Foreword

According to the requirements of Document JIANBIAOHAN [2005] No. 124 issued by the Ministry of Housing and Urban-Rural Development (MOHURD) - "Notice on Printing and Distributing 'the Development and Revision Plan (Second Batch) of National Engineering Construction Standards in 2005'", this code is prepared jointly by China ENFI Engineering Co., Ltd. and other participants.

In the process of preparation of this code, the preparation team has conducted extensive and in-depth investigations and researches, conscientiously summarized Chinese experience in constructing tailings facilities in the 60 years since the founding of the New China, especially in the 30 years since the implantation of reform and opening up policy, and finally, on the basis of extensive solicitation of comments, through repeated discussions, modifications and improvements, this code is reviewed and finalized.

This code consists of 13 chapters and 5 appendixes, covering general provisions, terms, tailings pond, tailings dam, dry-stacking of tailings, flood drainage design of tailings pond, closure design for tailings pond, tailings extraction, reclaimed water of tailings pond, thickening of tailings slurry, delivery of tailings slurry, tailings slurry pump station, and environmental protection measures of tailings facilities etc.

The provisions printed in bold type are mandatory ones and must be implemented strictly.

This code is under the jurisdiction of, and its mandatory provisions are interpreted by the Ministry of Housing and Urban-Rural Development of the People's Republic of China; The Management Office of Standards and Norms for Engineering Construction of China Nonferrous Metal Industry is responsible for its routine management, and China ENFI Engineering Co., Ltd. is in charge of the explanation of technical specifications. During implementation of this code, any comments and advices can be posted or passed on to China ENFI Engineering Co., Ltd (Address: No. 12 Fuxing Road, Beijing, Postcode: 100038).

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1 General provisions

1.0.1 This code is prepared with a view to unify the principles and technical requirements for the design of tailing facilities, so that it must meet the national policies and regulations, and the requirements for safe and reasonable storage of tailings, environmental protection and energy saving and water saving.

1.0.2 This code is applicable to the design for new construction, renovation and extension of tailings facilities at metal and nonmetallic mines and the wet storage yard of red mud from alumina plants. This code is not applicable to the design of tailings facilities for tailings with special properties, such as tailings of radioactive materials in the nuclear industry, tailings that require special way of disposal and slags/ashes from electric power plant.

1.0.3 Tailings facilities must be in place for any processing plant. Random discharge of tailings is strictly forbidden.

1.0.4 The design of tailings facilities shall be in accordance with the following requirements:

1 The service life of tailings pond shall meet the productive life of the processing plant according to the enterprise's general planning; a construction plan by stages for multiple ponds shall be prepared if it is reasonable, so that the tailings pond to be constructed in later stage will be completed and put into production 0.5 to 1 year earlier than the closure of the tailings pond constructed in earlier stage. The service life of each tailings pond constructed in each stage shall be 5 years at minimum for small-scale processing plants, and 10 years at minimum for large- and medium-scale processing plants. If it is reasonable to adopt the way of multiple processing plants sharing one pond, an appropriate operation plan shall be prepared for the shared pond.

2 Under the premise of meeting production requirements and ensuring safety, it is required to make full use of wasteland and barren land, avoid, minimize or slow down the occupation of farmland, and prepare a plan for reclamation and ecological restoration of the land after closure of the pond.

3 New technologies, new processes, new equipments and new materials should be used if that are safe, reliable and in line with domestic conditions, economically beneficial and reasonable.

4 Water in the tailings shall be sufficiently recycled and reused; if external discharge, the water quality shall meet the relevant provisions in currently effective national standards, including *Integrated Wastewater Discharge Standard* GB 8978, *Emission Standard of Pollutants for Copper, Nickel and Cobalt Industries* GB 25467, *Emission Standard of Pollutants for Aluminum Industry* GB 25465, *Emission Standard of Pollutants for Lead and Zinc Industry* GB 25466, *Emission Standard of Pollutants for Magnesium and Titanium Industries* GB 25468, *Discharge Standard of Water Pollutants for Iron and Steel Industry* GB 13456, etc..

5 The load level of power supply shall match the demand of that in the mineral processing plant.

1.0.5 The documents and drawings of detailed design stage shall include key instructions specially and relevant drawings for the safe production and management of tailings facilities, the key instructions specially and relevant drawings shall serve as the main basis for the production and operation of tailings facilities. Construction drawings shall include the following contents:

1 The total dam height, total storage capacity and the class of the tailings pond; the layout of the tailings pond, the longitudinal profiles of the tailings pond, the elevation-capacity curve of the tailings pond;

2 The method and requirements of discharging of the tailings, the method and requirements of construction of the tailings dam, the control of slope gradient of deposited beach, the requirements of earth covering, vegetation and water discharge on the dam slope, the control standard of phreatic line, and the cross-sectional of the tailings dam;

3 Flood control standards and control parameters of minimum flood regulation height, minimum free height and minimum beach width of the tailings pond for different operational stages;

4 Operation and plugging requirements of water drainage facilities of the tailings pond;

5 Tailings process parameters, including amount and particle size composition of tailings, concentration, flow of tailings slurry, etc.

6 Diagrams of thickening, delivery of tailings slurry and reclaim water system, control requirements of critical velocity of delivery of tailings slurry;

7 Configuration and operation requirements of the monitoring system of tailings facilities;

8 Other matters and attached drawings need to be explained.

1.0.6 The design of tailings facilities shall contain some or all of the following basic information:

1 Mineral processing data, including particle size composition of tailings, tailings slurry concentration, elevation discharge outlet from the mineral processing plant, etc.;

2 Amount, physical and chemical properties of tailings;

3 Sedimentation and thickening test data of tailings slurry;

4 Water quality analysis data and water treatment test data for the water in tailings slurry;

5 Hydraulic delivery test data or rheological test data of tailings slurry;

6 Soil mechanics test data of tailings;

7 Embankment test data and seepage test data;

8 Meteorological and hydrological data;

9 Topographic maps, engineering geological and hydrogeological survey (including seismic-related parameters) of the tailings pond area, the dam site, drainage structures site, the dam construction material yard and the route of pipe and channel for delivery of tailings slurry, etc.;

10 Regional topographic maps, regional geological maps, the mining right and mineral occurrence distribution diagram of the mining area and the surrounding areas;

11 Survey data of residential areas, important industrial facilities and industrial/agricultural economy on upstream and downstream area of tailings pond;

12 Agreement documents; occupation of land, demolition and resettlement of houses and other facilities, traversing of the the pipeline through railways, highways, navigable rivers, etc.;

13 Categorization of harmful properties and other environmental data of tailings and tailings water;

14 Environmental function requirements of receiving water.

1.0.7 The design of tailings facilities shall be in addition to the requirements stipulated in this code, those stipulated in the current relevant standards of the nation shall be complied with.

2 Terms

2.0.1 tailings pond

The site to receive tailings from mineral separation of metallic and nonmetallic mines.

2.0.2 whole storage capacity

The capacity below the elevation of the dam crest and above the bottom of the tailings pond (excluding the volume of the dam body not composed by tailings).

2.0.3 effective storage capacity

The capacity for storage of tailings (including suspended tailings slurry) below the deposited beach and above the bottom of the tailings pond.

2.0.4 flood regulation storage capacity

The capacity for storage of flood above the normal water level and below the designed flood level.

2.0.5 total storage capacity

The whole storage capacity when the dam crest reaches to the designed final elevation.

2.0.6 tailings dam

The peripheral structure of the tailings pond that blocks the tailings and water content. Usually refers to the starter dam and the embankment.

2.0.7 starter dam

The dam made of soil, stone and other materials, which is used as the seepage drainage facilities or supporting structure of the embankment.

2.0.8 embankment

The dam formed by deposit of the tailings during the production process.

2.0.9 upstream embankment method

The embankment method by deposit of the tailings at upstream of the starter dam is characterized by the stage-wise movement of the embankment crest axis to the upstream direction of the starter dam.

2.0.10 centerline embankment method

The embankment method by using coarse tailings separated by cyclone at the starter dam axis is characterized by stationary location of the embankment crest axis.

2.0.11 downstream embankment method

The embankment method by using coarse tailings separated by cyclone on downstream of the starter dam is characterized by the stage-wise movement of the embankment crest axis to the downstream direction of the starter dam.

2.0.12 phreatic line

The free surface of ground water in the dam body, which is reflected as a curve in the cross section.

2.0.13 criticaled position of the phreatic line

The position of the phreatic line where the anti-sliding stability safety factor of dam body meets the minimum requirements in this code.

2.0.14 controlled position of the phreatic line

The position of the phreatic line that meets both the requirement on the criticaled position of the phreatic line and the requirement on the minimum buried depth of the phreatic line on the downstream slope of the embankment.

2.0.15 normal production level

The water level that may meet production reclaim water and drainage requirements in the in-service tailings pond.

2.0.16 deposited beach

The surface of the sedimentary body formed by the tailings through hydraulic alluvial, which is divided into two parts according to the water surface in the tailings pond, that is the part above the water surface and the part below it.

2.0.17 beach crest

The intersecting line of the surface of the deposited beach and the surface of the outer slope of the embankment.

2.0.18 beach width

The horizontal distance from the water boundary inside the tailings pond to the beach crest.

2.0.19 free height

Under non-seismic operating conditions, for the embankment, it means the height difference between the beach crest elevation and the designed flood level; for the water dam and one-step constructed dam, it means the height difference between the sum of the designed flood level plus the maximum wave run-up plus the maximum wind backwater height and the dam crest elevation. Under seismic operating conditions, for the embankment, it means the height difference between the beach crest elevation and the sum of normal production level plus the earthquake subsidence height plus the earthquake backwater height; for water dam and one-step constructed dam, it means the height difference between the sum of normal production level plus the maximum wave run-up plus the maximum wind backwater height plus the earthquake subsidence height plus the earthquake backwater height and the dam crest elevation.

2.0.20 flood regulation height

The height difference between the normal starting flood drainage water level and the designed flood level.

2.0.21 tailings dam height

For upstream embankment method, it means the height difference between the embankment crest and the original ground level at the starter dam axis; for centerline and downstream embankment method, it means the height difference between the embankment crest and the original ground level at the embankment axis.

2.0.22 total dam height

The dam height in the final designed deposit elevation.

2.0.23 embankment height or accumulation height

For upstream tailings dam, it means the height difference between the embankment crest and the starter dam crest; for centerline and downstream tailings dam, it means the height difference between the embankment crest and the original ground level at the embankment axis.

2.0.24 water dam of tailings pond

The dam for long-term or moderately long-term water retaining, usually refers to the main or saddle dam that is not formed by deposit of the tailings.

2.0.25 length of tailings pond

The distance from the beach crest (or the dam axis for starter dam), along the direction perpendicular to the dam axis, to the furthest water boundary of the tailings pond; for the tailings pond with multiple embankments in the surrounding, it means the shortest distance from each embankment crest to the drainage outlet in the pond.

2.0.26 one-step constructed dam

A tailings dam that is constructed in one step or in multiple stages entirely using non-tailings materials.

3 Tailings pond

3.1 Site selection

3.1.1 The tailings pond shall not be located in the following areas:

1 Scenic spots, nature reserves, drinking water source protection areas;

2 Areas where mining is prohibited by national law.

3.1.2 Site selection of the tailings pond shall be determined after comprehensive comparison of multiple plans in technical and economic aspects and shall be in accordance with the following requirements:

1 The tailings pond shall not be located upstream of any large-size industrial and mining enterprise, large-size water source, important railway or highway, aquatic production base, or large-size residential area;

2 The tailings pond shall not be located on the upwind side of the dominant wind direction in the residential concentration area;

3 The tailings pond shall be considered to avoid or minimize the occupation of farmland, and avoid or minimize the relocation of residents;

4 The tailings pond shall not be located above any promising deposit;

5 The tailings pond shall have small catchment area but sufficient storage capacity;

6 For the upstream tailings pond with wet tailings discharging, the tailings pond shall have sufficient initial and final length of tailings pond;

7 The tailings pond shall entail small work amount of dam construction while facilitating production management;

8 Areas with complex geological structures and severely adverse geological phenomena shall be avoided;

9 The tailings pond shall entail short delivery distance, should entail gravity flow or small lift of the tailings slurry.

3.1.3 For construction of two or more tailings ponds in the same valley, the interrelationship and mutual impact between the tailings ponds shall be fully demonstrated during the design of the later tailings pond.

3.1.4 For storage of tailings using abandoned open pit or concave ground, special demonstration on safety shall be performed. However, open pit with ongoing mining activity underneath shall not be used for storage of tailings.

3.2 Storage capacity

3.2.1 The required effective storage capacity of the tailings pond shall be determined as follows:

$$V=\frac{W}{\rho_d} \tag{3.2.1}$$

Where: V—the required effective storage capacity of the tailings pond (m^3);

W—the tailings amount to be stored throughout the designed service life of the tailings pond (t);

ρ_d—the average dry density of deposited tailings in the tailings pond (t/m³).

3.2.2 ρ_d shall be determined based on tests or the field data of similar tailings ponds; if no data are available, for hydraulic alluvial tailings with density ρ_s of 2.7t/m³, ρ_d may be determined according to those specified in Table 3.2.2; for tailings with other densities, ρ_d which in Table 3.2.2 shall be multiplied by correction coefficient β. β may be calculated according to the following formula:

$$\beta = \frac{\rho_s}{2.7} \tag{3.2.2}$$

Table 3.2.2 ρ_d-Average dry density of deposited tailings in the tailings pond (t/m³)

Name of raw tailings	Coarse sand tailings	Medium sand tailings	Fine sand tailings	Silty sand tailings	Silt tailings	Silty clay tailings	Clay tailings
Average dry density of deposited tailings	1.45—1.55	1.40—1.50	1.35—1.45	1.30—1.40	1.20—1.30	1.10—1.20	1.05—1.10

Note: "Raw tailings" refers to the tailings discharged by the processing plant before natural or mechanical sorting takes place. The name of raw tailings is defined in Appendix A of this code.

3.2.3 The effective storage capacity and flood regulation storage capacity of the tailings pond shall be determined by calculation according to the deposited beach with different slope gradients and the bottom topography.

The gradient of tailings deposited beach i_t may be determined according to the physical properties of the tailings, the topography of the tailings pond, the field data of other tailings ponds with similar tailings discharge conditions or through test. When no data is available, i_t may be calculated according to Appendix B of this code. A larger value $1.0i_t$—$1.2i_t$ may be used for calculating the effective storage capacity while a smaller value $0.8i_t$—$1.0i_t$ may be used for calculating the flood regulation storage capacity.

3.3 Class of tailings pond and grade of corresponding structures

3.3.1 The class of tailing pond shall be determined according to those specified in Table 3.3.1 based on the final whole storage capacity and the final dam height. The designed class for each service stage of the tailings pond shall be determined according to those specified in Table 3.3.1 based on the whole storage capacity and dam height of the tailings pond at that stage. When the class determined by the whole storage capacity and that determined by dam height differ by one class, the higher value shall be taken; when the difference is more than one class, the higher value minus one class shall be taken.

For storage of tailings using abandoned open pit or concave ground, and no tailings dam is constructed in the surroundings, class determination may not mandatory. When building a tailings dam, the class of tailings pond shall be determined according to the dam height and the corresponding storage capacity.

Except class I, in case potential accident of the tailings pond would cause serious disasters to downstream important towns, industrial and mining enterprises, railway lines or highways, etc., the designed class shall be raised by one class after sufficient demonstration.

Table 3.3.1 Designed class of tailings pond in each service stage

Class	Whole storage capacity, V (10000 m^3)	Dam height H (m)
Ⅰ	$V \geq 50000$	$H \geq 200$
Ⅱ	$10000 \leq V < 50000$	$100 \leq H < 200$
Ⅲ	$1000 \leq V < 10000$	$60 \leq H < 100$
Ⅳ	$100 \leq V < 1000$	$30 \leq H < 60$
Ⅴ	$V < 100$	$H < 30$

3.3.2 The grade of corresponding structures shall be determined by the class of tailings pond and the importance of the structure according to those specified in Table 3.3.2.

Table 3.3.2 Grade of corresponding structures

Class of tailings pond	Grade of corresponding structures		
	Primary structures	Secondary structures	Temporary structures
Ⅰ	1	3	4
Ⅱ	2	3	4
Ⅲ	3	5	5
Ⅳ	4	5	5
Ⅴ	5	5	5

Notes: 1 Primary structures refer to the tailings dam, drainage and other structures the damage of which would cause disaster in the downstream;

2 Secondary structures refer to permanent structures other than the primary structures;

3 Temporary structures refer to structures that are used temporarily during construction.

3.4 Monitoring facilities

3.4.1 The tailings pond shall be set up with necessary safety and environmental monitoring facilities based on its design class, construction method of the dam, pollutant properties in tailings and tailings water, topographical and geological conditions, as well as geographical environment factors. Tailings pond of class Ⅲ or above shall be set up with safety monitoring facilities that combine automatic and manual monitoring means.

3.4.2 Monitoring equipment and facilities of advanced technologies shall be selected on the premise of ensuring reliability, durability, economy and suitability.

3.4.3 Safety monitoring items shall include:

1 For wet discharge tailings pond, water level, beach crest elevation, beach width, phreatic line depth, slope gradient of the dam and displacement shall be monitored;

2 For wet discharge tailings pond of class Ⅳ or above, precipitation shall in addition be monitored; for wet discharge tailings pond of class Ⅲ or above, pore water pressure, permeable water flow and water quality shall in addition be monitored when necessary.

3.4.4 Safety monitoring facilities shall be arranged in accordance with the following principles:

1 The facilities shall be capable of fully reflecting the operation state of the tailings pond;

2 The arrangement of the tailings dam displacement monitoring points shall extend to a certain extent beyond the dam foot;

3 Additional monitoring facilities shall be set up at positions of fault zone of dam abutment and bedrock as well as embedded culvert pipe in the dam.

3.4.5 Environmental monitoring items shall include:

1 Amount and composition of tailings entering the tailings pond, amount and composition of externally drainaged water shall be monitored;

2 Water quality of groundwater and surrounding water bodies near the tailings pond shall be monitored.

3.4.6 Layout of the environmental monitoring facilities shall meet the requirements of the operation state of the tailings pond.

3.5 Auxiliary facilities

3.5.1 Auxiliary facilities of the tailings pond, such as dam construction machinery, work vessel, engineering vehicle, access road, duty room, emergency equipment warehouse, communication and lighting facilities, etc., shall be set up according to the work amount of dam construction, type and operation requirement of drainage structure, the distance between the tailings pond area and the processing plant's area, and other factors. Dormitory and simple meteorological and hydrological observation points may also be set up when necessary.

3.5.2 Duty room and dormitory of the tailings pond should not be located at downstream of the dam.

4 Tailings dam

4.1 General requirements

4.1.1 Site selection of the tailings dam shall be determined in line with the principles of minimum work amount for dam construction (embankment deposit), maximum storage capacity and avoidance of poor engineering geological and hydrogeological conditions, through comprehensive demonstration in combination with material source for dam construction, construction conditions, tailings clarification distance, layout of drainage structure and other factors.

4.1.2 Type selection of the starter dam shall be in accordance with the following requirements:

1 The starter dam should be constructed with local materials;

2 The type of pervious dam should be selected for the starter dam of upstream tailings pond; other suitable type may be determined as necessary for the starter dam of centerline or downstream tailings pond;

3 The one-step constructed dam may be constructed in multiple stages. The first-stage dam shall meet the relevant requirements for the starter dam while the height of dam constructed in later stages shall always be higher than the required tailings accumulation height;

4 Impervious dam may be constructed if there is special requirement for tailings pond.

4.1.3 Height of the starter dam shall be determined according to the following requirements:

1 It shall be capable of storing the tailings amount generated in at least half a year after the processing plant is put into production;

2 It shall be capable of clarification of the tailings water content;

3 It shall satisfy the flood control standards for corresponding class of tailings pond when the beach crest reached the starter dam crest;

4 It shall be capable of storing the required storage and regulation capacity for water when using the tailings pond to supply produce water at the beginning of the operation;

5 Requirements of tailings discharging under ice shall be met if tailings facilities are located in the frozen area;

6 For new constructed upstream tailings dam, the proportion between the starter dam height and the total dam height should be 1/8—1/4.

4.1.4 The tailings dam must meet the seepage control and static and dynamic stability requirements.

4.1.5 Specialized research and treatment shall be carried out on the tailings dam foundation under any one of the following conditions:

1 Sand and gravel foundation prone to tailings leaking;

2 Foundation formed by easily liquefied soil, soft clay or wet collapsible loess;

3 Foundation with karst development;

4 Foundation on a gushing spring or mine well.

4.1.6 The embankment method shall be selected according to the following requirements:

1 Upstream embankment method should be adopted where seismic fortification intensity of 7 degrees or below; downstream or centerline embankment method should be adopted where the seismic fortification intensity of 8 to 9 degrees, aseismatic measures shall be used when upstream embankment method is selected.

2 For upstream embankment, direct alluvial deposit method may be used if the tailings is coarse; graded alluvial deposit method shall be adopted if the tailings is fine.

3 For downstream and centerline embankment, the content of particles with $d \geqslant 0.074$mm in the tailings used for embankment construction after grading should not be less than 75% and those of $d \leqslant 0.02$mm should not be more than 10%. Embankment test shall be carried out if the graded tailings particles do not meet the above requirements. The rising speed of embankment construction shall meet the requirements of the rising speed of the deposited beach.

4 For upstream embankment, when the tailings slurry concentration exceeds 35% (excluding dry deposited tailings), direct alluvial deposit method should not be used; otherwise, tailings embankment test and research shall be carried out.

5 For a wet tailings pond, one-step dam construction should be adopted when all tailings particles are fine (the content of particles with $d < 0.074$mm is more than 85%, or $d \leqslant 0.005$mm is more than 15%) and the dam may be constructed by stages; tailings embankment test and research shall be carried out when the particles are extremely fine and tailings are used for embankment.

4.1.7 For upstream embankment, direct alluvial deposit method may be used when tailings have enough medium and coarse grain sizes; otherwise graded alluvial deposit method should be adopted. The embankment in each stage should be constructed with tailings as well as may be constructed with waste rock and gravels.

4.1.8 The water dam shall be designed in accordance with the corresponding codes of reservoir water retaining dam, but the flood control standards shall not be lower than those provided in this code.

4.2 Minimum free height and beach width of deposited beach

4.2.1 For upstream embankment, the height difference between deposited beach crest and the designed flood level shall be in accordance with the minimum free height in Table 4.2.1. Meanwhile, the distance from the beach crest to the water boundary of the designed flood level shall be in accordance with the minimum beach width in Table 4.2.1.

Table 4.2.1 Minimum free height and beach width for upstream embankment (m)

Grade of dam	1	2	3	4	5
Minimum free height	1.5	1.0	0.7	0.5	0.4
Minimum beach width	150	100	70	50	40

Notes: 1 For tailings dam of Grade 3 or below, the minimum beach width may be reduced up to 30% than provided in the table after demonstration of seepage stabilization and safety.

2 If the embankment is located in a seismic zone, the minimum beach width shall also meet the relevant provisions in current national standard *Code for Seismic Design of Special Structures* GB 50191.

4.2.2 For downstream and centerline embankment, the distance between the outer edge of dam crest and the water boundary of the designed flood level should be in accordance with the provisions in Table 4.2.2; meanwhile, the height difference between the dam crest and the designed flood level shall be in accordance with the minimum free height in Table 4.2.1.

Table 4.2.2 Minimum beach width for downstream and centerline embankment (m)

Dam class	1	2	3	4	5
Minimum beach width	100	70	50	35	25

Note: If the tailings pond is located in a seismic zone, the minimum beach width shall also be in accordance with the relevant provisions in national standard *Code for Seismic Design of Special Structures* GB 50191.

4.2.3 For water dam of the tailings pond, the height difference between the dam crest and the designed flood level shall not be less than the sum of minimum free height as provided in Table 4.2.1, the maximum wind backwater height and the maximum wave run-up. The maximum wind backwater height and the maximum wave run-up values may be calculated according to the relevant provisions in current industry standard *Design Code for Rolled Earth-Rock Fill Dams* SL 274.

4.2.4 If the tailings pond is located in a seismic zone with earthquake horizontal acceleration of not less than 0.05*g*, the height difference between the deposited beach crest and the water level during routine production shall in addition not be less than the sum of the minimum free height as provided in Table 4.2.1, the earthquake subsidence height and the earthquake backwater height. In addition, for water dam and one-step constructed dam, the height difference between the dam crest and the water level during routine production shall not be less than the sum of the free height as provided in Table 4.2.1, the earthquake subsidence height, the earthquake backwater height, the maximum wind backwater height, and the maximum wave run-up. The earthquake backwater height may be calculated in accordance with the relevant provisions in the current industry standard *Specifications for Seismic Design of Hydraulic Structures* SL 203.

4.3 Requirements and measures for seepage control

4.3.1 Seepage calculation shall be carried out in the design of tailings dam and, for tailings dam of Class 1 and Class 2, special seepage simulation test shall also be carried out according to the topographical conditions. Seepage calculation shall be carried out in accordance with the following requirements:

1 During the feasibility study stage for new construction of a tailings dam, seepage calculation is only optional;

2 During the feasibility study stage for the extension or raising of an existing tailings dam, seepage calculation shall be carried out;

3 Seepage calculation shall be carried out during the preliminary design stage.

4.3.2 Influence of factors such as tailings discharge, rainfall and earthquakes shall also be analyzed during the determination of the phreatic line of tailings dam.

4.3.3 The minimum buried depth of the phreatic line at the downstream slope of the tailing dam shall not only meet the anti-sliding stability requirements for dam slopes but also be in accordance with those specified in Table 4.3.3.

Table 4.3.3 Minimum buried depth of the phreatic line at the downstream slope of the tailings dam (m)

Embankment height H	$H \geq 150$	$150 > H \geq 100$	$100 > H \geq 60$	$60 > H \geq 30$	$H < 30$
Minimum buried depth of the phreatic line	10~8	8~6	6~4	4~2	2

Note: The minimum buried depth of the phreatic line of embankment with any height may be determined using interpolation method.

4.3.4 For embankment, curve fitting method may be adopted during design to determine the critical position of the phreatic line during various service stages and various operating conditions; the controlled position of the phreatic line shall be determined according to the critical position of the phreatic line and the requirements in Table 4.3.3.

4.3.5 Seepage control measures for embankment must be taken to ensure that the phreatic line is below the controlled position of the phreatic line.

4.3.6 Measures to lower the phreatic line shall be determined through comprehensive analysis considering the grade of dam, dam stability calculation and aseismatic structure requirements, the following measures should be adopted:

1 During construction of the tailings pond, horizontal and vertical seepage drainage systems of the types such as seepage drainage mats (gravel or geotextile mats), seepage drainage pipes (or blind ditches) and seepage drainage wells may be constructed within the foundation of the embankment;

2 During operation of the tailings dam, seepage drainage systems of the types such as seepage drainage pipes, blind ditch, mats, vertical plastic drainage board or seepage drainage wells may be provided at appropriate time as the embankment raises;

3 During operation of the tailings dam, seepage drainage facilities such as seepage drainage pipes or seepage drainage well with radial pipes may be added to the embankment slope or deposited beach when the measured position of the phreatic line is higher than the controlled position of the phreatic line;

4 Reducing the water level in the tailings pond.

4.4 Stability calculation

4.4.1 Stability calculation of the tailings dam shall be in accordance with the following requirements:

1 The anti-sliding stability of the starter dam and the embankment shall be calculated according to the physical and mechanical properties of the dam materials and foundation. The stability shall be calculated using the simplified Bishop method or the Swedish slip circle method. The seismic load shall be calculated using pseudo-static method. The stability calculation shall be carried out as follows:

1) During the feasibility study stage for new construction of a tailings dam, stability calculation is only optional.

2) During the feasibility study stage for the extension or raising of an existing tailings dam, stability calculation shall be carried out.

3) The stability calculation shall be carried out during the preliminary design stage.

4) Comprehensive engineering geological and hydrogeological investigation shall be carried out when the embankment have deposited to 1/2—2/3 of the designed final total dam height for a tailings pond of Class Ⅲ or below, or 1/3—1/2 for a tailings pond of Class Ⅰ or Ⅱ. Comprehensive investigation may be carried out as required without considering the dam height limitation for tailings of special properties, major changes in the ore dressing scale or processing route, or significant deviation of tailings discharging method during production from the preliminary design. The design institute shall comprehensively demonstrate the stability of the final dam according to the investigation

results and determine the treatment measures in the later stage.

5) The stability calculation shall be carried out for the water dam the tailings pond.

2 The load to be used in the stability calculation of the tailings dam may be combination of those provided in Table 4.4.1-1 as per different operating conditions.

Table 4.4.1-1 Load combination for the stability calculation of tailings dam

Operating condition	Calculation method	Load category				
		1	2	3	4	5
Normal operation	Total stress method	Incl.	Incl.	—	—	—
	Effective stress method	Incl.	Incl.	Incl.	—	—
Flood regulation	Total stress method	—	Incl.	—	Incl.	—
	Effective stress method	—	Incl.	Incl.	Incl.	—
Special operation	Total stress method	Incl.	Incl.	—	—	Incl.
	Effective stress method	Incl.	Incl.	Incl.	—	Incl.

Notes: 1 Load category 1 means the stable seepage force of the normal water level during operation of the tailings pond;
2 Load category 2 means gravity of the dam;
3 Load category 3 means excess pore pressure in the dam body and the dam foundation;
4 Load category 4 means the potential stable seepage pressure when the designed flood water level is reached;
5 Load category 5 means the seismic load.

3 The safety factor of anti-sliding stability of the dam slope shall not be less than the values specified in Table 4.4.1-2.

Table 4.4.1-2 Minimum safety factor of anti-sliding stability of the dam slope

Calculation method	Operating condition	Grade of dam			
		1	2	3	4,5
Simplified Bishop method	Normal operation	1.50	1.35	1.30	1.25
	Flood operation	1.30	1.25	1.20	1.15
	Special operation	1.20	1.15	1.15	1.10
Swedish slip circle method	Normal operation	1.30	1.25	1.20	1.15
	Flood operation	1.20	1.15	1.10	1.05
	Special operation	1.10	1.05	1.05	1.00

4 The category of shear strength index of tailings dam materials and foundation soil shall be selected in Table 4.4.1-3 according to strength calculation method and soil type.

Table 4.4.1-3 Test methods of shear strength index of tailings dam materials and foundation soil

Strength calculation method	Soil type		Instrument employed	Test method and code	Strength index	Initial state of sample
Total stress method	Non-cohesive soil		Triaxial soil test apparatus	Consolidated undrained shear test (CU)	c_{cu}, φ_{cu}	I. Dam material: 1. Water content and density are consistent with that of the undisturbed sample; 2. Pre-saturation is required for the part under the phreatic line or underwater; 3. Test stress shall be consistent with the in-situ stress of the dam. II. Undisturbed soil for the dam foundation
	Slightly cohesive soil		Direct shear test apparatus	Consolidated quick shear test (CQ)		
			Triaxial soil test apparatus	Consolidated undrained shear test (CU)		
	Cohesive soil		Direct shear test apparatus	Consolidated quick shear test (CQ)		
			Triaxial soil test apparatus	Consolidated undrained shear test (CU)		
Effective stress method	Non-cohesive soil		Direct shear test apparatus	Slow shear test (S)	c', φ'	
			Triaxial soil test apparatus	Consolidated drained shear (CD)		
	Cohesive soil	Saturation less than 80%	Direct shear test apparatus	Slow shear test (S)		
			Triaxial soil test apparatus	Unconsolidated undrained pore water pressure (UU)		
		Saturation greater than 80%	Direct shear test apparatus	Slow shear test (S)		
			Triaxial soil test apparatus	Consolidated undrained pore water pressure (CU)		

Notes: 1 Non-cohesive soil means clay content of tailings or dam foundation soil less than 5%. Slightly cohesive soil means clay content of tailings or dam foundation soil less than 15%.

2 For soft tailings clay, if consolidated quick shear index is adopted, it shall be determined according to the degree of consolidation; if cross plate shear strength index is adopted, it shall be amended according to the degree of consolidation.

5 The profiles of a new tailings dam for stability calculation shall be generalized for stratigraphic regionalization based on the grain size of the particles and the consolidation degree of tailings. The physical and mechanical properties of the tailings in each partition may be determined in accordance with the survey data of similar tailings ponds or according to Appendix C of this code;

6 The profiles of an extensed, renovated or intermediately demonstrated tailings pond for stability calculation shall be generalized for stratigraphic regionalization based on survey data.

7 For tailings dam of Grade 3 or below, the designed seismic intensity may be determined according to the basic seismic intensity which is provided in the current effective national standard *Seismic Ground Motion Parameters Zonation Map of China* GB 18306; and if breach of the tailings dam would cause severe secondary disasters, the designed seismic intensity shall be increased by one level. For tailings dams of Grade 1 and Grade 2, the designed seismic intensity shall be determined according to the approved site hazard analysis results. The seismic load shall be calculated in accordance with the relevant provisions in the current industry standard *Specifications for Seismic Design of Hydraulic Structures* SL 203.

8 The site designed basic ground motion acceleration shall be determined according to those specified in Table 4.4.1-4 except for tailings dams of Grade 1 and Grade 2.

Table 4.4.1-4 Site designed basic ground motion acceleration a

Seismic intensity	VI	VII	VIII	≥IX
Horizontal acceleration a	0.05g	0.10g, 0.15g	0.20g, 0.30g	≥0.40g

4.4.2 Dynamic stress seismic calculation of the tailings dam shall be in accordance with the following requirements:

1 When calculating the anti-sliding stability of the tailings dams of Grade 1 and Grade 2, in addition to calculation with the pseudo-static method, special dynamic seismic calculation shall also be carried out, which includes seismic liquefaction analysis, seismic stability analysis and seismic permanent deformation analysis;

2 Simplified calculation may be adopted for seismic liquefaction analysis of tailings dam of Grade 3 in areas of designed seismic intensity of 7 degrees and tailings dams of Grade 4 and Grade 5 in areas of seismic intensity of 7 degrees or above; for tailings dam of Grade 3, dynamic seismic calculation shall also be carried out when the liquefaction analysis results are unfavorable;

3 For seismic stability analysis of tailings dams of all grades in areas of designed seismic intensity of 9 degrees, or those of Grade 3 or above in areas of designed seismic intensity of 8 degrees, in addition to the pseudo-static method, time-history method shall also be carried out;

4 Calculation and analysis with the time-history method shall be in accordance with the following requirements:

1) The initial shear stress state before earthquake shall be calculated according to the nonlinear stress-strain relationship of materials;

2) The dynamic deformation characteristics and liquefaction resistance of materials should be measured through laboratory dynamic test;

3) The seismic stress and acceleration response should be solved by using equivalent linear or non-linear time-history method;

4) The anti-sliding stability of possible sliding face and the permanent deformation of the dam which is induced by earthquake shall be calculated based on seismic action effects;

5) At least 2 or 3 field seismic acceleration records of similar sites with similar seismic and geological conditions, as well as one artificial fitted seismic acceleration time-history shall be selected;

6) The target spectral of artificial fitted seismic accelerations shall be the response spectrum of the site;

7) The peak value of seismic acceleration time-history shall be the site designed acceleration value;

8) The duration of the artificial fitted seismic acceleration time-history may be determined according to those specified in Table 4.4.2.

Table 4.4.2 Duration of the artificial fitted seismic acceleration time-history (s)

Potential seismic magnitude at epicenter	6.0	6.5	7.0	7.5	8.0
Duration	10—20	10—25	15—30	25—35	35—45

4.5 Construction requirements

4.5.1 If no vehicle passage is required, the minimum crest width of starter dam should be in accordance with those specified in Table 4.5.1; if vehicle passage is required, the crest width of starter dam and road construction shall meet the provisions in current national standard *Code for Design of Roads in Factories and Mining Areas* GBJ 22.

Table 4.5.1 Minimum crest width of starter dam (m)

Dam height	≤10	10—20	20—30	≥30
Minimum crest width	2.5	3.0	3.5	4.0

4.5.2 The crest width of downstream or centerline embankment shall be determined according to the provisions of Article 4.6.10 of this code.

4.5.3 The slope should not be steeper than 1:1.6 for upstream slope of pervious rockfill dam; upstream slope may be slightly steeper than downstream slope for soil fill dam. Downstream slope ratio of the starter dam may be initially determined according to those specified in Table 4.5.3.

Table 4.5.3 Downstream slope ratio of the starter dam

Dam height (m)	Downstream slope ratio of soil fill dam	Downstream slope ratio of pervious rock fill dam	
		Rock base	Non-rock base (excluding soft base)
5—10	1:1.75—1:2.0	1:1.6—1:1.75	1:1.75—1:2.0
10—20	1:2.0—1:2.5		
20—30	1:2.5—1:3.0		

4.5.4 When geotextile combination filter layer is adopted for upstream slope of pervious starter dam, it should set up embedded platform, with height difference of 10m—15m and width not less than 1.5m. Depth of embedded geotextile base and abutment shall not be less than 0.5m and shall be compacted.

4.5.5 A berm shall be set up every 10m—15m along the elevation on the downstream slope of the starter dam of upstream embankment and the width of the berm should not be less than 1.5m. When vehicle passage is required on tailing embankment, a berm shall be set up every 10m—15m along the elevation on the downstream slope and the width of the berm should not be less than 5m.

4.5.6 Abutment cut-water ditches shall be set up on the transition position with downstream slope of tailings dam and hill slopes on both sides, and steps of width not less than 1.0m should be set up on the starter dam.

4.5.7 Drainage ditches shall be set up every 5m—10m along the elevation in combination with the seepage drainage facilities on the downstream slope of the upstream embankment.

4.5.8 Measures shall be taken on the upstream slope of the starter dam to prevent direct erosion of the starter dam by initial tailings discharge.

4.5.9 Cut-water ditches shall be set up at the transition position with downstream slope of embankment and hill slopes on both sides.

4.5.10 The following measures should be taken to maintain the downstream slope of embankment:

1 Cover the slope surface with gravels, waste rock or hill soil;

2 Plant grasses or shrubs on the slope;

3 Construct fork shaped or mesh drainage ditches on the slope;

4 Construct steps every 500m along the axial direction of the dam.

4.6 Construction of centerline embankment and downstream embankment

4.6.1 Centerline embankment and downstream embankment should be constructed using coarse tailings graded with cyclones. The coarse tailings used for embankment construction shall meet the requirements of Clause 3 of Article 4.1.6 of this code.

4.6.2 Starter dam and water filtering dam shall be set up for centerline embankment and downstream embankment, there may be more than one water filtering dam, seepage drainage facilities shall be set up in the base scope between the starter dam and the water filtering dam.

4.6.3 Flood between centerline embankment or downstream embankment and the water filtering dam shall be seeped out through the water filtering dam or through drainage facilities set up in front of the water filtering dam. The flood control standard should be 50-year return period.

4.6.4 In addition to meeting the relevant provisions in Article 4.1.3 of this code, the height of the starter dam shall also meet the requirements for balanced increment speed of downstream coarse tailings and upstream remaining tailings.

4.6.5 The height of the water filtering dam may be determined according to the actual needs.

4.6.6 Seepage drainage facilities in dam foundation may take the form of mattress, blind ditch (pipe) or other types. Its cross-sectional size shall meet seepage discharge requirements.

4.6.7 Balance calculation shall be carried out according to the height of coarse tailings embankment and others deposited in the tailings pond throughout the service life of the tailings pond. The rising speed of embankment crest shall meet the requirements for rising speed of the deposited beach in the tailings pond and the requirements for flood control, and the coarse tailings produced rate required for each stage shall be determined accordingly. The final coarse tailings produced rate of the selected equipment and grading process should not be less than 1.2 times of the respective maximum coarse tailings produced rate required in each stage.

4.6.8 When underflow tailings graded with cyclones is used for direct filling for embankment construction, the underflow tailings slurry concentration may be adjusted but shall not be less than the non-graded concentration.

4.6.9 Downstream slope of the tailings embankment shall be determined by stability calculation, and should not be steeper than 1:3 in the initial calculation.

4.6.10 Crest width of the tailings embankment shall meet the requirements for grading equipment, pipe erection and traffic, and should not be less than 20m. Maintenance platform and drainage facilities shall be set up for the final downstream embankment slope. The width of the maintenance platform should not be less than 3m.

4.6.11 Hydraulic cyclones should be used as grading equipment of tailings. The type, working pressure and parameters of the grading equipment should be provided by the manufacturer according to particle size, produced rate and concentration of underflow tailings determined in the design and shall be verified through test.

4.6.12 Spare grading equipment shall be configured according to actual need.

5 Dry-stacking of tailings

5.1 General requirements

5.1.1 Dry-stacking of tailings may be adopted in case of lack of water or in case the longitudinal depth of the tailings pond may not meet the requirements for wet-stacking of tailings, or in case of other special requirements, provided it is technically and economically reasonable.

5.1.2 In dry-stacking of tailings, the tailings from the processing plant shall be dewatered and shall meet the dry transportation, piling and roller compaction requirements before being stacked.

5.1.3 For dry-stacking of tailings, the surface of the tailings pond area shall be free of rainwater during the non-raing season. During the rainy season, the accumulated rainwater of the pond area shall be timely drained, the duration of draining all the flood from the tailings pond shall not exceed 72h.

5.1.4 Tailings discharged into the tailings pond shall be leveled and roller-compacted.

5.1.5 The tailings pond with dry-stacking of tailings shall not be mixed with tailings slurry.

5.2 Tailings dewatering equipment selection

5.2.1 Either dewatering after concentration or direct dewatering technology may be adopted after comparison. When tailings particles are coarse, high-frequency vibrating sieve should be used to screen tailings suitable for stacking, which directly transported to the tailings pond, while the remaining part shall be concentrated and dewatered. The concentrating equipment may be selected in accordance with the requirements in Chapter 10 of this code.

5.2.2 The type, size and quantity of dewatering equipment shall be determined by such factors as output, character of the tailings of the processing plant, transportation and terrain conditions and shall be equipped standby.

5.2.3 The reasonability of dewatering equipment shall be demonstrated through tests. Frame filter press, ceramic filter press or other equipment shall be used as dewatering equipment and shall be in accordance with the following requirements:

1 The size and quantity of frame filter press shall be determined through tests;

2 The size and quantity of ceramic filter press shall be determined through tests, with the impact of attenuation of dewatering capacity of the unit throughout the production process taken into consideration.

5.2.4 Anti-freezing measures shall be adopted for dewatering system in extremely cold regions. Additional factory may be built and heating.

5.3 Dry tailings discharging and stacking method

5.3.1 Dry tailings discharging method should include discharging method at the rear, front, center or surroundings of the tailings pond. Reclaimed water settling pond shall be set up downstream of the tailings pond. All types of dry tailings discharge methods shall be in accordance with the following requirements:

1 Discharge of tailings at the rear of the tailings pond shall be discharged from the rear (upstream) of the pond area to the front (downstream) of the pond area. Discharged tailings shall be compacted layer by layer from bottom to top and steps shall be formed. The height of the steps shall be the same as that of the final external slope surface of embankment. The top surface of each compaction layer shall have 1%—2% slope ratio towards the retaining dam.

2 Discharge of tailings at the front of the tailings pond shall proceed from the retaining dam toward the pond rear. Compaction and side slope trimming shall be carried out at the same time of stacking.

3 Discharge of tailings at the center of the tailings pond shall proceed from the center toward the rear and the front of the pond. Compaction shall be carried out at the same time of stacking. External slope shall be trimmed in one go when the designed final stacking height has been reached.

4 Discharge of tailing from the surrounding of the tailings pond shall proceed toward the pond center. Stacking height of the surroundings shall always be maintained higher than the center. Compaction and side slope trimming shall be carried out at the same time of stacking.

5.3.2 The final external slope surface shall be set up with steps every 5m—10m of height. Permanent longitudinal and lateral drainage ditches shall be set up on the steps.

5.4 Dry tailings transportation, leveling and compaction

5.4.1 Belt conveyor or motor vehicle transport should be adopted for transport of dry tailings.

5.4.2 Movable belt conveyor, loader and bulldozer may be adopted for transport and leveling of tailings within the pond area. Mechanical roller compaction shall be adopted, the parameters of mechanical roller compaction shall be determined through tests. Areas that influence the stability of the embankment shall be compacted layer by layer from bottom to top, to a degree of compaction not less than 0.92. The compaction standard may be appropriately reduced for areas that do not influence the stability of the embankment.

5.4.3 For discharge of tailings at the rear of the tailings pond, the compaction layer by layer shall meet the minimum width requirement for the stress sustaining area of the embankment at the designed crest height.

5.5 Key calculation points of dry-stacking tailings dam slope stability

5.5.1 Stability of dry-stacking tailings dam slope shall meet the requirements provided in Table 4.4.1-2 of this code. For discharge of tailings at the rear of the tailings pond, the stability may not be calculated for operation under flood conditions.

5.5.2 The physical and mechanical properties indices of tailings deposited body shall be determined through compaction sampling test or field data from similar projects.

5.6 Flood discharge design for dry-stacking tailings pond

5.6.1 Flood retaining, cutoff and discharge facilities should be set up in the surrounding of the dry-stacking tailings pond according to different stacking method. The position of these facilities shall be determined according to the comprehensive needs during the entire service life of the tailing pond. Flood control standards shall be enforced according to the provisions in Article 6.1.1 of this code. If the final stacking height of the tailings pond is greater than 60m, additional intermediate flood cutoff ditches shall also be set up. Flood cutoff and discharge facilities shall also be set up in case the upstream catchment area is large and the terrain is suitable.

5.6.2 For discharge of tailings at the front of the tailings pond, starter dam shall be constructed in front of the pond. Flood discharge facilities of the tailings pond shall be designed according to wet-stacking tailings pond.

5.6.3 Flood discharge design for discharge of tailings at the rear of the tailings pond shall be in accordance with the following requirements:

1 Retaining dam shall be constructed in front of the pond to form storage capacity enough to store amounts of sand carried by one occasion of flood, which may be determined according to field survey or estimated according to Appendix D of this code. The height of the retaining dam should be 1/8—1/4 of the total embankment height but should not be less than 5m.

2 Drainage wells, tubes or other drainage facilities shall be provided in front of the retaining dam. The drainage outlet shall be 0.5m—1.0m higher than sand sedimentation elevation. Tailings nearby the retaining dam shall be cleared in time.

3 Temporary discharge ditches shall be set up in the deposited area of tailings when the pond area is large, to discharge the water into flood cutoff ditches on both sides. Permanent longitudinal and lateral discharge ditches shall also be set up on the final downstream slope of the embankment.

5.7 Other technical requirements for dry-stacking tailings pond

5.7.1 When there is spring water or perennial water flow in the tailings pond, blind ditches (pipes) or other facilities shall be set up to discharge the water outside of the pond.

5.7.2 Sprinkler spray and other measures may be adopted for dust control in the tailings deposited area of the tailings pond. Earth covering and vegetation greening shall be carried out on the embankment slope.

5.8 Determination of filtering plant location

5.8.1 Filtering plant should be located in the vicinity of the tailings pond, except when there are special requirements.

5.8.2 For discharge of tailings at the rear of the tailings pond, the filtering plant should be located at slightly upstream of the center of the pond and should be higher than the final embankment crest elevation.

6 Flood drainage design of tailings pond

6.1 General requirements

6.1.1 Flood control standard of tailings pond shall be in accordance with the following requirements:

1 Flood control standard during each stage of the service life of the tailings pond shall be determined by the class, storage capacity, dam height and service life of the tailings pond as well as degree of potential harm on the downstream, as shown in Table 6.1.1.

Table 6.1.1 Flood control standards of the tailings pond

Class of tailings pond during different stage	Ⅰ	Ⅱ	Ⅲ	Ⅳ	Ⅴ
Flood return period (years)	1000—5000 or PMF	500—1000	200—500	100—200	100

Note: PMF means probable maximum flood.

2 The lower limit of flood control standard may be taken when the storage capacity or dam height of tailings pond of a given class is closer to the lower limits of the class, the service life of the pond is short or possible accident would not cause severe harm to the downstream. The upper limit of flood control standard shall be taken when the storage capacity or dam height of tailings pond of a given class is closer to the upper limits of the class, the service life of the pond is long or possible accident would cause severe harm to the downstream. The flood control standard shall be raised by one class for very high embankment or when important residential area is located in the downstream. Flood control standard shall be raised for the tailings pond that possible accident would cause extremely serious harm to the downstream environment. If necessary, tailings pond shall be designed according to PMF.

3 For utilization of abandoned open pit or concave ground as the tailings pond, the flood control standard shall be based on 100-year return period if no tailings dam has been constructed in the surroundings; otherwise, the class and flood control standard of the tailings pond shall be determined according to the dam height and the corresponding storage capacity.

6.1.2 Flood drainage facilities must be constructed for the tailings pond.

6.1.3 The drainage method of the tailings pond and its layout shall be determined after technical and economic comparison according to topography, geological conditions, total flood amount, flood regulation storage capacity, tailings properties, water reclaiming method and water quality requirements, operating conditions, service life and other factors, and shall be in accordance with the following requirements:

1 Flood drainage system composed of drainage wells (or chutes) - drainage culvert pipes (or tunnels) should be adopted for upstream embankment method.

2 Spillway may be adopted for flood drainage when the geological conditions permit in case of one-step constructed dam at the same time the operating water level should be regulated in the pond using drainage wells (or chutes).

3 Joint flood drainage system composed of flood cutoff dam at the upstream and a separate flood drainage system in the tailings pond may be adopted when the upstream catchment area is large and the flood control requirements may not be met by sole flood drainage system in the tailings pond. The flood drainage system above the flood cutoff dam outside the tailings pond should not be merged with the flood drainage system within the tailings pond; otherwise, the reasonability of the merge shall be demonstrated and free surface flow control should be adopted for the drainage culvert pipe (or tunnel) after the merge. Technical study (including hydraulic model test when necessary) shall be carried out to demonstrate the reliability if pressure flow control is adopted.

4 Flood drainage shall not be implemented in the form of flood cutoff ditches for tailings pond of Class Ⅲ and above, except for discharge of dry stacking tailings at the rear of the tailings pond.

5 For the tailings ponds of Class Ⅳ and Ⅴ, flood cutoff ditches may be used for flood cut or diversion after demonstration of its suitability, when the surrounding terrain and geological conditions permit.

6.1.4 It shall be avoided to establish the foundation of the flood drainage structures at locations of adverse geological conditions or where earth filling is required. Foundation treatment design shall be carried out if such conditions may not be avoided. Flood drainage structures shall not be located directly on the deposited beach.

6.1.5 Underground flood drainage structures shall be made of reinforced concrete structure, which shall be placed on a bedrock foundation with sufficient bearing capacity. For underground flood drainage structures on non-rock foundation, engineering measures shall be taken to meet the requirements of the foundation bearing capacity.

6.1.6 Structural design of reinforced concrete flood drainage structures shall comply with the relevant provisions in the current industry standard *Design Code for Hydraulic Concrete Structures* SL191. Drainage tunnel design shall be in accordance with the relevant provisions in the current industry standard *Specification for Design of Hydraulic Tunnel* SL 279 and *Specifications for Load Design of Hydraulic Structures* DL 5077.

6.1.7 Engineering measures shall be taken to prevent mudslides, landslides, trees and other debris that influence the flood drainage capacity of the tailings pond.

6.2 Hydrological, hydraulic & flood regulation calculation

6.2.1 Flood regulation calculation of the tailings pond shall be in accordance with the following requirements:

1 It shall be calculated according to the provincial hydrological maps or the very small catchment area method recommended by the relevant departments. Local hydrological parameters shall be used in the calculation based on national uniform formulae. Field flood investigation shall be performed to assist verification if conditions permit. Two or more methods shall be used for calculation of the tailings pond of Class Ⅲ or above, preferably using the recommended formulae in the provincial hydrological maps, or selecting the large value.

2 When the interior water surface area of the pond is not more than 10% of the entire basin area, calculation may be performed according to land surface catchment for the whole area. When the interior water surface area of the pond is larger than 10% of the entire basin area, the area for water surface catchment and that for land surface catchment shall be calculated separately.

6.2.2 Rainfall duration shall be 24h for the calculation of design flood level. A shorter duration may also be used after demonstration of reasonability.

6.2.3 Calculation of flood regulation storage capacity shall comply with Article 3.2.2 of this code.

6.2.4 The type and size of tailings drainage structures shall be designed based on hydraulic calculation and flood regulation calculation, and shall meet flow regime and flood control safety requirements. Hydraulic model test should be carried out for verification in case of extremely complex flood drainage system.

6.2.5 The designed maximum flow velocity of the flood drainage structure shall not exceed the allowable flow velocity of the structure material.

6.2.6 Flood regulation calculation shall be calculated using water balance method according to the following formula:

$$\frac{1}{2}(Q_s + Q_z)\Delta t - \frac{1}{2}(q_s + q_z)\Delta t = V_Z - V_s \tag{6.2.6}$$

Where: Q_s, Q_Z—flood inflow to the pond at the start and end of the considered time period (m^3/s);

q_s, q_z—flood drainage from the pond at the start and end of the considered time period (m^3/s);

V_s, V_Z—flood storage in the pond at the start and end of the considered time period (m^3);

Δt—the considered time period (h).

6.2.7 The duration of draining all the flood from the tailings pond shall not exceed 72h.

6.2.8 Mechanical drainage shall not be used for the tailings pond.

6.3 Structures for flood drainage

6.3.1 The type of water intake structures shall be determined according to water drainage amount, terrain conditions of the tailings pond, and whether or not the structures will serve as reclaimed water facilities. When the water drainage amount is large, frame type of drainage wells should be used; when the water drainage amount is small, window type of drainage wells or chutes should be used; the inner diameters of drainage wells should not be less than 1.5m.

6.3.2 Absorption pit shall be set up at the bottom of the drainage well. Absorption and scour prevention measures shall be adopted according to actual conditions at the positions where the grade change points, turns and exits of drainage culvert pipes or tunnels.

6.3.3 The internal height of the drainage culvert pipe or chute should not be less than 1.2m.

6.3.4 The internal height of the drainage tunnel shall not be less than 1.8m, its internal width shall not be less than 1.5m, and its minimum design gradient should not be less than 0.3%.

6.3.5 For trench-buried and flat-buried types of drainage culvert pipes, backfill soil on both sides shall be compacted while the top filling shall be loose with a depth not less than 0.5m. For raise-buried drainage pipes, the vertical load on the top of the culvert pipe shall be determined with an additional coefficient based on the depth of the covering tailings sand.

6.3.6 The slit distance of the drainage culvert pipe between extension joints or settlement joints shall be determined according to the temperature and foundation conditions. Drainage culvert pipes built on rock base should be set up with an extension joint every 10m—20m distance and with a settlement joint at every position of lithological change or fault. Drainage culvert pipes built on non-rock base should be set up with a settlement joint every 4m—8m distance. The joint position shall be protected with rubber (or plastic) sealing belt, the depth of which shall meet the requirements of internal and external working water pressures. If the tailings seepage would not pollute the downstream environment, reversed filter connector may also be used for non-pressurized pipes. Sleeve shall always be equipped at joint positions. In seasonal frozen soil area, the drainage culvert pipe base shall be set up below the depth of the frozen soil.

6.3.7 The outer wall of the drainage culvert pipe shall be coated with asphalt.

6.3.8 When the rock condition is favorable in the tunnel and the water flow velocity is within the permissible limit, un-lined tunnel or combination of anchorage and shotcrete support may also be employed.

6.3.9 Flood drainage facilities shall be plugged upon termination of service. After plugging, safety shall be ensured for the permanent structures downstream of the plugged segment, the seepage stability safety of embankment upstream of the plugged segment and the safety of nearby drainage buildings.

6.3.10 Upon termination of service of the drainage well, plugging measures shall be taken above the well seat, on the well seat, at the inlet of the branch well or inside the branch well. The plugging body should be of rigid structure, and shall comply with the relevant provisions in current industry standard *Specification for Design of Hydraulic Tunnel* SL 279. The plugging body shall not be set on the well top.

7 Closure design for tailings pond

7.0.1 Closure design shall be performed for tailings pond that has reached the designed final embankment height and no longer heightens or expands, or that has been terminated from service in advance without reaching the designed embankment height.

7.0.2 Closure design shall be performed on the basis of fully understanding any nonconformity with national provisions on various potential hazards and risks for safety and environment protection in relation to tailings ponds out of service.

7.0.3 Practical rectification measures shall be designed against the potential hazards in the closure design. Design focus shall include the followings:

1 Rectification of dam body (including starter dam, embankment and saddle dam);

2 Rectification of flood drainage system;

3 Rectification of surrounding environment;

4 Improvement of monitoring facilities;

5 Management requirements after closure.

7.0.4 Rectification of tailings dam shall include the followings:

1 Dam body reinforcement, lowering of the phreatic line and other measures shall be taken where stability of the dam is insufficient, so that the stability of the dam may meet the requirements of this code;

2 Rectify any collapse, fracture or gully on the dam body;

3 Improve drainage ditch and earth or stone cover on the dam surface or vegetation greening, abutment cutoff ditch, monitoring facilities, etc.

7.0.5 Rectification of the flood drainage system shall include the followings:

1 Flood control capacity after closure of the tailings pond shall meet the flood control requirements specified in this code. If the flood control capacity is insufficient, measures shall be taken such as increasing the flood regulation storage capacity or construction of additional drainage systems, and when necessary, additional permanent spillways.

2 When the original drainage facilities may not meet the structural strength requirements or are badly damaged, it shall be reinforced; if necessary, new permanent drainage facilities shall be constructed, meanwhile, the original drainage facilities shall be plugged.

8 Tailings extraction

8.0.1 Geological survey shall be carried out on the resources in order to extract the tailings for reconcentration. Extraction and reconcentration shall be carried out only after confirming the worthiness for doing so and readiness of tailings storage site. Extraction and discharge of tailings shall not be carried out simultaneously in the same tailings pond.

8.0.2 Design of tailings extraction shall be in accordance with the following requirements:

1 The extraction method shall be technically reasonable, safe and reliable;

2 Ensure the safety of the tailings pond and the integrity and reliability of the environmental protection facilities throughout the extraction process.

8.0.3 Tailings extraction should be carried out in a balanced manner from center of the pond to the surrounding and from top to bottom layer by layer. Tailings extraction from upstream wet discharge tailings pond shall not proceed from embankment towards the center of the pond.

8.0.4 The class of the tailings pond during extraction shall be determined according to the whole storage capacity and dam height provided in Article 3.3.1 of this code. The flood control standard during extraction shall be determined according to Article 6.1.1 of this code. The minimum free height and beach width of deposited beach shall be determined according to Section 4.2 of this code.

8.0.5 Stability of the embankment during extraction shall meet the requirements in Section 4.4 of this code. The minimum factor of safety against sliding in the inner slope caused by extraction may be determined depending on the circumstances and selected from the values provided in Table 4.4.1-2 of this code.

8.0.6 Flood drainage facilities shall be in place during tailings extraction, the duration of draining all the flood from the tailings pond shall not exceed 72h.

Tailings within 15m range from any drainage well, drainage chute, drainage culvert or other facilities in the tailings pond shall not be extracted mechanically using excavator but only manually or using a water gun or wet extraction method while measures shall be taken to protect and prevent the blocking of the original flooddrainage facilities.

8.0.7 Tailings extraction design shall include the following main elements:

1 Tailings extraction scale and total amount;

2 Planning and sequence of extraction, including extraction technologies, transportation methods, equipment configuration, disposal of discharged tailings after extraction and utilization and protection of original facilities;

3 Stability analysis and safety measures for the slope of the tailings dam and the extraction slope in the pond during extraction;

4 Flood control standards, flood regulation calculation and flood control safety measures of the tailings pond during extraction;

5 Monitoring facilities in the tailings pond during extraction;

6 Rectification and reclamation plan of the tailings pond upon completion of extraction.

9 Reclaimed water of tailings pond

9.0.1 Ratio of reclaimed water of the tailings pond shall be determined comprehensively in combination with the reclaimed water in the whole processing plant area, the clarified water shall be reclaimed from the tailings.

9.0.2 Amount of reclaimed water shall be determined through water amount balance based on water intake, evaporation and loss of seepage water on the premise of ensuring the designed guarantee ratio of reclaimed water. The designed guarantee ratio of reclaimed water shall be the consistent with designed guarantee ratio of fresh water sources. When rainwater is reclaimed, the designed guarantee ratio of rainfall shall be consistent with the designed guarantee ratio of reclaimed water from the tailings pond. The designed frequency of evaporation shall correspond to the designed guarantee ratio of reclaimed water from the tailings pond. Loss of seepage water may be estimated based on thickness of water loss layers listed according to those specified in Table 9.0.2. The losses of seepage water from dam body, dam foundation, pond bottom and along the banks shall be calculated separately for tailings ponds of special engineering geological conditions.

Table 9.0.2 Thickness of water loss layers in tailings pond (m)

Hydrogeological condition	/Year	/Month
Slight permeability (impervious stratum)	0.5	0.04
Moderate permeability	0.5—1.0	0.04—0.08
Significant permeability (pervious stratum without water)	1.0—2.0	0.08—0.16

9.0.3 Design for reclaimed water from the tailings pond shall take full advantage of the potential energy of water in the pond. Static pressure water reclamation shall be adopted if the conditions permit. Reclamation using tramway trolley or storage boat pump stations should be adopted for tailings pond with high dam, high reclaimed rate and high requirement on balance as well as for tailings ponds with short surface frozen period.

9.0.4 Reclaimed water pump station should be designed with sufficient redundancy.

9.0.5 The distance from the water taking spot in the pond to the water boundary of deposited beach shall not be less than the required length for water settlement and clarification throughout the service life of the tailings pond. The distance required for water settlement and clarification shall be determined according to field measurement data of similar tailings ponds or calculation.

9.0.6 The storage tank for reclaimed water should not be less than supply of reclaimed water for a duration of 4h—6h in case of medium or small sized processing plants and not be less than 1h—3h in case of large sized processing plants.

10 Thickening of tailings slurry

10.0.1 When it is required to reclaim water in the processing plant area or increase the concentration of tailings slurry for delivery after technical and economic comparison, the tailings slurry shall be thickened. For dry tailings discharged, the tailings slurry may be thickened at first and then dewatered.

10.0.2 The design of tailings thickening shall meet the requirements of suspended matter content of overflow reclaimed water (the water quality requirements of beneficiation or mining process), the requirements of tailings concentration for delivery and the requirements of allowable solid load of the thickener. For dry tailings discharged, the requirements for filtration and dewatering shall also be met.

10.0.3 The type, specification and quantity of thickener shall be determined by such factors as output, property, feed concentration and discharge concentration of tailings of the processing plant and topographic condition. Standby thickener may not be set up. The site may be reserved when the mine has a potential to be enlarged.

10.0.4 The area required for thickener shall be comprehensively determined based on the suspended matter content in the overflow water, discharge concentration, the allowable solid load requirements, static settlement test or dynamic settlement test of the representative tailings samples, the actual operation data of similar tailings concentration or by calculation. The calculation shall be in accordance with the following provisions:

1 The area required for thickener shall be calculated according to its processing capacity per unit area. The area may be calculated according to the following formulas:

$$A=\frac{G_d}{q} \quad (10.0.4\text{-}1)$$

$$D=1.13\sqrt{A} \quad (10.0.4\text{-}2)$$

Where: A —area of thickener (m^2);

G_d —solid amount fed to thickener (t/d);

q —processing capacity per unit area [(t/d)/m^2], it may be selected based on industrial test, static settlement test or dynamic settlement test; if no test data is available, it may be selected based on the actual production index of similar processing plants;

D —diameter of thickener (m).

2 The area required for thickener shall be calculated according to the settling velocity of the largest particle in the overflow. The area may be calculated according to the following formulas:

$$A=\frac{G_d(m_1-m_2)k_1}{86.4u_0 k\rho_0} \quad (10.0.4\text{-}3)$$

$$u_0=545(\rho_s-1)d^2 \quad (10.0.4\text{-}4)$$

$$u=\frac{Q}{A}\times 1000 \quad (10.0.4\text{-}5)$$

$$u<u_0 \quad (10.0.4\text{-}6)$$

Where: m_1 —ratio of water weight and solid weight in the tailings slurry before thickening (water-solid ratio);

m_2—water-solid ratio of tailings slurry after thickening;

k_1—fluctuation coefficient of tailings quantity, $k_1=1.05—1.20$;

k— effective area coefficient of thickener, $k=0.85—0.95$;

u_t—free settling velocity of the largest particle in the overflow (mm/s), it may be acquired by test. If no test data is available, it may be calculated according to Formula (10.0.4-4);

ρ_w—water density (t/m^3);

ρ_s—tailings density (t/m^3);

d—the largest tailings particle diameter allowed in the overflow (mm), tailings d=0.01mm—0.005mm;

Q_1—overflow quantity of thickener (m^3/s);

u—upward flow velocity of thickener (mm/s).

10.0.5 The arrangement of thickener shall be determined in combination with the processing plant and tailings facilities, and it shall feature compact arrangement, short line, small quantities and convenient management. The tailings thickening system with requirements on water reclaimed in the processing plant area shall be located in the processing plant area, and the thickening system of dry tailings discharged shall be determined according to the actual situation. The large thickener, especially those located in cold area, should be adopted by semi-underground arrangement.

10.0.6 In probable freezing area, the peripheral traction thickener outdoor shall be gear-driven. Anti-freezing measures shall be adopted or more plant buildings shall be built for thickener in extremely cold area and heating facilities shall be established.

10.0.7 The feed pipes (channels) of thickener shall be installed on the truss, with the sidewalk no less than 0.8m wide reserved, and safety protection measures shall be taken. The drain grating shall be installed in front of the feed port, and the clear distance between grids should be 15mm—25mm.

10.0.8 The cross section of the overflow tank and outlet around the thickener shall be determined by hydraulic calculation. The width of the overflow tank shall not be less than 0.2m.

10.0.9 The overflow weir may adopt the sharp-crested weir, the triangular weir, broad-crested weir and submerged orifice, and the uniform water flow requirement shall be met. If the diameter of the thickener is comparatively large or the foundation condition is poor, the broad-crested weir should not be used, and the adjustable sharp-crested weir or triangular weir should be adopted. If the tailings slurry contains foam or floating objects, the baffle shall be provided in front of the overflow weir, if necessary, water spray defoaming or chemical defoaming measures may be adopted.

10.0.10 There shall be at least 2 discharge ports at the bottom of the thickener, and double valves shall be provided to the discharge ports. The cone base at the bottom of the thickener shall be provided with a water pipe for cleaning, with the water pressure no less than 300kPa. The flexible waterproof wall bushing shall be installed at the place where the discharge pipe passes through the wall.

10.0.11 The clear height of the bottom passageway should not be lower than 2.2m, the sidewalk width should not be less than 0.7m. Side drainage ditch shall be provided within the passage. The slope in the vertical and horizontal directions of the grade level shall be no less than 1%. There shall be safety lighting and ventilation requirements within the passageway. If the natural ventilation requirement may not be met, mechanical ventilation shall be provided.

10.0.12 The overload alarm, limit switch for raising rake tooth and necessary protection device shall be provided for the common thickener. The metering and test instruments shall be installed when necessary. The high efficiency thickener and the deep cone paste thickener shall be equipped with automatic monitoring facilities including the self-circulation shear pump, torque transducer, displacement transducer, automatic rake lifting mechanism, flocculation zone height monitoring, underflow concentration monitoring and frequency conversion control of underflow pump according to the requirements of equipment.

10.0.13 The safety and lighting facilities shall be provided for the parts of the thickener requiring operation and overhaul.

10.0.14 The high-efficient thickener and deep cone paste thickener shall be provided with flocculant preparation and addition facilities. The type and addition amount of flocculant shall be determined by test according to pH value and material properties of tailings slurry. The addition of flocculant may be done at two or more points or at one point, which shall be determined by test.

11 Delivery of tailings slurry

11.1 General requirements

11.1.1 The hydraulic delivery of wet tailings may adopt gravity flow without pressure, gravity flow under static pressure and pressurized delivery or the combination of the above according to topographic conditions. The dry tailings should be transported by tape or truck.

11.1.2 The selection and design of the route for tailings delivery pipe and channel shall be in accordance with the following requirements:

1 It shall be in line with the general layout requirements of companies and regions where the route passes through;

2 The gravity flow or local gravity flow should be adopted;

3 Occupation of farmland shall be avoided or minimized;

4 The route shall be short and the quantities of earthwork and structures shall be minimized;

5 The intersection angle of the plane and the vertical section shall be decreased and reduced. V-shape pipe section should not be developed;

6 It should not pass through the residential area, railway and highway;

7 Bad engineering geologic sites and flooded areas shall be avoided; It shall not pass through subsidence (collapse) zone, zone with explosion hazard and waste rock dumping area, etc.;

8 It shall be adjacent to road, water source and power supply, and easy for construction and maintenance.

11.1.3 The delivery capacity of tailings pipe and channel shall match the amount of tailings discharged by the processing plant. When the tailings quantities of different stages of the processing plant vary greatly, and one pipeline is not technically and economically reasonable, two or more pipelines may be laid by stages.

11.1.4 The weight concentration of tailings slurry delivery of the large or medium-sized processing plants should not be less than 35%, which shall be determined by technical and economic comparison.

11.1.5 There may be no standby gravity flow pipe and channel without pressure. The gravity flow delivery pipe under static pressure and the pressurized delivery pipe should adopt the wear-resisting pipes and fittings and the standby pipe should be provided for tailings slurry with large abrasiveness.

11.1.6 The emergency tailings discharge valve and tank should be provided at the lowest place of the delivery pipe.

11.1.7 If the tailings slurry in the delivery pipe and channel in cold area should be frozen according to thermal calculation, anti-freezing measures shall be taken.

11.2 Hydraulic calculation

11.2.1 A small-scale static test of tailings slurry delivery shall be done. For major projects, if the delivery distance of tailings is more than 10km or special slurry is delivered, the semi-industrial round-pipe test shall be conducted in addition to the small-scale static test. The tests of tailings slurry delivery shall be carried out in accordance with Appendix E of this code.

11.2.2 The rheological parameters of tailings slurry shall be determined by tests. If measured data is unavailable, the rheological parameters for reference may be calculated according to the relevant empirical formula.

11.2.3 The normal flow of tailings slurry discharged by the processing plant may be calculated according to the following formulas:

$$Q_{s}=\frac{W}{86400}\left(\frac{1}{\rho_{s}}+\frac{m}{\rho_{s}}\right) \tag{11.2.3-1}$$

$$m_{s}=\frac{1-C_{W}}{C_{W}} \tag{11.2.3-2}$$

Where: Q_s —normal flow of tailings slurry (m^3/s);

W —solid tailings weight (t/d);

m —ratio of water weight and solid weight in tailings slurry (water-solid ratio);

ρ_s —particle density of tailings (t/m^3);

ρ_s —water density (t/m^3);

C_W —weight concentration of tailings slurry, in decimals.

11.2.4 The large flow regulating device should not be provided for tailings slurry delivery, the flow shall be the normal flow added with a certain range of fluctuation. When the processing plant process may not provide accurate data, the fluctuation range of delivery flow may be taken as ±10%.

11.2.5 The critical flow velocity and friction loss of tailings slurry delivery shall be determined, which may be determined according to relevant tests or calculated with the relevant empirical formula according to the slurry properties. The design shall be based on reliable test data, empirical data, calculation results and operation data of similar systems, and then determined after comprehensive analysis.

11.2.6 In the hydraulic calculation of pipe delivery of tailings slurry, the critical diameter D_{max} and D_{min} shall be checked and calculated according to Q_{max} and Q_{min} respectively, and the appropriate standard pipe diameter D shall be selected and meanwhile be in accordance with the following requirements:

1 When calculating the friction loss, the value of flow and pipe diameter shall be in accordance with the following provisions:

1) When $D<D_{min}$, the flow shall take Q_{max}, the pipe diameter shall take D;

2) When $D>D_{max}$, the flow shall take Q_{max}, the pipe diameter shall take D_{max};

3) When $D_{min}<D<D_{max}$, calculate with Q_{min} and D_{min} and Q_{max} and D respectively, take whichever is larger.

2 In the hydraulic calculation of open channel delivery of tailings slurry, take Q_{max} as the flow value for calculation of the flow section and take Q_{min} for calculation of friction loss.

3 The safety coefficient of the design friction loss of pipe delivery and open channel delivery shall take 1.1—1.2.

11.2.7 The maximum design fullness of gravity flow pipe for delivery of tailings slurry may be determined according to those specified in Table 11.2.7.

Table 11.2.7 Maximum design fullness of gravity flow pipe for delivery of tailings slurry

Pipe diameter (mm)	Maximum design fullness
150—300	0.55
350—450	0.65
500—900	0.70
≥1000	0.75

11.2.8 The cross section of open channel for delivery of tailings slurry may be rectangular, trapezoidal or U-shaped, and the minimum width of the channel bottom should be 0.2m. The water free height of gravity-flow tank should be within the range of 0.2m~0.4m. The large section and large flow rate should take the larger one while the small section and small flow rate should take the smaller one. The free height of corner or reducing slope may be increased appropriately by experience or calculation.

11.2.9 The maximum design flow rate for tailings slurry delivery by gravity flow open channel, gravity flow pipe under static pressure and pressurized pipe should not exceed 1.3times that of the critical flow rate, and the minimum design flow rate should not be less than 1.0m/s.

11.3 Pipe and channel laying

11.3.1 The tailings pipe may be open-laid, partly buried or buried underground. The long-distance slurry pipe shall be buried underground, and the gravity-flow channel of tailings slurry should be open-laid. If the open-laid pipe and channel has adverse impacts on transportation or environment, it may be laid underground in the trench or passageway, and cover plate may be added for the gravity-flow channel. The tunnel or pipe bridge should be adopted when the pipe passes through the mountain with complex geological conditions and large topographic slope.

11.3.2 The turning angle of plane of the gravity-flow channel should not be greater than 60°, and channel shall be developed into curve, the radius of the curve shall not be less than 5times of the channel width. When the angle is larger than 60°, or if it is not larger than 60° but it may not be developed into curve due to terrain limits, the turning angle well may be used; if there is head, the drop well may be used. The elbow at the pipe angle should not be greater than 45°, when the turning angle is small, it may be adjusted by the joint deflection.

11.3.3 The minimum bending radius of on-site cold-forming bend shall be in accordance with the following requirements:

1 For the pipe diameter less than or equal to 300mm, the minimum bending radius shall not be less than 18times of the outer diameter of the pipe;

2 For the pipe diameter of 350mm, the minimum bending radius shall not be less than 21times of the outer diameter of the pipe;

3 For the pipe diameter of 400mm, the minimum bending radius shall not be less than 24times of the outer diameter of the pipe;

4 For the pipe diameter of 450mm, the minimum bending radius shall not be less than 27times of the outer diameter of the pipe;

5 For the pipe diameter less than or equal to 500mm, the minimum bending radius shall not be less than 30times of the outer diameter of the pipe;

6 The straight pipe section no less than 2m long should be provided at both ends of the bend.

11.3.4 When the gravity-flow channel is connected with the pipe, the connection well should be provided.

11.3.5 The width of subgrade surface of pipe and channel shall be determined according to factors including the size of its section, the distance between its outer walls and the distance between its outer wall and the curb, and the width of the sidewalk or the simple lane and so forth. The distance between the outer walls of the pipe and channel shall not be less than 0.4m, and the distance from the outer wall to the curb shall not be less than 0.3m and the width of the sidewalk should be 0.6m—0.8m.

11.3.6 The drainage of subgrade of pipe and channel shall adopt drainage ditch at one side or both sides according to topography and engineering geological conditions. The subgrade surface shall have drainage ditch in the direction of 2% transverse slope. The longitudinal gradient of drainage ditch shall be the same as that of the subgrade.

11.3.7 The slope ratio of subgrade cutting may be determined according to the engineering geological investigation report or Table 11.3.7.

If there is groundwater in slope, the slope ratio shall be determined according to stability calculation, and drainage facilities shall be provided.

Table 11.3.7 Slope ratio of subgrade cutting for pipe and channel

No.	Types of rock and soil		Slope height (m)	Slope ratio
1	Cohesive soil		<15	1:1—1:1.5
2	Loess and loess-like soil		<15	1:0.5—1:1.25
3	Gravel (rubble) and cobbly (pebble) soil	Cemented soil (compact)	<15	1:0.5—1:1
		Medium dense	<15	1:1—1:1.5
4	Strongly weathered rock		<15	1:0.35—1:1.25
5	Moderately weathered rock		<15	1:0.2—1:1
6	Weakly weathered rock		<15	Vertical to 1:0.75

11.3.8 The slope ratio of the embankment for pipe and channel may be determined according to the physical and mechanical properties of fillings and embankment height. For moderately dense rock and soil, it may be determined by Table 11.3.8.

Table 11.3.8 Slope ratio of the embankment for pipe and channel

No.	Types of rock and soil	Slope height (m)	Slope ratio
1	Cohesive soil	<12	1:1.5—1:1.75
2	Gravelly soil, coarse sand and medium sand	<12	1:1.5
3	Gravelly soil and cobbly soil	<12	1:1.5
4	Easily weathered rock	<8	1:1.5
5	Weathering-resistant rock	<8	1:1.3

The slope ratio of the flooded part of embankment shall take 1 : 2, and slope reinforcement and protection measures shall be taken when necessary.

11.3.9 The pipe spanning or crossing highway and railway shall be in accordance with the following requirements:

1 The approval from relevant authorities shall be acquired;

2 When crossing, the existing bridge and culvert shall be used at first. When the existing bridge and culvert are not available, the special culvert or bushing shall be provided;

3 The railway or highway should be vertically crossed.

11.3.10 When the delivery pipe and channel is designed to cross river, the following requirements shall be in accordance with:

1 The approval from relevant authorities shall be acquired;

2 The river should be vertically crossed;

3 When crossing river, the existing bridge should be used.

11.3.11 The blind ditch for laying tailings delivery pipe and channel shall be designed to be accessible or inaccessible according to the pipe and channel depth or maintenance requirements. The sidewalk width of the inaccessible blind ditch shall not be less than 0.6m with the clear height of no less than 1.8m. When it intersects with other underground facilities, the local height may be lowered to 1.2m. The clear distance between the ditch wall and the pipe wall and that between pipe walls shall not be less than 0.3m. For long accessible blind ditches, the ventilation measures shall be taken.

11.3.12 The section of tunnel for laying tailings delivery pipe and channel shall be in accordance with the following requirements including minimum section required for construction, sidewalk width no less than 0.6m, clear height no less than 1.8m, clear distance between the tunnel wall and the pipe wall and that between pipe walls no less than 0.3m.

11.3.13 When the topographic slope is too large, the design of gravity-flow channel shall take local energy dissipation measures including artificial roughening and single or multi-level head drop along the steep slope; the design of pressure pipeline shall take local energy dissipation measures including reducing the pipe diameter and increase on-way resistance along the steep slope and single-orifice or multi-orifice regulation ring pipe and so forth.

11.3.14 For the tailings pipeline requiring no emptying when the pump shuts down, its laying slope shall not be larger than the glide slope of tailings particles in the pipe; for those requiring emptying, the laying slope should not be less than the calculated hydraulic gradient of the tailings slurry; for those with laying slope not reaching the calculated hydraulic gradient, the pipe cleaning measures shall be taken.

11.3.15 The diameter of V-shaped pipe section of tailings delivery pipeline shall not exceed the critical diameter. The emergency tailings discharging valve and emergency tank should be provided at the lowest place. The operation of tailings discharging valve may be controlled manually or automatically as required.

11.3.16 For the tailings delivery pipe and channel with long length and large cross-section, the common simple lane shall be built for the construction and maintenance of tailings pump station and tailings pond (dam).

11.3.17 The distance between tailings discharging branch pipes on the dam crest should be 8m—15m. The sum of section areas of tailings discharging branch pipes shall be 1.5times—2.0times larger than the section area of the main pipe. At the beginning of tailings discharging, the tailings discharging branch pipes shall be extended to the upstream of tailings dam heel. For the long tailings dam, the tailings slurry valve shall be adopted to divide the main pipe into several sections and tailings discharging shall be done by section and area.

11.4 Pipe and channel material and accessory device

11.4.1 The pipe with the operating pressure above 1.6MPa, V-shaped pipe and the elevated pipe and local pipe with special requirements of the tailings slurry pipe should adopt the corrosion-resistant and high-strength steel pipe or the composite pipe with corrosion-resistant lining; for the pipe with the operating pressure no more than 1.6MPa, HDPE pipe, UHDPE pipe and nylon pipe meeting the pressure requirements may be adopted. The tailings discharging pipe on the dam should adopt the steel pipe or plastic pipe. The gravity-flow tank may adopt the concrete and reinforced concrete structures and so forth. The elevated flume may adopt the steel structure as well.

11.4.2 The tailings slurry pipe and channel shall be designed with wearing layer or liner. The gravity-flow channel may adopt the concrete channel wall with wearing layer, cement mortar layer or wearable liner; the pressure pipe may be provided with additional wall thickness for wearing or lined with other wear-resistant materials.

11.4.3 The steel pipe may be connected with welded and flanged quick couplers or couplers which may be easily disassembled and assembled. The plastic pipe may adopt hot melt connection or flange connection.

11.4.4 The tailings pipe open-laid on the subgrade and the pipe bridge shall be placed on the sleeper. The sleeper may be prefabricated with concrete, with the clear height of no less than 0.2m; the distance between sleepers shall be determined according to the material, wall thickness and pipe diameter of the pipe.

11.4.5 For the pipe passing through the steep slope, the uphill and downhill section with large height or the horizontal corner, thrust calculation shall be done according to temperature, pipe material, tailings slurry properties, operating pressure and pipe laying, and the fixed structures and piers shall be provided.

11.4.6 The number and location of the extension joints of the open-laid pipe shall be determined by calculation according to the factors including the local temperature difference, pipe arrangement, interface connection mode and strength and so forth. The locations of adjacent extension joints on two parallel pipes shall adopt the staggered arrangement. The extension joint shall be provided between two fixed points. The extension joint may not be provided when using the quick coupling or other measures to compensate the extension amount.

11.4.7 The special valve for tailings slurry with good corrosion resistance shall be provided in the tailings pipe and pump station, and the valve for clear water shall not be adopted.

11.4.8 The exhaust device shall be provided at the obvious uplift point of the tailings slurry pipe.

11.4.9 Corrosion prevention measures shall be taken on the outer surface of steel pipe and steel pipe fittings.

11.4.10 The sampling & metering device and drain grating may be provided near the starting point or at the appropriate position of the delivery pipe and channel as required. The clear distance between grids should be 15mm—25mm, and the total area of the grid spacing should not be less than 1.5times—2.0times of the flow cross section of the pipe and channel.

12 Tailings slurry pump station

12.1 General requirements

12.1.1 The tailings slurry pump should adopt a series of products recommended by the state; when there are a variety of pump types to be selected, optimized determination shall be done based on pump performance parameters, unit cost, project investment and operation and maintenance and other factors. The same type of pump should be selected for the same system.

12.1.2 The number of pump station for tailings slurry delivery shall be determined by hydraulic calculation results under different operating conditions, available pump types and techno-economic verification. If the equipment performance allows, the number of pump station shall be reduced.

12.1.3 The delivery pump should be provided with the frequency control device.

12.1.4 The location of the pump station shall be in accordance with the following requirements:

1 It should be designed to be on the ground, and excessive excavation shall be avoided;

2 It shall be located on a stable foundation;

3 The grade level of pump station shall be more than 0.5m higher than the flood water level of 50-year return period. In special cases, other flood control measures may be taken;

4 It should be located in the areas with favorable transportation conditions;

5 When the multi-stage pump stations are required, the location of intermediate pump stations shall be determined by the allowable pressure of the pump and the topographic & geological conditions and transportation, water supply and power supply conditions of the pump station. The last stage pump station shall be located in the area which does not cause excessive residual pressure of the terminal; when it is unavoidable, the pipe section length generating accelerated flow and the strength of accelerated flow shall be reduced.

12.2 Slurry tank and clean water tank

12.2.1 Each set (unit) of pump should be provided with a separated tailing slurry tank. The volume of slurry tank for the centrifugal slurry pump may adopt 1min—3min lifting slurry amount; for the positive displacement pump, the 10min lifting slurry amount may be adopted. The initial station of long-distance pipe delivery may adopt the slurry amount of no less than 8h lifting, and mixing facilities shall be provided. The volume of slurry tank used as the regulation or emergency tank shall be enlarged appropriately.

12.2.2 The suction inlet with slope ratio of 1:1—1:3 shall be provided at the bottom of the slurry tank. The electric stirring device shall be provided in the high concentration slurry tank and large capacity slurry tank.

12.2.3 The slurry tank may be installed outdoor with the inclined ladder, inside ladder and operating platform with railing.

12.2.4 The slurry tank shall be equipped with the overflow pipe and its discharge capacity shall be determined according to the maximum slurry flow. The overflow slurry shall be introduced into the emergency tank.

12.2.5 For the tailings delivery system requiring water flushing and regulation, the water supply pipe shall be connected to each slurry tank of the first pump station, and the setting position for controlling the valve shall be easily operable. The valve should be automatically controlled. Antifreeze measures shall be taken for outdoor water supply pipes in cold areas.

12.2.6 The flexible waterproof bushings shall be provided at the positions where the suction pipe of the slurry pump passes through the wall of slurry tank.

12.2.7 The drain grating shall be provided in front of the slurry tank. For the positive displacement pump, the safety sieve with the mesh size of 2mm—3mm shall be provided at the inlets of slurry tank and stirring chest.

12.2.8 For the water isolation pump, the separated clean water tank and water supply pipe shall be provided. The volume of the clean water tank should adopt the slurry amount of 10min lifting. The flow of the water supply pipe shall be 5%—10% of the lifted slurry amount within the unit time; the clean water tank may be provided indoor or outdoor, and each set (unit) of pump should be provided with a one-lattice clean water tank. If the clean water tank is more than two lattices, the overflow port may be set at 3/4—4/5 of total height of the clean water tank.

12.3 Equipment selection and configuration

12.3.1 The type selection of tailings slurry pump shall meet the requirements of design flow and design lift of tailing slurry and the flow and lift fluctuation range of the processing plant. In case of the normal flow lift, the centrifugal slurry pump shall operate within the high efficiency range. In case of the highest and lowest flow lift, it shall ensure safe and stable operation of the pump.

12.3.2 The lift of the tailings slurry pump shall be larger than the total lift required for the tailings slurry delivery. The total lift required for the delivery of tailings slurry shall be calculated according to the following formula:

$$P_k = \rho_k g \cdot H + \rho_w g \cdot i_k L + P_j + P_n + P_s \qquad (12.3.2)$$

Where P_k—total lift for delivery of tailings slurry (kPa);

H—height of the lifted tailings slurry (m);

ρ_k—slurry density (t/m^3);

ρ_w—water density (t/m^3);

L—pipe length (m);

i_k—friction loss along the pipe (mH_2O/m);

P_j—local friction loss of the pipe (kPa), it may take 5%—10% of the pressure loss due to friction along the pipe;

P_n—friction loss of pipe parts within the pump station (kPa), it may be determined by calculation or take 20kPa—30kPa for each pump station;

P_s—residual lift at the end (kPa), take 20kPa—30kPa for each outlet.

12.3.3 The total lift of the centrifugal slurry pump shall be calculated according to the following formulas:

$$P_c = \sum P_s \left(\frac{\rho_k}{\rho_s}\right) \cdot K_p K_H \qquad (12.3.3\text{-}1)$$

$$K_p = 1 - 0.25C_W \qquad (12.3.3\text{-}2)$$

Where, P_k—total lift of slurry pump for delivery of tailings slurry (kPa);

P_s—lift of slurry pump for delivery of clean water (kPa);

K_t—the lift reduction rate of the slurry pump for delivery of tailings slurry may be determined according to Formula (12.3.3-2);

K_n—the lift reduction rate of slurry pump after corrosion may take 0.85—0.98, and the small open pump with large corrosion amount and the diameter less than and equal to 100mm should take the minimum value, while the large closed pump with small corrosion amount and the diameter equal to or more than 200mm may take the maximum value.

C_w—weight concentration of tailings slurry.

12.3.4 The total lift of the positive displacement slurry pump shall be calculated according to the following formula:

$$P_k = \sum P_e \cdot K \tag{12.3.4}$$

Where, P_e—rated pressure of pump (kPa);

K—the pressure reserve coefficient of the pump, the diaphragm pump, plunger pump, piston pump and water isolation pump shall take 0.75—0.95. For the tailings slurry pipe requiring no emptying during power failure, the smaller value shall be taken.

12.3.5 The motor power of the centrifugal slurry pump shall be calculated according to the following formula:

$$N = K_1 \frac{Q_j P_s}{\eta_1 \eta_b} \left(\frac{\rho_k}{\rho_s} \right) \tag{12.3.5}$$

Where, N—required motor power of the pump (kW);

K_1—reserve coefficient of motor power, take 1.2 when $N \leqslant 40$kW and 1.1 when $N > 40$kW;

Q_j—calculated flow of pumped tailings slurry (m^3/s);

η_1—the transmission efficiency of the unit, take 1.0 for the coupling transmission, take 0.95—0.96 for the v-belt transmission and 0.97—0.98 for the gear transmission;

η_b—efficiency of pump when lifting clean water.

12.3.6 The motor power of the positive displacement slurry pump shall be calculated according to the following formula:

$$N = K_1 \frac{Q_j P_k}{\eta_v \eta_z} \tag{12.3.6}$$

Where, η_v—volume efficiency of pump shall take the value provided by the manufacturer or 0.85—0.90;

η_z—total mechanical efficiency, take 0.94.

12.3.7 The quantity of standby slurry pump shall be determined according to the factors in Table 12.3.7 including the corrosion of tailings, the type and material of the selected slurry pump, the working conditions of the pump station and the maintenance level and so forth. In case of serious wear or other unfavorable conditions, the larger value shall be taken, and if there are minor wear or other favorable conditions, the smaller one shall be taken.

When the slurry pump is used to clean pipe, the number of standby pump shall also meet the requirements of cleaning pipe.

Table 12.3.7 Quantity of standby slurry pump

Pump type	Specifications	Number of operating sets (units)	Number of standby sets (units)
Centrifugal slurry pump	Diameter ≤200mm	1	1
		2	2
		3—4	2—3
	Diameter >200mm	1	1—2
		2	2—3
		3—4	3—4
Diaphragm pump, plunger pump and piston pump	—	1	1
		2	1—2
		3—4	2
Water isolation pump	—	1—2	1
		2—4	2

12.3.8 When the centrifugal slurry pump needs water-seal water, the water quantity, water quality and water pressure shall be determined as the requirements of the equipment. If there is no specific data, the water quantity may be calculated by 1%—2% of the slurry flow; the water quality shall meet the requirements such as the content of suspended solids in the water shall be less than or equal to 300 mg/L, and the water pressure at the inlet of the slurry pump shall be 50kPa—200kPa larger than the operating pressure of the slurry pump. The water pump for water-seal water shall be provided with the standby pump.

12.3.9 The water of the pump station shall be discharged to the nearby emergency tank and shall not be randomly discharged.

12.3.10 When the centrifugal slurry pump is used to lift the slurry in multiple segments, the pump stations should be connected by the slurry tank, or they may be directly connected in series in remote distance. When they are directly connected in series at short range within the same pump station, the total lift shall be within the allowable range of the pump body strength.

12.3.11 When the centrifugal slurry pump needs to change the revolution so as to change the lift and flow of the pump in production, measures including frequency control and variable speed machine may be taken. When the positive displacement slurry pumps are in series operation, each set of pumps shall have the same speed regulation device, so as to ensure synchronous operation of the positive displacement slurry pump.

12.3.12 When the centrifugal slurry pump is driven by a v-belt or coupling, the safety guard shall be provided.

12.3.13 The buffers of diaphragm pump, plunger pump and piston pump should adopt high-pressure charging. The pump station shall be equipped with special and standby air-charging systems. The air charging pressure shall be 300kPa—500kPa greater than the operating pressure of the pump, and its capacity may be 0.4m^3/min—1.0m^3/min. The buffer shall also be equipped with a safety overpressure protection device.

12.3.14 The water supply system shall be provided when the plunger pump or water isolation pump is installed in the pump station, and the water supply quantity, water pressure and water quality requirements shall be provided by the manufacturer.

12.3.15 The lifting equipment of tailings pump station shall be determined according to those specified in Table 12.3.15.

Table 12.3.15 Lifting equipment of tailings slurry pump station

Weight of pump or motor (t)	Lifting equipment
<0.5	Manual or electric fixed monorail crane
0.5—1.5	Electric fixed monorail or manual bridge crane
>1.5	Electric bridge crane

The weight of the centrifugal pump shall be calculated as a whole; for diaphragm pump, piston pump, piston pump and water isolation pump, the weight shall be calculated by the largest component.

The level of lifting equipment shall take the larger one in Table 12.3.12 in case of serious corrosion of slurry pump, frequent maintenance, more than 3 sets (units) of operating pump or the underground pump station.

12.3.16 For the frequently operated valves on the slurry pipe in the pump station, the manual or hydraulic slurry valve should be adopted when the diameter is less than *DN*250mm. When the diameter is equal to or larger than *DN*250mm, the electric, pneumatic or hydraulic slurry valve should be used.

12.3.17 The configuration of the slurry pump shall be designed as press-in type, the feeding pressure of the positive displacement slurry pump should not be less than 300kPa, and the feeding pressure of the water isolation pump should not be less than 150kPa.

12.3.18 The slurry pipe in the pump station shall adopt the steel pipe, and the quick coupling or extension joint shall be provided at the appropriate positions on the pipe sections at the inlet and outlet of the slurry pump.

12.3.19 The arrangement of slurry pump, pipes and valves in the pump station shall be in accordance with the following requirements:

1 When it is technically and economically reasonable, the "one pump one pipe" system of one delivery pipe for one set (unit) of pump should be adopted;

2 The valve shall be installed for easy operation and maintenance. When the valve is more than 1.2m above the ground, the operation platform shall be provided;

3 The arrangement of the pipe shall feature short route, less valves, small turning angle and less turning points and avoid intersection and excessively long dead angle;

4 The pipe shall be installed on the ground or the platform, and the clear distance between the wall of the pipe and the ground or between walls shall not be less than 0.3m. When the pipe obstructs passage, the walkway spanning the pipe shall be provided;

5 The emergency tank shall be provided at the lowest position of the pipe;

6 The pipe shall not pass over the electrical equipment;

7 Pipes and valves shall be equipped with necessary support.

12.4 Pump station configuration

12.4.1 The plane arrangement of the pump station shall be in accordance with the following requirements:

1 The width of passageway between the bases of pump units, between the parts of pump unit extending out of the base and between the parts of pump unit extending out of the base and the wall shall be determined according to those specified in Table 12.4.1-1;

Table 12.4.1-1 Width of passageway inside pump station

Type and operating conditions of pump		Width of passageway between bases (m)	Width of passageway between the parts of main pump unit extending out of the base (m)	Clear width between the parts of main pump unit extending out of the base and the wall, between the auxiliary equipment and its surrounding (m)
Centrifugal slurry pump	Low voltage motor	≥1.2	≥1.2	≥1.0
	High voltage motor	≥1.5		
Water isolation slurry pump, diaphragm pump, plunger pump and piston pump		≥2.5	≥3.0	≥1.5

2 The width of passageway in front of the switchboard shall not be less than 2m, if there is any protruding part of the building at some locations of the passage, its width may be reduced to 1.5m;

3 The high voltage switchgear shall be isolated from the machines;

4 The pump station shall be equipped with repair site, and the area of repair site may be determined according to those specified in Table 12.4.1-2;

Table 12.4.1-2 Area of repair site

Pump type	Area of repair site (m^2)
Centrifugal slurry pump	≥9
Water isolation slurry pump, diaphragm pump, plunger pump and water flushing pump and so forth	30—50
Diaphragm pump	>50

5 The plane size of pump station shall be in accordance with the requirements of building module.

12.4.2 The height of the pump station shall be in accordance with the following requirements:

1 The effective height between the machines of the ground-type pump station shall be determined according to the requirement that the clear distance between the bottom of the lifted object and the top of the crossed object shall be no less than 0.5m. The clear height of centrifugal slurry pump station shall not be less than 3.2m. The clear height of the water isolation mud pump station shall not be less than 8.0m. The clear height of diaphragm pump station shall not be less than 6.0m;

2 The height of the parts above ground of the underground pump station shall be determined according to the requirements of equipment handling, but shall not be less than 3m.

12.4.3 The feeding pump of the water isolation mud pump station and the feeding pump of the high-pressure water pump and the diaphragm pump should be separated from the main pump by the partition wall or installed in a separated subsidiary room whose clear height shall not be less than 4.5m.

12.4.4 The pump station shall be provided with the separated central control room, the duty room and the spare parts warehouse and so forth, which should be arranged in the subsidiary room. The ground level of the distribution room should be 0.15m—0.3m higher than the main workshop. When the pump station is far away from the processing plant and the residential area of workers, appropriate living facilities shall be provided.

12.4.5 The width of the gate of the pump station shall be determined as the requirements for direct entry of the largest equipment or component carried by the truck. The slurry tank and clean water tank shall be located outdoor and an access door to the slurry tank and clean water tank shall be provided at the pump station.

12.4.6 The pump station shall be provided with a trench. Its width shall not be less than 0.3m, its slope should not be less than 0.01, and it shall incline to the emergency tank. The slope of indoor floor level inclining to the trench should not be less than 0.01.

12.4.7 The pump station shall be provided with emergency storage tank and cleaning pump for emergency storage tank.

12.4.8 The safety enclosure facilities should be provided within the pump station.

12.5 Power supply, communication and other facilities

12.5.1 The slurry tank shall be provided with a liquid level indicator, whose indication part shall be located indoor for easy observation. The alarm shall sound at the highest and lowest levels and the pump shall automatically shut down at the lowest level.

12.5.2 The inspection power and contact phone shall be provided within the pump station.

12.5.3 Lighting shall be provided inside and outside the pump station and above the slurry tank, the inspection lighting shall be provided when necessary.

12.5.4 The flow and pressure measuring instruments shall be installed and the slurry density measuring instruments should be provided within the pump station.

12.5.5 The pipe flushing water, dilution water and floor flushing water systems shall be provided within the pump station.

12.5.6 The heating and ventilation facilities shall be provided for pump stations which may not meet the requirements of heating and ventilation.

13 Environmental protection measures of tailings facilities

13.1 General requirements

13.1.1 The environmental pollution control indicators of tailings facilities shall be in accordance with relevant provisions of the current national standards including *Standard for Pollution Control on the Storage and Disposal Site for General Industrial Solid Wastes* GB 18599 and *Standard for Pollution Control on the Security Landfill Site for Hazardous Wastes* GB 18598, and shall also meet the requirements of the other relevant current national, industry and local environmental protection standards.

13.1.2 The wet-discharged tailings pond is one of the purification facilities of beneficiation wastewater, with self-purification functions such as precipitation, oxidation and adsorption, and the length of water surface shall meet the requirements of clarification distance.

13.1.3 The clarified water of tailings pond shall be returned to beneficiation and mining processes. When it must be discharged to the environment, the water quality shall meet the requirements of the current national standards including *Emission Standard of Pollutants for Copper, Nickel and Cobalt Industry* GB 25467, *Emission Standard of Pollutants for Aluminum Industry* GB 25465, *Emission Standard of Pollutants for Lead and Zinc Industry* GB 25466, *Emission Standard of Pollutants for Magnesium and Titanium Industry* GB 25468, *Discharge Standard of Water Pollutants for Iron and Steel Industry* GB 13456 and *Integrated Wastewater Discharge Standard* GB 8978 and other relevant local environmental protection standards. When the relevant requirements of the above standards may not be met, the tailings water treatment system shall be designed.

13.1.4 The tailings pond should adopt the measures of diverting clean water from wastewater.

13.1.5 The atmospheric pollution of tailings pond including dust shall meet relevant requirements of "unorganized emission" in current relevant national standards.

13.1.6 The environmental protection measures of tailings facilities shall be designed, constructed and accepted simultaneously with the main works of tailings facilities.

13.1.7 The design of the environmental protection measures of tailings facilities shall also be in accordance with the provisions of current relevant national standards in addition to this code.

13.2 Seepage control design for tailings pond environmental protection

13.2.1 The properties of tailings shall be identified according to provisions of relevant national regulations and standards. After the properties of tailings are identified, the groundwater quality shall be evaluated according to relevant provisions of the current national standard *Quality Standard for Ground Water* GB/T 14848 when the tailings pond is put into operation, and the corresponding environmental protection and anti-seepage measures shall be taken according to the functional requirements of groundwater in the tailings pond. The environmental protection and anti-seepage measures may be implemented in stages.

13.2.2 Tailings shall be classified into Category Ⅰ General Industrial Solid Waste and Category Ⅱ General Industrial Solid Waste and Hazardous Waste in accordance with relevant provisions of the current national standards including *Standard for Pollution Control on the Storage and Disposal Site for General Industrial Solid Wastes* GB 18599, *Identification Standards for Hazardous Wastes* GB 5085 and *National Catalogue of Hazardous Wastes*.

13.2.3 According to the categories of tailings, the tailings pond may be classified into the following three categories based on the strictness of environmental protection requirements:

1 Category Ⅰ tailings pond for Category Ⅰ general industrial solid waste;

2 Category Ⅱ tailings pond for Category Ⅱ general industrial solid waste;

3 Hazardous waste tailings pond for hazardous waste;

13.2.4 The tailings slurry with highly strict environmental protection requirements shall not be discharged into the tailings pond with less strict environmental protection requirements.

13.2.5 The Category Ⅱ tailing pond shall meet the requirements of environmental protection and anti-seepage, and shall prevent tailings and tailings water of tailings pond from polluting the groundwater and surface water, and shall prevent the groundwater from entering the tailings pond.

13.2.6 The environmental protection and anti-seepage requirements of Category Ⅱ tailings pond include that a layer of anti-seepage system shall be provided at the bottom and in the periphery of the pond, with the anti-seepage performance equal to a clay layer with the saturated permeability coefficient no more than 1.0×10^{-7}cm/s and thickness no less than 1.5m. The materials of the anti-seepage layer may adopt clay and other natural materials, or geosynthetic materials such as geomembrane and composite geomembrane and composite anti-seepage materials including the sodium geosynthetic clay liner (GCL). The anti-seepage layer may adopt the structure of single layer compacted natural clay or modified clay, or the combined structure of geomembrane and compacted clay or GCL.

13.2.7 The properties, type and thickness of anti-seepage materials used in Category Ⅱ tailings pond shall be selected according to the water head above materials, the properties of tailings and the deposited load and laying conditions of the materials. The thickness of geomembrane shall not be less than 1.5 mm. In addition that the anti-seepage layer shall have the physical and mechanical properties, hydraulic properties and durability as required in the design, the anti-seepage structure design shall be conducted according to relevant provisions of the current national standard *Technical Standard for Applications of Geosynthetics* GB 50290.

13.2.8 In order to monitor the groundwater pollution caused by the tailings water of Category Ⅱ tailings pond, no less than 3 underground water quality monitoring wells shall be provided around the tailings pond. The first well shall be provided in the upstream of the pond along the flow of groundwater as the reference well (background well). The second well shall be provided in the downstream of the pond along the flow of groundwater as the pollution monitoring well. The third well shall be located in the area around the pond which is most likely to be affected by the pollution diffusion as the pollution diffusion monitoring well.

When the groundwater aquifer is determined to be deep according to the hydrogeological data, and it has been proved that the groundwater will not be polluted, the groundwater quality monitoring well may not be provided.

13.2.9 After the anti-seepage system is completed and before tailings are stored, leak detection shall be conducted for the anti-seepage system and vulnerabilities of seepage control system shall be dealt with.

13.2.10 When the groundwater level is high and has adverse impacts on the anti-seepage system, the groundwater collection and drainage system shall be provided. The top of the groundwater collection and drainage system shall be no less than 1.0m from the bottom of the anti-seepage system.

13.2.11 If there are appropriate engineering geological and hydrogeological conditions, the Category Ⅱ tailings pond may also adopt the vertical anti-seepage system, with the anti-seepage effect in accordance with the anti-seepage equivalent principle in the environmental protection and anti-seepage requirements of Article 13.2.6 in this code.

13.2.12 The tailings of hazardous waste category shall be subject to safe disposal in accordance with relevant provisions of the current national standard *Standard for Pollution Control on the Security Landfill Site for Hazardous Wastes* GB 18598 and other hazardous waste regulation.

13.3 Other environmental protection measures of tailings facilities

13.3.1 The outer slope of the embankment shall be covered with gravel soil or planted with grass and shrubs as the embankment gets higher. The dry deposited beach shall adopt the water spraying measures to prevent dust pollution.

13.3.2 The emergency tank (pond) shall be provided near the tailings pump station and the lowest point of the V-shaped pipe section of delivery pipe. The emergency tank shall be cleaned in a timely manner.

13.3.3 The tailings facilities shall adopt environmental protection measures including water and soil conservation and land reclamation and so forth.

13.3.4 In order to protect the downstream water environment of the pond area, the tailings pond may be provided with the surrounding cutoff ditch to divert clean water from wastewater if the topographic and geological conditions of the pond area permit. The design standard of flow section of cutoff ditch should be determined according to the environmental classification of tailings: the design standard may be prepared according to the mean annual 24h rainstorm for Category Ⅰ general industrial solid waste; it may be prepared according to the 10-year return period rainstorm for Category Ⅱ general industrial solid waste; and it may be prepared according to 100-year return period rainstorm for hazardous waste.

13.3.5 The seepage collection facilities shall be provided in the downstream of the tailings dam, and the unacceptable seepage shall be collected, reused or treated.

Appendix A　Classification list of fresh tailings

Table A　Classification list of fresh tailings

Name of fresh tailings		Discrimination criteria
Type	Name	
Sand tailings	Gravel sand tailings	Particles with particle size larger than 2mm accounting for 25% ~ 50% of the total mass
	Coarse sand tailings	Particles with particle size larger than 0.5mm accounting for 50% of the total mass
	Medium sand tailings	Particles with particle size larger than 0.25mm accounting for 50% of the total mass
	Fine sand tailings	Particles with particle size larger than 0.074mm accounting for 85% of the total mass
	Silty sand tailings	Particles with particle size larger than 0.074mm accounting for 50% of the total mass
Silt tailings	Silt tailings	Particles with particle size larger than 0.074mm accounting for no more than 50% of the total mass and the plasticity index no more than 10
Clay tailings	Silty clay tailings	Plasticity index larger than 10, and less than or equal to 17
	Clay tailings	Plasticity index larger than 17

Notes: 1　The name shall be determined according to grain size gradation from large to small, whichever matches it first;

2　The plasticity index shall be calculated according to the liquid limit determined by the 76g cone penetrometer at the depth of 10mm in soil.

Appendix B Determination method for the tailings deposited beach slope

B.0.1 The average slope of any beach width may be calculated according to the following formula:

$$i_l = i_{100}(100/L)^{1/3} \tag{B.0.1}$$

Where, i_l —average slope of the calculated beach width;

L —calculated beach width(m);

i_{100} —average slope of 100 m beach width, which may be obtained from Table B.0.1.

Table B.0.1 Average slope of 100m beach width

Average particle size of tailings (mm)	Discharging flow (L/s)	i_{100} (%)				
		When the discharging weight concentration is p(%)				
		10	15	20	25	30
0.03	5	0.64	0.74	0.83	0.94	1.04
	10	0.47	0.54	0.60	0.69	0.77
	30	0.35	0.41	0.45	0.51	0.58
	100	0.26	0.30	0.33	0.38	0.42
0.05	5	1.24	1.44	1.60	1.83	2.04
	10	0.94	1.09	1.17	1.34	1.49
	30	0.68	0.79	0.88	1.00	1.12
	100	0.50	0.58	0.64	0.73	0.82
0.075	5	2.10	2.44	2.70	3.09	3.43
	10	1.54	1.78	1.98	2.26	2.52
	30	1.16	1.32	1.49	1.70	1.90
	100	0.85	0.98	1.09	1.24	1.39
0.10	5	2.59	3.00	3.33	3.80	4.24
	10	1.89	2.19	2.43	2.78	3.10
	30	1.42	1.65	1.83	2.09	2.33
	100	1.04	1.20	1.34	1.53	1.71
0.15	5	3.47	4.01	4.46	5.09	5.68
	10	2.54	2.94	3.26	3.73	4.15
	30	1.91	2.21	2.45	2.80	3.12
	100	1.39	1.61	1.79	2.05	2.28
0.20	5	4.27	4.94	5.48	6.27	6.99
	10	3.12	3.61	4.01	4.58	5.11
	30	2.35	2.71	3.01	3.44	3.84
	100	1.71	1.98	2.20	2.52	2.81
0.40	5	7.03	8.13	9.02	10.32	11.52
	10	5.14	5.95	6.60	7.55	8.42
	30	3.86	4.47	4.96	5.67	6.33
	100	2.83	3.27	3.63	4.15	4.63

Appendix C Average physical & mechanical property indices of tailings dam material

Table C Average physical & mechanical property indices of tailings dam material

Item	Medium sand tailings	Fine sand tailings	Silty sand tailings	Silt tailings	Silty clay tailings	Clay tailings
Mean particle size d_p(mm)	0.35	0.2	0.074	0.05	0.035	<0.02
Effective particle size d_{10}(mm)	0.10	0.07	0.02	0.01	0.003	0.002
Uniformity coefficient d_{60}/d_{10}	3	3	4	6	10	5
Natural unit weight γ(g/cm³)	1.8	1.65	1.9	2.0	1.95	1.8
Pore spare ratio e	0.8	0.9	0.9	0.95	1.0	1.4
Inner fraction angle φ(°)	34	32	30	28	16	8
Cohesion C(kPa)	7.84	7.84	9.8	9.8	10.78	13.72
Compression coefficient a_{1-2}(1/kPa)	1.[illegible]×10⁻⁴	1.7×10^{-4}	1.6×10^{-4}	2.1×10^{-4}	4.1×10^{-4}	9.2×10^{-4}
Permeability coefficient k(cm/s)	1.5×10^[illegible]	1.3×10^[illegible]	7.75×10^[illegible]	1.25×10^[illegible]	3.0×10^[illegible]	2.0×10^[illegible]

Notes: 1 The indices in the table are mean values from the sampling test of the dam;

2 C and φ values are direct shear (consolidated quick shear) strength indices.

Appendix D Estimation formula of sediment volume washed by the heaviest flood at one time for landslide dam

D.0.1 The sediment volume washed by the heaviest flood at one time for retaining dam may be calculated according to the following formula.

$$W_{CH}=1000H_{P}aF \quad (D.0.1)$$

Where, W_{CH}—sediment volume washed by the heaviest flood at one time (m^3);

H_P—maximum 24h rainfall of 20—50 year return period flood (mm);

a—coefficient of fineness of tailings (refer to Table D.0.1-1);

F—area of final tailings deposited zone km^2;

P—class of coefficient tailings pond (refer to Table D.0.1-2).

Table D.0.1-1 Fineness coefficient *a* of tailings

Content of tailings with particle size less than 0.074mm (%)	a value
<75	0.1
75—80	0.15
80—85	0.2
>85	0.25

Table D.0.1-2 Class coefficient *P* of tailings pond

Grade of tailings pond	I	II	III	IV	V
P value	0.45	0.35—0.4	0.3—0.35	0.25—0.3	0.2—0.25

Appendix E Tests of tailings slurry delivery

Table E Tests of tailings slurry delivery

No.	Test item	Test content
1	Water properties	Total acidity, total alkalinity, CO_3^{2-}, HCO_3^-, S^{2-}, Ca^{2+}, Mg^{2+}, SO_4^{2-}, Cl^-, K^+, Na^+, DO and pH
2	Material properties	Specific gravity, particle size and distribution, hardness and chemical composition
3	Slurry properties	Deposition, limit concentration, rheological parameters and pH
4	Pipe properties	Critical flow rate, resistance loss, optimum concentration, optimum pipe diameter, etc.
5	Operating characteristics	Shutdown start flow rate and limits, etc
6	Corrosive properties	Determine annual corrosion rate of pipe

Notes: 1 Items 1, 2, 3 in the table require less tailings samples and small test scale and therefore it is referred to as the small static test of the laboratory;

2 Items 4, 5 and 6 in the table require more tailings samples and large test scale and therefore it is referred to as the semi-industrial round-pipe-test.

Explanation of wording in this code

1 Words used for different degrees of strictness are explained as follows in order to mark the differences in implementing the requirements of this code.

1) Words denoting a very strict or mandatory requirement:

"Must" is used for affirmation, "must not" for negation.

2) Words denoting a strict requirement under normal conditions:

"Shall" is used for affirmation, "shall not" for negation.

3) Words denoting a permission of a slight choice or an indication of the most suitable choice when conditions permit:

"Should" is used for affirmation, "should not" for negation.

4) "May" is used to express the option available, sometimes with the conditional permit.

2 "Shall comply with..." or "shall meet the requirements of..." is used in this code to indicate that it is necessary to comply with the requirements stipulated in other relative standards and codes.

List of quoted standards

GB 50191 *Code for Seismic Design of Special Structures*
GB 50290 *Technical Standard for Application of Geosynthetics*
GB 5085 *Identification Standards for Hazardous Wastes*
GB 8978 *Integrated Wastewater Discharge Standard*
GB 13456 *Discharge Standard of Water Pollutants for Iron and Steel Industry*
GB 16297 *Integrated Emission Standard of Air Pollutants*
GB 18306 *Seismic Ground Motion Parameters Zonation Map of China*
GB 18598 *Standard for Pollution Control on the Security Landfill Site for Hazardous Wastes*
GB 18599 *Standard for Pollution Control on the Storage and Disposal Site for General Industrial Solid Wastes*
GB 25465 *Emission Standard of Pollutants for Aluminum Industry*
GB 25466 *Emission Standard of Pollutants for Lead and Zinc Industry*
GB 25467 *Emission Standard of Pollutants for Copper, Nickel and Cobalt Industry*
GB 25468 *Emission Standard of Pollutants for Magnesium and Titanium Industry*
GB/T 14848 *Quality Standard for Ground Water*
GBJ 22 *Code for Design of Roads in Factories and Mining Areas*
SL 191 *Design Code for Hydraulic Concrete Structures*
SL 203 *Specifications for Seismic Design of Hydraulic Structures*
SL 274 *Design Code for Rolled Earth-Rock Fill Dams*
SL 279 *Specification for Design of Hydraulic Tunnel*
DL 5073 *Specification for Seismic Design of Hydraulic Structures*
DL 5077 *Specifications for Load Design of Hydraulic Structures*