2nd Seminar

01 Seminar on Risk Management for Dam II

Ministry of Public Works and National Housing
Directorate General of Water Resources
Japan International Cooperation Agency

Risk Management
in Dam Design & Construction

COMPOSING RISK MANAGEMENT SYSTEM IN INDONESIA

NOVEMBER 16, 2024

NATIONAL SEMINAR, INDONESIA COMMITTEE ON LARGE DAM (INACOLD)

BY JICA, DAM CONSTRUCTION ADVISORS

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Definition of Risks for Risk Management in Dam Design & Construction

Definition of Dam Risks in Design & Construction

ICOLD

defined as "**Risks of Dam Collapse or Malfunction** that may occur after the construction of a dam."

Risk is a measure of the probability and severity of an adverse effect on life, health, property, or the environment.

Due to ;

1. Occurrence of a extra loads (e.g. flood, earthquake, etc.),
2. Adverse structural response (e.g. dam failure, damaging spillway, etc.), and
3. the magnitude of the consequences resulting from that adverse event (life loss, economic damages, environmental damages, etc.).

In this Study

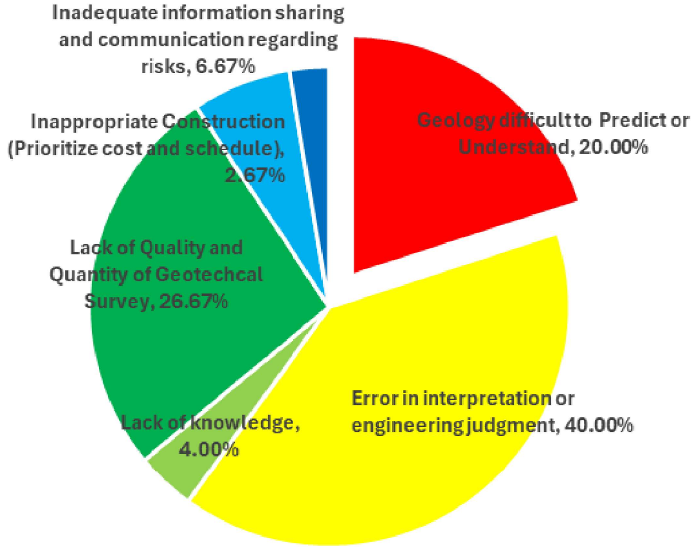
defined as **"Risks that arise in the Dam Projects** during geological surveys, design, and construction of Dam".

By **identifying potential risks in advance** and taking measures to the greatest extent possible, we aim not only to **ensure the safety of the dam** after completion, but also **to prevent accidents, delays**, and rising construction costs during the construction period."

Proactive Approach .

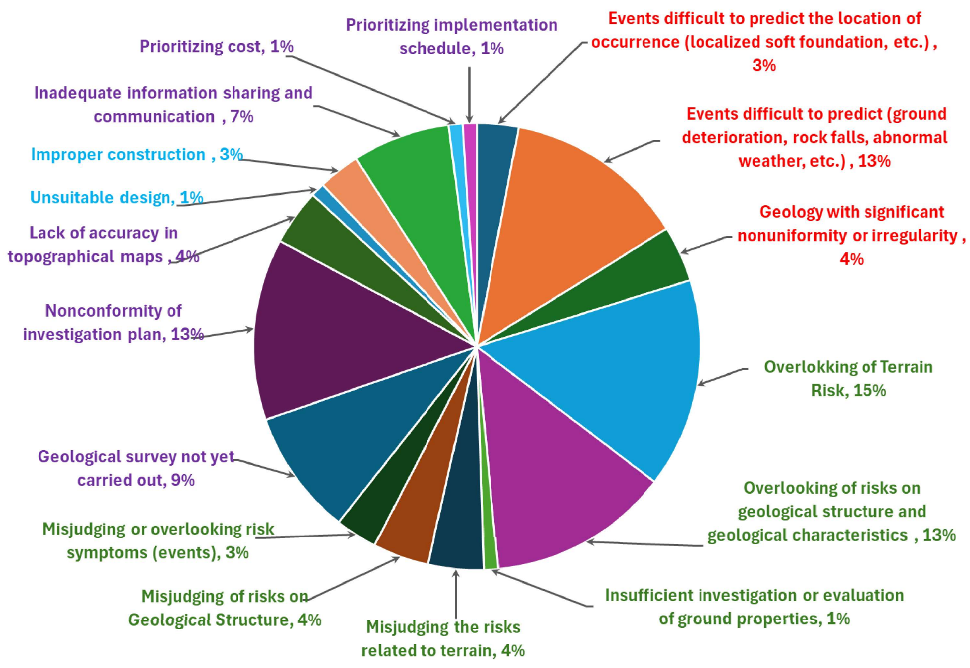
Risks Occurring in Civil Engineering Projects: Examples of Geological Issues in Japan

1. Natural Factors account for 20% of the overall risk, while Human Factors account for **80%.**
2. Project owner, Consultant and Contractors must recognize that "Human Factors play an important role in the occurrence of risk and to avoid such risks is own responsibility".



Impacts of Human Factors to Risks

Breakdown of Risk Factors (Sample number, n=75)



Pie Chart Legend

Red:	Natural factors (unpredictable events, etc.)
Green:	Lack of research skills
Purple:	Management issues
Blue:	Design and construction issues

Source: The 1st Geological and Geotechnical Risk Management Review Committee (analysis of case studies collected by the Society of Geological Risk Management)

Necessity of Risk Management in Dam Construction Project

Dam Design & Construction

- Constructed by the **Maximum Use of the Nature** such as regional geology, climate, and natural resources. *Nature is difficult to control,*
- Almost always many issues arise during construction stage.
- Many of such issues are originated in geology at site.

Face to Issues

1. **In Dam Design Stage**, predict risks to be arose during construction and operation in advance, and reflect them in design, as much as possible.
2. **In Dam Construction Stage**, establish a system that allows for quick and timely responses.

Risk Management System

- To promote recognition of these issues, one effective method may be "**Establishment of "Risk Management System**" and **Preparation of "Database of Issues"**.

Effects of Risk Management

To avoid such human error risks, it is well known that **Risk Management** is functioned effectively.

Effect 1: Adequate Response to Risks in Advance

It is difficult to ensure the efficient and safety of dam Projects, since the uncertainty issues or geological issues has been handled depending on the experience of field engineers.

Effect 2: Appropriate Evaluation of Uncertain Risks

Supporting the lack of experienced personnel and reducing human errors.

Effect 3: Appropriate Timing for Risk Response

Conducting the risk response in appropriate timing (during survey and design stages), arising risks (during construction stage) can be significantly reduced.

Utilizing of Dam Risk Database in Risk Management

1. **Database of Risk Cases** that have occurred in past dam projects, can help reach a cases and common consensus on dam risks.
2. **Risk Management** in dam construction projects , so that early awareness of risks, reduction of oversight of risks, and rational response to risks can be achieved.
3. To accumulate such risk Information, data shall be shared among the Engineers and reconfirm or update them at each phase (planning, investigation, design, construction and maintenance).

Risk Analysis Arising in Dam Projects

CASES OCCURRED AT ONGOING 61 DAM PROJECTS

Method of Risk Analysis

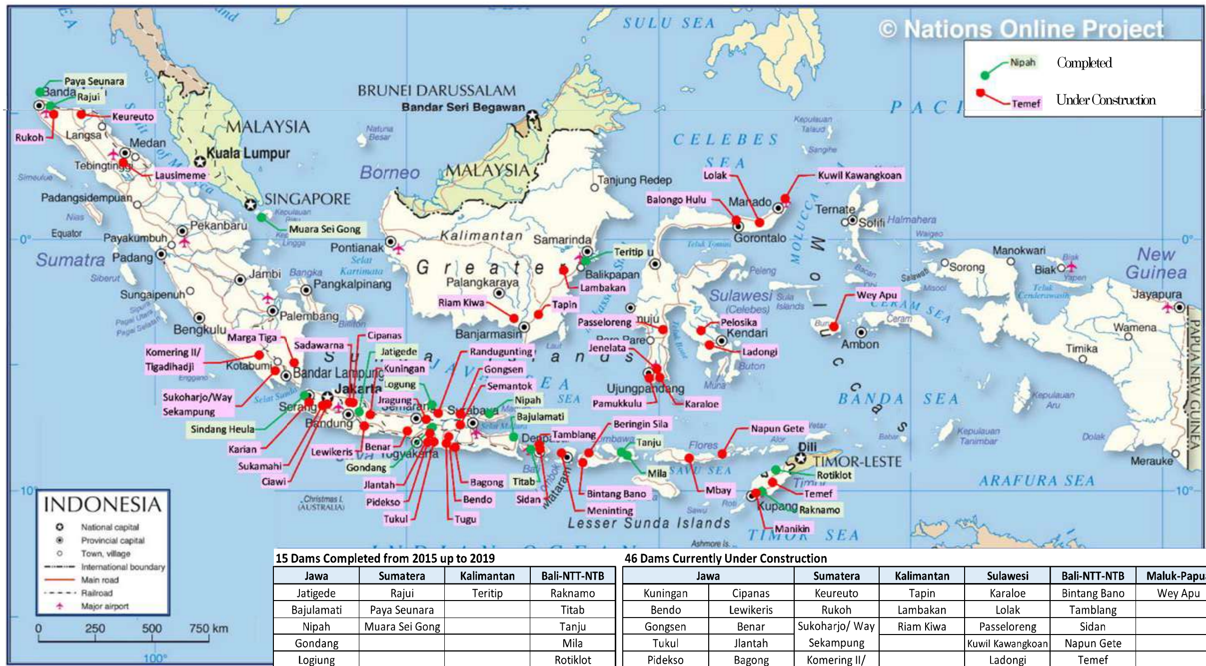
Applied Data

- Based on dam design documents and materials for technical session submitted to the Dam Safety Commission, 100 risk cases were extracted and assessed for 61 dams across Indonesia. However, it is the Limitation of Data

Format for Compiling Data

- In sorting out the 100 risk cases, a format was filled for each identified risk. The items classified in this form were sorted into:
  1. Risk factors,
  2. Situation (location, occurrence), and
  3. Response and problematic items.

Applied Dam Projects in the Study



15 Dams Completed from 2015 up to 2019

Jawa	Sumatera	Kalimantan	Bali-NTT-NTB
Jatigede	Rajui	Teritip	Raknamo
Bajulamati	Paya Seunara		Titab
Nipah	Muara Sei Gong		Tanju
Gondang			Mila
Logiung			Rotiklot
Sindang Heula			

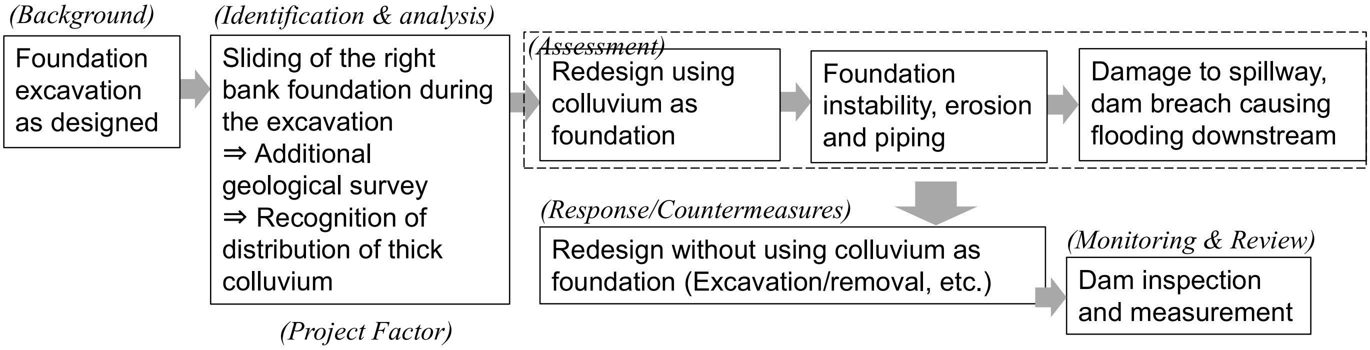
46 Dams Currently Under Construction

Jawa		Sumatera	Kalimantan	Sulawesi	Bali-NTT-NTB	Maluk-Papua
Kuningan	Cipanas	Keureuto	Tapin	Karaloe	Bintang Bano	Wey Apu
Bendo	Lewikeris	Rukoh	Lambakan	Lolak	Tamblang	
Gongsen	Benar	Sukoharjo/ Way Sekampung	Riam Kiwa	Passeloreng	Sidan	
Tukul	Jlantah			Kuwil Kawangkoan	Napun Gete	
Pidekso	Bagong	Komering II/ Tigadihadji		Ladongi	Temef	
Tugu	Randugunting			Pamukkulu	Mbay	
Ciawi	Jragung	Lausimeme		Pelosika	Manikin	
Sukamahi	Semantok	Marga Tiga		Jenelata	Meninting	
Karian	Sadawarna			Bulango Ulu	Beringin Sila	

Format for Database & Organizing of Risks

Format of Risk Cases for Database

- Risk is identified through issues or events in planning, investigation, design, construction and Operation.
- The risk identification, analysis, assessment, and response in this study are positioned in a cause-and-effect relationship as shown in the diagram below.



Example of Database Format

Form A

ID: **Name:** Bagong **Dam Type:** Rock-fill dam with central core **Dam Hight:** 82.0 *m*

Contents of Risk	1	*When the risk was identified (date)*	7-Jul-22
	2	*Project phase in which risks were recognized*	Construction
	3	*Location (Structure/Area)*	Dam / Foundation, Spillway / Foundation
	4	*Contents of risk*	Instability of the foundation, Piping of the foundation
	5	*Risk factors*	Sliding of colluvium (rock mass sliding) used as foundation, Unequal settlement
	6	*Events in which risks were recognized*	Sliding of the right bank cut slope occurred during the foundation excavation.
	7	*Condition/Situation for risk realization*	Foundation deterioration over time, Impounding, Heavy rains, Earthquakes
	8	*Impact if the risk realize*	Dam breach causing flooding downstream, Damage to spillway
Perspectives on Risk Classification	9	*Where risk exists*	Geology / Strength, Permeability, Design / Foundation treatment
	10	*Character*1*	B: Mainly due to technical factors
	11	*Phase of Realization*2*	Ⅱ: Operation, Ⅲ: Due to large-scale external force action, Ⅳ: Due to long-term use
	12	*Impact if the risk realize*3*	S: Affects dam safety / F: Affects dam function
	13	*Corresponding to risks*4*	α: Basically risk avoidance

Overview of Causal Relationships

Foundation excavation as designed ⇒ Sliding of the right bank cut slope occurred =>Additional geological survey => Recognition of the distribution of thick colluvium ⇒ Redesign using colluvium as foundation ⇒ Instability of the foundation, Piping of the foundation ⇒ Dam breach causing flooding downstream, Damage to spillway

Redesign without using colluvium as foundation (to be determined) ⇒ Risk avoidance

Explanatory Diagram (Schematic Diagram/ Photos, etc.)

Photo-1 Before the cut slope sliding (July 3, 2022)

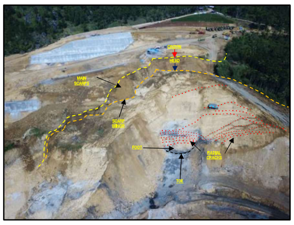


Photo-2 After the cut slope sliding (July 7, 2022)

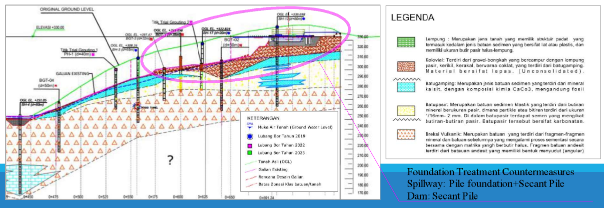


Figure-1 Right bank geologic cross section based on additional survey results

Form B

ID: **Name:** Bagong **Dam Type:** Rock-fill dam with central core **Dam Hight:** 82.0 *m*

History	*Recognition or not in the past*	Unrecognized	
	When the risk was recognized	*Project Phase:* Construction	*Date:* 7-Jul-22
	Status of corresponding	Considering countermeasure methods	
Project Phase	*History of correspond to risks*		
Plan			
Design	The design was to use bedrock as the foundation.		
Construction	As the distribution of thick colluvial soil was confirmed during foundation excavation, the use of colluvial soil as the foundation is being considered.		

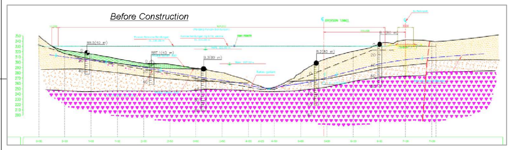


Figure-1 Dam axis geologic cross section (During investigation/design)

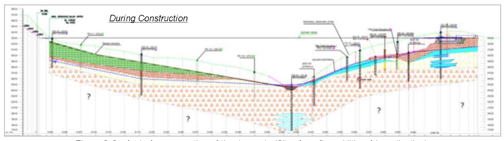


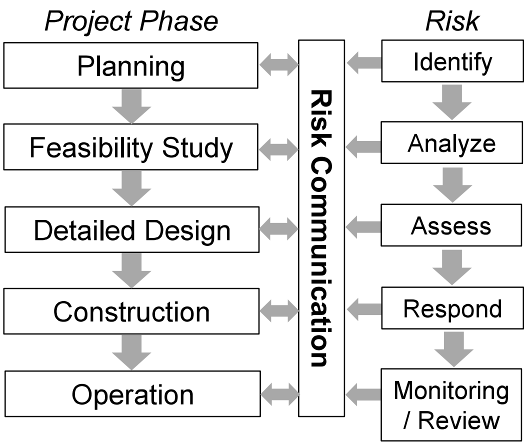
Figure-2 Geological cross section of the dam axis (Site plan after additional investigation)

Investigation /analysis	*Investigation/analysis to identify factors, etc.*		-
	Research/analysis, etc. to assess impact		-
	Analysis, etc. to determine the need for and methods of response		-
How to respond to risk	*Contents of measures (avoidance, reduction, transfer) or retention*		Reduction
	Measures	*How to deal with*	<Foundation Treatment> Spillway: Pile foundation+Secant Pile Dam: Secant Pile
		Basis for decision	Ground conditions, Construction cost
	Retention (no measures)	*Reason*	-
		Expected impact	-
	Availability and method of monitoring		-
	Availability and method of information sharing		-
Special Notes	***Challenges: 1) Technical issues, 2) Constraints in project implementation requirements (Construction time, costs, etc.), 3) Constraints in dam operation, 4) Issues due to human and organisational factors, results of risk response - 5) Impact on processes, costs, etc., 6) Reflection points (room for improvement of risk management methods), etc.***		
	1) Technical issues, 2) Constraints in project implementation requirements (Construction time, costs, etc.)		
	The geological conditions at the dam site differed significantly between the geological investigation/design and construction phases. The following risks should be considered once again when adopting the current countermeasure plan. 1) Sliding along the boundary between the collapsed soil and bedrock 2) Piping at the foundation where the spillway meets the dam due to unequal settlement		
Applicable standards	(Describe standards related to geological study, dam design, and countermeasure design.)		
Keywords.	Colluvium, Weathering, Creep		
References	*Meeting Minutes:*		2023.09.21 RDT Spillway Bagong [Z-AF] + CL (rev) Cap 226-KKB Laporan Inspeksi dlm rangka Pelaksanaan Konstruksi B. Bagong
	Meeting Materials:		Paparan BTB shimitzu
	Other:		LAPORAN AKHIR STUDY NEOTEKTONIK, Laporan Progress Pengeboran hasil MASW

Identified Risk Ledger

Organizing Risk Cases

- ***Knowing past risk cases:***
  - ✓ It will be possible to respond quickly to risks similar to past cases
  - ✓ Improve the ability to identify risks, and enables early identification of risks
- ***Keeping records of issues and responses to them:***
  - ✓ Preventing schedule delays and cost increases due to redesign and countermeasures during construction.
  - ✓ Increasing the safety of completed structures



Risk Management Flow

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No.	Dam Name	Dam Type	Dam Hight (m)	Risk Awareness: Location (Structure/Area) (3, 9)	Risk Awareness: Anticipated Events	Risk Awareness: Condition/Situation (6)	External				Geology						Material			Internal			Phenomenon				Stability (S)			Function (F)				(P)	Others	
							Flood / Heavy Rain	Earthquake	Society / Natural Environment	Differences from Standards	Geological Stratigraphy	Geological Structure	Strength / Deformability	Permeability	Existing / Potential Landslides	Groundwater (including spring)	Volume	Quality	Deterioration	Design	Construction	Management	Hydraulics	Water Quality	Sedimentation	*Factors are unclear	Dam Body	Foundation Strength	Foundation Permeability	Water Use	Reservoir (Water Storage)	Discharge Facility	Power Generation	Project Efficiency	Safety of Human Life	Impact on Stakeholders
1	Tapin	Rockfill	70.0	Spillway	Leakage	Water leakage was observed at upper part of spillway with many crack during an inspection after dam impounding.										1				1												1			1	1
2	Tapin	Rockfill	70.0	Tunnel (Diversion)	Leakage	Water leakage was observed in top wall of diversion during an inspection after dam impounding.										1				1												1				
3	Tapin	Rockfill	70.0	Tunnel (Diversion)	Leakage	It was observed that tunnel floor is flooded due to clogged channel during an inspection after dam impounding.										1			1	1						1						1				
4	Tapin	Rockfill	70.0	Dam site	Sliding	The dam site is located relatively close to the active Meratus Fault.		1				1								1							1								1	1
5	Tukul	Rockfill	70.3	Dam foundation	Leakage	More faults were observed than estimated during the design phase during foundation excavation.						1		1													1		1						1	1
6	Tukul	Rockfill	70.3	Dam body	Leakage	Piezometer monitoring show that there is high pore water pressure in dam body (core zone).																				1	1								1	1
7	Tukul	Rockfill	70.3	Dam body	Subsidence	Multilayer settlement instrument show high settlement of dam body (>1%).																				1	1								1	1
8	Tukul	Rockfill	70.3	Reservoir	Sedimentation	It had been mentioned that Tukul Dam has high sedimentation potential during design phase.																			1						1					
9	Napun Gete	Rockfill	52.0	Dam body	Leakage	During inspection for operation permit, the leakage of dam body was observed in downstream of dam (toe and abutment).										1		1									1								1	1
10	Napun Gete	Rockfill	52.0	Dam body	Sliding	The zoning of the embankment differed between the design and construction. Stability analysis after impounding was carried out and show that sliding plane through the rock fill zone deeply.												1		1							1								1	1
11	Napun Gete	Rockfill	52.0	Dam body	Subsidence	Multilayer settlement instrument show sudden settlement of dam body.																				1	1								1	1
12	Kuningan	Rockfill	43.0	Dam body	Leakage	Piezometer monitoring at downsteam and upstream of grouting almost has same presure value.																				1	1								1	1

No.	Character*1 (10)			Phase of Realization*2 (11)					Impact*3 (12)			Correspondence: Actual*4				Better way*4 (13)			Certainty*5				Risk Recognition Phase: Actual (2)	Ideal*6		Expected Effects*7 (when actual and ideal differ)	Items to Consider: Major Divisions*8		Subdivision
	A	B	C	I	II	III	IV	V	S	F	P	α	β	γ	Outline	α	β	γ	a	b	c	d							
1		1			1				1				1		Grouting		1			1			Operation	4	Construction	D	8	Foundation Treatment	Grouting
2		1			1					1			1		Additional drainage		1			1			Operation	5	Operation	-	9	Discharge Facility Design	Drainage
3		1			1					1				1	Additional study of tunnel leakage (No countermeasures have been implemented)		1					1	Operation	3	Design	D	9	Discharge Facility Design	Material
4	1						1		1			1			As the Meratus Fault is located more than 50 km from the dam site, its impact on the project is assessed as minor.	1				1			Operation	2	Dam site / Dam type selection	-	2	Earthquake	Active Fault
5		1		1					1			1			Removal of the surface layer of the fault, replacement with concrete, and installation of instruments	1			1				Construction	4	Construction	-	8	Foundation Treatment	Concrete replacement
6		1			1				1					1	Keeping a close eye on monitoring results			1			1		Operation	5	Operation	-	11	Monitoring Equipment	Pore pressure
7		1			1				1					1	Keeping a close eye on monitoring results	1					1		Operation	4	Construction	D	11	Monitoring Equipment	Settlement
8		1				1	1			1			1		Sabo or sediment control facility will be installed at upstream area.		1			1			Design	1	Plan	D	15	Operation / Maintenance Plan	Sedimentation
9		1			1				1				1		Additional counter weight for controlling water pressure at abutment (under consideration)		1			1			Operation	4	Construction	D	8	Foundation Treatment	Grouting
10		1				1			1				1		Additional counter weight (under confirmation of material condition)	1					1		Operation	3	Design	D	7	Embankment Design (Load / Foundation)	Stability analysis
11		1			1				1					1	Keeping a close eye on monitoring results	1					1		Operation	4	Construction	D	11	Monitoring Equipment	Settlement
12		1			1				1			1			Blanket grouting was carried out.	1					1		Operation	4	Construction	-	11	Monitoring Equipment	Pore water pressure

No.	Dam Name	Dam Type	Dam Hight (m)	Risk Awareness: Location (Structure/Area) (3, 9)	Risk Awareness: Anticipated Events	Risk Awareness: Condition/Situation (6)	External				Geology						Material			Internal			Phenomenon				Stability (S)			Function (F)				(P)	Others	
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11	Napun Gete	Rockfill	52.0	Dam body	Subsidence	Multilayer settlement instrument show sudden settlement of dam body.																				1	1								1	1
14	Way Sekampung	Rockfill	47.0	Spillway	Erosion	Erosion and sliding were observed on the excavation surface* around the outlet of the channel. *sandstone-conglomerate with moderately to highly weathered (class D to CL).							1							1	1											1				

No.	Dam Name	Dam Type	Dam Hight (m)	Risk Awareness			Categories – Risk Factors (7, 4, 5): External				Geology						Material			Internal			Phenomenon				Risk (8, 12): Stability (S)			Function (F)				(P)	Others	
				Location (Structure/Area) (3, 9)	Anticipated Events	Condition/Situation (6)	Flood / Heavy Rain	Earthquake	Society / Natural Environment	Differences from Standards	Geological Stratigraphy	Geological Structure	Strength / Deformability	Permeability	Existing / Potential Landslides	Groundwater (including spring)	Volume	Quality	Deterioration	Design	Construction	Management	Hydraulics	Water Quality	Sedimentation	*Factors are unclear	Dam Body	Foundation Strength	Foundation Permeability	Water Use	Reservoir (Water Storage)	Discharge Facility	Power Generation	Project Efficiency	Safety of Human Life	Impact on Stakeholders
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12	Kuningan	Rockfill	43.0	Dam body	Leakage	Piezometer monitoring at downsteam and upstream of grouting almost has same presure value.																				1	1								1	1

No.	Perspectives on Risk Classification – Character*1 (10): A	B	C	Phase of Realization*2 (11): I	II	III	IV	V	Impact*3 (12): S	F	P	Correspondence – Actual*4: α	β	γ	Outline	Better way*4 (13): α	β	γ	Certainty*5: a	b	c	d	Risk Recognition Phase – Actual (2)	Ideal*6		Expected Effects*7 (when actual and ideal differ)	Items to Consider – Major Divisions*8		Subdivision
1		1			1				1				1		Grouting		1			1			Operation	4	Construction	D	8	Foundation Treatment	Grouting
2		1			1					1			1		Additional drainage		1			1			Operation	5	Operation	-	9	Discharge Facility Design	Drainage
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12		1			1				1			1			Blanket grouting was carried out.	1					1		Operation	4	Construction	-	11	Monitoring Equipment	Pore water pressure

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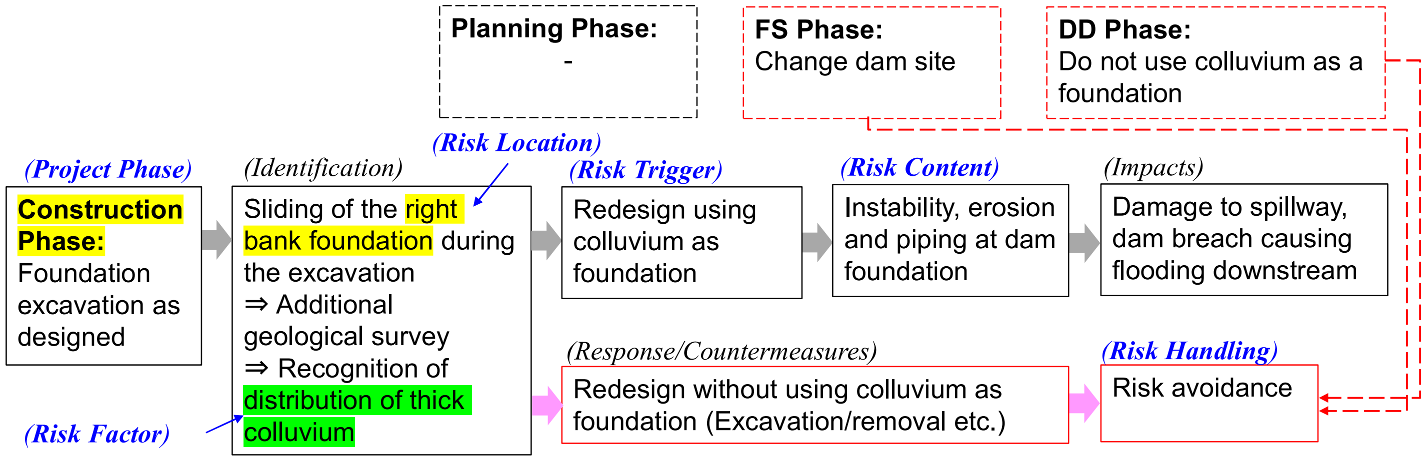
No.	Dam Name	Perspectives on Risk Classification – Character*1 (10): Natural (External)	Human	Others	Phase of Realization*2 (11): Project in progress	Operation	Large External Forces	Long-term Deterioration	Others	Impact*3 (12): Dam Safety	Dam Function	Schedule and Cost	Correspondence – Actual*4: Avoidance	Reduction	Retention	Outline	Better way*4 (13): Avoidance	Reduction	Retention	Certainty*5: High	Middle	Low	Special Cases	Risk Recognition Phase – Actual (2)	Ideal*6		Expected Effects*7 (when actual and ideal differ)	Items to Consider – Major Divisions*8		Subdivision	Check Item
1	Tapin		1			1				1				1		Grouting		1			1			Operation	4	Construction	D	8	Foundation Treatment	Grouting	Were records kept of spring locations and how they were dealt with during construction?
5	Tukul		1		1					1			1			Removal of the surface layer of the fault, replacement with concrete, and installation of instruments	1			1				Construction	4	Construction	-	8	Foundation Treatment	Concrete replacement	Have the foundation excavation surfaces been observed and recorded?
11	Napun Gete		1			1				1					1	Keeping a close eye on monitoring results	1					1		Operation	4	Construction	D	11	Monitoring Equipment	Settlement	Are the monitoring instruments properly installed?
14	Way Sekampung		1		1						1			1		The slope surface was protected by shotcrete.		1		1				Operation	3	Design	D	10	Foundation/Cutting Slope Design for Other Facilities	Slope Protection	Has slope protection been considered (including whether it is necessary)?

Results of Risk Analysis

Dam Risk Analysis for Dam Projects

- 100 risk cases were identified in the 61 target dam projects.
- Risk cases were analyzed from 6 perspectives (written in blue).



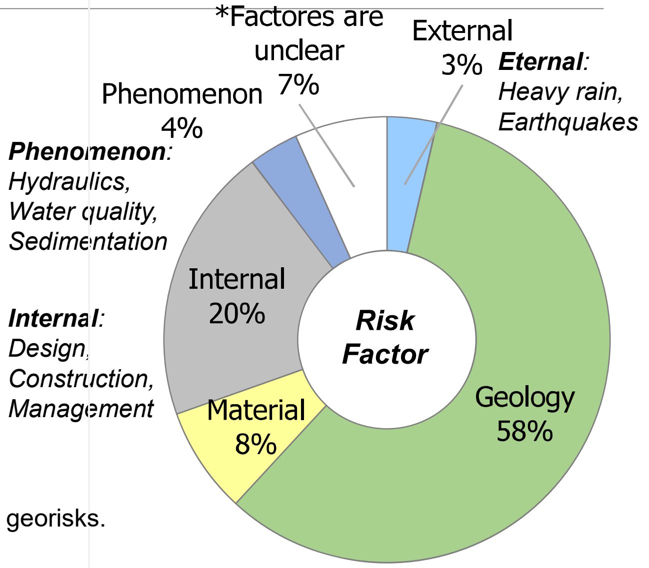
Cause and Effect Relationship

Dam Risk Analysis :
1 Risk Factor

- ◆ Risk factors are factors that have the potential to realize a risk.
- ◆ Approximately 60% of the identified risks are geological factors, and 20% are internal factors. Of the internal factors, approximately 70% are design-related.

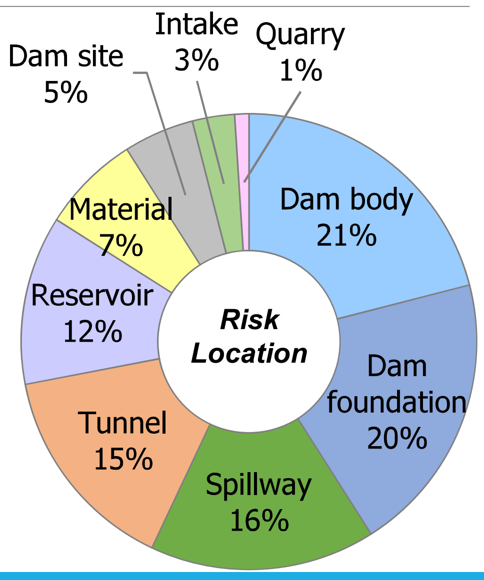
Geological study is very important !

Note: In this study, geological risk factors are referred to as georisks.



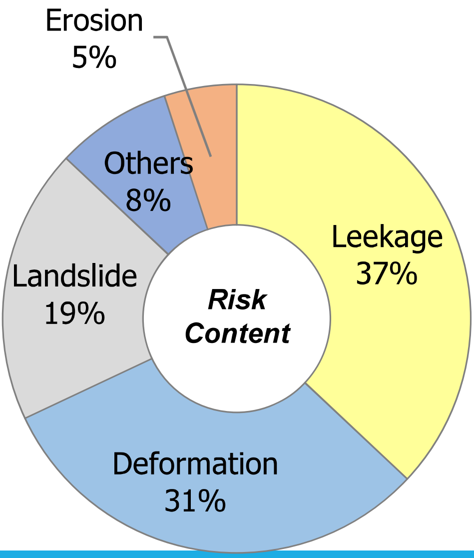
Dam Risk Analysis :
2. Location

- ◆ Risks observed in almost all areas of dam construction site, and the cause is largely related to geology.
- ◆ Approximately 50% of the risk factors are identified in the dam body, foundations and materials, with the rest in spillways, tunnels and reservoirs.



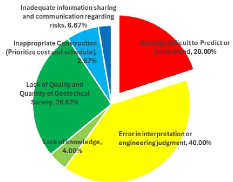
Dam Risk Analysis :
3. Type of Risk

1. Water Leakage and Spring Water
   - ▶ from dam foundation, dam body, tunnel and other structures,
2. Deformation
   - ▶ foundation, dam body (in particular core zone), tunnels and other structures including sliding at structural foundation,
3. Landslides
   - ▶ collapse of natural slopes and cut slopes), and
4. Erosion at waterway.



◆ Leakage, deformation and Landslide,

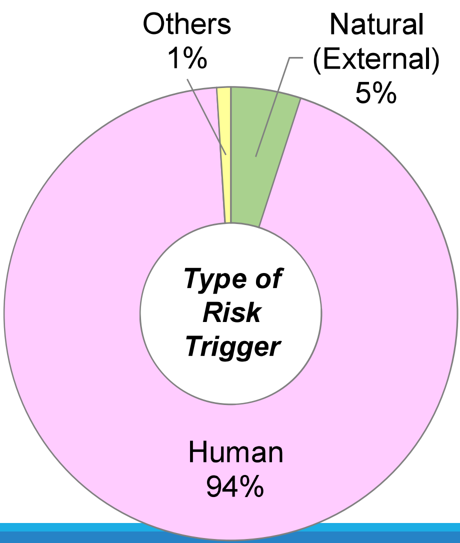
Dam Risk Analysis :
4. Trigger



- ◆ The most of risks (classified as Human-rerated factor) can be avoided (94%) in case carrying out adequate survey and design.
- ◆ In each project stage, risk analysis and assessment, namely "RISK Management" should be conducted to recognize the potential risks and respond them.

⇩

- ◆ By accumulating experience and improving technical capabilities of Engineers, it is expected that risks can be avoided or reduced !

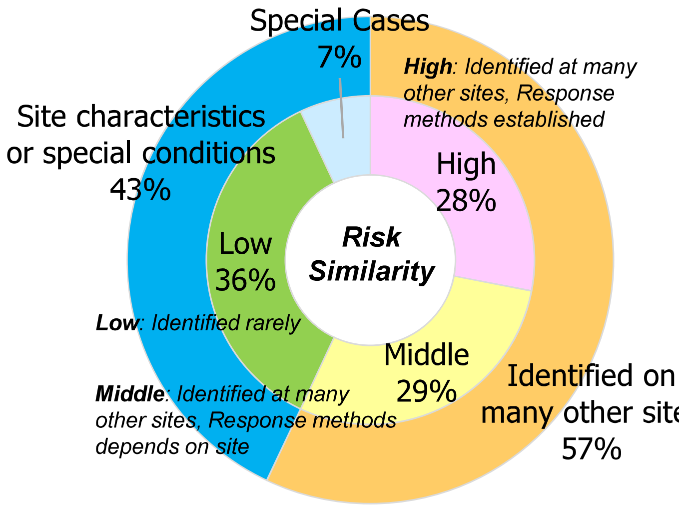


Risk Analysis :
Similarity

Categorization of Risk Similarities:
1. Risks that observed at many other sites
2. Risks that arise on special site conditions

Categorized depending on Response
a. High: Response methods are established.
b. Middle: Response methods are not established or vary from site to site
c. Low: Risks that be expected difficult
d. Special Cases

- *60% of the identified risks are similar to risks observed at other sites, so It is expected that risks will be respond efficiently based on similar risk cases.*
- *40% of the identified risks are due to the characteristics of each site.*
- *In many cases, it is possible to efficiently respond to the risks by applying "Learned from Risk Analysis".*

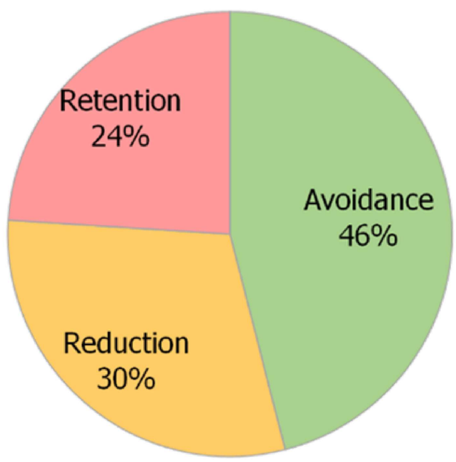


Risk Analysis:
Results of Response to Risk

Of the recognized risks, 46% are avoided, 30% are reduced, and 24% are retained.

- Avoidance refers to redesign and providing countermeasures,
- Reduction refers to mainly repairs, and
- Retention involves only monitoring.

Even if these risks can be addressed after completion, it is essential that ricks are eliminated before the dam is completed.

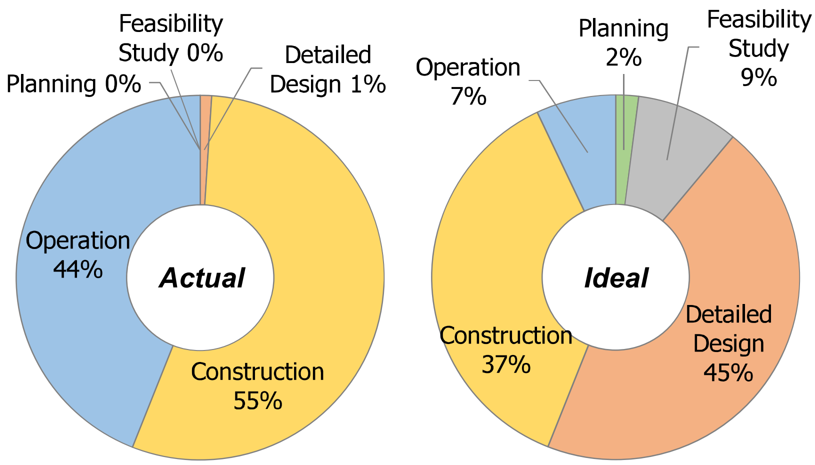


Risk Analysis:

Project Phase for Risk Response

- By identifying risks in an early phase and handling them at the appropriate phase, it is often possible to avoid increased costs !

To respond to risks at the appropriate phase, Risk information is carried over to the next phase through risk communication!



Risk Analysis

Findings of Results of Risk Analysis

1. **Geological Risks** : more than 60%
   → Importance of appropriate geological surveys, improvement of the capabilities of geological engineers and advice from experienced engineers.
2. Most Risks are due to **Human Factors** (insufficient investigation, misinterpretation of geology, inappropriate design, etc.)
   → Improve the capabilities of dam engineers and have experienced engineers' review.
3. Of the identified risks, approximately 60% were **Similar Risks** that were observed in other dams.
   → If risks are recognized earlier, measures can be taken .
4. 55% of risks were **Recognized during Construction Stage** and 44% after completion.
   → More than 50% of risks can be recognized at the time of survey and design stage. Many risks can be prevented if risks are recognized.

Importance of Risk Recognition

in early stage of the Project (Planning/Survey/Design Stages)

Risk Management System

to recognize potential risks and propose response at an earlier stage

Establishment of Risk Management System in Indonesia

FOR DESIGN AND CONSTRUCTION OF DAM

What is Risk Management

Risk Management:

- Risk Management is “Practice of Recognition, Evaluation, Investigation and Mitigation some menace/negative issues in the activities”.
- Not only avoiding risks, but also minimizing damage in emergency.

Process for Risk Management

1. Risk Identification & Recognition,
2. Risk Analysis and Assessment,
3. Risk Treatment,
   - Dealing with each risk assessed by selecting one of the four types of risks: "Reduction," "Avoidance," "Transfer (sharing)," and "Acceptance“.
4. Monitoring and Improvement

Risk Management in Civil Engineering Project: Initiatives in Japan

In Japan, there are **Damages/Accidents caused by Geological Issues** in construction or after completion, same as in Indonesia.

Many **Geological Risks**, containing in dam projects, have been treated through so-called **“Tacit Knowledge“** of the well experienced engineers.

Currently, due to a **“Lack of Experienced Engineers”**, it has become difficult to expect this.

Furthermore, **Social Monitoring** has become stricter, because of several issues at site such as serious accidents, cost increases, delay of schedule, and modification/change of projects. So **“More Efficient Project Implementation”** is required,

In response to this, in 2020, MLIT (Ministry of Land, Infrastructure, Transport and Tourism) with PWRI (Public Works Research Institute) published the **"Guidelines for Geological and Ground Risk Management in Civil Engineering Projects“**[*1].

This guideline aims **“to Eliminate Undesirable Elements”** that occur during construction and management by conducting risk management for uncertain elements in the promotion of civil engineering projects.

*1) The guideline and supporting data are available in; https://www.pwri.go.jp/jpn/research/saisentan/tishitsu-jiban/iinkai-guide2020.html

Proposal of Risk Management System in Indonesia

Concept of Risk Management Guideline

1. **To make clear Procedure of Risk Recognition**
   - ✓ To manage risks in the Projects, *firstly recognizing expected risks*.
   - ✓ *how to handle various risks* in projects;
   - ✓ *how to respond to them*, as well as the structure and process of general risk management.
2. **Practical Uses of Risk Management System in Project**
   - ✓ *Implementation Procedures* of risk management in recognition of risks
   - ✓ *Methods and Notable Points* that can be applied during implementation.

Preparation of Guidelines
Basic Policy of Guideline

1. **Concepts and Basic Ideas** of risk management in civil engineering projects
2. **Roles and Functions** of the *project office* conducting risk management and *the parties involved*, as well as the **ideal form of collaboration**.
3. **Procedures and Methodologies** for introducing and implementing geological/ground risk management
4. **Notable Points** when operating geological/ground risk management
5. **ISO 31000 (Risk Management - Guidelines)**
   Refer to the concept and adapt it to civil engineering projects.

Preparation of Guidelines
Focus Points

1. ***Impact of Uncertainties*** on Projects
   - Geology and ground are formed naturally, and their distribution and properties are *nonuniformity and complex*.
   - This uncertainty causes an impact on project safety, such as the occurrence of accidents.
2. ***Handling of Uncertainties*** on Projects
   - It is necessary to evaluate risks after understanding the estimation and uncertainty of geological and ground conditions.
   - There is a need for a framework for stakeholders to recognize and share geological and ground uncertainties, and a mechanism for assessing the impact on projects and responding to risks.

Preparation of Guidelines
Application of ISO31000 Risk Management

This guideline compiles the concepts of frameworks and procedures, as well as their introduction and operation, in accordance with the concepts of ISO 31000 (Risk Management - Guidelines).

Risk management for civil engineering projects, including dam projects, has not only a purpose ***to avoid unfavorable impacts*** such as accidents and losses, but also ***to obtain advantageous opportunities*** such as to select a geologically advantageous damsite or dam type.

ISO 31000 (Risk Management - Guidelines) also defines risk management as **“Creating and Protecting Value."**

In other words, by creating an optimal plan and design for the entire project, we aim ***to create new value*** through efficient project Implementation.

The goals of both are the same.

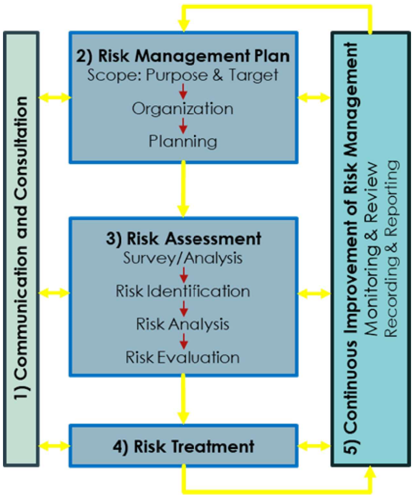
Establishment of Risk Management System in Indonesia

Risk Management Plan

- **No Need to built up a fixed system**:
  It is implemented using the most appropriate system available at the time, depending on the purpose and characteristics of the project.
- **Maximum Use of Existing System:**
  If there is an existing management system, it may be possible to utilize and reorganize this and add or improve the necessary parts to the system.

Risk Assessment

- **Sets Up the Data Compiling and Display of Risk Level**, based on the policy of risk assessment.
- For setting them up
  - to consider to be applicable in the risk assessment and risk treatment,
  - "Communication and Consultation" within the team shall be held,
  - Select applicable methods based on the purpose of the project and target structures.

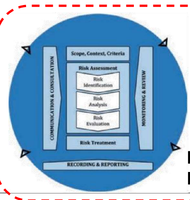


Composition of Risk Management

"Guideline of Dam Risk Management for Dam Design & Construction" consists of the following 5 categories.

1. Communication and consultation
2. Risk Management Plan
3. Risk Assessment
4. Risk Treatment
5. Continuous Improvement of Risk Management

How to Proceed Risk Management in projects

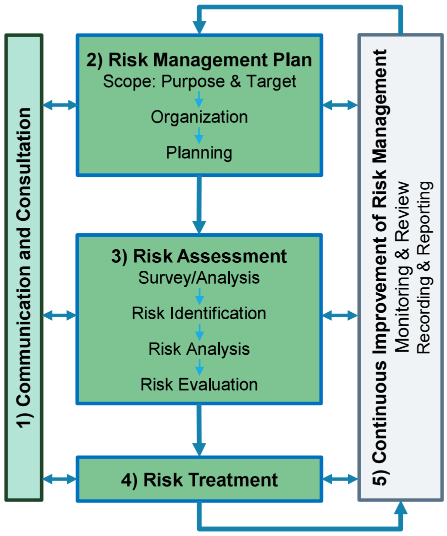


Risk Management Process in ISO-31000

Implementation method (right diagram)
- following ISO-31000 methodology.

Implementation Procedures
- Communication and Consultation,
- Risk Management Plan,
- Risk Assessment
- Risk Treatment
- Continuous Improvement.

Optimization of Processing System
- Applicable to various stages in the project
- Continuously implemented throughout the project



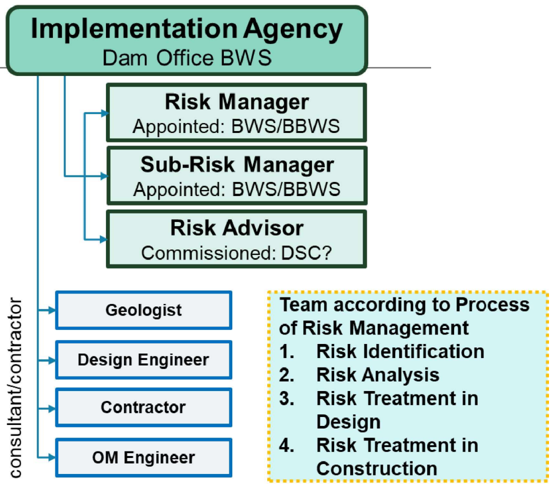
Proposed Process
Geological Risk Management

Organizing Risk Management Team

Team for Risk management shall be;
- **Consists of internal and external parties** with the necessary abilities and knowledge, and
- Possible to ensure a **collaborative system** among these parties, acting as **"One-Team"**.

The Main **Team Members**
(refer to right diagram)
- Project Implementation Agency, Risk Managers, Risk Sub-manager, Geotechnical engineer, Design Engineer, Construction Engineer and OM Engineer.

Note:
This is an example based on the general project of the MLIT Japan, so that arrangements would be required depending on the circumstances of each country.

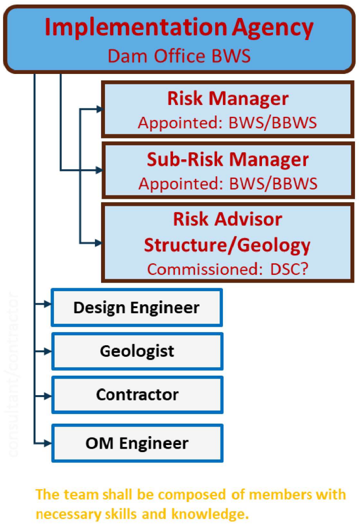


The team shall be composed of members with necessary skills and knowledge.

Image of Risk Management Team Organization

Organizing of Management System in Each Stages of Project

Member	Role
Implementing Agency (Dam Office / BWS)	A person who makes decisions of project implementation, planning and management of geological surveys, etc., and risk treatment.
Risk Manager (Appointed by IA)	A person in charge of overall dam engineering (structural/geological) risk management in/from the Implementing Agency.
Risk Sub-Manager (Appointed by IA)	A person who assists in the operation of risk management conducted by the risk manager.
Dam/geology Risk Advisors (Commissioned / DSC)	A dam and geology specialists who supports dam risk managers and risk management operations from a professional standpoint.
Dam Design Dngineer (the Consultant/dam engineer)	A person who designs dam/structures, etc.
Geotechnical Engineer (the Consultant/geologist)	A person who conducts geological survey and analysis, etc.
Construction Engineer (the Contractor)	A person who constructs structures, etc. based on the design.
OM Engineer (if necessary) (the Consultant)	A person who conducts inspections in the maintenance and management of structures.



Timing of Risk Management

The risk management is a concept **applicable at any stage** of the project but early conducting can be expected more benefits.

Benefits of Starting Early

- **More Options** for dealing with the uncertainties and risks.
- To achieve **Better Results** (even if the start is in the middle of project).

These were confirmed by analyzing the collected data for organizing the guideline in Japan.

Timing of Risk Management
Early Implementation of Risk Management

Early Start of RM can be expected more benefits.

Example of Benefit

- ✓In dam projects, there is a possibility to avoid a risky damsite in an early stage, but once the project has commenced, it becomes difficult to change the site, and due to countermeasures, there is a high risk of increasing of construction cost and extending of construction time.
- ✓In case information would not be obtained sufficiently, decision making for finalizing the treatment may be postponed. Because an insufficient information or many assumptions, even though carrying out the precise design, the result will be in overdesign, or in the worst case, too optimistic assumptions may derive accidents.

By **Identifying risks early** which have a large impact and **Responding strategically**, the project may be implemented more efficiently.

Utilization of the System

Followings are idea of procedure for implementing with dam projects while being aware of risks, as well as methods that can be applied during implementation and points to keep in mind.

1. **Timings of Risk Management** are mainly set based on the technical session by dam safety commission (but the session maybe need more frequently).
2. Before the technical session, the dam implementation agency (such as BWS), etc.) shall conduct a ``**Risk Recognition** in the project using Event Summary Report and Database."
3. Prior to the technical session, **Preliminary Discussions** regarding the content of the check list shall be carried out with specialists (such as BTB (DSU), PUSAIR, BINTEK, etc.)
4. Applying this process, all dam implementing agencies can prepare the **Individual Event Summary Report** at the necessary stage.

Conclusion

- ✓ Currently, to ensure the safety of dams, **Dam Safety Commission (KKB) and Unit** have been conducting technical reviews at each stage of dam design, impounding, and operation, in Indonesia. This system has been *working very effectively*.
- ✓ During my dam construction site inspection, however, I found many risks arising at site due to oversight in design, mis-interpretation of geological structure and so on.
- ✓ Risks are unavoidable in dam construction due to uncertain and diverse factors in Dam Project.
- ✓ It is supposed that adaptation of **"Risk Management System"** into the current review system by Dam Safety Commission as well as the design and construction on project site will help to minimize risks in dam construction.
- ✓ From now on, we, dam technical advisors would like to have discussion with PUPR (DSC, DSU and BTB) regarding improvement of dam construction status in Indonesia.

Thank you for your kind attention

Dam Engineer must Innovative but Conservative for dam safety

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WhatsApp: +62 8124286509

2nd Seminar

02 Seminar on Risk Management for Dam_Geo2

Ministry of Public Works and National Housing
Directorate General of Water Resources
Japan International Cooperation Agency

Geological Considerations for Dam Risk Management.

November 16, 2024

National Seminar, Indonesia Committee on Large Dam (INACOLD)

By JICA, Dam Geological Advisors
Naoya Mizuno

1

Table of Contents

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1. Introduction
1.1 Define and Identify Risk

- In our study, risk refers to a situation/condition where the occurrence of an event may have significant undesirable impacts on the dam project.
- The impacts refer to dam breaches and the failure of dam functions, as well as negative effects of the projects on stakeholders.

<Goals for Our Dam Risk Management>

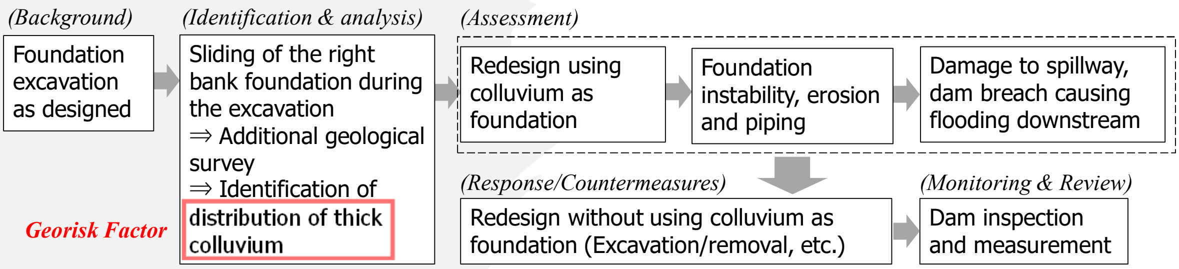
✓Dam safety and functionality

✓Rationalization of Project Costs

3

1. Introduction
1.2 Geological Risk Factor (Georisk Factor)

- Risk is identified through issues or events in planning, investigation, design, construction and operation phase.
- The risk identification, analysis, assessment, and response in our study are positioned in a cause-and-effect relationship as shown in the below diagram.



Cause-and-Effect Relationship for Risk Management (Bagong Dam)

4

2. Considerations for Each Phase

- The main considerations for each project phase are as follows.

2.1 Planning & Preliminary Design

- ✓ Active fault
- ✓ Sedimentation
- ✓ Landslide around Reservoir

2.2 Detailed Design

- ✓ Dam Foundation (including Grouting)
- ✓ Cut slope
- ✓ Tunnel

2.3 Construction

- ✓ Dam Foundation
- ✓ Cut slope
- ✓ Tunnel

2.4 Operation

- ✓ Sedimentation
- ✓ Landslide around Reservoir

2. Considerations for Each Phase
2.1 Planning & Preliminary Design

(1) Active Fault

- Active faults have a huge impact on dam safety.
- Is it possible that there are any active faults around the dam site other than those indicated on existing active fault maps?

⇩

*It is recommended that **active fault study** be carried out during the planning and preliminary design phase.*

Active fault study also helps to identify the georisk factors of potential dam sites from the perspective of regional structural geology.*

**Loosening of rock mass, Landslides, Reservoir sedimentation, etc.*

(A) Literature Review

Compilation of active fault maps based on literature review (Within 50 km)

(B) Topographic Interpretation

Extraction of lineaments through topographic interpretation (Within 10 km)

(C) Site Inspection

Target: Faults with a length of 10 km or more, or located within 3 km of the dam site

(D) Comprehensive Evaluation

Possibility of active faults existing at the dam site

No → *Dam Site Selection*

Yes → ***(E) Geological Survey***

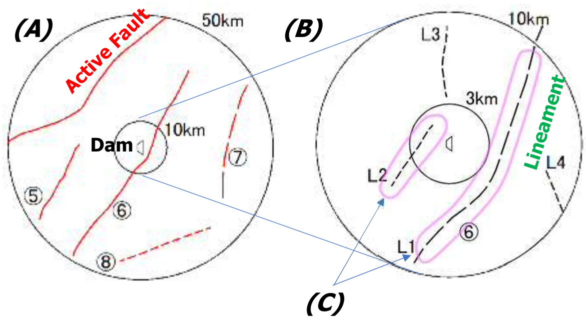
Trench survey of lineaments that are likely to be active faults

(F) Comprehensive Evaluation

Distribution of potential active faults at the dam site

No → *Dam Site Selection*

Yes → *Dam Site Change*



Flow of Active Fault Study for Dam Projects in Japan (FS Phase)

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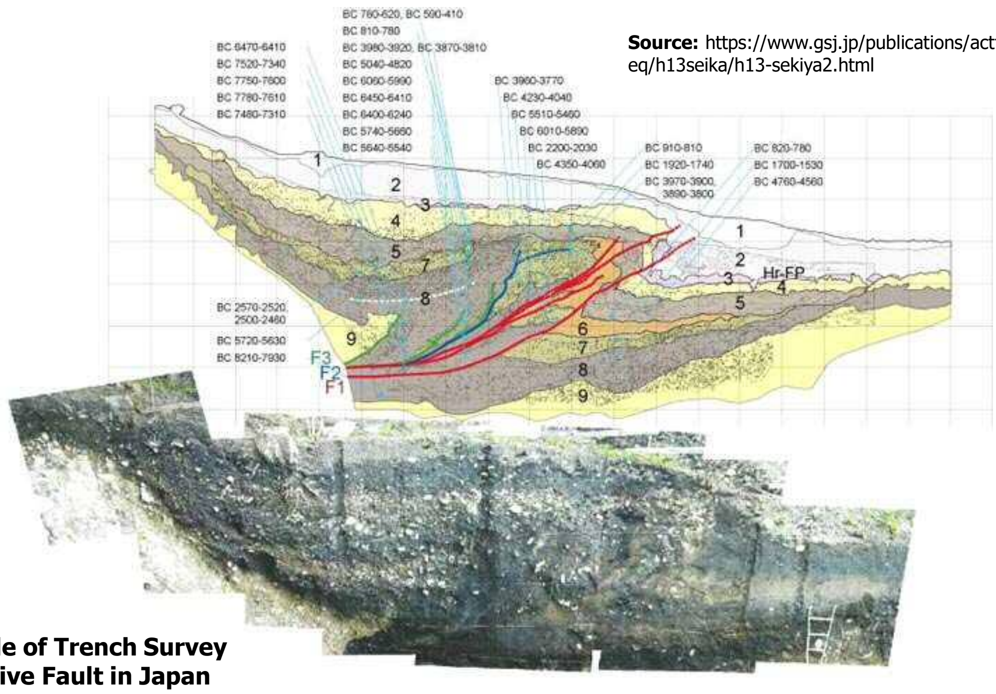
Source: https://www.gsj.jp/publications/actfault-eq/h13seika/h13-sekiya2.html



Example of Trench Survey of Active Fault in Japan

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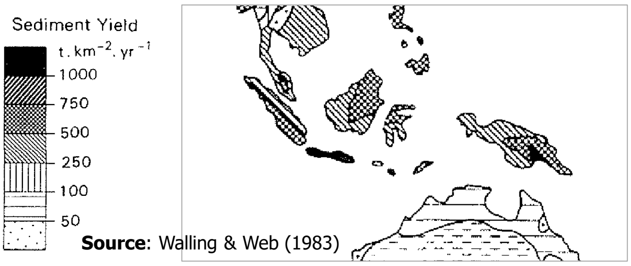
2. Considerations for Each Phase
2.1 Planning & Preliminary Design

(2) Sedimentation

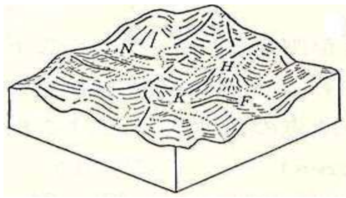
- Sedimentation has a huge impact on maintaining the dam functions.

*It is recommended that **sediment yield study** be carried out during the planning and preliminary design phase.*

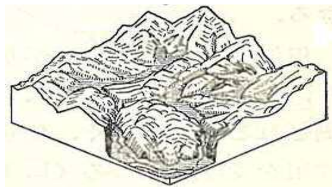


Source: Walling & Web (1983)

Suspended Sediment Yield around Indonesia



(a) Low Sediment Yield



(b) High Sediment Yield

Different Topography of Sediment Yield

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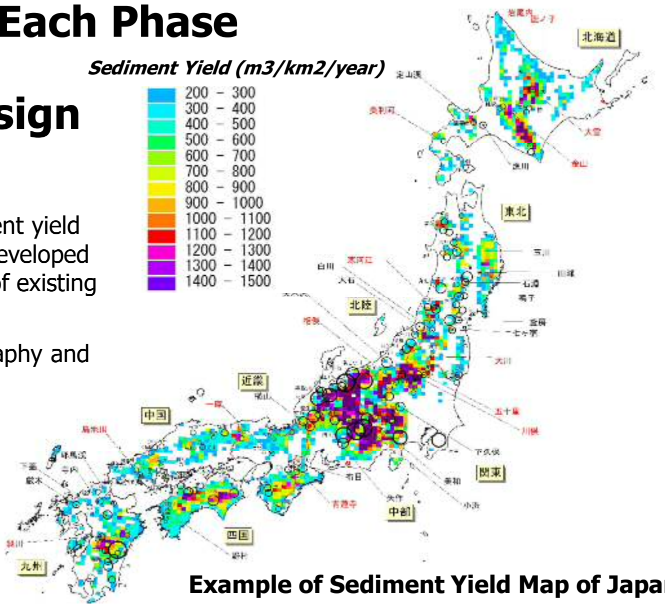
2. Considerations for Each Phase
2.1 Planning & Preliminary Design

<Sediment Yield Map>

- This map estimates the potential sediment yield for Japan using an estimation formula developed based on the actual sediment volumes of existing dam reservoirs.
- The estimation formula uses the topography and geology of the basin as parameters.

Note: This potential sediment yield is the long-term annual average value, and the amount of sediment runoff during floods would be much greater.



Example of Sediment Yield Map of Japan

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2. Considerations for Each Phase
2.1 Planning & Preliminary Design

(3) Landslides around Reservoir

- The occurrence of large-scale landslides or many landslides around the reservoir would have a huge impact on the safety and functionality of the dam.
- The construction of countermeasures after impounding often results in increased costs.

⇩

*It is recommended that **potential landslide study** around the reservoir be carried out during the planning and preliminary design phase.*

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(A) Literature Review

Compilation of potential landslide maps based on literature review

(B) Topographic Interpretation

Extraction of potential landslides through topographic interpretation

(C) Site Inspection

Developing a map of potential landslides around the reservoir

(D) Comprehensive Evaluation

Need for geological survey and analysis

Yes → ***(E) Geological Survey and Analysis***: Drilling surveys, testing, etc. Slope stability analysis

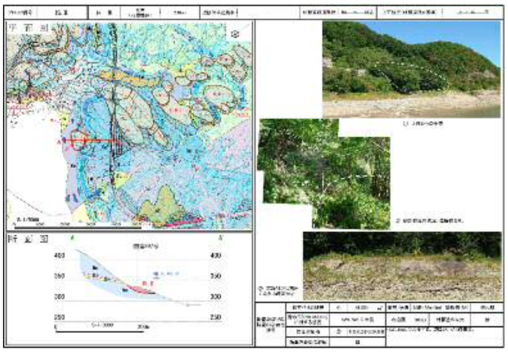
No → *Inspection or monitoring during Impounding*

(F) Comprehensive Evaluation

Need for countermeasures

No → *Inspection or monitoring during Impounding*

Yes → *Design of countermeasures Planning of monitoring*



Ledger of Potential Landslide

Flow of Potential Landslide Study for Dam Projects in Japan

12

These photos show a large landslide that occurred in a dam reservoir in Japan in 2008 by a magnitude 7.2 earthquake. The landslide was about 900m wide and 1,300m long, 67 million m³ volume.
Fortunately, this landslide occurred about 1 km upstream from the dam, so the dam breach did not ocurre.

(a) Before Countermeasure

(b) After Countermeasure

Large-scale Landslide in the Dam Reservoir

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This is a large landslide that occurred upstream of Bili-Bili Dam in 2004, with an estimated volume of 200 million m³.

Large-scale Landslide in the Upstream of Bili-Bili Dam (2004)

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2. Considerations for Each Phase
2.1 Planning & Preliminary Design

(4) Keep in Mind

- ✓ Consider how to deal with the risks identified in the planning and preliminary design phase.
- ✓ All information regarding risks identified in the planning and preliminary design phase will be carried over to the detailed design phase without exception.
- ✓ During the detailed design phase, investigations and considerations will be carried out on risks that can not be avoided during the planning and preliminary design phase.

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2. Considerations for Each Phase
2.2 Detailed Design

(1) Dam Foundation

- ◆ The risks located in the dam foundation have a huge impact on the safety of the dam body.
- ◆ Redesigning a dam foundation during construction would delay the project schedule and increase costs.

*During the detailed design phase, it is important that the geological conditions of the site are **interpreted properly** and reasonable excavation line are designed.*

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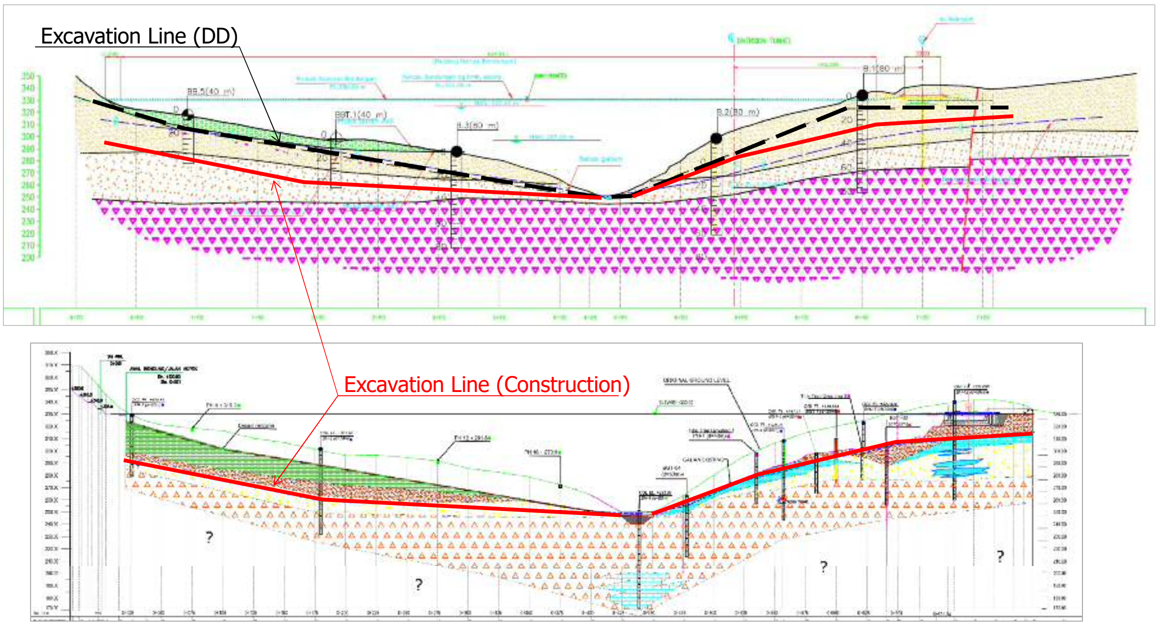


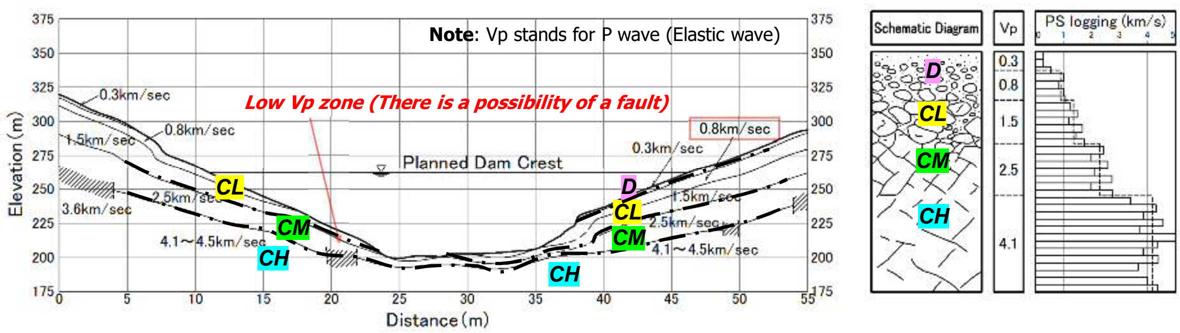
Example of Change in Foundation Excavation Line (Bagong Dam)

17

2. Considerations for Each Phase
2.2 Detailed Design

<Seismic Exploration>

- To estimate spatially the boundary between soil and bedrock and the bedrock conditions, it is recommended to use seismic (Elastic wave) exploration in addition to drilling surveys.



Schematic Analysis Result of Seismic Exploration

18

2. Considerations for Each Phase
2.2 Detailed Design

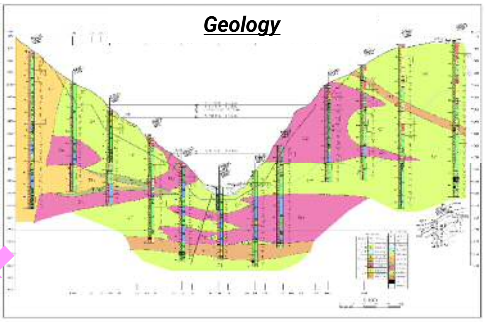
<Grouting: Characteristics of Each Geology>

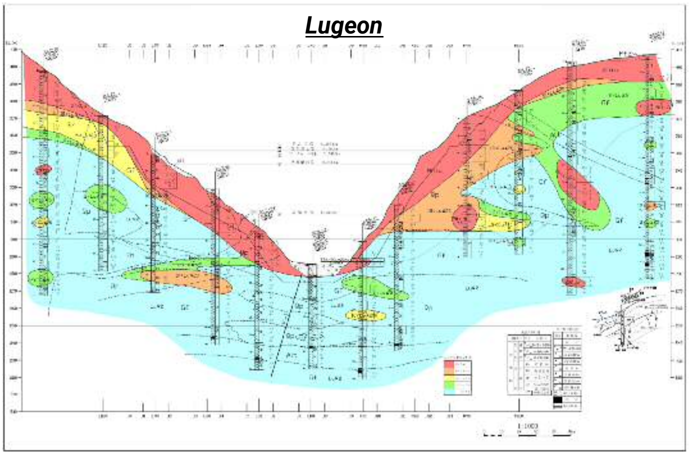
- It is recommended that grouting be designed considering the geological characteristics shown in this table.

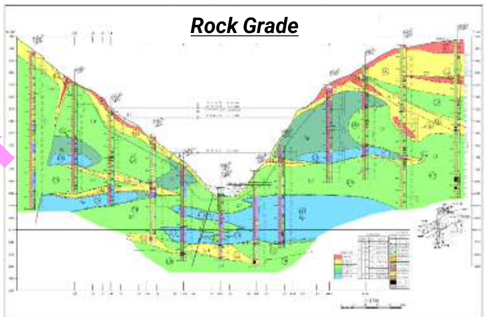
Rock Type	Geological Characteristics	Precautions for Grouting
Pre-Neogene sedimentary rocks	Intact rocks are hard, but because the bedrock has many faults, open cracks develop in the weathered areas. Limestone areas have cavities and are highly permeable.	Improvement is relatively easy. Cement milk with a high mortar concentration is often used to fill cavities in limestone.
Crystalline schist	The fractures are highly anisotropic and often involve large fault zones parallel to the foliation.	The improvement effect is often dependent on the schistosity. It is necessary to consider a method for seaming the schistosity of the surface.
Granite	Weathering occurs deep down to form decomposed sand. The strongly weathered zone is thick on the gently sloping ridge. Some fault fracture zones are large in scale.	Weathered granite has a permeability of 10 Lu or more and a low critical pressure. In embankment dams, there are many issues with excavation lines and grouting methods.
Neogene sedimentary rocks	Sandstone and conglomerate are relatively well consolidated, but mudstone and tuff are prone to weathering and slaking. Large-scale faults can be seen in tuffs.	Since the properties of strata vary depending on the rock type, the improvement effect varies widely, and improvement may be difficult in some areas.
Quaternary strata	The strata are generally unconsolidated to lowly consolidated, and there are cases where the gravel layer is thick.	There are many highly permeable layers. Careful consideration is required regarding methods and materials.
Extrusive rocks	It is accompanied by columnar and tabular joints, autofracture and autoalteration. The intrusive rock may be accompanied by alteration zones.	Generally, the permeability is high, a large amount of grouting material is required, and the total grouting hole length is long. Setting improvement areas is relatively difficult.
Pyroclastic rocks	The agglomerates and tuff breccias are heterogeneous with soft and brittle matrices. The welded tuff is heterogeneous and interbedded with unconsolidated layers. The volcanic gravel layer is unconsolidated and highly permeable.	There are many issues with deformation of the unconsolidated layer and piping, and large-scale treatment is required. When the critical pressure is low and the Lugeon value is high, improvement is difficult.

<Grouting: Lugeon Map>

- To design a reasonable curtain grouting, it is necessary to study the Lugeon map considering the geological stratigraphy, geological structure and rock grade.







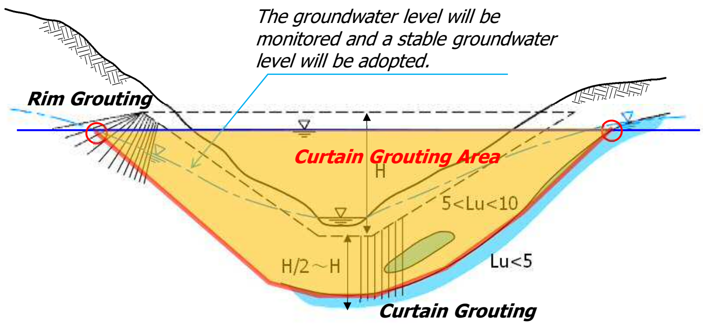
2. Considerations for Each Phase
2.2 Detailed Design

<Grouting: Curtain Grouting Area>

- The area of the curtain and rim grouting (water-tightness improvement area) is designed so that the dam body and foundation work together to provide water-tightness.

✓ **Width (Rim)**: From the foundation to the intersection of the groundwater level with the reservoir water level or with the low permeability zone.

✓ **Depth (Curtain)**: From the foundation to the low permeability zone. However, empirically, the depth is set to between half the dam height and the equivalent of the dam height.

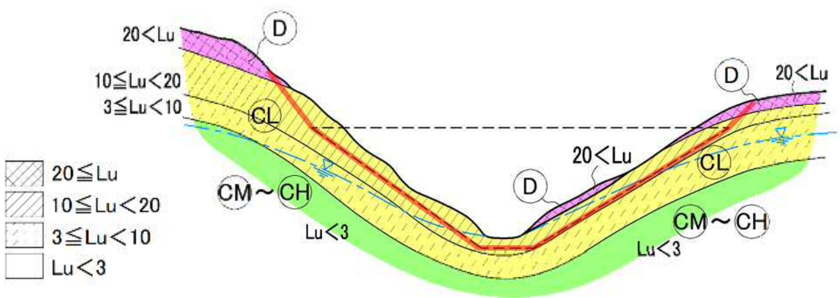


Basic Concept of Curtain Grouting Area

2. Considerations for Each Phase
2.2 Detailed Design

<Reasonable Excavation Line>

- The foundation excavation line is examined comprehensively based on the strength and deformability required for the foundation (refer to Rock grade), water permeability (refer to Lugeon map) and improvement by grouting (refer to Grouting test results).



Example of Excavation Line Setting for Impervious Zone Foundation

2. Considerations for Each Phase
2.2 Detailed Design

(2) Cut Slope

- The occurrence of a landslide on a large cut slope can have a huge impact on the safety and functionality of a dam.
- At dam sites, large cut slopes are often constructed around spillways, intake towers, and tunnel entrances.

During the detailed design phase, the layout of facilities, the cutting gradient, drainage facilities and protective works are designed considering the* ***loosening*** *and* ***strength reduction due to excavation*** *and* ***georisk factors****.*

**The layout of the facilities are related to the scale and direction of the cut slope.*

(A) Literature Review

Regional geology,
Distribution of potential landslides, etc.

(B) Topographic Interpretation

Extraction of georisk factors
that may destabilize the cut slope

(C) Site Inspection

Check the topographical and geological
conditions around the planned cut slopes

(D) Comprehensive Evaluation

Need for geological survey and analysis

Yes → ***(E) Geological Survey and analysis***

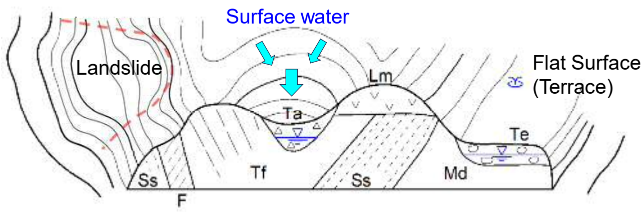
Drilling surveys, testing, etc.
Slope stability analysis

(F) Comprehensive Evaluation

Need for countermeasures

Yes → *Design of countermeasures*
Planning of monitoring

No → *Design, Construction*



Examples of Topographical Factors to be Focused

Geological Study Flow for Large Cut Slope Design in Japan

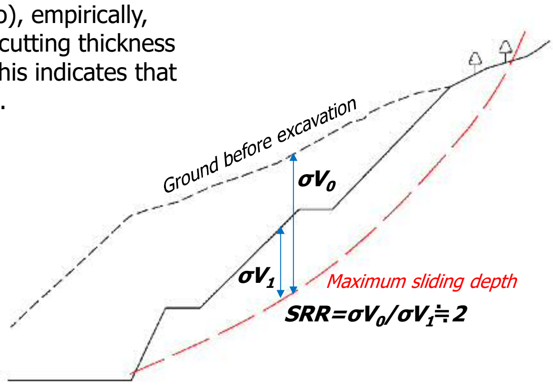
2. Considerations for Each Phase
2.2 Detailed Design

<Loosening due to Excavation >

- According to the idea of SRR (Stress Release Ratio), empirically, sliding of a maximum thickness equivalent to the cutting thickness is estimated in the middle part of the cut slope. This indicates that the impact of loosening due to excavation is large.

$SRR=\sigma V_0/\sigma V_1$
Here,
σV_0 : Overburden pressure before cutting
σV_1 : Overburden pressure after cutting

Source: Kimura et.al (2015)



Idea of SRR (Stress Release Ratio)

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2. Considerations for Each Phase
2.2 Detailed Design

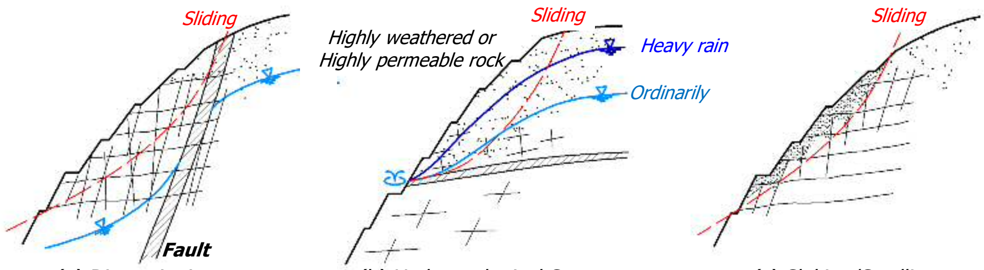
<Georisk Factors>

- Cut slopes will be designed considering the following georisk factors:

a) **Discontinuity**: At sites with well-developed folds and faults, there are many cases of sliding.

b) **Hydrogeological Structure**: Weathering structures, extrusive rock/tuff boundaries, faults, etc.

c) **Slaking/Swelling**: Mainly mudstone, tuff



(a) Discontinuity (b) Hydrogeological Structure (c) Slaking/Swelling

Georisk Factors of Cut Slope

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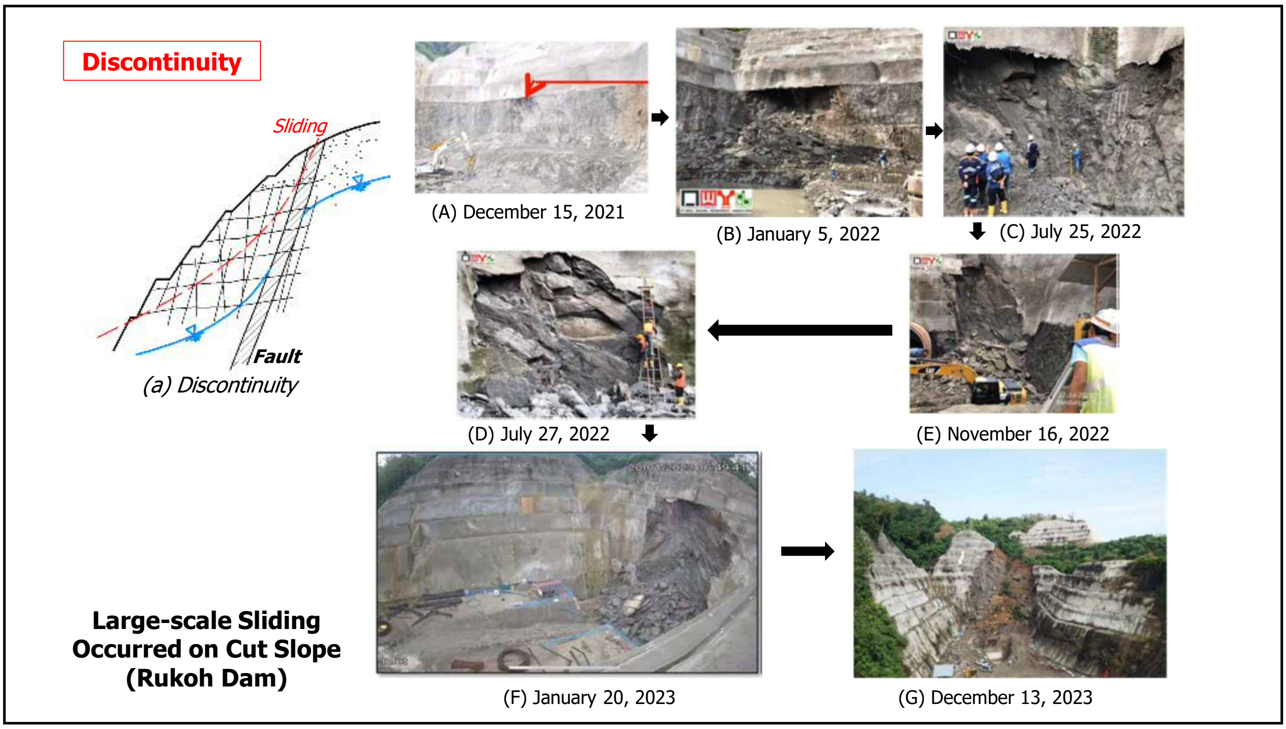
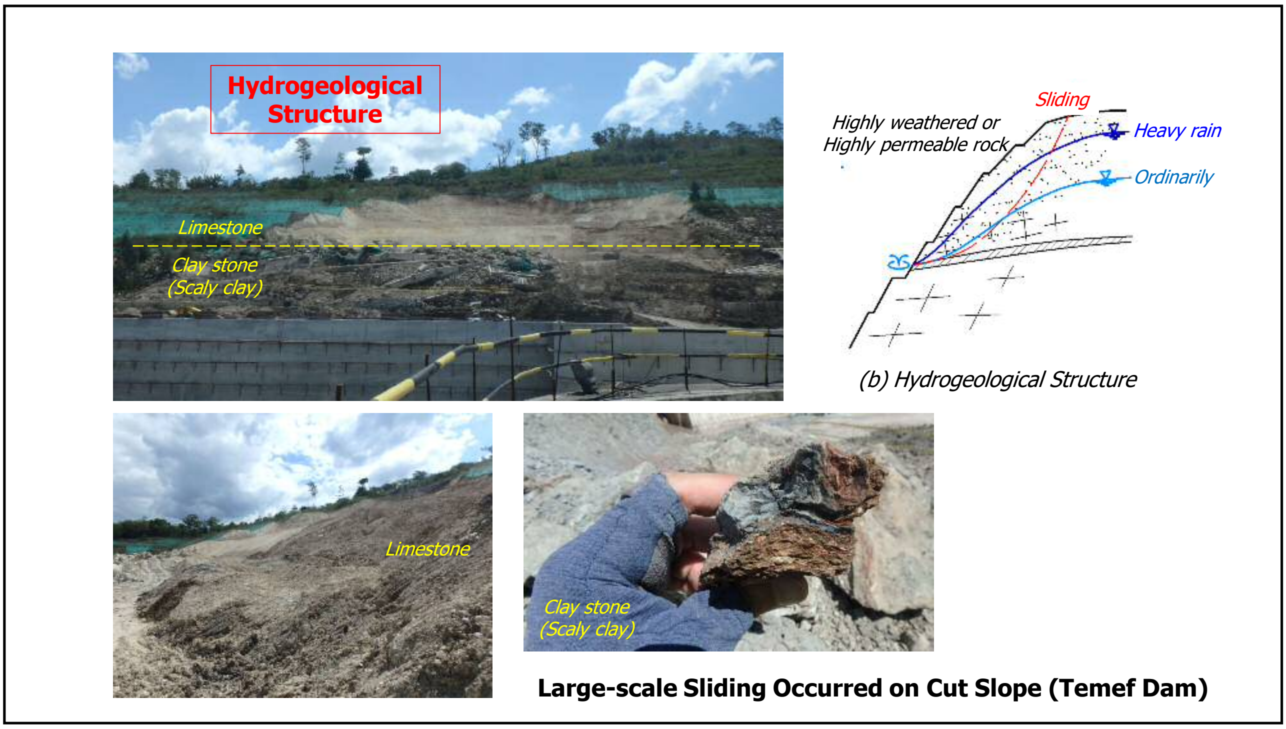

Discontinuity
Sliding
Fault
(a) Discontinuity
(A) December 15, 2021
(B) January 5, 2022
(C) July 25, 2022
(D) July 27, 2022
(E) November 16, 2022
Large-scale Sliding Occurred on Cut Slope (Rukoh Dam)
(F) January 20, 2023
(G) December 13, 2023

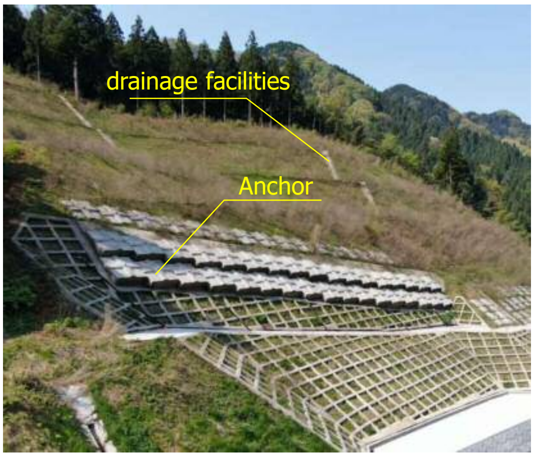
27


Hydrogeological Structure
Limestone
Clay stone
(Scaly clay)
Sliding
Highly weathered or
Highly permeable rock
Heavy rain
Ordinarily
(b) Hydrogeological Structure
Limestone
Clay stone
(Scaly clay)
Large-scale Sliding Occurred on Cut Slope (Temef Dam)

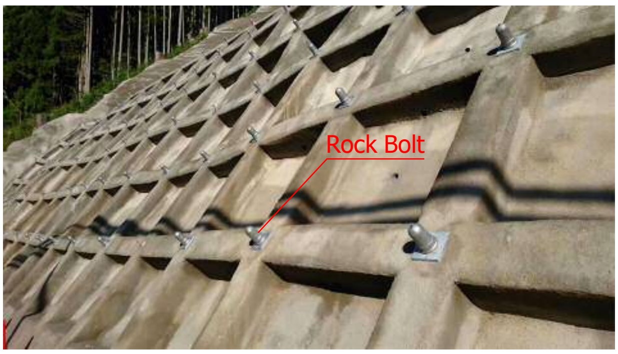
28

Large-scale Sliding Occurred on Cut Slope (Jragung Dam)

29



(a) Anchor & Framework



(b) Rock Bolts & Framework

30

2. Considerations for Each Phase
2.2 Detailed Design

(3) Tunnel

- Deformation or collapse of the intake and discharge tunnels has a significant impact on the schedule and cost during construction, maintaining the dam's functions after impouding.

During the detailed design phase, reasonable supports system will be designed, considering deformability of the ground and georisk factors.

(A) Desk Study
Literature review ,
Topographic interpretation, etc.

(B) Site Inspection
Topography, Geology, Geotechnical features,
Planning of geological survey

(C) Geological Survey
Seismic Exploration, Drilling surveys,
In-situ and laboratory tests

(D) Comprehensive Evaluation
Need for additional geological survey
Yes → (E)
No → *Design, Construction*

(E) Additional Geological Survey
Drilling surveys, testing, etc.
Tunnel ground rating (Cr, Cf)

(F) Comprehensive Evaluation
Need for special or auxiliary measures
Yes → *Design of special or Auxiliary measures*
No → *Design, Construction*

Geological Study Flow for Tunnel Design in Japan

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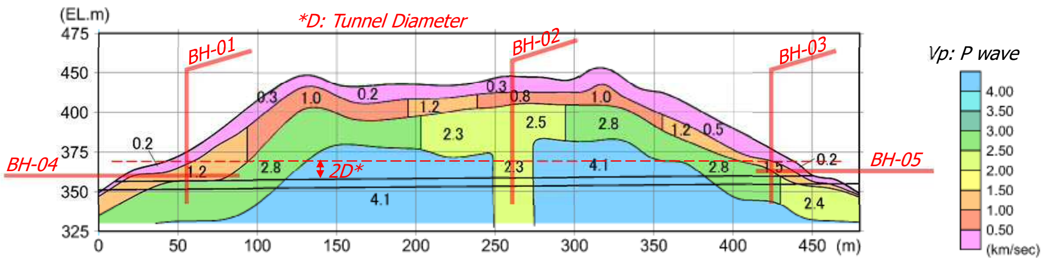
2. Considerations for Each Phase
2.2 Detailed Design

<Seismic Exploration>

- To obtain sufficient geological information along the planned tunnel, seismic exploration will be used in addition to drilling surveys.
- If possible, it is more efficient to determine the drilling survey plan based on the results of seismic exploration.



Seismic Exploration Results and Drilling Survey Layout

32

2. Considerations for Each Phase
2.2 Detailed Design

<Crack Coefficient and Competence Factor>

- To evaluate the tunnel ground, "Crack coefficient (Cr)" is useful as an index for cracked rock mass, while "Competence factor (Cf)" is useful as an index for soft rock mass.

Crack coefficient: $\mathbf{Cr=1-(Vp_1/Vp_0)^2}$

Competence factor: $\mathbf{Cf=qu/P}$

for Fissured rock mass: $\mathbf{Cf=qu'/P}$

$qu'=(1-Cr) \times qu$, $P=\gamma H$

Here, Vp_1: *P-wave velocity of rock mass*

Vp_0: *P-wave velocity of rock*

qu: *Compressive strength of rock*

qu': *Compressive strength of fissured rock mass*

P: *Overburden pressure*

γ: *Unit Weight*

H: *Overburden height*

Cr (%)	*Rock mass condition*
< 25	Fresh with almost no cracks.
25 - 50	Fresh and with few cracks.
50 - 70	Slightly weathered and has some cracks.
70 - 80	Weathered and has relatively many cracks.
> 80	Strongly weathered and has many cracks.

Cf	*Earth pressure characteristics*
> 10	Soft rock mass stands up well.
4 - 10	No plastic earth pressure occurs.
2 - 4	Plastic earth pressure may occur.
< 2	Plastic earth pressure often occurs.

2. Considerations for Each Phase
2.2 Detailed Design

<Georisk factors>

- The tunnel will be designed considering the following georisk factors same as the cut slopes:

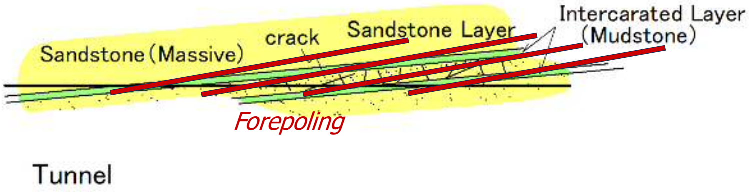
a) **Discontinuity**: Direction of development of discontinuities

b) **Hydrogeological Structure**: Large amounts of spring water

c) **Swelling**: Deformation due to swelling (swelling pressure)

Discontinuity

Tunnel Roof Collapse (Bagong Dam)



Auxiliary Construction for Tunnel Roof Collapse

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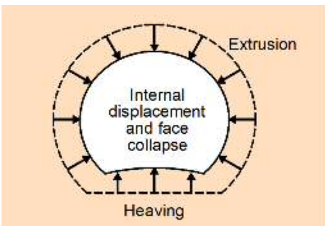
Slaking/Swelling

Tunnel Deformation due to Swelling (Manikin Dam)



Conceptual Diagram of Tunnel Deformation due to Swelling

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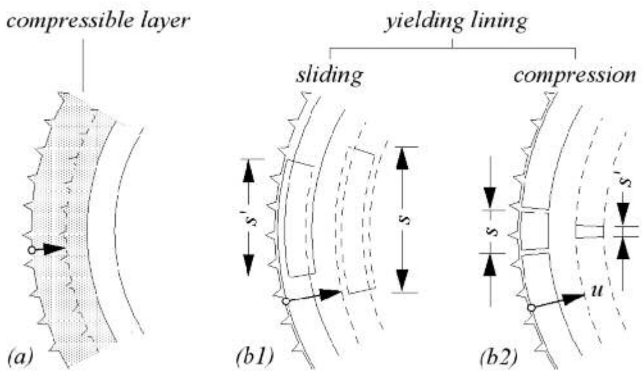
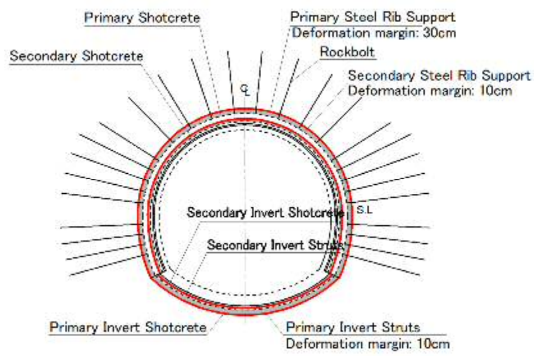


a) Yielding Support



b) Multiple Steel Rib Support (NATM)

Support System for High Earth Pressure

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2. Considerations for Each Phase
2.2 Detailed Design

(5) Keep in Mind

- ✓ Consider how to deal with the risks identified in the detailed design phase.
- ✓ All information regarding risks identified in the detailed design phase will be carried over to the construction phase without exception.
- ✓ During the construction phase, additional investigations and considerations will be carried out on risks that were carried over from the detailed design phase to avoid or reduce risks.

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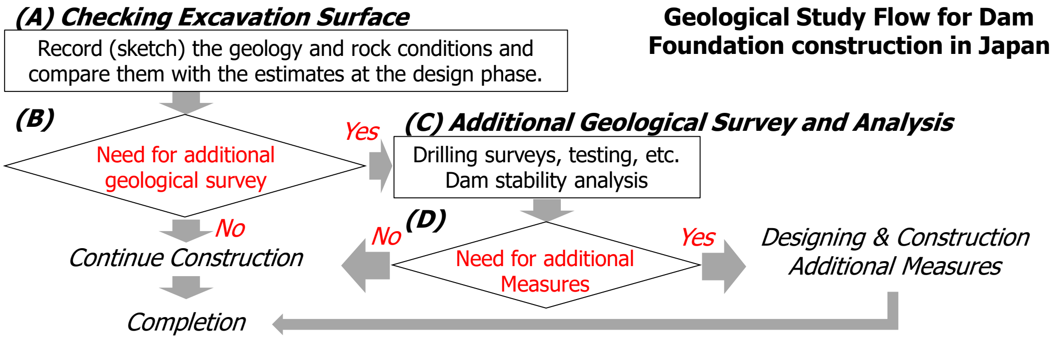
2. Considerations for Each Phase
2.3 Construction

(1) Dam Foundation: Checking Excavation Surface

- Geological engineers will check the excavation surface and evaluate its suitability as a dam foundation in terms of strength, deformability and permeability, and will propose the implementation of dental work and auxiliary grouting if necessary.

Geological Study Flow for Dam Foundation construction in Japan



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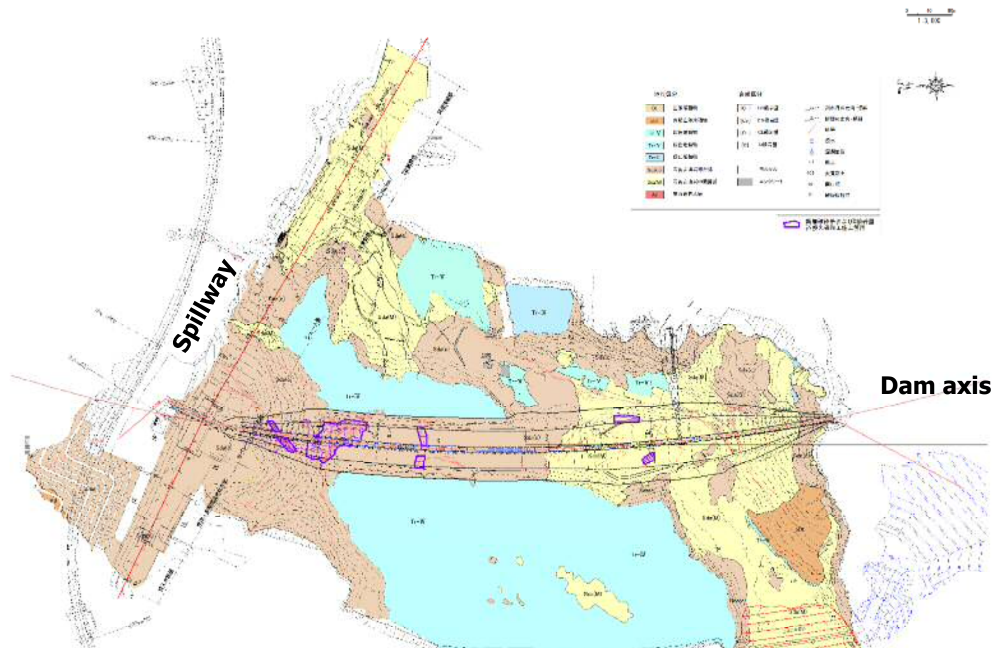
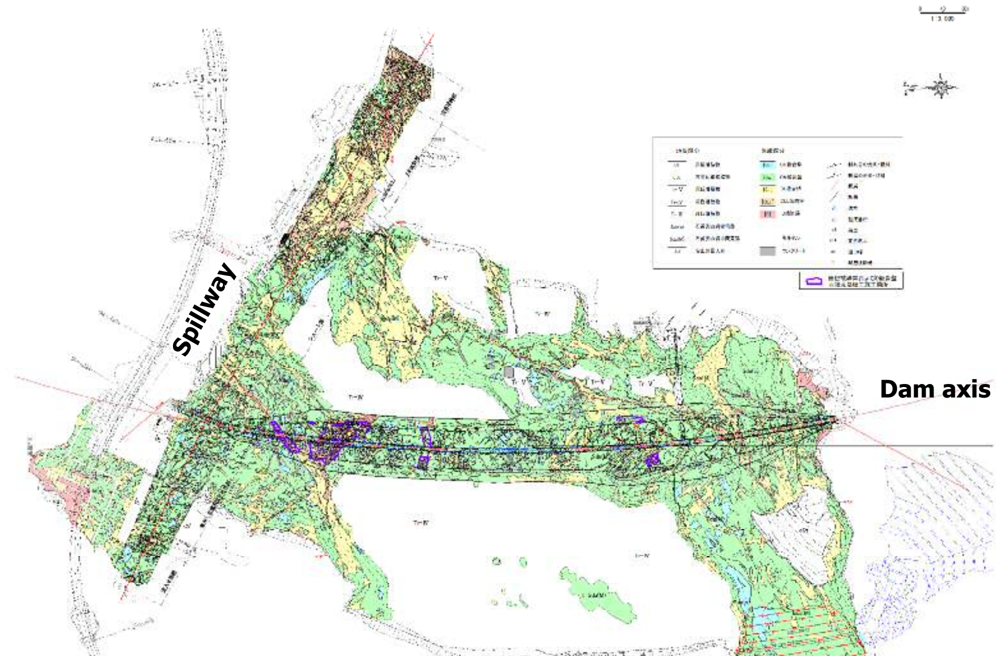


Geotechnical Sketch of Rockfill Dam Foundation (Geology)

40

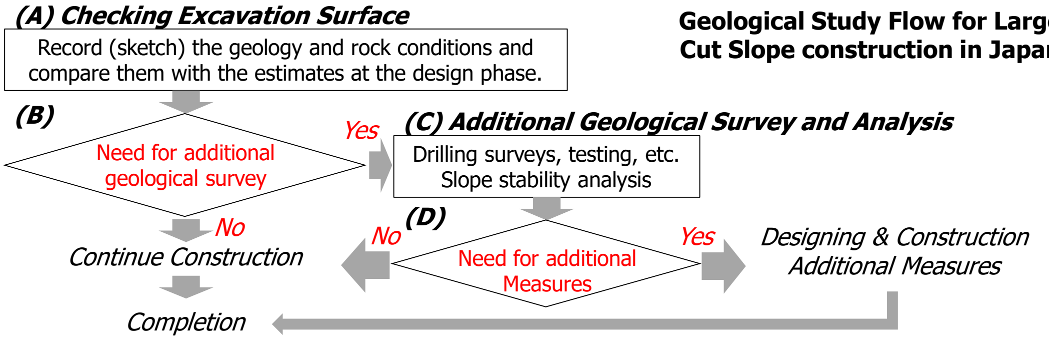


Geotechnical Sketch of Rockfill Dam Foundation (Rock Grade)

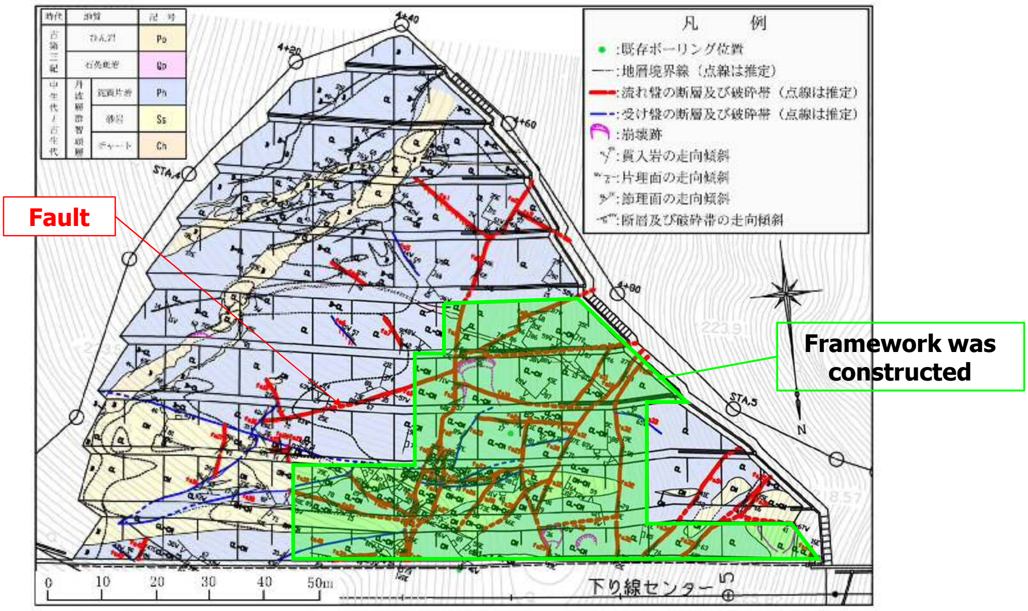
2. Considerations for Each Phase
2.3 Construction

(2) Cut Slope: Checking Excavation Surface

- Geological engineers will check the excavation surface and evaluate the suitability of the cut slope design. If necessary, they will propose countermeasures such as re-excavation, or the slope protection.
- It is recommended for large cut slopes to measure the surface displacement by surveying during construction.



Geological Study Flow for Large Cut Slope construction in Japan



Geotechnical Observations of a Large Cut Slope **Source:** Okazaki et al. (2005)

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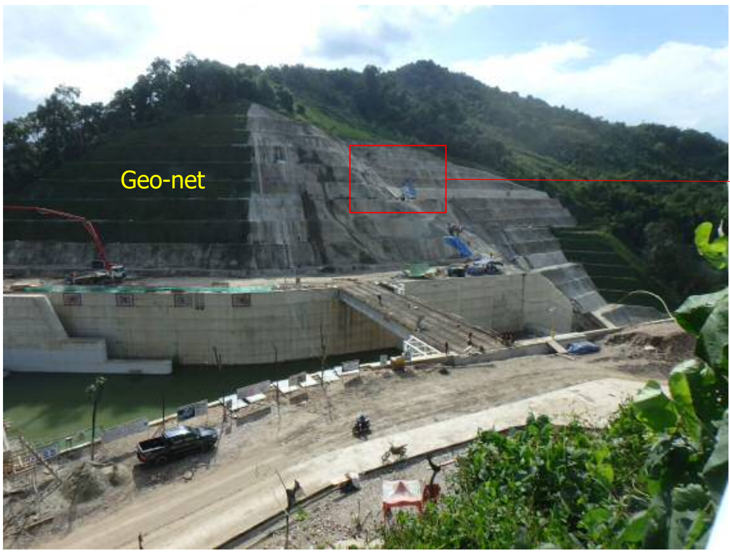

Construction of Countermeasures based on Geotechnical Observations (Ameroro Dam)

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2. Considerations for Each Phase
2.3 Construction

(3) Tunnel: Ahead Survey

- For the safety of construction and the selection of a reasonable support system, it is useful to understand the geological conditions ahead of the tunnel face in advance. There are the following survey methods.

a) **Drilling Survey:** Collecting core samples

b) **Drilling Exploration:** Sounding only

c) **Elastic Wave Exploration**

a) Drilling Survey (Horizontal)

Source: https://www.kajima.co.jp/gallery/const_museum/tunnel/gijutsu/article/tunnel_g_06.html

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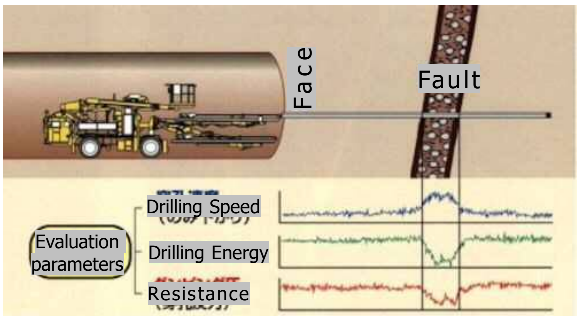
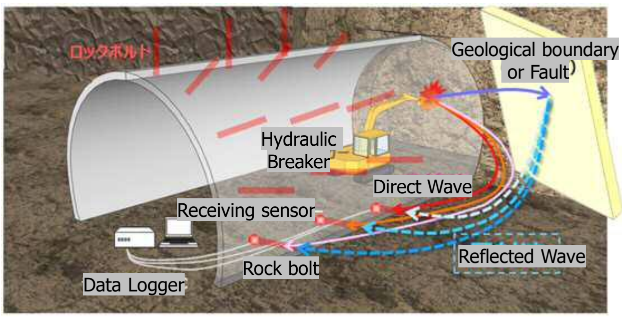
2. Considerations for Each Phase
2.3 Construction

<Tunnel: Ahead Survey>



b) Drilling Exploration

Source: https://kensetsu.ipros.jp/product/detail/2000557827



c) Elastic Wave Exploration

Source: https://www.shimz.co.jp/company/about/about/news-release/2019/2019034.html

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2. Considerations for Each Phase
2.3 Construction

(4) Keep in Mind

- ✓ All information regarding the results of risk responses during the construction phase, as well as any newly identified risks, will be carried over to the operation phase.
- ✓ All records of design changes and quality control during construction will be carried over to the operation phase.

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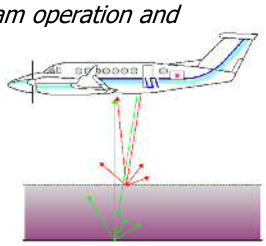
2. Considerations for Each Phase
2.4 Operation

(1) Sedimentation

- ◆ The progression of reservoir sedimentation, which far exceeds the initial plan, could have a significant impact on the dam's function in the future.

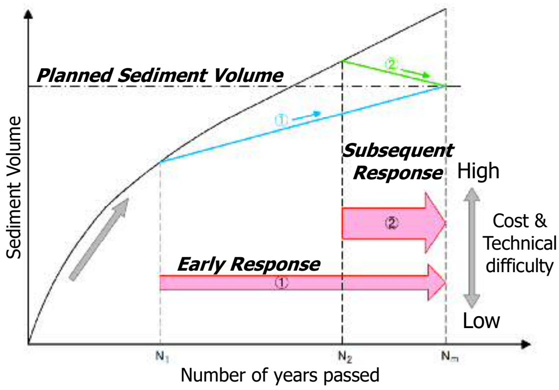
Regular surveys of reservoir sedimentation are recommended as part of dam operation and maintenance.

a) Multibeam Echo Sounding



b) Airborne Laser Bathymetry

Recent Bathymetry Technology



Changes in Sediment Volume Over Time

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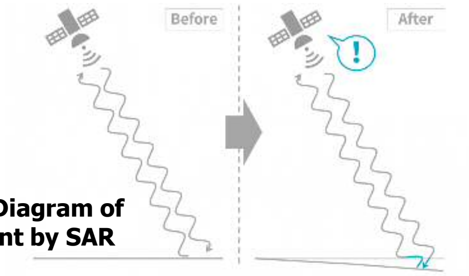
2. Considerations for Each Phase
2.4 Operation

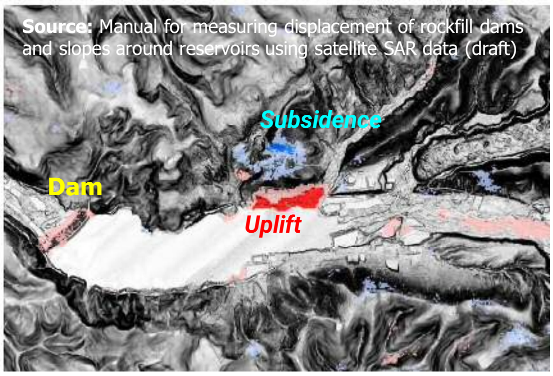
(2) Landslides around Reservoir

- The inflow of large amounts of sediment into a reservoir due to a large landslide can have a significant impact on the dam's function.

It is desirable to develop a method that can monitor efficiently the movement of slopes around reservoirs.



Conceptual Diagram of Measurement by SAR



Displacement Distribution Map

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3. Goals for Geologists
3.1 Perspective and Imagination

- It is recommended to imagine the geological conditions of the site not only at the normal scale but also at the macro-scale and micro-scale to avoid overlooking the georisks at the project site.

✓ **Macro-scale**: Wide-area topographical and geological features, distribution of active faults, as well as the arrangement of plates and the formation of islands, etc.

✓ **Micro-scale**: The rocks that make up the bedrock, the minerals that make up those rocks, the types of minerals and their chemical properties, etc.

✓ **Normal-scale**: Site and outcrop inspections consideration macro- and micro-scale site geology.

Source: https://www.istockphoto.com/jp/

Different Perspective on Scale

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3. Goals for Geologists
3.2 Integrated Interpretation

- Geological analysis requires integrated interpretation of the results of various surveys or scales, and this interpretation is essential for identifying and assessing georisks.
- Appropriate geological interpretation (presentation of geological conditions to design engineers) and collaboration between geologists and design engineers are essential for reasonable design.
- Thinking the distribution of strata and geological structures in ***three dimensions*** is one of the good practices for integrated interpretation.

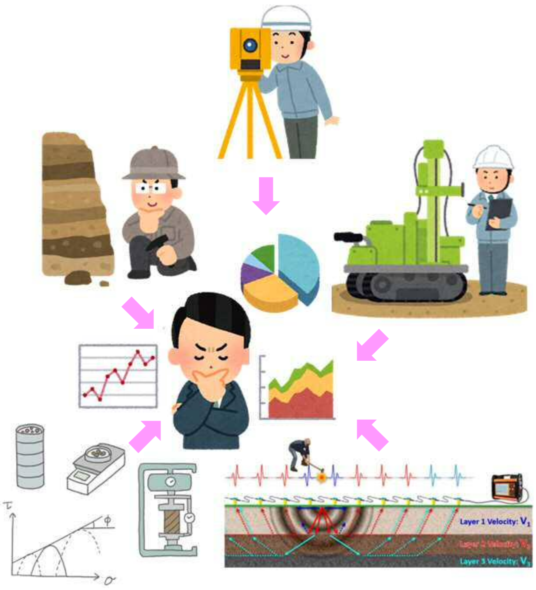

Image of Integrated Interpretation

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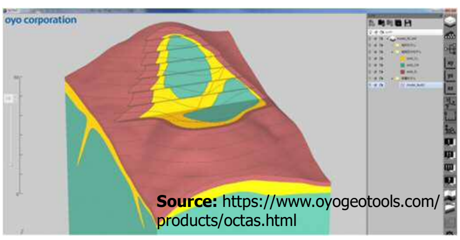
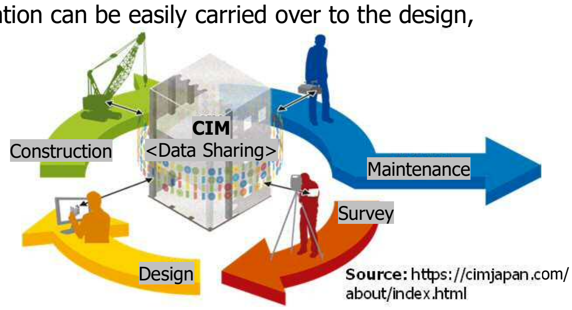
3. Goals for Geologists
3.2 Integrated Interpretation

<CIM: Construction Information Modeling/Management>

- In recent years, CIM has been introduced into the design of civil engineering structures in Japan to improve the efficiency of construction and maintenance. CIM has the following main features:
- ✓ It is a three-dimensional model, and survey and test results can also be stored as attribute data.
- ✓ CIM can be shared among stakeholders, and information can be easily carried over to the design, construction, and operation phases.



3D Model of Cut Slope for Design (Rock Grade)



Basic Concepts of CIM

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2nd Seminar

03 2024 INACOLD-- Risk Management of Ageing Dam

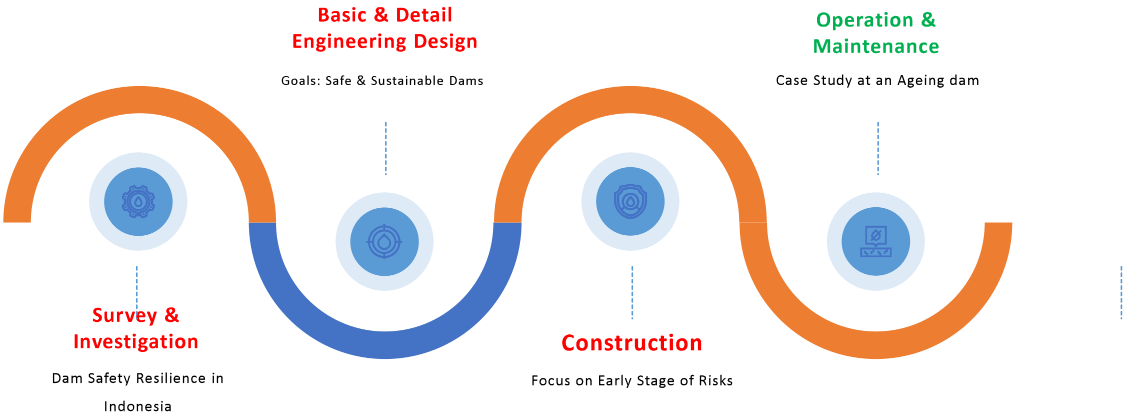
Risk Assessment of Dams in Indonesia

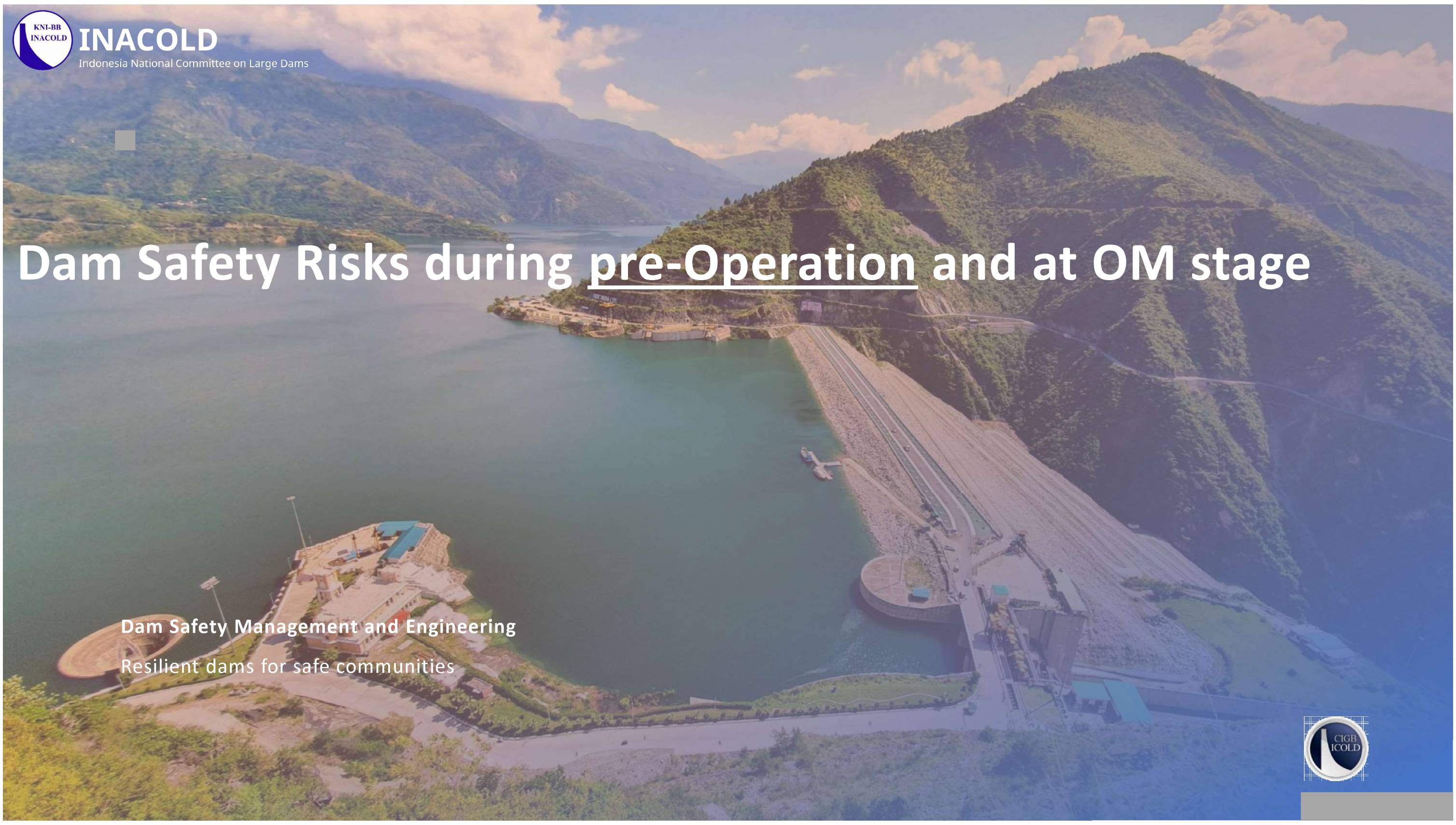
- 2024 Annual Meeting & National Seminar (presented at Workshop organized by JICA)

INACOLD
Indonesia National Committee on Large Dams

- Dam Safety Management and Engineering

Outline of Risks Identification





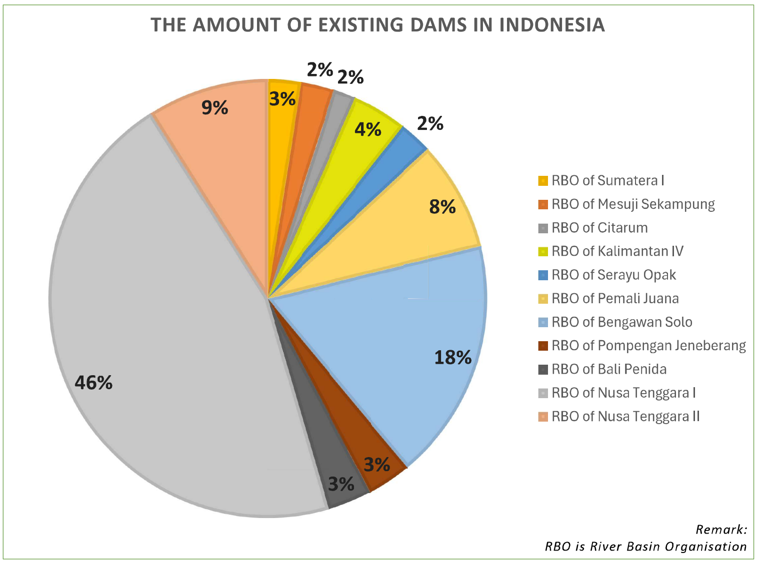
Dam Safety Risks during pre-Operation and at OM stage

Dam Safety Management and Engineering

Resilient dams for safe communities

Dam Safety Management and Engineering

Dams Rehabilitation through DOISP Phase II Funding



Over 140 Existing Dams

Over 140 Existing Dams that have entered a relatively old age (20-50 years)

46%

Approximately of 56 existing dams located in Lombok Island under the authority of RBO of Nusa Tenggara I.

18%

Approximately of 22 existing dams located in Central Java under the authority of RBO of Bengawan Solo.

The remained

Spread in several province in Indonesia

Sources: Report of Technical Implementation Unit for Dam Engineering, 2023.

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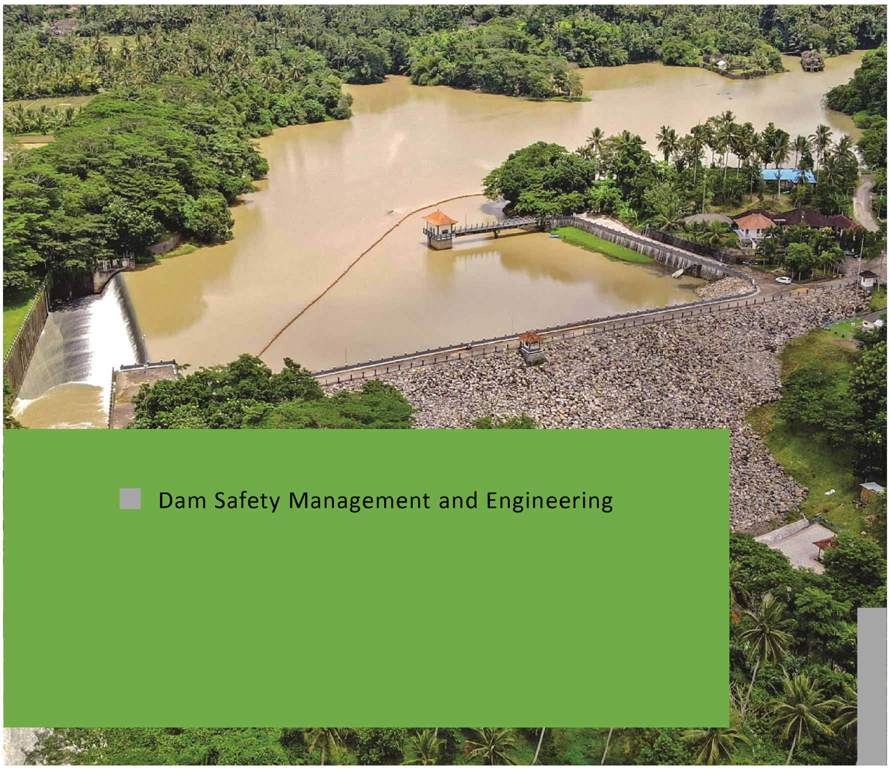
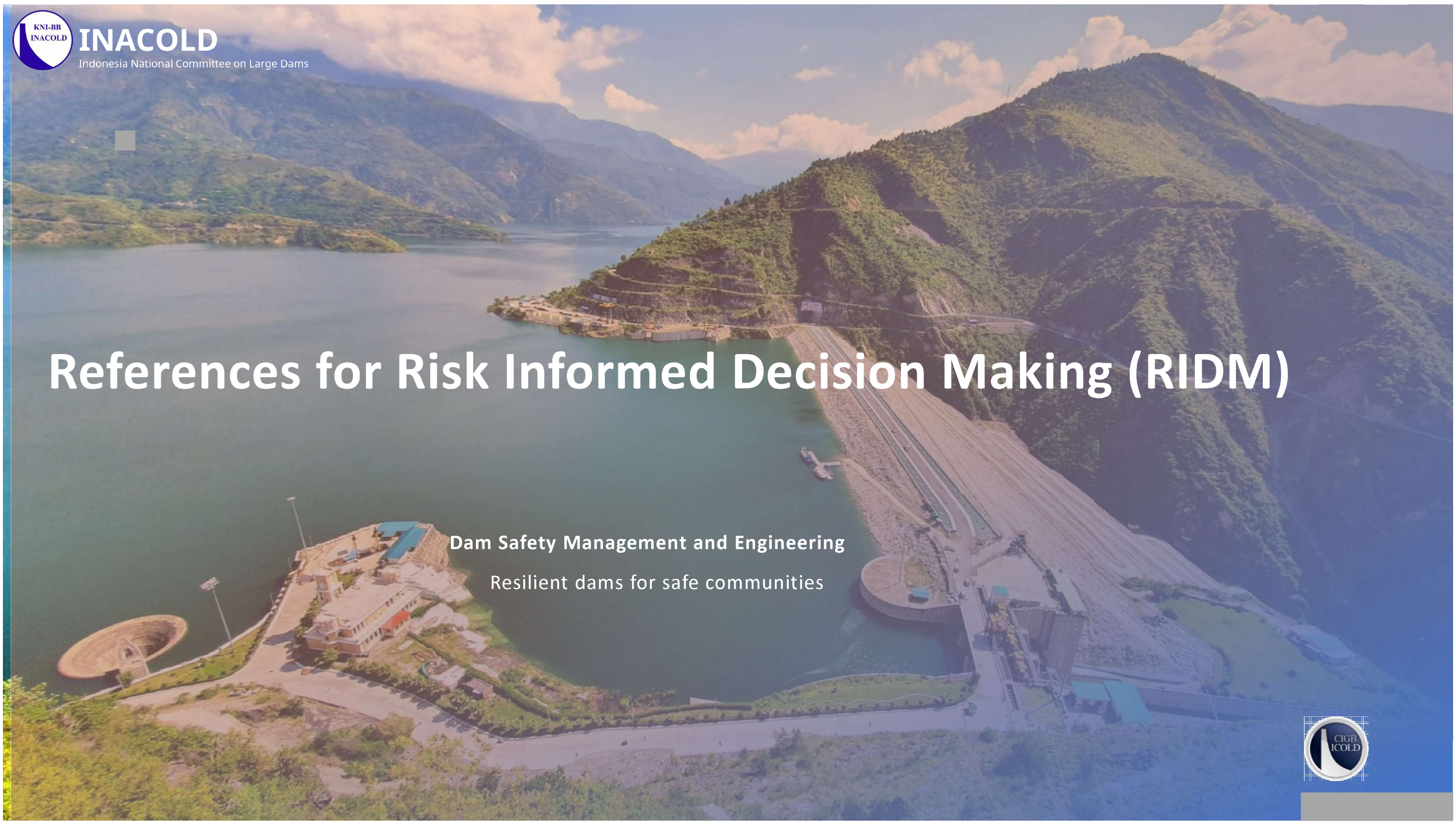


Dam Safety Management and Engineering

In accordance with PUPR Regulation No.27 of 2015, the implementation of dam operations is carried out based on dam operation permits issued by the Minister. As of 2018, only 16 dams have operating licenses.

Nowadays, dam operation permits issued by the Minister have retrieved roughly 64 dams of operating licenses.

More dam operation permits will be in the process, including those of PU, PLN, private sector dams either for 1st operating license or the extension.



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References for Risk Informed Decision Making (RIDM)

Dam Safety Management and Engineering

Resilient dams for safe communities

ICOLD BULLETIN 189:
"Current State of Practice in RIDM for Dams & Levees"
(Tech. Comm on Dam Safety)

Notional Framework for discriminating between risk assessment types

Estimated probability	CONSEQUENCE			
	Catastrophic	Major	Minor	Negligible
High	Qn	Qn	Qn	Ql
Moderate	Qn	Qn	sQn	Ql
Low	Qn	sQn	sQn	NR
Very low	Qn	sQn	Ql	NR
Negligible	sQn	Ql	Ql	NR

Quantitative	Qn
Semi-quantitative	sQn
Qualitative	Ql
Not Required	NR

The risk evaluation process which is not shown in the above matrix may influence the distribution of risk assessment types in the notional matrix above. For example, it may well be that some catastrophic situations (e.g. Frequent-Catastrophic) are to be avoided at all costs and in such cases a decision to eliminate the risk could be made on the basis of a preliminary qualitative risk assessment.

Dam monitoring outcome

DOISP Phase II program was continued the program that had not been fully implemented and increase the number of dams to 140 dams. The government through the Director for Operation and Maintenance has also prepared a strategic plan for dam management.

- Rationalization of Instruments (Piezometer, Inclinometer, V-Notch, Seismograph, Microtremor, Vibration Sensor)
- Periodic updating of Safety Components (Inspection, Reservoir Operation Patterns, O & M Guidelines, RTD)
- Fulfillment of Minimum O & M Facilities and Infrastructures
- Improvement and Optimization of Reservoir Services
- Capacity Building (UPB Institution and Officers)
- Real-time monitoring
- Empowering upstream and surrounding communities

Dam monitoring activities include activities on the upstream and downstream sides of the dam.

- **On the upstream side**, monitoring activities include:
  1) real-time monitoring activities for weather conditions, inflow, travel time, sediment control;
  2) observation of water quality.
- **On the downstream side**, monitoring activities include:
  1) monitoring of water availability;
  2) water requirements;
  3) planting plan, and water control points.
- **In dams**, monitoring activities include:
  1) visual inspection;
  2) monitoring instrumentation;
  3) monitoring water quality and availability;
  4) monitoring sedimentation.

Failure Mode & Risk Analysis (B-130 ICOLD)

Typically, risk analysis involves determining the response of complex systems to complex natural phenomena. In many cases, there may be little or no past experience, making it necessary to construct "Type A" (Lambe, 1973) or "before event" predictive models in order to analyse the risk. As the degree of difficulty of the modelling effort is essentially pre-determined by the complexity of the risk problem, it will often be necessary to construct a number of sub-models for the different sub-systems and elements to make the modelling endeavour tractable. Linking all of the sub-models together constitutes part of the overall analysis process. As in all modelling, the system models should concisely and efficiently represent the logic of the system, influences upon the system, and uncertainties affecting system performance. The enterprise of system modelling seeks a relatively simple representation with comparatively few parameters, which despite its simplicity closely represents the behaviour of the actual physical system.

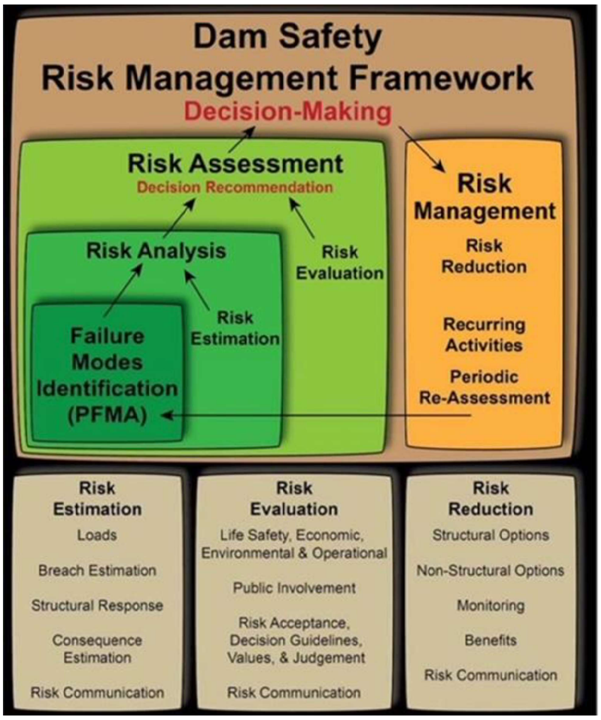
3.2.3. Failure – modes, hazards, mechanisms and effects

The concepts presented in this sub-section are illustrated in Fig. 3.5.

Fig. 3.5
Failure – Modes, Hazards, Mechanisms and Effects
Défaillance – modes, risques d'accident, mécanismes et effets

Failure effect level	Niveau d'impact de la défaillance
Failure mode level	Niveau du mode de défaillance
Hazard (failure cause) level	Niveau de danger (cause de la défaillance)
Failure of section i	Défaillance de la section i
Overtopping	Déversement
Wave overtopping	Submersion par des vagues
Sliding along weak plane	Glissement sur plan de fracture
Piping	Renard

Risk Informed Decision Making (FERC, March 2016)



Federal Energy Regulatory Commission (FERC)

Chapter 1: Introduction to RIDM (page 1-9)

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Dams Rehabilitation

CHRONOLOGY OF LANDSLIDE OCCASION IN NOTOPURO DAM

April 2020

Shallow Landslide Downstream, length and wide roughly 3,50 m and 5,50 m, respectively.

March 2021

The landslide on the reservoir supply channel embankment.

November 2021

The landslide on the embankment was located ±200 m to the right of the intake gate.

December 2021

Location of the landslide around the guard house.

December 2022

There was a ground movement upstream of the dam of about 23 cm and a vertical displacement of about 40 cm in the south of the dam.

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Dams Rehabilitation

CHRONOLOGY OF LANDSLIDE OCCASION IN NOTOPURO DAM

February 2023

Seepage was identified in the main dam near the V-Notch area, when the MAW condition was +94.22 m.

March 2023

The settlement of the downstream slope on was 14-15 cm along a 40 m length.

April 2023

The downstream slope settlement that occurred since March 2023 continued increasing to around 45-50 cm.

June 2024

Evaluating landslide occasion.

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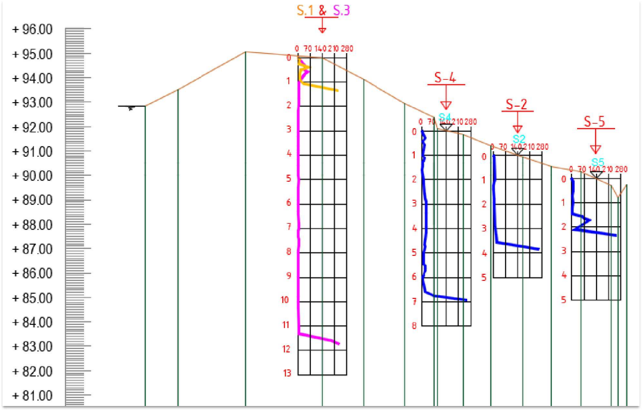
Dams Rehabilitation

COUNTERMEASURE OF LANDSLIDE

Additional **Geotechnical Investigation**	Ensuring the technical parameters of embankment material doesn't contain **swelling potential.**
Carried out **Cone Penetration test**	Conducting in 4 point that represent the entire embankment on the main dam.
Installing **New Geotechnical Instrumentation**	**Open Standpipe Piezometer** and **Observation Well**
Short-term **Countermeasure**	Piling a funnel (bamboo/dolken), diameter min. 10 cm, depth 1,50 – 3,50 m.
Long-term **Countermeasure**	• Replacing swelling and porous material with new material. • Repair of concrete slab on the upstream side

COUNTERMEASURE OF LANDSLIDE



Carried out **Cone Penetration test**

Conducting in 4 point that represent the entire embankment on the main dam.

Regarding on the results of the 4-point CPT investigation, at points S1 and S3, generally the characteristics of q_c values in the field are unequal. The q_c value starts escalating to roughly 70-85 kg/cm^2 from the surface to a depth of 1.5 m. However, it falls back to around 10-20 kg/cm^2 and solidifies again with q_c rising back up to $q_c \geq 250$ kg/cm^2).

RISK ASSSESSMENT? Still big question mark

Sources:
PT. Aditya Engineering Consultant, 2024.

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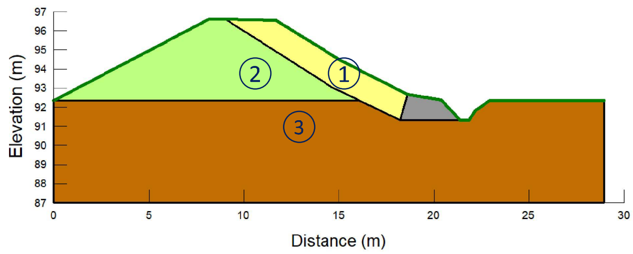
Dams Rehabilitation

COUNTERMEASURE OF LANDSLIDE

- Replacing swelling and porous material with new material.
- Repair of concrete slab on the upstream side

Long-term **Countermeasure**



Zona	Material	γ_{dry} (kN/m^3)	γ_{sat} (kN/m^3)	c' (kPa)	ϕ' (°)	k (cm/s)
1	Timbunan (Clayey Sand with Gravel)	18	19	1	28	1.00E-03
2	Tubuh bendungan eksisting Clayey Silt, Soft	15	16	5	24	1.00E-05
3	Foundation Silty Clay, Medium	16	17	7	28	1.00E-06
4	Rock toe	21	22	1	40	1.00E-02

The parameters used are based on the results of interpretation and laboratory tests of the last backfill material on March 27, 2023.

USULAN TITIK PENYELIDIKAN GEOTEKNIK NOTOPURO (2024)

Kode Hand Bor	Koordinat X	Koordinat Y	Posisi
HBNP-1	576680	9172021	Lereng hilir
HBNP-2	576430	9172307	
HBNP-3	576325	9172470	
HBNP-4	576390	9172712	

Kode Sondir/CPT	Koordinat X	Koordinat Y	Posisi
SNP-1	576681	9172026	Puncak Bendungan
SNP-2	576421	9172332	
SNP-3	576331	9172467	
SNP-4	576401	9172725	

Kode Sondir/CPT	Koordinat X	Koordinat Y	Posisi
SNP-5	576892	9171951	Puncak Bendungan
SNP-6	576524	9172879	

Usulan penyelidikan geoteknik:

- Hand boring 4 titik
- Sondir/CPT 4 titik
- Sondir/CPT tambahan 2 titik untuk segmen yang kondisinya cukup bagus.
- Pengujian in-situ permeability

CONCLUDING REMARKS

- Raising water in the reservoir requires risk analysis for dam safety under various types of loading
- Impounding is always a **critical stage of pre O/M** at the end of construction
- Dam risks assessment during O/M has NOT been considered as a priority yet (**incl. for saddle dam**)
- All related parties in dam design, construction & operation must be familiar with the details of Risk Informed Decision Making (RIDM) & PFMA
- Updated version of Guidelines for Dam Risk Analysis in Indonesia shall be made available and disseminated very soon NOT later

XPXN- LAOS NOT BALI


Thank You
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Let’s Save Our Dams Together

INACOLD Webinar

20240710 RCC Dam Basic Concepts

Ministry of Public Works and National Housing
Directorate General of Water Resources
Japan International Cooperation Agency

JICA

Design & Construction of RCC and RCD Dams

WEBINAR ON WEBINAR ON DESIGN AND CONSTRUCTION METHOD OF RCC
INACOLD & BBWS CILICIS
JULY 31, 2024

SHIMIZU Hiroshi
JICA Dam Construction Advisor
CTI Engineering International Co., Ltd.

Contents

1. History of RCC Dam Construction

In 1960’s-1970s’, USA and Japan had been trying to apply RCC to dams.

In USA:

Aiming to built dams quickly and cheaply applying RCC:
Willow Creek RCC Dam (1982) and was built as a first large RCC Dam in USA which had problems with leaks and cracks.

In Japan,

Aiming to build a conventional concrete gravity dam using RCC
that had the watertightness and strength required CGD,
Named **RCD (Roller Compacted Dam-Concrete)** was established
Shimajigawa Dam (1978).

Around this time, ICOLD was also discussing RCC/RCD Dams.

Since then, many RCC/RCD dams have been built and improved upon in the United States as Roller Compacted Concrete Gravity Dams and in Japan as Roller Compacted Dam-Concrete Dams.

2. Advantage of RCC

Rapid Construction:

- Using only common-equipment
- No need large-scale temporary facilities (cable cranes etc.)

Economical:

- Costs will be reduced through shorter construction periods and Minimizing Temporary Facilities.

Compared to Fill-Type Dams,

- ***Shorter construction period*** because of smaller dam volume.
- ***Dam-related facilities*** spillway and water intake facilities can be installed inside the dam body.
- ***Diversion works*** can be made small-scale (in general, design discharge of fill-type dam is 20-year flood while RCC Dam is 1 to 2-year flood.

3. Disadvantages of RCC

Water Tightness

- There are concerns about water leakage
  Higher permeability compared to slump concrete
- Leakage from Layer Joint

Weakening of Layer Joints

Temperature Control of Concrete

- Difficulty of installation of cooling pipes

4. RCC Dam and RCD Dam

RCC Dams : fully take advantages of RCC : focusing on

- rapid construction
- cost reduction.

RCD Dams : to be same concept as conventional concrete gravity dams.

- Installation of **Traverse Joints** to prevent cracks caused by temperature stress
- Reliable layer surface **joint treatment** (Green Cut and placing Mortar)
- **Outer Concrete** is provided : RCC alone cannot ensure sufficient durability and watertightness.

To be causes of the longer construction period and higher cost du to such additional works and Reducing the advantage of using RCC.

5. RCC/RCD Dam Innovation

a. Improvement of RCC Dam

EM 1110-2-2200 - Gravity Dam Design mentioned

Control of Leakage from RCC dams,

Traverse Joints,

Outer Concrete (conventional concrete) for the purpose of ensuring durability and preventing weak points in strength, and

Layer Surface Joint Treatment, and describes standard design and construction methods.

EM 1110-2-2006 - Roller-Compacted Concrete.

- Mix design method of RCC

In recent years, China has proposed and implemented **Grout Enriched RCC (GE-RCC)** for outer concrete and the **Slope Layer RCC Placing Method**, which aims for rapid construction.

b. Improvements of RCD Method

As an effort to shorten the construction period, RCD developed a new construction method called the Cruising RCD Construction Method, in which the internal concrete (RCC) is poured in advance and the external concrete is poured when the Batching Plant is not in use, shortening construction time and making effective use of the plant.

In recent years, China has proposed Grout Enriched RCC (E-RCC) exterior concrete and the Slope Layer RCC Placing Method, which aims for rapid construction.

Both RCC and RCD are constantly evolving. I feel that in the near future, both RCD and RCC will undergo further improvements and become a single established construction method.

Cruising RCD Construction Method

Conventional RCD method

- 1 lift (1m) is divided into 3 parts,
- Lift up in 3 days.

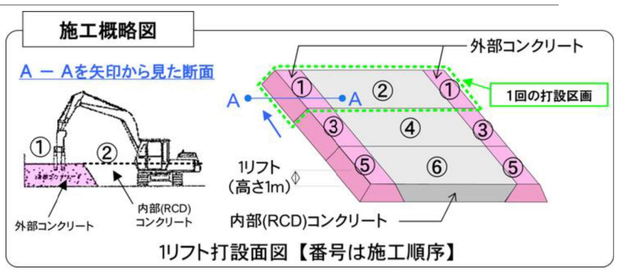
These are the obstacles to increasing pouring speed

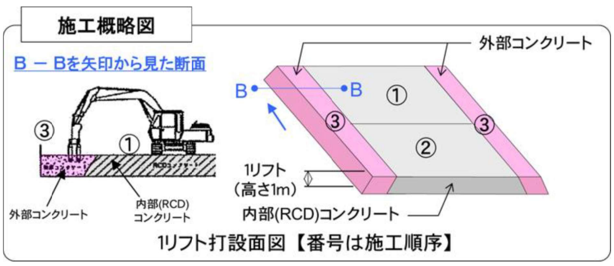
Cruising RCD method

- Outer Concrete Placed,
- stop pouring interior concrete at any point

Effects

- Full Utilization of Batching Plant Capacity
- Pouring speed can be maintained before and after stopping
- 1 lift is completed in 2.5 days
- Reliable Compaction of Outer Concrete,
- Avoiding complicated work by separating interior and exterior concrete pouring points





6. Points to note regarding design and construction

a. Consideration of RCC/RCD adoption

In Design of RCC/RCD Dams

1. **To carefully consider the RCC construction met**hod, in particular arrange the dam structure and facilities within the dam according to the construction method.
2. **To ensure availability of sufficient high-quality materials** are available, and there are cases where it is problematic to ensure that high-quality polazon, especially fly ash, which is essential for RCC, is available.
3. After considering these points, it is necessary to determine whether RCC/RCD has advantages over conventional construction methods in tarms of both economically and construction period, and then decide whether to adopt them.

b. Specific check items

i. Material for RCC

1. Cement
2. **Fly ash**
3. Aggregates
4. Water
5. Additives

表 23-9　フライアッシュの品質

JIS 規格改訂年			1996 年	1999 年			
項目 ＼ 種類			－	Ⅰ種	Ⅱ種	Ⅲ種	Ⅳ種
二酸化けい素		%	45.0 以上	45.0 以上			
湿分		%	1.0 以下	1.0 以上			
強熱減量		%	5.0 以下	3.0 以下	5.0 以下	8.0 以下	5.0 以下
密度		g /cm^3	1.95 以上	1.95 以上			
粉末度	45 μm ふるい残分（網ふるい方法）	%	40 以下	10 以下	40 以下	40 以下	70 以下
粉末度	比表面積（ブレーン方法）	cm^2/g	2,400 以上	5,000 以上	2,500 以上	2,500 以上	1,500 以上
フロー値比		%	92 以上	105 以上	95 以上	85 以上	75 以上
活性度指数 %	材齢 28 日		80 以上	90 以上	80 以上	80 以上	60 以上
活性度指数 %	材齢 91 日		90 以上	100 以上	90 以上	90 以上	70 以上

ii. Layout Design

The thickness of the external concrete, the spacing of the traverse joints, and the layout of facilities inside the embankment must be determined in advance.

The layout of the discharge pipes and inspection gallery was carefully considered. Precast materials were used.

Downstream slope formwork: Slide Form or Precast Embedded Form

Ensuring quality materials: quantity and quality of cement, porazon (fly ash), aggregate, water, additives (water reducer, retarder)

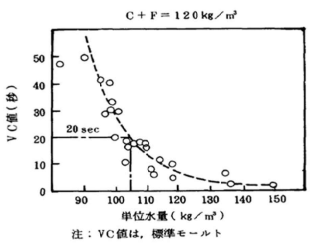
Temperature control: joint width, Pre-cooling, Post Cooling

iii. Mix design of RCC concrete

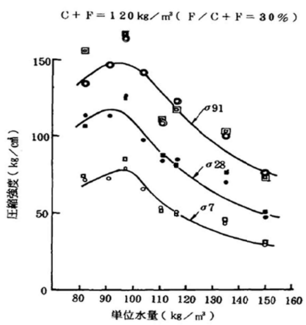
- Unit cement amount
- Fine aggregate ratio
- Additives such as Porson (Fly Ash) retarder

Laboratory Testing

Field test: Hot, worm and cold joint regulations (conditions and time), pouring surface treatment



図—1 単位水量と VC 値



図—2 単位水量と圧縮強度

iv. quality management

1. Consistency ⇒ Evaluated by VC value
2. Strength Compressive strength of RCC Adhesion of poured surface
3. Permeability coefficient

7. Conclusion

The stability of RCC dams is evaluated in the same way as for regular concrete gravity dams, by

- overturning,
- sliding, and
- compressive stress,

There are differences in materials and construction methods, when RCC Dam adopted, dam design should take in to account of advantages of the RCC,

take into account the points mentioned above.

To take into account the construction characteristics of RCC at the design stage.

Thank you for Kind Attention

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