カンボジア国
鉱工業エネルギー省
カンボジア電力庁

カンボジア国

電力技術基準およびガイドライン整備計画調査にかかるフォローアップ調査（電力技術基準細則整備（水力））

ファイナルレポート（別冊）

平成 21 年 10 月
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独立行政法人
国際協力機構(JICA)

委託先
電源開発株式会社
中国電力株式会

カンボジア国

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目　次

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Japan International Cooperation Agency (JICA)

Ministry of Industry, Mines and Energy (MIME)
Electricity Authority of Cambodia (EAC)
Kingdom of Cambodia

SPECIFIC REQUIREMENTS
OF
ELECTRIC POWER
TECHNICAL STANDARDS
FOR
HYDROPOWER FACILITIES
(DRAFT)

October 2009

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Table of Contents

Part 3 Electrical Facilities

Chapter 10 General Provisions

Section 1 Definition

Section 2 Safety Policy

Section 3 Prevention of Pollutions

Chapter 11 Electrical Equipment for Hydropower Station

Section 1 Insulation Level

Section 2 Thermal Strength

List of Tables

Part 1
General Provisions

Chapter 1 General Provisions

Article 1 Definitions

In the Specific Requirements of Electric Power Technical Standards for Hydropower Facilities, unless the context otherwise requires, the terms below shall have the following meanings assigned to them:

1. Civil Structures and Hydromechanical Equipment

"Civil Structures and Hydromechanical Equipment" means all facilities constructed for storing, taking, conveying and releasing the water for power generation and their related facilities including dams, spillways, waterways, powerhouses, gates and penstocks of the hydropower stations.

2. EAC

"EAC" is the acronym for the Electricity Authority of Cambodia.

3. EDC

"EDC" is the acronym for the Electricite du Cambodge.

4. Electrical Facilities

"Electrical Facilities" means all facilities for generation, transformation, distribution and use or consumption of electric power including machines, apparatuses, devices, and electrical conductors connecting such equipment except those of the civil structures and hydromechanical equipment.

5. Electric Power Facility

"Electric Power Facility" means power stations, substations, switching stations, electrical lines, and dispatching centers, including equipment, buildings, dams, waterways, fuel storage yards, ash disposal areas, etc.

6. Electric Power Service

"Electric Power Service" means all business activities for power supply including generation, transmission, distribution as well as electric power import and export to be performed by electric power service providers.

7. GREPTS

"GREPTS" is the acronym for the General Requirements of Electric Power Technical Standards of the Kingdom of Cambodia.

8. Hydropower Facilities

"Hydropower Facilities" means all facilities involved in hydropower projects including civil structures, hydromechanical equipment and electrical facilities.

9. Hydropower Station

"Hydropower Station" means a place consisting of a series of entire hydropower facilities constructed to generate electric power.

10. License

"License" means a permit issued by EAC to any organization, enterprises or persons to engage in the electric power services in the Kingdom of Cambodia.

11. Licensee

"Licensee" means an electric power service provider to whom a license has been issued by the EAC.

12. MIME

"MIME" is the acronym for the Ministry of Industry, Mine and Energy.

13. Owner

"Owner" means any organization, the Government and provincial administrative organs, EDC, public or private enterprises, or persons that are authorized to engage in the electricity business in the Kingdom of Cambodia.

14. SREPTS

"SREPTS" is the acronym for the Specific Requirements of Electric Power Technical Standards of the Kingdom of Cambodia.

15. The Technical Standards

"The Technical Standards" means "Electric Power Technical Standards of the Kingdom of Cambodia" that includes "GREPTS", "SREPTS", "EXPLANATION SHEET" for SREPTS and "GLOSSARY" for SREPTS.

Article 2 Purpose

The SREPTS for Hydropower Facilities, hereinafter referred to as "SREPTSHP," prescribes the basic requirements necessary to regulate the existing and the planned hydropower facilities in the Kingdom of Cambodia. SREPTSHP provides requirements mainly for facility security and safety operation of the most important parts of the hydropower facilities so as to meet the following four (4) objectives in principle:

1. Hydropower facilities shall not harm the human or damage any object.
2. Hydropower facilities shall be installed so as not to cause any electrical or magnetic interference that may affect other electrical facilities.
3. There shall be no significant effect on power supply under any failure or damage of the hydropower facilities.
4. Hydropower facilities shall not have adverse effects on the surrounding environment.

The owner shall proceed with a project in its planning, design, construction and operation giving the utmost respect to the above purposes.

Article 3 Scope of Application

All hydropower facilities in the Kingdom of Cambodia shall conform to the requirements prescribed in SREPTSHP.

All persons including licensees, consultants, contractors and consumers who are related to the study, design, construction, installation, operation and maintenance of hydropower facilities shall follow the provisions of SREPTSHP.

SREPTSHP provides with the fundamental requirements concerning the hydropower facilities and such technical contents that should satisfy the fundamental requirements. SREPTSHP may not cover all the technical contents that should satisfy the fundamental requirements, and if proposed alternative should have sufficient technical basis to fulfill the fundamental requirements, such alternative shall be judged to be of conforming to the fundamental requirements.

Article 4 Applicable Standards and Codes

An owner intending to install, rehabilitate, operate and maintain hydropower facilities in the Kingdom of Cambodia shall comply with internationally recognized standards and codes, or any other equivalent ones in designing, constructing, operating, and maintaining such facilities so as to satisfy the provisions of SREPTSHP.

Chapter 2 Particular Provisions

Section 1 Requirements for Project Implementation

Article 5 Assignment of Chief Engineers

The owner shall assign chief engineers responsible for the technical matters in the fields of design, construction, installation, operation and maintenance respectively concerning the hydropower facilities and submit a notice of such assignment to MIME, EAC and EDC when EDC is the signer of PPA.

1. An assigned chief civil engineer shall be responsible for technical matters on design, construction, operation and maintenance of civil structures and hydromechanical equipment and shall perform duties prescribed below:

   (1) Handover between the assigned chief civil engineer in charge of design and the assigned chief civil engineer in charge of construction

   The assigned chief civil engineer responsible for the technical matters in design and the assigned chief civil engineer responsible for the technical matters in construction shall conduct handover of their duties based on the documents for design and construction of the civil structures and hydromechanical equipment concerned.

   The owner shall report the contents of the handover to MIME, EAC and EDC when EDC is the signer of PPA.

   (2) Handover between the assigned chief civil engineer in charge of construction and the assigned chief civil engineer in charge of operation and maintenance

   The assigned chief civil engineer responsible for the technical matters in construction and the assigned chief civil engineer responsible for the technical matters in operation and maintenance shall conduct handover of their duties based on the documents for design, construction, operation and maintenance of the civil structures and hydromechanical equipment concerned.

   The owner shall report the contents of the handover to MIME, EAC and EDC when EDC is the signer of PPA.

2. An assigned chief electrical engineer shall be responsible for technical matters on design, installation, operation and maintenance of electrical facilities and shall perform duties prescribed below:

   (1) Handover between the assigned chief electrical engineer in charge of design and the assigned chief electrical engineer in charge of installation

   The assigned chief electrical engineer responsible for the technical matters in design and the assigned chief electrical engineer responsible for the technical matters in installation shall conduct handover of their duties based on the documents for design and installation of the electrical facilities concerned.

The owner shall report the contents of the handover to MIME, EAC and EDC when EDC is the signer of PPA.

(2) Handover between the assigned chief electrical engineer in charge of installation and the assigned chief electrical engineer in charge of operation and maintenance

The assigned chief electrical engineer responsible for the technical matters in installation and the assigned chief electrical engineer responsible for the technical matters in operation and maintenance shall conduct handover of their duties based on the documents for design, installation, operation and maintenance of the electrical facilities concerned.

The owner shall report the contents of the handover to MIME, EAC and EDC when EDC is the signer of PPA.

Article 6 Environmental Protection

An owner intending to design, construct/rehabilitate, operate and maintain hydropower facilities shall comply with the laws and regulations prescribing environmental protection and conservation in the Kingdom of Cambodia.

Article 7 Order of Remedy for Conformance to Technical Standards

Whenever EAC confirms that the hydropower facility does not conform to SREPTSHP, EAC shall have the right to order the owner to repair or rehabilitate the hydropower facility so as to conform thereto, to suspend the use of such hydropower facility, or to restrict the operation of such hydropower facility or hydropower station.

Article 8 Obligation for Reporting

An owner shall report the matters concerning design, construction, installation, operation and maintenance of the hydropower facilities to each responsible agency as prescribed in the following paragraphs.

1. Construction Commencement Report

"Construction Commencement Report" shall be submitted to MIME and EDC when EDC is the signer of PPA with a copy to EAC for approval of construction commencement after passing the examination for commencement of construction prescribed in Article 172 (Scope of Examination for Commencement of Construction). The Construction Commencement Report shall describe the conformity of construction plan and design of civil structures and hydromechanical equipment to SREPTSHP.

2. Operation Commencement Report

After passing the examination before initial impounding prescribed in Article 174 (Scope of Inspection prior to Initial Reservoir Impounding) and before starting operation, “Operation Commencement Report” shall be submitted to EAC and EDC when EDC is the signer of PPA with a copy to MIME for approval of operation commencement.

3. Accident Report

If there arises any serious accident which violates the principles of SREPTSHP shown in Article 2 (Purpose) concerning the civil structures and hydromechanical equipment and electrical facilities, such accident shall be promptly reported to EAC and EDC when EDC is the signer of PPA with a copy to MIME.

Furthermore, reports concerning the civil structures and hydromechanical equipment shall include items below:

4. Flood Management Rules

For dams categorized as "Large" or “Medium” in Article 21 (Design Flood), a dam management system, discharge procedure, and measures to mitigate danger to downstream areas under flood situations shall be described in the Operation Commencement Report that shall be submitted to EAC with a copy to MIME and EDC when EDC is the signer of PPA.

5. Report of Usual Monitoring Results

The results of usual monitoring prescribed in Article 26 (Monitoring and Inspections)-1 shall be reported to EAC with a copy to MIME and EDC when EDC is the signer of PPA in annual basis.

6. Report of Emergency Inspection Results

The results of emergency inspection prescribed in Article 26-2 shall be reported to EAC with a copy to MIME and EDC when EDC is the signer of PPA on a case-by-case basis.

Article 9 Safety and Technical Training

The owner shall have his/her engineers and/or technicians who operate and maintain their civil structures and hydromechanical equipment and electrical facilities receive a concerned training program or course. The owner shall make a report of contents of the safety and technical training and the list of trainees to EAC and EDC when EDC is the signer of PPA.

Section 2 Exemptions

Article 10 Exemptions for Small Projects

All hydropower facilities in the Kingdom of Cambodia shall conform to SREPTSHP in accordance with Article 3 (Scope of Application) in principle.

However, MIME and EAC may exempt such small hydropower facilities that satisfy the following conditions from the application of SREPTSHP in order to facilitate the rural electrification:

1. such hydropower station that is classified into "micro hydro scheme" in accordance with the MIME's classificatory criteria;
2. such hydropower station that construction, operation and/or any failure of the hydropower facilities would not be harmful to public safety; and
3. such hydropower station that any failure of the facilities does not seriously affect the connected power grid or its power supply area that is isolated from the existing power grid.

Article 11 Exemptions for Projects under Implementation

MIME and EAC may exempt any hydropower facilities under implementation from the application of SREPTSHP at the time of its enforcement by issuing an official certificate for exemption. However, the owner shall try to do his utmost so that such hydropower facilities conform to SREPTSHP as much as possible.

Article 12 Exemptions for Projects under Operation

The hydropower facilities under operation are exempt from the application of SREPTSHP and could be operated till the time of its renewal or replacement unless they are harmful to public safety.

Article 13 Exception of Exemptions

The owner shall be always responsible for reporting prescribed in Article 8 (Obligation for Reporting) and monitoring and inspections prescribed in Article 26 (Monitoring and Inspections) regardless of any exemption described in Article 10 (Exemptions for Small Projects) to Article 12 (Exemptions for Projects under Operation) as well as for conformity to the requirements directly related to public safety.

Part 2
Civil Structures and Hydromechanical Equipment

Chapter 3 General Provisions

Article 14 Definitions

1. Dam body height

"Dam body height" is the difference in elevation between the lowest part of the dam body foundation and the crest of the non-overflow section of the dam body.

2. Design flood

"Design flood" is the maximum flow which can be discharged from a spillway safely.

3. ISO

"ISO" is the acronym for the International Organization for Standardization.

4. Maximum credible earthquake (MCE)

"Maximum credible earthquake" is the greatest earthquake which can reasonably be expected to be generated by a specific source on the basis of seismological and geological evidence.

5. Maximum power discharge

"Maximum power discharge" is the maximum flow rate used for power generation in a hydropower station.

6. Non-overflow section

"Non-overflow section" is a part of a dam section where crest spillway does not exist and no overtopping is allowed.

7. Operating basis earthquake (OBE)

"Operating basis earthquake" is an earthquake which can reasonably be expected to occur within the service life of the project, that is, with a 50% probability of exceedance during the service life.

8. Target strength of concrete

"Target strength of concrete" is a required strength of concrete to satisfy the design strength considering dispersion of strength of concrete placed at a site.

Chapter 4 Fundamental Requirements

Article 15 Prevention of Overtopping from Non-overflow Sections of Dams

1. Every dam shall be equipped with a spillway or spillways designed to be capable of sure and safe discharge of the design flood.
2. The dam body shall have a sufficient freeboard depending on the type of dam, presence or non-presence of a spillway gate, and wave height.

Article 16 Dam Stability

1. A dam and its foundation, including bedrock on which a dam is founded and a surface of contact between a dam body and the bedrock, shall have the required water-tightness and strength against expected loads.
2. A concrete dam body shall be so designed as to neither slide nor overturn against expected loads.
3. A fill dam body shall be so designed as to neither break by sliding nor seepage against expected loads.
4. A dam foundation, including bedrock on which a dam is founded and a surface of contact between a dam body and the bedrock, shall not slide, or break by sliding or seepage against expected loads.

Article 17 Prevention of Failure of Waterways

1. A waterway shall be stable against expected loads and shall not be damaged by a landslide or flood.
2. A waterway shall be able to convey and control designed discharge safely and securely and be stable against expected hydraulic phenomena.
3. A waterway shall be designed in such a manner that sand, dust, driftwood or any other substances which may damage a turbine do not flow into.

Article 18 Prevention of Failure of Other Structures

Any structures related to civil structures of hydropower facilities, including powerhouses, maintenance roads, and temporary facilities for construction, shall be stable against expected loads and be protected against damage by landslide or flood.

Article 19 Prevention of Damage to Ground surrounding a Reservoir

Establishing a reservoir shall not cause serious damage to surrounding ground.

Article 20 Prevention of Damage to Upstream and Downstream Areas

1. Discharge from a dam during a flood shall not aggravate damage to the downstream area.
2. Appropriate measures shall be taken when there is a possibility that an inundation of properties such as houses at upper reach areas will occur because of the rising water level due to sedimentation.
3. Appropriate measures shall be taken when there is a possibility that damage of the downstream area will occur by rapid change of water level due to the discharge from the tailrace of the hydropower station.
4. Appropriate measures shall be taken so that necessary discharge may be implemented for water utilization and river environment protection of the affected zone downstream of a dam or an intake.

Chapter 5 Dams

Section 1 Common Rules

Article 21 Design Flood

1. Design flood shall be established appropriately to prevent dam failure based on sufficient meteorological and hydrological research and review.

2. Design flood shall be set in accordance with Table 21-1 based on the dam classification specified in Table 21-2.

Table 21-1 Design Flood

Dam classification	Design flood
Large	Probable maximum flood (PMF)
Medium	Between PMF and the flood of 1,000 years return period
Small	Between PMF and the flood of 100 years return period

Table 21-2 Dam Classification

		Gross reservoir capacity (Million m^3)		
		Less than 10	10 to 100	More than 100
Dam height (m)	Less than 15	Small	Medium	Large
	15 to 30	Small	Medium	Large
	Higher than 30	Medium	Large	Large

Article 22 Basic Water Levels

Basic water levels, on which the specifications of a dam are to be determined, shall be set as follows:

1. Normal high water level (NHWL) shall be the highest level of water stored in the reservoir of a dam during a non-flood period.

2. Flood water level (FWL) shall be the highest water level when the design flood flows over the spillway. In the case that the storage effect of the reservoir is absolutely identified, the flood water level may be the water level that is calculated taking account of reservoir storage effect.

3. Low water level (LWL) shall be the lowest level of water stored in the reservoir of a dam under normal reservoir operation.

Article 23 Freeboard

The non-overflow section of the dam body shall satisfy the following:

1. The non-overflow portion of the dam body shall be higher than either the normal high water level plus freeboard or the flood water level plus freeboard. Freeboard shall be set separately for the

flood water level and the normal high water level by considering the type of a dam, wind-induced waves, earthquake-induced waves, and presence or non-presence of a spillway gate.

(1) Freeboard for normal high water level (normal freeboard)

hw + he + ha + hi or higher,
at least 2 meters for a concrete dam and 3 meters for a fill dam in a minimum

(2) Freeboard for flood water level (minimum freeboard)

hw + ha + hi or higher,
at least 1 meter for a concrete dam and 2 meters for a fill dam in a minimum

Where,
hw: the wave height caused by wind
he : the wave height caused by earthquake
ha : the margin for a rise in a reservoir water level due to malfunction of spillway gate(s)
0.5 meter for a dam with a spillway gate and 0 meter for a dam without a spillway gate
hi : the margin to be applied to a fill dam to prevent a dam body from overtopping
1 meter for a fill dam and 0 meter for a concrete dam

2. In the case of a fill dam, the crest level of the impervious zone shall be equal to or higher than either the normal high water level plus free board or the flood water level plus freeboard.

Article 24 Loads

Loads imposed on the dam body shall be set as follows:

1. The loads which shall be considered in the design of a dam body shall be defined in Table 24-1.

Table 24-1 Loads Imposed on Dam Bodies

Basic load condition		Type of dam: Concrete gravity dam	Arch dam	Fill dam
Usual	Normal operating	• self-weight • hydrostatic pressure at NHWL • mud pressure • uplift	• self-weight • hydrostatic pressure • mud pressure • uplift • thermal load	• self-weight • hydrostatic pressure • pore pressure
Unusual	Construction	• self weight • empty reservoir		• self weight • pore pressure, ,and • empty reservoir
	Flood	• self-weight • hydrostatic pressure at FWL • mud pressure • uplift	• self-weight • hydrostatic pressure at FWL • mud pressure • uplift • thermal load	• self-weight • hydrostatic pressure at FWL • pore pressure
	Normal operating with OBE	• self-weight • hydrostatic pressure* • hydrodynamic pressure* • horizontal earthquake acceleration in downstream direction • mud pressure • uplift*	• self-weight • hydrostatic pressure* • hydrodynamic pressure* • mud pressure • uplift* • thermal load • dynamic OBE load	• self-weight • hydrostatic pressure* • horizontal earthquake acceleration • pore pressure
	Construction with OBE		• self weight • empty reservoir • thermal load • dynamic OBE load	
Extreme	Construction with OBE	• self weight • horizontal earthquake acceleration in upstream direction • empty reservoir		
	Normal operating with MCE	• self-weight • hydrostatic pressure* • hydrodynamic pressure* • horizontal earthquake acceleration in downstream direction • mud pressure • uplift*	• self-weight • hydrostatic pressure* • hydrodynamic pressure* • mud pressure • uplift* • thermal load • dynamic MCE load	
	PMF	• self-weight • hydrostatic pressure at PMF • mud pressure • uplift	• self-weight • hydrostatic pressure at PMF • mud pressure • uplift and • thermal load	

* : The reservoir water level shall be selected as the one which occurs relatively frequently during the course of the year.
Note : Loads in the above table act statically except annotated.

It is possible that arch dams have minimum safety factor against sliding failure for the following conditions.

- The reservoir water level is at LWL or less than that due to some circumstances; and
- The seismic force acts in the upstream direction.

It is possible that fill dams have minimum safety factor against sliding failure at the intermediate reservoir water level between NHWL and LWL.

2. Pore pressure and uplift

(1) Pore pressure for a fill dam shall be determined by considering the permeability of the materials used for the dam body, and drainage, and based on calculations, tests and experience through actual measurements of seepage flow.

(2) Stability of a fill dam shall be studied if residual pore pressure in a dam body damages the stability in case of rapid drawdown.

(3) Uplift for a concrete dam shall be determined by considering the permeability of the foundation after treatments, and drains as shown in Table 24-2.

Table 24-2 Uplift under Various Conditions

Foundation Condition	**Uplift**		
	at Up-stream End	**at Drains**	**at Down-Stream End**
Horizontal cross section without drains		—	
Horizontal cross section with drains		When $H_4 \geq H_2$ $H_3 = (1-E) \times (H_1-H_4) \times \frac{L-X}{L} + H_4$ When $H_4 < H_2$ $H_3 = (1-E) \times (H_1-H_2) \times \frac{L-X}{L} + H_2$	
Horizontal cross section with drains near upstream end	H_1	When $X \leq 0.05H_1$ If $H_4 > H_2$ $H_3 = (1-E) \times (H_1-H_4) + H_4$ If $H_4 < H_2$ $H_3 = (1-E) \times (H_1-H_2) + H_2$	H_2
Horizontal cross section cracked base with drains, zero compression zone not extending beyond drains		$T \leq X$ When $H_4 \geq H_2$ $H_3 = \left[(H_1-H_4) \times \frac{L-X}{L-T} + H_2-H_4\right] \times (1-E) + H_4$ When $H_4 < H_2$ $H_3 = \left[(H_1-H_2) \times \frac{L-X}{L-T}\right] \times (1-E) + H_2$	
Horizontal cross section cracked base with drains, zero compression zone extending beyond drains		$T > X$ $H_3 = H_1$	

Where,

H_1 : Upstream water depth

H_2 : Downstream water depth

H_3 : Uplift at drains

H_4 : Height of gallery from dam base

X : Distance of drains from upstream end of dam base

L : Base length of dam body

E : Drain effectiveness expressed as a decimal

T : Zero compression length

(Note) The uplift in this table is calculated with a proportional method.
Drain effectiveness depends on depth, size, and spacing of the drains; the character of the foundation; and the facility with which the drains can be maintained.

3. Seismic force

The pseudo static analysis with seismic coefficient is used in determining the resultant location and sliding stability of concrete gravity dams and static loads acting on arch dams. A dynamic method of analysis such as response spectrum analysis or time-history analysis under the MCE and OBE conditions shall be used for internal stress calculation of concrete gravity dams, design of arch dams and estimation of deformation in fill dams after earthquake.

Article 25 Dam Foundations

Dam foundations shall satisfy the following:

1. Dam foundations shall be provided with appropriate geologic investigation, permeability tests and strength tests depending on the dam size.
2. Dam foundations shall have a required bearing capacity and a shearing strength, and shall not have serious settlement, serious cracks, sliding failure and serious erosion.
3. Appropriate measures such as grouting or drainage shall be taken at the dam foundation required in order to prevent excessive uplift, serious water leakage or seepage failure.
4. Any fault or other weak stratum in the foundation shall be provided with appropriate treatment when required so that the foundation satisfies the required strength and water-tightness.

Article 26 Monitoring and Inspections

1. In principle, monitoring equipment shall be established in dams with the following conditions and usual monitoring shall be implemented depending on the conditions of the safety of the dam body and the progress of sedimentation of the reservoir in order to confirm the safety and proper functioning of a dam body, and proper functioning of a reservoir. The inspection items shall be as specified in Table 26-1.

Table 26-1 Usual Monitoring Items

Classification			Monitoring items
Dam type		Height from foundation (m)	
Concrete gravity		Less than 50	Leakage and uplift
		From 50 and up	Leakage, deformation and uplift
Arch		Less than 30	Leakage and deformation
		From 30 and up	Leakage, deformation and uplift
Fill	Homogeneous type	All	Leakage, deformation and seepage line
	Other type	All	Leakage and deformation

2. In the case that abnormal loads such as earthquake or flood occur, an emergency inspection shall be implemented immediately in order to confirm the safety and proper functioning of the dam. The inspection items shall be as specified in Table 26-2.

Table 26-2 Emergency Inspection Items

Dam type	Concrete dam	Fill dam	
		Homogeneous type	Other type
Inspection items	Volume of water leakage from dam and abutment, uplift, and deformation	Volume of water leakage from dam and abutment, seepage line, and deformation	Volume of water leakage from dam and abutment, and deformation
	Proper functioning of the discharge facilities		

3. In principle, it is desirable to establish a gallery in a dam applicable to conditions of the paragraph 1 in accordance with necessity for inspections and repairs.

Section 2 Concrete Dams

Article 27 Concrete Materials

Concrete materials used for a dam shall satisfy the following conditions and requirements specified in an applicable standard such as ISO (International Organization for Standardization), or they shall be materials as specified in a standard such as ISO which specify the following Paragraphs:

1. Cement shall conform to the specified level of cementing and solidifying according to the type of material.
2. Aggregate shall be appropriately strong and durable.
3. Aggregate, water, and admixture shall be free of acid, salt, organic substances, or mud which prevents concrete cementing, seriously rusts reinforcing bars, or prevents adhesion between concrete and reinforcing bars.
4. Concrete properties such as unit weight, strength, deformation modulus and Poisson's ratio shall be determined by testing with specified method.

Conformity of the concrete material to the above conditions shall be verified the tests specified in an applicable standard such as ISO.

Article 28 Foundations for Concrete Dams

Requirements of foundation for concrete dams described in Article 25 (Dam Foundations) shall be verified in the following manner.

1. The shear strength, internal friction coefficient and modulus of deformation shall be determined by the results of in-situ tests in principle, taking into consideration the geology of the foundation.
2. In conducting an in-situ test, representative points that are appropriate for determining the foundation properties of the dam shall be selected based on careful consideration of the geology of the dam foundation.

Article 29 Stress Conditions

1. Stress inside the concrete gravity dam body shall not exceed the allowable stress as described below:
   (1) The allowable compressive stress of concrete shall be 0.3 times as much as the design compressive strength for usual load conditions, 0.5 times for unusual and 0.9 times for extreme, respectively.
   (2) The allowable tensile stress of concrete shall be zero for usual load conditions, 0.6 times as much as two thirds power of the design compressive strength for unusual and 1.5 times as much as two thirds power for extreme, respectively.
2. Stress inside the arch dam body shall not exceed the allowable stress as described below:
   (1) The allowable compressive stress of concrete shall be 1/4 of the design compressive strength for usual load conditions, 1/2.5 for unusual and 1/1.5 for extreme, respectively.
   (2) The allowable tensile stress of concrete shall be equal to tensile strength determined by splitting tensile tests.
3. The design compressive strength of concrete shall be determined by an unconfined compressive strength test at the age of 365 days in principle.
4. The target strength of concrete shall be decided with an additional rate which shall be determined depending on variance of compressive strength to the required compressive strength as follows:

$$\begin{pmatrix}\text{Target}\\ \text{strength}\end{pmatrix} = \begin{pmatrix}\text{Required}\\ \text{compressive strength}\end{pmatrix} \times \begin{pmatrix}\text{Additional rate determined by}\\ \text{variance of the compressive strength}\end{pmatrix}$$

Article 30 Stability of Concrete Gravity Dams

A concrete gravity dam shall satisfy the following:

1. For usual load conditions, the resultant of all forces along the plane of study shall remain within the middle third to maintain compressive stresses in the concrete. For unusual load conditions, the resultant shall remain within the middle half of the base. For extreme load conditions, the resultant shall remain within the base.

2. The dam body and the contact zone between the dam body and the foundation shall be stable against sliding. The safety factor of sliding calculated by the following formula shall be 2.0 or more for usual load conditions, 1.7 for unusual and 1.3 for extreme, respectively.

   $n = (f \times v + \tau \times l) / H$

   Where,
   n : Shear friction safety factor
   f : Internal friction coefficient
   τ : Shear strength (N/m^2)
   v : Total vertical force acting on the shear plane per unit width (N)
   H : Total horizontal force acting on the shear plane per unit width (N)
   l : Area resisting with respect to the shear force per unit width (m^2)

3. Foundation bearing pressure shall be equal or less than allowable bearing capacity for usual and unusual load conditions and 1.33 times as much as or more than allowable bearing capacity for extreme, respectively.

Article 31 Stability of Arch Dams

Arch dams shall satisfy the following:

1. The contact zone between the dam body and the foundation and any part of the foundation shall be stable against sliding.

   The safety factor of sliding calculated by the following formula shall be 2.0 or more for usual load conditions, 1.3 for unusual and 1.1 for extreme, respectively.

   $n = (f \times v + \tau \times l) / H$

   Where,
   n : Shear friction safety factor
   f : Internal friction coefficient
   τ : Shear strength (N/m^2)
   v : Total vertical force acting on the shear plane per unit width (N)
   H : Total horizontal force acting on the shear plane per unit width (N)
   l : Area resisting with respect to the shear force per unit width (m^2)

2. Arch dams are deigned for two groups of load combinations. The first group combines all the static loads and the second group takes into account the effects of earthquake.

Article 32 Structural Details of Concrete Dam Body

A concrete dam body shall satisfy the following:

1. Contraction joints shall be appropriately arranged to prevent detrimental cracks.
2. Drainage holes shall be arranged as necessary at the gallery to reduce uplift that acts on the dam body, at the contact rock between the dam body and the foundation, and/or acts in the foundation rock.
3. The area surrounding the openings, such as galleries, water discharge equipment or penstocks installed inside the dam body, shall be structurally safe against stress concentration and thermal stress.
4. Waterstops shall be arranged near and upstream of transverse joints. They shall have water-tightness and durability, and shall be able to follow movement of the joints.

Article 33 Temperature Regulation for Concrete Dam Body

Concrete temperature of a dam body shall be so regulated as not rise above a specified temperature by applying appropriate measures such as cooling.

Section 3 Fill Dams

Article 34 Embankment Materials

Any embankment material shall satisfy the following:

1. Materials conforming to the respective purposes in terms of mechanical properties shall be used for a dam body.
   (1) Soil materials used for impervious zone shall comply with the following:
      1) Soil materials after compaction shall have adequate strength and water-tightness for dam stability.
      2) Soil materials shall be firmly compacted and so as to cause limited deformation.
      3) Soil materials shall be free of expansion and shrinkage that may cause problems to dam stability.
      4) Soil materials shall not be prone to softening.
      5) Soil materials shall contain no organic matter and shall not be water-solvent.
      6) The coefficient of permeability, strength, and compaction characteristics shall be identified from the actual materials to be used.

(2) Semi-pervious materials shall comply with the following:

1) Semi-pervious materials shall have adequate strength and drainage properties for dam stability.
2) Semi-pervious materials shall have the required grain size distribution.
3) Semi-pervious materials shall be firmly compacted so as to cause limited deformation.
4) The coefficient of permeability, strength, and unit weight shall be identified from the actual materials to be used.

(3) Pervious materials shall comply with the following:

1) Pervious materials shall have adequate strength and drainage properties for dam stability.
2) Pervious materials shall be hard and durable.
3) Pervious materials shall be firmly compacted so as to cause limited deformation.
4) The coefficient of permeability, strength, unit weight, and durability shall be identified from the actual materials to be used.

(4) Materials used for the surface of the dam body shall not be seriously eroded by waves or rainfall.

2. When materials are selected, they shall be tested appropriately to identify their characteristics before actual use. When the strength of any selected material is determined for stability calculation, its consolidation and drainage conditions shall be considered in setting the strength.

Article 35 Foundations for Fill Dams

Dam foundations of a fill dam shall satisfy the following:

1. Foundations of impervious zones require rock foundations and shall have adequate water-tightness and strength.
2. In the case of foundations other than rock, the water-tightness, strength and deformation shall be investigated through in-situ and laboratory tests.
3. Sand-gravel foundations shall require measures to be taken as necessary in order to secure adequate stability against seepage failure.
4. Soil foundations shall require measures to be taken as necessary in order to secure adequate stability against sliding and deformation.

Article 36 Stability of Fill Dams

A fill dam shall satisfy the following:

1. A dam body and its foundation shall be stable against sliding. The analyses against sliding shall be conducted by conventional limit equilibrium methods such as circular arc methods. In the case that sliding lines which include the foundation are expected, the calculations along the sliding lines, not only circular, shall be implemented. Minimum safety factors of dam body and its foundation against sliding shall be as specified in Table 36-1.

Table 36-1 Minimum Safety Factors of Fill Dams

Analysis condition		Required minimum safety factor	Slope
Usual	Normal operating*	1.5	Upstream and downstream
Unusual	Just after completion and before filling	1.3	Upstream and downstream
	Design flood	1.4	Downstream
	Rapid drawdown	1.1 to 1.3	Upstream
Extreme**	Normal operating with OBE*	>1.0	Upstream and downstream

* The reservoir water level is between NHWL and LWL, and the seepage flow in the dam is in steady state.
** Pseudo-static analysis seismic coefficient method may be used only in the feasibility study stage.

2. In the case of appropriate dynamic method of analyses such as response spectrum analysis and time-history analysis shall be used to evaluate liquefaction potential and/or to estimate deformations for dam body and foundation materials subjected to strong ground motions corresponding to MCE and OBE.

Article 37 Restrictions on Facilities such as Discharge Facilities

Discharge facilities or waterways which have a possibility of cracks occurring inside the dam body shall not be constructed inside the dam body.

Article 38 Particular Applications for Fill Dams

1. Design for Homogeneous Type Fill Dams

For homogenous type fill dams constructed with impervious materials, the seepage line shall not appear on the downstream slope of the dam. Appropriate drainage shall be arranged as necessary to reduce pore pressure.

2. Design for Zoned Type Fill Dams

For zoned type dams, zones shall be appropriately allocated. Grading of embankment zones contacting with each other shall not be too much different in order that movement of material particles in each zone does not occur.

3. Design for Surface Diaphragm Type Fill Dams

A surface diaphragm type fill dam shall satisfy the following:

(1) A surface diaphragm type fill dam shall be designed and constructed so that cracking that damages the sealing function of the diaphragm may not occur.

(2) Appropriate measures shall be taken, depending on the permeability of the foundation, to prevent seepage failure at the foundation.

Section 4 Spillways and Other Discharge Facilities

Article 39 Spillways

Spillways shall satisfy the following:

1. All dams shall be equipped with spillways designed to safely discharge a volume of water equal to or smaller than the design flood.
2. For a fill dam, no spillways shall be constructed on/in the dam body.
3. The bottoms of structures such as bridges or hoisted gate leaves shall be sufficiently apart from the surface of the water discharged from spillways under the design flood condition.
4. The energy of water flowing down through spillways shall be dissipated to prevent negative impacts on the dam body and the downstream areas.
5. A spillway shall have the stability required in Article 30 (Stability of Concrete Gravity Dams) or Article 31 (Stability of Arch Dams) with respect to loads as provided for by the applicable specifications for concrete gravity dams and the loads under the design flood condition.

Article 40 Spillway Gates and Auxiliaries

Spillway gates and any auxiliaries shall satisfy the following:

1. A spillway gate, as defined herein including a valve and any auxiliaries, shall have sufficient water-tightness and durability.
2. A spillway gate and any auxiliaries shall be designed so as to be operated easily and firmly without harmful vibrations.
3. A spillway gate and any auxiliaries shall be stable against expected loads and spillway gates and concrete structures such as gate piers shall be designed so as to convey the imposed loads to the dam body and foundation rock safely.
4. Materials used for a spillway gate and any auxiliaries shall be of conforming to an applicable standard such as ISO.
5. In the case that a power-drive device is used to operate the spillway gate, back-up device shall be installed to ensure gate operation.

Article 41 Other Discharge Facilities

Other discharge facilities shall satisfy the following:

1. Discharge facilities shall be installed in a fill dam in order to lower the reservoir water level for inspection and repair and in an emergency. It is recommended that discharge facilities be equipped also in a concrete dam. If outlets for other purpose or spillways already have this function, such discharge facilities are not required.
2. In case discharge facilities are not usually used, periodic operation checks shall be conducted to ensure proper gate operation.

Chapter 6 Waterways

Article 42 Common Rules

Waterways shall satisfy the following:

1. A waterway shall not be damaged by a flood, land sliding and so on.
2. The construction of a waterway shall not cause serious water leakage, landslides, or any other detrimental consequences.
3. A waterway shall not be significantly damaged by driftwood, floating debris, or sediments which flow into the waterway.
4. A waterway shall have a function to safely eliminate the excess volume of water if water in excess of the design discharge flows into the waterway.
5. Concrete to be used for a waterway shall satisfy the provisions in Article 27 (Concrete Materials). Steel materials to be used for a waterway shall satisfy the required properties specified in an applicable standard such as ISO. Other materials to be used for a waterway shall have required strength and durability.

Article 43 Intakes

Intakes shall satisfy the following:

1. An intake shall be stable against expected loads.
2. A hydraulic gate or stoplog shall be installed to allow inspections and repairs of a waterway and prevent over inflow.
3. The location and structure of an intake shall be designed so as to prevent inflowing sediment, debris, garbage and so on.
4. In the case that an intake is connected to pressure conduits of a headrace or penstock, the location and structure of the intake shall be designed so as to prevent air intrusion.

Article 44 Settling Basins

Settling basins shall satisfy the following:

1. A settling basin shall be stable against expected loads.
2. A settling basin shall have the capacity to settle sediments which damage a downstream waterway or a turbine.
3. A settling basin shall have the structure in which accumulated sediment can be flushed easily.

Article 45 Headraces

Headraces shall satisfy the following:

1. A headrace shall be stable against expected loads.
2. Any leakage from a headrace inside shall not cause damages to the surrounding grounds or other structures.
3. A headrace shall not significantly cause damage to the downstream waterways or a turbines due to slitting.
4. In the case that cave-in of surrounding ground is expected, countermeasures such as lining shall be taken.
5. In the case of a pressure conduit, it shall be placed below the lowest hydraulic gradient line connecting the lowest water level of an intake and a surge tank.

Article 46 Head Tanks

Head tanks shall satisfy the following:

1. A head tank shall be stable against expected loads.
2. A head tank shall have an adequate water capacity to prevent air intrusion to penstocks when the head tank is operating normally or even if loads increase rapidly,
3. A head tank shall have a spillway so that it can control the maximum designed discharge safely when the full load is shut off. Notwithstanding the preceding, if facilities other than the spillway have functions to safely control spillage, this may not apply.
4. When spillage overflows, the spillway of a head tank shall be designed so that the increase of water level does not cause damage to the upstream headrace.
5. The spillway of a head tank shall be designed so that discharge from the spillway does not cause damage to surrounding facilities or a river course.
6. The structures of a head tank shall be designed in order that garbage or sand does not flow into penstocks and turbines, and the accumulated sediment can be flushed easily.

Article 47 Surge Tanks

Surge tanks shall satisfy the following:

1. A surge tank shall be stable against expected loads.
2. The fluctuation of the water level in the surge tank shall not accelerate and shall return to equilibrium in a short period.

3. When the full load is shut down or the load increase from half to full at a powerhouse, (a) the fluctuation of the surge tank water level shall not lead to an overflow at the up surge and (b) the lowest down-surging shall be higher than the crown of the waterway and the penstock below a surge tank. Notwithstanding the preceding, the condition (a) above may not apply if a spillway pipe or spillway channel is installed to allow safe discharge of spilled stream at the top of the surge tank.

Article 48 Penstocks

Penstocks shall satisfy the following:

1. A penstock shall be stable against expected loads depending on the types of penstock as follows: Exposed type, Rock-embedded type, Earth-embedded type
2. The crown of a penstock shall be placed below the lowest hydraulic gradient line which appears when the water level of a head tank or a surge tank is at its lowest point.
3. A penstock pipeshell shall be stable with respect to vibrations, buckling and erosions.
4. A penstock pipe shall not cause serious water leakage.
5. In the case of exposed type penstocks, anchor blocks or saddles shall be installed in order to support the penstock pipeshells. An anchor block or saddle shall be stable against expected loads. The supporting part of a saddle shall be structured so that a pipeshell can move smoothly as the pipeshell contracts and expands.

Article 49 Tailraces

Tailraces shall satisfy the following:

1. A tailrace shall be stable against expected loads.
2. Any leakage from the tailrace inside shall not cause damages to the surrounding ground or other structures.
3. A tailrace shall not significantly cause damage to the downstream waterways due to collapse of the waterways.
4. In the case that cave-in of surrounding ground is expected, countermeasures such as lining shall be taken.
5. In the case that a surge tank is installed at a pressure tailrace, it shall be installed as provided for in Article 47 (Surge Tanks), Paragraph 1.

Article 50 Gates, Valves, and Auxiliaries

Gates, valves and any auxiliaries shall satisfy the following:

1. Gates, valves and any auxiliaries shall be stable against expected loads.
2. Gates, valves and any auxiliaries shall be watertight.
3. Gates, valves and any auxiliaries shall be operated easily.
4. Gates, valves and any auxiliaries shall not have harmful vibrations when they are working.
5. Gates leaves shall not be buckled under expected loads.

Chapter 7 Powerhouse and Other Facilities

Article 51 Powerhouse Structures

Powerhouses shall satisfy the following:

1. A powerhouse building shall be stable against expected loads.
2. Structures around a turbine shall be stable against vibrations.
3. A powerhouse building shall not be inundated by floods and shall not be damaged by landslides.

Article 52 Other Facilities

Other hydropower civil structures such as maintenance roads or temporary facilities for construction (those other than dams, waterways, powerhouses or reservoirs) shall satisfy the following:

1. Permanent facilities such as a maintenance road shall be designed to be structurally stable and, as much as possible, shall not cause serious turbid water.
2. Temporary facilities for construction works shall be stable considering required time spans during construction, and it is desired that they do not cause serious turbid water flow out of the construction areas.

Chapter 8 Reservoirs

Article 53 Prevention of Landslide

Reservoirs shall satisfy the following:

1. At the planning stage of dam location and structure, the permeability of surrounding ground shall be investigated and the possibility of landslides shall be studied. In particular, narrow ridges and land slide areas shall be investigated minutely.
2. An impounded reservoir shall not cause harmful leakage or landslides which could damage human habitations, farms, roads, etc. And if necessary, water sealing measures or countermeasures against landslides shall be taken.

Article 54 Sedimentation and Water Quality

1. Appropriate measures such as dredging, flushing or constructing check dams shall be taken as necessary so that damage due to serious water rise around upper reach areas or serious reduction of reservoir capacity does not occur because of excessive sedimentation. When flushing is implemented, the impact on downstream areas shall be minimized.
2. If the deterioration of water quality in a reservoir or downstream such as cold water discharge or turbid water is expected due to the establishing of the reservoir, appropriate measures, such as cleaning of the reservoir area etc., shall be taken according to advice of the approved EIA report.

Chapter 9 Downstream Area

Article 55 Regulation of Discharge to Downstream Areas

Discharge to downstream areas shall take place in accordance with the following manner:

1. If a serious negative environmental impacts or damages to humans and/or social assets due to the rapid water level changes by the discharge from a hydropower station are expected, appropriate measures shall be taken to mitigate possible negative impacts or damages. These include establishing a re-regulation pond to be able to relieve such water level changes and warning systems by means of sirens for downstream areas.

2. The discharge of flood water shall be implemented so that flood damages to the downstream area are not increased compared with expected flood damages before a dam was established, and that the volume of outflow from a reservoir does not increase compared with the volume of inflow to the reservoir. Appropriate measures such as warning by sirens and sending notice to the residents along downstream areas shall be taken so that damages to the downstream areas are minimized.

Article 56 Facilities to Discharge to Downstream Areas

Facilities which provide a dam or other appropriate structures with the function to discharge a necessary amount of water for water utilization or environmental preservation to affected zones between a dam or inlet and an outlet shall be installed with the capability to discharge a required amount of water, and shall be stable against vibrations during partial discharge.

Part 3
Electrical Facilities

Chapter 10 General Provisions

Section 1 Definition

Article 57 Definition

In this Specific requirement of Electrical Power Technical Standards, unless the context otherwise requires, the terms below shall have the following meanings assigned to them:

1. Connected Branch Electrical Circuit

“Connected branch electrical circuit” means the branch wires or cables from one point to another point without supporting structure.

2. Electrical Wires and Cables

“Electrical wires and cables” means electric conductors, insulated conductors and insulated conductors with protective sheath used to carry high electric current.

3. Electrical Circuits and Lines

“Electrical Circuits and Lines” means where energizes in normal condition.

4. Electrical Equipment

“Electrical Equipment” means the machine or apparatus which consist of electrical circuits and lines such as turbine, generator, transformer etc.

5. Electrical Lines

“Electrical Lines” means the electrical cables, wires, its supporter and protector used for power station, substation, switching station, similar facilities and connection lines between the places which use electricity.

6. Electrical Wiring

“Electrical wiring” means the electrical wires and cables for the places where use electricity.

7. Hydropower Station

“Hydropower station” means a place to generate electric power using generator with hydraulic turbines as the prime mover and other power facilities.

8. Optical Fiber Cable

"Optical fiber cables" means transmission media used for optical signal transmission with protective sheath.

9. Optical Fiber Cable Lines

"Optical fiber cable lines" means optical fiber cable and its supporters and protectors.

10. Reactive Power Compensator

"Reactive Power Compensator" means the electrical facilities to control the reactive power.

11. Substation (grid station)

"Substation" means where transforming the electricity from outside the station by transformer, rotary converter, rectifier and so on, and transformed electricity transmits to outside again.

12. Supporting Structure (only for Part 3 Electrical Facilities)

"Supporting structure" means the structure to support electrical wires and cables, telecommunication lines and optical fiber cables such as wooden poles, steel poles, reinforced concrete poles and steel towers.

13. Switching Station

"Switching station" means where opens and closes electrical circuits and lines by switchgear except power station, substation and consumer side's facilities.

14. Telecommunication Cables

"Telecommunication cables" means insulated metallic conductor used for signal and communication not for power supply purpose.

15. Telecommunication Metallic Lines

"Telecommunication metallic line" means telecommunication cables and its supporters and protectors.

Article 58 Classification of Voltage

AC voltage shall be as follows:

Table 58-1 Voltage Classification

Voltage Classification	Range of Nominal Voltage	Nominal Voltage	Highest Voltage
Low Voltage	600V or less	230/400V	
Medium Voltage	Over 600V 35kV or less	22kV	24kV
High Voltage	Over 35kV	115kV	123kV
		230kV	245kV

If in the interest of development of the power sector in the Kingdom of Cambodia it becomes necessary to use a nominal voltage other than that given in Table 58-1, MIME may allow the use of such nominal voltage as a standard voltage through issuing the Prokas.

Section 2 Safety Policy

Article 59 Prevention of Electrical Shock and Fire Caused by Electrical Equipment

Electrical equipment shall be installed so as to prevent electrical shock, fire or other threats which may endanger the human body and objects.

Article 60 Insulation for Electrical Circuits and Lines

The electrical circuits and lines shall be insulated from the ground except the following cases:

1. There is no danger in normal operating condition and it is difficult to connect to ground due to its structure.
2. Safety devices against invasion of high voltage are provided.
3. The insulation level of electrical circuits and lines is higher than the expected maximum abnormal voltage.

Article 61 Prevention of Disconnection of Electrical Wires and Cables

The electrical wires and cables, guy wires, overhead grounding wires, communication cables, optical fiber cables and other lines for electrical equipment shall have enough strength against normal operating condition.

Article 62 Connection for Electrical Wires and Cables

The electrical wires and cables shall be connected so as not to increase electrical resistance at the connection point, not to decrease insulation level and not to cause disconnection of wires and cables under the normal operating condition.

Article 63 Thermal Strength for Electrical Equipment

The electrical equipment to be installed in electrical circuits and lines shall have enough heat resistance against produced heat from the equipment in normal operation.

Article 64 Prevention of Hazard for Medium and High Voltage Electrical Equipment

Medium voltage and high voltage electrical equipment shall have protection against unauthorized person not to touch the equipment easily. If there is no danger in touch on the equipment, this article is not applicable.

Medium voltage and high voltage switchgears, circuit breakers, surge arresters and similar equipment, which may emanate an electrical arc at operating condition, shall be placed away from the inflammable wooden wall or ceiling. If there is a fireproof separative device, this article is not applicable.

Article 65 Grounding of Electrical Equipment

On necessary points in electrical equipment, grounding shall be provided so as to prevent electrical shock, fire or other accidents that may harm the human body and damage objects caused by happening or invasion of abnormal high voltage.

Article 66 Method of Grounding for Electrical Equipment

The grounding for the electrical equipment shall be connected to ground firmly to flow the current safely and smoothly.

Article 67 Prevention of Fire Caused by Transformers Connected to High and Medium Voltage Circuits and Lines

The transformers, which connect high or medium voltage circuits and lines with low voltage circuits and lines, shall provide the grounding at proper points of the transformer to prevent electrical shock, fire or other accidents of low voltage circuit side due to voltage invasion from high and medium voltage side to low voltage side.

The separative grounding from the transformer can be accepted in the following cases:

1. It is difficult to provide grounding on the transformer due to structure.
2. There is no risk at low voltage side.
3. The medium and high voltage transformers shall provide an electrical discharge device with grounding to prevent electrical shock, fire or other accidents of lower voltage circuit side caused by high voltage invasion.

Article 68 Restriction of High and Medium Voltage Transformer convert Directly into Low Voltage

High and medium voltage transformers which convert into low voltage directly shall not be installed except for the following cases:

1. The place is prevented from entry of unauthorized person into the premises, such as power station.
2. There is no risk of danger by installation of contact preventing plate between the windings.
3. There is protective device which automatically disconnects the circuits or lines in case of contact of windings happens or other countermeasure against the contact of windings.

Article 69 Protection for Electrical Wires, Cables and Electrical Equipment against Over-current

On necessary points in electrical circuits and lines, an over-current protective devices shall be installed so as to protect electrical wires, cables and electrical equipment from overheating burnout due to over-current, and to prevent fire.

Article 70 Protection against Grounding Fault

Grounding fault circuit breaker or other appropriate measures shall be provided in electric circuits and lines against grounding fault to prevent for damage of electrical equipment, electrical shock, fire or other accidents. If there is no risk of grounding fault because of installation at dry place or other reasons, this article is not applicable.

Article 71 Prevention of Electrical or Magnetic Interference to Electrical Facilities

The electrical facilities shall be installed in such a manner so as not to cause electrical or magnetic interference to the functions of other electrical facilities and objects.

Article 72 Prevention of Interference for Facilities which Use High Frequency Wave

The facilities which use high frequency wave shall be installed in such a manner so as not to cause serious interference continuously to the functions of the other facilities which use high frequency wave.

Article 73 Prevention of Electric Power Outage Caused by Electrical Facilities

High and medium voltage electrical facilities shall be installed in such a manner so as not to cause any serious obstacle to power supply from public power supply industry due to damage or destruction of such electrical facilities.

High and medium voltage electrical facilities for power supply purpose shall be installed in such a manner so as not to interrupt the power supply seriously by damage or destruction of such electrical facilities.

Section 3 Prevention of Pollutions

Article 74 Prevention of Pollutions

The hydropower station and associated facilities shall comply with the environmental laws and regulations of the Kingdom of Cambodia in order to prevent environmental pollution as follows:

1. The drain water from hydropower station and its associated facilities shall comply with the environmental laws and regulations of the Kingdom of Cambodia in order to prevent environmental pollution.
2. The transformer with grounded shall have facility so as not to flow out its insulation oil to ground or outside the premises.
3. The hydropower station and its associated facilities shall be installed so as not to cause any vibrations or noises in accordance with environmental laws and regulations of the Kingdom of Cambodia.
4. The hydropower station and its associated facilities, electrical circuits and lines or telecommunication equipment for electric power system shall be installed so as not to trigger the landslide and corruption of hilly land.
5. The electrical equipment which uses insulation oil contained the polychlorinated biphenyl (PCB) shall not be used in electrical circuit and lines.
6. SF6 gas shall be collected at the time of installation, inspection and removal in order not to discharge SF6 gas to atmosphere.

Chapter 11 Electrical Equipment for Hydropower Station

Section 1 Insulation Level

Article 75 Insulation Level of Transformers

The electrical circuits and lines of transformers shall have enough insulation level so as to withstand the following testing voltage for 10 minutes:

Table 75-1 Testing Voltage of Electrical Circuits and Lines of Transformers

No.	Type of Winding	Testing voltage
1	Winding with maximum working voltage 7kV or less	1.5 times of maximum working voltage (In case of less than 500V, 500V shall be applied.)
2	Winding with maximum working voltage over 7kV, 15kV or less (neutral ground system)	0.92 times of maximum working voltage
3	Winding with maximum working voltage over 7kV, 60kV or less (other than No. 2)	1.25 times of maximum working voltage (In case of less than 10.5kV, 10.5kV shall be applied.)
4	Winding with maximum working voltage over 60kV (isolated ground system, other than No. 8)	1.25 times of maximum working voltage
5	Windings with maximum working voltage over 60kV only for Star connection or Scott connection to be connected to neutral ground system and surge arrester is installed for neutral point of Start connection and between Teaser winding and main winding of Scott Windings (other than class No. 6 and 8)	(1) In case of surge arrester at neutral point a. Terminal other than neutral point 1.1 times of maximum working voltage (In case of less than 75kV, 75kV shall be applied.) b. Terminal for neutral point 0.64 times of maximum working voltage (In case of Scott connection, 0.96 times of maximum working voltage shall be applied) (2) Other cases 1.1 times of maximum working voltage (In case of less than 75kV, 75kV shall be applied)
6	Windings with maximum working voltage over 170kV of neutral ground system and connection of surge arrester at neutral point. (other than No. 8)	(1) Terminal other than neutral point 0.72 times of maximum working voltage (2) Neutral terminal 0.3 times of maximum working voltage
7	Windings with maximum working voltage over 170kV of neutral ground system and direct connection of neutral point. (other than No. 8)	0.64 times of maximum working voltage (Terminal other than neutral point)
8	Windings with maximum working voltage over 60kV connection with rectifier	1.1 times of maximum working voltage of AC side (AC voltage) or 1.1 times of maximum working voltage of Dc side (DC voltage)
9	Other windings	1.1 times of maximum working voltage (In case of less than 75kV, 75kV shall be applied)

Article 76 Insulation Level of AC Electrical Equipment except Transformers

The electrical circuits and lines of AC electrical equipment shall have enough insulation level so as to withstand the following testing voltage for 10 minutes except following cases:

1. Connection lines and bus-bar which use cable for electrical lines can withstand DC voltage of 2 times of the following AC testing voltage for 10 minutes.
2. Underground lines with maximum working voltage over 170kV neutral ground system can withstand 0.64 times of maximum working voltage for 60 minutes.
3. Rotating machines except rotary rectifier can withstand DC voltage of 1.6 times of the following AC testing voltage for 10 minutes.

Table 76-1 Testing Voltage of Electrical Circuits of Electrical Equipment

No.	Type of circuit	Testing voltage
1	Electrical equipment with maximum working voltage 7kV or less	1.5 times of maximum working voltage (In case of less than 500V, 500V shall be applied.)
2	Electrical equipment with maximum working voltage over 7kV, 15kV or less (neutral ground system)	0.92 times of maximum working voltage
3	Electrical equipment with maximum working voltage over 7kV, 60kV or less (other than No. 2)	1.25 times of maximum working voltage (In case of less than 10.5kV, 10.5kV shall be applied.)
4	Electrical equipment with maximum working voltage over 60kV (isolated ground system, other than No. 8)	1.25 times of maximum working voltage
5	Electrical equipment with maximum working voltage over 60kV (neutral ground system, other than No. 6, 7, 8)	1.1 times of maximum working voltage (In case of less than 75kV, 75kV shall be applied.)
6	Electrical equipment with maximum working voltage over 170kV (neutral ground system other than No. 7, 8)	0.72 times of maximum working voltage
7	Electrical equipment with maximum working voltage over 170kV neutral ground system to be connected to hydropower station (other than No. 8)	0.64 times of maximum working voltage
8	Electrical equipment with maximum working voltage over 60kV connection with rectifier	1.1 times of maximum working voltage of AC side (AC voltage) or 1.1 times of maximum working voltage of DC side (DC voltage)

Article 77 Insulation Level of Electrical Equipment to be Connected to DC Circuit

The electrical equipment to be connected to DC circuit shall have enough insulation level so as to withstand the following testing voltage for 10 minutes:

Table 77-1 Testing Voltage of Electrical Equipment to be connected to DC Circuit

Classification		Testing voltage
Rotating Machine (other than rotary converter)	Maximum working voltage 7kV or less	1.5 times of maximum working voltage (In case of less than 500V, 500V shall be applied.)
	Maximum working voltage over 7kV	1.25 times of maximum working voltage (In case of less than 10.5kV, 10.5kV shall be applied.)
Electrical equipment with maximum working voltage over 60kV connection with DC side of rectifier		1.1 times of maximum working voltage of AC side (AC voltage) or 1.1 times of maximum working voltage of DC side (DC voltage)
		$E = V \times \frac{1}{\sqrt{2}} \times 0.5 \times 1.2$
Other	Maximum working voltage 7kV or less	1.5 times of maximum working voltage (In case of less than 500V, 500V shall be applied.)
	Maximum working voltage over 7kV	1.25 times of maximum working voltage (In case of less than 10.5kV, 10.5kV shall be applied.)

Article 78 Insulation Level of Rotary Converter and Rectifier

The rotary converter and rectifier shall have enough insulation level so as to withstand the following testing voltage for 10 minutes:

Table 78-1 Testing Voltage of Rotary Converter and Rectifier

Classification		Testing Voltage
Winding of rotary converter		1.0 times of maximum working AC voltage at DC side (In case of less than 500V, 500V shall be applied.)
Rectifier	Maximum working voltage 60kV or less	
	Maximum working voltage over 60kV	1.1 times of maximum working voltage of AC side (AC voltage) or 1.1 times of maximum working voltage of DC side (DC voltage)

Section 2 Thermal Strength

Article 79 Thermal Strength of Turbine Bearing

Maximum allowable temperature of turbine bearing shall be of 65°C. However, in case of consultation with concerned parties and agree, this article is not applicable.

Location of embedded temperature detector for bearing shall be in which indicates maximum temperature.

Article 80 Thermal Strength of Rotating Machines

Maximum allowable temperature of directly air cooled rotating machines at rated load condition shall be as shown in the following table:

Table 80-1 Maximum Allowable Temperature of Directly Air Cooled Rotating Machines (°C)

Thermal Classification	**A**			**E**			**B**			**F**			**H**		
Th=Thermometer R=Resistance ETD=Embedded temperature detector	Th	R	ETD	Th	R	ETD	Th	R	ETD	Th	R	ETD	Th	R	ETD
Part of machine															
AC Stator Winding	90	100	100	105	115	115	110	120	120	125	140	140	145	165	165
AC Armature Winding with Commutator	90	110		105	115		110	120		125	145		145	165	
Insulated Stationary Field Winding	90	100		105	115		110	120		125	140		145	165	
Multi Layer Field Winding	90	100		105	115		110	120		125	140		145	165	
Low Resistance Field Winding	100	100		115	115		120	120		140	140		165	165	
Single Layer Winding with Exposed Bare	105	105		120	120		130	130		150	150		175	175	
Field Winding with cylindrical Rotor								130			150			165	
Core and Other Parts with proximity of Insulated Winding	100			115			120			140			165		
Brush and Brush Holder	Temperature which not to obstacle mechanical parts and injury to insulated part of vicinity														
Commutator and Slipring	100			110			120			130			140		
Bearing(Self cooled)	80°C at surface, 85°C at embedded at metal, 95°C at surface using lubricating oil														

Reference ambient temperature shall be 40°C.

Article 81 Thermal Strength of Transformer

Maximum allowable temperature of oil immersed transformer at rated load condition shall be as shown in the following table:

Table 81-1 Maximum Allowable Temperature of Oil Immersed Transformer

Part of Transformer		**Method**	**Maximum Allowable Temperature (°C)**
Winding	Natural Circulation	Resistance	95
	Forced Circulation	Resistance	100
Oil	Oil contacts directly with air	Thermometer	90
	Oil contacts indirectly with air	Thermometer	95
Surface vicinity of core or insulated metal part		Thermometer	Temperature which not to injury to vicinity of insulating materials

Maximum allowable temperature of gas immersed and dry type transformers at rated load condition shall be as shown in the following table:

Table 81-2 Maximum Allowable Temperature of Gas Immersed and Dry Type Transformer

Part of Transformer	Method	Thermal Classification	Maximum Allowable Temperature (°C)
Winding	Resistance	A	95
		E	110
		B	115
		F	135
		H	160
Core Surface	Thermometer	Temperature which not to injury to vicinity of insulating materials	

Reference ambient temperature for oil immersed transformer, gas insulated transformer and dry transformer shall be 40°C.

Article 82 Thermal Strength of AC Circuit Breaker

Maximum allowable temperature of AC circuit breaker at rated load condition shall be as shown in the following table:

Table 82-1 Maximum Allowable Temperature of AC Circuit Breaker

Measurement Place and Materials			Method	Maximum Allowable Temperature (°C)
Contacting Part	Copper	Air SF6 Oil	Thermometer, Resistance	75 105 80
	Silver, Nickel	Air SF6 Oil		105 105 90
	Tin	Air SF6 Oil		90 90 90
Connection Point of Conductor	Copper, Aluminum	Air SF6 Oil		90 115 100
	Silver, Nickel	Air SF6 Oil		115 115 100
	Tin, Tin solder	Air SF6 Oil		105 105 100
Connection Point of Main Circuit	Copper, Aluminum Silver Tin			90 105 105
Oil for Oil Circuit Breaker				90
Insulating Material and Metal contacting insulating material	A E B F H 200 220 250			105 120 130 155 180 200 220 250
Part of Mechanical Structure	Insulator with Cement			95
Part of Mechanical Structure	Others	Touchable Approachable Surface Part Non-approachable Surface Part		50 70 110

Reference ambient temperature shall be 40°C.

Article 83 Thermal Strength of Disconnecting Switch

Maximum allowable temperature of disconnecting switch at rated load condition shall be as shown in the following table:

Table 83-1 Maximum Allowable Temperature of Disconnecting Switch

Measurement Place and Materials			Method	Maximum Allowable Temperature (°C)
Contacting Part	Copper	Air SF6 Oil	Thermometer, Resistance	75 105 80
	Silver, Nickel	Air SF6 Oil		105 115 90
	Tin	Air SF6 Oil		90 90 90
Connection Point of Conductor	Copper, Aluminum	Air SF6 Oil		90 115 110
	Silver, Nickel	Air SF6 Oil		115 115 100
	Tin, Tin solder	Air SF6 Oil		105 105 100
Connection Point of Main Circuit	Copper, Aluminum Silver Tin			90 105 105
Insulating Material and Metal contacting insulating material	A E B F H 200 220 250			105 120 130 155 180 200 220 250
Part of Mechanical Structure	Insulator with Cement			95
Part of Mechanical Structure	Others	Touchable Approachable Surface Part Non-approachable Surface Part		50 70 110

Reference ambient temperature shall be 40°C.

Article 84 Thermal Strength of Gas Insulated Switchgear

Maximum allowable temperature of gas insulated switchgear at rated load condition shall be as shown in the following table:

Table 84-1 Maximum Allowable Temperature of Gas Insulated Switchgear

Measurement Place and Materials		Method	Maximum Allowable Temperature (°C)
Contacting Part	Copper Silver Tin	Thermometer, Resistance	105 115 90
Connection Point of Conductor	Copper, Aluminum Silver Tin, Tin solder		115 115 105
Connection Point of Main Circuit	Copper, Aluminum Silver Tin		90 105 105
Insulating Material and Metal contacting insulating material	A E B F H		105 120 130 155 180
Part of Mechanical Structure	Insulator with Cement Others Touchable Approachable Surface Part Non-approachable Surface Part		95 50 80 110

Reference ambient temperature shall be 40°C.

Article 85 Thermal Strength of Load Breaker Switch

Maximum allowable temperature of load breaker switch at rated load condition shall be as shown in the following table:

Table 85-1 Maximum Allowable Temperature of Load Breaker Switch

Measurement Place and Materials			Method	Maximum Allowable Temperature (°C)
Contacting Part	Air Oil 	Copper Silver Copper Silver		75 105 70 80
External Connection Terminal and Connection point of Conductor	Air Oil 	Copper. Aluminum Tin, Tin Solder Silver Copper, Aluminum Tin, Tin Solder Silver		80 85 105 80 80 80
Metal Part with Spring Action			Thermometer	Temperature under not losing elasticity
Conductive Part and Mechanical Part of Metal	Air Oil			105 80

Measurement Place and Materials			Method	Maximum Allowable Temperature (°C)
Metal contacting insulating material	Insulator with Cement			90
	A	Air		105
	E	Air		120
	B	Air		130
	F	Air		155
	H	Air		180
	200	Air		200
	All Insulating Materials	Air		80
Part of Insulating Material other then above	Oil			80
Oil				80

Reference ambient temperature shall be 40°C.

Article 86 Thermal Strength of Power Fuse

Maximum allowable temperature of power fuse at rated load condition shall be as shown in the following table:

Table 86-1 Maximum Allowable Temperature of Power Fuse

Measurement Place and Materials			Method	Maximum Allowable Temperature (°C)
Contacting Part of Fuse Link	Spring Pressure	Copper, Brass	Thermometer	75
		Silver		105
		Tin		95
	Bolting	Copper, Brass		90
		Copper, Tin		105
Terminal	Copper, Brass			90
	Silver, Tin			105
Insulator with Cement				90
Insulating Part of Fuse Link	A			105
	E			120
	B			130
	F			155
	H			180
	200			200

Reference ambient temperature shall be 40°C.

Article 87 Thermal Strength of Capacitor Voltage Transformer

Maximum allowable temperature of capacitor voltage transformer at rated load condition shall be as shown in the following table:

Table 87-1 Maximum Allowable Temperature of Capacitor Voltage Transformer

Measurement Place	Method	Maximum Allowable Temperature (°C)
Winding	Resistance	95
Oil	Thermometer	95
Surface of Terminal Vicinity of Insulating Material		Temperature under not injury vicinity insulating Material

Reference ambient temperature shall be 40°C.

Article 88 Thermal Strength of Instrument Transformer

Maximum allowable temperature of instrument transformer at rated load condition shall be as shown in the following table:

Table 88-1 Maximum Allowable Temperature of Instrument Transformer

Measurement Place			Method	Maximum Allowable Temperature (°C)
Winding	Dry Type with Natural Convection	A	Resistance	95
		B		115
	Oil Immersed Type with Natural Convection	A		95
Oil			Thermometer	95
Surface of Terminal Vicinity of Insulating Material				Temperature under not injury vicinity insulating Material

Reference ambient temperature shall be 40°C.

Article 89 Thermal Strength of Bushing

Maximum allowable temperature of bushing at rated load condition shall be as shown in the following table:

Table 89-1 Maximum Allowable Temperature of Bushing

Measurement Place			Method	Maximum Allowable Temperature (°C)
Terminal at Air	Finishing	Copper	Thermometer	80
		Tin, Solder Galvanizing		85
		Silver Galvanizing		105
Supporting Fittings				95
Other than Above Part				105

Reference ambient temperature shall be 40°C.

Article 90 Thermal Strength of Metal Enclosed Switchgear and Control Gear

Maximum allowable temperature of metal enclosed switchgear and control-gear shall be as shown in the following table:

Table 90-1 Maximum Allowable Temperature of Metal Enclosed Switchgear and Control Gear

Part, Material and Type of Insulating Material			Method	Maximum Allowable Temperature (°C)
Contacting Part	Bare Copper, Composition Metal	Air SF6 Oil	Thermometer, Thermoelectric Pile	75 90 80
	Silver and, Nickel Galvanizing	Air SF6 Oil		105 105 90
	Tin Galvanizing	Air SF6 Oil		90 90 90
Bolting Terminal	Bare Copper, Composition Metal	Air SF6 Oil		90 105 100
	Silver and, Nickel Galvanizing	Air SF6 Oil		115 115 100
	Tin Galvanizing	Air SF6 Oil		105 105 100
Bolting Terminal Connecting to External Conductor	Bare Copper Silver, Nickel and Tin Galvanizing			90 105
Insulating Oil for Oil Immersed Switchgear				90
Material used for Insulating Material and Metal Part contacting Insulating Material	Y A E B F H 200			90 105 120 130 155 180 200
Optional Part of Metal contacting Oil or Insulating Material other than Contacting Part				100

Reference ambient temperature shall be temperature of outside the cubicle and shall be 40°C.

Article 91 Thermal Strength of Bus-bar and Conductor

Maximum allowable temperature of bus-bar and conductor shall be as shown in the following table:

Table 91-1 Maximum Allowable Temperature of Bus-bar and Conductor

Type of Bus-bar	Method	Maximum Allowable Temperature (°C)
Hard Drawn Copper Wire	Thermometer	90
Hard Drawn Copper Stranded Wire		90
Hard Drawn Aluminum Stranded Wire		90
Hard Drawn Aluminum Wire		90
Aluminum Pipe		90
Heat Resisting Aluminum Alloy Wire		150

Reference ambient temperature shall be 40°C.

Article 92 Thermal Strength of Power Cable

Maximum allowable temperature of power cable shall be as shown in the following table:

Table 92-1 Maximum Allowable Temperature of Power Cable

Type of Cable		Maximum Allowable Temperature (°C)
Solid Type Cable	6,600V or less	80
	11,000V	75
	22,000V	70
	33,000V	65
Low Gas Compression Cable		75
OF Cable	Normal Insulating Paper	80
	Low Loss Paper	85
PGC, PGF Cable		80
POF Cable	Normal Insulating Paper	80
	Low Loss Paper	85
Butyl Rubber Cable		80
Ethylene-Propylene Cable		80
Natural Rubber Cable		60
Polyethylene Cable		75
Crosslinked Polyethylene Cable		90
Vinyl Cable		60
Cambric Cable		80
Silicon Rubber Cable		180

Section 3 Structure, Performance and Installation

Article 93 Structure, Performance and Installation of Load Breaker Switch and Disconnecting Switch

1. Installation Place

The medium and high voltage load breaker switch and disconnecting switch shall be installed at each pole side.

2. Installation Method

The medium and high voltage load breaker switch and disconnecting switch which emanate an arc during operation shall be placed away 1 meter from wooden wall or roof for medium voltage, 2 meter for high voltage. However, if there is fire resistance separative device, this article is not applicable.

3. Performance

(1) The load breaker switch shall have necessary making and breaking capability for load current in normal operating condition.

(2) The disconnecting switch which operates for excitation and charging current shall have necessary capability for operation of excitation and charging current.

4. Structure

(1) The medium and high voltage load breaker switch and disconnecting switch shall have status indicator following of their operation. However, if status can be seen easily, this sub-article is not applicable.

(2) The medium and high voltage load breaker switch and disconnecting switch which may be operated spontaneously by gravity shall have a locking device, a safety clutch etc. so as to prevent for spontaneous operation.

(3) The medium and high voltage load breaker switch and disconnecting switch shall withstand mechanical shock caused by short circuit current.

(4) The medium and high voltage disconnecting switch shall have interlocking device for opening operation during turning on of load current.

Article 94 Structure, Performance and Installation of Neutral Point Device

1. Capacity of Current

Resistance, reactor and associated equipment to be connected to neutral point of electrical circuits and lines shall have enough capacity for fault current.

2. Installation Method

Live parts of resistance, reactor and associated equipment to be connected neutral point of electrical circuits and lines shall be installed so as not to be touched by maintenance person easily.

Article 95 Structure, Performance and Installation of Surge Arrester

1. Installation of Surge Arrester

(1) The medium and high voltage electrical circuits and line to be connected to overhead lines shall have the surge arrester either of following point;

1) Adjacent point of bus-bar or transformer terminal
2) Incoming and outgoing point

(2) Mentioned above (1) is not applicable in case of following cases;

1) Electrical line to be connected to bus-bar is short length
2) High voltage electrical circuits and lines with over 60kV, number of overhead lines to be connected to bus-bar are 5 circuits or more in case of total connected overhead lines are under 7 circuits and 4 circuits or more in case of total connected overhead lines are under 8 circuits. When 2 circuits to be installed at same supporting structure, number of overhead line shall be regarded as 1 circuit.
3) Switching station
4) Incoming point of high voltage consumer whose capacity is less than 500kW

2. Installation of Protective Air Gap

Protective air gap shall be provided at incoming and outgoing point following cases even though not installation of the surge arrester in accordance with above mentioned sub-article 1.(1).

1) Hydropower station to be connected to transmission lines which has frequent lightning
2) Hydropower station to be connected to bus-bar which spreads extensive area and cannot be protected by the surge arrester
3) Hydropower station to be connected to over-insulated transmission lines
4) Hydropower station which is disconnected by circuit breaker due to invasion of frequent lightning

The clearance of the air gap is shown in the following table:

Table 95-1 Clearance of the Protective Air Gap

Nominal Voltage (kV)	LIWL (kV)	Standard Clearance (mm)
66	350	415
77	400	490
110	550	720
154	750	1,020
187	750	1,020
220	900	1,200

3. Installation of Surge Arrester which Emanate Arc

The surge arrester or related equipment which emanates an arc during operation shall be placed away from 1 meter from wooden wall or roof for medium voltage, 2 meter for high voltage. However, if there is fire resistance separative device, this sub-article is not applicable.

Article 96 Structure, Performance and Installation of Control Gear and Metal Enclosed Switchgear

1. Structure

Structure of control-gear and metal enclosed switchgear shall be inspected easily such as electrical parts and wire.

2. Installation

In case of installation of medium and high voltage electrical equipment and wire at control-gear and metal enclosed switchgear, appropriate protective devices or inspection route shall be provided in order not to cause any danger to maintenance person.

Article 97 Structure, Performance and Installation of Gas Insulated Switchgear

1. Installation

The gas insulated switchgear to be placed at hydropower station shall be installed following manners;

(1) Pressurized part over 100kPa and to be exposed to open air shall withstand 1.5 times of working pressure for 10 minutes by water pressure and not any leakage. However, the gas insulated switchgear to be not connected to the gas compressor shall withstand 1.25 times of working pressure for 10 minutes by water pressure and not any leakage.

(2) The gas insulated switchgear which has the gas compressor shall have safety valve at the end stage of gas compressor which operates maximum working pressure or less.

(3) Insulated gas shall not be flammable, corrosive and toxicity.

(4) If anti-corrosion materials to be used for external surface, it shall be painted by rust proofing paint.

2. Mechanical Strength

The gas insulated switchgear shall withstand mechanical shock caused by short circuit current.

Article 98 Structure, Performance and Installation of Bus-bar and Conductor

1. Mechanical Strength

Bus-bar, conductor and their supporting insulator shall withstand mechanical shock caused by short circuit current.

2. Clearance of Bus

The clearance of bare bus-bar is shown in the following table:

Table 98-1 Clearance of Bare Bus-bar

Nominal Voltage (kV)	Outdoor (cm)		Indoor (cm)	
	Between Phases	To the Ground	Between Phases	To the Ground
3.3	50	25	25	10
6.6	50	25	25	12
11	60	30	30	18
22	70	40	45	30
33	90	50	58	42
66	150	85	100	73
77	170	100	-	-
110	230	140	-	-
154	300	190	-	-
187	300	190	-	-
220	360	230	-	-

Notes: 1. Not applied to metal enclosed switchgear and gas insulated switchgear
2. Not applied lead wires to electrical equipment

3. Connection Method

In case of connection of each wire and wire and cable for medium and high voltage bus-bar, electric resistance shall not be increased and shall be as follows;

(1) Conductor shall be connected in such a manner so as not to decrease over 20% of tensile strength. However, in case of jumper connection or tension force is extremely small, this sub-article is not applicable.

(2) Connection pipe or other appropriate device shall be used for connection point and shall be soldered.

(3) In case of connection of aluminum and copper conductor, it shall be connected in such a manner so as not to arise any electric corrosion.

(4) Connection point shall be covered enough by insulated materials. However, in case of using of sufficient insulated material, this sub-article is not applicable.

Article 99 Structure, Performance and Installation of Turbine

The turbine shall be installed as follows;

1. Turbine shall not be damaged severely invasion of driftwood, debris and sand.
2. Part to be pressurized by water shall withstand maximum water pressure caused by load rejection.
3. Rotating part shall withstand maximum rotating speed caused by load rejection.
4. There shall not be any harmful vibration which may damage seriously to turbine during operation.
5. Rapid shut off device shall be equipped for inflow water. However, if rotating part of turbine can be structurally safe until stopping of run away speed, not to cause any harm to human body in downstream or not to cause any damage to its structure, this sub-article is not applicable.
6. Materials to be used for inlet valve shall not exceed their allowable stress for dead load, water pressure and earthquake load.
7. Automatic stopping device shall be installed for turbine in order to prevent any damage in case of over speed or other abnormal condition. However, if rotating part of turbine can be structurally safe until stopping of run away speed, not to cause any harm to human body in downstream or not to cause any damage to its structure, this sub-article is not applicable.

Article 100 Structure and Performance of Inlet Valve

Structure of inlet valve shall be as follows;

1. Inlet valve shall have water tightness.
2. Valve disc shall be operated easily and securely.
3. Material to be used for valve disc shall have necessary chemical and mechanical performance.
4. There shall not be any harmful vibration during operation of inlet valve.
5. Valve disc shall have mechanical strength against buckling.
6. Inlet valve shall have such structure that applied load to valve disc shall transmit to foundation safely.

Chapter 12 Auxiliary Equipment

Section 1 Grounding Work

Article 101 Classification of Grounding Work

Value of grounding resistance and type of grounding work shall be as shown in the following table:

Table 101-1 Classification of Grounding Work and Value of Grounding Resistance

Classification of Grounding Work	Value of Grounding Resistance	
Class A	10Ω or less	—
Class B	10Ω or less (When $\frac{230}{I^{*1}}$ is less than 10, resistance to earth shall be the value of $\frac{230}{I^{*1}}$ or less.)	In the case where voltage to earth of a low-voltage electrical circuit exceeds 230V due to power contact between the medium-voltage electrical circuit and the low-voltage electrical circuit of the transformer, when an earth leakage breaker that cuts off the electrical circuit within 1 second is installed, $\frac{600}{I^{*1}}$Ω or less. When $\frac{230}{I^{*1}}$ becomes 5Ω or less, it shall not be necessary to obtain resistance 5Ω or less.
Class C	10Ω or less	In the case where grounding arises in a low-voltage electrical circuit, when an earth leakage breaker that acts within 0.5 seconds is installed, the resistance value shall be of 500Ω or less.
Class D	100Ω or less	

Remarks: *1 - I is Single-line earth fault current (A)

Article 102 Grounding of Electrical Equipment

1. Application of Grounding

Electrical equipment shall be solidly grounded to the earth in accordance with the following table:

Table 102-1 Application of Grounding

Place of Grounding	Classification of Voltage	Classification of Grounding	Remarks
Metallic casing, housing and steel base for electrical equipment	Medium/high voltage Low voltage over 300V Low voltage 300V or less	Class A Class C Class D	(1) For transformer and instrumental transformer, which do not have metallic housing, core shall be grounded. (2) Electrical equipment that casing is used as energized condition and there is no possibility to touch by persons, this rule is not applicable
Stabilizing winding, idle winding and other similar winding of transformer	Medium and high voltage	Class A	This rule only applies that there is necessary to protect the winding from transfer voltage with one point grounding of its winding

Place of Grounding	Classification of Voltage	Classification of Grounding	Remarks
Low voltage side of neutral point for medium and high voltage transformer which converts to low voltage directly		Class B	In case of grounding work to neutral point is complicated due to transformer's structure, one terminal grounding at low voltage side can be permissible only 300V or less.
Contact preventing plate of low voltage short proof transformer with isolated neutral system to be connected to medium and high voltage		Class B	
Secondary circuit of instrumental transformer	High voltage Medium Voltage	Class A Class D	If there is neutral point, any neutral point shall be grounded. If there is no neutral point, any one of the electrical circuits shall be grounded.
Surge arrester	High voltage Medium voltage	Class A Class A	
Metal casing for underground cable lines		Class D	Except anticorrosion portion

2. Exception

Above mentioned sub-article is not applicable following cases for steel base and metallic casing to be installed at electrical circuits and lines.

(1) Working voltage which is 300V DC or less, 150V DC or less in dry condition
(2) Low voltage electrical equipment to be installed on dried wooden plate or insulated materials
(3) High voltage electrical equipment to be installed on high place in order not to be touched by person
(4) Appropriate insulated base to be provided around steel base or housing
(5) Instrument transformer to be covered by rubber, synthetic resin or other insulated materials
(6) Earth leakage breaker to be installed
(7) Electrical equipment with double insulation structure to be installed
(8) Insulating transformer to be installed for low voltage isolated neutral system

Article 103 Types of Grounding Wire

1. Types of Grounding Wire

The grounding wire to be connected to electrical equipment shall be anticorrosion metallic wire and shall have enough capacity for fault current as follows:

Table 103-1 Types of Grounding Wire

Types of Grounding Work		Types of Grounding Wire	Nominal Cross Section (mm^2)
Class A	Neutral point of generator and medium and high voltage transformer	Metallic wire tensile strength over 2.4kN or annealed copper wire diameter over 4.0mm	14
	Other	Metallic wire tensile strength over 1.04kN or annealed copper wire diameter over 2.6mm	5.5
Class B	Short proof plate of transformer which converts medium/high voltage to low voltage directly	Metallic wire tensile strength over 2.46kN or annealed copper wire diameter over 4.0mm	14
	Neutral point of low voltage side of transformer which converts medium/ high voltage to low voltage directly		
	Neutral point of low voltage side of transformer which converts medium voltage or less than 15,000V neutral grounding system to low voltage	Metallic wire tensile strength over 1.04kN or annealed copper wire diameter over 2.6mm	5.5
Class C and D		Metallic wire tensile strength over 0.39kN or annealed copper wire diameter over 1.6mm	3.5

2. Types and Cross Section of Flexible Grounding Wire

The grounding wire which is required flexibility shall have enough capacity for fault current and have the following types of wire and cross section.

Table 103-2 Types and Cross Section of Flexible Grounding Wire

Types of Grounding Work	Types of Grounding Wire	Nominal Cross Section (mm^2)
Class A and B	All kind of wires	8
Class C and D	Multi-core chord or one of multi-core cab-tire cable	0.75
	Flexible annealed copper wire other than above	1.25

Article 104 Installation of Grounding Electrode and Grounding Wire

1. Prevention of Danger around Grounding Electrode

The grounding electrode shall be installed in such a manner so as not to cause any danger to human body, livestock or other objects due to the potential difference of fault current.

2. Prevention of Danger by Accident Influence

(1) Supporting structure with class A or B grounding work shall not install any grounding wire for lightning rod.

(2) Connection object such as telephone wire between hydropower station and other facilities shall be installed in such a manner so as not to cause any danger due to high voltage invasion of accident.

3. Restriction of Installation

Circuit breaker and power fuse shall not be connected to the grounding wire except circuit breaker which is used for changing of neutral resistance and reactor circuit.

4. Thermal Strength of Grounding Wire

Grounding wire shall have enough capacity for fault current. Especially, connection point of grounding wire shall have enough thermal strength as well as mechanical strength.

Section 2 Pressure Oil and Compressed Air Supply System

Article 105 Volume of Pressure Oil Container

Volume of pressure oil container shall have enough capacity to stop turbine and generator without replenishing of pressure oil from pressure pump in case of remarkable decrease of oil pressure. However, this sub-article does not apply in the following cases:

(1) Capacity of generator is less than 500kVA.

(2) A container is provided with self closing device, spring closing device, counter weight closing device of guide vane and emergency pressure container or emergency servomotor.

Article 106 Volume of Compressed Air Container

Capacity of compressed air container to be used for switchgear or circuit breaker shall have enough capacity for one (1) time of open-close operation continuously without replenishing of air.

Article 107 Pressure Tightness of Pressure Oil and Compressed Air Supply System

Pressurized parts of pressure oil and compressed air supply system shall withstand 1.5times of maximum working pressure by water for 10 minutes without any leakage. If it is not suitable to be tested by water, the following measures can be permissible:

(1) 1.5 times of maximum working pressure by fluid pressure

(2) 1.25 times of maximum working pressure by air pressure or fluid/air pressure

Article 108 Safety Valve and Pressure Gauge of Pressure Oil and Compressed Air Supply System

1. Installation Place of Safety Valve

(1) Safety valve for pressure oil supply system

Safety valve or other safety device shall be provided for oil pressure supply system. The safety valve shall operate to start to maximum working pressure or less and shall control within 110% of maximum working pressure.

(2) Safety valve of compressed air supply system

Safety valve or other safety device shall be provided for end stage of compressor or piping to be connected to air container and its pipe. The safety valve and other safety device shall operate to start to maximum working pressure or less and shall control with in 110% of maximum working pressure.

2. Structure of Safety Valve

Structure of safety valve shall be as follows;

(1) Safety valve shall have enough blow off capacity in case of partial damage
(2) Adjusting screw of spring shall have loose free structure
(3) Valve body shall not come out in case of damage of spring
(4) Safety valve shall be sealed so as not to adjust the pressure easily
(5) Safety valve with toxicity or flammable gas shall not be open type
(6) Attachment part of safety valve shall have enough strength against reaction of exhaust air
(7) Screwed end type safety valve shall have surface of spanner in case of fixing

3. Capacity of Safety Valve

Capacity of safety valve shall be as follows;

(1) Required blow off volume

Required blow off volume shall be over maximum replenish volume to pressure oil container and air container in order to prevent excess pressure.

4. Other Device other than Safety Valve

(1) Device which can stop pressure rising automatically
(2) Pressure reducing valve which to be installed at second side
(3) Alarm device combined with safety valve
(4) Relief valve or relief pipe
(5) Bursting disk

The items of (2) and (3) above can be used for only pressure less than 1MPa.

5. Pressure Gauge

Pressure gauge shall be provided at each different pressure part of oil pressure and compressed air supply system as follows;

(1) Maximum index of scale plate of pressure gauge shall indicate over 1.5 times of design pressure and 3 times or less.

(2) Butt end of pressure gauge shall be located at vertical part and handle shall be open condition in case of same direction with tube axial.

Article 109 Pressure Recovery Device for Pressure Oil and Compressed Air Supply System

Automatic pressure recovery device shall be provided for oil pressure container and main air pressure container in case of decreasing of pressure.

Section 3 Others

Article 110 Protective Fences for Inspection Route

Protective fences or protective screens shall be provided at inspection points and inspection routes to prevent to touch live part easily for inspection of medium and high voltage equipment by inspector. Minimum clearance between protective fences or protective screens shall be as shown in the following table except for surge arrester:

Table 110-1 Clearance Between Protective Fence & Screen and Live Parts

Nominal Voltage (kV)	Outdoor (cm)	Indoor (cm)
3.3	25	10
6.6	25	12
11	30	18
22	40	30
33	50	42
66	85	73
77	100	85
110	140	-
154	190	-

Article 111 Phase and Status Indication Device for Medium and High Voltage Bus-bar

Phase indication device shall be provided at a conspicuous place for medium and high voltage bus-bar.

Status indication device shall be provided at a conspicuous place for medium and high voltage bus-bar by indication of mimic bus-bar or other method.

Article 112 Installation of Prevention Facility for Invasion of Small Animals

Appropriate prevention facilities for invasion of small animals shall be provided at hydropower station so as not cause any accident.

Article 113 Installation of Emergency Power Supply System

The emergency power facilities to be used in case of outage of ordinary power supply shall not be connected to the ordinary power supply circuit electrically by means of independent electrical circuit or providing inter-locking devices.

Chapter 13 Electrical Facilities for Station Service

Section 1 Prevention of Electrical Shock and Fire

Article 114 Prevention for Electrical Shock and Fire of Electrical Wiring

The electrical wiring shall be installed in such a manner so as not to cause any electrical shock or fire taking its circumstance and working voltage into consideration.

In case of connection of mobile cables with electrical equipment, they shall be connected so as not to cause any electrical shock or fire due to inappropriate connection.

The mobile cables shall not be used for high voltage electrical equipment regardless of the mentioned above sub-article. If there is no danger to touch energized parts and it is indispensable to connect the electrical equipment, this sub-article is not applicable.

Article 115 Application for Electrical Wiring

The electrical wirings shall have proper strength and insulation level taking its circumstance and working voltage into consideration so as not to cause any electrical shock or fire.

The bare wires shall not be used for the electrical wiring. If the electric wiring is installed so as not to cause electrical shock or fire taking no insulation of the wires into consideration and having enough mechanical strength, this sub-article is not applicable.

The trolley cables shall not be used for high voltage electrical wiring.

Article 116 Insulation Level for Low Voltage Electrical Circuits and Lines

The insulation resistance between each low voltage electrical wires and between low voltage electrical circuits/lines and ground shall be not less than the values given by the following table for each section into which the electrical circuits and lines can be divided by switching devices or over-current circuit breakers.

Table 116-1 Insulation Resistance

Classification of Working Voltage of Electrical Circuits and Lines		Insulation Resistance
300V or less	Voltage to ground is 150V or less	0.1MΩ
	Other	0.2MΩ
300V over		0.4MΩ

Article 117 Prevention for Electrical Shock and Fire of Electrical Equipment for Station Service

The electrical equipment for station service shall be installed so as not to exposure any live parts and no risk of fire by overheating and to prevent any danger to the human body. If the exposure of live part or overheating is indispensable for use of electrical equipment and there is no risk of electrical shock or fire, this article is not applicable.

Section 2 Prevention of Risk to Other Electrical Wiring and Other Structures by Electrical Wiring

Article 118 Prevention of Risk to Other Electrical Wiring and Other Structures by Electrical Wiring

The electrical wiring, which is installed closely or crossing other electrical wiring or telecommunication lines, shall be installed so as to prevent any electrical shock or fire caused by accidental contact.

The electrical wiring shall be installed in such a manner so as not to damage to the water pipes or gas pipes which are closed or crossed to the electrical wiring and also not to cause any electrical shock or fire caused by leakage or discharge current.

Section 3 Protective Measure against Abnormal Condition

Article 119 Protection for Low Voltage Electrical Trunk Line against Over-current

The low voltage electrical trunk line, low voltage electrical brunch line to be connected electrical equipment directly and low voltage electrical circuits and lines not through the low voltage trunk line shall have switching devices and the circuit breaker at appropriate places so as to protect the concerned electrical circuit against the over-current. If there is not possibility of over-current caused by the short circuit of the electrical circuit, this article is not applicable.

Article 120 Protection for Overload of Motor

The electrical motor, whose capacity is over 0.2kW, to be installed in indoor shall have the over-current circuit breaker or other appropriate devices so as to prevent fire caused by overheating of the motor. If there is not possibility of harmful over-current for the motor taking structure of the motor or characteristics of the load into consideration, this article is not applicable.

Article 121 Cutting Off for Medium Voltage Mobile Cables and Trolley Cables in case of Abnormal Conditions

The electrical circuits and lines to be connected to medium voltage mobile cables and trolley cables shall have over-current circuit breaker in order to protect them against over-current.

The mentioned above electric circuits and lines shall have earth fault circuit breaker or other appropriate devices so as to prevent any electrical shock or fire.

Section 4 Prevention of Electrical and Magnetic Interferences

Article 122 Prevention of Interferences of Telecommunication Facilities Caused by Electrical Equipment or Trolley Cables

The electrical equipment or trolley cables at hydropower station shall be installed in such a manner so as not to cause any interference continuously and seriously with the telecommunication facilities caused by radio wave or high frequency current.

Section 5 Restriction of Installation at Special Locations

Article 123 Electrical Equipment Installed in the Place Where May Decrease Insulation Level by Dust

The electrical equipment to be installed in dusty place shall be installed in such a manner so as to prevent any electrical shock or fire caused by decreasing of insulation level or conductivity.

Article 124 Prohibition of Installation for Electrical Equipment at Volatile Places Caused by Flammable Gas

The electrical equipment to be installed following places shall be installed in such a manner so as not to ignite any explosion or fire in the normal operating condition.

1. Place where there is flammable gas or inflammable vapor which might cause for explosion
2. Place where there is dust which might cause for explosion
3. Place where there is explosive material.
4. Place where manufacture or store the explosive material such as celluloid, match or petroleum.

Article 125 Prohibition of Installation for Electrical Equipment at Corrosive Places

The electrical equipment to be installed at places which exhale corrosive gas or liquid shall take preventive measures against electrical shock or fire caused by decreasing of insulation level or conductivity.

Article 126 Prohibition of Installation for Electrical Equipment at Explosive Magazine

The electrical equipment except for lighting purpose (except switchgear and over-current circuit breaker) shall not be installed in explosive magazine despite of Article mentioned above. If there are special measures to prevent ignition of the explosive and there is special reason to install electrical equipment, this article is not applicable.

Chapter 14 Electrical Facilities for Outgoing Line

Section 1 Prevention of Electrical Shock and Fire

Article 127 Prevention of Electrical Shock and Fire for Electrical Lines

The electrical lines shall be installed in such a manner so as not to cause any electrical shocks or fire taking its circumstance and working voltage into consideration.

Article 128 Prevention of Electrical Shock for Overhead Lines and Underground Electrical Lines

The insulated cables shall be used for low and medium voltage overhead lines so as not to cause any electrical shocks to the human body taking working voltage into consideration. If there is no risk of any electrical shocks in normal operating condition, this article is not applicable.

The insulated cable shall be used for underground electrical lines so as not to cause any electrical shocks to the human body taking working voltage into consideration.

Article 129 Insulation Level for Low Voltage Electrical Lines

Insulation resistance for low voltage electrical lines shall be of not exceeding 1/2,000 of maximum current of the lines in accordance with working voltage.

Article 130 Prevention of Entry by Unauthorized Persons into Hydropower Station

The hydropower station and its associated facilities, which have high or medium voltage electrical equipment or bus-bar, shall provide a notice of high voltage that the electrical equipment and bus-bar are dangerous to any persons. Furthermore, measures shall be provided to keep out the unauthorized persons from hydropower station and its associated facilities.

Article 131 Prevention of Climbing Supporting Structure for Overhead Electrical Lines

The supporting structure for overhead electrical lines shall be installed in such a manner so as not to be climbed the support structure easily by unauthorized person.

Article 132 Height for Overhead Lines

The overhead electrical lines and overhead telecommunication equipment for electric power system shall be installed in high position not to cause electrical shock by contacting or electromagnetic induction and not to interfere with traffics.

The guy wires shall be installed in high position not to interfere with traffics.

Article 133 Prevention of Electrical Shock against Workers of Other Electrical Lines

The supporting structure of the overhead lines shall not be installed passing through the other overhead lines, telecommunication lines or optical fiber lines. If permission is obtained from the manager of overhead lines, telecommunication lines or optical fiber lines, this article is not applicable.

The overhead lines shall not be installed between the other overhead lines, telecommunication lines and optical fiber lines. If the overhead lines are installed on same supporting structure of other lines and permission is obtained from the manager of the lines, this article is not applicable.

Article 134 Prevention of Electrical Shock Caused by Electrostatic or Electromagnetic from Overhead Lines

The high voltage overhead electrical lines shall be installed in such a manner so as not to be sensed any electrostatic induction which shall not be exceeding 3kV/m at 1 meter from ground level. If there is no risk to the human body because of mountain area or arable land where rarely person is there, this article is not applicable.

The high voltage overhead electrical lines shall be installed in such a manner so as not to cause any danger to the human body by electromagnetic induction through telecommunication lines except telecommunication equipment for electric power system.

The telecommunication equipment for electric power system shall be installed in such a manner so as not to cause any danger to the human body by electrostatic or electromagnetic induction emanated from the overhead electric line.

Section 2 Prevention of Hazard to Other Electrical Wires, Cables and Structures

Article 135 Prevention of Contact between Electrical Wires and Cables

The electrical lines and telecommunication equipment for electric power system to be installed near other lines or on same supporting structures of other lines shall be installed not to cause any electrical shock, fire or damage to electrical wires, cables or telecommunication lines by contacting or disconnection of lines.

Article 136 Prevention of Hazard to Other Structures by Electrical Wires and Cables

The wires and cables for electrical lines which come close or cross over other structures shall be installed not to cause damage to the structures and not to cause electrical shock or fire due to contacting or disconnection of lines.

Article 137 Prevention of Hazard to Other Electrical Wires, Cables and Structures by Underground Electrical Cables

The underground wires and cables to be installed on other structures such as buildings, tunnel and so on, which come close or cross over other electrical wires and cables, telecommunication cables or pipes, shall be installed so as not to cause damages on wires and cables or pipes by electric arc at failure. If there is no risk of electrical shock or fire, manager of other electrical lines agrees, this article is not applicable.

Article 138 Prevention of Obstruction to Overhead Electrical Lines by Abnormal Voltage

In case of installation of high and low voltage overhead electrical lines same supporting structures together, appropriate measures such as the grounding shall be taken in order not to cause any damage to low voltage side of facilities by invasion of abnormal voltage from high voltage side.

When low voltage electrical equipment is installed above the high voltage overhead electrical lines on same supporting structures together, appropriate measures such as the grounding shall be taken in order not to cause any damage to low voltage side of facilities by invasion of abnormal voltage from high voltage side.

Section 3 Prevention of Hazard by Collapse of Supporting Structure

Article 139 Prevention of Collapse for Supporting Structures

The material and structure of supporting structure of overhead electrical lines and guy wires shall be installed safety enough taking tension load, wind load of 32m/s, weather conditions, vibrations, impacts and other external environmental influences into consideration. If the supporting structures of overhead electrical lines are installed in urban area and the structures are installed taking the condition of place into consideration, wind load of 20m/s shall be applied for installation for strength of support structures.

Supporting structures of high voltage overhead electrical lines shall be installed safety enough so as not to cause any collapse by chain-reaction.

Section 4 Prevention of Hazard by High Pressure Gas

Article 140 Prevention of Hazard for Gas Insulated Equipment

The gas insulated equipment, switchgear or compressed air supply system for circuit breaker to be installed at hydropower station and its associated facilities shall be installed as the following manners;

1. The materials and structures of pressurized portion shall withstand the maximum operation pressure sufficiently and safely.
2. The container of compressed air supply system shall be of corrosion resistance.
3. In the case where the pressure rises, the system shall have the function to reduce the pressure before it reaches the maximum operation pressure.
4. In the case where the pressure of main air container decreases, compressed air supply system shall have the function to restore the pressure automatically.
5. The system shall have the function to detect any abnormal pressure in the early stage.
6. The insulated gas to be used for the gas insulated switchgear shall not be of inflammable, corrosive and poisonous.

Article 141 Installation for Pressurized Facilities

The compressed gas to be used for cable terminal shall be installed as the following manners:

1. The pressurized portion shall withstand the maximum operation pressure sufficiently and safely.
2. In the case where automatic supplying gas system, if there is possibility to increase the pressure sharply due to failure of the system, the materials and structure of the system shall withstand the pressure sufficiently and also shall have function to release the pressure before the maximum operation pressure.
3. The pressured gas shall not be of inflammable, corrosive and poisonous.

Section 5 Prohibition of Installation for Dangerous Facilities

Article 142 Restriction of Installation for Oil-filled Switchgear

The insulated oil-filled switchgear, disconnecting switch and circuit breaker shall not be installed on the supporting structure of the overhead electrical lines.

Article 143 Prohibition of Installation for House Wiring

Electrical lines shall not pass through interior of building, not to be installed at interior side, roof, or ground of premises of other manager of the electrical facilities. If the manager of the land or facilities, on which the electrical lines are installed, accepts it, this article is not applicable.

Article 144 Prohibition of Connected Branch Electrical Lines

The connected branch electrical lines shall not be installed for medium and high voltage electrical lines. If the manager of the facilities, on which the electrical lines are installed, accepts it, this article is not applicable.

Article 145 Prohibition of Installation for Electrical Lines at Cliff

The electrical lines shall not be installed at the cliff other than facilities which is over the building, crossing the road, railways, telecommunication lines, overhead lines, come close to these facilities and special circumstances.

Article 146 Prohibition of High Voltage Overhead Electrical Lines at Urban Area

The high voltage overhead electrical lines shall not be installed at urban area except that electrical lines are cables. If measures against risk of disconnection of wire or collapse of the supporting structure are provided, this article is not applicable.

Article 147 Prohibition of Connection for Telecommunication Equipment for Power Supply System to Other Telecommunication Equipment for Power Supply System of High Voltage Electrical Lines at Urban Area

The telecommunication equipment for power supply system at urban area shall not be connected to other telecommunication equipment for power supply system of high voltage electrical lines at urban area.

If the measures against induction voltage not to cause electrical shock are provided, this article is not applicable.

Section 6 Prevention of Electrical and Magnetic Interference

Article 148 Prevention of Telecommunication Interference

The electrical lines shall be installed so as not to generate electromagnetic waves which cause serious obstacle to the radio transmission equipment continuously.

The electrical lines shall be installed so as to prevent any inductive interference to the telecommunication lines. If there is consent by manager of the telecommunication lines on the above mentioned matters, this article is not applicable.

Section 7 Prevention of Electric Power Outage

Article 149 Prevention of Electric Power Outage Caused by Electrical Facilities Damage

The generators, fuel cells or battery shall have a function to disconnect the electrical circuits and lines automatically in case that there may be serious destruction to other electric power facilities or serious obstacle to the concerned electrical facilities.

High voltage transformers and reactive power compensator shall have a function to disconnect the electrical circuits and lines automatically in case that there may be serious destruction to other electric power facilities or serious obstacle to the concerned electrical facilities.

Article 150 Mechanical Strength for Generators and Other Electrical Facilities

The generators, transformers, reactive power compensator, bus-bar and insulator for bus-bar shall withstand the mechanical shock caused by short-circuit current.

Rotating parts of generator to be connected to turbine shall withstand the mechanical shock against the maximum speed at full load rejection.

Article 151 Protection for Underground Lines

The underground lines shall be installed so as to withstand the vehicle's weight or heavy load objects on those and shall have proper indications, which show the location of underground lines, and to prevent any influences from excavation works.

Tunnels or rooms, which have space to work inside for underground line shall have fire prevention equipment.

Article 152 Prevention for Electric Power Outage Caused by High Voltage Overhead Line

The high voltage overhead lines which exceed the voltage of 170,000V shall not be installed at urban area or crowded area. If there is no possibility of serious electric power outage caused by collapse of the overhead line due to fire, this sub-article is not applicable. If the measures against collapse of overhead lines due to fire are provided, this article is not applicable.

The horizontal distance between high voltage overhead lines exceed the voltage of 170,000V and any structures shall be of 3 meters or more in order not to cause serious power outage caused by collapse of the overhead line due to fire.

The high voltage overhead lines with voltage of 170,000V or less to be installed beneath buildings, roads or pedestrian bridge shall be taken safe distance 3 meter or more horizontally in order not to cause serious electric power outage caused by collapse of the those structures.

Article 153 Installation of Surge Arrester for Medium and High Voltage Electrical Circuits and Lines

The surge arrester or other necessary facilities shall be installed at points listed below or at locations close to such point, in order to prevent damage by lightning surge voltage. If there is no risk against lightening surge voltage, this article is not applicable.

1. Incoming and outgoing points of overhead electrical lines in the hydropower station and its associated facilities.
2. Medium and high voltage side of distribution transformers which are connected to overhead electrical lines and have protective devices such as over-current protective device.
3. Incoming points of medium and high voltage overhead electrical lines.

Article 154 Installation for Telecommunication Equipment for Electric Power System

The telecommunication equipment for electric power system shall be installed among the hydropower station, its associated facilities, load dispatching center and similar electrical facilities where staffs are stationed so as to secure the security and to prevent the electric power outage.

The telecommunication equipment for electric power system shall be installed in such a manner so as to prevent destruction of telecommunication function caused by mechanical shock or fire.

Article 155 Maintaining for Telecommunication Equipments in case of Disasters

The structure and materials for the antenna of the radio communication or the reflective plate shall withstand against wind velocity of 60 meter per second so as not to cause any destruction of telecommunication function. If antenna of the radio communication is installed at the support structure of the overhead electrical lines for the purpose of supervising for the circumference of the overhead lines, this article is not applicable.

Chapter 15 Measuring and Protective Device

Section 1 Measuring Device

Article 156 Purpose of Installation for Measuring Devices

Purpose of installation for measuring devices shall be as follows:

1. Voltmeter
   Voltmeter shall be installed for supervision of operation voltage, confirmation of synchronizing, voltage of transmission line on fault condition and management of transmission line's voltage.
2. Ammeter and Wattmeter
   Ammeter and wattmeter shall be installed for supervision of operating condition, power flow and status condition of circuit breaker.
3. Watt-hour Meter and Var-hour Meter
   Watt-hour meter and var-hour meter shall be installed for confirmation of generated energy and consumed energy, assumption of demand and transaction purpose.
4. Frequency Meter
   Frequency meter shall be installed for supervision of synchronizing and frequency.
5. Synchroscope
   Synchroscope shall be installed for measuring of synchronizing and phase angle in case of loop changeover.
6. Zero-phase Voltmeter and Neutral Point Ammeter
   Zero-phase voltmeter and neutral point ammeter shall be installed for supervision of ground fault of power system.
7. Thermometer
   Thermometer shall be installed for supervision of temperature for electrical equipment.
8. Pressure Gauge
   Pressure gauge shall be installed for supervision of pressure for turbine, pressure oil supply system, compressed air supply system and gas insulated switchgear.

Article 157 Measuring Devices of Hydropower Station

The following measuring devices shall be installed at hydropower station.

Table 157-1 Measuring Devices of Hydropower Station

Classification	Measuring Device	Neces-sity	Remarks
Gas insulated equipment	Pressure gauge	✓	
Oil and air supply system	Pressure gauge	✓	Recording instrument cab be substituted
Turbine	Pressure gauge	✓	
	Bearing thermometer	✓	
Generator	Var meter or power factor meter	✓	
	Ammeter or wattmeter	✓	Recording instrument cab be substituted
	Stator winding thermometer	✓	
	Bearing thermometer	✓	
	Voltmeter	✓	
Main Transformer	Voltmeter	✓	Except if voltage can be measured by voltmeter of generator Recording instrument cab be substituted
	Ammeter or wattmeter	✓	Except of they can be measured by ammeter or wattmeter of generator Recording instrument can be substituted
	Thermometer	✓	Only for high voltage Recording instrument can be substituted
Transmission line	Ammeter or wattmeter	✓	
Distribution line	Ammeter	✓	
Synchroscope		✓	Except other than synchronous generator and generator which does not do synchronizing
Oil pressure system	Oil level gauge	✓	
DC circuit	Voltmeter	✓	
Station service circuit	Ammeter	✓	
Oil filled equipment	Oil level gauge	✓	
Necessary point	Watt-hour meter	✓	
	Var-hour meter	✓	

Section 2 Protective Device

Article 158 Protective Device for Turbine and Generator

Protective device for turbine and generator shall be provided in accordance with capacity of the generator as shown in the following table:

Table 158-1 Protective Devices for Turbine and Generator

Capacity of Generator	Abnormal Condition	Necessity of Automatic Stop	Necessity of Automatic Shutdown
Less than 500kVA	Over-speed		
	Remarkable decrease of oil pressure for oil supply system or power source for electrical guide vane etc.		
	Remarkable temperature rise of bearing		
	Over-current		✓
Over 500kVA less than 2,000kVA	Over-speed	✓	
	Remarkable decrease of oil pressure for oil supply system or power source for electrical guide vane etc.	✓	✓
	Remarkable temperature rise of bearing		
	Over-current		✓
Over 2,000kVA	Over-speed	✓	
	Remarkable decrease of oil pressure for oil supply system or power source for electrical guide vane etc.	✓	✓
	Internal failure of generator	✓	✓
	Remarkable temperature rise of bearing	✓	✓
	Over-current		✓

Oil pressure supply system, electrical guide vane, electrical needle or electrical deflector shall be installed as follows by the time of stopping of generator securely in case of abnormal condition. However, if the guide vane has self-closing, spring closing, counter weight, emergency oil tank or emergency servomotor, this article is not applicable.

(1) Oil pressure tank shall have enough capacity to stop generator without replenishing of oil pressure.

(2) Emergency power source shall be provided for electrical guide vane, electrical needle or electrical deflector.

Article 159 Protective Device for High Voltage Transformer

Protective devices for high voltage transformer shall be provided in accordance with capacity of transformer as shown in the following table:

Table 159-1 Protective Devices for High Voltage Transformer

Capacity of Transformer	Abnormal Condition	Necessity of Automatic Shutdown	Necessity of Alarm
Less than 5,000kVA	Over-current	✓	
Over 5,000kVA less than 10,000kVA	Over-current	✓	
	Internal failure	✓	✓
	Remarkable temperature rise		✓
Over 10,000kVA	Over-current	✓	
	Internal failure	✓	
	Remarkable temperature rise		✓
Forced circulating cooling system	Remarkable temperature rise or failure of cooling device		✓

Article 160 Protective Device for Gas Insulated Switchgear

Alarm device for remarkable decrease of insulated gas shall be provided for the gas insulated switchgear. However, if there is no risk of insulation breakdown caused by decrease of gas pressure, this article is not applicable.

Article 161 Earth Fault Protective Device for Electrical Circuits and Lines

Automatic cutting-off device shall be provided for medium and high voltage electrical circuits and lines at incoming or outgoing point of hydropower station in case of happening of earth fault in order to prevent accident, disaster and influence to the human body.

Article 162 Protective Device for High Voltage Overhead Lines

Protective device for earth fault and short circuit fault shall be provided for high voltage overhead lines in the following manner:

Table 162-1 Protective Device for High Voltage Overhead Lines

Classification	Voltage	Necessity of Automatic Cut-off	Breaking Time
High voltage overhead lines	100kV or less	✓	Within 3 seconds
	Over 100kV	✓	Within 2 seconds
High voltage overhead lines to be installed at urban area	Over 100kV	✓	Within 1 seconds
	170kV or less	✓	Within 1 seconds

Article 163 Protective Device for Bus-bar

Protective device against earth and short circuit fault shall be provided for bus-bar taking power system characteristics and influence of accident into consideration.

Article 164 Safety Alarm for Hydropower Station

Hydropower station which is controlled remotely from control center shall have an alarm device so as to transmit alarm to administrative office or control center in case of accident as shown in the following table:

Table 164-1 Safety Alarm for Hydropower Station

Abnormal Condition	Alarm to Administrative Office or Control Center
Turbine stops automatically	✓
Necessary circuit breaker cut-off automatically	✓
Remarkable temperature rise or failure of cooling device for high voltage transformer with forced circulating cooling system	✓
Internal failure of transformer (over 5,000kVA, 10,000kVA or less)	✓
Remarkable decrease of insulated gas for gas insulated switchgear	✓
Remarkable decrease of voltage for control power source	✓
Fire	✓

Article 165 Supervisory Device for Operation of Turbine and Generator

Necessary supervisory device shall be provided at hydropower station for supervision of condition of turbine and generator.

Article 166 Load Regulation Device

Load regulation device shall be provided at hydropower station in accordance with its type of control system or type of reservoir.

Article 167 Fire Extinguisher System for Transformer

Fire extinguisher system of transformer with over 170kV which to be connected earthed neutral system shall be operated automatically in case of fire.

Part 4
Examination and Inspection

Chapter 16 General Provisions

Article 168 Definitions

1. Authority

"Authority" means MIME or organizations upon which MIME devolves specified competence in enforcement of inspection of hydropower stations.

2. Owner

"Owner" shall mean as stipulated in Article 1.

3. Inspector

"Inspector" means a person, belonging to or appointed by MIME, carrying out inspection based on the Electricity Law, GREPTS and SREPTSHP.

4. In-progress Inspection

"In-progress Inspection" means inspection to be conducted to confirm appropriate implementation of each stage of design and construction work in terms of quality and safety.

5. Completion Inspection

"Completion Inspection" means inspection to be conducted to confirm appropriate completion of construction work in terms of quality and safety.

6. Periodical Inspection

"Periodical Inspection" means inspection to be conducted to confirm appropriateness of maintenance and operation works to be done in terms of quality and safety during operation period

Article 169 Purpose

The purpose of examination and inspection prescribed in Part 4 of SREPTSHP (hereinafter referred to as "Part 4") is to confirm whether required quality and safety are satisfied in construction, operation and maintenance of hydropower facilities and to take countermeasures appropriately if necessary. Examinations and inspections are classified into 3 categories. These are in-progress inspection, completion inspection and periodical inspection.

Article 170 General Provisions

1. The Owner shall conduct all the inspections according to SREPTSHP. The Owner shall conduct the inspection by himself under witness of the Inspector in principle. The Owner may have contractors conduct the inspections on his own responsibility. In that case, the Owner should have contractors observe this technical standard. The Owner shall supervise the inspections, demand to submit the inspection report, check the report in terms of purposes, contents, methods and results of the inspection.

2. The Authority shall check the compliance of the Owner with SREPTSHP. In case of violation or non-conformity to the requirements related to Part 4, the Authority may order the Owner to take necessary improvement and countermeasures.

3. Part 4 stipulates legal minimum requirements for major structures and equipment in point of prevention of public hazards and huge power system collapse. Therefore the Owner shall carry out necessary examination and inspection to detect failure potentials, and shall take necessary countermeasures if necessary in addition to the provisions of Part 4.

4. Part 4 provides basic requirements for examination and inspection on hydropower facilities. The Owner shall decide methods and detailed procedures of examination and inspection based on the status of each facility. The method is not limited to those presented in SREPTSHP. The inspection can be conducted by any other appropriate methods if they have technological grounds that can accomplish the purpose of inspection.

5. Besides the above provisions, the Authority may implement an immediate inspection when he/she judges the inspection necessary.

Chapter 17 Examination and Inspection on Civil Structures and Hydromechanical Equipment

Section 1 In-progress Inspection

Article 171 General Provisions

In-progress inspection determined in SREPTSHP consists of 3 kinds of inspection, “Examination for commencement of construction”, “Inspection on dam foundation”, and “Inspection prior to initial reservoir impounding”.

“Examination for commencement of construction” shall be conducted to confirm that plan and design of civil structures and hydromechanical equipment conform to SREPTSHP before the commencement of construction.

“Inspection on dam foundation” shall be conducted in the case that the dam is classified as “Large” or ”Medium,” or has difficult foundation problems and/or is of unusual design even if the dam is classified as “Small” as shown in Table 21-2 to check whether the foundation conditions are appropriate for construction of dam body. It shall be conducted after the completion of excavation for the dam foundation and before the commencement of construction of the dam body.

“Inspection prior to initial reservoir impounding” shall be conducted in the case that the dam is classified as “Large” or ”Medium”, or has difficult foundation problems and/or is of unusual design although the dam is classified as “Small” as shown in Table 21-2 to check whether constructed and installed facilities are ready for impounding. It shall be conducted prior to the commencement of reservoir impounding.

Article 172 Scope of Examination for Commencement of Construction

Examination shall be conducted as to whether civil structures and hydromechanical equipment concerned conform to SREPTSHP from the view point of probability of planning, credibility of design and safety to environment, etc.

Article 173 Scope of Inspection on Dam Foundation

Inspection on dam foundation shall be conducted to confirm appropriateness of dam foundation in terms of quality and safety for commencing the construction of dam body. It shall be conducted by the visual inspection and examination of survey and measurement records from the viewpoint of water-tightness, durability and surface condition of dam foundation.

Article 174 Scope of Inspection prior to Initial Reservoir Impounding

Inspection prior to initial reservoir impounding shall be conducted to confirm the appropriateness of constructed facilities to be ready for reservoir impounding. The facilities and equipment subjected to this Inspection are all civil structures related to reservoir impounding including dams, spillways and intakes and hydromechanical equipment including spillway gates, intake gates and their auxiliary equipment. The Inspection shall be basically conducted by visual inspection and the check on quality management records, instrumentation monitoring records and other construction records. Operation tests under dry conditions shall also be conducted for related hydromechanical equipment.

Section 2 Completion Inspection

Article 175 General Provisions

Completion Inspection shall be conducted when construction works have been completed for each hydropower station.

Completion Inspection shall be conducted to confirm appropriate completion of construction work in terms of quality and safety for acceptance of each civil structures and hydromechanical equipment to be put into operation in the two stages.

The first stage is “completion inspection before operation”.

The second stage is “completion inspection under operation condition”.

Article 176 Scope of Completion Inspection

Completion Inspection is basically conducted by visual inspection and examination on construction records, instrumentation monitoring records and quality management records.

In the “completion inspection before operation”, the examination and inspection shall be conducted covering the following items:

1. Operation test of gates
2. Examination on instrumentation monitoring records of the dam including deformation of the dam body, leakage from the dam body, seepage from the dam body/dam foundation, uplift pressure at the dam foundation

In the “completion inspection under operation condition”, the check on the performance of civil structures and hydromechanical equipment under operation condition is conducted.

If serious problems and/or defects on facilities have been detected in the “completion inspection under operation condition”, detailed examination and inspection should be conducted, if necessary, by stopping the operation and dewatering for such facilities in question.

Section 3 Periodical Inspection

Article 177 General Provisions

Periodical Inspection shall be conducted to confirm the appropriateness of maintenance and operation works during operation period in terms of quality and safety. It shall be carried out according to the following manner.

As for dams, this Inspection shall be conducted in the case that the dam is classified as "Large" or "Medium" as shown in Table 21-2 of Article 21 or the dam has difficult foundation problems and/or is of unusual design even if the dam is classified as "Small".

1. Periodical Inspection consists of two parts; one is the examination of the documents of operation and maintenance and monitoring records by the Inspector. The other is the visual inspection of facilities. Considering characteristics such as the latest condition and potential of the hazard risks of each hydropower station, visual inspection may be selectively carried out according to judgment of the Authority.
2. Periodical Inspection shall be carried out basically every three years in principle for each hydropower station.
3. The Authority may shorten the interval between the last periodical inspection and the next one, in case that the result of the last inspection does not satisfy the provisions of SREPTSHP from the viewpoint of quality or safety.
4. The first periodical inspection shall be carried out after the interval specified in paragraph 2 of this article from the Completion Inspection.
5. In the case that water level of the reservoir reaches NHWL for the first time after the previous completion inspection conducted prior to commencement of operation, additional check as the final completion inspection shall be conducted.
6. The second or subsequent periodical inspections shall be carried out at the interval specified in paragraph 2 of this article.

Article 178 Scope of Periodical Inspection

Periodical Inspection shall be basically conducted by the visual inspection and the check on operation and maintenance records and quality management records. Main inspection items and timings for each facility are as follows.

Dams and reservoirs are examined and inspected mainly based on instrumentation monitoring records including the deformation of dam body, leakage/seepage from dam body/dam foundation, uplift pressure at the dam foundation and on maintenance records under operation condition.

Civil structures of waterways and hydromechanical equipment are inspected mainly based on maintenance records under operation condition.

If serious problems and/or defects have been detected in the Periodical Inspection on facilities, detailed examination and inspection should be conducted, if necessary, by stopping the operation and dewatering for such facilities in question.

Chapter 18 Examination and Testing on Electrical Facilities

Section 1 General

Article 179 Examination and Testing

Electrical equipment to be installed at hydropower station shall be examined and tested in accordance with SREPTSHP and submitted plan, and examination and testing items shall be as follows:

1. Visual inspection
2. Measurement of grounding resistance
3. Measurement of insulation resistance
4. Dielectric strength test
5. Operation test
6. Load test

Section 2 Visual Inspection

Article 180 Visual Inspection

Visual inspection is to confirm the electrical equipment to be installed in accordance with SREPTSHP and other relevant regulation/standard after installation or before commissioning testing.

The visual inspection for electrical equipment shall be done in accordance with the following:

Table 180-1 Visual Inspection for Electrical Equipment

No.	Items of Visual Inspection	Inspection Method
1	Inspection for Grounding	To confirm by visual inspection for grounding to be connected to electrical equipment. Confirmation of grounding condition shall be done by sampling method and other shall be confirmed by documentation.
2	Inspection for arc emanated equipment	To confirm distance between arc emanated circuit breaker, disconnecting switch and flammable object to be taken more value than SREPTS by documentation or actual measurement.
3	Inspection for live parts of equipment	To confirm live parts to be covered, enough distance to be taken between insulated part and live part by documentation or visual inspection.
4	Inspection for status indicator of circuit breaker	To confirm status indicator of circuit breaker to be seen easily. Operation of status indication shall be done during operation test.
5	Inspection for over-current circuit breaker	To confirm installation of over-current circuit breaker in accordance with submitted document by visual inspection.
6	Inspection for earth fault circuit breaker	To confirm installation of ground fault circuit breaker in accordance with submitted document by visual inspection. Confirmation of operation shall be done during protective test.

No.	Items of Visual Inspection	Inspection Method
7	Inspection for Surge Arrester	To confirm installation of surge arrester in accordance with submitted document by visual inspection.
8	Inspection for fence, wall	To confirm installation of fence, wall by visual inspection. To confirm installation of locking device, indication plate of keep out by visual inspection. To confirm distance between fence, wall and live part by documentation or actual measurement.
9	Inspection for prevention facilities of oil drain	To confirm installation of prevention facilities of oil drain of transformer by visual inspection. Required capacity shall be checked by document.
10	Inspection for phase indication	To confirm installation of phase indication by visual inspection. To confirm installation of status indication such as mimic bus-bar by visual inspection.
11	Inspection for protective device	To confirm installation of appropriate protective device by visual inspection. Confirmation of operation shall be done during operation test of the equipment.
12	Inspection for pressure container (1) Gas pressure gauge (2) Gas leakage (3) Protective and measurement device	(1) To confirm installation of alarm for gas pressure decrease device or gas measurement device by visual inspection. (2) To confirm pressure container to be tested in accordance with relevant standard by inspection record or name plate. (3) To confirm installation of protective and measurement device by visual inspection Confirmation of operation shall be done during operation test of the equipment.
13	Inspection for control-board	To confirm installation of inspection route around control-board by visual inspection and documentation. To confirm installation of protective device for live parts by visual inspection.

Section 3 Measurement of Grounding Resistance

Article 181 Measuring Method of Grounding Resistance

Measurement of grounding resistance is to confirm the required grounding resistance to be taken by grounding mesh or earth electrode. If the grounding resistance is not sufficient, additional grounding mesh or earth electrode shall be installed accordingly. The measurement of grounding resistance shall be done before energizing of hydropower station.

Grounding resistance of Classification A, B, C and D in hydropower station shall be measured by direct indicating earth resistance meter. However, grounding resistance for wide spread mesh network grounding shall be done by fall of the potential method.

Measurement of grounding resistance for expansion and improvement work of hydropower station shall be confirmed by test of continuity of existing grounding and expansion grounding.

Section 4 Measurement of Insulation Resistance

Article 182 Measuring Method of Insulation Resistance

Measurement of insulation resistance is to confirm the electrical equipment to be installed in accordance with required insulation level after installation. If required insulation resistance is not sufficient, necessary countermeasures shall be taken to improve the insulation resistance.

1. Insulation resistance shall be measured by 500V insulation resistance tester for low voltage electrical circuits and lines, 1,000V insulation resistance tester for medium and high voltage electrical circuits and lines respectively.
2. Measurement of insulation resistance for low voltage electrical circuits and lines shall be done only necessary circuits and lines such as field circuits of generator and other.
3. Measurement of insulation resistance for medium and high voltage circuits and lines shall be done in accordance with each circuit of dielectric strength test.
4. Time of insulation resistance value shall be 1 minute.

Article 183 Insulation Resistance Value

1. Insulation Resistance Value of Low Voltage Electrical Circuits and Lines

Insulation resistance value of each conductor, between conductor and earth shall be satisfied in accordance with every circuits and lines divided by disconnecting switch or circuit breaker as shown in the following table:

If the measurement of insulation resistance is hard, leakage current shall be of 1mA or less in accordance with working voltage.

Table 183-1 Insulation Resistance Value of Low Voltage Electrical Circuits and Lines

Classification of Working Voltage of Electrical Circuits and Lines		Insulation Resistance Value
300V or less	Voltage to ground is 150V or less	Over 0.1MΩ
	Others	Over 0.2MΩ
Over 300V		Over 0.4MΩ

2. Insulation Resistance Value of Medium and High Voltage Electrical Circuits and Lines

Insulation resistance value of medium and high voltage electrical circuits and lines can be permissible only that electrical circuits/lines and ground are insulated.

Section 5 Dielectric Strength Test

Article 184 Dielectric Strength Test Method for Transformer

The dielectric strength test for transformer is to confirm the transformer which has necessary dielectric strength in accordance with SREPTSHP or other relevant standard/regulation after installation. If dielectric strength is not sufficient, necessary countermeasures shall be taken so as to improve the dielectric strength.

Dielectric strength test of winding of transformer shall be executed in accordance with the type of windings and connections as shown in the following table:

Table 184-1 Dielectric Strength Test Method for Transformer

Cate-gory	Type of Winding	Test Method
1	Winding with maximum working voltage 7,000V or less	Un-tested winding, core and tank shall be grounded, testing voltage shall be applied between winding and ground for 10 minutes.
2	Winding with maximum working voltage over 7,000V 15,000V or less (Neutral grounding system)	Un-tested winding, core and tank shall be grounded, testing voltage shall be applied between winding and ground for 10 minutes.
3	Winding with maximum working voltage over 7,000V 60,000V or less (except category 2)	Un-tested winding, core and tank shall be grounded, testing voltage shall be applied between winding and ground for 10 minutes.
4	Winding with maximum working voltage over 60,000V (Isolated neutral grounding system, except category 8)	Un-tested winding, core and tank shall be grounded, testing voltage shall be applied between winding and ground for 10 minutes.

Cate-gory	Type of Winding	Test Method
5	Winding with maximum working voltage over 60,000V (Y-connection, Scott connection, neutral grounding system, except category 6, 7)	(1) Winding with surge arrester at neutral point a) Tested by 3-phase AC Any terminal other than tested winding of neutral point, any other terminal of winding and core/tank shall be grounded, testing voltage shall be applied to any winding other than neutral point for 10 minutes. Number of test shall be done 2 or 3 times to change the each terminal. b) Tested by Single-phase AC Any terminal other than tested winding of neutral point, any other terminal of winding and core/tank shall be grounded, testing voltage shall be applied between any winding terminal of neutral terminal, any other terminal other than grounded and ground for 10 minutes. Number of test shall be done 2 or 3 times to change the each terminal . c) Tested by 3-phase and single-phase AC Core and Tank shall be grounded, then single-phase testing voltage shall be applied to tested winding neutral terminal, 3-phase testing voltage shall be applied to other windings, testing voltage shall be applied between any winding terminal other than neutral point terminal and ground for 10 minutes. Number of test shall be done 3 times to change the phase angle. (2) Other Untested winding, core and tank shall be grounded, testing voltage shall be applied between tested winding and ground for 10 minutes.
6	Winding with maximum working voltage over 170,000V (Y-connection, neutral grounding system, arrester at neutral point, except category 8)	Any terminal other than tested winding of neutral point, any terminal other than winding and core/tank shall be grounded, testing voltage shall be applied between any terminal other than neutral terminal and ground for 10 minutes. Number of test shall be done 2 or 3 times to change the each terminal
7	Winding with maximum working voltage over 170,000V (Y-connection, neutral grounding system, except category 8)	Any terminal other than tested winding of neutral point, any terminal other than winding and core/tank shall be grounded, testing voltage shall be applied between any terminal other than neutral terminal and ground for 10 minutes.
8	Winding with maximum working voltage over 60,000V to be connected to rectifier	Testing voltage shall be applied between tested winding and other windings, core, tank for 10 minutes.
9	Other windings	Testing voltage shall be applied between tested winding and other windings, core, tank for 10 minutes.

Article 185 Dielectric Strength Test Method for Electrical Equipment

The dielectric strength test for electrical equipment is to confirm the electrical equipment which has necessary dielectric strength in accordance with SREPTSHP or other relevant standard/regulation after installation. If dielectric strength is not sufficient, necessary countermeasures shall be taken so as to improve the dielectric strength.

Dielectric strength test of electrical equipment shall be executed as follows;

1. For electrical equipment, testing voltage shall be applied between winding terminal/live parts and ground for 10 minutes.
2. For cable to be used as electrical wire, testing voltage shall be applied between conductor and ground for 10 minutes. However, in case of multi-core cable that conductors are covered by ground voltage, dielectric strength test between each conductor can be excluded.
3. For rotating machine such as generator, motor or rotary condenser, 1.6 times of DC voltage can be applied for 10 minutes instead of AC voltage.
4. For cable to be used as connection wire or bus-bar, 2 times of DC voltage can be applied for 10 minutes instead of AC voltage.
5. For underground lines with maximum working voltage over 170,000V of neutral grounding system, 0.64 times of testing voltage can be applied for 60 minutes instead of above mentioned.
6. In case of confirmation of having required dielectric strength by power frequency withstand voltage test and withstand for 10 minutes, above mentioned method cannot be applied.

Section 6 Operation Test

Article 186 Operation Test for Hydropower Station

Operation test is to confirm the electrical equipment, control and protective equipment at hydropower station to be installed in accordance with SREPTSHP, other relevant standard/regulation and technical specifications before commercial operation. If results of operation test is not satisfied, necessary countermeasures or modifications shall be taken.

Operation test for electrical equipment, control equipment and protective equipment at hydropower station shall be done as shown in the following table:

Table 186-1 Operation Tests for Hydropower Station

No.	Test Item	Verification Method of Test and Operation
1	Protective equipment test	Concerned relays shall be operated by hand making or by actual operation, then operation of relevant circuit breaker, fault indicator, alarm system, and status indicator shall be verified.
2	Circuit breaker and switching device (1) Interlock test	Interlock test is to verify the interlocking function between circuit breaker and relevant switching device and test shall be done in no voltage condition. Verification shall be done by condition of circuit breaker, switching device and indication lamp.

No.	Test Item	Verification Method of Test and Operation
	(2) Auxiliary container capacity test	a. Continuous operation test Auxiliary container shall have capacity for 1 or more time of closing and opening operation without replenishment of compressed air or oil by pressure measurement of before and after and status indicator. b. Locking device test In order to prevent imperfection closing operation for circuit breaker, operation/alarm for locking and reset pressure relay and status of circuit breaker shall be verified by fluctuation of auxiliary pressure container.
	(3) Automatic operation test for compressor and oil pressure pump	Automatic start operation shall be verified at setting pressure by means of opening of drain valve of auxiliary container. Automatic stop operation shall be verified at setting pressure by means of operation of compressor or oil pump and then closing drain valve of auxiliary container.
	(4) Safety valve operation test for compressor, oil pump and auxiliary container	Safety valve operation shall be verified at setting pressure by means of closing of outlet valve and operation of compressor and oil pump.
3	Oil supply and compressed air supply system test	Automatic start-stop and safety valve operation test for oil supply and compressed air supply system test shall be done in accordance with above mentioned test (3) and (4).
4	Automatic start-stop operation test for turbine	Automatic start-stop operation for the turbine shall be done from stop to load, load to stop step by step and time of each step, device operation and status indicator shall be confirmed in accordance with sequence.
5	Load rejection test	Load rejection test is to verify the transferring the turbine-generator safely from load condition to no-load condition by means of opening of circuit breaker by hand at 1/4, 2/4, 3/4 and 4/4 load. Immediately after the load rejection, operation of guide vane, rotating speed, penstock's pressure and generator's voltage shall be measured and speed variation, maximum pressure and generator's voltage build-up rate shall verified within the guaranteed value.
6	Emergency stop test	Emergency stop test is to verify the transferring the turbine-generator safely from load condition, opening of circuit breaker, closing of guide vane, closing of inlet valve and to stop of turbine-generator in accordance with sequence by means of hand making of emergency stop protective relay and each step of operation shall be measured and relevant indication and alarm shall be confirmed.
7	Quick stop test	Quick stop test is to verify the transferring the turbine-generator safely from load condition, closing of guide vane, opening of circuit breaker, closing of inlet valve to stop of turbine-generator in accordance with sequence by means of decreasing of oil pressure and each step of operation shall be measured and relevant indication and alarm shall be confirmed.
8	No-load, no-excitation test	No-load, no-excitation test is to verify the transferring the turbine-generator safely from load condition, closing of guide vane, to no-excitation condition in accordance with sequence by means of hand making of relay elements and each step of operation shall be measured and relevant indication and alarm shall be confirmed.

No.	Test Item	Verification Method of Test and Operation
9	Sudden load increase test	Sudden load increase test is to verify the transferring the turbine-generator safely from 1/2 load to 4/4 load condition by means of sudden increase of load and water level of surge tank shall be confirmed that there is no abnormality.

Section 7 Load Test

Article 187 Method of Load Test

Load test of hydropower station is to measure and verify the generator's temperature, transformer's temperature, bearing temperature, vibration of turbine-generator, oil leakage, water leakage, strange sound and abnormality of auxiliary equipment at rated output, rated rotating speed, rated voltage and rated power factor and saturation of temperature in accordance with SREPTSHP, other relevant standard/regulation and technical specifications before commercial operation. If results of load test is not satisfied, necessary countermeasures or modifications shall be taken.

Load tests of hydropower station shall be done following manners:

1. Voltage and power factor shall be kept as much as closely to rated voltage and rated power factor.
2. If rated output operation cannot be done for run-off-river type hydropower station due to fluctuation of inflow water, test shall be done at partial load and temperature rise shall be estimated from measured partial value or shall be estimated from shop test value.
3. If transformer is tested at shop and measured for temperature rise, test at site can be simplified.
4. Temperature rise of equipment other than generator and transformer shall be confirmed by shop test records.

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カンボジア国

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説明資料（案）

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Electricity Authority of Cambodia (EAC)
Kingdom of Cambodia

EXPLANATION SHEET
FOR
SPECIFIC REQUIREMENTS
OF
ELECTRIC POWER
TECHNICAL STANDARDS
FOR
HYDROPOWER FACILITIES
(DRAFT)

October 2009

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Tokyo, Japan
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Table of Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF PHOTOGRAPHS

Part 1
General Provisions

Chapter 1 General Provisions

For Article 1 Definitions

Terms to which specific meanings are given to stipulate SREPTSHP are listed in this article.

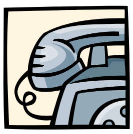
For Article 2 Purpose

The purpose of SREPTSHP includes the ideas shown below:

Review "Purpose of Technical Standards"

1. Danger

Hydropower facilities shall not harm the human or damage any object



2. Electrical and magnetic interference

Hydropower facilities shall be installed so as not to cause any electrical or magnetic interference that may affect other electrical facilities.

3. Damage and effect on power supply and to other facilities

There shall be of no significant effect on the power supply despite of the hydropower facilities being broken down or damaged.

4. Environment

Hydropower facilities shall not have adverse effects on the surrounding environment.

1. Safety concerned with Hydropower civil structures

- Dam failure
- Flooding
- Landslide
- Collapse of waterway
- Environmental impact against natural conservation, water quality etc.
- Socio-economic impact

2. Safety concerned with Electrical Facilities

Table 2-1 Safety Items Concerned with Electrical Facilities

Items	Causes	Effects	Measures
1. Danger	Overcurrent Earth fault Breakage of electrical conductors Collapse of supporting structures	Electric shock Fire Damage to other facilities (building, plant, telecommunication line, and so on)	Insulation Provision of earthing Isolation
2. Electrical and magnetic interference		Electrical and magnetic Interference (radio wave and telecommunication line)	
3. Damage and effect on power supply and to other facilities	Damage and/or destruction of electrical facilities (caused by overvoltage, short current, and so on)	Serious obstacle to power generation and power supply Damage to other electrical facilities	Insulation Provision of earthing
4. Environment	Pollution (air, water, noise, vibration, discharge of insulating oil)		

3. References

The General Requirements of Electric Power Technical Standards (GREPTS) has the following main purposes:

(1) Clause 2: Purpose

1. To specify the technical, design, and operational criteria of Electrical Power Facility, House Wiring and Electrical Appliance,
2. To ensure that the basic rules for supply of electricity are fair and non-discriminatory for all Consumers of the same category, and
3. To maintain the technical standards (levels) of Electrical Power Facility, House Wiring and Electrical Appliance installed in the Kingdom of Cambodia

(2) Clause 9: Prevention of Electric Power Disasters

The electrical equipment shall be installed in such manner as not to cause electrical shock, fire and other accidents.

(3) Clause 10: Prevention of Accidents Caused by Electric Power Facilities

The electric power facilities shall be installed with proper measures for operators not to touch their moving parts, hot parts and other dangerous parts, and not to fall from them, accidentally.

For Article 3 Scope of Application

1. Explanation

Article 3 stipulates that all hydropower facilities and all related persons shall conform to the provision prescribed in SREPTSHP as the basic policy. On the other hand, Article 3 provides an intention to accept alternative technical contents other than those stipulated in SREPTSHP provided that such alternatives shall satisfy the fundamental requirements in SREPTSHP. Application of such alternative or additional technical contents required for judging the conformity of hydropower facilities to the fundamental requirements in SREPTSHP shall be examined in the project by project basis.

Furthermore, besides the provisions in this article, exemptions are provided in Article 10 to Article 12 so that enforcement of SREPTSHP may not obstruct stable electric power supply.

2. Reference

(1) GREPTS Clause 4: Enforcement
4.1 Jurisdiction

All persons who are related to electric power supply, electrical works, use of electricity, manufacturing electric power facilities, trading in the facilities in the Kingdom of Cambodia shall strictly follow the Technical Standards. The Technical Standards will not exempt any concerned conditions stipulated in any other law or Regulations even though the matters not stipulated in the Technical Standards.

For Article 4 Applicable Standards and Codes

There are no internationally unified technical standards or codes to regulate all elements of hydropower facilities, and developers and consultants may design the facilities based on the technical standards or codes accepted in their home country. Considering those situations, this article is provided.

In Article 4, general policy for applicable standards and codes is provided. If, such standards and/or codes, which may be proposed by the owner or developer or consultant of a hydropower project, are internationally recognized ones or equivalent with the international ones, such standards and codes could be accepted to use for hydropower facilities in the Kingdom of Cambodia as long as they comply with the provisions of SREPTSHP.

Chapter 2 Particular Provisions

Section 1 Requirements for Project Implementation

For Article 5 Assignment of Chief Engineers

This article is provided to clarify a person responsible for technical matters of hydropower facilities.

Table 5-1 Assignment of Chief Engineers

Process / Person in charge	Design	Construction	Operation and Maintenance
		▽ Commencement	▽ Commencement
MIME/EAC/EDC (when EDC is the signer of PPA)	5-1-(1), 5-2-(1)	5-1-(2), 5-2-(2)	
Owner	Report to the Authority	Report to the Authority	
Chief Engineer in charge of design	Handover		
Chief Engineer in charge of construction		Handover	
Chief Engineer in charge of operation and maintenance			

Note: Numbers in the third row correspond to an article and paragraph of SREPTSHP.
Example: 5-1-(1) means "Article 5, paragraph 1 (1)"

For Article 6 Environmental Protection

1. Explanation

In view of the environmental conservation, an owner intending to design, construct/rehabilitate, operate and maintain hydropower facilities shall comply with the environmental laws and regulations in the Kingdom of Cambodia, specifically Law on Environmental Protection and Natural Resources Management, Law on Protected Area, Sub-decree on Environmental Impact Assessment (EIA) Process, etc.

As provided in the Sub-Decree on Environmental Impact Assessment Process, an owner who plans and/or constructs a hydropower project with its output more than 1MW shall conduct an Initial Environmental Impact Assessment (IEIA) and submit the IEIA report to the Ministry of Environment (MOE) for approval. The owner shall submit a revised IEIA report or an Environmental Impact Assessment (EIA) report in answer to the MOE's request for approval.

According to the requirements under the environmental laws and regulations in the Kingdom of Cambodia, an owner shall conduct Environmental and Social Impact Assessment (ESIA) and submit a report to MOE for reviewing expected impacts before construction phase

2. References

(1) GREPTS Clause 14: Compliance with the Environmental Standards
To prevent the environmental pollution, the electric power facilities shall be in accordance with the environmental laws and regulations in the Kingdom of Cambodia.

(2) Sub-Decree on Environmental Impact Assessment Process, Ministry of Environment, 11 August, 1999

For Article 7 Order of Remedy for Conformance to Technical Standards

Provisions of this article shall be applied preserving the balance of public safety and stable electric power supply.

For Article 8 Obligation for Reporting

1. Explanation

This article is provided with for MIME, EAC and EDC (when EDC is the signer of PPA) to know the situation of hydropower facilities.

Table 8-1 Obligation for Reporting

Process / Person in charge	Design	Construction	Operation and Maintenance
		▽ Commencement	▽ Commencement
MIME/EAC/EDC (when EDC is the signer of PPA)	8-1	8-2,4	8-3 8-5,6
Owner	Examination Report	Examination Report	Report Report
Chief Engineer in charge of design	Handover		
Chief Engineer in charge of construction		Handover	
Chief Engineer in charge of operation and maintenance			

Note: Numbers in the third row correspond to an article and paragraph of SREPTSHP.
Example: 8-1 means "Article 8, paragraph 1"

2. Examples

(1) General

On the first page of every report to be submitted pursuant to the provisions stipulated in Article 8, name of hydropower station, name of dams, company name, and submission date of the report should be indicated. The contents which shall be described in the reports are, but not limited to, the following:

(2) Contents of the Reports and Rules

1. Construction Commencement Report

    1) Scheduled date of construction commencement
    2) Date and No. of the certificate of "Examination for Commencement of Construction"
    3) Name of owner

    Appendix-1: Copy of the certificate of "Examination for Commencement of Construction"
    Appendix-2: Documents which are used in the Examination for Construction of Construction

2. Operation Commencement Report

    1) Scheduled commencement date of operation
    2) Date and No. of the certificates of "Inspections on Dam Foundation", "Inspection prior to Initial Reservoir Impounding" and "Completion Inspection"
    3) Name of owner

    Appendix-1: Copy of the certificates of "Inspections on Dam Foundation", "Inspection prior to Initial Reservoir Impounding" and "Completion Inspection"
    Appendix-2: Documents which are used in "Inspections on Dam Foundation", "Inspection prior to Initial Reservoir Impounding" and "Completion Inspection"
    Appendix-3: Flood Management Rules (if a dam classified as "Large" or "Medium" is included in the facilities)

3. Accident Report

    1) Date and time of accident
    2) Name of hydropower station
    3) Summary of accident
    4) Explanation of accident
    5) Restore treatments
    6) Preventive measures

    Appendix-1: Location maps
    Appendix-2: Drawings describing accident
    Appendix-3: Photos describing accident

Appendix-4: Restore schedule

4. Flood Management Rules

1) General

Name of chief engineer of hydropower station assigned or to be assigned for operation and maintenance of civil structures and hydromechanical equipment, description of dams[1] and reservoir[2]

2) Rules of flood management of a dam

a. Flood control rules including water level control and spillway discharge control

b. Spillway gate operation rules including steps for discharging water from the dam, etc.

c. System and rule of warning for downstream area before discharging from spillway

3) Special rules during flood discharge

4) Supplementary Provisions

Appendix-1: Alert and notification tree in case of emergency

Appendix-2: Description of major alert and notification equipment

Appendix-3: Hydrological and meteorological observation systems (observation items, names and address of observation stations, specifications of observation equipment, observation frequency of each item, etc.)

Appendix-4: Items and observation frequencies of monitoring

Appendix-5: Flood routine calculations including hydrographs and reservoir storage curves

5. Report of Usual Monitoring Results

1) Organization chart for operation and maintenance
2) Rules of usual monitoring
3) Location maps and drawings of usual monitoring
4) Detailed records of usual monitoring
5) Records of major history of constructions and repairs
6) Daily record of reservoir water level
7) Sedimentation measurement results
8) Conditions of facilities

Inspection results of a dam body, dam abutments, slopes surrounding a reservoir, spillway gates, other major facilities

[1] Dam and spillway gates and valves; the height, width and crest level of the dam, the number of spillway gates and valves and the opening/closing speed of each spillway gate and valve, the design flood of the dam, etc.

[2] Catchment area, reservoir area, flood water level, normal high water level, low water level, effective capacity of the reservoir, the maximum discharge for power generation.

6. Report of Emergency Inspection Results

    1) Dates of emergency inspection
    2) Dates of prior inspections
    3) Description of the emergency situation
    4) Description of leakage and/or seepage water from a dam
    5) Description of cracks on the body and/or foundation of a dam
    6) Description of leakage and/or seepage water, cracks, slope failures and landslides on the abutment of a dam
    7) Description of leakage water from discharge facilities, obstacles which may harm the discharge functions of spillways, and reserve power systems
    8) Description of major topics in the previous inspections related to failure of facilities, if any
    9) Remarks related to the safety of dams, reservoirs and grounds surrounding them.

For Article 9 Safety and Technical Training

1. Explanation

This article is provided to oblige an owner to employ qualified engineers and/or technicians. The owner shall have his/her engineers and/or technicians who operate and maintain their civil structures, hydromechanical equipment and electrical facilities receive a concerned training program or course regularly to maintain their technical level.

The training programs or courses for the engineers and/or technicians or a system to certify engineers who received an acceptable training program or course shall be specified by a relevant authority for the purpose of Article 9.

2. Reference

(1) GREPTS Clause 4: Enforcement

4.3 Licensees of power utilities shall employ qualified electrical engineers or technicians as appropriated for supervision, operation and maintenance of the power facilities as provided in the Technical Standards and other regulations.

Section 2 Exemptions

For Article 10 Exemptions for Small Projects

1. Explanation

In most cases, micro scale hydropower facilities are constructed and operated for rural electrification in an isolated system, and a unit cost for construction, operation and maintenance is higher than larger scale hydropower facilities. If stop of electric power service does not affect a wide area but a limited area, a community or a village, and if a failure in the facilities would not damage public safety, technical requirements for the micro scale hydropower facilities may be eased. However, an owner shall try to do his utmost so that the facilities conform to the provisions in SREPTSHP.

2. Reference

(1) GREPTS Clause 29: Renewable Energy, Portable Generators and Small Hydro Generations

In General, the Technical Standards shall also applicable to renewable energy generating facilities including photovoltaic generation, wind power, bio-mass or bio-gas generation, portable generators and small hydropower generation including micro-hydro generation. However, some of the conditions of the clauses stipulated in the Technical Standards which may be difficult to be applied to such generating facilities because of special features of the facilities and/or the circumstances. Relaxation from these conditions may be allowed on application from the prospective owner with the reasons if it is judged reasonable.

For Article 11 Exemptions for Projects under Implementation

Application of SREPTSHP may force an owner to take time and additional expenses for design change in his/her hydropower facilities at design or construction stage. If basic specifications of hydropower facilities have been fixed when SREPTSHP is enforced, such facilities are exempted from SREPTSHP except for the provisions that does not affect to the conditions or agreements made between the relevant of authorities of the Royal Government of Cambodia including MIME/EAC/EDC (when EDC is the signer of PPA) and the owner of the project under implementation being effective at the time of enforcement of SREPTSHP.

For Article 12 Exemptions for Projects under Operation

1. Explanation

Application of SREPTSHP may force an owner to stop operation of his/her hydropower facilities and the stop of electric power service may affect social life and industries. Article 12 is provided to prevent SREPTSHP from affecting stable electric power supply by exempting the hydropower projects under operation at the time of enforcement of SREPTSHP provided that an occurrence of failure on the facilities would not damage public safety. However, an owner shall try to do his utmost so that the facilities conform to the provisions in SREPTSHP and shall modify such facilities harmful to public safety including natural environment in accordance with the provisions in Clause 5 of GREPTS.

2. Reference

(1) GREPTS Clause 5: Transitional Provision

1. The existing electric power facilities not harmful to human beings, animals and trees could be operated till the time of its renewal or replacement.
2. The existing electric power facilities harmful to human beings, animals and trees shall be modified within two years to be satisfactory with the requirements of the Technical Standards.

For Article 13 Exception of Exemptions

Article 13 is provided for the sake of ensuring the public safety taking into account of importance of monitoring and inspection and the reporting of their records to detect any symptom of failure on hydropower facilities especially civil structures which would damage public safety.

The above articles in Section 2 do not mean that an owner who operates and maintains hydropower facilities corresponding to Article 10 to Article 12 is exempted from all obligations of SREPTSHP. All owners shall conduct monitoring and inspections prescribed in Article 26 (Monitoring and Inspections) and report to EAC with a copy to MIME and EDC (when EDC is the signer of PPA) on the matters prescribed in Article 8 (Obligation for Reporting).

Part 2
Civil Structures and Hydromechanical Equipment

Chapter 3 General Provisions

For Article 14 Definitions

1. Dam body height

"Dam body height" is defined for each dam type as follows:

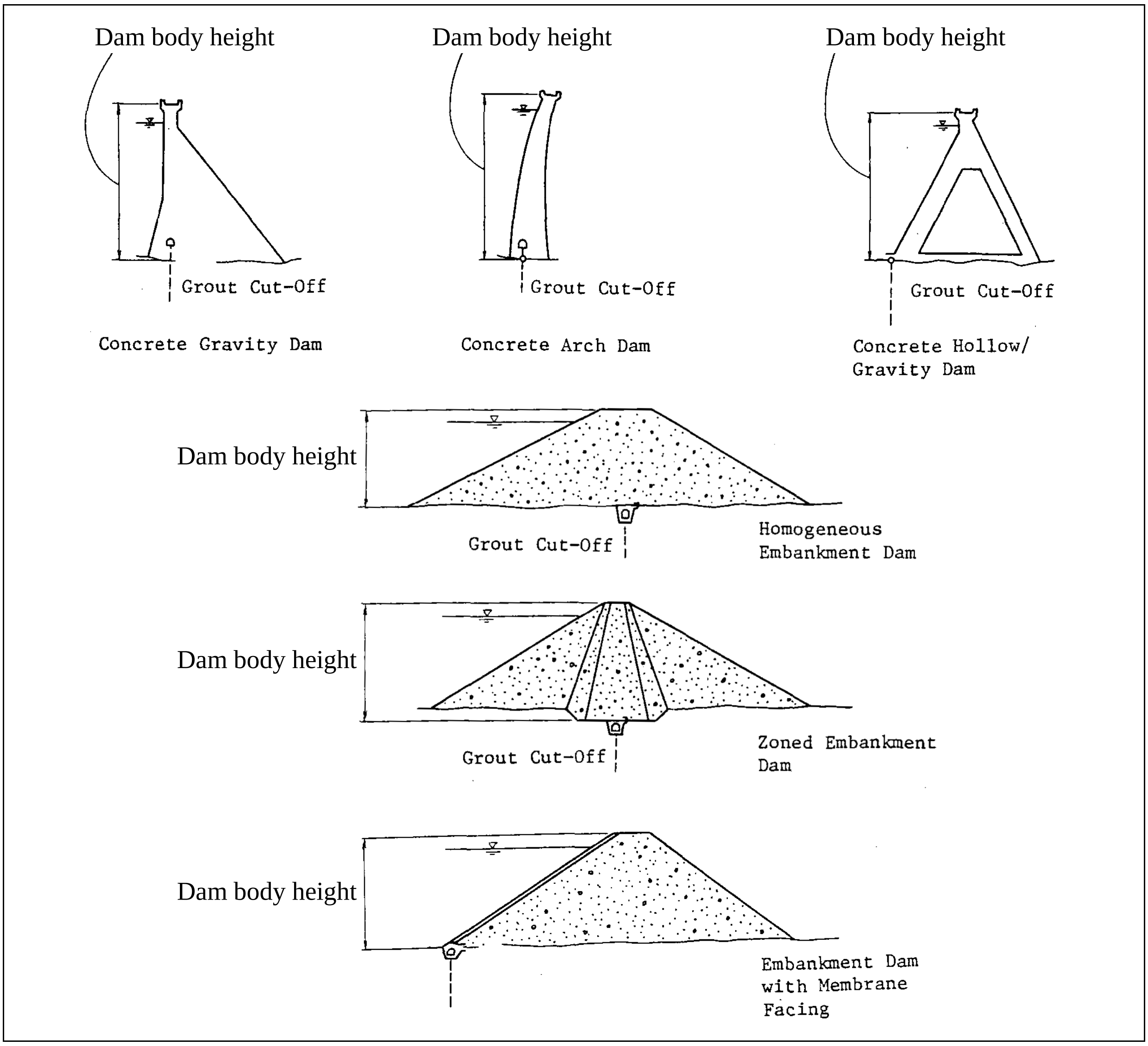


Fig. 14-1 Dam Body Height

2. Design flood

It is common to apply PMF, Probable Maximum Flood, to a design flood if reliable river discharge data, especially peak flood discharge, are not available.

3. ISO

There are no internationally unified technical standards or codes to regulate all elements of hydropower facilities. ISO standards relate to a part of technical requirements and test methods of materials, civil structures, electrical facilities, etc. which compose hydropower facilities.

4. Maximum credible earthquake (MCE)

"Maximum credible earthquake" is the greatest earthquake which can reasonably be expected to be generated by a specific source on the basis of seismological and geological evidence. The MCE is determined by means of deterministic seismic hazard analysis, and a common approach to define the corresponding earthquake loading at the site is based on the use of response spectral attenuation relationships. Using an attenuation relationship, it is possible to generate estimates of spectral ordinates based on the design earthquake magnitude and distance.

5. Maximum power discharge

Maximum power discharge is decided based on hydrological analyses and a type of a hydropower station.

In Japan, it is usual that maximum power discharge for a run-of-river type hydropower is a daily average river flow rate which does not fall below for 70 to 90 days in a year. It is desirable that river flow be measured for more than 10 years to estimate a hydrological trend of a river flow rate precisely.

6. Non-overflow section

See the explanation of Article 23 (Freeboard).

7. Operating basis earthquake (OBE)

"Operating basis earthquake" is an earthquake which can reasonably be expected to occur within the service life of the project, that is, with a 50% probability of exceedance during the service life. The associated performance requirement is that the project function with little or no damage, and without interruption of function. The OBE is determined by probabilistic seismic hazard analysis.

8. Target strength of concrete

See the explanation of Article 29 (Stress Conditions).

Chapter 4 Fundamental Requirements

For Article 15 Prevention of Overtopping from Non-overflow Sections of Dams

1. Commentaries

Paragraph 1 “sure”

When gates of the spillway are provided, the gates are operated by operators, electrical equipment and mechanical equipment. Therefore, these operations shall be implemented surely in terms of having reliable backup devices. Electrical and mechanical equipment shall also be installed surely, and gate operations shall be easy for operators to understand.

Paragraph 1 “safe”

When an inflow design flood is discharged over a spillway, it is important for the energy of flow to be dissipated so that the dam body, the spillway or surrounding facilities are not damaged.

2. Reference

(1) GREPTS Clause 26: Dams, Waterways, Powerhouses and Other Facilities
26.1 Prevention of Overflow from Non-overflow Sections of Dams

Every dam shall be equipped on or near its body with a spillway capable of safe and secure discharge of an inflow design flood, and every dam body shall have an adequate freeboard, in order to prevent overflow of water from non-overflow sections of the dam for dam safety.

Photograph 15-1 Overflow of Dam (Teton Dam Case in the USA)

For Article 16 Dam Stability

1. Commentaries

Paragraph 1 “required water-tightness”

Adequate impermeability means water tightness to ensure accepted water leakage volume and seepage velocity assumed by the design. It is established depending on the particular conditions of each dam.

Paragraph 1 “required strength”

A dam foundation shall have bearing capacity against various loads to be conveyed from a dam body. It is important for the settlement or deformation not to threaten the dam stability. The bearing capacity depends on each type and size of dam.

2. Reference

(1) GREPTS Clause 26: Dams, Waterways, Powerhouses and Other Facilities
26.2 Dam Stability

1. Dam bodies shall be stable for sliding, overturning, and have required strength and durability for dam stability. Fill dam bodies shall be stable for sliding, and have required strength and durability for dam stability.
2. Dam foundations and the contact areas between the dam body and its foundations shall be stable for sliding, and have the required strength for dam stability.

(2) 26.3 Prevention of Seepage Failure of Dams

1. Dam foundations shall have required water-tightness and seepage failure shall not occur in dam foundations.
2. Dam bodies shall have required water-tightness. Excessive uplifts shall not occur under concrete dam bodies. Seepage failure shall not occur in fill dam bodies.
3. Seepage failure shall not occur at the contact areas between a dam body and its foundations.

(3) 26.4 Prevention of Serious Deformations and Cracks of Dams

1. Dam foundations shall have the required bearing capacity.
2. Serious cracks shall not occur in concrete dam bodies.
3. Fill dam bodies shall be embanked with adequate materials in order to prevent serious settlement and cracks.

For Article 17 Prevention of Failure of Waterways

1. Commentaries

Paragraph 2 “safely” ”securely”

A waterway shall be so designed that inflow water discharge may not exceed the design value. Where gates or valves are used to control inflow volume, this electrical or mechanical equipment shall be operated securely.

Paragraph 3

Inflow of sand or silt particles into a waterway is inevitable. However, inflow of large amount of sand or silt particles which may deteriorate turbines shall be avoided.

Photograph 17-1 Inflow of Sand or Silt Particles into a Waterway

2. Reference

(1) GREPTS Clause 26: Dams, Waterways, Powerhouses and Other Facilities
26.5 Prevention of Failure of Waterways

1. Waterways shall be structurally stable for anticipated loads, and not be damaged by disasters such as a landslide and a flood.
2. Waterways shall be able to safely and securely discharge and control a design plant discharge, and be hydraulically stable.

For Article 18 Prevention of Failure of Other Structures

1. Reference

Photograph 18-1 Flooded Powerhouse (Nam Phao Hydropower Station Case in Lao PDR)

(1) GREPTS Clause 26: Dams, Waterways, Powerhouses and Other Facilities
26.6 Prevention of Failure and Damage of Powerhouses and Other Facilities

Structures related to hydroelectric power civil structures such as powerhouses, maintenance roads, and temporary facilities for construction works shall be stable for anticipated loads, and not suffer failure and damage due to a landslide and a flood.

For Article 19 Prevention of Damage to Ground surrounding a Reservoir

1. Commentaries

<u>"serious"</u>

A little water leakage due to the establishing of a reservoir is inevitable. However, water leakage which exceeds designed value which causes seepage failure of surrounding ground or damages the functioning of the reservoir shall be avoided.

<u>"serious damage"</u>

A little erosion due to the establishing of a reservoir is inevitable. However, large landslides which may cause a hydraulic bore and may damage areas surrounding the reservoir and downstream area such as that which occurred at the Vaiont Dam shall be avoided.

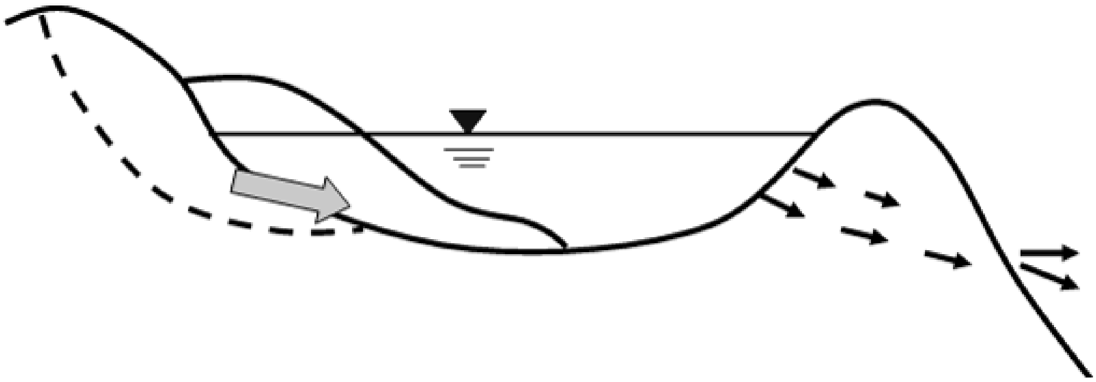


Fig. 19-1 Damage to the Area Surrounding the Reservoir

2. Reference

(1) GREPTS Clause 27: Prevention of Damage caused by Hydroelectric Power Plant
27.1 Prevention of Damage to Reservoirs and Ground around Reservoirs

1. Reservoirs shall not cause harmful water leakage to the surrounding ground, seepage failure of the ground, and large-scale landslides.
2. Proper measures shall be taken if submergences of properties such as houses and buildings may occur at upstream areas of a reservoir due to rises in water level caused by the reservoir sedimentation.

For Article 20 Prevention of Damage to Upstream and Downstream Areas

1. Commentaries

Paragraph 1 "aggravate"

It is impossible to prevent damage absolutely to downstream areas by a flood. However, when a flood occurs, damage caused by making outflow more than inflow shall be avoided.

Paragraph 2 "properties"

Houses, roads, fields and other public facilities

Paragraph 3 "appropriate measures"

Relocations of properties which have a possibility to be damaged or compensations for inundation.

Paragraph 3 "rapid"

Rapid changes of water level due to peak operation of a hydropower station are inevitable. But inconvenience, or damage to water utilization of downstream areas, or damage to revetments shall be avoided.

Paragraph 3 "appropriate measures"

Establishing a re-regulation pond, restriction of a peak operation, warning or notice to downstream areas, revetments of downstream river, etc.

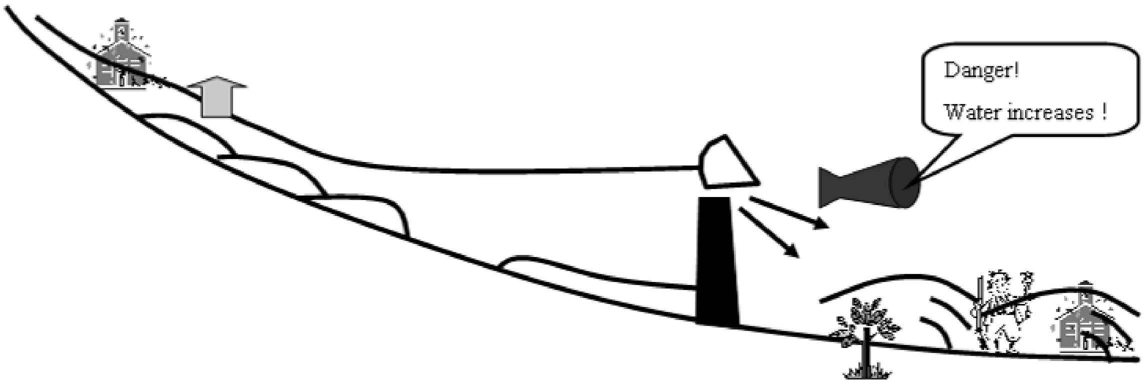


Fig. 20-1 Warning or Notice to Downstream Areas

2. Reference

(1) GREPTS Clause 27: Prevention of Damage caused by Hydroelectric Power Plant
27.2 Prevention of Damage to Downstream Areas of Dams and those of Outlets

1. Damage due to discharge from a dam to the downstream area under conditions of floods shall not increase in comparison with the damage of no dam existence)
2. Proper measures shall be taken if damage to humans or properties, and impacts on the surrounding environment and so on may occur at the downstream areas due to discharge from dams.
3. Proper measures shall be taken if a rapid change in water level at downstream area of an outlet due to discharge from a hydroelectric power plant may cause damage to the downstream area.

3. Explanations

Meteorological and hydrological measurement shall be conducted to clarify characteristics of river discharge in an ordinary state and during flood.

The owner shall establish meteorological and hydrological measurement stations and conduct their measurement if these stations are not located near the project site.

Measures shall be taken against the affected zone downstream of a dam or an intake according to advices of the approved EIA report

Chapter 5 Dams

Section 1 Common Rules

For Article 21 Design Flood

1. Explanations

In practice, Table 21-1 is considered as the dam classification.

Table 21-1 Dam Classification

		Gross reservoir capacity (Million m^3)		
		Less than 10	10 to 100	More than 100
Dam height (m)	Less than 15	Small	Medium	Large
	15 to 30	Small	Medium	Large
	Higher than 30	Medium	Large	Large

2. Commentaries

Paragraph 1 “appropriately” “sufficient”

There are not sufficient hydrological data in the Kingdom of Cambodia due to lack of flow gauging stations at major rivers. Most precipitation data have not been collected for long periods. So in order to get hydrological data, river discharge data at dam sites cannot help being made up by many run-off analyses based on presumptions. The run-off analyses have reliability and have been used in many past cases. And also many kinds of analyses are used.

It is desirable that river discharge during flood at a hydropower project site shall be measured to estimate flood hydrograph and peak discharge. When a hydropower project is planned, it is important to gauge river discharge even if the period between the plan and the construction is short.

Design flood is determined by the damage of the dam failure taking into account economical reasons.

It is necessary for large dams to establish PMF as it is common to apply PMF for design flood of most large dam projects in the world.

It is expected to be difficult to obtain enough hydrological data while estimating PMP, PMF and return period of flood because of a lack of hydrological data.

It is important to gauge discharge even if the period between the planning and the construction is short.

3. Reference

(1) Example of Japan

1. Concrete dams

The largest value shall be selected among the following methods:

1) A flood estimated to occur at a rate of once in 200 years
2) The maximum flood that has occurred at the dam site
3) The flood which is obtained by Creager's formula, i.e. $q = C \times A \times (A^{-0.05}-1)$.
   q: specific yield($m^3/s/km^2$), A: catchment area(km^2), C: location factor

2. Fill dams

1.2 times of a concrete dam

Source: Governmental Ordinance for Structural Standard for River Administration Facilities, Ministry of Land, Infrastructure, Transport and Tourism, Japan, July 20, 1976.

(2) Example of P.R. China

Table 21-2 Criteria for Project Ranking

Rank of projects	Storage capacity (100 MCM)	Ranking			
		Flood control		Irrigation	Installed capacity of hydropower station (MW)
		Town and industrial down to be prevented	Cultivated land area (10^4ha)	Irrigation land area (10^4ha)	
1	>10	Very important	>33.3	>10	>750
2	10~1	Important	33.3~6.67	10~3.33	750~250
3	1~0.1	Intermediate	6.67~2.0	3.33~0.33	250~25
4	0.1~0.01	Ordinary	20~0.33	0.33~0.03	25~0.5
5	0.01~0.001	–	<0.33	<0.03	<0.5

Note MCM : Million Cubic Meters

Source: Unified Design Standard for Reliability of Hydraulic Engineering Structures, GB-50199-94, P.R. China, Nov. 01, 1994.

Table 21-3 Criteria of Design Flood (Return Period to be Applied)

Rank of projects	Normal operation (design) (year)	Extreme operation (check) The dam failure shall not cause large damage.	
		Fill dam (year)	Concrete dam (year)
1	2,000～500	10,000	5,000
2	500～100	2,000	1,000
3	100～50	1,000	500
4	50～30	500	300
5	30～20	300	200

Source: Flood Control Standards, GB-50201-94, P.R. China, Jan. 01, 1995.

(3) Example of U.S. Army Corps of Engineers

Table 21-4 Size Classification

Category	Reservoir capacity ($10^6 m^3$)	Height of the dam (m)
Small	From 0.062 to 1.23	From 7.6 to 12.2
Intermediate	From 1.23 to 61.5	From 12.2 to 30.5
Large	>= 61.5	>= 30.5

Table 21-5 Hazard Potential Classification

Category	Loss of life (Extent of development)	Economic loss (Extent of development)
Low	None expected (No permanent structures for human habitation)	Minimal (Undeveloped to occasional structures or agriculture)
Medium	Few (No urban developments and no more than a small number)	Appreciable (Notable agriculture, industry or structures)
High	More than few	Excessive (Extensive community, industry or agriculture)

Table 21-6 Recommended Safety Standards

Hazard	Size	Safety standard
Low	Small	50-year to 100-year flood
	Intermediate	100-year to 50% of the PMF
	Large	50% to 100% of the PMF
Medium	Small	100-year to 50% of the PMF
	Intermediate	50% to 100% of the PMF
	Large	PMF
High	Small	50% to 100% of the PMF
	Intermediate	PMF
	Large	PMF

Source of Table 21-4 to 21-6: Engineering Regulation ER-1110-2-106, Recommended Guidelines for Safety Inspection of Dams, Appendix D, U.S. Army Corps of Engineers, Sept. 26, 1979.

(4) Example of Norway

Norway adopts a double design criterion:

The 1,000 year probable inflow flood is prescribed as design flood for normal operation of dam spillway system, while the stability of the dam is subject to the PMF.

(5) Example of Canada

Table 21-7 Criteria for Hazardous Level

	Loss of life	Economic, social and environment	Inflow design flood
Very high	Large increase expected	Excessive increase in economic social and/or environment	Probable maximum flood (PMF)
High	Some increase expected	Substantial increase in economic social and/or environment	Annual Exceedance probability between 1/1,000 to the PMF
Low	No increase expected	Low increase in economic social and/or environment	Annual Exceedance probability between 1/100 to the 1/1,000
Very Low	No increase	Small dams with minimal social, economic and/or environmental losses. Losses generally limited to the owner's property; damages to other property are accepted to society.	

For Article 22 Basic Water Levels

1. Necessity

There are many names of water levels such as High Water Level, Full Supply Level, Exceptional Operating Level, Maximum Water Level, etc.

This article standardizes the usage of these words and defines principal water levels for the reservoir.

2. Explanations

These water levels shall not be the water levels which are affected by the back water at upper reach areas and the velocity head in front of the spillways.

3. Commentaries

The conditions of "In the case that the storage effect of the reservoir is absolutely identified," are as follows:

1. The hydrograph of the design flood has reliability.
2. The water level when the design flood flows into the reservoir is known.
3. The operation rule of flood discharge is established.
4. The storage volume between flood water level and the water level at the time the inflow design flood flows into the reservoir is large.

Therefore, when the flood water level is established taking into account the storage effect of the reservoir, sufficient studies are required. In practicality,

1. There are no spillway gates. (Because the spillway gate operation is related with humans, electrical equipment and mechanical equipment, the possibility of error is inevitable.)
2. The water level when the design flood flows into the reservoir is obvious.

3. It is required that many features of floods such as duration, peak of inflow and total volume of flood are presumed, and discharge simulations from the dam are implemented.

For Article 23 Freeboard

1. Explanations

(1) The wave height caused by wind

The wave height due to wind is able to be determined by the S.M.B. Method. When the upstream face of a dam is nearly vertical, the height of a wave above the reservoir water surface becomes twice the half-wave height as shown in Fig. 23-1, i.e., the whole wave height; therefore, the calculation is to be made using the following formula as shown in Fig. 23-2.

$hw = 0.00086\ V^{1.1} \times F^{\ 0.45}$

Where,

V : 10-minute-mean wind velocity (m/s) [In general, 30 m/s or 20 m/s is adopted.]

F : Maximum fetch (m) measured from the dam at the design flood level.

Note: Fetch is the distance over which a wind blows.

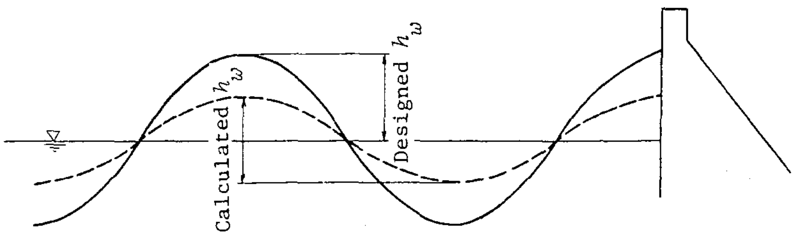


Fig. 23-1 Height of a Wave above the Water Surface of a Reservoir

When the upstream face is inclined as in the case of an embankment dam, the run-up height of the wave along the dam shall be considered, and the calculation is able to be made using Saville's Method.

Fig. 23-3 shows a diagram used for obtained the run-up height (R) inclusive of the wave height against the fetch and the wind speed. It was prepared by the combined use of the wave height obtained by the S.M.B. Method, and the inter-relation of the slope of the upstream face, slope protection materials, and the run-up height versus the wave height as derived from Saville's Method.

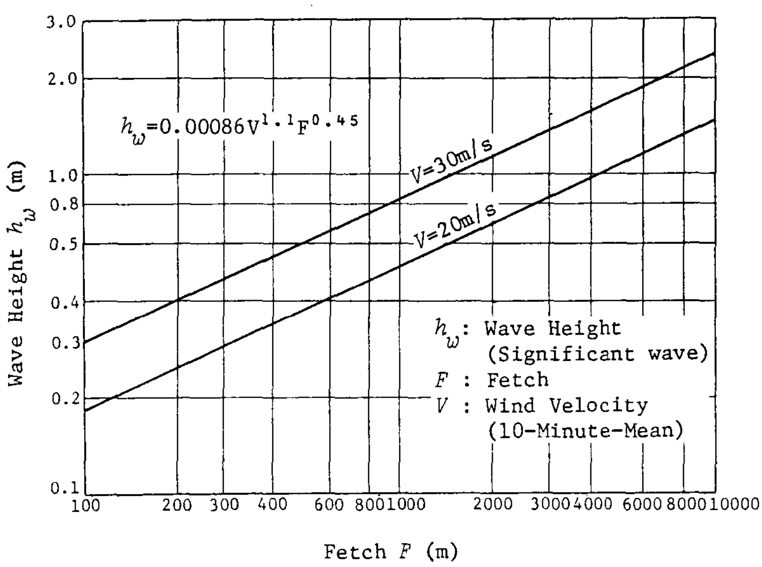


Fig. 23-2 Wave Height Obtained by the S.M.B. Method

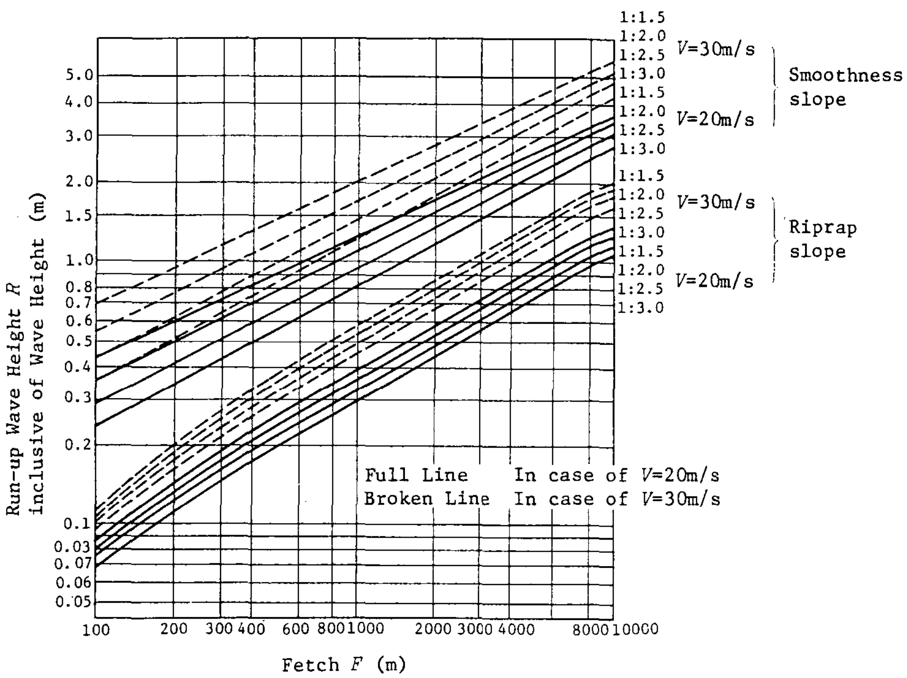


Fig. 23-3 Run-up Wave Height (Inclusive of Wave Height)
Obtained by a Combined Use of the S.M.B. Method and Saville's Method

(2) The wave height caused by earthquake

The calculation of the wave height due to seismic motion is able to be conducted using a formula after Seiichi Sato as follows:

$$he = (1/2) \times (K\tau/\pi) \times (gHo)^{0.5}$$

Where,

K : Design seismic intensity at the normal high-water level

τ : Seismic frequency (s) (Often taken as I sec.)

H_0 : Depth of reservoir (m) at the normal high-water level

g : Acceleration of gravity is 9.8 m/s^2

For instance,

he = 0.6 to 0.7m for K = 0.15,

τ = 1 sec,

H_0 = 60 to 100m.

For a fill dam, a crest of non-overflow section is a crest of an impervious zone, and not a dam crest. Generally, a crest of non-overflow section of a fill dam is covered with a pervious material to protect the impervious zone from rainwater and splashes of waves as shown in Fig. 23-4.

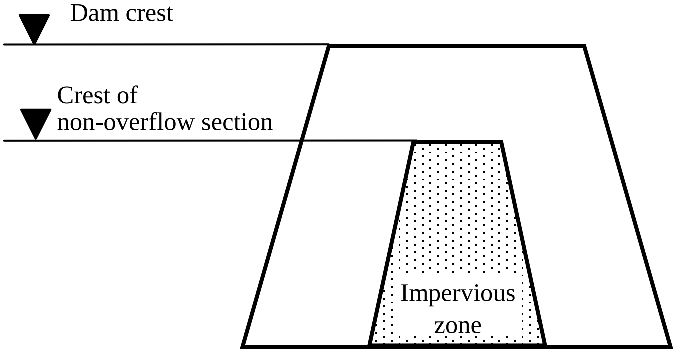


Fig. 23-4 Crest of Non-overflow Section of Fill Dam

2. Reference

(1) Examples of Japan

The height of the non-overflow section of the dam shall be higher than the sum of the highest of (1) the design flood water level, (2) the surcharge water level, or (3) the normal high water level and the freeboard required for each water level, where the freeboard is derived from the type of the dam and whether or not it has a spillway gate.

Freeboards are provided in the lower row of Table 23-1 to correspond with the categories of dams listed in the upper row of the table.

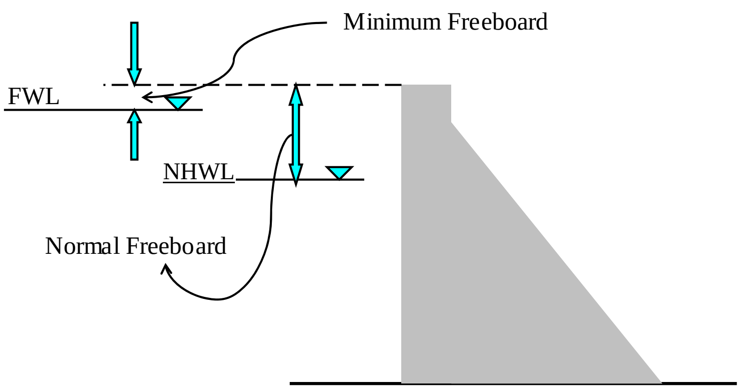


Fig. 23-5 Freeboard Corresponding to Basic Water Levels

Table 23-1 Criteria of Freeboard

Category	Water level	Gravity dam, hollow gravity dam, and arch dam		Fill dam	
Freeboard	normal high	$Hf = h_w + h_e + h_a$	where $H_f \geq 2$	$H_f = h_w + h_e + h_a + 1$	where $H_f \geq 3$
	surcharge	$Hf = h_w + \frac{h_e}{2} + h_a$	where $H_f \geq 2$	$H_f = h_w + \frac{h_e}{2} + h_a + 1$	where $H_f \geq 3$
	design flood	$Hf = h_w + h_a$	where $H_f \geq 1$	$H_f = h_w + h_a + 1$	where $H_f \geq 2$

[Note]

H_f is the freeboard (in units of m).

h_w is the height of waves caused by wind (in units of m).

h_e is the height of waves caused by an earthquake (in units of m).

h_a is the margin for a rise in a reservoir water level due to malfunction of spillway gate(s) and 0.5 m for dams with a spillway gate and 0 m for dams without a spillway gate.

The freeboard provided in Paragraph above can be changed from [$H_f \geq 3$] to [$H_f \geq 2$] for fill dams if they do not have a spillway gate and their overflow depth of water is less than 2.5 m when the flow of water discharged from the spillway flows down at the design flood water level.

(2) Examples of the USA

Table 23-2 Wave Heights by Fetch and Wind Velocity

Fetch (km)	Wind velocity (m/s)	Wave height (m)
1.6	22.5	0.8
1.6	33.8	0.9
2.5	22.5	1.0
2.5	33.8	1.1
2.5	45.0	1.2
5	22.5	1.1
5	33.8	1.3
5	45.0	1.5
10	22.5	1.4
10	33.8	1.6
10	45.0	1.8

Table 23-3
Normal Freeboard and Minimum Freeboard
(the least amount recommended)
in the case of an earth dam with ripraps

Fetch (km)	Normal freeboard (m) Wind velocity: 45m/s	Minimum freeboard (m) Wind velocity: 22.5m/s
Less than 1.6	1.2	0.9
1.6	1.5	1.2
4.0	1.8	1.5
8.0	2.4	1.8
16.1	3.0	2.1

For Article 24 Loads

Loads to be considered

Table24-1 Loads Imposed on Dam Bodies

<table>
<tr><th colspan="2" rowspan="2">Basic load condition</th><th colspan="3">Type of dam</th></tr>
<tr><th>Concrete gravity dam</th><th>Arch dam</th><th>Fill dam</th></tr>
<tr><td>Usual</td><td>Normal operating</td><td>• self-weight
• hydrostatic pressure at NHWL
• mud pressure
• uplift</td><td>• self-weight
• hydrostatic pressure
• mud pressure
• uplift
• thermal load</td><td>• self-weight
• hydrostatic pressure
• pore pressure</td></tr>
<tr><td rowspan="4">Unusual</td><td>Construction</td><td>• self weight
• empty reservoir</td><td></td><td>• self weight
• pore pressure, ,and
• empty reservoir</td></tr>
<tr><td>Flood</td><td>• self-weight
• hydrostatic pressure at FWL
• mud pressure
• uplift</td><td>• self-weight
• hydrostatic pressure at FWL
• mud pressure
• uplift
• thermal load</td><td>• self-weight
• hydrostatic pressure at FWL
• pore pressure</td></tr>
<tr><td>Normal operating with OBE</td><td>• self-weight
• hydrostatic pressure*
• hydrodynamic pressure*
• horizontal earthquake acceleration in downstream direction
• mud pressure
• uplift*</td><td>• self-weight
• hydrostatic pressure*
• hydrodynamic pressure*
• mud pressure
• uplift*
• thermal load
• dynamic OBE load</td><td>• self-weight
• hydrostatic pressure*
• horizontal earthquake acceleration
• pore pressure</td></tr>
<tr><td>Construction with OBE</td><td></td><td>• self weight
• empty reservoir
• thermal load
• dynamic OBE load</td><td></td></tr>
<tr><td rowspan="3">Extreme</td><td>Construction with OBE</td><td>• self weight
• horizontal earthquake acceleration in upstream direction
• empty reservoir</td><td></td><td></td></tr>
<tr><td>Normal operating with MCE</td><td>• self-weight
• hydrostatic pressure*
• hydrodynamic pressure*
• horizontal earthquake acceleration in downstream direction
• mud pressure
• uplift*</td><td>• self-weight
• hydrostatic pressure*
• hydrodynamic pressure*
• mud pressure
• uplift*
• thermal load
• dynamic MCE load</td><td></td></tr>
<tr><td>PMF</td><td>• self-weight
• hydrostatic pressure at PMF
• mud pressure
• uplift</td><td>• self-weight
• hydrostatic pressure at PMF
• mud pressure
• uplift and
• thermal load</td><td></td></tr>
</table>

*: The reservoir water level shall be selected as the one which occurs relatively frequently during the course of the year.
Note: Loads in the above table act statically except annotated.

It is possible that arch dams have minimum safety factor against sliding failure for the following conditions.

- The reservoir water level is at LWL or less than that due to some circumstances; and
- The seismic force acts in the upstream direction.

It is possible that fill dams have minimum safety factor against sliding failure at the intermediate reservoir water level between NHWL and LWL.

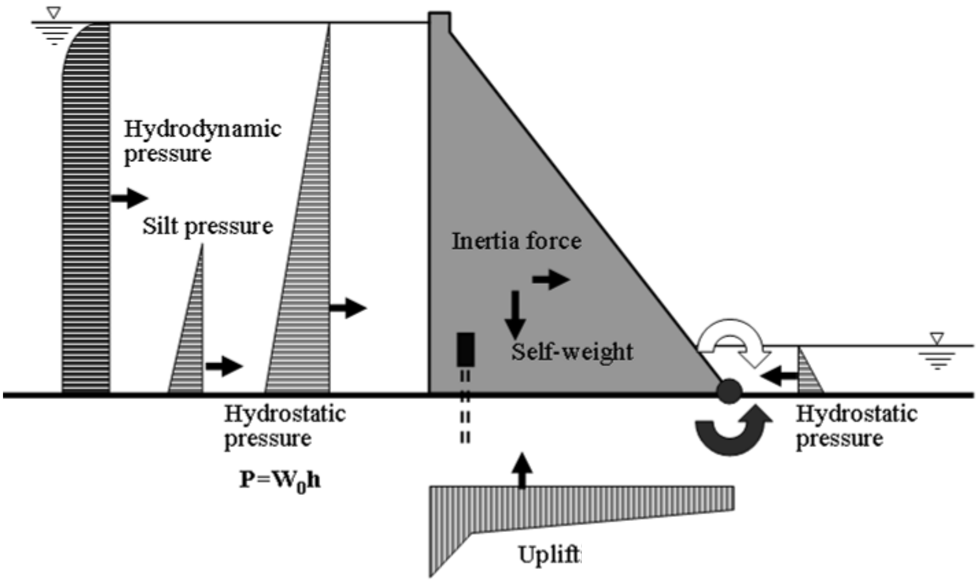


Fig. 24-1 Typical Loads Acting on a Dam Body

Table 24-2 Basic Definition of Loads

Loads	Formula		
Self-weight	Based on unit weights of the dam body materials		
Hydrostatic pressure	$P = W_0h$	P W_0 h	: Hydrostatic pressure : Unit weight of water : Depth of water including wave height
Uplift	Based on the condition of foundation treatment and location of drains $Ux = W_0Hx$	 Ux Hx	 : Uplift pressure at location x : Depth of water at location x
Silt pressure	$P_e = C_eW_0d$	P_e C_e d	: Horizontal silt pressure : Silt pressure coefficient : Thickness of silt
Seismic force	$I = Wk$	I W k	: Inertial force of the dam body during an earthquake : Self weight of a dam body : Design seismic coefficient
Hydrodynamic pressure	$P_d = 0.875W_0k(Hh)$^0.5	P_d W_0 k h H	: Hydrodynamic pressure : Unit weight of water : Design seismic coefficient : Depth of water from reservoir water surface to foundation bed : Depth of water from reservoir water surface to the point of action of hydrodynamic pressure

Paragraph 2 Uplift

1. Explanation

The coefficient of uplift depends much on the construction work and deterioration in the function of drainage system during operation as shown in Table 24-3 and Fig. 24-3. The reliability of drains is relatively low, especially in a small hydropower station. Therefore, the coefficient of uplift shall not be mentioned as a standard, but rather mentioned as a reference although the Japanese standards allow deduction of uplift downstream from drains as shown in Fig. 24-2.

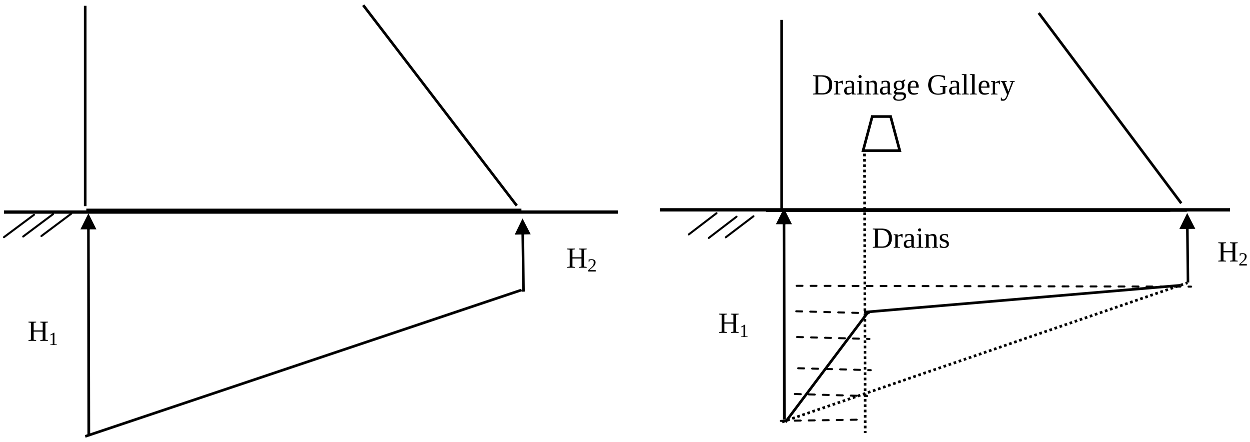


Fig. 24-2 Expected Function of Drains

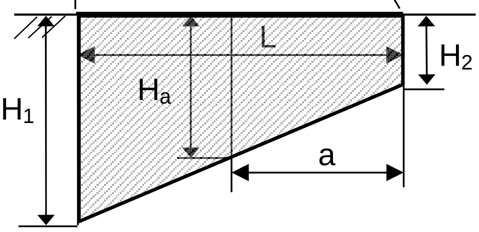
Table 24-3 Uplift under Various Conditions

Foundation Condition	Uplift: at Up-stream End	Uplift: at Drains	Uplift: at Down-Stream End
Horizontal cross section without drains		—	
Horizontal cross section with drains		When $H_4 \geq H_2$ $H_3 = (1-E) \times (H_1-H_4) \times \frac{L-X}{L} + H_4$ When $H_4 < H_2$ $H_3 = (1-E) \times (H_1-H_2) \times \frac{L-X}{L} + H_2$	
Horizontal cross section with drains near upstream end	H_1	When $X \leq 0.05H_1$ If $H_4 \geq H_2$ $H_3 = (1-E) \times (H_1-H_4) + H_4$ If $H_4 < H_2$ $H_3 = (1-E) \times (H_1-H_2) + H_2$	H_2
Horizontal cross section cracked base with drains, zero compression zone not extending beyond drains		$T \leq X$ When $H_4 \geq H_2$ $H_3 = \left[(H_1-H_4) \times \frac{L-X}{L-T} + H_2-H_4\right] \times (1-E) + H_4$ When $H_4 < H_2$ $H_3 = \left[(H_1-H_2) \times \frac{L-X}{L-T}\right] \times (1-E) + H_2$	
Horizontal cross section cracked base with drains, zero compression zone extending beyond drains		$T > X$ $H_3 = H_1$	

Where,

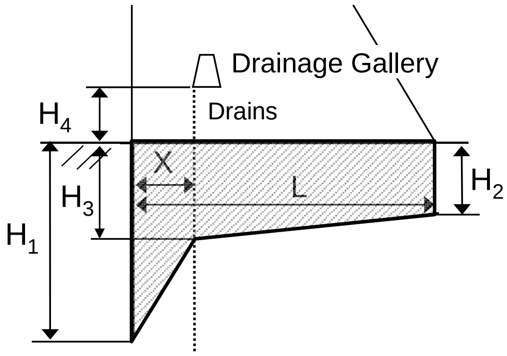
- H_1 : Upstream water depth
- H_2 : Downstream water depth
- H_3 : Uplift at drains
- H_4 : Height of gallery from dam base
- X : Distance of drains from upstream end of dam base
- L : Base length of dam body
- E : Drain effectiveness expressed as a decimal
- T : Zero compression length

$$H_a = H_2 + \frac{a}{L} \times (H_1 - H_2)^*$$



* The uplift in this table is calculated with a proportional method.

1. Without foundation drains



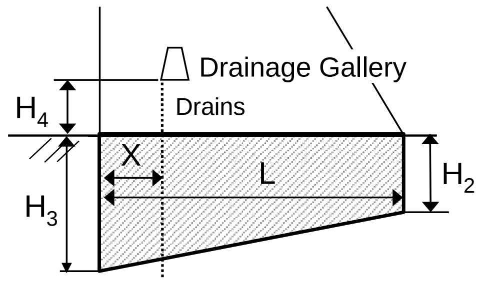
When $H_4 \geq H_2$

$$H_3 = (1-E) \times (H_1 - H_4) \times \frac{L-X}{L} + H_4$$

When $H_4 < H_2$

$$H_3 = (1-E) \times (H_1 - H_2) \times \frac{L-X}{L} + H_2$$

2. With drains



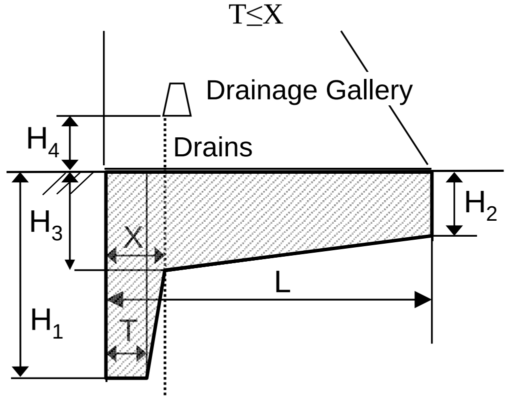
When $X \leq 0.05H_1$

If $H_4 \geq H_2$ $\quad H_3 = (1-E) \times (H_1 - H_4) + H_4$

If $H_4 < H_2$ $\quad H_3 = (1-E) \times (H_1 - H_2) + H_2$

3. With drains near upstream end

T≤X



When $H_4 \geq H_2$

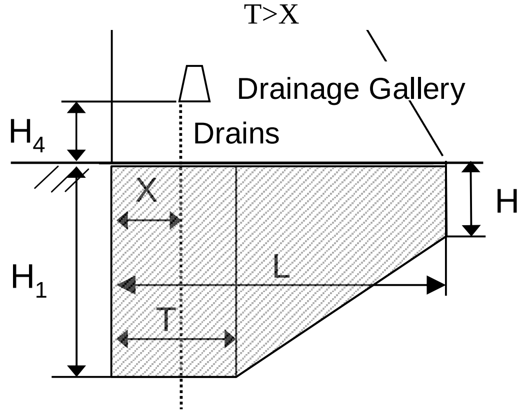
$$H_3 = \left[(H_1 - H_4) \times \frac{L-X}{L-T} + H_2 - H_4 \right] \times (1-E) + H_4$$

When $H_4 < H_2$

$$H_3 = \left[(H_1 - H_2) \times \frac{L-X}{L-T} \right] \times (1-E) + H_2$$

4. Cracked base with drains, zero compression zone not extending beyond drains

T>X



(Note) Drain effectiveness depends on depth, size, and spacing of the drains; the character of the foundation; and the facility with which the drains can be maintained.

5. Cracked base with drains, zero compression zone extending beyond drains

Source: Engineer Manuals EM 1110-2-2200, Gravity Dam Design, pp 3-4 to 3-5, U.S. Army Corps of Engineers, 30 June, 1995

Fig. 24-3 Distribution of Uplift along Dam Base

2. Example of Actual Condition

(1) Nam Ngum Dam in Lao PDR

Table 24-4 Example of Uplift Distribution Applied in the Actual Design

Description	Uplift		
	Upstream end	Drains or joint area between upstream and downstream ends	Downstream ends
Section with drains	H_1	$H_2 + 1/3 \times (H_1 - H_2)$	H_2
Section without drains	H_1	$H_2 + 3/5 \times (H_1 - H_2)$	H_2

3. Reference

(1) the USA

Actual uplifts measured in the dam foundations of existing dams are as follows:

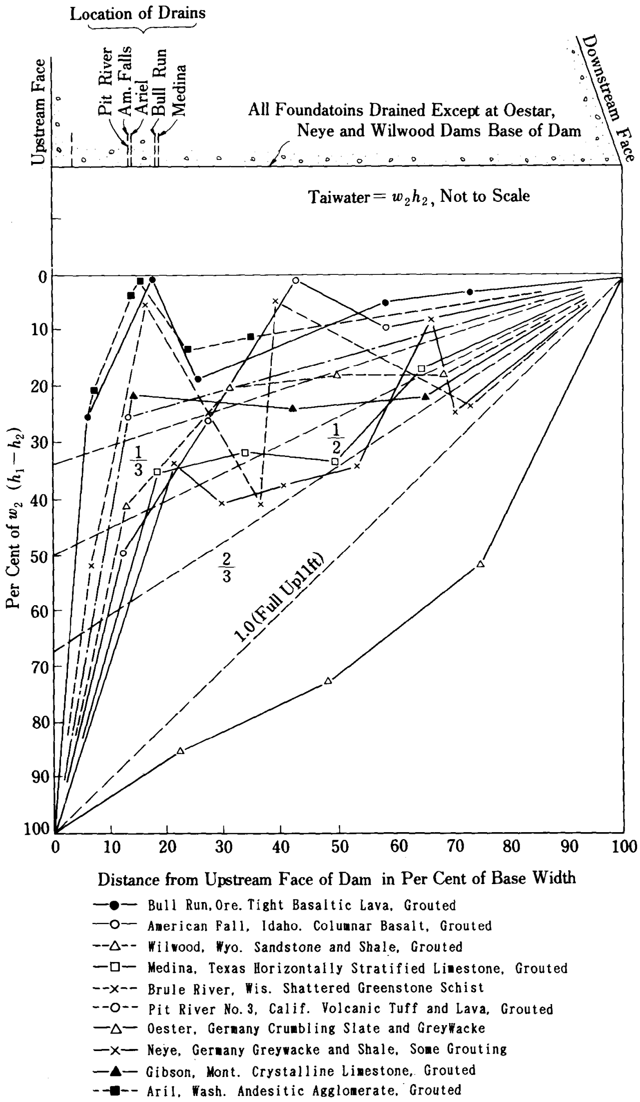


Fig. 24-4 Uplift Distribution in Dam Foundations of Gravity Dams (Uplift in Masonry Dams)

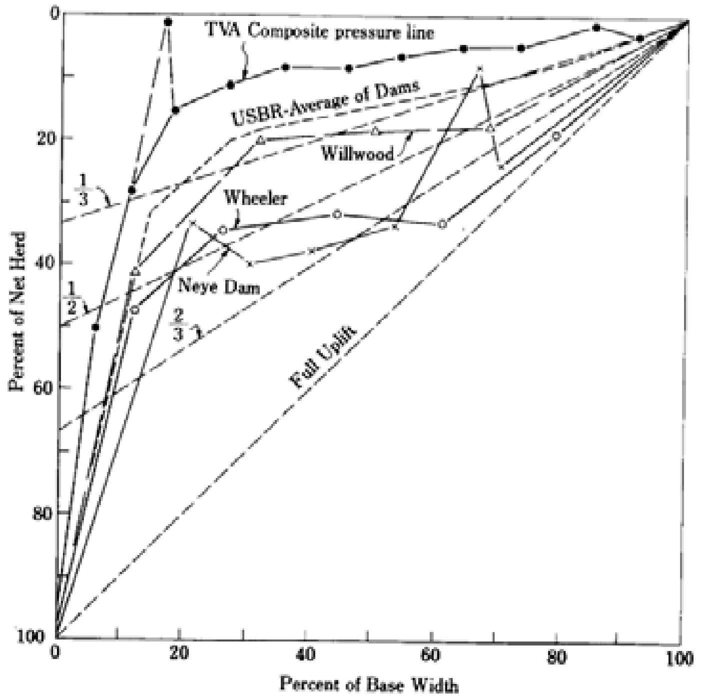


Fig. 24-5 Uplift Distribution in Dam Foundations of Gravity Dams completed by U.S. Bureau of Reclamation after 1930 (1) (Uplift in Masonry Dams)

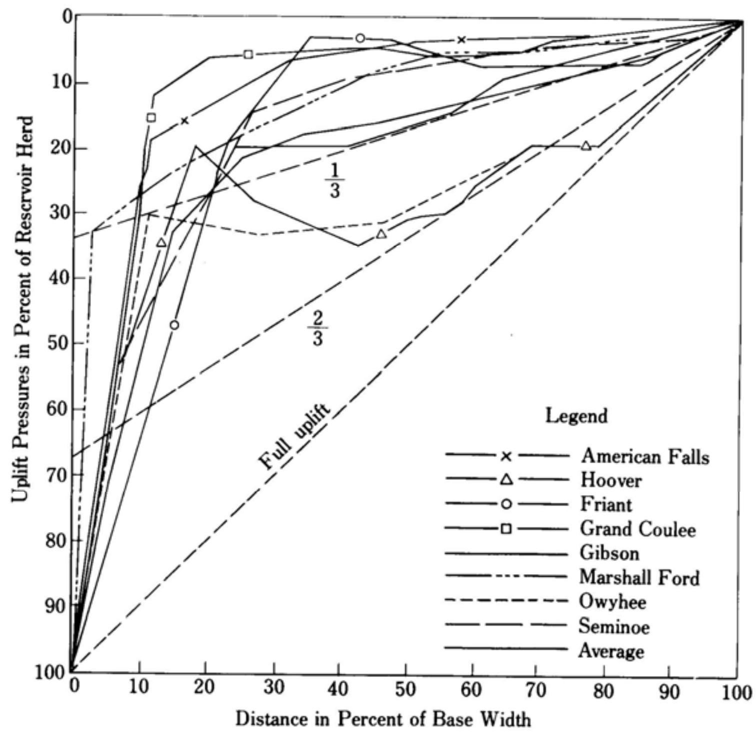


Fig. 24-6 Uplift Distribution in Dam Foundations of Gravity Dams completed by U.S. Bureau of Reclamation after 1930 (2) (Uplift in Masonry Dams)

(2) Japan

Uplift coefficients, adopted in the dam stability analysis in Japan, are as follows:

Table 24-5 Uplift Coefficients Constructed before 1945

Dam	Dam height (m)	Completion of construction	Uplift coefficient				
			In dam body		Contact face		
			Upstream	Down-stream	Up-stream	at Drains	Down-stream
Komaki	79.2	1930	0.2	0	0.66		0
Tsukabaru	87	1938	0.3	0	0.4		0
Miure	83.2	1945	0.3	0	0.5		0

Table 24-6 Uplift Coefficients Constructed before 1965

Dam	Dam height (m)	Completion of construction	Uplift coefficient				
			In dam body		Contact face		
			Upstream	Down-stream	Up-stream	at Drains	Down-stream
Miomote	82.5	1953	0.40	0	0.40	-	0
Tase	81.5	1954	0.33	0	0.50	-	0
Ikari	112.0	1956	0.33	0	1.00	0.33	0
Miyagawa	88.5	1956	0.30	0	0.40	-	0
Sakuma	155.5	1956	0.35	0	1.00	0.35	0
Nagase	87.0	1956	0.33	0	1.00	0.33	0
Ogochi	149.0	1957	0.66	0	0.66	0.33	0
Sarutani	74.0	1957	0.20	0	0.40	-	0
Fujiwara	95.0	1957	0.33	0	0.33	-	0
Sasaogawa	76.0	1957	0.30	0	0.40	-	0
Miwa	69.1	1959	0.35	0	0.40	-	0
Tagokura	145.0	1959	0.33	0	1.00	0.40	0.2
Ichifusa	78.5	1959	0.35	0	0.40	-	0
Arimine	140.0	1959	0.35	0	1.00	0.20	0
Okutadami	157.0	1960	0.30	0	1.00	0.20	0

Table 24-7 Uplift Coefficients Constructed after 1965

Dam	Dam height (m)	Completion of construction	Uplift coefficient				
			In dam body		Contact face		
			Upstream	Down-stream	Up-stream	at Drains	Down-stream
Tsuruta	117.5	1965	0.33	0	1.0	0.20	0
Kanno	87.0	1965	0.33	0	1.0	0.20	0
Shimokubo	129.0	1968	0.3	0	1.0	0.25	0
Midorikawa	76.5	1970	0.35	0	1.0	0.20	0
Matsubara	83.0	1972	0.4	0	1.0	0.20	0
Ishitegawa	87.0	1972	0.33	0	1.0	0.20	0
Kusaki	140.0	1976	0.3	0	1.0	0.20	0
Sameura	106.0	1977	0.33	0	1.0	0.20	0
Hayadegawa	82.5	1979	0.33	0	1.0	0.25	0
Ohishi	87.0	1980	0.33	0	1.0	0.33	0
Nomura	60.0	1981	0.33	0	1.0	0.20	0
Shimajigawa	89.0	1981	0.3	0	1.0	0.30	0
Aha	86.0	1982	0.33	0	1.0	0.20	0
Hitokura	75.0	1983	0.33	0	1.0	0.20	0
Ikimigawa	90.0	1984	0.3	0	1.0	0.30	0

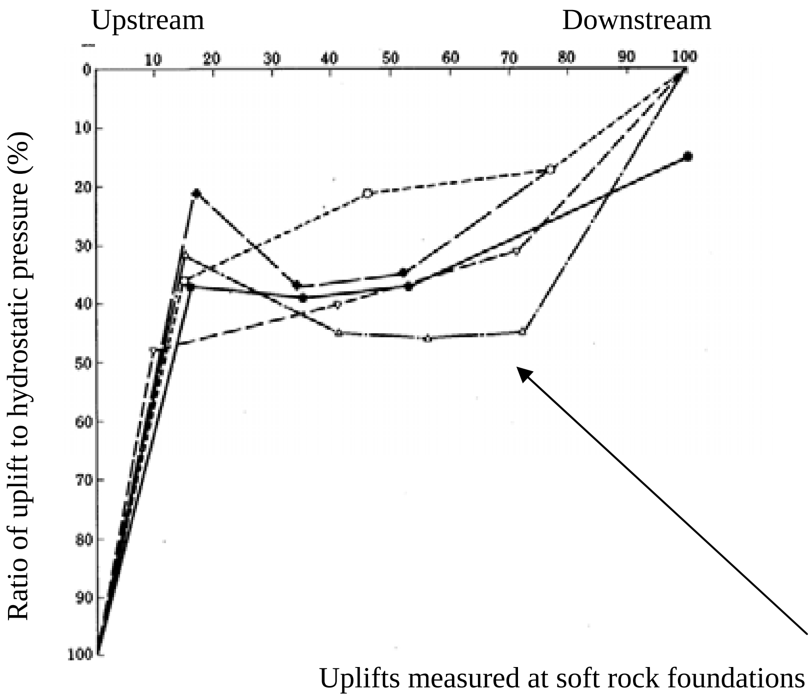


Fig. 24-7 Uplifts Measured at Soft Rock Foundations

Paragraph 3 Seismic Force

1. Necessity

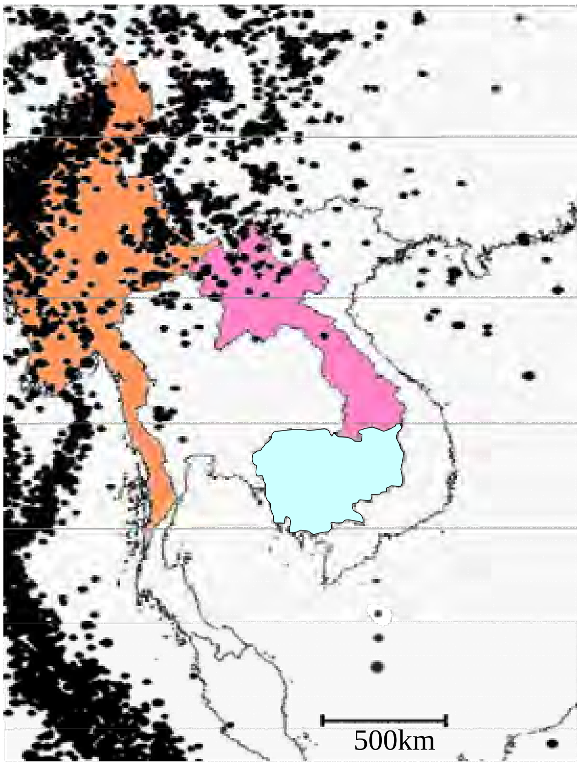
There are no seismic records or seismometers in the Kingdom of Cambodia. However, fortunately, there have been hardly any earthquakes in the Kingdom of Cambodia. Accordingly, SREPTSHP mentions the necessity of consideration of seismic forces.

2. Commentaries

See Article 14 “4. Maximum credible earthquake (MCE)” and “7. Operating basis earthquake (OBE).”

3. Reference

(1) Seismicity distribution map in the South East Asia and the neighboring area for seismic design



Source: International Seismological Centre (U.K.)

Fig. 24-8 Major Earthquakes Occurred in South-East Asia (1904 - 1996)

A severe earthquake zone exists in the northern part of Lao PDR and Myanmar. However, the entire area of the Kingdom of Cambodia is in the area with very small danger of gigantic earthquakes.

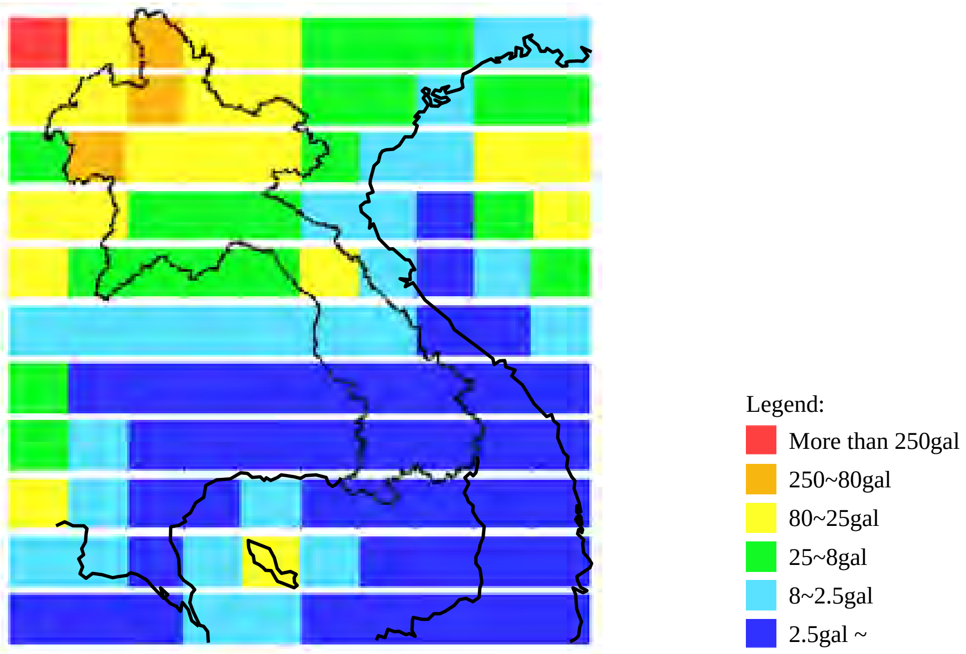
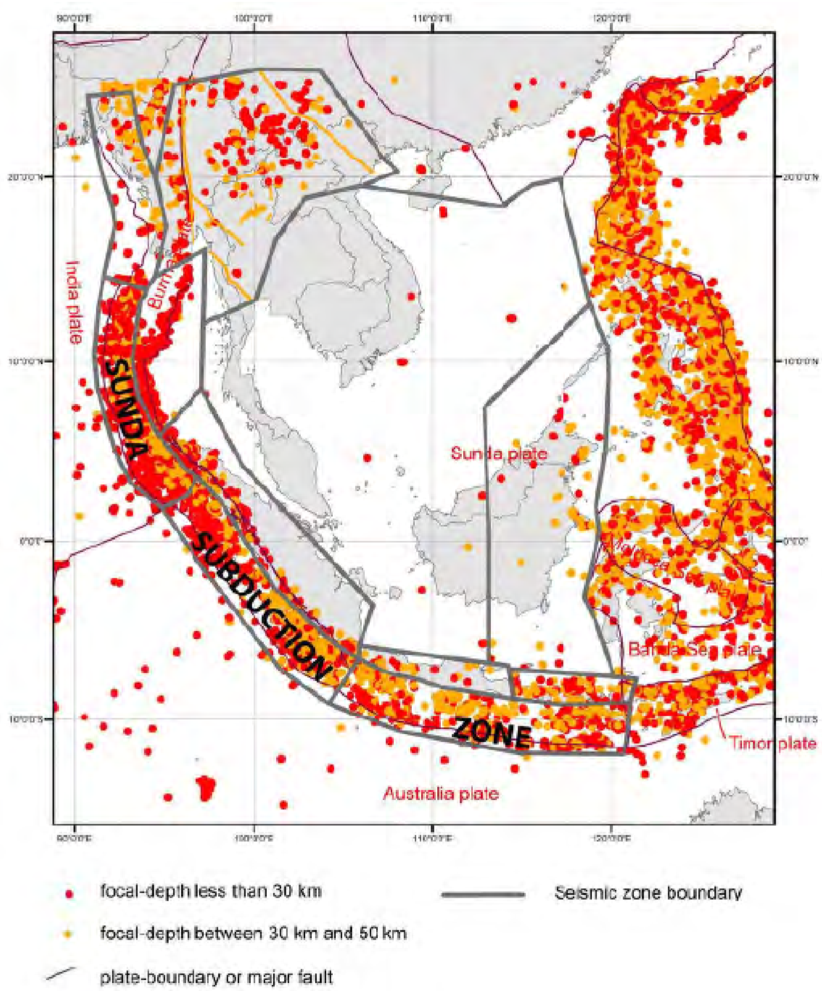


Fig. 24-9 Earthquake Acceleration Distribution Map Classified by Area

According to the distance attenuation for earthquakes (ISC:1904-1996) which occurred in the radius of 200km for every one latitude and longitude, the territory of the Kingdom of Cambodia is in a low maximum earthquake acceleration zone of less than 8 gal except one point in the range from 80 to 25 gal.

Note: The attenuation of vertical peak acceleration used for figure creation is computed by the 'Joyner & Boore formula' with globally high operating frequency.

The Kingdom of Cambodia is located on the tectonic plate named Sunda Plate. The northern boundary of the plate is relatively quiescent compared with the eastern, southern, and western boundaries which are tectonically complex and seismically active. As shown in Fig.24-10, there has been no earthquake in the whole of the Kingdom of Cambodia for the period of 1964 to 2005.



Source: Documentation for the Southeast Asia Seismic Hazard Maps, USGS, September, 2007

Fig. 24-10 Seismic Hazard Map of Southeast Asia

Based on the technical standards in the neighboring countries and the regional seismological and geological data, it is estimated that the Kingdom of Cambodia belongs to a minor seismic zone. Accordingly, the seismic coefficients shown in Table 24-8 are proposed, based on the expected earthquake acceleration level in the Kingdom of Cambodia and also referring to the technical standards in the neighboring countries, for the pseudo static method of analysis that may be performed in the feasibility study for dams to be constructed in the territory of the Kingdom of Cambodia. It shall be noted, however, that application of the pseudo static method shall be limited to the design of dams performed in the feasibility stage or prior and shall not allowed for the final design of dams in principle.

Table 24-8 Seismic Coefficients in Cambodia

Zones of earthquake acceleration level	Concrete gravity dam	Arch dam	Fill dam	
			Homogeneous dam (Earth fill dam)	Rock fill dam
Minor (below 8gal)	0.06	0.12	0.07	0.06

Here, the estimated seismic coefficients for each zone of earthquake acceleration level and the examples in the neighboring area are shown in Table 24-9 and Table 24-10.

Table 24-9 Estimated Seismic Coefficient by Zone of Earthquake Acceleration Level and Examples in Neighboring Area

Zones of earthquake acceleration level	Concrete gravity dam	Arch dam	Fill dam	
			Homogeneous dam (Earth fill dam)	Rock fill dam
Severe (250~80gal)	0.12	0.24	0.15	0.15
Middle (80~25gal)	0.12 (Theun Hinboune: 0.12)	0.24	0.15	0.12
Moderate (25~8gal)	0.10 (Nam Ngum:0.03)	0.20	0.12	0.10 (Nam Leuk: 0.10)
Minor (below 8gal)	0.06 (Xeset: 0.07)	0.12	0.07 (Houay Ho: 0.10)	0.06

( ) adopted coefficient

Table 24-10 Examples of Seismic Coefficient Adopted to the Dams in the Neighboring Country

Name	Adopted seismic coefficients
Nam Ngum	0.03
Nam Leuk	OBE (“Operating Basis Earthquake”): 0.02 MCE (“Maximum Credible Earthquake”): 0.1
Xeset	0.07
Theun Hinboune	Horizontal direction: 0.12（1/1,000years） Vertical direction: 0.06
Houay Ho	Unusual Condition: 0.02 Extreme Condition: 0.1

Note: There are no cases which implemented dynamic analyses for check the dam stability.

For Article 25 Dam Foundations

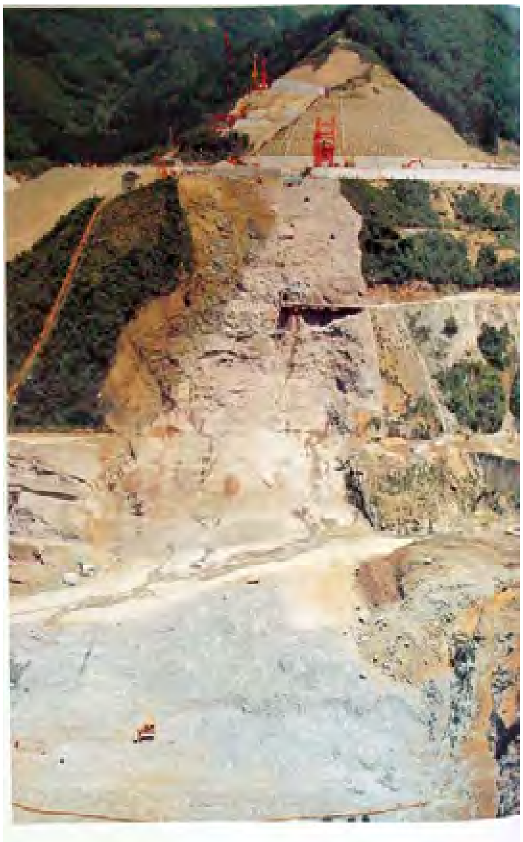
1. Necessity

This article mentions only fundamental and common matters such as strength, deformation and fault treatments. Particular matters for each type of dams are mentioned in each article.

2. Commentaries

Paragraph 1 “appropriate”

Geological surveys consist of drilling, adit excavation, Lugeon tests, strength tests, etc. It is important to identify distribution and properties of weak strata, and strength and permeability of foundations.



Photograph 25-1 Foundation of Dam

Paragraph 2 “required”

A dam foundation shall have a bearing capacity to support loads which is transmitted from a dam body. The settlement and the deformation shall not threaten the dam stability.

Paragraph 2 “serious”

A little settlement, a few cracks or a little erosion at faults is inevitable and treatment cannot improve weak strata entirely. However, excessive settlement, cracks or erosion which threatens the dam stability shall be avoided.

Paragraph 3

If it is judged that the natural permeability of a dam foundation cannot secure the stability to satisfy requirements of Article 16 (Dam Stability), measures such as grouting or drainage shall be taken.

The actual cases of geological survey are as follows:

3. Explanations

Paragraph 1 Geologic investigation

(1) Outline

The process from planning to operation and maintenance of hydropower projects is classified into (1) investigation and planning, (2) design, (3) construction and (4) operation and maintenance stages as shown in the following flow chart.

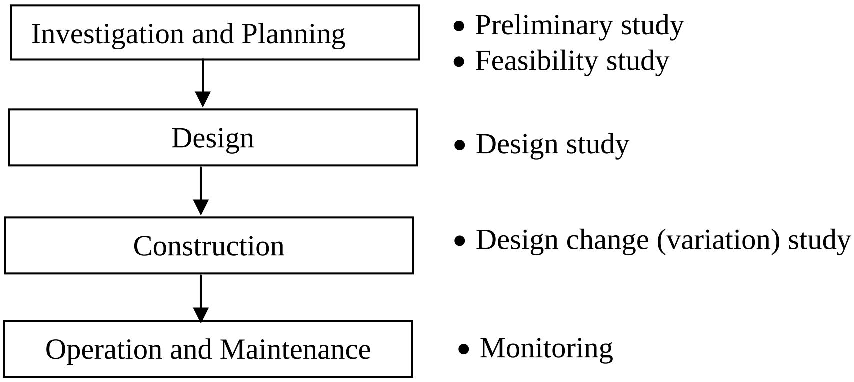


Fig. 25-1 Implementation Stages and Activities for a Project

In advancing the investigation and study, the general method is to upgrade the quality of the work gradually while considering the work efficiency and cost efficiency. For example, in the preliminary study stage, easily obtainable 1:50,000 to 1:100,000 scale maps are used to make plans for several sites. Highly accurate topographic maps of 1:1,000 to 1:5,000 scale are then produced for those promising sites from economic and technical point of view. Geologic surveys by drilling and so on at the dam site are done accordingly. On the results of these investigations, feasibility study is executed at the selected dam site in detail based on the topographic maps of 1:1,000 to 1:5,000 scale.

Table 25-1
Geological Investigations Implemented for Design of the Hydropower Stations in Japan

Dam	Type	Comp. Year	Dam height (m)	Crest length (m)	Seismic prospecting		Drilling		Horizontal adit excavation		Vertical adit excavation	
					Lines	Total Length (m)	Q'ty	Total length (m)	Q'ty	Total length (m)	Q'ty	Total length (m)
Tsuruta	G	1965	118	488			94	2,346	18	759	3	60
Sonohara	G	1965	86	127	27	1,500	23	374	15	202	0	0
Shiroyama	G	1965	75	260			110	3,083	20	317	0	0
Shizunai	G	1966	66	208			15	256	6	84	0	0
Shimokubo	G	1968	129	626	38	9,440	45	1,330	87	2,226	0	0
Shijushida	G	1968	50	480			61	3,762	3	160	3	45
Toyofusa	G	1969	38	115			33	482	3	60	3	12
Eigenji	G,F	1969	68	338			39	1,019	11	571	1	11
Tamagawa	G	1970	56	260			40	791	11	405	0	0
Yahagi	G	1970	38	149			28	910	5	390	0	0

(2) Investigation and Planning (Preliminary study, Feasibility study)

1) Purposes of the investigations

- Feasibility of the dam construction
- Study of alternatives
- Study of the scale, type and so on of the dam

2) Outputs through the investigations

- Outline of geological structure surrounding of the dam site
- Rock characteristic
- Hydro-geological characteristic
- Characteristic of the ground surrounding the reservoir

3) Investigations methods

a. Topographic survey

Approximately 1:5,000 to 1:10,000 scale topographic maps are necessary for a small reservoir, and 1:10,000 to 1:25,000 scale topographic maps for a large reservoir. Approximately 1:1,000 scale topographic maps are required for the area neighboring major structures such as the dam and powerhouse. Orthophoto maps (aerial photograph with contours) are used to study the items of compensation in the reservoir and resettlement area.

b. Ground survey (Site reconnaissance)

- Observation of rock and geologic survey formation outcrop
- Observation items where there are no rock outcrops
- Topographic observation items

Table 25-2
Rock Classification proposed by Dr. Tanaka, (A rock classification commonly used in Japan)

Symbol		Features
A		Rocks are very fresh, and rock-forming minerals are neither weathered nor altered. They are almost free from joints, and the few joints are closed. The rocks are differently colored, but are very hard in their lithologic character.
B		Among rock-forming minerals, feldspar and other colored minerals are partially weathered and somewhat brown. The rocks have joints, but the joints are closed and do not contain brown mud or clay.
C	C_H	Between B and C_M in hardness and freshness.
	C_M	Rocks are very weathered, and rock blocks surrounded joints are weathered brown or dark greenish black on the surface even though relatively fresh inside. As for rock-forming minerals, feldspar and other colored minerals are reddish brown, excluding quartz. Joints contain mud or clay or have some void, with water dropping. Rock blocks themselves may be hard.
	C_L	Rocks are more weathered than those of C_M.
D		Rocks are remarkably weathered and colored generally brown. They are destroyed by hammering. Those weathered still more are destroyed like sand and partially become soil. Though joints are rather unclear, some rock blocks which are hard contain large open joints developed between hard rocks.

c. Physical prospecting

- Seismic prospecting (velocity of elastic wave propagation)
- Electric prospecting (electric characteristics including the specific resistance)
- Gravity prospecting (density)
- Magnetic prospecting (magnetic characteristics)

d. Drilling investigation

e. Exploratory adits

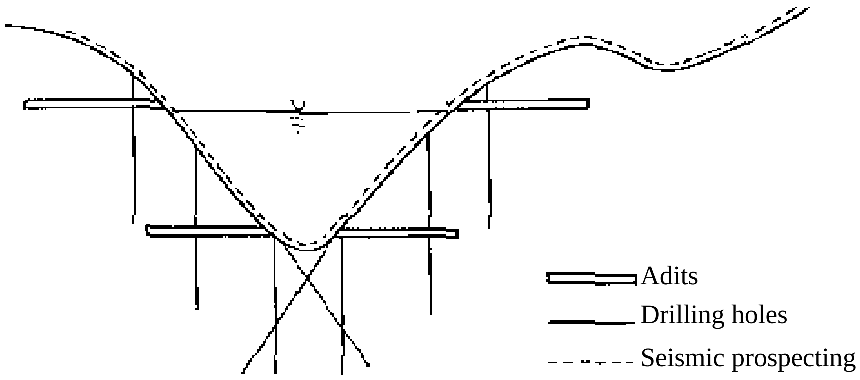
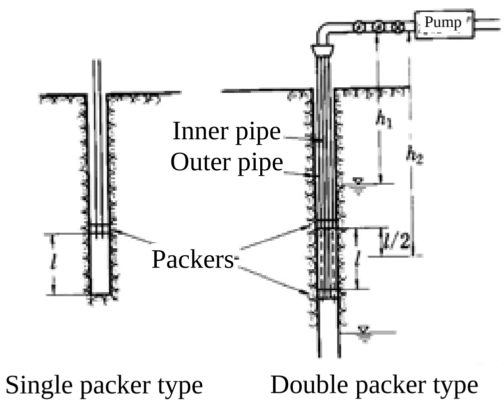


Fig. 25-2 Example of Layout of Adits, Drilling Holes and Seismic Prospecting

A typical layout of adits, exploratory drilling holes and seismic prospecting is shown in Fig.25-2.

f. Permeability test



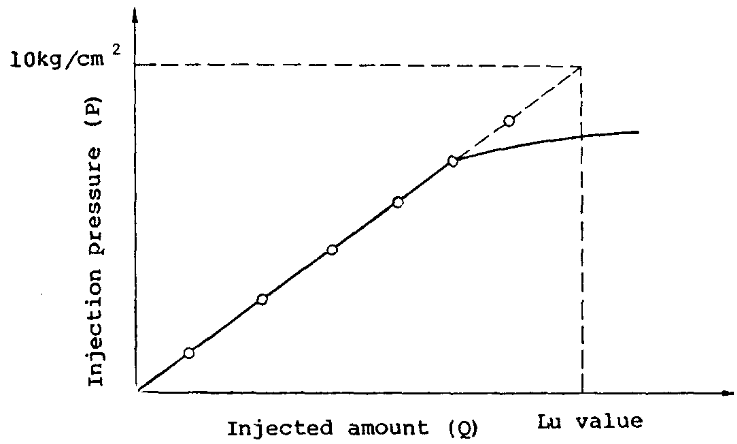
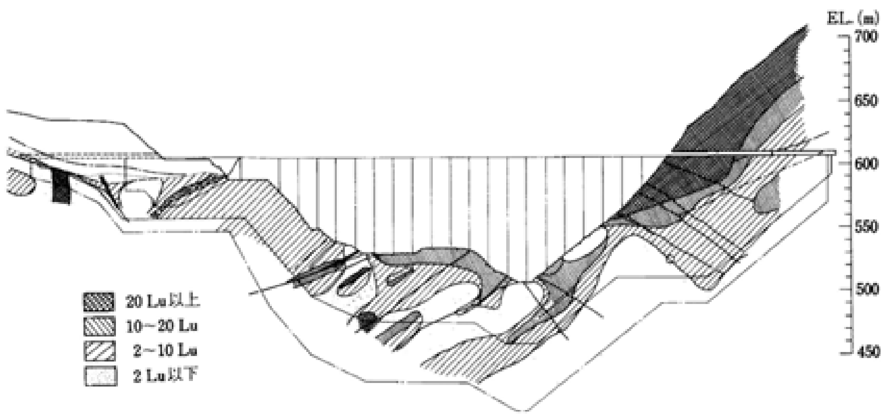


Fig. 25-3 Lugeon Test **Fig. 25-4 Injection Pressure and Injected Volume Curve**



Note: Lugeon value: the injected volume per minute per meter under the injection pressure, 10 kgf/cm^2. (l/min.)

Fig. 25-5 Example of Lugeon Map

(3) Design (Design study)

1) Purposes of the investigations

- Determination of type and scale of a dam
- Study of construction plans and methods of a dam

2) Outputs through the investigations

- Dam axis
- Strength of dam foundation
- Deformation of dam foundation
- Permeability of dam foundation
- Identification of weak stratum or faults in dam foundation
- Determination of excavation depth
- Determination of measures of dam ground such as grouting

3) Methods of the investigations

a. Topographic survey

Approximately 1:1,000 or 1:500 scale topographic maps are required for the area neighboring major structures such as the dam and powerhouse.

b. Ground survey (Site reconnaissance)

c. Physical prospecting

d. Drilling investigation

e. Exploratory adit

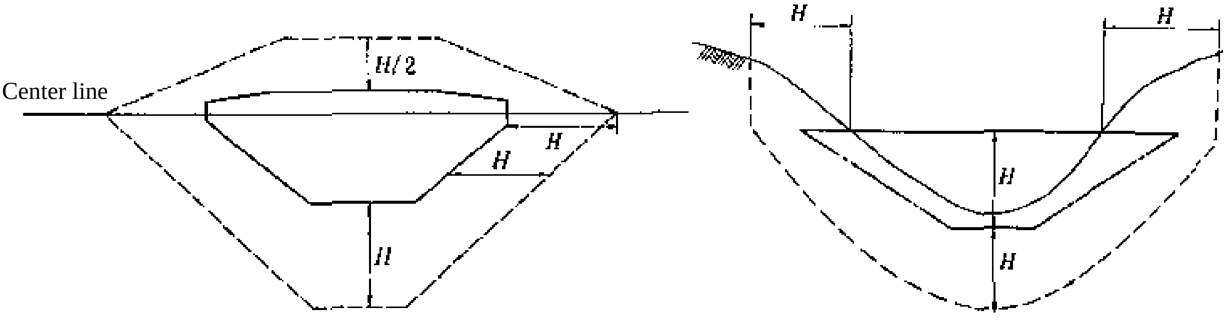
f. Permeability test

g. Laboratory tests

Specific gravity, water content, water absorbability, wearing test, compressive test, tensile test, shear test, etc.

h. In-situ tests (Rock test)

Deformation tests (jack test, underground loading test, camber test, etc.), strength tests (block shear test, rock shear test, rock tri-axis test, etc.)



Plan Profile

Fig. 25-6 Area to be Surveyed by the Topographic and Geological Investigations

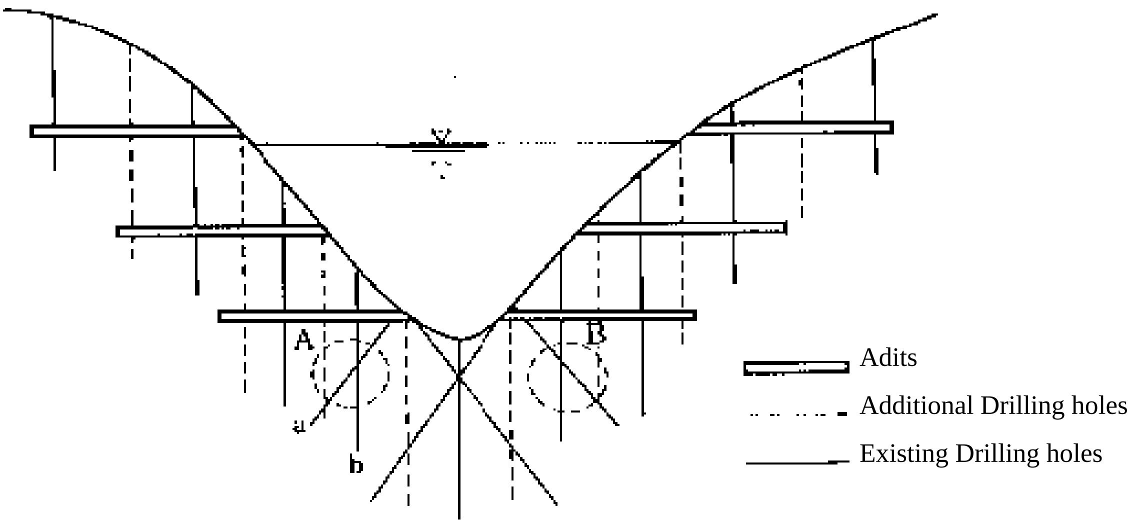


Fig. 25-7 Example of Layout of Adits, Drilling Holes and Seismic Prospecting

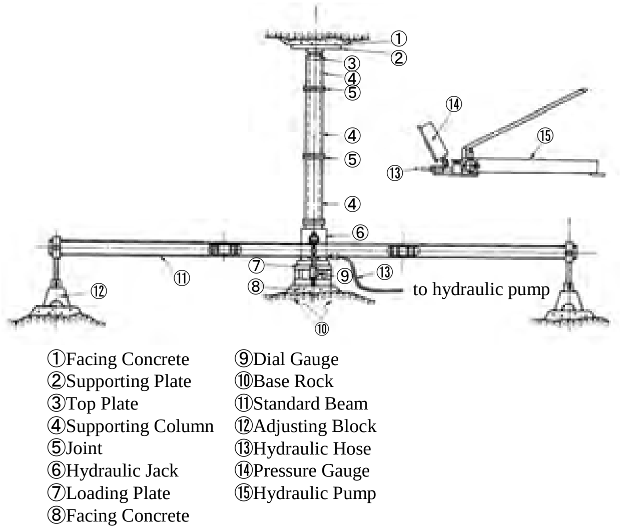


Fig. 25-8 Example of Deformation Test (plate loading)

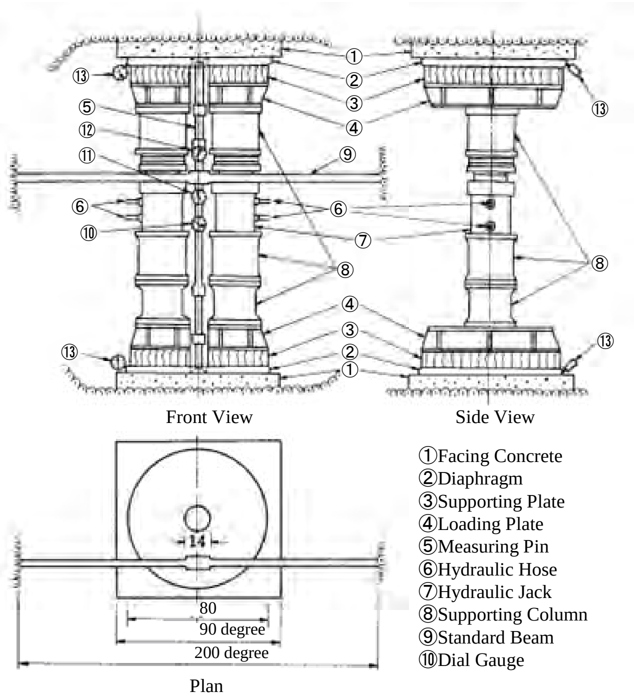


Fig. 25-9 Plate Loading Test

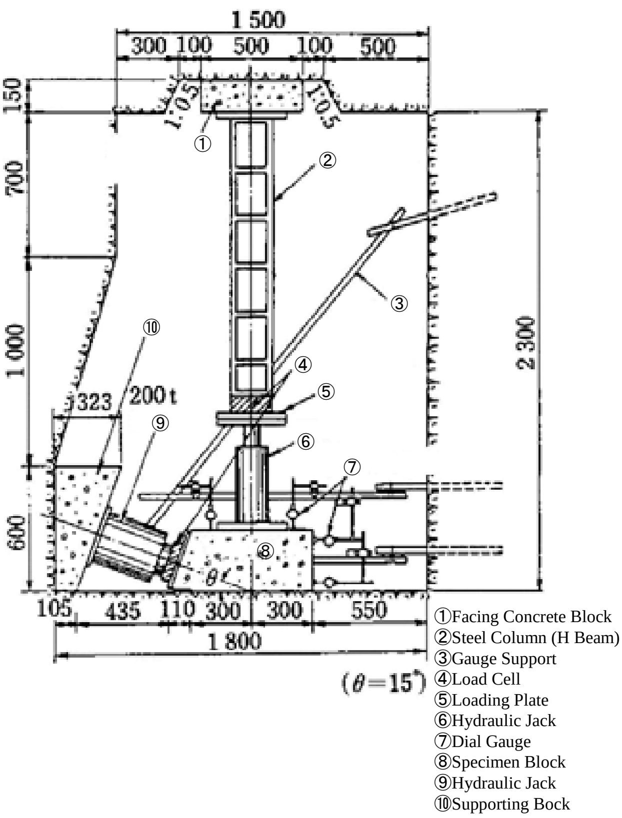


Fig. 25-10
Example of Block Shear Test

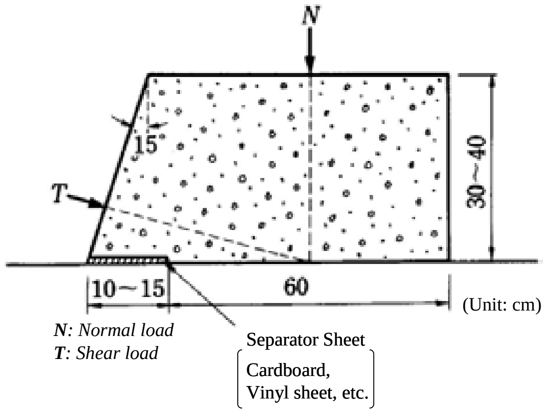


Fig. 25-11
Example of Block Arrangement for Block Shear Test (1)

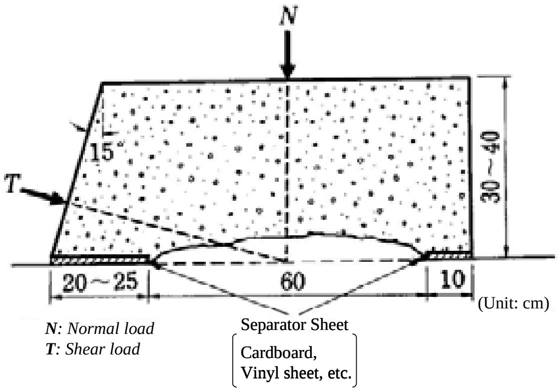


Fig. 25-12
Example of Block Arrangement for Block Shear Test (2)

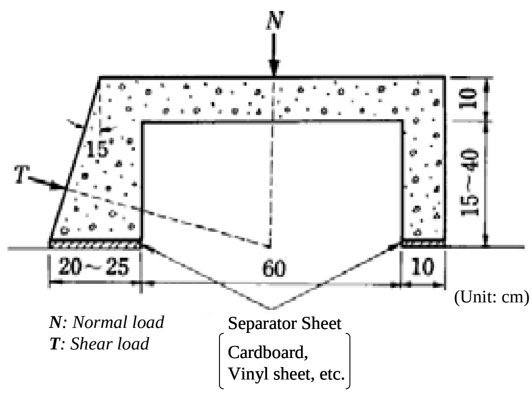


Fig. 25-13
Example of Block Arrangement for Block Shear Test (3)

(4) Construction (Design change study/ variation study)

1) Purposes of the investigations

- Study of design change
- Determination of measures against unexpected geology or problems

2) Outputs through the investigations

- Identification of problems
- Detail study of problems

3) Methods of the investigations

a. Drilling investigation
b. Permeability test
c. Exploratory adit
d. In-situ test
e. Physical prospecting
f. Investigation of excavated surface

(5) Operation and maintenance (Monitoring)

1) Purpose of the investigations

- Confirmation/evaluation of dam stability

2) Outputs through the investigations

- Volume of water leakage
- Underground water level

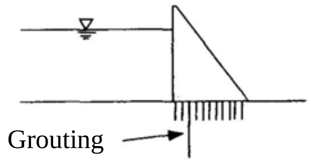
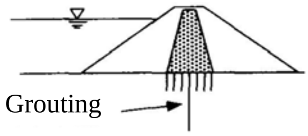
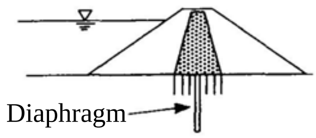
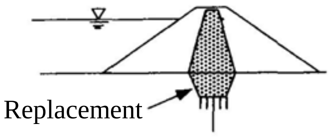
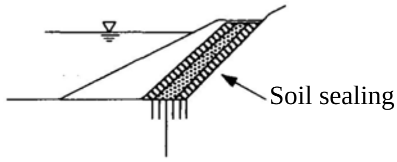
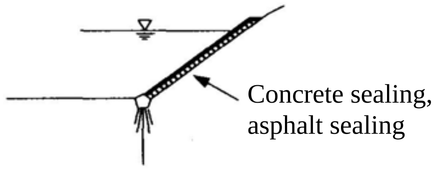
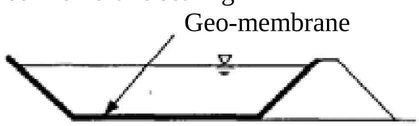
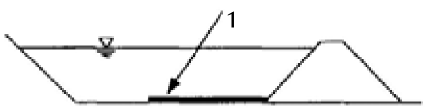
3) Methods of the investigations

a. Drilling investigation
b. Permeability test

Paragraph 3&4 Foundation Treatments

(1) Grouting

Table 25-3 Types of Water Sealing Methods

<table>
<tr><th></th><th>Underground</th><th>Ground</th></tr>
<tr><td>Types of water sealing methods</td><td>(1) Grouting


(2) Diaphragm wall

(3) Replacement methods
</td><td>(4) Soil sealing

(5) Concrete sealing, asphalt sealing

(6) Geo-membrane sealing

(7) Soil blanket
</td></tr>
</table>

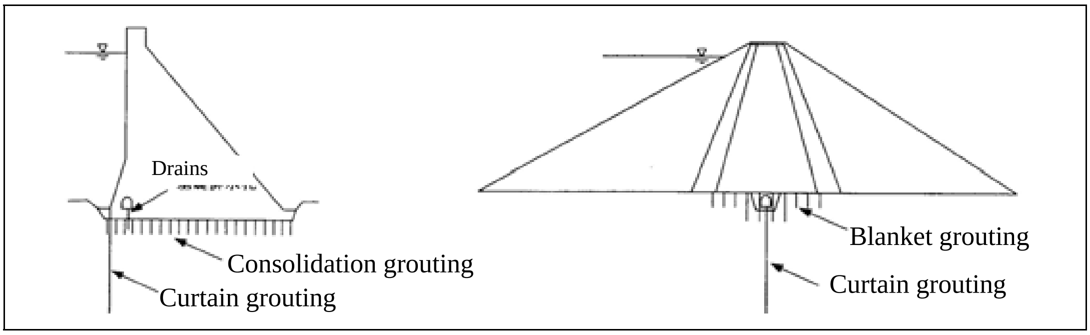


Fig. 25-14 Types of Grouting

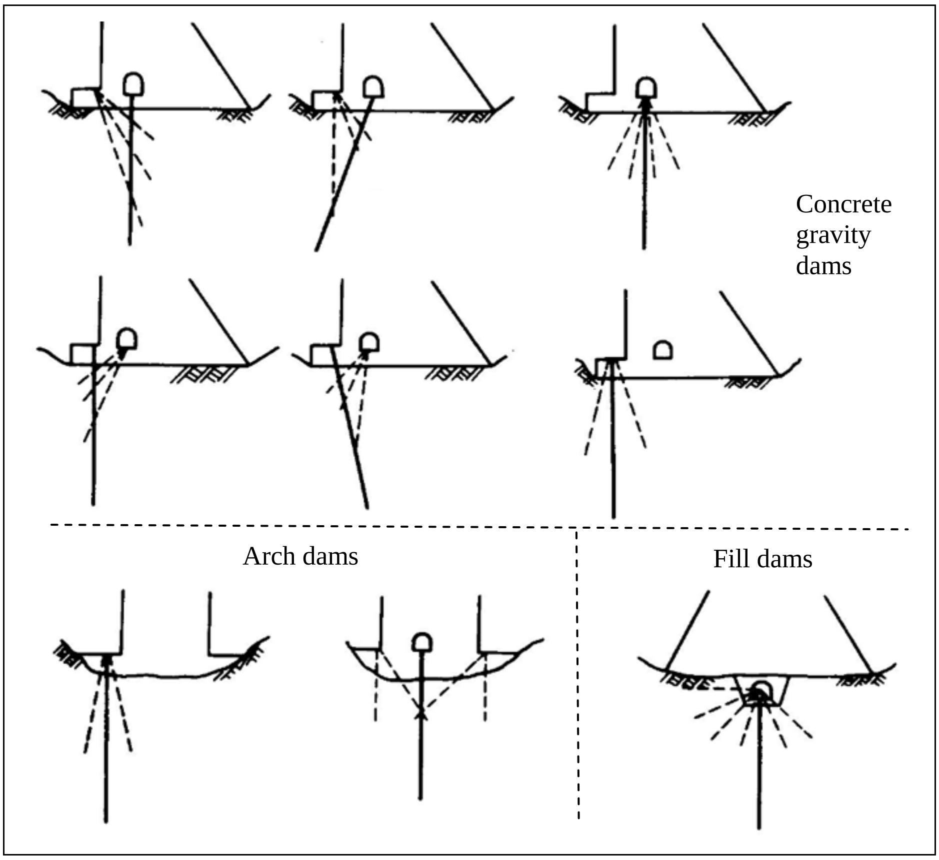


Fig. 25-15 Examples of Arrangements of Curtain Grouting (1)

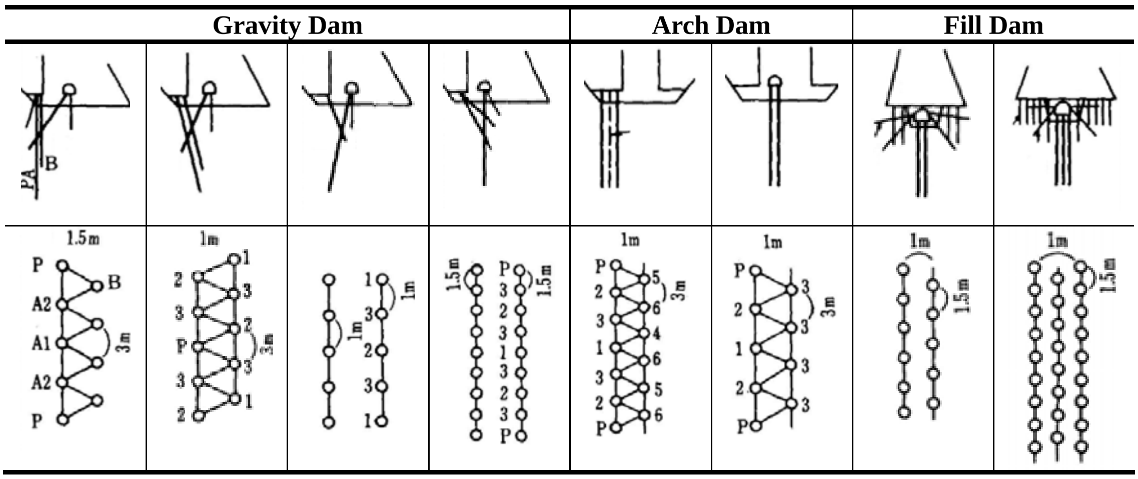


Fig. 25-16 Examples of Arrangements of Curtain Grouting (2)
– Typical Hole Arrangement in Section and Plan

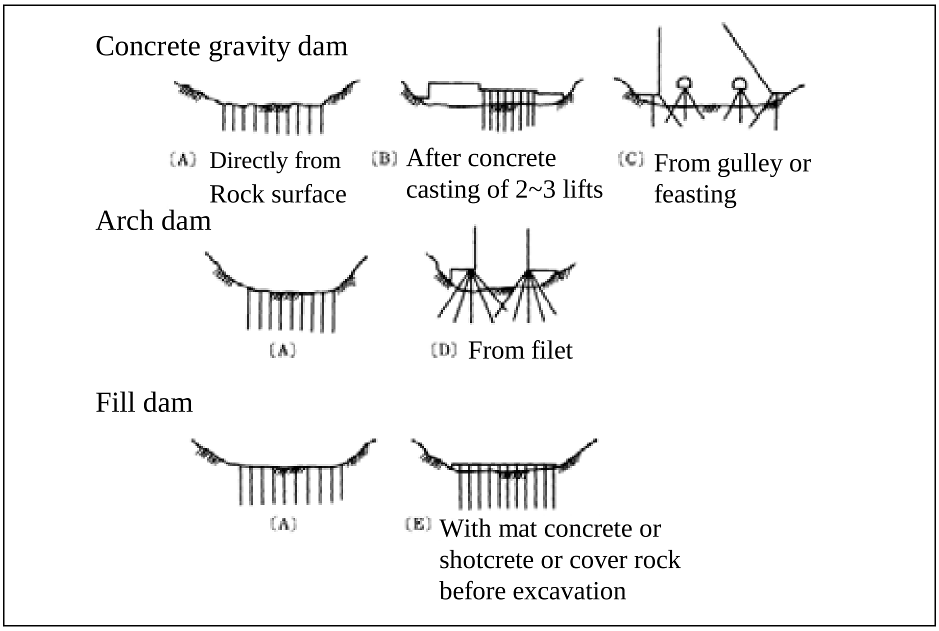


Fig. 25-17 Arrangements of Consolidation Grouting (1)

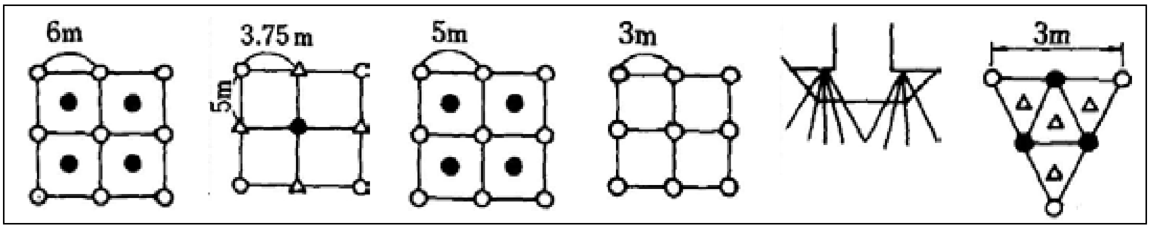


Fig. 25-18 Arrangements of Consolidation Grouting (2)

(2) Diaphragm wall

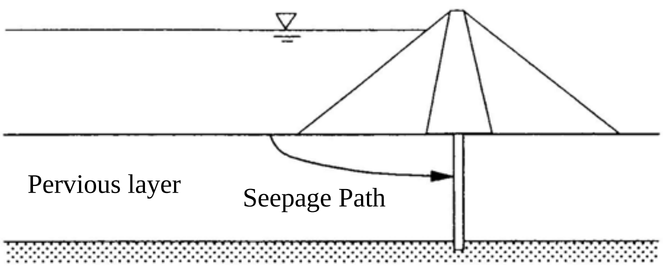


Fig. 25-19 Diaphragm Wall

(3) Soil Blanket

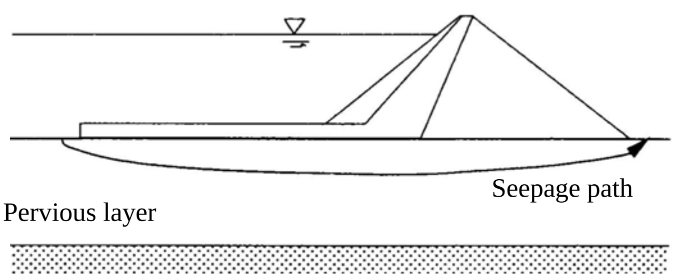


Fig. 25-20 Soil Blanket

(4) Replacement Methods

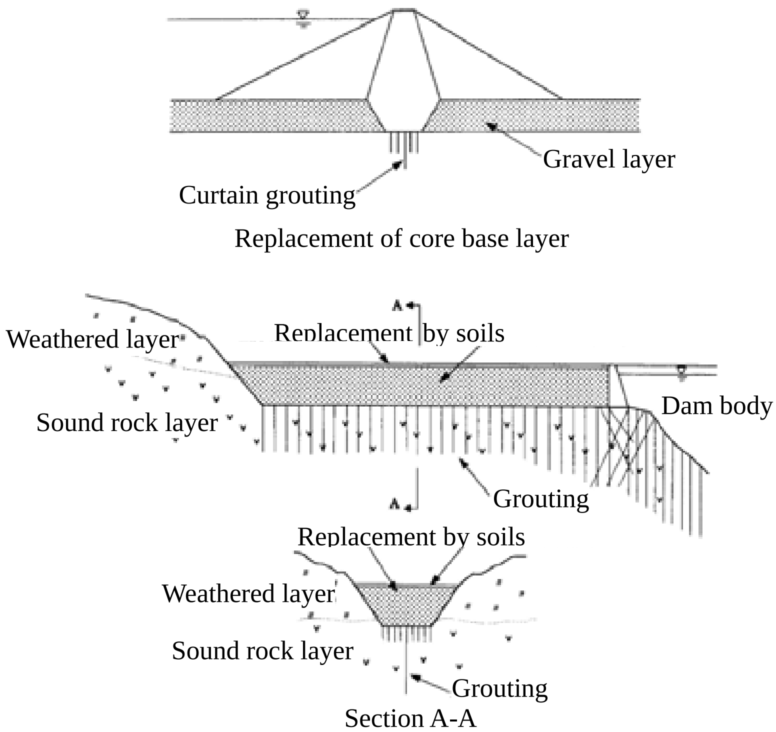


Fig. 25-21 Replacement Methods

For Article 26 Monitoring and Inspections

1. Necessity

This article mentions only minimum required monitoring items. If the results of monitoring show the safety of the dam, the frequency of the monitoring items can decrease.

2. Commentaries

The monitoring shall be started before the initial impounding to get initial values of monitoring and inspection.

3. Explanation

(1) In Japan, MLIT, Ministry of Land, Infrastructure, Transport and Tourism, stipulates that following items shall be monitored for a dam body.

Table 26-1 Monitoring Items for Dams by Type

Classification			Monitoring items
Dam type		Height from foundation (m)	
Concrete gravity		Less than 50	Leakage and uplift
		From 50 and up	Leakage, deformation and uplift
Arch		Less than 30	Leakage and deformation
		From 30 and up	Leakage, deformation and uplift
Fill	Homogeneous type	All	Leakage, deformation and seepage line
	Other type	All	Leakage and deformation

MLIT also stipulates that an emergency inspection shall be implemented when earthquake, flood or heavy rain of which magnitude is larger than the following scale occurs.

1. Earthquake
   Earthquake measuring maximum acceleration of 25 gal installed at the dam foundation, or Earthquake of four on the Japanese seven-stage seismic scale if seismometers are not installed at the dam
2. Flood
   Flood discharge which occurs once per three years at the dam site
3. Heavy rain
   Daily rainfall which occurs once per three years at the dam site

(2) Frequency of monitoring and inspection on dam and sedimentation in a reservoir is provided in Table 26-2.

In the table, monitoring frequency for each item is determined based on the following three (3) stages:

Stage I : Two (2) months or more after the initial impounding at the normal water level
Stage II : Between Stage I and Stage III
Stage III : After dam and its foundation settlement become stable, which means that monitoring results are getting steady and/or linear response against the external load condition such as water level and dam body.

Table 26-2 Frequency of Monitoring and Inspection

Items & Frequency / Dam Type	Moni-toring Stage	Monitoring and Inspection Item				Sediment-ation in Reservoir
		Water Leakage	External Deformation	Uplift	Permeation Line	
Concrete Gravity	Stage I	Daily	Daily	Weekly	—	Yearly
	Stage II	Weekly	Weekly	Monthly	—	
	Stage III	Monthly	Monthly	Every 3 Months	—	
Arch	Stage I	Daily	Daily	Weekly	—	Yearly
	Stage II	Weekly	Weekly	Monthly	—	
	Stage III	Monthly	Monthly	Every 3 Months	—	
Zoned Type Fill and Surface Diaphragm Type Fill	Stage I	Daily	Weekly	—	—	Yearly
	Stage II	Weekly	Monthly	—	—	
	Stage III	Monthly	Every 3 months	—	—	
Homogeneous Type Fill	Stage I	Daily	Weekly	—	Weekly	Yearly
	Stage I	Weekly	Monthly	—	Monthly	
	Stage III	Monthly	Every 3 Months	—	Every 3 Months	

Photograph 26-1
Monument for External Deformation Survey

Photograph 26-2
Instrument for Monitoring Seepage

Section 2 Concrete Dams

For Article 27 Concrete Materials

1. Necessity

There is no standard about materials (e.g. cements, concrete, steel) for hydropower stations such as JIS (Japanese Industrial Standard), EN (European Norm), ASTM (American Society for Testing and Materials) or TIS (Thai Industrial Standard) in the Kingdom of Cambodia itself.

2. Explanations

Strength of concrete depends on materials such as cement and admixture, mix proportions and production and placement methods (quality control procedures) and so on. It is important for the concrete properties to be derived from examinations using the actual concrete to be used.

3. Actual conditions

There are cement factories in the Kingdom of Cambodia. The cement from the factories is mainly supplied for small structures such as buildings. Hydropower stations use imported cements. Most of the cement to be used at hydropower stations in the Kingdom of Cambodia is imported from neighboring countries such as Thailand, P.R. China and Vietnam, so these countries' standards such as TIS (Thai Industrial Standard) are used for materials of hydropower stations.

There is little possibility that beach gravels would be used.

Photograph 27-1 Placing of Dam Concrete

Table 27-1 Examples of Standards

Standards which are mentioned in the below table are some examples and they are not all of applicable standards for SREPTSHP

Materials	Material specification/ Testing	ISO International Organization for Standardization		JIS Japanese Industrial Standards		BS/EN British Standards/European		ASTM American Society for Testing and Materials		ACI American Concrete Institute	
Cement	Materials			JIS R 5210	Portland cements	BS12:1996	Specification for Portland cement	C150-00	Standard Specification for Portland Cement		
				JIS R 5211	Slag cements	BS146:1996	Specification for Portland blastfurnace cements			233R-95	Ground Granulated Blast-Furnace Slag as a Cementitious Constituent in Concrete
						BS4246:1996	Specification for high slag blastfurnace cement			232.1R-00	Use of raw or processed Natural Pozzolands in Concrete
				JIS R 5212	Silica cements	BS6610:1996	Specification for Pozzolanic pulverized-fuel ash cement	C593-95	Standard Specification for Fly Ash and Other Pozzolans for Use Lime	232.1R-94	Use of Natural Pozzolans in Concrete
				JIS R 5213	Flyash cements	BS6588:1996	Specification for Portland pulverized-fuel ash cement			232.2R-96	Use of Fly-Ash in Concrete
	Testing	ISO679:1989	Methods of testing cements-Determination of strength	JIS R 5201	Physical tests for cements	BS EN196-1:1995	Methods of testing cement. Determination of strength	C917-98	Standard Test Method for Evaluation of Cement Strength Uniformity From a Single Souece		
		ISO9597:1989	Cements-Test methods-Determination of setting times and soundness					C191-01a	Standard Test Method for Time of Setting of Hydraulic Cement by Vicat Needle		
		ISO680:1990	Cement-Test methods-Chemical analysis								
		ISO863:1990	Cement-Test methods-Pozzolanicity test for pozzolanic cements								
		ISO3048:1974	Gypsum plasters-General test conditions			BS EN196-6:1992	Methods of testing cement. Determination of fineness	C188-95	Standard Test Method for Density of Hydraulic Cement		
		ISO3049:1974	Gypsum plasters-Determination of physical properties of powder			BS EN196-3:1995	Methods of testing cement. Determination of setting time and soundness	C115-96a	Standard Test Method for Fineness of Portland Cement by the Turbidimeter		
Concrete	Testing	ISO4012	Concrete-Determination of compressive strength of test specimens	JIS A 1108	Compressive strength testing methods	BS EN12390-3:2002	Testing hardened concrete. Compressive strength of test specimens	C397/C3M-01	Standard test method for compressive strength of cylindrical concrete specimens		
		ISO4108	Concrete-Determination of tensile splitting strength of test specimens	JIS A 1113	Tensile strength testing method	BS EN12390-6:2000	Testing hardened concrete. Tensile splitting strength of test specimens	C496-96	Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens		
		ISO4013:1978	Concrete-Determination of flexural strength of test specimens	JIS A 1106		BS EN12390-5:2000	Testing hardened concrete. Flexural strength of test specimens	C78-00	Standard Test Method for Flexural Strength of Concrete		
		ISO6784:1982	Concrete-Determination of static modulus of elasticity in compression			BS 1881-121:1983	Testing concrete. Method for determination of static modulus of elasticity in compression	C469-94	Standard Test Method for Static Modulus of Elasticity and Poisson's Ratio of concrete in Compression		
		ISO6275:1982	Concrete, hardened-Determination of density			BS EN12350-6:2000	Testing fresh concrete. Density	C642-97	Standard Test Method for Density, Adsorption and		

Materials	Material specification/ Testing	ISO International Organization for Standardization		JIS Japanese Industrial Standards		BS/EN British Standards/European		ASTM American Society for Testing and Materials		ACI American Concrete Institute	
Concrete	Testing	ISO1920	Concrete tests-Determinations, tolerances and applicability of test specimens	JIS A 1127		BS EN1881-209:1990	Testing concrete. Recommendation for the measurement of dynamic modulus of elasticity				
		ISO2736-2	Concrete tests-Test specimens –Part 2: making and curing of test specimens for strength tests	JIA A 1132	Method of making and curing concrete specimens	BS EN12390-3:2002	Testing hardened concrete. Compressive strength of test specimens	C397/C3M-01	Standard test method for compressive strength of cylindrical concrete specimens		
		ISO4108	Concrete-Determination of tensile splitting strength of test specimens	JIS A 1113	Tensile strength testing method	BS EN12390-6:2000	Testing hardened concrete. Tensile splitting strength of test specimens	C496-96	Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens		
		ISO4013:1978	Concrete-Determination of flexural strength of test specimens	JIS A 1106		BS EN12390-5:2000	Testing hardened concrete. Flexural strength of test specimens	C78-00	Standard Test Method for Flexural Strength of Concrete		
		ISO6784:1982	Concrete-Determination of static modulus of elasticity in compression			BS 1881-121:1983	Testing concrete. Method for determination of static modulus of elasticity in compression	C469-94	Standard Test Method for Static Modulus of Elasticity and Poisson's Ratio of concrete in Compression		
		ISO6275:1982	Concrete, hardened-Determination of density			BS EN12350-6:2000	Testing fresh concrete. Density	C642-97	Standard Test Method for Density, Adsorption and Voids in Hardened Concrete		
		ISO1920	Concrete tests-Determinations, tolerances and applicability of test specimens	JIS A 1127		BS EN1881-209:1990	Testing concrete. Recommendation for the measurement of dynamic modulus of elasticity				
		ISO2736-2	Concrete tests-Test specimens –Part 2: making and curing of test specimens for strength tests	JIA A 1132	Method of making and curing concrete specimens						
		ISO6782:1982	Aggregates for concrete-Determination of bulk density	JIS A 1104	Testing method for bulk density	BS EN1097-3	Test for mechanical and physical properties of aggregates. Determination of loose bulk density and voids	C29/C29M-97	Standard test method for bulk density ("unit weight") and voids in aggregates		
Mixture	Materials			JIS A6201	Flyash for concrete	BS EN450:1995	Fly ash for concrete. Definitions requirements and quality control	C618-01	Standard specification for Coal fly ash and raw or calcined natural Pozzolan for use as a mineral	232.2R-96	Guide for structural lightweight aggregates concrete
				JIS A 6202	Expansive additive for concrete	BS EN480	Admixture for concrete mortor and grout				
				JIS A 6204	Chemical mixture for concrete	BS EN934	Admixture for concrete mortor and grout. Concrete admixture	C494/C494m-99ae1	Standard specification for chemical admixtures for concrete	212.3R-91	Chemical admixture for concrete
				JIS A 6205	Corrosion inhibitor for concrete						
				JIS A 6206	Blast-furnace slag for concrete	BS EN6699:1992	Specification for ground granulated blastfurnace slag for use with Portland cement	C989-99	Standard specification for ground granulated blast-furnace slag for use in concrete and mortor	233.R-95	Ground granulated blast-furnace slag as a cementitious constituent in concrete
Water	Materials Testing			JSCE B 101	Specification of mixing water for concrete	BS EN1008	Mixing water for concrete. Specifications and tests current				

For Article 28 Foundations for Concrete Dams

1. Necessity

Article 25 mentions general matters for dam foundations. Article 28 mentions detailed matters about concrete dams.

2. Commentary

Paragraph 2 “appropriate”

In-situ tests shall be carried out at suitable places so that the geological conditions of the whole dam foundation can be understood.

3. Explanations

Table 28-1 Check List of Foundations for Concrete Dams

Items to be checked	Test Methods	Items to be evaluated	Necessary Improvement Works
Strength	• Block (Rock) shear test in situ • 3-component test • Single-plane shear	Shear strength: τ Coefficient of internal friction: f Coefficient Angle of internal: φ	Fault treatment Pre-stress method, and etc.
Deformability	• Loading test in situ • 3-component test	Elastic modulus: E Modulus of deformation: D	Consolidation grouting Contact grouting Fault treatment, and etc.
Permeability	• Lugeon test • Permeability test based on Darcy’s principal	Lugeon value Coefficient permeability: k	Grout cut off Blanket grouting Contact grouting Fault treatment Blanket relief well Drainage, diaphragm wall, and etc.

For Article 29 Stress Conditions

1. Reference

General Practical Flow for determination of Necessary Target Strength implemented in Japan

Step 1. Stress inside the dam body is assumed or obtained through dam stability analyses.

Step 2. Required Compressive Strength
= Stress inside the dam body × [Necessary Safety factor]
Note: Necessary Safety factor shall be changed according to considered loading condition.

Step 3. Specified Concrete Strength = Required Compressive Strength

Step 4. Coefficient of Fluctuation (at the mixing concrete)
= (normal distribution) / (mean) × 100%

Step 5. Additional Rate for variance of compressive strength = Coefficient of Surcharge

Coefficient of Surcharge is determined based on Fig. 29-1 showing the relationship between Coefficient of Fluctuation and Coefficient of Surcharge.

Step 6. Target Strength = Specified Concrete Strength × Coefficient of Surcharge i.e. Additional Rate

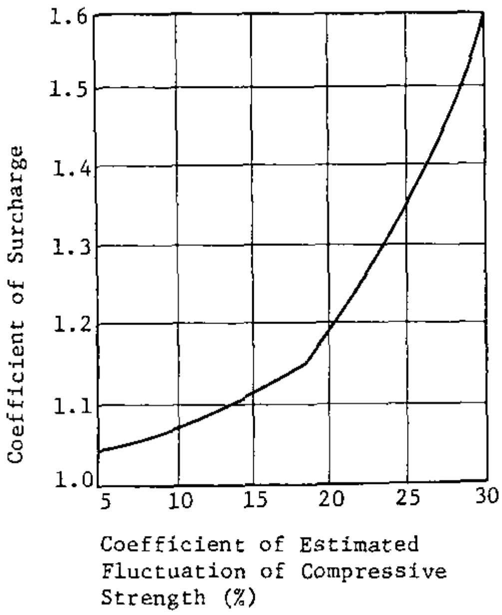


Fig. 29-1
Coefficient of Surcharge for a General Case

Note:

- Target Strength is the strength of concrete or concrete mixture at sites considering variance of strength of concrete placed at the site.
- Specified Concrete Strength is strength of concrete for dam design, assumed or obtained through dam stability analysis.

Reference:

- Allowable Compressive Stress = Compressive Strength / *[Necessary Safety factor]*
- Compressive Strength is actual concrete strength, confirmed by laboratory and in-situ tests.

Design mixture of concrete shall be determined throughout laboratory and in-situ tests so as to ensure calculated target strength. In case concrete can ensure it through the tests, the Specified Concrete Strength and dam design shall be modified based on actual working condition at sites.

The difference of compressive strength in a shape of concrete test specimen shall be carefully considered. In general, it is assumed that a cubic specimen shows a higher compressive strength than a cylindrical one and the difference is up to 25%, however, the difference will decrease at increasing strength levels.

For Article 30 Stability of Concrete Gravity Dams

1. Explanations

(1) Comparison with International Standards

1) SREPTSHP is modeled on U.S. Army Corps of Engineers' standards.
2) SREPTSHP takes three cases to be reviewed, usual, unusual and extreme conditions.
3) The minimum safety factor against sliding, using Henny's formula, shall be 2.0 under usual condition, 1.7 under unusual condition and 1.3 under the extreme condition.

4) About overturning/cracking, the application center of the resultant force shall be located within the middle third for usual condition, within the middle half for unusual condition, and within the base for the extreme condition.
5) About concrete strength, the allowable compressive stress in a dam body shall be 0.3 times as much as the one-year unconfined compressive strength of dam concrete for usual condition, 0.5 times for unusual condition, and 0.9 times for the extreme condition.

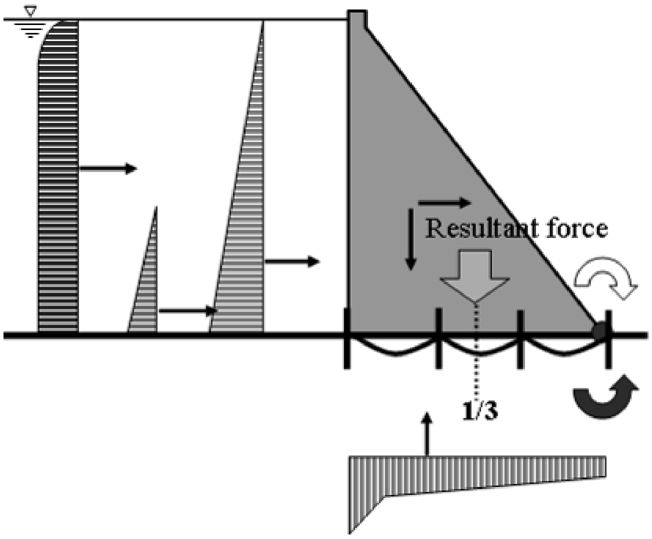


Fig. 30-1 Resultant Force Acting on Dam Body

Table 30-1 Comparison Table for Design Standard of Gravity Dam

	Gravity dam design U.S. Army Corps of Engineering			**Design of gravity dam U.S. Bureau of Reclamation**			**Dam safety guidelines Canadian Dam Safety Association**				**Manual for river works in Japan River Bureau, MLIT**		**SREPTS for Hydropower in Cambodia**		
Design loads	self-weight, hydrostatic pressure,(U/D) uplifting pressure, ice pressure, silt pressure, seismic force(OBE,MCE), hydrodynamic pressure			self-weight, hydrostatic pressure,(U/D) uplifting pressure, ice pressure, silt pressure, seismic force, hydrodynamic pressure			self-weight, hydrostatic pressure,(U/D) uplifting pressure, ice pressure, silt pressure, seismic force, hydrodynamic pressure				self-weight, hydrostatic pressure,(U) uplifting pressure, silt pressure, seismic force, hydrodynamic pressure		self-weight, hydrostatic pressure,(U/D) uplifting pressure, silt pressure, seismic force(OBE,MCE), hydrodynamic pressure		
Loading Conditions	Usual	unusual	extreme	Usual	Unusual	Extreme	Usual	Unusual	Earthquake	Flood	Usual	Earthquake	Usual	Unusual	Extreme
Overturning Resultant force	Middle1/3	Middle1/2	Within base	-	-	-	Middle1/3	-	-	-	Middle1/3		Middle1/3	Middle1/2	Within base
Sliding Safety factor	2.0	1.7	1.3	(1) Sliding through contact b/w dam body and dam foundation			(1) In case of conducting no geological tests				4.0		2.0	1.7	1.3
				3.0	2.0	1.0	3.0	2.0	1.3	2.0					
				(2) Sliding through dam foundation			(2) In case of conduction no geological tests								
				4.0	2.7	1.3	2.0	1.5	1.1	1.5					
							(3) In case of evaluation of stability for residual sliding								
							1.5	1.1	1.0	1.3					
Stress in concrete(compressive)	0.3F'	0.5F'	0.9F'	3.0	2.0	1.0	0.45F				4.0	3.08 (=4.0/1.3)	0.3F'	0.5F'	0.9F'
					Safety Factor										
(tensile)	0.0	0.6F'^(2/3)	1.5F'^(2/3)	3.0	2.0	1.0	0.1F(within mass concrete), 0.05F(joint)				Compressive strength X 1/40		0.0	0.6F'^(2/3)	1.5F'^(2/3)
Bearing capacity of ground	<=allowable	<=allowable	<=1.33* allowable	4.0	2.7	1.3	-	-	-	-	-		<=allowable	<=allowable	<=1.33* allowable
Remark	F': unconfined compressive strength of concrete (Concrete age: 365day) Multiple wedge analysis*1) and single plane failure of analysis*2) are used in some case. *1) analyzing sliding along the base and within the foundation. *2) analyzing sliding of any surface within the structure and single planes of the base.			Usual: normal water level, dead loads, uplift, silt, ice and tailrace water and temperature loads Unusual: maximum water level, dead loads, uplift, silt, ice and tailrace water and temperature loads Extreme: Maximum credible earthquake, normal water level, dead loads, uplift, silt, ice and tailrace water and temperature loads			F: compressive strength of concrete Unusual: post earthquake				-		F': unconfined compressive strength of concrete (Concrete age: 365day)		
Material strength	specified concrete compressive strength : 365day (tensile strength) =2.3*(compressive strength)^2/3(psi) ; tensile strength increased by 50% at earthquake			Age of concrete determined by designer (generally 365 day) Tensile strength = compressive strength * (4 to 6)%			-				specified concrete compressive strength : 91day		specified concrete compressive strength : 365day (tensile strength) =2.3*(compressive strength)^2/3 (psi) ; tensile strength increased by 50% at earthquake		
Foundation strength	(τ, φ) set on basis of lab. test			(τ, φ) set on basis of lab. test			-				(τ, φ) set on basis of lab. test		(τ, φ) set on basis of lab. test		
Consideration for Earthquake	The U.S. is divided into 6 seismic zones (0-4). 1) Pseudo static analysis: seismic coefficient method (1-4) 2) dynamic analysis: response spectrum analysis, time-history analysis (2-4) (changing from 1) to 2)in accordance with the phase of project design) Operating Basis Earthquake (OBE):unusual ,extreme Maximum Credible Earthquake (MCE):extreme			①Pseudo static analysis: seismic coefficient method ②dynamic analysis: response spectrum analysis, time-history analysis (2-4)			Static analysis: seismic coefficient method (pseudo static analysis) selecting the MDE based on the consequences of dam failure Consequence category / Maximum Design Earthquake: Deterministically derived / Probabilistically derived Very high: MCE / 1/10.000 High: 50-100%XMCE / 1/1,000-1/10,000 low: - / 1/100-1/1,000				Pseudo static analysis : seismic coefficient method (Japan is divided into 3 seismic zones.)		Pseudo static analysis with seismic coefficient is used in determining resultant location and sliding stability of concrete gravity dams. Dynamic method of analysis such as response spectrum analysis or time-history analysis using MCE and OBE shall be used for internal stress calculation. Operating Basis Earthquake (OBE):unusual ,extreme Maximum Credible Earthquake (MCE):extreme		

Note MLIT : Ministry of Land, Infrastructure, Transport and Tourism, Japan

(2) Example in the region

1) Procedures

In order to determine criteria of gravity dam stability for the Laotian technical standards, the following case study was carried out:

Step 1.	The same parameters of Nam Ngum dam are used as shown in Fig.30-2 (e.g. dam height, seismic coefficient, shear resistance, strength of concrete and so on).
Step 2.	Criteria of Japan, U.S. Bureau of Reclamation and criterion which Nam Ngum has adopted in those days are used for the case study.
Step 3.	Necessary downstream slope from each criterion is obtained as the results of the case study.
Step 4.	The criteria of the Laotian technical standards are determined by the comparison of the results.

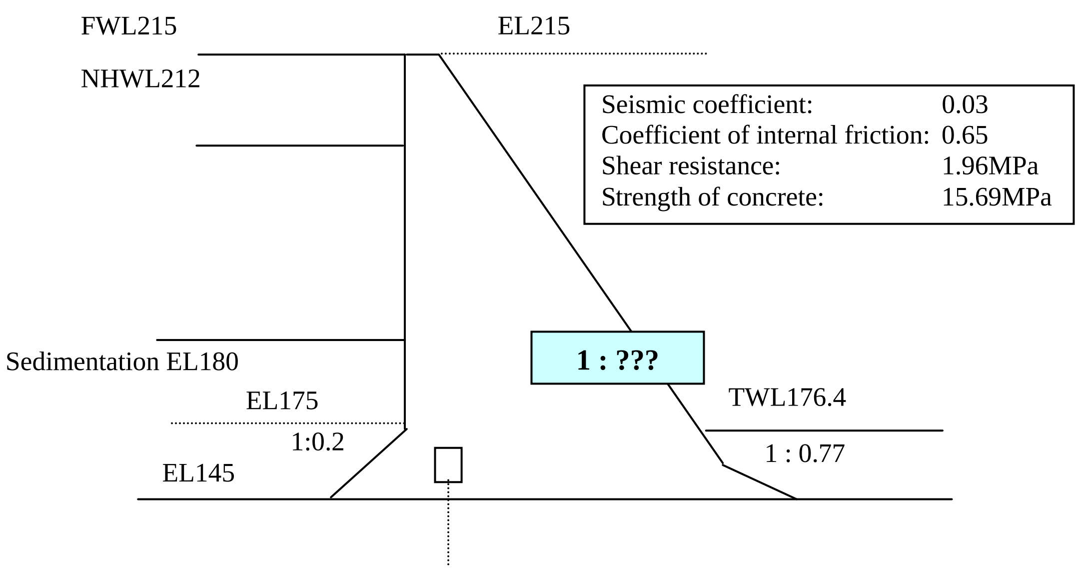


Fig. 30-2 Example of Case Study for Dam Stability Design

2) Analysis Results

Table 30-2 Necessary Downstream Slope Gradient Obtained by Case Study

		MLIT, Japan			**U.S. Army Corps of Engineers**			**Nam Ngum Criteria**		
		NHWL	**FWL flood**	**NHWL Earth-quake**	**Usual NHWL**	**Unusual flood**	**Extreme**	**Usual NHWL**	**Unusual flood**	**Extreme**
Overturning	Location of resultant force	Middle 1/3	Middle 1/3	Middle 1/3	Middle 1/3	Middle 1/2	Within base	Middle 1/3	Middle 1/3	Middle 1/3
Sliding	Safety factor	4.0	4.0	4.0	2.0	1.7	1.3	4.0	4.0	4.0
Overstress	Safety factor	4.0	4.0	4.0	3.0	2.0	1.1	4.0	4.0	4.0
Necessary slope		0.61	0.67	0.65	0.63	0.56		0.63	0.69	0.68
Necessary slope gradient for downstream slope		0.67			0.63			0.69		

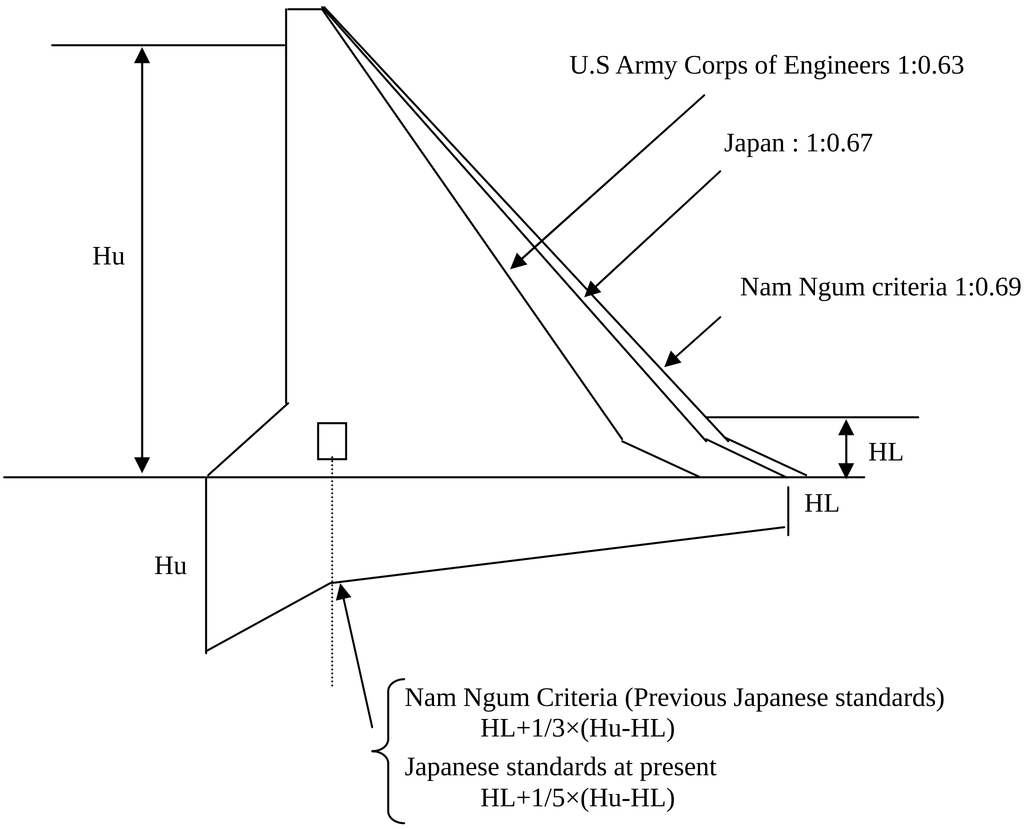


Fig. 30-3 Example Results of Dam Stability Design by Various Standards

For Article 31 Stability of Arch Dams

1. Explanation

(1) Comparison with International Standards

1) SREPTSHP is modeled on U.S. Army Corps of Engineers' standards.
2) SREPTSHP takes three cases to be reviewed, usual, unusual and extreme conditions.
3) The minimum safety factor against sliding, using Henny's formula, shall be 2.0 for usual condition, 1.3 for unusual condition, and 1.0 for the extreme condition.
4) About overstressing, i.e. the safety factor of the allowable strength, the safety factor for compression shall be 4.0 for usual condition, 2.5 for unusual condition, and 1.5 for the extreme condition.

Table 31-1 Comparison Table for Design Standard of Arch Dam

	Arch dam design U.S. Army Corps of Engineering			Design of arch dam U.S. Bureau of Reclamation			Dam safety guidelines Canadian Dam Safety Association				Manual for river works in Japan River Bureau, MLIT		SREPTS for Hydropower in Cambodia		
Design loads	self-weight, hydrostatic pressure,(U/D) uplifting pressure, ice pressure, silt pressure, seismic force(OBE,MCE), hydrodynamic pressure			self-weight, hydrostatic pressure, uplifting pressure, ice pressure, silt pressure, seismic force, hydrodynamic pressure, temperature load			self-weight, hydrostatic pressure, uplifting pressure, ice pressure, silt pressure, seismic force, hydrodynamic pressure, temperature load				self-weight, hydrostatic pressure, uplifting pressure, silt pressure, seismic force, hydrodynamic pressure, temperature load		self-weight, hydrostatic pressure,(U/D) uplifting pressure, ice pressure, silt pressure, seismic force(OBE,MCE), hydrodynamic pressure		
Loading Conditions	Usual	Unusual	Extreme	Usual	Unusual	Extreme	Usual	Unusual	Earthquake	Flood	Usual	Earthquake	Usual	Unusual	Extreme
Safety factor sliding	2.0	1.3	1.1	3.0	2.0	1.0	4.0	2.0	1.3	2.7	4.0		2.0	1.3	1.1
Stress in foundation (compressive)				4.0	2.7	1.3	4.0	2.0	1.3	2.7	—				
Allowable stress in concrete (compressive)	F'/4.0	F'/2.5	F'/1.5	3.0	2.0	1.0	3.0	1.5	1.1	2.0	4.0 Modification due to 3-dimentional effect	3.08 (=4.0/1.3) Modification due to 3-dimentional effect	F'/4.0	F'/2.5	F'/1.5
(tensile)	Ft'	Ft'	Ft'	1.03MPa	1.55MPa	—	—	—	—	—	Compressive strength X 1/40		Ft'	Ft'	Ft'
(shear)				3.0	2.0	1.0	3.0	1.5	1.1	2.0	—				
Material strength	F': unconfined compressive strength of concrete (Concrete age: 365day) F'>27.6 MPa Assumed in design stage Ft' : tensile strength of concrete = compressive strength X 10% Dynamic value Fd' = 1.30*F' F'td = 1.30*F't			Age of concrete determined by designer (generally 365 day) Allowable tensile strength = Allowable compressive strength X 10% Usual: normal water level, dead loads, uplift, silt, ice and tailrace water and temperature loads Unusual: maximum water level, dead loads, uplift, silt, ice and tailrace water and temperature loads Extreme: Maximum credible earthquake, normal water level, dead loads, uplift, silt, ice and tailrace water and temperature loads			Unusual: Post earthquake				specified concrete compressive strength : 91day		F': unconfined compressive strength of concrete (Concrete age: 365day) F'>27.6 MPa Assumed in design stage Ft' : tensile strength of concrete = compressive strength X 10% Dynamic value Fd' = 1.30*F' F'td = 1.30*F't		
Foundation strength				(τ, φ) selected on basis of site test			-				(τ, φ) selected on basis of site test		(τ, φ) selected on basis of site test		
Consideration for Earthquake	The U.S. is divided into 6 seismic zones (0-4). 3) Pseudo static analysis: seismic coefficient method (1-4) 1) dynamic analysis: response spectrum analysis, time-history analysis (2-4) (changing from 1) to 2)in accordance with the phase of project design) Operating Basis Earthquake (OBE):unusual ,extreme Maximum Credible Earthquake (MCE):extreme			①Pseudo static analysis: seismic coefficient method ②dynamic analysis: response spectrum analysis, time-history analysis (2-4)			Static analysis: seismic coefficient method (pseudo static analysis) selecting the MDE based on the consequences of dam failure Consequence category / Maximum Design Earthquake: Deterministically derived / Probabilistically derived Very high / MCE / 1/10,000 High / 50-100%XMCE / 1/1,000-1/10,000 low / - / 1/100-1/1,000				Static analysis : seismic coefficient method (Japan is divided into 3 seismic zones.)		Pseudo static analysis with seismic coefficient is used in determining resultant location and sliding stability of concrete gravity dams. Dynamic method of analysis such as response spectrum analysis or time-history analysis using MCE and OBE shall be used for internal stress calculation. Operating Basis Earthquake (OBE):unusual ,extreme Maximum Credible Earthquake (MCE):extreme		

Note MLIT : Ministry of Land, Infrastructure, Transport and Tourism

For Article 32 Structural Details of Concrete Dam Body

1. Commentaries

Paragraph 1 “appropriately”

For preventing cracks in concrete due to thermal stress, contraction joints are arranged in a concrete dam in general at appropriate intervals. A joint normal to the dam axis is called a transverse joint; that parallel to the dam axis is longitudinal joint.

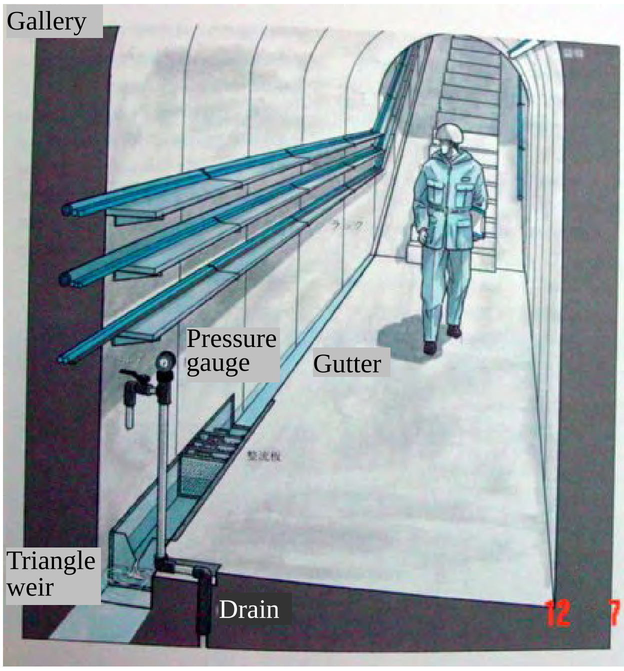
Irregular cracks in a direction normal to the dam axis become a decisive drawback regarding the water sealing of the body. For that reason, transverse joints are provided at 15 meters intervals along the dam axis in most cases for preventing cracks due to thermal stress. There are, however, cases where wider intervals are adopted on the basis of a careful control of the quality of the concrete and temperature.

Paragraph 1 “detrimental”

Some cracks in a concrete dam body are inevitable. However, cracks which threaten the dam stability due to unexpected uplift pressure along the cracks shall be avoided.

Paragraph 2 “as necessary”

It is required that drainage holes in the gallery are arranged. The number and location of the holes depend on each dam.



Photograph 32-1
Example of Drain Hole in Gallery

For Article 33 Temperature Regulation for Concrete Dam Body

1. Explanations

(1) [Treatments for temperature regulation]

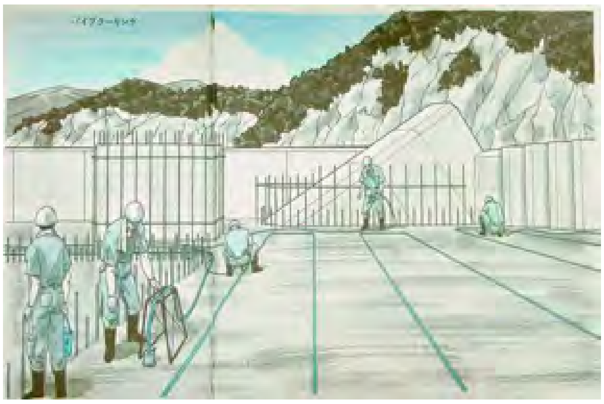
1. To avoid placing concrete under high atmospheric temperature such as in the daytime.
2. To suppress heat generation for either way of using cement with a lower hydration heat, or reducing the cement per unit volume.
3. Pipe cooling methods
   Pipe cooling is a method to suppress a rise in temperature of concrete by flowing cold water in previously arranged steel pipes at the time of the dam concreting for the purpose of

absorbing the hydration heat of the cement. In performing joint grouting, it is necessary to lower the temperature of the concrete to a stable value. Thus, pipe cooling is indispensable.

4. Pre-cooling method

This is a method used in concreting under high atmospheric temperature, where pre-cooling is made of a part or the whole portion of concrete materials to obtain a lower concreting temperature. It enables a reduction in the maximum rise in temperature. Also the temperature difference of the materials at an early stage of aging and the atmospheric temperature for reduction of the thermal gradient are minimized. For cooling the materials, chilled air or chilled water is used. Regarding the use of chilled water, it is not suitable in general for cooling fine aggregates from the view point of mixing-water control; therefore, it is used mainly for cooling coarse aggregates.

Pre-cooling



Pipe cooling

Photograph 33-1 Cooling Method

Section 3 Fill Dams

For Article 34 Embankment Materials

1. Commentaries

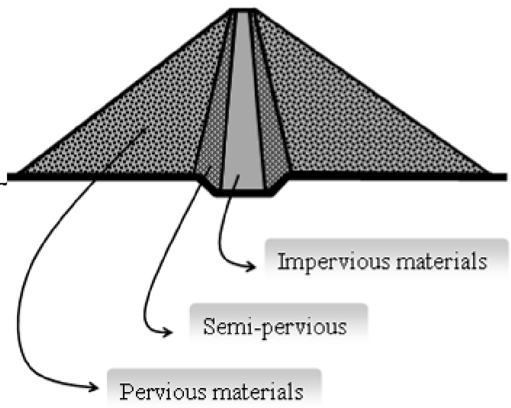
<u>Paragraph 1 (4) "seriously eroded"</u>

Erosion is inevitable for soil materials. However, it is not allowed that materials are so deteriorated that the strength of materials becomes lower than the design strength or the designed shape is lacking due to erosion.

2. Explanations

Table 34-1 Material Tests for a Fill Dam

	First-stage survey and selection of material		Second-stage (making decisions regarding design value and construction plan)	
	Fine-grained material	Coarse material	Fine-grained material	Coarse material
Requisite test for all materials	Grain size Water content Specific gravity Consistency Compaction (standard) Permeability (standard)	Grain size Specific gravity and content of water absorption Mono-axle compressive strength	Grain size Water content Specific gravity Consistency Compaction (Energy change) Permeability (Energy change) Shear ($\overline{CU}$ saturation) Site collection, embankment	Grain size Specific gravity and content of water absorption Large-scale shear (CD unsaturated) Compaction
Necessary test for particular materials	Compaction (Energy change) Permeability (Energy change)	Durability	Large-scale compaction (Energy change) Large-scale permeability (Energy change) Shear (UU unsaturated)	Mono-axle compressive strength Large-scale shear ($\overline{CU}$, CD unsaturated) Site collection, embankment
Test to be conducted if necessary	Contents of organic substances Contents of water-soluable material Expansion due to water absorption Consolidation Shear	Contents of organic substances	Consolidation Shear ($\overline{CU}$ unsaturated)	Durability Large-scale permeability



3. Reference

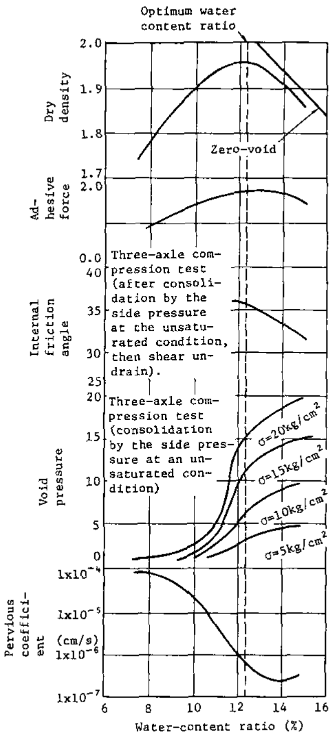


Fig. 34-1
Change in the Borrow Material's Properties as a Function of the Water Content Ratio

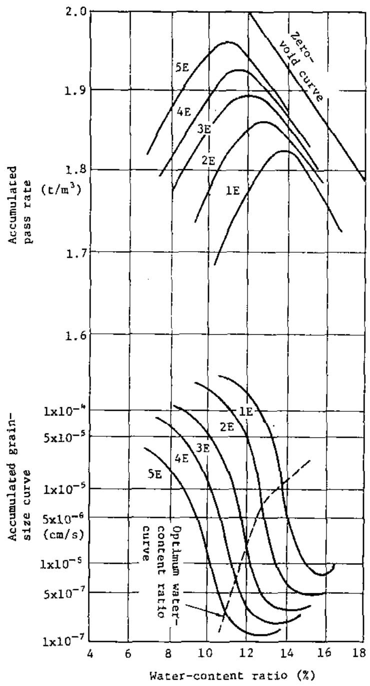


Fig. 34-2
Dry Density, Permeability Coefficient-water Content Ratio Curve for Various Compaction Energy

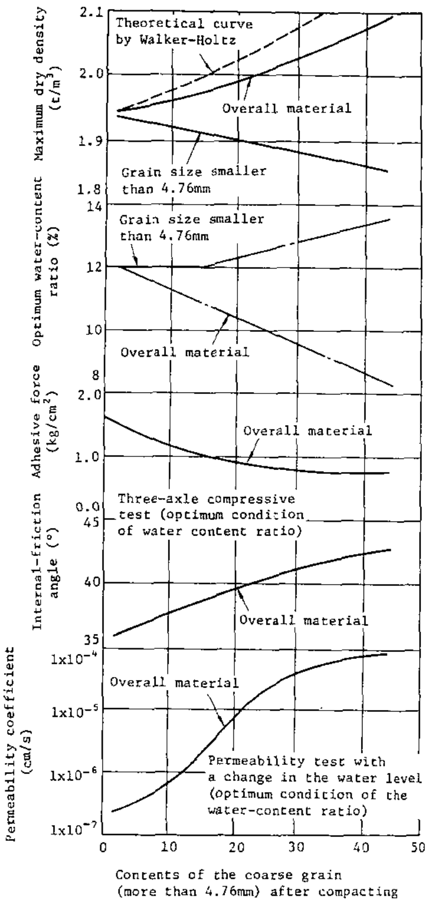


Fig. 34-3
Property Change Regarding the Contents of the Coarse Grain of a Borrow Material (more than 4.76 mm)

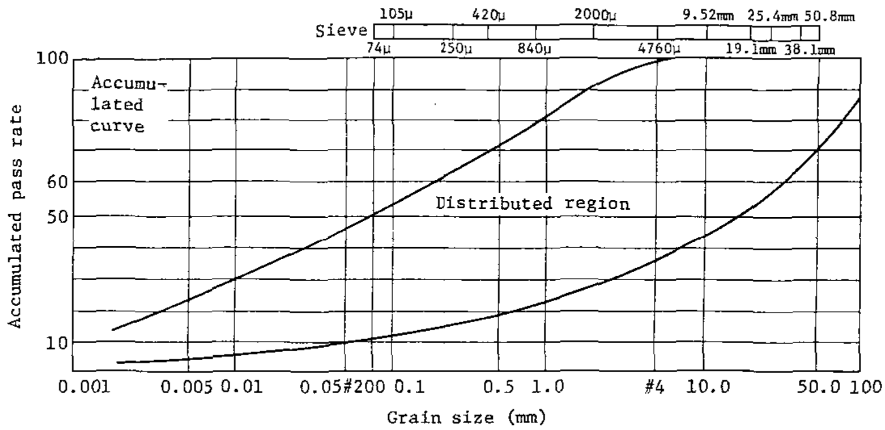


Fig. 34-4
Grain-size Range of the Borrow Material

For Article 35 Foundations for Fill Dams

1. Necessity

Article 25 mentions general matters for dam foundations. Article 35 mentions detailed matters about fill dams.

2. Commentaries

Paragraph 1 “rock foundations”

The impervious zone of a fill dam is the most important zone in fill dam to secure water-tightness.

3. Explanations

(1) Water sealing methods

Table 35-1 Water Sealing Methods

Dam Foundation	Water Sealing Methods
Sand gravel foundation	1) Grouting method 2) Replacement method 3) Sheet pile method 4) Cutoff wall method 5) Blanket method 6) Drain method, pressure-relief well method 7) Counter weight fill method
Soil foundation	1) Consolidation method 2) Counter weight fill method

(2) Theoretical treatments

A theoretical treatment regarding seepage failure is generally difficult; however, the following method can be used as a reference:

1) Method for a Limited Flow Rate (Justine's Method)

Justine determined the limited value of seepage flow rate for a specific diameter of the soil grain which moves at a higher speed than the limited value (to cause piping). This flow speed is called the limited flow speed, and can be expressed by the following equation:

$$Vc = (Wg/A\gamma w)^{0.5}$$

Where,

W : Weight of the soil in water (gf)

A : Area of the soil received the soil flow (cm^2)

γw : Unit-volume weight of water (gf/cm^3)

g : Gravity acceleration (cm/s^2)

With the above equation, the relation between grain diameter and the limited flow speed can be found as shown in Table 35-2, Fig. 35-1 and Fig. 35-2.

Table 35-2 Relation between the Grain Size and the Critical Flow Speed

Grain Size (mm)	Critical flow velocity (cm/s)
4.0 - 4.8	20
2.8 - 3.4	17
1.0 - 1.2	10
0.7 - 0.85	8.5
0.4 - 0.7	7
0.25 - 0.5	4.2
0.11 - 0.25	3.5
0.075 - 0.11	2.5
0.044 - 0.075	2

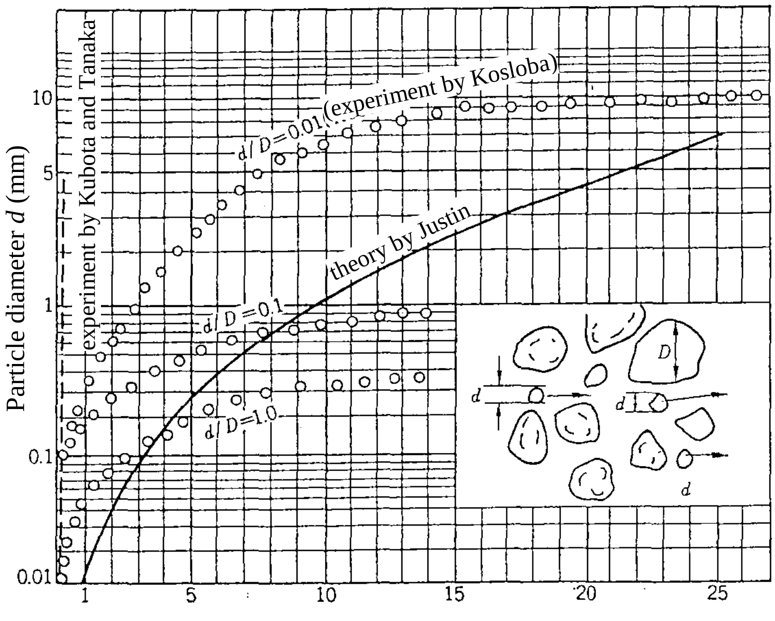


Fig. 35-1 Critical Seepage Velocity for Various Particle Diameter

If Va>Vc: safety

Va<Vc: seepage failure

Va : seepage velocity

Va = k×i = k×(H/L)

Where,

k : coefficient permeability (cm/s)

i : hydraulic gradient

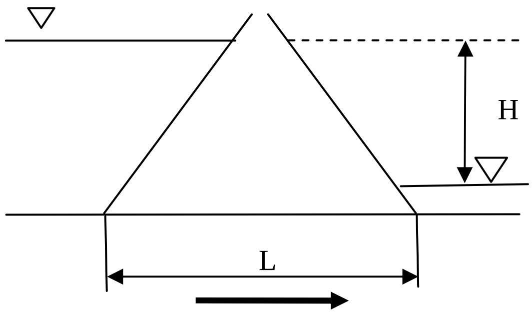


Fig. 35-2 Judgment of Seepage Failure by Seepage Velocity

2) Limited Hydraulic-gradient Method

When the water stays still, the water pressure acting on soil grain is only the pore water pressure; however, for flowing water the soil grain is exposed to the percolation water pressure. When the hydraulic gradient increases over a certain limit, the percolation water pressure exceeds the resistant force acting between the soil grain, to move the soil grain. This hydraulic gradient is called the limited hydraulic gradient.

Terzaghi explains that the hydraulic gradient, when receiving the percolation water pressure, can be expressed by the following equation:

$ic = \gamma'/\gamma w=(1-n)(Gs-1)=(Gs-1)/(1+e)$

Where,

γ' : Unit volume weight of soil in water
n : Pore percentage of soil
e : Pore ratio of soil
Gs : Specific gravity of soil grain
γw : Unit-volume weight of water

The resistance force between grains of soil depends on the adhesion force of the soil and the state of combination. However, it can be qualitatively said that a soil with a large plastic index shows a large resistance force. This reduces with a decreasing plastic index. For fine-grained particles without an adhesion force, the limited hydraulic gradient is said to be 0.5 to 0.8.

If $i<ic$: safety
$i>ic$: seepage failure

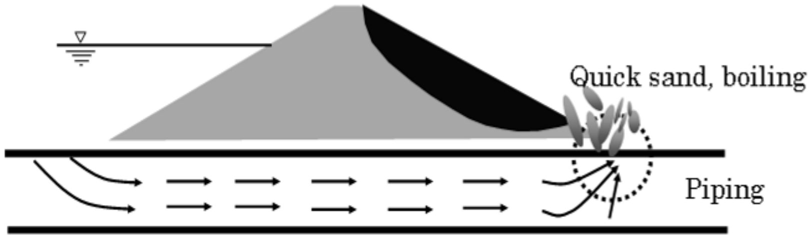


Fig. 35-3 Seepage Failure of Dam Foundation

3) Method for mean hydraulic gradient

It is presupposed that seepage failure occurs the contact areas between the dam body and the dam foundation.

Cr: Critical creep ratio

a. Lane's method Cr< = (L/3 + 2×t1 + 2×t2)/H

b. Bligh's method Cr< = (L + 2×t1 + 2×t2)/H

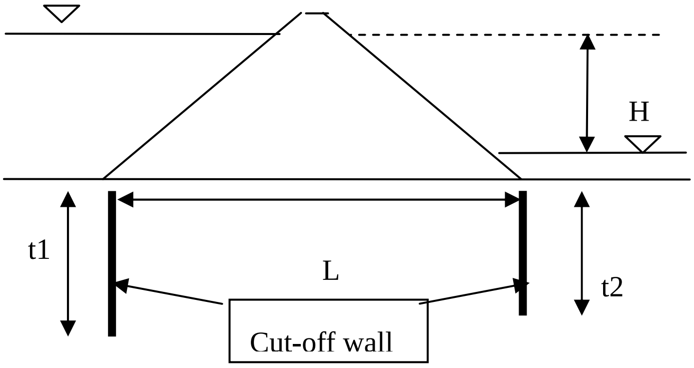


Fig. 35-4 Critical Creep Ratio

Table 35-3 Critical Creep Ratio; Cr for Blight's Method and Lane's Method

Soil material Dia.(mm)		Critical creep ratio; Cr	
		(1) Blight's method	(2) Lane's method
Very fine sand		18	8.5
Fine sand	(0.074-0.42)	15	7
Medium sand		-	6
Coarse sand	(-2.0)	12	5
Gravel	(2.0)	9	4
Coarse gravel		4-6	3
Cobble stone	(150-180)	-	2.5

4) Hydraulic fracturing

In the case that pore water pressure increases higher than the sum of effective compressive stress and tensile strength, there is a possibility that cracks occur.

$$P \geq |\sigma' + \sigma t|$$

Where,

P : Pore water pressure

σ' : Effective compressive stress

σt : Tensile strength of soil

(3) Measures against Seepage Failure

1) Method using drainage and a relief well

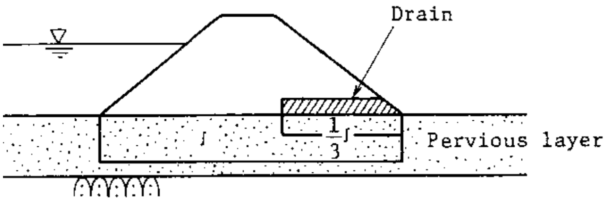


Fig. 35-5 Arrangement of a Drain

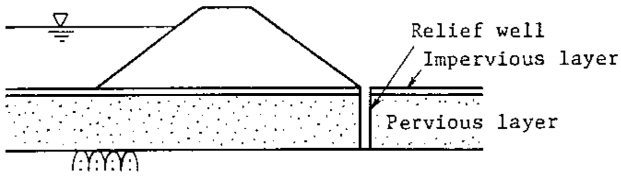


Fig. 35-6 Arrangement of a Relief Well

2) Method for lengthening a seepage path

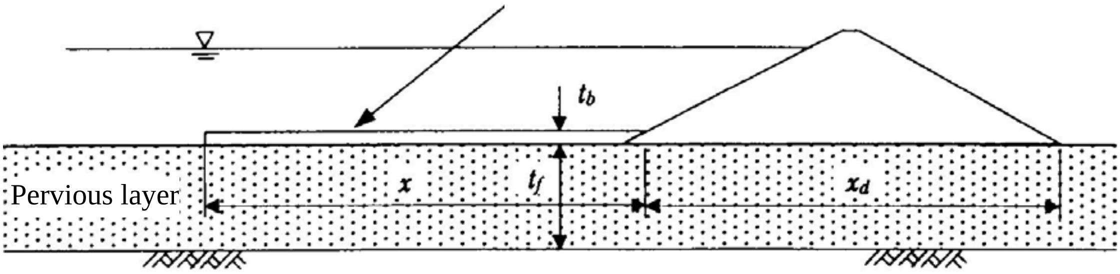


Fig. 35-7 Sealing of Gravel Foundation by Blanket (1)

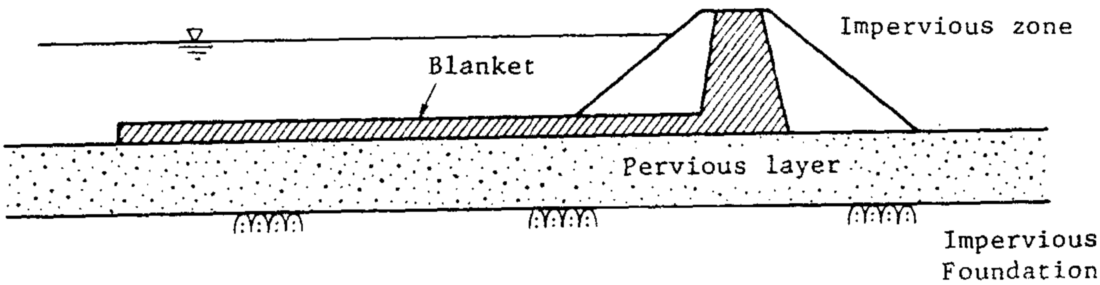


Fig. 35-8 Sealing of Gravel Foundation by Blanket (2)

For Article 36 Stability of Fill Dams

1. Commentaries

Paragraph 1 "circular arc methods"

A circular arc method has been used in many past cases. Generally, Spencer's method, Bishop's method, Swedish method, and so on are used.

2. Explanations

Determination of a technical standard in the region (Laotian technical standards case)

In order to determine criteria of fill dam stability of the Laotian technical standards, the following case study was carried out.

Conditions of the case study are as follows:

1. The same parameters of Nam Leuk dam are used (e.g. dam height, seismic coefficient, strength of materials and so on).
2. Criteria of Japan, U.S. Bureau of Reclamation or U.S. Army Corps of Engineers and criterion which Nam Leuk has adopted in those days are used for the case study.
3. Necessary upstream/downstream slopes from each criterion are obtained as the results of the case study.
4. The criteria of the Laotian technical standards are determined by the comparison of the results.

(1) The parameters to be used for the case study

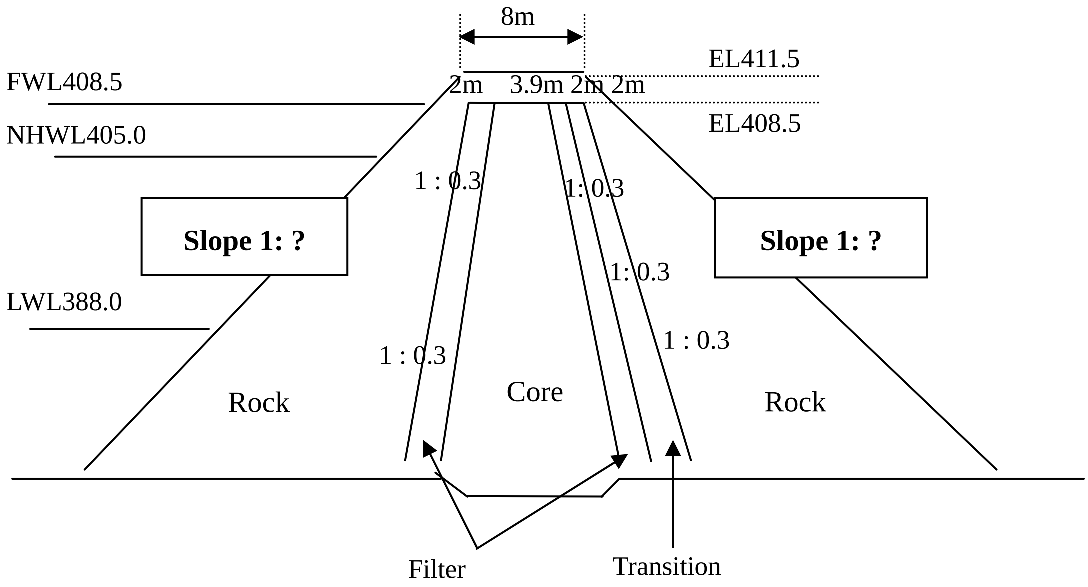


Fig. 36-1 Typical Dam Section

Table 36-1 Unit Weights and Strengths of Materials

Materials	γt (kN/m³)	γs (kN/m³)	φ (°)	c (kPa)	Test conditions
Core	20.9	21.1	31 0	22.5 60.0	$\overline{CU}$ UU
Filter	19	20	38	0	$\overline{CU}$
Transition	19	20	38	0	$\overline{CU}$
Rock	27	27.4	φ Effective normal stress (MPa) 47 < 0.1 45 < 0.2 42 < 0.5 40 >= 0.5		
Foundation		21.1	35	2000	

Note CU: Consolidated and undrained
UU: Unconsolidated and undrained

(2) Necessary upstream and downstream slopes gradient obtained by the case study

Table 36-2 Example of Calculation for Upstream and Downstream Slope for Various Methods

For normal condition For earthquake Necessary design seismic coefficient		**U.S. Bureau of Reclamation and U.S. Army Corps of Engineers**		**Japan**		**Nam Leuk**	
		Bishop method		**Fellenius (Swedish) (Conventional method)**		**Bishop method**	
		Necessary safety factor	Necessary slope	Necessary safety factor	Necessary slope	Necessary safety factor	Necessary slope
End of construction	Upstream	1.4 1.0 (0.1)	1:1.4 1:1.2	1.2 1.2 (0.05)	1:1.2 1:1.3	1.3 1.15 (0.05)	1:1.3 1:1.2
	Downstream	1.4 1.0 (0.1)	1:1.4 1:1.2	1.2 1.2 (0.05)	1:1.2 1:1.3	1.3 1.15 (0.05)	1:1.3 1:1.2
Normal operation (Normal water level)	Up stream	1.5 1.0 (0.1)	1:1.5 1:1.3	1.2 1.2 (0.1)	1:1.2 1:1.7	— —	
	Downstream	1.5 1.0 (0.1)	1:1.5 1:1.2	1.2 1.2 (0.1)	1:1.2 1:1.5	1.5 1.0 (0.1)	1:1.5 1:1.2
Flood water level	Upstream	1.5 —	1:1.5	1.2 —	1:1.2	– –	
	Downstream	1.5 —	1:1.5	1.2 —	1:1.2	1.4 –	1:1.4
Normal operation (Middle water level)	Upstream	1.5 1.0 (0.1)	1:1.5 1:1.3	1.2 1.2 (0.1)	1:1.2 1:1.7	— —	
	Downstream	1.5 1.0 (0.1)	1:1.5 1:1.2	1.2 1.2 (0.1)	1:1.2 1:1.5	— —	
Drawdown	Upstream	1.3 —		1.2 1.2 (0.05)		1.25 —	
	Downstream	— —		1.2 1.2 (0.05)		— —v	
	Necessary slope		1:1.5		1:1.7		1:1.5

(3) Determination of criteria

1) SREPTSHP is modeled on U.S. Army Corps of Engineers' standard.
2) SREPTSHP takes five cases to be reviewed, normal operating, just after completion and before initial impounding, design flood, rapid drawdown, and normal operating with OBE.
3) The safety factor against sliding shall be 1.5 for normal operating and 1.3, 1.4, 1.1 to 1.3 and 1.0 in order of the remaining four cases in the previous section 2), respectively.

Table 36-3 Comparison Table for Design Standard of Fill Dam

	Design loads	Conditions			Minimum Safety Factor	Target slopes	Stability Analysis	Considerations for Earthquake	Remark
Stability of Earth and Rock-Fill Dam the U.S. Army Corps of Engineers	self-weight, hydrostatic pressure, seismic force, pore pressure	Surcharge W.L.			1.4	D	:circular arc method :sliding wedge method :infinite slope method(FYI)	Pseudo static analysis :seismic intensity method	:*) at the earthquake :specified material strength determined with in situ test
		Normal W.L.			1.5 (1.0)*	D			
		Intermediate W.L.			1.5 (1.0)*	U			
		Rapid drawdown (from spillway crest or top of gate)			1.1	U			
		Rapid drawdown (from maximum W.L.)			1.3	U			
		End of construction			1.3 (1.0)*	U/D			
Embankment Dams No.13 the U.S. Bureau of Reclamation	self-weight, hydrostatic pressure, (seismic force), pore pressure	End of construction	E*1	Generation of excess pore pressures in embankment and foundation materials with laboratory determination of pore pressure and monitoring during construction	1.3	-	:Spencer method of limit equilibrium analysis (The procedure assumes that resultant side forces acting on each slice are parellel to each other. The solution for the factor of safety is obtained by successive iterations of side force inclination and safety factor in order to satisfy the equilibrium boundary conditions.) :infinite slope method	Dynamic analysis :Deformation analysis shall be done with Newmark's approach :Liquefaction analysis shall be done with residual strength after liquefaction if there is possibility of liquefaction.	:*1)Effective stress method :*2)Total stress method :specified material strength determined with in situ test
				Generation of excess pore pressures in embankment and foundation materials and no field monitoring during	1.4	-			
				Generation of excess pore pressure in embankment only with or without field monitoring during construction and no laboratory determination,	1.3	-			
			U*2	method by undrained shear strength	1.3				
		Steady-state seepage	E	Steady-state seepage under active conservation pool	1.5	D			
		Operational conditions	E/U	Steady-state seepage under maximum reservoir level	1.5	D			
				Rapid drawdown from normal water level to inactive water level	1.3	U			
				Rapid drawdown from maximum water level to inactive water level	1.3	U			
		Unusual	E/U	Drawdown at maximum outlet capacity	1.2	-			
Dam Safety guidelines Canadian Dam Safety Association	self-weight, hydrostatic pressure, seismic force, pore pressure	Normal Water Level			1.5	D	:limit equilibrium analysis :FEM	Pseudo static analysis :seismic intensity method :Liquefaction analysis shall be done if there is possibility of liquefaction.	
		Rapid drawdown (much water-use)			1.2	U			
		Rapid drawdown (little water-use)			1.3	U			
		End of construction			1.25-1.3	U/D			
Manual for river works in Japan River Bureau, MLIT	self-weight, hydrostatic pressure, seismic force, pore pressure	Normal Water Level			1.2	U/D	:circular arc method, :infinite slope method	Pseudo static analysis :seismic intensity method	: specified material strength determined by the result of the proper tests used at similar dam sites and calculation.
		Surcharge Water Level				U/D			
		Design flood Water Level				U/D			
		Intermediate Water Level				U			
		Rapid drawdown				U			
		End of construction				U/D			
SREPTSHP in the Kingdom of Cambodia	self-weight, hydrostatic pressure, seismic force, pore pressure	Surcharge W.L.			1.4	D	:limit equilibrium analysis :FEM	Pseudo static analysis :seismic intensity method Dynamic analysis: to evaluate liquefaction potential and/or to estimate deformations for dam body and foundation materials subjected to strong ground motions corresponding to MCE and OBE	:*) at the earthquake :specified material strength determined with in situ test
		Normal W.L.			1.5 (1.0)*	D			
		Intermediate W.L.			1.5 (1.0)*	U			
		Rapid drawdown (from spillway crest or top of gate)			1.1	U			
		Rapid drawdown (from maximum W.L.)			1.3	U			

Note MLIT : Ministry of Land, Infrastructure, Transport and Tourism, Japan

For Article 37 Restrictions on Facilities such as Discharge Facilities

1. Explanations

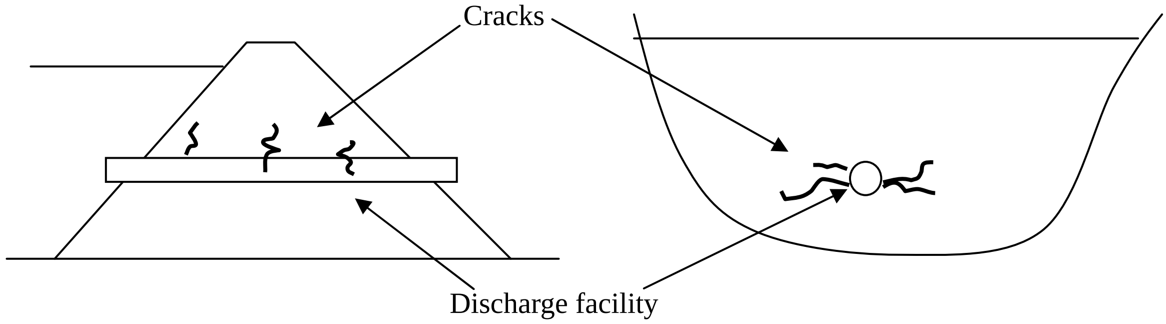


Fig. 37-1 Prohibited Case

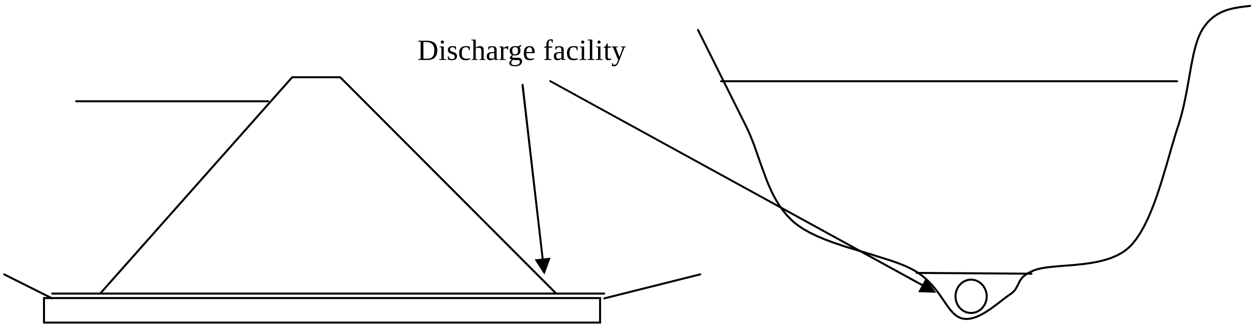


Fig. 37-2 Acceptable Case

For Article 38 Particular Applications for Fill Dams

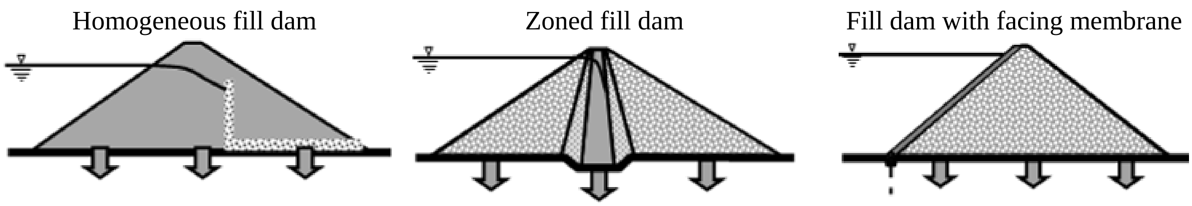


Fig. 38-1 Typical Types of Fill Dams

I. Design for Homogeneous Type Fill Dams

1. Commentaries

“as necessary”

Generally, drainage is established for almost all homogeneous type fill dams.

“appropriate”

Many kinds of drainage types are adopted in homogeneous type fill dams. The type of drainage depends on the design.

2. Explanations

A homogeneous type fill dam consists of impervious materials, so that the dam's stability shall not be damaged due to a seepage line appearing at the downstream slope for the case without a drain. It is difficult to release the pore pressure during construction entirely, resulting in a deterioration of the stability. This requires an appropriate drain inside the dam.

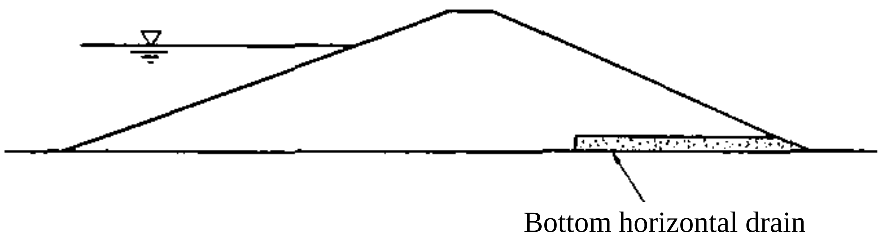
The arrangement of the dam depends on the estimated water pressure in the void and the permeable-flow rate. A typical arrangement is shown in Fig. 38-2. Type 1) and 2) can be used for a lower dam and Type 2) has an effect on the decrease in water pressure inside the foundation, and may be with a band type drain.

For a dam with a height of about 30m Type 3) can be used to lower the line of the seepage level. Type 4) may be applied in Type 3) structures with several horizontal drains. In this case, each drain is effective for releasing the water pressure in the void during construction. The horizontal drain at the upstream face is to reduce the residual water pressure in the void during a rapid decrease in the water level. The vertical drain at the downstream face is to lower the line of the seepage level.

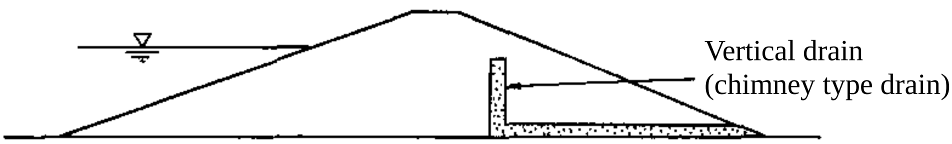
The permeability coefficient of the drain material is necessary to be <u>at least 10 to 100 times</u> that of the dam material. Between the drain material and the dam it is required to install some filters.

1) Drain at the downstream slope

2) Horizontal drain



3) Vertical drain



4) Complex drain

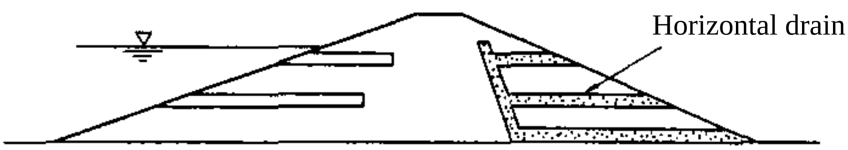


Fig. 38-2 Drains in Homogeneous Type Fill Dams

3. Reference

Table 38-1 Type of the Fill Dam and Special Factors to be Applied

Factors	Homogeneous type	Zoned type	Facing type
Dam height	Lower than 30m	No limit	Lower than 70m
Dam material	Borrow material	Borrow material Pervious material Semi-pervious material	Pervious material Other transition material
Topography at the dam site	-	Central-core type is adequate for a sharp abutment.	Disadvantages of a sharp abutment
Geology at a dam site	Suitable for a soil foundation	Suitable for a rock foundation	Suitable for a rock foundation
Weather	Disadvantageous for cold and heavy rain-fall areas	Thin coater-sealing zone type is adequate for cold and heavy rail-fall areas.	Advantages for a heavy rail-fall area
Application plan for a reservoir	Disadvantages regarding a rapid decrease in the water level	Slopping type is not adequate for a rapid decrease in the water level.	Advantageous regarding a rapid decrease in the water level

II. Design for Zoned Type Fill Dams

1. Explanations

A semi-pervious material shall be supplied from non-adhesive material which is fine grained compared to pervious material, and plays a role to gradually change in grain size between impervious and pervious zones. It also prevents impervious materials from seepage failure. The semi-pervious zone is sometimes called a transition zone.

When the semi-pervious zone plays the role of a filter, the relation with the material to be protected is required to meet the following criteria for a filter. Riverbed sand is one type of preferable material for the filter.

1) $$\frac{\text{F15: 15\% grain size of the filter material}}{\text{B15: 15\% grain size of the material to be protected by the filter}} > 5$$

2) $$\frac{\text{F15: 15\% grain size of the filter material}}{\text{B85: 85\% grain size of the material to be protected by the filter}} < 5$$

3) The grain-size curve of the filter material shall preferably be parallel to that of the material to be protected.

4) When the material to be protected contains coarse-grained material, items "1)" and "2)" are applied regarding the grain size of a material smaller than 25 mm.

5) The filter material shall be non-adhesive and shall not contain material smaller than 0.074 mm (over 5% of the material). For the adhesive material to be protected, however, this requirement can be loosened.

Materials meeting these requirements can be considered to have good drainage ability and high resistance to a seepage failure of the material to be protected. It is adequate that the permeability coefficient of the filter material is 10 to 100 times that of the material to be protected (in general).

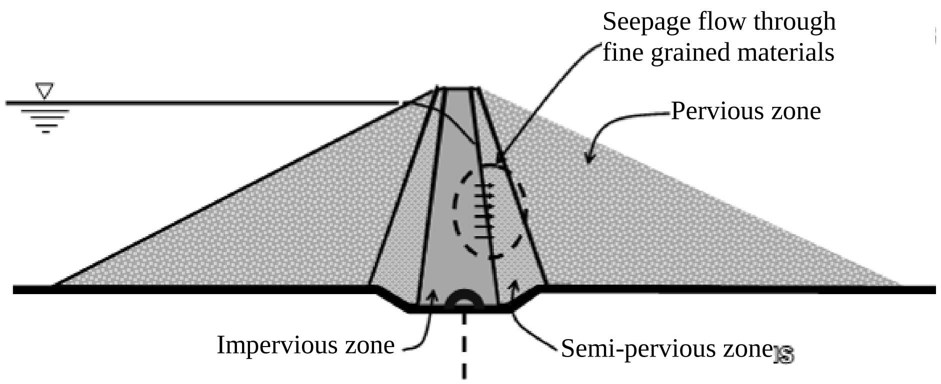


Fig. 38-3 Seepage Flow in Zoned Type Fill Dams

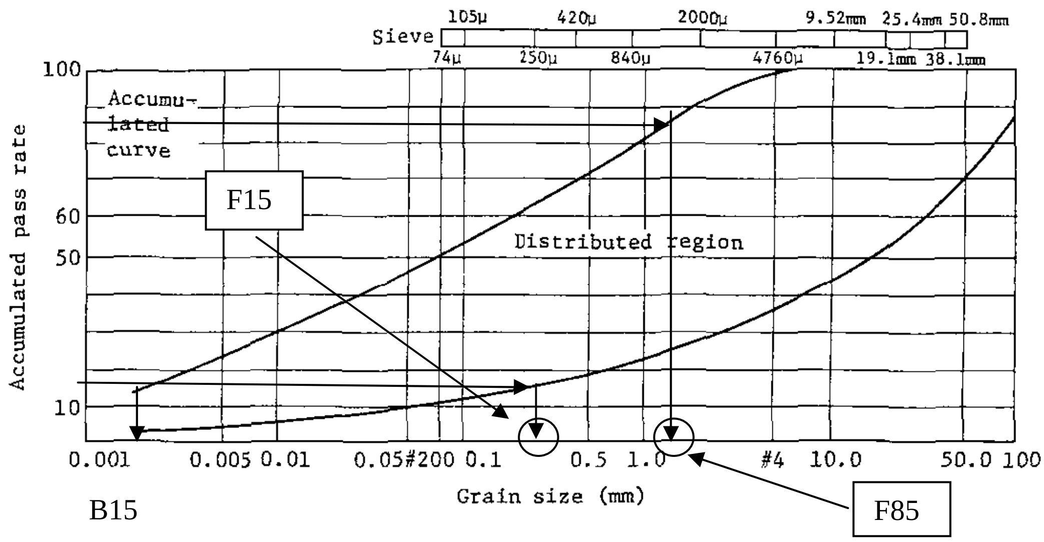


Fig. 38-4 Grain-size Range of the Borrow Material

2. Reference

Table 38-2 Example of the Structure for a Zoned Dam - 1

Name of dam	Name of construction	Year of comple-`tion	Height of dam H (m)	Length of dam top (m)	Width of dam top (m)	Water-sealing		Min. thickness of the filter		B/H	Extra banking (m)	Slope gradient		Remarks
						Max. width B (m)	Min. width (m)	Up-stream	Down-stream			Up-stream	Down-stream	
Daisetsu	Ministry of Land, Infrastructure, Transport and Tourism (MLIT)	1974	86.5	440.0	12.0	37.32	6.0	4.00 Equal thickness	4.00 Equal thickness	0.43	2.0	2.65	1.9-2.1	General-core
Hirose	Yamanashi Prefecture	1974	75.0	255.0	10.0	48.7	4.0	3.00	3.00	0.65	1.0	2.5	2.0	ditto
Iwaya	Japan Water Agency (JWA) (Chubu Electric Power Co. Inc.)	1976	127.5	366.0	10.0	42.25	4.0	10.25 Equal thickness	1.50	0.33	2.0	2.5	2.0	Sloping-core type
Terauchi	Japan Water Agency	1977	83.5	420.0	10.0	49.0	5.0	4.50	3.60	0.59	1.5	2.7	2.1	General-core type
Takase	Tokyo Electric Power Co. Inc.	1978	17.6	362.0	14.0	94.0	6.0	2.0 Transition	2.00 (Fine) 2.00	0.53	3.0	2.6	2.1	ditto
Nankura	Tokyo Electric power Co. Inc.	1978	125.0	340.0	12.0	62.0	6.0	3.00 (Fine) 2.00	3.00 (Fine) 2.00	0.50	1.5	2.7	2.0	ditto
Seto	Kansai Electric Power Co. Inc.	1978	110.5	342.8	11.0	37.15	4.0	2.00	2.00	0.34	1.0	2.5	2.0	ditto
Miho	Kanagawa Prefecture	1978	95.0	590.0	15.0	39.25	6.0	3.00	3.00	0.41	2.0	3.4	2.8	ditto
Tedorigawa	Electric Power Development Co. Ltd.	1978	153.0	420.0	12.0	67.5	6.0	6.00 Equal thickness	6.00 Equal thickness	0.44	4.0	2.6	1.85	ditto

Table 38-3 Example of the Structure for a Zoned Dam - 2

Name of dam	Name of construction	Year of comple-`tion	Height of dam H (m)	Length of dam top (m)	Width of dam top (m)	Water-sealing		Min. thickness of the filter		B/H	Extra banking (m)	Slope gradient		Remarks
						Max. width B (m)	Min. width (m)	Up-stream	Down-stream			Up-stream	Down-stream	
Urushizawa	Miyagi Prefecture	1979	80.0	308.4	10.0	35.0	4.0	5.00 Equal thickness	5.00 Equal thickness	0.44	1.0	2.8	2.5	General-core type
Isarigawa	MLIT	1980	45.5	270.0	10.0	21.4	5.0	4.00 Equal thickness	4.00 Equal thickness	0.47	1.0	3.2	2.1	ditto
Shirakawa	MLIT	1981	66.0	348.2	10.0	31.0	5.0	2.00	2.00	0.47	1.0	2.5	2.3	ditto
Maekawa	Yamagata Prefecture	1982	50.0	265.5	10.0	24.5	4.5	3.00	3.00	0.49	1.3	3.0	2.4	ditto
Gosho	MLIT	1982	52.5	210.0	10.0	23.0	4.0	2.13	2.13	0.44	0.5	3.3	2.5	Complex type
Tokachi	MLIT	1984	84.3	443.0	12.0	46.0	6.0	6.00 Equal thickness	6.00 Equal thickness	0.55	2.0	2.6	2.0	ditto
Nanakita	Miyagi Prefecture	1985	74.0	420.0	10.0	41.0	4.0	1.00	1.00	0.55	1.0	3.0	2.2	General-core type
Terayama	Tochigi Prefecture	1985	62.0	260.0	10.0	31.0	4.0	2.00	2.00	0.50	1.5	2.5	2.0	ditto

Note: 1. In the column of remarks, the central-core type includes the slow-gradient sloping-core type.
2. Refer to Figure 38-5 for the dam height H and the maximum width B of the water-sealing zone.

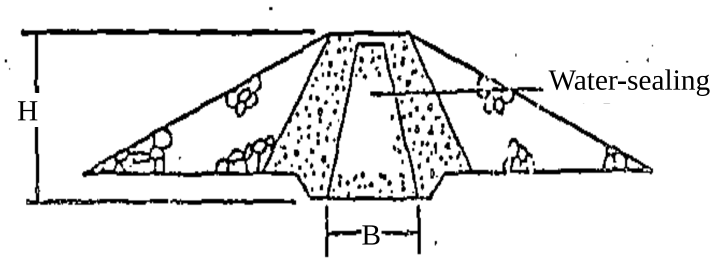


Fig. 38-5 Description of "H (dam height)" and "B (max. water sealing width) in Tables 38-2 and 38-3

III. Design for Surface Diaphragm Type Fill Dams

1. Reference

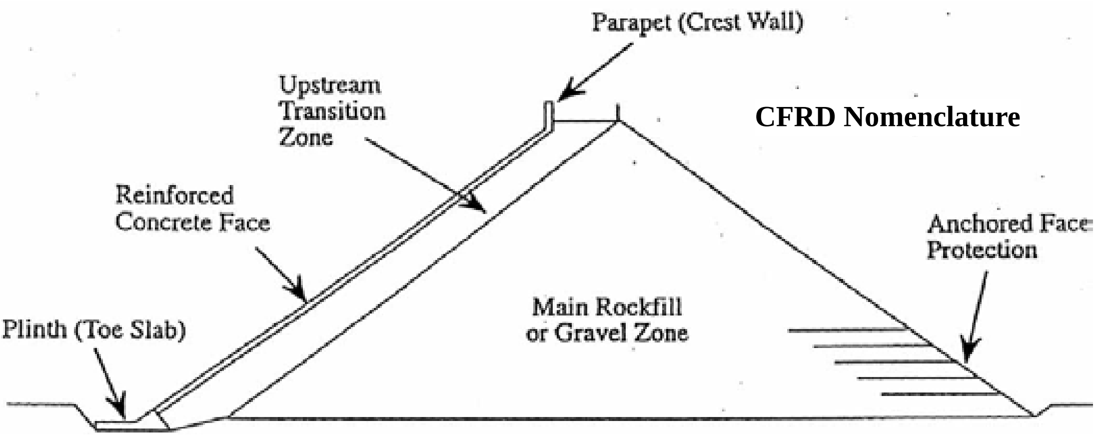


Fig. 38-6 Example of Typical Section of CFRD

(1) Canadian Dam Safety Association (CDSA) mentions as follows:

CONCRETE-FACED ROCKFILL DAMS

Concrete faced rockfill dams (CFRDs) have several advantages:

- Hydrostatic thrust in a favorable direction
- Minimum volume of fill material (slopes as steep as 1.3H : 1V)
- No additional wave protection is required
- Short construction period
- Face accessible for repair
- Fill is dry and offers good earthquake resistance

The disadvantages are:

- Deformation of rockfill may damage facing
- Artificial materials of which the face is constructed may deteriorate with time

The faced rockfill dam is covered in general terms by Goize (1977), and the CFRD is covered in detail by Thomas (1976), Cooke (1984) and (1991), Neidert and Toniatti (1991), Beach et al. (1991), Marulanda et al. (1991) and in the ICOLD bulletin No. 70 (1989).

Early CFRDs were built with dumped rockfill and deformation under hydrostatic load limited their height. Currently, heavily compacted wetted rockfill is used for the mass and compacted transition zones underlay the facing, In the vulnerable perimeter joint zone, fine filters are included which permit sealing by silty materials in the event of leakage. The concrete face is relatively thin, the thickness T being of the order of t = 0.3+ 0.003 h, where h is the water head in meters.

CFRDs have an excellent record for stability, provided they are built of good quality, hard rockfill. The exterior slopes of CFRDs are established more by precedent than by analysis. Records of the dam behavior when operated at maximum design reservoir level will assist with the evaluation of the static stability.

(2) "Guidelines on concrete-faced rockfill dams" 1991 Australian National Committee on Large Dams

A fundamental consideration is the hydraulic gradient to be used, i.e. the ratio of the reservoir head to the plinth width. The acceptable hydraulic gradient depends on the assessment of the erodibility of the foundation rock and its defects under each section of plinth.

The following is a general guide only:

Table 38-4 Foundation Erodibility and Acceptable Hydraulic Gradient

Foundation erodibility in terms of rock condition	Acceptable hydraulic gradient
Fresh	20
Slightly to moderately weathered	10
Moderately to highly weathered	5
Highly weathered	2

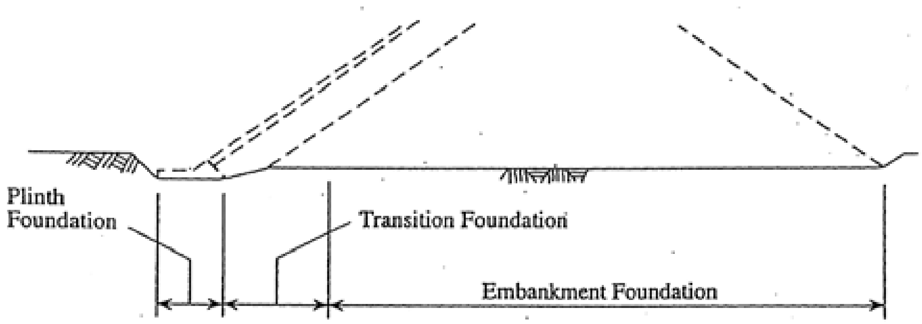


Fig. 38-7 Foundation Zones

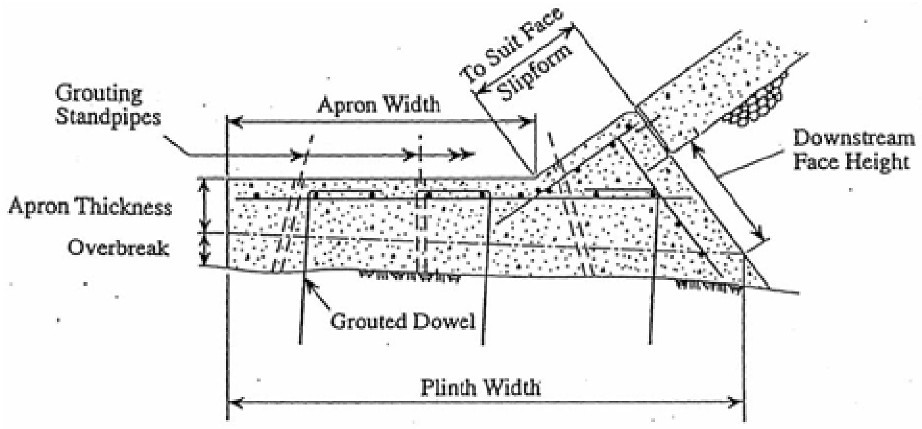


Fig. 38-8 Plinth Nomenclature

A detailed assessment and classification of the foundation conditions at the site are required for design purposes. In making this assessment, particular attention needs to be given to the foundation, and to the erodibility of any altered or infill materials in joints and defects of adverse orientation.

A decrease in hydraulic gradient can be achieved by the use of reinforced concrete or shotcrete slabs on the foundation usually downstream of the plinth. The effect on plinth stability of extensions upstream or downstream shall be carefully considered.

Section 4 Spillways and Other Discharge Facilities

For Article 39 Spillways

1. Explanation

Paragraph 1

Reliable calculation methods shall be used in designing spillways or discharge facilities. In case calculations alone are not sufficient to produce satisfactory results, hydraulic model tests shall be conducted to verify safety.

Paragraph 2

The spillway of fill dam shall be surely placed on bedrock to prevent the erosion and structural failure of dam material caused by leakage water from the spillway.

Paragraph 3

To ensure secure discharge and to prevent serious accident, the distance between the bottom of bridges or gate leaves and the surface of the design flood water shall be 1.5m or more.

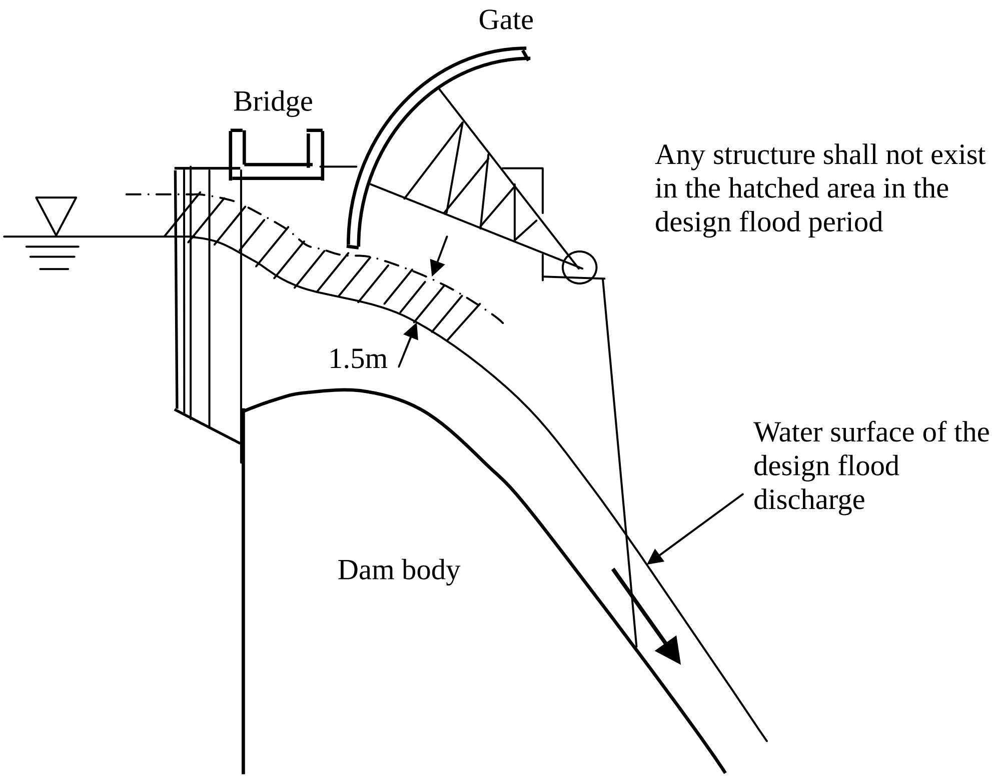


Fig. 39-1 Distance between the Bottom of the Structure and Water Surface

Paragraph 4

Energy dissipator is generally placed to prevent the damage to dam body and downstream river course. The type of the energy dissipator shall be selected by considering the hydrology, land features, geological condition and environment at the site.

The types of commonly used energy dissipator are shown as below.

1) Hydraulic-jump type
2) Ski jump type
3) Free-fall type

2. Reference

Photograph 39-1
Downstream of O'Chum 2 Dam Spillway with No Gate (Hydraulic-Jump Type)

Photograph 39-2
Spillway with Gate (Semi-Hydraulic-Jump Type)

For Article 40 Spillway Gates and Auxiliaries

Refer to the explanation for Article 50 (Gate, Valves and Auxiliaries)

1. Reference

Photograph 40-1 Spillway Gate (Radial Gate) and Hoist

For Article 41 Other Discharge Facilities

Once abnormal incident, such as rapid increase of leakage water and serious deformation of dam body, happens, as compared with concrete gravity dam, fill type dam is easily and seriously damaged in a short time. And that could cause catastrophic impact to the downstream area. Therefore, fill type dam shall be equipped with discharge facility such as a bottom drainage gate or valve to drain reservoir water off effectively in case of emergency.

The type and the capacity of discharge facilities are adopted in view of their purpose, operation frequency, condition of discharge and operation and maintenance matter.

The maximum discharge capacity is determined by “considering discharge requirement during flood operation,” “necessary period of reducing reservoir water level during checking and repairing dam and reservoir” and “emergency response.”

In case of emergency, it is preferable that a discharge facility can reduce reservoir water level as low as reasonably achievable within a week.