"Doing the Wrong Things Right" Site Investigations in Soft Soil

M. H. Jamilus[1], A.J.M.S. Lim[2], A T S Azhar[3] and M A M Azmi[4]
[1]KLIA Premier Holdings Sdn. Bhd., Wisma KLIA Holding
[2,3,4]Research Center for Soft Soil (RECESS), Universiti Tun Hussein Onn Malaysia, 86400, Parit Raja, Batu Pahat. Johor

E-mail: saifulaz@uthm.edu.my

Abstract. Site investigation is a very important process by which geotechnical, geological and other relevant information which might affect the construction or performance of a civil engineering or building project is acquired. However, common practice in site investigations is not always in accordance to the standard that has been defined. Reliability on the information obtained depends upon several factors that involves correct procedures and competent workers and also supervision. Several examples on site investigation methods are discussed in this paper. Explanation on the difference between the site investigation methods used for real practices in the field and how it should be done are discussed in detail. Therefore, it is hoped that site investigation should always be uniquely planned and should be an interactive and flexible process of discovery and changes according to the condition of the soil.

Keywords: Sampling, Boring, Undisturbed samples, Soft soil

1. Introduction

Site investigation should be an integral part of the construction process. Unfortunately it is often seen as a necessary nuisance, a process which must be gone through by a designer if he or she is to avoid being thought incompetent [1]. Site investigation should be a carefully considered process of scientific discovery, tailored both to the conditions existing on site and to the form of construction which is expected to take place. Every civil engineering project has one simple requirement, that is to build it right the first time and there are no second chances in making it right then. In today's engineering technology, advanced design software and computers were used in the design of foundations and structures. However, if the basic design procedure is incorrect then vast problems in the construction of structures could occur. The available existing information and resources to carry out the desk study for site investigation are usually very limited in Malaysia [2]. The ground is a vital element of all structure which rest on the ground. There is no other element of a structure about which less is known, but the properties and behaviour of the ground must be known to achieve a safe and economical structure [3].

In geotechnical engineering, the basic knowledge that is required for any design purpose is actually the reliability of ground information obtained from site investigations. The reliability of this information is depended upon several factors as stated as follows:

[1] KLIA Premier Holdings Sdn. Bhd., Wisma KLIA Holding.
[2] Research Center for Soft Soil, Universiti Tun Hussein Onn Malaysia, 86400 Batu Pahat Johor, Malaysia

i. Using proper equipment and ancillary
ii. Competent operator
iii. Adherence to procedures
iv. Competent supervision
v. Intelligent observations
vi. Factual reporting

2. Undertaking Site Investigation

In geotechnical engineering, almost all site investigation operations involve boring or drilling and sampling or testing supplemented by different testing methods such as non-destructive test where necessary. All soil sampling/testing are remotely carried out at some distance below the ground, working from above the ground. Therefore, the prime requirement of any boring and sampling in subsoils is by taking a small volume of the subsoil that needs to be tested where it is imperative that the sample must not be changed or altered before testing is done. All of this process is done where the prime purpose of it is to get a reasonable picture of the sub-soils below the ground surface. With site investigations, the information on the properties and characteristics of the soil for each strata can be obtained [3]. Examples of these important information are the thickness and orientation of the soil, the material constituents, chemical constituents and the strength of the soil (Figure 1).

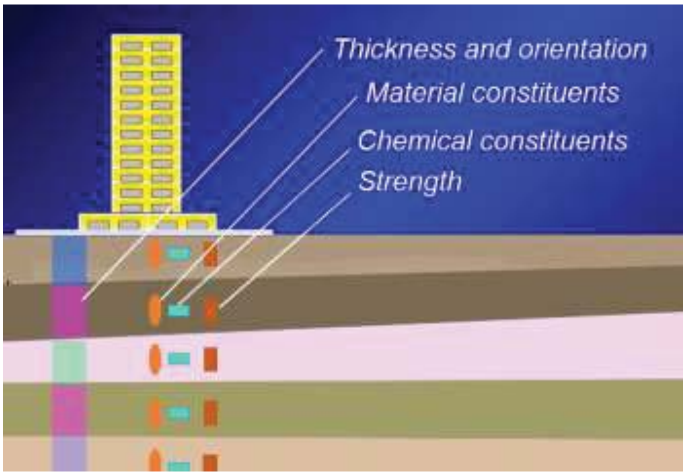


Figure 1 Investigation on each location of the soil strata

3. Boring Methods and Standard Penetration Test

To obtain all of the site investigation information, firstly an engineer must carefully observe and make notes of everything that he/she sees and needs to be done during site investigation operations [4]. Site investigation that involves drilling or boring methods as shown in Figure 2 (a) is a careful and delicate work. As the drilling progresses, the cutting bit dislodges the soil below ground where it is brought up by water. An engineer needs to keep a careful eye on the returning water from the borehole (Figure 2(b)). As the dislodged soil is brought up, the returning slurry soil on the surface can give estimation on the changes in the strata by just observing the changes in the colour of the water and the type of cut material that comes with it. With this, vital information on where the change in strata is and where a sample or a test should be carried out. Once it is bored to the test depth, the drills rods can be taken out and the depth is measured with a measuring tape and compared with the bore depth.

Standard penetration test (SPT) then can be done at the predetermined depth in the borehole. The blow counts from SPT which is the N values are the results that are used to calculate the capacities of various foundation elements like piles in sandy sub-soils. The SPT is an empirical test where there is no basis for it and because of this, engineer has to be careful when doing SPT. Any variation in the procedure will affect the usability of the data. For example, variation in the drop, wobbles in the rods, the angle of drop, tightening of rods, state of the SPT spoon may all affect the usability of the data.

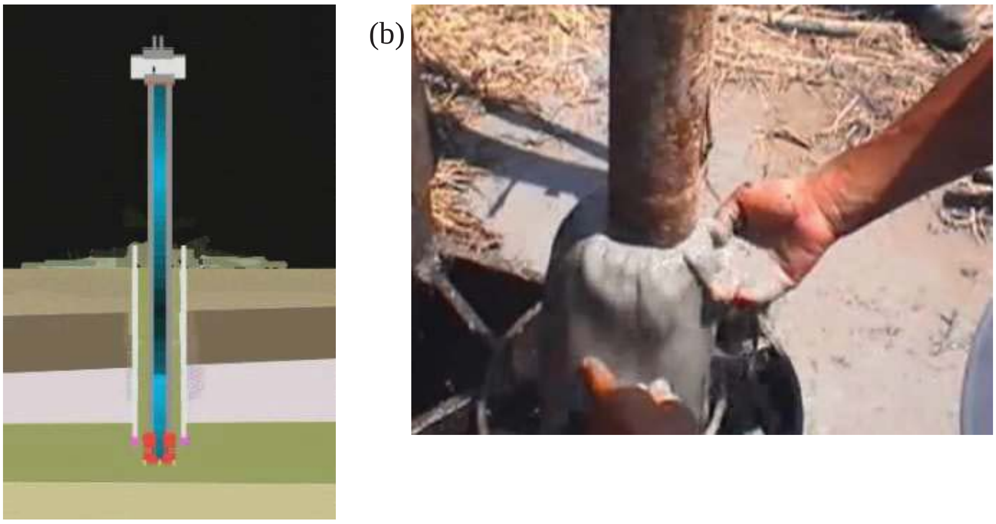
(a) (b)


Figure 2 (a) Drilling methods (b) the returning water from the borehole

4. Undisturbed Samples and Laboratory Test

Though SPT is most common, SPT is actually not suitable for soft soils. Sample obtained from the SPT tube can be tested for soil constituent and will help refine the N values for design purposes. This can be done by doing various laboratory tests on undisturbed soils samples. Therefore, it is important that the sampling must be carefully done especially on soft soils to obtain representative samples that are very close to the condition on the field [5]. To do this, there are number of ways of doing this depending upon the type of soils.

One of the prime examples of obtaining a good undisturbed representative soil sample is the stationary piston sampler (Figure 3). The procedure follows by inserting a tube with a piston acting as a plug. The piston is hold in place and the tube is pushed into the soft soil in one continuous stroke. This creates enough vacuum to hold the sample and cause very little disturbance to the sample. Then the sample is carefully extracted and sealed which is then to be transported to the laboratory for further testing to obtain suitable design parameters.

The undisturbed samples should give reliable results on the properties of the soft soils assuming that the samples come from uniform strata. However, soils may have discontinuities which may require test results to be modified or require more testing to be sure. These discontinuities are not easy to observe, where some examples are shown in Figures 4 and 5 to show the discontinuities in the soil after it has been tested in the laboratory.

The Figure 4 shows undisturbed samples that has been cut open straight after suitable testing was done. When allowed to dry, the clay portion will shrink exposing discontinuities like partings filled with fine sands and sand lenses as shown in Figure 5. Such discontinuities act as additional water paths and if it’s not taken into account in the design of settlement calculations, it can cause huge problems when constructing structures. The Figure 6 shows an undisturbed sample taken from a borehole where when extruded and was allowed to dry, it shows up all the discontinuities of the soil strata. The test results obtained from laboratory testing are not enough to be used for design considerations. The results from soil testing that should be used in the design calculations must also take the discontinuities into account [6].

IOP Conf. Series: Materials Science and Engineering **160** (2016) 012079 doi:10.1088/1757-899X/160/1/012079

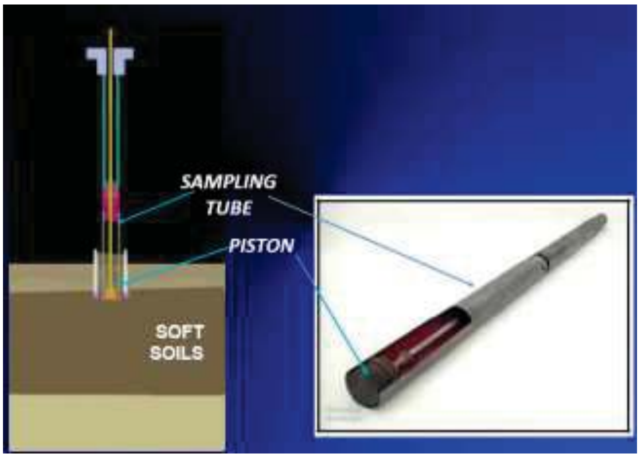


Figure 3 Stationary piston sampler

Figure 4 Undisturbed samples cut open after testing

Figure 5 Clay portion will shrink exposing discontinuities

Figure 6 Undisturbed samples taken from a borehole

Consolidation test done on undisturbed sample is usually carried out on the clay portion of the sample. If the results are blindly used in the design calculations, disaster can happen due to the natural water paths that are already there. Hence, this might cause the settlement to take place much faster and the installation of vertical drains will be far too uneconomical. If these discontinuities were not taken into account, settlements that may have taken years to take place may occur within a few months if additional loads from structures are built on the surface of the ground [7].

5. The Correct and Wrong Procedures

Errors in judgement cause a lot problem where the site investigation data is badly obtained at the preliminary stage. In rotary drilling, the right practice is supposed to be where the hole is advance by a cutting tool at the end of the rod string and casing [8]. The water then brings up the cutting to the top as shown in Figure 7(a). Meanwhile, in practice the hole is advance by a rotating and surging using water jetting (Figure 7(b)).

(a)

(b)

Figure 7 (a) Water then brings up the cutting to the top, (b) Water jetting where the hole is advanced by a rotating and surging action

With rotary boring, the advancing hole is done by the cutting action of the drill bit with water bringing up the cutting inside the casing as shown in Figure 8(a). However, water jetting advances the hole in the ground by brute force of water with the cutting coming outside of the casing as what it is appears to show in Figure 8(b). The use of rotary boring leaves the test volume intact and reliable where sampling or testing is possible. Water jetting however, alters the test volume where sampling or testing that needs to be done is not possible. It is also possible to identify the strata of the soil as compared to the water jetting technique where it disrupts the original condition of the soil. The Table 1 shows the difference between the advantages and disadvantages of rotary boring and water jetting.

IOP Conf. Series: Materials Science and Engineering **160** (2016) 012079 doi:10.1088/1757-899X/160/1/012079

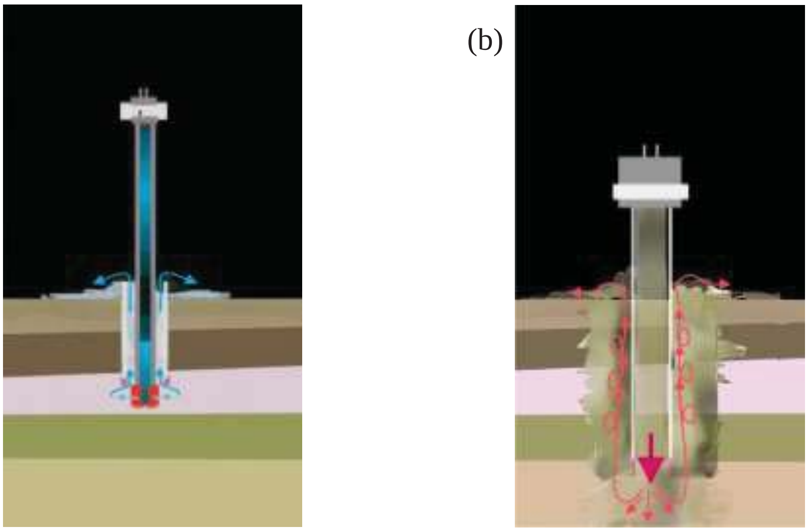


Figure 8 (a) Cutting action of the drill bit with water (b) water jetting advances the hole in the ground by brute force

Table 1 The difference between the advantages and disadvantages of rotary boring and water jetting

	Rotary boring	Water jetting
Advantages	- Can identify strata changes. - High quality sampling/testing. - Negligible disturbance to sub soils.	- Good for rock coring, fast rock verification. - Cheap and Fast.
Disadvantages	- Rods, casing, bits must be compatible. - Little or no ingress of water in sub soils. - High capital costs machine and ancillary.	- Hole advanced mainly by brute force of high water pressure - High ingress of water into soils below. - Not good for sampling or testing.
Skill	- Require training and skills.	- Not required.
Usage	- Extensively used in US. Australia and Hong Kong and world over but rapidly being replace by hollow machine auger.	- Not an acceptable method anywhere for sampling or testing.

6. Case Study for a Linear Project

For a linear project such as for rails and roadways, it is required to remove top soils to some depth and replace it with a selected more compacted soils [9]. Assuming that the criteria for removal and replacement is when the in situ soils have a SPT, N value of N=5. For example of the case where the site investigation is properly carried out, the ground may have a SPT value of 5. Removal and replacement will apply to all material above the green line as shown in Figure 9. However, when the site investigation is badly carried out such as using water jetting, there will be lots of loosening of soils below and will alter the condition of the soil [10]. With that the N value may decrease or maintain the same value of 5 with an increase in depth as shown by the black line in Figure 9. This will result in an additional amount of soil to be removed for replacement as shown by the white line in Figure 10. Because of this, there will be an additional cost for the work done and it will be a waste of money [11].

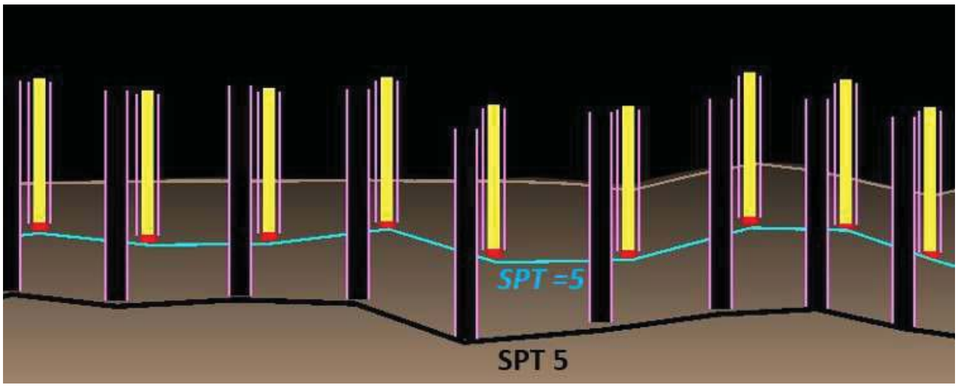


Figure 9 The roadway construction removal and replacement of the soil will apply to all material above the SPT = 5 green line

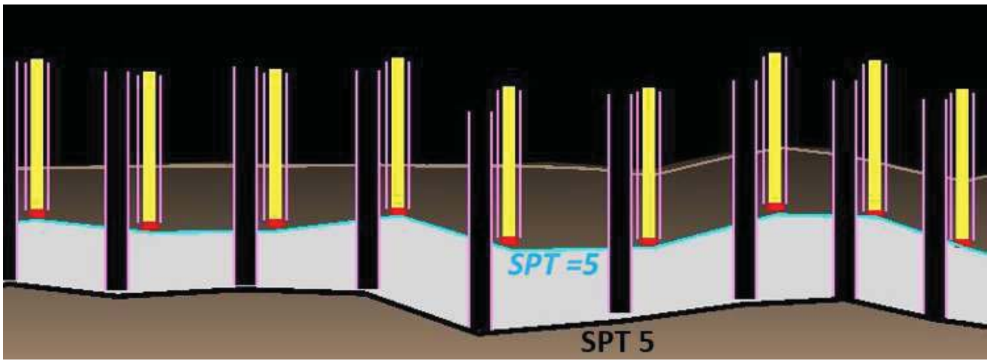


Figure 10 Due to bad site investigation techniques additional amount of soil to be removed for replacement as shown by the white line where the SPT still reads N = 9

Conclusion

As a conclusion, site investigation is a very important process that should not be left out in any civil engineering construction. It is recommended that site investigations must be uniquely planned for site and the job that needs to be undertaken by the engineer. Site investigation must also be supervised under a Geotechnical Advisor. It is also very important that to avoid any unwanted wrong-doings, site investigation must only be awarded to a competent contractor. Most importantly, site investigation must be interactive and a flexible process of discovery and changes. These conditions and recommendation are required by almost all regularity bodies for engineers.

Acknowledgement

The authors would like to thank the Research Centre for Soft Soil, Universiti Tun Hussein Onn Malaysia, and also the Ministry of Higher Education Malaysia, for their grant awarded to conduct this research through Exploratory Research Grant Scheme (ERGS) Vot. 040.

References

[1] Clayton C R, Matthews M C & Simons N E, 1995 Site Investigation. Wiley-Blackwell, 2 Edition.
[2] Liew S S, 2005 Common Problems of Site Investigation Works in a Linear Infrastructure Project. IEM-MSIA Seminar on Site Investigation Practice.

[3] Telford T, 1993 Without Site Investigation, Ground is a Hazard. Thomas Telford Services Ltd. London.
[4] Ali A W M, Sabarudin M , Mohd I M M , Saiful A A T , Ismail B , Adnan Z , Azrul Z K & Ling J H, 2016 Construction of Buildings on Peat: Case Studies and Lessons Learned, MATEC Web of Conferences, **47** 03013
[5] Ling J H, Sabarudin M , Saiful A A T , Syazie N A M, Ismail B, Mohd I M M, Adnan Z & Ali A W M, 2016 Construction of Infrastructure on Peat: Case Studies and Lessons Learned, MATEC Web of Conferences, **47** 03014
[6] D C Wijeyesekera, L M S Alvin John & Z Adnan, 2016 Embedded Empiricisms in Soft Soil Technology, IOP Conference Series: Materials Science and Engineering, **136**.
[7] Shawn C G, Brady R C & Ellen M. R, 2016 Challenges associated with site response analyses for soft soils subjected to high-intensity input ground motions, Soil Dynamics and Earthquake Engineering, **85** 1–10.
[8] M Saravanan & B N Ibrahim, 2016 Construction Shortfall and Forensic Investigation on Soft Ground, IOP Conf. Series: Materials Science and Engineering **136**.
[9] T Batey, 2009 Soil compaction and soil management – A Review, Soil Use and Management **25** 335–345.
[10] Raju V R, 2002 Vibra replacement for high earth embankments and bridge abutment slopes in Putrajaya, Malaysia International Conference on Ground Improvement Techniques, Malaysia 607-614.
[11] Hung N K & Phienwej N, 2016 Practice and experience in deep excavations in soft soil of Ho Chi Minh City, Vietnam KSCE J Civ Eng, **20** 2221.