Analysis of Site Selection and Design Example of Spoil Ground

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Abstract. As an auxiliary project of engineering construction, spoil ground is often not given enough attention. Unreasonable spoiled materials not only have negative impacts on the local natural environment, but also generate the risk of secondary disasters. The selection and design of spoil ground is an important part of earthwork. And thus it is necessary to select the site of spoil ground reasonably and carefully and carry out detailed design of spoil, protection and flood drainage. First of all, the basic selection principles of spoil ground were discussed in this paper. Then, combined with the spoil ground design of the Heat and Power Cogeneration Power Workshop Project in Zhenfeng County's Coal, Electricity and Metallurgical Integration Industrial Park, the author presented elaboration of the technical key points of site selection, slope stability, blocking engineering and flood drainage system of large-scale spoil ground. The analysis in this paper can be used as a reference for similar spoil ground design.

Keywords: Zhenfeng Project; spoil ground; site selection; design example.

1. Introduction

In the construction of a project, spoil mainly come from the spoiled materials and the unusable excavation after the earthwork allocation. Spoil ground is a place where this kind of materials are disposed of or stacked. The selection and design of spoil ground is an important part of earthwork. And thus it is necessary to select the location of spoil ground reasonably and carefully and carry out detailed design of spoil, protection and flood drainage. If there is no sufficient attention being paid to the location of the spoil ground and the method of spoiling, random spoiling may cause the natural slope to collapse and lose stability, which not only has negative impacts on the local society and natural environment, but also brings difficulties to project governance and even leads to an additional increase in project cost. In order to avoid secondary hazards (landslides, mudslides, etc.) caused by random piles of spoiled materials and excessively high and steep slopes of the spoil ground and to eliminate slope stability and engineering hazards, the spoil ground must be designed reasonably [1-3].

Based on the current design specifications, combined with the Heat and Power Cogeneration Power Workshop Project in Zhenfeng County's Coal, Electricity and Metallurgical Integration Industrial Park (hereinafter referred to as Zhenfeng Project) spoil ground that the author participated in the design, this paper systematically introduced the key points of spoil ground design technology, hoping to provide reference for related engineering design.
The construction of Zhenfeng Project is a 4×1100t/h supercritical, primary reheating circulating fluidized bed boiler + 4×350MW supercritical cogeneration unit. This project has a large amount of spoiled materials. The site of the plant cannot meet the requirements for spoil stacking, and thus another spoil ground is needed. The spoil ground is located on the southwest side of the power plant, in Zhedong Village, Baiceng Town, Zhenfeng County, Guizhou Province. It is connected by rural roads and the spoiled materials can be transported by vehicles. The maximum pile height of the spoiled materials is about 68m, the storage capacity is about 705×10^4 m^3 and the land acquisition area is about 34 hectares, which can meet the storage requirements of the spoiled materials of the power plant. Due to the long construction period of this project, the top of the spoil ground can also be used as a temporary living area for all parties involved in the project construction after the spoil ground is completed.

2. Basic principles for site selection of spoil ground

According to the author's experience in the hydraulic structure design of thermal power plants, the source of spoiled materials in the spoil ground in the past was mainly the earth and stone spoil of thermal power plants, and the spoil was relatively concentrated. Wind power projects have been on the rise in recent years. The author has presided over the spoil site design of several wind plants and found that spoil materials of such kind are relatively scattered. Regardless of whether the spoil is concentrated or scattered, the site selection of spoil ground must consider factors such as the type of spoil ground, stacking plan, geological and hydrological conditions, building materials, construction machinery, and so on. In addition, many other factors such as capacity, haul distance, economy and whether it will cause soil erosion should also be considered. Code for Design of Soil and Water Conservation Engineering (GB51018-2014) (hereinafter referred to as the Code for S&W Conservation) specifies the principles of spoil site selection from many aspects.

In addition, based on years of design experience, the author believed that the following factors should be considered in the site selection of spoil ground: (1) avoid woodland and basic farmland; (2) avoid crushing ore; (3) avoid environmentally sensitive points such as nature reserves, water protection areas and upstream of reservoirs; (4) avoid special-purpose land, such as tomb groups, high-voltage power grids, and high-value-added surface attachment land or high-value industrial land; (5) make full use of waste land around the project.

The site selection process of spoil ground includes preliminary selection of multiple spoil sites, site comparison and selection, and location determination. At the beginning, the relevant personnel involved in the site selection of Zhenfeng spoil ground project roughly circled the stacking points on the topographic map after analysis. Then, we calculated the preliminary spoil storage capacity and related engineering quantities one by one, and determined the final stacking point through site survey, comprehensively taking into account storage capacity, transportation distance, economic efficiency and other indicators. The plane layout of the spoil ground is shown in Figure 1.

![Figure 1. Plane layout of the spoil ground of Zhenfeng Project](image)
3. Design of spoil ground

After the location of a spoil ground is determined, its detailed design can be started when the geological survey and hydrological data are available. The level of the spoil ground needs to be determined according to its capacity, maximum pile height and possible harm to the surrounding environment, following the principles of economy, reasonability, safety and reliability. And the next step is to determine the blocking and flood drainage project level, the spoil ground flood standard and overall stability requirements of the spoil ground. According to the Code of S&W Conservation, the level of the spoil ground of Zhenfeng Project is level 2, and the level of the blocking engineering building is level 2; the flood control standard is designed for once-in-a-century flood and checked according to the standard for once-in-two-century flood.

(1) Calculation of slope stability of the spoil ground

The stability calculation of the spoil ground includes the anti-sliding stability calculation of the side slope and its foundation. The anti-sliding stability should be calculated according to the level of the spoil ground, topography and geological conditions; in terms of spoil stacking form, stacking height, spoil composition and spoil physical and mechanical parameters, the representative section should be selected for calculation. The slope ratio should not be less than 1:1.5.

According to the Code for S&W Conservation, the anti-sliding stability safety factor limit of Zhenfeng Project spoil ground is 1.20 (Swedish circle method), and the slope ratio finally adopted is 1:4.0, which has been calculated to meet the specification limit requirements. In addition, a 8m-wide bridle path is set at every 10m high on the empty slope, and a 300m-wide drainage ditch is set on the inside of the bridle path.

(2) Blocking engineering design

In order to block the spoiled materials and waster slag, a blocking project is built at the bottom of the free slope of the spoil ground. The flood interception spoil ground is usually adopted, and the principle of blocking first and then discarding is adhered to. The initial dam is built first, and the spoiled materials are used to build and heighten the dam in stages above the primary dam. The height of the primary dam should be 8~10m. The primary dams can be grout stone dam, dry stone dam, rock fill dam, etc. The slope protection of the spoil ground can adopt rockfill, dry masonry, mortar masonry, concrete slabs, face bricks (as shown in Figure 2), frame beams, geosynthetics and turf, etc. Materials should be selected based on comprehensive conditions such as spoil site type, design flood level and water flow velocity.

![Figure 2. Paving bricks on the free slope of the Zhenfeng Project spoil ground](image)

The retaining dam of the Zhenfeng Project spoil ground is composed of the primary dams and the later heightened dams. There is a primary dam on the upstream and downstream of the field respectively. The upstream primary dam is a mortar masonry dam with a base anti-sliding stability safety factor limit
of 1.08 and an anti-overturning safety factor limit of 1.45. The downstream stream primary dam is a roller compacted rockfill dam, with a base anti-sliding stability safety factor limit of 1.3 and an anti-overturning safety factor limit of 1.50. The upstream primary dam is about 11m in the dam height, 3.5m in the width of the dam crest and about 56m in dam length, and the inner and outer slopes are both 1:0.5 (as shown Figures 3 and 4 for details). The downstream primary dam is about 16m in the dam height, 4.0m in the width of the dam crest and about 123m in the dam length; and the inner and outer slopes are both 1:2.5 (as shown in Figures 5 and 6 for details). After rechecking with geotechnical calculation software, they meet the specification limit requirements.

The later heightened spoil dam refers to the permanent slope gradually formed by layering and rolling the soil on the initial dam foundation with the pile of spoil, with a slope ratio of 1:4.0. Limestone is widely exposed and distributed in the site, with relatively high strength, and thus these limestone blocks are used as the dam building material.

![Figure 3. Vertical view of the upstream primary dam](image)

![Figure 4. Sectional drawing of the upstream primary dam](image)

![Figure 5. Vertical view of the downstream primary dam](image)
Figure 6. Sectional drawing of the downstream primary dam

(3) Flood drainage design of spoil ground

A perfect ring-shaped flood intercepting ditch should be set up in the spoil ground to intercept and drain the catchment of the surrounding slope surface to prevent surface water from directly eroding and loosening the spoiled materials. This is off-site drainage. If floods tend to concentrate in the upstream of the spoil ground, drainage ditches should also be set up in the spoil ground. In other words, blind ditches, hidden culverts and hidden pipes should be set along the original trench or low-lying terrain at the bottom of the spoil, so that the upstream flood can pass through the dam smoothly. Splayed diversion wing walls should be arranged at the entrance and exit of flood interception ditch and hidden culvert. When the flow rate of centralized flood discharge is high, stilling pools, apron and other water-dropping as well as energy-dissipating facilities should be installed at the exit. After the energy is dissipated, remote transmission should be conducted to prevent water accumulation and erosion at the toe of the spoil ground, so as to keep the safety and stability of the spoil ground.

The inner slope of the flood discharge facility should not be steeper than 1:1, and the size of the cross section of flow should be determined by the surrounding water catchment. The flood intercepting ditch in the spoil ground should be built on the surrounding stable natural slope as far as possible. After the spoil ground reaches the final piled soil elevation, a top closed layer should be set up, and rammed earth can be used as the closed layer. The slope should be found from the middle to the surroundings, with a slope of 3‰ and a thickness of 500mm at the thinnest part, which will help the surface water to quickly flow into the drainage ditches.

The spoil ground of Zhenfeng Project is located at the exit of the gully, and the collected flood flow is relatively large. In the upstream primary dam, the flow rate of once-in-a-century flood was 99.8m\(^3\)/s and that of the once-in-a-century flood was 112m\(^3\)/s. In this context, the interception and drainage capacity of the flood intercepting ditch is insufficient. Therefore, a flood discharge culvert is added along the original trench at the bottom of the spoil ground, and a water inlet bell-mouth is set at the entrance. The bottom plate of the bell-mouth is equipped with an overflow weir and stone pier, and the exit is equipped with a stilling pool and apron (as shown in Figure 7 and Figure 8 for details). Adopting measures suiting local conditions, grouted masonry and brick masonry are adapted as materials of the intercepting ditches (as shown in Figures 9-12 for details).
Figure 7. Top view of the bell-mouth at the entrance of the flood drainage culvert

Figure 8. Top view of the stilling pool at the exit of the flood drainage culvert

Figure 9. A sample of a grouted masonry flood intercepting ditch
Figure 10. A sample of a grouted masonry flood intercepting ditch

Figure 11. Actual view of the grouted masonry intercepting ditch

Figure 12. The actual view of the brick masonry flood intercepting ditch
(4) Requirements for compaction of spoiled materials

The compaction of the spoiled materials plays an important role in the slope stability of the spoil ground. When other conditions have been determined, the higher the degree of compaction of the spoil materials, the greater the angle of internal friction and the more stable the slope. The compaction of earth and stone in the spoil ground shall adopt layered vibratory rolling or dynamic consolidation according to different situations. The layer thickness of the layered rolling zone should be determined by the field rolling test according to the selected construction equipment and filler properties. The layer thickness of the dynamic consolidation area should be determined by trial compaction. The thickness of the back-filled layer should not be more than 5.0m. The dynamic consolidation zone in the spoil ground of Zhenfeng Project is divided into compaction zone and soil piling area. The compaction coefficient of the compaction zone is not less than 0.94, and the porosity is not greater than 25%; the compaction coefficient of the soil piling area is not less than 0.93, and the porosity is not greater than 32%. In a certain range around the flood drainage culvert (as shown in Figure 13 for details) and near the permanent slope, the layered vibratory rolling method should be adopted.

**Figure 13.** Schematic diagram of the banking around the flood drainage culvert

**Figure 14.** Overall view of the spoil ground of Zhenfeng Project
4. Conclusion
Spoil ground is an auxiliary project of engineering construction. If the waste materials are not properly spoiled, it will not only cause soil erosion and severely damage the local ecological environment, but also may cause geological disasters. Therefore, the reasonable design of spoil ground is getting more and more attention.

The design of the spoil ground of Zhenfeng Project is reasonable in site selection and relatively convenient in terms of transportation. The final ratio adopted for the slope is 1:4.0, which has been calculated to meet the specification limit requirements. A bridle path with a width of 8m is set at every 10m high on the empty slope, and a 300-wide drainage ditch is set on the inside of every bridle path. Primary dams are built at the upstream and downstream of the site. The upstream primary dam was a grouted-masonry-built dam, which is about 11m in dam height, 3.5m in the width of the dam crest and about 56m in the dam length. The inner and outer slopes of the dam are both 1:0.5. The downstream primary dam is a roller compacted rockfill dam, with a height of about 16m, a crest width of 4.0m and a length of about 123m. The internal and external slopes of the are both 1:2.5. After analyzed with the geotechnical calculation software, all design indexes meet the specification limit requirements. A perfect annular flood intercepting ditch is set up in the spoil ground, and a flood discharge culvert is set up along the original trench at the bottom. The bottom plate of the bell-mouth is equipped with overflow weir and stone pier, and the exit is equipped with a stilling pool and apron.

In summary, the spoil ground of the Zhenfeng Project has typical significance in terms of the site selection, slope stability, blocking works and flood drainage system, and thus it can be used as reference for the design of other similar spoil grounds.

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