



UNITED NATIONS  
INDUSTRIAL DEVELOPMENT ORGANIZATION



Technical Guidelines for the  
Development of Small Hydropower Plants  
**DESIGN**

**Part 7: Construction Planning**

**SHP/TG 002-7:2019**



## **DISCLAIMER**

This document has been produced without formal United Nations editing. The designations and the presentation of the material in this document do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations Industrial Development Organization (UNIDO) concerning the legal status of any country, territory, city or area of its authorities, or concerning the delimitation of its frontiers or boundaries, or its economic system or degree of development. Designations such as “developed”, “industrialized” and “developing” are intended for statistical convenience and do not necessarily express a judgement about the stage reached by a particular country or area in the development process. Mention of company names or commercial products does not constitute an endorsement by UNIDO. Although great care has been taken to maintain the accuracy of information herein, neither UNIDO nor its Member States assume any responsibility for consequences which may arise from the use of the material. This document may be freely quoted or reprinted but acknowledgement is requested.

© 2019 UNIDO / INSHP- All rights reserved

Technical Guidelines for the  
Development of Small Hydropower Plants  
**DESIGN**

**Part 7: Construction Planning**

**SHP/TG 002-7:2019**

## ACKNOWLEDGEMENTS

The technical guidelines (TGs) are the result of a collaborative effort between the United Nations Industrial Development Organization (UNIDO) and the International Network on Small Hydro Power (INSHP). About 80 international experts and 40 international agencies were involved in the document's preparation and peer review, and they provided concrete comments and suggestions to make the TGs professional and applicable.

UNIDO and the INSHP highly appreciate the contributions provided during the development of these guidelines and in particular those delivered by the following international organizations:

- The Common Market for Eastern and Southern Africa (COMESA)
- The Global Network of Regional Sustainable Energy Centres (GN-SEC), particularly the ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE), the East African Centre for Renewable Energy and Energy Efficiency (EACREEE), the Pacific Centre for Renewable Energy and Energy Efficiency (PCREEE) and the Caribbean Centre for Renewable Energy and Energy Efficiency (CCREEE).

The Chinese government has facilitated the finalization of these guidelines and was of great importance to its completion.

The development of these guidelines benefited greatly from the valuable inputs, review and constructive comments as well as contributions received from Mr. Adnan Ahmed Shawky Atwa, Mr. Adoyi John Ochigbo, Mr. Arun Kumar, Mr. Atul Sarthak, Mr. Basse Edet Nkposong, Mr. Bernardo Calzadilla-Sarmiento, Ms. Chang Fangyuan, Mr. Chen Changju, Ms. Chen Hongying, Mr. Chen Xiaodong, Ms. Chen Yan, Ms. Chen Yueqing, Ms. Cheng Xialei, Ms. Chileshe Kapaya Matantilo, Ms. Chileshe Mpundu Kapwepwe, Mr. Deogratias Kamweya, Mr. Dolwin Khan, Mr. Dong Guofeng, Mr. Ejaz Hussain Butt, Ms. Eva Kremere, Ms. Fang Lin, Mr. Fu Liangliang, Mr. Garaio Donald Gafiye, Mr. Guei Guillaume Fulbert Kouhie, Mr. Guo Chenguang, Mr. Guo Hongyou, Mr. Harold John Annegam, Ms. Hou Ling, Mr. Hu Jianwei, Ms. Hu Xiaobo, Mr. Hu Yunchu, Mr. Huang Haiyang, Mr. Huang Zhengmin, Ms. Januka Gyawali, Mr. Jiang Songkun, Mr. K. M. Dhahesan Unnithan, Mr. Kipyego Cheluget, Mr. Kolade Esan, Mr. Lamysier Castellanos Rigoberto, Mr. Li Zhiwu, Ms. Li Hui, Mr. Li Xiaoyong, Ms. Li Jingjing, Ms. Li Sa, Mr. Li Zhenggui, Ms. Liang Hong, Mr. Liang Yong, Mr. Lin Xuxin, Mr. Liu Deyou, Mr. Liu Heng, Mr. Louis Philippe Jacques Tavernier, Ms. Lu Xiaoyan, Mr. Lv Jianping, Mr. Manuel Mattiat, Mr. Martin Lugmayr, Mr. Mohamedain Seif Elnasr, Mr. Mundia Simainga, Mr. Mukayi Musarurwa, Mr. Olumide Taiwo Alade, Mr. Ou Chuanqi, Ms. Pan Meiting, Mr. Pan Weiping, Mr. Ralf Steffen Kaeser, Mr. Rudolf Hüpfl, Mr. Rui Jun, Mr. Rao Dayi, Mr. Sandeep Kher, Mr. Sergio Armando Trelles Jasso, Mr. Sindiso Ngwenga, Mr. Sidney Kilmete, Ms. Sitiraka Zarasoa Rakotomahefa, Mr. Shang Zhihong, Mr. Shen Cunke, Mr. Shi Rongqing, Ms. Sanja Komadina, Mr. Tareq Emtairah, Mr. Tokihiko Fujimoto, Mr. Tovoniaina Ramanantsoa Andriampaniry, Mr. Tan Xiangqing, Mr. Tong Leyi, Mr. Wang Xinliang, Mr. Wang Fuyun, Mr. Wei Jianghui, Mr. Wu Cong, Ms. Xie Lihua, Mr. Xiong Jie, Ms. Xu Jie, Ms. Xu Xiaoyan, Mr. Xu Wei, Mr. Yohane Mukabe, Mr. Yan Wenjiao, Mr. Yang Weijun, Ms. Yan Li, Mr. Yao Shenghong, Mr. Zeng Jingnian, Mr. Zhao Guojun, Mr. Zhang Min, Mr. Zhang Liansheng, Mr. Zhang Zhenzhong, Mr. Zhang Xiaowen, Ms. Zhang Yingnan, Mr. Zheng Liang, Mr. Zheng Xiongwei, Mr. Zheng Yu, Mr. Zhou Shuhua, Ms. Zhu Mingjuan.

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

# Table of Contents

Foreword	VII
Introduction	VIII
1 Scope	2
2 Normative references	2
3 Terms and definitions	2
4 Construction of a river diversion	2
4.1 General provisions	2
4.2 Flood standard for river diversion	1
4.3 Mode of diversion	4
4.4 Cofferdam	5
4.5 Diversion and spillage structure	7
4.6 River closure	9
4.7 Foundation pit drainage	10
4.8 Impoundment, navigation, and ice clearing during the construction period	10
5 Construction of the main works	11
5.1 General provisions	11
5.2 Open excavation of earth-rock works	12
5.3 Foundation treatment	14
5.4 Selection, planning and exploitation of the borrow area	14
5.5 Earthwork filling	17
5.6 Production and placement of concrete	19
5.7 Underground construction	23
5.8 Installation of hydro mechanical structures and electromechanical equipment	26
6 Construction planning of roads and transportation	27
6.1 General provisions	27
6.2 External traffic	28
6.3 On-site traffic	29
7 Construction of plant facilities	29
7.1 General provisions	29
7.2 Sand and stone processing system	30
7.3 Concrete production system	31
7.4 Pre-cooling and preheating systems for concrete	32
7.5 Compressed air, water supply, power supply and communication system	34
7.6 Machinery repair processing plant	35
8 General construction layout	36
8.1 General provisions	36
8.2 General construction layout and site selection	37
8.3 Construction zone planning	38
8.4 Earthwork balance and slag site planning	39
8.5 Construction land	40

9 Overall construction programme	41
9.1 General provisions	41
9.2 Construction programme for the preparatory construction	42
9.3 Construction programme for the river diversion works	42
9.4 Construction programme for the foundation excavation and foundation treatment	43
9.5 Construction programme for the earthwork filling project	44
9.6 Construction programme for concrete work	44
9.7 Construction programme for the surface powerhouse	45
9.8 Construction programme for underground works	45
9.9 Construction programme for hydro mechanical structures and electromechanical installation	46
9.10 Construction labour and main technical supply	46
10 Construction safety	46
10.1 General provisions	46
10.2 Hazard identification	47
10.3 Countermeasures	48
Appendix A (Informative) Temperature control of concrete during construction	49
Appendix B (Informative) Ventilation quantity and wind speed values for tunnel/chamber excavations	52
Appendix C (Informative) Formula for the estimation of compressed air demand	53
Appendix D (Informative) Estimation of storage space in general construction layout	54
Appendix E (Informative) Standards for works suspension periods (for earth-rockfill dams and concrete works - due to weather factors)	56

## 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](http://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 30MW.

- 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 river diversion, construction of the main engineering works, construction and planning of roads and transportation, construction of the plant facilities, the general construction layout, the 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 of a river diversion

### 4.1 General provisions

4.1.1 River diversion design shall be supported by adequate basic data and involve a comprehensive analysis of various factors, in order to select a technically feasible, and economically viable, diversion programme that brings benefits from the project, as soon as possible.

4.1.2 The River diversion design shall properly solve water-retaining, spillage 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 river diversion

4.2.1 Flood control standards for the construction of diversion structures shall be expressed as the recurrence period of flood prevention, which can be determined according to Table 1. Flood standards for river diversions should also meet the relevant requirements of the laws and regulations of the country. Under the following conditions, the upper limit given in Table 1 shall be adopted as the flood standard for a diversion structure:

- a) The actual hydrographic data (based on real measurements taken for the river in question) of the river is limited (less than 20 years), or the project locates at the area which strong rainstorms frequently occur.
- b) The diversion structure is a new structural type of cofferdam.
- c) The project is under a key construction phase, and any accident may cause serious consequences.

- 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 to become a part of the permanent structure, the flood standards for diversion structures in Table 1 shall still prevail. However, the part that becomes the permanent structure shall be subject to the flood 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 allow for the regulation and release from the cascade reservoir, and shall be selected through technical and economic evaluation.

4.2.4 The minimum refilling elevations for different months during the cofferdam building period shall be able to safely retain the maximum design flow rate of the following month. The recurrence period of maximum design flow rate in each month may be calculated by adopting the standard for normal operation of the cofferdam, which may be appropriately lowered based on actual observations.

4.2.5 The diversion period shall be selected by analysing the hydrographic characteristics, the climatic conditions, the status of cofferdam construction, the general construction progress and navigation requirements of the river. An ideal choice is the low flow period after the flood season. For areas that experience severe cold, the period chosen for diversion should not be during drift ice or freeze-up 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 rate may be determined by analysing the actual measured data.
- b) If pondage and regulation of upstream and downstream cascade reservoirs have altered the river's hydrographic characteristics, the design diversion flow rate should be determined through special studies.

4.2.7 When the dam elevation exceeds the cofferdam crest elevation, the temporary flood standard for the 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 dam body construction in flood season**

Dam type	Recurrence interval of flood (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 After blockage of the diversion structure, if the permanent structure for flood passing cannot yet fully provide the design flood passing capacity, 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 programming for the blockage of the diversion structure shall be determined according to the overall construction programme based on the premise of meeting the flood retention and impoundment requirements 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 analysing the actually measured hydrographic data. The design standard for diversion flow during the construction period shall be selected from within the range of the recurrence period from five to twenty years, and shall be based on the engineering importance of the project and assessment of risks.

4.2.10 The impoundment standard of a reservoir during the construction period shall be determined on the basis of the requirements for power generation, irrigation, navigation and water supply and the safety of the dam. The guaranteed frequency 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 requirements shall be met.

### **4.3 Mode of diversion**

4.3.1 Diversion modes may include a phased cofferdam diversion mode and a 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 escape structures, during the construction process. The diversion mode shall be selected after a comprehensive evaluation of various alternatives.

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

- a) The diversion mode shall be adaptive to the hydrographic characteristics of the river and the topographical and geological conditions.
- b) The construction period is short, and the construction is safe, flexible and convenient.
- c) The permanent structure is effectively utilized, and both the quantity and the cost of the diversion works are optimized.
- d) The diversion mode shall meet navigation, ice clearing, and ecological flow and water supply 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 during the first phase of the works.

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 characteristics, and the cofferdam operation conditions. If the use of the diversion tunnel has to go through different diversion phases, it shall be designed on the basis of the flood standard during 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 to an elevation above the flood level, under the dam flood control standard, during a low flow period.
- b) Although the foundation pit is flooded during flood season, it has little impact on the engineering programme 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 stability, anti-seepage, and anti-scouring requirements.
- 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 is 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) Low water head, crib cofferdams, bamboo cage cofferdams, and straw-earth cofferdams may be acceptable, based on material availability, environmental protection and skill-availability considerations.

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  $10^{-6}$  m/s. If there are abundant, local, 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  $10^{-4}$  m/s; natural sandy cobble or rock ballast can 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 does not include special loads. The cofferdam crest width shall meet both the construction requirements and the emergency flood fighting requirements.

4.4.5 The safety calculations for concrete cofferdams shall meet the following conditions:

- a) The maximum and minimum vertical normal stresses are calculated using the material mechanics formula. Under the design operating conditions of a cofferdam, 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 be achieved in the following ways:

- a) When the covering layer and depth of water are shallow, a temporary lower cofferdam may be installed with water pumped out and a trench excavated, or a trench can be excavated underwater in order to construct a cut-off wall for seepage control.
- b) Depending on the covering layer thickness and composition, the following options may be considered: High-pressure injection grouting, a concrete cut-off wall or a self-solidifying mortar trough, cement or clay cement grouting, a sheet pile poured wall, or a 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 2m.

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 shall be from 2 m below the lowest water level up to the cofferdam crest. The underwater protection material may be asinking 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 should 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 for the foundation pit slopes shall be treated, in advance, with reverse filtration.
- b) The overflow surface material and the anti-scouring material should be assessed; the overflow surface of an earth-rockfill overflow 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 0.5m to 0.3m.
- 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 corewall type cofferdam.
- c) The potential impacts on the crest elevation from surge events or deflected backwater currents should be considered. Where 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. Freeboard should not be added.

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

- a) When the factor of safety for a gravity type concrete cofferdam or a masonry cofferdam is calculated, using the shear-break strength formula, the factor of safety shall not be less than 3.0; if drainage failure is considered, the factor of safety shall not be less than 2.5. If they are calculated with the shear strength formula, the factor of safety shall not be less than 1.05.
- b) The stability factor of safety for an earth-rockfill cofferdam side slope shall not be less than 1.05.

## 4.5 Diversion and spillage structure

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

- a) The channel shall have a large capacity but only require relatively small excavation quantity.
- b) There shall be few bends. Excavations in areas with landslides, collapses and high slopes, should be avoided.
- c) There shall be easy access to the foundation pit.
- d) The joint between the inlet/outlet and the cofferdam shall meet the anti-scouring requirements of the cofferdam foundation.
- e) Excessive water level difference caused by lateral flows shall be avoided; scouring in the downstream areas and construction facilities shall be avoided during flood conditions.

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

4.5.3 The cross section of an open channel shall be designed to facilitate blockage at a later date. Lining method shall be chosen based on geological and hydraulic conditions.

4.5.4 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 for the stability of the surrounding rock and for safe operation. When conditions permit, the diversion tunnels should be used as part of the permanent tunnels. If this can be achieved, the tunnel axes, the cross section type and the lining structure for the permanent section shall meet both the permanent operational requirements and the diversion requirements.

4.5.5 The tunnel cross section type 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, a good flow connection, and to avoid erosion due to cavitations. The tunnel cross section should facilitate ease of 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.

4.5.6 When a diversion tunnel is used, measures shall be taken to prevent erosion due to cavitation, shock waves, or vibration that may damage the tunnel, in case that pressure flow and open flow occur alternatively in turn, or there is pressure flow with high velocity. The tunnel lining specifications, type and blockage measures shall be determined through technical and economic evaluation.

4.5.7 The number, elevation and size of the diversion tunnels should be determined taking into consideration the tunnel closure, flood season, blockage, ice clearing, and downstream water supply requirements. 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 usage requirements. If the temporary diversion opening embedded in the dam body is no longer used, it shall be blocked with the same grade of concrete as the dam concrete. Measures shall be taken to ensure good bonding between the existing concrete and the newly poured concrete.

4.5.8 The width of the diversion bottom holes inside the dam should not be greater than half the width of the dam section, and should be arranged at the junction of two edges.

4.5.9 The axes for a diversion conduit should be straight. The requirements for the intake are provided in Section 4.5.5 for a tunnel, and 4.5.7 for the bottom holes. No alternating pressure and non-pressure flows are allowed inside the conduit. In order to avoid uneven settlement of the conduit top, and the two sides of the dam body, all or most part of the conduit should be embedded into the base rock. When a 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 arising from any uneven settlement or temperature stresses.

4.5.10 A channel or opening shall be prepared in the dam body in a concrete gravity dam, an arch dam or other solid structures during the course of construction, in order to jointly release flooding along 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.

4.5.11 The channel or opening through the dam body should be placed on the portion of the riverbed, so as 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.

4.5.12 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 intensive analysis on the hydraulic parameters, the construction conditions and closure difficulty, and the quantity and nature of the casting objects. Design should then be finalized through 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 closure design shall include specific requirements for the removal of the construction cofferdam of the diversion structure or any other water barriers.

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

4.6.4 The closure gap width and position shall be determined according to the following principles:

- a) When the riverbed width is less than 80 m, the reserve section is 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 quantity of work required for the closure gap should be as small as possible.

4.6.5 If the surface layer of the riverbed at the closure gap section is likely to be washed away, then riprap, wire boxes (reinforcing cage), or alloy string bags shall be used to protect the river bottom. The protection scope may be determined by reference to experience from similar projects. The bottom protection length downstream of the vertical closure embankment axis shall be 2 to 4 times the average water depth at the closure gap, while the upstream length shall be 1 to 2 times the maximum water depth. The elevation of the top surface of the bottom protection shall be determined after analysing the hydraulic conditions and the protection materials. The bottom protection width shall be determined on the basis of the maximum scouring width.

4.6.6 The materials that shall be used for the closure shall be selected according to the following principles:

- a) The filling materials for the reserve sections should be excavation slag and local natural materials.
- 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) Sizes of the boulder materials shall be easy to manoeuvre and transport.

## **4.7 Foundation pit drainage**

4.7.1 The total drainage volume at the initial stage shall be calculated in light of the water quantity existing in the foundation pit (after blockage of the cofferdam), the seepage flow through the cofferdam and foundations (during the pumping process), the water quantity in the cofferdam body and the overburden within the foundation pit, together with the precipitation. The precipitation adopted shall be the multi-year average daily precipitation during the pumping period.

4.7.2 Routine drainage shall be calculated from the seepage of both the cofferdam and the foundation, taking into consideration the design head, the water in the overburden, the precipitation and the waste water. The precipitation shall be calculated on the assumption that the maximum daily precipitation during the pumping period is drained within one day; the waste water during construction and the precipitation shall not accumulate. The seepage in the foundation pit may be appropriately increased after taking into consideration the cofferdam type, the seepage control mode, the cofferdam foundation, the reliability of the geological data and the seepage head.

4.7.3 When ascertaining the pumping rate for the foundation pit, at the initial stages, the descending rate of water level in the foundation pit, shall be determined based on the seepage stability requirements for different cofferdam types.

4.7.4 The pumping equipment shall have standby power in addition to are liable 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 spillage structures. The following conditions shall be analysed:

- a) The construction programme for the project associated with the impoundment, and the blockage plan of the diversion works;
- b) Land acquisition, resettlement and reservoir clearing, and the environment protection requirements;
- c) Hydrographic data, the reservoir storage capacity curve and the reservoir impoundment duration curve;
- d) The flood control standards, flood passage and flood protection 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 water retention by the cofferdam, shall be considered.

4.8.2 When deciding the impoundment date during the construction period, in addition to calculating the storage level of the reservoir by month according to the water storage standard, the water level during flood season shall also be calculated according to the flood control standard, and the top elevation of the dam before the onset of the flood season shall be established. A grouting plan of concrete dam joints shall also be determined.

4.8.3 The temporary navigation programme, during the construction period, shall be considered together with the construction of the diversion structure, and the programme shall be determined through technical and economic evaluation. When a decision is made to stop navigation, during the construction period, the passengers and freight transportation companies, shall be properly notified and informed.

4.8.4 When considering the construction of diversion structures in a river carrying drift ice, especially where the drift ice is large and may obstruct the spillage structures capacity in releasing flood water safely, 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, economically and reasonably realize, the overall design scheme of the SHP project, and ensure 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 Emphasis should be placed on the evaluation of construction schemes with the following individual project elements:

- a) Elements that control the programme;
- b) Elements that dominate a larger proportion of overall investment;
- c) Elements that affect construction safety or quality;
- d) Elements that have high construction complexity or for which new construction technologies are being adopted.

5.1.3 The chosen construction scheme shall be selected based on the following principles. The scheme shall:

- a) Ensure construction safety, project quality and ensure that the construction progress can be adhered to.
- b) Strive to reduce the length of the construction period, reduce the auxiliary work quantities and additional construction workload, and reduce the construction costs.
- c) Strive to coordinate and balance, between previous and subsequent operations, between civil engineering and electromechanical installation, between constructional and operational optimization and among working procedures, and reduce any conflicts.
- d) Be technically advanced and reliable, and the new construction technology selected shall pass the production tests or appraisals.

- e) Balance the rate of construction and the demands on the construction equipment, materials, labour forces and other resources.
- f) Strive for the conservation of water and soil, environmental protection and workers' health.
- g) Be conducive to protecting the safety and health of all of the workers.

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

- a) They should be applicable for the construction conditions in the project location and meet the design requirements. The production capacity shall meet the target construction programme requirements.
- b) The equipment should be flexible and efficient with low energy consumption. It should be able to be operated safely and reliably, and meet the environmental protection requirements.
- c) The equipment shall be selected according to the working site, the construction intensity and the construction method of the individual item, which shall be favourable for the allocation of personnel and equipment. Any potential waste of resources shall be minimized.
- d) The equipment should be versatile and should be able to be used at different stages within the project.
- e) The equipment procurement and operational expenses are to be relatively low, and parts should be easily obtained. The equipment maintenance, management and dispatching shall be convenient.
- f) Any new types of construction equipment for the project should be purchased as a complete set. If single construction equipment is used, it should be in line with the existing construction equipment in use.
- g) 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 demarcation of overwater and underwater elevation shall be determined through analysing the terrain, geology, excavation period and hydrological conditions.

5.2.3 The protective layer should be kept 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, shockproof measures shall be taken, such as a protective layer cushion 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, and based on the premise that the foundation pre-splitting requirements are met, then radial hole blasting may be adopted.

5.2.6 Based on the general construction layout and overall construction programme, the earthwork and the stonework of the whole project shall be balanced, in combination with soil and water conservation measures. Based on the premise that the overall construction programme and the environmental protection requirements are met, 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 For the excavation of rock foundations forming part of hydraulic structures, blasting shall not be undertaken by the centralized charge method.

5.2.8 When blasting will be carried out close to particular areas, such as newly-poured mass concrete, a newly grouted area, a newly pre-stressed anchorage area, or a newly bolt shotcrete (or shotcrete) supporting area, the blast's influence shall be studied and controlled blasting shall be adopted. The vibration velocity of the blasting particles shall not exceed the allowable safety standard.

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

- a) Top-down construction procedures should be adopted.
- b) Pre-split blasting or smooth blasting should be used to avoid secondary slope cutting.
- c) Any slopes with support requirements should be supported in sufficient time, after the excavation of each layer.
- d) For slopes with a cut-off ditch at the top of the slope, the construction of the cut-off ditches should be completed first, and then the excavation of the slopes should be carried out.

5.2.10 The selection of the construction methods and equipment for underwater excavation should be determined according to factors such as water depth, water 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 should follow the following principles:

- a) The layout of a slag road should be uniformly planned according to factors such as excavation mode, construction schedule, transportation intensity, location of slag site, vehicle type and topographic conditions.
- b) When there is difficulty in entering the slag road for 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 pits, and difficult to arrange slag roads, other slag discharge methods can be studied.
- c) It shall be able to meet the construction needs of subsequent projects, and not occupy any part of any structures, should not involve more occupation or less occupation of these sites which will be deeply excavated.

- d) It should be short, flat and straight, and reduce the plane intersection.
- e) Roads with high traffic density should be equipped with dual lanes or circulation lanes; In an area with low slag discharge intensity and steep terrain, the slag discharge road can adopt a single lane, and a passing lane should be set. The distance between passing lanes should not be more than 200m.

## **5.3 Foundation treatment**

5.3.1 For the foundation treatment, based on the requirements for the 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 construction site for curtain grouting shall meet the working requirements of a slurry preparation system and the grouting equipment. It shall also meet the requirements for strengthening grouting, if necessary. If conditions permit, the curtain grouting should be carried out in the gallery.

5.3.3 The consolidation grouting of the dam foundation with seepage berm shall be carried out after the concrete has reached the required strength.

5.3.4 The foundation grouting should be carried out as per the sequence of consolidation before curtain grouting. The grout curtain should be constructed by gradual compaction, per sequence.

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

5.3.6 The length of cut-off wall trenches shall be determined based on 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 5m to 8m. For the deep trench section, and the section where the trench wall is prone to collapse, the smaller value should be adopted.

5.3.7 The quality and quantity of earth material for the cut-off wall construction shall meet the trench making and trench clearing requirements. The clay content of the earth material for slurry preparation should be more than 50%, the plasticity index not less than 20, and the sand content less than 5%.

5.3.8 The construction scheme for a thin wall concrete cut-off wall should be selected through technical and economic evaluation based on the seepage-proof requirement of a hydraulic structure, the geological conditions, the construction equipment, the construction technology, the material, the construction period and other factors.

## **5.4 Selection, planning and exploitation of the borrow area**

### **5.4.1 General provisions**

- a) Natural construction materials can be used as material sources for concrete aggregate, earth-rock dam filling materials and engineering backfilling materials.
- b) The exploration reserves of natural construction materials should meet the design requirements. The

design requirements should take into account all kinds of losses such as mining, processing, transportation and storage of materials, as well as the reserve factor of 1.25 to 1.5 times.

- c) Material source selection should be based on the requirements of quantity, quality and supply intensity of various natural construction materials. Selection should be made on the basis of geological investigations and testing, through comprehensive analysis of the material source distribution, reserves, quality, mining and transportation conditions, and material balance planning, according to the basic principles of high quality, economy, energy conservation and nearby materials. After technical and economic comparison, priority should be given to the utilization of engineering excavation materials.
- d) The selection sequence of the material sites should be first near and then far, first above water and then underwater, 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.
- e) The design of the material mining site should be based on the topography and geological conditions, taking into account factors such as the mining layout, the mining methods and transportation modes, and an economic and rational mining design shall be proposed.
- f) The design of the material yard slope should be considered in conjunction with the material mining site design, and a safe, reliable and economical support scheme, should be selected.
- g) The selection and mining of the material site should meet the relevant requirements of environmental protection and water and soil conservation.

#### 5.4.2 Material source selection

- a) Concrete aggregate material sources can be selected from engineering excavation materials, natural sand and gravel, stone mining materials or commercial materials. Priority should be given to selecting excavation materials as the source materials. Natural sand and gravel with rich reserves, relatively small stripping and mining, and good gradation and mining conditions, can also be used as the preferred material source, if the environment permits. When there is no suitable natural sand and gravel, then the nearest quarry should be chosen. If a single type of material source does not meet the needs, a variety of materials with different proportions of admixtures should 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 given priority. 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 used within a single building should use the same category of aggregate source. If an aggregate source of different categories is adopted, it should pass relevant tests and verification.

The alkali activity of a concrete aggregate should be tested. Alkaline-activated aggregates should not be used unless specifically demonstrated to be suitable.

- c) Asphalt concrete aggregate should be well graded, hard in texture, and with properties that will not change as a result of heating. Artificial aggregate should be crushed from alkaline rock. When natural gravel or acid rock is used as a crushing material, experimental study and demonstration should be carried out to prove suitability.

If natural sand and gravel materials from the site are chosen they should have concentrated distribution, good gradation, uniform quality, good mining conditions and their excavation should have little influence on the waterway and water intake.

- d) A material source site which has uniform soil quality, a thick soil layer, easy quality control, a 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 areas and the flood areas of the reservoirs.
- e) Rockfill material sources should be given priority to engineering excavation material, and any shortfall can be made up of mined in a nearby material site.
- f) Transition materials should be given priority over materials excavated from engineering caverns. Natural sand and gravel should be selected as the source of filter materials or bedding materials. Where there is a lack of qualified natural sand and gravel near the project, manual preparation material, can be used.
- g) Material balance planning should be based on the construction schedule in order to coordinate the mining programme and mining intensity of various sources, to rationally arrange the material flow direction, and to reduce the required material storage and transit. Computer dynamic simulation methods can be used for this analysis, if necessary.

#### **5.4.3 Material site mining planning**

- a) According to the engineering characteristics and requirements, the topography and geological conditions of the material site, the mining, transportation, slope support and soil and water conservation plan are determined after comprehensive analysis.
- b) Soil sites, natural sand and gravel sites and stone sites should be planned according to the planned mining volumes required. Planned mining volumes shall be determined as being between 1.05 and 1.25 times the design demand.
- c) For the soil material field which will be affected by the flooding in the construction period, the affected parts shall be mined and stored prior to the flooding taking place. The amount of soil material to be prepared shall be 1.2 times the amount of soil material required during the stoppage period.
- d) The material site mining period and mining plan for natural sand/gravel sites should be determined according to the hydrological characteristics, the topographic conditions, the natural gradation distribution, the design grading requirements and other factors of the material site. 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 strength requirements of the feeding in each period. For continuous feeding, two or more mining working faces shall be set.
- g) Stone sites shall be exploited by step blasting, and the height of the steps 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 in use. 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 factors such as topographic conditions, mining plan, material characteristics, transportation

volumes, transportation intensity, transportation distance and the configuration of the transportation equipment.

- j) The excavation slope of a material site shall be stable. Material shall be excavated with slope support, and stepped excavation shall be adopted, and timely supports shall be provided.

## 5.5 Earthwork filling

5.5.1 To undertake the selection of an earthwork filling scheme, the long-term observational data of meteorological stations in the region where the project is to be 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 that these might have 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, the topographic conditions of the construction area, the transportation volumes, the mining methods, the type of transportation equipment, distances 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, contaminated or reduced, in 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 undertake overall planning for the transportation, including making rational arrangements and connections between various transportation modes.
- d) The number of transportation and transit links should be kept as low as possible, resulting in lower transportation costs, simple temporary facility arrangements, and less preparation work.

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

- a) The standards for each section of road shall meet the requirements of transportation intensity and construction safety, and shall be determined after analysing the total transportation volume, the service life, the type of transport equipment and the local meteorological conditions for 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) Other construction transportation requirements such as the transportation required for both banks and for the filling of the dam body shall be taken into consideration. Any temporary road shall ultimately be connected to the permanent highway.

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

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

- b) The cross section of a dam shall be filled flat and raised in a balanced way. In order to meet the needs of flood season and early water storage, it is also necessary to study the filling of the temporary water-retaining section.
- 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 can be selected according to factors such as 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 shall 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 along the direction of the axis of the dam. The staggered distance method shall 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 together within the same layer of cushion material or filter material.

5.5.8 Cushion material shall be filled by the backward method and rolled together within the same layer of transition material. The upstream slope of the cushion material can be protected by an extruding side wall, slope mortar solidified with the turning over forms method, rolling cement mortar, shotcrete or emulsified asphalt.

5.5.9 Impermeable soil material shall 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 suitably arranged in the rainy season. During the rainy season, suitable soil construction schemes should be selected, and reliable rainproof measures should be taken.

5.5.11 Water shall not be added when filling stone under negative temperature conditions. During these conditions the thickness of the paving shall be reduced and the amount of rolling shall be increased. On a day when the average temperature is lower than 0°C, the soil material shall be assessed based on the construction standards during low temperatures. When the average temperature is below - 10°C, it is not suitable to fill the soil material, otherwise technical and economic demonstration should be carried out. During the construction of soil materials during low temperatures, the heat preservation and anti-freezing measures should be assessed.

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

- a) The length of joints and blocks of geomembrane shall be determined according to the construction conditions, and the length and quantity of joints shall be reduced, where possible.
- b) The geomembrane connections shall be undertaken using the method of membrane seam welding ensuring correct overlap alignment and levelling.

- c) Geomembranes shall be sprayed with a cement slurry or backfilled with a protective layer, after completion of laying.
- d) The geomembrane corewall shall be arranged in a zigzag pattern, and the paving schedule shall be in line with the filling schedule for the dam body.
- e) Construction machinery shall 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 amount and weight of the construction machinery and equipment in use at any given time, should be assessed compared to the average strength of the dam. A safety margin should also be included within this calculation.

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

- a) It shall meet the basic requirements of stability, seepage and ultra-high safety.
- b) The top width of the temporary section shall meet the width requirements for emergency repairing of the sub-weir when the flood exceeds the design standard.
- c) An inclined wall and narrow core dam shall not be divided into temporary sections.
- d) After the dam foundation is cleared, the downstream portion of the dam body shall be completely backfilled as per the whole section of the anti-filtration and drainage structure up to the top, and then it shall be started sloping up to the dam crest.
- e) The upstream rock slope and cushion shall be filled to the floodgate elevation according to the design requirements. If these requirements are not met, temporary protection measures shall be taken.

## 5.6 Production and placement of concrete

5.6.1 The Production and Placement of concrete shall be selected based on the following principles:

- a) The processes involved, such as concrete production, transportation, pouring, curing and temperature control measures, can be reasonably interlinked.
- 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 in the initial stages, middle stages and later stages shall be coordinated and balanced.
- e) There is no conflict between concreting operations and the installation of hydro mechanical and electromechanical structures, taking into consideration both primary and secondary concrete placement.

5.6.2 The concrete pouring procedures and pouring locations, in different phases and at different elevations, shall be coordinated with the material supply routes, the lifting equipment arrangements and the 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 is suitable for the pouring locations, at all planes and elevations.
- b) The main equipment has good performance and high productivity, and the supporting equipment can supplement the production capacity of the main equipment.
- c) Within the given working scope, the equipment can continuously work and the equipment utilization rate is high.
- d) In intervals between pouring, the equipment can undertake the hoisting of formwork, 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 pouring rate requirements during the peak period, based on the premise that the quality is ensured.
- 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 transportation distance is relatively large, a concrete mixing truck should be adopted.

5.6.4 The concrete lifting equipment quantity may be determined through calculation, or engineering analogy method, according to the monthly peak pouring rate, cage capacity, hourly circulation time 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.

5.6.5 The hourly circulation time 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, the availability of supporting equipment, the construction management level and the technical proficiency of the workers.

5.6.6 The planning and design for the concrete construction should be selected through the evaluation of alternatives; the mixing, transportation and lifting equipment quantities and their productivity, the pouring rates and the total pouring period shall be determined.

5.6.7 The formwork may be selected based on the following principles:

- a) The formwork shall be in accordance with the characteristics of the concrete structure, the construction conditions and the pouring methods.
- b) It is preferable to use steel moulds rather than wood moulds.
- c) The structural type shall 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.

5.6.8 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.

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

- a) The joint grouting shall be done 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. After effective measures are taken, the concrete age should not be less than 4 months.
- b) The grouting zone height in the same dam joint shall be about 10 m to 15 m.
- c) The allowable height difference between grouting elevation for arch sealing of an arch dam, and the top surface of the pouring layer, shall be determined based on the stress during the construction period.

5.6.10 In mass concrete construction, the temperature control shall be planned. The temperature control requirements shall 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 for construction shall be taken during the summer and thermal insulation measures shall be taken during the winter.

5.6.11 The fly ash mixed in the mass concrete should meet the following guidelines:

- a) The humid curing time for the exposed surface of fly ash mixed concrete shall not be less than 21 days.
- b) For the construction of fly ash mixed concrete at low temperatures, close attention shall be paid to the surface thermal insulation, and the formwork removal time shall be properly prolonged.

5.6.12 The necessity of concrete construction during a low temperature season shall be determined through technical and economic evaluation and analysis according to the overall programme of the project. For concrete construction in a low temperature season, thermal insulation and anti-freezing measures shall be taken. Refer to Appendix A for the temperature standards and thermal insulation and anti-freezing measures.

5.6.13 The roller compacted concrete raw materials and mixing requirements shall meet the following guidelines:

- a) The cementing material content should not be less than  $130 \text{ kg/m}^3$  and the maximum aggregate particlesize should not be more than 80 mm.
- b) Fly ash, volcanic grey matter and other active materials may be used as the admixtures of roller compacted concrete, their suitability may be determined through experimental studies.
- c) The mix -ratio of roller compacted concrete shall be determined through testing.
- d) The Vc value of consistency (or structural viscosity) of roller compacted concrete material should be determined through field testing.
- e) Both the gravity type and forced type mixing equipment may be used for the mixing of roller compacted concrete.

5.6.14 The construction of roller compacted concrete shall be subject to the following principles:

- a) Construction during high temperatures should be avoided, and design shall be carried out for temperature control.
- b) The concrete filling should be carried out with the continuous rise of thin layers. If the tests and

experiments prove that the quality is ensured, the thickness may be correspondingly increased.

- c) The roller compacted concrete may be directly poured by dump truck or poured by a belt conveyor assisted by trucks to transfer the materials. If the roller compacted concrete material is conveyed using a negative pressure chute (pipe), its dip angle shall be more than 45°, and the single stage fall should not be more than 70 m.
- d) The roller compacted concrete 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, vibrating rollers of different models and powers should be provided.

5.6.15 The powerhouse concrete pouring and electromechanical installation shall be properly coordinated, the mutual interferences avoided or reduced, and the concrete works related to the power generation of the first unit, should be poured first.

5.6.16 Concrete construction of a toe slab for a faced rockfill dam shall be completed before the cushion, transition materials and main rock-fill area of the adjacent blocks, are filled. When the dam height is no more than 70 m, the slab concrete shall be poured in a single pour. 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 is to pour the middle slab first and then both sides.

5.6.17 An asphalt concrete construction plan shall be determined according to the project layout, the structure type of the anti-seepage body, the climatic conditions of the project area and the construction equipment together with other factors, 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 construction conditions, construction equipment, construction operation and other conditions.
- b) The thickness of the paving layer for a rolled asphalt concrete corewall shall be determined by a rolling test, and can be 0.2 m to 0.3 m. The paving layer shall be levelled and pressed with the filling of the transition layer on both sides. The poured asphalt concrete corewall shall be constructed with a steel mould which can be disassembled and assembled.

5.6.18 Self-compacting concrete shall meet the requirements of setting time, cohesion and water-holding capacity of an ordinary concrete mixture, as well as the requirements for a self-compacting performance. Construction using self-compacting concrete shall comply with the following provisions:

- a) The mixing station (building) shall be used for centralized mixing, and the mixer truck shall be used for transportation, and insulation and other measures shall 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 shall not be too fast, and the pouring process shall maintain continuity.

5.6.19 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 shall not exceed 150 mm. Continuous mixing equipment with a large output and high efficiency shall be used to mix cemented sand and gravel.

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

5.7.1 Underground construction methods and parameters shall be selected based primarily on the classification of the rocks surrounding the underground works, their deformation characteristics, their cross-sectional shape and sizes as well as their drainage characteristics.

5.7.2 If the underground work is constructed by the drilling and blasting method, a drilling frame carrier and multi-arm drilling machine, should be considered for 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, the construction method, the construction equipment, schedule requirements, topographic and geological conditions and other factors.

5.7.4 If the tunnel is excavated by the 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 analysing the cross section of the chamber, the surrounding rock category, the construction method and procedures, the construction equipment and the 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 excavation may be done from top to bottom across the full cross section.
- 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 using 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, then slagging off and slag sliding measures should be provided; for a medium and large cross section inclined shafts, a pilot shaft may be adopted for excavation widening.

- d) If the dip angle is  $45^\circ$  to  $75^\circ$ , 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  $75^\circ$ , 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 study of the topographic and geological conditions, the structural type and layout, the construction method and the construction programme requirements. If the drilling and blasting method is to be adopted for the construction, 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 shall 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 transportation density and passage requirements, 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 not be more than 14%.
- g) The intersection angle of an adit axis and the main tunnel axis should not be less than  $40^\circ$ , 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  $25^\circ$ , 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 not 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, the drill hole arrangement and the hole depth, the 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, the duration of various working procedures and the interdependencies are selected based on the following conditions:

- a) If the rock surrounding the tunnel easily or very 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, the total length of the drill hole, the blasting volume, the productivity of drilling, and the 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 large, 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, then 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 turnaround (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 the sidewalk edge and a 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: if the vertical shaft is not deeper than 40 m, and there is no guiding equipment, the speed of the cage shall not exceed 0.7 m/s; 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; 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, then 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 guidelines:

- a) Wet rock drilling shall be adopted for underground excavation.
- b) Within the tunnel, low-polluting 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 formwork shall be selected based on the following principles:

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

- b) A movable formwork 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 formwork should be adopted.
- d) For a short tunnel, a transition section, and a flare groove, assembled formwork may be adopted.
- e) For the straight walls of a tunnel fixed assembly steel formwork should be adopted.
- f) If steel formwork cannot be adopted or is not economical, wooden formwork may be adopted.

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

- a) Each working face shall be provided with a carrier. The number of steel formwork units shall meet the continuous concrete pouring requirement.
- b) The formwork 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 analysing the surrounding rock characteristics, the pouring capacity, the form work type and the deformation characteristics of the structure.

5.7.15 The segmentation of concrete lining for an inclined shaft and vertical shaft shall be determined after analysing the surrounding rock characteristics, the structural type and pouring mode and other factors. If the stability condition of the surrounding rock is relatively poor, the lining length shall be consistent with the excavation length, so that 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) Full use shall be made of the existing lifting equipment and hoisting capacity at 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 that can be flexibly dispatched and has high efficiency should be selected.

5.8.2 The installation 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 employed in the large section installation. 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 should be installed and ready for operation so as to facilitate installation works.

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 the hoisting of a turbine generator unit for a power station, permanent lifting equipment shall be adopted.

5.8.5 The installation of a turbine generator unit shall be reasonably combined 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 shall be used. Using separate equipment for this purpose is not advised.

5.8.7 For the installation of a main valve, it is suggested that integrated installation or parts installation be adopted, based on the main valve weight, the lifting capacity and the site conditions.

## **6 Construction planning of roads and transportation**

### **6.1 General provisions**

6.1.1 The construction traffic and transportation may be divided into external traffic and on-site traffic. The external traffic and on-site traffic schemes shall be selected through comparative study based on the general construction layout and the overall construction programme requirements. The upper limit of transportation requirements should be reasonably established. The scope of external traffic and on-site traffic shall be determined in compliance with the following guidelines:

- a) The external traffic scheme shall ensure the connectivity between the construction site and national or local roads, railway stations and shipping ports, and shall be capable of fulfilling the tasks of transporting external materials during the construction period while minimizing standard local traffic.
- b) The on-site traffic scheme shall ensure traffic connectivity between working areas 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 traffic.

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

- a) The technical parameters for the main traffic arteries, such as maximum longitudinal gradient, minimum horizontal and vertical curve radius and sight distance, shall be reasonably selected within the ranges stipulated in the current relevant standards, based on the construction characteristics. Based on the premise that the safe operation and construction requirements are met, the standard for roads, other than main roads, on the site may be properly lowered through full analysis.
- b) The design standard for subgrade, pavement and construction shall be determined based on the road grade and shall meet the requirements of major vehicle models and transportation intensity during the construction period. A small number of heavy pieces may be transported by taking temporary measures.
- c) The flood control standard for temporary, but main, trafficked roads on the site shall be consistent with the flood control standard for the construction site.

6.1.3 For the construction traffic and transportation system, facilities such as safety, traffic management, and repair and maintenance facilities, shall be provided.

## **6.2 External traffic**

6.2.1 For the external traffic and transportation scheme, technical and economic evaluation shall be undertaken, and the technically reliable and economically reasonable scheme, which has convenient operation, little disturbance, a short construction period and is convenient for connection with on-site traffic, shall be selected.

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

- a) Traffic and transportation facilities available within the project location;
- b) The total transportation volume during the construction period, the annual transportation volume, and the transportation rate;
- c) The transportation conditions for the major components, especially generators and transformers, taking into consideration variability of the seasons;
- d) Connection with traffic arteries, both on-site and off-site;
- e) Construction period and the cost of the traffic and transportation project;
- f) Construction status of the transit stations, the main bridges and the culverts, ferries, wharfs, stations and tunnels;
- g) Consideration of possible delays and custom procedures 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) The number of transfer steps for material transportation is kept to a minimum, freight expenses are minimized, and the transportation proposals are timely, safe and reliable.
- c) Based on the local transportation development planning, full use shall be made of the existing national and local traffic roads, and other special roads of industrial and mining enterprises.

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

6.2.5 The transportation scheme for major equipment shall be determined based on knowledge of existing road conditions, technical standards of structures and passage conditions. Any required 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. The number of times transshipment of major equipment occurs should be limited.

6.2.6 At the transit locations, where the transportation mode for external materials is changed, transfer stations may be provided. The scale of the transfer station shall be determined through negotiation with the relevant departments, according to the material source, variety and delivery status.

### **6.3 On-site traffic**

6.3.1 The on-site traffic shall be comprehensively planned, through analysis and calculation, based on the transportation volumes and rates, determined in the overall construction schedule, and in consideration of the general construction layout.

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

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

## **7 Construction of plant facilities**

### **7.1 General provisions**

7.1.1 The construction plant facility shall ensure the preparation of the construction materials required, the supply of water, power and compressed air, the establishment of communication and contact inside and outside of the construction site, and repair and maintenance of the construction equipment. The construction plant facility shall also have small workshops where certain uncomplicated parts and simple hydro mechanical structures can be fabricated.

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

- a) For the determination of scale for the construction plant facility, the possibility and rationality of using local industrial and mining enterprises, for manufacturing and technical cooperation, shall be considered. These shall also be considered in relation to the combining of construction requirements for this project and for the cascade power stations.
- b) The plant site should be located close to the service object and user centre, in a convenient position in relation to traffic and transportation, and water and power supply. The reverse transportation of goods

shall be avoided.

- c) The living quarters shall be separated from the production area. Construction plants with close cooperative relationships should be arranged in a centralized manner. The distance and locations between centralized and decentralized arrangements shall meet the fire protection, safety, health and environmental protection requirements.

7.1.3 For the design of construction plant facilities, a fabricated structure shall generally be preferred, and universal, and multifunctional, equipment should be selected.

7.1.4 The production scale, the floor area, the building area, the power load, the production personnel and other parameters for 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 sand and stone raw material demand shall be determined based on the concrete demand and any other demands for sand and stone materials with grading requirements. Any loss and waste during the exploitation, processing and transportation processes, shall be taken into account.
- b) The processing capacity of the sand and stone processing system shall be calculated according to the monthly average aggregate demand, during the peak period of concrete production, as well as other demands 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 shall be positioned near the quarry area. If there are multiple quarry areas, it shall be positioned in the main quarry area. Separate plants may be considered, through analysis. The plant should 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 1km to 2 km from the quarry area.
- c) The main facilities are to be installed on stable foundations that have sufficient bearing capacity.
- d) The plant site should be close to the existing traffic and transportation routes, a water source and power transmission lines.
- e) If the plant is near the living quarters, it is essential that the 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 requirements, 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, to facilitate process change or device replacement, when necessary.

- 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, but any electrical equipment shall be properly protected.

7.2.4 The total reserves of sand and stone materials 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 reserves shall be checked. The total reserve should 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 For the stacking of the finished aggregate, a partition, shall be provided together with a well-designed drainage system.

7.2.6 For a sand and stone processing system design, dust removal and noise reduction measures shall be taken. 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 quality, the variety, the out-of-mixer temperatures and the pouring rate requirements. The hourly production capacity shall be calculated based on the monthly peak rate, 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 shall 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 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; the high-rise structures or material piles shall have sufficient safe distance from the power transmission equipment and lines.
- c) The raw material feed direction, and the concrete discharge direction, are to be staggered.
- d) When the system is to be constructed, and put into production, by stages, or when it is to be removed in succession, the concrete pouring requirements, during different construction periods, shall still be met.

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

- a) 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 .

- b) The concrete transportation routes on both banks cannot be connected.
- c) The sand and stone quarry areas are spread out, and the aggregate transportation would be inconvenient, or uneconomical, if the arrangement were centralized.

7.3.5 Adapt the total reserves of a stock yard for precast concrete parts, to an optimal production system. Under standard conditions this should not exceed three to five days of the daily average demand, in the peak month, of concrete pouring. If it is especially difficult, it may be decreased to a one day demand.

7.3.6 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 any 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.

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

7.3.8 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-cooled concrete shall be determined according to the pouring strength of the pre-cooled concrete, in each month during the high temperature period, and it shall be checked to ensure that it is in line with the maximum concrete pouring area within the same period. 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-cooled 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 can be calculated as follows:

- a) When the surface of the finished aggregate piles wet and the pile height is above 6m, 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°C and 2°C lower than the local monthly average temperature.
- b) The temperature of cement and admixtures can be determined according to factors such as factory temperature, time of production, transportation and storage methods, and local temperatures. These temperatures can be between 40 °C and 60 °C during high temperature seasons.
- c) The temperature of an ice sheet or ice debris can be assumed to be 0°C for calculation purposes, 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 for the pre-cooling system shall be combined with the overall layout for 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 for fire prevention, explosion protection, sanitation, transportation, power supply and distribution, water supply and drainage.
- d) The refrigeration system mainly produces cold air, cold water and flake ice. An 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 can 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 configuration shall meet the requirements for pre-cooled concrete production and adapt to fluctuations in the ambient temperature. The main equipment configuration shall also take into account the appropriate load coefficient.
- c) Auxiliary equipment for the 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-cooled concretes, and shall be flexibly allocated.

7.4.6 The production capacity for pre-heated 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 can be adopted:

- a) When the aggregate is to be transported from different locations, the initial temperature shall be consistent with the outdoor temperature; When the aggregate is to be 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°C and 15°C, according to factors such as the outdoor air temperature, the transportation time and the storage conditions.

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

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 a large, single 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 comprehensive analysis of the distribution of air users, the load features, the construction programme, any pressure loss in the pipe network and the 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 where the air is clean and ventilation is good. 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 The water supplied for the construction shall meet not only the daily peak water consumption requirements for the construction works together with the domestic water requirements, in different periods, but should also meet the required water demand for firefighting.

7.5.4 The water source shall be selected based on the following principles:

- a) The water is abundant, reliable and close to the user.
- b) The water quality requirements are met, or the requirements can 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, the water consumption, the user distribution, the water source, the 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 to be completely supplied by the captive power supply, its capacity shall meet the maximum load requirements for construction.
- b) If it is to act as the supplemental power supply for the system, its capacity shall be the difference between the maximum load for construction and the system power supply capacity.
- c) For the emergency standby power supply, its capacity shall meet the power requirement 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 “rapid, accurate, safe and convenient” principles. The composition and scale of the communication system shall be determined according to the project scale, the 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. If there are many vehicles or the working areas are relatively dispersed, Class I maintenance may be provided in a dispersed manner, and Class II maintenance 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, the pipe wall thickness, the 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, the component and wooden formwork, and 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 member variety, the specification, the quantity, the maximum weight, the supply plan, the raw material source, and the 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, the type of turbine generator, and the transportation conditions.

## **8 General construction layout**

### **8.1 General provisions**

8.1.1 The general construction layout shall be reasonably determined, based on: comprehensive analysis of the layout of hydraulic structures, the scale, type and features of the main structures, the construction conditions and the social and natural conditions of the region where the project is located. The relationships between environmental protection, water and soil conservation and the layout of the construction site shall be properly resolved; and until then, the integrated planning of temporary facilities that service the construction, shall be carried out.

8.1.2 For the general construction 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 through comprehensive and systematic evaluation and analysis.

8.1.3 The following indices shall be comprehensively studied during scheme comparison for general construction layout:

- a) Road traffic quantities 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 quantities, materials and equipment for the pipelines for 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 the 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

8.1.4 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 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 General construction layout and site selection

8.2.1 The general construction layout shall be gradually formed, by stages, based on the construction requirements, and shall meet the construction requirements in each different stage, and the processes shall be properly coordinated. In the initial stage, the site levelling scope should be determined based on the final requirements of the general construction layout.

8.2.2 For the general construction layout, after the construction diversion scheme and zoning of the main construction works are determined, emphasis shall be laid on the evaluation of the following aspects:

- 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 usable site;
- d) Site for production and living facilities;
- e) Combination of the temporary project and the permanent facilities;
- f) Impacts and, accordingly, the treatment measures concerning environmental protection, water and soil conservation in the areas of production and the living headquarters.

8.2.3 The construction layout shall be selected through comparison in accordance with the topographic and geological conditions, the land requisition and the demolishing difficulty, the environmental impacts and their relationships with the project layout, as well as taking into consideration the construction zoning plan, and the layout conditions of the main traffic accesses both inside and outside the project site.

8.2.4 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.

8.2.5 For the general construction 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 environmental protection and water and soil conservation requirements.

8.2.6 No temporary construction facilities shall be established at the following locations:

- a) Hazardous areas where mudslides, mountain torrents, sandstorms or snow slides may occur;
- b) Areas with key cultural relics under protection, historical sites, scenic spots or natural reserves;
- c) Areas which interfere with important resource development;
- d) Areas seriously affected by blasting or other factors.

8.2.7 For the flood control standards for the main construction site, established along the banks of the river, the protective measures for floods occurring once every 10 to 20 years shall be taken, and the site protection scope shall be reasonably defined.

8.2.8 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 standard and the rainstorm standard, 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, then 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 The SHP construction zoning plan shall be simplified and recommended as below:

- a) Main works and river diversion works construction area;
- b) Construction plant areas (including the 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 building 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 installation sites of electromechanical equipment and hydro mechanical structures should be close to the main installation location.
- c) For the layout of the construction management and living quarters, the wind direction, sunlight, noise, water source and water quality and other factors shall be considered. The construction management and living quarters shall have a clear dividing boundary with the production facilities.
- d) Main material warehouses, stations, yards, and other storage and transportation systems, should be arranged at the on-site and off-site traffic connecting points.
- e) For the construction zone layout 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 hot work material, oil and other special material warehouses shall meet the relevant fireproof, safety and environmental protection requirements.

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 the relevant safety regulations. A customized, standardized and fabricated structure, should be adopted, where possible.

8.3.7 Minimize temporary facilities and check the feasibility of permanent use of structures 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, the quality characteristics of the excavation materials and the technical requirements for the engineering construction materials, the excavation materials from on-site structures shall be used as filling materials and as concrete aggregate sources.
- b) Excavation materials shall be directly used to reduce the quantity of stored slag materials.
- c) The storage and disposal of the slag site shall be reasonably planned, so that the filling materials and slag materials are transported smoothly and the transportation distance is short.
- d) The loose coefficient of slag and the compaction coefficient of filling materials, as well as the total amount of slag and the utilization amount of materials, shall be reasonably determined.
- e) Construction loss shall be considered according to the source of the excavation materials and the construction characteristics.

8.4.2 The slag site shall be divided between the area where the materials can be temporarily stored and the area where the waste materials are permanently stored. The site selection for the slag site and the stock for each slag site shall be balanced in combination with the earthworks. Slag site selection shall follow 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 facilitate 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 can be located below the dead storage capacity of the reservoir, but it shall not impede the normal operation of the 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) Internal traffic, 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 excluding the locations prohibited by the law. The security of the projects, residential areas, traffic arteries or other important infrastructure cannot 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 (interception) 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.
- h) 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.

8.5.2 Construction areas shall be close to each other and planned in succession to avoid intersection of small construction areas.

8.5.3 The scope of the construction land shall be determined based on comprehensive analysis of the site conditions, the general construction layout, the nature of the land use, the 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.

8.5.4 Construction land is divided into temporary land for construction, and permanent land. Temporary land for construction and permanent land shall be planned, as a whole, and permanent land shall be given priority in project construction.

8.5.5 Temporary construction land shall be based on the external contour lines for the temporary construction facilities, and factors such as safety, maintenance, construction influence and management convenience, shall be taken into consideration.

8.5.6 The land used for areas such as material sites and waste slag sites shall be given priority for reclamation and shall be listed as temporary land; land that cannot be reclaimed, or is difficult to reclaim, 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 requirements of the owner on the total construction period, and to observe the following principles:

- a) Comply with basic construction procedures.
- b) Plan the construction period reasonably, on the basis of the average (advanced) construction level within the country.
- 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 based on the premise of ensuring construction safety and construction quality over the total construction period.

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

- a) Preparing to build phase: Refers to the period of time before the official commencement of the project, during which the owner shall complete the external traffic plans, the construction power supply and communication system plans, the land acquisition, the resettlement of residents' plans, bid invitations,

bidding evaluation and the signing of the contract, in order to get the mobilization and commencement conditions ready for the main project construction.

- b) Preparation phase: Refers to the construction period from the commencement of the preparatory construction to the commencement of the main project on the critical path 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 for the main project: Refers to the construction period from the commencement of the main project, on the critical path, or from the Phase I river closure, to the moment when the first generator set for the hydropower station is put into operation or the moment when the project starts giving benefits.
- d) Completion phase: Refers to the construction period from the moment when the first generator set for the hydropower station is put into operation, or when the project starts giving benefits, up until the completion of works. When preparing the total 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 elements (elements on the critical path) and the important project elements. It shall also clarify the dates for commencement, river closure, water filling, and power generation of the first generator unit and project completion.

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 finalized.

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 requirement for the main project.

9.2.3 Other preparatory construction work, such as ground levelling, and construction of the power supply system, the water supply system, the air supply system, the in-plant communication system, construction plant and facilities, as well as living and production houses, shall be arranged in coordination with the construction programme for the main project to be served.

9.2.4 If conditions permit, the external traffic, in-plant trunk roads, underground construction passageway 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 river diversion works**

9.3.1 The river 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 during the later stages of the flood season, but it should not be arranged in a period of freezing weather or a period of ice floating. The channel closure time shall be determined through reasonable analysis based on the construction period for the cofferdam construction and for the safe flood protection requirements, and in combination with the average discharge for each month, or each 10 days, in the selected period of time.

9.3.3 After the construction of the cofferdam and after the anti-seepage construction of the cofferdam foundations are completed, the foundation pit pumping operation may be performed. In reference to the foundation pit for an earth-rock cofferdam with soft foundations, the control of drainage reduction rate shall be considered.

9.3.4 When adopting an overflow cofferdam diversion scheme, it is necessary to analyse the influence that the overflow duration and the situation before and after the water overflows has on the construction period. In a river with heavy sediment, it is necessary to consider the impact that a desilting period could have, after water overflows the cofferdam.

9.3.5 It is necessary to determine the temporary flood protection period, in the construction period, in accordance with the construction programme for a water-retaining structure, and demonstrate whether the construction of the water-retaining structure can reach the requirements for blocking the design flood.

9.3.6 After the river diversion is completed by the diversion and discharge structure, the closing period should be selected after the flood season, so that the closure project can be completed within one dry season. If the river closure is undertaken before the flood season, then all the measures required to ensure safe flood protection, shall be fully prepared and fully demonstrated.

## **9.4 Construction programme for the foundation excavation and foundation treatment**

9.4.1 The bank slope excavation for the dam foundations, and the foundations for the powerhouse within the river channel, shall be arranged to be constructed in parallel with the river diversion works, and shall be completed prior to the river channel closure. The excavation of the riverbed foundations shall be arranged after the construction of the cofferdam and after the drainage of the foundation pit.

9.4.2 It is necessary to analyse and calculate the excavation rate for the dam foundations and the corresponding construction periods. This should be undertaken with reference to the foundation pit excavation area, 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, the treatment scheme, the work quantity, the construction procedures, the construction level, the equipment production capacity and the total programme requirement. For foundation treatment with complex geological conditions, or with highly technical requirements or treatment that controls the total construction period, the influence on the overall construction programme shall be analysed and demonstrated.

9.4.4 The treatment for foundations with unfavourable geological conditions should be fully completed, prior to any building work on the foundations, taking place. Consolidation grouting should be arranged

after concrete pouring of at least 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 path 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 In reference to dam foundations with geological weaknesses on the slope of both banks, the construction period shall be arranged in accordance with the foundation treatment scheme. If the treatment position is beyond the scope of the dam foundation, or is underground, then the treatment may be undertaken together with the dam body pouring (filling), and shall be completed before the reservoir is filled, according to the design requirement.

## **9.5 Construction programme for the earth work filling project**

9.5.1 It is necessary to study the flood retention scheme for the dam, to demonstrate the filling rate of the dam and determine the staged-filling elevation of the dam, in accordance with the diversion and safe flood protection requirements.

9.5.2 The dam filling rate for an earth-rock dam shall be envisaged according to the following principles:

- a) The total construction period, and the project construction completion requirements for various phases, shall be met, and the construction rate should be balanced.
- b) The monthly peak filling amount shall be coordinated in proportion with the total filling amount required.
- c) The dam face filling rate shall be coordinated with the production and transportation capacity of the qualified materials from the borrow/quarry area.

9.5.3 The effective days of construction shall be analysed in accordance with the hydrological and meteorological conditions. Refer to the provisions in Appendix E for the work suspension standards for rainy days.

9.5.4 With regard to an overflow earth-rockfill dam, after water flows over the dam the time taken to resume normal construction, shall be analysed, and it shall be demonstrated that the construction of the protective engineering for the dam body can be completed before the dam overflows.

9.5.5 The rising speed of an earth-rockfill dam shall meet the design requirement for controlling the rising speed of a plastic corewall (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 factor for the filling period for rolled earth-rock dams should be less than 2.0.

## **9.6 Construction programme for concrete work**

9.6.1 When the construction programme for concrete is planned, the effective days of work 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

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 shall be related to the dam type, the quantity of concrete blocks, the pouring height, the capacity of the pouring equipment and the temperature control requirements, and should be determined by actually pouring blocks, or through engineering analogy.

9.6.3 The average rising speed of a roller compacted concrete shall be determined through comprehensive analysis of the block surface area, the thickness of the paved layer, the 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 for flood protection 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) has been 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 to be performed in parallel. However, it is to be ensured that the blasting excavation does not have an adverse influence on the old or young concrete.

9.7.2 The average rising speed of a powerhouse shall be related to the powerhouse type, the quantity of concrete blocks, the pouring height, the capacity of the pouring equipment and the temperature control requirements; and 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 kinds of embedded parts. The operability of permanent hoists and lifting devices, taking into account the necessary curing periods, shall be considered.

## **9.8 Construction programme for underground works**

9.8.1 Procedures for the underground cavern group shall be comprehensively planned and arranged, the network schedule shall be edited and it shall be determined which construction items are on the critical path and the connection sequences between all the items. And natural ventilation shall be utilized as much 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 drill advance index for underground works, per month, may be calculated through analysis, or determined through engineering analogy, in accordance with the geological conditions, the construction method, the equipment performance and the working site.

## **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 programme for hydro mechanical structures and electromechanical installation, the intersections and connections with the civil engineering construction works, shall be coordinated. The time for delivery of civil engineering works that controls 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 annual average number of people required for production, and the average number of people required for production over the total construction period, shall be analysed and calculated in accordance with the overall target construction programme. This shall be undertaken according to yearly, monthly and further subdivided works, in combination with the average-advanced construction level of the country, or with reference to data from similar projects undertaken within the country.

9.10.2 The total number of working day for construction may be determined according to the average number of people for production, in the total construction period, multiplied by the number of working days, per year.

9.10.3 The resources for the overall construction programme shall be optimized to propose a general table of labour-force and main construction equipment, as well as the supply schedule for the main materials.

# **10 Construction safety**

## **10.1 General provisions**

10.1.1 The construction planning shall be designed with comprehensive consideration to the requirements for environmental protection, occupational health and safety. All kinds of possible dangerous and harmful factors in the construction period shall be analysed according to the engineering characteristics for proposing the main technical safety measures and the safety management requirements during the construction period.

10.1.2 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. Risk analysis shall be conducted for the main hazards first.

## 10.2 Hazard identification

The individual project components with relatively high risks refer to the individual operations during which the construction might cause death, injuries, occupational diseases, tangible losses or serious adverse social impact. The individual project components with relatively high risks, mainly include the following:

- a) Support and protection of the foundation pit: The support and protection work 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 work for a foundation pit (slot) with an excavation depth exceeding 3 m (inclusive).
- c) Formwork and support systems:
  - 1) All kinds of formwork: Including large panel formwork, sliding formwork, creeping formwork and flying formwork;
  - 2) Concrete formwork support works: The concrete formwork 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<sup>2</sup> 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 work, 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 Countermeasures**

For individual project operations with relatively high risks, the main construction technologies shall be analysed first, including technical parameters, process flow and main construction methods. For such individual projects, with relatively high risks, the engineering measures and other measures shall be proposed first.

## 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, the temperature control standards as well as the calculation requirements and temperature control anti-cracking measures may be selected in accordance with the contents 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**

Serial 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 flyash; (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	<p>(1) Determine the concrete out-of-mixer temperature and the temperature of the concrete during construction of the dam;</p> <p>(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 ;</p> <p>(3) Determine the pre-cooling method, the pre-cooling time and the temperature for the concrete aggregate;</p> <p>(4) Determine the temperature difference and the maximum allowable temperature of the dam foundation;</p> <p>(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;</p> <p>(6) Calculate the temperature field and temperature stress field of the dam body, and determine the stable design temperature of the dam body;</p> <p>(7) Determine the temperature of the concrete during construction of the dam body in each month;</p> <p>(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;</p> <p>(9) Determine the time taken for joint grouting of the dam body;</p> <p>(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;</p> <p>(11) Determine the protection methods for concrete surfaces, as well as the variety and specification of protective materials.</p>
3	Temperature control anti-cracking measures	<p>(1) Optimize raw materials and mixing ratios, and reduce temperature rise due to hydration heat;</p> <p>(2) Divide joints and blocks reasonably;</p> <p>(3) Arrange the concrete construction procedures and construction programme reasonably, and control the maximum temperature of the dam body;</p> <p>(4) Control the height difference between adjacent dam blocks and dam sections;</p> <p>(5) Determine a reasonable layer thickness and the intervals of concrete pouring;</p> <p>(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;</p> <p>(7) Reduce temperature recovery in the transportation process and in the pouring surface;</p> <p>(8) Water cooling in the dam in the early, intermediate and later stages;</p> <p>(9) Heat preservation and curing of the concrete surface;</p> <p>(10) Comprehensive management of temperature control.</p>

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

Serial 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°C, over a five-day period or the minimum atmospheric temperature is continuously lower than -3°C, over a five-day period.
2	Thermal insulation and anti-freezing measures	<p>(1) Temperature of concrete during construction should not be lower than 5°C for the dam and not be lower than 10° C for the powerhouse;</p> <p>(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°C to 20°C;</p> <p>(3) Thermal insulation forms may be adopted, and shall not be removed in the entire low temperature period;</p> <p>(4) An air-entraining agent may be added, and the quantity of entrained air shall be determined through testing;</p> <p>(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;</p> <p>(6) When the daily average atmospheric temperature is lower than -10°C, a warm shed should be placed over the concrete;</p> <p>(7) The maturity of the concrete enduring the cold shall not be less than 1800°C •h.</p>

## Appendix B (Informative)

### Ventilation quantity and wind speed values for tunnel/ chamber excavations

B.1 The ventilation quantity 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  $0.05 \text{ m}^3/\text{s}$  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 40l 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  $0.068 \text{ m}^3/\text{s}$  per kilowatt, and the air for the personnel working within the tunnel shall also be considered;

B.1.4 When the ventilation quantity 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 between 1.2 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 quantity shall be multiplied by the elevation correction factor;

B.1.6 The calculated ventilation quantity 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  $28^\circ\text{C}$  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 ( $^\circ\text{C}$ )	<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 Formula C.1:

$$Q = K_1 K_2 K_3 \sum (nqK_4 K_5) \dots\dots\dots (C.1)$$

where

- $Q$  is the compressed air demand, in m<sup>3</sup>/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<sup>3</sup>/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	1219	1524	1829	2134	2433	2743	3049	3653	4572
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 general construction 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):

$$q = Qdk / n \dots\dots\dots(D.1)$$

where

- $q$  is the storage volume of required materials, in m<sup>3</sup>;
- $Q$  is the total demand of materials in peak year, in m<sup>3</sup>;
- $n$  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 general construction 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 <sup>2</sup> )	Floor area (m <sup>2</sup> )	Meaning of symbols in formula
Assembly yard for a turbine generator set		$F = \frac{QK_B t}{pa}$	/	<p><math>F</math> is the area of assembly yard, in m<sup>2</sup>;</p> <p><math>Q</math> is the weight of heaviest pre-assembled metal component, in kg;</p> <p><math>K_B</math> is the component assembly ratio, take 0.7 to 0.8;</p> <p><math>t</math> is the tacking coefficient, take 1.25;</p> <p><math>p</math> is the assembly amount per unit area, in kg/m<sup>2</sup>; take 200 to 400;</p> <p><math>a</math> is the site utilization factor; take 0.81 for a gantry crane and take 0.78 to 0.8 for an overhead crane</p>
Warehouse for construction equipment		$W = \frac{na}{K}$	$A = \sum WK$	<p><math>W</math> is the area of warehouse for construction equipment, in m<sup>2</sup>;</p> <p><math>n</math> is the quantity of construction equipment stored;</p> <p><math>a</math> is the floor area per piece of equipment, in m<sup>2</sup>;</p> <p><math>K</math> is the 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.</p>
Warehouse for materials and apparatuses		$W = \frac{q}{PK_1}$		<p><math>W</math> is the area of warehouse for materials and apparatuses, in m<sup>2</sup>;</p> <p><math>q</math> is the storage volume of the required materials, in m<sup>3</sup>;</p> <p><math>K_1</math> is the utilization coefficient of area;</p> <p><math>P</math> is the storage volume of materials per m<sup>2</sup> of effective area, in t or m<sup>3</sup>.</p>
Permanent warehouse for mechanical and electrical equipment	Total area of the warehouse	$F_{total} = 2.8Q$		<p><math>F_{total}</math> is the total area of the equipment warehouse (including floor area of the railway and unloading yard), in m<sup>2</sup>;</p> <p><math>F_{custodial}</math> is the net storage area of the warehouse (refers to the total area of warehouse minus the floor area of the unloading yard), in m<sup>2</sup>;</p> <p><math>Q</math> is the total weight of unit equipment stored in the warehouse at the same time, in t.</p>
	Net storage area of the warehouse	$F_{custodial} = 0.5 F_{total}$		
	Open warehouse	$F_{open} = (17\% \sim 20\%) F_{total}$		
	Enclosed warehouse	$F_{closed} = (20\% \sim 25\%) F_{total}$		
	Thermally insulated warehouse	$F_{thermal\ insulation} = (8\% \sim 10\%) F_{total}$		
	Open storage yard	$F_{open} = (45\% \sim 55\%) F_{total}$		

## **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 10mm/day (for a project with a low degree of mechanization) or 20mm/day (for a project with a relatively high degree of mechanization).

E.2.2 When the monthly average atmospheric temperature is more than 25°C 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°C; the overall construction shall be suspended when the daily average atmospheric temperature is lower than -20°C or the minimum atmospheric temperature is lower than -30°C.

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 100m.

**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)			Average atmospheric temperature(° C)			
		0~0.5	0.5~5	5~10	≥30	≥5	≤4mm	
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	Suspend	Suspend	
		Suspended in rainy days	Suspended in rainy days	Suspended in rainy days	Suspended in rainy days, and suspended for a day after rain	Normal construction	Normal construction	
		Suspended in rainy days	Suspended in rainy days	Suspended in rainy days	Suspended in rainy days, and suspended for a day after rain	Normal construction	Normal construction	
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		Normal construction	
		Suspended in rainy days	Suspended in rainy days	Suspended in rainy days	Suspended in rainy days, and suspended for a day after rain	Normal construction	Normal construction	
		Normal construction	Suspended in rainy days	Suspended in rainy days	Suspended in rainy days, and suspended for a day after rain	Normal construction	Normal construction	
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		Normal construction	
		Normal construction	Normal construction	Suspended in rainy days	Suspended in rainy days, and suspended for a day after rain	Normal construction	Normal construction	
		Normal construction	Normal construction	Suspended in rainy days	Suspended in rainy days, and suspended for a day after rain	Normal construction	Normal construction	





**UNITED NATIONS  
INDUSTRIAL DEVELOPMENT ORGANIZATION**

Vienna International Centre  
P.O. Box 300 · 1400 Vienna · Austria  
Tel.: (+43-1) 26026-0  
E-mail: [info@unido.org](mailto:info@unido.org)  
[www.unido.org](http://www.unido.org)



**INTERNATIONAL NETWORK  
ON SMALL HYDROPOWER**

136 Nanshan Road  
Hangzhou · 310002 · P.R.China  
Tel.: (+86-571)87132793  
E-mail: [secretariat@inshp.org](mailto:secretariat@inshp.org)  
[www.inshp.org](http://www.inshp.org)