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DESIGN OF A STEEL FRAME BRIDGE ON THE RONGKONG RIVER, KALIMBU VILLAGE, SABBANG DISTRICT, NORTH LUWU WITH A FOCUS ON FLOOD DISASTER MITIGATION

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Abstract

This study discusses the design of a steel truss bridge on the Rongkong River, focusing primarily on flood mitigation and structural safety. Geotechnical analysis was conducted based on Standard Penetration Test (SPT) data from two drilling points, supported by laboratory testing to determine shear strength parameters, soil classification, and groundwater level conditions. The results indicate that the soil at the site is dominated by very dense gravelly sand with an NSPT value of more than 60 at a depth of approximately two meters, making it suitable for use as a support layer for well foundations or short bored piles. The hydrological characteristics of the Rongkong River, including seasonal water level fluctuations and potential for local scour, were analyzed to ensure the long-term stability of the bridge structure. The proposed design integrates structural aspects with flood mitigation strategies through raising the girder elevation, optimizing foundation depth, and protecting against riverbed erosion. This study contributes to the development of a safe and flood-resilient bridge design based on the geotechnical and hydraulic conditions of the site.

Keywords:steel truss bridge, flood mitigation, foundation design, Rongkong River.

INTRODUCTION

Transportation infrastructure plays a fundamental role in supporting economic growth and social connectivity between regions. In North Luwu Regency, South Sulawesi, the presence of a bridge across the Rongkong River in Kalimbu Village, Sabbang District, is essential to ensure smooth daily accessibility and logistics distribution. However, this location is in an area with significant hydrological risk, characterized by high intensity and frequency of flooding, particularly during the extreme rainy season. The development of transportation infrastructure, particularly bridges, is one way to improve connectivity and accessibility between regions. Bridges play a strategic role in supporting public mobility, the distribution of goods, and regional economic development. The Rongkong River in North Luwu Regency is a major river system that requires bridges to support community activities. The geographical conditions and dynamics of this river's flow require bridge structural design that prioritizes stability and safety.

Flood disasters not only cause socio-economic losses due to the disruption of access, but also pose serious structural threats to bridges. The main threats include: (1) Lateral hydrodynamic loads that compress the superstructure; (2) Impact of debris that can damage structural elements; and most damagingly, (3) Scouring erosion of the foundation pillars. Scouring can erode the soil material around the foundation to a critical depth, reducing the bearing capacity, and in extreme cases, causing total structural failure (Hasan & Rahman, 2020). This vulnerability demonstrates that bridge planning on the Rongkong River can no longer be limited to structural strength and functionality analysis alone. A paradigm shift is needed toward an approach that integrates disaster resilience through flood mitigation from the design stage. This aligns with the demands of sustainable development and infrastructure that adapts to climate change (BAPPENAS, 2020). One of the crucial stages in bridge planning is investigating soil conditions as the basis for designing the foundation structure. Soil, as the supporting medium for structural loads, has highly variable characteristics, both horizontally and vertically. These variations affect the bearing capacity, potential settlement, and overall foundation stability. Therefore, soil investigations are necessary to accurately determine local geotechnical conditions before determining the appropriate foundation type. Failure to predict soil behavior is often a major cause of damage or failure of bridge structures. A soil investigation report at the planned site of the Rongkong River Bridge in North Luwu indicates that the soil is dominated by rocky sand with a relatively high density. The results of the Standard Penetration Test (SPT) and laboratory tests such as water content, unit weight, sieve analysis, and shear tests provide an overview of the characteristics of the soil layers, groundwater table conditions, and shear strength parameters required in foundation design. Based on this data, an in-depth study is required to assess the feasibility of the type of foundation to be used and its implications for the safety of the bridge structure. Based on this background, this study aims to analyze the soil conditions resulting from field and laboratory investigations at the planned location of the Rongkong River Steel Truss Bridge, and evaluate their geotechnical implications for bridge foundation planning. This study also aims to provide recommendations for foundation types that are appropriate to the soil characteristics and local hydrological conditions. The scope of the study includes analysis of SPT values, physical and mechanical parameters of the soil, and interpretation of geotechnical data to support the design of the bridge substructure.

LITERATURE REVIEW

1. Soil Investigation

Soil investigation is a systematic process for obtaining the physical and mechanical characteristics of soil necessary for planning the foundation of a structure. The investigation stages include visual observation, drilling, field testing, and laboratory testing.(Prayogo & Saptowati, 2016)Soil investigations are conducted to determine, among other things, the type of foundation to be used in building construction. Furthermore, the results of the soil investigation can determine how the soil will be treated to ensure its bearing capacity supports the proposed construction. Based on these soil investigations, the most economical yet safe foundation type, depth, and dimensions are selected. Soil investigation is a fundamental step in civil engineering construction planning. Its purpose is to understand the characteristics and geotechnical conditions of the subsurface soil layers that will support the structure of a building, bridge, or other infrastructure.

According to Bowles (1997) and Terzaghi (1943), the theoretical basis of soil investigation includes several main aspects:

a. **Land Property Classification and Index:**The theory is that each soil type (clay, silt, sand) has unique physical and mechanical properties. Field investigations (such as drilling and sampling) and laboratory tests (Atterberg limit tests, sieve analysis) are conducted to identify and classify soils. This data provides basic information about the soil's consistency, plasticity, and grain gradation.
b. **Soil Shear Strength (τ):**Shear strength is the ability of soil to resist shear failure (collapse). Coulomb's theory (1776), which was later developed by Mohr, states that the shear strength of soil depends on the normal stress (σ) on the shear plane, the angle of internal friction (ϕ), and cohesion (c). The formula is: $\tau = c + \sigma \tan(\phi)$. Field tests such as the Standard Penetration Test (SPT) and laboratory tests such as triaxial or direct shear tests are used to determine the parameters c and ϕ.
c. **Bearing Capacity and Settlement:**The c and ϕ data are crucial for calculating the ultimate bearing capacity of foundation soils. Furthermore, soil investigations also measure compressibility, particularly in clay soils, to predict the amount of settlement that may occur over the life of the structure.

2. *Standard Penetration Test*(SPT)

Standard Penetration Test(SPT) aims to obtain the N-value, which reflects the relative density of the soil layer being tested, and provides an overview of the soil layer based on type and color through visual observation.(Rahim, 2025). In addition, the N-value is used to calculate the bearing capacity of the soil, because it reflects the compactness of the soil layer.(Agustiawan & Alizar, 2025).

3. Soil Classification Based on Grain Size

Soil classification serves to group soils based on their particle size distribution and plasticity properties. Modern classification systems such as USCS and AASHTO are widely used in geotechnical practice. According to(Fahriana et al., 2019)The soil classification system that is commonly used is the USCS (Unified Soil Classification System) soil classification system which is grouped into two groups:

a. Coarse-grained soil, namely gravel and sand soil that is less than 50% of the total weight of the soil sample passing through sieve No. 200. The symbol for this group is G for gravelly soil and S for sandy soil.
b. Fine-grained soil, which is soil in which more than 50% of the sample weight passes through the No. 200 sieve. The symbol for this group is C for inorganic clay and O for organic silt. The symbol Pt is used for peat and soil with a high organic content.
c.

4. Soil Physical Parameters

Physical parameters of soil such as water content, bulk density, and specific gravity are crucial in understanding the condition of a soil mass. Water content is the ratio of the weight of water to the weight of solid particles. Water content is closely related to particle size, soil bulk density, and porosity. Determination of water content is performed through laboratory soil analysis using a bulk density test. Fine-textured soils, such as clay, have more pore space, thus allowing them to hold more water. Water content affects soil consistency and volumetric changes, while bulk density is related to the soil's density.(Kusuma & Yulfiah, 2018). Specific gravity of soil is the mass of soil per unit volume. Unit weight depends on the amount of water in the soil's pore space and varies with each soil type. In soil mechanics, two types of unit weight are recognized: dry unit weight and moist unit weight. The difference lies in the weight of the soil used. Dry unit weight uses oven-dried soil, while wet unit weight uses the weight of solid particles and water. The weight of air is assumed to be zero.(Kusuma & Yulfiah, 2018)

5. Bridge Foundation

A foundation is a construction at the base of a structure/building (substructure) that functions to transfer the load from the upper structure/building (upper-structure) to the soil layer below it without causing shear failure and excessive settlement of the soil/foundation. Several buildings can be built because the foundation is the main component of a building, including bridges. In general, there are two types of foundations, namely shallow foundations and deep foundations. Shallow foundations are used when the building above them is not too large, while deep foundations are foundations used in buildings on soft soil and multi-story buildings.(Roschedy et al., 2019)

6. The Influence of Groundwater Level on Foundation Planning

The groundwater table affects pore pressure, permeability, bearing capacity, and soil stability. In granular soils, a shallow water table can reduce effective stress, potentially lowering the soil's shear strength. Water content significantly impacts soil. If the soil is not compacted and the water content is below or above the Optimum Moisture Content (OMC), it will affect the dry density of the soil.(Giandara & Agustina, 2018).

7. Flood-Resistant Bridge Design Criteria

a. Hydrological and Hydraulic Criteria

This is the most fundamental criteria for flood mitigation.

1) Bridge Floor Elevation (Freeboard):

- The bridge floor (superstructure) must be at a sufficiently high elevation above the Planned Flood Water Level (MAB).
- The minimum height of Vertical Clearance (Freeboard) must be determined based on standards, usually between 1 to 2 meters above the design MAB (Q50 or Q100). This prevents floodwaters from overflowing (overtopping) and prevents direct collision between the superstructure and floating drift material.

2) Minimizing Flow Restrictions:

- The number of piers placed across the river channel should be minimized or avoided altogether (e.g. by using long span bridges such as Steel Frame or Cable-stayed).
- If piers are required, they should be hydrodynamic in shape (e.g., elliptical or tapered) and parallel to the main flow direction of the river to reduce turbulence and water pressure.

3) Ideal Bridge Placement:

- Bridges should be placed in stable river channels perpendicular to the flow direction. Placement on meanders should be avoided as they increase the risk of erosion and scour.

2. Criteria for the Resistance of the Substructure (Foundation and Pillars)

The substructure is the part most vulnerable to failure due to flooding.

- **Scour Protection:**
- Foundations must be designed at depths exceeding the predicted maximum scour depths (general scour, local scour, and scour due to bends).

- If necessary, scour protection systems such as riprap (rock formations), gabions (gabion wire), geotextiles, or biotextiles should be installed around the pillars and abutments to stabilize the subgrade.
- **Lateral Force Resisting Strength:**
  - Pillars and foundations must be designed to withstand the enormous hydrostatic pressure and hydrodynamic forces (drag) from flood flows, as well as the impact forces from washed-out material.

3. Material and Superstructure Criteria

- **Corrosion Resistance:**
  Structural materials must be highly resistant to corrosion, especially if frequently exposed to water and high humidity during flooding. For steel-frame bridges, the anti-corrosion coating system (epoxy paint or galvanization) must be of high quality and well-maintained.
- **Superstructure Stability:**
  The superstructure (girders and deck) must be securely attached to the abutments and piers. The bearings must be secure to prevent the bridge from sliding or lifting due to extreme water pressure.

4. Location and Environmental Criteria

- **Soil Stability:**
- The location of the abutments and approaches (approach roads) must be on stable ground and free from the risk of local or global landslides, especially when saturation occurs due to flooding.
- **Oprit Drainage System:**
- The approach road (oprit) and the road body around the bridge must be equipped with a good drainage system to drain rainwater and floodwater quickly and prevent puddles that can weaken the approach embankment.

METHOD

a. Location and Point of Investigation

The investigation was conducted at two drilling points, BH-01 and BH-02, located within the planned bridge construction area. Both points were used for SPT testing and soil sampling for laboratory analysis.

b. Field Investigation Method (SPT)

SPT values are taken at depth intervals of 1.5–2.0 meters, or when significant changes in the soil layers occur. The number of impacts is recorded for the first 15 cm (N1), second (N2), and third (N3) penetrations. The SPT value is calculated by adding:

$$\mathbf{NSPT = N2 + N3}$$

For the interpretation of NSPT values, standard references are used to classify clay soil consistency and sandy soil density. The reference table is located as follows:

Consistency	NSPT SPT Value
Very Soft	<2
Soft	2 – 5
Firm	5 – 10
Stiff	10 – 20
Very Stiff	20 – 40
Hard	>40

Table 2. Sand Density based on NSPT Value

Density	Relative Density	NSPT SPT Value	Internal Friction Angle (Ø°)
Very Looser	<0.15	<4	<28
Loose	0.15 – 0.35	4 – 10	28 – 30
Medium Dense	0.35 – 0.65	10 – 30	30 – 40
Dense	0.65 – 0.85	30 – 50	40-45
Very Dense	>0.85	>50	>45

c. Field Condition Observation

During drilling, soil characteristics were recorded, including soil color, density, gravel/rock material, and groundwater depth.

d. Soil Sampling

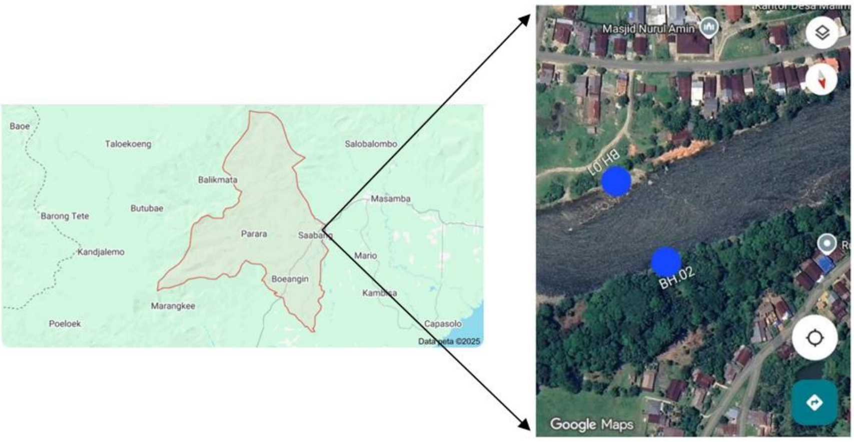
Soil samples were taken from several depths at BH-01 and BH-02. The samples were packaged in sealed containers and labeled before being transported to the laboratory.

e. Laboratory Testing

Laboratory testing is carried out to obtain soil parameters which include:

a. Water content
b. Soil bulk density
c. *Specific gravity*(Gs)
d. Sieve analysis
e. Direct shear test

RESULTS AND DISCUSSION



Location Map & Position of Field Test Points

The implementation of the Standard Penetration Test (SPT) at two drilling points, namely BH-01 and BH-02, provides a direct picture of the soil conditions at the planned construction site of the Rongkong River Steel Frame Bridge. The test was conducted using a rotary drill machine, a split barrel sampler, a 63.5 kg hammer with a drop height of 75 cm, and a series of other supporting equipment. The configuration of the test equipment used is shown in Figure 1. Sketch of the SPT Test Equipment.

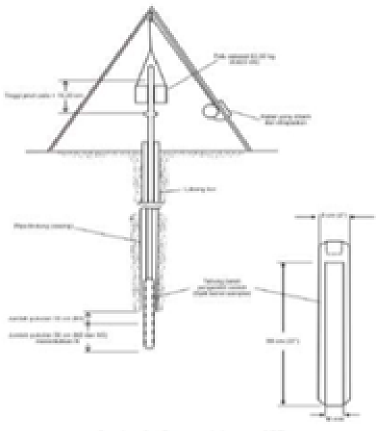


Figure 1. Sketch of SPT Test Equipment

During the test, the borehole conditions indicated relatively stable soil, allowing the sampler installation and lowering of the drill string to proceed without significant obstacles. Field observations showed that every 15 cm penetration interval could be clearly recorded, and changes in soil resistance began to be visible at depths greater than one meter. The test implementation scheme is shown in Figure 2. SPT Test Implementation Scheme.

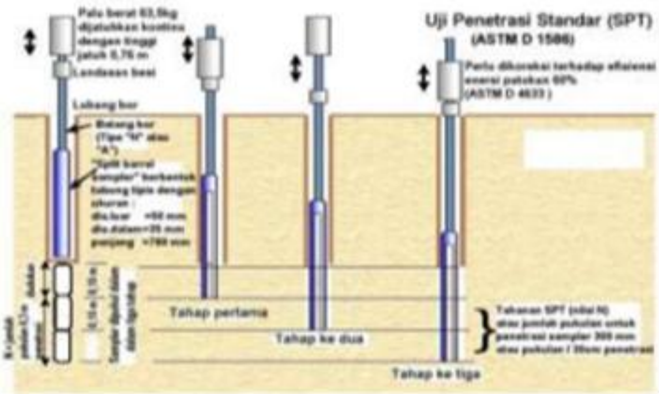


Figure 2. SPT Test Implementation Scheme

Figure 3. Photo of drilling locations BH-01 and BH-02

Table 3. Test Point BH 01

Project : Perencanaan Jembatan RB. S. Rongkong — Spec Diameter = 6,35 cm
Site : Desa Kalimbu, Kec. Sabbang, Luwu Utara — Spec Cross Sec = 31,65 cm²
Owner : Pemda Kabupaten Luwu Utara — Spec Cov Weight = 390 gr
Depth : Titik Uji BH 01 / 1,00 – 1,50 m — Date : October 2025

Time (min)	Load = 3,167 kg		Load = 6,334 kg		Load = 9,501 kg		Normal Stress (kPa)	Shear Stress (kPa)
	Rdgs	Shear Load (N)	Rdgs	Shear Load (N)	Rdgs	Shear Load (N)		
0,00	0,00	0,00	0,00	0,00	0,00	0,00	10	7,39
0,25	0,03	1,80	0,07	4,20	0,08	4,80	20	18,01
0,50	0,08	4,80	0,15	9,00	0,18	10,80	30	23,89
0,75	0,14	8,40	0,24	14,40	0,21	12,60		
1,00	0,19	11,40	0,36	21,60	0,34	20,40		
1,25	0,23	13,80	0,48	28,80	0,47	28,20		
1,50	0,28	16,80	0,61	36,60	0,63	37,80		
1,75	0,33	19,80	0,74	44,40	0,79	47,40		
2,00	0,36	21,60	0,81	48,60	0,98	58,80		
2,25	0,39	**23,40**	0,88	52,80	1,17	70,20		
2,50	0,39	23,40	0,95	**57,00**	1,26	**75,60**		
2,75	0,39	23,40	0,95	57,00	1,26	75,60		
3,00	0,39	23,40	0,95	57,00	1,25	75,00		

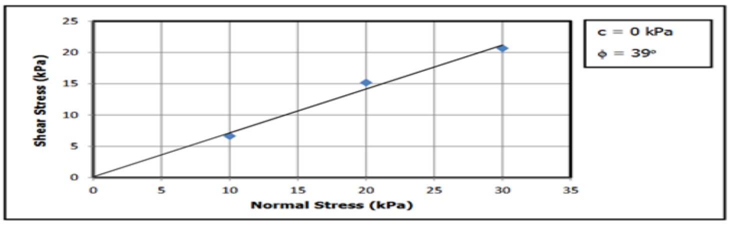
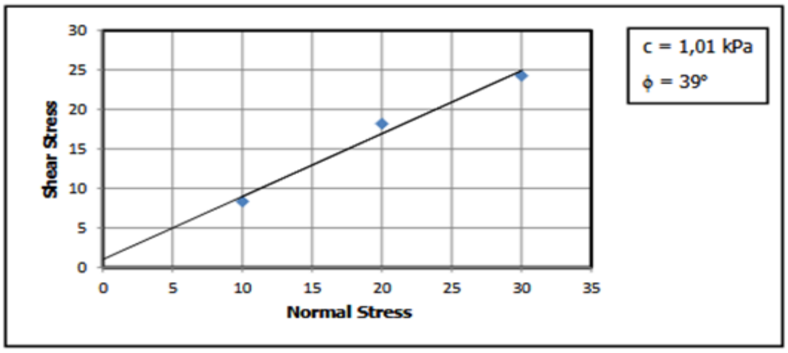


Table 3. Test Point BH 02

Project	**: Perencanaan Jembatan RB. S. Rongkong**	**Spec Diameter = 6,35 cm**
Site	**: Desa Kalimbu, Kec. Sabbang, Luwu Utara**	**Spec Cross Sec = 31,65 cm²**
Owner	**: Pemda Kabupaten Luwu Utara**	**Spec Cov Weight = 390 gr**
Depth	**: Titik Uji BH 02 / 0,50 – 1,00 m**	**Date : March 2025**

Time (min)	Load = 3,167 kg		Load = 6,334 kg		Load = 9,501 kg		Normal Stress (kPa)	Shear Stress (kPa)
	Rdgs	Shear Load (N)	Rdgs	Shear Load (N)	Rdgs	Shear Load (N)		
0,00	0,00	0,00	0,00	0,00	0,00	0,00	10	8,34
0,25	0,03	1,80	0,07	4,20	0,08	4,80	20	18,20
0,50	0,08	4,80	0,15	9,00	0,18	10,80	30	24,27
0,75	0,14	8,40	0,24	14,40	0,21	12,60		
1,00	0,19	11,40	0,36	21,60	0,34	20,40		
1,25	0,24	14,40	0,48	28,80	0,47	28,20		
1,50	0,31	18,60	0,61	36,60	0,63	37,80		
1,75	0,35	21,00	0,74	44,40	0,79	47,40		
2,00	0,39	23,40	0,81	48,60	0,98	58,80		
2,25	0,44	26,40	0,88	52,80	1,17	70,20		
2,50	0,44	26,40	0,96	57,60	1,28	76,80		
2,75	0,43	25,80	0,96	57,60	1,27	76,20		
3,00	0,43	25,80	0,95	57,00	1,25	75,00		



The impact recording results showed a significant increase in the impact value (N-value) at both drill points. At BH-01, the surface soil layer was dense brown rocky sand, then the impact value increased sharply to reach NSPT ≥ 60 at a depth of about 2 meters, which indicates a very dense to rocky layer. A similar condition was also found at BH-02, where the initial layer of dense clayey sand changed to very dense rocky sand at the same depth, with an NSPT value ≥ 60.

Groundwater level observations showed variations between the two test points. At BH-01, the groundwater level was at a depth of approximately 0.6 meters, while at BH-02, it was measured at approximately 1.8 meters. This variation indicates local differences in soil permeability and hydrological conditions.

The results of field investigations in the form of drilling/SPT tests obtained:

1. Hard soil layer (rock/rock) with SPT value (NSPT ≥ 60) at an average depth of 2 m from the ground surface.
2. Test point BH 01: The surface soil layer is a layer of dense brown rocky sand until it reaches a rocky layer (very dense grey rocky sand) at a depth of about 2 m.
3. Test point BH 02: The surface soil layer is a layer of dense brown clayey sand until it reaches a rocky layer (very dense brown rocky sand) at a depth of about 2 m.
4. The groundwater level varies from a depth of 0.6 m at test point BH 01 to 1.8 m at test point BH 02.

CONCLUSION

Based on the results of the discussion, the following conclusions can be drawn:

1. The soil conditions of both drill points (BH-01 and BH-02) show relatively dense to very dense soil characteristics at a depth of more than 2 meters, with an NSPT value of ≥ 60. The surface layer at BH-01 is dense rocky sand, while at BH-02 it is dense clayey sand. Both drill points then transition into a very dense rocky sand layer, indicating the presence of stable and strong soil conditions to support bridge construction.
2. The borehole was stable enough during the test to allow sampler installation and pipe lowering without significant obstruction. This facilitated recording of N values at 15 cm intervals and monitoring changes in soil resistance.
3. The groundwater level varies across the test sites. BH-01 has a groundwater level at a depth of approximately 0.6 meters, while BH-02 is at a depth of approximately 1.8 meters. This difference indicates local variations in soil permeability and hydrological conditions, which must be considered in bridge foundation design.

4. The high NSPT value and good soil stability implications for construction indicate that this location has the potential to safely support bridge structural loads. However, differences in groundwater levels and surface layer characteristics must be taken into account in the design of the bridge's foundation and drainage system.

REFERENCES

Agustiawan, R., & Alizar. (2025). Soil Investigation Analysis for the Rawa Buaya Service Center Development Project, West Jakarta. 5(5), 1698–1706.

Fahriana, N., Ismida, Y., Lydia, EN, & Ariesta, H. (2019). SOIL CLASSIFICATION ANALYSIS USING THE USCS METHOD (MEURANDEH KOTA LANGSA).

Giandara, E., & Agustina, DH (2018). The effect of water content on soil shear strength. 1(1), 259–266.

Hasan, SF, & Rahman, ASB (2020). Scour Assessment and Mitigation Measures for Bridges in Tropical River Basins. Journal of Water Resources Engineering, 9(2), 115-128. (Focus on scour assessment and mitigation in tropical climates).

Kastono, (2020) The Effectiveness of the Green Open Space of Pancasila Field, Palopo City. Dewantara Journal of Technology, 25–29. http:// jurnal.atidewantara.ac.id/ index. php/ djtech/ article / view/20

Kastono, et.al (2022) Mitigation and public coordination for Flood Disaster Risk Reduction (FDRR) in the implementation of North Luwu sustainable development," in IOP Conference Series: Earth and Environmental Science, vol. 1109, no. 1. doi: 10.1088/1755-1315/1109/1/012018.

Kastono, et.al (2024) Adaptation and mitigation model for flood disaster resilience in West Malangke District, North Luwu Regency, Indonesia. International Journal of Safety and Security Engineering, Vol. 14, no. 5, pp. 1627-1633. https://doi.org/10.18280/ijsse.140529

Kusuma, MN, & Yulfiah. (2018). RELATIONSHIP BETWEEN POROSITY AND PHYSICAL PROPERTIES OF SOIL IN INFILTRATION GALLERY.

Prayogo, K., & Saptowati, H. (2016). INVESTIGATION OF SOIL STRUCTURE AND CHARACTERISTICS FOR THE DESIGN OF GAMMA IRRADIATOR FOUNDATIONS WITH A CAPACITY OF 2 MCi. 10(1978).

Putra, AR, Wibowo, A., & Arifin, R. (2022). Hydrological Risk Analysis and Optimization of Steel Frame Bridge Spans for Reducing Pillars in Flood-Prone Rivers. Journal of Civil and Environmental Engineering, 10(1), 45-56. (Relevant for steel frame structure selection and span optimization).

Rahim, A. (2025). Correlation Study of Sondir Values Against SPT Value Data in Soil Investigation Work for the Construction of Mimika Regency Hospital, Central Papua. 6(1), 30–33.

Roschedy, G., Manoppo, FJ, & Mandagi, AT (2019). Analysis of the bearing capacity of the Gorr I bridge foundation. 7(4), 397–408.