

# Soil Investigation Analysis Using Drilling and Standard Penetration Test (SPT) Methods at Blang Mane Bridge

Julsena<sup>1</sup>, Nura Usrina<sup>2\*</sup>, David Sarana<sup>3</sup>, Herman Fithra<sup>4</sup>, Liza Afra<sup>5</sup>

<sup>1</sup>Department of Civil Engineering, Faculty of Engineering, Universitas Islam Kebangsaan Indonesia, Bireuen, Indonesia

<sup>2,3,4,5</sup>Department of Civil Engineering, Faculty of Engineering, Universitas Malikussaleh, Lhokseumawe, Indonesia

\*Koresponden email: nura.usrina@unimal.ac.id

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## Abstract

Soil investigation is a fundamental process in geotechnical engineering to assess subsurface conditions for construction projects. This study focuses on the experimental site at Blang Mane, where a borehole designated as BH-01 was drilled to evaluate soil stratification and properties. The investigation aimed to characterize the soil layers through drilling, sampling, and laboratory testing, including Standard Penetration Tests (SPT), to determine geotechnical parameters essential for foundation design. The surface soil layer at Borehole (BH-01) location consists of 1.0 m of medium-dense gravelly sand. From 1.0 to 3.5 m depth, a layer of silty clay with medium to stiff/hard consistency is observed. Between 3.5 and 10.5 m lies a very dense sand layer, underlain by medium-dense silty clay at 10.5–12.5 m. A medium-dense sandy silt layer extends from 12.5 to 24.0 m, followed by medium-dense sand at 26.0–30.0 m. A very dense sand layer occurs at 30.0–32.0 m, transitioning to medium-stiff/hard clayey silt at 32.0–37.0 m. Sandy silt of medium density is present from 37.0 to 47.0 m, while very dense gravelly sand comprises the deepest layer (47.0–60.0 m). The groundwater table (GWT) at BH.01 is located 7.0 m below ground level.

**Keywords:** *Standard Penetrometer Test, Drilling, Soil investigation, Geotechnical.*

## Abstrak

Investigasi tanah merupakan proses dasar dalam teknik geoteknik untuk menilai kondisi bawah permukaan dalam proyek konstruksi. Penelitian ini berfokus pada lokasi eksperimen di Blang Mane, di mana sebuah lubang bor yang dinamakan BH-01 dibor untuk mengevaluasi stratifikasi dan sifat-sifat tanah. Investigasi ini bertujuan untuk mengkarakterisasi lapisan tanah melalui pengeboran, pengambilan sampel, dan pengujian laboratorium, termasuk Uji Penetrasi Standar (SPT), untuk menentukan parameter geoteknik yang penting dalam desain fondasi. Lapisan permukaan tanah di lokasi Borehole (BH-01) terdiri dari pasir bergravel kepadatan sedang setebal 1,0 m. Pada kedalaman 1,0–3,5 m terdapat lempung kelanauan berkonistensi sedang hingga kaku/keras, diikuti lapisan pasir sangat padat (3,5–10,5 m). Lapisan lempung kelanauan kepadatan sedang terletak pada 10,5–12,5 m, sedangkan lanau kepasiran kepadatan sedang menyusun lapisan 12,5–24,0 m. Lapisan pasir kepadatan sedang terdapat pada 26,0–30,0 m dan pasir sangat padat pada 30,0–32,0 m. Lanau kelempungan kepadatan medium–kaku/keras teridentifikasi di kedalaman 32,0–37,0 m, diikuti lanau kepasiran kepadatan sedang (37,0–47,0 m) serta lapisan terdalam pasir bergravel sangat padat (47,0–60,0 m). Muka air tanah (MAT) di BH-01 berada pada kedalaman 7,0 m dari permukaan.

**Kata Kunci:** *Pengujian SPT, Pengeboran, Penyelidikan tanah, Geoteknik.*

## 1. Introduction

Soil investigation is a critical preliminary step in any construction project [1]. Naturally, soil layers exhibit highly variable conditions, and subsurface heterogeneity is often unknown beforehand. In many cases, field investigations become an iterative process of exploration and interpretation, where the scope of work may require adjustments based on newly acquired field data. For the Blang Mane Bridge Replacement Project, a soil investigation was conducted to characterize the subsurface stratigraphy. To achieve this, soil samples were collected through deep drilling (boring) and subsequently tested in a

laboratory to determine geotechnical parameters. Additionally, Standard Penetration Tests (SPT) were performed during drilling to provide rapid insights into soil layer properties [2].

Soils are broadly classified into coarse-grained and fine-grained categories. The two most widely used classification systems are the AASHTO (American Association of State Highway and Transportation Officials) and the USCS (Unified Soil Classification System). Under AASHTO, soils are divided into two primary groups. The first group comprises coarse-grained materials (A-1, A-2, and A-3), defined by having 35% of particles passing the No. 200 sieve. The second group consists of fine-grained soils (A-4 to A-7), where >35% passes the No. 200 sieve. Further classification incorporates the liquid-plastic limit indices [3].

Soil is a natural aggregate of uncemented mineral particles, organic matter, and voids filled with fluids (water/air). It serves as both a construction material and a foundation support in civil engineering. Clay soils, composed of microscopic to submicroscopic particles, exhibit plasticity at intermediate moisture levels and become cohesive when saturated [4]. The shear strength of soil its resistance to deformation under stress depends on field conditions, soil type, moisture content (especially in clays), and loading characteristics. Shear failure occurs not due to particle disintegration but through relative displacement between particles [5].

## 2. Material and Methods

Pore water pressure depends on the placement moisture content of embankment fill and the rate of construction. A commitment to rapid completion will result in high pore water pressure at the end of construction. However, the construction period for embankment dams is typically long enough to allow partial dissipation of excess pore water pressure, particularly in dams with internal drainage. The dissipation of excess pore water pressure can be accelerated by installing horizontal drainage layers within the dam. Nevertheless, a total stress analysis would yield an overly conservative design. Therefore, effective stress analysis is preferred [6].

Soil structure refers to the physical arrangement of soil aggregates and the pore spaces between them. Soil consists of three phases: solid, liquid, and gas. Among the most common soil types is clay, which is composed of silicate-based mineral particles [7].

The study area is located at coordinates 5°05'45.0"N 96°45'46.0"E Blang Mane, Peusangan Selatan Subdistrict, Bireuen Regency, Aceh Province, as illustrated in Figure 1 below:



Figure 1. Site Location

### 2.1 Soil Investigation

Soil investigation is a critical preliminary stage in construction planning to determine the characteristics and conditions of the project site. For the optimal placement of steel plate shear walls (SPSW), symmetric positioning has been shown to provide safer results, producing lower internal forces, vibration periods, and bending moments compared to asymmetric configurations [8]. The primary

objective of soil investigation is to obtain technical parameters such as bearing capacity, density, degree of saturation, and soil stratification [9]. These data serve as the basis for foundation and substructure design [10].

## 2.2 Soil Drilling Methods

Soil drilling is conducted to retrieve samples from specific depths for laboratory or in-situ analysis. The drilling process typically employs rotary drilling or auger boring, depending on soil type and target depth [11]. The collected samples are used for laboratory tests, including gradation analysis, consistency tests, and shear strength evaluation [12].

Undisturbed soil samples (UDS) were extracted from the borehole using a tube soil sampler. To preserve sample integrity, both ends of the tube were sealed with paraffin wax before transportation to the laboratory. Each sample was labeled with the project name, location, and sampling depth.

Undisturbed sampling was only feasible for cohesive soils (clay or silt), as these materials possess sufficient cohesion to adhere to the sampler walls. For granular soils (sand or gravel), only disturbed soil samples (DS) could be collected. All samples both UDS and DS were systematically arranged in core boxes according to their depth intervals to facilitate identification [13].

## 2.3 Standard Penetration Test (SPT)

The SPT is one of the most widely used field tests in geotechnical investigations. It measures the relative density or consistency of soil by recording the resistance to penetration of a split-spoon sampler driven into the ground. The blow count, termed the N-value (N-SPT), correlates with soil parameters such as internal friction angle ( $\phi$ ), elastic modulus (E), and bearing capacity [14].

To conduct the Standard Penetration Test (SPT), drilling operations were first carried out using a YBM-brand rotary drilling rig equipped with a hydraulic spindle. The drilling method was selected based on soil conditions: wet drilling (flushing) for sandy soils, semi-wet drilling for soft soils, and dry drilling (non-flushing) for loose sands. The retrieved soil cores were carefully described and stored in labeled core boxes to ensure preservation. Each core box label included the borehole location, borehole number, and depth interval.

The SPT was performed at 2-meter intervals within the borehole. The test employed a Raymond split-spoon sampler, which was driven into the soil using a 63.5 kg hammer dropped freely from a height of 75 cm. For each test, three penetration readings ( $N_1$ ,  $N_2$ , and  $N_3$ ) were recorded, where N represents the number of hammer blows required to drive the sampler 15 cm into the soil. The SPT N-value was calculated as  $N_1 + N_2$ . The soil samples collected from the split-spoon sampler were individually sealed in plastic bags for further analysis.

SPT results are interpreted to evaluate soil properties, such as the density of sandy soils or the consistency of clayey soils. Empirical correlations developed by geotechnical experts link N-values to mechanical soil parameters ([12]; [11]). However, interpretation must account for field conditions, soil type, and test depth to ensure accuracy [11].

## 2.4 Laboratory Testing

The comprehensive series of laboratory tests were conducted on the collected soil samples to thoroughly evaluate their physical and mechanical properties, including:

- Grain size analysis (utilizing both sieve analysis for coarse particles and hydrometer analysis for fine-grained soil fractions)
- Natural water content determination (measured by oven-drying method at 110°C until constant mass was achieved)
- Unit weight measurement (calculating both wet and dry densities of the soil specimens)
- Specific gravity test (performed using pycnometer method according to ASTM D854 standards)
- Atterberg limits (comprising liquid limit test using Casagrande apparatus, plastic limit test by thread-rolling method, and derived plasticity index)
- Direct shear test (conducted under consolidated-drained conditions to determine soil shear strength parameters)
- Consolidation test (performing oedometer tests to evaluate compression characteristics and settlement parameters)

### 3. Results and Discussion

The results are organized systematically, beginning with field test data followed by laboratory analysis, to provide a comprehensive understanding of subsurface conditions. Particular attention is given to comparing measured values with established empirical relationships and evaluating their consistency with expected soil behavior patterns.

#### 3.1 SPT Test Results

The Standard Penetration Tests conducted at the investigation site yielded N-values that indicate soil resistance characteristics at various depths. The complete SPT results are presented in Table 1, showing the correlation between penetration resistance and soil layer composition.

Table 1. SPT N-values at Borehole BH.01

No.	Depth (m)	BH.01
1	2.00	26
2	4.00	7
3	6.00	>60
4	8.00	>60
5	10.00	14
6	12.00	18
7	14.00	7
8	16.00	12
9	18.00	14
10	20.00	14
11	22.00	10
12	24.00	19
13	26.00	14
14	28.00	13
15	30.00	15
16	32.00	58
17	34.00	30
18	36.00	18
19	38.00	27
20	40.00	28
21	42.00	25
22	44.00	32
23	46.00	>60
24	48.00	>60
25	50.00	>60
26	52.00	>60
27	54.00	>60
28	56.00	>60
29	58.00	>60
30	60.00	>60

#### 3.2 Seismic Conditions

The Aceh Province is located within the Pacific Ring of Fire, making it particularly vulnerable to seismic activities. The presence of the Great Sumatran Fault (Semangko Fault) further increases the earthquake risk, with potential seismic sources originating from both onshore and offshore tectonic movements. This geological setting necessitates special consideration in foundation design to account for potential ground shaking.

### 3.3 Groundwater Table

The groundwater table (GWT) at borehole location BH01 was encountered at 7.0 meters below ground surface. This depth measurement was confirmed through continuous monitoring during drilling operations and subsequent piezometer readings.

### 3.4 Physical Properties Testing

Laboratory testing of soil samples revealed important physical characteristics that influence foundation design parameters. The comprehensive test results, including grain size distribution and Atterberg limits, are summarized in Table 2.

The particle size distribution analysis shows significant variation between different soil layers, with the upper strata being predominantly sandy while deeper layers contain more cohesive materials. This stratification pattern has direct implications for load-bearing capacity and settlement characteristics.

Table 2. Physical Properties Test Results

No	Parameter	Unit	BH 01	
			5.5–6 m	12.5–13 m
1	Gravel Content	%	0.77	0.2
2	Sand Content	%	79.23	11.7
3	Silt Content	%	13.53	65.6
4	Clay Content	%	6.50	22.50
5	Water Content	%	19.93	20.40
6	Wet Unit Weight	kN/m <sup>3</sup>	18.77	26.62
7	Dry Unit Weight	kN/m <sup>3</sup>	1.702	1.732
8	Specific Gravity	-	1.433	1.368
9	Liquid Limit	%	2.662	2.624
10	Plastic Limit	%	NP	37.82
11	Plasticity Index	%	NP	21.49

### 3.5 Mechanical Properties Testing

The mechanical behavior of soil samples was evaluated through a series of laboratory tests to determine strength and deformation characteristics. Key parameters including shear strength and consolidation properties are presented in Table 3.

The direct shear test results demonstrate how shear strength parameters vary with depth, showing higher friction angles in granular layers and more cohesive behavior in clayey strata. These variations must be carefully considered in foundation design calculations.

Table 3. Mechanical Properties Test Results

No	Parameter	Unit	BH 01	
			5.5–6 m	12.5–13 m
1	Cohesion	kg/cm <sup>2</sup>	0.0994	0.1232

2	Internal Friction Angle	°	31.25	23.88
3	Void Ratio	-	NP	0.783
4	Coefficient of Consolidation	cm <sup>2</sup> /s	NP	6.75E-03
5	Compression Index	-	NP	0.1704
6	Permeability	cm/s	NP	2.28E-07

### 3.6 Foundation Bearing Capacity Analysis

The ultimate bearing capacity of pile foundations was calculated using Meyerhof's method based on SPT N-values [15]. The analysis considers both end-bearing resistance and skin friction components through the following equations:

$$Q_u = Q_{t1} + Q_{t2} \quad (1)$$

$$Q_i = Q_{t1} / F_1 + Q_{t2} / F_2 \quad (2)$$

$$Q_{t1} = 40 \times N_r \times A_p \quad (3)$$

$$Q_{t2} = (A_s \times N_k) / 5 \quad (4)$$

$$A_s = A_p \times L \quad (5)$$

Where:

Qu = Ultimate bearing capacity

Qi = Allowable bearing capacity

Nr = Average N-value within 4D above and D below pile tip

D = Pile diameter

Ap = Pile cross-sectional area

As = Embedded pile surface area

Nk = Average N-value along embedded pile length

Ak = Pile circumference

Li = Embedded pile length

FK1 = Safety factor for end bearing (taken as 3)

FK2 = Safety factor for skin friction (taken as 5)

The graphical representation of calculated bearing capacity values at various depths is presented in Figure 2, showing the relationship between pile length and load-carrying capacity. This analysis provides crucial data for determining optimal pile dimensions and installation depths.

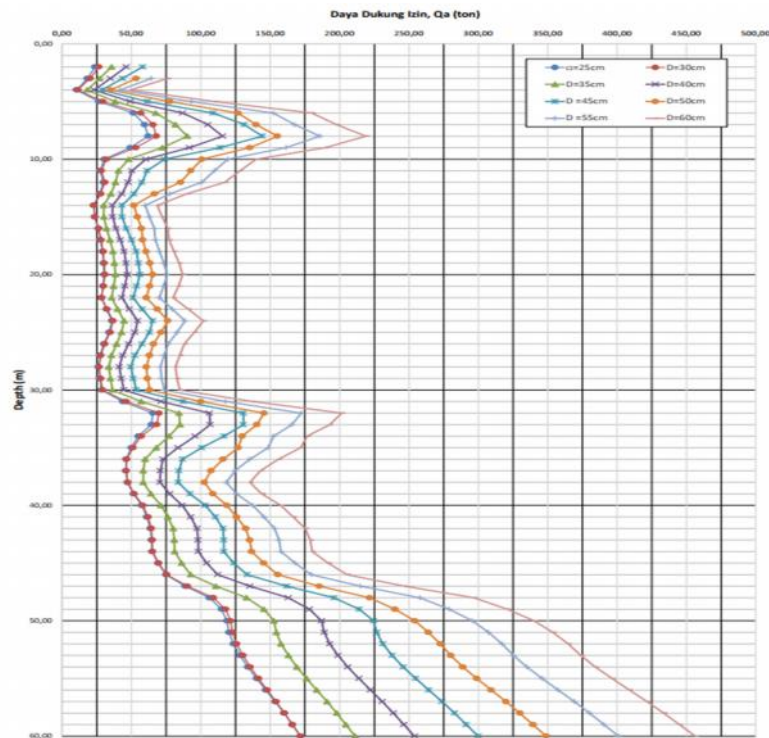


Figure 2. N SPT Test Results

#### 4. Conclusion

The borehole investigation at location BH-01 revealed a stratified soil profile with distinct geotechnical characteristics. The following conclusions were drawn from the field observations and laboratory test results:

- The subsurface conditions exhibit significant variation with depth, beginning with a 1.0-meter thick surface layer of medium-dense gravelly sand. Between 1.0-3.5 meters depth, a layer of silty clay with medium to stiff consistency was encountered. This is underlain by a very dense sand layer extending from 3.5-10.5 meters depth. A transitional zone of medium-dense silty clay exists at 10.5-12.5 meters, followed by medium-dense sandy silt from 12.5-24.0 meters.
- The soil profile continues with medium-dense sand at 26.0-30.0 meters, overlaying a very dense sand layer at 30.0-32.0 meters. Between 32.0-37.0 meters, clayey silt of medium to stiff density was observed. The subsequent layer consists of medium-dense sandy silt from 37.0-47.0 meters, with the deepest investigated layer comprising very dense gravelly sand from 47.0-60.0 meters.
- The complete physical and mechanical properties of each soil layer are documented in Appendix III. Of particular importance is the groundwater table (GWT) elevation, which was identified at 7.0 meters below ground surface. This hydrological condition significantly influences the foundation design considerations for the site.

#### 5. Acknowledgment

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