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Analysis of Retaining Wall Calculations in the Pollux Meisterstadt Habibie Batam Project with Indian Standard

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A B S T R A C T

Soil retaining wall infrastructure is an important supporting structure in preventing soil cladding. This infrastructure has as much in the city as a basement development. The design of the infrastructure requires effective and efficient standardization and with the difference in standardization of other countries, it does not hurt to try to use foreign standards to find out the difference. This research aims to analyze the moment of upsizing, shearing force with Indian Standard where data obtained from the field. The methods that have been used for this analysis are observational studies, literatures and interviews with consultants. In this research, the author produced calculations by the author regarding the reinforcements used in the field with SNI and the results of comparisons calculated by the author with the Indian Standard. This analyst started from calculating the moment of scrolling, the sliding force that will occur on the retaining wall then from the moment and we got the required reinforcement on the retaining wall. With existing loads and factors used according to Indian standards, especially in IS 456-2000. The resulting report on the results of comparison and the cause of the need for reinforcements realized with those that have been taken into account.

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1. Introduction

The standard used in Indonesia is the Indonesian National Standard (SNI). The SNI policy is used by all development products in Indonesia where SNI guarantees the quality and safety. In infrastructure which is a supporting structure in the main structure is also built with SNI, the soil retaining wall of the development and design policy can use SNI 8460 2017 [1] as the alloy. Infrastructure is a structural system needed for economic guarantees, meaning technical or physical infrastructure that supports a network of structures. Infrastructure is very important because in addition to the main structure, supporting structures are very helpful in human life and support various main structures. Pollux property is one of the property developers that focuses exclusively on property development in the modern era. Construction starts from the work on the lower structure of the building or foundation to the upper structure. One of the pollux properties projects is Meisterstadt Batam.

Pollux Meisterstadt is located on Jl Ahmad Yani, Batam Center, Riau Islands, Indonesia. Where this project is a collaboration between PT Pollux Properti Indonesia and the 3rd President of Indonesia Prof. Dr. Ing. BJ Habibie built a Mega Superblock on 9 acres of land. Because this project has a basement, a retaining wall is needed. The retaining wall of the soil is useful for resisting the force caused by the ground behind the wall [2] [3]. Retaining wall is a structure designed to maintain and maintain two different ground elevation faces [4] [5]. With the construction of a retaining wall in Pollux's consultants have used SNI, the author will compare with Indian standards due to the similarities in the climate of Indonesia and India as well as differences in aspects such as checking the overturn and sliding [6] [7] on the pedestal and will find out whether Indian standardization can be applied or not.

Jeremiah Hadibroto P in 2019 [8] ever analyzes the stability of the soil retaining wall in the basement including the calculation of the coefficient of active soil pressure (Ka), horizontal pressure of the soil (Pa), analysis of shear, rolling, and carrying capacity of soil permits. On the sloping ground surface, the force of gravity will push the ground down [9] [10] [11]. The author aims to find out the stability of the retaining wall in the basement of the Sky View Setia Budi apartment hut construction project. The lateral soil pressure caused by the ground behind the retaining wall, tends to roll over the wall with a center of rotation at the end of the front foot of the foundation plate [12] [13]. The results of this study are the assumption of the initial dimensions of the soil retaining wall, already safe against rolling stability and soil carrying capacity but not safe against shear stability. In another study, Gali Pribadi (2019) [14] analyzed and took into account on the planning of the design of the construction of the earth retaining wall. Ramadhan (2020) [15] also provided the results of the analysis that the strength of the retaining wall can withstand the load of landfills and avalanches that occur in East Kalimantan.

Indian uses IS 456-2000 to designs the dimensions of the retaining wall [16]. Chalisgaonkar (2020) got a conclusion from his research that Wherever the retaining walls are built to retain soil and resist the lateral pressure of the soil against the wall only, earth face of wall with negative batter be constructed to achieve economy without sacrificing safety [17]. The research of Keerthi, etc in 2019 tells that retaining wall is a rigid one which supports the soil mass at the different levels and also soils with different sloped profiles, reinforced retaining walls uses reinforcing steel to take care of thetension forces and stresses being developed in the concrete mass [18]. This study aims to determine the stability of the carrying capacity of the soil retaining wall is greater than the pressure of the soil sliding and rolling without leaving economic factors.

The result of this study is that the use of shoring piles is declared safe and able to withstand cladding and rolling forces. From all previous studies using SNI standards, researchers want to make a comparison between calculations using SNI Standards compared to Indian Standards to see the stability of each Standard. The resulting output is a profile of the

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soil retaining wall of each standard. The purpose of this study is to find out the moment of rolling that occurs when using Indian standards, find out the shear force that occurs if using Indian standards, find out the reinforcement used according to the moment and shear force that occurs and compare it with Indonesian standards.

2. Research Method

2.1 Stages of Research

This section contains research design or research design, research targets and targets (population and samples), data collection and analytical techniques [19]. This research began with a literature review and secondary data collection, then obtained data and planning results from the consultant, from secondary data the researcher re-planned the manual with the is 456: 2000 standard [20]. The results of the manual design are compared with the consultant's data and discussed then get conclusions and suggestions then completed.

2.2 Research Location

This study was conducted at the location of Jl. Laksamana Bintan, Simpang Frangky, Batam City District, Batam City, Riau Islands 29444. The object of this study is the retaining wall or soil retaining wall structure in the construction of the Pollux Meisterstadt Habibie Project. Where this retaining wall holds the ground around the basement of the apartment which has a height of 4.75 m. The data that is inhabited is secondary data. In this study, the secondary data used were data on retaining wall plan drawings, durability carrying capacity values, point location drawings, and borehole 1 data.

3. Description and Technical

3.1 Definition of Retaining Wall

Retaining wall is one of the constructions which have functions of holding loose soil, resisting the occurrence of shifts or the completeness of the sloping soil, and providing stability to the slope [21] The soil retained by the structure has an active pressure or push on the structure of the retaining wall so that the structure is designed to prevent overturning or shifting.

3.2 Types of structure retaining wall

Based on the way to achieve stability, the structure of the soil retaining wall is classified into several types, namely, the type of clasp-type soil retaining wall or it can be called a cantilevered soil retaining wall, then there is also a mass soil retaining wall or gravity retaining wall, there is also a counterfort type soil retaining wall, turap type retaining wall or sheet pile, gabion retaining wall, reinforced wall-type soil retaining wall, and the latter concrete block type retaining wall. Some types of soil retaining walls are as follows [22].

- Gravity Type Soil Retaining Wall (Gravity Wall)

Gravity-type soil retaining walls are a wall that hold the soil by relying on their weight to achieve soil stability. This type of soil retaining wall can be used for various things such as withstanding lateral soil pressure on soil deposits or it can be soil on sloping to steep cliffs. The material or materials used in this type of resistant retaining wall are usually masonry but can also be reinforced concrete. In this type of soil retaining wall, reinforcement is installed because it prevents surface cracks due to temperature changes where the reinforcement is located on the surface of the wall. This type of earthen retaining wall usually has a height of no more than 4 metres. In Figure 1 is a gravity-type soil retaining wall where the figure has a force acting on the wall.

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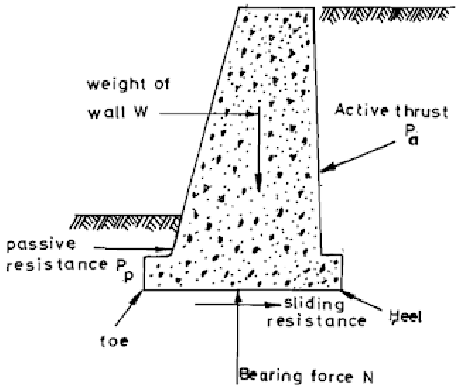


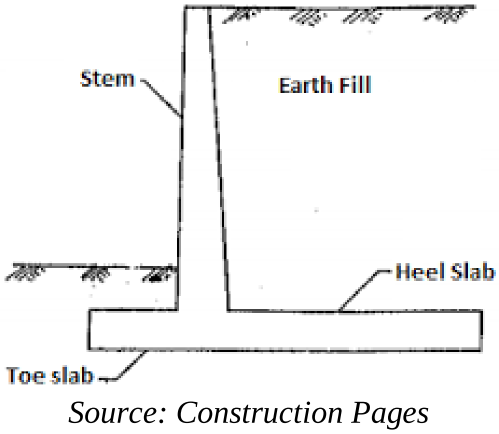
Source: Pengadaan's Blogsite

Figure 1. Gravity Ground Retaining Wall

- Cantilever Type of Soil Retainning Wall

This cantilever-type soil retaining wall [23] is formed from a mixture between the wall and the reinforced concrete foundation which has the look of the letter T. This type of soil retaining system is similar to the semi-gravity type, but the cantilever has a fairly thin level, because it uses steel reinforcement that will support the moment and latitude force. In general, this cantilevered earthen retaining wall is built with a height of about 5 to 7 metres. The working principle of this type of soil retaining wall relies on clamping power, where the elongated palm-shaped wall is cantilever clamping and maintaining stability from the pressure of the soil and on the cliff. The cantilever retaining wall is made of concrete composed of floor treads and vertical walls.

In Figure 2 shows that this type of soil retaining wall has 3 parts of the structure, namely the vertical wall or called stem or ground retaining wall body, then there is also the end of the tread foot which is usually referred to as the toe usually located at the front and in the passive ground pressure section, finally, the heel of the tread or what is usually referred to as a heel, this part is usually located in the defending or in the area on the ground or material to be held.



Source: Construction Pages

Figure 2. Cantilever Ground Retaining Wall

- Counterfort Type Soil Retaining Wall

Contrafort wall is a retaining wall [24] where the part of the wall that is vertically directed or its body with the heel wall or base is put together so that the pressure of the soil held can be channeled in various directions. As in Figure 3, this wall is composed of reinforced concrete walls where the thickness is quite thin. In general, this wall is used in retaining wall structures that have a height of more than 7 metres because this type of wall is much more economical but there are still shortcomings in this type of wall where the design and

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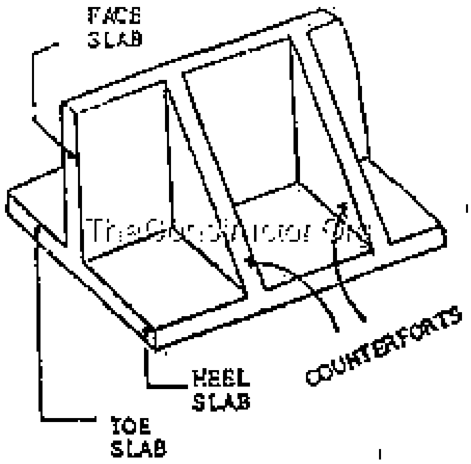
construction are quite complicated. Additionally walls of this type are used in case of activeness of the retained soil itself.



Source: theconstructor.org

Figure 3. Retaining Wall Counterforts

If the type of soil held by the wall has a large enough active soil pressure, it can affect the vertical wall of the retaining wall. The counterfort serves as a vertically pulling fastener of the wall and is placed on the part of the heap soil or material or soil that is held between the distances of the counters known to be taken into account to prevent overturning. Later the residual space on the plates is filled with urug soil.

3.3 Checking on Overturn

The force reacting to the retaining wall of the ground [19] based on the assumption of the Rankin theory the active pressure occurs along the vertical wall to the heel of the tread.

$$P_p = \frac{1}{2} Kp\gamma_2 D^2 + 2c'_2\sqrt{K_p D} \quad (1)$$

Where:
γ_2 = specific gravity of the soil in front of the heels of the footwear and under the tread / slab
K_P = Passive soil pressure coefficient
c'_2 = Cohesion
$\emptyset_2$ = Swipe Angle

Safety factor against the return of the toe of the tread.

$$FS = \frac{\sigma M_R}{\sigma M_O} \quad (2)$$

Where:
σM_R = Total moments of force that prevent overturning from occurring
σM_O = Total moments of force that cause overturning

3.4 Checking for Sliding Along the Base

Faktor The safety factor against shifting [25] can be expressed by the following equation.

$$FS = \frac{\sigma F_{R\prime}}{\sigma F_d} \quad (3)$$

Where:
$\sigma FR'$ = Total horizontal force that resists shift
σFd = Total horizontal force drive

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4. Results and Discussions

The data known to the retaining wall of the soil to be analyzed can be seen in Table 1.

Table 1. Planning Data

No.	Parameters	Values	Unit
1	Height of Earth Retaining Wall	3.75	m
2	Foundation Depth	1	m
3	Safe Bearing Capacity Tanah	24	kN/m2
4	Friction Concrete and Soil	0.6	kN/m3
5	Angle	30	
6	Thickness of the upper vertical wall	0.25	m
7	Bottom vertical wall thickness	0.45	m
8	Concrete Quality	K-300	
9	Reinforcement	BJ 41	

Source: Personal Data Research Results, 2022

Table 1 was collected from the contractor on the field project. Concrete quality that used on the project was K-300 that due to the rule of Indonesian Standard on SNI. The reinforcement used BJ 41 from the consideration of the consultant.

Proportions of Retaining Walls could be determined from the calculation below.
- Base Thickness: [1/10 – 1/14] H : 0,4 m
- Working Floor Width: [0,5 – 0,6] H : 2,8 m
- Heel Width: [1/3 – 1/4] H : 1,2 m

H = h' +Df

Where:

$$D_f = \frac{SBC}{\gamma}\left[\frac{1-\sin\emptyset}{1+\sin\emptyset}\right]^2 \quad D_f = \frac{230}{25}\left[\frac{1-\sin 30}{1+\sin 30}\right]^2 = 1$$

$$H = h' + D_f = 3{,}75 + 1 = 4{,}75$$

4.1 Data Stem

Stem data calculations can be seen in Table 2 below.

Table 2. Recapitulation of Stem Data Calculations

No.	Parameters	Values	Unit
1	K_a	0.333	
2	P_a	78.765	kN
3	M	114.21	kN - m
4	M_u	171.31	kN - m

Source: Personal Data Research Results, 2022

The calculation of ultimate moment (M_u) resulted a value of 171.31 KNm. This M_u will be used to now the dimensions of the profile. The moment from all of the profile should be compared to the ultimate moment to know the profile was safe or not.

<u>Design within 1 metre</u>

$$\text{Min. Ast} = \frac{0{,}85}{Fy}bd = \frac{0{,}85}{410}1000.45 = 932\ mm^2$$

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- Trial D10@300mm Cts.

Trial with D10@300mm Cts could be seen in Table 3 below.

Table 3. Recapitulation of Trial Calculation from D10@300mm Cts

No.	Parameters	Values	Unit
1	γ	0,85	
2	k_u	0,551	
3	M_c	188	kNm

Source: Personal Data Research Results, 2022

$M_C = 188$ kNm > 171.31 (M_u), So that will be OK!

<u>Curtailment of Bars-stem</u>

Curtail 50% steel from above

$$\left(\frac{h_1}{h_2}\right)^2 = \left(\frac{h1}{4.75}\right)^2 = \frac{1}{2}$$

h_1=3.36m

Cut off point = 3.36 - Ld = 3.36 – 47 x Reinforcement diameter = 2.89 m from above with 300 mm cts.

Development length = 47x10 = 470 mm

For secondary reinforcement, because of pressure we can use 0.12% from base area. So, 0.12/100 x 500 x 1000 = 600 mm^2. We could use reinforcement D8 – 300 mm cts. Because the distribution reinforcement is also the same, the necessary reinforcement is equalized.

<u>Checking for shear</u>

Safety Factor max, Pa = 78,765 kN

Ultimate SF = Vu = 1,5 x 75,19 =118,15 kN

Values of shear tension ζ_v= (118,15 x 1000)/(1000 x 450) = 0,26 MPa

$\zeta_c = 0{,}14\% \ = 0{,}29$ MPa

$0{,}29 \text{ MPa} > 0{,}26 \text{ MPa} = \text{OK!}$

From the calculation of shear tension, we could see that share tension is above on the safe shear tension values.

<u>Stability Analysis</u>

We could see the recapitulation of stability Analysis in the table 4. Table 4 will explain how we got the value of the total weight (W) and MR.

Table 4. Recapitulation of Stability Analysis

Load	Magnitude, kN	Distance from A,m	BM about A kN-m
Stem W1	0.25 x 4.35x 1 x 25 = 27,19	1.525	41.47
Stem W2	½ x 0.2 x 4.35 x 1 x 25 = 10,88	1.2 + 2/3 x 0.2 = 1.333	14.51
B. slab W3	2.8 x 0.4 x 1 x 25 = 28	1.4	39.2
B. fill W4	1.15 x 4.35 x 1 x 18 = 90.045	2.225	200.35
Total	∑W = 27.19 + 10.88 + 28 + 90.045 ∑W = 156.115		∑MR = 41.47 + 14.51 + 39.2 + 200.35 ∑MR = 295.53
Earth Pre. (Ph)	Ph = 0.333 x 18 x 4.35^2 /2 Ph = 56,71	H/3 = 4.35/3=1,45	Mo = 82.2285

Source: Personal Data Research Results, 2022

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Checking for Overturning

$FOS = \frac{295.53}{82.2285} = 3.59 > 1.55$ **SAFE**

Checking for Sliding

$FOS = 0.6 \times \frac{156.115}{56.71} = 1.65 > 1.55$ **SAFE**

Checking for Subsidence

X = 1.37 m > b/3

e = b/2 – x = 2.8/2 – 1.37 = 0.3 m < b/6

Pressure below the base slab

$$Qmax = Q\ toe = \frac{156.115}{2.8}\left(1+\frac{6 \times 0.3}{2.8}\right)$$

$= 91.55\ kNm^2 <$ SBC , **SAFE**

$$Qmin = Q\ heel = \frac{156.115}{2.8}\left(1-\frac{6 \times 0.03}{2.8}\right)$$

$= 20{,}07\ kNm^2 >$ zero , **SAFE**

3.1 Heel Design

Mu = 1.5 x 40,2361 = 60.35 kNm

Designed within 1 metre

$$Min.Ast = \frac{0{,}85}{Fy} bd = \frac{0{,}85}{410} 1000.350$$

$= 725\ mm^2$

Trial D8@250 mm Cts.

$M_C = 0.85 f_C^{'} \gamma k_u (1-0.5\gamma k_u) bd^2$

γ = 0.85 (for 24 MPa)

$$k_u = \frac{1}{0.85\gamma} \times \frac{f_{sy}}{f_c^{'}} \times \frac{A_{st}}{bd}$$

$$k_u = \frac{1}{0.85 \times 0.85} \times \frac{410Mpa}{24Mpa} \times \frac{804mm^2}{1000mm \times 350mm}$$

$= 0.054$

$M_C = 0.85 \times 24 \times 0.85 \times 0.054 (1-0.5 \times 0.85 \times 0.054) \times 1000 \times 350^2$

$M_C = 112\ kNm > 60.35$ = OK!

Development length = 47 x 8 = 376mm

With the same distribution rebar, D8 @250 mm

Shear check

Safety Factor max, Pa = 64,605 kN

Ultimate SF = Vu = 1,5 x 64,605 =96,91 kN

Values of shear tension

= 96,91 x 1000 / 1000x400 = 0,24 MPa

$\zeta_c = \frac{100Ast}{bd} = 0{,}22\% = 0{,}339$ MPa

0,339 > 0,24 = OK!

Mu = 1.5 x 38,79 = 58.185 kNm

Designed within 1 meter

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$$Min.Ast=\frac{0,85}{Fy}bd=\frac{0,85}{410}1000.350=725\ mm^2$$

<u>Trial D8@250 mm Cts</u>.

$M_C=0.85f'_C\gamma k_u(1-0.5\gamma k_u)bd^2$

γ =0.85 (for 24 MPa)

$$k_u=\frac{1}{0.85\gamma}x\frac{f_{sy}}{f'_c}x\frac{A_{st}}{bd}$$

$$k_u=\frac{1}{0.85x0.85}x\frac{410Mpa}{24Mpa}x\frac{804mm^2}{1000mmx350mm}=0.054$$

M_C=0.85x24x0.85x0.054(1-0.5x0.85x0.054)x1000x350^2

M_C=112 kNm > Mu, so it's OK!

Development length = 47 x 8 = 376 mm

<u>Shear check</u>

Safety Factor max, Pa = 71,59 kN

Ultimate SF

= Vu = 1,5 x 71,59 =107,385 kN

Values of shear tension

= 143,385 x 1000 / 1000x400 = 0,27 MPa

$\zeta_c=\frac{100Ast}{bd}$ = 0,22% = 0,339 MPa

0.339 > 0.27 = OK!

In the analysis of the calculation of the soil retaining wall due to the difference in the area of Indonesian and Indian reinforcement, the author uses Indonesian convertible reinforcement which uses the type of reinforcement in Indonesia. Table 5 is the result of the analysis of retaining wall calculations with Indian Standard.

Table 5. Recapitulation of Indonesian Standard and Indian Standard

No.	Parameter	SNI	Indian
1	Reinforcement stem	D10 @150mm	D10 @300mm
2	Reinforcement toe	D16 @150mm	D8 @250mm
3	Reinforcement cut off point	D10 @250mm	D8 @300mm
4	The shape of the base	Form L	Form T
5	FOS Overturning	2	3.59 > 1.55 (SAFE)
6	FOS Sliding	1.5	1.65 > 1.55 (SAFE)

Source: Personal Data Research Results, 2022

Table 5 shows the comparison of the results of dimensional calculations between SNI and Indian Standard. The results of the SNI calculation above are obtained from the results of calculations made by project consultants in the field. Calculations with SNI resulted a larger profile than Indians' with reinforcement stem having a D10 @150mm profile, reinforcement toe D16 @150mm and reinforcement cut off point D10 @250mm. Profiles with Indian Standard calculations tend to be smaller, namely with reinforcement stem D10 @300mm, reinforcement toe D8 @250mm and reinforcement cut off point D8 @300mm. The use of a smaller profile than indian standard is still safe due to the safety factor that is still good. This can be seen from fos overturning has a value of 3.59 greater than the lower limit of 1.55 and FOS Sliding is worth 1.65 which is greater than the carry limit of 1.55. The use of smaller profiles will certainly use less funds although these results still have to be tested and tried first in the field.

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5. Conclusion and Suggestion

5.1 Conclusion

During the continuation of the analysis, various materials were found that we did not get or teach in lectures. From this analysis, the author found several conclusions that the soil retaining wall is resistant to the moment of overturning because the Moment of Resistance compared to the Moment of Overturning has a safety factor of 3.59 which is greater than 1.55 so it is safe, the retaining wall of the soil is resistant to shifting because the total load divided The horizontal soil pressure has a safety factor of 1.65 which is greater than 1.55 so it is safe, The repeating calculated by the author on the vertical wall or stem D10 with a distance of 300mm, the repeating on the heel of the foot or heel D8 with a distance of 250mm, the repeating on the tip of the foot or toe using D8 a distance of 250mm, and the repeating at the cutting point which is D8 with a distance of 300mm. From this analysis, we could conclude that profil from Indian Standard is smaller than Indonesian standard profil. It will make Indian standard's profil cheaper than Indonesian's. However, this does not necessarily guarantee that the structure of the Indian Standard will be better than the Indonesian Standard.

5.1 Suggestion

Suggestions that can be submitted by the author as material for research consideration are the need to prepare complete data and visit the field so that they know which parts of the soil are being held to facilitate research. The need for standard documents used to be guidelines in design. If we want to be more accurate, we could take into account on higher soil retaining walls and use software or we could make a prototype of the product and test it to know the strength of the profile.

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