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ANALYSIS OF FUNCTION IMPROVEMENTS DUE TO CHANGES IN CORE ZONE MATERIAL BASED ON VALUE ENGINEERING AT URUGAN BATU DAM

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Abstract: An embankment dam is a large artificial embankment made by placing and compacting various compositions of soil, sand, clay or rock. One of the rock fill dams located in the Buleleng Regency, Bali Province, namely the Tamblang Dam which is planned to be utilized to meet the raw water needs in the Buleleng Regency in particular and the Bali Province of 510 liters/second, irrigates irrigated rice fields in Bungkulan and in Bulian with an area of 588 Ha, as a micro hydro power generator of 2 x 269 MW, as well as other uses for flood control and tourism. At first the Tamblang Dam was a rock fill dam with an upright core made of clay material. After conducting test pits at 30 borrowed areas and soil investigations at an independent laboratory, the volume of the core zone material according to specifications cannot meet the needs of the core material. There are alternative solutions to the problem, namely bringing in core zone material from outside the project site or changing the original clay core design into an asphalt concrete core. This study applies the Value Engineering (VE) method in which an increase in function at a fixed cost or an increase in function will be obtained by reducing costs or reducing costs for a fixed function or increasing costs and increasing functions.

Keywords: Dam; Value Engineering; Clay; Asphalt Concrete.

INTRODUCTION

The selection of urugan-type dams in Indonesia is not only supported by their topography, the availability of material is also adequate so that it is more economical than other types of dams. Besides having great and more economical benefits, urugan-type dams can also bring danger in the event of dam failure because they are heavy construction. To avoid the occurrence of collapses in urugan dams, it is necessary to analyze the stability of the dam both at the time of design, during the implementation and operation of the dam (Azdan and Samekto, 2008).

Tamblang Dam is one of the dams in Indonesia located in Bali Province and a rock urugan dam type with an upright core that has a dam peak elevation located on El. +185 m with a peak length of 260 m, and a height of 68 m from the bottom of the deepest foundation. Tamblang Dam located in the Tukad Daya watershed is planned to be used to meet raw water needs, especially in the Buleleng Regency, Bali Province, raw water of 510 liters / second, irrigating irrigated rice fields in Bungkulan and in Bulian covering an area of 588 ha, as a micro hydro power plant of 0.38 MW, as well as other uses as flood control and tourism.

Tamblang Dam was originally a rock urugan dam with an upright core with clay material. After pit tests at 30 points and soil investigation in an independent laboratory at the prospective borrow area location, the clay parameter values in the form of Plastic Indek and Permeability did not meet the engineering specifications.

MATERIALS AND METHODS

Tamblang Dam, most of the constituent material is in the form of random rock urugan which has an upright core divided into 6 (six) zones, namely zone 1 is an impermeable core, zone 2 is a fine filter, zone 3 is a coarse filter zone, zone 4 is a rock heap, zone 5 is a random rock, zone 5a is a random weathered rock and zone 6 is a rip rap pair that can be seen in Figure 2.8 so that it belongs to the type of rock urugan dam with an upright core (BWS Bali Penida, 2022).

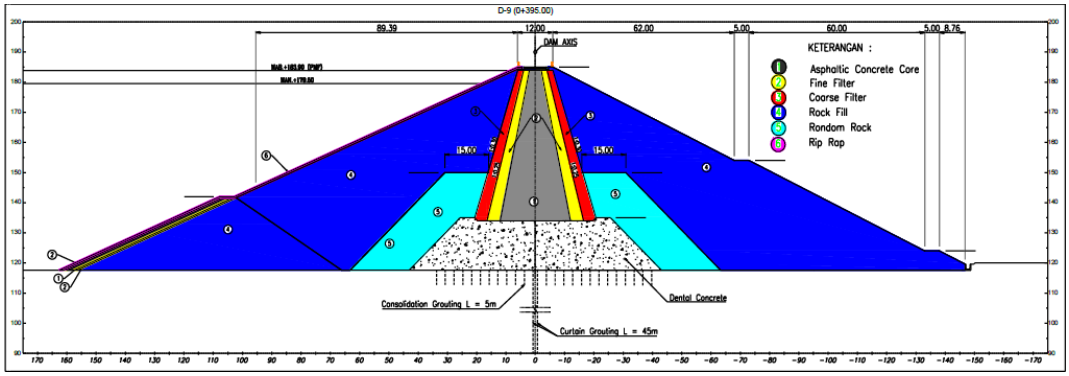


Figure 1. Cross section of the core zone with loamy soil

(Source : BWS Bali Penida,2021)

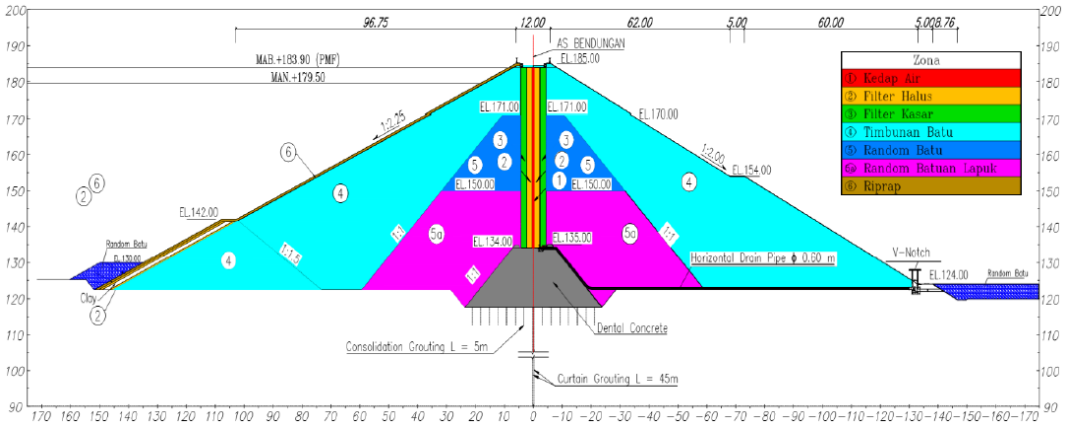


Figure 2. Cross Section of the Core Zone with Concrete Asphalt

(Source : BWS Bali Penida,2021)

An overview of the layout of the Tamblang dam consisting of the main dam body, evasion tunnel, spillway, intake, and outlet can be seen in figure 4.3 below.

Figure 3. Tamblang Dam Layout

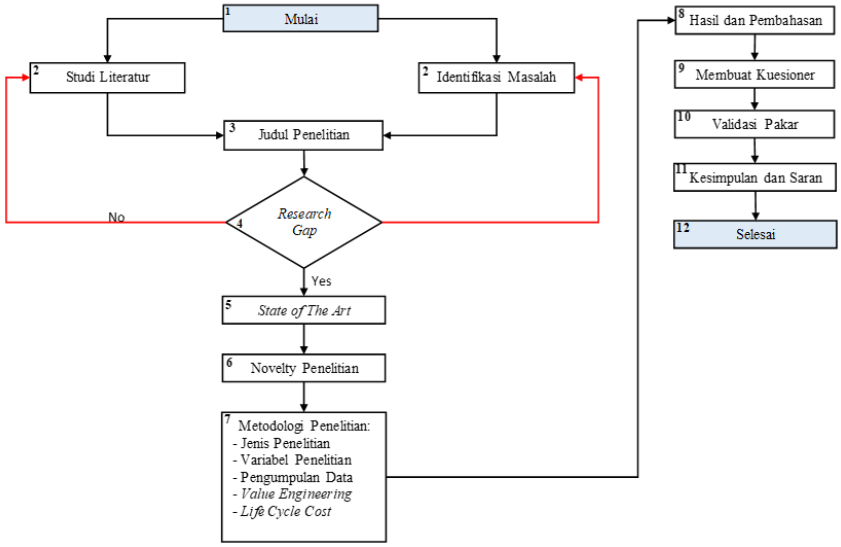


Figure 4. Research Flowchart

RESULTS AND DISCUSSION

A. general description

The overall scope of Tamblang Dam construction work includes preparatory work, entrance, and road inspection work, evasion tunnel work, *main dam* work, *spillway* building work, *intake* building work, hydromechanical work, facility building work, and other works. Technical data of the work – the work based on the results of a detailed *design review* is:

1. Reservoirs
a. River Name: Tukad Daya
b. Inundation Length: 2,236 Km
c. Luas DAS: 78,63 Km^2
d. Inundation Area: 35.9 H
e. Total Spool Volume: 7.6m^{m3}
f. Effective Spool Volume: 5.6m^{3m}
g. Dead Spool Volume: 2.0m^3
h. Minimum Water Level Elevation: +161.0 m
i. Normal Water Level Elevation: +179.5 m
j.Maximum Water Level Elevation:+182.2 m

2. Main Dam
a.Type: Urugan Stone With Upright Core
b. Waterproof Layer Position and Type: In the Middle
c. Flood Discharge Q1000: 712 m^3/s
d. PMF Flood Discharge: 1514 m^3/s
e.Foundation Type: Rocks
f.Height of the Deepest Foundation Base: 68 m
g. Height From the Bottom of the Deepest River: 66 m
h. Dam Volume: 960,184^{m3}
- Core and *Coffer Dam*: 94,502.44m^3
- Fine Filter: 50,991.62 m^3
- Coarse Filter: 44,085.94^{m3}
- Rock Heap: 905,619.74 m^3
- Rip Rap: 23.915,08 m^3

i.Peak Elevation: 185 m
j.Peak Length: 260 m
h.Peak Width: 12 m
i.Upper Slope: 1H : 2.25
j. Slope of Downstream Slope: 1H : 2.0
k.High Care: 2.8 m

3. Evasive Building
A. Cofferdam
a. Type: Stone Heap
b. Peak Elevation: El 142.0
c. Height of the Deepest Foundation: 27 m
d. Panjang Puncak: 140 m
e. Debit Plan (Q25):1.10 $^3/s$
B. Terowongan
a.Type: Horseshoe Tunnel
b.Elevasi Inlet: El 128.00 m
c.Elevasi Outlet: El 118.90 m
d.Diameter: 4.50 m
e.Panjang: 355 m

4. Spillway Building
a. Type: Side spillway, OGEE type lighthouse
b.NoDoor/doorless/combination: No Door
c.Kapasitas (m3/dt): 712 m $^3/dt$
d.Elevation of Mercu (m): + 179.50 m
e.Lighthouse Length (m): 70 m
f.Launcher Channel Length (m): 209.82 m
g.Energy Reducer Type: Sky Jump

B. Cost Data

At the information stage, the Budget Plan (RAB) for the construction work of the Tamblang dam as a whole assuming the initial availability of sufficient material at the Tamblang dam area site.

Table 1. Overall Tamblang Dam Construction RAB (assuming sufficient material needs in the Tamblang dam area)

NO.	URAIAN PEKERJAAN	BIAYA
1	PEKERJAAN PERSIAPAN	Rp4.333.908.570
2	PEKERJAAN JALAN MASUK DAN JALAN INSPEKSI	Rp85.347.122.742
3	PEKERJAAN TEROWONGAN PENGELAK	Rp89.847.705.471
4	PEKERJAAN BENDUNGAN UTAMA (MAIN DAM)	Rp267.316.158.764
5	PEKERJAAN BANGUNAN PELIMPAH (SPILLWAY)	Rp216.498.393.889
6	PEKERJAAN BANGUNAN PENGAMBILAN (INTAK	Rp19.321.590.477
7	PEKERJAAN HIDROMEKANIKAL	Rp31.225.155.820
8	PEKERJAAN BANGUNAN FASILITAS	Rp11.342.325.522
9	PEKERJAAN LAIN-LAIN	Rp6.250.749.596
A	**JUMLAH BIAYA**	**Rp731.483.110.853**

(Source: BWS Bali Penida,2021)

In the construction work of the Tamblang dam core zone, one alternative solution to the problem of clay material needs is to bring in material from outside the project that has a high Plasticity Index to mix with the core material in the borrow area located around the Titab Dam which is approximately 60 km from the Tamblang Dam location. The cost estimate is based on *engineer's estimate* if the construction of the Tamblang dam construction by bringing in clay material which is approximately 60 km from the Tamblang dam is as follows:

Table 2. Tamblang Dam Work Rab Overall (bringing in clay soil material from outside)

NO.	URAIAN PEKERJAAN	BIAYA
1	PEKERJAAN PERSIAPAN	Rp4.333.908.570
2	PEKERJAAN JALAN MASUK DAN JALAN INSPEKSI	Rp85.347.122.742
3	PEKERJAAN TEROWONGAN PENGELAK	Rp89.847.705.471
4	PEKERJAAN BENDUNGAN UTAMA (MAIN DAM)	Rp341.670.183.704
5	PEKERJAAN BANGUNAN PELIMPAH (SPILLWAY)	Rp216.498.393.889
6	PEKERJAAN BANGUNAN PENGAMBILAN (INTAK	Rp19.321.590.477
7	PEKERJAAN HIDROMEKANIKAL	Rp31.225.155.820
8	PEKERJAAN BANGUNAN FASILITAS	Rp11.342.325.522
9	PEKERJAAN LAIN-LAIN	Rp6.250.749.596
A	**JUMLAH BIAYA**	**Rp805.837.135.793**

(Source: Own Processed Products)

Specifically, the work of the Tamblang dam core zone includes main coffer dam work (dewatering and earthworks), and *main dam* work consisting of dewatering work, earthworks, stockpile work, instrumentation work, supporting equipment for operation and maintenance, miscellaneous work, jetty and trash boom work. Based on *the engineer's estimate*, the following is the Cost Budget Plan (RAB) for the *main coffer dam* workand the main dam work *with* clay soil material imported from outside:

Table 3. Main Dam Work Rab at Tamblang Dam (Material imported from outside)

NO.	URAIAN PEKERJAAN	BIAYA
1	**PEKERJAAN *MAIN COFFER DAM***	**Rp14.116.595.176**
	A. PEKERJAAN *DEWATERING*	Rp200.000.000
	B. PEKERJAAN TANAH	Rp13.916.595.176
2	**PEKERJAAN BENDUNGAN UTAMA (*MAIN DAM*)**	**Rp327.553.588.527**
	A. PEKERJAAN DEWATERING	Rp370.000.000
	B. PEKERJAAN TANAH	Rp39.154.259.513
	C. PEKERJAAN TIMBUNAN	Rp217.679.733.517
	D. PEKERJAAN DRILLING DAN GROUTING	Rp50.692.331.226
	E. PEKERJAAN INSTRUMENTASI	Rp11.188.368.000
	F. PERALATAN PENUNJANG OP	Rp3.804.692.908
	G. PEKERJAAN LAIN - LAIN	Rp3.326.513.580
	H. PEKERJAAN JETTY DAN *TRASHBOOM*	Rp1.337.689.784
JUMLAH BIAYA		**Rp341.670.183.704**

(Source: Own Processed Products)

C. Pareto Analysis

The following is the result of a thorough analysis of the Tamblang Dam Construction Pareto assuming it brings in clay material from outside the project area:

Table 4. Thorough Pareto Analysis of Tamblang Dam

NO.	KOMPONEN PEKERJAAN	BIAYA KOMPONEN	KUMULATIF BIAYA KOMPONEN TOTAL	PROSENTASE KOMPONEN PEKERJAAN	KUMULATIF PROSENTASE KOMPONEN PEKERJAAN
		(Rp.)	(Rp.)	(Rp.)	(Rp.)
1	PEKERJAAN BENDUNGAN UTAMA (MAIN DAM)	341.670.183.704	341.670.183.704	11%	11%
2	PEKERJAAN BANGUNAN PELIMPAH (SPILLWAY)	216.498.393.889	558.168.577.593	11%	22%
3	PEKERJAAN TEROWONGAN PENGELAK	89.847.705.471	648.016.283.065	11%	33%
4	PEKERJAAN JALAN MASUK DAN JALAN INSPEKSI	85.347.122.742	733.363.405.807	11%	44%
5	PEKERJAAN HIDROMEKANIKAL	31.225.155.820	764.588.561.627	11%	56%
6	PEKERJAAN BANGUNAN PENGAMBILAN (INTAKE)	19.321.590.477	783.910.152.104	11%	67%
7	PEKERJAAN BANGUNAN FASILITAS	11.342.325.522	795.252.477.626	11%	78%
8	PEKERJAAN LAIN-LAIN	6.250.749.596	801.503.227.223	11%	89%
9	PEKERJAAN PERSIAPAN	4.333.908.570	805.837.135.793	11%	100%
	TOTAL	**805.837.135.793**		**100%**	

(Source: Own Processed Products)

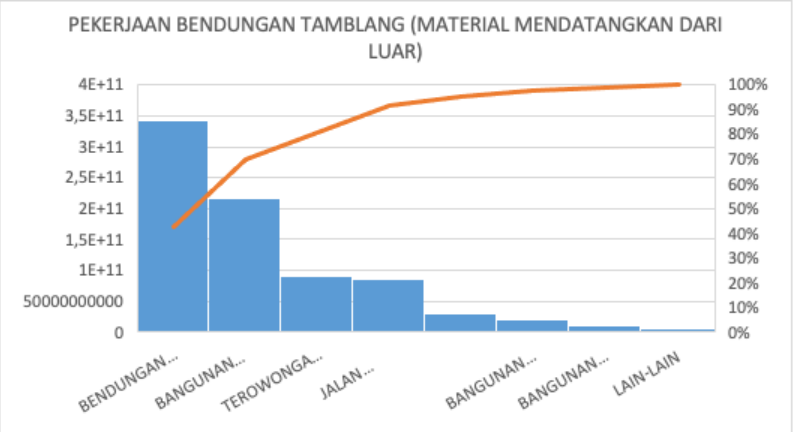


Figure 4. Overall Tamblang Dam Pareto Graph
(Source: Own Processed Products)

The following is the result of Pareto's analysis of the construction of the core zone of the Tamblang Dam, especially on the *main dam* work by bringing in clay core material from outside the project area:

Table 5. Pareto Analysis of Main Dam Work (*Main Dam*)

NO.	KOMPONEN PEKERJAAN	BIAYA KOMPONEN	KUMULATIF BIAYA KOMPONEN TOTAL	PROSENTASE KOMPONEN PEKERJAAN	KUMULATIF PROSENTASE KOMPONEN PEKERJAAN
		(Rp.)	(Rp.)	(Rp.)	(Rp.)
1	PEKERJAAN TIMBUNAN	217.679.733.517	217.679.733.517	13%	13%
2	PEKERJAAN DRILLING DAN GROUTING	50.692.331.226	268.372.064.743	13%	25%
3	PEKERJAAN TANAH	39.154.259.513	307.526.324.256	13%	38%
4	PEKERJAAN INSTRUMENTASI	11.188.368.000	318.714.692.256	13%	50%
5	PERALATAN PENUNJANG OP	3.804.692.908	322.519.385.164	13%	63%
6	PEKERJAAN LAIN - LAIN	3.326.513.580	325.845.898.743	13%	75%
7	PEKERJAAN JETTY DAN *TRASHBOOM*	1.337.689.784	327.183.588.527	13%	88%
8	PEKERJAAN DEWATERING	370.000.000	327.553.588.527	13%	100%
	TOTAL	**327.553.588.527**		**100%**	

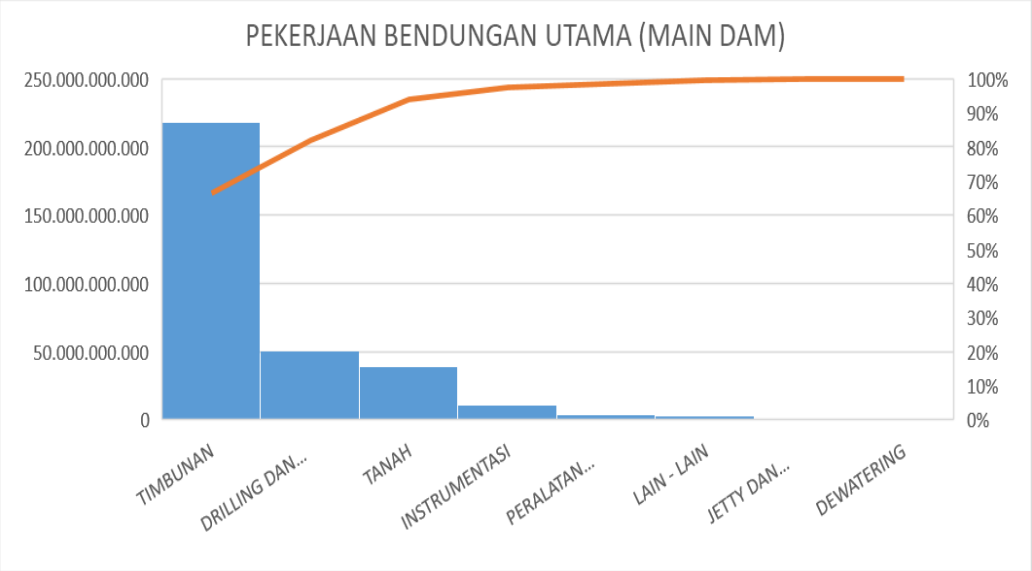


Figure 5. Main *Dam* Works Pareto Graph
(Source: Own Processed Products)

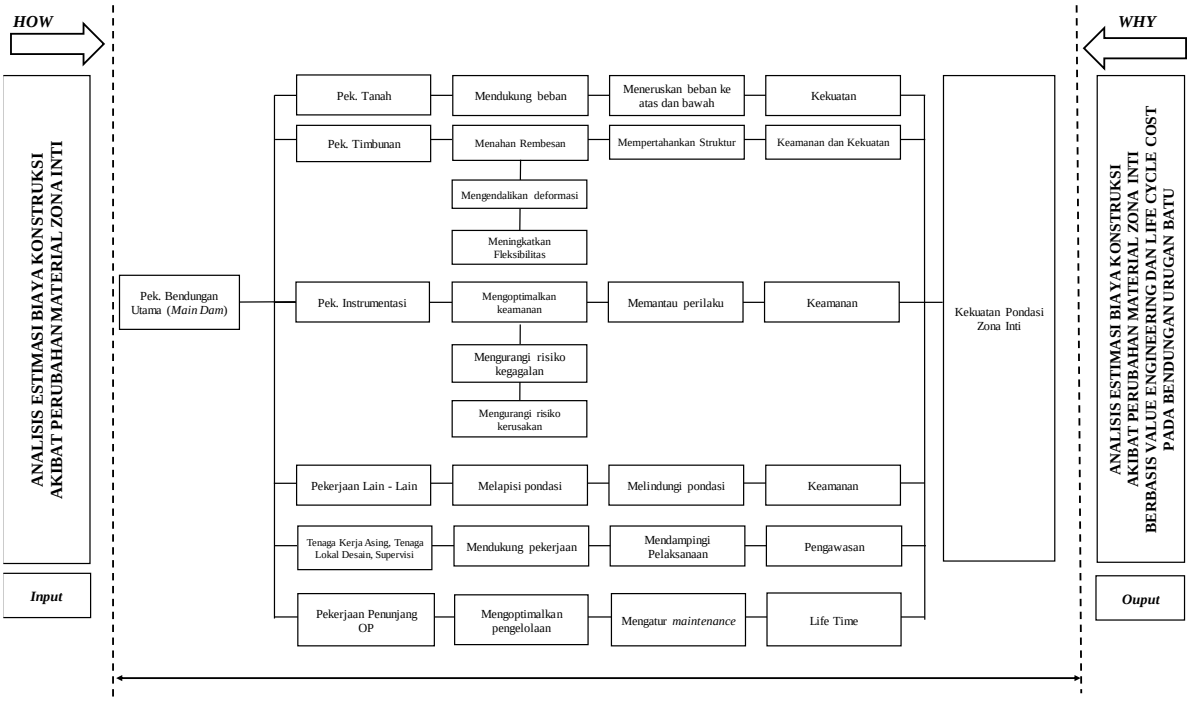
- Function Analysis Stage
  The results of identifying the function of the core zone of the urugan batu dam are as follows:

Table 6. Identification of Dam Core Zone Functions

Komponen Pekerjaan	Fungsi	
	Kata Kerja	Kata Benda
Zona Inti Bendungan	Meningkatkan	Fleksibilitas
	Mengurangi	permeabilitas
	Mengoptimalkan	Keamanan
	Menahan	Rembesan
	Mengendalikan	Deformasi
	Mencegah	Erosi

(Source: Own Processed Products)

Then the Function Analysis System Technique (FAST) is carried out to see the identification of basic functions and complementary functions by compiling the functions in the *Fast Diagram* as follows:

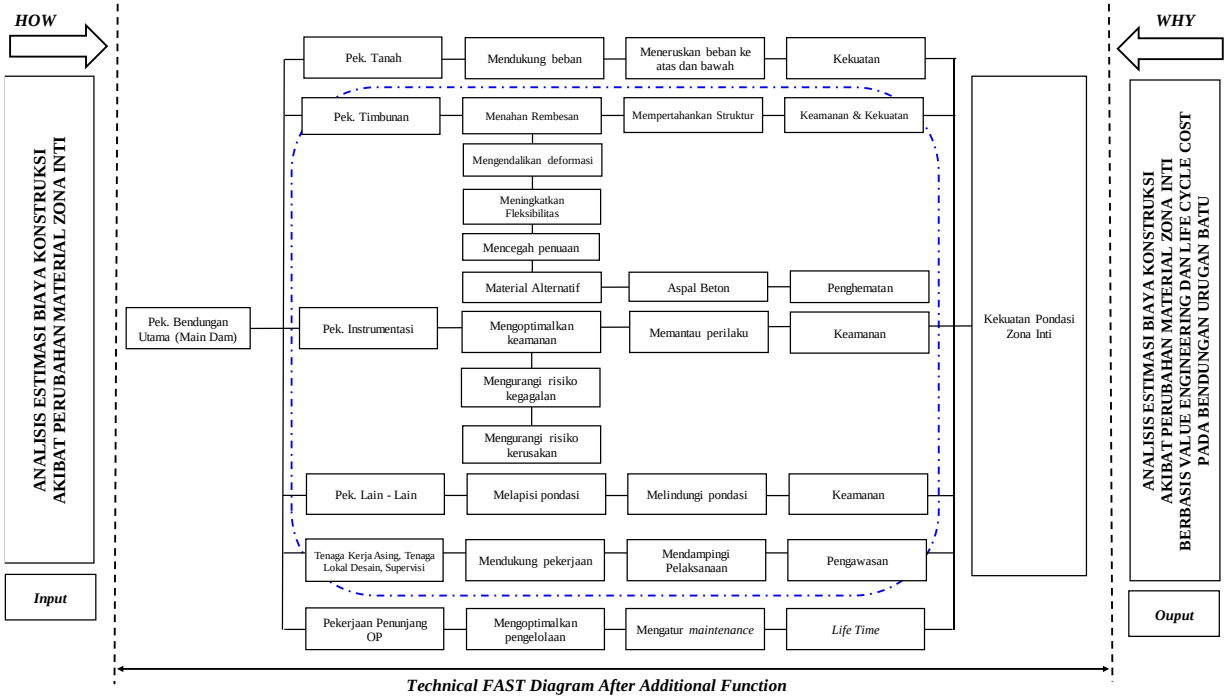


Technical FAST Diagram Before Additional Function

Figure 6. *Fast Diagram* Before Function Addition
(Source: Own Processed Products)

- Creative Stage

The Fast diagram presented below is a series of functions of the core zone of the urugan batu dam, where there is no function of avoiding *piping* which can increase the safety of the dam without adding construction work items.



Technical FAST Diagram After Additional Function

Figure 7. *Fast diagram* after function addition
Source : Self-Processed Products

The addition of the core zone function of the urugan batu dam is as follows:

Table 7. Addition of Dam Core Zone Functions

Komponen Pekerjaan	Penambahan Fungsi	
	Kata Kerja	Kata Benda
Zona Inti Bendungan	Menghindari	Penuaan/piping

(Source: Own Processed Products)

- Evaluation/Discussion Stage

In the evaluation stage, an evaluation of the results of the application of *value engineering* to changes in the material of the Tamblang dam core zone has been obtained at the stages that have been carried out previously. *Life Cycle Cost Analysis.* The opinions of 5 (five) experts in the field of water resources are required using the questionnaire instrument as attached. The selected experts are personnel who have a dam expertise certificate (SKA Dam), undergraduate education level (S1), and experience of more than 5 (five) years of dam construction work as well as dam operation and maintenance activities. Experts fill out questionnaires by giving statements of agreeing or disagreeing with each indicator and sub-indicator, and experts can provide responses/suggestions to the indicators and sub-indicators presented.

Based on the filling of the questionnaire by 5 (five) experts related to what factors support the analysis of construction cost estimates due to changes in core zone materials based on *value engineering* and *life cycle costs* in the urugan batu dam, the following are the validation results from 5 (five) experts consisting of PT Supervision Consultants. Mettana, Contractor of PT. PP (Persero), Directorate General of Water Resources, Ministry of PUPR which includes from the Dam Engineering Center, the Directorate of Dams and Lakes, and the Directorate of Operation and Maintenance Development.

Table 8. Expert Questionnaire Recap

Variabel/ Sub Variabel	Indikator/Sub Indikator	Pakar					Kesimpulan
		P1	P2	P3	P4	P5	
X1	**Biaya konstruksi**						
X1.1	Estimasi Biaya	√	√	√	√	√	√
X1.2	Efisiensi Biaya	√	√	√	√	√	√
X2	**Life Cycle Cost**						
X2.1	Biaya Pemeliharaan	√	X	X	√	X	X
X2.2	Biaya Demolisi	√	X	X	X	X	X
X3	**Keamanan bendungan**						
X3.1	Kedap Air (Menahan Rembesan)	√	√	√	X	√	√
X3.2	Potensi Erosi di zona inti yang menyebabkan piping	√	√	√	X	√	√
X4	**Ketersediaan Material**						
X4.1	Pembebasan Lahan untuk Borrow Area	√	√	√	√	√	√
X4.2	Alternatif Material	√	√	√	√	√	√
X5	**Penerapan Value Engineering**						
X5.1	VE Dapat Mengoptimalkan Kegiatan yang Telah Diprogramkan / Direncanakan	√	√	√	√	√	√
X5.2	Penerapan VE terbatas hanya pada Proyek/Pekerjaan yang "Besar"	√	X	X	X	X	X
X5.3	Jenis Proyek	√	√	√	√	√	√
X5.4	Biaya Awal Proyek	√	√	X	X	√	√
X5.5	Gambar Proyek	√	√	√	X	√	√
X5.6	Fungsi Bangunan dan Bagiannya	√	√	√	√	√	√
X5.7	Permasalahan Proyek	√	√	√	√	√	√
X5.8	Perbandingan antara Desain Awal dengan Desain Alternatif ditinjau dari Sudut Pandang Teknik	√	√	√	√	√	√
X5.9	Perbandingan antara Desain Awal dengan Desain Alternatif ditinjau dari Sudut Pandang Biaya	√	√	√	√	√	√
X5.10	Meneliti Item yang Berbiaya Tinggi/Dominan	√	√	√	X	√	√
X5.11	Gagasan Alternatif Item Pekerjaan/Metode Pekerjaan untuk Menghemat Biaya	√	√	X	√	√	√
X5.12	Memilih Alternatif yang Paling Memungkinkan dalam Penghematan Biaya	√	√	√	√	√	√
X5.13	Menyusun Urutan Prioritas Alternatif sesuai dengan Penghematan yang Dihasilkan	√	√	√	√	√	√

(Source: Own Processed Products)

- Recommendation Stage

A. Recommendations

1. First Alternative

An alternative solution to the problem of insufficient needs for clay core materials is to bring in material from outside the project that has a high Plasticity Index to *mix* with the core material in the *borrow* area. However, this alternative has the potential to require a considerable additional cost because the borrow *area* is approximately 60 km from the Tamblang dam.

2. Second Alternative

Another alternative is to replace the core material with other materials such as concrete asphalt which is an anti-seepage (waterproof) part formed from asphalt material, coarse aggregate, fine aggregate, and *filler*. Concrete asphalt cores are more waterproof than *clay cores* (k = 10-7 cm/s), where the permeability coefficient ranges from 10-8 - 10-10 cm/s (ICOLD, 2018). Because the concrete asphalt core is more waterproof than the clay core, so the safety of

the dam against seepage in the core is safer and in terms of cost more efficient because it does not require land acquisition and asphalt material is taken from AMP which is located not far from the Tamblang Dam project site.

B. Cost Savings Calculation

The following is a cost estimate calculation based on *engineering estimate* calculations of alternative substitutes for clay soil material into concrete asphalt in the construction of the Tamblang dam core zone:

Table 9. Rab of Overall Tamblang Dam Work With Brbasis Concrete Asphalt Core Zone VE

NO.	URAIAN PEKERJAAN	BIAYA
1	PEKERJAAN PERSIAPAN	Rp4.333.908.570
2	PEKERJAAN JALAN MASUK DAN JALAN INSPEKSI	Rp85.347.122.742
3	PEKERJAAN TEROWONGAN PENGELAK	Rp89.847.705.471
4	PEKERJAAN BENDUNGAN UTAMA (MAIN DAM)	Rp294.533.295.070
5	PEKERJAAN BANGUNAN PELIMPAH (SPILLWAY)	Rp216.498.393.889
6	PEKERJAAN BANGUNAN PENGAMBILAN (INTAK	Rp19.321.590.477
7	PEKERJAAN HIDROMEKANIKAL	Rp31.225.155.820
8	PEKERJAAN BANGUNAN FASILITAS	Rp11.342.325.522
9	PEKERJAAN LAIN-LAIN	Rp6.250.749.596
A	**JUMLAH BIAYA**	**Rp758.700.247.158**

(Source: Own Processed Products)

Table 10. RAB Main Works Dam With VE-Based Concrete Asphalt Core Zone

NO.	URAIAN PEKERJAAN	BIAYA
1	**PEKERJAAN *MAIN COFFER DAM***	**Rp14.116.595.176**
	A. PEKERJAAN *DEWATERING*	Rp200.000.000
	B. PEKERJAAN TANAH	Rp13.916.595.176
2	**PEKERJAAN BENDUNGAN UTAMA (*MAIN DAM*)**	**Rp280.416.699.893**
	A. PEKERJAAN DEWATERING	Rp370.000.000
	B. PEKERJAAN TANAH	Rp39.154.259.513
	C. PEKERJAAN TIMBUNAN	Rp181.320.620.125
	D. PEKERJAAN DRILLING DAN GROUTING	Rp36.443.474.184
	E. PEKERJAAN INSTRUMENTASI	Rp11.740.647.500
	F. PERALATAN PENUNJANG OP	Rp3.804.692.908
	G. PEKERJAAN LAIN - LAIN	Rp4.465.115.880
	H. PEKERJAAN JETTY DAN *TRASHBOOM*	Rp1.337.689.784
	I. TENAGA KERJA ASING, TENAGA LOKASL (DESAIN DAN SUPERVISI)	Rp1.780.200.000
JUMLAH BIAYA		**Rp294.533.295.070**

(Source: Own Processed Products)

Table 11. Calculation of Increase/Cost Savings

Uraian Pekerjaan	Estimasi Biaya		
	RAB Awal	Alternatif	
	Tanah Lempung (Tercukupi di Lokasi Proyek)	Tanah Lempung (Mendatangkan dari Luar Proyek)	Aspal Beton
RAB Pekerjaan Keseluruhan	Rp 731.483.110.853	Rp 805.837.135.793	Rp 758.700.247.158
RAB Pekerjaan Bendungan Utama (Main Dam)	Rp 267.316.158.764	Rp 341.670.183.704	Rp 294.533.295.070

(Source: Own Processed Products)

CONCLUSIONS

From the results of the analysis, the following conclusions were obtained:

The application of value engineering to the change of core zone material to concrete asphalt of Tamblang Dam to improve the function of the asphalt core is more resistant to aging (wear) than clay material. Clay core zone materials with a lifespan of more than 50 (fifty) years have the potential to piping. Meanwhile, based on the construction of Concrete Asphalt Core dams in Europe and China (ICOLD, 2018), over a period of 60 years since 1960 the construction of the first dam with concrete asphalt cores in Germany, did not show any leakage through the concrete asphalt core.

Based on the research that has been done, here are some suggestions that we get, including:

There needs to be further research related to the application of value engineering to find out other factors to increase the effectiveness of budget use.

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