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Wall and Piles for Hydroocarbon Pipes in Soft Soil in Slope Areas

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Abstract

Pipes laying on an unstable slope of soft soil are prone to movement. Pipelines that are buried in unstable slope areas will move due to lateral loads from soil movement which can cause damage to the pipeline. A laboratory small-scale model of the reinforcement system of piles supported retaining walls was conducted to investigate the effect of lateral load on the reinforcement. In this experiment, the lateral forces of 0.3 kN, 0.35 kN, and 0.4 kN and vertical force of 0.05 kN, 0.1 kN, and 0.15 kN were used. Lateral load from electric jack is equipped with load cell and vertical load used cement- steel box. To validate the experimental result, a finite element program was used. The experimental results showed that an increase in lateral loading, increased the displacement of the reinforcement system. For a Vertical Load 0.05 kN and versus a lateral load of 0.3 kN causes a horizontal displacement of 0.34 mm and an increased of 2.94 % for loading of 0.35 kN and an increased of 8.82% for loading 0.4 kN. The pattern is the same in the finite element method analysis, where there was a 2.3 8% increased for 0.35 kN loading and an increased to 33.33 % for 0.4 kN loading. In the same Load, the Reinforcement System is reliable as shown in Safety Factor on dry condition were 3,33, 2,828 and 2,476, and on wet condition were 2,99, 2,524 and 2,237.

Keywords
soft soil; displacement wall; wall-piles for supporting pipes

I. Introduction

The condition of soft soil in slope area is a separate issue that must be addressed immediately if the pipeline will be laid down in slopes areas, and according to (A. Pratiko, 2019) states that around 30% of Indonesia's total land is soft soil, with a low bearing of carrying capacity. Some of the solutions that are found in handling the problems of pipe movement due to the movement of soft soil in slope area are by making the slope and wooden shoring, and only making the retaining wall without pile, but this solution often fails. However, in this research, the solution to the problem of pipe movement in soft soil from landslides is to create a reinforcement method with a wall-pile system.

Wall and Piles System is one of the solutions for soft soil in slope areas, it consists of piles and walls. It worked as a simultaneous to resist the pipe-soil movement. If we compared it to a retaining wall without piles, the retaining wall is considered to be stronger in bending due to the lateral load which pushing it, but is very weak for the slope stability, because the surface failure or slip line is under the bottom of the wall, it can increase the strength of the support system of pipes-soil interaction so that it is expected that landslide will not occur.

II. Research Methods

Wall and piles system for resisting pipes in soft soil in slope areas (Mutadi, 2021), and pipe-soil interaction play an important role in the pipe stress analysis subjected to soil movement due to slope instability and/or slope failure. As the soils/slopes begin to fail, a single or a group of pipes buried inside the failure zone will bear additional loads which frequently lead to overstressing or buckling (Endra, 2018). According to (Razanajatovo, 2020) to the soil engineer, the word "soil" means a material which is used in any kind of civil engineering job, either as foundation material to support the load exerted by structures, or as construction material itself, as in the case of highway constructions. However, the best growth was obtained in the mixture of top-soil and saw dusts medium (Saani, 2020). Such mining mechanisms can lead to different problems such as polluting the soil, water, and air of the mining sites, recycling of hazardous metals/chemicals through the food chain, falling adjacent residences to different health risks (Gebru, 2020).

2.1 Prototype and Instrumentation

The LVDT is used to monitor the displacement horizontal for the wall and in addition, the monitoring instrument from the strain gauge is attached to the piles, wall, and pipes are connected to the data logger and directly monitored by the computer. Wall and piles system is from steel ASTM-A36, fit-up, welding and fabricated in a workshop. After the wall-piles system was installed in the container in the laboratory and then the LVDT and strain gauge was attached as well on the wall-piles system and pipes. The electric jack is equipped with a load cell installed on the small platform attached to the container to give the lateral load. The load cell will control the lateral load was given for the experiments. The 3 e.a. jack equipped with load cells will install for this experiment. The first jack- load cell will be installed on the top platform and connected to the wall with the round bar to give the lateral load, the second jack and load cell will be installed in the middle of the platform and connected with a round bar to give the lateral load, and the third jack and load cell be installed on the bottom platform and connected to piles with a round bar to give lateral load. The stages of installation monitoring systems on wall-piles system and pipes, as shown in Fig. 1,2.3,4

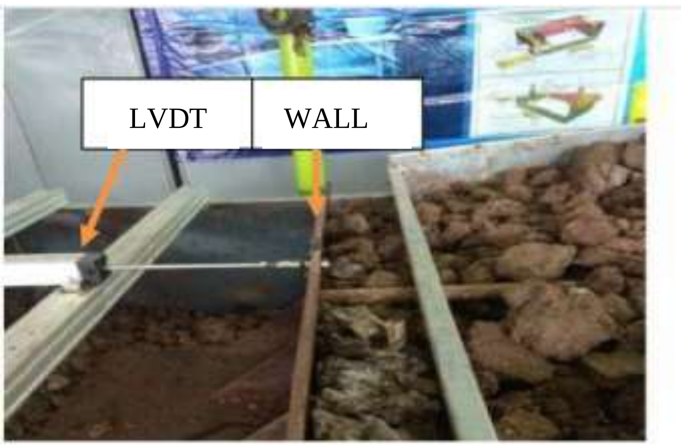

Figure 1. *LVDT Conect to the Wall*

Figure 2. *The 3 e.a Jack-Load Cell*

Figure 3. Container, Jack, Strain Gauge and Logger and Computer Installed

Figure 4. *Complete View*

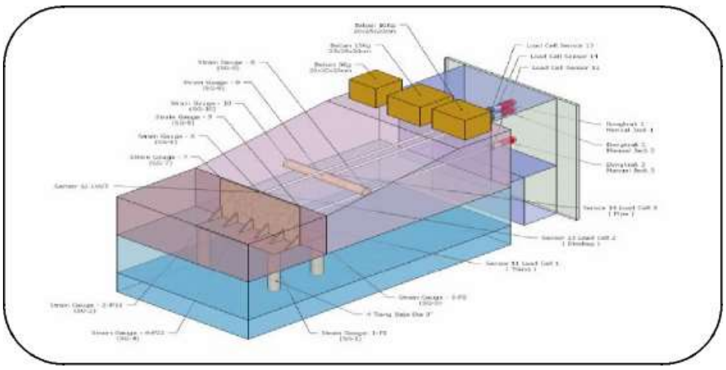

Figure 5. *3D Model*

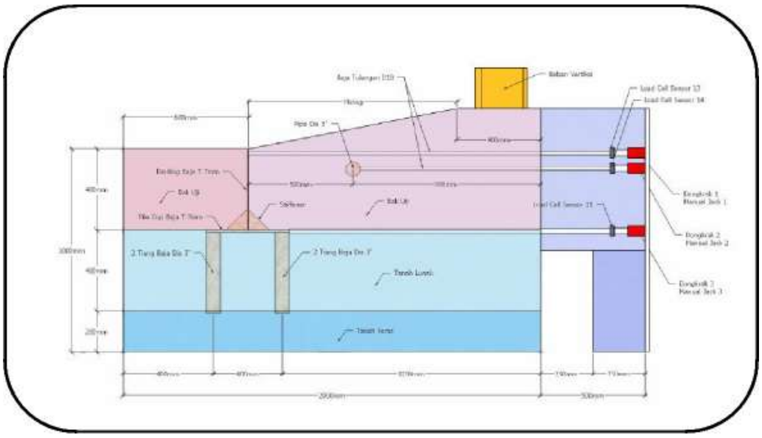

Figure 6. *Section View*

2.2 Soil Properties and Sample Preparation

Soft soil was used in the container or test box and the results of soil testing can be seen in Table 1. This was used in the test box and compacted according to the level of density in the field, the stages in compaction in the test box are 20 cm per layer. Compaction was done to achieve the desired consolidation (Guow, 2017).

Table 1. Soft Soil Properties

No.	Parameter	Unit	Average
1	Spesific Gravity, GS	-	2.65
2	Consistency Limits Liquid Limit, LL Plastic LimitPL Plasticity Index, PI	 % % %	 87,8 37,62 50,18
3	Water Content, w	%	53.22
4	Bulk Density,	kN/m^3	16.27
5	Dry Density, d	kN/m^3	11.14
6	Tri Axial UU Shear Test Cohession, c Friction Angle, ɑ	 kN/m2 deg	 3.63 6.79
7	CBR	%	1.69
8	Soil Clasificatio AASHTHO ASTM D 4318, USCS		 A-7-6 CH

2.3 Finite Element Method

The finite element method analysis, 2D Plaxis is used to determine changes and movements of the wall–piles system. The general setting for the geometry is simulated by the plane strain model. In the initial condition for the slope surface of the soil, the K0 Procedure and gravity loading are to be applied. The undrained analysis was used for the soft soil as well. Between walls and soil, piles and soil, and pipe and soil will put the interface elements. The boundaries will be put far enough to avoid the influence of boundary conditions. Standard absorbent limits were used to avoid false reflections. Fig. 7 shows the wall and piles model.

Input plaxis data for soil and steel: Modulus Young of steel (E) = 2.1 0E+09kN/m2, Poisson's ratios of steel (μ) = 0.15, Unit weight of steel (γs) = 78 kN/m3. The properties of soft clay are taken as γunsat = 11.14 kN/m3, γsat =16.27 kN/m3, Eref =15000 kN/m2, Rinter =0.5, C = 2.63 kN/m2, ϕ = 6.79,Poisson's ratios of soil μ=0,3.Input plaxis data for soil and steel : Modulus Young of steel (E) = 2.1 0E+09kN/m2, Poisson's ratios of steel (μ) = 0.15, Unit weight of steel (γs) = 78 kN/m3. The properties of soft clay are taken as γunsat =11.14 kN/m3, γsat =16.27 kN/m3, Eref =15000 kN/m2, Rinter =0.5, C = 3.63 kN/m2, ϕ = 6.79,Poisson's ratios of soil μ=0,3.

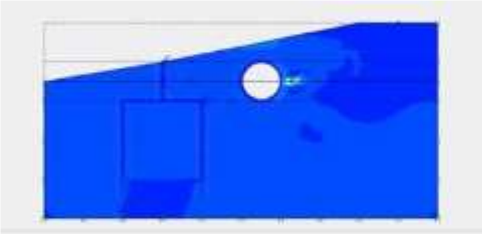

Figure 7. *2D Finite Element Model*

III. Discussion

3.1 Analysis of Experiment vs Finite Element Method (FEM)

The result of the calculation with the finite element method in Fig. 8 shows that the largest displacement is on the top end of the Wall. For lateral loading of 40 kg or 0.4 kN and Vertical Load of 15 kg or 0.15kN is 0.6 mm. For lateral loading of 35 kg or 0.35 kN and Vertical Load of 15 kg or 0.15kN is around 0.51 mm. For lateral loading of 30 kg or 0.3 kN and Vertical Load of 15 kg or 0.15kN is 0.50 mm. For other smaller Lateral loading and vertical loading, the result can be found in table 2.

The pattern of the experiment's test result is similar to the calculation with finite element method analysis. For lateral loading of 40 kg or 0.4 kN and Vertical Load of 15 kg or 0.1 5kN is around 0.43 mm. For lateral loading of 35 kg or 0.35 kN and Vertical Load of 15 kg or 0.15kN is around 0.39 mm, for lateral loading of 30 kg or 0.3 kN and Vertical Load of 15 kg or 0.15kN is around 0.37 mm.

From the above results, it can be seen and ascertained that the results of the experimental tests are still below the permissible horizontal displacement when compared from the finite element method analysis match with the research of (Mutadi, 2021).

Fig. 8 shows the change of deformation, Fig 9 illustrating displacement of the Wall in the top end and the bottom edge of the Wall when applied lateral loads from finite element method analysis.

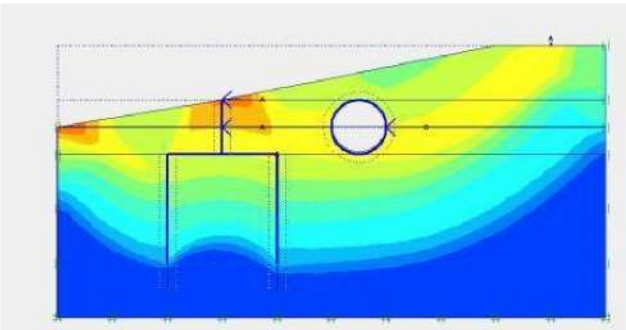

Figure 8. *Chnges of Displacement after Applied Loading*

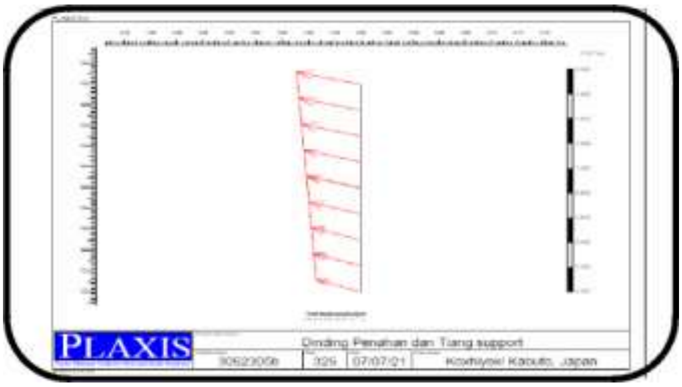

Figure 9. *Horizontal Wall Displacement after Applied Loading*

3.2 Deflection of Wall

Displacement analysis of wall had been done to find the extent effect of lateral loading on the wall displacement, and this result will be compared with the results of finite element method analysis using plaxis. The results of the analysis can be seen in Table 2.

Table 2. Accumulation Deflection of Wall

	Measured LL			FEM LL		
	LL Kg	LL Kg	LL Kg	LL Kg	LL Kg	LL Kg
VL (Kg	30	35	40	30	35	40
15	0.37	0.39	0,43	0.51	0,51	0,60
10	0.36	0.37	0.39	0.46	0.49	0,57
5	0.34	0.35	0.37	0.42	0.43	0,56

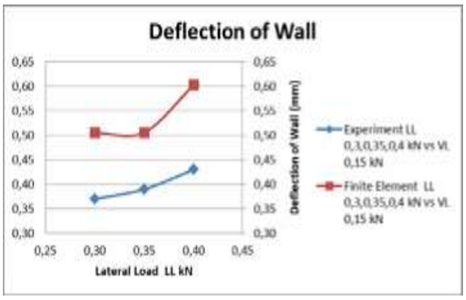

Figure 10. *Deflection of Wall Measured vs FEM Model LL 30 Kg, 35Kg, 40 Kg, VL 15 Kg*

Figure 10, deflection of Wall Measured vs FEM Model LL 30 Kg, 3 5Kg, 40 Kg, VL 15 Kg distinguish finite element method analysis and experiment test results, where the wall displacement in the top end of the wall from the experiment test was 0,43 mm while the finite element method analysis results was 0,60 mm. These results indicate that the finite element method results are greater when it is compared with the experimental results, this indicates that the experiment test results are still considered safe.

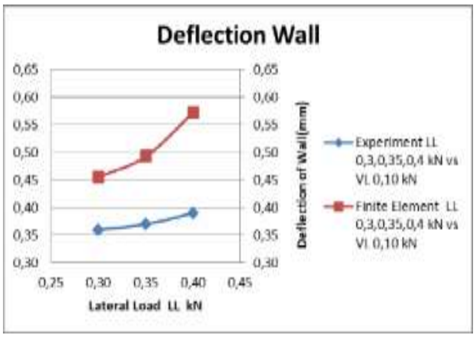

Figure 11. *Deflection of Wall Measured vs FEM Model LL 30 Kg, 35Kg, 40 Kg, VL 10 Kg*

Figure 11 distinguish finite element method analysis and experiment test results, where the wall deflection in the top of wall from the experiment test is 0.39 mm while the finite element method analysis results are 0,57 mm. These results indicate that the finite element method results are greater when compared with the experimental results, this indicates that the experiment test results are still considered safe.

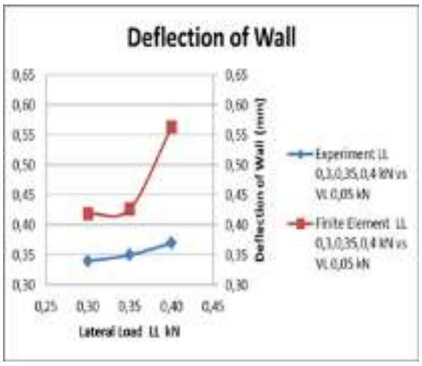

Figure 12. *Deflection of Wall Measured vs FEM Model LL 30 Kg, 35Kg, 40 Kg, VL 5 Kg*

Fig. 12 distinguish finite element method analysis and experiment test results, where the wall deflection on the top of the wall from the experiment test is 0,37 mm while the finite element method analysis results are 0,56 mm. These results indicate that the finite element method results are better when it is compared to the experimental test results, this indicates that the experiment test results are still considered safe.

3.3 Displacemet Horizontal of Pile

Pile deflection analysis was conducted to determine the extent of the effect of lateral loading on the pile deflection, and this result will be compared with the results of finite element method analysis using plaxis.

Table 3. Accumulation Deflection of Pile P1

Acumulation Displacement of Pile 1						
	Measured			FE Model		
	LL Kg			LL Kg		
VL Kg	30	35	40	30	35	40
15	0.333	0.35	0.37	0.38	0.39	0.41
10	0.28	0.32	0.34	0.29	0.34	0.35
5	0.27	0.29	0.32	0.28	0.31	0.34

Tabel 4. Accumulation Deflection of Pile P2

Acumulation Displacement of Pile 2						
Measured				FE Model		
	LL Kg			LL Kg		
VL Kg	30	35	40	30	35	40
15	0.37	0.38	0.43	0.47	0.48	0.51
10	0.34	0.35	0.39	0.37	0.42	0.43
5	0.33	0.34	0.37	0.36	0.39	0.42

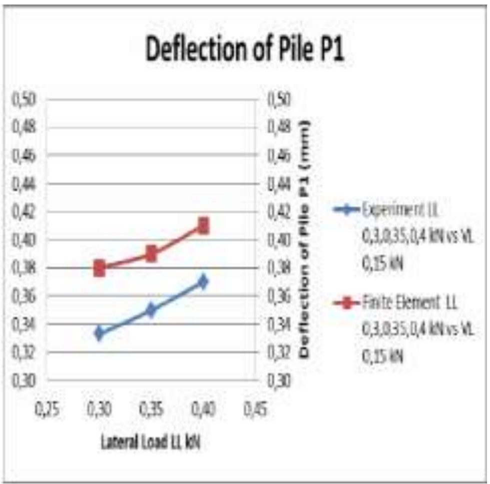

Figure 13. *Deflection of Pile P1 Measured vs FEM Model LL 30 Kg, 35Kg, 40 Kg, VL 15 Kg*

Fig. 13 distinguish finite element method analysis and experiment test results applied for lateral loading of 30Kg, 35Kg, and 40 Kg. These results show that there is a similar pattern between experiment test and finite element method analysis, for lateral loading of 40Kg deflection of the top pile is 0, 37 mm for experiment test and 0,41 mm for finite element method analysis. This result for Pile P2 on LL 40 Kg vs VL 15 Kg. For other results, it can be seen in table 4 and for pile P2 in table 3. But all the results from experiment deflection are still below the allowable deflection from the results of the finite element method analysis.

3.4 Deflection of Pipes

Pipe deflection analysis was operated to determine the extent effect of lateral loading on the pipe deflection, and this result will be compared with the results of finite element method analysis using plaxis.

Table 5. Accumulation Deflection of Pipe

Acumulation Displacement of Pipe						
Measured				FE Model		
	LL Kg			LL Kg		
VL Kg	30	35	40	30	35	40
15	0.38	0.4	0.46	0.42	0.51	0.60
10	0.36	0.38	0.44	0.37	0.42	0.49
5	0.35	0.36	0.39	0.36	0.38	0.42

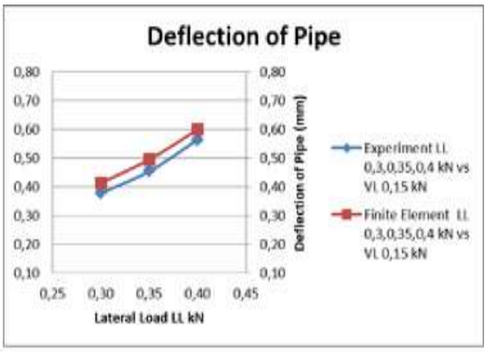

Figure 14. *Deflection of Pipe Measured vs FEM Model LL 30 Kg, 35Kg, 40 Kg, VL 15 Kg*

Fig. 14 distinguishes finite element method analysis and experiment test results for applied lateral loading of 30 Kg, 35Kg, and 40Kg. These results show that there is a similar pattern between experiment test and finite element method analysis. For lateral loading of 40Kg deflection of pipe is 0,56 mm for experiment test and 0,60 mm for finite element method analysis. This result for LL 40 Kg vs VL 15 Kg. For other results, it can be seen in table 5. But all the results from experiment deflection are still below the permissible deflection from the results of the finite element method analysis.

3.5 Safety Factor

Safety Factor analysis was operated to compare in dry Condition versus wet condition. The result can be seen in table 6.

Table 6. Safety Factor of Slope Stability

Safety Factor (SF) of Slope						
Dry				Wet/Raining		
	LL kN			LL kN		
VL Kg	0.30	0.35	0.40	0.30	0.35	0.40
15	3.329	2.821	2.472	2.97	2.521	2.229
10	3.330	2.824	2.474	2.98	2.522	2.235
5	3.330	2.828	2.476	2.99	2.524	2.237

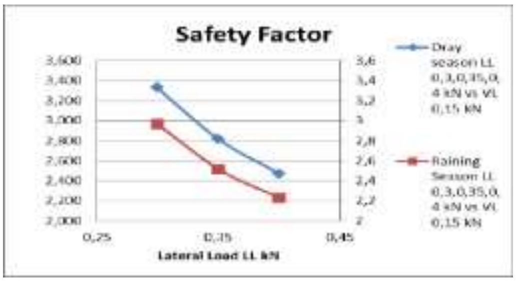

Figure 15. *Safety Factor Dry vs Raining LL 30 Kg, 3 5Kg, 40 Kg, VL 15 Kg*

Fig. 15 distinguishes finite element method analysis during Dry condition and raining! wet condition of Safety Factor results for applied lateral loading of 30 Kg, 35Kg, and 40Kg versus vertical load 15 Kg. These results show that there was a similar pattern between Dry condition and Wet condition finite element method analysis. For lateral loading of 40Kg Safety Factor of slope stability was 2,472 for dry condition, and 2,229 for wet! raining condition. This result for LL 40 Kg vs VL 15 Kg. For other results, it can be seen in table 6. But all the results shown that increase in lateral load decreased the Safety Factor for dry and wet condition.

IV. Conclusion

1. In carrying out the design for buried pipes in soft soil in slope areas, it should be considered the lateral and vertical loading effects on the stability of the wall-pile system, when applied in the field.
2. The bigger the lateral and vertical loading, the bigger will the deflection of the resulting wall, pile and pipebe.
3. For maximum lateral load up to 40Kg and vertical load up to 15 Kg, wall, pile, and pipe deflection are still below the allowed deflection.
4. The Wall-Piles system was reliable for the installation pipeline of hydrocarbon in soft soil of slope area.

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