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Application of Building Information Modelling (BIM) in the Design of Riverbank Retaining Walls: A Case Study of the Belimbing River, Padang, West Sumatra

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Abstract

River normalization is a technical initiative aimed at reinstating its natural role as a water distribution conduit and a supporting ecology for the surrounding community. A primary difficulty in the normalization process is riverbank erosion, which can jeopardize the stability of the adjacent ecosystem. This study investigates the utilization of Building Information Modelling (BIM) in the design of earth retaining walls (ERW) for the Belimbing River, employing Autodesk Civil 3D, Subassembly Composer, InfraWorks, Navisworks, and Plaxis 2D software. This research presents a cohesive digital methodology that includes geometric modelling, visual simulation, cost estimation, construction scheduling, and thorough slope stability analysis.

1.0 INTRODUCTION

In Indonesia, water-related calamities result in annual economic damages of 2-3 billion US dollars. Over 100 million individuals, approximately 38% of the population, face flood risk, with 325 cities and regions designated as high-risk locations. The frequency of flood incidents nearly increased from 2006 to 2017 (OECD, 2023). The level of climate related risk in Indonesia compared to the global average is presented in **Figure 1.** Figure 1 indicates that Indonesia has a higher climate risk score than the global average, highlighting the urgency of improving flood mitigation strategies, particularly in urban river systems. Many river basins in Indonesia face critical challenges, such as siltation, changes in channel morphology, and erosion. These elements increase the probability of disasters, particularly floods that can undermine infrastructure, disrupt community operations, and jeopardize human safety. Flood discharge should, in principle, be retained as much as possible in the upstream area to reduce the volume of water flowing directly downstream. Expansive riverbanks are essential to augment river capacity. The Regulation of the Minister of Public Works and Housing No. 28/PRT/M/2018 defines the riverbank boundaries in urban regions, stipulating a distance of 10 meters from both the left and right banks of the riverbed. However, this is impractical in densely crowded areas due to limited land availability. Padang City, a key growth area in West Sumatra, is particularly susceptible to flooding. From 2020 to 2024, there were 121 documented flood incidents resulting in total losses of Rp1,786,150,000 (Harvia et al., 2024).

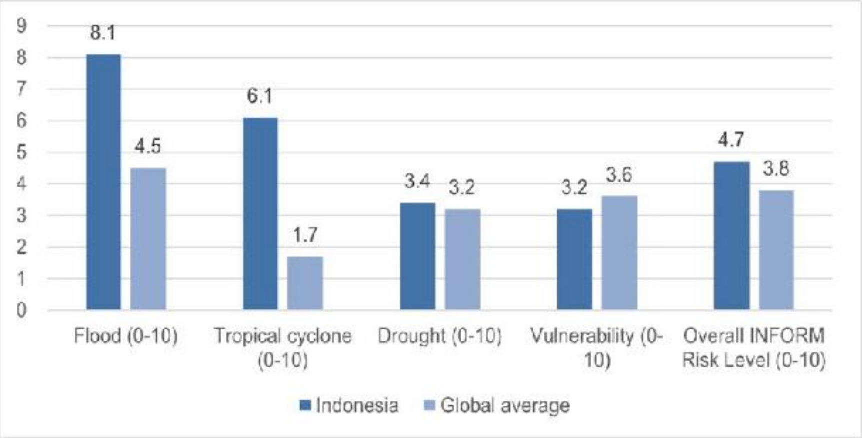


Figure 1. Climate risks scores in Indonesia, compared to global average score.
Source: Water Financing and Disaster Risk Reduction in Indonesia: Highlights of a National Dialogue on Water (OECD, 2023)

River normalization is a technical procedure that improves flow capacity without expanding the riverbanks. Multiple studies suggest that river normalization may reduce flood intensity, particularly during the rainy season (Nurhamidah et al., 2021). Regrettably, river normalization attempts, intended as a sustainable solution, sometimes garner insufficient attention. Traditional construction methods employed in the design and execution of normalization projects are frequently time-intensive, expensive, and rigid in accommodating field conditions (Fawji et al., 2022).

With the digital change in the construction industry, Building Information Modelling (BIM) has arisen as a novel method to enhance planning efficiency, save project expenses, and provide superior infrastructure quality (Petschek et al., 2024). In Indonesia, the trend of BIM adoption has demonstrated favorable progress; nonetheless, its implementation is inconsistent throughout all project phases. The application of BIM remains predominantly confined to 3D modelling in the design phase and has not achieved comprehensive integration across processes or disciplines (Zhabrina et al., 2018). Industry surveys reveal that around 60% of participants are acquainted with and have utilized BIM, but to differing extents. The primary hurdles consist of substantial investment expenditures, a lack of qualified personnel, and the deficiency of comprehensive rules (Hatmoko et al., 2019; Pantiga & Soekiman, 2021). The inconsistent adoption is also seen in the application of BIM for water resources infrastructure, especially in river normalization projects, where its utilization is notably restricted. Prior research has predominantly concentrated on the building and transportation sectors, but the capacity of BIM to tackle river morphological challenges has been largely overlooked.

This study targets the Belimbing River in Padang City to highlight the pressing necessity for strategic and comprehensive management of river morphology and slope stability challenges. Bank collapses and structural failures frequently stem from elevated flow velocities and unstable river configurations, underscoring the imperative for a cohesive planning strategy. This study addresses the necessity by broadening the application of Building Information Modelling (BIM) to river infrastructure and providing a pragmatic contribution through the creation of a BIM-based implementation model designed to enhance the efficiency and adaptability of river normalization planning. The study not only showcases these applications but also assesses BIM's capacity to tackle technical issues in river normalization projects, emphasizing its benefits compared to traditional planning methods.

1.1 Study Area

The research area is located in Nanggalo District, within the Batang Belimbing Watershed (DAS). **Figure 2** illustrates the Belimbing River segment located in Nanggalo District, which is influenced by the hydrological conditions of the Batang Kuranji watershed. This location is selected due to its high flood vulnerability.This watershed constitutes the downstream segment of the Batang Kuranji Watershed, and consequently, its hydrological conditions are significantly affected by the attributes of the Batang Kuranji Watershed.

Figure 2. Study Area. Source: Google Earth.

The Batang Kuranji Watershed has an average maximum monthly rainfall of 405.58 mm. In addition to significant rainfall, the area exhibits a considerable elevation difference: the upstream region lies at an elevation of 150–175 m above sea level, the middle part at 125–150 m, and the downstream area at only 1–12 m (Utama, 2022). The steep slope gradient facilitates the swift movement of rainfall from the upstream region to the downstream area. Consequently, peak discharge in the downstream region escalates significantly, amplifying the flood danger in the Batang Belimbing Watershed. This condition is further intensified by the convergence of two streams, Banda Lurus and Batang Kurao, which amalgamate within the research region. When the effluents from these rivers converge, the flow volume substantially escalates, heightening the probability of water inundating adjacent settlements.

2.0 LITERATURE REVIEW

2.1 River Normalization

River normalization is a flood management technique that enhances the river channel to augment its capacity and flow. This endeavor generally encompasses sediment dredging, channel expansion, bank reinforcement, levee construction, and riverside area management. Its objective is to facilitate water movement, mitigate inundation, and limit the risk of infrastructure damage and loss of life during floods (Murniningsih & Mustafa, 2020; Yatsrib et al., 2021). Numerous studies in Indonesia indicate that river normalization can produce substantial outcomes if meticulously developed and underpinned by suitable spatial planning regulations.

2.2 Revetments

Revetments are protection structures constructed along riverbanks to prevent erosion and preserve the banks. Revetments can be fabricated from various materials, including concrete, stone, geotextile bags (geobags), or other engineered alternatives. Revetments operate by absorbing and redirecting the energy of flowing water, thereby reducing the erosive effects on riverbanks. There are various types of revetments, such as permeable and impermeable, each influencing soil moisture, nutrient content, and ecosystem functionality differently. (Khajenoori et al., 2021; Man et al., 2022; Yu et al., 2020). Ecological revetments, employing natural or semi-natural materials, are increasingly preferred due to their diminished carbon emissions and lower costs compared to traditional structural revetments. (Liu & Wang, 2020; Yu et al., 2020).

2.3 BIM (Building Information Modelling

BIM (Building Information Modelling) is a collection of technologies that consolidates essential information via processes for the digital management of design, construction, operation, and maintenance of facilities. The adoption of BIM in construction enables the evaluation of a building without physical construction, hence optimizing the analytical process for construction professionals. BIM promotes collaboration among all project stakeholders via a cohesive digital platform. This ensures effective management of all information relevant to the construction process, hence reducing the likelihood of hazards occurring. (Berlian P. et al., 2016).

BIM dimensions refer to the classifications of information and their representation inside a BIM model, enhancing data relevant to the model to promote understanding and clarity in construction projects (Usamah, 2023). BIM dimensions denote the digital representation of three-dimensional forms classified as 3D (physical characteristics: height, width, and depth), 4D (temporal elements), 5D (financial aspects), 6D (sustainability factors), and 7D (facility management) (Heryanto et al., 2020).

Software is a crucial component in the execution of BIM technology. BIM software is a technology utilized for creating visualizations, conducting simulations, evaluating designs, and improving team cooperation to expedite the construction process. The search results reveal a restricted implementation of BIM software currently. This project will employ various directly integrated software that facilitates rapid modelling updates for Quantity Take-Off (QTO) calculations in reaction to modifications in the river cross-section design. The subsequent software is employed:

i. Autodesk Civil 3D 2024. This application is employed to analyze field-collected data.
ii. Autodesk Subassembly Composer 2024. This application is employed for the design of river barriers.
iii. Autodesk InfraWorks 2024. This software is designed to emulate subjects integrated with Autodesk Civil 3D 2024.

iv. Autodesk Navisworks 2024. This application enables 5D modelling, allowing direct interaction with Autodesk Civil 3D 2024 and Microsoft Project.

v. Plaxis 2D is a two-dimensional finite element software employed for analyzing deformation, stability, and groundwater flow in geotechnical engineering.

3.0 METHODOLOGY

This study approach commences with the identification of the projection system, subsequently incorporating terrestrial surface data and pertinent measurement information. Subsequent to the generation and modification of river cross-sections, the cross-sectional designs undergo further development and refinement. A standardized river cross-section is created using Autodesk Subassembly Composer 2024, and the resultant data are transmitted to Autodesk Civil 3D 2024 for integration with the existing cross-sectional data. The procedure advances with the finalization of cross-section and longitudinal section designs, together with the computation of excavation, backfill, and material volumes. The design data are ultimately uploaded to Autodesk InfraWorks 2024, yielding final outputs including design charts, volumetric data, and graphic representations. The research workflow is illustrated in Figure 3. The methodology consists of three main stages; data collection, processing, and modelling.

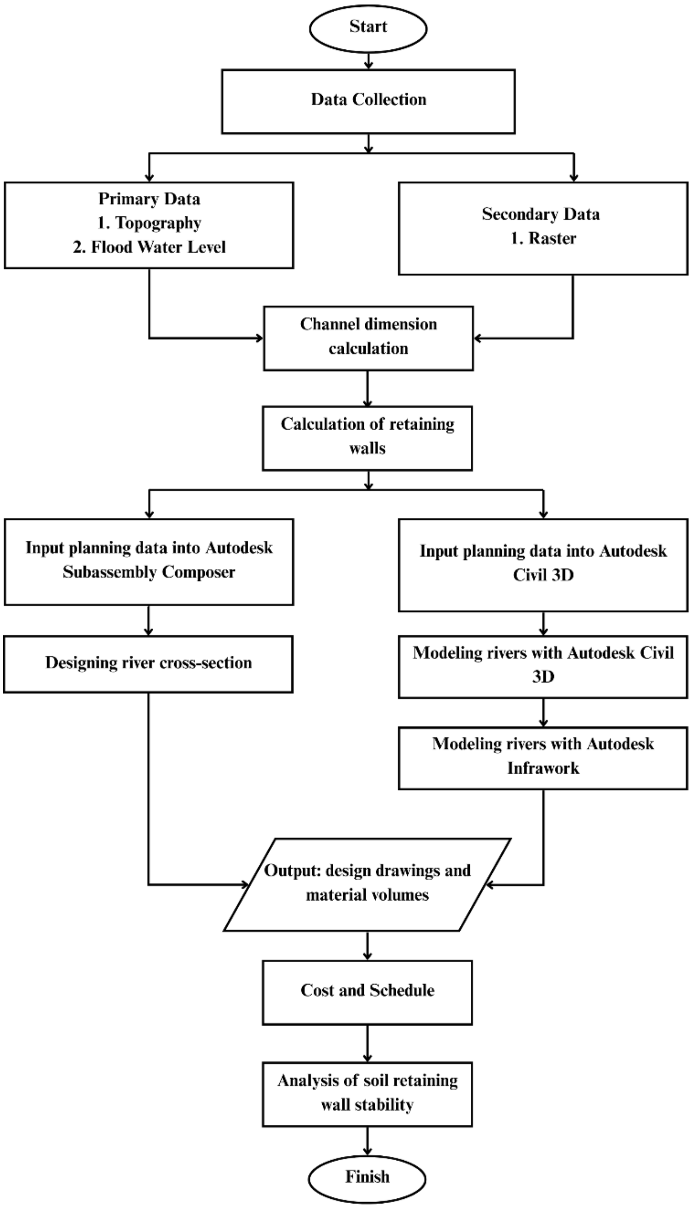


Figure 3. Research flowchart

3.1 Data Collection

Data acquisition is conducted with Geodetic GPS. The surveyed region encompasses river trunks extending to the riverbanks, which will be modified to normalize the river. The data retrieval process is initiated based on the tool employed. This approach employs the N-Trip protocol, necessitating internet connectivity and direct access to all available and cost-effective GPS satellites.

3.2 Data Processing

The initial step in data processing is generating contour maps utilizing the Civil 3D tool. The initial phase involves the cross-referencing of input data collected in the field. Upon completion of data entry, the subsequent stage is to generate a topographic map by constructing a new surface. A topographic surface was generated using the Civil 3D surface creation tool by integrating field survey points into a digital terrain model as presented in the following **Figure 4**. This stage seeks to obtain the river topography through the utilization of points.

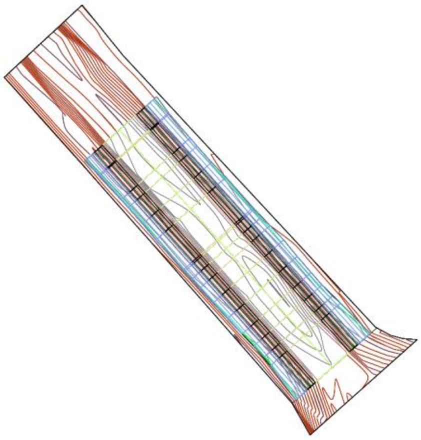
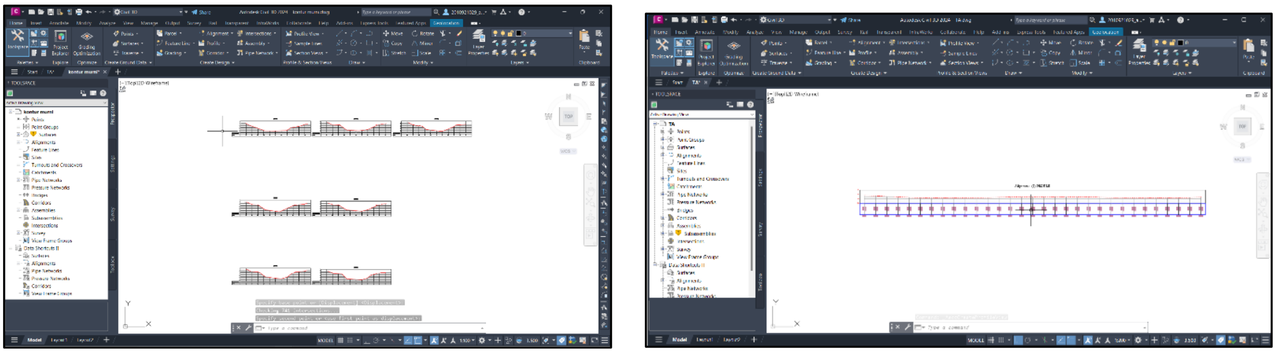


Figure 4. The Existing model

Subsequently, construct a cross-section through the Section View menu, select the Create Multiple Views option, and continue by clicking Create Section Views. Adjust the cross-section display as necessary and place it in an available area of the worksheet. Longitudinal sections of the river alignment were generated alongside cross sections. The technique entailed selecting the Profile View menu, clicking on Create Profile View, and then clicking Create Profile View in the ensuing dialog box to exhibit the results. These longitudinal sections illustrate the land surface elevation along the river alignment, which is crucial for hydraulic analysis and subsequent technical planning. This method yields a graphical depiction of the river's cross-section and longitudinal profile, based on topographic data obtained from actual field measurements. **Figure 5(a)** shows the variation of river cross-sections along the study area, while **Figure 5(b)** illustrates the longitudinal profile used to analyze elevation changes. These profiles are essential for determining the retaining wall dimensions.



(a) (b)

Figure 5. (a) Cross Section and (b) Long section.

3.3 Design and Analysis of Riverbank Retaining Walls

The planned retaining wall in this study relates to the topographical conditions depicted in the river's cross-section. The height of the retaining wall is determined by the cross section with the highest elevation, as the wall to be constructed follows a standard design to be uniformly applied along a certain segment of the river. The study reveals that the cross-section with the maximum height is located at STA 0+000. The maximum ground elevation at this cross section serves as the principal reference for determining the height of the retaining wall, precisely ±6.5 meters (**Figure 6**). The design dimensions of the retaining wall conform to the standards given in SNI 8460:2017 regarding Geotechnical Design Requirements. These dimensions consider wall stability, active soil pressure, and safety concerns related to landslides.

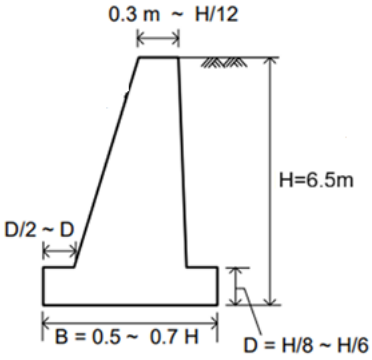


Figure 6. Typical dimensions of Riverbank Retaining Wall (BSN, 2017)

Figure 7 depicts the ultimate proportions of the engineered retaining wall, which were simulated by Subassembly Composer 2024. The retaining wall is 7.600 m in height, with a base width of 6.520 m and a top width of 0.600 m. The rear surface of the wall is sloped at an inclination of 50°, enhancing stability against lateral earth pressures.

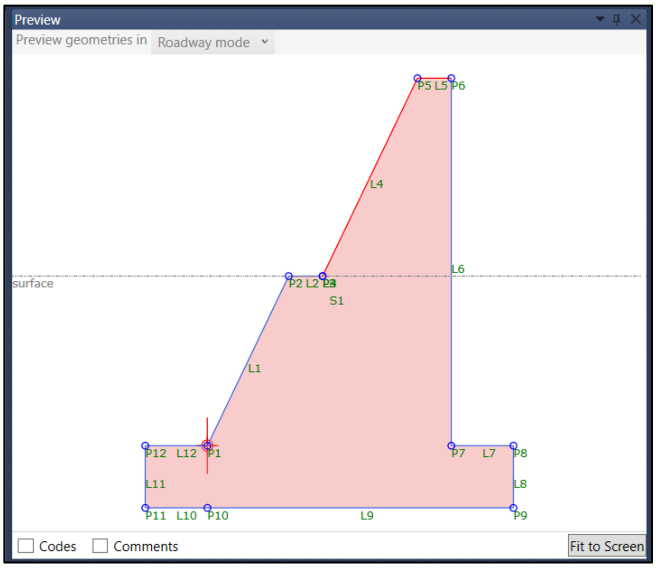


Figure 7. Specifications of Riverbank Retaining Wall.

3.4 Assembly Modelling

Following the modelling of the retaining wall in Subassembly Composer, the design was imported into Autodesk Civil 3D via Tool Palettes - New Palettes - Import Subassemblies. A river assembly was subsequently generated via the Create Assembly command, with the Assembly Type designated as Divided Crowned Road and the Assembly Style classified as Basic. The parameters utilized encompassed Lane Superelevation AOR for lane configuration, subsequent to which the intended retaining wall (DPT) was incorporated into the assembly, followed by the integration of a Daylight Basin component to finalize the depiction of the normalized river cross-section. Following the modelling of the retaining wall in Subassembly Composer, the design was imported into Autodesk Civil 3D through the Tool Palettes feature. A river assembly was then generated using the Create Assembly command, with parameters adjusted to represent the intended river cross-section as depicted in Figure 8. The corridor modelling result is presented in Figure 9. Figure 9 demonstrates the integration of the retaining wall assembly into the river corridor model. This output is used as the basis for volume calculations and further BIM-based analysis.

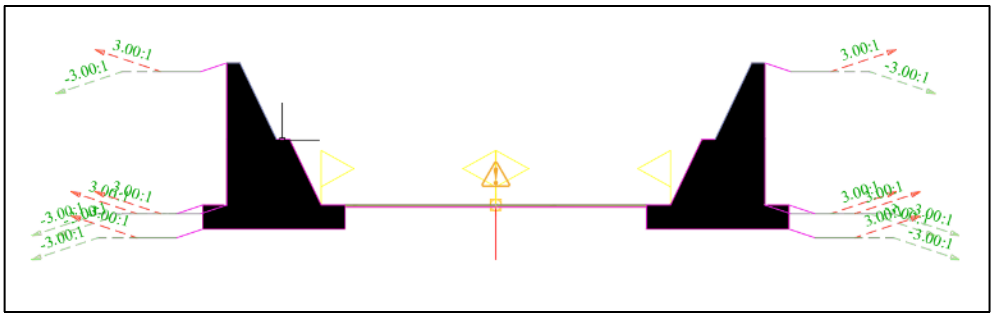


Figure 8. Assembly

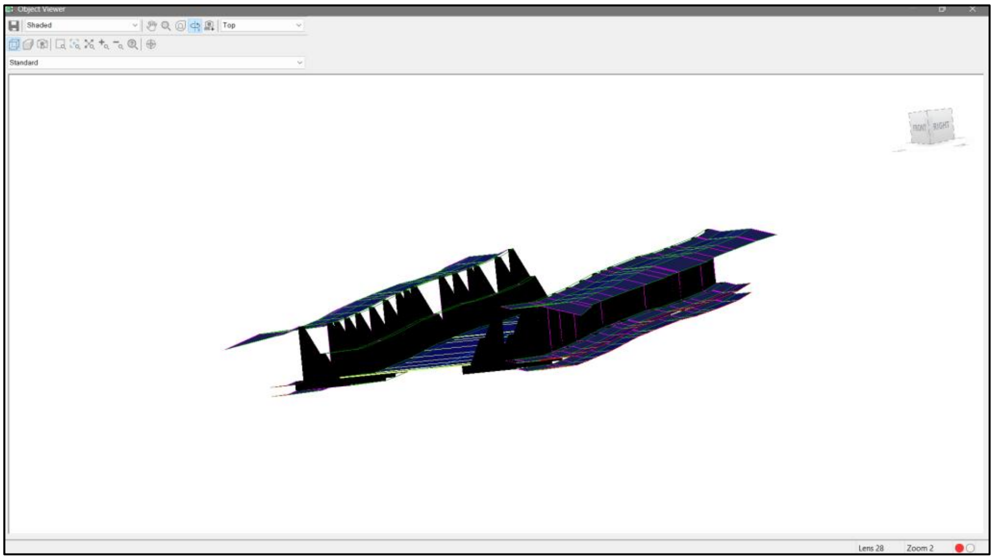
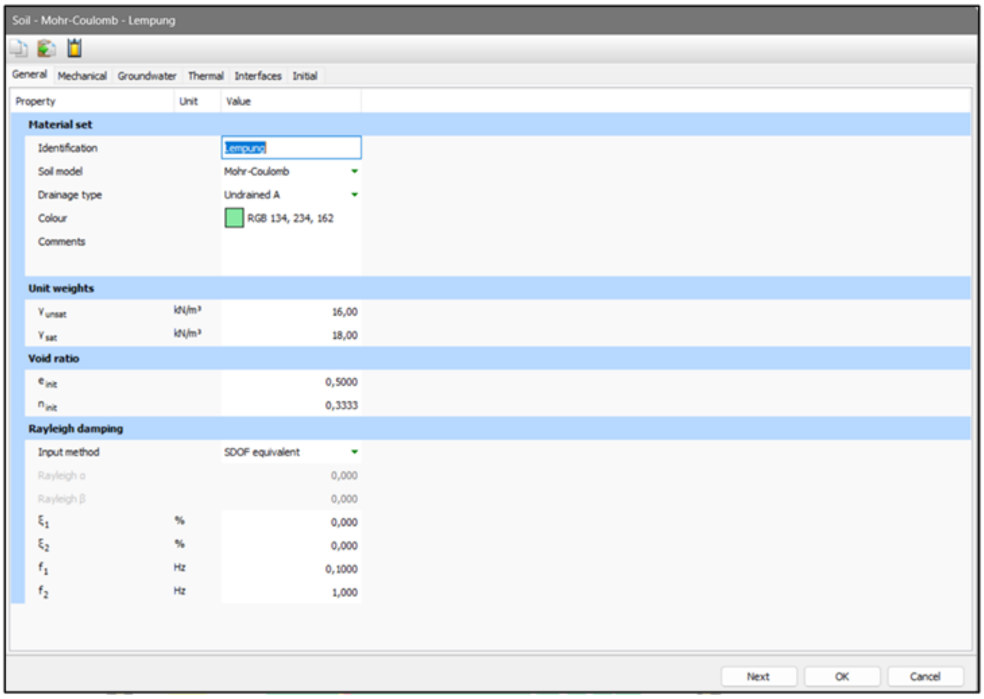


Figure 9. Corridor modelling results showing river cross-section alignment with retaining walls.

4.0 RESULT AND DISCUSSION

4.1 Analysis of Slope Stability Utilizing Plaxis 2D

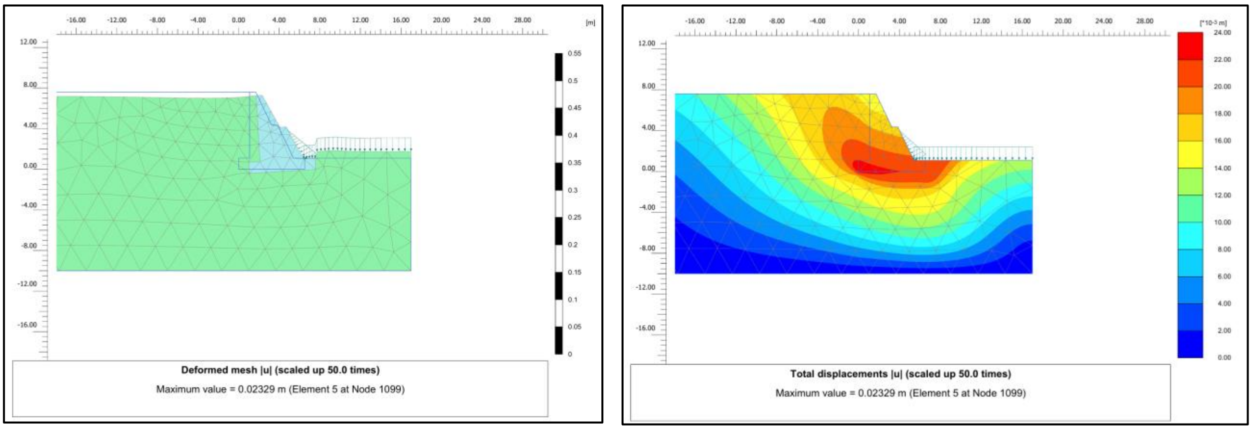
An analysis of slope stability was performed to assess the safety factor values of the previously built Earth Retaining Wall (ERW) utilizing Plaxis 2D software. Initially, modelling was conducted in Plaxis 2D by generating soil polygons and constructing the ERW structure and slope for analysis. Following that, material characteristics were established in accordance with specifications. A linear elastic soil model with non-porous drainage was employed for concrete. The elastic modulus (E) for concrete was established at 25×10^6. The Mohr-Coulomb model with undrained A drainage type was employed for the soil. The parameters for clay soil were established as follows: elastic modulus (E) of 14×10^3, internal friction angle (ϕ) of 17 degrees, and cohesion (c) of 9.807 kN/m². The material properties used in the slope stability analysis are defined in Plaxis 2D as shown in **Figure 10.**



Property	Unit	Value
Material set		
Identification		Lempung
Soil model		Mohr-Coulomb
Drainage type		Undrained A
Colour		🟩 RGB 134, 234, 162
Comments		
Unit weights		
γ_{unsat}	kN/m³	16,00
γ_{sat}	kN/m³	18,00
Void ratio		
e_{init}		0,5000
n_{init}		0,3333
Rayleigh damping		
Input method		SDOF equivalent
Rayleigh α		0,000
Rayleigh β		0,000
ξ_1	%	0,000
ξ_2	%	0,000
f_1	Hz	0,1000
f_2	Hz	1,000

Figure 10. Input parameters for soil and concrete materials in Plaxis 2D based on the Mohr-Coulomb model

Thereafter, the mesh formation process and node selection are performed on the structure intended for assessment. The groundwater level is determined by the elevation of the groundwater in the field. The next stage is to implement the work phase to reproduce the collapse conditions for analysis. The phases designated for the DPT stability analysis are the Initial Phase, DPT, and Safety Factor. The calculations are performed in the final phase by creating these steps, and the results are displayed through the menu View Calculation Results, Safety Factor, Project Calculation Information. This phase facilitates the acquisition and analysis of the DPT safety factor value. The deformation and displacement results from the slope stability analysis are presented in **Figure 11**. Figure 11 shows the deformation pattern of the retaining wall and the surrounding soil mass. The maximum displacement occurs near the slope surface, indicating the critical zone of potential movement. However, the magnitude of displacement remains relatively small, suggesting that the structure is stable under the analyzed conditions.

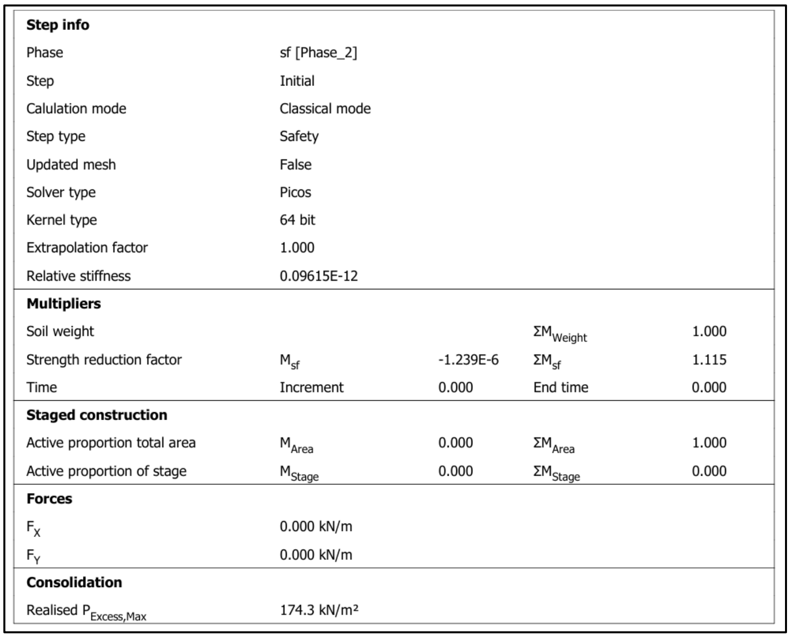


Deformed mesh |u| (scaled up 50.0 times)
Maximum value = 0.02329 m (Element 5 at Node 1099)

Total displacements |u| (scaled up 50.0 times)
Maximum value = 0.02329 m (Element 5 at Node 1099)

Figure 11. Deformed mesh and complete displacement in the design of retaining walls

The Strength Reduction Factor (ΣMsf) calculated by Plaxis 2D is 1.11. This value indicates that the DPT structure is still in a stable condition because the safety factor surpasses the general minimum limit employed, which is 1.0. This signifies that the soil and DPT construction can endure the load without failure under current conditions. The calculated maximal excess pore pressure (P^{excess}, Max) is 174.3 kN/m², as shown in **Figure 12**, and remains within the permissible limits for analysis without long-term consolidation. Consequently, it can be inferred that the design of the earth retaining wall derived from the modelling has satisfied the stability criteria and is appropriate for execution during the building phase.

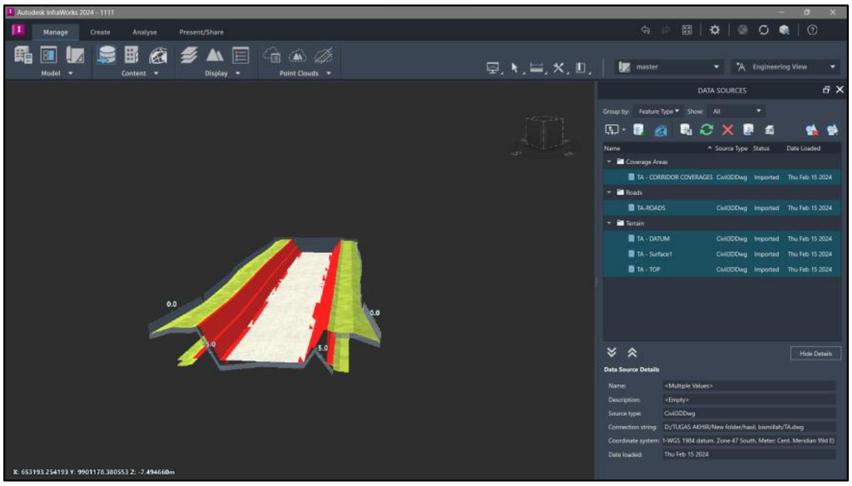


Step info				
Phase	sf [Phase_2]			
Step	Initial			
Calulation mode	Classical mode			
Step type	Safety			
Updated mesh	False			
Solver type	Picos			
Kernel type	64 bit			
Extrapolation factor	1.000			
Relative stiffness	0.09615E-12			
Multipliers				
Soil weight			ΣM_{Weight}	1.000
Strength reduction factor	M_{sf}	-1.239E-6	ΣM_{sf}	1.115
Time	Increment	0.000	End time	0.000
Staged construction				
Active proportion total area	M_{Area}	0.000	ΣM_{Area}	1.000
Active proportion of stage	M_{Stage}	0.000	ΣM_{Stage}	0.000
Forces				
F_X	0.000 kN/m			
F_Y	0.000 kN/m			
Consolidation				
Realised $P_{Excess,Max}$	174.3 kN/m²			

Figure 12. Computed slope stability results

4.2 Design Drawing and Material Volume

This part delineates the conclusive outcomes of the river cross-section planning process, shown as design drawings and material need estimates derived from work volume calculations. The cross-section was developed by consulting the previously modeled assembly, which encompasses primary components such as the riverbed, slopes, and retaining walls (DPT). The final cross-section diagram illustrates the river's geometric conditions and acts as the principal reference for on-site construction execution. Moreover, excavation and fill volume computations are conducted to objectively assess construction material necessities. The volume estimations are obtained via corridor modelling and quantity takeoff calculations within the modelling software.



Name	Source Type	Status	Date Loaded
Coverage Areas			
TA - CORRIDOR COVERAGES	Civil3DDwg	Imported	Thu Feb 15 2024
Roads			
TA-ROADS	Civil3DDwg	Imported	Thu Feb 15 2024
Terrain			
TA - DATUM	Civil3DDwg	Imported	Thu Feb 15 2024
TA - Surface1	Civil3DDwg	Imported	Thu Feb 15 2024
TA - TOP	Civil3DDwg	Imported	Thu Feb 15 2024

Data Source Details

Name: <Multiple Values>
Description: <Empty>
Source type: Civil3DDwg
Connection string: D:/TUGAS AKHIR/New folder/hasil. bismillah/TA.dwg
Coordinate system: t-WGS 1984 datum, Zone 47 South, Meter; Cent. Meridian 99d E)
Date loaded: Thu Feb 15 2024

Figure 13. 3D Modelling with Infrawork 2024

Figure 13 illustrates the outcomes of 3D modelling for a retaining wall design developed for river normalization planning. The modelling utilized Autodesk InfraWorks 2024, incorporating geometric and corridor data imported from Civil 3D for enhanced visualization in a full 3D model. The model illustrates the engineered river arrangement, with the retaining wall constructions depicted in red on either side of the river channel. The white core region signifies the normalized riverbed, whilst the green portions illustrate the current land contour characteristics. This modelling seeks to guarantee that the river's geometric configuration, including the dimensions and placement of the retaining walls, corresponds with field conditions and adheres to technical standards. **Table 1** shows that excavation activities dominate the project, with a cumulative cut volume of 11,587.64 m^3. This indicates that the existing riverbed elevation is generally higher than the planned design elevation. As shown in **Table 2**, the material volume increases proportionally with the cross-sectional area, confirming the consistency of the BIM-based quantity take-off results.

Table 1. The Total Volume of Cut and Fill

Station	Fill Area	Cut Area	Fill Volume (m^3)	Cut Volume (m^3)	Cumulative Fill Volume (m^3)	Cumulative Cut Volume (m^3)
0+000	12.85	52.05	0.00	0.00	0.00	0.00
0+025	3.66	91.61	106.37	1795.70	206.37	1795.70
0+050	4.81	81.58	105.80	2164.78	312.37	3960.48
0+075	5.52	73.16	129.09	1934.25	441.26	5894.24
0+100	6.35	69.68	148.41	1785.51	589.67	7680.24
0+125	4.73	83.29	138.55	1912.13	728.22	9592.37
0+150	7.64	76.33	154.67	1995.27	882.89	11587.64

Table 2. Volume of Material

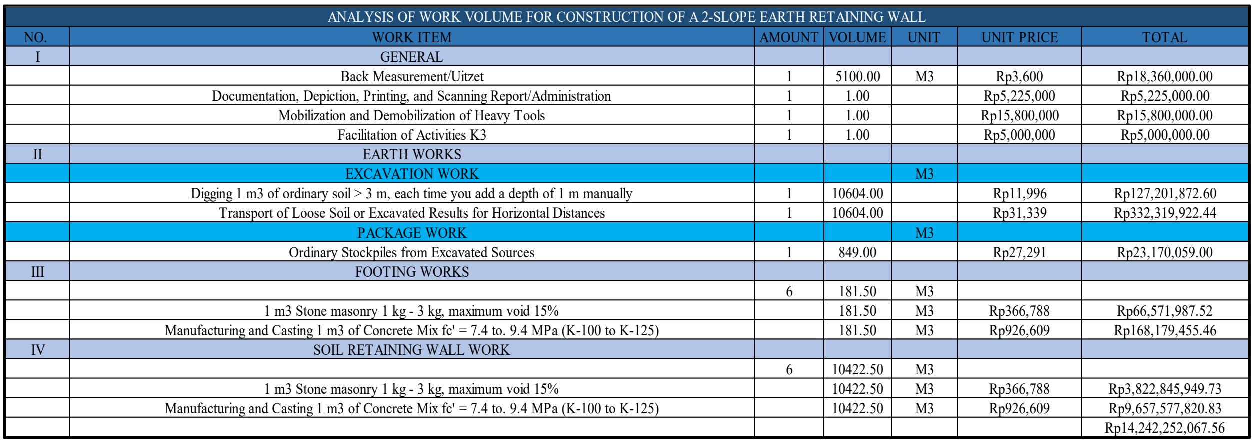
Station	Area	Volume (m$^{3)}$	Cumulative Volume
0+000	52.05	0.00	0.00
0+025	91.61	1795.70	1795.70
0+050	81.58	2164.78	3960.48
0+075	73.16	1934.25	5894.73
0+100	69.68	1785.51	7680.24
0+125	83.29	1912.13	9592.37
0+150	76.33	1995.27	11587.64

The Total Volume Table and Material Table indicate that excavation activities predominate in river normalization work, with a cumulative total volume of 11,587.64 m^3 up to STA 0+150. The maximum excavation volume occurs at STA 0+050, totaling 2,164.78 m^3; however, the backfill need is very minimal, equal to only 882.89 m^3. This signifies that the current river height in the majority of segments exceeds the proposed elevation, requiring substantial soil excavation.

The Material Table data demonstrates a correlation between the cross-sectional area and the computed material volume, with the maximum area recorded at STA 0+025, measuring 91.61 m^2. This volume estimate is essential for assessing material needs, scheduling execution, and planning the management or disposal of excavated materials during the construction process.

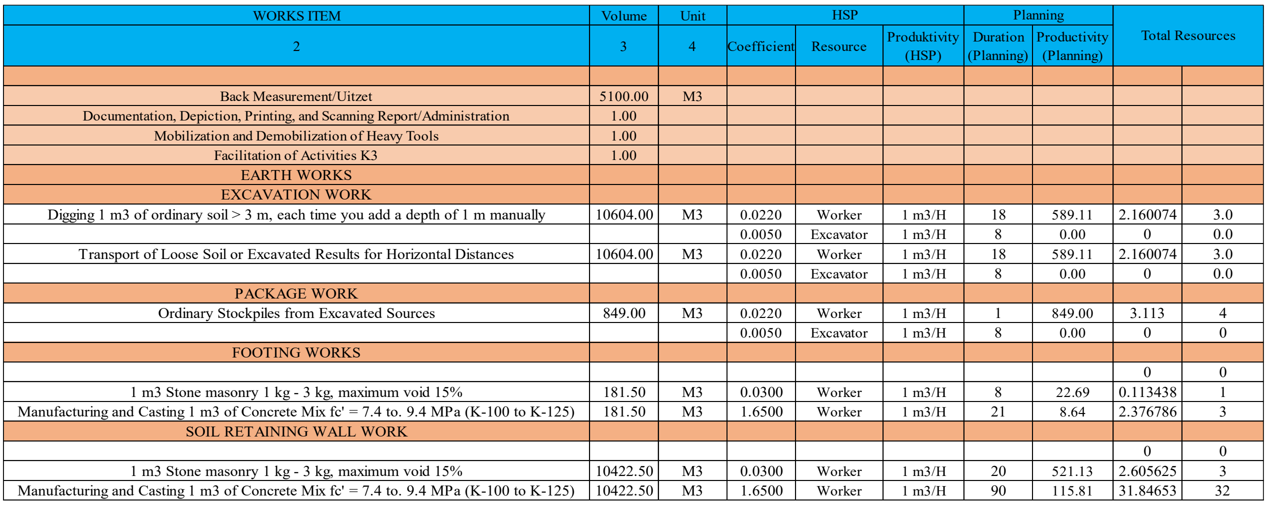
4.3 Scheduling and Cost

After conducting design modelling and volume calculations using the BIM approach, the next step is to compile detailed work durations based on the volume data and types of work that have been determined. This information encompasses all primary and ancillary work items in the project, subsequently assessed to ascertain the time requirements, manpower, and other resources necessary for construction. The outcomes of the BOQ (Bill of Quantities) computations and the standardized work duration schedule are defined below **(Figure 14-16)**.



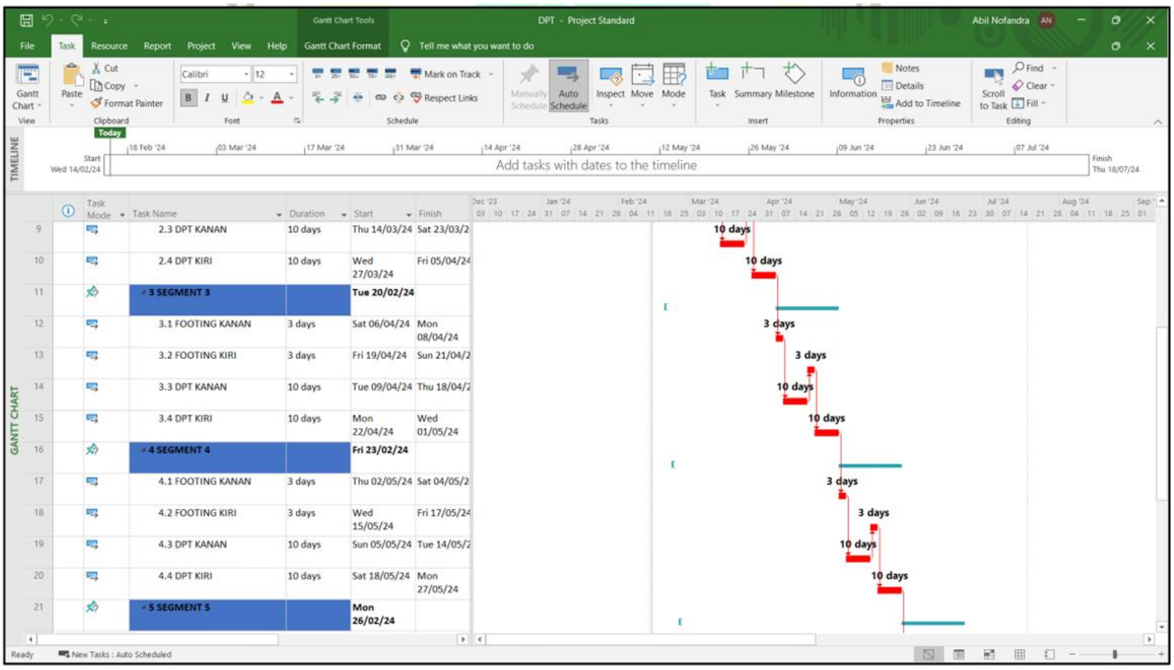
ANALYSIS OF WORK VOLUME FOR CONSTRUCTION OF A 2-SLOPE EARTH RETAINING WALL						
NO.	WORK ITEM	AMOUNT	VOLUME	UNIT	UNIT PRICE	TOTAL
I	GENERAL					
	Back Measurement/Uitzet	1	5100.00	M3	Rp3,600	Rp18,360,000.00
	Documentation, Depiction, Printing, and Scanning Report/Administration	1	1.00		Rp5,225,000	Rp5,225,000.00
	Mobilization and Demobilization of Heavy Tools	1	1.00		Rp15,800,000	Rp15,800,000.00
	Facilitation of Activities K3	1	1.00		Rp5,000,000	Rp5,000,000.00
II	EARTH WORKS					
	EXCAVATION WORK			M3		
	Digging 1 m3 of ordinary soil > 3 m, each time you add a depth of 1 m manually	1	10604.00		Rp11,996	Rp127,201,872.60
	Transport of Loose Soil or Excavated Results for Horizontal Distances	1	10604.00		Rp31,339	Rp332,319,922.44
	PACKAGE WORK			M3		
	Ordinary Stockpiles from Excavated Sources	1	849.00		Rp27,291	Rp23,170,059.00
III	FOOTING WORKS					
		6	181.50	M3		
	1 m3 Stone masonry 1 kg - 3 kg, maximum void 15%		181.50	M3	Rp366,788	Rp66,571,987.52
	Manufacturing and Casting 1 m3 of Concrete Mix fc' = 7.4 to. 9.4 MPa (K-100 to K-125)		181.50	M3	Rp926,609	Rp168,179,455.46
IV	SOIL RETAINING WALL WORK					
		6	10422.50	M3		
	1 m3 Stone masonry 1 kg - 3 kg, maximum void 15%		10422.50	M3	Rp366,788	Rp3,822,845,949.73
	Manufacturing and Casting 1 m3 of Concrete Mix fc' = 7.4 to. 9.4 MPa (K-100 to K-125)		10422.50	M3	Rp926,609	Rp9,657,577,820.83
						Rp14,242,252,067.56

Figure 14. Bill of Quantities for Construction



WORKS ITEM	Volume	Unit	HSP			Planning		Total Resources	
2	3	4	Coefficient	Resource	Produktivity (HSP)	Duration (Planning)	Productivity (Planning)		
Back Measurement/Uitzet	5100.00	M3							
Documentation, Depiction, Printing, and Scanning Report/Administration	1.00								
Mobilization and Demobilization of Heavy Tools	1.00								
Facilitation of Activities K3	1.00								
EARTH WORKS									
EXCAVATION WORK									
Digging 1 m3 of ordinary soil > 3 m, each time you add a depth of 1 m manually	10604.00	M3	0.0220	Worker	1 m3/H	18	589.11	2.160074	3.0
			0.0050	Excavator	1 m3/H	8	0.00	0	0.0
Transport of Loose Soil or Excavated Results for Horizontal Distances	10604.00	M3	0.0220	Worker	1 m3/H	18	589.11	2.160074	3.0
			0.0050	Excavator	1 m3/H	8	0.00	0	0.0
PACKAGE WORK									
Ordinary Stockpiles from Excavated Sources	849.00	M3	0.0220	Worker	1 m3/H	1	849.00	3.113	4
			0.0050	Excavator	1 m3/H	8	0.00	0	0
FOOTING WORKS									
								0	0
1 m3 Stone masonry 1 kg - 3 kg, maximum void 15%	181.50	M3	0.0300	Worker	1 m3/H	8	22.69	0.113438	1
Manufacturing and Casting 1 m3 of Concrete Mix fc' = 7.4 to. 9.4 MPa (K-100 to K-125)	181.50	M3	1.6500	Worker	1 m3/H	21	8.64	2.376786	3
SOIL RETAINING WALL WORK									
								0	0
1 m3 Stone masonry 1 kg - 3 kg, maximum void 15%	10422.50	M3	0.0300	Worker	1 m3/H	20	521.13	2.605625	3
Manufacturing and Casting 1 m3 of Concrete Mix fc' = 7.4 to. 9.4 MPa (K-100 to K-125)	10422.50	M3	1.6500	Worker	1 m3/H	90	115.81	31.84653	32

Figure 15. Analysis of workload.



	Task Mode	Task Name	Duration	Start	Finish
9		2.3 DPT KANAN	10 days	Thu 14/03/24	Sat 23/03/2
10		2.4 DPT KIRI	10 days	Wed 27/03/24	Fri 05/04/24
11		3 SEGMENT 3		Tue 20/02/24	
12		3.1 FOOTING KANAN	3 days	Sat 06/04/24	Mon 08/04/24
13		3.2 FOOTING KIRI	3 days	Fri 19/04/24	Sun 21/04/2
14		3.3 DPT KANAN	10 days	Tue 09/04/24	Thu 18/04/2
15		3.4 DPT KIRI	10 days	Mon 22/04/24	Wed 01/05/24
16		4 SEGMENT 4		Fri 23/02/24	
17		4.1 FOOTING KANAN	3 days	Thu 02/05/24	Sat 04/05/2
18		4.2 FOOTING KIRI	3 days	Wed 15/05/24	Fri 17/05/24
19		4.3 DPT KANAN	10 days	Sun 05/05/24	Tue 14/05/2
20		4.4 DPT KIRI	10 days	Sat 18/05/24	Mon 27/05/24
21		5 SEGMENT 5		Mon 26/02/24	

Figure 16. Bar chart for job duration in MS. Project.

The overall anticipated cost for the building project planning of riverbank retaining walls, as part of river normalization efforts, is Rp14,377,852,621.91. This value is derived from the comprehensive Bill of Quantity (BOQ) encompassing all tasks, including general works, excavation, foundations, and the primary earth-retaining wall construction. This estimate has been created with 3D modelling volume data and unit costs for construction activities (AHSP and HSBGN) for the first quarter of 2023. The project is projected to require 137 calendar days, determined by worker productivity assessments and heavy equipment specifications for each task. This timeframe encompasses all project phases sequentially, considering available resources.

5.0 DISCUSSION

The findings of this study demonstrate that BIM provides significant advantages over conventional design methods in river normalization projects. The obtained safety factor of 1.11 indicates that the retaining wall design satisfies the minimum stability requirement. However, this value is relatively close to the threshold, suggesting that further refinement using more advanced soil models and dynamic loading conditions is necessary. Compared to previous studies, this research extends the application of BIM beyond building and transportation sectors. Fawji et al. (2022) demonstrated BIM integration in hydraulic structures, but its application in riverbank retaining wall design remains limited. This study fills that gap by integrating geotechnical analysis, modelling, and construction planning within a unified BIM framework. Furthermore, the dominance of excavation work identified in this study highlights the importance of accurate volume estimation in cost planning. The BIM-based approach ensures higher reliability in quantity take-off compared to traditional manual calculations.

Nonetheless, this study possesses several drawbacks. The investigation utilized a linear Mohr-Coulomb soil model and static groundwater conditions, which may inadequately capture long-term consolidation effects or extreme flood scenarios. Moreover, the cost estimation was derived from prevailing unit pricing and is subject to change over time. Future research should use updated hydrological data, probabilistic slope stability methodologies, and real-time construction monitoring to further substantiate the advantages of BIM in river normalization initiatives.

6.0 CONCLUSIONS

This study highlights the critical role of BIM as a whole approach rather than just a standalone software, demonstrating its effectiveness in the planning, design, and implementation of infrastructure projects, such as river normalization. Various software applications, including Autodesk Civil 3D, ensure accuracy in design and efficiency in project management. Moreover, the research outlines a cohesive and interconnected workflow, emphasizing the need for software integration in efficient project coordination. The research promotes enhanced dimensional analysis, a sophisticated scheduling methodology to tackle unexpected challenges, and revised soil data to improve slope stability assessments for future implementations. These improvements will optimize the efficiency, safety, and cost-effectiveness of the river normalization project.

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