Comparisson of Physical Properties of Very Soft Soil in Gedebage

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Abstract

Gedebage, located in the eastern part of Bandung City, has undergone rapid urban development supported by various infrastructure projects. However, this area is geologically underlain by thick lacustrine deposits from the Kosambi Formation, which present serious geotechnical challenges due to their very soft soil characteristics. These soils are known for high compressibility, excessive moisture content, and low shear strength, making them problematic for construction. Given the limited comprehensive studies in this region, a detailed investigation into the physical properties of very soft soils in Gedebage is urgently required. This study employed a descriptive-quantitative approach combining field sampling and laboratory testing. Soil samples were collected from 1–3 meters depth using hand augers and analyzed to determine water content, specific gravity, bulk and dry density, void ratio, porosity, and Atterberg limits. The results were then compared with previous studies in Gedebage and other soft soil regions to contextualize the findings. The analysis revealed that the soils exhibit extremely high water content (112%), low dry density (0.65 g/cm³), a void ratio of 3.06, porosity of 75.24%, and a high plasticity index (41.78%), classifying the soil as CH (high-plasticity clay) according to USCS. These findings confirm that Gedebage's soil is highly saturated, weak, and compressible—posing considerable risks to infrastructure stability. Academically, this study contributes to the geotechnical characterization of Bandung Basin soils, while socioeconomically it offers essential insights for safer, more adaptive infrastructure planning in rapidly urbanizing regions built on very soft soil foundations.

Keywords: Very Soft Soil, Physical Properties, Void Ratio, Plasticity Index, Lacustrine Deposit, Bandung Basin

1. INTRODUCTION

The rapid urban expansion of Bandung, especially in lowland areas such as Gedebage, which has given rise to extensive residential development in the Gedebage area (1). Gedebage, located in the eastern part of Bandung City, is a strategic area being developed as a City Service Center (PPK) based on the City Planning Guidelines and the 2018 Bandung Mayoral Regulation (2). Accelerated infrastructure development in this area—such as high-speed rail projects, toll roads, and residential areas—has made it a new growth hub. However, this development expansion has raised serious concerns regarding the geotechnical reliability of the subsoil, particularly because Gedebage sits atop an ancient lacustrine deposit known as the Kosambi Formation. This formation formed from the Early to Late Quaternary period due to tectonic, volcanic, and sedimentary processes, resulting in a very soft clay layer reaching 30–40 meters thick, even more in the eastern part (3,4).

Technically, the lacustrine soils in this region exhibit extreme geotechnical characteristics, such as very high natural water content (up to 300%), a large void ratio (reaching 4.0), a degree of saturation approaching 100%, and a low wet unit weight (approximately 1.1–1.6 g/cm³) (5,6). These properties indicate a highly compressible and mechanically weak soil structure, which directly impacts the reduction in bearing capacity and the risk of long-term consolidation. Based on modeling data, the Gedebage area has experienced land subsidence of up to 161 cm since 1986, triggered by a combination of groundwater exploitation and natural consolidation of the soft clay layer (4,7).

In this context, understanding the physical properties of very soft soils—including water content, specific gravity, void ratio, porosity, and Atterberg limits—is key to a comprehensive geotechnical evaluation. These parameters not only reflect soil consistency and plasticity but are also important indicators in predicting long-term settlement behavior and foundation stability. Unfortunately, despite ongoing development, comprehensive studies on the physical behavior of soft soils in the Gedebage area are still limited. Therefore, this study aims to compare the physical properties of very soft soils in the Gedebage area to provide a scientific basis for more adaptive and sustainable infrastructure planning.

1.1. Geology of the Bandung Basin

The Bandung Basin is a tectonic depression formed by regional geodynamic activity, which was then filled by volcanic eruptions and lacustrine sediments since the Quaternary Period. These processes produced a complex lithology consisting of volcanic, alluvial, lacustrine, and lahar deposits. According to research by (3), the Bandung ancient lake system formed as a result of a block collapse (graben) and was covered by lava flows from Mount Tangkuban Parahu and Mount Sunda, trapping water and forming a vast lake that persisted for tens of thousands of years. The Gedebage area is located in the northeastern part of the Bandung Basin and geomorphologically falls within a floodplain zone filled with fine-grained lacustrine deposits.

1.2. Characteristics of Lacustrine Soils in the Gedebage Area

Lacustrine deposits in the Gedebage area generally consist of dark gray to black fine-grained clay, possibly containing organic matter, with low permeability and very high water content. This formation is known as the Kosambi Formation, which can reach a thickness of more than 30 meters (3,6) . Based on geotechnical data from various studies, this soil has a natural water content above 100–200% (5), a high void ratio (>3.0), and a degree of saturation (Sr) approaching 100% (6,8). These properties indicate that the lacustrine soil in Gedebage is very soft, highly compressible, and susceptible to settlement due to external loading and natural consolidation (4).

1.3. Characteristics of Very Soft Clay

Very soft clay is a type of soil with low shear strength, high deformability, and is often fully saturated. This soil generally has an unconfined compressive strength (qu) of <25 kPa and a SPT N of <4 (Terzaghi, 1996), and a natural water content that often exceeds the liquid limit. Very soft clay is characterized by a large void ratio, low dry unit weight, and high plasticity, indicating weak interparticle bonds and a high potential for deformation (5,6).

In the context of civil and geotechnical engineering, the presence of very soft clay layers poses a serious challenge in foundation design and infrastructure development. This soil generally has a low bearing capacity and exhibits significant secondary consolidation (creep) behavior. Previous studies have shown that the soft soil in Gedebage is highly saturated, plastic, and prone to significant long-term settlement (4,8). Therefore, examining physical properties—such as water content, specific gravity, porosity, and Atterberg limits—is crucial for evaluating the level of geotechnical risk and establishing the basis for soil classification for construction projects on the land.

2. METHOD

This research was designed to identify and analyze the physical characteristics of very soft soil in the Gedebage area through an experimental approach consisting of field surveys and laboratory testing. The research stages included secondary data collection, site mapping, soil sampling using a hand auger, and testing in a geotechnical laboratory. The research focused on determining the physical properties of the soil, specifically identifying the soil type and assessing the extent of its plastic deformation capacity based on Atterberg limit testing results, as well as potential geotechnical issues in very soft soil, particularly in the context of construction and infrastructure planning. This research was descriptive-quantitative in nature, using a case study approach at specific locations in the Gedebage area.

2.1. Sample Collection

Very soft soil samples for this study were collected from Gedebage District, Bandung City (coordinates: -6.952059° Latitude and 107.711582° Longitude). Soil samples were taken from the research location at a depth of 1-3 meters from the ground surface with A hand auger method was used to collect soil samples to obtain soil from the dominant very soft layer. Disturbed soil samples were collected in airtight plastic bags to maintain their natural air content and immediately transported to the laboratory for further testing.

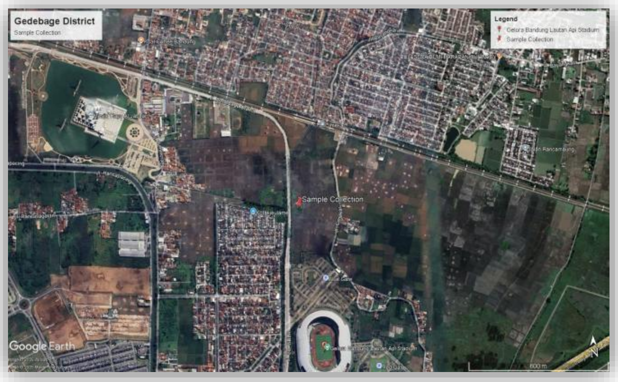


Figure 1 Location of Soil Data Collected (Gedebage, Bandung, Indonesia)

2.2. Laboratory Testing

Collected soil samples were tested to determine their physical properties. Laboratory testing was conducted to determine the physical properties of the soil samples, including water content(9), specific gravity(10), unit weight(11), Atterberg limits (liquid limit, plastic limit, and plasticity index) (12), and to analyze grain size distribution using a combination of sieve and hydrometer methods (13,14). The results of these tests were used to classify soil types according to classification systems such as the USCS (Unified Soil Classification System) and to provide initial information regarding the plasticity and potential compressibility of the very soft soils at the study site.

Table 1. Reference standard for soil properties testing

Laboratory Test	Refers
Water content	ASTM D 2216-98
Specific gravity (particle density)	ASTM D854
Unit weight	ASTM C 29
Atterberg limit (liquid limit & plastic limit)	ASTM D4318
Grain size distribution (sieve & hydrometer analysis)	ASTM D1140, ASTM D 442-63

Figure 2 Laboratorium Testing

2.3. Comparative Analysis

As part of the analysis, the results of soil physical properties testing in Gedebage will be compared with data from previous studies conducted on very soft soils in Indonesia especially Gedebage District. This comparison aims to evaluate the suitability or differences in soil characteristics and to place the results of this study in a broader context. Comparative data was obtained from scientific publications, technical reports, and other relevant sources, focusing on parameters such as high water content, plasticity index, and soil classification type. This approach is expected to strengthen the validity of the findings and provide a general overview of the position of Gedebage's soil characteristics compared to areas with similar characteristics.

3. RESULTS AND DISCUSSION

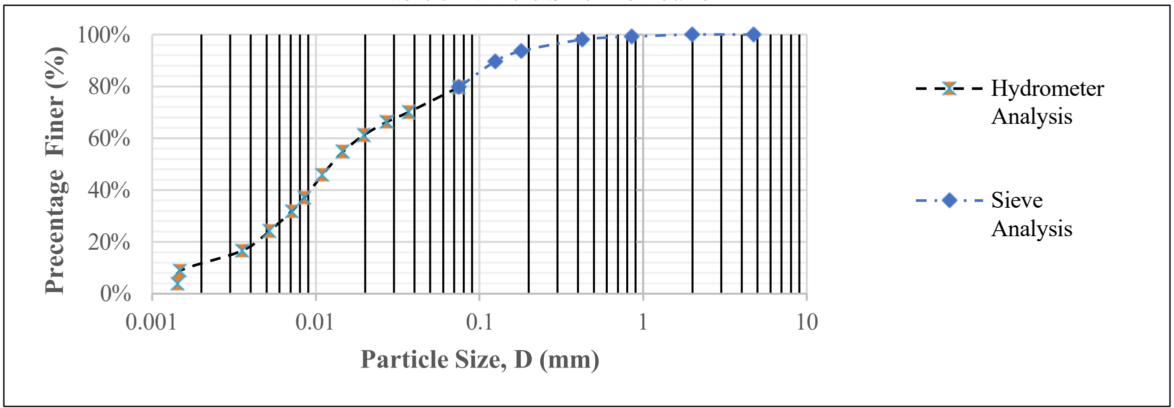
3.1. Physical Properties of Soil

Laboratory test results show that the basic physical properties of the soil are very soft.

Table 2 Result Physical Properties of Gedebage District Soil

Soil Properties	Value
Water Content (%)	112%
Specific Gravity	2.61
Bulk Density, γ_n (gr/cm³)	1.37
Dry Density, γdry (gr/cm³)	0.65
Degre of Saturation, Sr (%)	95.55%
Void Ratio, e	3.06
Porosity, n (%)	75.24%
Liquid Limit (%)	76.27%
Plastic Limit (%)	34.49%
Plasticity Index (%)	41.78%

Table 3 Particle Size Distribution



Physical testing of soil samples from the Gedebage area revealed that the soil at the study site is very soft with extreme physical characteristics. The natural water content reached 112%, indicating a very high water-holding capacity and a saturated state. The wet unit weight of 1.37 g/cm³ and dry unit weight of 0.65 g/cm³ reflect low soil mass density, consistent with high porosity. This is supported by a void ratio (e) of 3.06 and a porosity (n) of 75.24%, indicating a large pore volume within the soil structure. Furthermore, the degree of saturation (Sr) of 95.55% indicates that the soil pores are almost entirely filled with water.

Meanwhile, consistency parameters such as liquid limit (LL) = 76.27%, plastic limit (PL) = 34.49%, and plasticity index (PI) = 41.78% indicate that the soil belongs to the high-plasticity clay group. The provisional classification based on the USCS system points to the CH (inorganic clay with high plasticity) group. These characteristics support the classification of highly compressible soil with the potential for long-term deformation, particularly when subjected to loading in infrastructure projects.

3.1.1 Moisture Content and Density Characteristics

The structural composition of soil particles was further evaluated through the void ratio and porosity parameters, which provide important insights into the soil's compressibility and permeability characteristics. Test results showed a void ratio (e) of 3.06 and a porosity (n) of 75.24%, very high values for natural soil.

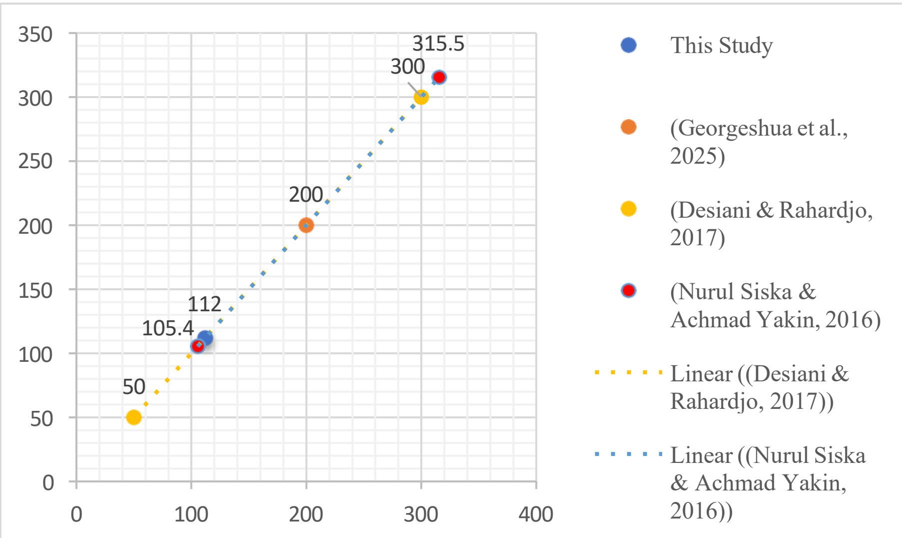


Figure 3 Comparison Water Content This Study and Previous Study

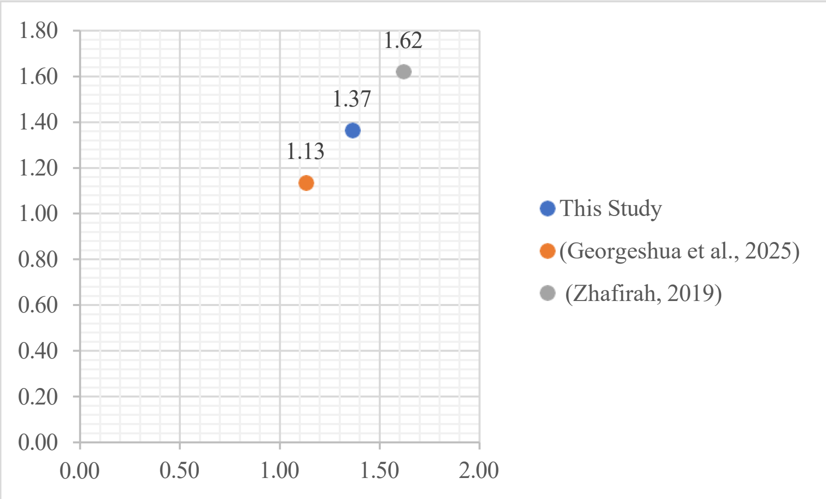


Figure 4 Comparison Unit Weight This Study and Previous Study

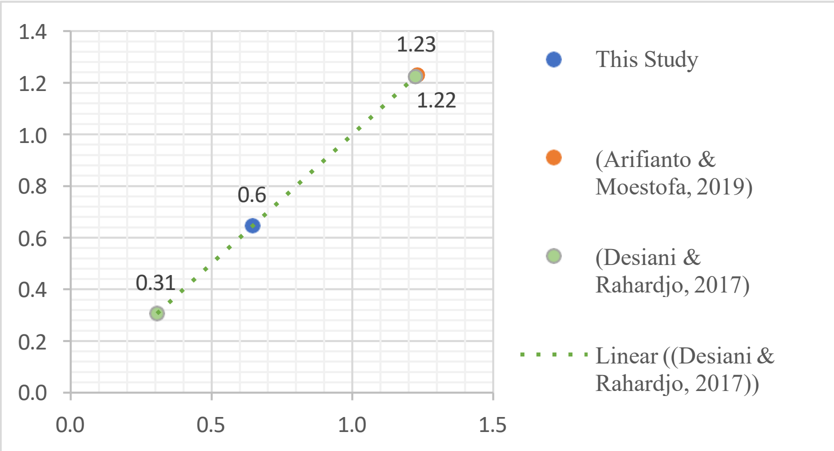


Figure 5 Comparison Dry Unit Weight This Study and Previous Study

Previous studies have reported similar characteristics of soft soils in the Gedebage area. For instance, (5)documented a natural water content of up to 200%. At the same location and at comparable depths, (6,8)observed a wide range of water content values, from 50% to 300% in Figure 6, and noted that the degree of saturation (Sr) typically ranged between 90% and 100%, indicating nearly fully saturated conditions. In terms of unit weight, (5,15) reported wet unit weights of 1.13 g/cm³ and 1.62 g/cm³, respectively—values that bracket the bulk density obtained in this study which can be seen in the Figure 7. Additionally, (6) reported dry unit weights ranging from 0.31 g/cm³ to 1.22 g/cm³, which aligns well with the current result of 0.65 g/cm³ in Figure 8. These consistent findings across multiple studies further reinforce the classification of the soil in Gedebage as highly saturated, loose, and of very soft consistency.

These values reflect a very open and unconsolidated soil structure, typically found in organic or alluvial deposits with a large proportion of fine-grained particles and minimal cementation. High porosity and void ratio are often directly related to low shear strength, increased compressibility, and high potential for settlement under loading. In engineering practice, soils with these characteristics are considered problematic and require special soil improvement measures or deep foundation solutions. The observed physical conditions also align with the low dry density and high water content discussed previously, depicting a consistent picture of a highly saturated and unstable soil layer.

3.1.2 Void Ratio and Porosity Assessment

The structural composition of soil particles was further evaluated using the void ratio and porosity parameters, which provide important insights into the soil's compressibility and permeability characteristics. Test results indicated a void ratio (e) of 3.06 and a porosity (n) of 75.24%, very high values for natural soil.

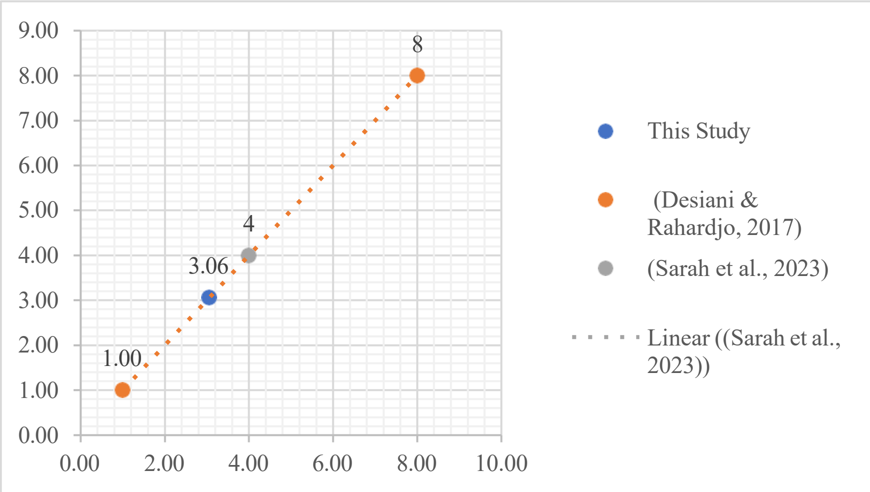


Figure 9 Comparison Void Ratio in This Study and Previous Study

Previous studies, such as (4) reported that soil at depths of 0-30 m had higher void ratios than this study. However, a similar study at the same location in Gedebage District by (6) found e values in the range of 1-8 which can be see in *Figure 10*, which not only validates this study but also provides additional evidence that the soil in Gedebage District generally has very high porosity, not just at specific test points.

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3.2. Consistency Limits and Plasticity Characteristics

3.2.1 Atterberg Limits Results

Soil consistency behavior was assessed using the Atterberg limit test to evaluate the plasticity and workability of the soil under various moisture conditions. The results showed a liquid limit (LL) of 76.27%, a plastic limit (PL) of 34.49%, and a plasticity index (PI) of 41.78%. A PI greater than 40% typically indicates a soil with very high plasticity, likely clay with expansive potential and significant volume change behavior.

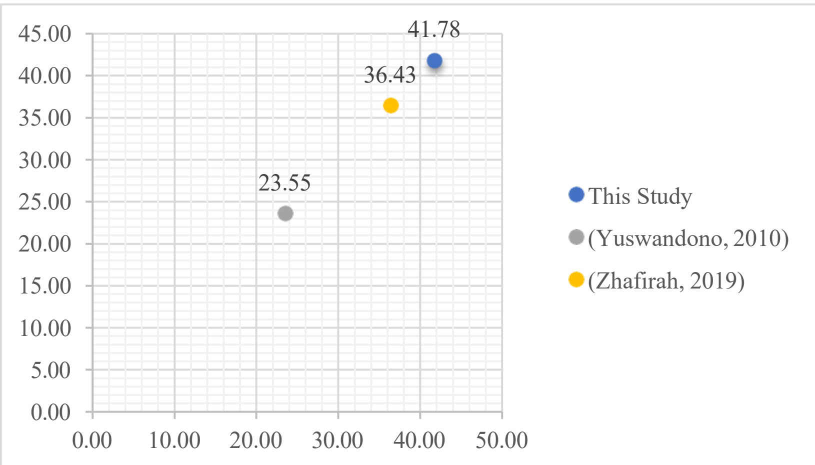

Figure 11 Comparison Plasticity Index In This Study and Previous Study

Previous research by (15,16) reported plasticity values much lower than this study, but still within the high plasticity classification. Other studies even described this soil as exceeding the limits of the Cassagrande diagram (5,6). This indicates lateral variations in clay mineral content or varying degrees of local weathering. Therefore, the PI values in this study can still be considered valid, especially in locations with low elevations and active sedimentation around the depositional area.

Soils in this plasticity range are highly sensitive to moisture fluctuations, potentially leading to shrinkage-swelling behavior and delayed settlement due to time-dependent deformations such as secondary compression (creep). The combination of high PI and high natural water content confirms the critical consistency condition of the material at the time of sampling, indicating that the soil is in a plastic to near-liquid phase under natural conditions. This behavior is crucial in the design of embankments, shallow foundations, and earthworks, especially when exposed to long-term loading or fluctuating groundwater conditions.

3.2.2 Soil Classification According to USCS

Based on the Atterberg limits and grain size characteristics, the soil was classified according to the Unified Soil Classification System (USCS). The high liquid limit and plasticity index, as well as the plot of the plasticity index against the liquid limit, placed the soil well above line A on the Casagrande plasticity diagram. Combined with the predominance of particles passing the No. 200 sieve (80%), the soil was classified as CH (High Plasticity Clay).

Previous research by (15,17) also examined similar soil and found that it was classified as CH (High Plasticity Clay). Another study found that the same soils were mostly classified as MH (High Plasticity Silt) and the remainder as CH (High Plasticity Clay) at a certain depth (5,6) which can be see in table.

Table 4 Comparison USCS In This Study and Previous Study

Refrence	Lokasi	USCS	PI (%)
This Study	Kecamatan Gedebage	CH	41.78
(Arifianto & Moestofa, 2019)	Kecamatan Gedebage	CH	54
(Zhafirah, 2019)	Kecamatan Gedebage	CH	36.43
(Desiani & Rahardjo, 2017)	Kecamatan Gedebage	MH-CH	Over Cassagrande Chart
(Georgeshua et al., 2025)	Kecamatan Gedebage	MH-CH	Over Cassagrande Chart

This soil classification is known for its low bearing capacity, high compressibility, and poor drainage characteristics. In the context of the Gedebage area, which is characterized by lowland topography and an alluvial depositional environment, this classification is consistent with field observations and previous regional studies. From a geotechnical engineering perspective, CH soils require careful design interventions, such as preloading with vertical drainage, the use of geosynthetics, or deep foundations to mitigate the risk of excessive settlement and instability due to infrastructure loads. Therefore, this classification not only confirms the problematic nature of the soil but also highlights the importance of combining conservative and adaptive engineering solutions in any development plans in the region.

4. CONCLUSIONS

1. The physical characteristics of the very soft soil in Gedebage indicate very weak and unstable geotechnical properties. Laboratory test results show:
- Natural water content of 112%,
- Low dry unit weight (0.65 g/cm³),
- High void ratio (3.06),
- Porosity of 75.24%, and
- Near-perfect degree of saturation (95.55%).

These findings indicate that the soil has low density and is highly compressible under load.

2. Atterberg limit test results show:
- Liquid limit (LL): 76.27%,
- Plasticity index (PI): 41.78%.

Based on the USCS classification system, the soil is categorized as CH (highly plastic inorganic clay), which indicates high compressibility potential, low permeability, and low shear strength.

3. Comparison with previous studies:

Previous studies (Georgeshua, 2025; Desiani, 2017; Siska, 2016) reported water contents of up to 300%, void ratios >3.0, and comparable wet/dry unit weight values. This indicates that the findings in this study are valid and consistent with the regional geotechnical conditions of Gedebage, which is a very soft soil zone.

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