INTERNATIONAL JOURNAL ON ADVANCED TECHNOLOGY, ENGINEERING, AND INFORMATION SYSTEM
(IJATEIS)
Volume 2 Issue 1 (2023)

CONSTRUCTION ANALYSIS OF SOLAR PANEL FOUNDATION ON THE SURFACE OF DAM WATER BODY WITH DAM SLOPE (Case Study: Jatibarang Dam Solar Power Plant - Semarang)

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Abstract

Indonesia's potential solar panel renewable energy capacity is 207.8 GW, currently only 0.135 GW has been realized or 0.02% has only been achieved. The development is still very broad and far ahead. The best place for a PLTS (Solar Power Plant) location is in the dam area. Why? The dam has a very large area and is owned by the government. This paper investigates the comparison of the cost and time of implementing PLTS foundation construction at the location of the Dam Slope (Landed) and on the Surface of the Dam Water Body (Floating). The research was conducted based on a case study of the application of PLTS in the Jatibarang Dam. Where in 2017 the construction of PLTS has been realized at the location of the Dam Slope. The PLTS Floating model was developed with a design simulation based on real data at the same dam location. The cost and time indicators for both Landed and Floating foundation models are then calculated and compared. From the analysis results, in terms of costs, the application of the PLTS Floating foundation is 41% higher than the foundation on the slopes. But in time 31% faster than the Slope foundation. By knowing the cost and time comparison between the two PLTS laying models, the aim is to design a PLTS development strategy for the Dam area based on the most optimal considerations.

Keywords: *Cost, Floating, Foundation, Slope, Solar Panel*

1. INTRODUCTION

The Indonesian government is actively participating in efforts to control the ongoing issue of climate change. This commitment aligns with Law No. 16 of 2016, which ratifies the Paris Agreement under the United Nations Framework Convention on Climate Change.

During a presentation by the Ministry of Energy and Mineral Resources Directorate General of New Energy and Renewable Energy, specific policies, regulations, and initiatives for solar energy development in Indonesia were discussed. The aim is to accelerate the establishment of solar power plants in the country, targeting a capacity of 6.5 GW by the year 2025. This presentation, titled "Accelerating the Development of Solar Power Plants in Indonesia to Reach 6.5 GW by 2025" and held on October 10, 2019, emphasized the Indonesian government's commitment to reducing greenhouse gas (GHG) emissions. They have pledged to reduce emissions by 29% using their own resources and achieve a reduction of 41% with the help of international support. The promotion and development of renewable energy (EBT) are significant factors contributing to this reduction in GHG emissions.

Indonesia possesses considerable potential for renewable energy sources, particularly solar energy, which is estimated to have a potential of 4.8 kWh/m2/day (as reported by the Ministry of Energy and Mineral Resources News on "Indonesia's Renewable Energy Potential" on August 24, 2008). Thus, solar energy in Indonesia has great potential to be utilized. One of them is what the Ministry of Public Works through the Directorate General of Water Resources has done by pioneering a pilot project for solar energy development in the form of PLTS (Solar Power Plant) in the dam area, with the installation of 936 solar panels measuring 1.6 meters x 1 meter on the north slope of Jatibarang Dam, Semarang City, Central Java in 2017. The installed electricity capacity generated is 304.2 kilowatt-peak (kWp) or equivalent to 291,000 kilowatt-hours (kWh) per year.

Along with the development of technology and government regulations (PerMen PU on floating foundations) related to EBT Solar Panels, the "Floating PV" pilot project is now being introduced. This type is different from the one that was implemented in 2017 and operated in 2018 at the Jatibarang dam. As the name Floating PV implies, this type of PLTS is placed on the water surface of the dam, with a floating system. The trial has been conducted by the University of Indonesia (Floating Solar Photovoltaic owned by the Faculty of Engineering, University of Indonesia, November 25, 2020). Meanwhile, when this research was written, there were still no projects that applied this type in existing dams in Indonesia. Even though there are research results about the results of solar energy produced by floating PV is greater than that produced by solar panels installed on the ground (Andri Agus Sasmanto, Tresna Dewi, Rusdianasari, Eligibility Study on Floating Solar Panel Installation Over Brackish Water in Sungsang, South Sumatra, Emitter International Journal of Engineering Technology, 2020).

This paper will examine the comparison between the construction costs of solar panel foundations installed in the water body of the dam compared to those installed on the dam slope with reference to solar panel installation project data at Jatibarang Dam. The construction cost of solar panel foundations is one of the things that is very influential in determining the policy of where solar panels will be installed.

Through this research, it is hoped to provide a comprehensive comparison of the construction costs between solar panel foundations installed in the water body of the dam and those installed on the slopes of the Jatibarang Dam. This valuable comparison will assist stakeholders and the government in making informed decisions regarding the type of Photovoltaic Solar Power Plant (PLTS) to be implemented in the dam area in the future. Additionally, the findings can serve as a crucial reference point for policy-making and further research endeavors.

2. LITERATURE REVIEW

In conducting construction planning and calculations, researchers use the following theoretical basis:

a. Theoretical Basis for Calculation of Buoyancy Force; Giancolli, Douglas C. 2000. Physics for Scientists & Engineers with Modern Physics, Third Edition, New Jersey, Prentice Hall.
b. Foundation theory; Ir. Sardjono HS. Pile foundation volume 2.
c. Theoretical basis of reinforced concrete calculation; Chu-Kia Wang, Charles G Salmon, Binsar Hariandja, Design of Reinforced Concrete Fourth Edition.

Secondary data used refers to real data at the case study site at Jatibarang Dam and related Government Regulation data. The data are in the form of:

a. Siteplan contour drawing of Jatibarang Dam.
b. Cross section and long section drawings.
c. Technical planning documents for the foundation of the solar panel dam slope (DED and BoQ).
d. PerMen PUPR no 28 th 2016, as the basis for preparing AHSPK (Analysis of Unit Price of Work).
e. Perwali Kota Semarang no 61 of 2020 (Standard unit price of labor and materials).

2.1. Construction Costs

Construction costs are the costs required to carry out a project activity. In this study, the construction costs to be calculated are aspects of labor, material, equipment and overhead costs according to applicable regulations.

2.2. Foundation

Foundation is the strong base of a building that sits beneath the building being erected. The foundation serves to support and maintain the stability and safety of a building structure from vertical and lateral loads acting on it. Foundations are usually underground and are an important part of building construction, as the quality and strength of the foundation will affect the overall robustness and lifetime of the building.

2.3. Solar Panel

Solar Panels are electronic devices consisting of several solar cells or photovoltaic cells designed to capture and convert sunlight energy into electricity. Solar cells in solar panels are made of semiconductor materials, such as silicon, which have the ability to generate electric current when illuminated by sunlight.

2.4. Water Body Dam

A body of water is a collection of water whose size depends on, among other things, the relief of the earth's surface, the size of the barrier rock, rainfall, temperature and so on, such as rivers, swamps, lakes, dams, seas, and oceans. So, a dam water body is a body of water that exists in a dam.

2.5. Dam Slope

A slope is the sloping side of the land. The dam slope is part of the dam structure which is a sloping surface or basin on the upper and lower sides of the dam. These slopes play an important role in holding and distributing the water pressure generated by the water behind the dam.

3. RESEARCH METHODS

The research subject of this paper is PLTS Jatibarang Dam Semarang-Central Java, which is a pilot project for the application of PLTS on the slopes of dams (reff news Kemeterian PUPR 6 April 2018), and researchers are actively involved in realizing the project.

The data collection procedures in this study were as follows:

a. Determine the primary data used in the study.
   The primary data used in this study are planning data (auction documents) on the Jatibarang Dam Solar Panel System Procurement Project in fiscal year 2017, which consists of foundation items, solar panel frames, PV Procurement, Electrical Mechanics. In this case, only the foundation item was taken, as needed by researchers in this study. The data is used as a reference in making foundation design plans and planning in determining the budget design/cost of foundation construction, both for solar panel foundations on the dam slope and in the dam water body.
b. Determining secondary data as a basic design reference in designing the foundation of solar panels in the dam water body. Secondary data used in this research is obtained from browsing journals and national and international research.
c. Determine the project financing reference data.
   The financing reference in this study is the Unit Price Analysis of Work and Activities in Semarang Mayor Regulation No. 61 of 2020, concerning standardization of unit prices of building materials, wages and work analysis for Semarang city government development activities in fiscal year 2021.

3.1. Analysis of Solar Panel Foundations on DAM Slopes

The primary data for the foundation of the solar panel on the dam slope is part of the planning document for the Procurement of Solar Panel System for Jatibarang Dam in the 2017 budget year.

Analysis of solar panel foundations in the dam water body (Floating).

a. Modeling the construction of solar panels on the water surface of the dam based on the basic design reference, which is harmonized with the conditions of the planned placement location (contour and elevation).
b. Structure design analysis

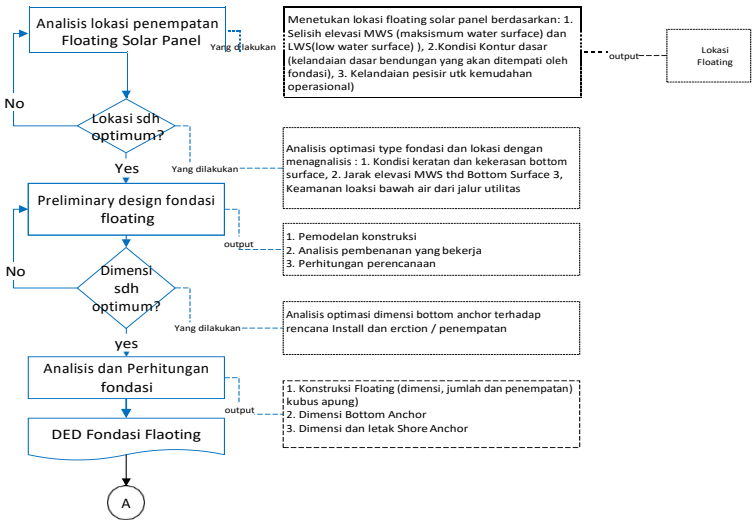


Figure 1. Explanation of Structure Analysis Flow Chart,

Based on the results of the calculation analysis of the solar panel foundation on the dam slope and in the dam water body, a comparison of the cost and construction time of the foundation will be analyzed.

4. RESULTS AND DISCUSSION

The data used by researchers in conducting research consists of two types of data. For the analysis of the cost and time of the foundation of the solar panel on the dam slope using existing primary data, namely planning data on the Jatibarang Dam Solar Panel System Procurement Project in 2017. As for the cost and time analysis of the foundation of solar panels on the surface of the dam water body, with secondary data referring to journal data and research and similar project reports.

4.1. Description of Solar Panel Foundation Data for Dam Slope

Data for the cost and time analysis of the foundation of the solar panel on the dam slope uses data from the planning document for the Solar Panel System Installation Project at Jatibarang Dam in 2017. The data used are:

a. Foundation Planning Document.
b. Foundation Drawing Document of the Jatibarang Dam Solar Panel System Procurement project in 2017.
c. RAB document of Jatibarang Dam Solar Panel System Procurement project in 2017.

The document used as the basis for calculating the cost of the foundation of the solar panel slope dam uses BoQ data in the project planning document for the Jatibarang Dam Solar Panel System Procurement in 2017.

a. Recapitulation

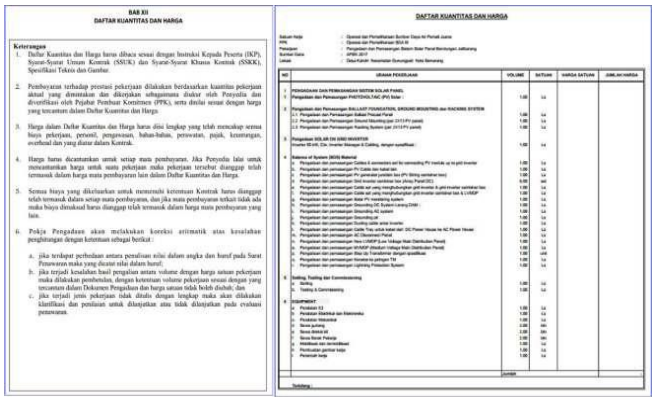
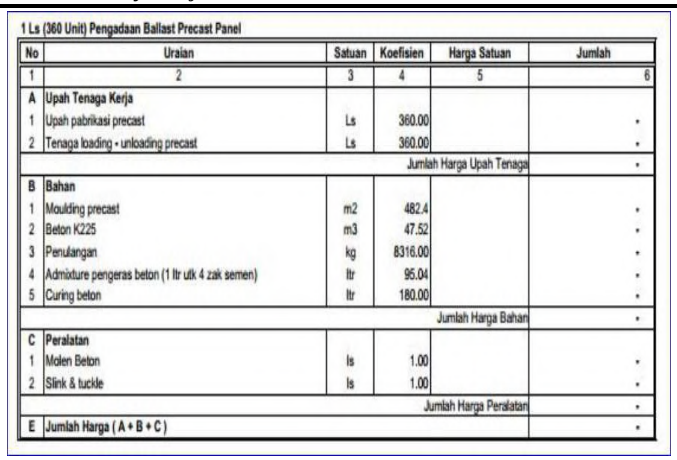


Figure 2. BoQ recapitulation

Source: procurement document of the Jatibarang Dam solar panel system procurement project in 2017

b. Foundation RAB

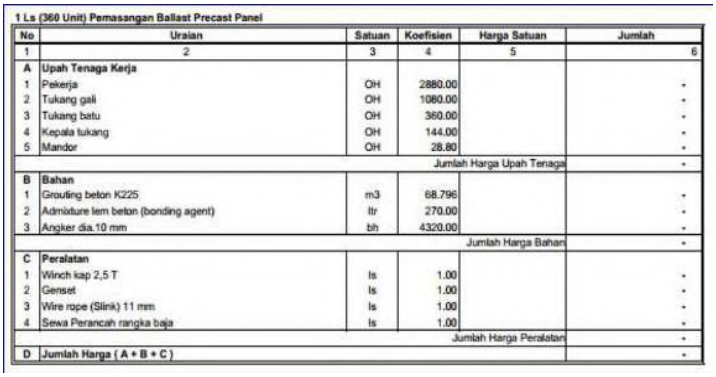
To calculate the cost of the foundation of the solar panel slope dam, the work items analyzed are only the scope of foundation work, as written in the figure below:



1 Ls (360 Unit) Pengadaan Ballast Precast Panel

No	Uraian	Satuan	Koefisien	Harga Satuan	Jumlah
1	2	3	4	5	6
A	Upah Tenaga Kerja				
1	Upah pabrikasi precast	Ls	360.00		-
2	Tenaga loading - unloading precast	Ls	360.00		-
				Jumlah Harga Upah Tenaga	-
B	Bahan				
1	Moulding precast	m2	482.4		-
2	Beton K225	m3	47.52		-
3	Penulangan	kg	8316.00		-
4	Admixture pengeras beton (1 ltr utk 4 zak semen)	ltr	95.04		-
5	Curing beton	ltr	180.00		-
				Jumlah Harga Bahan	-
C	Peralatan				
1	Molen Beton	ls	1.00		-
2	Slink & tuckle	ls	1.00		-
				Jumlah Harga Peralatan	-
E	Jumlah Harga (A + B + C)				-

Figure 3. BoQ for foundation procurement
Source: procurement document of Jatibarang Dam solar panel system procurement project.



1 Ls (360 Unit) Pemasangan Ballast Precast Panel

No	Uraian	Satuan	Koefisien	Harga Satuan	Jumlah
1	2	3	4	5	6
A	Upah Tenaga Kerja				
1	Pekerja	OH	2880.00		-
2	Tukang gali	OH	1080.00		-
3	Tukang batu	OH	360.00		-
4	Kepala tukang	OH	144.00		-
5	Mandor	OH	28.80		-
				Jumlah Harga Upah Tenaga	-
B	Bahan				
1	Grouting beton K225	m3	68.796		-
2	Admixture lem beton (bonding agent)	ltr	270.00		-
3	Angker dia.10 mm	bh	4320.00		-
				Jumlah Harga Bahan	-
C	Peralatan				
1	Winch kap 2,5 T	ls	1.00		-
2	Genset	ls	1.00		-
3	Wire rope (Slink) 11 mm	ls	1.00		-
4	Sewa Perancah rangka baja	ls	1.00		-
				Jumlah Harga Peralatan	-
D	Jumlah Harga (A + B + C)				-

Figure 4. BoQ items for foundation installation
Source: Jatibarang Dam solar panel system procurement project document

4.2. Foundation Design Analysis of Solar panel Surface Water Body Dam

a. Design Schematic
For the structural schematic, the researcher refers to the World Bank Group journal. ESMA & Solar Energy Research Institute of Singapore, Where Sun Meets Water: Floating Solar Market Report. Described in the figure are the components of the floating foundation.

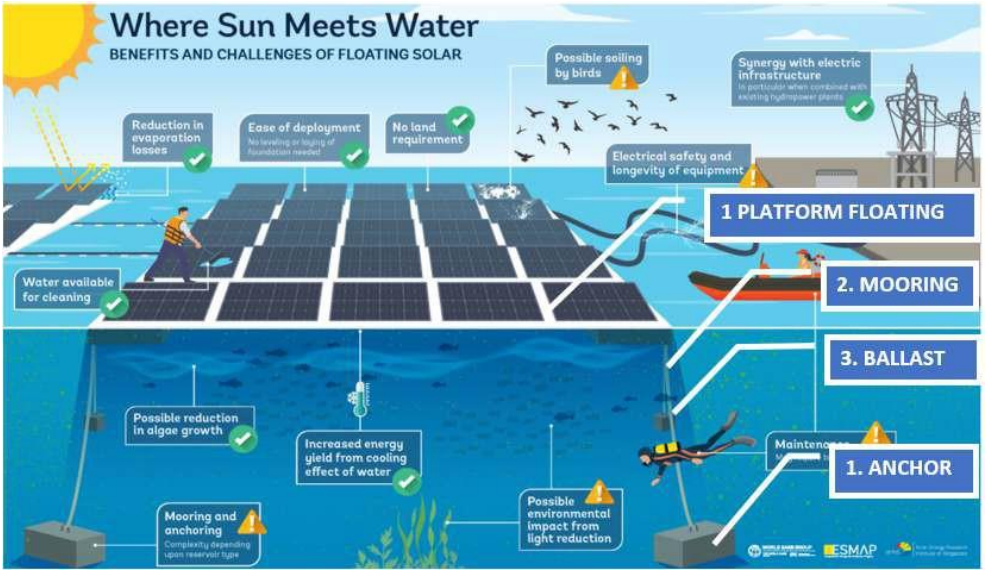


Figure 5. Schematic of Floating Solar Panel structure
Source: Solar Energy Research Institute of Singapore (SERIS)

As a basis for planning the floating foundation, the researcher refers to the proposal journal: ERM for Asian Development Bank (ADB) and Da Nhim-Ham Thuan-Da Mi Hydro Power Joint Stock Company, Proposed Loan and Admnistration of Loans Da Nhim - Ham Thuan - Da Mi Hydro Power Joint Stock Company Floating Solar Energy Project (Vit Nam), October 2018. Where in the journal report that there are 2 important things are explained related to the floating foundation components. These components are:

- Floating structural components (float system) in the form of floating components in the form of floating cubes made of HDPE material.
- Anchoring system. Anchoring system consists of two components, namely Anchor (foundation tether) and Mooring (hook rope).

b. Location Determination

In this study, the basic technical considerations used are as follows:

- Floating Solar panel construction must be in a body of water, or in this case at least at LWS elevation.
- Flatness and hardness of the bottom surface for the anchor area.
- The condition of the shore anchor placement location.

The cutaway drawing below is a cutaway of the land contour at the floating solar panel location. The cut shows the height distance of MWS (maximum water surface), LWS (low water surface) and Bottom Surface.

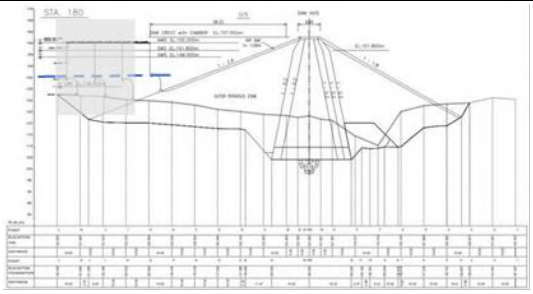


Figure 6. Longitudinal section
Source: Jatibarang Dam planning drawings.

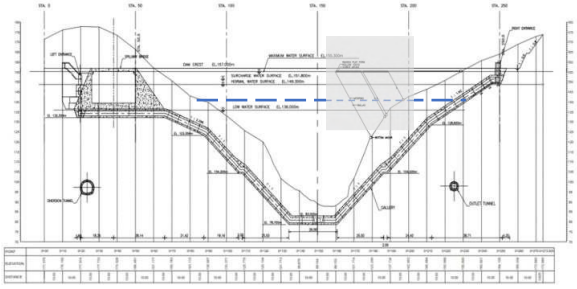


Figure 7. Cross section
Source: Jatibarang Dam planning drawings.

Based on the above considerations, the location of the floating solar panel at the Jatibarang dam is determined as shown in the figure below (based on LWS elevation considerations):

Figure 8. Location of Floating Solar Panel
Source: Google Earth imaging 2021

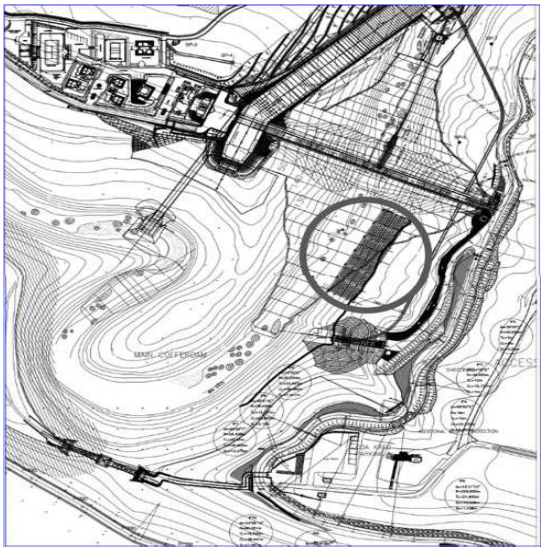


Figure 9. Location of Floating Solar Panels on The Site Plan Drawing
Source: Jatibarang Dam Site Plan.

c. Structure Modeling
Based on World Bank Group, ESMAP & SERIS (Solar Energy Research Institute of Singapore) journal; "When sun meets the water" Floating photovoltaic system and land-based photovoltaic system: Comparison of plant design aspects, the main components of the floating solar panel foundation structure are:
- Floating platform structure
- Anchoring and Anchoring System

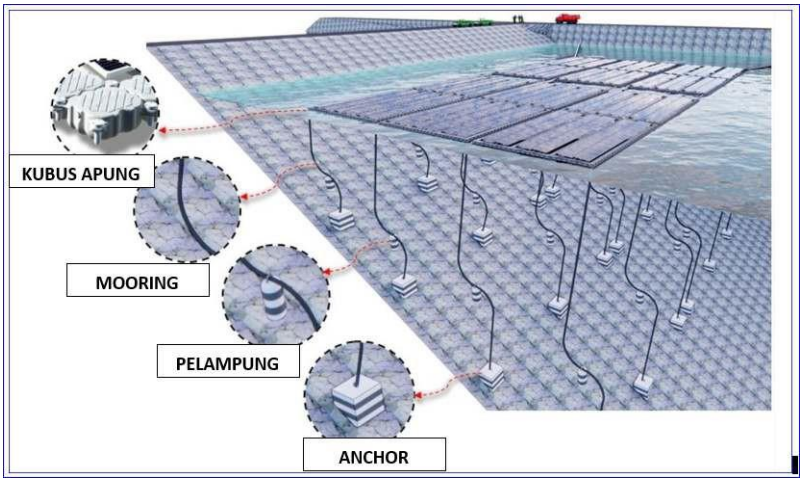


Figure 10. Modeling of the Foundation Structure of the Floating Solar Panel Dam
Source: researcher's engineering

d. Anchoring System
   Based on the journal proposal ERM for Asian Development Bank (ADB) and Da Nhim-Ham Thuan-Da Mi Hydro Power Joint Stock Company, Proposed Loan and Admnistration of Loans Da Nhim - Ham Thuan - Da Mi Hydro Power Joint Stock Company Floating Solar Energy Project (Vit Nam), October 2018, the anchoring system consists of two components, namely:
   - Bottom Anchoring (precast concrete) is an anchor that is anchored below the surface of the water body, located at the bottom surface, henceforth researchers call it a water anchor.
   - Shore Anchoring is an anchor that is anchored at the edge of the water body, henceforth researchers mention land anchors.

e. Floating Platform (HDPE Floating Cube)
f. Outputs Water Body Surface Solar Panel Foundation Design Drawing

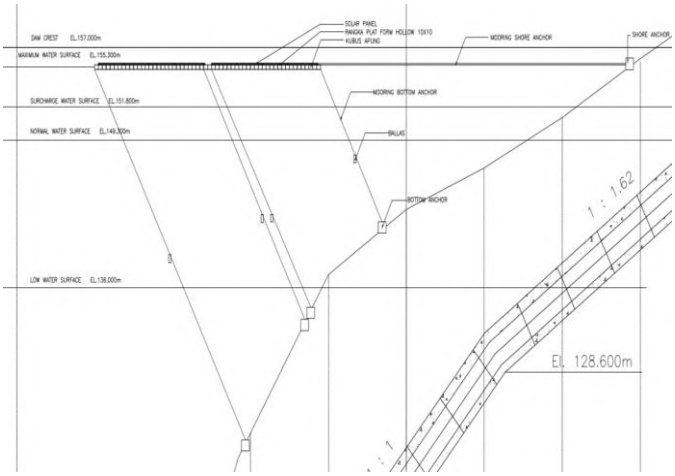


Figure 11. Top View
Source: researcher engineering

Figure 12. Cross Section
Source: researcher engineering

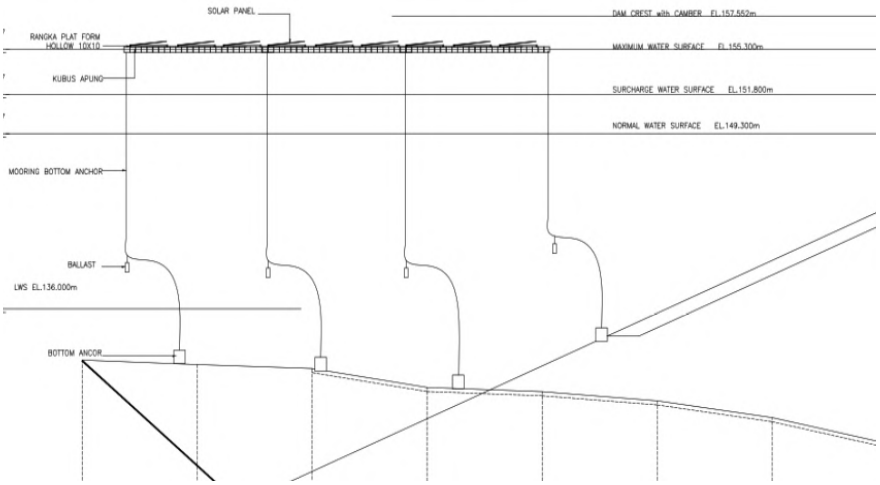


Figure 13. Longitudinal Cut
Source: researcher engineering

4.3. Analysis of the Construction Cost of Solar Panel Foundations on Dam Slopes

Calculated data for the cost of the foundation of the solar panel slope of the dam using data from the planning document of the Solar Panel System Installation Project at Jatibarang Dam in the 2017 Budget. The foundation RAB in the Foundation Work Unit Price Analysis is updated with the unit price of work according to Semarang Mayor Regulation No. 61 of 2020.

a. Recapitulation

Table 1. Recapitulation of Construction Cost of Solar Panel Foundations on Dam Slopes

NO	URAIAN PEKERJAAN	VOLUME	SATUAN	TH 2017		TH 2021	
2	Pengadaan dan Pemasangan BALLAST FOUNDATION, GROUND MOUNTING dan RACKING SYSTEM						
	2.1 Pengadaan dan Pemasangan Ba	1,00	Ls	1.550.855.800	1.550.855.800	1.912.177.700	1.912.177.700
		Jumlah			1.550.855.800		1.912.177.700
		PPN10%			155.085.580		191.217.770
		Total Harga			1.705.941.380		2.103.395.470
		Total Harga Setelah Dibulatkan			1.705.940.000		2.103.390.000
	jumlah panel				936		936
	harga pondasi lereng/panel				1.822.585		2.247.212

b. Analysis of unit price & RAB

Table 2. Unit Price & RAB

1 Ls (360 Unit) Pengadaan Ballast Precast Panel							
No	Uraian	Satuan	Koefisien	TH 2017		TH 2021	
				Harga satuan	Jumlah	Harga Satuan	Jumlah
A	**Upah Tenaga Kerja**						
1	Upah pabrikasi precast	unit	360,0	450.000,00	162.000.000,00	693.798,79	249.767.563,71
2	Tenaga loading - unloading precast	unit	360,0	200.000,00	72.000.000,00	308.355,02	111.007.806,09
Jumlah Harga Upah Tenaga					234.000.000,00		360.775.369,80
B	**Bahan**						
1	Moulding precast	m2	482,4	350.000,00	168.840.000,00	396.719,75	191.377.607,40
2	Beton K225	m3	47,5	1.350.000,00	64.152.000,00	1.442.045,45	68.526.000,00
3	Penulangan	kg	8.316,0	16.500,00	137.214.000,00	23.843,41	198.281.769,23
4	Admixture pengeras beton (1 ltr utk 4 zaks	ltr	95,0	77.500,00	7.365.600,00	82.784,09	7.867.800,00
5	Curing beton	ltr	180,0	125.000,00	22.500.000,00	133.522,73	24.034.090,91
Jumlah Harga Bahan					400.071.600,00		490.087.267,54
C	**Peralatan**						
1	Molen Beton	ls	1,0	22.500.000,00	22.500.000,00	25.503.412,50	25.503.412,50
2	Slink & tuckle	ls	1,0	7.500.000,00	7.500.000,00	8.501.137,50	8.501.137,50
Jumlah Harga Peralatan					30.000.000,00		34.004.550,00
E	**Jumlah Harga (A + B + C)**				**664.071.600,00**		**884.867.187,34**
F	**Harga Satuan Pekerjaan per-unit (dibulatkan)**				**664.071.600,00**		**884.867.100,00**

1 Ls (360 Unit) Pemasangan Ballast Precast Panel							
No	Uraian	Satuan	Koefisien	TH 2017		TH 2021	
				Harga satuan	Jumlah	Harga Satuan	Jumlah
A	**Upah Tenaga Kerja**						
1	Pekerja	OH	2.880,0	85.000,00	244.800.000,00	105.000,00	302.400.000,00
2	Tukang gali	OH	1.080,0	100.000,00	108.000.000,00	110.000,00	118.800.000,00
3	Tukang batu	OH	360,0	100.000,00	36.000.000,00	130.000,00	46.800.000,00
4	Kepala tukang	OH	144,0	110.000,00	15.840.000,00	140.000,00	20.160.000,00
5	Operator crane	OH	27,0	225.000,00	6.075.000,00	346.899,39	9.366.283,64
6	Mandor	OH	28,8	125.000,00	3.600.000,00	130.000,00	3.744.000,00
Jumlah Harga Upah Tenaga					414.315.000,00		501.270.283,64
B	**Bahan**						
1	Grouting beton K225	m3	68,8	2.750.000,00	189.189.000,00	2.937.500,00	202.088.250,00
2	Admixture lem beton (bonding agent)	ltr	270,0	85.000,00	22.950.000,00	90.795,45	24.514.772,73
3	Angker dia.10 mm	bh	4.320,0	15.000,00	64.800.000,00	18.444,44	79.680.000,00
Jumlah Harga Bahan					276.939.000,00		306.283.022,73
C	**Peralatan**						
1	Truck crane kap 20T	unit bulan	0,9	37.400.000,00	33.660.000,00	42.392.339,00	38.153.105,10
2	BBM solar industri	ltr	1.215,0	8.350,00	10.145.250,00	7.538,19	9.158.906,25
3	Genset	ls	1,0	225.000,00	225.000,00	255.034,13	255.034,13
4	Wire rope (Slink) 11 mm	ls	1,0	1.500.000,00	1.500.000,00	2.167.582,42	2.167.582,42
5	Sewa CatWalk - 6 unit utk bersamaan peng	ls	1,0	150.000.000,00	150.000.000,00	170.022.750,00	170.022.750,00
Jumlah Harga Peralatan					195.530.250,00		219.757.377,89
D	**Jumlah Harga (A + B + C)**				**886.784.250,00**		**1.027.310.684,26**
E	**Harga Satuan Pekerjaan per-unit (dibulatkan)**				**886.784.200,00**		**1.027.310.600,00**

Based on the analysis and calculation of the cost of the dam slope foundation carried out in 2017 amounting to IDR 1,705,940,000. The equivalent if done in 2021 is IDR 2,103,390,000. This value will be compared with the cost of the foundation of the Solar Panel Surface of the Dam Water Body with the same number of PV panels of 936 PV units.

4.4. Analysis of the Construction Cost of Solar Panel Foundations in Dam Water Bodies

Table 3. List of Total List of Total Cost of Solar Panel Foundation Construction in the Dam Water Body

I. REKAPITULASI

1. Struktur Floating	Rp 1.452.275.228
2. Bottom Anchoring System	Rp 984.416.917
3. Shore Anchoring System	Rp 263.188.549
Jumlah	Rp 2.699.880.694
Ppn 10%	Rp 269.988.069
Total setelah Ppn	**Rp 2.969.868.764**

II. RAB

1. STRUKTUR FLOATING					**Rp 1.452.275.228**
1	Pengadaan dan perangkaian Precast Kubus Apung HDPE	unit	281	Rp 1.035.899	Rp 291.087.483
2	Pekerjaan Rangka Platform hollow 10x10	kg	7.741,0	Rp 70.329	Rp 544.418.947
3	Install dan erection Rangka Paltform dan kubus apung	m2	2.381,6	Rp 258.975	Rp 616.768.797
2. BOTTOM ANCHORING SYSTEM					**Rp 984.416.917**
1	Pengadaan precast bottom anchor 50x50x40 cm	unit	160,0	Rp 313.735	Rp 50.197.535
2	Pengadaan Mooring Bottom Anchor	m	392,0	Rp 52.325	Rp 20.511.400
3	Install dan erection bottom anchor	m	160,0	Rp 342.309	Rp 54.769.440
4	Install dan erection mooring bottom anchor	m	392,0	Rp 2.191.170	Rp 858.938.542
3. SHORE ANCHOR					**Rp 263.188.549**
1	Pekerjaan angker penambat Strousspile	m	24,0	Rp 1.569.248	Rp 37.661.957
2	Pekerjaan Pilecap Beton Bertulang	m3	0,9	Rp 5.278.104	Rp 4.750.294
3	Pengadaan Mooring shore anchor	m	98,4	Rp 52.325	Rp 5.149.163
4	Install dan erection mooring shore anchor	m	98,4	Rp 2.191.170	Rp 215.627.136

III. PERHITUNGAN VOLUME

1. STRUKTUR FLOATING					
1	Pengadaan dan perangkaian Precast Kubus Apung HDPE	unit	281		
2	Pekerjaan Rangka Platform hollow 10x10	kg	7.741,0		
	perhitungan dalam 1 modul				
	panjang melintang	m	15,2		
	jumlah row melintang	unit	8,0		
	panjang memanjang	m	13,1		
	jumlah row memanjang	unit	3,0		
	Total panjang	m	160,5		
	Berat 80x80x16 / m	kg	4,0		
	Berat / modul	kg	645,1		
	jumlah modul	unit	12,0		
3	Install dan erection Rangka Paltform dan kubus apung	m2	2.381,6		
	perhitungan dalam 1 modul				
	panjang melintang	m	15,2		
	panjang memanjang	m	13,1		
	Luas/modul	m2	198,5		
	jumlah modul	unit	12,0		
2. BOTTOM ANCHORING SYSTEM					
1	Pengadaan precast bottom anchor 50x50x40 cm	unit	160,0		
2	Pengadaan Mooring Bottom Anchor	m	392,0		
	Jumlah bottom anchor	bh	16,0		
	Panjang mooring/anchor	m	24,5		
3	Install dan erection bottom anchor	unit	160,0		
4	Install dan erection mooring bottom anchor	m	392,0		
3. SHORE ANCHOR					
1	Pekerjaan Strousspile				
1.1	Pekerjaan Bor	m	24,0		
1.2	Pekerjaan Beton bertulang	m3	1,1		
	diameter strousspile	m	0,3		
	kedalaman strousspile	m	6,0		
	jumlah titik strousspile	bh	4,0		
2	Pekerjaan Pilecap Beton Bertulang	m3	0,9		
	panjang	m	1,5		
	lebar	m	0,6		
	tebal	m	0,5		
	jumlah	bh	2,0		
3	Pengadaan Mooring shore anchor	m	98,4		
	jarak titik tambat melintang	m	39,0		
	jarak titik tambat memanjang	m	30,0		
	jarak diagonal	m	49,2		
	jumlah titik	bh	2,0		
4	Install dan erection mooring shore anchor	m	98,4		

IV. ANALISA HARGA SATUAN PEKERJAAN								
Item & Koefisien pekerjaan : Permen PU no 28 th 2016								
Harga satuan: Perwali Kota Semarang								
I. STRUKTUR FLOATING	Code	Sat	Koef	Hg Sat		Jumlah Harga		
1 Pengadaan dan perangkaian Precast Kubus Apung HDPE	**A.4.2.1.3. Pengerjaan perakitan 100kg -> identik dg 14.3unit Kubus Apung**							
A. Tenaga								
1. Pekerja		OH	0,1	Rp	105.000	Rp	10.500	
2. Tk Besi		OH	0,1	Rp	130.000	Rp	13.000	
3. Kepala Tukang		OH	0,001	Rp	140.000	Rp	140	
4. Mandor		OH	0,003	Rp	130.000	Rp	390	
B. Bahan								
1. Kubus Apung HDPE 50x50x40 (7kg/unit)		UNIT	14,3	Rp	900.000	Rp	12.857.143	
C. Peralatan								
Jumlah A + B + C						Rp	12.881.173	
Overhead + profit			15%			Rp	1.932.176	
Harga satuan Pekerjaan 14,3 unit						Rp	14.813.349	
Harga satuan Pekerjaan /unit						Rp	1.035.899	
2 Pekerjaan Rangka Platform hollow 80x80x16 (4kg/m) - kg						**Rp**	**70.329**	
2.1 Pengelasan dg las listrik	A.4.2.1.5. Penegrjaan 10cm pengelasan dengan las listrik							
a) Asumsi per module: pengelasan profil 80x80 keliling untuk 8 row memanjang x 3 row melintang = 8cm x 4 keliling x 8 memanjang x 3 melintang		cm	768,0					
b) berat hollow per module		kg	645,1					
c) konversi panjang pengelsan ke berat profile		cm/kg	1,2					
A. Tenaga								
1. Pekerja		OH	0,05	Rp	105.000	Rp	5.000	
2. Tk Besi		OH	0,02	Rp	130.000	Rp	3.095	
3. Kepala Tukang		OH	0,002	Rp	140.000	Rp	333	
4. Mandor		OH	0,002	Rp	130.000	Rp	310	
B. Bahan								
1. Kawat las listrik		kg	0,5	Rp	42.730	Rp	20.349	
2. Solar		ltr	0,0	Rp	8.800	Rp	210	
3. Minyak Pelumas		ltr	0,0	Rp	28.000	Rp	1.333	
C. Peralatan						Rp	-	
1. Sewa alat las		jam	0,2	Rp	7.143	Rp	1.446	
Jumlah A + B + C						Rp	32.076	
Overhead + profit			15%			Rp	4.811	
Harga satuan Pekerjaan /kg						Rp	36.887	
2.2) Pemasangan 1kg besi profil	A.4.2.1.1. Pemasangan 1kg besi profil							
A. Tenaga								
1. Pekerja		OH	0,06	Rp	105.000	Rp	6.300	
2. Tk Las Konstruksi		OH	0,06	Rp	130.000	Rp	7.800	
3. Kepala Tukang		OH	0,006	Rp	140.000	Rp	840	
4. Mandor		OH	0,003	Rp	130.000	Rp	390	
B. Bahan								
1. Hollow galvanized 80x80x16		kg	1,0	Rp	13.750	Rp	13.750	
C. Peralatan								
Jumlah A + B + C						Rp	29.080	
Overhead + profit			15%			Rp	4.362	
Harga satuan Pekerjaan /kg						Rp	33.442	
3 Install dan erection Rangka Paltform dan kubus apung	**m2**		**25%**	**Rp**	**1.035.899**	**Rp**	**258.975**	
Asumsi dengan ponton tugboat								

II. BOTTOM ANCHORING SYSTEM+A134:B1A134:B149	Code	Sat	Koef	Hg Sat	Jumlah Harga
1 Pengadaan precast bottom anchor 50x50x40 cm	**unit**				**Rp 313.735**
1.1) Pembuatan 1m2 bekisting utk balok beton pracetak	A.4.1.2.6.				
A. Tenaga					
1. Pekerja		OH	0,004	Rp 105.000	Rp 420
2. Tk Kayu		OH	0,038	Rp 130.000	Rp 4.940
3. Kepala Tukang		OH	0,004	Rp 140.000	Rp 560
4. Mandor		OH	0,001	Rp 130.000	Rp 130
B. Bahan					
1. Kayu kaso 5/7		m3	0,0	Rp 13.212.500	Rp 66.063
2. Phenol film 12mm		lbr	0,0	Rp 230.000	Rp 9.890
3. Minyak bekisting		lbr	0,2	Rp 16.800	Rp 3.360
4. Paku		kg	0,0	Rp 30.090	Rp 1.384
5. Dinabolt d12mm		buah	0,7	Rp 5.640	Rp 3.909
C. Peralatan					
Jumlah A + B + C					Rp 90.655
Overhead + profit			15%		Rp 13.598
Harga satuan Pekerjaan /m2					Rp 104.253
Harga pekerjaan 1 unit uk 50x50x40 cm		m2	1,2		Rp 125.104
1.2) Penuangan beton utk balok beton pracetak/m3	A.4.1.2.6.				
A. Tenaga					
1. Pekerja		OH	0,069	Rp 105.000	Rp 7.245
2. Tk Batu		OH	0,242	Rp 130.000	Rp 31.460
3. Tk Vibrator		OH	0,138	Rp 130.000	Rp 17.940
4. Kepala Tukang		OH	0,037	Rp 140.000	Rp 5.180
5. Mandor		OH	0,073	Rp 130.000	Rp 9.490
B. Bahan					
1. Beton mixed K300		m3	1,1	Rp 1.300.000	Rp 1.430.000
C. Peralatan					
Jumlah A + B + C					Rp 1.501.315
Overhead + profit			15%		Rp 225.197
Harga satuan Pekerjaan /m3					Rp 1.726.512
Harga pekerjaan 1 unit uk 50x50x40 cm		m3	0,1		Rp 172.651
1.3) Pemasangan dan membuka bekisting 1 buah komponen balok beti	A.4.1.2.9.				
A. Tenaga					
1. Pekerja		OH	0,089	Rp 105.000	Rp 9.345
2. Tk Kayu		OH	0,03	Rp 130.000	Rp 3.900
3. Mandor		OH	0,005	Rp 130.000	Rp 650
B. Bahan					
C. Peralatan					
Jumlah A + B + C					Rp 13.895
Overhead + profit			15%		Rp 2.084
Harga satuan Pekerjaan /unit					Rp 15.979
2 Pengadaan Mooring Bottom Anchor dia 10mm		**m**	**1,3**	**Rp 40.250**	**Rp 52.325**
3 Install dan erection bottom anchor	**bh**	**A.4.1.2.15. Ereksi 1 buah komponen utk balok**			**Rp 342.309**
A. Tenaga					
1. Operator Crane		OH	0,004	Rp 230.000	Rp 920
2. Pembantu op crane		OH	0,038	Rp 120.000	Rp 4.560
3.pekerja		OH	0,004	Rp 105.000	Rp 420
4. Tk Batu		OH	0,001	Rp 130.000	Rp 130
5. Tk Ereksi		OH	0,001	Rp 130.000	Rp 130
6. Kepala Tukang		OH	0,001	Rp 140.000	Rp 140
7. Mandor		OH	0,001	Rp 130.000	Rp 130
B. Bahan					
1. Solar		lbr	6,1	Rp 8.800	Rp 53.768
C. Peralatan					
1. Sewa crane		unit hari	0,1	Rp 3.442.000	Rp 209.962
2. Sewa Schacfolding		unit hari	1,1	Rp 25.000	Rp 27.500
Jumlah A + B + C					Rp 297.660
Overhead + profit			15%		Rp 44.649
Harga satuan Pekerjaan /bh					Rp 342.309

4 Install dan erection mooring bottom anchor	**ttk**	**A.4.1.2.24 Upah 1 titik joit dengan sling**			**Rp 2.191.170**
a) Panjang 1 ttk joint sling		m	24,5		
b) konversi titik ke panjang m		ttk	24,5		
A. Tenaga					
1. Pekerja		OH	5,39	Rp 230.000	Rp 1.239.700
2. TukangKayu		OH	0,539	Rp 120.000	Rp 64.680
3. TukangBesi		OH	5,39	Rp 105.000	Rp 565.950
4. mandor		OH	0,2695	Rp 130.000	Rp 35.035
B. Bahan					
C. Peralatan					
Jumlah A + B + C					Rp 1.905.365
Overhead + profit			15%		Rp 285.805
Harga satuan Pekerjaan /ttk					Rp 2.191.170

III. SHORE ANCHOR	Code	Sat	Koef	Hg Sat	
1 Pekerjaan angker penambat Strousspile	m			Rp	1.569.248
2 Pekerjaan Pilecap Beton Bertulang	m3			Rp	5.278.104
3 Pengadaan Mooring shore anchor	m			Rp	52.325
4 Install dan erection mooring shore anchor	m			Rp	2.191.170

Based on the analysis and calculation of the cost of the foundation of the solar panel on the surface of the dam water body, the total value (including Ppn) is IDR 2,969,868,764.

4.5. Analysis of the Implementation Time of Foundation Work on the Dam Slope

The period of implementation of the dam slope foundation work uses reference data from the period according to the planning document for the Jatibarang Dam Solar Panel System Project, for 55 (fifty-five) calendar days.

4.6. Analysis of the Implementation Time of Foundation Work on the Surface of the Dam Water Body (Floating)

a. Construction Implementation Procedure

The construction implementation procedure refers to the journal: Kim 1, Seung-Cheol Baek 2, Ki-Bong Choi 1 and Sung-Jin Park 3, Design and Installation of 500-kW Floating Photovoltaic Structures Using High-Durability Steel, 2020. MDPI journal energies Korean Building Code and Commentary (2016) [18], Energies 2020, 13, 4996.

b. Flow Chart of Work Implementation Process

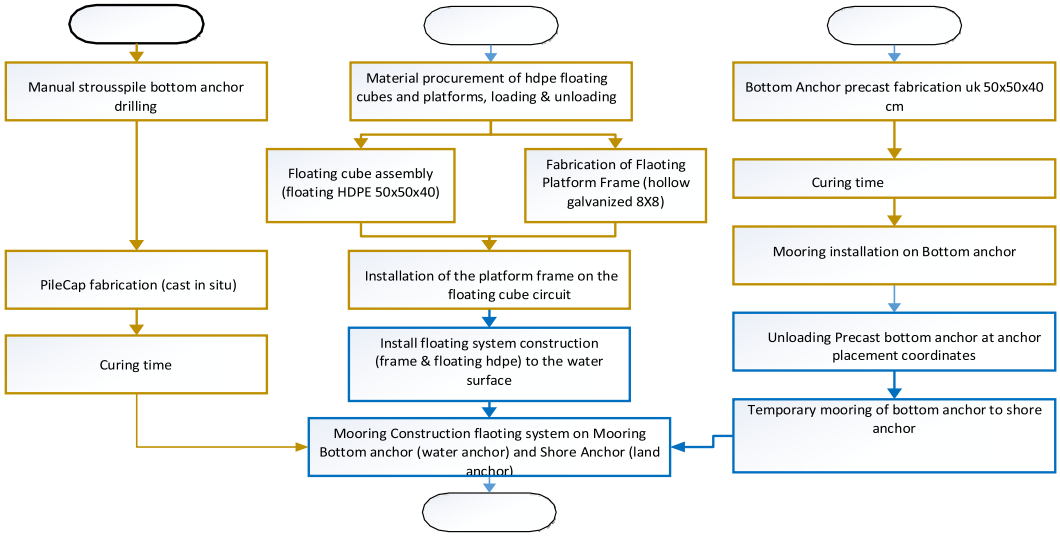


Figure 14. Chart of Work Implementation Process

c. Analysis and Calculation of Work Time

- Floating Structure Platform

Table 4. Floating Structure

1. STRUKTUR FLOATING								
I. SYARAT DAN KONDISI								
1 Pekerjaan perangkaian dan pemasangan dilakukan secara manual								
2 Lokasi pekerjaan : permukaan badan air bendungan								
3 Jam kerja efektif per-hari								
II ANALISIS DESKRIPSI ITEM PEKERJAAN (WBS) & VOLUME PEKERJAAN								
1 Pengadaan dan perangkaian Precast Kubus Apung HDPE				unit	281			
2 Pekerjaan Rangka Platform hollow 80x80				kg	7.741			
3 Install dan erection Rangka Paltform dan kubus apung				m2	2.382			
III KAPASITAS PRODUKSI								
No	*Uraian pekerjaan*	*satuan*	*Koefisien*	*Kapasitas Produksi*	*Jumah Tenaga*	*Total Kap Produksi*	*Volume Pekerjaan*	*Waktu Pelaksanaan*
								Hari
1	**Pengadaan dan perangkaian Precast Kubus Apung HDPE**	**unit**			*3,00*	*30*	**281,0**	**10,0**
	1. Pekerja	*OH*	*0,1*	*10,0*				
2	**Pekerjaan Rangka Platform hollow 80x80**	**kg**			*12,00*	*504*	**7.741,0**	**16,0**
	2. Tk Besi	*OH*	*0,02*	*42,0*				
3	**Install dan erection Rangka Paltform dan kubus apung**	**m2**			*12,00*	*200*	**2.381,6**	**12,0**
	2. Tk Las Konstruksi	*OH*	*0,06*	*16,7*				

- Bottom Anchor

Table 5. Bottom Anchor

2. BOTTOM ANCHOR

I. ASUMSI, SYARAT DAN KONDISI

1	Pekerjaan Pabrikasi precast bottom anchor beton		
2	Lokasi pekerjaan : permukaan badan air bendungan		
3	Precast bottom anchor dimensi 1 x 1 x 1 di urai menjadi		
4	Loading dari lokasi pabrikasi menuju alat angkut air		
5	Jam kerja efektif per-hari	7,00	Jam
6	Satuan Install dan erection bottom anchor berdasarkan koefisien tenaga kerja utk 1 titik dd volume mooring panjang 24,5m	24,5	m/titik

II ANALISIS DESKRIPSI ITEM PEKERJAAN (WBS) & VOLUME PEKERJAAN

1	Precast Bottom Anchor 50x50x40 cm	160,00	bh
2	Mooring Bottom Anchor	392,00	m unit
3	Install dan erection bottom anchor	160,00	bh
4	Install dan erection mooring bottom anchor	392,00	m unit

III KAPASITAS PRODUKSI

No	Uraian pekerjaan	satuan	Koefisien	Kapasitas Produksi	Jumah Tenaga	Total Kap Produksi	Volume Pekerjaan	Waktu Pelaksanaan Hari
1	**Precast Bottom Anchor 50x50x40 cm**							
	1.1) Pembuatan 1m2 bekisting utk balok beton pracetak	*unit*			*2,00*	*43,9*	*160,0*	**4,0**
	2. Tk Kayu	*OH*	*0,0456*	*21,9*				
	1.2) Penuangan beton utk balok beton pracetak/m3	*unit*			*2,00*	*82,6*	*160,0*	**2,0**
	2. Tk Batu	*OH*	*0,0242*	*41,3*				
	1.3) Pemasangan dan membuka bekisting 1 buah komponen balok beton	*unit*			*3,00*	*100,0*	*160,0*	**2,0**
	2. Tk Kayu	*OH*	*0,03*	*33,3*				
2	**Mooring Bottom Anchor**	**m unit**			*2,00*	*500,0*	**392,0**	**1,0**
	3. Kepala Tukang	*OH*	*0,004*	*250,0*				
3	**Install dan erection bottom anchor**	**bh**			*1,00*	***250,0***	**160,0**	**1,0**
	1. Operator Crane	*OH*	*0,004*	*250,0*				
4	**Install dan erection mooring bottom anchor**	**m unit**			*15,00*	**2,8**	**16,0**	**6,0**
	3. TukangBesi	*OH*	*5,39*	*0,2*				

- **Shore Anchor**

Table 6. Shore Anchor

3. SHORE ANCHORING

I. ASUMSI, SYARAT DAN KONDISI

1	Pekerjaan pile anchor darat (shore anchoring)		
2	Lokasi pekerjaan : di darat		
3	Jam kerja efektif per-hari	7,00	Jam

II ANALISIS DESKRIPSI ITEM PEKERJAAN (WBS) & VOLUME PEKERJAAN

1	Pekerjaan angker penambat Strousspile	24,00	m
2	Pekerjaan Pilecap Beton Bertulang	0,90	m3
3	Pengadaan Mooring shore anchor	98,41	m
4	Install dan erection mooring shore anchor	98,41	m

III KAPASITAS PRODUKSI

No	Uraian pekerjaan	satuan	Koefisien	Kapasitas Produksi	Jumah Tenaga	Total Kap Produksi	Volume Pekerjaan	Waktu Pelaksanaan Hari
1	Pekerjaan angker penambat Strousspile	m			5,00	8,0	24,00	3
2	Pekerjaan Pilecap Beton	m3			3,00	0,5	0,90	2
3	Pengadaan Mooring shore anchor	m			2,00	49,2	98,41	2
4	Install dan erection mooring shore anchor	m			2,00	98,4	98,41	1

d. Time Schedule

Table 7. Time Schedule

NO	DESKRIPSI	SDM	DURASI hari	BIAYA Rp	BOBOT %	M1	M2	M3	M4	M5	M6
	hari ke					*1*	*8*	*15*	*22*	*29*	*36*
	sd hari ke					*7*	*14*	*21*	*28*	*35*	*42*
1.	**STRUKTUR FLOATING**										
1	Pengadaan dan perangkaian Precast Kubus Apung HDPE	9	4	291.087.483	10,78%				10,78%		
2	Pekerjaan Rangka Platform hollow 10x10	9	21	544.418.947	20,16%	6,72%	6,72%	6,72%			
3	Install dan erection Rangka Paltform dan kubus apung	9	16	616.768.797	22,84%					11,42%	11,42%
2.	**BOTTOM ANCHORING SYSTEM**										
1	Pengadaan precast bottom anchor 50x50x40 cm			50.197.535	1,86%	0,93%	0,93%				
	1.1) Pembuatan 1m2 bekisting utk balok beton pracetak	3	3								
	1.2) Penuangan beton utk balok beton pracetak/m3	3	2								
	1.3) Pemasangan dan membuka bekisting 1 buah komponen balok beton pracetak	1	5								
	curing time beton		*21*								
2	Pengadaan Mooring Bottom Anchor	2	2	20.511.400	0,76%					0,76%	
3	Install dan erection bottom anchor	1	5	54.769.440	2,03%						2,03%
4	Install dan erection mooring bottom anchor	15	6	858.938.542	31,81%						31,81%
3.	**SHORE ANCHOR**										
1	Pekerjaan angker penambat Strousspile	5	3	37.661.957	1,39%	1,39%					
2	Pekerjaan Pilecap Beton Bertulang	5	2	4.750.294	0,18%	0,18%					
	curing time beton		*21*								
3	Pengadaan Mooring shore anchor	2	2	5.149.163	0,19%					0,19%	
4	Install dan erection mooring shore anchor	2	1	215.627.136	7,99%						7,99%
	Progress/minggu			2.699.880.694	100%	9%	8%	7%	11%	12%	53%
	Kumulatif Progress					9%	17%	24%	34%	47%	100%

Based on the time schedule analysis, the implementation period of the floating foundation work is 42 calendar days.

4.7. Comparative Analysis of Cost and Construction Time of Solar Panel Foundation on the Surface of Dam Water Body with Dam Slope

Table 8. Comparison of Costs

I. PERBANDINGAN BIAYA	Fondasi Solar Panel Lereng Bendungan	Fondasi Solar Panel Permukaan Badan Air Bendungan
1 Pengadaan Ballast Precast Panel 360 unit - PV 936 panel	Rp 884.867.100	
2 Pemasangan Ballast Precast Panel 360 unit	Rp 1.027.310.600	
1 Struktur Floating (2.382 m2) - PV 936 panel		Rp 1.452.275.228
2 Bottom Anchor (16 titik)		Rp 984.416.917
3 Shore Anchor (2 titik)		Rp 263.188.549
JUMLAH	Rp 1.912.177.700	Rp 2.699.880.694
PPN	Rp 191.217.770	Rp 269.988.069
TOTAL SETELAH PPN	**Rp 2.103.395.470**	**Rp 2.969.868.764**
Perbandingan Biaya Floating thd Lereng	**141%**	

Table 9. Comparison of Time

II. PERBANDINGAN WAKTU	Fondasi Solar Panel Lereng Bendungan	Fondasi Solar Panel Permukaan Badan Air Bendungan
JANGKA WAKTU (HARI)	55	42
Perbandingan Biaya Floating thd Lereng	76%	

5. CONCLUSION

Based on the results of the discussion above, it can be concluded that:

a. The cost of foundation construction for solar panels installed on the surface of the dam water body amounted to Rp 2,969,868,764, while the cost of foundation construction on the dam slope amounted to Rp 2,103,395,470.
b. The period of foundation implementation for solar panels installed on the surface of the dam water body takes 42 calendar days, while the time required for the implementation of the foundation on the dam slope is 55 calendar days.
c. The results of comparing the two types of solar panel foundations on the surface of the dam water body and those on the dam slope are as follows:
   - The cost comparison of the floating solar panel foundation compared to the dam slope foundation is: Rp 2,969,868,764 / Rp 2,103,395,470 = 141%, or 41% more than the cost of the foundation on the surface of the dam water body.
   - From the time comparison of the floating foundation (surface of the water body) compared to the foundation of the dam slope is: 55 / 42 = 76%, or 31% faster than the time required for the implementation of the solar panel foundation on the dam slope.

This research can be further developed or complemented by the Simulation Method of Selection: type, dimension of bottom anchor to achieve the most optimal results, by considering the deliverable, installment, and erection factors. The simulation method should also consider factors such as MWS, LWS, Bottom anchor elevation vs. underwater terrain conditions, and access to loading & unloading of precast materials. Detailed cost and time analysis should be conducted by reviewing and examining the production capacity of the equipment involved in the process of installing and erecting floating foundation components vs. the construction method used. Additionally, an analysis and comparative study of the two types of solar panel plants (Floating vs. Slope) should be carried out from an economic perspective related to the overall construction investment cost (Foundation and Solar Panel), including assessing the energy value (=sale value of electricity) that can be absorbed in each type of solar panel plant.

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