Quest Journals
Journal of Architecture and Civil Engineering
Volume 9 ~ Issue 6 (2024) pp: 14-24
ISSN(Online) : 2321-8193
www.questjournals.org

Research Paper

A Comparison of Existing Value with the Remedial Workproject Value of a Dam in Reducing the Risk of Dam Failure At Tolotangga Dam Of Bima Regency In West Nusa Tenggara Province

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ABSTRACT : *This research was conducted at Tolotangga Dam in Tolo Uwi Village, Monta district, of Bima Regency. Body of the dam is built on tuff sandstone where the tuff sandstone section still maintained resulted in clear water leakage found in the downstream part of the dam. Construction of the dam aims to ensure water availability to support and fulfill necessities according to the existing demand around the dam location, such as: (1) for irrigation purpose, (2) fulfillment of raw water needs, and (3) for electricity generator, etc.*
The main objectives of Remedial Work Project (RWP) for this research are include: (1) ensure the dam condition always monitored, (2) early initiation to problems that starting to develop in the dam, so it can be identified as early as possible, (3) the appropriate action can be taken before the occurred problem develop more seriously, (4) thus, the safety and sustainability of the dam can always be maintained.
This research discusses analysis of risk index of dam safety level at the Tolotangga Dam using the ICOLD Modification Method. This modified ICOLD method emphasizes to assess visual inspection results focused on design weakness and downstream risks. By employing the ICOLD modified risk index, it is found that Tolotangga Dam classified as high risk with risk value of 46.5. However, after conducting Remedial Work Project (RWP) activities under the budget of 16.53 billion makes the risk level decline into low risk level with value of 33.
KEYWORDS: *ICOLD, Tolotangga Dam, Existing Condition, Remedial Work Project (RWP).*

R*eceived 25 June, 2024;* ***R****evised 30 June, 2024;* ***A****ccepted 08 July, 2024 © The author(s) 2024.*
P*ublished with open access at* ***www.questjournals.org***

I. INTRODUCTION

Remedial Work Project (RWP) is a planning project of construction maintenance activity for rehabilitating a dam aimed to reduce dam failure risk. The effectivity in reducing risk of dam failure can be measured by comparing the condition, value and risk level from the existing dam with the condition, value and risk level after RWP activities have been carried out.

The government law on Public Works and Public Housing number 27/PRT/M/2015 in article 2 stated the Dam construction and its management is carried out based on the Dam Safety Concept (*Konsep Keselamatan Bendungan)* consisted under 3 (three) pillars of [1]:

1. Structure safety, in the forms of safety against structural failure, hydraulic failure, and leakage failure,
2. Operation, maintenance and monitoring activities,
3. Readiness for emergency action.

For obtaining the three pillars of dam safety concept, it also requires the completion of study documents that contains dam safety concept including:

1. Examination of the Dam Capacity Documents conducted by the dam manager or the owner to draw conclusion about the safety of the dam structure;
2. Examination of the Dam Operational and Maintenance Guidance Documents which include the monitoring activity; and
3. Examination of Dam Emergency Action Plan Document as the completion of the three pillars concept.

The project implementation time is 16 (sixteen) months or 480 (four hundred and eighty) calendar days since the Work Commencement Order (*Surat Perintah Mulai Kerja* or abbreviated as SPMK) issued by the government.

Figure 1: Site location of Totangga Dam

II. LITERATURE REVIEW

An evaluation to dam risk is very important to execute in every stage of dam work to make the risk of dam failure can be maintained as low as reasonably practicable/ALARP. The risk assessment is carried out by including the analysis for normal load, anomalous load and extreme load also the earthquake load in identifying, assessing and managing risks. [2]

During the period of operation and maintenance project, the dam must be supervised, monitored and repaired as needed to guarantee the safety from the dam. Reasons to do repairing or rehabilitating dams are stated by Brown, 2017 below:

1. There has been a change in the dam safety standards.
2. Excessive or more deficiencies occurred within the dam in real life than during the design and construction phase.
3. Restoring the concrete strength that flawed due to concrete damage.
4. Raising the dam.

Indonesia has plenty of dams without complete information record such as missing the built drawings, dam history, and instrument records. so, the work of prioritizing, repairing and evaluating dams tend to use risk analysis method. For the research analysis part, a modified ICOLD method was applied for the analytical method in this research. [3]

The ICOLD modification method is a method emphasizing on weaknesses of dam design and downstream risks. In this method, definition of structure that able to cause collapsing of a dam is divided into 3 group: static stability, flood capacity and earthquake resistance. [4]

Meanwhile, the risk level divided into four risk indices as listed below [5]:

1. 0-15 risk index, considered as ‘low’ hazard classification.
2. 16-45 risk index, considered as ‘moderate’ hazard classification.
3. 46-75 risk index, considered as ‘high’ hazard classification.
4. > 75 risk index, considered as ‘extreme’ hazard classification.

The ICOLD modification method mentioned in this paper referred as a risk assessment method involving two parts, the dam factor and the related factor to the dam. The dam factor consists of the flood capacity, dam height, data availability of dam construction and its maintenance, data of instrumentation observation, dam stability, and flood evaluation. Meanwhile, for factor related to dam are filled with risk of damage to downstream areas due to dam failure, business risks, and community evacuation requirements. [5]

A sensitivity analysis is a study of how the uncertainty part of the output from a mathematical model or system (numerical and others) can be divided and allocated into many uncertainly source of the input. The purpose of implementing a sensitivity analysis is observing for what will happen to the project results when there are errors or changes in the basis of calculating costs or benefits. Apart from it, the primary aim of a sensitivity analysis:

1. Improves way of project which being implemented,
2. Improves the design of the project so it able to increase the NPV,
3. Reduces the risk of loss by indicating several precautions which must be taken in prior time.

III. RESEARCH METHOD

In this study, the dam risk assessment will be carried out by a standard-based modified ICOLD method with 11 (eleven) main risk indices to be assessed namely [4]:

1. Reservoir storage capacity
   The capacity of reservoir storage refers to the size of planned capacity of the dam for storing water. Reservoir capacity can be determined through topographic and bathymetric surveys which are evaluated against the planned capacity.
2. Data of the Dam
   For the risk assessment based on the dam data, the chosen risk index is the biggest risk value of the risks posed by the dam height, dam length and the foundation conditions.
3. Deficiency related to earthquake
   Important matter needs to observe from deficiencies related to evacuation is the residents who are exposed to risk and emergency action plans. Both matters can be obtained from analysis and surveys of areas that will be affected by the dam failure. Determination of deficiency risk value related to evacuation is the same, by taking the biggest risk value from the risks of population being exposed to risks and the emergency action plans.
4. Potency of downstream damage to existing structure
   If the dam collapsing, downstream area of the dam possesses a potential risk of experiencing damages related to socio-economic, environmental and business risks. Therefore, in relation to three things above are being inventoried so that the risk of the dam can be assessed. Determination of risk value from potential downstream damage to the existing structure is the same as before, selected based on the biggest risk value of many related factors.
5. Historical recording of maintenance and construction
   The construction historical recording refers to the availability of documents from the time of the dam was planned until the dam construction was completed such as feasibility documents, dam design documents, and built drawing documents. Meanwhile, the maintenance historical recording refers to the availability of standard operation procedure documents for operating dam equipment and instruments, along with dam inspection activities and other activities included within maintenance program. The historical documents completeness for a dam acted as important consideration for understanding the dam condition from time to time.
6. Instrumentation deficiency
   There are two important parts in instrumentation deficiency which are the availability of dam instrumentation and the availability of the data reading or the measurement of the equipment. The dam instrumentation tools could be a piezometer, sliding stakes, v-notch, peilschall and observation wells.
7. Prior level of the safety/precaution efforts
   The level of safety precaution refers to orderliness of dam inspection activities implementation. After the completion of activities, report regarding dam inspections is made or not. Then recommendation to improve dam safety have been followed up or not been followed up.
8. Development plan at downstream area
   Such matters in relation to risk values determination in downstream development planning include readiness in planning and managing emergency actions in the planning area that affected by dam collapse. There are factors to be concern such as whether is there a zoning plan or not, an emergency action plan that already socialized until community who live in the downstream area of the dam, and other mitigation plans related to flood arrival time at downstream area of the dam.
9. Flood deficiency
   Risk assessment to dam deficiency to flooding taking form of technical analysis and visual inspection. Technical analysis consisted of examining spillway capacity in dealing with extreme loads such as PMF and visual inspection is needed to check spillway structure condition and controller building (spillways) responsible for outflow from the dam.
10. Static stability deficiency
    Risk assessment to static stability deficiency carried out by technical analysis, visual inspection, and dam historical documents. The risk assessment is determined based on whether the dam building is in good condition or there are signs of damage such as leakage, cracks and slope instability. The risk value taken is the greatest risk value from the current condition of the dam.
11. Deficiency related to earthquake

The risk assessment for earthquake deficiency aims to determine the dam vulnerability to earthquake loads from aspects of dam geometry, filtration, foundation, earthquake zoning and dam stability in the face of MDE earthquakes. [5]

Eleven items explained above are assessed based on weights that have been standardized in the ICOLD Modification method so the risk level or the importance of the dam can be understood.

IV. RESULT AND DISCUSSION

4.1. Risk Assesment

Risk assessment in this research is divided into two parts: the risk assessment in existing condition and the risk assessment after implementation of the Remedial Work Project (RWP). Analysis of the two assessments uses the modified ICOLD method.

Table 1. Reservoir storage capacity

No	Risk Level	Extreme	High	Moderate	Low
	Weight of Risk Index	**6**	**4**	**2**	**0**
1	Reservoir capacity C = (ML x 10^2)	C > 10	120 > C > 40	1,0 > C > 0,5	C < 0,1
2			40 > C 2,0	2,0 > C > 1,0	0, 5 > C > 0,1

Table 2. Risk assessment of dam data

No	Type of Dam	Dam Data					
		Risk Level	**Extreme**	**High**	**Moderate**	**Low**
		Risk Index	**6**	**4**	**2**	**0**
1	All types of dams	Height of dam, H (in meters)	H > 45 (6)	30 < H < 45 (4)	15 < H < 30 (2)	H < 45 (0)
2	Embankment	Length of dam, L (in meters)	L > 2000 (6)	500 < L < 2000 (5)	200 < L < 500 (3)	L < 200 (1)
		Foundation	Poor (6)	Adequate (5)	Good (2)	Very Good (1)

Table 3. Deficiency related to evacuation

No	Risk Level	Extreme	High	Moderate	Low
	Weight of Risk Index	**12**	**8**	**4**	**0**
1	People Affected risk (PenRis/PAR)	PAR > 100.000 (12)	1.000 < PAR < 10.000 (8)	10 < PAR < 100 (4)	PAR < 1 (0)
2					
3			10.000 < PAR < 10.000 (10)	100 < PAR < 1.000 (6)	1 < PAR < 10 (2)
4					
5	Emergency plan (RTD/EAP)	No RTD (12)	RTD & PenRis Are not stimulated (9)	Evacuation route is available (5)	RTD/EAP has been spreader out (1)
6					
7				Inundation map is not distributed widely (7)	Early warning system available (3)

Table 4. Potential of damage on downstream area to the existing structure

No	Risk Level	Extreme	High	Moderate	Low

<table>
<tr><th></th><th>Weight of Risk Index</th><th>12</th><th>8</th><th>4</th><th>0</th></tr>
<tr><td>1</td><td rowspan="7">Socio-economy</td><td rowspan="7">Municipality with commercial activities and vast industries (18)</td><td rowspan="4">National main road/ interstate/ electricity (13)</td><td rowspan="4">Development of major scale residence area (6)</td><td rowspan="2">Agricultural area of ranch (1)</td></tr>
<tr><td>2</td></tr>
<tr><td>3</td><td rowspan="2">Development of minor scale residence area (5)</td></tr>
<tr><td>4</td></tr>
<tr><td>5</td><td rowspan="3">Great dam of downstream area (15)</td><td rowspan="2">Small dam at downstream area (10)</td><td>None or less housing/residence structure (2)</td></tr>
<tr><td>6</td><td>Several permanent structure (3)</td></tr>
<tr><td>7</td><td>Plantation or medium ranch (8)</td><td>Development of minor scale residence area (5)</td></tr>
<tr><td>8</td><td rowspan="2">Environment</td><td rowspan="2"></td><td>Reversible loss (12)</td><td rowspan="2">Habitat is protected by law (7)</td><td>No habitat loss (1)</td></tr>
<tr><td>9</td><td>Habitat loss (16)</td><td>Minimum loss (3)</td></tr>
<tr><td>10</td><td rowspan="3">Business risk at downstream area</td><td rowspan="3"></td><td>Major airport/port and navigation service (14)</td><td rowspan="2">Water or wastewater treatment agency (9)</td><td>Undeveloped land (0)</td></tr>
<tr><td>11</td><td rowspan="2">Industrial/ Commercial/ Shopping center area (17)</td><td>Small scale industry, commercial activity (4)</td></tr>
<tr><td>12</td><td>Small cities/port & navigation services (7)</td><td>No infrastructure or port facility, navigation services (1)</td></tr>
</table>

Table 5. Historical recording of construction and maintenance

<table>
<tr><th rowspan="2">No</th><th rowspan="2">Additional Data</th><th>Risk Level</th><th>Extreme</th><th>High</th><th>Moderate</th><th>Low</th></tr>
<tr><th>Risk Index</th><th>3</th><th>2</th><th>1</th><th>0</th></tr>
<tr><td rowspan="2">1</td><td rowspan="3">Historical recording of construction and maintenance</td><td rowspan="2">Construction</td><td rowspan="2">No record</td><td rowspan="2">Concept or feasibility design</td><td rowspan="2">Basic design</td><td>Specification plan (0)</td></tr>
<tr><td>As-built drawing (0.5)</td></tr>
<tr><td>2</td><td>Manual O & P</td><td>No procedure</td><td>There is existing procedure but not applied</td><td>Disorderly inspection or repairs</td><td>Regular inspection and repairs as needed</td></tr>
</table>

Table 6. Instrumentation deficiency

No	Additional	Risk Level	Extreme	High	Moderate	Low

	Information	Weight of Risk Index	3	2	1	0
1	Historical recording of construction and maintenance (BDSF)	Poor or not available	No instrumentation			Pore pressure
2					leakage	
3				deformation		
4		Number of instrumentation tool availability		40% < reading < 60%	60% < 1 < 80%	1> 80%
5	Data	Instrumentation reading based on O & M Manual	Not available	40% < reading < 60%	60% < reading < 80%	reading < 80%
6		Data availability, in year		> 1	> 3	> 5

Table 7. Previous level of the safety efforts/precaution

No	Additional Data	Risk Level	Extreme	High	Moderate	Low
		Weight of Risk Index	3	2	1	0
1	Document	Inspection	No irregular inspection or major delays	Significant delays in analysis and reporting	Analysis and reporting often delayed	Procedure is available
2		Reports	Unavailable report	Reports are sent irregularly	No recommendation	Report is available
3		Follow up	No corrective action	Only the most important deficiency is addressed	All corrective actions were taken but not completed	Corrective action was taken as recommended by dam safety report

Table 8. Development plan at downstream area

No	Risk Level	Extreme	High	Moderate	Low
	Weight of Risk Index	3	2	1	0
1	Development plan	No land usage/ zoning area	RTD is not distributed widely	Evacuation route is stimulated	RTD is available and implemented
2			No contingency planning for the business	DBA & inundation speed and depth maps are not available	Local planning is available

Table 9. Flood deficiency

No	Risk Level	Extreme	High	Moderate	Low
	Weight of Risk Index	**6**	**4**	**2**	**0**
1	Spillway capacity	Overtops (6)	Freeboard < 5% (4,5)	Freeboard < 10% (3)	There are no disadvantages (0)
2			Q1000 (5)		
3			1/2 PMF (5,5)	Flood design (2)	
4	Flow control	The door cannot be operated (6)	Backup power (5)	Concrete gravity (2)	The flow control system can be operated (1)
5					
6			Access to location (4)	Electromechanical equipment deficiency (3,5)	
7					
8			Dam embankment (4,5)	Masonry gravity dam (3)	
9					
10	Structure of spillway	Rebar visible/ EDA broken (6)	Progressive erosion, broken EDA (5)	Missing joints apparent; sign of erosion apparent (2)	There is no adverse condition (1,5)

Table 10. Static stability deficiency

No	Risk Level	Extreme	High	Moderate	Low
	Weight of Risk Index	**18**	**12**	**6**	**0**
1	Embankment	Boils downstream toe increasing over time (18)	No filters (12)	Inadequate filter (7)	No bad condition (0)
2			Piping in embankment (17)	Saturated area & high RWL (8)	Damp/ moist surface area & moderate RWL (2)
3				Active leakage at surface (6)	
4		Many sinkholes are large and have collapsed (18)	There are large sinkholes that are isolated or collapsed (15)		No sign of sinkholes (3)
5	Conduits			Damages at the buried pipes (11)	Pipes are not encased in concrete (5)
6	Cracks		Transverse at the top with a depth of > 50% of freeboard	Transverse at the top with a	No sign of crack (2)

			(14)	depth < 50 % of freeboard (10)	
7	Slope stability	Instability of top slope (18)	Settlement or axis transfer (16)	Earth fill condition is full of plants and animal excavations (11)	Adequate slope protecting and benching (4)
8			Slumping/ decreasing under high piezometric pressure (17)	Slope is steeper than 1V : 2H (9)	Structure stability where $S_f > 1,2$ (1)
9	Geological foundation		Adverse geological or geomorphological structure	Piping in foundation (6)	

Table 11. Earthquake deficiency

No	Risk Level	Extreme	High	Moderate	Low
	Weight of Risk Index	**12**	**8**	**4**	**0**
1	Design feature		No filters (9)	Inadequate internal filter (6)	Seismic design is in accordance with the seismic map issued by BMKG (0)
2			The slope is steeper than 1H:1V Structure at the top (10)	Poor compaction. The appurtenant structure is susceptible to damage (7)	Zoned embankment with adequate filter (3)
3	Verifiable material	Saturated material (cobble stones and or sand) (12)	Loose sand in abutments or in foundation (11)	Cracks lengthwise erosion (6)	
4	Instability of Rim Reservoir		Landslides identified along the reservoir edge (10)	Rim slopes > 1:1 (5	
5	Earthquake zone	Zone > V (12)	Zone IV (8)	Zone III (4)	Zone I & II (1)
6	Acceleration at top ground	apt > 0,25 g & cesar < 10 km (12)	apt > 0,25 g & no cesar within 10 km (8)	0,01 g < apt < 0,25 g (4)	apt < 0,10 g (2)

Description:

: Existing Condition

: Remedial Work Project (RWP) Condition

4.2. Risk Assesment to Existing Risk of Totangga Dam

The result of risk assessment to the existing dam was analyzed by the modified ICOLD method.

Table 12. Existing risk assessment to Tolotangga Dam

No	Risk Index	Risk Value
1	Reservoir storage capacity	2
2	Data of the dam	3
3	Deficiency related to evacuation	12
4	Potential of downstream damage to the existing structure	8
5	Historical recording of construction and maintenance	3
6	Instrumentation deficiency	3
7	Previous level of the safety efforts	3
8	Development plan at downstream area	2,5
9	Flood deficiency	2
10	Static stability deficiency	4
11	Earthquake resistance deficiency	4
	Total	**46,5**
	Class of Risk	**High**

4.3. Risk Assesment by Remedial Work Project (RWP) to Tolotangga Dam

The result of the risk assessment by Remedial Work Project (RWP) to the dam was analyzed by modified ICOLD method.

Table 13. Risk assessment by Remedial Work Project (RWP) at Tolotangga Dam

No	Risk Index	Risk Value
1	Reservoir storage capacity	2
2	Data of the dam	3
3	Deficiency related to evacuation	5
4	Potential of downstream damage to the existing structure	8
5	Historical recording of construction and maintenance	3
6	Instrumentation deficiency	1
7	Previous level of the safety efforts	2
8	Development plan at downstream area	1
9	Flood deficiency	2
10	Static stability deficiency	2
11	Earthquake resistance deficiency	4
	Total	**33,0**
	Class of Risk	**Moderate**

Difference in reducing building risk:

Table 14. Difference in risk assessment

Existing Risk Value	RWP Risk Value	Difference	Percentage of Reduction
46,5	33,0	13,5	29,03 %

4.4. Sensitivity Analysis

In this research, the sensitivity analysis was carried out by using the budget allocation condition by dividing it into four models presented below.

Table 15. The sensitivity analysis of budget condition

No	Budget Allocation	Description	Total Budget

1	Existing condition	= No Budget	Rp. 0
2	Budget condition minus 60%	= Control - (Control*60%)	Rp. 6.611.006.395,31
3	Actual budget	= Control	Rp. 16.527.515.988,28
4	Budget condition minus 60%	= Control + (Control*60%)	Rp. 26.444.025.581,25

Table 16. Risk value of budget allocation condition

No	Risk Index	Risk Assessment			
		Existing	RWP - 60%	RWP	Max
1	Reservoir storage capacity	2	2	2	2
2	Data of the dam	3	3	3	3
3	Deficiency related to evacuation	12	9	5	1
4	Potential of downstream damage to the existing structure	8	8	8	8
5	Historical recording of construction and maintenance	3	3	3	0
6	Instrumentation deficiency	3	2	1	0
7	Previous level of the safety efforts	3	3	2	0
8	Development plan at downstream area	2,5	2	1	0
9	Flood deficiency	2	2	2	2
10	Static stability deficiency	4	3	2	0
11	Earthquake resistance deficiency	4	4	4	4
Amount		**46,5**	**41,0**	**33,0**	**20,0**
Class of Risk		**High**	**Mode rate**	**Mode rate**	**Mode rate**

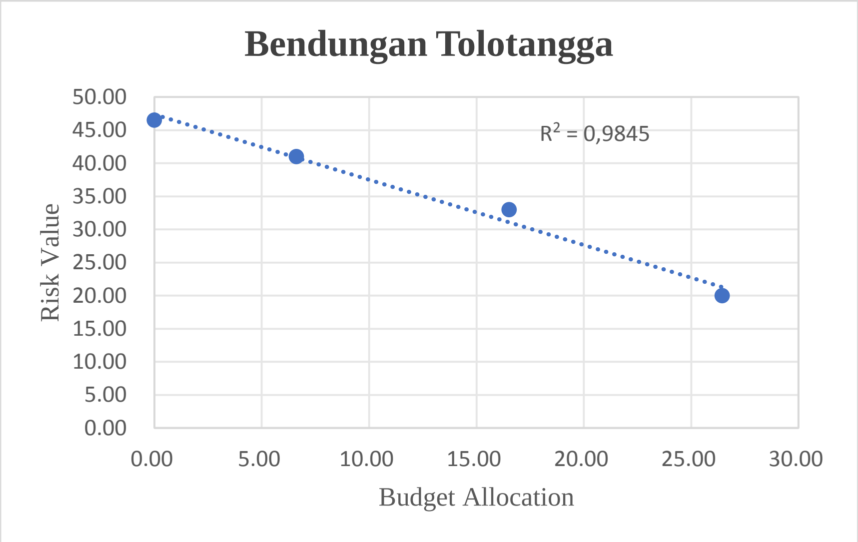

Figure 2: Budget allocation graph

From the graph is evident that budget allocation treated with RWP work has a positive impact on reducing risk with a deterministic value of 0.9845.

V. CONCLUSION

The result of major inspection conducted by DOISP II to the condition of the existing dam showing condition of top part of the dam is still a pile of soil in a wavy condition, the parapet condition also has not been properly arranged, condition of existing dam body has traits of leakage, condition of the surface of the existing riprap at the downstream and upstream areas requires surface smoothing and addition of riprap material. After the remedial work project activity were carried out, the top part of the dam was asphalted, parapet walls were created with concrete, added layers of concrete to the dam body, arranged and added riprap materials to the downstream and upstream side of the dam.

According to the research analysis above, it is found the difference between the existing value and RWP in an effort to reduce the risk of dam failure at the Tolotangga Dam is 29.03%. Whereas the risk value for the existing dam is 46.5 stated as a "high" risk class and the risk value for the remedial work project (RWP) is 33 stated as a "low" risk class.

The sensitivity analysis of RWP budget allocation carried out in this research showed that budget project providing influences to risk reduction (of the dam) with a deterministic value of 0.98. This value is considered as high value which means the budget allocation has a big influence on reducing risk value of the Tolotangga Dam. As a conclusion, it is evident that RWP activities are very effective in reducing risk of dam failure.

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