The Analysis of Lateral Deformation of Diaphragm Wall by using 2-Dimensional Finite Element Method in Basement Construction of the BRI Tower Medan

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ABSTRACT

Land availability for multi-story buildings can be managed by constructing a multi-story building with a basement. The basement construction of Menara BRI Medan is surrounded by office buildings. The soil is composed of sand, medium sand, clay silt, and gravel, resulting in the construction of a retaining wall comprised of a diaphragm wall 17,50 meters deep with a wall thickness of 0,60 meters. During the deep excavation work, the diaphragm wall was reinforced by temporary supports (strut). The strut installation consists of 2 layers with a distance of 3 meters in between struts. This minimizes the deformation that occurs. The lateral deformation was calculated using the finite element method in PLAXIS 2D with Mohr-Coulomb soil modeling at drill point BH-02. The deformation results in PLAXIS 2D will be compared with the on-site monitoring results by taking Inclinometer-I2 measurements. The result of the lateral deformation of the diaphragm wall from the analysis using PLAXIS 2D modeling was found to be 7,72 mm. In addition, the lateral deformation value from the monitoring results during the measurement of inclinometer-I2 on site was 7,55 mm. However, during the comparison between the deformation results in PLAXIS 2D and the monitoring results on site, discrepancies were identified due to alterations of parameters during the execution of the deep excavation work.

Keywords: deformation; diaphragm wall; basement; deep excavation; finite element method.

INTRODUCTION

The excavation work for the basement construction in the BRI Tower Project will deform the retaining wall. The basement construction is based on a diaphragm wall. The problem that frequently appears in making a basement is the high-rise buildings around the basement which therefore requires a sturdy retaining wall and supporting structure. The installation of the diaphragm wall is one method to avoid disruption to the existing buildings around the project.

Figure 1. The construction site of BRI tower Medan

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A retaining wall in the shape of a diaphragm wall was used on the 17,50 m deep basement construction with a wall thickness of 0,60 m. However, the lateral deformation values were calculated using the finite element method and the analytical results were compared with the analytical results during the monitoring period. Prior research on the deformation analysis of basement walls in Sudirman has used the back analysis method from the results of monitoring (Frando Wadino, 2018) diaphragm wall analysis in basement construction in Jakarta (Calvin Wijaya., 2020), 7-story basement in Jakarta (Novia Sabina., 2020), wall deformation in the basement using the top-down method with a construction stage analysis and conventional analysis (Raynaldi., 2021).

RESEARCH METHODS

This research was undertaken in an urban area located precisely on Jl. Putri Hijau No. 2a, Kesawan, Kec. Medan Barat, Medan City, North Sumatra. This study measured the soil samples of bored hole point 2. Secondary data collection includes soil data, diaphragm wall data, construction methods, and Inclinometer measurements. Once the soil data was collected, the correlation of soil parameters was performed to obtain the soil parameters required to analyze the deformation of the retaining wall. Calculate lateral earth pressure and analyze the deformation of the retaining wall empirically using the finite element method with PLAXIS 2D. Discuss the analysis of the deformation results of the diaphragm wall. The final stage of this research was comparing the results of the analysis. Subsequently, beneficial conclusions will be formulated. The research sequence is depicted in the work flow diagram shown in Figure 2.

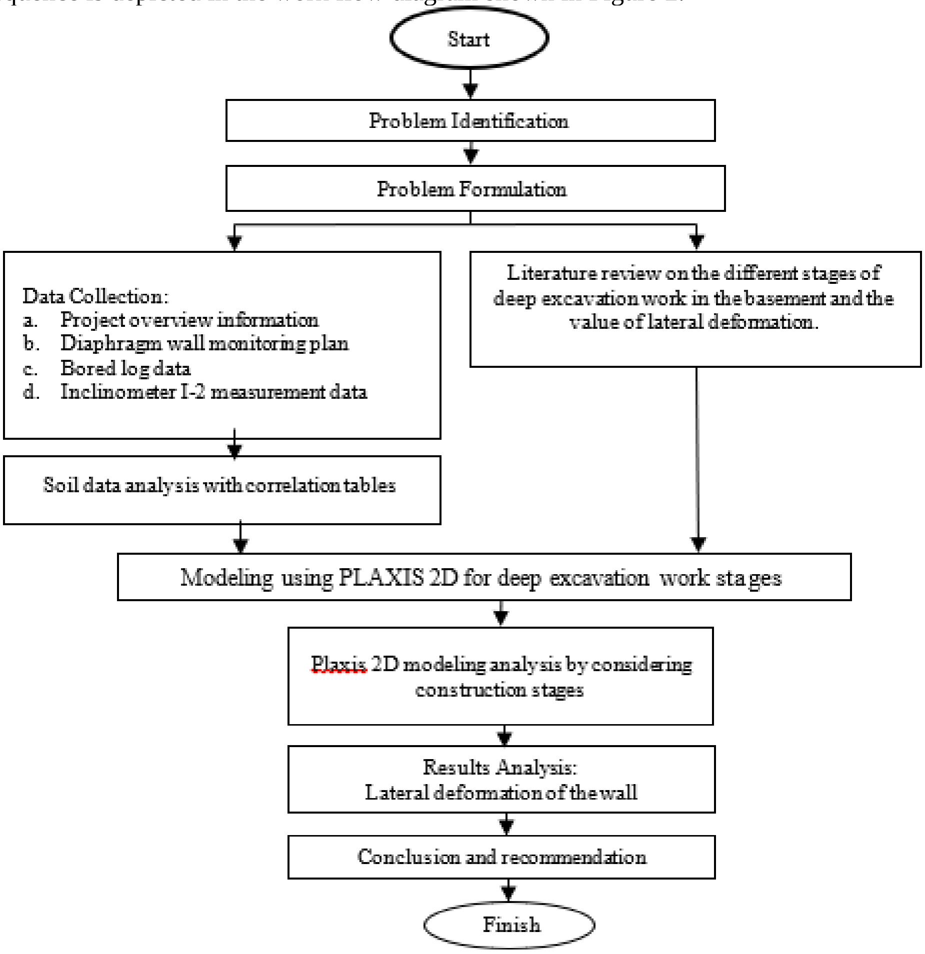

Figure 2. Flow chart

Data Analysis

The construction project of the BRI Medan Tower Building used the retaining walls with a type of diaphragm wall around the excavation with the following specifications:

1. Wall type : Type A
2. The upper elv. of the wall : +25,00
3. Wall height : 17,50 m
4. Wall thickness : 0,60 m
5. Concrete quality of diaphragm wall : 30 Mpa
6. Strut type (temporary support) : a. Layer 1: KC 400 x 200 x 8 x 13
   b. Layer 2: KC 500 x 200 x 10 x 16

Table 1. Retaining Wall Parameters

Parameter	Symbol	Score	Unit
Modulus of Elasticity	E	2,57E+07	kN/m^2
Compressive Strength	fc'	30	Mpa
Cross-sectional Area of Profile	A	10,5	m^2/m
Profile Inertia	I	2,68E+02	m^4/m
Weight	w	25200	kN/m^2
Poisson's ratio	υ	0,49	-
Axial Stiffness	EA	2,70E+08	kN/m^2
Flexural Stiffness	EI	6,90E+09	kN/m^2/m

The monitoring data on site to be used was the Inclinometer I-2 measurement data. The recapitulation of the Inclinometer I-2 measurement results can be seen in Table 2.

Tabel 2. Recapitulation of monitoring results on Inclinometer I-2 measurement

Visit	Date of Test	Elevation of Excavation (m)	Movement from prior measurement (mm)	Cumulative of base reading movement (mm)
1	August 18th, 2021		Base Reading	
2	August 25th, 2021		6,93	6,93
3	September 2nd, 2021		-1,18	5,75
4	September 8th, 2021		0,34	6,09
5	September 15th, 2021		-0,05	6,04
6	September 23rd. 2021	+20,355	-0,21	5,83
7	September 29th, 2021		1,72	7,55
8	October 6th, 2021		0,60	8,15
9	October 14th, 2021		-2,07	6,08
10	October 27th, 2021		2,33	8,41
11	November 10th. 2021		0,20	8,61

RESULT AND DISCUSSION

The deformation results in PLAXIS 2D will be compared with the monitoring results in the field using the back analysis method through the results of inclinometer readings. Results were obtained from excavations in the final stage.

Modeling in PLAXIS 2D requires the input of certain soil parameters for modeling. The type of modeling that will be used for soil is modified Mohr-Coulomb.

Table 3 shows the soil material properties that will be needed in the following analysis:

Table 3. Soil Parameters

Description	Unit	Material Properties							
		Gravel	Silt	Silty Sand	Clay Silt	Clay to Silty Sand	Sand 1	Silty Clay	Sand 2
Material Model		Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Depths	meter	0-3,90	3,90-6,50	6,50-10,75	10,75-18,50	18,50-20,50	20,50-	42,00-43,40	43,40-60,00

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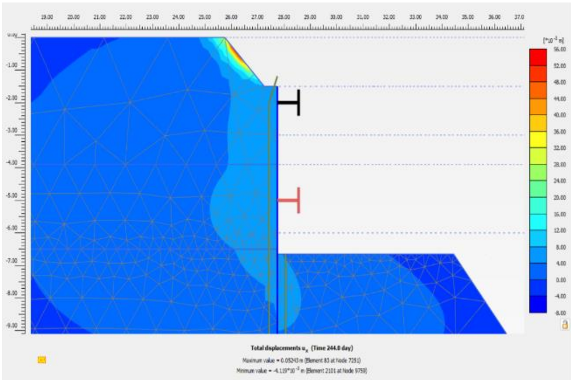
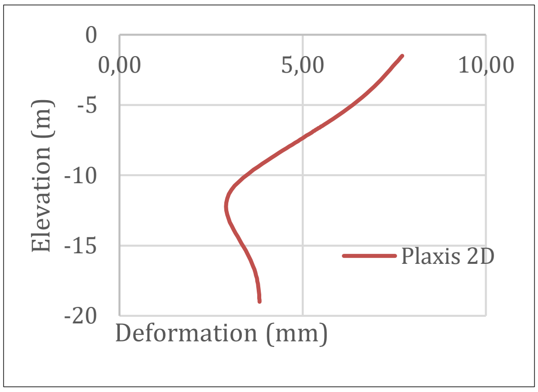
Description	**Unit**	**Material Properties**							
		Gravel	**Silt**	**Silty Sand**	**Clay Silt**	**Clay to Silty Sand**	**Sand 1**	**Silty Clay**	**Sand 2**
							42,00		
Drainage Type		drained	undrained	drained	undrained	undrained	drained	undrained	drained
γ_{unsat}	kN/m^3	17,000	15,600	16,400	16,400	16,667	20,500	16,667	18,000
γ_{sat}	kN/m^3	20,5000	19,2435	20,0290	23,5635	19,4399	21,6511	19,4399	21,9099
E	kN/m^2	51000	54000	66000	102000	57000	150000	57000	150000
υ (nu)		0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3
C	kN/m^2	0	9	11	22	19	30	19	30
ϕ (phi)	°	36,75	37	38	45	37,25	45	37,25	44
k_X	m/day	6,94E-04	3,47E-09	5,61E-08	2,63E-06	3,50E-04	3,13E-07	3,50E-04	3,13E-07
k_Y	m/day	6,94E-04	6,94E-09	5,61E-08	5,27E-06	7,00E-04	6,25E-07	7,00E-04	6,25E-07
k_Z	m/day	0	6,94E-09	5,61E-08	5,27E-06	7,00E-04	6,25E-07	7,00E-04	6,25E-07
N-SPT		17,00	18,00	22,00	34,00	19,00	50,00	19,00	50,00





a. The deformation of the 5th stage of excavation of the diaphragm wall in PLAXIS 2D modeling.

b. Graph of deformation results from PLAXIS 2D modeling

Figure 3. The results of lateral deformation in PLAXIS 2D

(a)The deformation of the 5th stage of excavation of the diaphragm wall in PLAXIS 2D modeling and (b) Graph of deformation results from PLAXIS 2D modeling

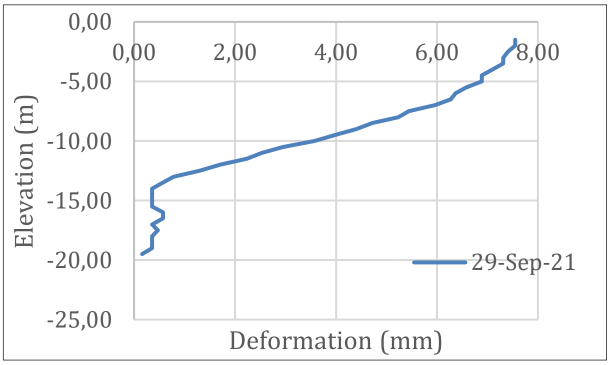


Figure 4. Graph of Inclinometer I-2 measurement results on September 29th, 2021

After analyzing the lateral deformation using modified Mohr-Coulomb on PLAXIS 2D, the deformation value was found to be 7,72 mm at -1,50 m elevation. As seen in Fig. 3 (a) and (b). The maximum lateral deformation can be seen during the final stage of excavation, which is stage 5 of excavation. In the results of monitoring the final Inclinometer I-2 measurement, the deep excavation work at the research point ended on September 29th, 2021. The graph can be seen in Figure 4.

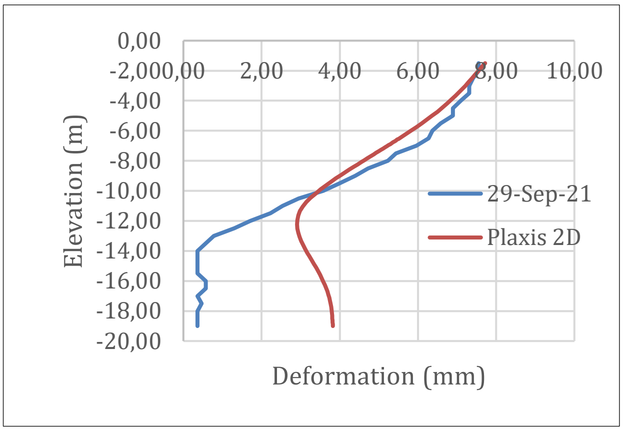


Figure 5. Comparative deformation graph between monitoring results on-site and PLAXIS 2D modeling.

There is a difference between the deformation results in the monitoring measurement and the deformation results in the PLAXIS 2D modeling. The reading on the Inclinometer I-2 was taken during the final excavation work stage at elevation -13,35 m on September 29, 2021. The maximum deformation value that was observed was 7,55 mm. Deformation was recorded at elevation -1,50m. The error percentage of lateral deformation can be seen in Table 4 below.

Table 4. The Comparison of Inclinometer Lateral Deformation Results and PLAXIS 2D

Lateral Deformation	Plaxis (mm) 7,72	*Inclinometer* (mm) 7,55
Percentage of Error	2,25%	

CONCLUSION

The result of lateral deformation in PLAXIS 2D modeling using modified Mohr-Coulomb is 7,72 mm which is found at an elevation excavation of -1,50 m. The maximum deformation of the diaphragm wall occurred at stage 5 of excavation. This deformation remains smaller than the deformation required by SNI, which is 85 mm. Comparison of the lateral deformation analysis results in the PLAXIS 2D program using modified Mohr-Coulomb with the results of the Inclinometer I-2 measurement, shows an error percentage of 2,25% against the monitoring results. There was no visible effect of the presence of a temporary support (strut) attached to the retaining wall of the diaphragm wall, both on the results of Inclinometer I-2 monitoring and the modeling using the PLAXIS 2D program.

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