SITE INVESTIGATION

PART 2

By Ir. Shaik Abdul Wahed, Director, Perunding GEA (M) Sdn Bhd

The basic premise in any sub-soil sampling or testing is simple. It assumes that the volume of subsoil about to be sampled or tested should not be altered or disturbed before we do our sampling or testing. We would call this a "prime requirement".

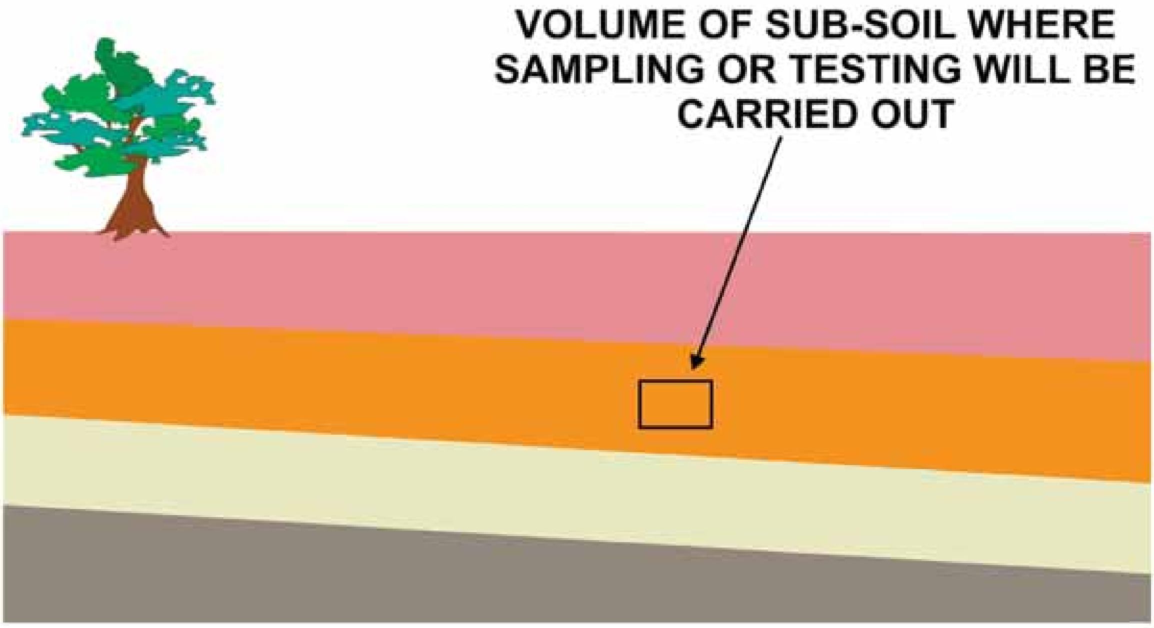


Figure1

The terms "sampling" and "testing" in this article are interchangeable.

Where this prime requirement is not met, sampling or testing in an altered sub-soil volume—whether 20% or 90% altered—has no meaning. Alternatively, it can be said that the test is carried out in sub-soil volume that is 80% or 10% undisturbed. That is also not quite right. Such figures tend to imply accuracy and give false confidence. When we think of it, there is no way we can tell what percentage of disturbance has occurred because we cannot actually see it happening or see the volume of sub-soil affected. Using again our medical analogy, this is like saying that a patient is 20% or 90% sick, which is ridiculous because if he is sick, he is sick. It would be difficult to console the person's family that he died of sickness between 20% to 90%.

Because site investigation (SI) has become a contracting exercise, we tend to forget that an SI is an INVESTIGATION. As in any investigation, it is an iterative process. For the information to be reliable, adherence to procedures is important. SI is the most procedure-oriented operation within the civil engineering discipline. This is more so because the sub-soils, having gone through millions of years of weathering/changes, are very variable. Property assessment of every sample or test carried out is affected by these variations and also by the process we use for sampling/testing. This includes equipment we use for sampling and testing, the test procedures we follow and the person carrying them out, all these add errors both related to equipment and humans, which we may refer to as "human error". We cannot completely eliminate human errors, but we can minimise them. When we stick to same equipment and procedures over number of sample/tests we can expect human error to remain nearly the same, hence variations in test results would be directly related to the sample properties. Where equipment and procedures are standardized, test results from one location to another, even world over become comparable. This is where procedures and standardization play their role in a big way. If we do not pay attention to this, the human errors become variable added to soil properties which are also variable we have such a mess we cannot compare soil properties on even on the same site.

This means that everything from methods used to equipment used, such as various sized rods and casings to almost every ancillary used in SI have to be standardized and are internationally standardized and have been provided with designations. Such standardization, which is the culmination of years of experience, is accepted and used worldwide. For example, if we ask for "N" sized rods, steel type to the diameters are already defined. Any ancillaries such as drag bits, drill bits, and samplers will operate inside the appropriate matching sized casing and should cut a hole of a diameter sufficient to allow the insertion of the next smaller designated casing if required. That is to say if an "N" size core barrel is run inside an "N" casing, it will cut a hole which will enable a "B" sized casing to be inserted into it. In effect, a B casing can be nested inside an "N" casing. This "nesting" feature is an important aspect of international standards. Nesting allows us to achieve great sampling depths for our sampling and testing. In addition, the standards show the minimum material strengths of the steels from which the equipment should be manufactured. Using standardized rods and casings also provide assurance that we can obtain and use ancillaries such as cutting bits (e.g., drag-bits, roller bits, and so on) by simply quoting the type of rods or casing. Therefore, to claim that Malaysian made rods, of size "N" are 'slightly' larger or smaller than imported N rods is not acceptable as this means that the whole purpose of compatibility is lost and subsequently we have to settle with 'make-dos' as we try to force use different sizes of ancillaries and make them fit through a host of ad-hoc adapters.

As far as procedures are concerned, they are provided for in Codes of Practice and Specifications or Terms of Reference (TOR) and also specified by each manufacturer for their specific instruments. The Codes of Practice provides good guidance whereas Specifications or TOR outlines specific requirements for given job. Adherence to these documents is necessary but such adherence alone without some training and skill will still produce SI data that is lacking.

If procedures are adhered to by following the manufacturer's manuals or Codes of Practice, we can standardize our SI information to be comparable with SI at any place in the country and even overseas. Codes of Practice not only advises on what to do or not to do but provides guidelines on almost all aspects of reliable data acquisition and even for uniform description of soil samples and how to describe them in such a way that just a description of a sample gives a very good idea of the soil sampled. We call this "sample logging". Add to this digital, high-quality, cheap photographs available to us today and our SI information could become a work of art, comparable, reliable and providing high degree of confidence. Needless to say, such quality of SI information requires training, knowledge of procedures and familiarity with guide documents such as TOR and Codes of Practice. Simply put, we need trained operators and supervisors.

In Malaysia, we have followed the British Codes of Practice for SI work, BS5930, and the JKR Terms of Reference (TOR) for SI, and almost all practicing engineers are familiar with them. The Malaysian Codes of Practice for SI, MS2038:2006, was developed about four years ago and is based mainly on British Codes of Practice BS5930 with some differences to suit local conditions. The JKR Terms of Reference, with which just about every engineer is familiar with, has not changed much over the last 25 years. Drilling and boring methods worldwide have not changed much either. However, the quality of SI information in our country has changed over last few decades from acceptable then to horrifying now. To understand this we compare our methods 30 or so years ago to the methods we use now against the requirements of the JKR Terms of Reference as about the easiest reference document we have.

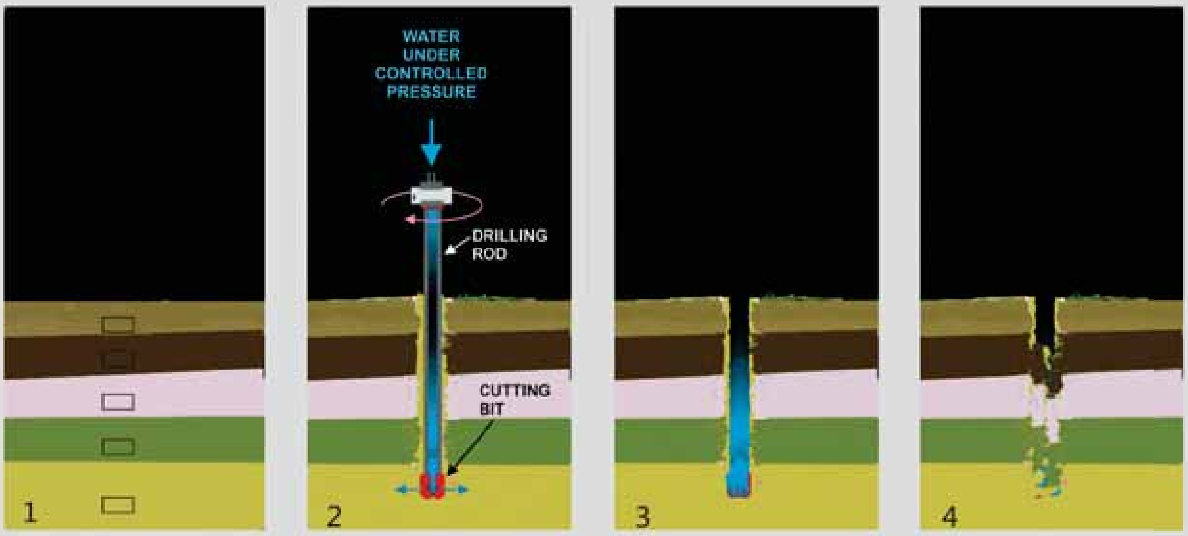
There are a number of methods for assessing sub-soil parameters depending on the project and type of expected sub-soils (as assessed from preliminary studies or desk study). Any method used must, of course, meet the prime requirement. Prime requirement, however, only ensures that sampling/testing is carried out on sub-soils in their natural state. It does not ensure that the sample/test is reliable. Reliability depends also on how we actually take the sample. For reliability we have to ensure that the sampling and testing is carried out in accordance with accepted procedures from the field to the end of testing in laboratory by operators who know what they are doing. When what we say here is followed, we can use the results obtained with confidence, that is to say, the information is reliable.

The method of getting ground information via boring/sampling is frequently used as it is closest to direct sampling as described in Part 1. It entails in–place testing and provides physical samples one can see and feel. It gives a better overall picture of sub-soils than any other method.

However, it is also the method most misunderstood and prone to abuse. (For the purpose of this article, boring is defined as the provision of hole in overburden soils and drilling applies to hard materials where coring has to be used.)

Again, we have a number of methods available to us for boring in soils, depending on the purpose for which we are boring/drilling. For sampling and testing we use a method known as "rotary boring", which is also used in other countries. However, the rotary boring that use in our country for almost all our sampling and testing in sub-soils is very different from that expected by JKR TOR or Codes. What we call rotary boring is also known locally as "Wash Boring", "Malaysian Style boring" and so

FIGURE 2: BORING IN SOIL



Slide 1: Let us assume that the ground below has variations similar to that shown in above figure and the sampling volumes are at locations represented by the black rectangles.

Slide 2: Boring in the soil below involves using a rod or number of rods attached together, which is referred to as the "drill string" with a "cutting bit" attached to the bottom. When the drill string is rotated pushed downwards under controlled downward thrust, the cutting bit dislodges soil particles or grinds them as it goes down. This dislodged material is referred to as the" cutting". Water is pumped through the rod and discharged sideways from the cutting bit below, and dislodged soil particles are brought to the surface by water. Water must be under controlled pressure and has to be discharged sideways from the drill bit to avoid disturbance to soils below the cutting bit. Water returning to surface carrying cuttings from below is referred to as the "return water". The function of water (or any drilling fluid) is to "lubricate" the cutting bit and bring the cuttings up.

Slide 3: Once the required depth is reached, the drill rod is pulled out, the test/sampling assembly is inserted into the hole and the required testing/ sampling is carried out.

Slide 4: Holes with only water in them are not stable, and will usually collapse, blocking access to the sampling volume below. To prevent this from happening, casings are used, and such borehole is referred to as a "cased hole". Chemicals such as drilling mud (bentonite) or foam can be used to keep the hole open, and this method may be referred to as an "open hole". However, open hole boring requires considerable skill and care. Open holes, when properly carried out meet the requirement of the JKR TOR 2.2, which mandates that the portion of the soil to be sampled is not unduly disturbed.

on with quality of SI information varying from acceptable to rubbish, mostly rubbish.

To understand this, let us look at rotary boring and boring variations we use today and their compliance with the base document, JKR TOR, particularly Clause 2.2 of the JKR TOR.

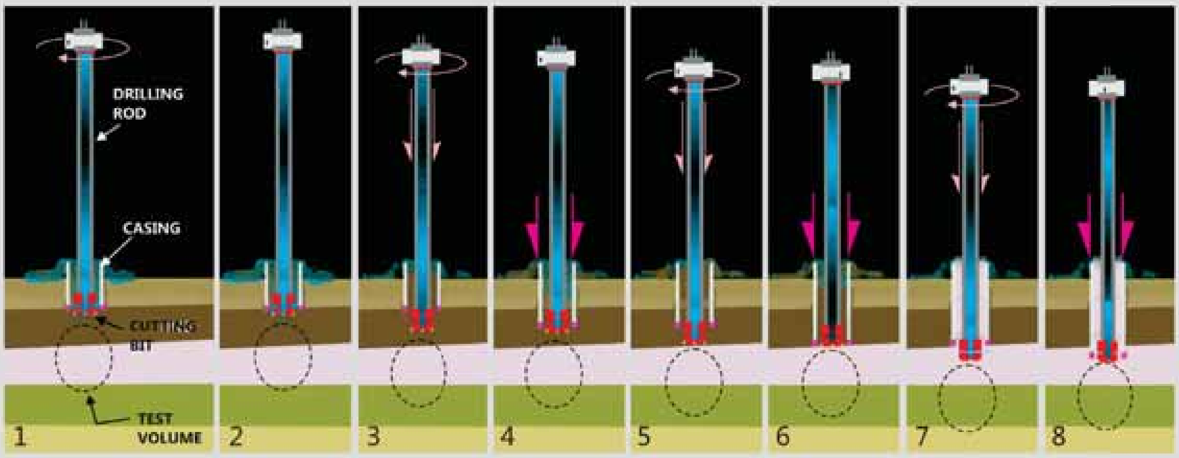
"2.2 Method of Advancing Boreholes
The method used shall be such that an accurate and continuous observation of the soils encountered is possible throughout the process. No mingling of soils from different levels shall be allowed to occur. When an undisturbed sample is to be taken, a reasonably clean hole shall be provided and the portion of soil to be sampled is not unduly disturbed".

In rotary boring the casings are driven (hammer tapped) or rotated down, depth will be reached when friction along the outside of casing is so much that the casing cannot be driven or rotated down anymore. In this case we can insert a smaller sized casing inside the 'stuck' casing and continue by using smaller rods and samplers. Or we can drive a larger casing outside the 'stuck' casing to some depth, thus reducing frictional resistance on the stuck casing (also referred to as 'releasing' the casing). Once 'unstuck', we can continue boring as before. Casings inside another are referred to as nested casings.

Rotary boring allows for good samples to be taken and for reliable in-situ (on site) tests to be carried out as there is no mingling of soils from different layers and the volume to be tested remains intact. Today many of us believe that the boring methods we use is as shown in Figure 3 and that we are getting reliable information. This is far from the truth. What we may be getting is very different and hardly in compliance with either JKR TOR, the Codes of Practice BS5930 or MS2038:2006.

In our country since about 1985, we have progressed backwards to methods variously referred to today as "Rotary Wash Boring", "Rotary Boring" and "Malaysian Style Boring", implying that we are using the proper boring method as described in Figure 3. As stated above, this is not correct. Method for boring in

FIGURE 3: ROTARY BORING IN SOIL USING CASING



Slide 1: Boring assembly is the same as in Figure 2, except that a suitable casing is added to prevent the sides of the hole from collapsing.

Slide 3: The drill string is rotated under hydraulic thrust and with water under controlled pressure to a short distance below the casing.

Slide 4: Casing is then either driven or pushed to follow to the cutting bit position.

Slide 5: Drill string is rotated further down below the casing as described in Slide 3.

Slide 6: Drive/push the casing to follow the rod-cutting bit.

Slide 7: Repeat Slide 5.

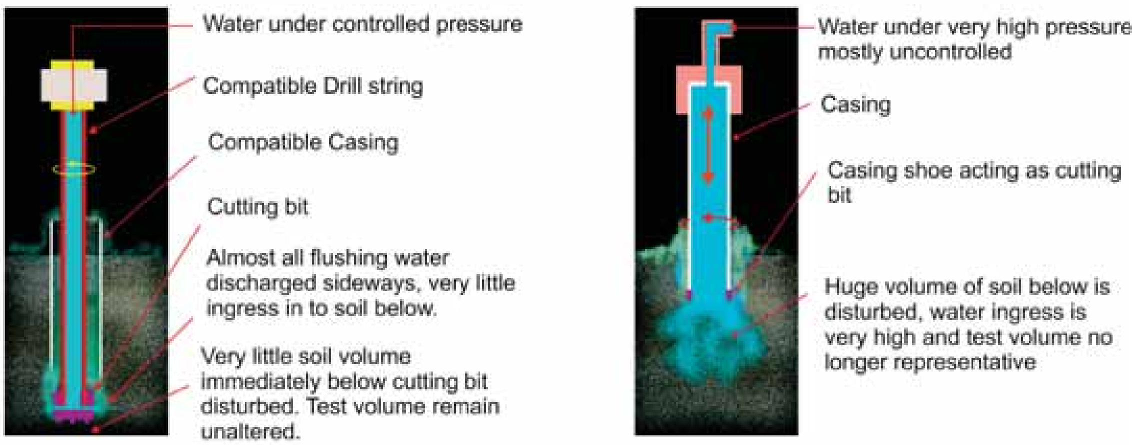
Slide 8: Repeat Slide 6. This way we can bore down to just about any depth we want in overburden soils and still ensure that the volume of sub-soil below the cutting bit remains unaltered. The same condition can still be met if we were to drive the casing ahead of the cutting bit and use the cutting bit to cut and wash the soil out from the inside of the casing. This method meets the JKR TOR requirement.

soil we have adopted is very different from the 'prescribed' method, and this adopted method has become the most used method in our country today. Method we use largely now is fast and cheap, but does not meet requirements of either JKR TOR or any other TOR. Method we largely use now does not assure the compliance with requirement that volume to be tested/ sampled will not be unduly disturbed.

The method we actually use is described in MS2038:2006 as waterjetting. Figure 4 gives some comparisons between rotary boring as we should be using and waterjetting, which we are actually using and think it is rotary boring.

Below we compare rotary boring and waterjetting.

FIGURE 4: COMPARING ROTARY BORING AND WATERJETTING



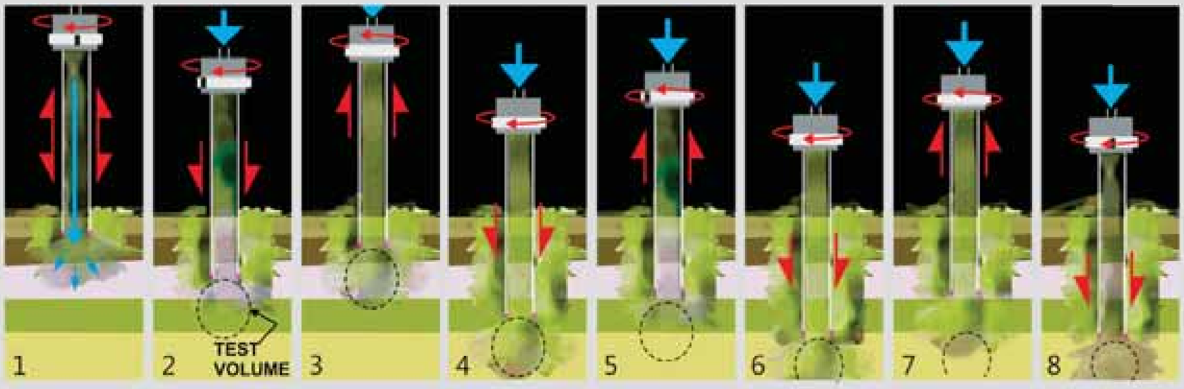
ROTARY BORING

The hole is advanced by rotation of a drill string under hydraulic thrust with drilling fluid under controlled pressure. A cutting bit attached to the bottom of the drill string dislodges soil particles, which are brought to the surface by the returning drilling fluid. Drilling fluid (usually CLEAN water) is discharged mainly sideways from the bottom of drill bit and brings up cuttings to surface. Almost all water returns to the surface. Rotary boring requires a combination of compatible drill string and casing string. *Cutting of the soil is done by the cutting bit, while the role of drilling fluid (water) is simply to transport cuttings to the surface inside of the casing. All water returns to surface INSIDE of the casing and does not mix with soils above making strata identification possible. Only a small amount of water escapes downwards.*

WATER JETTING

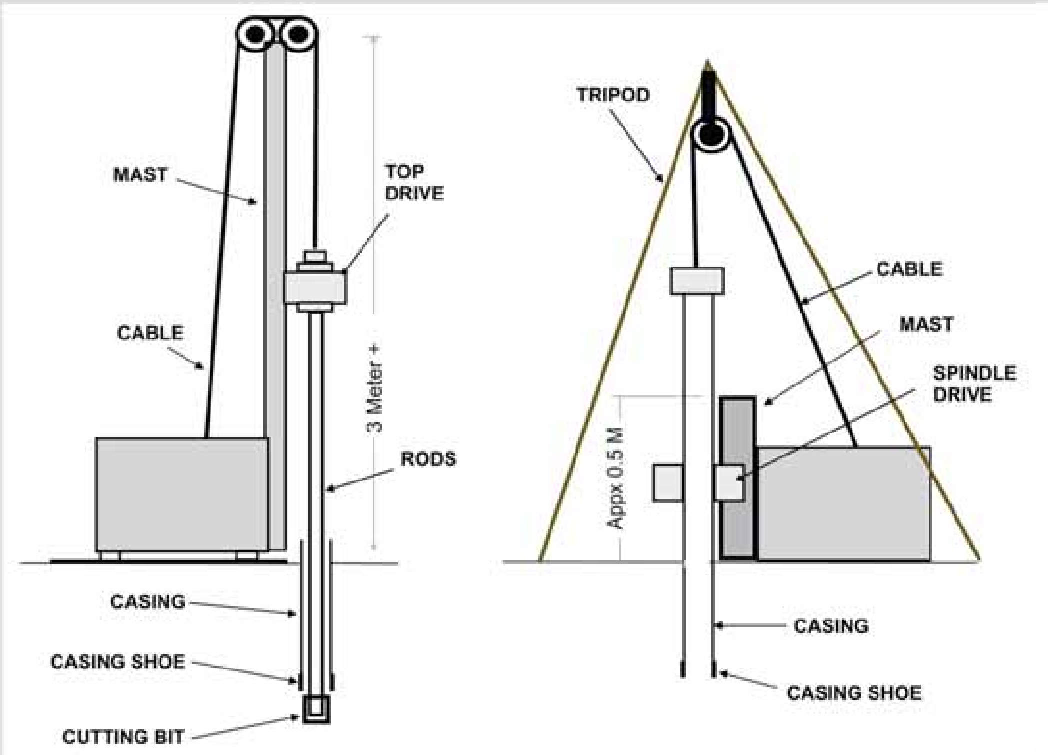
Hole is advanced by surging and rotating action of casing, plus eroding and destructive action of water under very high pressure. There is no drill string or cutting bit. Water ingress into soils below causes considerable disturbance to the volume of soil to be tested. Considerable volume of water is lost in sub-soils below. The test volume of soil below the casing is badly altered. *Cutting of soil is done by brute force of water under very high pressures – cuttings are also transported to surface OUTSIDE of the casing on the way mixing with soils above and making identification of strata changes difficult. Also a great volume of water is forced downwards into the soils below.*

FIGURE 5: BORING IN SOIL USING WATERJETTING



[Slide 2—Test volume]
Slides 1 to 8. The borehole is advanced using water under high pressure, with the casing rotating and surging upwards and downwards. Cutting, if any, is mostly done by the brute force of the water. Washed material is brought up to the surface by some of the water returning to the surface outside the casing. A lot of water, depending on the type of sub-soil below, is forced into the sub-soils below the casing and alters the test volume. Waterjetting does not meet the requirements of Clause 2.2 of the JKR TOR.

FIGURE 6 : BORING MACHINES AND ANCILLARIES



ROTARY BORING RIG (MACHINE)
Good hydraulic control. TOP driven. Long mast allows for handling long rods and stable sampling and testing.

WATER JETTING RIG (MACHINE)
Very short "mast", SIDE driven, uses tripod to handle rods, sampling and testing. Sampling and testing are not stable.

MACHINES AND ANCILLARIES

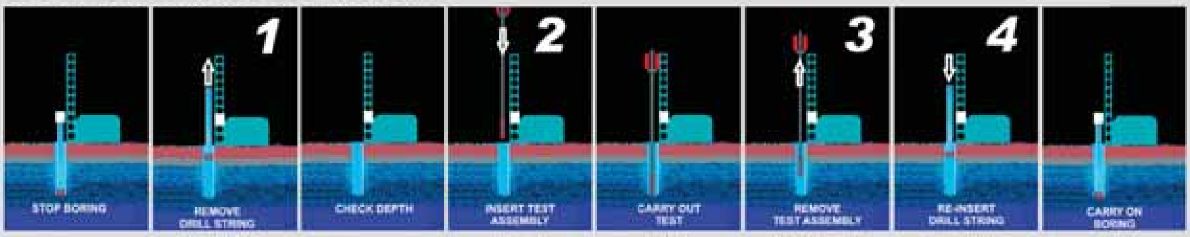
Rotary boring uses equipment that allows good control over the boring process and sampling/testing. There are numerous variations to the drilling machines (e.g., Drill rigs, or simply, the Rig) in size and capacity. From portable machines that can be carried manually to huge trailer mounted rigs, all of them can use standard ancillaries. As the drilling method is used world over, almost all ancillaries have been standardized and as such they are easily exchangeable. Even the rods and casings used are standardized by designations such as "A", "B", "N", "H" and further by Ax, Bx, Nx or Bw, Nw. To order ancillaries such as core-barrels and bits, we just specify the type designation and the supplier will know exactly what to provide. This way, we know that an N-size rod will reliably operate inside an "N" casing, and an "N" casing will fit inside an "H" casing. This allows us to have a casing inside a casing inside a casing (B inside N inside H) and enable us to carry out drilling, sampling or testing with confidence at very large depths. Long, stable masts also provide stability for test equipment such as SPT by stabilizing the vertical drop of the hammer and continuous thrust needed for undisturbed sampling.

Waterjetting for boring in soils as used locally uses machine not designed for boring where sampling and testing is required, but more for rock coring and has number of shortcomings. This rig is a 'make-do' substitute for rotary boring rig and standardization hardly applies and virtually anything goes. However, this does not mean waterjetting is totally bad. When properly used, it has its advantages such as quickly locating limestone in Krastic formation before rock coring. Waterjetting is not acceptable in overburden soils because this method disturbs the soil volume to be tested/sampled. Apart from the fact that soil volume is altered as a result of waterjetting, the testing/sampling itself is also not acceptable as the wobbling of test equipment cannot be controlled when hung from a tripod thus introducing yet more errors to sampling/testing.

OPERATIONS: ROTARY BORING AND WATER JETTING

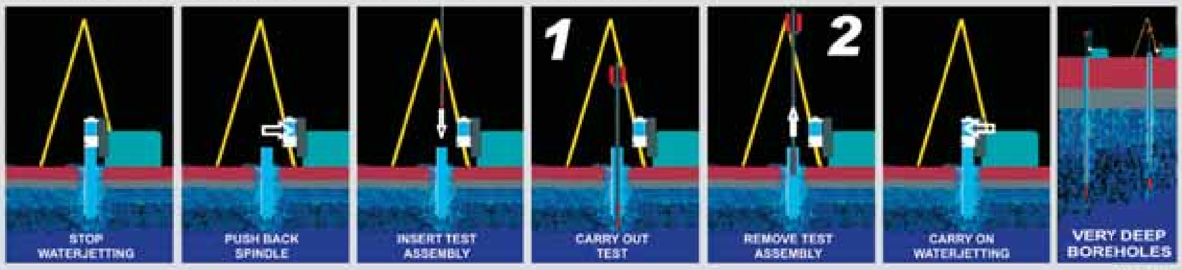
Rotary boring seems slow and much more expensive because it uses four distinct operations per testing/sampling as against water jetting which uses only two operations. This is explained in figures 7A & 7B.

FIGURE 7A: SAMPLING OPERATIONS



Rotary Boring There are four steps for each sampling/testing in rotary boring: (1) Take out drill string, (2) Insert test assembly, (3) Take out the test assembly and (4) Reinsert the drill string and carry on with boring.

FIGURE 7B: SAMPLING OPERATIONS – WATERJETTING



As only a casing is used, there are only two steps for each sampling/testing: (1) Insert test assembly and (2) Take out the test assembly and carry on with waterjetting.

In case of DEEP BOREHOLES exceeding 25 metres or so, in the case of waterjetting each test/sampling may take from 10 to 30 minutes. In the case of rotary boring, the same test can take from 20 minutes to 120 minutes.

COSTS

When we compare field operations between rotary boring and waterjetting, the latter is considerably cheaper. The cost of boring using waterjetting is about RM20 per metre. On the other hand, properly carried out rotary boring should cost between RM120 to RM180 per metre.

On the surface, costs for rotary boring are prohibitive, but one should compare costs against the value of the data obtained. In the case of waterjetting, it is cheap and fast but provides data that is not reliable and does not comply with TOR, therefore useless. In the case of rotary boring, it is costlier and slow, but provides data that is in compliance with TOR and can be used with confidence.

Had we maintained the boring methods we used 25 years ago, such comparisons today just should not occur. Because of our neglect or apathy we have digressed, we are now comparing useless against useful.

Consider as an example, from a competitive tendered cost of boring at RM60 per metre (in about 1981), the cost per metre today would have at least doubled or tripled and should today stand at RM120 to RM180 per metre. Instead, the cost of boring today is about RM20 per metre despite the fact that the basic method of soil boring remain about the same, there has been no startling cost effective changes in boring methods. Meanwhile every other associated costs including labour today has almost doubled those in 1981. In short, the cost of SI has come down a third of what it was in 1981 despite the fact that all associated costs have doubled or tripled since 1981. How come?

It does not take much to see that something is odd. Due to our need for speed and pressures for cost cutting, we seem to have digressed into getting SI information at cheapest and fastest without really asking what it is that we were getting. It may be because both methods discussed involve rotation, hence any method involving rotation is rotary boring.

The cost of SI for a structure worth RM100 million using, say, 5 boreholes should cost about RM50,000 or less today instead of RM300,000 if our TOR are to be followed. So what are we comparing? We are comparing RM50,000 for just about nothing as against RM300,000 for information that is reliable and will pay back many times over in reduction of hidden costs and design confidence and reduction in mid-construction surprises and safety of our structure.

Because virtually every SI contract uses the same method of waterjetting and there are so many arguments put forward in the defense of waterjetting, we could argue until "the cows come home". What we should be concerned with is, do the methods we use comply with our TOR and Codes of Practice? Are these methods providing information we can use. Are we happy taking aspirin which is cheap against proper medication that may cost a lot more? If we still insist on using waterjetting, then we have to have enough justification to modify the TOR and Codes of Practice, which would be very difficult since the basic requirements of these documents are universal.

GETTING SUB-SOIL INFORMATION

Clause 2.2 Method of Advancing Boreholes

The method used shall be such that an accurate and continuous observation of the soils encountered is possible throughout the process. No mingling of soils from different levels shall be allowed to occur... "

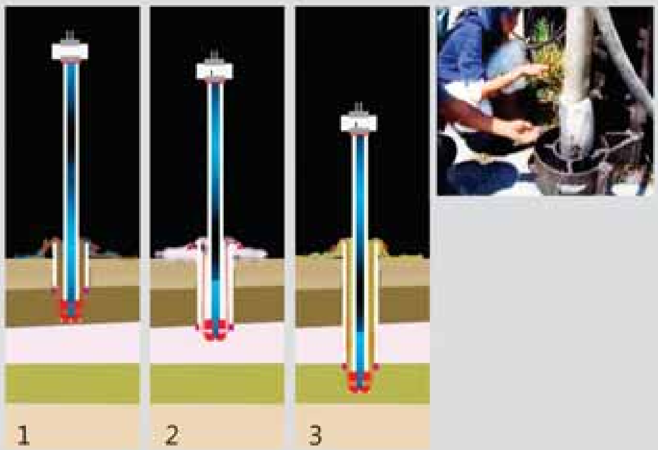


FIGURE 8A

When the casing follows the cutting bit attached to the bottom most rod, the cutting bit advances by dislodging/cutting soil below. The water discharged via the cutting bit returns to the surface, along the annulus between the outside of the rod and inside of the casing. The cuttings are carried to the surface by the return water. There is no mixing of return water from the layers above. Therefore, the contents (cuttings) and the colour of return water represent the soil at the bottom of the hole. Changes in colour and content give good guide to strata variations (Figure 8A: 1,2 & 3). This also allows us to take samples close to the change of soil type/strata below based on variations in the return water. Diagrams 1 to 3 show such changes. This complies with Clause 2.2 of the TOR.

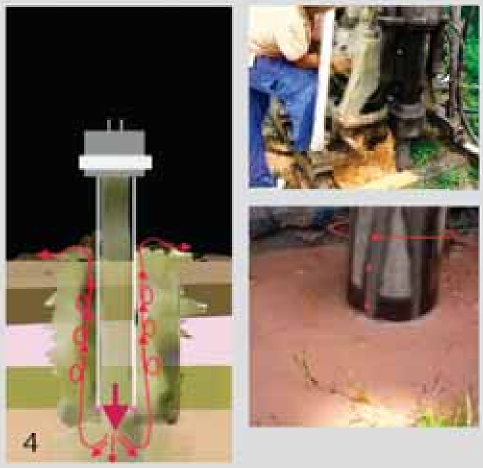
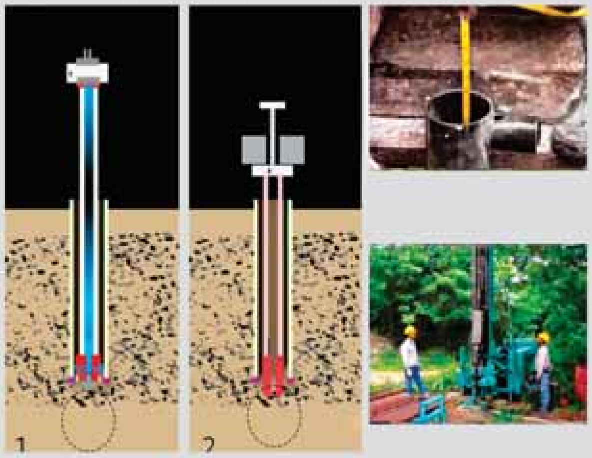


FIGURE 8B

Since the dislodging of soil below is carried out to a very small extent by the thin edge of casing and to a very large extent by the brute force of water under very high pressures plus the surging action of the casing, a lot of water is actually lost in the soil below, thus altering the soil volume to be tested. The water that returns to the surface brings soil dislodged by water to the surface OUTSIDE of the casing, thus mixing with all other soil layers above making both the contents and colour no longer representative of the soil at the cutting bit position. The return water has no value. In lot of cases even mingling of soils may occur due to unwashed soils still left in the casing. This does not comply with the requirement of Clause 2.2.

SAMPLING AND TESTING



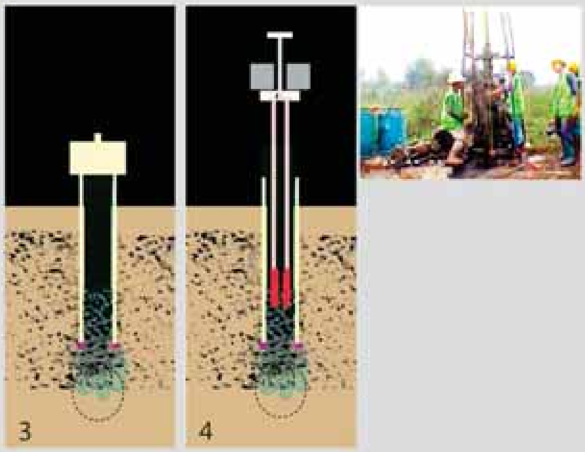


FIGURE 9A: 1 & 2

The hole is advanced by the cutting bit, and all dislodging of soil is carried out by the cutting bit only. The cutting bit position represents the bottom of the hole. Nevertheless, to guard against unknowns, it is standard practice to measure the depth of the hole to ascertain the test position before a test is carried out. Taking the length of the drill string (number of rods used) as indication of the depth before a test is carried is not acceptable. Because, a long, fixed mast is used assuring stability for testing and sampling operations, the testing/sampling can be easily controlled in terms of vertical position, thrust and speed.

FIGURE 9B: 3 & 4

The hole is advanced by surging and rotating of casing under very high water pressure. Only a minute amount of cutting is done by the thin edge of the casing, all dislodging of soil particles is carried out by surging and brute force of water under high pressure. In cases where material cannot be eroded completely, this method can form a cone inside the casing. In other cases where material consists of very coarse gravelly sand, fine material such as silt and clay will be washed out but solids such as coarse sand and gravel may remain in the casing. Since the depth of hole is rarely measured, tests are very likely to be carried out on the material INSIDE the casing. Such tests on material confined by casing can give very high results and can be misleading and dangerous. Also, because a tripod is used in place of long mast, there is very little stability and little or no control on verticality or meet requirement of continuous thrust as required for sampling (the mast of such machine has less than metre run).

USAGE OF WATERJETTING

In the discussion up to now, it has been demonstrated that the method of waterjetting, adopted for about 90 percent or more in the acquisition of our SI information, provides information of negligible use. We have been using waterjetting for more than 20 years. At times, we do in fact supervise waterjetting to assure 'reliable' information and even go as far as to give demonstrations of SI using waterjetting – all of which is not correct but it does indicate that we have been practicing bad methods so long that waterjetting has now become the accepted method. Some voices in the wilderness like this one protesting against this method have gone unnoticed and faced ridicule. We have also gone on with seminars and workshops on SI and have successfully bypassed the basic issue of waterjetting by simply ignoring the issue.

MACHINES

Replacing spindle-type with top-driven machine alone will not change the quality of SI. Spindle-type machine has its shortcomings, one of which is that boring requires usage of rods and casing and can be very slow with spindle type machine. An understanding of the methods to be used is also very important. There are cases where "top-driven" machines with mast have failed to provide good tests and samples because the method of boring adopted was waterjetting. (It is also important to note that although the JKR TOR does not say what machine to use, its requirements are that the sub-soil volume to be tested should not be disturbed–a condition waterjetting cannot meet).

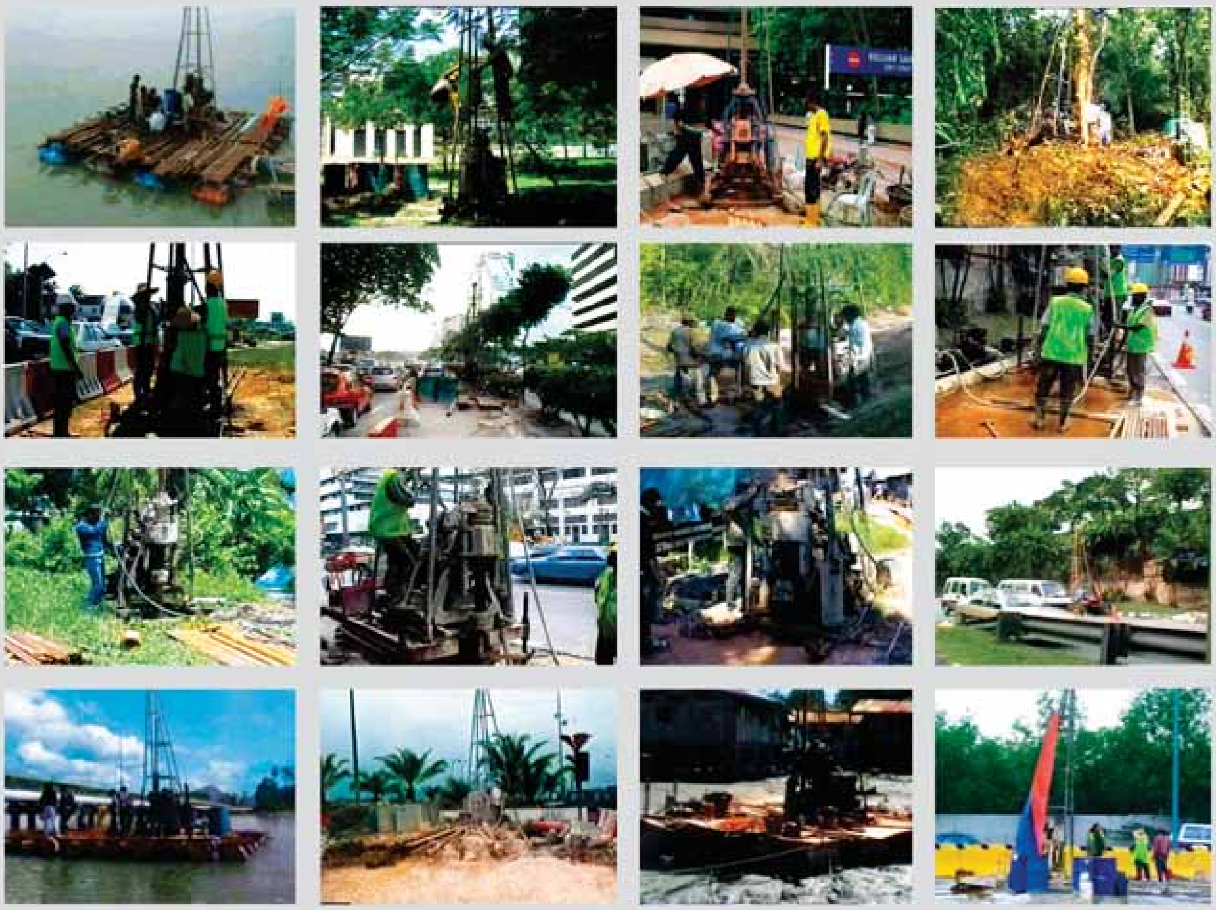
Today, although there are a range of machines available for rotary boring, from portable to skid mounted to trailer mounted for almost any kind of terrain, these are no longer in seen in the country. In Malaysia, almost all machines used for specific requirements of rotary boring today are the same machines used for micro piles and tend to be huge. This has led to the belief that rotary boring can only be carried out by these huge machines, and thus cannot be used where staging is required over water or where boring is needed on top of a difficult hill. The result of this belief is an almost countrywide acceptance of waterjetting over the years, and top–driven machines are no longer available as they become too expensive to use. Today, there are almost no portable or skid-mounted drilling machines (rigs) left in the country. Therefore, the rare few operators who insist on using rotary methods have to put up with the huge machines, and have to virtually beg the contractor to take on the job. Because requisite skills and proper ancillaries have to be provided, most contractors are reluctant to offer these machine at the present rates, particularly so called the "Schedule of Rates". Despite our apathy towards good practice in SI, there are still a number of contractors in the SI industry capable of providing reliable SI information but not at present rates. If we are to improve our SI information we must not only look at just the cost of SI information but the value of reliable information to our project.

FIGURE 10: ROTARY BORING RIGS

PORTABLE RIG SABAH 1979 | FEDERAL HIGHWAY 1978 | ON JACK UP, KELANTAN 1982 | SI IN SWAMP SABAH 1980

MELAKA 2010 | KL 2007 | PENANG 2010 | SHAH ALAM 2008

FIGURE 11: WATERJETTING RIGS



'MAKE-DO' CULTURE

As we have seen, today, almost all machines used for SI can effectively do only waterjetting. Results do not comply with the TOR. This rarely matters as TOR or codes are hardly referred to or available on-site to control field operations and just about anything goes. This has led to a horrifying culture of make do's and backyard substitutions (Figure 12,12a to 12d show some of these make do's). These substitutions, ad hoc procedure changes, use of unsuitable ancillaries and mismatching of rods/casing, drilling accessories and samplers are not limited just to waterjetting sites, but also to rotary boring and where permitted, percussion boring sites. This happens not because the contractor is trying to cut costs but more because of the engineering apathy and lack of competent supervision. This is also further aggravated by the fact that the SI contractor, particularly second-level or third-level sub-contractor is rarely treated as part of the "design team" even though he is responsible for the most important aspect of the Civil design and is probably very badly paid. Not all contractors have trained geotechnical or geological personnel on their team, they hardly need them, which also does not help towards reliability of SI information.

"Part 1 of this article may be downloaded from: http://www.gea.com.my/docs.html"

FIGURE 12:MAKE DO'S

Figure 12a: Different soil type require different cutting bit, and cutting bits vary from simple wings to spiked rollers. (A) Roller bit with compatible rod but used in wrong soil type. (B) "Dragbit" being passed off as roller bit. (C) Correct soil type, acceptable rig but roller bit smaller than drill string.

Figure 12b: (A) & (B) SPT samples from rotary boring. (C)&(D) SPT samples fromwaterjetting.

Figure 12c: Non-standard sampling tube with filed cutting edge and easily dented. (B) Sampling tube made out of exhaust pipe with obstructive seam on the inside. (C) Badly sealed and badly being transported undisturbed sample wrapped in loose plastic.

Figure 12d: (A) Coring into rock using compatible drill string and core barrel combination inside compatible casing. (B) Red in red, compatible rod and casing combination; blue in red, not so compatible combination. White in red, bad combination where rod is too small for casing. (C) White in red type combination causing whipping in drill string and wobbling in the core barrel below, thus causing fractures in the rock being sampled. (D)Whipping in drill string. (E) Recovered core with added fractures due to whipping.