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MODELING AND ANALYSIS OF RETAINING *WALL STRUCTURE* AT *CRUSHING PLANT* AT COAL PORT

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ABSTRACT

The development of coal port infrastructure requires a safe and efficient structural design to support the increase in production capacity, one of which is through the construction of a crushing plant equipped with a retaining wall. This study aims to analyze the structural strength and stability of soil retaining walls that function to withstand lateral soil pressure and dynamic loads due to dumping activities in the Run of Mine (ROM) hopper area. Structural modeling was carried out using SAP2000 software by considering dead load, live load, and active ground pressure. The analysis of the bearing capacity of the foundation was carried out using the Converse-Labare, Los Angeles Group Formula, and the Seiler-Keeney Formula, while the bending moment control was evaluated against the cracking moment capacity based on the specifications of the reinforced concrete pile.

In addition, the analysis process refers to national and international planning standards, namely SNI 8460:2017 regarding geotechnical planning, SNI 2847:2019 regarding structural concrete requirements for buildings, and SNI 1727:2020 regarding minimum loads. Wall stability standards such as USACE EM 1110-2-2502 and AASHTO LRFD lateral load guidelines are also used as a reference in evaluating the stability of bolsters, shears, and bearing capacity of pile foundations.

The results of the analysis show that the retaining wall structure model consists of three main parts, namely Section 1 and 2 with a length of 10 meters and Section 3 with a length of 18 meters. In the 10-meter retaining wall structure, the total weight of the structure is 365,665 tons with a combined carrying capacity of 405,046 tons of mini square pile and spun pile, which shows a safe condition against vertical loads. The moment control results showed that the maximum working moment on the mini pile (23.842 kN·m) and the D600 spun pile (101.3516 kN·m) was smaller than the permissible crack moment, so the structure was declared safe against bending cracking. In the 18-meter retaining wall model, similar results were obtained with a larger foundation carrying capacity than the total weight of the structure and the bending moment of work that is still below the material crack limit according to the design standards used.

Keywords: structure analysis, coal, *crushing plant, retaining wall, SAP2000*

INTRODUCTION

Port development carried out by coal companies aims to increase the capacity and efficiency of operational activities, especially in supporting the increase in the scale of coal production and distribution to various destination areas. In order to achieve this goal, it is necessary to build adequate supporting facilities, one of which is *the Crushing Plant* (CP). The construction *of a crushing plant* functions to process raw coal into a more uniform size and according to market standards, thereby simplifying the process of transportation, storage, and improving the quality and selling value of coal products before being sent to consumers or export terminals. *A crushing plant* or crushing machine is an integrated installation used to break down (crush) large materials (such as stones, mining stones, construction materials) into smaller sizes or as per the needs of the construction or mining industry (Agro, 2023).

Retaining wall on the *Looping* and *dumping dump truck (DT)* is an essential element of civil works that is directly integrated with the system *coal crushing plant*. This retaining wall serves as the main structure of the former *dump pocket* or *Run of Mine (ROM) wall* around the mouth *hopper*, a coal mine (*ROM coal*) spilled by *dump truck*. The retaining wall design is designed to withstand the lateral pressure of the soil as well as the dynamic forces due to dumping activities, thus maintaining structural stability and operational safety around the hopper area. In addition, this wall plays a role in regulating the direction of material flow so that it goes directly to the hopper without spilling outside the collection area, as well as minimizing the risk of material avalanches during the dumping process (Project, 2020).

A retaining wall needs to be designed and planned in order to ensure safety against forces that could cause structural failure. The construction of retaining walls needs to be able to withstand forces such as rolling moments, self-weight, active-passive ground/water lateral forces, sliding forces, and lifting forces (*uplift*) (Khuzaifah, 2019). Therefore, the construction planning of retaining walls must be made to be able to withstand these forces. The retaining wall can be said to be stable, if the security figure obtained is above the limit taken. In this study, the location of the retaining wall construction is presented in the following Figure 1:

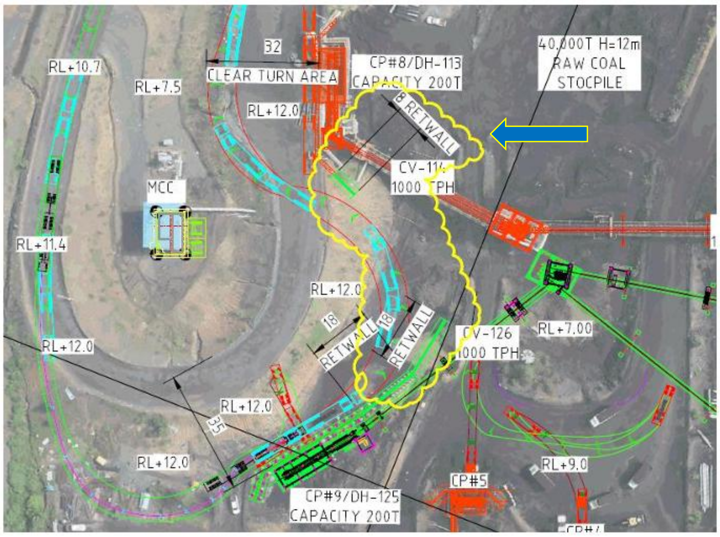

Figure 1. Layout of the retaining wall work site at the research site

In Figure 1 it can be seen that *retaining wall* Surrounding the area *ROM hopper* and CV-114 conveyor line, which became part of the initial coal processing system before being shipped to the *crushing plant*. This wall functions to hold the soil mass around the area *dump pocket*, where dump trucks spill crude coal (*run of mine/ROM coal*). With this retaining wall, the soil and material load from the side of the heap can be controlled, preventing avalanches that can disrupt operations or damage mechanical facilities such as conveyors and hoppers (Das dan Sobhan, 2006). To support the plan to build infrastructure facilities that will be carried out in the coal mining area, an appropriate structural analysis is needed so that the structural building can be declared safe to build and use. The purpose of this study is to provide an analysis of the structural strength of retaining walls (*retaining wall*) as a reference for the development of the area *Crushing plant* coal companies.

LITERATURE REVIEW

2.1 Retaining *Wall*

Soil retaining wall (*retaining wall*) be Civil engineering structures that function to withstand lateral soil pressure to maintain stability slope or elevation soil, especially On-site with the difference in surface height big such as roads, ports, and areas mine (Money) *et al*., 2021). Retaining walls are a very important type of structure in civil engineering. As a typical representation of a retaining wall (Al-Shukur dan Al-Rammahi, 2017). *Retaining wall* built around the dump pocket/ROM hopper at the mining facility serves as a holding structure that allows the heavily loaded dump truck (haul truck) to perform reversing maneuvers and spill coal or ore directly into the *Hopper* or *Crusher* (Geoquest Group, 2025).

2.2 Structural *Analysis of Wall Retaining*

The analysis of the retaining wall structure includes an assessment of existing deformation and lateral forces, as well as the impact of vehicle loads and water level conditions behind the wall. The finite element (FEM) method is often used to obtain a more precise distribution of active and passive ground pressure and to forecast the moment and shear force of structural elements (Jia *et al*., 2019). Research Experimental about wall Anchoring that utilize reinforced landfill (*reinforced backfill*) Show that pemilihan materials and technique Construction that appropriate get strengthen structural capacity of the wall, so that the working moment (*bending moment*) appears on service conditions remain below the cracking moment and Fractures Flex is not visible macroscopically (Karunakaran and Tan, 2024).

2.3 SAP200 Structural Modeling and Analysis Software

SAP2000 is one of the most popular structural analysis software due to its ability to model 2D and 3D structural elements such as beams, columns, plates, as well as complex truss systems involving dead loads, live loads, and lateral loads. Analysis with SAP2000 can quickly and precisely generate internal forces, bending, shear, and deformation moments, and make it easy to manually validate results for fairly simple structures such as single beams (Hasibuan and Qolby, 2023). SAP2000 is used to analyze the upper and lower structures including the foundation under the condition of vertical and lateral loads according to local standards, which directs the calculation of the dimensions of columns, beams, and foundations thoroughly (Nabil) *et al*., 2023).

2.4 Soil and Foundation Retaining Wall Planning Standards (SNI & AASHTO)

Planning of retaining walls and foundations in reference to several main standards. SNI 8460:2017 is a basic geotechnical reference that regulates the determination of active–passive soil pressure, soil shear strength parameters, and safety factors against shear, rolling, and soil carrying capacity. For reinforced concrete structural elements such as stem walls and foundations, SNI 2847:2019 is used, which contains the requirements for bending, shearing, and cracking moment control capacity in reinforced concrete components.

In load planning, the provisions of SNI 1727:2020 are used regarding dead loads, live loads, and additional loads from heavy equipment activities in the mining area. In addition to national standards, international references such as AASHTO LRFD and USACE (EM 1110-2-2502) are also used, especially in the determination of lateral soil pressure, wall stability design, and minimum safety factor criteria (FS $\geq$ 1.5 for shearing/rolling and FS $\geq$ 3 for ground bearing capacity).

For the pile foundation, axial capacity and subsidence control follow the provisions of SNI 8460:2017, and are supported by empirical methods such as Converse–Labare, Los Angeles Group, and Seiler–Keeney. Meanwhile, the bending capacity and cracking moment of mini piles and spun piles follow the provisions of SNI 2847:2019 and the pre-tensioned concrete guidelines.

This additional standard ensures that the retaining wall analysis considers safety, structural strength, and geotechnical stability according to the operational demands of the crushing plant.

RESEARCH METHODOLOGY

This research was conducted at the coal mining company PT. Borneo Indobara Bunati Village, Angsana District, Tanah Bumbu Regency, South Kalimantan in June-September 2025. Here we explain the steps:

1. Data Collection
Collect structural geometry data, soil data, loading data (dead load, live load, dumping load), as well as material parameters required for structure analysis.
2. Structural Modeling in SAP2000
Create a 3D model of the retaining wall (Sections 1, 2, and 3) along with the pile foundation by including material properties, loads, and laying conditions (spring).
3. Analysis of Styles in Structure
Run modeling to obtain the output of axial force, bending moment, shear force, and deformation on retaining wall elements and on foundation posts.
4. Analysis of the Bearing Capacity of the Pole Foundation
Calculate the pile foundation capacity using the Converse-Labare, Los Angeles Group, and Seiler-Keeney methods, then compare it to the total load of the structure to ensure its safety.
5. Control of the Bending Moment on the Pile
Comparing the working moment (M_work) of the SAP2000 result with the crack moment capacity (M_cr) on mini pile and spun pile based on SNI 2847:2019. The structure is safe if M_work < M_cr.
6. Evaluate the Stability of the Retaining Wall
Checking for potential structural failures such as overturning, sliding, and bearing capacity in accordance with SNI 8460:2017 and USACE standards.
7. Conclusion Drawing
Conclude whether retaining walls are safe based on modeling results, foundation capacity, and bending moment control for each section (10 m and 18 m).

ANALYSIS AND DISCUSSION

Plan the plan to build a retaining wall on the CP in the coal area was analyzed based on Geotechnical, structural, and functional aspects of mine operations. This analysis was carried out so that the retaining wall design was able to withstand soil pressure and workload safely, efficiently, and according to field conditions. The Soil Retaining Wall (DPT) is one of the important components in civil structure work in the coal mining facility area, especially in the zone *Dumping* and *crushing plant* (Bowles & Guo, 1996). The plan of the DPT construction plan is presented in Figure 2.

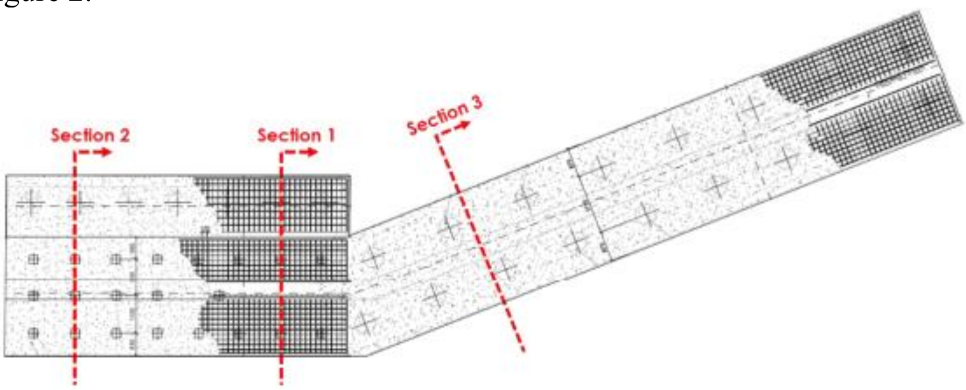

Figure 2. DPT plan and *DPT* section

In the drawing of the plan, the Soil Retaining Wall (DPT) is divided into three main parts: **Section 1**, **Section 2**, and **Section 3**.

- **Section 1** describes the initial part of the wall that receives the greatest soil pressure due to its proximity to *the hopper dumping area* and significant elevation differences. Therefore, in this part, tighter reinforcement and thicker foundations are used to maintain the stability of the structure against the active pressure of the soil and the dynamic load of loading and unloading activities.

- **Section 2** is the middle part that functions as a transition from an area with high elevation to a more sloping area. In this part, the wall is designed with a medium height and a drainage system behind the wall to reduce the water pore pressure (*hydrostatic pressure*).
- **Section 3** shows the end of the wall which is longer and relatively sloping. This structure functions as a light heap holder and a guide to the soil contour to the conveyor line. Since the soil pressure in this area is relatively small, the structural design is simpler with lower reinforcement requirements.

These three sections as a whole form a continuous soil retention system that functions to maintain soil stability around the facility *crushing plant*. In the design, geotechnical aspects such as soil bearing capacity, active and passive pressure, and safety factors against shear and rollover are carefully considered to meet construction safety standards accordingly *SNI 8460:2017* and geotechnical planning guidelines (*Soil Mechanics and Foundation Engineering*) (Safitri, 2021).

4.1 Modeling of *10 Meter* Retaining Wall Structure

A three-dimensional model of the DPT structure with a width of 10 meters representing Section 1 and Section 2 in the CP as follows:

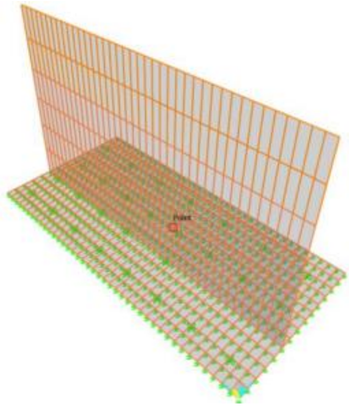

Figure 3. Modeling of 10 Meter Retaining Wall Structure (Section 1 & 2)

The model consists of two main elements, namely: **Vertical wall (*stem wall*)** which serves as the main element that holds the lateral pressure of the soil from the back side (*backfill*). This element is modeled with an orange vertical mesh, depicting a reinforced concrete plane that receives bending forces due to active soil pressure and additional loads from dumping activities. **Bottom foundation (*base slab* or *Footing*)** depicted with a green horizontal mesh, which serves to channel vertical and horizontal loads to the bottom soil. This foundation also plays a role in resisting shear forces (*Sliding*) and the moment of rolling (*overturning*) arising from soil pressure. In making soil retaining wall modeling, a retaining construction is required. Basement construction requires embedded retaining walls (*embedded walls*) like *contiguous piles, secant piles,* and diaphragm wall If soil around the excavation does not collapse (Luanga dan Susilo, 2022).

4.2 Bearing Capacity Control Structure Analysis Grub Pole Mini *Square Pile Retaining Wall* 10 Meter (Section 1 & 2)

Lateral compressive force analysis is an important aspect in *retaining wall* planning in the CP area, considering that this area often receives dynamic and heavy loads due to coal spilling activities and heavy equipment movement. The value of compressive force due to the retaining *wall structure* is obtained as follows:

Table 1. Axial Force Output of 10 Meter *Retaining Wall* Structure (Section 1 & 2) and count

Retaining wall					
Pile point	*Output Case*	F3 (Tonf)	Pile point	*Output Case*	F3 (Tonf)
392	D+L	30.865	368	D+L	13.427
405	D+L	23.969	408	D+L	12.602
384	D+L	22.686	472	D+L	9.328
449	D+L	20.17	360	D+L	8.024

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432	D+L	19.304	464	D+L	7.941
441	D+L	17.832	1020	D+L	7.888
1018	D+L	17.576	1136	D+L	7.765
1130	D+L	15.254	169	D+L	7.686
440	D+L	15.142	174	D+L	7.523
1017	D+L	14.197	178	D+L	7.489
448	D+L	13.942	148	D+L	6.606
424	D+L	13.706	156	D+L	6.407
1137	D+L	13.689	151	D+L	5.588
400	D+L	13.653	184	D+L	5.406

Information:
D (Dead load): dead load; L (*Live load*): live load; F3: Force in 3-direction; Tonf: Your Strength

From the results of the reaction point of the structure placement, it can be known that the total weight of the structure is 365,665 tons, then control is carried out on the capacity of the greb pole. The following is an analysis of *the mini square pile grub pole* as follows:

KONTROL EFISIENSI TIANG

Formula Converse - Labare

$$Ce = 1 - \frac{\arctan\left(\frac{\varphi}{S}\right)}{90^o} x \left(2 - \frac{1}{m} - \frac{1}{n}\right)$$

Diameter tiang	=	0.25	m
jarak antar tiang (S) = 3D	=	1.20	m
jumlah baris tiang dalam group (m)	=	8	buah
jumlah kolom tiang dalam group (n)	=	3	buah
D/S	=	0.21	
arctan D/S	=	11.77	
Ce	=	0.80	

Los Angeles Group Formula

$$Ef = \left[1 - \frac{36s}{(75s^2 - 7)}\left(\frac{m+n-2}{m+n-1}\right)\right] + \frac{0,3}{m+n} \quad = \quad 0.850$$

Seiler-Keeney Formula

$$Ef = 1 - \frac{D}{\pi s}\left(\frac{m(n-1) + n(m-1) + (m-1)(n-1)\sqrt{2}}{m \times n}\right) \quad = \quad 0.645$$

KONTROL DAYA DUKUNG TIANG GRUP

Daya dukung satu tiang	=	12.06	Ton
Jumlah Tiang	=	21	buah
Daya dukung kelompok tiang (Pn_{group})	=	163.3	Ton

As for the spun pile diameter of 600, it is obtained:

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KONTROL EFISIENSI TIANG

Formula Converse - Labare

$$Ce = 1 - \frac{\arctan\left(\frac{\varphi}{S}\right)}{90^{o}} x \left(2 - \frac{1}{m} - \frac{1}{n}\right)$$

Diameter tiang	=	0.60	m
jarak antar tiang (S) = 3D	=	1.43	m
jumlah baris tiang dalam group (m)	=	7.00	buah
jumlah kolom tiang dalam group (n)	=	1.00	buah
D/S	=	0.42	
arctan D/S	=	22.83	
Ce	=	0.78	

Los Angeles Group Formula

$$Ef = \left[1 - \frac{36s}{(75s^2 - 7)}\left(\frac{m+n-2}{m+n-1}\right)\right] + \frac{0,3}{m+n} \quad = \quad 0.885$$

Seiler-Keeney Formula

$$Ef = 1 - \frac{D}{\pi s}\left(\frac{m(n-1) + n(m-1) + (m-1)(n-1)\sqrt{2}}{m \times n}\right) \quad = \quad 0.735$$

KONTROL DAYA DUKUNG TIANG GRUP

Daya dukung satu tiang	=	52.02	Ton
Jumlah Tiang	=	7	buah
Daya dukung kelompok tiang (Pn_{group})	=	267.6	Ton

so that the bearing capacity of the grub pile is:

Pn total = Ef (Pn minipiles + Pn spunpiles)

= 0.94 (163.3+267.6)

= 405.046 Ton > 365.665 Ton

Because the bearing capacity is greater than the total weight of the structure, the bearing capacity of the structure **can be declared safe.** This is in accordance with the results of the research Dhamdhere *et al*. (2018), if the bearing capacity of the soil exceeds the weight and load of the foundation structure, then the condition of bearing capacity failure is considered to have not occurred and the structure is safe.

4.3 Moment Control of *10 Meter Retaining Wall* Structure (Section 1 & 2)

To get the value of the force in the moment on the pile then modeling is made with spring placement.

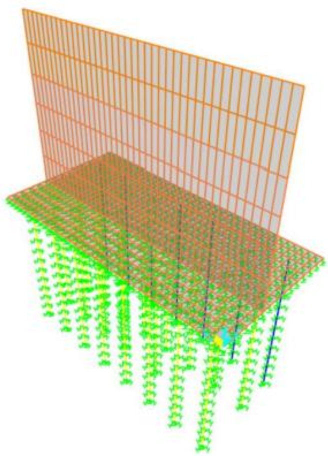

Figure 4. Modeling of 10 Meter Retaining Wall Structure (Section 1 & 2)

From the modeling analysis, it was obtained that the maximum moment value on a 250 x 250 Mini square pile was 23,842 kN.m. *Mini square pile* used is a dimension of 250 x 250 class B with a crack moment of 24.7 kN.m > 23,842 kN.m. The moment that occurs on the pole is smaller than the capacity of the crack moment so it is stated ***mini pile* Crack safe**. Moment output on *spun pile* D600 obtained a maximum value of 101.3516 kN.m. *Spun pile* used is a diameter of 600 mm class B with a crack moment of 245.2 kN.m > 101.35 kN.m. The moment that occurs on the pole is smaller than the capacity of the crack moment so it is stated ***spun pile* D600 is safe against cracking.** This is in accordance with the results of the research Gatto dan Montrasio (2021) which explains that the moment of work (*bending moment*) that occurs on the pole compared to the capacity of the bending moment and the cracking moment so that it shows that the pole is still within the safety limit when the working moment < the crack moment.

4.4 Modeling of 18 Meter Retaining Wall Structure

The modeling drawing of the 18 Meter Retaining Wall Structure is as follows:

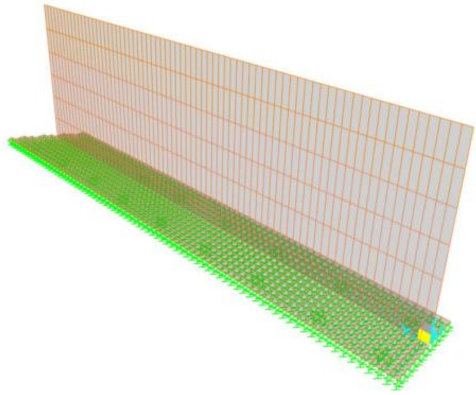

Figure 5. Modeling of 18 Meter Retaining Wall Structure

Figure 5 shows Retaining Wall Structure Model with a height of 18 meters which is part of the main soil retention system in the *Crushing Plant* Coal. This modeling shows the configuration Vertical Plate (Stem Wall) and Basic foundations (*base slab*) reinforced with repeating grid elements (green and orange colors), depicting the rigidity distribution of the structure in the horizontal and vertical directions. This 3D model is used to analyze the deformation and stress response (*stress distribution*) along the height of the walls due to active ground pressure (*active earth pressure*) and passive pressure at the foot of the wall. With a width of 18 meters, the lateral pressure at the base of the wall increases significantly so that special attention is paid to the stability of the bolster (*overturning*), shear (*Sliding*), and the carrying capacity of the foundation soil (*bearing capacity*) (Chheng and Likitlersuang, 2017).

4.5 Control Bearing Capacity Structure Analysis Grub Pole Mini *Square Pile Retaining Wall* 18 Meter (Section 3)

The value of the compressive force that occurs on the structure *retaining wall* is the result of a combination of the structure's own weight, the active ground load behind the wall, as well as the additional load above ground level (Ash *et al*., 2024). Value of compressive force due to structure *retaining wall* The following results were obtained:

Table 2. Axial Force Output Retaining *Wall* Structure 18 Meter

Retaining wall					
Pile point	*Output Case*	F3 (Tonf)	Pile point	*Output Case*	F3 (Tonf)
1785	D+L	49.337	1285	D+0.7Ex	40.8465
1050	D+L	49.294	1921	D+0.7Ex	40.6144
1061	D+L	49.205	1047	D+L	40.4124
1811	D+L	48.026	1275	D+0.7Ex	40.1456
1808	D+L	47.371	1931	D+0.7Ex	40.0927
1796	D+L	47.245	1264	D+0.7Ex	34.4139

1059	D+L	47.073	2096	D+0.7Ex	33.5503
1910	D+0.7Ex	41.015	2130	D+L	24.7118
1288	D+0.7Ex	41.012			

Information:
D (Dead load): dead load; L (*Live load*): live load; F3: Force in 3-direction; Tonf: Your Strength

From the results of the reaction point of the structure placement, it can be known that the total weight of the structure is 365,665 tons, then control is carried out on the capacity of the greb pole. The following is an analysis of the mini square *pile grub pole*.

KONTROL EFISIENSI TIANG

Formula Converse - Labare

$$Ce = 1 - \frac{\arctan\left(\frac{\varphi}{S}\right)}{90^o} x \left(2 - \frac{1}{m} - \frac{1}{n}\right)$$

Diameter tiang	=	0.60	m
jarak antar tiang (S)	=	2.30	m
jumlah baris tiang dalam group (m)	=	2	buah
jumlah kolom tiang dalam group (n)	=	8	buah
D/S	=	0.26	
arctan D/S	=	14.62	
Ce	=	0.77	

Los Angeles Group Formula

$$Ef = \left[1 - \frac{36s}{(75s^2 - 7)}\left(\frac{m + n - 2}{m + n - 1}\right)\right] + \frac{0{,}3}{m + n} \quad = \quad 0.829$$

Seiler-Keeney Formula

$$Ef = 1 - \frac{D}{\pi s}\left(\frac{m(n-1) + n(m-1) + (m-1)(n-1)\sqrt{2}}{m \times n}\right) \quad = \quad 0.840$$

KONTROL DAYA DUKUNG TIANG GRUP

Berat total struktur (Pu)	=	714.37	Ton
Daya dukung satu tiang	=	107.95	Ton
Jumlah Tiang	=	17	buah
Daya dukung kelompok tiang (Pn_{group})	=	1416.5	Ton

Syarat :

$$P_u \leq P_{ngroup}$$

$$714.4 \leq 1416.5 \quad \rightarrow \quad \text{(OK)}$$

Based on the above analysis, it was obtained that the capacity of the grub pole is greater than the total weight of the structure, so the bearing capacity of the structure **can be declared safe.** When the capacity of the pile group is greater than the load of the structure with adequate safety factors, the system is declared safe against drop and failure (Hoang *et al*., 2024).

4.6 Moment Control of 18 Meter *Retaining Wall* Structure (Section 3)

To get the value of the force in the moment on the *pile* then modeling is made with spring placement. The modeling design is presented in Figure 6.

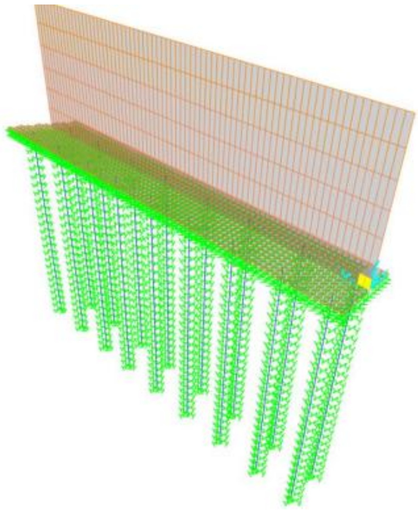

Figure 6. Modeling of 18 Meter Retaining Wall Structure

Safety assessment of bending cracks in centrifugal concrete poles (*spun pile* D600) is done by comparing Working bending moment (M_work) arising from the load of the field with Crack Moment (M_cr) from the cross-section of the pole (Zhang *et al*., 2022). From the modeling analysis, it was obtained *Output* the maximum moment on the D600 spun pile is 212.1904 kN.m. This value is then compared to the specification of the crack moment. Mini Square Pile capacity 250 x 250. *Spun pile* used is a diameter of 600 mm class B with a crack moment of 245.2 kN.m > 212.19 kN.m. The moment that occurs on the pole is smaller than the capacity of the crack moment so it is declared the spun pile D600 **safe against cracking.** Safety assessment of bending positions It is generally done by comparing the moment of bending work (M_*Work*) which arises due to field load with a moment of cracking (*cracking moment*, M_cr) from the cross-section of the pole (Pin, 2022).

CONCLUSION

1. The retaining wall is divided into three main parts: Section 1, Section 2, and Section 3.
2. A three-dimensional model of the DPT structure with a width of 10 meters representing Section 1 and Section 2, and Section 3 with a width of 18 meters.
3. The carrying capacity of the analysis structure of the 10 meter grub mini square pile retaining wall (Section 1 & 2) **is greater than the total weight of the structure**, which is the carrying capacity **of 405,046 tons** > the weight of the structure **is 365,665 tons**, then the bearing capacity of the structure can be declared safe.
4. The 10 Meter Retaining Wall Structure Moment Control (Section 1 & 2) on the pole is smaller than the crack moment capacity so that the mini pile is declared to be crack safe, which is **a maximum working moment of 23.842 kN·m** < a **cracking moment of 24.7 kN·m**.
5. The carrying capacity value of the 18-meter mini square pile retaining wall grub pole analysis (Section 3) **is greater than the total weight of the structure** so that the bearing capacity of the structure can be declared safe. (mast capacity > total load; the figures in the Section 3 model still show the safe margin).
6. The 18 Meter Retaining Wall Structure Moment Control (Section 3) on the pole is smaller than the crack moment capacity so that the D600 pile spun is declared to be crack safe, which is **a maximum working moment of 212.1904 kN·m** < a **cracking moment of 245.2 kN·m**.

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