Geotechnical Site Investigations

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1. Introduction

In 2004, the building pit of a metro tunnel under construction collapsed in Singapore resulting in the death of four people (Van Baars, 2011). This could have been avoided had they acted upon the warnings given to them regarding the design of the building pit (Van Baars, 2011) as there were multiple inconsistencies between design criteria and codes (Endicott, 2015). It was constructed on a reclaimed land which consisted of soft marine clay 30 meters deep, nine levels of struts were placed 30 meters deep which resulted in base failure (Endicott, 2015). Site investigations are the basis of constructing foundations for structures, by obtaining information about subsurface conditions at the site of the proposed construction (Arora, 2004). Site investigations are imperative for any construction, and are an essential step for having a productive, efficient and safe construction environment (Alsaggaf, 2020). Specifically referred to as 'geotechnical site investigations', it is defined as the study of the physical properties of soil and rock to evaluate and identify potential construction problems. This literature review explores the significance of performing a site investigation and discusses the different stages involved. It also considers the methods of exploration for collecting soil samples and summarizes the contents of a sub-soil investigation report.

2. Purpose of a Site Investigation

In the engineering realm, data and statistics are required to create layouts and designs that satisfy guidelines to ensure all infrastructure design and work is kept consistent. Specific to the field of geotechnical engineering, the predominant method of data collection is through site investigations.. According to Goldsworthy, 2006, a geotechnical engineer is defined as the engineer responsible for carrying out the geotechnical site investigation and deals with materials that have generally been provided by nature.

The primary purpose of a site investigation is to evaluate and identify potential problems and hence prevent possible failures. A site investigation investigates the suitable construction techniques required, ascertaining the suitability and bearing capacity of the soil (Arora, 2004) to determine the appropriateness of the site. Through this process, key information such as the physical and mechanical properties of the rock and soil at the site will be reviewed. A geotechnical engineer must have utmost precision when executing such a key task, as soils and rocks are complex engineering materials with properties and parameters that are commonly not unique or constant (Agaiby &

Ahmed, 2016). Another imperative task following site investigations is ground improvement. Ground improvement methods are those which can improve the characteristics of the land such as an increase in bearing capacity, reduction in permeability, reduction of swelling and cracking of soils and much more (Patel, 2019). All the characteristics of the layers of land must be taken into account in order to successfully complete a site investigation and provide an accurate proposal.

3. Stages of a Site Investigation

Conducting a thorough site investigation requires precision and meticulous detail. The different stages involved in a geotechnical site investigation are enlisted below and is summarized in Figure 1.

- reconnaissance (preparatory phase) (Mishra, 2019)
- preliminary site investigation (Arenson, 2020)
- detailed site investigation (contingent on preliminary investigation)
- site investigation report and recommendations (Arenson, 2020)

The foremost task in executing a site investigation is the reconnaissance or preparatory phase where the initial information of the site is collected. This includes collecting surface conditions and climate conditions, which provide critical information useful in the preliminary site investigation. This initial information can be collected either physically at the site or remotely through public records. Subsequently the available information is assembled to characterize the conditions at the site and guide the development of further stages in the investigation (Arenson, 2020). Preliminary investigations (Stage 2) consist of desktop study, which provide concrete data. In this stage, the physical properties of the site such as nearby structures, seismicity and surface and groundwater hydrology are collected (Arenson, 2020). These properties can be collected in the form of borings or test pits and are useful in determining the depth, thickness and composition of the soil stratum at the site (Arora, 2004). Proceeding the preliminary investigation, a detailed site investigation (Stage 3) will occur contingent on whether the findings of the preliminary investigation are insufficient or not. Most major projects will require a secondary investigation, which includes lab testing of soil and rock. Field tests will be conducted to extract the properties of the soil in the natural state (Arora, 2004).

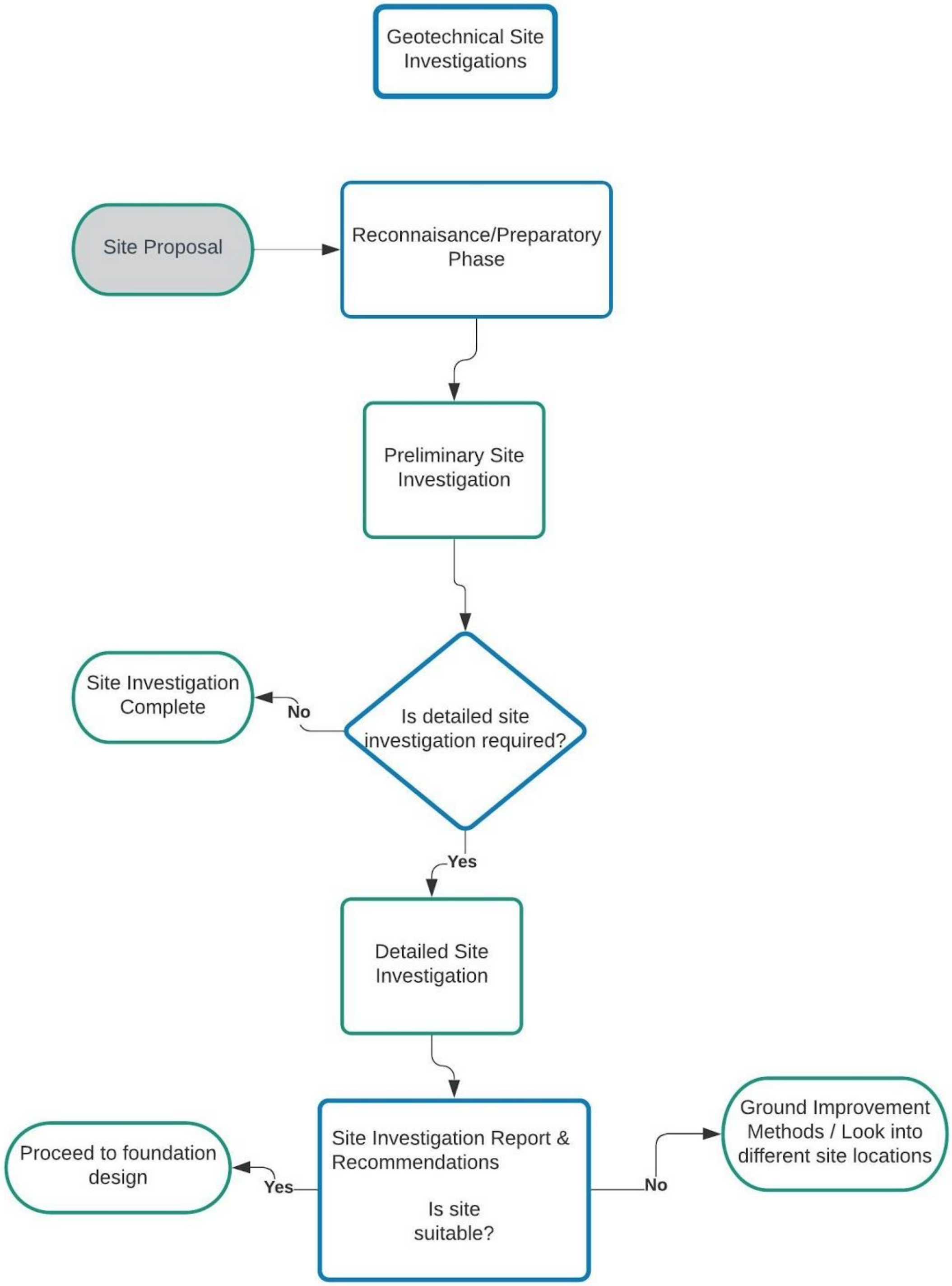

Figure 3 (Adapted from Arenson, 2020)

Following the detailed investigation, a site investigation report will be prepared (stage 4) by including all data received as a part of the investigation along with a risk assessment of the site. A structure should not be planned in isolation of its surroundings. Hence, the risk assessment includes the surrounding environment of the proposed site as it is vital for any construction.(Alsaggaf, 2020). On completion of the major stages, further recommendations for ground improvement, foundation recommendations and suitability of the site will be discussed (Arenson, 2020).

4. Methods of Site Investigation

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a. Borings for exploration

There are multiple ways to conduct a site investigation, the primary method of preliminary site investigations is in the form of borings or test pits (Arora, 2004). Borings include soil and rock pits to understand the ground profile as well as groundwater conditions of a site (Patel, 2019) This method is more suitable for site investigations as they can be taken to greater depths and are used to inspect the subsurface strata. The most common methods of boring are auger boring, wash boring, percussion drilling and rotary core drilling (Mishra, 2019). Auger boring consists of helical screws, which are drilled into the ground through rotation. However, this method is labour intensive and has a depth limitation compared to wash boring (Patel, 2019). Wash boring consists of a drill rod rotated downwards whereby the soil particles are loosened using a pressurized water jet at the bottom of the drill rod. Percussion drilling is used for making holes in rocks, boulders and other hard strata (Arora, 2004). It involves the lifting and dropping of a heavy cutting or hammering bit attached to a rope or cable and lowered into an open hole (Patel, 2019). Rotary core-drilling provides good-quality samples when used with soft rock (Patel, 2019) and is efficient as the core is retained within the core barrel (Mishra, 2019).

b. In-situ tests

The Standard Penetration Test (SPT) is the most commonly used in-situ test for determining the strength of soil samples. SPT is conducted within boreholes, holes are drilled to a desired depth and a mass is dropped with a standard falling height. Cone Penetration Test (CPT) is another method to characterize the strength and compressibility of the soil (Arora, 2004), it tests the in situ resistance to soil penetration. (Patel, 2019). CPT tests measure the in situ resistance of the soils to penetration, in this procedure a hammer is dropped from a certain height at a controlled rate and data is recorded at periodic intervals (Patel, 2019). The cone penetrometer is equipped with a sensor at the tip which records the penetration resistance.

Vane shear test and plate load tests are conducted during detailed site investigations where excavated soil & rock undergoes lab testing to observe the properties and the bearing capacity of the land. Vane shear tests are used to test the shear strength of mainly clay soils, by using a rod with four radial vanes at the end (Patel, 2019). This test can be conducted in situ and even in a lab on a smaller scale. The vane shear is thrust into the ground till the test depth in a single movement, then is rotated to determine the shear strength through the rod to resistance measurement (Patel, 2019). Plate load tests are designed to measure load carrying capacity and to which extent the soil undergoes settlement under a given load (Patel, 2019). All the collected samples from the detailed site investigation will undergo lab testing and are then classified and characterized (Mishra, 2019).

5. Subsoil Investigation Report

Preparing a sub-soil investigation report is an important step in a geotechnical site investigation. These reports are a way of communicating the in situ testing and laboratory test findings of the investigation with planners, architects and various technical personnel (Patel, 2019). Subsequently, the report must be certified by the geotechnical engineer ensuring that the report is explicit and precise, any clarifications and enquiries regarding the report will be dealt with by the responsible engineer. The different components of a sub-soil investigation are enlisted below :

- project overview (Menon, 2018)
- summary of subsurface investigation & laboratory/field results (Patel, 2019) (Menon, 2018)
- interpretation & analysis of data (Patel, 2019)
- recommendations & conclusions

The project overview and scope entail the background of the project, description of the site and the methods and equipment used for the investigation (Patel, 2019). Proceeding the project overview, a detailed description of the borings, groundwater table conditions and soil stratification is included in the report. Results from borings include the number, depth and type of borings and provide a thorough understanding of the site (Menon, 2018). Laboratory results provide quantitative data regarding the index properties of the soil, shear strength and bearing capacity, (Mishra, 2019). The data collected will be analyzed, and methods and formulae used to draw conclusions regarding the subsurface data will be explored (Patel, 2019). All major geotechnical issues extracted from the site investigation data will be reviewed and discussed for potential alternatives (Patel, 2019). Site-specific features and nearby infrastructure are also reviewed to ensure there are no discrepancies and site suitability (Arenson, 2020). Recommendation regarding the ground and site improvement, building foundation and any special construction procedures are proposed (Menon, 2018). Limitations are also discussed based on the overall investigation and conclusions are drawn. Graphical presentations may also be attached to the report to provide a visual analysis, and it includes a site location map, layout map of the trial pits and boreholes (Patel, 2019), boring logs, certified laboratory test results (Menon, 2018).

6. Conclusion & Acknowledgements

This report is aimed towards exploring geotechnical site investigations and the methods through which they are conducted. Site investigations are often a fraction of the total project cost, thus worth the investment. A site investigation is extremely thorough, therefore it includes multiple methods of testing and site assessments. Methods discussed in this report are the principal techniques used when conducting a site investigation, although there are various other methods of site investigation which are niche to specific properties of the strata. The subsoil investigation report integrates all results and findings providing an in-depth explanation reviewing the site investigation. It is important to recognize the limitations within this research as strata varies from site to site. Performing a geotechnical site investigation greatly reduces the chance of an engineering failure but doesn’t completely avert it.

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