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A Comparative Analysis of Cantilever and Gravity Retaining Wall Dimensions on The Temuireng-Jetis Road Section In Mojokerto District

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ABSTRACT

The construction of retaining walls in Mojokerto Regency is essential due to the region's hilly topography and the increasing risk of slope instability caused by high rainfall and lateral soil pressures. Retaining walls play a crucial role in stabilizing slopes, preventing landslides, and ensuring road infrastructure and mobility are preserved in areas prone to geotechnical challenges. This study focuses on determining the dimensions, costs, and construction timelines of cantilever and gravity retaining walls along the Temuireng-Jetis road section, a strategic route affected by frequent landslides. Using Coulomb's theory and triaxial soil test data, the analysis comprehensively compares the structural stability, safety factors, and economic efficiency of both designs. Results indicate that cantilever retaining walls achieve higher shear stability with a lower construction duration but incur higher costs due to the use of reinforced concrete and steel reinforcements. Conversely, gravity walls are more cost-effective, relying on their own weight for stability, but demand longer construction periods due to their massive size and additional requirements such as drainage systems. These findings contribute to efficient and sustainable infrastructure development, offering practical solutions for areas with varying topographic challenges and soil conditions.

Keywords: *retaining wall, cantilever, gravity, stability analysis, infrastructure development*

INTRODUCTION

Mojokerto district, particularly Jetis sub-district, faces significant geotechnical challenges due to its hilly topography that has resulted in slope instability in several locations. Strategic routes such as the Temuireng - Jetis road section are often affected by landslides, requiring robust infrastructure planning to ensure soil stability and road user safety. This problem has led to the importance of applying appropriate soil retaining structure technology, both cantilever and gravity types, to ensure the safety and efficiency of infrastructure development (National Standardization Agency, 2005; 2013).

Retaining walls play a key role in stabilizing slopes, particularly in areas with high soil lateral pressure. Previous research by A. Tanjung & Y. Afriza (2016) showed that the selection of retaining wall type should be tailored to the soil conditions and acting loads. This study is relevant to the research site in Mojokerto which faces a combination of alluvial soil conditions and lateral pressure due to high rainfall. In this context, an understanding of design parameters such as optimal dimensions is important.

Retaining wall technology is rapidly evolving with methods such as Value Engineering approaches (Asfarina & Makarim, 2019) that focus on cost efficiency without compromising structural quality. The study in Serpong by Asfarina et al. highlights the importance of construction material optimization for efficiency. In projects involving cantilever and gravity types, consideration of material efficiency is essential to minimize costs without compromising structural stability (National Standardization Agency, 2833, 2016).

Planning techniques such as Coulomb's theory are the basis for analyzing lateral soil pressures and retaining wall dimension requirements. According to Hardiyatmo (2011), shear and overturning stability analysis should be a priority in the design of retaining structures. In Mojokerto, with varying soil conditions, a combination of analytical methods and field testing such as triaxial tests is an important step to ensure the accuracy of design parameters (Dermawan, Syaiful, Alimuddin, & Fachruddin, 2022).

Previous research has also shown that earthquake-induced lateral pressure must be considered in design. Standard SNI 2833 (2016) underlines the importance of earthquake load calculation in retaining wall structures. Mahdi et al. (2023) developed a decision-making model to determine the optimal type of retaining wall in a constrained location, which is highly relevant for the conditions in Mojokerto.

Cantilever-type walls offer the advantages of material efficiency and their ability to withstand large loads, while gravity-type rely on their weight for stability. Studies by Diantoro (2023) show that gravity walls are more suitable for low to medium lateral pressures, while cantilever walls are more efficient for high pressures. However, cost and implementation time are the main differentiating factors that influence the decision to select a wall type.

The study in Kudus by Noviyanti et al. (2021) used a Value Engineering approach to compare the construction costs of the two types of retaining walls. Results showed that the cantilever type required a higher initial cost but had the advantage of a shorter implementation time. In contrast, the gravity type is more economical in material cost but takes longer. The importance of slope stability analysis was recognized in a study by Fachrurrozi et al. (2022), which emphasized the role of stability evaluation as the basis for selecting a retaining method. Another study by Kurniawan & Endayanti (2022) states that stability evaluation should include simulation of actual loads to improve design accuracy.

The use of software such as PLAXIS (Syafi'i, Rohman, Soedarsono, & Pratikso, 2020) provides an efficient alternative in analyzing the stability and deformation of soil retaining structures. This approach provides more detailed results than manual calculations, especially in simulating dynamic loads due to earthquakes (National Standardization Agency, 2005; 2013). In the local context, research such as that by Thomson & Prihatiningsih (2021) underscores the importance of considering peat soil properties in retaining wall design. Although the Mojokerto case did not involve peat soils, the lesson from this research is the need for in-depth analysis of local soil parameters.

The study in Samarinda by Mohammad Robbi Hidayat (2024) shows that a combination of slope stability analysis and retaining wall dimension adjustment can reduce the risk of structural failure. Meanwhile, research at the Sembayat Gerak Dam by Rachmat Hakim Tri K (2017) confirmed that quality control of construction materials is essential to ensure the sustainability of the structure. In the Mojokerto project, adjusting the retaining wall dimensions based on stability needs is essential. A previous study by Soemitro et al. (2021) highlighted that this approach not only improves stability but also reduces long-term operational costs. This study is relevant in designing efficient and durable retaining walls.

In conclusion, the planning of retaining walls on the Temuireng - Jetis road section should consider various technical and economic parameters. Adopting a data-driven approach as proposed by Huidrom & Deb (2023) can improve project efficiency. By combining technical analysis and cost evaluation, the resulting solution is expected to provide long-term benefits for infrastructure stability in Mojokerto. Slope instability on the Temuireng - Jetis road section of Mojokerto district poses a risk to road user safety and infrastructure sustainability. In this context, cantilever and gravity retaining walls are a viable solution to address the lateral soil pressure and landslide risk. Therefore, it is important to determine the required dimensions for each type of wall, taking into account soil pressure, earthquake loads and cost efficiency. In addition, planning should include cost and implementation time analysis to ensure overall project feasibility. With a data-driven approach, the resulting solution is expected to be not only efficient but also sustainable, making a positive contribution to infrastructure development in Mojokerto district.

Literature Review

Retaining Walls and Their Functions

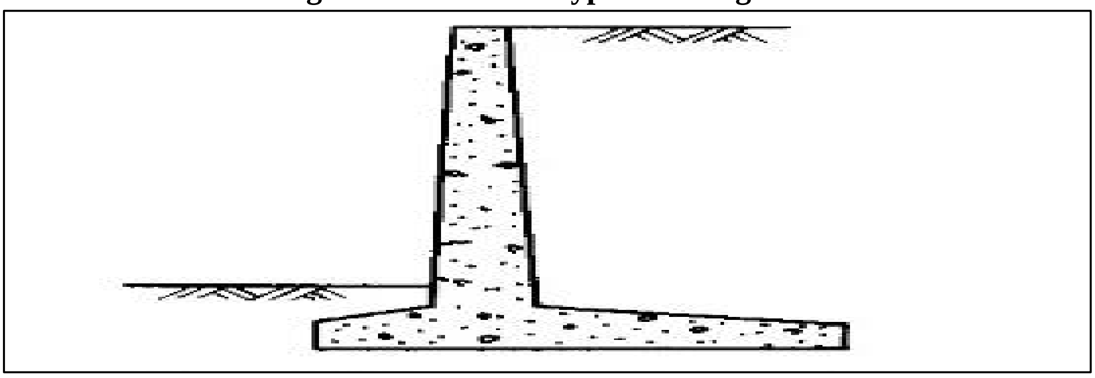
Retaining walls are structures designed to resist the lateral pressure of the soil and prevent landslides. These structures are usually used in areas with hilly topography or landslide-prone locations such as in Mojokerto. According to Hardiyatmo (2008), retaining walls should be designed with consideration of lateral soil loads, water pressure, and other additional loads.

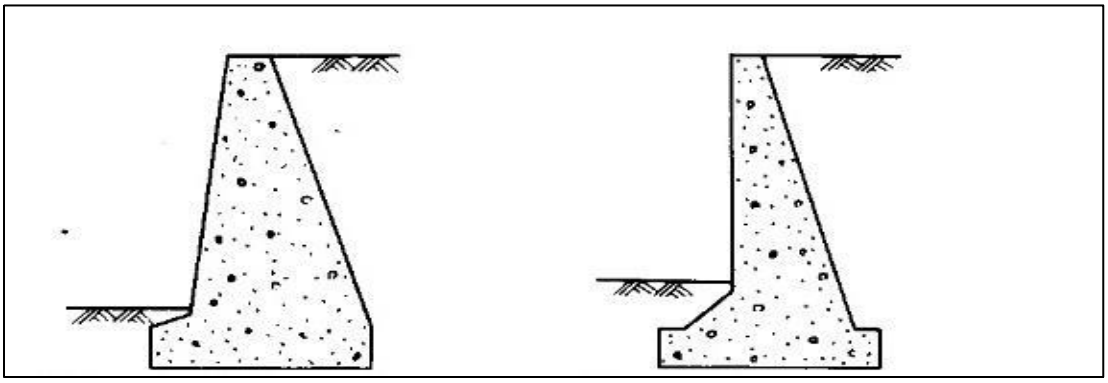
The main function of retaining walls is to stabilize slopes and support infrastructure structures such as roads and bridges. In large projects, the type of retaining wall is selected based on soil conditions and expected working loads (National Standardization Agency, 2005). In addition, an efficient design can reduce the risk of structural failure, especially in areas with high lateral soil pressures (Oetomo, Priyoto, & Uhad, 2017).

Types of Retaining Walls

Types of retaining walls include cantilever, gravity, diaphragm, sheet pile and gabion types. Cantilever-type walls use the structural strength of reinforced concrete to resist lateral soil pressure, while gravity walls rely on their own weight (Hardiyatmo, 2014). The choice of wall type depends on site conditions, cost, and material availability. Research by Diantoro (2023) states that gravity walls are more economical for low to medium heights. In contrast, cantilever walls are more suitable for high lateral pressure. Both types are often used in road and bridge projects due to their material and construction efficiency (Nugroho & Marleno, 2020).

Figure 1. Cantilever type retaining wall





Gravity and semi-gravity walls

Structure Stability and Analysis

The stability of retaining wall structures involves control of shear, overturning and soil bearing capacity. According to Hardiyatmo (2011), the Coulomb method is used to calculate active and passive soil lateral pressures. This approach is effective in ensuring that the structure is able to withstand loads with an adequate factor of safety. Stability analysis also considers earthquake loads, especially in earthquake-prone Indonesia. SNI 2833 (2016) recommends the use of peak acceleration parameters in retaining wall planning. With this method, the wall design can be adjusted to deal with dynamic conditions.

Value Engineering Approach

Value engineering is an approach to improve cost efficiency without compromising quality. Asfarina & Makarim (2020) showed that the use of alternative materials such as site mix can reduce construction costs by up to 20%. This technique is particularly relevant for projects in areas with limited budgets. This approach also encourages innovation in retaining wall design. In a case study in Serpong, Value Engineering successfully resulted in a more economical and environmentally friendly design (Noviyanti, 2021). The implementation of this method had a significant impact on the sustainability of the project.

Influence of Soil Conditions on Design

Soil conditions greatly influence the design and stability of retaining walls. Alluvial soils, such as those found in Mojokerto, have lower lateral pressures than rocky soils, but these conditions can change due to heavy rainfall which increases the risk of landslides (National Standardization Agency, 2013). The study by Dermawan et al. (2022) highlights the importance of soil testing, such as triaxial tests, to determine stability parameters. In addition, design adjustments based on test results can improve safety factors and construction cost efficiency. With this approach, the risk of structural failure can be minimized.

Although numerous studies have investigated retaining wall designs, there is limited research comparing the economic and structural efficiency of cantilever and gravity retaining walls in the context of hilly areas with high rainfall and frequent landslides, such as Mojokerto. Existing studies often emphasize individual designs without providing a comprehensive comparative analysis that includes both cost and construction timelines tailored to specific geotechnical conditions.

The urgency of this research lies in addressing the persistent challenges posed by slope instability along critical roadways, particularly the Temuireng-Jetis road section in Mojokerto. Frequent landslides disrupt transportation and pose risks to road users and surrounding infrastructure. A thorough comparison of retaining wall designs can provide sustainable solutions to enhance safety and ensure the longevity of infrastructure in landslide-prone areas.

This study offers a novel contribution by combining structural stability, cost analysis, and construction timeline evaluation for cantilever and gravity retaining walls in a single framework. By applying Coulomb's theory and integrating soil test data, this research not only compares the designs but also provides actionable insights for decision-making in geotechnically challenging regions, such as Mojokerto's hilly terrains.

The primary objective of this study is to evaluate and compare the structural stability, cost efficiency, and construction timelines of cantilever and gravity retaining walls for the Temuireng-Jetis road section. It aims to provide a comprehensive analysis to guide the selection of the most suitable retaining wall type based on geotechnical conditions and project requirements.

This research provides practical recommendations for engineers and policymakers in designing and implementing retaining walls that balance cost and structural integrity. Academically, it expands the knowledge base on retaining wall design in hilly and high-rainfall areas. For the local community, it ensures safer and more reliable infrastructure, reducing disruptions caused by slope instability and supporting regional development.

METHOD

This research uses a quantitative approach with descriptive analysis to evaluate the comparison of cantilever and gravity type retaining walls. This method aims to analyze the dimensions, stability, and construction cost efficiency based on technical data obtained from the research site. The data used included soil laboratory test results, topographic data, and technical parameters according to applicable standards. This approach allows the collection of measured and relevant data to produce an optimal design. In addition, this research also considers environmental factors such as geotechnical conditions and earthquake potential, so that the results can be applied to locations with similar characteristics.

The research site is located on the Temuireng-Jetis road section, Mojokerto Regency, which has a hilly topography and alluvial soil. This area was chosen due to the frequent occurrence of landslides, thus requiring an effective soil retaining structure. The analysis was conducted on the road segment most prone to landslides to ensure design efficiency. The selection of this location was also based on the availability of supporting geotechnical data, such as sondir and triaxial tests. The field conditions at this location provided a real picture of the technical challenges faced in designing retaining walls.

RESULTS AND DISCUSSION

Dimensions of cantilever type retaining wall

The dimensions of the cantilever type retaining wall were designed to meet the need for stability against lateral soil pressure on the Temuireng - Jetis road section. Based on the analysis, the total height of the wall was determined to be 5 meters with the width of the bottom foundation reaching 3 meters. The bottom foot section has a thickness of 0.5 meters, while the wall body is designed with a thickness of 0.3 meters to ensure adequate structural strength. These parameters were adjusted according to the results of triaxial testing to determine the shear strength of the soil. The width of the lower foundation is designed to be larger to increase the bearing capacity and prevent the risk of overturning. Based on the calculation results, the maximum pressure at the base of the foundation is 150 kPa, which is within safe limits. This value was validated using the Coulomb method to analyze soil lateral pressure. With a safety ratio against shear and overturning of more than 1.5, this design is considered adequate.

The addition of steel reinforcement at the bottom of the wall was carried out to increase the structural capacity against dynamic loads. The reinforcement thickness was designed based on SNI 2847 (2013) standards to ensure sufficient tensile strength. In addition, the placement of reinforcement at a certain distance also considers the effect of deformation due to lateral pressure. This design considers alluvial soil conditions at the research site. Field test results showed that the active lateral pressure acting on the wall was 12 kN/m². This pressure was used as the basis for determining the thickness of the wall body. Overall, the dimensions of the cantilever wall were designed to provide material efficiency without compromising stability.

Table 1. Recap of dimensions against stability control in cantilever-type DPTs

Dimension (m)			Stability Control			Pile Support Capacity
H	B	D	FK slide	FK bolster	DDT	Single
5,00	2,50	0,50	5,07	1,26	281,58	247,27
5,00	2,80	0,50	6,32	1,47	285,22	247,27
5,00	3,00	0,50	7,23	1,63	287,64	247,27

Table 1. contains a recap of dimensions against stability control in cantilever walls, relevant to be placed here for reference. This data provides a detailed overview of the dimensional analysis results that meet the stability criteria.

Dimension of Gravity Type Retaining Wall

The dimensions of the gravity-type retaining wall were designed with a different approach, relying on the weight of the wall to resist the lateral pressure of the soil. Based on the analysis, the total height of the wall was designed at 4.5 meters with the bottom foundation width reaching 2.5 meters. The thickness of the wall body varies, with the lower part being 1 meter thick and the upper part being 0.5 meters thick, following a terraced design. The gravity wall was designed using conventional concrete material with a specific gravity of 24 kN/m³. This wall weight ensures stability against an active lateral pressure of 10 kN/m², as measured through field testing methods. The design considered a safety factor against overturning with a ratio of more than 1.5. The analysis was validated using the Rankine method.

The foundation width was expanded to distribute the load evenly on the subgrade. Sondir tests showed a soil bearing capacity of 200 kPa, which was sufficient to support the gravity wall. The addition of a drainage layer on the back side of the wall was designed to reduce water pressure that could affect stability. The varying wall thickness ensures material efficiency without compromising structural stability. Analysis results show that this design minimizes deformation due to lateral pressure and ensures resistance to sliding. In addition, the use of reinforced concrete in the foundation increases the bearing capacity against vertical loads

Table 2. Recap of dimensions against gravity-type DPT stability control

Dimension (m)			Stability Control			Funnel Supportability	
H	B	D	FK slide	FK bolster	DDT (kN)	Single (kN)	Group (kN)
5,00	2,80	0,80	5,76	1,38	58,71	41,44	165,79
5,00	3,00	0,80	6,26	1,46	62,35	41,44	165,79
5,00	3,20	0,80	6,26	1,57	65,99	41,44	165,79

Overall, the gravity wall dimensions were designed to meet the technical and environmental requirements of the study site. Table 2. provides a recap of the dimensions against the stability control of the gravity wall, relevant to provide additional context to these results.

Discussion

The dimensions of cantilever and gravity type retaining walls have significant differences in the design approach. Cantilever walls are designed to rely on the structural strength of reinforced concrete, while gravity walls rely on their own weight. This difference affects material efficiency, cost and construction time. Based on the analysis, the cantilever type requires a higher cost but has a shorter implementation time than the gravity type.

The stability analysis results show that both wall types have safety ratios against shear and overturning that meet the standards. Cantilever walls have the advantage of handling high lateral pressures with slimmer dimensions. In contrast, gravity walls are more effective for low to medium lateral pressures with more massive dimensions. The choice of wall type is highly influenced by the soil conditions and the applied loads.

The choice of wall dimensions also considers cost efficiency. Cantilevered walls require a large amount of reinforced concrete material, which increases the initial cost of construction. However, this design saves space due to its smaller dimensions. In contrast, gravity walls use conventional concrete which is cheaper but requires more space due to its massive size.

From an execution time perspective, cantilevered walls are superior due to their faster installation process. The use of reinforced concrete materials and steel reinforcement allows for more efficient construction. Meanwhile, gravity walls take longer due to their size and weight, as well as the need for additional drainage layers to reduce water pressure. The choice of retaining wall type should consider field conditions, cost efficiency and implementation time. For the Temuireng - Jetis road section, the cantilever type is more suitable for segments with high lateral pressure, while the gravity type is more economical for segments with low lateral pressure. The results of this study provide a sound basis for retaining wall design decisions at similar sites.

CONCLUSION

This study has compared cantilever and gravity retaining walls for the Temuireng - Jetis road section of Mojokerto Regency. The analysis shows that the dimensions of the cantilever type wall have a total height of 5 meters and a bottom foundation width of 3 meters, while the gravity type has a height of 4.5 meters and a bottom foundation width of 2.5 meters. Both types were designed to meet the need for stability against lateral soil pressure.

Cantilever-type walls offer the advantage of handling high lateral pressure with slimmer dimensions. A wall body thickness of 0.3 meters is considered to increase material efficiency without compromising structural strength. In contrast, gravity walls are more effective for low to medium lateral pressures, with a more massive design to rely on its own weight. Stability analysis showed that both wall types met the safety criteria against shear and overturning. The ratio of the factor of safety against shear and overturning for the cantilever wall is more than 1.5, while the gravity wall shows similar results. This indicates that both designs are reliable for the study site conditions.

In terms of cost, the cantilever type requires a higher initial investment due to the use of reinforced concrete and steel reinforcement. However, it is more efficient in terms of execution time, making it suitable for projects with short time requirements. In contrast, the gravity type is more economical in materials but requires a longer construction time. In conclusion, cantilever type walls are recommended for road segments with high lateral pressure, while gravity type is more suitable for areas with low to moderate lateral pressure. The selection of wall type should consider cost efficiency, implementation time, and geotechnical conditions at the project site.

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