Quest Journals
Journal of Architecture and Civil Engineering
Volume 8 ~ Issue 5 (2023) pp: 26-38
ISSN(Online) : 2321-8193
www.questjournals.org

Research Paper

A Selection between Conventional and Precast Constructions as Flood Control Effort in Bontang City By Analytical Hierarchy Process (Ahp) Method Approach

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Abstract
Flood control constructions in general are using a conventional construction model by a combination of concrete structures and mountain stone masonry. However, a serious concern and current dilemma relate to exploration of type C excavation material (mountain stones) are ongoing since it can cause erosion and loss of water absorption in the upstream area. However, on the other hand, the use of mountain stone has been considered as the most efficient type of construction among the other construction models for generations. In this study, the authors also want to carry out a migration pattern in the determination of suitable construction type for riverbank reinforcement project.
The research method applied for this study was selecting the proper construction for Bontang Riverbank reinforcement by Analytical Hierarchy Process (AHP) approach. The result of this study found the preference value for Conventional retaining wall was 0.302 while the preference value for Precast retaining wall was 0.698. As finding of this study, it was concluded the Precast retaining wall had better rank compare to the Conventional retaining wall and it suggested to use the Precast retaining wall (in T-shape Gutter style) for the riverbank reinforcement construction project in Bontang city under consideration of a minimum usage of C excavation material. Furthermore, Precast retaining wall brings some positive characteristics such as fast execution time, good tidiness level, also from the use of construction cost aspect which was not so significant to conventional type of construction (Composite retaining wall).
***Keywords**: Conventional retaining wall, Precast retaining wall, Analitical Hierarchy Process.*

***R**eceived 17 May, 2023; **R**evised 28 May, 2023; **A**ccepted 31 May, 2023 © The author(s) 2023.*
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I. INTRODUCTION

The Bontang Riverbank reinforcement construction is one example of a successful flood controls. The success of this development became a benchmark in achieving the priority program of their Regional Government, both from the Bontang City Govenent and the East Kalimantan Provincial Government to be one leading sector of the construction/building of flood control in East Kalimantan Province.

The construction of Bontang riverbank reinforcement stretches from upstream to downstream area with approximate length of 13.8 kilometers, located in Bontang City, East Kalimantan Province and has a purpose for facilitating and improving the river streams to make the balance of Bontang River Catchment Area/Bontang Watershed Area can be maintained and be further enhanced. With its river reinforcement construction, it is expected to be able to reduce floods impact in Bontang city which currently hit the city in frequent times. Moreover, in the future, the river reinforcement construction could brings positive effects on socio-economic condition for areas along the Bontang riverbank in particular also for the Bontang residents in general.

In essence, flood control can be conducted in various ways, however, most important is to consider it altogether to seek the most optimal system. Meanwhile, the flood control activities according to the location/control area can be divided into two activities: (1) in the upstream part by building control dams which able to decelerate or slowing down the flood arrival time also reduce amount of flood discharges, and constructs water reservoirs that can change the pattern of flood hydrographs also reforestation in the watershed area and (2) in the downstream part by repairing the river channels and its embankments, cutting corners on the critical channels, constructing flood control channels, and utilization of inundation area for retarding basin together with other related activities.

Figure 1. An Illustration of Conventional Retaining Wall
Source: Data Survey (2023)

For Bontang City, the flood control in downstream area generally uses a conventional construction model by a combination from concrete structure and mountain stones masonly (stone installment). The highlighted problem which gained serious concern and becomes current dilemma is the exploration of type C excavation material (mountain stone) that undergoes restrictions from the East Kalimantan Provincial Government and having a strict control carried out by the law enforcement officials. Moreover, the government considers excavation of type C material triggers erosion which lead to the loss of water absorption in the upstream area. On the other hand, the use of mountain stone already treated as a hereditary construction model for a riverbank reinforcement construction because it is considered the most efficient construction model among other models.

To this extent, discussions related to decision analysis on selecting types of conventional construction and types of precast construction to be implemented as an effort to overcome floods in Bontang City has not been carried out by many researchers. Thus, problem raised in this study was how to choose a suitable construction method for the Bontang riverbank reinforcement construction with Analytical Hierarchy Approach (AHP) process?

II. LITERATURE REVIEW

2.1 Construction Structure Design

In a construction technical planning, the design of the construction structure is a part of the initial stage, where in this study the authors focused on the design of retaining wall structure or oftenly referred as *Turap* in Indonesia language. Retaining wall is a building structure functions to maintain soil stability for not experiencing shear or landslides. For Tambing, *et.al* (2021) retaining walls are C-1 class concrete with a slump standard of 18 ± 2 and a compressive strength of 20 MPa. In the riverbank areas, retaining wall always has other functions as riverbank building to control the river stream rate also as a deterrent to the high flood overflow that often occur in the river basin/watershed areas.

To carry out the construction of retaining wall, there are several plannings that necessary must be conducted among others as follows:

a. Estimates dimensions or required size from the retaining wall. In selecting the initial dimension of the retaining wall, the authors are assisted by their field experiences and the use of several tables containing ratios between width of base and height of the standard retaining wall.

b. Calculates the amount of soil pressure to the retaining wall, both in analytical and graphical ways.

c. Designing the basis of retaining wall where it must be sufficient to mobilize the bearing capacity of the soil, so any stresses due to construction force plus the other forces do not exceed the allowable bearing capacity.

d. Calculates the structural strength of retaining wall by examining the allowable shear stress and compressive stress of the retaining wall structure.

e. The completed retaining wall must be secure against its sliding stability also its overturning stability.

f. The construction planners need to conduct a review of the environmental location from the retaining wall placement to be built.

There are several factors must be taken into consideration when planning a retaining wall construction such as:

a. The stability of retaining wall must be sufficient to form an active earth pressure and when the pressure decreases, it will not tear the front wall of the reinforcement structure.

b. Additional load impacted on backfill work causes increase pressure in lateral earth pressure and in vertical pressure for each layer of the retaining wall.

c. Corrosion can be a critical factor when the reinforcement material are made of metal. It is suggestive to add a thick reinforcing concrete blanket to resist corrosion process so the building able to last longer.

d. Wall collapse can occur due to pull strength on the reinforcement, and make the bearing capacity of the bottom soil as supporter of the wall slides and impacting on the entire wall slipped.

The earth pressure along with many type of forces acting on the retaining wall are greatly affect the stability of the retaining wall itself. In general, placement or material usage in the wall construction will give strengthen force to the soil mass which also affect piles amount behind the retaining wall. For avoiding collapse incident of the retaining wall which about to be built, it must have stability against several matters of:

1. Any slide/shear movement and wall body decline caused by lateral earth pressure over the wall body.
2. Shear or bending moments from basis of the wall body caused by loading of the wall produces earth pressure on the thread (or base) of the retaining wall.

Soil has tendency to move downwards on a non-horizontal ground surface. The ground movement triggered by gravity, when the weight component of the soil that affected by gravity so large, then its shear resistance will be exceeded and a slope/cliff failure will occur. The resistance strength of the soil against occurance of external forces is called stability, thus, the ability of soil resistance that is not horizontal to the occurring forces called as slope stability (Hardiyatmo, H.C., 2003).

Evaluate the retaining wall stability on slopes becomes crucial since concern about slope stability currently rising due to many occurances of slope failure cases. There were so many observations on slope behaviours which often accompanied by slope failure incidents have led to the development of an understanding about changes in soil parameters over time.

In relation to the ways to achieve its stability, the retaining wall can be classified into several types of:

1. Retaining wall with gravity type or *Gravity Wall*

According to Patola and Wirawan (2023) a gravity-type retaining wall is a construction structure build to hold sloped soil where the stability of the soil is not guaranteed by the soil itself. This wall is made of unreinforced concrete or stone mansory/installment and sometimes equipped with reinforcement that installed on the wall surface to prevent surface cracks due to temperature changes. In addition, for construction project that requires special attention, retaining walls are rarely used. The Gravity Wall is illustrated in figure 2.1 below.

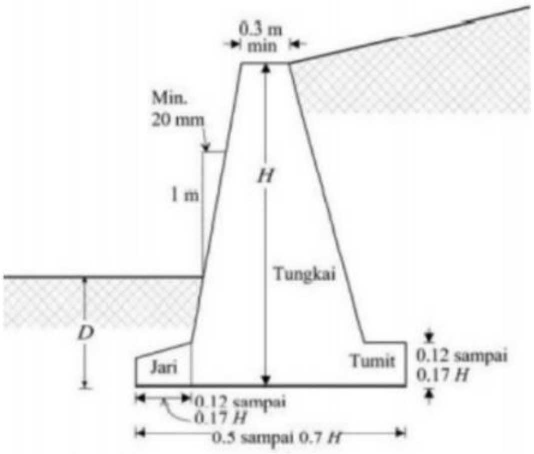

Figure 2. Grafity Wall Type

Source: Badan Standardisasi Nasional Standar Nasional Indonesia Persyaratan Perancangan Geoteknik, 2017

2. Retaining wall with cantilever type or *Cantilever Wall.*

According to Pamungkas (2021), Cantilever Wall consists of a combination of T-shaped reinforced concrete walls. Thickness of both sections is relatively thin and fully reinforced to hold the moment and withstand transverse forces acting on the wall. Its construction stability obtained from the self-weight of the retaining wall and the weight of soil above the heel. There are three parts of the structure function as a cantilever: (a) vertical wall (steem), (2) heel of the tread (heel) and (3) toe of the tread (toe). The height of this type of retaining wall is not more than 6-7 meters. The Cantilever Wall is illustrated in figure 2.2 below.

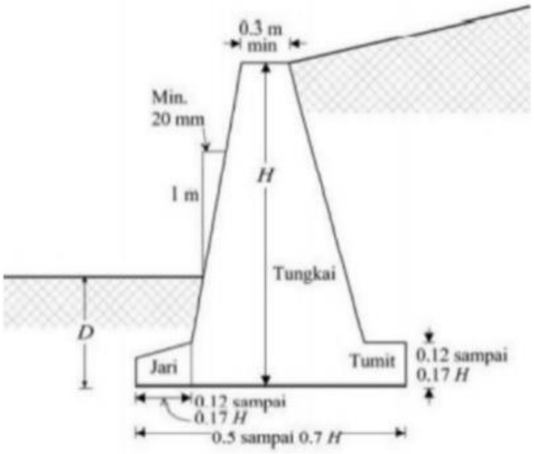

Figure 3. Cantilever Wall Type
Source: Badan Standardisasi Nasional Standar Nasional Indonesia Persyaratan Perancangan Geoteknik, 2017

3. Retaining wall with counterfort type or *Counterfort Wall*

According to Hardiyatno (2014) this wall consists of a thin reinforced concrete wall which on the inside at a certain distance is supported by vertical plates or walls called as counterforts (reinforcing walls). Space above the foundation plate filled with land soil, thus, when active earth pressure on the vertical wall is large enough then the vertical wall and heel sections need to be merged to create a counterfort.Counterfort functions as a vertical wall tension binder and placed on the embankment at certain intervals. The counterfort walls will be more economical to use if height of the wall is more than 7 meters. Planning the retaining wall dimensions for the counterfort system, for instance with width of 0.45H to 0.75H, the counterfort wall can be placed at a distance of 0.30 H to 0.60 H, with a thickness of not less than 20 centimeters. The counterfort height should be the same as the vertical wall height, but if a smaller height is desired, it can be reduced by 0.12H to 0.24H. The Counterfort Wall is illustrated in Figure 2.3 below.

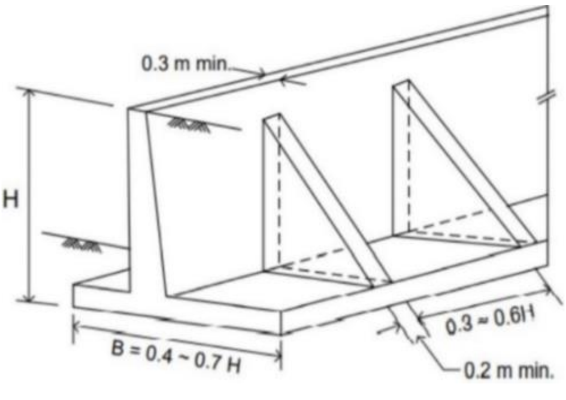

Figure 4. Counterfort Wall Type
Source: Badan Standardisasi Nasional Standar Nasional Indonesia Persyaratan Perancangan Geoteknik, 2017

2.2. Analysis of AHP

AHP is a decision support method develop by an Iraqi-born mathematician professor at the University of Pittsburgh, Saaty (2012). AHP is a method to create sequence of alternative decisions and to select the best alternative when a decision maker has several objectives or criterias in making an important decision.

First step in carrying out this analysis is creating a paired matrix for risk frequency and risk impact that obtained from the assessment of each criterion in accordance with table 2.6 (AHP Rating Scale Table). For carrying out the weighing and risk assessment by Analysis of Hierarchy Process (AHP) method, it started by creating a pairwise matrix for the risk frequency and the risk impact, determining the matrix weighing, calculating the matrix consistency, determining risk factor values and determining Ranking and Risk level.

Table 1. AHP Rating Scale
Source: Fundamental Scale of AHP (Saaty, 2012)

Intensity of Importance	Definition	Explanation
1	Equal Importance	Two elements contribute equally to the objective
3	Moderate importance of one over another	Experience and judgment strongly favor one element over another
5	Essential of strong importance	Experience and judgment strongly favor one element over another
7	Very strong importance	An element is strongly favored and its dominance demonstrated in practice
9	Extreme importance	The experience favoring one element over another is of the highest possible order of affirmation
2,4,6,8	Intermediate values between the two adjacent judgments	Compromise is needed between two adjacent values

III. RESEARCH METHOD

3.1 Location and Research Sample
The location of this study was the site of Bontang Riverbank Reinforcement Construction located on the Bontang riverbank with the characteristic of riverbank reinforcement for ± 120 meters in length and ± 6 meters in height. The selected sampling technique for this study was non-random sampling or also known as non-probability sampling with the composite wall as representative of conventional retaining wall and T-shape gutter as representative of precast retaining wall.

3.2 Data Collection
In this study, the authors applying both source of data; the primary and secondary data with following description as follow:

1. Primary Data, including:
- Collection of the sample of soil's carrying capacity taken by Sondir and Boring Log tests.
- Calculation of Construction Design for Precast Retaining Wall and Composite Retaining Wall.
- Calculation of Unit Price Analysis for each product model
- Analysis Calculation of CPM Method for testing the work execution time.

2. Secondary Data, including:
- Construction material basic price (vendor price survey or HSP of Bontang City)
- Construction workers' wage basic price (UMK or HSP Bontang City)
- Data of Equipment Production Capacity (brochure or tool manual book).
- Other supportive literature for this research (SNI standard)

Whereas the dependent and independent variables in this study are:

1. Dependent variable (constraint): low implementation costs, short implementation time, low use of type C material (mountain stone/quarry stone).
2. Independent variable (free): Conventional retaining wall (Stone Mountain Composite Retaining Wall) and Precast retaining wall (T-shape Gutter Retaining Wall).

3.3 Data Analysis by Application of AHP
For this study, the authors were applying the AHP (Analytical Hierarcy Process) concept approach. Here, the authors describe the thinking framework in selecting alternatives from several criterias determined for selecting type of riverbank reinforcement construction as illustrates below.

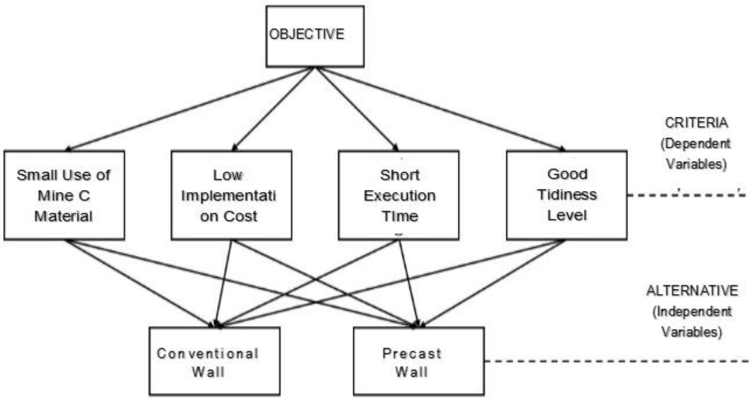

Figure 5. Diagram of Decision

The stages of AHP (Analytical Hierarcy Process) are explained as follow:
1. Problem decomposition by systematical description.
2. Assesment or weighing to compare elements in each hierarchy based on their relative importance.
3. Arrange a pairwise matrix to normalize weight of the importance level of each element in their respective hierarcy.
4. Setting priority in every hierarchy.
5. Decision making or determining decision. This is a process where the alternatives made were selected to find the best decision based on the established criterias.

3.4 Research Flowchart

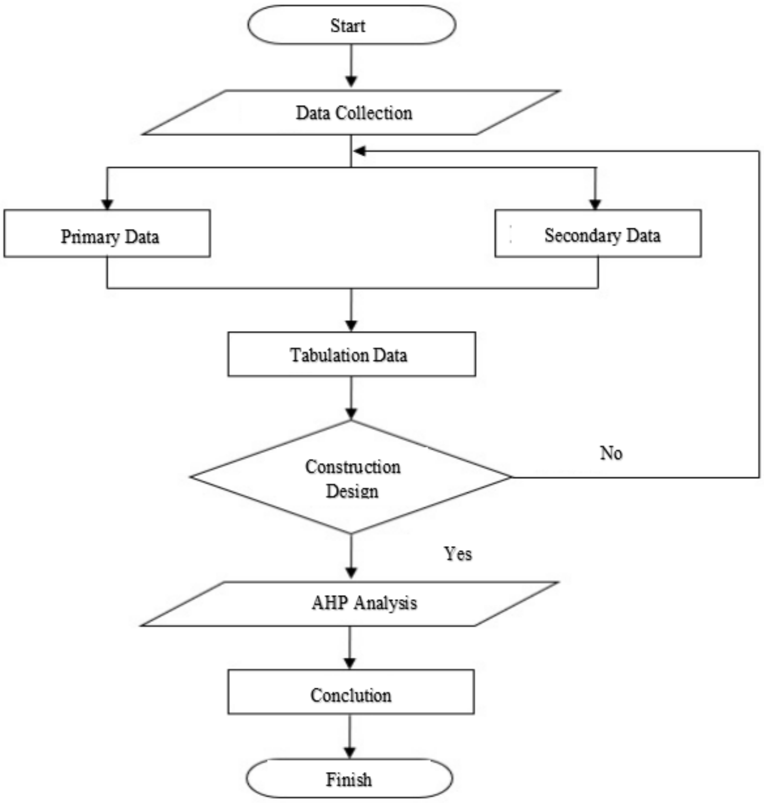

Figure 6. Research Flowchart

IV. RESULT AND DISCUSSION

4.1. The Construction Design

1. Conventional Retaining Wall (*Composite Wall*)

The following section is the result of construction design in the form of Composite Retaining Wall Plan drawings (The Loading Design of Conventional Retaining Wall is attached).

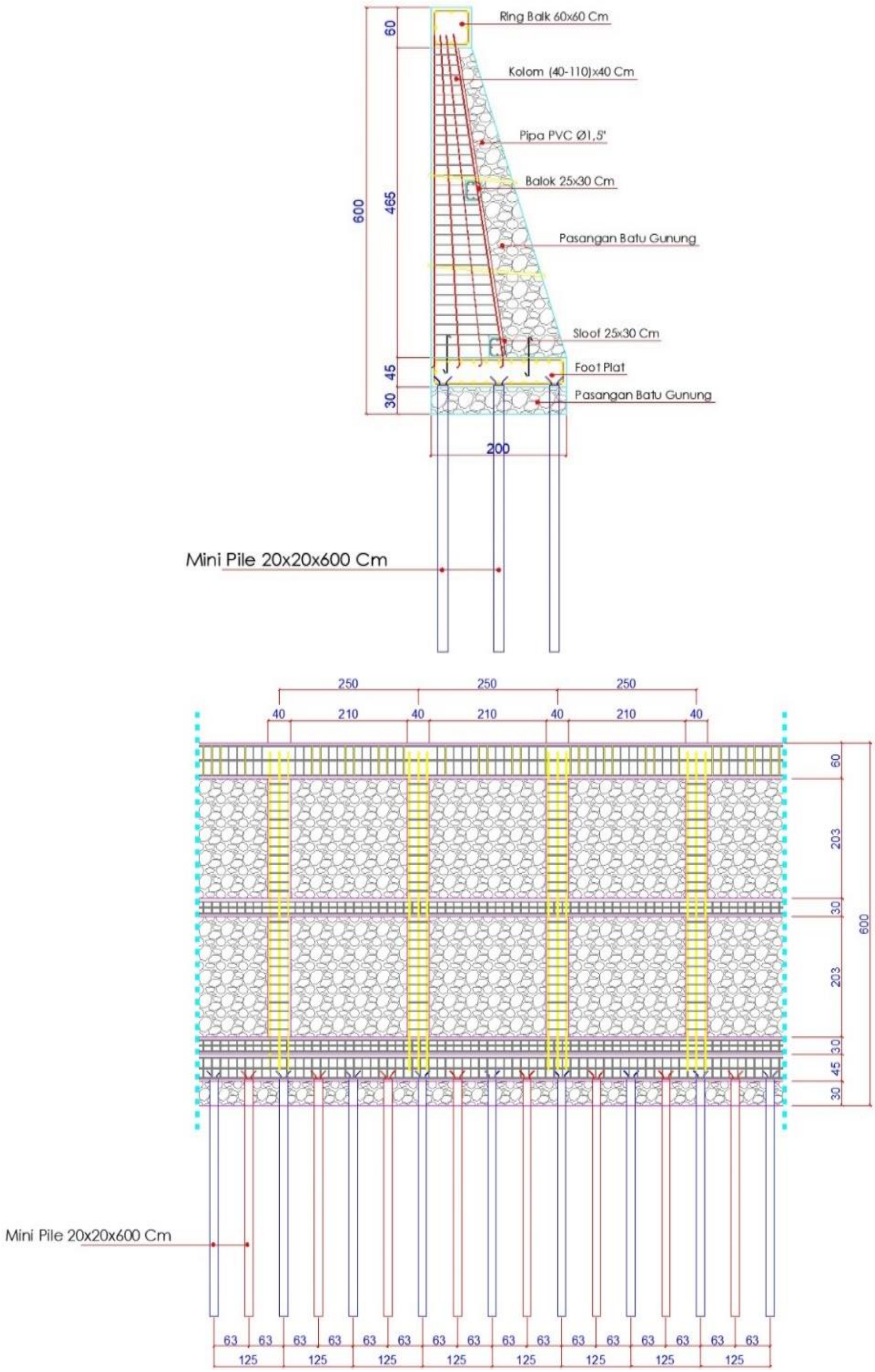

Figure 7. Composite Wall (Side View and Front View)

2. Precast Retaining Wall (*T-Shape Gutter Wall*)

The following section is the result of construction design in the form of T-Shape Gutter Wall drawings (The Loading Design of Precast Retaining Wall is attached).

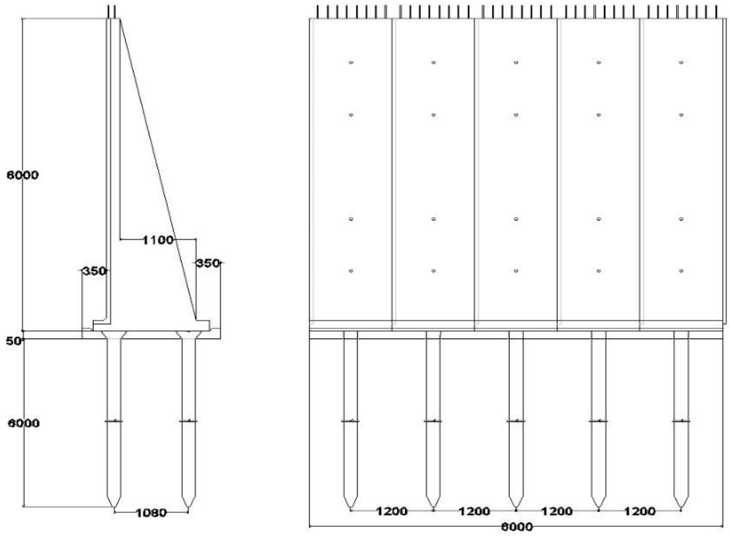

Figure 8. T-Shape Gutter Wall (Side View and Front View)

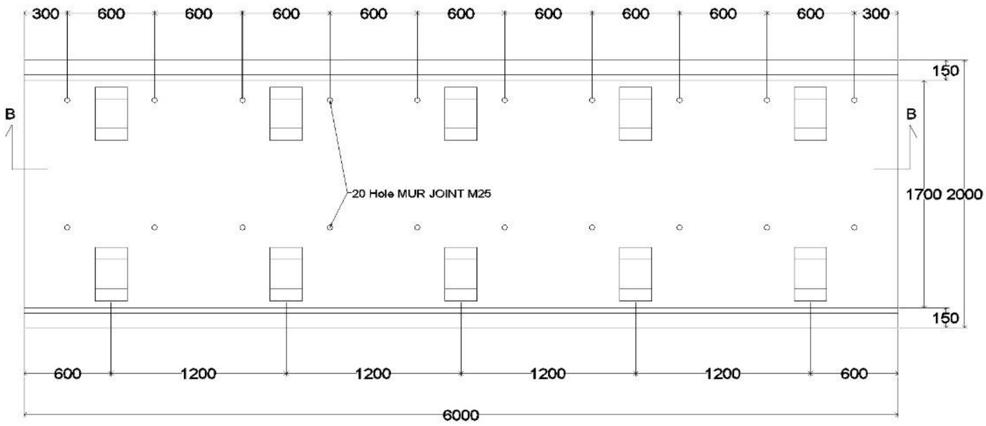

Figure 9. T-Shape Gutter Wall (Foundation View)

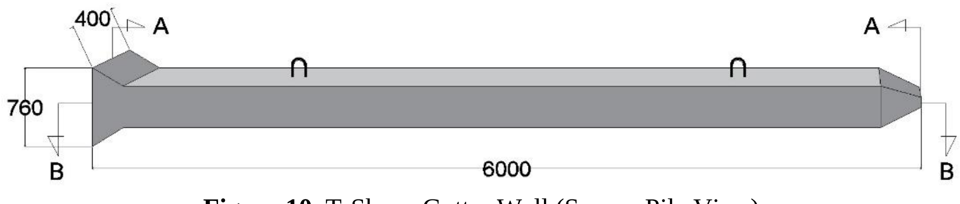

Figure 10. T-Shape Gutter Wall (Square Pile View)

4.2. Analytical Hierarchy Prosess (AHP)

In making a decision by AHP method application, the authors carrying out stages of decision-making analysis as stated below.

1. Make a problem definition.

In this stage, the authors define the study problem in a relationship between the objectives, criterias and alternatives. Definition of the problem discussed is also explained by the authors in research methodology chapter in data analysis section (Figure III.1 The Diagram of Decision)

2. Decide the Prioritize Element Criteria

By several stages as explained below.

- Analyze Pairwise Comparison from each criterion.

The authors analyze the pairwise comparison of each criterion with an objective approach then put inside into the following table.

Table 2. Pairwise Comparison for Each Criterion

Intensity of Importance	Description
7	Small use of Mine C material is ABSOLUTELY MORE IMPORTANT than Good Tidiness Level
5	Small use of Mine C Material is MORE IMPORTANT than Short Execution Time
5	Low Implementation Cost is MORE IMPORTANT than Good Tidiness Level
3	Small Use of Mine C material is SLIGHTLY MORE IMPORTANT than Low Implementation Cost
3	Low Implementation Cost is SLIGHTLY MORE IMPORTANT than Short Execution Time
3	Short Execution Time is SLIGHTLY MORE IMPORTANT than Good Tidiness Level
1	Two elements compared are THE SAME (having the same importance level)

- Creating A Pairwise Comparison Matrix

Before making a pairwise comparison matrix of each criterion, the author started with a symbol creation to represent the name of each existing criterion such as letters that stated below:

A = Small Use of Mine C Material
B = Low Implementation Cost
C = Short Execution Time
D = Good Tidiness Level

Table 2. Pairwise Comparison Matrix for Each Criteria

OBJECTIVE /GOAL		CRITERIA			
		A	B	C	D
CRITERIA	A	1	3	5	7
	B	0,33	1	3	5
	C	0,20	0,33	1	3
	D	0,14	0,20	0,33	1

3. Synthesis of Criteria

Table 3. The Calculation of Criteria Matrix

OBJECTIVE /GOAL		CRITERIA			
		A	B	C	D
CRITERIA	A	1	3	5	7
	B	0,33	1	3	5
	C	0,20	0,33	1	3
	D	0,14	0,20	0,33	1
Σ		1,68	4,53	9,33	16,00

- Calculating the Normalize Matrix Value (Eigen Value).

Under provision of dividing each value from the column by the related total coloumn.

Table 4. The Normalize Matrix Value (Eigen Value)

OBJECTIVE /GOAL		CRITERIA				EIGEN VALUE			
		A	B	C	D				
CRITERIA	A	1	3	5	7	0,60	0,66	0,54	0,44
	B	0,33	1	3	5	0,20	0,22	0,32	0,31
	C	0,20	0,33	1	3	0,12	0,07	0,11	0,19
	D	0,14	0,20	0,33	1	0,09	0,04	0,04	0,06
Σ		1,68	4,53	9,33	16,00				

- Calculating the Normalize Matrix Value (Eigen Value)

Table 5. The Calculation of Normalize Matrix Value (Eigen Value)

OBJECTIVE /GOAL		CRITERIA				EIGEN VALUE				Total Eigen Value
		A	B	C	D					
CRITERIA	A	1	3	5	7	0,60	0,66	0,54	0,44	2,23
	B	0,33	1	3	5	0,20	0,22	0,32	0,31	1,05
	C	0,20	0,33	1	3	0,12	0,07	0,11	0,19	0,49
	D	0,14	0,20	0,33	1	0,09	0,04	0,04	0,06	0,23
Σ		1,68	4,53	9,33	16,00					

- Calculating the Average Normalize Matrix Value (Eigen Value)

Under provision of dividing each number of Eigen values from each criterion row by the number of existing criterion elements.

Table 6. The Calculation of Average Normalize Matrix Value (Eigen Value)

OBJECTIVE /GOAL		CRITERIA				EIGEN VALUE				Total Eigen Value	Average Eigen Value
		A	B	C	D						
CRITERIA	A	1	3	5	7	0,60	0,66	0,54	0,44	2,23	0,56
	B	0,33	1	3	5	0,20	0,22	0,32	0,31	1,05	0,26
	C	0,20	0,33	1	3	0,12	0,07	0,11	0,19	0,49	0,12
	D	0,14	0,20	0,33	1	0,09	0,04	0,04	0,06	0,23	0,06
Σ		1,68	4,53	9,33	16,00						1,000

The average value of the matrix normalization value (the average of Eigen value) describes level of importance from an element in each of the existing criteria. The higher the average value, the higher its importance level.

4. Measuring the Criteria Consistency

In the decision making stage, consistency level is crucial to guarantee there will be no low consistency value in the decision making process. The maximum value of Consistency Ratio (CR) ≤ 0,1 or 10%. Whereas for the steps will be taken in this process are explained as follow:

- Calculating the Consistency Indeks (CI)

With formula of:

$CI = \frac{(\lambda\ maks - n)}{n-1}$ ....(IV.1)

Where:

n = number of Criteria Elements
= 4

λ max = Σ {(number of coloumn element) x (average of Eigen elemen)}
= (1, 68x0, 56) + (4,53x0, 26) + (9, 33x0, 12) + (16, 00x0, 06)
= 4,177

So, CI = $\frac{(4{,}177-4)}{(4-1)}$ = 0,059

- Calculating the *Index Random* (IR)

With formula of:

$IR = \frac{1{,}98\ (n-2)}{n}$ ....(IV.2)

Where:

1, 98 = Provision Value

n = number of Criteria Elements
= 4

So, IR = $\frac{1{,}98\ (4-2)}{4}$ = 0, 99

- Calculating *Consistency Rasio* (CR)

With formula of:

$CR = \frac{CI}{IR}$ ....(IV.3)

Where:

CI = *Consistency Indeks*
= 0,059

IR = *Indeks Random*
= 0,99

So, CR = $\frac{0{,}059}{0{,}99}$ = 0,059 ⇨ 0,059 ≤ 0,1 ....*(consistent)*

After conducted a comparative analysis to the criterias, the next step of this study was to carry out a comparative analysis to the alternatives taken based on the criteria used. Stages of analysis were the same as the comparative analysis of the criteria. The analysis is displayed below.

a. Analysis of Small Use of Mine C Material

Table 7. Alternative on the Criteria of Small Use of Mine C Material

Small Use of Mine C Material		ALTERNATIVE		EIGEN VALUE		Total Eigen Value	Average Eigen Value
		Conventional Wall	Precast Wall				
ALTERNATIVE	Conventional Wall	1	0,14	0,13	0,13	0,25	0,13
	Precast Wall	7	1	0,88	0,88	1,75	0,88
Σ		8,00	1,14				

b. Analysis of Low Implementation Cost

Table 8. Alternative on the Criteria of Low Implementaiton Cost

Low Implementation Cost		ALTERNATIVE		EIGEN VALUE		Total Eigen Value	Average Eigen Value
		Conventional Wall	Precast Wall				
ALTERNATIVE	Conventional Wall	1	3	0,75	0,75	1,50	0,75
	Precast Wall	0,33	1	0,25	0,25	0,50	0,25
Σ		1,33	4,00				1,00

c. Analysis of Short Execution Time

Table 9. Alternative on the Criteria of Short Execution Time

Short Execution Time		ALTERNATIVE		EIGEN VALUE		Total Eigen Value	Average Eigen Value
		Conventional Wall	Precast Wall				
ALTERNATIVE	Conventional Wall	1	0,20	0,17	0,17	0,33	0,17
	Precast Wall	5	1	0,83	0,83	1,67	0,83
Σ		6,00	1,20				1,00

d. Analysis of Good Tidiness Level

Table 10. Alternative on the Criteria of Good Tidiness Level

Good Tidiness Level		ALTERNATIVE		EIGEN VALUE		Total Eigen Value	Average Eigen Value
		Conventional Wall	Precast Wall				
ALTERNATIVE	Conventional Wall	1	0,33	0,25	0,25	0,50	0,25
	Precast Wall	3	1	0,75	0,75	1,50	0,75
Σ		4,00	1,33				1,00

The final step was analyzing the preferences of each alternative based on criterias used by the following formula:

Alternative Rank = Σ {(average value of Eigen Criteria x (average value of Eigen alternative)}

Table 11. Alternative Rank

CRITERIA		ALTERNATIVE			
Type	Average Eigen Value	Conventional R.Wall		Precast R.Wall	
		Average Eigen Value	Rank Value	Average Eigen Value	Rank Value
a	b	c	d = b x c	e	f = b x e
Small Use of Mine C Material	0,56	0,13	0,070	0,88	0,488
Low Implementation Cost	0,26	0,75	0,198	0,25	0,066
Short Execution TIme	0,12	0,17	0,020	0,83	0,102
Good Tidiness Level	0,06	0,25	0,014	0,75	0,043
Total Ranking (Σ)			0,302		0,698

The correction indicator of preferences from each alternative was to add up total ranking of these alternatives as explained below:
Correction Indicator = Σ Conventional Retaining Wall + Σ Precast Retaining Wall
= 0.302 + 0.698
= 1…………… (*Ok*)

V. CONCLUTION

Rank: 1 (one) when the result from correction indicator is equal to 1 (one), then the above calculation can be declared as a correct result. The highest preference value is the alternative chosen in making decisions regarding the suitable type of construction that will be used or will be functioned as an effort to control frequent floods occurances in Bontang City. The selected type of reinforcement construction plan is the Precast Retaining Wall.
From several analysis held in this study, the result of *Analytical Hierarchy Process* was obtained in quantitative form with details stated below.

a. The Preference of Conventional Retaining Wall
- Value : 0, 302
- Rank : 2 (two)

b. The Preference of Precast Retaining Wall
- Value : 0.698
- Rank: 1 (one)

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