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Technical Guidelines for the Development of Small Hydropower Plants

DESIGN

Part 7: Construction Planning

SHP/TG 002-7:2019

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Further recommendations and suggestions for application for the update would be highly welcome.

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Foreword

The United Nations Industrial Development Organization (UNIDO) is a specialized agency under the United Nations system to promote globally inclusive and sustainable industrial development (ISID). The relevance of ISID as an integrated approach to all three pillars of sustainable development is recognized by the 2030 Agenda for Sustainable Development and the related Sustainable Development Goals (SDGs), which will frame United Nations and country efforts towards sustainable development in the next fifteen years. UNIDO's mandate for ISID covers the need to support the creation of sustainable energy systems as energy is essential to economic and social development and to improving quality of life. International concern and debate over energy have grown increasingly over the past two decades, with the issues of poverty alleviation, environmental risks and climate change now taking centre stage.

INSHP (International Network on Small Hydro Power) is an international coordinating and promoting organization for the global development of small hydropower (SHP), which is established on the basis of voluntary participation of regional, subregional and national focal points, relevant institutions, utilities and companies, and has social benefit as its major objective. INSHP aims at the promotion of global SHP development through triangle technical and economic cooperation among developing countries, developed countries and international organizations, in order to supply rural areas in developing countries with environmentally sound, affordable and adequate energy, which will lead to the increase of employment opportunities, improvement of ecological environments, poverty alleviation, improvement of local living and cultural standards and economic development.

UNIDO and INSHP have been cooperating on the World Small Hydropower Development Report since year 2010. From the reports, SHP demand and development worldwide were not matched. One of the development barriers in most countries is lack of technologies. UNIDO, in cooperation with INSHP, through global expert cooperation, and based on successful development experiences, decided to develop the SHP TGs to meet demand from Member States.

These TGs were drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of these TGs may be subject to patent rights. UNIDO and INSHP shall not be held responsible for identifying any such patent rights.

Introduction

Small Hydropower (SHP) is increasingly recognized as an important renewable energy solution to the challenge of electrifying remote rural areas. However, while most countries in Europe, North and South America, and China have high degrees of installed capacity, the potential of SHP in many developing countries remains untapped and is hindered by a number of factors including the lack of globally agreed good practices or standards for SHP development.

These Technical Guidelines for the Development of Small Hydropower Plants (TGs) will address the current limitations of the regulations applied to technical guidelines for SHP Plants by applying the expertise and best practices that exist across the globe. It is intended for countries to utilize these agreed upon Guidelines to support their current policy, technology and ecosystems. Countries that have limited institutional and technical capacities, will be able to enhance their knowledge base in developing SHP plants, thereby attracting more investment in SHP projects, encouraging favourable policies and subsequently assisting in economic development at a national level. These TGs will be valuable for all countries, but especially allow for the sharing of experience and best practices between countries that have limited technical know-how.

The TGs can be used as the principles and basis for the planning, design, construction and management of SHP plants up to 30 MW.

- The Terms and Definitions in the TGs specify the professional technical terms and definitions commonly used for SHP Plants.

- The Design Guidelines provide guidelines for basic requirements, methodology and procedure in terms of site selection, hydrology, geology, project layout, configurations, energy calculations, hydraulics, electromechanical equipment selection, construction, project cost estimates, economic appraisal, financing, social and environmental assessments—with the ultimate goal of achieving the best design solutions.

- The Units Guidelines specify the technical requirements on SHP turbines, generators, hydro turbine governing systems, excitation systems, main valves as well as monitoring, control, protection and DC power supply systems.

- The Construction Guidelines can be used as the guiding technical documents for the construction of SHP projects.

- The Management Guidelines provide technical guidance for the management, operation and maintenance, technical renovation and project acceptance of SHP projects.

Technical Guidelines for the Development of Small Hydropower Plants-Design
Part 7: Construction Planning

1 Scope

This Part of the Design Guidelines sets out the principles for construction planning for an small hydropower (SHP) station and the specific requirements for construction diversion, construction of the main engineering works, construction and planning of roads and transportation, construction of the plant facilities, construction general layout, overall construction progress and safety measures. Most of the given guidance will need to be simplified accordingly when dealing with smaller capacity stations (below 10 MW).

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

SHP/TG 001, *Technical guidelines for the development of small hydropower plants—Terms and definitions*.

3 Terms and definitions

For the purposes of this document, the terms and definitions given in SHP/TG 001 apply.

4 Construction diversion

4.1 General provisions

4.1.1 Construction diversion design shall be supported by adequate basic data and comprehensively analyse various factors, and select a diversion scheme which is technically feasible, economically viable, and can make the project bring benefits into play as soon as possible.

4.1.2 Construction diversion design shall properly solve water-retaining, drainage and impounding issues throughout all of the diversion stages. The diversion characteristics of the different stages and their relationships shall be analysed systematically, planned in an all-round manner and coordinated to resolve the contradiction between flooding and construction.

4.2 Flood standard for construction diversion

4.2.1 The flood control standards of construction diversion structures shall be expressed as the recurrence period of the flood, which may be determined according to Table 1. Under the following conditions, the upper limit values given in Table 1 may be adopted as the flood standard for a diversion structure:

a) The hydrologic data series of the river is relatively short (less than 20 years), or the project is located in the center of the rainstorm;

b) A new type of cofferdam structure is adopted;

c) The project is under a key construction phase, which may cause serious consequences after the accident;

d) There is no significant difference between the upper and lower limits in terms of engineering scale, investment and technical difficulty.

Table 1 Flood standards for diversion structures

Diversion structure type	Recurrence interval of flood (year)
Soil and rock structure	5～10
Concrete, masonry structure	3～5

4.2.2 If the diversion structure is combined with the permanent structure, the flood standard for diversion structure may still adopt the values in Table 1. However, the design of the part that becomes the permanent structure shall be subject to the flood control standards for permanent structures.

4.2.3 If there is a reservoir upstream of the river where the project is located, the flood standard for diversion structures, and the design discharge for diversions, shall consider the influence of the regulation and operation of the upstream cascade reservoir, and shall be selected by technical and economic comparison.

4.2.4 The minimum refilling elevation of each month during the cofferdam construction period shall be able to safely retain the maximum design flow that may occur next month. The recurrence period that is used to calculate the maximum design flow in each month may be appropriately reduced after demonstration, adopted the standard of normal use of cofferdam.

4.2.5 The closure period shall be selected based on the comprehensive analysis of hydrological characteristics, climatic conditions, cofferdam construction conditions, construction progress and navigation requirements. The closure period should be arranged in the dry period after, and severe cold area should avoid ice and freezing period.

4.2.6 The standard diversion discharge may be the monthly, or the ten-day average flow rate, for a recurrence period of five to ten years during the diversion period, and shall meet the following conditions:

a) For rivers with more than 20 years of actually measured hydrographic data available, the design diversion flow may be determined by analysing the actual measured data.

b) If pondage and regulation of upstream and downstream cascade reservoirs have changed the hydrographic characteristics of the river, the design diversion flow should be determined by special demonstration.

4.2.7 When the dam elevation exceeds the cofferdam crest elevation, the temporary flood standard for flood control of dam body during flood season, shall be determined on the basis of the dam type as indicated in Table 2.

Table 2 Temporary flood standards for flood control of dam body in construction period

Dam type	Flood recurrence period (year)	
	Flood retention by the dam in flood season, during the construction period	Flood control by the dam after the blockage of the diversion structure
Earth-rockfill dam	10～20	20～30
Concrete dam, masonry dam	5～10	10～20

4.2.8 If the permanent flood discharge structure is not equipped with the design flood discharge capacity after the diversion structure is blocked, the flood control standard for the dam body shall be determined on the basis of the dam body construction and operational requirements, as indicated in Table 2. The height of the dam body achieved prior to the flood season shall meet the flood retention requirements, and the curtain grouting and joint grouting elevations shall meet the impoundment requirements.

4.2.9 The blocking time of the diversion structure shall be determined according to the overall construction progress based on the premise of meeting the requirements of flood retention and impoundment for the reservoir. The design flow rate during the blockage may be the monthly or ten-day average flow rate for the recurrence period of five to ten years, or it may be determined by the analysis of the actually measured hydrologic statistical data. The design standard of diversion during the construction period shall be selected according to the importance of the project, accident consequences and other factors within five to twenty years recurrence period.

4.2.10 The impoundment standard of a reservoir during the construction period shall be determined on the basis of the requirements of power generation, irrigation, navigation and water supply and the safety of the dam, and the guarantee rate should be 75% to 85%.

4.2.11 During the blockage of a diversion structure and the impoundment of a reservoir, the downstream water supply shall be guaranteed.

4.3 Mode of diversion

4.3.1 Construction diversion may include phased cofferdam diversion mode and one-time riverbed cut-off cofferdam diversion mode, and the supporting works may include open channel diversion, tunnel diversion, conduit diversion, bottom outlet diversion, dam-gap diversion and combined diversions of different flood releasing structures. The diversion mode shall be selected after a comprehensive evaluation of various alternatives.

4.3.2 The selection of the construction diversion mode shall comply with the following principles:

a) The diversion mode shall be adaptive to the hydrological characteristics of the river and the topographical and geological conditions.

b) The construction period shall be short, and the construction shall be safe, flexible and convenient.

c) The permanent structure shall be effectively utilized to reduce the quantity and cost of the diversion works.

d) Construction diversion mode shall meet navigation, ice clearing, ecological flow, water supply and other requirements.

e) Diversion works from initial to later stages (i.e. river closure, cofferdam water retention, dam body flood control, blockage of diversion works and water supply) shall be reasonably integrated during the construction period.

4.3.3 When the phased cofferdam diversion mode is used, the first-phase cofferdam position shall be determined on the basis of the layout of hydraulic structures, the terrain of the longitudinal cofferdam, the geological and hydraulic conditions, the construction site, and the required transportation and access to the foundation pit. Permanent structures for power generation, navigation, ice clearing and sediment outflow should be constructed in the first phase.

4.3.4 If the tunnel diversion is adopted, the dimensions of the tunnel cross-sections and the number of tunnels shall be determined on the basis of the river hydrographic characteristics, the rock integrity and the cofferdam operation conditions. If the use of the diversion tunnel goes through different diversion phases, it shall be designed on the basis of the flood standard of the control stage.

4.3.5 Under the following conditions, a cofferdam which retains water during low flow periods should be adopted as the diversion mode:

a) The permanent structure (or temporary water retention structure cross section) can be built above the flood level, under the dam flood control standard, during a low flow period.

b) Although the foundation pit is flooded during the flood season, it has little impact on the project schedule and the loss is insignificant.

4.4 Cofferdam

4.4.1 The selection of cofferdam type shall comply with the following principles:

a) The cofferdam shall be safe and reliable enough to meet the requirements of stability, anti-seepage, and anti-scouring.

b) The cofferdam shall have a simple structure, shall be easy to build and remove, and shall be built with local materials and excavation slag.

c) The cofferdam foundation shall be easy to construct, and the cofferdam body shall be easy to connect to the bank slope or existing structures.

d) The cofferdam can be built with the required cross section and elevation within the scheduled construction period, and meet the construction programme requirements.

4.4.2 Different cofferdam types shall comply with the following requirements:

a) Earth-rockfill cofferdams shall fully utilize local materials, shall be low cost, and be of simple construction.

b) Concrete cofferdams should be a gravity cofferdam.

c) For the low water head, crib cofferdams, bamboo cage cofferdams, and straw-earth cofferdams may be adopted.

4.4.3 Earth-rockfill cofferdam filling materials shall meet the following requirements:

a) The seepage coefficient of soil materials for seepage control should not be more than 1×10^{-6} m/s. If there are abundant weathered materials or gravels, that have been proven to meet seepage control requirements, these materials may be selected.

b) The external surface of a corewall, or a sloping core, earth-rockfill cofferdam, shall be filled with non-cohesive materials with a seepage coefficient of more than 1×10^{-4} m/s; natural sandy cobble or rock ballast should be used.

c） The underwater section of a cofferdam rockfill should not be built with stones with a softening coefficient of more than 0.7.

4.4.4 The design load combination for cofferdam structures shall not include special load. The cofferdam crest width shall meet both the construction requirements and the emergency flood fighting requirements.

4.4.5 The safety calculations of concrete cofferdam shall meet the following conditions：

a） The maximum and minimum vertical normal stresses are calculated using the material mechanics formula. When the cofferdam is under design，a principal tensile stress of under 0.15 MPa is allowable for the upstream surface，and under 0.2 MPa for the cofferdam body.

b） The anti-sliding stability of a cofferdam foundation plane should be calculated with shear strength formula or shear-break strength formula.

4.4.6 Seepage control of a cofferdam foundation covering layer may adopt the following methods：

a） When the covering layer and water depth are relatively shallow，a temporary lower cofferdam may be installed to pump water and excavate the trench，or excavate the trench underwater，and construct a cut-off wall for seepage control.

b） Depending on the thickness and composition of the covering layer，the following options may be considered：high-pressure jet grouting，concrete cut-off wall or self-solidifying mortar trough，cement or clay cement grouting，sheet pile poured wall，or seepage control geomembrane.

c） The ratio of the seepage coefficient for the cofferdam foundation covering layer to the seepage coefficient for the bedding soil material should be more than 50，and the bedding thickness should not be less than 2 m.

4.4.7 At the joint between an earth-rockfill cofferdam and the sluiceway，the guide wall should be appropriately lengthened，or a spur shall be built，to divert the main flow away from the cofferdam in order to prevent the cofferdam foundation from being washed away. The scope for the required protection of the upstream face slope of an earth-rockfill cofferdam may be from 2 m below the lowest water level up to the cofferdam crest. The underwater protection material may be a sinking mattress，a willow pillow，a bamboo cage，or a concrete flexible raft；while the protection material above water may be masonry or reinforced gabions.

4.4.8 For an overflowing cofferdam，the following measures may be adopted to improve the flow regime and the upstream-downstream water surface connection，in the event that the most unfavourable flooding is encountered：

a) Prior to the overflow, the foundation pit shall be filled with water to form a water pillow, and the covering layer of the foundation pit slope shall be treated, in advance, with reverse filtration.

b) The overflow surface material and the anti-scouring material should be compared; the overflow surface of an earth-rockfill cofferdam shall be protected by a bamboo cage, a reinforced gabion or concrete flexible plates, depending on the water flow velocity and the construction conditions, with a cushion (reversed filter) installed underneath.

c) Gravity flow-deflecting piers shall be built on rock foundations.

d) Engineering measures shall be taken at the joints between banks to prevent erosion of the bank slopes.

4.4.9 A non-overflow cofferdam shall meet the following conditions with regards to the cofferdam crest elevation and cofferdam crest freeboard:

a) The cofferdam crest elevation shall not be less than the sum of the construction flood static water level, the wave height and the cofferdam crest freeboard level, which shall not be less than 0.5 m to 0.3 m.

b) The freeboard at the top of a seepage control structure of an earth-rockfill cofferdam shall be within the following constraints: 0.8 m to 0.6 m above the design flood static water level for a sloping core type cofferdam; 0.6 m to 0.3 m above the design flood static water level for a core-wall type cofferdam.

c) When there is a downstream tributary, various backwater flow conditions shall be combined to check the proposed cofferdam crest elevation.

4.4.10 The crest elevation of an overflow cofferdam shall be determined by the static water level plus the wave height.

4.4.11 The stability and safety factor of a concrete cofferdam, a masonry cofferdam and an earth-rockfill cofferdam shall meet the following requirements:

a) When the stability and safety factor of gravity concrete cofferdam and masonry cofferdam are calculated by the shear-break strength formula, the safety factor shall not be less than 3.0; if drainage failure is considered, the safety factor shall not be less than 2.5. When calculated with the shear strength formula, the safety factor shall not be less than 1.05.

b) The stability and safety factor of an earth-rockfill cofferdam side slope shall not be less than 1.05.

4.5 Diversion and discharging structure

4.5.1 The diversion channel shall meet the following requirements:

a) The arrangement of a diversion channel shall comply with the following principles:

1) The channel shall have a large capacity but only require relatively small excavation quantity.

2) There shall be few bends. Excavations in areas with landslides, collapses and high slopes, should be avoided.

3) There shall be easy access to the foundation pit.

4) The joint between the inlet/outlet and the cofferdam shall meet the anti-scouring requirements of the cofferdam foundation.

5) Excessive water level difference caused by lateral flows shall be avoided; scouring in the downstream areas and construction facilities shall be avoided during flood discharging.

b) The bottom width, bottom slope and inlet/outlet elevations of open channel shall be designed to ensure good transition between upstream and downstream flows and to meet the diversion, closure, navigation and ice clearing requirements, during construction period. For the open channel built on soft foundations, effective energy dissipation and anti-scouring facilities should be constructed.

c) The cross section of an open channel shall be convenient for later plugging. Lining method shall be determined based on geological and hydraulic conditions.

4.5.2 The diversion tunnel shall meet the following requirements:

a) The diversion tunnel route shall be selected on the basis of the topographical, geological and hydraulic conditions to ensure safe tunnel construction and operation. The clear distance between two adjacent tunnels, the spacing between a tunnel and permanent structures, and the thickness of the strata at the tunnel inlet and tunnel roof, shall all meet the requirements of stable and safe operation of surrounding rocks. When conditions permit, the diversion tunnels should be used as part of the permanent tunnels. The tunnel axes, the cross section type and the lining structure of the combined part shall meet both the permanent operational requirements and the diversion requirements.

b) The type of diversion tunnel cross section and the inlet/outlet elevations should be designed with comprehensive consideration of the diversion works, the closure works and other operations to ensure smooth inflows, good flow connection, and no cavitation damage. The tunnel cross section should be convenient for construction and the longitudinal slope of the tunnel bottom shall be selected based on discharge requirements and other conditions. Energy dissipation and anti-scouring measures at the outlet and the bank slopes shall be considered.

c) When a diversion tunnel is used, measures shall be taken to prevent cavitation erosion, shock waves, or vibration caused by alternating full flow or high speed pressure flow. The scope, type and blockage measures of tunnel lining shall be determined after technical and economic evaluation.

4.5.3 The diversion bottom holes shall meet the following requirements:

a) The number, elevation and size of diversion bottom holes should be taken into account of the requirements of tunnel closure, flood season, blockage, ice clearing, and downstream water supply. When the diversion tunnel will be used as the permanent tunnel for flood discharging, sediment clearing, and reservoir emptying during the project operation period, it shall meet both the permanent and the temporary operation requirements. After the temporary diversion bottom holes in the dam has completed its function, they shall be backfilled with concrete with the same designation of the dam body, and measures shall be taken to ensure the good combination of new and old concrete.

b) The width of the diversion bottom hole in the dam should not exceed half of the width of the dam section, and should be arranged in parallel joints.

4.5.4 The axes of the diversion conduit should be straight. The requirements of the intake may refer to the relevant provisions of the diversion tunnel and bottom hole. Alternating pressure and non-pressure flows are not allowed inside the conduit. In order to avoid uneven settlement of the conduit top and the dam body on both sides, all or most part of the conduit should be embedded into the bedrock. When the conduit is laid onto a soft foundation, measures shall be taken to reinforce the conduit structure or foundation. Segmented expansion joints shall be built to avoid conduit cracks caused by uneven settlement or temperature stresses.

4.5.5 The dam gap shall meet the following requirements:

a) In the construction of concrete gravity dam, arch dam and other solid structures, the dam gap shall be prepared in the dam body, in order to jointly release flooding with other diversion facilities. Overflowing is prohibited through non-solid structures such as the dam whose powerhouse is located inside the dam body until the closure of the powerhouse cavern is achieved; if overflowing is required, measures shall be taken to ensure the safety of the dam body.

b) The dam discharge gap should be placed on the riverbed, to avoid the bank slopes' scouring or erosion. For an earth-rockfill dam under construction that is required for temporarily overflow, the refilling height of the dam body, the overflow cross section type, the hydraulic conditions and the corresponding protective measures, shall be determined.

4.5.6 Except powerhouses with specifically designed overflows, the overflow from a powerhouse is prohibited during the construction period.

4.6 River closure

4.6.1 The closure mode shall be selected on the basis of the analysis on the hydraulic parameters, construction conditions and closure difficulty, and quantity and nature of the casting objects, and the technical and economic evaluation. Different closure modes shall be selected on the basis of the following conditions:

a) If the closure depth does not exceed 3.5 m, a single embankment vertical closure should be selected. If the energy level and water flow rate is high through the closure gap, heavy and large casting materials shall be used.

b) If the closure flow rate is large, and the closure gap is more than 3.5 m, a double embankment or multiple embankment vertical closure should be selected.

4.6.2 The specific requirements for the removal of the construction cofferdam or any other water barriers shall be put forward in the closure design.

4.6.3 The embankment axis shall be selected by analysing the topographical, geological and transportation conditions of the riverbed and banks of both sides, the cofferdam seepage control, the main flow direction, the navigation requirements and other factors. The embankment should be part of the cofferdam body.

4.6.4 The following principles shall be observed in determining the width and position of the closure gap:

a) When the riverbed width is less than 80 m, the reserve section may not necessary and no closure gap shall be built.

b) The head of the reserve section shall not be washed away.

c) The closure gap should be built on the riverbed with shallow water, a thin covering layer, or exposed basement rock.

d) The amount of work for the closure gap should be small.

4.6.5 If the sour resistance on the riverbed overburden at the closure gap section is low, riprap, wire boxes (reinforcing cage), or alloy string bags may be used in advance to protect the riverbed. The protection scope may be determined by reference to experience from similar projects. The bed protection length downstream of the vertical closure embankment axis may be 2 to 4 times of the average water depth at the closure gap, while the upstream length may be 1 to 2 times of the maximum water depth. The elevation of the top surface of the bed protection shall be determined after analysing the hydraulic conditions and the protection materials. The bed protection width shall be determined on the basis of the maximum possible scour width.

4.6.6 The following principles shall be observed in the selection of materials for the closure:

a) Excavation slag and local natural materials should be used for the filling materials of the reserve sections.

b) A certain amount of materials used for backup purposes, such as boulders, reinforced gabions or concrete tetrahedrons, shall be stocked for the closure. The reservation coefficient (Total stock/Required stock) should be between 1.2 and 1.3.

c) The total material stock for the closure shall be calculated by assessing the stockpiling of the closure materials, the transportation conditions, the possible loss of materials, the potential for embankment subsidence, and an appropriate amount of such materials that shall be reserved, with a reservation coefficient of between 1.2 and 1.3.

d) The bulk materials shall be easy to lift and transport.

4.7 Pit drainage

4.7.1 The total drainage volume at the initial stage shall be calculated in light of the water volume of the foundation pit after the cofferdam is closed, the water seepage of the cofferdam and foundation during the pumping process, the water volume of the cofferdam body and the foundation pit overburden, together with the possible precipitation. The possible precipitation may be calculated by the multi-year average daily precipitation during the pumping period.

4.7.2 The seepage of both cofferdam and foundation, water volume in the overburden, the precipitation during drainage and the waste water during construction shall be calculated respectively for regular drainage. The precipitation shall be calculated according to the maximum daily precipitation during the pumping period on the same day; the waste water during construction shall not overlap with the precipitation. The seepage of foundation pit may be appropriately increased after analysing the cofferdam type, seepage control mode, cofferdam foundation pit, reliability of geological data and the seepage water head.

4.7.3 When ascertaining the initial pumping strength of the foundation pit, the water level descending rate of the foundation pit shall be determined according to the requirements of different cofferdam types for seepage stability.

4.7.4 The pumping equipment shall have a certain standby and reliable power supply.

4.8 Impoundment, navigation, and ice clearing during the construction period

4.8.1 During the construction period, the reservoir impoundment date shall be determined considering the blockage of the diversion and drainage structures. The following conditions shall be analysed:

a) The construction schedule of the project associated with the impoundment, and the blockage plan of the diversion works;

b) Requirements for land acquisition, resettlement and reservoir clearance, and environment protection in the reservoir area;

c) Hydrological data, reservoir capacity curve and reservoir impoundment duration curve;

d) Flood control standards, flood discharge and flood control measures, and dam stability after impoundment;

e) Navigation, irrigation, ecological flow and other downstream water supply requirements;

f) When conditions permit, the possibility of benefiting from cofferdams in retaining water shall be considered.

4.8.2 The impoundment date during the construction shall meet the following requirements:

a) Calculate the reservoir water level according to the storage standard monthly;

b) Calculate the water level during flood season according to the flood control standard, and determine the elevation of the dam construction top surface and joint grouting plan of concrete dam before flood season.

4.8.3 The temporary navigation programme during the construction period shall be determined by technical and economic analysis with the construction diversion scheme. When a decision is made to stop navigation, during the construction period, the passengers and freight issues shall be properly solved.

4.8.4 When the amount of the flow ice and the ice size is too large, which results in the failure of the drainage structure to discharge smoothly, ice breaking or interception measures shall be taken.

5 Construction of the main works

5.1 General provisions

5.1.1 The construction method of the main works shall be able to realize the overall design scheme of the SHP project economically and reasonably, and ensure the project quality and construction safety. The complete and feasible construction method shall be determined, the rationality and feasibility of the overall construction programme shall be demonstrated, any alteration suggestions shall be raised for the layout of the hydraulic structures and building types, and the required data shall be provided for the compilation of the project estimate.

5.1.2 The following single project construction schemes should be studied with emphasis:

a) Works that control the progress;

b) Works with a large proportion of investment;

c) Works that affect the construction safety or quality;

d) Works with high construction complexity or with new construction technologies.

5.1.3 The following principles shall be observed in the selection of construction scheme:

a) Ensure construction safety, project quality and construction schedule;

b) It is conducive to shortening the construction period, reducing the auxiliary work quantities and additional construction workload, and reducing the construction costs;

c) It is conducive to the coordination and balance between successive operations, civil engineering and electromechanical installation, constructional and operational optimization, and the reduction of interference among all processes;

d) The technology shall be advanced and reliable, and the new construction technology selected should pass the production tests or appraisals;

e) Relatively balanced construction intensity and demand for construction equipment, materials, labour and other resources;

f) It is conducive to water and soil conservation and environmental protection;

g) It is conducive to the protection of workers' safety and health.

5.1.4 The selection of the construction equipment and the use of labour force should comply with the following principles:

a) The equipment should be applicable for the construction conditions at the site of the project and meet the design requirements. The production capacity shall meet the requirements of construction intensity;

b) The equipment should be flexible and efficient with low energy consumption, safe and reliable in operation, and meet the environmental protection requirements;

c) The equipment shall be selected according to the working site, construction intensity and construction method of each single work;

d) The equipment should be favourable for the allocation of personnel and equipment and minimized the waste of resources;

e) The equipment should be versatile and should be able to be used at different stages within the project;

f) The price of equipment and operational expenses are relatively low, and components should be easily obtained. The equipment maintenance, management and dispatching shall be convenient;

g) Any new types of construction equipment should be purchased as a complete set in a project. If a single construction equipment is used, it should be in line with the existing construction equipment in use;

h) On the basis of equipment selection, according to the working site, working shift systems and the construction methods in use, an optimal design of the combined labour-force shall be made by pooling different professions. Reference should also be made to the average-advanced skill levels within the country of work.

5.2 Open excavation of earth-rock works

5.2.1 The excavation level of the rock and soil shall be determined based on the actual geological conditions at the site.

5.2.2 The earth-rock excavation shall be carried out in layers from top to bottom. The layer thicknesses shall be determined through comprehensive analysis. The excavation of the dam foundation above water on both banks should be completed or substantially completed before the river closure. The elevation of the boundary between overwater and underwater parts may be determined by analysing the terrain, geology, excavation period and hydrological conditions.

5.2.3 The protective layer should be reserved between the bottom of blasting holes of the conventional excavation bench adjacent to the foundation surface and the foundation surface. For the rock excavation above the foundation protective layer, extended explosive charging and bench blasting should be adopted.

5.2.4 For the excavation of the surface of the designed side slopes, seismic measures shall be taken, such as a protective layer reserved and controlled blasting.

5.2.5 If adits are to be excavated, and the foundation excavation terrain, geology and excavation layer thickness meet the requirements, the radiant hole blasting may be used under the condition of satisfying the requirements of foundation pre-splitting.

5.2.6 Based on the construction general layout and overall construction schedule, the earthwork and the stonework of the whole project shall be balanced in combination with soil and water conservation measures. On the premise of meeting the overall construction schedule and the environmental protection requirements, the excavated rock ballast should be made use of. A reasonable arrangement shall be made to reduce secondary transportation, and any stacked slag shall not pollute the environment.

5.2.7 The centralized charge blasting shall not be used in the excavation of the rock foundation of hydraulic structures.

5.2.8 Controlled blasting shall be carried out in the vicinity of newly-poured mass concrete, newly grouted area, newly pre-stressed anchorage area, or newly shotcrete supporting area after analysis, and the vibration velocity of the blasting particles shall not exceed the allowable safety standard.

5.2.9 The excavation design of high slope shall abide by the following principles:

a) Top-down construction procedures shall be adopted.

b) Pre-split blasting or smooth blasting shall be used to avoid secondary slope cutting.

c) Any slopes with support requirements shall be supported in sufficient time, after the excavation of each layer.

d) The slope with cutting drainage ditches at the top of the slope shall be completed first and then the slope excavation shall be carried out.

5.2.10 The construction method and equipment selection of underwater excavation shall be determined according to such factors as water depth, flow velocity, topography, geology, excavation range and excavation volume.

5.2.11 The excavation of available materials should be based on the excavation conditions, the excavation strength, the quantity of available materials, the physical and mechanical properties, the quality requirements and other factors. Appropriate excavation, transportation methods and equipment should also be studied.

5.2.12 The layout of a slag road shall follow the following principles:

a) The layout of a slag road shall be uniformly planned according to such factors as excavation mode, construction schedule, transportation intensity, location of slag site, vehicle type and topographic conditions.

b) When there is difficulty in the slag road into the foundation pit, the maximum longitudinal slope may be increased, as appropriate, depending on the performance of the transport equipment and the length of the longitudinal slope, but it should not be greater than 15%. In the case of complex terrain, deep foundation pit and other conditions or difficult to lay out slag roads, other slag discharge methods may be studied and adopted.

c) It shall be able to meet the requirements of subsequent project engineering construction, and shall not occupy any part of structures, and should not occupy the parts of deep excavation with less pressure.

d) It should be short, flat and straight, and reduce the plane intersection.

e) The road with high traffic density should be equipped with dual lanes or circular lanes; in an area with low slag discharge intensity and steep terrain, a single lane may be used for slag discharge, and a passing lane should be set. The distance between passing lanes should not be more than 200 m.

5.3 Foundation treatment

5.3.1 For the foundation treatment, based on the requirements on foundations of hydraulic structures, the hydrological and geological conditions shall be carefully analysed. A technically feasible and economically reasonable construction scheme with reliable outcomes and a short construction period shall be selected through technical and economic evaluation.

5.3.2 The curtain grouting shall meet the following requirements:

a) The area of curtain grouting construction site shall not only meet the requirements layout of grouting system and grouting equipment, but also consider the needs of reinforcing grouting if necessary. Suitable curtain grouting should be carried out in the gallery.

b) Consolidation grouting of dam foundation with seepage berm shall be carried out after the concrete has reached the required strength.

c) Foundation grouting should be carried out as per the sequence of consolidation before curtain grouting. Curtain grouting should be constructed in a gradual and orderly way.

5.3.3 The anti-seepage wall shall meet the following requirements:

a) The plan size of the anti-seepage wall platform shall meet the requirements of trench making, slag clearing, concrete pouring and traffic.

b) The length of cut-off wall trenches shall be determined by comprehensive analysis of the strata characteristics, the trench depth, the performance of trench making machinery, the construction schedule requirements and the concrete production capacity, which may be 5 m to 8 m. For the deep groove and easy collapse section, the smaller value should be adopted.

c) The quality and quantity of earth material used in the construction of cut-off wall shall meet the requirements of trench making and trench clearing. The clay content of the earth material should be more than 50%, the plasticity index should be no less than 20, and the sediment content should be less than 5%.

d) The construction scheme of a thin wall concrete cut-off wall shall be selected according to the comprehensive analysis on the seepage-proof requirements of a hydraulic structure, the geological conditions, the construction equipment, the construction technology, the material, the construction period and other factors, and after the comparison of technology and economy.

5.4 Selection, planning and exploitation of the borrow area

5.4.1 Natural construction materials may be used as the material sources of concrete aggregate, earth-rock dam filling materials and engineering backfilling materials. The exploration reserves of natural construction materials shall meet the design requirements. The design requirements shall take into account various losses such as mining, processing, transportation and storage of materials, as well as the reserve coefficient of 1.25 to1.5 times.

5.4.2 Material sources shall be selected according to the construction requirements for the construction materials' quantities, quality and supply intensity. After a comprehensive analysis of material source distribution, reserves, quality, exploitation and transportation conditions, and working out an excavation-fill balancing plan, both on the basis of geological explorations and experiments, the selection shall be finalized through technical and economic comparison under the principle of high quality and cost effectiveness. Material source selection shall meet the following requirements:

a) Concrete aggregate material sources may be selected from engineering excavation materials, natural sand and gravel, stone mining materials or commercial materials. Priority should be given to the excavation materials as the source materials. Natural sand and gravel with rich reserves, relatively small stripping and mining, and good gradation and mining conditions, may also be used as the preferred material source, if there is no environmental constraint. When there is no suitable natural sand and gravel, the nearest quarry may be chosen. If a single type of material source does not meet the needs, a variety of materials with different proportions of admixtures may be chosen.

b) For the artificial aggregate of concrete, rock with a small linear expansion coefficient, good particle shape and moderate hardness after crushing, shall be used as the material source, and limestone material should be preferred. When using stone materials with joint and fissure development, especially blind joint development, the acceptability of the material should be proven by experimentation. The concrete of the same building should use the same type of aggregate source. If different types of aggregate source are used, it should be verified by test. The alkali activity of concrete aggregate shall be tested. Alkaline-active aggregate shall not be used without a specific demonstration.

c) Asphalt concrete aggregate shall be well graded, hard in texture, and not change in properties due to heating. Artificial aggregate should be crushed by alkaline rock. When natural gravel or acid rock is used as a crushing material, it shall be tested and proved. Natural sand and gravel site should be selected for their concentrated distribution, good gradation, uniform quality, good mining conditions and less influence of mining on environment, waterway and water intake.

d) Material source site with uniform soil quality, thick soil layer, easy quality control, high output rate, and a natural moisture content of soil material, close to the optimal filling moisture content, should be selected for the soil material field. Priority should be given to selecting soil material source sites within the engineering excavation area and the reservoir submerged area.

e) Rockfill material source shall be given priority to engineering excavation material, and the insufficient part may be mined in the nearby material site.

f) Transition materials should be made used of the excavation material of engineering cavern in priority. Natural sand and gravel should be selected as the source of filter materials or bedding materials. Where there is a shortage of qualified natural sand and gravel near the project, artificial preparation material may be used.

g) According to the construction schedule, the material balance planning shall make overall arrangements for the mining programme and mining intensity of various material sources, reasonably arrange the material flow direction, and reduce the stockpiling and transfer of materials. Computer dynamic simulation methods may be used for analysis, if necessary.

5.4.3 The selection sequence of the material sites should be first near and then far, first above water and then under water, first in the reservoir area and then outside the reservoir area. Material at high altitudes is to be used at high altitudes, material at low altitudes is to be used at low altitudes, and the cross-use of upstream and downstream materials shall be reduced.

5.4.4 Material site mining planning shall meet the following requirements:

a) According to the engineering characteristics and requirements, the topographic and geological conditions of the material site, the mining, transportation, slope support and soil and water conservation plan should be determined after comprehensive analysis.

b) Soil sites, natural sand and gravel sites and stone sites shall be planned according to the planned mining volumes required, which shall be determined according to 1.05 to 1.25 times of the design demand.

c) Soil material site affected by flood during construction period shall be mined and stockpiled before the flood. The amount of soil material shall be 1.2 times of the amount of soil material required during the stoppage period.

d) The material site mining period and mining plan for natural sand/gravel sites shall be determined according to the hydrological characteristics, topographic conditions, natural gradation distribution, design grading requirements and other factors. When the mining is stopped during the flood season, or the freezing period, it should be prepared at 1.2 times the required amount, during the stoppage period.

e) The influence of sand and gravel mining on river navigation shall be taken into account in the river sections with shipping requirements, and corresponding treatment measures shall be taken.

f) The working face and discharging line of the quarry shall be determined according to the requirements of material strength in each period. Two or more mining faces should be set up for continuous feeding.

g) Stone sites should be exploited by ladder section blasting, and the height of ladder section should be generally between 10 m and 15 m.

h) The maximum particle size of the stone in the concrete aggregate site shall be suitable for the excavation and crushing equipment. The rock-fill of the dam body shall be mined in different areas according to the design requirements of the dam material, and the requirements of lithology, weathering degree, particle size and grading.

i) The mining and transportation plan of the material site shall be determined by comprehensive comparison based on topographic conditions, mining plan, material characteristics, transportation volumes, transportation intensity, transportation distance and transportation equipment configuration.

j) The excavation slope of the material site shall be kept stable. Material must be excavated with slope support, and stepped excavation shall be adopted, and timely support should be provided.

k) The selection and mining of the material site shall meet the relevant requirements of environmental protection and water and soil conservation.

5.5 Earthwork filling

5.5.1 To select an earthwork filling scheme, the long-term observation data of meteorological stations in the region where the project is located shall be analysed. It is advisable to count the days of precipitation, temperature, evaporation, strong winds, freezing and other meteorological elements of different magnitudes, and determine the degree of influence on the use of various dam materials.

5.5.2 The transportation mode for the filling materials shall be determined by technical and economic comparison according to the building type, topographic conditions of the construction area, transportation volume, mining methods, transportation equipment model, distance and other factors, and shall conform to the following provisions:

a) The filling strength requirements shall be met.

b) The materials shall not be mixed, polluted or reduced in the physical and mechanical properties during transportation.

c) Different kinds of filling materials should adopt the same transportation mode. When using a variety of transport mode, it is advisable to make overall planning, including making rational arrangement and connection between them.

d) Transit links should be fewer, resulting in lower transportation costs, simple temporary facilities, and less preparatory work.

5.5.3 Road layout for the earthwork filling construction shall conform to the following provisions:

a) The standards of each section shall meet the requirements of transportation intensity and construction safety, and shall be determined after analysing the total transportation volume, the service life, the vehicle model and the local meteorological conditions in each section. Technical and economic comparison shall be made for special sections. Under the condition of limited slope length (not more than 200 m), the maximum longitudinal slope of the road shall not be more than 15%.

b) With consideration given to the topographic conditions, the accesses shall be applied during each construction stage.

c) It can give consideration to other construction transportation, cross-banks transportation and over-fill transportation during construction period, which should be combined with permanent highway.

5.5.4 The dam filling planning of rolled earth-rock dam shall conform to the following provisions:

a) The construction of impermeable soil-core rockfill dam shall be undertaken along the axis of the dam. However, on a wide river course, according to the requirements of construction procedure and overall construction schedule, the sectional construction method may also be considered.

b) The cross section of the dam body shall be filled in flat and rise equably. If necessary, the temporary water-retaining section may also be studied.

c) Transport vehicles shall not pass through the corewall, inclined wall or toe board, and special construction measures shall be proposed, if necessary.

5.5.5 The type of soil and rock compaction equipment may be selected according to the nature of the soil and rock, and construction parameters such as the thickness of the paving materials. The number of roller compactions shall be determined by analysis and research, or engineering analogy method, according to the nature of soil and rock and the performance of the compaction equipment.

5.5.6 Rock-fill material shall be paved by the progressive method, better graded rocks, gravel (pebble) and other materials should be paved by the backward method, and mixed paving shall be used for rock-fill with a thickness of more than 1.0 m. The rolling direction shall be carried out along the axis of the dam. The staggered distance method should be used for rolling, and water should be added properly before rolling.

5.5.7 The transition material shall be filled by the backward method and shall be rolled with the same layer of cushion material or reversed filter material.

5.5.8 Cushion material should be filled by the backward method and rolled with the same layer of transition material. The upstream slope of the cushion material may be protected by extrusion side wall, overturning slope mortar, rolling cement mortar, shotcrete or emulsified asphalt.

5.5.9 The impermeable soil material should be paved and filled with the progressive method, and the rolling direction shall be parallel to the axis of the building. The difference between the soil moisture content and the optimal moisture content shall be adjusted. The slope degree of the joint and cutting shall be determined according to the selected construction machinery and equipment.

5.5.10 Soil construction shall be arranged in the rainy season. During the rainy season, suitable soil construction scheme shall be selected, and reliable rainproof measures shall be taken.

5.5.11 Water shall not be added when filling stone under negative temperature conditions, and the thickness of the paving material shall be reduced and the amount of rolling shall be increased. When the average temperature of the day is lower than 0 ℃ the soil material shall be assessed based on the construction standards in low-temperature season. When the average temperature of the day is lower than −10 ℃, it is not suitable to fill the soil material, otherwise technical and economic demonstration shall be carried out. During the construction of soil materials in low temperature season, the insulation and anti-freezing measures shall be assessed.

5.5.12 The construction of geomembrane impervious body shall conform to the following provisions：

a） The length of joints and blocks shall be determined according to the construction conditions，and the length and quantity of joints shall be reduced.

b） The connection shall be undertaken using the method of membrane seam welding ensuring correct overlap alignment and levelling.

c） After completion of laying，cement slurry shall be sprayed or the protective layer shall be backfilled in time

d） The core wall should be arranged in a zigzag pattern，and the paving schedule shall be in line with the dam filling schedule.

e） Construction machinery should not span the geomembrane.

5.5.13 The construction machinery selected for an earth-rock dam shall be suitable for use on an earth-rock dam. The number of the equipment may be calculated according to the average strength during the construction peak period，with an appropriate margin.

5.5.14 The following principles shall be observed in the design of a temporary section of dam during flooding：

a） The basic requirements of stability，seepage and ultra-high safety shall be met.

b） The top width shall meet the width requirements of repairing the sub-weir when the flood exceeds the design standard.

c） Inclined wall and narrow core dam should not be divided into temporary sections.

d） After the dam foundation is cleared up，the downstream dam body shall be completely filled to above the backfilter water body and then retracted for slope.

e） The upstream rock slope and cushion shall be filled to the flood retaining elevation according to the design requirements. If these requirements are not met，temporary protective measures shall be taken.

5.6 Concrete construction

5.6.1 Concrete construction scheme shall be selected based on the following principles：

a） The concrete production，transportation，pouring，curing and temperature control measures and other construction links shall be reasonably connected.

b) The construction technology is advanced, the equipment is reasonably allocated, and the overall production efficiency is high.

c) There are minimum transit steps during the transportation process, the transportation distance is short, and the temperature control measures are simple and reliable.

d) The pouring rate at primary, middle and later stages shall be coordinated and balanced.

e) There is little interference between concreting operation and installation of hydro mechanical and electromechanical structures, taking into consideration both primary and secondary concrete placement.

5.6.2 The concrete pouring procedure and pouring location at different elevation of each period shall be coordinated with the material supply routes, lifting equipment arrangement and electromechanical installation programme. Factors such as the height difference of adjacent blocks and temperature control measures and other relevant requirements shall also be accounted for. The progress during different phases shall meet the requirements of river closures, flood retention and flood protection, hole sealing and water storage.

5.6.3 The concrete pouring equipment shall be selected based on the following principles:

a) The lifting equipment may control the pouring parts on the whole plane and elevation.

b) The main equipment has good performance and high productivity, and the supporting equipment can give full play to the production capacity of the main equipment.

c) Within fixed working range, the equipment can continuously work and the equipment utilization rate is high.

d) In intervals between pouring, the equipment can undertake the hoisting of mould, metal components and small equipment at the work face and other auxiliary work.

e) The pouring block is not compressed, or the pouring period is not extended due to the block compressing.

f) The production capacity can meet the requirements of pouring intensity during the peak period on the premise of ensuring the quality.

g) The concrete should be directly lifted and placed into the block. Advanced, efficient and reliable equipment should be selected for the concrete pouring and transportation.

h) If the concrete is carried far away, a concrete mixing truck should be adopted.

5.6.4 The concrete lifting equipment shall meet the following requirements:

a) The number of the concrete lifting equipment may be determined through calculation, or engineering analogy method, according to the monthly peak pouring rate, cage capacity, hourly circulation times of equipment, quantity of placement blocks available for pouring, and auxiliary lifting workload. The auxiliary lifting workload may be calculated as a percentage of the equivalent concrete lifting time, and the value may be selected within the following ranges: 10% to 20% for gravity dams; 20% to 30% for light dams; 30% to 50% for powerhouses.

b) The hourly circulation times for the concrete lifting equipment shall be determined through analysis and calculation, or engineering analogy method, according to the equipment operational speed, horizontal and vertical transportation distance from the material fetching point to unloading point, availability of supporting equipment, construction management level and technical proficiency of workers.

5.6.5 Concrete construction design should be selected through scheme comparison; the quantity of mixing, transportation and lifting equipment and their productivity, the pouring rate and the total pouring period shall be determined.

5.6.6 The mould may be selected based on the following principles:

a) The mould shall be in accordance with the characteristics of the concrete structure, construction conditions and pouring methods.

b) It is preferable to use steel moulds rather than wood moulds.

c) The structural type should be standardized and serialized; it shall be convenient for production, installation, dismantling and lifting and it shall be conducive to mechanized operation and a large number of turnovers.

5.6.7 The maximum pouring face for a dam body should be determined by analysing the concrete performance, pouring equipment capacity, temperature control measures, construction period requirements and other factors. If the concrete is poured by a plane pouring method, the equipment production capacity shall ensure that the whole placement block is poured before the initial setting of the concrete. If the area of placement block is too large to match the equipment production capacity, the pouring by bench method may be adopted.

5.6.8 The joint grouting of a dam body shall be subject to the following principles:

a) The joint grouting shall be carried out after the concrete in the grouting area, and the above cooling layer, reaches the stable temperature of the dam body or the design specified value. If effective measures are taken, the concrete age should not be shorter than 4 months.

b) The grouting partition height within the same dam joint shall be about 10 m to 15 m.

c) The allowable height difference between grouting elevation of arch sealing of an arch dam and the top surface of pouring layer shall be determined based on the stress during construction period.

5.6.9 Temperature control shall be planned in mass concrete construction. Temperature control requirements may be subject to the relevant guidelines in Appendix A. If possible, the optimum combination of various measures should be determined by the systemic analysis method. According to the project characteristics, construction conditions, climate conditions and temperature control requirements, cooling measures in summer and thermal insulation measures in winter shall be taken.

5.6.10 The mass concrete mixed with fly ash should meet the following rules:

a) The humid curing time for the exposed surface shall not be less than 21 days.

b) Under low temperature, surface insulation shall be paid close attention to, and the mould removal time shall be properly prolonged.

5.6.11 The necessity of concrete construction during a low temperature season shall be determined through technical and economic evaluation and analysis according to the overall progress. For concrete construction in a low temperature season, thermal insulation and anti-freezing measures shall be taken. The temperature standards and thermal insulation and anti-freezing measures shall be implemented in accordance with Appendix A.

5.6.12 Raw materials and mixing of roller compacted concrete (RCC) shall meet the following requirements:

a) The cementing material content should not be less than 130 kg/m^3 and the maximum aggregate particle size should not be greater than 80 mm.

b) Fly ash, volcanic ash and other active materials may be used as the admixtures of RCC, and their applicability may be determined through experimental studies.

c) The mix -ratio of RCC shall be determined through testing.

d) The Vc value of RCC material consistency (or structural viscosity) should be determined through site tests.

e) Both the gravity type and forced type mixing equipment may be used for mixing RCC.

5.6.13 RCC construction shall meet the following principles:

a） Construction in high temperature season should be avoided，and temperature control design should be carried out.

b） The concrete filling should be carried out with the continuous rise of thin layers. The thickness may be correspondingly increased according to the experience.

c） RCC may be directly poured into powerhouse by dump truck or by rubber belt conveyor assisted by trucks. If negative pressure chute（pipe）is used to transport RCC materials，its dip angle shall be greater than 45°，and the single stage fall should not be greater than 70 m.

d） RRC may be paved by swamp bulldozer，or paver，and compacted by vibrating roller. To meet the rolling compaction requirements for different parts of the dam body，vibratory rollers of different models and power should be provided.

5.6.14 The powerhouse concrete pouring and electromechanical installation shall be properly coordinated to avoid or reduce mutual interference. Concrete works related to the first turbine-generator unit should be poured first.

5.6.15 The toe slab concrete construction of the faced rockfill dam shall be completed before the filling of the bedding，transition materials and the main rock-fill area of the adjacent blocks. When the dam height is no more than 70 m，the slab concrete should be poured in one time. Slab concrete pouring shall be carried out from bottom to top by the sliding mode，and sequence pouring methods shall be adopted between strips. The pouring sequence of the slab concrete should be to pour the central slab first and then both sides.

5.6.16 An asphalt concrete construction plan shall be determined according to the factors such as the project layout，the structure type of anti-seepage body，the climatic conditions of the project area and the construction equipment，after comprehensive analysis and research. The paving shall comply with the following provisions：

a） The slope length and width of asphalt concrete slabs shall be determined according to the construction conditions，construction equipment，construction operation and other conditions.

b） The thickness of the paving layer for a rolled asphalt concrete core wall should be determined by roller compacted test，and 0.2 m to 0.3 m may be used. The paving layer shall be levelled and pressed with the filling of the transition layer on both sides. The poured asphalt concrete core wall should be constructed with a steel mould which can be disassembled and assembled.

5.6.17 Self-compacting concrete shall meet the requirements of setting time，cohesion and water retention，as well as self-compacting performance of ordinary concrete mixes. Self-compacting concrete construction shall comply with the following provisions：

a） The mixing station（building）shall be used for centralized mixing，and the mixer truck should be used for transportation, and insulation and other measures should be taken.

b) Machines, tools and pouring methods shall be selected according to the structural characteristics of the pouring parts and the self-compacting performance of the concrete.

c) The pouring speed should not be too fast, and the pouring process shall be continuous.

5.6.18 The construction of cemented sand and gravel shall comply with the following provisions:

a) The construction layout shall conform to the corresponding requirements for construction intensity, material characteristics and construction site conditions.

b) The maximum particle size of sand and gravel should not exceed 150 mm. Continuous mixing equipment with a large output and high efficiency should be used to mix cemented sand and gravel.

c) Cemented sand and gravel should be transported by dump truck, conveyors and loaders, and the levelling equipment should be carried out by a scraper, bulldozers, loaders and backhoe excavators.

d) Cemented sand and gravel should be layered, opened and continuously paved. The paving area shall be in accordance with the paving capacity and the allowable interval between layers. The interval between layers shall be controlled within the allowable time of direct paving, and the cushion shall be used for layers that exceed the allowable time for direct paving.

5.7 Underground engineering construction

5.7.1 The construction methods and parameter selection of underground engineering shall be primarily based on the classification of surrounding rocks and the deformation characteristics and cross-sectional shape, size and drainage of underground engineering.

5.7.2 When drilling and blasting method is adopted in undergrounding engineering, a drilling frame carrier and multi-arm drilling machine should be considered as the drilling equipment.

5.7.3 The construction plan for tunnels shall be determined through technical and economic evaluation according to the layout and scale of underground works, construction methods, construction equipment, schedule requirements, topographic and geological conditions and other factors.

5.7.4 If the tunnel is excavated by drilling and blasting method, the construction method shall be selected through economic evaluation according to the cross section size, surrounding rock type, equipment performance, and construction technology. If possible, full cross section excavation should be adopted. If partial excavation is adopted for the circular tunnel, the expanding excavation of the base angle should be avoided. For a large tunnel chamber, the pilot tunnel should be excavated first, and then partial excavation in benches is to be carried out. The pilot tunnel location and the size of partial-bench excavation shall be determined by the analysis on the cross section of the chamber, surrounding rock category, construction method and procedures, construction equipment and mucking route.

5.7.5 The excavation method for vertical shafts shall be selected based on the following guidelines:

a) The muck should be removed from the shaft bottom. If the muck cannot be removed from the shaft bottom, the full cross section may be excavated from top to bottom.

b) If a mucking route exists at the shaft bottom, a pilot shaft may be constructed by the raise boring machine. The climbing method and the cage-lifting method shall be used with caution.

c) If there is a passageway under the vertical shaft, and the cross section is relatively large, the excavation may be undertaken with the pilot shaft method. The excavation for widening should be done from top to bottom. If the surrounding rock is loose and fragmented, or is extremely prone to collapse, supporting work shall immediately follow excavation of the face.

5.7.6 The excavation of an inclined shaft shall meet the following guidelines:

a) If the dip angle is less than 6°, the excavation shall be undertaken using the adit method.

b) If the dip angle is 6° to 30°, the full cross-sectional excavation, from top to bottom may be undertaken.

c) For a small cross section inclined shaft whose dip angle is 30° to 45°, excavation from top to bottom may be undertaken. If the excavation is undertaken from bottom to top, slagging off and slag sliding measures should be provided; for a medium and large cross section inclined shaft, a pilot shaft may be adopted for excavation widening.

d) If the dip angle is 45° to 75°, the excavation of a pilot shaft from bottom to top, followed by the widening of the excavation from top to bottom, or full cross section excavation from bottom to top, may be adopted.

e) If the dip angle is more than 75°, the excavation may be done by the vertical shaft method.

5.7.7 A construction adit arrangement shall be subject to the following principles:

a) The selection of a construction adit shall be determined based on the comprehensive studies on the topographic and geological conditions, structural type and layout, construction method and construction programme requirements. If the drilling and blasting method is adopted, the spacing of the construction adits should not exceed 3 km.

b) If the topographic and geological conditions permit, the adit length should be short and a horizontal adit, slightly inclined towards the tunnel mouth, should be preferred.

c) The geological conditions along the adit shall be relatively good, the rock mass at the entrance of the adits hall be stable, and the adit portal shall be placed above the high flood.

d) There is sufficient space nearby for temporary facilities and muck disposal.

e) The type and size of the cross section of the adit shall meet the requirements of transportation density and passage, and there shall be adequate space for the air and water pipelines, side drains and a sidewalk.

f) The longitudinal gradient of a horizontal adit shall be not more than 2% for track transportation and not more than 9% for trackless transportation. The corresponding restricted slope length shall be no more than 150 m and the local maximum longitudinal gradient should be not more than 14%.

g) The intersection angle of an adit axis and the main tunnel axis should not be less than 40°, and a flat section with a length not less than 20 m, shall be established at the intersection.

h) The dip angle of an adit for an inclined shaft should not be more than 25°, the longitudinal cross section of the shaft body should be free from slope change and bending, and the lower horizontal section length should not be less than 20 m.

i) A vertical shaft shall be provided on the side of a tunnel generally, and the clear lateral distance with the tunnel shall be 15 m to 20 m.

j) At the bottom of an inclined shaft or a vertical shaft, a turnaround and drainage sump shall be provided.

k) On one side of an adit for an inclined shaft, a sidewalk with a width of no less than 0.7 m shall be provided. A firm and safe ladder shall be provided in the vertical shaft.

l) The excavation shall progress in benches, and the ventilation and de-fuming requirements in underground tunnels and caverns, shall be met.

5.7.8 In drilling and blasting design, the mode of drilling holes, drill hole arrangement and hole depth, blasting material and blasting pattern shall be determined based on the cross sectional shape and size as well as the surrounding rock category. The smooth blasting or pre-splitting blasting method shall be adopted. The advance per excavation cycle, duration of various working procedures and interdependencies are selected based on the following conditions:

a) If the rock surrounding the tunnel easily collapses, the cyclic advance should not exceed 1.5 m.

b) The duration of hole drilling and mucking procedures shall be determined according to the amount of drill holes in a cycle, total length of the drill hole, blasting volume, productivity of drilling, and loading and transportation equipment being used. The duration of other working procedures in the cycle shall be determined by the engineering analogy method.

5.7.9 The muck transportation method should be selected based on the following principles:

a) If the transportation distance is relatively long, track transportation with a battery locomotive should be adopted; the average speed of the locomotive in the tunnel shall be 6 km/hr.

b) If the tunnel cross section allows passage of vehicles, trackless transportation should be adopted. The average speed of a vehicle inside and outside the tunnel shall be 10 km/hr. and 25 km/hr. respectively. If the excavation width fails to meet the vehicle turn around requirements, a turn-around (meeting) niche should be provided every 200 m or so, or a mobile turning circle/turntable shall be provided in the tunnel.

c) For lifting arrangements in an inclined shaft, a winch should be adopted. The operational speed of the winch should not be more than 2 m/s. For a sloping section, a sidewalk shall be provided. The safe distance between sidewalk edge and vehicle shall not be less than 0.3 m. For lifting arrangements within a vertical shaft, a cage shall be adopted in most cases. The operational speed of the cage shall be as follows:

1) If the vertical shaft is within 40 m, and there is no guiding equipment, the speed of the cage shall not exceed 0.7 m/s;

2) If the shaft depth is in the range of 40 m to 100 m and the lifting is undertaken via guiding equipment, it shall not exceed 1.5 m/s;

3) If the shaft depth is more than 100 m and the lifting is undertaken via guiding equipment, it shall not exceed 3 m/s.

5.7.10 The ventilation modes and parameters shall be selected based on the following principles:

a) In the construction process, natural ventilation conditions shall be provided as early as possible. Before natural ventilation is provided, mechanical ventilation shall be adopted.

b) If the heading is more than 1 km from the portal, long pumping and short blowing ventilation should be adopted.

c) The ventilation quantity and wind speed required for the excavation of tunnels and caverns are to be determined with reference to Appendix B and Appendix C.

5.7.11 The comprehensive treatment measures for dust-proof and harmful gas control shall meet the following provisions:

a) Wet rock drilling shall be adopted for underground excavation.

b) Within the tunnel, low-polluted diesel machinery with an exhaust purification device should be provided. Gasoline machinery should not enter the tunnel.

c) Long tunnel construction should employ track transportation.

d) For underground works involving gas, special prevention and control measures shall be prepared.

5.7.12 The mould shall be selected based on the following principles:

a) A full cross section mould carrier should be adopted for circular long tunnels.

b) A movable mould should be adopted for the base plate of medium and small cross section tunnels and for an inclined shaft.

c) For a vertical shaft with regular cross section, a sliding mould should be adopted.

d) For a short tunnel, a transition section, and a flare groove, assembled mould may be adopted.

e) For the straight walls of a tunnel fixed assembly steel mould should be adopted.

f) If steel mould cannot be adopted or is not economical, wooden mould may be adopted.

5.7.13 A steel mould carrier shall be selected based on the following principles:

a) Each working face shall be provided with a carrier. The number of steel mould units shall meet the continuous concrete pouring requirements.

b) The mould removal time shall be determined according to the concrete properties and spans of the tunnels and caverns and other factors, and it shall be within 24 hrs to 72 hrs after the concrete pouring.

5.7.14 For the concrete lining for an adit, the lining sequence for the side wall, both overt and invert, shall be determined, based on the premise that the construction safety and engineering quality are ensured. If possible, a one-off lining for the full cross section may be undertaken. For a large cross section tunnel, or chamber, the lining of the overt shall generally be undertaken first. The lining section length shall be determined after analysis on the surrounding rock characteristics, pouring capacity, the mould type and deformation characteristics of the structure.

5.7.15 The segmentation of concrete lining for an inclined shaft and vertical shaft shall be determined after analysis on the surrounding rock characteristics, structural type and pouring mode and other factors. If the stability conditions of the surrounding rock is relatively poor, the lining length shall be consistent with the excavation length, two jobs may be done alternately. The point at which the outline of a structure varies should be regarded as the boundary between lining sections.

5.7.16 Grouting in a hydraulic tunnel should be carried out in the order of backfill grouting, then consolidation grouting and then joint grouting.

5.8 Installation of hydro mechanical structures and electromechanical equipment

5.8.1 The lifting method for hydro mechanical structures shall be selected based on the following principles:

a) The lifting method shall be determined according to the overall dimensions of the component, the position of the centre-of-gravity, the weight of a single piece, and the dimensions of the tunnels and passageways at the installation position.

b) It shall make full use of the existing lifting equipment and hoisting capacity in the construction site. If special hoisting equipment is used, the installation and fabrication time shall meet the requirements of the installation period.

c) The possibility of installing permanent hoisting equipment in advance should be considered.

d) Lifting equipment with flexible scheduling and high efficiency should be selected.

5.8.2 The installation of hydro mechanical structures shall be subject to the following principles:

a) Cross operation shall be reduced, and production shall be balanced.

b) If the lifting and transportation conditions permit, a steel pipe should be installed in large sections. Installation and concrete pouring should be done alternately by sections. The length of each section should ensure the concrete pouring quality.

c) The gate installation scheme shall be determined according to the gate type and construction condition.

d) A hoist shall be installed and ready for operation.

5.8.3 The manufacturing mode for a penstock and steel lining should be determined through technical and economic evaluation according to the project scale, external transportation conditions and the processing and manufacturing capacity.

5.8.4 For hoisting the units, permanent lifting equipment shall be adopted.

5.8.5 The installation of a turbine-generator unit shall be reasonably connected with the civil engineering construction, and large piece pre-assembly should be done on site.

5.8.6 For the lifting and transportation of auxiliary equipment on-site, the lifting and transportation equipment for the main equipment may be used, and it is not suitable to use separate equipment.

5.8.7 The installation of a main valve shall be determined as a whole or in parts according to the weight of the main valve, lifting equipment capacity and site conditions.

6 Construction transportation

6.1 General provisions

6.1.1 Construction transportation may include external transportation and on-site transportation. The external and on-site transportation schemes shall be selected through comparison based on the construction general layout and the overall construction programme requirements to reasonably solve the over-limit transportation. The scope of external traffic and on-site traffic shall comply with the following guidelines:

a) The external transportation scheme shall ensure the connectivity between the construction site and national or local highways, railway stations and shipping ports, and shall be capable of fulfilling the tasks of transporting external materials during the construction period while minimizing the impact on local traffic.

b) The on-site transportation scheme shall ensure transportation connectivity between each work area across the construction site including local material production areas, waste disposal areas, production areas and living quarters. The main on-site roads shall be connected with the external transportation.

6.1.2 The design standards for on-site and external transportation arteries, and main structures, shall be determined according to the construction characteristics and current relevant national technical specifications. If road transportation is adopted, the following principles shall be followed:

a) The technical parameters for the main transportation arteries, such as maximum longitudinal gradient, the minimum horizontal and vertical curve radius and the visual distance, shall be reasonably selected within the ranges stipulated in the current relevant standards, based on the construction transportation characteristics. On the premise of meeting the requirements of safe operation and construction, the standard for roads, other than main roads, on the site may be properly lowered through full analysis.

b） The design standards for subgrade，pavement and buildings shall be determined based on the road grade and meet the requirements of major vehicle models and transportation intensity during the construction period. Temporary measures may be taken for the transportation of a small number of heavy pieces.

c） The flood control standards for main temporary traffic roads on the site shall be consistent with those of the construction site.

6.1.3 Special facilities such as safety，traffic management，a maintenance inspection facilities，shall be provided in the construction transportation system.

6.2 External transportation

6.2.1 Technical and economic evaluation shall be taken，and the external transportation scheme with reliable technology，reasonable economy，convenient operation，less interference，short construction period and convenient connection with the on-site traffic shall be selected.

6.2.2 The transportation scheme shall be selected based on the following factors：

a） Transportation facilities available within the project location；

b） The total transportation volume during the construction period，the annual transportation volume，and the transportation intensity；

c） The transportation conditions for the major components，especially generators and main transformers，and seasonal variation factors；

d） Connection with traffic arteries，both on-site and off-site；

e） Construction period and the cost of the transportation project；

f） Construction status of the transit stations，the main bridges and the culverts，ferries，wharfs，stations and tunnels；

g） Possible delays and customs clearance if the transport has to cross national borders.

6.2.3 The transportation scheme shall be selected based on the following principles：

a） The transportation capacity of the roads can meet the requirements for bulk goods，materials and equipment during the construction period，and meet the transportation requirements for over-weight and oversized pieces.

b） Fewer transit links for transporting goods and materials，less freight cost，timely，safe and reliable.

c) Based on the local transportation development planning, the existing national and local traffic roads and other special roads of industrial and mining enterprises shall be fully utilized.

6.2.4 For external transportation, road transportation should be utilized. If possible, the waterway and railway transportation, or a combination of several modes shall be considered.

6.2.5 The transportation scheme for large and heavy equipment shall be determined based on knowledge of existing road conditions, technical standards of structures and passage conditions. Corresponding improvement measures shall be formulated and then agreement shall be reached with the departments concerned. If necessary, a special report shall be submitted to the competent authorities, for approval. It is advisable to reduce the times of transhipment of large and heavy equipment.

6.2.6 Transfer station may be set up if the transportation mode for external materials is changed. The scale of the transfer station shall be determined in consultation with the relevant departments according to the material source, variety and delivery status.

6.3 On-site transportation

6.3.1 On-site transportation shall be comprehensively planned, through analysis and calculation, based on the transportation volumes and intensity determined in the overall construction schedule, combined with the construction general layout.

6.3.2 The accesses to the ordinary auxiliary facilities (such as the water supply, power supply, lighting and production and residential buildings) should be comprehensively planned, and the specialized auxiliary yards (such as the standard track locomotives, vehicle overhaul, equipment maintenance, and vehicle parking) shall be designed according to the relevant professional standards.

6.3.3 For selecting the position of on-site river crossing facilities (bridge, ferry, etc.), the construction requirements for permanent works and diversion works shall be met.

7 Construction plant facilities

7.1 General provisions

7.1.1 The construction plant facilities shall ensure the preparation of required construction materials, the supply of water, power and compressed air, the establishment of communications inside and outside of the construction site, and the repair and maintenance of construction equipment. A small number of components and hydro mechanical structures may be processed in the plant.

7.1.2 The layout of the construction plant shall be subject to the following principles:

a) The scale of construction plant facilities shall be determined by the possibility and rationality of using local industrial and mining enterprises for manufacturing and technical cooperation as well as combining with the construction requirements of this project and the cascade power stations.

b) The plant site should be located close to the service object and the customer centre, at a convenient place of transportation and water and power supply. The reverse transportation of goods shall be avoided.

c) Living areas shall be separated from production areas. Construction plants with close cooperative relationships should be arranged in a centralized manner. The distance between centralized and decentralized arrangements shall meet the requirements of fire prevention, safety, health and environmental protection.

7.1.3 For the design of construction plant facilities, a fabricated structure should be gradually promoted, and universal and multi-functional equipment should be selected.

7.1.4 The production scale, floor area, building area, power load, production personnel and other indicators of various construction plants shall be calculated.

7.2 Sand and stone processing system

7.2.1 The sand and stone processing system design shall be subject to the following principles:

a) The amount of sand and stone raw material required shall be determined based on the concrete and other sand and stone materials with grading requirements, including the loss and waste during mining, processing and transportation.

b) The processing capacity of the sand and stone processing system may be calculated according to the monthly average aggregate demand during the peak period of concrete production and other demand in the same period.

7.2.2 The sand and stone processing system plant site shall be selected based on the following principles:

a) It should be positioned near the quarry area. If there are multiple quarry areas, it should be positioned near the main quarry area. Separate plant may be considered through analysis. The plant may also be close to the concrete production system plant if the sand and stone utilization rate is high, the transportation distance is short, and the site conditions permit.

b) The coarse crushing plant for sand and stone processing system should be within the range of 1 km to 2 km from the quarry area.

c) The foundations of the main facilities is stable and has sufficient bearing capacity.

d) The plant site should be close to the existing transportation routes, water sources and power transmission lines.

e) If the plant is near the living quarters, it is essential necessary protective distance shall be kept and noise and dust reduction measures shall be taken.

7.2.3 Sand and stone processing plants shall be arranged based on the following principles:

a) They shall be flexible enough that the production capacity can be provided, in advance, to meet the sand and stone demand before construction, and also so that the production mode can be adjusted to adapt to any changes in particle sizes of the raw materials and differing aggregate grading requirements.

b) Aggregate grading imbalance shall be avoided, and oversized and undersized particles shall be reduced. If several devices of the same specification are being used for the same operation, they should be arranged symmetrically, or on the same axis, on the same elevation.

c) The internal transportation of the finished product and the site drainage are simplified by alignment with the terrain.

d) Except for cold regions, the crushing, screening and sand preparation plants may be provided in the open air, and all the electrical equipment shall be properly protected.

7.2.4 The total reserves of sand and stone shall be considered as being between 50% and 80% of the monthly average value during the peak period. When the exploitation is suspended during the flood season and frost period, the total reserve shall be based on the aggregate demand plus an additional 20% allowance. The capacity of the stockpile area for the finished product shall meet the natural dewatering requirements for sand and stone. If the total capacity of the stockpile area is relatively large, more unfinished materials or semi-finished products should be stacked. The unfinished materials or semi-finished products may be stacked to a relatively large height.

7.2.5 Finished aggregate storage shall be provided with partition walls and a good drainage system.

7.2.6 Dust removal and noise reduction measures shall be taken in the design of sand and stone processing system. The waste slag produced during the sand and stone processing shall be transported to a designated location for stacking and disposal.

7.3 Concrete production system

7.3.1 The concrete production system shall meet the requirements of quality, variety, out-of-mixer temperature and pouring rate. The hourly production capacity may be calculated based on the monthly peak intensity, with a non-uniform coefficient of 1.5. The production capacity shall be checked against the full usage capacity of the pouring equipment.

7.3.2 The production capacity of the batching plant shall be calculated when pre-cooling concrete, hard concrete or low slump concrete is produced.

7.3.3 The concrete production system shall be arranged based on the following principles:

a) It should be close to the pouring site, the terrain shall be reasonably utilized, and the main structures shall be provided on stable and solid foundations, whose bearing capacity meets the relevant requirements.

b) The concrete production system should be arranged in a centralized manner. However, under the following circumstances, it may be arranged in a decentralized manner:

1) The hydraulic structures layouts are scattered or with a great height across each other, or have high pouring intensity or the concrete grade varies greatly, or the concrete needs to be transported over a long distance, resulting in difficult centralized supply.

2) The concrete transportation routes on both banks cannot be connected.

3) The sand and stone quarry areas are spread out, and the aggregate transportation would be inconvenient, or uneconomical, if the arrangement were centralized.

c) The construction requirements in the earlier stages and later stages are overall planned and considered, the midway relocation shall be avoided, and it does not foul with the permanent structures; a sufficient safe distance shall be maintained between high-rise buildings or materials stacks and power transmission equipment and lines.

d) The feeding direction of raw materials is staggered from the concrete discharging direction.

e) The system can be constructed and put into production by stages or when demolished successively, which can meet the requirements of concrete pouring during different construction periods.

7.3.4 The total reserves of the finished stock yard of the concrete production system shall meet the requirements of the optimal production system. Under normal circumstances, the total reserves should not exceed three to five days of the average daily demand for the monthly peak of concrete pouring. If it is especially difficult, it may be decreased to a one-day demand.

7.3.5 The productivity of an asphalt mixing plant may be calculated as being between 65% and 75% of the rated productivity of the equipment. The asphalt mixing plant should be located far away from the living quarters and inflammable structures, and it is to be provided in a centralized manner near the paving site. The transportation time for the asphalt mixture should not exceed 30 minutes.

7.3.6 The asphalt storage shall be determined based on the supply mode, transportation and daily demand.

7.3.7 Cement shall generally be supplied in bulk. The reserve of cement and fly ash at the construction site should be determined based on the number of days that these materials can be supplied to the project.

7.4 Pre-cooling and preheating systems for concrete

7.4.1 The production capacity for pre-cooling concrete shall be determined according to the pouring strength of the pre-cooling concrete, in each month during the high temperature period, and it shall be checked according to the requirements of the maximum concrete pouring area in the same section. The pre-cooling load shall be determined according to the pre-cooling concrete pouring strength, outlet temperature, water temperature, air temperature, humidity and other factors during the high temperature period, and converted according to the standard working conditions.

7.4.2 The outlet temperature of naturally mixed concrete and pre-cooling mixed concrete shall be calculated according to the principle of thermal balance. The outlet temperature of the concrete shall be determined according to the pouring temperature of the concrete and the temperature rise value in the process of transportation and pouring the concrete.

7.4.3 The value of the natural temperature of the concrete raw materials may be calculated as follows:

a) When the surface of the finished aggregate piles is wet and the pile height is above 6 m, and ground material is used, the temperature value can be set according to the local average monthly temperature. When a sunshade or spray mist is used over the top of a yard and the relative temperature is low, the material temperature value can be taken as being between 1 ℃ and 2 ℃ lower than the local monthly average temperature.

b) The temperature of cement and admixtures may be determined according to the factors such as factory temperature, time of production, transportation and storage methods, and local temperatures. These temperatures can be between 40 ℃ and 60 ℃ during high temperature seasons.

c) The temperature of an ice sheet or ice debris may be assumed to be 0 ℃ for calculation purpose, and the utilization rate for the ice cooling capacity is 85% to 100%.

7.4.4 Pre-cooling system layout and process design shall meet the following requirements:

a) The overall layout of the pre-cooling system shall be combined with the overall layout of the concrete production system, and the terrain shall be rationally utilized according to the characteristics of the technological processes.

b) The pre-cooling system shall be positioned close to the cooling load centre.

c) The location of the main workshop shall take into account the wind direction, and meet the requirements of fire prevention, explosion protection, sanitation, transportation, power supply and distribution, water supply and drainage.

d) Ammonia refrigeration system should be adopted.

e) The pre-cooling method for concrete aggregate shall be determined after technical comparison. Single or multiple measures such as cold water, ice, air cooling and water cooling may be adopted.

7.4.5 Pre-cooling system equipment shall meet the following requirements:

a) The pre-cooling compressor of the refrigeration plant shall be selected according to the scale of standard working conditions.

b) The main equipment configurations shall meet the requirements for pre-cooling concrete production and adapt to fluctuations in the ambient temperature. The main equipment configurations shall also take into account the appropriate load coefficient.

c) Auxiliary equipment for pre-cooling system shall match the designed operating conditions of the refrigeration main engine.

d) The equipment capacity for upper and lower processes shall be matched, the equipment model for the same processes shall be consistent, and the number of pieces of equipment shall adapt to the production requirements for different pre-cooling concrete, and shall be flexibly allocated.

7.4.6 The production capacity for pre-heating concrete shall be calculated so as to conform to the monthly pouring peak during the low temperature period. The preheating load shall be calculated, and determined, according to the heat required for heating the various raw materials, concrete outlet temperature, water for washing equipment and building heating.

7.4.7 The production shift system for the pre-cooling and preheating systems shall be the same as that for the supporting production systems for concrete.

7.4.8 During the design of low temperature seasonal preheating systems, the initial temperature of the aggregate, water and cement shall be determined by actual measurements. When there is no actual measurement data at the design stage, the following provisions may be adopted:

a) When the aggregate is transported from different locations, the initial temperature shall be consistent with the outdoor temperature; when the aggregate is transported from the nearest open air stack, the initial temperature of the aggregate shall be taken as one half of the calculated outdoor air temperature.

b) The initial temperature of the cement shall be selected as being between 10 ℃ and 15 ℃ according to factors such as outdoor air temperature, transportation time and storage conditions.

c) The initial temperature of the mixing water shall be selected as being between 2 ℃ and 5 ℃.

7.4.9 The layout and process design for the preheating system shall conform to the following provisions:

a) The design of the concrete preheating system shall be undertaken in combination with the sand and stone processing facilities and the concrete production process facilities.

b) Heating facilities shall be centrally arranged to be close to the heat load centre.

c) The layout of main workshops and facilities shall meet the requirements for fire prevention and explosion protection as stipulated in the relevant standards.

d) The heating temperature for the concrete raw materials shall be determined by thermal balance calculations, based on the outlet temperature.

7.4.10 The equipment selected for the preheating system shall meet the requirements for preheating concrete pouring. Mixing equipment with large capacity shall be preferred. The selected boiler shall have high thermal efficiency and shall be able to adapt to changes in thermal loading.

7.5 Compressed air, water supply, power supply and communication system

7.5.1 For a compressed air system, the centralized or dispersed air supply mode shall be determined according to the comprehensive analysis of the distribution of air users, load features, construction schedule, pressure loss in the pipe network and efficiency of the pipe network.

7.5.2 The compressor station should be positioned close to the air consumption load centre, and close to both power and water supply points. The compressor station should be located in a place with clean air and good ventilation. Traffic access should also be convenient, and the station should be located away from places that require a quiet and vibration-free environment.

7.5.3 Construction water supply shall meet the needs of daily peak production water and domestic water in different periods, and shall be checked according to the water consumption of firefighting.

7.5.4 Water source shall be selected based on the following principles:

a) Water is abundant, reliable and close to the user.

b） Water quality requirements are met，or the requirements may be met after proper treatment.

c） The gravitational flow or groundwater meeting the required health standards should be used as the domestic drinking water.

d） The cooling water，or other construction wastewater，shall be recycled and purified as the construction cyclic water source，according to the environmental protection requirements and economic analysis results.

7.5.5 For the domestic water and production water，the centralized or dispersed water supply mode should be determined through technical and economic evaluation，according to the water quality requirements，water consumption，user distribution，water source，layout of pipelines and water intake structures.

7.5.6 The maximum power load during different construction stages should be calculated based on the demand coefficient method. If the data is deficient，the peak power load may be estimated as being between 25% and 40% of the total capacity of the electrical equipment for the whole project. For a Class I load，which may cause personal injury or equipment accident and serious property loss due to power failure at the construction site，a continuous power supply shall be ensured，and more than two power sources shall be provided.

7.5.7 The capacity of the captive power supply shall be determined based on the following principles：

a） If a power load is completely supplied by the captive power，its capacity shall meet the maximum load requirements for construction.

b） When the system is used as a supplementary power supply，its capacity shall be the difference between the maximum construction power load and the system power supply capacity.

c） The capacity of the emergency standby power shall meet the power consumption requirements for Class I load at the construction site，when the system power supply is interrupted.

d） The captive power supply shall meet the construction power supply load and the starting voltage requirements for a large motor，and shall also have proper standby capacity，or a backup unit.

7.5.8 The voltage class for power transmission and distribution voltage in the power supply system shall be determined according to the transmission radius and capacity.

7.5.9 The communication system shall comply with the principles of "rapid，accurate，safe and convenient". The composition and scale of the communication system shall be determined according to the project scale, construction facility layout and user distribution.

7.6 Machinery repair processing plant

7.6.1 The machinery repair plant site shall be close to the construction site, for the purpose of transportation of construction machinery and raw materials. There shall be sufficient areas for the storage of equipment and materials in the vicinity. It shall also be close to the vehicle repair workshop.

7.6.2 Vehicle maintenance stations should be provided in a centralized manner.

7.6.3 The processing and fabrication site for penstocks should be determined based on the steel pipe diameter, pipe wall thickness, fabrication and transportation conditions and other relevant factors. Large diameter steel pipes should be fabricated at the construction site. If the diameter is relatively small and the pipe wall is relatively thick, the steel pipe may be fabricated in sections or pieces, at the factory and then transported to the construction site for final assembly.

7.6.4 The scale of a wood-processing plant should be determined based on the total volume of logs required by the project, the wood source and transportation mode, the demand and supply plan for the converted timber, components and wooden mould, as well as on-site transportation facilities.

7.6.5 The scale of a rebar processing plant shall be determined according to the daily average demand in the peak month.

7.6.6 The scale of a concrete member prefabrication plant should be determined according to the variety, specification, quantity, maximum weight, supply plan, raw material source, and supply and transportation mode.

7.6.7 Oxygen used in construction shall be purchased in the vicinity of the project. If the supply capacity of an oxygen plant near the project fails to meet the requirements, or the transportation distance is long, or transportation is difficult, an oxygen production plant may be provided at the construction site.

7.6.8 The assembly sites for large equipment and hydro mechanical structures shall be close to the main installation location. The assembly site shall be determined according to the main dimensions of the gate and hoist, type of turbine-generator and transportation conditions.

8 Construction general layout

8.1 General provisions

8.1.1 Construction general layout shall be comprehensive analysis of hydraulic structures layout, scale, type and features of the main structures, construction conditions and the social and natural conditions of the project region; the relationships between environmental protection, water and soil conservation and layout of the construction site shall be properly resolved; and all temporary facilities for construction shall be reasonably determined and planned.

8.1.2 Construction general layout shall be formed in stages based on the construction requirements, and shall meet the construction requirements in each stage, and the processes shall be properly coordinated.

8.1.3 For construction general layout, the concept of "cherishing and making reasonable use of land" shall be implemented, and the principles of "adjusting measure to the conditions and circumstances, being favourable for production and convenient for living, easy management, being safe and reliable, with the emphasis on environmental protection, reduction of water and soil loss, harmonious coexistence of humans and nature and being economically reasonable" shall be adhered to. The scheme shall be finally selected after comprehensive and systematic evaluation and analysis.

8.1.4 The following indices shall be studied and comprehensively analysed in the comparison of construction general layout schemes:

a) Traffic road quantity or construction cost index, and transportation volume and transportation equipment demand;

b) Estimates of earth-rock work for different schemes and the planning of the waste disposal sites, and estimated quantities of earth-rock work in the site formation;

c) Main quantity, materials and equipment for the pipelines of air, water and power systems;

d) Building areas and floor areas for the production facilities, and the living quarters;

e) Aspects of land requisition for construction, relocation and rehabilitation under the different schemes;

f) Civil engineering and installation quantities for construction plant facilities;

g) Station, wharf and warehouse handling equipment requirements;

h) Other temporary project quantities;

i) The engineering quantities in each scheme that concerns environmental protection, water and soil conservation.

8.1.5 For the layout of the main construction plant facilities and the temporary facilities, the flood effects during the construction period shall be considered. The flood control standards shall be adopted within the range of a 5-year to 20-year recurrence period, according to the project scale, construction period and hydrological characteristics after analysing the impact of floods for different standards. If it is higher or lower than the above-mentioned standard, comprehensive analysis shall be done.

8.2 Construction general layout and site selection

8.2.1 For the construction general layout, after the construction diversion scheme and zoning of the main construction works are determined, the following contents shall be emphatically studied:

a) Composition, scale and layout of the temporary construction facilities;

b) External traffic connection modes, location of stations, layout of main traffic arteries and river crossing facilities;

c) Relative position, elevation and area of available site;

d) Site for production and living facilities;

e) Combination of the temporary project and the permanent facilities;

f) Impacts of production and living quarters on environmental protection and water and soil conservation.

8.2.2 The construction layout shall be selected after comparison in accordance with the topographic and geological conditions, land requisition and demolishing difficulty, environmental impact and the relationship with the project layout, considering the requirements of construction zoning plan and combining with the layout conditions of the main traffic accesses both inside and outside the project site. The initial site levelling scope should be determined based on the final requirements of the construction general layout.

8.2.3 If a site near the project is narrow and the construction layout is difficult, the following measures may be taken:

a) The site in the reservoir area shall be properly utilized to facilitate the temporary construction works during the earlier stages.

b) Small benches are constructed making full use of the mountain slope.

c) The storeys in the temporary buildings shall be increased and the spacing between buildings shall be properly reduced.

d) The site shall be repeatedly utilized.

e) Any low-lying land or gullies shall be filled with the waste slag to form the construction site.

8.2.4 For the construction general layout, the excavation and filling balance of earth rockwork shall be carefully undertaken, the stacking and waste disposal sites shall be properly planned, and the excavated slag shall be fully utilized. The waste slag shall meet the requirements of environmental protection and water and soil conservation.

8.2.5 Temporary construction facilities shall not be installed at the following locations:

a) Hazardous areas where mudslides, mountain torrents, sandstorms or snow slides may occur;

b) Key cultural relics under protection, historical sites, scenic spots or natural reserves;

c) Areas that interfere with the development of important resources;

d) Areas seriously affected by blasting or other factors.

8.2.6 The main construction site, established along the river shall adopt the protective measures according to the flood control standards for floods occurring once every 10 to 20 years, and the site protection scope shall be reasonably defined.

8.2.7 The construction site drainage shall meet the following guidelines:

a) The flood volume in the gully and in the stream within the site shall be calculated according to the flood control standards and the rainstorm standards, and the flood passage or retention measures shall be reasonably selected.

b) For adjacent sites, the relative height difference should be reduced to avoid low-lying land water logging; if the height difference of the bench layout is relatively large, retention protection and drainage facilities shall be established.

c) The drainage system shall be complete, unimpeded and reasonably interlinked.

d) The sewage and wastewater treatment shall meet the relevant discharge requirements.

8.3 Construction zone planning

8.3.1 SHP construction zone planning shall be simplified and recommended as below:

a) Main works and river diversion works construction area;

b) Construction plant areas (including comprehensive processing plant, repair plant, etc.);

c) Local building material exploitation area;

d) Storage and transportation system areas (including the on-site road, transfer station, dock, warehouse, etc.);

e) Project material stock and waste material stacking area;

f) Construction management and living quarters.

8.3.2 The construction zone planning layout shall be subject to the following principles:

a) For a key project dominated by concrete structures, the construction area should be arranged with the focus on sand and stone exploitation and processing, concrete mixing, and pouring systems. For a project dominated by a dam with local materials, the construction area should be arranged with the focus on the earth-rock material exploitation and excavation, processing, borrow area and the transportation route to the dam.

b) The assembly area of electro-mechanical and hydro mechanical structures should be close to the main erection bay.

c) For the construction management and the layout of living quarters, the wind direction, sunlight, noise, water source and quality and other factors shall be considered. The construction management and living quarters shall have a clear boundary with the production facilities.

d) Storage and transportation systems such as main material warehouses and stations should be arranged at the transportation connection points inside and outside the site.

e) For the construction zone planning, the effects of construction activity on the surroundings shall be carefully considered, and the hazard of noise, dust and other pollutants to the sensitive areas (such as schools and residential areas) shall be avoided.

8.3.3 The warehouse of fire work material, oil and other special materials shall meet the relevant requirements of fireproof, safety and environmental protection.

8.3.4 The construction and production building areas and floor areas for the project are determined by the construction plant facility design. The storage, building areas and floor areas for warehouses and stacked materials, may be estimated with reference to Appendix D.

8.3.5 The building area for offices and living quarters may be calculated based on the annual average number of workers over the total construction period, multiplied by the comprehensive index for building area, per capita.

8.3.6 The building standards for construction plant facilities, stations, yards and warehouses shall meet the production technological process, technical requirements and relevant safety regulations. A customized, standardized and fabricated structure should be adopted.

8.3.7 Temporary facilities shall be minimized and the feasibility of permanent use of structures shall be checked after construction.

8.4 Earthwork balance and slag site planning

8.4.1 Earthwork balance shall abide by the following principles:

a) According to the topographic and geological conditions of the excavation area, quality characteristics of the excavation materials and technical requirements for the engineering construction materials, building excavation materials should be used as filling materials and concrete aggregate sources.

b) Excavation materials should be directly used to reduce the quantity of stored slag materials.

c) A reasonable plan shall be made for the storage and disposal of slag site to ensure the smooth and short transportation distance of filling materials and slag materials.

d) The slag loose coefficient and the filling material compaction coefficient shall be reasonably determined, as well as the total amount of slag and the amount of materials used.

e) Losses in construction shall be considered according to the source of the excavation materials and construction characteristics.

8.4.2 The slag site may include temporary storage of usable materials and permanent storage of waste materials. The slag site selection and the stock for each slag site shall be balanced in combination with the earthworks. Slag site selection shall meet the following principles:

a) It shall meet the requirements for environmental protection, water and soil conservation and local urban and rural construction planning.

b) The slag site shall be convenient for slag recovery and reduce reverse transportation.

c) The slag site shall be located close to the trench, hillside, wasteland, river bank or other sections of the excavation operational area, and shall not occupy, or occupy a very small amount of, cultivated (forest) land. The foundation bearing capacity shall meet the requirements for a slag heap.

d) The slag site shall not be arranged in areas prone to natural landslides, debris flows, karst, water gushing and other geological hazards.

e) When conditions permit, the slag site may be located below the dead storage capacity of the reservoir, but it shall not impede the normal operation of permanent structures.

f) When a downstream beach is used as a slag site, it shall not affect the normal flood discharge, navigation or elevation of the downstream water level.

g) On-site transportation, slag sources and other factors shall be considered.

h) The slag sites shall be selected according to the related national and professional standards and requirements and shall not be arranged in areas prohibited by law. The safety of the projects, residential areas, traffic arteries or other important infrastructure shall not be affected.

8.4.3 Slag site planning shall observe the following principles:

a) The slag and discarded slag shall be stored separately, and the capacity of the slag storage site and discarded slag site shall be appropriately reserved.

b) When the slag storage site and discarding site are planned at the same site, the principle that the lower part is the discarded slag site and the upper part is the slag storage site, shall be followed.

c) The step height and stable slope of the layered stack shall be determined according to the properties of the stockpiled materials, to keep the shape of the stockpiles stable.

d) The operational procedures for the slag site shall be put forward according to the general construction schedule, and temporary or permanent drainage facilities for the slag site shall be set up.

e) Water diversion, drainage and retaining facilities shall be set up around both the storage and discarded slag sites.

f) The slag site shall be closed as per the programme, and shall be used as the construction site or for afforestation and land reclamation.

g) The grade and flood control standards for the slag site shall meet the requirements in the related national and professional standards.

8.5 Construction land

8.5.1 The planning of construction land shall comply with the principles of scientific, reasonable, economical and intensive use of land, with convenient management during construction and operation, and convenient for construction. Construction land should be close to each other and planned in succession to avoid intersection of small construction areas.

8.5.2 The scope of the construction land shall be determined based on comprehensive analysis of the site conditions, construction general layout, nature of the land use, time limit for use, and compensation for land expropriation and resettlement. Land-use shall be considered in combination with local planning, construction and traffic requirements, and development planning requirements for the country.

8. 5. 3 Construction land is divided into temporary construction land, and permanent land. Temporary construction land and permanent land shall be planned as a whole, and the permanent land should be given priority in project construction.

8.5.4 Temporary construction land should be determined on the basis of the external contour lines of the temporary construction facilities, taking into account such factors as safety, maintenance, construction impact and management convenience.

8.5.5 Priority shall be given to reclamation of the land such as material sites and waste slag sites and shall be listed as temporary land; land that cannot or is difficult to be reclaimed, may be classified as permanent land.

9 Overall construction programme

9.1 General provisions

9.1.1 When preparing the overall construction programme, it is necessary to analyse and demonstrate the owner's requirements for the total construction period, and to observe the following principles:

a) Comply with basic construction procedures.

b) Use the local average advanced construction level to reasonably plan the construction period.

c) Balance the allocation of resources such as human resources, materials and funding.

d) Coordinate the construction programme for individual projects with the general construction programme. The construction procedures for various projects shall be planned comprehensively and connected reasonably, to realize the objectives of creating little disturbance and providing balanced construction.

e) Maximize the investment benefits on the premise of ensuring construction safety, construction quality and total construction period.

9.1.2 The whole process of engineering construction may be divided into four construction phases:

a) Preliminary phase: refers to the period before the official commencement of the project, during which the owner shall complete the external transportation plans, construction power supply and communication system plans, land acquisition, resettlement of residents' plans, bid invitations, bidding evaluation and signing the contract.

b) Preparation phase is to prepare the construction period from the commencement of the project to the commencement of the main works on the critical lines or before river channel closure. It usually includes "making water, electricity, roads and communication available on the construction site and levelling the ground", river diversion works, temporary houses and building of the construction plant and facilities.

c) Construction phase of the main project: refers to the construction period from the commencement of the main works, on the critical lines, or from the Phase I river closure, to the moment when the first generator is put into operation or the moment when the project creates benefits.

d) Completion phase: refers to the construction period from the moment when the first generator of the hydropower station is put into operation, or the project creates benefits, up until the completion of works. When preparing the overall construction programme, the total construction period for the project shall be the sum of the latter three construction phases. The work in two adjacent phases may be performed alternately during the construction period.

9.1.3 The overall construction programme shall emphasize the primary and secondary key projects (projects on the critical paths) and important projects. The dates of commencement, river closure, water filling, and power generation of the first unit and project completion shall be specified.

9.1.4 The overall construction programme shall be set out using a Gantt chart or network diagram.

9.2 Construction programme for the preparatory construction

9.2.1 The construction of the main roads shall be arranged first, and the time required to put the construction road into service shall be determined.

9.2.2 The conditions should be created in advance to establish an aggregate processing system and a concrete production system, and the construction time for putting the systems into normal operation shall be determined in accordance with the construction programme requirements for the main project.

9.2.3 Other preparatory construction works, such as ground levelling, and construction of the power supply system, water supply system, air supply system, on-site communication system, construction plant and facilities, as well as living and production houses, shall be arranged in coordination with the overall construction programme.

9.2.4 If conditions permit, the external transportation, on-site trunk roads, underground construction passageways and power supply should be preferentially arranged and constructed during the preparation phase and the service commissioning time shall be determined.

9.3 Construction programme for the diversion works

9.3.1 The diversion works for Phase I which employs a one-time cutting off and a staged diversion should be arranged within the construction preparation phase. If it is a key element of the project, it shall be arranged in advance, according to the engineering demands.

9.3.2 The river channel closure should be arranged in the dry season or the later period of flood, but not in the freezing or glacial period. The channel closure time shall be determined reasonably based on the construction period required by cofferdam construction and the requirements of safety and flood control, and in combination with the average flow of each month, or each 10 days, in the selected period.

9.3.3 The foundation pit pumping operation shall be performed after the cofferdam sealing and weir foundation seepage prevention. For the foundation pit of earth-rock cofferdams and soft foundation, the control of drainage reduction rate shall be considered.

9.3.4 When the cofferdam diversion scheme is adopted, the influence of the cofferdam overflow period and the situation before and after overflow on the construction period shall be analyzed. In a river with heavy sediment, the time limit for dredging of cofferdams shall be considered.

9.3.5 The temporary flood control period shall be determined according to the construction programme of the water-retaining structure, and the construction of the water-retaining structure before the required time shall be demonstrated to meet the requirements of flood control standards of the blocking design .

9.3.6 After the diversion is completed, the blocking period should be selected after the flood season, and the closure project shall be completed within a dry season. If the river is blocked before the flood season, all the measures required to ensure safe flood protection shall be fully prepared and demonstrated.

9.4 Construction programme for the foundation excavation and foundation treatment

9.4.1 Bank slope excavation of the dam foundation and the riverbed powerhouse foundation may be arranged in parallel with the river diversion works, and completed before river channel closure. The excavation of the riverbed foundation shall be arranged after the construction of the cofferdam and the drainage of the foundation pit.

9.4.2 It is advisable to analyse and calculate the excavation strength of the dam foundation and the corresponding construction period according to the excavation area of the foundation pit, the rock-soil grade, the excavation method, and the mucking route as well as the performance and quantity of the construction equipment allocated as per the working site.

9.4.3 The construction programme for the foundation treatment shall be determined through studies based on the geological conditions, treatment scheme, work quantity, construction procedures, construction level, equipment production capacity and total programme requirements. For the foundation treatment with complex geological conditions, high technical requirements and controlling effect on the total construction period, the influence on the overall construction programme shall be analysed and demonstrated.

9.4.4 The treatment for poor geological foundations should be fully completed before covered by the building. Consolidation grouting should be arranged after concrete pouring of one to two layers, but it may be performed prior to concrete pouring if appropriate analysis is undertaken. Curtain grouting may be performed on the concrete pouring face of the dam foundation or gallery, but should not be arranged on the critical lines of the total construction time. It shall be completed after the consolidation grouting has been completed for the dam foundation for both that dam section and the adjacent dam section.

9.4.5 For the dam foundation with geological defects on bank slope of both sides, the construction period shall be arranged in accordance with the foundation treatment scheme. If the treatment part is beyond the scope of the dam foundation, or is underground, the treatment may be undertaken together with the dam body pouring (filling), and the treatment shall be completed before the reservoir impoundment, according to the design requirements.

9.5 Construction programme for the earth work filling project

9.5.1 According to the requirements of diversion and safe flood control, the flood retaining scheme of the dam shall be studied, the strength of the upper dam shall be demonstrated, and the elevation of dam filling shall be determined by stages.

9.5.2 The dam filling intensity for an earth-rock dam shall be comply with the following principles:

a) The total construction period and the project construction completion requirements for various phases shall be met, and the construction intensity should be balanced.

b) The monthly peak filling amount should be coordinated in proportion with the total filling amount required.

c) The dam face filling intensity shall be coordinated with the production and transportation capacity of the qualified materials from the borrow/quarry area.

9.5.3 The corresponding effective construction days shall be analysed in accordance with the hydrological and meteorological conditions. The work suspension standards in rainy days is specified in Appendix E.

9.5.4 It is necessary to analyse the time required for the restoration of normal construction after overflow and demonstrate that the construction of dam protection works shall be completed before the overflow time required by the design.

9.5.5 The rising speed of an earth-rockfill dam shall meet the design requirements for controlling the rising speed of a plastic core wall (or sloping core).

9.5.6 For the construction of a concrete face rockfill dam, the construction time for the concrete face shall be reasonably arranged to reduce the mutual interference between the face construction and dam shell filling.

9.5.7 The monthly unbalanced coefficient of the rolling earth-rock dam filling period should be less than 2.0.

9.6 Construction programme for concrete works

9.6.1 When the construction programme for concrete is planned, the effective work days shall be analysed; if it is required to accelerate the pouring progress after engineering analysis, the construction may be carried out in winter, rainy season and summer with relevant measures taken before construction, to ensure the construction quality. The working days per month for concrete pouring may be counted on the basis of 25 days. With regard to the working days for controlling straight-line construction period, the number of suspended days under the influence of meteorological factors should be deducted from the design number of calendar days.

9.6.2 The average rising speed of normal concrete should be determined by actually pouring blocks, or through engineering analogy.

9.6.3 The average rising speed of RCC shall be determined through comprehensive analysis on the block surface area, thickness of the paved layer, production and transportation capacity of the concrete and the rolling compaction.

9.6.4 The multi-year flood protection elevation and the engineering features of a concrete dam during the construction period shall be determined, according to the construction diversion requirements.

9.6.5 The progress of joint grouting (including the joint grouting between the powerhouse and the dam) of the concrete shall comply with the safety requirements of flood control and reservoir filling during the construction period.

9.7 Construction programme for the surface powerhouse

9.7.1 The concrete pouring shall be undertaken for the surface powerhouse, after the foundation excavation (except for the protective layer) completed. If the construction of the powerhouse is a key project element in terms of controlling the programme, the excavation and concrete pouring may be arranged in parallel. However, it is to be ensured that the blasting excavation does not have an adverse influence on the old or new concrete.

9.7.2 The average rising speed of a powerhouse should be determined by pouring blocks or through engineering analogy.

9.7.3 The concrete pouring shall be arranged with full consideration of the installation procedures for electromechanical equipment, hydro mechanical structures and all embedded parts. The operability of the permanent hoists and lifting devices and necessary maintenance period shall be considered.

9.8 Construction programme for underground works

9.8.1 The underground cavern group construction procedures shall be comprehensively planned and arranged in an overall manner, and the network schedule shall be edited to determine the construction items on the critical path and the connection sequences between various items. Natural ventilation conditions shall be formed as soon as possible.

9.8.2 The construction programme for underground works shall be arranged with full consideration of the excavation, shoring, pouring, grouting, hydro mechanical structures and electromechanical installation.

9.8.3 The underground works may be constructed all year round. The construction procedures, as well as the coordination between tunnels and caverns and between working procedures and reasonable construction periods, shall be determined with critical path analysis and in accordance with the scale, geological conditions, construction methods and equipment allocation, for the works.

9.8.4 The monthly progress index of underground works may be determined by analysis and calculation or engineering analogy according to the geological conditions, construction methods, equipment performance, working site and other conditions.

9.9 Construction programme for hydro mechanical structures and electromechanical installation

9.9.1 The construction programme for hydro mechanical structures and electromechanical installation, on the construction critical path, shall be defined item by item, in the overall construction programme.

9.9.2 For the construction schedule of hydro mechanical structures and electromechanical installation shall be coordinated with the construction of civil engineering. The delivery and installation time of the civil works that control the progress of the hydro mechanical structures and electromechanical installation shall be determined item by item.

9.10 Construction labour and main technical supply

9.10.1 The average annual personnel and the average personnel over the total construction period shall be calculated according to the overall construction programmed, based on the annual, monthly and sub-project, combined with the national average advanced construction level, or reference to the similar domestic project data.

9.10.2 Total working days may be determined according to the average number of workers during the total construction period, multiplied by the number of working days in each year.

9.10.3 Resources shall be optimized for the overall construction programme, and annual supply schedules of labour, major construction equipment and major materials shall be proposed.

10 Construction safety

10.1 General provisions

The construction organization shall be designed with comprehensive consideration to the requirements of environment, occupational health and safety. All possible dangerous and harmful factors during the construction period shall be analysed according to the engineering characteristics, and the main safety technical measures and safety management requirements during the construction period shall be proposed.

10.2 Hazard identification

10.2.1 The identification of potential hazards includes unsafe behaviour and objects left in an unsafe state. These can exist in each process within the engineering construction area (construction site of the dam, tunnels and powerhouse), as well as the natural hazards identified through the entire operation. A preliminary risk analysis shall be conducted for the main hazards.

10.2.2 A single project with relatively high risks shall mean a single project that may cause death, injury, occupational disease, tangible losses or serious adverse social impact. A single project with high risk mainly includes the following scope:

a) Support and protection of the foundation pit: the supports and protection works for the foundation pit (slot) with an excavation depth exceeding 3 m (inclusive), or with excavation depth not exceeding 3 m but with complex geological conditions and surroundings.

b) Earthwork and stonework excavation: the earthwork and stonework excavation works for a foundation pit (slot) with an excavation depth exceeding 3 m (inclusive).

c) Mould and support systems:

1） All kinds of mould：including large panel mould，sliding mould，creeping mould and flying mould；

2） Concrete mould support works：the concrete mould support works with an erection height of 5 m or greater，an erection span of 10 m or greater，a total construction load of 10 kN/m^2 or greater，a concentrated linear load of 15 kN/m or greater and a height greater than the horizontal projection width of the support，and which shall be relatively independent，without connecting members；

3） Load-bearing support system：the full support system for the installation of steel structures.

d） Lifting，installation and dismantling：

1） The lifting works，with the use of unconventional lifting equipment and methods，and with a unit hoisting weight of 10 kN or bigger；

2） The works installed with lifting machinery；

3） The installation，and dismantling，of the lifting machinery itself.

e） Scaffolding：

1） Floor type，steel pipe scaffolding with an erection height of 24 m or bigger；

2） Attached integral and split hoisting scaffolding；

3） Suspension scaffolding；

4） Basket scaffolding；

5） Self-made unloading platform and movable operating platform；

6） New type and uncommon-shaped scaffolding.

f） Removal and blasting engineering.

g） Cofferdam engineering.

h） Underground excavation engineering（tunneling engineering）.

i） High slope engineering：higher than 15 m for earth slopes and higher than 30 m for rock slopes.

j) Other projects with relatively high risks.

10.3 Solutions

It is necessary to make a preliminary analysis of the main construction technologies, including technical parameters, process flow and main construction methods. The corresponding engineering measures shall be proposed for the single project with high risks.

Appendix A
(Informative)
Temperature control of concrete during construction

A.1 The selection and determination of the basic parameters for temperature control of large-volume concrete, temperature control standards as well as calculation requirements and temperature control anti-cracking measures may be selected in accordance with the content listed in Table A.1.

Table A.1 Selection and determination of basic parameters for temperature control of large-volume concrete, temperature control standards as well as calculation requirements and temperature control anti-cracking measures

No.	Items		Construction requirements
1	Selection and determination of basic parameters of atmospheric temperature standards	Hydrologic and meteorologic data	(1) Average monthly(ten-day) atmospheric temperature, water temperature and ground temperature of the region over the years; (2) Statistical information (the scale of, and times of, drops in temperature) on sudden drops in air temperature (daily mean value of temperature drops); (3) Other meteorological data concerning sunlight and wind speed.
		Raw material of concrete	(1) Test data on the physical and mechanical properties, the hydration heat and chemical study of the cement; (2) Source, dosage and index of fly ash; (3) Source, dosage and index of additives; (4) Source and physical and mechanical parameters of the sand and gravel aggregate.
		Thermodynamic index of concrete and bedrock	(1) Concrete grade and main physical and mechanical parameters; (2) Lithology and main thermodynamic parameters of bedrock.
2	Temperature control standards and calculation requirements		(1) Determine the concrete out-of-mixer temperature and the temperature of the concrete during construction of the dam; (2) Determine the quantity of ice or cold water to be added for mixing, per cubic meter of concrete, the mixing time required and the quantity of concrete; (3) Determine the pre-cooling method, the pre-cooling time and the temperature for the concrete aggregate; (4) Determine the temperature difference and the maximum allowable temperature of the dam foundation;

Table A.1 (*continued*)

No.	Items		Construction requirements
2	Temperature control standards and calculation requirements		(5) Determine the temperature difference between the inside and outside of the dam body, the temperature difference between the upper and lower layers and the temperature difference of the cooling water pipes; (6) Calculate the temperature field and temperature stress field of the dam body, and determine the stable design temperature of the dam body; (7) Determine the temperature of the concrete during construction of the dam body in each month; (8) Determine the time, flow, cold water temperature and area for feeding the low temperature water to the dam body concrete, in early, intermediate and later stages of construction; (9) Determine the time taken for joint grouting of the dam body; (10) Determine the process flows of refrigerating or freezing systems, as well as the name, specification, model and quantity of equipment allocated, and the consumption index of the refrigerant; (11) Determine the protection methods for concrete surfaces, as well as the variety and specification of protective materials.
3	Temperature control anti-cracking measures		(1) Optimize raw materials and mixing ratios, and reduce temperature rise due to hydration heat; (2) Divide joints and blocks reasonably; (3) Arrange the concrete construction procedures and construction programme reasonably, and control the maximum temperature of the dam body; (4) Control the height difference between adjacent dam blocks and dam sections; (5) Determine a reasonable layer thickness and the intervals of concrete pouring; (6) Control the concrete out-of-mixer temperature by pre-cooling of the aggregate (by secondary air cooling or water cooling, plus air cooling, where necessary), and by using ice or cold water to mix the concrete; (7) Reduce temperature recovery in the transportation process and in the pouring surface; (8) Water cooling in the dam in the early, intermediate and later stages; (9) Heat preservation and curing of the concrete surface; (10) Comprehensive management of temperature control.

A.2 The atmospheric temperature standards, and the thermal insulation and anti-freezing measures for concrete construction in low temperature, may be selected according to the content listed in Table A.2.

Table A.2 Atmospheric temperature standards and thermal insulation and anti-freezing measures for concrete construction in low temperature seasons

No.	Item	Construction requirements
1	Atmospheric temperature standards	The concrete construction shall be performed in the low temperature season when the daily atmospheric temperature is continuously lower than 5 ℃, over a five-day period or the minimum atmospheric temperature is continuously lower than −3 ℃, over a five-day period.
2	Thermal insulation and anti-freezing measures	(1) Temperature of concrete during construction should not be lower than 5 ℃ for the dam and not be lower than 10 ℃ for the powerhouse; (2) When concreting on bedrock or an old concrete face in negative temperatures, the bedrock or old concrete shall be heated to the normal temperature; the heating depth shall not be less than 0.1m and the temperature difference between the upper and lower layers shall not exceed 15 ℃ to 20 ℃; (3) Thermal insulation forms may be adopted, and shall not be removed in the entire low temperature period; (4) An air-entraining agent may be added, and the quantity of entrained air shall be determined through testing; (5) The mixing time for the concrete shall be extended appropriately when compared to the normal temperature seasons, and the specific time extension should be determined through testing; (6) When the daily average atmospheric temperature is lower than −10 ℃, a warm shed should be placed over the concrete; (7) The maturity of the concrete enduring the cold shall not be less than 1 800 ℃·h.

Appendix B
(Informative)
Ventilation rate and wind speed values for tunnel/chamber excavations

B.1 The ventilation rate for tunnel/chamber excavations shall be determined according to the following requirements, and the maximum value shall be taken:

B.1.1 Fresh air shall be supplied at a rate of 0.05 m^3/s per person, according to the maximum number of people working in the tunnel at any one time;

B.1.2 The harmful gases at the working face of a tunnel shall be exhausted or diluted to the allowable concentration, within 20 minutes after blasting. The blasting from a single kilogram of explosives can generate around 40 L carbon monoxide;

B.1.3 When the diesel-fired machinery is used for construction within the tunnel, the air shall be supplied at the rate of 0.068 m^3/s per kilowatt, and the air for the personnel working within the tunnel shall also be considered;

B.1.4 When the ventilation rate is calculated, the increased value due to air leakage shall be considered, according to the ventilation mode and distance; the air leakage factor may be between1.2 and 1.5;

B.1.5 If the tunnel or shaft is located in a place with altitudes above 1 000 m, the calculated ventilation rate shall be multiplied by the elevation correction factor;

B.1.6 The calculated ventilation rate shall be verified according to the maximum and minimum allowable wind speed, and the wind speed required by the corresponding tunnel temperature.

B.2 The minimum wind speed near the working face shall not be lower than 0.25 m/s and the maximum wind speed shall not exceed the following provisions:

B.2.1 The maximum wind speed at the working face of a tunnel, vertical shaft or inclined shaft shall not exceed 4 m/s;

B.2.2 The maximum wind speed in a transportation tunnel or ventilation tunnel shall not exceed 6 m/s;

B.3 The average temperature in the tunnel/chamber shall not exceed 28 ℃ and the wind speed value in the tunnel/chamber at different temperatures shall meet the provisions of Table B.1.

Table B.1 Wind speed values for tunnel/chamber excavations

Temperature (℃)	<15	15～20	20～22	22～24	24～28
Wind speed (m/s)	<0.5	5～1.0	1.0～1.5	1.5～2.0	>2.0

Appendix C
(Informative)
Formula for the estimation of compressed air demand

C.1 The scale of the compressor station shall be calculated based on the quantity of pneumatic machines simultaneously in use, during a period of peak air consumption and including the rated air consumption of the machine, or configured as per air consumption.

C.2 The compressed air demand may be estimated using the Formula C.1:

$$Q = K_1 K_2 K_3 \sum (nqK_4 K_5) \qquad \text{(C.1)}$$

where

Q is the compressed air demand, in m^3/min;

K_1 is the coefficient to be adopted due to the efficiency reduction of an air compressor together with small amounts of unexpected air consumption. This should be taken as a value between 1.05 and 1.1;

K_2 is the air leakage factor of the pipe network, to be taken as a value between 1.1 and 1.3. The larger value shall be taken when the pipe network is long or the laying quality is poor;

K_3 is the plateau correction factor; to be selected from Table C.1;

n is the quantity of pneumatic machinery of the same variety working at the same time;

q is the air consumption of one piece of pneumatic machinery, in m^3/min; the rated air consumption of the pneumatic machinery should be taken;

K_4 is the coincident working factor of pneumatic machinery; to be selected from Table C.2;

K_5 is the abrasion correction factor of pneumatic machinery.

Table C.1 Plateau correction factor of compressed air

Sea level elevation (m)	0	305	610	914	1 219	1 524	1 829	2 134	2 433	2 743	3 049	3 653	4 572
Plateau correction	1.00	1.03	1.07	1.10	1.14	1.17	1.20	1.23	1.26	1.29	1.32	1.37	1.43

Table C.2 Coincident working factor of jack drills

Quantity of jack drills working at the same time	1	2	3	4	5	6	7	8	9	10	12	15	20	30
Working factor	1.0	0.9	0.9	0.85	0.82	0.8	0.78	0.75	0.73	0.71	0.68	0.61	0.59	0.50

Appendix D
(Informative)
Estimation of storage space in construction general layout

D.1 The storage volume of various materials shall be determined according to the construction, supply and transportation conditions. With regard to materials influenced by seasonal conditions, the construction and production interruption factors shall be considered. In reference to water transportation, flood levels and low water levels and cold season influences shall be considered. The storage volume of materials may be estimated in accordance with the Formula (D.1):

$$q = Qdk/n \qquad \text{(D.1)}$$

where

q is the storage volume of required materials, in m^3;

Q is the total demand of materials in peak year, in m^3;

n is the working days per year;

d is the days of storage of required materials;

K is the non-uniform coefficient of total demand of materials; take 1.2 to 1.5.

D.2 The stockpile yard and warehouse areas in the construction general layout may be estimated by the means of formulas in Table D.1.

Table D.1 Estimation of stockpile yard and warehouse areas

Name	Area of structure (m^2)	Floor area (m^2)	Meaning of symbols in formula
Assembly yard for a turbine generator set	$F = \frac{QK_B t}{pa}$	—	F —Area of assembly yard, in m^2; Q —Weight of heaviest pre-assembled metal component, kg; K_B —Component assembly ratio, take 0.7 to 0.8; t —Stacking coefficient, take 1.25; p —Assembly amount per unit area, kg/m^2; take 200 to 400; a —Site utilization factor; take 0.81 for a gantry crane and take 0.78 to 0.8 for an overhead crane

Table D.1 (*continued*)

Name		Area of structure (m^2)	Floor area (m^2)	Meaning of symbols in formula
Warehouse for construction equipment		$W=\frac{na}{K}$	$A=\sum WK$	W —Area of warehouse for construction equipment, in m^2; n —Quantity of construction equipment stored; a —Floor area per piece of equipment, m^2; K —Utilization coefficient of area; take 0.3 where there is a travelling crane in the warehouse and take 0.17 where there is not travelling crane.
Warehouse for materials and apparatuses		$W=\frac{q}{PK_1}$		W —Area of warehouse for materials and apparatuses, in m^2; q —Storage volume of the required materials, m^2; K_1 —Utilization coefficient of area; P —Storage volume of materials per m^2 of effective area, in t or m^3.
Permanent warehouse for mechanical and electrical equipment	Total area of the warehouse	$F_{total}=2.8Q$		F_{total} —Total area of the equipment warehouse (including floor area of the railway and unloading yard), in m^2; $F_{custodial}$ —Net storage area of the warehouse (refers to the total area of warehouse minus the floor area of the unloading yard), in m^2; Q —Total weight of unit equipment stored in the warehouse at the same time, in t.
	Net storage area of the warehouse	$F_{custodial}=0.5\ F_{total}$		
	Open warehouse	$F_{open\ roof}=(17\%\sim20\%)\ F_{total}$		
	Enclosed warehouse	$F_{closed}=(20\%\sim25\%)\ F_{total}$		
	Thermally insulated warehouse	$F_{thermal\ insulation}=(8\%\sim10\%)\ F_{total}$		
	Open storage yard	$F_{open}=(45\%\sim55\%)\ F_{total}$		

Appendix E
(Informative)
Standards for works suspension periods (for earth-rockfill dams and concrete works -due to weather factors)

E.1 Work suspension standards for general protective measures taken for earth-rockfill dam.

E.1.1 Refer to Table E.1 for suspension standards for general protective measures taken for rolled compacted earth-rockfill dams.

E.2 Suspension standards for meteorological effects on concrete pouring.

E.2.1 The construction should be suspended if there are no rain control measures when the precipitation is more than 10 mm/day (for a project with a low degree of mechanization) or 20 mm/day (for a project with a relatively high degree of mechanization).

E.2.2 When the monthly average atmospheric temperature is more than 25 ℃ and the expenses for temperature control measures are considered too high, a construction shutdown during the day may be considered, after technical and economic comparison.

E.2.3 The pouring of concrete in the open air, shall be suspended when the daily average atmospheric temperature is less than −10 ℃ the overall construction shall be suspended when the daily average atmospheric temperature is lower than −20 ℃ or the minimum atmospheric temperature is lower than −30 ℃.

E.2.4 The construction should be suspended when the wind speed is higher than a strong breeze.

E.2.5 The construction should be suspended when the visibility is less than 100 m.

Table E.1 Work suspension standards for general protective measures taken for earth-rockfill dams

Serial No.	Construction items	Suspension standard											Remarks
		Daily amount of precipitation (mm)					Daily evaporation	Average atmospheric temperature(℃)					
		0～0.5	0.5～5	5～10	10～30	>30	<4 mm	>5	5～0	0～−5	−5～−10	<−10	
1	Spreading out soil material	Suspended in rainy days	Suspended in rainy days	Suspended in rainy days	Suspended in rainy days, and suspended for a day after rain	Suspended in rainy days, and suspended for a day after rain	Suspend	Normal construction	Normal construction	Protective construction	Protective construction	Suspend	—
2	Filling of clay material	Normal construction	Suspended in rainy days	Suspended for half a day after rain	Suspended in rainy days, and suspended for a day after rain	Suspended in rainy days, and suspended for a day after rain	—	Normal construction	Normal construction	Protective construction	Protective construction	Suspend	—
3	Filling of gravel soil, blending soil and saprolite	Normal construction	Normal construction	Suspended in rainy days	Suspended in rainy days, and suspended for a day after rain	Suspended in rainy days, and suspended for a day after rain	—	Normal construction	Normal construction	Protective construction	Protective construction	Suspend	—

Table E.1 (*continued*)

Serial No.	Construction items	Suspension standard											Remarks
		Daily amount of precipitation (mm)					Daily evaporation	Average atmospheric temperature(℃)					
		0～0.5	0.5～5	5～10	10～30	>30	<4 mm	>5	5～0	0～−5	−5～−10	<−10	
4	Filling of filter material	Normal construction	Normal construction	Normal construction	Suspended in rainy days	Suspended in rainy days	—	Normal construction	Normal construction	Protective construction	Protective construction	Suspend	When constructing simultaneously with the seepage control material, the number of effective construction days is the same as that of the seepage control materials
5	Filling of aggregated rock	Normal construction	Normal construction	Normal construction	Normal construction	Suspended in rainy days	—	Normal construction	Normal construction	Protective construction	Protective construction	Suspend	—
6	Paving of rolled compacted asphalt concrete	Normal construction	Normal construction	Suspended in rainy days	Suspended in rainy days	Suspended in rainy days	—	Normal construction	Normal construction	Protective construction	Suspend	Suspend	Refer to Appendix E.2 for the suspension standards for the general concrete construction

NOTE Suspend construction during statutory holidays, but excluding Saturday and Sunday.