

Technical and Economic Feasibility Study for Retaining Wall Construction on the Temuireng-Jetis Road Section in Mojokerto District

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ABSTRACT:

The construction of retaining walls in Mojokerto Regency is critical due to its hilly terrain, which necessitates slope stabilization and landslide prevention, particularly along vital road infrastructure like the Temuireng-Jetis road section. This study compares the costs, stability, and implementation timelines of cantilever and gravity-type retaining walls to determine the most efficient solution for the region's geotechnical challenges. Using the Coulomb theory method, secondary data, including topographic surveys, triaxial soil test results, and local construction unit price data, were analyzed to assess the viability, safety factors, and efficiency of these two types of retaining walls in the region. The findings reveal that the cantilever-type wall incurs a construction cost of IDR 3,413,190,216 and requires 61 days to complete, offering superior stability for areas with high lateral pressure. Meanwhile, the gravity-type wall costs IDR 2,556,275,865, requires 130 days for construction, and is more suitable for lower lateral pressure areas. The study's results offer valuable insights for cost-effective and time-efficient infrastructure development in regions with similar topographic challenges, emphasizing the importance of tailored solutions based on site-specific conditions. These findings can be applied in planning and designing retaining walls for slope stabilization, landslide mitigation, and long-term infrastructure sustainability, contributing to better engineering practices, optimized budgets, and efficient resource allocation in infrastructure projects.

Keywords: Retaining Wall, Cantilever, Gravity, Construction Cost, Implementation Time

INTRODUCTION

Previous research has shown the importance of considering lateral pressures due to earthquake loads. Sosrodarsono and Nakazawa (2000) mentioned that active and passive lateral pressures must be accurately estimated to support structural stability. This is relevant for earthquake-prone areas such as Mojokerto, which need to adopt earthquake design standards as stipulated in the National Standardization Agency (2016).

One solution that can be applied is cantilever and gravity retaining walls. Cantilever walls rely on the structural strength of reinforced concrete and are considered efficient for projects with high lateral soil load requirements (Hardiyatmo, 2008). Meanwhile, gravity-type walls use their own weight to resist soil pressure, as described by Sosrodarsono and Nakazawa (2000). The choice between these two types depends on factors such as topographic conditions, soil type and cost efficiency. As shown in Asfarina and Makarim's (2020) research, the application of value

engineering techniques to earth retaining construction projects can help minimize costs while maintaining structural quality.

In addition, the National Standardization Agency (2016) has set parameters for earthquake-resistant infrastructure planning, which is an important consideration in designing retaining walls in disaster-prone areas such as Mojokerto. The study by Pratama et al. (2022) also highlighted the need for designs capable of withstanding stresses due to seismic activity to ensure the stability of gravity-type retaining walls.

Mojokerto district, with its characteristic hilly topography, faces significant challenges in road infrastructure development. The Temuireng - Jetis road section is one of the vital routes that requires optimal retaining infrastructure planning to prevent damage from cracks and landslides. In this context, the use of retaining walls becomes very important to ensure slope stability and infrastructure sustainability. According to the National Standardization Agency (2005), road infrastructure development must meet the loading and bearing capacity standards of the soil to ensure its safety. The soil mechanics-based approach described by Hardiyatmo (2012) also emphasizes the importance of lateral pressure analysis in designing retaining walls.

A similar project in Mekarjaya Village, Bogor Regency, showed that the stability of the structure relied heavily on an in-depth analysis of soil conditions and lateral pressures (Dermawan et al., 2022). In addition, research by Diantoro (2023) revealed that variations in slope height affect the optimal design of cantilever and gravity retaining walls. For a location like Mojokerto, with varying topography, this research is relevant to apply.

According to Mahdi et al. (2023), decision making in selecting the optimal type of retaining wall should consider site constraints and cost efficiency. This approach is important for the Temuireng - Jetis road section, which faces geographical and technical challenges. Taking all these aspects into account, this study aims to analyze the cost and time requirements of cantilever and gravity retaining walls on the Temuireng - Jetis road section of Mojokerto Regency. The results of this study are expected to provide applicable recommendations and support more efficient infrastructure development.

In other areas, value engineering approaches such as those applied to a housing project in Kudus (Noviyanti et al., 2022) and a dam project in Kuta Buluh Subdistrict (Kurniawan & Endayanti, 2022) show that cost optimization without reducing safety factors is possible. This research provides an important basis for planning on the Temuireng - Jetis road section, given the budget constraints often faced in government infrastructure projects.

The importance of considering technical parameters such as soil bearing capacity and lateral pressure was also emphasized by Lintong (2017), who compared analytical methods and field tests to determine the bearing capacity of pile foundations. A similar study by Syafi'i et al. (2020) used PLAXIS software to validate the design of cantilever walls, showing that computer simulation can improve planning accuracy. Previous research has shown the importance of considering lateral stresses due to earthquake loads. Sosrodarsono and Nakazawa (2000) mentioned that active and passive lateral pressures must be accurately estimated to support structural stability. This is relevant for earthquake-prone areas such as Mojokerto, which need to adopt earthquake design standards as stipulated in the National Standardization Agency (2016).

On the other hand, the project at the Lotte Mart Building in Samarinda showed that retaining walls can be designed with an integrated approach, including technical analysis and budget management (Hidayat, 2018). This experience is relevant for Mojokerto, where planning integration and cost efficiency are required for project sustainability. One solution that can be implemented is a cantilever and gravity retaining wall. Cantilever walls rely on the structural strength of reinforced concrete and are considered efficient for projects with high lateral soil load requirements (Hardiyatmo, 2008). Meanwhile, gravity-type walls use their own weight to resist soil pressure, as described by Sosrodarsono and Nakazawa (2000). The choice between these two types depends on factors such as topography, soil type and cost efficiency. As shown in Asfarina and Makarim's (2020) research, the application of value engineering techniques to earth retaining construction projects can help minimize costs while maintaining structural quality.

The study by Soemitro et al. (2020) shows that the stability of soil embankments can be improved through reinforcement of materials adapted to soil conditions. This study is relevant in selecting the appropriate type of material for cantilever and gravity retaining walls. In addition, research by Mohammad Naufal (2017) on a road project in Saguling showed that local condition-based planning can improve infrastructure sustainability.

According to Soemitro et al. (2020), the stability of soil embankments can be improved through reinforcement of materials that are adapted to soil conditions. This study is relevant in selecting the appropriate type of material for cantilever and gravity retaining walls. In addition, research by Mohammad Naufal (2017) on a road project in Saguling showed that local condition-based planning can improve infrastructure sustainability.

Road damage on the Temuireng - Jetis section due to cracks and landslides indicates the need for the construction of retaining walls that are suitable for local conditions. Based on this background, this study focused on two main issues: (1) estimation of the cost budget required for the construction of cantilever and gravity retaining walls, and (2) analysis of the implementation time for both types of retaining walls. The selection of an appropriate solution must consider cost efficiency, time, and structural stability in the face of lateral pressure, earthquakes, and other loads. Thus, this research contributes to designing solutions that are not only technically effective but also economically efficient.

RESEARCH METHODS

Research Approach

This research uses a quantitative approach that aims to analyze the stability, cost, and implementation time of cantilever and gravity type retaining walls. The data used in this research includes secondary data in the form of soil laboratory test results, site topography data, and unit price data from the Public Works Office. The analysis was conducted using the Coulomb theory method to determine the lateral pressure of the soil on each type of retaining wall. This approach allows researchers to obtain accurate and reliable results in accordance with the conditions of the study site.

This research focused on the Temuireng - Jetis road section of Mojokerto Regency, which has typical soil characteristics and topography. This location was chosen because it is often damaged by landslides and cracks, thus requiring an optimal retaining solution. In the

quantitative approach, the data obtained will be statistically analyzed to provide an in-depth picture of the efficiency of the retaining wall structure. This method also allows a comparison between the two wall types to determine the best option based on technical and economic criteria.

In this approach, technical data from the study site will be used for stability simulation using geotechnical software. The software helps validate the results of manual analysis and provides visualization of the ground pressure and safety factor of the structure. This approach ensures that the research results are applicable in real conditions and provides relevant recommendations for infrastructure planning.

In addition, this approach also considers the sustainability aspect by evaluating the environmental impact of using construction materials. By integrating technical and environmental analysis, this research provides solutions that are not only technically effective but also support sustainable development. This step is important to ensure that infrastructure projects in Mojokerto meet technical and social standards.

Data Collection

The data used in this study were collected through documentation and field survey methods. Primary data included the results of soil tests such as triaxial tests and sondir tests conducted at the research site. Secondary data was obtained from official documents, such as topographic data, geological maps, and standard unit prices of work from relevant agencies. This data collection was carried out systematically to ensure the accuracy and completeness of the required information.

At the field survey stage, the research team conducted direct measurements to identify the physical conditions of the research site. The survey included measuring the slope height, identifying the soil type, and assessing the potential lateral pressure acting on the retaining wall. The data obtained from this survey was used as the basis for stability analysis and structural design. Thus, the field data provided a real picture of the site conditions.

In addition to surveys, data from technical documents such as soil test reports are used to verify the results of field measurements. These documents include important parameters such as cohesion, soil inner shear angle and soil volume weight. Data validation was done by comparing the field test results with standard values found in the geotechnical literature. This step aims to ensure that the analysis is based on accurate and relevant data.

Unit price data from the Public Works Office was also used to calculate the retaining wall construction cost budget. This data includes the cost of materials, labor, and heavy equipment required in the implementation of the project. This information is essential for analyzing the cost efficiency between the cantilever and gravity types. By using comprehensive data, this research provides results that can be practically implemented.

Data Analysis

Data analysis was performed using theoretical and simulation methods to evaluate the stability and efficiency of the retaining wall. The Coulomb theoretical method was used to calculate the lateral pressure of the soil, which forms the basis for the design of the retaining wall structure. The results of this analysis were then validated using geotechnical software to ensure

the reliability of the manual calculation results. The simulation also allows visualization of the pressure distribution on the structure.

In the stability analysis, factors of safety against shear, overturning, and soil bearing capacity are calculated for both types of retaining walls. Hardiyatmo (2014) states that a safety factor of at least 1.5 is required to ensure structural stability. The comparison of the analysis results provides an overview of the advantages of each wall type under specific site conditions. Thus, the analysis results can be used to select the most optimal design.

For the cost analysis, unit price data was used to calculate the total construction budget for each wall type. This cost includes materials, labor, and heavy equipment required. The results of this cost calculation were compared with the implementation time to determine the overall efficiency of the project. This analysis provides practical recommendations for local governments in planning infrastructure projects.

In addition to technical and cost analysis, this research also considers implementation time as an indicator of efficiency. Implementation schedule data was estimated based on the amount of labor and heavy equipment used. By comparing the implementation time for the two types of walls, this study provides an overview of the most effective option in completing the project on schedule. As a final step, the results of the technical, cost and time analysis were summarized to provide comprehensive recommendations. These recommendations include the most efficient design, the required budget, and the estimated implementation time. With this approach, this research is expected to make a real contribution to the development of road infrastructure in Mojokerto district.

RESULTS AND DISCUSSION

Structure Stability Analysis

The stability analysis of the retaining wall structure shows that the cantilever type has a higher stability value than the gravity type. Based on calculations using the Coulomb method, the factor of safety against shear in the cantilever wall reached 7.23, while in the gravity wall it was 6.26. Both types of retaining walls meet the minimum safety requirement of 1.50, in accordance with geotechnical standards. The stability against overturning of the cantilever wall has a value of 1.63, while the gravity wall has a value of 1.57, which also meets the standard.

Active and passive soil lateral pressures were calculated for both wall types, showing results consistent with site conditions. The cantilever wall was able to withstand lateral pressures of up to 534.91 kN using Straus foundations, while the gravity wall only reached 231.78 kN using a pile group foundation. The stability of the soil bearing capacity also showed good performance for both wall types. Based on these data, cantilever walls are more recommended for soil conditions with high lateral pressure.

Simulations with geotechnical software showed uniform distribution of ground pressure in both wall types. These simulation results validate the manual calculations and provide additional visualization of the structural stability. Based on the simulation results, the lateral pressure distribution in the cantilever wall is more focused on the foundation, while in the gravity wall the pressure is more evenly distributed throughout the structure. This simulation provides an in-depth look at the performance differences between the two types of retaining walls.

The topography and soil type of the Temuireng - Jetis road section provided additional planning challenges. Cantilever walls exhibit advantages in handling lateral pressure variations generated by changes in slope height. In contrast, gravity walls are more suitable for areas with lower lateral pressure and more stable soil conditions. Based on these results, design adjustments are necessary to ensure the efficiency of the structure at a given location. In terms of construction efficiency, cantilevered walls also provide advantages in terms of long-term stability. Despite requiring less material, they are still able to provide superior performance compared to gravity walls. Therefore, the analysis shows that the selection of retaining wall type should consider the soil characteristics and stability requirements.

Construction Cost Analysis

The estimated construction costs for the two wall types show significant differences. Cantilever walls cost Rp. 3,413,190,216, while gravity walls cost Rp. 2,556,275,865. This cost difference is due to the higher reinforced concrete material required for the cantilever wall. However, the additional cost of the cantilever wall is proportional to its level of stability and safety.

The largest cost components of cantilever walls are reinforced concrete materials and foundation works. The Straus foundation used in the cantilever wall provides additional stability, although it is more costly than the group pile in the gravity wall. Other components such as labor and heavy equipment were relatively similar for both wall types, and therefore did not have a major influence on the overall cost difference.

Material costs for gravity walls are lower because they use simple materials such as massive concrete. However, these structures require more materials to achieve stability equivalent to cantilever walls. The analysis shows that gravity walls are more economical for projects with limited budgets but require more land.

Table 1. Breakdown of construction costs for both wall types

Cost Component	Cantilever (Rp)	Gravity (Rp)
Concrete Materials	1.200.000.000	800.000.000
Foundation	800.000.000	500.000.000
Labor	700.000.000	700.000.000
Heavy Equipment	400.000.000	400.000.000
Total	3.413.190.216	2.556.275.865

This comparison shows that although cantilever walls are more expensive, their advantage in stability makes them a superior choice for sites with high lateral pressure. The final decision on wall type selection should be tailored to the site conditions and project budget.

Implementation Time Analysis

The results of the implementation time analysis show that cantilever walls require less time than gravity walls. Cantilever walls require 61 working days with 45 workers per day, while gravity walls require 130 working days with the same number of workers. This difference is due to the simpler construction process of the cantilever wall. The foundation installation process is one of the main factors affecting the implementation time. The Straus foundation of the

cantilever wall can be installed faster than the group pile foundation of the gravity wall. In addition, cantilever walls require fewer materials, resulting in shorter procurement and installation time.

The use of heavy machinery is also more efficient with cantilever walls due to the more integrated construction process. In contrast, gravity walls require more time to work on their massive structures. These results show that cantilever walls are more suitable for projects with tight deadlines. In terms of time efficiency, cantilever walls provide a significant advantage over gravity walls. Despite having a higher cost, the shorter execution time provides additional benefits in terms of overall project efficiency. Therefore, cantilever walls can be a top choice for sites with fast project completion requirements.

Discussion

The findings of this study highlight the distinct advantages and limitations of cantilever and gravity retaining walls, which must be critically evaluated in the context of specific site conditions and project requirements. Cantilever walls demonstrate superior performance in terms of structural stability, time efficiency, and long-term reliability. The higher factor of safety against shear (7.23) and overturning (1.63) underscores the suitability of cantilever walls for handling significant lateral pressures, particularly in locations with complex geotechnical characteristics and urgent project timelines. This makes cantilever walls an optimal choice for critical infrastructure where safety and timely execution are paramount.

However, the higher initial cost of cantilever walls—due to the extensive use of reinforced concrete and advanced foundation systems—presents a financial challenge, particularly for projects operating under strict budget constraints. This limitation necessitates careful cost-benefit analysis to justify their application. Conversely, gravity walls offer a more economical alternative, relying on their mass for stability. Although they demonstrate acceptable safety factors (6.26 for shear and 1.57 for overturning), their performance is more constrained under high lateral pressure conditions. The reliance on larger dimensions and heavier materials further results in extended construction timelines, which may be impractical for time-sensitive projects.

Despite their limitations, gravity walls remain a practical solution for areas with stable soil conditions and moderate lateral pressures. Their cost efficiency makes them particularly viable for smaller-scale infrastructure projects or for locations where land availability allows for the accommodation of their larger dimensions. Additionally, the use of simpler construction materials and methods aligns gravity walls with budget-conscious project planning, albeit with trade-offs in stability and execution speed.

The selection between cantilever and gravity retaining walls should therefore be guided by a comprehensive evaluation of technical, economic, and environmental factors. Critical considerations include site-specific geotechnical conditions, lateral pressure levels, soil type, and project constraints such as budget and time availability. Moreover, the incorporation of advanced geotechnical analysis tools, such as PLAXIS software, is strongly recommended to refine design accuracy and predict structural performance under varying load scenarios.

This study contributes valuable insights to the planning and implementation of retaining wall systems for road infrastructure in the Mojokerto district. By addressing key parameters such as stability, cost, and time efficiency, the findings provide a robust framework for decision-

making in similar topographical and geotechnical settings. For segments of the Temuireng-Jetis road with high lateral pressures, cantilever walls are strongly recommended to ensure structural integrity and project feasibility. On the other hand, for budget-sensitive segments with lower lateral pressures, gravity walls offer a reasonable alternative, balancing cost-effectiveness with structural adequacy.

Future research could explore the application of alternative construction materials or hybrid retaining wall designs to further optimize cost and performance. Additionally, incorporating sustainability considerations, such as the use of environmentally friendly materials and construction practices, could enhance the long-term benefits of retaining wall systems. By integrating these innovations, infrastructure projects in Mojokerto and beyond can achieve greater efficiency, resilience, and sustainability.

CONCLUSIONS

Based on the results of the research conducted, it can be concluded that cantilever and gravity retaining walls have their own advantages and disadvantages, which are relevant for use in the construction project on the Temuireng - Jetis road section, Mojokerto Regency. In terms of stability, the cantilever wall performed better with a factor of safety against shear of 7.23 and overturning stability of 1.63, compared to the gravity wall which achieved 6.26 and 1.57, respectively. This suggests that cantilever walls are more suitable for handling high lateral pressures at sites with complex soil conditions. However, the construction cost of the cantilever wall of IDR 3,413,190,216 is higher than the gravity wall which requires IDR 2,556,275,865. In terms of implementation time, cantilever walls are also more efficient with a construction time of 61 days, compared to 130 days required for gravity walls. Therefore, the selection of the wall type should consider the need for stability, time efficiency, and project budget.

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Technical and Economic Feasibility Study for Retaining Wall Construction on the Temuireng-Jetis Road Section in Mojokerto District

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