ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)

Vol 11, Issue 7, July 2024

Design of Diagonally Strutted Soldier Pile for Two Level Basement Excavation in Bali - Indonesia

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Abstract— ***Bali is one of the most famous tourist destinations in the world. In some of its most visited areas, land for public spaces and parking facilities is really limited. To upgrade its public facilities, it is planned to build a 2-level basement for parking, with a park for public use on the ground level. The excavation for the building is -12 meters deep from the ground level. The support system for this deep excavation consists of concrete so006Cdier piles with lateral support. The lateral support is provided by diagonal H-steel beam struts at an angle between 30 and 45 degrees. This excavation support system complies with the Indonesian code for geotechnical design, where the critical safety factor (SF) is 1.5 and the maximum deformation of the soldier pile is 58 mm.***

Index Terms—excavation, lateral support, solider pile.

I. INTRODUCTION

Bali is one of the most famous tourist destinations in the world [1]. In some of its most visited areas, land for public spaces and parking facilities is really limited. To upgrade its public facilities, it is planned to build a 2-level basement for parking, with a park for public use on the ground level. The excavation for the building is -12 meters deep from the ground level. The objective of this study is to design a safe earth retaining structure for that excavation and minimize the disturbance to the nearby building and infrastructure. One of the methods to achieve this, is to use solider pile with diagonal support [2].

Soldier pile walls, are a versatile and cost-effective method of earth retention commonly used in construction and civil engineering projects [3]. These walls are constructed using vertical piles driven into the ground at regular intervals, with horizontal lagging placed between the piles to retain the soil.

One of the critical enhancements to the traditional soldier pile system is the incorporation of diagonal supports, which provide additional stability and strength to the retaining wall [4]. These diagonal supports, typically made of steel, extend from the soldier piles to anchor points in the surrounding soil or adjacent structures. This configuration helps to distribute loads more evenly and resist lateral earth pressures more effectively.

II. SITE SURVEYING AND SOIL TESTING

A. Site Surveying

This project is located in the middle of the city center in Bali. The adjacent infrastructure of the project is consisted of main roads, school, government building, and residential housing. Due to that condition, this excavation project has to control the soil deformation in order not to cause disturbance or damage to the nearby infrastructure.

B. Soil Testing

Series and soil test are conducted to obtain the soil characteristic of the area. 1 SPT and 2 CPT test is conducted to obtain the soil condition on that area, also take soil sample to determine the soil type. Soil type of the location is as shown in table below:

Table 1. Summary of Soil Test Result

Depth	Soil Type	Unit Weight	Angle of Friction	Cohesion
0 – 11 m	Silty Clay	17 KN / m^3	20°	14 KN/m2
11 m – 20 m	Dense Sand	18 KN / m^3	30°	0 KN/m2

III. SOIL RETAINING SYSTEM

The excavation project will utilize a retaining wall system made of 17-meter-deep secant piles, supported by diagonal steel struts and wall-to-wall struts. The excavation will be conducted in multiple phases, with each phase being monitored for safety factors, moments, and forces on the wall, as well as any deformations. The analysis will be performed using Plaxis 2D 8.2 software. The steps for the excavation is described in the table below:

Table 2. Stage of the excavation

Stage	Description
1	17 m deep secant pile installation
2	• Excavate to -2.00 m elevation • Install 1st waller beam at -1.50 m elevation
3	Excavate to elevation -11.00 m with top of berm at -5.00 elevation
4	Strut beam installation from bottom to 1st waller beam
5	• Excavate to -8.00 m elevation.

ISSN (Online) 2456-1290
International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 11, Issue 7, July 2024

Stage	Description
	• Install 2nd waller beam at -5m elevation
6	• Install strut beam to 2nd waller beam
7	• Excavate to -11.00 m elevation

Table below is summary result of the calculation showing factor of safety, deformation, and moment maximum of the soil retaining system

Table 3. Calculation Result Summary

Stage	Factor of Safety	Deformation Maximum (mm)	Moment Maximum (KNm/m)
1	-	-	-
2	2.6	35	65
3	1.5	44	106
4	1,5	45	107
5	1.8	50	185
6	1.8	49	184
7	3.1	58	331

Figure Below is to show model calculation on plaxis 8.2.

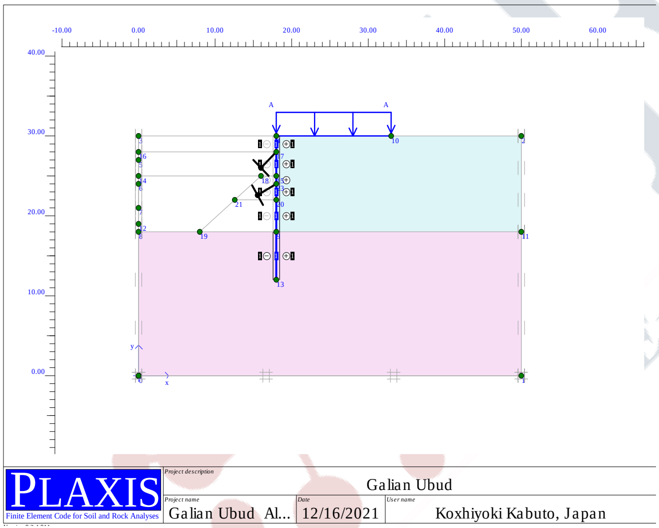

Figure 1. Calculation model on Plaxis 2D

IV. PILE AND STRUT DIMENSIONING

A. Soldier Pile Dimensioning

To design size and rebar reinforcement of the secant pile, moment maximum and shear force maximum is used in the calculation [5]. From calculation obtain moment maximum is 662 KNm/m and shear force maximum is 374 KN/m. Summary of the pile use is as follows:

Table 4. Summary of Soldier Pile

Pile Type	Concrete Bore Pile
Dimension	800 mm
Compressive Strength	25 MPa
Rebar Reinforcement	20 D22

B. Strut Dimensioning

Diagonal strut is designed to withstand axial load from the soldier pile [4]. To design the strut, maximum axial load from previous analysis is used. Summary of the strut used is as follows:

Table 5. Summary of Diagonal Strut

	1st Level Strut	2nd Level Strut
Maximum Axial Load	385 KN/m	1565 KN/m
Dimension	H.400x400x13x21	H.400x400x13x21
Installation Interval	7 m	5 m
Steel Quality	BJ 37	BJ 37
Maximum Strut Length	20 m	20 m

C. Waller Beam Dimensioning

Waller beam is design to withstand the uniform load from the wall (soldier pile). To design Waller beam uniform load from previous analysis is used. Summary of the Waller beam used is as follows:

Table 6. Summary of Waller Beam

	1st Level Waller Beam	2nd Level Waller Beam
Uniform Load	69 KN/m	187 KN/m
Dimension	IWF.700x300x13x24	IWF.700x300x13x24
Steel Quality	BJ 37	BJ 37

D. Strut base plate dimensioning

Base plate is design to withstand shear force and pulling force from the strut. Summary of the base plate strut used is as follow:

Table 7. Summary of Strut Base Plate

Dimension	700 mm x 700 mm
Thickness	25 mm
Bolt	16
Anchorage	570 mm

V. DISCUSSION AND SUMMARY

As presented above, a series of calculation is conducted to obtain comprehensive stability of the earth retaining structure for excavation project. External and internal stability is calculate carefully. This calculation is also follow the Indonesian code for geotechnical design (SNI 8640 - 2017) [6], Indonesian code for structure and concrete work (SNI 1728 – 2015), Indonesian code for steel design (SNI 2847).

For external stability calculation, the least factor of safety is 1.5, which is already comply with the minimum factor of safety required in the Indonesian geotechnical design code. The largest deformation occurs at stage 5, to obtain more safety, it is suggested to use geotechnical monitoring instrument. During its implementation, the retaining wall system must be continuously monitored. The use of geotechnical instruments (inclinometer, settlement plate, piezometer) is required on each side outside the excavation.

VI. ACKNOWLEDGEMENT

We extend our sincere gratitude to all who contributed to this study. Thank you to civil engineering department Politeknik Negeri Bali for its continuous support.

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