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RESEARCH ARTICLE

Geoengineering Characteristics of Site Soil Profile Analysis using Cone Penetration Tests Data

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Abstract

Classification and stratification of subsurface soils are critical aspects for a geotechnical site assessment to design and construct geotechnical structures. A probabilistic interpretation method is devised to adequately account for the uncertainty associated with subsurface soil categorization and stratification based on cone penetration test (CPT) data. CPT data is frequently directly employed in the construction of deep and shallow foundations, as well as a range of other purposes. It is advantageous to employ CPT data to create stratigraphic profiles as well, in order to generate more cost-effective designs. The method is demonstrated using CPT data from several locations in the Banda Aceh area. From limited CPT data, the approach accurately identifies subsurface soils in a 2D vertical cross-section. The objectives of this paper are to utilize CPT data to examine the soil profile in Banda Aceh, Indonesia. Additionally, soil parameters must be evaluated to obtain a better knowledge of Banda Aceh's soil conditions. The evaluation indicates that the average depth of the hard layer in the Kuta Alam District ranges from 5 to 8 meters beneath the ground surface. However, at certain locations, the hard soil stratum reaches a depth exceeding 18 meters. The findings are expected to be one source for determining the preliminary soil profile condition in Banda Aceh before doing additional soil investigation for construction design requirements.

Keywords: Cone Penetration Test, Interpretation, Site Characterization, Soil Profile

1. Introduction

Subsurface soil classification and stratification are important attributes in geotechnical site assessment for the design and construction of geotechnical structures (Alhaddad et al., 2021; Munirwansyah et al., 2018). Due to constraints in budget, time, or availability of subsurface soils, the soil profile information obtained from site investigation (e.g., boreholes, cone penetration test) is frequently limited, posing a significant challenge in interpreting the site investigation data and significant uncertainty in inferred soil stratification and classification at the site of interest (Hu and Wang, 2020). This unpredictability in stratification and classification may result in unanticipated site circumstances during construction (Munirwansyah et al., 2020). This uncertainty also affects the anticipated geotechnical structures' performance (Madabhushi, 2021; Munirwansyah et al., 2019).

Cone penetration test (CPT) is a type of in-situ test that is frequently employed in geotechnical engineering. It entails inserting a cone penetrometer through underlying soils and analyzing the soil's resistance to the cone as well as the skin friction on the sleeve (Oberhollenzer et al., 2021). CPT has been applied to characterize subsurface soils, to estimate their stratification, and to estimate associated uncertainty (Zhang et al., 2018). Numerous researchers have undertaken various studies on soil profile analysis (Aditama et al., 2021; Idris et al., 2018; Prabowo et al., 2020; Sugiyanto et al., 2018; Tanjung et al., 2020). More comprehensive soil profile characterization by using CPT was also conducted by several researchers (Lorenzo et al., 2014; Luiz et al., 2019; Oberhollenzer et al., 2021; Wang et al., 2021; Zhang et al., 2018). While the present study community is very interested in pursuing more accurate definitions of locations as random fields, additional research is needed to expedite the application of methodologies for the characterization of site variability based on existing CPT interpretation practice (Salgado et al., 2019).

The correlation exists between variables at various locations on a site, but the correlation develops progressively weak as the distance between the points considered increases (Salgado et al., 2019). The geographic variability of data from the cone penetration test (CPT) has been investigated using a variety of different metrics of variability (Ganju et al., 2017; Lorenzo et al., 2014). If the variability of the CPT parameters is significant during the site research phase, additional CPTs can be undertaken to better define soil properties; on the other hand, if the variability is low, it may be possible to minimize the number of CPT from the initial design. Naturally, such judgments should be made with prudence, taking into account the area's natural variance in soil profile and geology (Schneider et al., 2001).

The purpose of this study is to analyze the soil profile in the Banda Aceh area using CPT data. Additionally, it is required to evaluate soil parameters that can contribute to a general understanding of the soil conditions in Banda Aceh. The results are expected to contribute as one of the sources for estimating the preliminary soil profile condition in Banda Aceh prior to further soil investigation for construction design purposes.

2. Methodology

Soils are frequently classified in practice engineering depending on their grain size distribution. Those can be determined experimentally (through hydrometer and sieve measurements) or subjectively through experience. On the other hand, soils' in-situ behavior is highly dependent on their density, stress history, consolidation, and other physical and chemical mechanisms.

Fig. 1. Description of the CPT test configuration.

CPT is a common type of in-situ test used in geotechnical engineering (see Fig. 1). CPT results obtained at a standard rate of 2 cm/s can be interpreted using soil behavior type (SBT) charts, which allow for interpretations based on in-situ measurements or normalized characteristics. Modified versions of Tumay and Robertson's SBT charts (see Fig. 2) were used to develop the soil profiles in this study. This choice was decided in part due to engineers' experience with these two graphs and in part because the charts included certain basic characteristics necessary for the development of a rational, quantitative algorithm for CPT interpretation. The selected charts have been modified to remove any ambiguity linked with behavior kinds. These improvements were required to construct an algorithm for logical stratigraphic profiling utilizing CPT data.

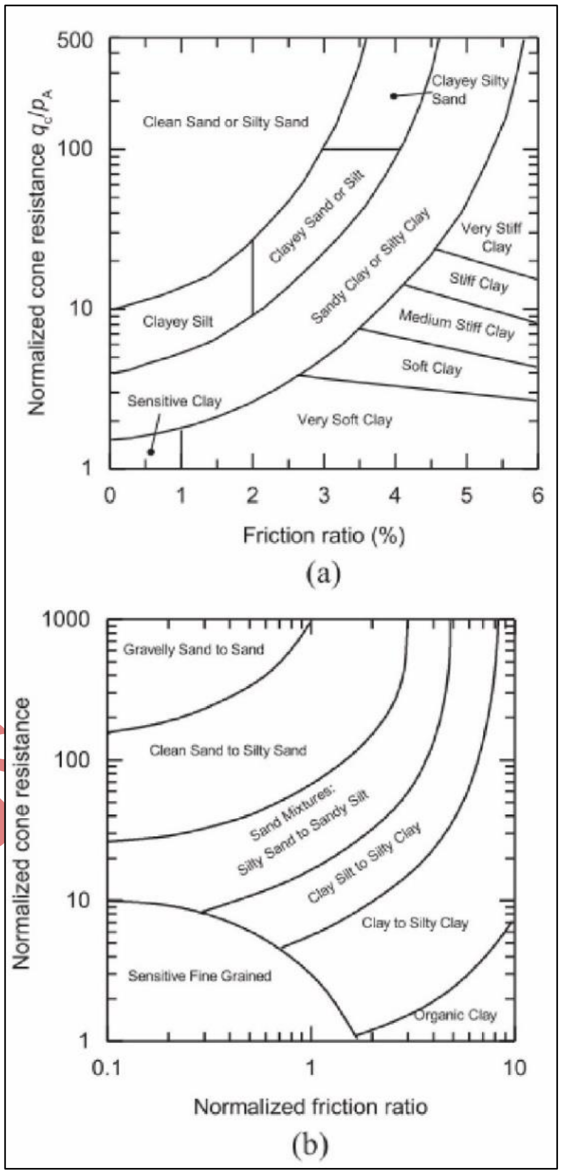

Fig. 2. Soil behavior type charts with modifications used to generate soil profiles. (a) Adjusted Tumay chart. that has been modified. (b) Adjusted Robertson chart (Salgado et al., 2019).

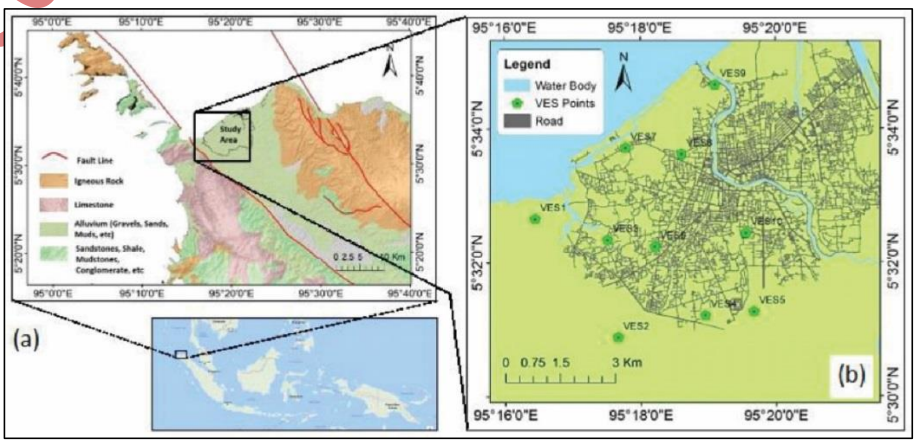

Fig. 3. Map of the geology surrounding Banda Aceh (Sugiyanto et al., 2018).

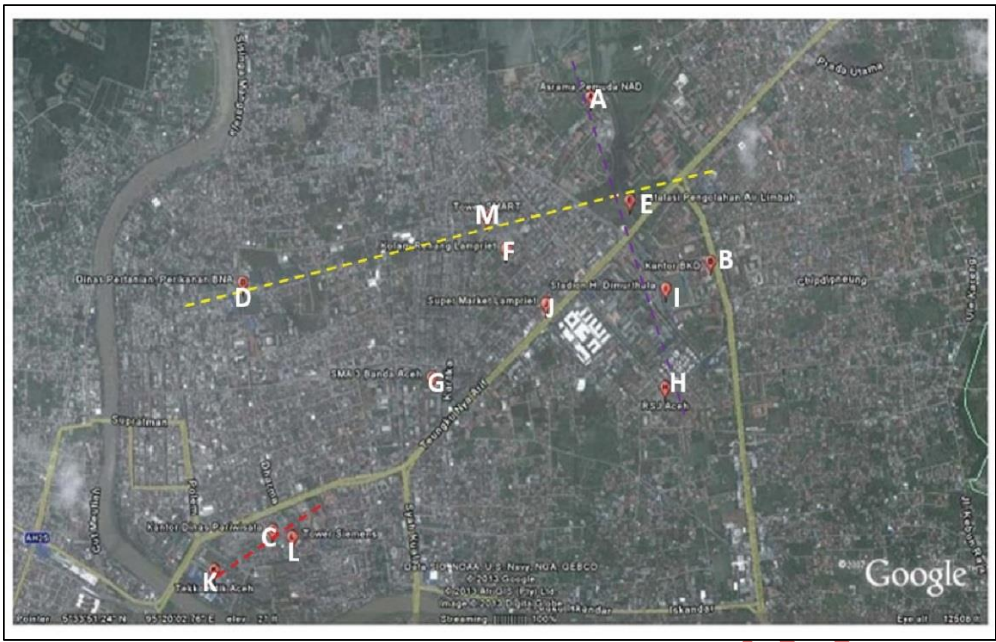

Fig. 4. Distribution of CPT data around Kuta Alam District, Banda Aceh

The data for this study was obtained from CPT and included up to 13 datasets dispersed across the Kuta Alam District, Banda Aceh, Indonesia. GPS is used to determine the coordinates of the sites. Google Earth was used to map the study region. The geological and site locations of this study can be seen in Figs. 3 and 4. Kuta Alam was chosen as the district of research due to the availability of supporting data that will be required for subsequent computations and analysis. The coordinates of each location of CPT data can be seen in Table 1.

Table 1. Description of CPT test location

Site No.	East Longitude Coordinate X	North Latitude Coordinate Y	CPT Depth (m)
A	95 20 16.0	5 34 20.0	7
B	95 20 33.6	5 33 57.4	7.4
C	95 19 29.3	5 33 20.9	4.6
D	95 19 24.9	5 33 54.6	18.2
E	95 20 21.7	5 34 05.8	19.6
F	95 20 03.5	5 33 59.2	7.4
G	95 19 52.6	5 33 41.8	7.8
H	95 20 26.9	5 33 40.4	4.6
I	95 20 27.0	5 33 53.8	6.8
J	95 20 09.4	5 33 51.7	9.2
K	95 19 20.7	5 33 15.5	4.0
L	95 19 32.2	5 33 20.0	6.2
M	95 20 00.7	5 34 03.6	20.0

3. Result and Discussion

Cone penetration tests (CPT) have been conducted in order to aid in the preparation of preliminary soil profile surveying in the Banda Aceh area, as well as to provide information for construction design in the Banda Aceh area. The CPT tests still very popular across the engineers to be used in order to determine the soil profile of for foundation design (Adamidis and Madabhushi, 2021; Gavin et al., 2021; Guan et al., 2021; Zeng et al., 2021). CPT data from locations typical of Kuta Alam and Banda Aceh are shown in order to demonstrate how they can be used for design purposes. In addition to being utilized as an initial study, the data collected can be used for site characterization assessments.

To perform the analysis, initial soil profiles were developed using adjusted Tumay and Robertson charts in Fig 2 as well as suggested soil profile generation algorithms from previous studies (Ganju et al., 2017; Salgado et al., 2019). A representative CPT from pre-mapped locations is shown to provide details on the hard bearing layer with depth, as well as the hard bearing layer itself.

Table 1, Fig. 3 and Fig. 4 illustrate the research location for interpreting the bearing capacity of the soil layer. Additionally, the coordinates of the study area and the depth of the CPT data are shown in Table 1. In general, CPT indicates that the hard layer is located between 5-8 meters beneath the ground surface which is quite corelated with result obtained by (Zikrilah et al., 2016).

However, in sites D, E, and M, the soil was evaluated to a depth greater than 18 meters below the ground surface, as illustrated in sections I-I Fig. 5 and Fig. 6. As illustrated in Fig. 5, the hard soil layer is approximately 18 meters underneath the ground surface. Figs. 7 and 8 depict additional soil layer sections based on the information in Fig. 6.

Two important observations can be drawn from the profile: first, the developed profile is composed of layers with a minimum thickness of 3-5m, and second, layers related to the hard bearing strata region were further categorized for the purpose of design (Xu et al., 2020). In this way, a more coherent profile can be generated, and descriptors of the in-situ conditions can be separated into intrinsic and state variable-based classifiers of the in-situ conditions (Harbowo and Zahra, 2021). In accordance with the profile shown in Figs. 5 and 6, the soil profile at the site is primarily composed of medium and hard soils.

Hard soil stratum appearance is determined by this finding, which serves as the initial indicator for preliminary design consideration. However, more specialized detail geotechnical study methods for each specific site for construction are required to demonstrate the occurrence of the soil profile. By performing each specific site study, more detail geotechnical parameter will be defined.

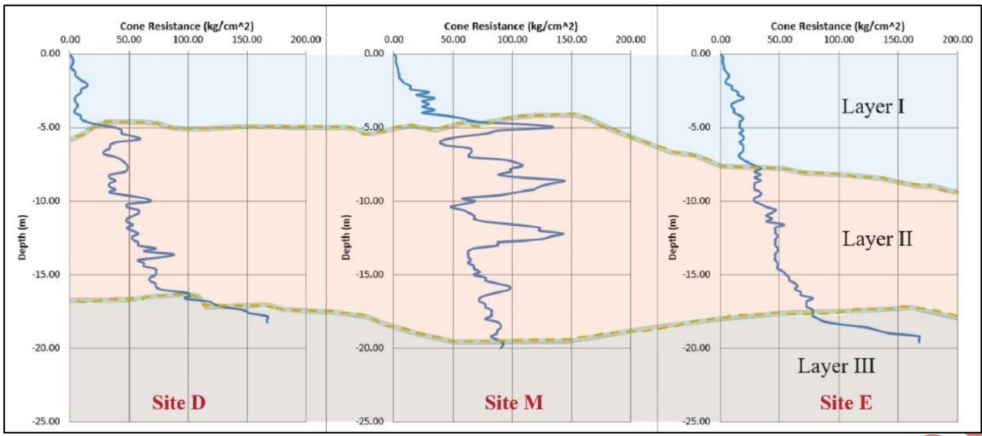

Fig. 5. Soil profile interpretation from CPT data of site D, M, E

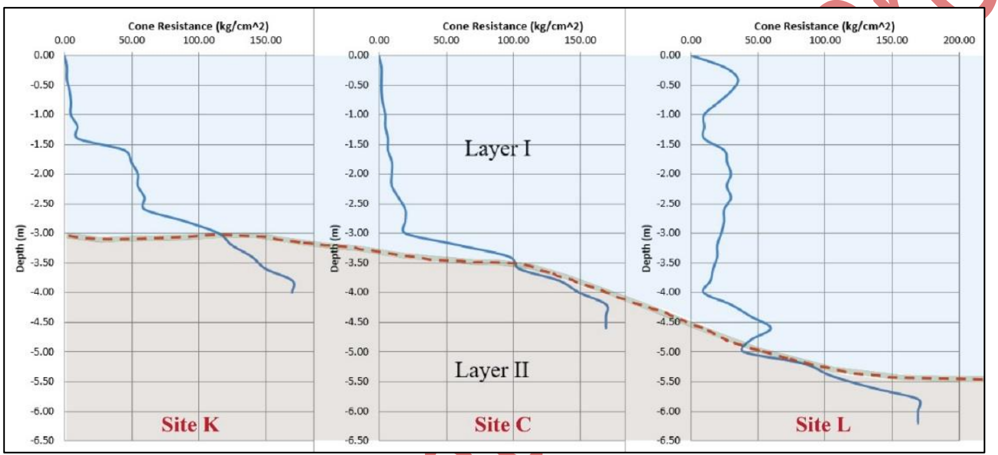

Fig. 6. Soil profile interpretation from CPT data of site K, C, L

4. Conclusion

Approaches for generating stratigraphic soil profiles using CPT data are discussed in this article. To begin, a baseline soil profile is created by plotting the qc – friction ratio pairings on a specified SBT chart. After generating an initial soil profile, several ways are used to re-examine the soil profile after it has been identified initially: (1) the SBT band method, (2) the soil group method, and (3) the mean qc method. Several conclusions may be derived from the results of the analysis and discussion that have been stated earlier. For example, it is known from this study that the average depth of the hard layer in Kuta Alam District is between 5-8 meters below the ground surface on average. However, there are some sites where the hard soil layer can be found at a depth of more than 18 meters. In addition, soil parameters must be examined to gain a better understanding of the soil conditions in Banda Aceh, Indonesia.

In order to determine the preliminary soil profile condition in Banda Aceh prior to conducting additional soil research for construction design requirements, the findings are intended to represent a starting point for further soil investigation. The approach provided in this research is initial and might be used to assess the stratigraphic profile of a site during post-processing of CPT data. Additionally, the proposed techniques can be employed in conjunction with evaluations of soil geographic variability to aid in the selection of resistance elements for design applications. Moreover, future research is required to improve the interpretation of the geotechnical soil parameter.

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