

Rehabilitation Strengthening of Riverbanks, Embankments, and Retaining Walls in the Tanjung Pura District, Langkat Regency

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Abstract

This study aims to analyze the condition of riverbanks, embankments, and retaining walls in Tanjung Pura District, Langkat Regency, as well as to identify the factors causing their damage, the impacts on flood risk and community livelihoods, and effective rehabilitation strategies. The research employs a descriptive qualitative approach, with data collected through in-depth interviews, participatory observation, and documentation. The findings indicate that damage to water-retaining infrastructure is caused by a combination of natural factors such as erosion, high rainfall, and unstable soil types and human factors, including land expansion, residential development, and lack of maintenance. This damage has increased flood risk, material losses, disruption of economic activities, and environmental degradation. Effective rehabilitation strategies include strengthening physical structures (retaining walls, sheet piles, gabions), improving hydrological management, implementing vegetation conservation, conducting regular maintenance, and promoting community participation. The implementation of these strategies is expected to stabilize riverbanks, embankments, and retaining walls, thereby enhancing the area's resilience against flooding and erosion.

Keywords: Riverbank, Embankment, Retaining Wall, Rehabilitation, Strengthening, Flood Risk, Qualitative.

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Introduction

The Tanjung Pura District in Langkat Regency is geographically located in a lowland area and traversed by several significant rivers. These rivers play a vital role in supporting the lives of local communities, serving as sources of irrigation water for agriculture, transportation routes, and enablers of local economic activities [1]. However, the condition of riverbanks, embankments, and retaining walls in this area faces various issues that require serious attention. Riverbank erosion and embankment damage have become major problems, especially during the rainy season. These conditions have led to environmental degradation along river areas, loss of productive agricultural land, and an increased risk of flooding that threatens residential areas. Furthermore, damaged retaining walls reduce their protective function against abrasion and sedimentation, thereby undermining the stability of riverbanks.

These problems are worsened by population growth and the expansion of economic activities, which increase pressure on the river environment. The lack of maintenance and rehabilitation of water-retaining structures in the region makes the existing damage difficult to address permanently. Consequently, communities frequently suffer material losses, disruption of agricultural activities, and rising socioeconomic risks due to floods and landslides [2]. Given these conditions, the rehabilitation and strengthening of riverbanks, embankments, and retaining walls represent strategic efforts to maintain regional stability, reduce disaster risk, and support the sustainability of local economic activities. This initiative not only aims to protect the physical environment but also to enhance community welfare by ensuring safety from flood and erosion threats [3]. Therefore, strengthening river infrastructure in Tanjung Pura District is an urgent need that must be systematically and sustainably planned.

Research on the rehabilitation and strengthening of riverbanks, embankments, and retaining walls in Tanjung Pura District, Langkat Regency, is crucial for several important reasons. First, the current condition of water-retaining infrastructure in the area has significantly deteriorated, leading to erosion, landslides, and floods that threaten public safety and damage productive agricultural lands. This problem requires a scientific study to formulate appropriate and sustainable reinforcement strategies. Second, this research contributes to the development of knowledge in the field of river management and the conservation of riverbanks, embankments, and retaining structures. The research findings are expected to serve as a reference for local governments and relevant stakeholders in planning effective, efficient, and environmentally safe rehabilitation programs. Third, the study holds socioeconomic significance. Proper rehabilitation can reduce potential losses from flood disasters, preserve agricultural land stability, and improve community welfare. Moreover, it supports sustainable development through environmental protection and disaster risk mitigation.

The phenomena observed in Tanjung Pura District indicate the area's vulnerability to disasters caused by damaged riverbanks, embankments, and retaining walls. During the rainy season, local communities often face flooding that inundates residential areas and farmlands. Riverbank erosion worsens with strong water flow, eroding productive land and degrading river environments. Additionally, damaged embankments and retaining walls fail to withstand water pressure effectively, leading to landslides in critical areas. This infrastructure damage is further exacerbated by human activities, such as agricultural expansion near riverbanks and unplanned residential development without proper risk mitigation. The resulting impacts are not only physical but also socioeconomic, as communities lose productive land, experience financial losses, and face disruptions to their daily economic activities.

This situation highlights the urgent need for systematic rehabilitation and reinforcement of riverbanks, embankments, and retaining walls. Without proper intervention, the damage will continue to worsen, disaster risks will escalate, and the region's environmental stability and community well-being will be at risk [4]. The urgency of research on the rehabilitation and strengthening of riverbanks, embankments, and retaining walls in Tanjung Pura District, Langkat Regency, is therefore extremely high, given the current deterioration of water-retaining

infrastructure and its link to increasing disaster risks. Damage to these structures directly contributes to higher risks of erosion, landslides, and flooding, which endanger public safety and disrupt agricultural and local economic activities.

Furthermore, this research is essential for providing a scientific foundation for planning river infrastructure rehabilitation and reinforcement. Without a systematic, data-based study, repair efforts may prove ineffective, costly, and even cause further environmental harm. Through this research, appropriate risk mitigation strategies, sustainable development plans, and preventive measures can be formulated to maintain regional stability [5]. Additionally, the urgency of this study also lies in its socioeconomic dimension: effective rehabilitation will protect productive land, reduce material losses, and improve the quality of life of local residents. Therefore, this research holds not only technical and scientific relevance but also tangible benefits for the community and environment in Tanjung Pura District.

Problem Identification

Based on the phenomena occurring in Tanjung Pura District, several major issues can be identified as follows:

1. **Riverbank Damage:** The riverbanks have experienced severe erosion, threatening the stability of surrounding land and triggering landslides.
2. **Embankment and Retaining Wall Damage:** The embankments and retaining walls are unable to withstand river water pressure, leading to potential flooding and infrastructure damage.
3. **Flood Disaster Threat:** Communities living near the river face a high risk of flooding, which disrupts daily activities and damages productive agricultural land.
4. **Socioeconomic Impacts:** Infrastructure damage causes material losses, disrupts community economic activities, and reduces residents' overall well-being.
5. **Lack of Rehabilitation Efforts:** There have been no systematic and sustainable rehabilitation or reinforcement measures, causing the same problems to recur each rainy season.

Research Problem

Based on the problem identification above, the research questions in this study are as follows:

1. What is the current condition of the riverbanks, embankments, and retaining walls in Tanjung Pura District?
2. What factors contribute to the damage of riverbanks, embankments, and retaining walls in the area?
3. How does the damage to water-retaining infrastructure affect flood risk and the livelihood of the local community?
4. What rehabilitation and reinforcement strategies are effective in stabilizing the riverbanks, embankments, and retaining walls in Tanjung Pura District?

Literature Review

1. **Basic Concepts of River Infrastructure Rehabilitation and Reinforcement**

Rehabilitation is the process of restoring the function and condition of structures or infrastructure that have been damaged or have deteriorated in quality [6]. In the context of rivers, rehabilitation aims to restore the natural functions of the river, such as water flow, erosion control, and protection of the surrounding environment. Reinforcement refers to efforts to enhance the strength or resistance of a structure against certain loads or pressures, such as water pressure, soil load, or shear forces.

According to Tominaga et al., the rehabilitation and reinforcement of river infrastructure must consider technical, environmental, and socio-economic aspects [7]. A holistic approach is required to ensure the sustainability and effectiveness of these efforts.

2. Riverbank and Embankment Reinforcement

The reinforcement of riverbanks and embankments aims to prevent erosion, landslides, or other types of damage that may threaten the stability of structures and surrounding environments. Several common reinforcement methods include [8]:

a) Sheet Pile: A vertical structure driven into the ground to resist lateral pressure. Bafandi stated in his research that the use of sheet piles is effective in preventing soil movement and maintaining riverbank stability.

b) Geotextile and Gabion: Geotextile materials and gabion structures are used to strengthen slopes and prevent erosion. Murti, in her thesis, compared the effectiveness of various slope reinforcement alternatives and found that the combination of geotextile and gabion provided optimal results in improving slope stability.

c) Retaining Walls (Gravity Wall and Cantilever Wall): These structures are designed to resist soil pressure by utilizing their self-weight. Rizki, using the finite element method in his research, analyzed the stability of retaining walls and found that appropriate design significantly increases the safety factor against shear and overturning forces.

3. Retaining Wall (Turap) Reinforcement

A retaining wall, or turap, functions to resist lateral soil pressure and prevent soil movement that could damage surrounding structures. According to Sianturi, Rankine's and Coulomb's theories are commonly used to analyze the safety factors in retaining wall stability [9]. In the design process, factors such as soil type, excavation depth, and external loads acting on the structure must be carefully considered.

Fatullah (2019) also emphasized the importance of stability analysis in preventing slope and excavation failures, particularly in riverine areas. Proper evaluation and design of embankments can reduce the risk of structural failure and enhance durability.

4. Planning and Evaluation Approaches

In planning and evaluating the rehabilitation and reinforcement of river infrastructure, it is essential to consider technical, environmental, and socio-economic aspects. Module 8 from the Center for Education and Training of Water Resources and Construction recommends that river structure planning take into account construction stability against overturning forces, shear forces, material strength, and soil bearing capacity [10]. Additionally, the selection of appropriate implementation and maintenance methods is a key factor in ensuring the success of river infrastructure rehabilitation and reinforcement projects.

Research Methodology

Research Approach

This study employs a descriptive qualitative approach, which aims to deeply understand social phenomena through participatory and interpretative perspectives. This approach aligns with who states that qualitative research is conducted in natural settings, where the researcher serves as the main instrument for both data collection and analysis [11].

Research Focus

The focus of this research is to explore the perceptions, experiences, and strategies of the community and related stakeholders in addressing the problems of riverbank, embankment, and retaining wall damage in the Tanjung Pura District. This aligns with Creswell's (2014) view, which emphasizes the importance of understanding the meanings constructed by individuals or groups who experience social issues.

Research Location and Subjects

This study was conducted in Tanjung Pura District, Langkat Regency, with research subjects including local communities, village officials, and relevant institutions such as the Public Works and Spatial Planning Agency of Langkat Regency. The selection of location and subjects was based on their relevance and direct relation to the issues under study.

Data Collection Techniques

The data collection techniques used in this study include:

- a. In-depth Interviews: Conducted to obtain detailed information from key informants regarding their experiences and perspectives on the issues being studied.
- b. Participant Observation: The researcher directly engaged in community activities to understand the social and cultural context more holistically.
- c. Documentation: Collection of secondary data such as documents, photographs, and archives relevant to the research topic.
- d. These techniques are consistent with Moleong (2019), who explains that in qualitative research, data are collected through interviews, observations, and documentation to achieve a comprehensive understanding.

Data Analysis Techniques

The collected data were analyzed using qualitative data analysis techniques, which include the following steps:

- a. Data Reduction: Filtering and selecting data relevant to the research focus.
- b. Data Display: Organizing data in narrative form to facilitate understanding.
- c. Conclusion Drawing: Developing conclusions based on the analyzed data.
- d. These steps follow the procedure outlined by Miles and Huberman (2014), who state that qualitative data analysis is interactive and occurs simultaneously with the data collection process.

Data Validity Testing Techniques

To ensure data validity, this study employs the triangulation technique, which involves comparing data obtained from various sources and collection methods. This is consistent with Sugiyono (2019), who emphasizes that triangulation is used to enhance the credibility of research findings.

Results

Current Condition of Riverbanks, Embankments, and Retaining Walls in Tanjung Pura District

Tanjung Pura District is one of the areas that is highly vulnerable to natural disasters, particularly flooding and erosion. This vulnerability is largely due to its geographical location near the Wampu River and Batang Serangan River. In recent years, high rainfall intensity has caused a significant increase in river discharge, which has adversely affected the stability of riverbanks, embankments, and retaining walls in the area.



Figure 1. Condition of Riverbanks, Embankments, and Retaining Walls in Tanjung Pura District, Langkat Regency

Riverbanks: Several sections of the riverbanks along the river flow have experienced severe erosion. This erosion process threatens the stability of agricultural land and residential areas located near the riverbanks. Moreover, erosion also reduces the river's flow capacity, which in turn increases the risk of flooding.

River Embankments: The embankments built to contain river overflow have suffered damage in several areas. In December 2022, embankments in several villages within Tanjung Pura District collapsed due to heavy rainfall and strong river currents. As a result, several villages were affected by floods, submerging hundreds of houses and agricultural lands.

Retaining Walls (Riverbank Revetments): The retaining walls that function to stabilize soil movement and prevent landslides have also been damaged. The deterioration of these retaining structures has made the surrounding soil unstable, thereby increasing the potential for landslides, especially during heavy rainfall.

Overall, the condition of the riverbanks, embankments, and retaining walls in Tanjung Pura District requires serious attention. Damage to these water-retaining infrastructures not only heightens the risk of natural disasters but also has significant social and economic impacts on the local community. Therefore, comprehensive rehabilitation and reinforcement efforts are urgently needed to reduce potential risks and improve the area's resilience against floods and erosion.

Factors Causing Damage to Riverbanks, Embankments, and Retaining Walls

Based on field observations and research findings, several main factors contribute to the deterioration of riverbanks, embankments, and retaining walls in Tanjung Pura District, Langkat Regency. These factors can be categorized into natural factors and human (anthropogenic) factors.

1. Natural Factors

a. Erosion and Sedimentation:

Strong river currents, especially during the rainy season, cause abrasion along the riverbanks. This erosion process gradually removes soil and weakens the bank's stability, increasing the risk of landslides. This finding is consistent with Murti (2023), who stated that uncontrolled water flow is a primary cause of riverbank degradation.

b. High Rainfall Intensity:

Prolonged heavy rainfall and significantly increased river discharge create additional pressure on embankments and retaining walls, making them more susceptible to cracking or collapse. Tominaga et al. (2019) also found that hydrological changes in river systems directly affect the stability of water-retaining structures.

c. Soil Texture and Composition:

Unstable soils with low bearing capacity facilitate ground movement along the banks and embankment bases. Sandy or clayey soils that absorb water easily tend to slide when subjected to hydraulic pressure from river flow.

2. Human (Anthropogenic) Factors

a. Land Expansion and Agricultural Activities:

The expansion of agricultural land along riverbanks without proper erosion control measures increases stress on the riverbanks and embankments. Such activities reduce vegetative cover that naturally stabilizes the soil, accelerating the degradation of the river's structural integrity.

b. Lack of Infrastructure Maintenance:

Many embankments and retaining walls built in previous years have deteriorated due to poor maintenance and monitoring. According to Rizki (2023), routine maintenance is a key factor in sustaining the strength and functionality of slope and embankment reinforcement structures.

c. Construction of Settlements and Infrastructure:

The development of housing and roads near riverbanks adds load pressure to the banks and embankments. This additional load accelerates the formation of cracks, landslides, or the collapse of retaining structures.

3. Interaction Between Natural and Human Factors

Damage to riverbanks, embankments, and retaining walls in Tanjung Pura District often results from a combination of natural processes and human activities. For example, heavy rainfall may trigger landslides, but the impact is worsened when riverside vegetation has been removed for agriculture or settlement expansion.

This condition highlights the need for a holistic rehabilitation approach, integrating technical, environmental, and social aspects. By understanding the underlying causes of damage, rehabilitation and reinforcement measures can be designed more effectively to reduce disaster risk and enhance community resilience against flooding and erosion in Tanjung Pura District.

Impacts of Water Retaining Infrastructure Damage on Flood Risk and Local Community Livelihoods

Damage to riverbanks, embankments, and retaining walls in Tanjung Pura District has significant impacts on increasing flood risk and affecting the livelihoods of local communities. Based on research findings and field observations, several major impacts can be identified from physical, social, and economic perspectives.

1. Impact on Flood Risk

Damage to embankments and retaining walls has reduced the ability of these infrastructures to contain river overflows. During the rainy season, when water discharge is high, rivers easily overflow due to decreased flow capacity caused by riverbank erosion and sedimentation. This condition has led to flooding in several villages along the river, such as the incident in December 2022, when several embankments collapsed and hundreds of houses were submerged.

This finding aligns with Fatullah (2019), who stated that damage to water-retaining walls directly increases the frequency and intensity of flooding.

2. Impact on Community Life

a. Material Losses:

Flooding caused by damaged infrastructure leads to destruction of houses, public facilities, and agricultural lands. Many residents suffer economic losses due to crop failure or damage to farmlands.

b. Disruption of Economic and Social Activities:

Floods disrupt transportation, the distribution of basic necessities, and local trade activities. Residents are forced to divert time and resources to repair homes and farmland, which reduces productivity and daily income.

c. Health and Safety Impacts:

Floodwaters that inundate residential areas increase the risk of waterborne and vector-borne diseases, such as diarrhea and dengue fever, and create unhygienic living conditions. Moreover, flooding poses safety risks, particularly to vulnerable groups such as children and the elderly.

3. Environmental Impact

Damage to riverbanks and retaining walls causes soil and sediment to be carried into the river flow, potentially clogging river channels and worsening flood conditions. Additionally, riverbank vegetation decreases due to erosion, leading to ecological imbalance and reduced environmental stability.

4. Long-Term Impact

If the damage to water-retaining infrastructure is not promptly addressed, flood risk will continue to increase during every rainy season, threatening the sustainability of agricultural land and settlements while reducing the overall quality of life for the community.

This condition highlights the urgent need for comprehensive and sustainable rehabilitation and reinforcement of riverbanks, embankments, and retaining walls. The study clearly shows that damage to water-retaining infrastructure not only affects the physical condition of the river but also has broad implications for the social, economic, and environmental aspects of the community. Therefore, risk mitigation and rehabilitation planning are essential to strengthen the resilience of Tanjung Pura District against floods and other hydrological disasters.

Effective Rehabilitation and Reinforcement Strategies to Stabilize Riverbanks, Embankments, and Retaining Walls in Tanjung Pura District

Based on the research findings in Tanjung Pura District, rehabilitation and reinforcement strategies for riverbanks, embankments, and retaining walls must be designed comprehensively by considering technical, environmental, and socio-economic aspects. Several key strategies have been identified as effective, including:

1. Strengthening of Physical Structures

a. Retaining Walls (Gravity Wall and Cantilever Wall):

The construction of retaining walls using gravity or cantilever methods has proven effective in resisting lateral soil pressure and stabilizing riverbanks. Rizki (2023) found that properly designed retaining walls based on soil stability analysis can significantly improve safety factors and reduce landslide risks.

b. Sheet Piles and Geotextiles:

The use of sheet piles driven into the ground, combined with geotextile layers, helps restrain soil movement and prevent erosion along riverbanks. Murti (2023) emphasized that this combination effectively increases slope resistance to strong water flow and surface erosion.

c. Gabions and Rockfill:

Installing gabions (wire mesh baskets filled with stones) along riverbanks and embankments provides flexible structural support that absorbs hydraulic energy and prevents scouring. This method also promotes natural vegetation growth, enhancing environmental resilience.

2. Hydrology and Drainage Management

Physical reinforcement strategies must be supported by proper management of river flow and drainage systems. Installing drainage channels within embankments and retaining walls prevents excessive water buildup that could trigger slope failure. Tominaga et al. (2019) highlighted that accurate hydrological planning plays a crucial role in reducing pressure on water-retaining structures.

3. Environmental Conservation and Vegetative Soil Stabilization

Planting local vegetation along riverbanks and embankment areas serves as a natural erosion barrier. Plant roots strengthen the soil structure, while vegetation absorbs excess water. This approach aligns with the eco-hydraulic principle, which integrates technical engineering solutions with environmental conservation efforts.

4. Regular Maintenance and Monitoring

Effective rehabilitation should not end with physical construction. Routine maintenance and periodic monitoring are essential to detect early signs of damage, prevent structural failure, and extend the lifespan of infrastructures. Moleong (2019) emphasized that the success of rehabilitation efforts depends on sustainable maintenance and active participation from local communities.

5. Community Participation and Engagement

The success of rehabilitation programs is also determined by the involvement of local communities in managing and maintaining embankments, retaining walls, and riverbanks. Community engagement through risk mitigation training, routine monitoring, and vegetation conservation activities enhances the overall effectiveness of rehabilitation strategies.

By implementing a combination of structural reinforcement (retaining walls, sheet piles, gabions), hydrological management, vegetation-based conservation, regular maintenance, and community participation, the stability of riverbanks, embankments, and retaining walls in Tanjung Pura District can be significantly improved. These integrated strategies not only reduce flood and landslide risks but also promote environmental sustainability and enhance the well-being of local communities.

Conclusion

Based on the research findings, several conclusions can be drawn as follows:

1. **Infrastructure Condition:** The riverbanks, embankments, and retaining walls in Tanjung Pura District have experienced significant damage, mainly caused by erosion, sedimentation, high rainfall, and human activities.
2. **Causes of Damage:** The damage is attributed to natural factors (such as erosion, heavy rainfall, and unstable soil) and human factors (including land expansion, residential development, and lack of maintenance).
3. **Impact of Damage:** The deterioration of water-retaining infrastructure has increased the risk of flooding, caused material losses, disrupted community economic activities, and degraded the environmental quality around the river area.
4. **Rehabilitation and Reinforcement Strategies:** Effective strategies include physical reinforcement (retaining walls, sheet piles, and gabions), hydrological management, vegetation conservation, regular maintenance, and community involvement.
5. **The implementation of these strategies can enhance the stability of riverbanks, embankments, and retaining walls, while also strengthening the regional resilience against flood and erosion hazards.**

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