International Journal of Scientific Engineering and Science
Volume 8, Issue 5, pp. 104-107, 2024
ISSN (Online): 2456-7361

Investigating the Tension of Retaining Walls in Cofferdams – A Case Study

Lies Kurniawati Wulandari
Department of Civil Engineering, National Institute of Technology
Jl. Bendungan Sigura-gura No. 2, Malang, Jawa Timur, Indonesia - 65141
Email address: lieskurniawatiw@lecturer.itn.ac.id

Abstract— *A retaining wall is a construction structure built to hold land that has a slope/slope where the stability of the land cannot be guaranteed by the land itself. The role of retaining walls is very important to withstand lateral earth pressure generated by filled soil or original soil that is unstable due to topographic conditions or due to other additional loads. This case study discusses the stress of cantilever-type retaining walls and sheet piles in PT cofferdams. PAL in Surabaya, Indonesia. Identification of alternative problem solutions is needed to formulate solutions other than loosening the anchor cable without control because it is not known with certainty what level of loosening is suitable for the long term without endangering the cofferdam structure as a whole. The main consideration is not only the effectiveness of the solution but also cost efficiency. This report explains how the solution for reducing the active soil load on the anchor cables was determined to be the best solution based on field studies.*

Keywords— *Cofferdam, Retaining wall, Case study.*

I. INTRODUCTION

Water transportation activities are an important part of economic activity, so that every time facilities are developed to be more adequate and facilitate the transportation of goods and services. The economic factors desired to realize sea transportation include several indicators, for example, cargo investment, design appropriate to the type of cargo, loading and unloading equipment, and procurement of logistics vessels according to the number of requirements [1]. In connection with this goal, in Indonesia, specifically in Surabaya, a company operating in the shipping industry was formed, namely PT. Indonesian Ship Factory commonly known as PT. PAL Indonesia. This company is the backbone of the shipping industry in Indonesia.

Until now, the company continues to develop, where currently PT. PAL, one of them, is currently expanding its buildings and other supporting facilities for the company's progress. This project is not only to build new facilities but also to rehabilitate existing buildings. To support this project, one of the new facilities built by PT. PAL is the manufacture of 30,000 DWT (dead weight tonnage) commercial ships that require a graving dock to work on. Because the location of the graving dock borders the sea, while the ship construction process must be dry, the type of graving dock made is a reinforced concrete buttress wall. This concept of course requires auxiliary construction, namely a cofferdam.

A cofferdam is a temporary construction made to prevent the flow of water into the excavation hole, thereby allowing work to be carried out free from water disturbance. The cofferdam will be dismantled after the graving dock construction is completed [2]. In principle, cofferdam construction consists of two sheet pile walls to hold the soil, a gording that unites the sheet piles, an anchor rod that functions to connect the two sheet pile walls (used tible), and filler material (used sea sand)[3, 4]. Tible is another type of tie-rod, where the rod consists of several steel strands twisted together. This steel or strand cable has high strength (breaking stress = 190 kg/mm2) and is wrapped in polyethylene resin to prevent rust.

Preliminary studies carried out in the field indicate that there are at least three problems with the cofferdam structure. The first problem, checking the tension of the tibles (anchor cables) in the cofferdam showed that several tibles experienced stresses that were greater than planned, namely 33.2 tons of allowable tensile load, and 50.4 tons of allowable tensile load due to the earthquake. The planned tension is around 25 tons. Some tables on one side have tensile stresses above 60 tons, approaching the elastic limit of 75.6 tons. The second problem, measuring the position of the top of the steel sheet piles on both sides of the cofferdam, shows that there is a problem, namely the movement of the sheet pile heads towards the south, starting from the time the cofferdam is first filled with soil (backfilled). This movement continues with smaller increases. The third problem, measurements of the curvature of the sheet pile in the vertical direction show that the sheet pile at several points is slightly curved and bulges inward.

Three problems encountered in the field require effective and efficient solutions so as not to endanger the implementation of company development projects. If the tible tension increases until it reaches the maximum limit, then the tible forces are directly transmitted to the tible on the left and right [5, 6, 7]. Furthermore, if the surrounding tibles are also unable to withstand the load, then the cofferdam structure has the potential to collapse [8]. This case study examines the excess tible stress in the cofferdam of one of PT's work facility construction projects. PAL Indonesia, then formulated the best alternative as a solution to the problem. However, it should be noted that this text does not discuss stresses that occur in sheet piles

http://ijses.com/

International Journal of Scientific Engineering and Science
Volume 8, Issue 5, pp. 104-107, 2024 ISSN (Online): 2456-7361

because the results of checking sheet pile stresses are still within safe limits.

II. Method

This research is a quantitative-based case study. The research object is the cofferdam on the PT construction project. PAL Indonesia, located in Surabaya City. Specifically, the temporary cofferdam construction is planned to use a type F 130 T table with the following characteristics:

TABLE 1. Cofferdam specifications

Composition	7 x ø 12,7
Section area	691,0 mm2
Weight of strand	5,45 kg/m
Weight of tible	6,54 kg/m
Breaking load	126,0 ton
Yield point	110,4 ton
Allowable tensile load at normal time	33,2 ton
Allowable tensile load at earthquake time	50,4 ton
Cross section	-

The table is in elastic (good) condition and can be used again if the working load does not exceed 75.6 tons. The area of commercial ship facilities is 17.66 Ha, of which the northern part is approximately 1.4 Ha and is a reclamation area. Above this area, a graving dock covering an area of 10,175 m2, a workshop covering an area of 66,750 m2, a jetfoil area of 6,900 m2, and a work field and road will require an area of 92,775 m2—construction of PT. PAL Indonesia (Persero) is implemented with a construction management system where development work is divided into 3 (three) work packages; civil work (revetment, unloading quay, north quay, outfitting quay, south quay, temporary cofferdam, and graving dock), building work (building work for workshops, offices, warehouses and assembly places), and utilities (mechanical and electrical work and facilities support).

Research data includes primary data and secondary data. Secondary data includes technical specifications of the cofferdam as well as other relevant data based on information from the project owner. The primary data includes data from field observations regarding the bearing capacity of the cofferdam. Data analysis was carried out quantitatively using engineering calculation formulas, which were then explained descriptively.

III. Results and Discussion

Cofferdams have important benefits and also hold great potential. If the Cofferdam collapses (breaks) it can cause flash floods which can result in damage to development plans, environmental damage, and threaten worker safety. Therefore, Cofferdams must be designed to be safe and technically feasible. A Cofferdam is considered safe if its construction and management have been carried out following the concept and principles of Cofferdam safety based on nationally applicable standards [2]. Table 2 explains the results of the inspection of the PT cofferdam graving dock. PAL Indonesia which is carried out directly at the project location.

TABLE II. Cofferdam inspection results

Tible Number	Inspection I		Inspection II		Inspection III		Inspection IV		Inspection V		Information
	13-08-1988		15-08-1988		16-08-1988		07-09-1988		-		
	MPA	TON	MPA	TON	MPA	TON	MPA	TON	MPA	TON	
22	26	50,2	13	± 25	14	27	15,5	29,9			Tible number 25 is relaxed until the Tible tension becomes ± 42.5 tons (originally 56 tons).
24	22	42,5			22	42,5	25,5	49,2			
	21,5	41,5									
	21,5	41,5									
25	29	56			26	50,2	29	56			The soil pile above Tible number 22 was excavated up to the Tible elevation (Tible tension before excavation was ± 50.2 tons).
	28	54									
	22	42,5									
26	26	50,2			27	52,1	27	52,1			The excavation at Tible number 22 was backfilled after the tension of Tible number 22 was checked (± 25 tons).
	25,5	49,2									
	27	52,1									

Furthermore, the evaluation of the results of checking the tension of the tible cofferdam is described as follows:

1. Area F2 – E2. Random tests of 30 tables showed that table numbers 11 to 61 had a tension of ± 30 tons.
2. Region E2 – D2. A random test of 9 tables showed that table numbers 62 to 123 had an average tension of <30 tons.
3. Area D2 – C2. Random tests of 17 tables showed that table numbers 124 to 185 had an average tension of <30 tons.
4. Area C2 – B2. Tests on 61 tibles showed that the tible tension was ± 40 tons. The tension in the northern part tends to exceed 40 tons, while in the southern part, it tends to be less than 40 tons. The largest tible tension was found in tible number 221 with a tension of 46,872 tons.
5. Area B2 – B5. Tests on 28 tibles showed that the tension on tible number 16 was 32 tons. As you go west, the pressure increases on tables number 25 (63,088 tons), 29 (67,168 tons), and 34 (60,640 tons). As you go further west, the tension tends to decrease again from table number 34 to table number 39, namely with a tension of 27,584 tons.

The type F 130 T table used in the cofferdam has the characteristics of a breaking load of 126 tonnes, a yield pint load of 110.4 tonnes, and an allowable tensile load of 33.2 tonnes for

Volume 8, Issue 5, pp. 104-107, 2024 ISSN (Online): 2456-7361

normal and 50.4 tonnes for the earthquake. At the time of observation, the table was still in an elastic condition and could be used again if the working load did not exceed 75.6 tons. Furthermore, evaluation in the field shows that the areas that are still safe are areas F2 - E2, areas E2 - D2, and areas D2 - G2. For areas that are no longer safe, namely areas C2 - B2, where the stress has exceeded the permitted limit but is still within the elastic limit (75.4 tonnes) it can still be used again. Periodic checks are needed for tible tension, especially when the excavation in the main pump room is deepened (currently the excavation evaluation is D1 - 8.00 which will later be changed to D1 - 11.40). In the C2 - B2 area, the tible stress is quite high, almost reaching the elastic limit (75.6 tons) which is permitted to be used again, which is a critical problem.

Due to this problem, several efforts need to be made to maintain the suitability of the cofferdam. These steps include the following:

1. The cofferdam load needs to be reduced, namely by reducing the cofferdam sand pile to a width of ± 10 M to a height of D1 + 2.00 along from table number 18 – 38 (35 M). It is expected that the tible stress will decrease because the active earth pressure is reduced.
2. On the inside of the sheet pile cofferdam, a sand pile is added (obtained from reducing the cofferdam sand) to increase the pressure capacity of the sand.
3. After points 1 and 2 have been implemented, it is then necessary to check the tible voltage to reduce the extent of the effect of the reduction.
4. Tibles with high pressure need to be loosened and leveled to increase reliability so that the tible tension is not too high. This is done based on the idea that loosening will cause deflection, so it is hoped that passive pressure can be mobilized to a greater or optimal extent.
5. A re-check is carried out, namely sometime after the steps in point 4 are carried out as further evaluation material to see whether there is an increase in voltage again.
6. If there is a tendency for the stress to increase again, maintenance is necessary to install tension rods which can help receive some of the additional stress.

Solution 1 - Reduce Active Soil Load

Actions to reduce the active soil load are very effective in overcoming the causes of subsidence of the embankment layer. This is because the backfill shows an increase in tible stress due to the soil load above the tible. Soil excavation in places where the tible stress is high is highly recommended to reduce the tible stress. The shape of the excavation can be seen as shown in the image below.

The minimum excavation length L is taken sufficiently, in such a way that the tible stress drops too close to the standard stress. Excavation is attempted up to the surface of the tible and later the soil can be backfilled until it reaches approximately 50cm above the tible (after the soil under and around the tible has been compacted). Active soil load reduction has two objectives, namely reducing the forces that arise on the sheet pile so that it is hoped to reduce the load on the tible and to reduce the soil load on the tible due to settlement. However, loosening the tible without excavation is not recommended because it is not known what level of loosening is suitable for the long term without endangering the overall cofferdam structure.

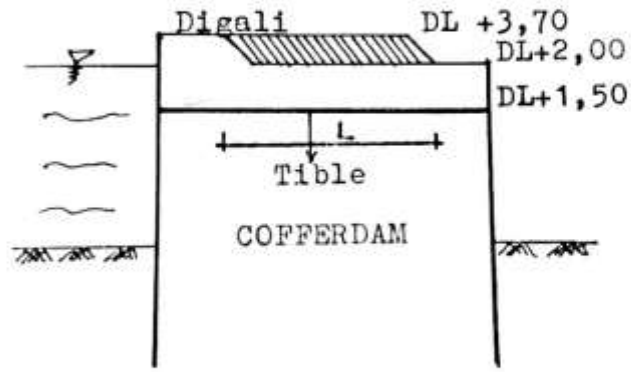

Fig. 1. Shape of cofferdam excavation

Solution 2 - Pump Out the Water in the Cofferdam

Because the water level is higher than planned, there will be an active force that is greater than expected. Several ways that can be done to reduce this problem include:

1. Close/reduce the entry of water into the cofferdam by covering the gaps between the sheet pile and the table with a waterproof material, such as asphalt or clay.
2. Pumping is carried out in the cofferdam.
3. The inner sheet pile is perforated so that incoming water can flow out.

The steps above will trigger an increase in tible pressure so that all three may need to be done at once, but still taking into account several aspects, such as ease of implementation, electricity, and fuel consumption, as well as safety or durability of material use. If you choose a solution to close the gaps between the sheet pile and the table to prevent water from entering, it is recommended to use a waterproof material.

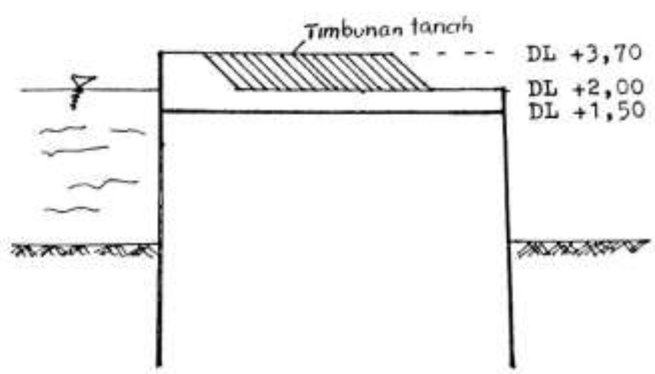

Fig. 2. Scheme for backfilling active soil on top of the tible

International Journal of Scientific Engineering and Science
Volume 8, Issue 5, pp. 104-107, 2024 ISSN (Online): 2456-7361

Solution 3 - Installing Tible Protectors Against Possible Drops

Installation of pipes/concrete in such a way can be done if the soil under the table has settled. In this way, the land above does not directly burden the table. From the results of field inspections and checking calculations, the priority order for problem-solving seen from the technical response level is sequentially reducing the pile of soil above the tible, installing tible protectors, and reducing or pumping water into the cofferdam. Furthermore, based on several economic considerations, excavation of the land above the table will be more economical.

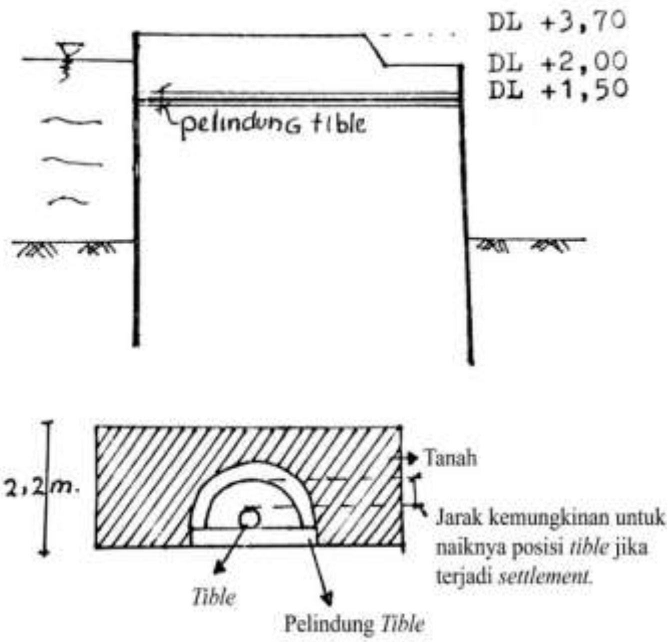

Fig. 3. Scheme of installing tible protectors and closing holes that allow seawater to enter the cofferdam, then pumping to a depth of 2 meters.

The cofferdam functions to divert the main water flow while dam construction work is being carried out. This means that the cofferdam has a very important function, so its specifications need to be ensured by standards, and evaluation also needs to be carried out during the main construction process [9]. Cofferdams are made by driving piles, usually, steel or plates made of heavy wood, steel, or a combination of both materials. Vertical piles are made to form a watertight fence and are supported by horizontal frame members. The sides of the cofferdam must be sturdy and well-supported to withstand shocks caused by heavy water flows. Cofferdams must also be able to withstand horizontal forces from surrounding water bodies, and are usually not planned to experience overtopping [10]. Therefore, the cofferdam design must be ensured to have good bearing capacity.

IV. Conclusion

Bearing capacity analysis of cofferdam buildings requires complete data, both from field observations, initial calculations, and recalculations. Overall, all of this determines the accuracy of selecting problem-solving alternatives. In this case study, it can be concluded that the increase in tible stress beyond the planned stress was caused by the subsidence of the soil above it. Furthermore, by looking at alternative solutions to the problem, loosening the tible without control is not recommended because it is not known what level of loosening is suitable for the long term without endangering the cofferdam structure as a whole. In the end, the solution stated that the best alternative was to reduce the active ground load above the tible so that technically the tible stress was reduced. Apart from that, this alternative is considered more economical and only requires a relatively short processing time.

References

[1] A. Jaelani, "Analisis Dinding Penahan Tanah/Retaining wall Underpass Unila Bandar Lampung," *Undergraduate Thesis - Teknik Sipil, Universitas Muhammadiyah Metro*, vol. 1, no. 1, pp. 1–138, 2020.

[2] Abadi, "Analisis Perhitungan Cofferdam Menggunakan Aplikasi Geo-Studio pada Pembangunan Bendungan PLTA Peusangan, Takengon, Kabupaten Aceh Tengah," *Jurnal Teknik Sipil Universitas Medan Area*, vol. 1, no. 1, pp. 1–108, 2022.

[3] T. Pangestu, "Penggunaan Ground Anchor, Soldier Pile dan Cofferdam untuk Pengendalian Banjir Air Rob di Kota Semarang," *Undergraduate Thesis - Institut Teknologi Sepuluh Nopember*, vol. 1, no. 1, pp. 1–286, 2018.

[4] M. Kalalo, J. H. Ticoh, and A. T. Mandagi, "Analisis Stabilitas Dinding Penahan Tanah (Studi Kasus: Area PT. Trakindo, Minahasa Utara)," *Jurnal Sipil Statik*, vol. 5, no. 5, pp. 285–294, 2017.

[5] M. Sulovska, J. Stacho, and M. Kopecky, "The Stability Analysis of a Cofferdam Using the Numerical Modelling," *IOP Conf Ser Mater Sci Eng*, vol. 96, no. 2, p. 022068, Dec. 2020, doi: 10.1088/1757-899X/960/2/022068.

[6] Y. Zhu *et al*., "Stability Analysis of Cofferdam with Double-Wall Steel Sheet Piles under Wave Action from Storm Surges," *Water (Basel)*, vol. 16, no. 8, p. 1181, Apr. 2024, doi 10.3390/w16081181.

[7] R. Xue, S. Bie, L. Guo, and P. Zhang, "Stability Analysis for Cofferdams of Pile Wall Frame Structures," *KSCE Journal of Civil Engineering*, vol. 23, no. 9, pp. 4010–4021, Sep. 2019, doi: 10.1007/s12205-019-1320-7.

[8] BP. Verma, *Problems in Mechanics - Second Edition*. 1975.

[9] J. Derksen, M. Ziegler, O. Detert, and H. Hangen, "Analysis of Bearing Capacity of Reinforced Retaining Structures," *Proceedings of the 11th International Conference on Geosynthetics*, pp. 16–21, 2018.

[10] T. Handayani and Sudarmadi, "The Evaluation of The Causes of Retaining Wall Structure Failure at A River Based on SNI 2847:2013," *M.I.P.I*, vol. 14, no. 3, pp. 251–258, 2020.