process, due to large-scale mechanical operations, it is easy to cause water disturbances and then cause sludge diffusion; Second, the moist sludge has a water content of up to 70%. If it is not handled properly, it is easy to secondary sludge and cause secondary pollution. Third, during the sludge treatment process, a large amount of high ss tail water will be generated.

4. Digestion of silt
   The dredging capacity of this project is as high as $35.48 \times 10^4 \text{ m}^2$. The conventional silt digestion method is generally landfill. However, the landfill capacity around the moat are limited in capacity and cannot accept such a large amount of silt. Therefore, its ultimate rational consumption is one of the difficulties of the project.

4. Research on environmental protection dredging construction technology

4.1. Low impact dredging construction technology
   In order to minimize the impact of construction on surroundings, the project mainly adopts the following measures:
   
   1. Water dredging operation
      In order to ensure the normal landscape function of the moat and the normal recreation and recreation of surrounding residents, this project adopts the environmental dredging operation method. Compared with the traditional dry dredging, the environmental dredging without water drainage The rear silt is exposed and foul odor, and there is no dust, noise, and traffic control caused by frequent entry and exit of construction machinery. At the same time, it will not be restricted by weather factors.
In this project, an environmentally friendly cutter suction vessel with a flow of 800m$^3$/h will be deployed in Area A, and an environmentally friendly cutter suction vessel with a flow of 1500m$^3$/h and a flow of 2000m$^3$/h will be deployed in Area B, and strictly practice 6:00~22:00 stipulates that its actual stable daily production capacity can reach 6,000 sludges below the water. Considering the dredging vessel transfer, shutdown and other emergency situations, considering 10 days of free time, all dredging operations can be completed within 70 days.

(2) Ectopic disposal of sludge

Considering that there is no silt disposal land and no implementation conditions of the moat extension line, the project adopts closed pipelines to transport the sludge to the red area (sludge disposal center) shown in Figure 2 for centralized treatment and external transportation. This area occupies an area of about 16,000 square meters, and the linear distance from the moat is about 500m. It is an empty space for demolition and all areas are to be demolished.

In addition, when laying the mud pipeline, the form of immersed pipe plus floating pipe is adopted, and the floating pipe is as close to the shore as possible to minimize the interference of the pipeline on the river cruise ship; when the mud pipeline crosses the sidewalk, the slope is erected and post warning signs to ensure normal traffic and repair after completion.
(3) Strengthening the protection of structures
When the cutter suction construction is carried out near the structure, the lower edge of the protected part of the moat on both sides, the plank roads on both sides and other structures are reserved with a safety distance of 2m (the lower edge is determined according to the actual situation), the slope ratio is 1:3 and then it is connected with the elevation of dredging control at the bottom of the river and adopts the method of digging into slopes. At the same time, the management staff is supervised by the station and closely inspected to ensure the safety and stability of the structure. Special personnel are used to observe and analyze the total station to understand the deformation of the structure; during actual construction, the supervision and design units should be promptly brought to the scene to resolve the risk areas where the construction according to the plan has a great risk of destabilizing the structure.

4.2. Construction technology for efficient sludge treatment and disposal
This project realizes the efficient treatment and disposal of sludge through the construction of a sludge disposal center (Figure 4). The adopted technology is the national-level engineering method-integrated treatment of sludge dehydration and consolidation in rivers and lakes. This process can realize the industrial operation of sludge treatment. Sludge slurry with a moisture content of 90% or more can be processed into a mud cake with a moisture content of 40% or less, and disinfection, passivation or consolidation of heavy metals, microorganisms, bacteria and other harmful substances can be completed as required. It is a set of sludge treatment system that can directly interface with commonly used dredging ships (especially environmental protection cutter suction ships), and is especially suitable for the ecological restoration of urban landscape water bodies with small construction sites and scarce land resources.
According to the production process, the sludge disposal center has four major systems: 

1. Pretreatment system

The pretreatment system mainly includes two units, a sedimentation tank and a mud tank. 

The sedimentation tank is designed as a steel-concrete advection sedimentation tank with a size of length×width×height= 23.6m×7m×2m, and its main function is to dissipate impurities (mud, stones, bricks, etc.). There are two rotary mechanical grids at the end of the sedimentation tank, the grid spacing is 10mm, and the plane size is 6m × 3.6m. It mainly intercepts domestic garbage and clam shells in the mud.

Taking into account that 2 meters below the ground in the mud pool area is backfilled soil, 2 to 5 meters below the ground is muddy soil, the soil quality is poor, and the groundwater level is high. In order to ensure the safety of the mud pool storage capacity and cofferdam structure, the mud pool uses the Larsen steel sheet pile and soil cofferdam. The designed mud storage tank of this project covers an area of about 7,230 m², the designed depth is 4.5m, the total designed storage capacity is 32,535m³, and the effective storage capacity is 28,920m³. After the pre-settlement of the cutter suction mud in the mud pool, the concentration can reach about 20% (original concentration is about 5%).

![Fig. 6 Integrated treatment process of river and lake silt dehydration and consolidation](image1)

![Fig. 7 Sedimentation tank (left) and mud tank (right)](image2)
(2) Conditioning and modification system

The conditioning and modification system\cite{2} is mainly composed of two units, a material addition system and a homogenization tank.

This project is equipped with a set of material adding system, including two 80m³ vertical storage tanks, two horizontal mud mixers (one for one use), two pharmaceutical systems (one for one use), and one material warehouse. The mud in the mud pool is conveyed to the horizontal mixer by the small cutter suction boat in the mud pool. The pharmaceutical system pumps the prepared conditioning agent solution into the slurry mixer at the same time. The tank is fully reacted to complete the conditioning process. The homogenization tank of this project is designed as a steel-concrete structure with dimensions of length×width×height=35m×16m×2.5m.

![Fig. 8 Material addition system (left) and homogenization tank (right)](image)

The conditioning agents used in this project mainly include three types of SWHB-A, SWHB-B, and SWHB-C. Agent A mainly allows colloids in the sludge to overcome the repulsive force between particles, and promotes the particles to flocculate and settle to achieve the effect of destabilization. Therefore, the sedimentation and dewatering performance of the sludge can be improved; the agent B can mainly destroy the structure of the sludge floc, so that more capillary bound water and surface adhesion water can be converted into free water; the agent C can mainly strengthen the floc skeleton and form more water outlet channels.

![Fig. 9 Conditioning agents SWHB-A(left)、SWHB-B(middle) and SWHB-C(right)](image)

(3) Mechanical dewatering system

This project is mainly equipped with 8800 flat diaphragm plate and frame filter presses for sludge dewatering system [1,3]. The 8 filter presses are arranged in two rows side by side in the dewatering plant. The size of the entire plant is length×width×height=79.6m×15.2m×9.6m.
After conditioning, the slurry is pumped to each filter press by 890KW feed pumps, the feed pressure is about 0.8MPa, and then passes through a series of processes such as squeezing, pressure relief, back blowing, and discharging, and finally forms a water content of less than 40%. Hard plastic mud cakes (Table 1), and the remaining water from the filter press flows into the mud pool through the pipe.

**Table 1. Quality test results of mud cake**

| Detection Indicator | Test Results | Limits of ‘urban quality for land improvement of sludge disposal in urban sewage treatment pants’ |
|---------------------|--------------|-------------------------------------------------------------------------------------------------|
| pH                  | 8.26         | 5.5~10                                                                                           |
| Water content(%)    | 37.5         | <65                                                                                              |
| Organic matter(%)   | 24.1         | ≥10                                                                                              |
| Total mercury(mg/kg)| 0.172        | 15                                                                                                |
| Total chromium(mg/kg)| 48.9       | 1000                                                                                             |
| Total arsenic(mg/kg)| 22.1         | 75                                                                                                |
| Total lead(mg/kg)   | 62.2         | 1000                                                                                             |
| Total copper(mg/kg) | 28.1         | 1500                                                                                             |
| Total zine(mg/kg)   | 85.5         | 4000                                                                                             |
| Total cadmium(mg/kg)| 0.31        | 20                                                                                                |
| Total nickel(mg/kg) | 25.7         | 200                                                                                              |

In this project, each filter press cycle is stable for about 70 minutes, and the dewatering workshop can achieve continuous operation for 24 hours. The full capacity of eight 800-type plate and frame filter presses can reach 7000 sludge below the water every day, and finally can produce mud cakes 2,200 square meters[4], that is, the sludge disposal center can fully match the progress of water dredging operations, and can complete the treatment of $3.548 \times 10^4$ m$^2$ silt within 70 days.

### 4.3. Environmental pollution prevention dredging secondary pollution prevention technology

Aiming at the potential secondary pollution risk points of this project, the following measures are taken to prevent and control:

1. **Prevention and control of silt diffusion during dredging**

   First, the three dredging vessels of this project are equipped with environmental protection cutter heads. The cutter heads are equipped with a solid steel protective cover. During the cutter suction operation, the cutter cutter rotates and cuts the bottom mud in the hood, which only causes disturbance of the mud water in the hood, and the mud water in the hood can be sucked away by the mud pump in time, thereby reducing the spread of the sludge.
Fig. 11 Environmental cutter

In addition, during the cutter suction operation, the surface layer of mud is "sucked without stirring", and the bottom sediment is "sucked and used" to minimize the secondary pollution and silt escape losses caused by the cutter suction process.

(2) Prevention and control of secondary sludge

During the sludge treatment of this project, three conditioning agents: SWHB-A, SWHB-B, and SWHB-C, were used in combination to modify it. The nature of the sludge has fundamentally changed. In addition, the modified sludge was subjected to plate and frame compaction. After filtration, its water content has dropped to less than 40%, and it is a hard plastic mud cake, which has good water stability and strength, and the remaining water will not be re-sludged, which can ensure the sludge during landfill or comprehensive utilization safety.

(3) Tail water purification treatment

The tail water of this project is mainly the surface overflow water at the end of the mud pool. Combined with the effluent requirements of this project, a tail water treatment zone is set up at the end of the mud pool. A total of two 10,000m$^3$/d ultra-magnetic separation integrated equipment is configured, covering an area of about 1500m$^2$. This project uses a lift pump to drive the tailwater into the supermagnetic separation system. After adding PAC, PAM agent, etc., it is mixed and stirred to form a micromagnetic floc, which flows into the supermagnetic separator freely. After the supermagnetic machine is salvaged, SS removal rate reaches 90–95%, algae removal rate is more than 95%, TP removal rate is 80–90%, COD removal rate is 40%–60%, and it has reached the level specified in the Comprehensive Wastewater Discharge Standard (GB8978-1996). The tail water finally enters the municipal sewage pipe network. The quality of the tail water after treatment is shown in the table below.

| Detection Indicator | Test results | Integrated waste water discharge standard |
|---------------------|--------------|------------------------------------------|
| pH                  | 7.54         | 6–9                                      |
| DO(mg/L)            | 5.00         | --                                       |
| COD$_{mb}$ (mg/L)   | 4.3          | --                                       |
| SS(mg/L)            | 42           | 70                                       |
| COD(mg/L)           | 16           | 20                                       |
| TP(mg/L)            | 0.09         | 8                                        |
| NH$_4^+$-N(mg/L)    | 0.117        | 15                                       |
| TN(mg/L)            | 0.20         | --                                       |
4.4. Comprehensive Utilization Technology of Silt

(1) Use nearby

Due to the limited capacity of the muck field around the moat, the mud cake volume of this project is about $15 \times 10^4$ m$^2$ (silk volume below the water: mud cake volume $\approx 3:1$). The way out of mud cake is a big problem restricting the implementation of this project. According to the preliminary survey, The Central Park under construction in Yuliangzhou needs a lot of land for soil improvement. According to the mud cake analysis results in Table 1, it can be known that the moat silt is non-toxic and harmless, and its moisture content and organic matter can meet the standards for land improvement. Therefore, the treated mud cake has the basic conditions for land improvement. After coordination among various parties, this project will eventually be partially dehydrated. The mud cake was transported to Yuliang Island for use as soil for land improvement.

(2) Resource utilization

The difficulty in disposing silt is a common problem of environmental protection dredging projects, especially for environmentally sensitive areas, there are few surrounding waste slag yards, and the capacity is limited. As land resources become increasingly tight, the number of waste slag yards will be gradually reduced, making the problem of silt difficult to be absorbed gradually enlarged. To solve this common problem, the multi-channel comprehensive utilization technology of developing sludge is the only solution.

In order to explore the multi-channel comprehensive utilization method of sludge and to promote the standardization of sludge comprehensive utilization and disposal technology, the project conducted a pilot test of sludge resource utilization. In this pilot project, the results of the preliminary pilot test were used, and the mud cake was used as the raw material to modify the mud cake to produce qualified garden planting soil and engineering soil. The design scale of pilot production is 100t/d, and the pilot period is 3 months. It is mainly equipped with a 1m$^3$ concrete mixer and a batching belt scale.

In this pilot test, engineering soil made from silt is mainly mixed with inorganic fine aggregate and a small amount of gelling materials, and after the processes of dispersion, stirring, and curing, it can produce engineering soil that meets design requirements. The added amount of decemented cake can reach 85% -95%, and the prepared engineering soil has no secondary pollution, and can be used for backfilling of road subgrades, dikes, depressions, and foundation pits in construction projects[5-7].

![Engineering soil prepared from silt(left), subgrade filling test(middle) and compaction test(right)](image)

This pilot test uses the engineering soil produced by mud cake to conduct subgrade filling tests. After testing, the subgrade compaction can reach 94%.

The preparation of garden soil by sludge mainly uses the nutrients such as nitrogen, phosphorus and organic matter present in the sludge. By adding straw, microbial inoculants, etc., and through processes such as stirring and curing, the garden soil with excellent performance can be prepared. and its relevant technical indicators fully meet the standard "Sludge Disposal of Urban Sewage Treatment Plants-Mud for Garden Greening ".
In this pilot test, a planting verification experiment was carried out using the soil used in the production of mud cakes. After half a year's observation, it was found that all the plants were growing well, indicating that the garden soil prepared by this process is feasible.

5. Conclusion
This project is a typical environmentally-friendly dredging project in an environmentally sensitive area. During the construction operation, it is difficult to implement the project due to factors such as the operating environment and the construction period. It is mainly reflected in the control of construction impact, performance on schedule, prevention of secondary pollution. In response to these four major problems, one of the project is through targeted measures to minimize the impact of the construction of the project; the other is through the use of cutter suction dredging processing factory mode under the average daily 6000 m$^2$ water. The sludge disposal has completed the main project construction within 70 days to achieve the scheduled performance; thirdly, the three potential secondary pollution risks of silt diffusion, tailwater pollution, and secondary sludge sludge were prevented through the use of environmentally friendly suction tips, integrated equipment for ultra-magnetic separation, and specialized sludge conditioning agents; fourthly, through the combined operation of soil improvement and soil transport outside the mud cake, the problem of silt absorption in this project was successfully solved. At the same time, the mud cake production engineering soil and landscaping soil were developed through the pilot test of sludge resource utilization. Process products lay a solid foundation for the multi-channel comprehensive utilization of sludge.

The implementation experience of this project can provide reference and reference for the design and construction of environmental dredging projects in similar environmentally sensitive areas.

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