

SITE INVESTIGATION: ITS PRACTICE TODAY

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ABSTRACT

At present all our Site Investigation information obtained using physical methods are sadly lacking. This is costing nation as a whole in millions in losses in over designs, construction problems and remedial. There is a strong need for improvement in acquisition of SI information. This paper examines our SI practices, what is being done about it and recommends improvements.

INTRODUCTION

In all civil engineering works, the most crucial is the reliability of the information about the ground on which the civil engineering project will be founded. We would call this SI, or Site Investigation Information or simply SI.

There are various methods of obtaining SI information, in this paper we will concentrate on most widely used method, that involving Boring and Drilling.

IMPORTANCE OF SI INFORMATION

We, the Engineers, all will agree that SI is a specialist operation. Almost all SI is remotely carried out (we are testing grounds below from surface!) and because of this, it is necessarily the most procedure oriented operation. Therefore, for SI information to be meaningful, it requires strict adherence to procedures and good practice. Which simply translated means, adherence to Code of Practice and Specifications. All Engineers fully agree with these statements.

On the basis of the data obtained via SI (costing less than 0.1 % of the project costs), millions or billions will be committed to the project. It therefore makes engineering sense that SI must only be carried out using suitable equipment and ancillaries and by trained persons under the supervision of equally if not better trained supervisors.

All SI specifications for Site Investigation in use today in one way or another emphasize workmanship supervision and have similar requirements namely:

1. Method of boring must be such that observations are possible and soil volume to be tested remain undisturbed before being tested.

2. Boring to be carried out using Drill Rods with bits attached to be used for advancing of bore holes
3. Judicial use of water
4. Testing requirements
5. References to SO, Supervisor or similar implying competent supervision
6. References to Code of Practice and Specification, insisting on adherence to procedures

SHORT COMINGS OF OUR SI PRACTICES

Surprising issue is, that all of us fully agree with nice statements like above, we even use reasonably good specification, yet if we were to visit any SI site anywhere in our country, we will find there is not a single SI site where any of these sentiments and requirements are met.

Attachment 1 presents photographs, mostly very recent, taken around the country, some involving projects costing billions.

Situation, at each SI location is virtually the same, namely

1. No reference documents (CP or specifications) on site
2. Machines and ancillaries in non-compliance with specifications
3. Unacceptable procedures, sampling, testing, transporting
4. Untrained operators
5. Untrained, usually non existent supervisors

SI information produced from these worksites, in the form of SI REPORTS are equally compatible to situation on the worksites and have following in common

1. All most all introduction portion of reports describe methods which are not same as on site
2. All presentations and soil descriptions in bore logs vary from company to company and in some cases different locations and pay no relevance to say, laboratory tests, consistency etc

From bore holes logs, based on presentation and lack of site observations, it also can be inferred that

3. All strata changes in ground below occurs at 1.5 meter intervals in Malaysia
4. There are never any occurrences of Water losses, change in water colors, water ingress, material changes below.

HOW SUCH PRACTICES AFFECT PROJECTS

All above results in final product called SI REPORT or FACTUAL REPORT. Such "FACTUAL" SI Reports, based on information as obtained from methods adopted to day present information which are far from being reliable, costly in long run and even dangerous. This reinforces common, but a very basic premise, "GOOD DECISION CANNOT BE MADE ON BAD INFORMATION"

Project costs and safety are have direct bearing on information we use in our designs. With no information we have no choice but to over design and prepare for worst. At least we are prepared. With bad / unreliable information, we can make bad choice, and may not realize it is a bad choice, and we are worst off than in the case of no information, because in this case we are not even prepared to expect problems, but we do get caught in all sorts of problems.

Attachment 2 describes some of this.

To day there is a tacit awareness that something is wrong with our SI, but nothing is changing, bad equipment, bad ancillaries, bad operators and where possible experienced bad supervisors continue to provide us with doubtful information and we keep designing and constructing and wasting money. We then point to these structures and say, "If SI was bad how come these buildings are standing up?"

In all these arguments we seem to forget the basics again, that every Civil structure is unique. Unlike motor vehicles which are tested to destruction at design stage, we cannot similarly test civil structures to destruction and rebuild it more economically. We have to be as correct as possible right from the beginning, and use Factors of Safety to mitigate some of these uncertainties. Due care and diligence is of prime importance in all Civil Engineering projects.

This is a lot more so in SI.

In SI, all work is remotely carried out, no same sample or test location can be tested twice, variables that can make results doubtful include equipment, ancillaries, how they are used , where and who they are used by. Results obtained from each location simply tell us how that location (the bore hole location) was like before testing (after testing it is no longer the same). We use number of these test results to develop a picture of the grounds below. This picture will never be 100 % accurate. Again some uncertainties are taken care of by Factor of Safety. Even with this, in is necessary to ensure that the results we obtained are as accurate as possible and properly taken, ie reliable to allow us to develop as accurate picture of grounds below as possible. We do this by following set procedures in boring, testing and sampling and even in how each sample is described. (logging). This way we ensure uniformity of procedures, uniformity of description and uniformity of reporting and cut down as many variables as possible. Uniformity of procedural reporting is very important, because once SI is carried out we are left with nothing but the FACTUAL SI REPORT. This report has to be such that designer utilizing his past experience and knowledge can develop accurate picture.

When reported as described, SI REPORT ALLOWS US TO assess variability in the ground reasonably accurately.

Now please consider the present situation of the SI REPORT, where Codes and Specification are rarely followed, no adherence to procedures, no uniformity in reporting. Under these circumstances, no matter what Factor of Safety we use, we are still playing engineerig version of Russian Roulett.

OUR BORING METHODS

Method of advancing of boreholes as we ask for in our specifications provides us with reliability of sampling and testing. This means, each method has to be such that it must not allow that volume of subsoil, (which we will test or sample,) to be changed or altered BEFORE it is tested.

Basic, in all this, is how the “hole” is made to reach the sampling/testing depth. This is referred to as boring. In case of boring in soils, most accepted method are Percussion Boring, Rotary Boring, Auger Boring. Properly used all these methods allow for reliable sampling and testing.

Properly used methods we would define as that using adequate and suitable equipment and ancillaries under the care of trained operators and supervised by trained supervisors.

Most commonly used methods is **Rotary Boring** (or Rotary Wash Boring) which involves a boring hole using drilling fluid (water or mud) pumped down a rod fitted at the bottom some sort of cutting bit. Advancing of hole is achieved by dislodging of soil below the rod by **the cutting bit** and the transport of these cuttings to surface by drilling fluid. (water or mud). Drilling fluid, under some pressure, is discharged from the drill bit at the bottom, mostly sideways and returns to surface bringing with it cuttings of soil dislodged by cutting bit. If casings are used to stabilize the hole, these always follow behind the rods.

Most important issue to note is that drilling fluid is **not discharged DOWN WARDS into soils below but SIDEWAYS** and thus **very little volume of soil below the rod is disturbed** or contaminated and almost all of the fluid used is returned to the surface to gather with soil cuttings. This is the method we ask for in all our specifications.

Method we actually use very different. It is more of water jetting than rotary boring. All good elements of Rotary Boring are missing. It involves advancing of borehole using only the Casing (no rod with cutting bit attached) under very heavy water pressures. All dislodging of soils below is achieved by brute force of water and surging/rotating action of the casing (water jetting). In short it only uses casing and water.

This is a very crude method. This method requires very little skill, and it is fast and most important, it is cheap.

However, as all water under high pressures is discharged from DOWNWARDS. Considerable amount of water is lost in soils below thus considerable volume of soil to be tested is contaminated or disturbed. This makes all testing and sampling unacceptable because we are now testing soils which are no longer representative of soil mass around it. Add to this situation lack of trained operators and untrained supervisors, no procedure, no uniformity and we have Malaysian SI.

Attachment 3 compares the two boring methods discussed.

OTHER SI METHODS OF OBTAINING SI INFORMATION

There are numerous other SI methods, which method used will depend upon site and expected soil types. There is no universal method for every condition. The other methods include CPT, Pressure Meter, Dilatometer, Seismic and so on.

Because of our lack of awareness, which allows us to expect cheapest at fastest speeds, just about every method of SI practiced is subject to suspicion and likely to be unacceptable since comments on basics like training and adherence to procedures apply here as well.

Every method used today has element of MAKE-DO about it. (CPT cone with friction sleeve smaller than cone to speed penetration, Electric Cones on Mechanical CPT Machines, Pressure meter tests without pressure regulators, shear vane tests with home made vanes and so on) This element of MAKE-DO will remain until we accept need for training, adherence to procedures and rejection of make-do equipment and ancillaries. Until this happens, no matter what method is used, it is not likely to inspire confidence in SI information.

PRACTICE OF SI TODAY

We must stop brushing off our present state of SI industry by assuming it has always been bad any way and therefore whatever will be, will be. This is not true.

Practitioners of SI around seventies used boring methods using Hydraulic fed, top driven machine, using compatible rods and casings, usually B, N, H sized casings and B and N sized rods. Every job required careful consideration of compatible and suitable equipment which included rods, casings, core barrels, various cutting bits and drilling bits. Each borehole took almost four times longer and nearly three times costlier than today. SI information, we like to believe, was at least reliable.

These equipment still exist and are available even today, but because of high operation costs, its practitioners cannot compete with today's wash boring or "WATER JETTING".

By late eighties, numerous operators with access to cheap machines entered the SI market. The machines they used were not right machines for boring and testing, but they were fast, and again very important, they were very cheap. They produced fast reports, in some cases even instantaneous reports. Quality and reliability of information became secondary to speed and price. Those with proper equipment and ancillaries could not compete and either left the field or simply joined in. Cost of SI kept coming down even though the cost of labor, fuel, ancillaries and equipment has almost doubled or tripled. There are no drastic innovations in basic SI technology. Nevertheless SI costs today are about ONE THIRD that used to be in seventies or early Eighties. Today SI operations are come to be regarded as lowest form of contracting and it seem as we just do not care.

COMPARING SOME SI RATES IN 1982 AND 2002			
ITEM	UNIT	1982 RATE IN RM	2002 RATE IN RM
Boring in Soil n.e. 10 m	Meter	45	18
Undisturbed Samples ne 10 m	No	60	20
Vaneshear Test ne 10 m	No	80	35
SPT n.e. 10 m	No	45	18
LL & PL	No	30	12
Sieve Analysis	No	35	15
Consolidation	No	180	60

Table above compares some rates taken from a successful tender document twenty years ago to that today.

WHAT IS REQUIRED

Most important thing required is CONSCIOUS AWARENESS amongst engineers that quality of SI needs improving and why. We must stop making excuses to justify bad SI instead we must at highest levels, start paying attention to awareness and training. This must also follow awareness amongst Project Owners to the importance of SI information to their projects.

Next most important issue to be addressed must be training of personnel involved in SI, both from contractors and supervisors and entrusting all SI operations are entrusted only to them.

Thirdly standardization of specifications, bill of quantities and reporting formats etc.

Last and most important awareness must be that good quality SI will not be cheap, but these costs are nothing compared to gains in cost reductions and reduction in construction and post construction problems. This has to be acceptable to both clients and engineers.

WHAT IS BEING DONE

Various bodies in the country are now looking at this problem of SI. One directly involved in SI practice is SI Improvement Committee.

Local SI Standards are now ready for comments, recommended standards SI Specifications are also ready for comments or use, Skill Standards for SI operators are ready and training issues are being addressed by CIDB at this moment under the advisement of SI Improvement Committee.

Training of Supervisors is also being looked at by BEM.

SI Contractors have formed their own association to with assurance to provide reliable SI information and police conduct of their members.

ATTACHMENT 1

BORING RIGS AROUND MALAYSIA



EAST COAST



KARAK TOWN



PENANG



SEREMBAN



**NEAR OLD
KL AIRPORT**



EAST COAST



KERTEH



PAKAR



PETALING JAYA

All sites visited had following in common:

- No copies of Specifications or CP on Site
- No Supervisors or they were having a drink elsewhere
- Sample logging varied from site to site, an accepted practice
- All machines were spindle type, none with “hydraulic Feed” as required by most Specifications
- All rods on site were A size, used only for SPT or sampling
- All holes were advanced using “water jetting” referred to as “Rotary Wash Boring”
- Most SPT spoons were badly worn-out and split spoons replaced with solid spoons
- Undisturbed tubes were unacceptable, with seams on the inside, or filed edges or dented.
- All used RETURN WATER even though clean water was available.
- High Pressure Piston Pumps had no pressure indicators

OTHER ISSUES



Commonly used Undisturbed sampling tube with obstruction on the inside □



Badly damaged Undisturbed sampling tube



Worn out SPT Spoon Cutter



Solid SPT Split Spoon



Samples ready for transport

Extruding Samples



Attachment 2

EFFECTS OF SI ON PROJECTS:

Considerable road and rail construction involves land improvement using methods like:

- Remove & Replace
- Vibro Flootation,
- Dynamic Compaction
- Stone Columns
- Others

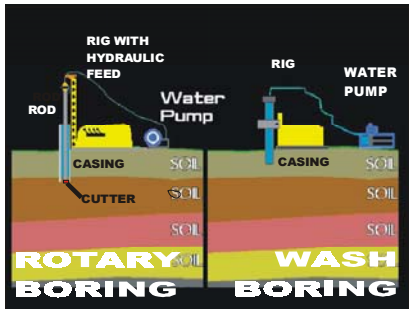
About the simplest of these would be Remove & Replace.

In case of remove and replace, the depth to which removal of insitu material will take place will depend upon some value obtained from SI. In one case this value was based on SPT $N=5$. However, since method of boring in use disturbs large volumes of soils before it is tested by pumping considerable amount of water where SPT's are taken, the SPT values will necessarily be lower than if the soil insitu was in natural condition and undisturbed. This means **removal & replace** depths based on lower N values will be lower. If we just assume that this lowered depth is off by one SPT interval or 1.5 meters. We will therefore be excavating and replacing to 1.5 meter extra depth which in actual case is wastage. Let us say cost of remove and replace is $Rm \ Z / \text{cubic metre}$, therefore funds wasted would be, for say, 50 km stretch of road about 30 meter excavation width $1.5 \times 50 \times 1000 \times 30 \times Z \dots = 2,250,000 \times Z$.

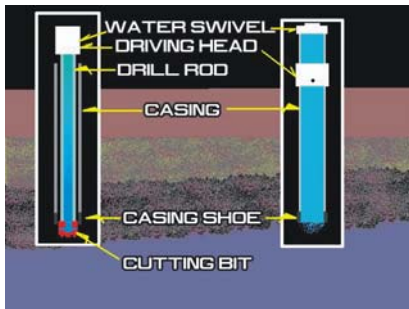
Taking example of compaction using vibro-flootation which requires fines contents less than, let us assume, 15 % for it to effectively work. Because of considerable amount of water entering soils below, considerable fines would have been washed out of soils sampled. This would mean 15% or less fines in soil reported could actually be lot more than reported, but we are not likely to realize this until work is awarded and actually starts and designed improvement process don't work, by then there would be problems all around....

In short, no matter which alternative of construction we use, if this is based on bad information, than the alternative chosen will rarely be the best. The work will rarely be smooth or satisfactory. Cost overruns would be in over-designs, design modifications and in being locked into selected alternative and trying to best with it. Frustrations do not stop here but continue to construction changes and post construction remedials, recriminations and unhappiness all around. Most important to note is, good information gives us right to make a good choice, bad information locks us into a choice, usually bad.

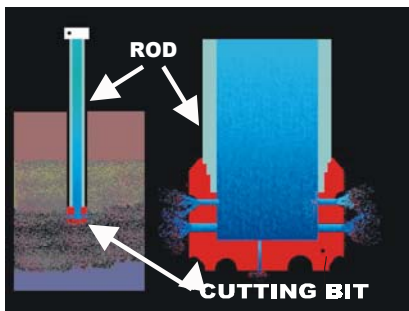
ATTACHMENT 3 ROTARY AND WASH BORING



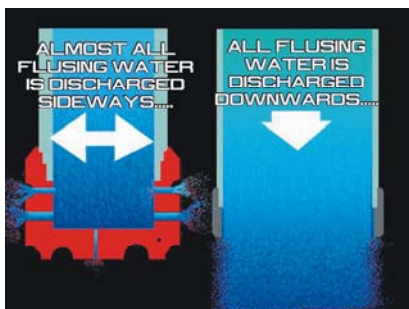
Comparing Boring set ups between Rotary Boring on Left and Wash Boring on the right. Note that in case of Rotary boring, components are Water Pump, Rig With atleast 1.5 meter working stroke, casing, rod with cutting bit. In case of Wash Boring, components are High Pressure Water Pump, Rig with 0.5 meter working stroke and casing.



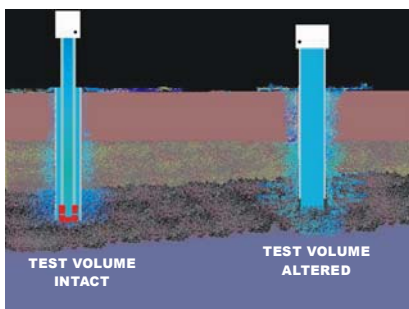
In case of Rotary Boring, rod is rotated from top and whole system consists of about six items. Wash boring does not need rod or cutter and has about 4 components, all cutting is achieved using water.



In case of Rotary Boring, the hole is advanced using cutting bit attached to the rotating rod. Rod is rotated and is under hydraulic pressure. Soil below is dislodged by grinding action of cutting bit on soil below. Dislodged cuttings are brought up by water returning to surface. Almost all water returns to surface.



Comparing the two methods at the bottom of the hole, in case of Rotary Boring all cutting is achieved by cutting bit rotating over the whole soil area to be cut and all water is discharged sideways. In case of Wash Boring, rotating casing contributes very little to dislodging of soils below, this is done by force of water and water has to be under very high pressures. All water is discharged DOWNWARDS and lot of it is mostly lost in soils below.



In case of Rotary Boring, disturbance below Rod is very little and almost all water returns to surface allowing changes in soil types are easily noticed. Disturbance below is very little and samples obtained are representative of soil mass. In case of Wash Boring, considerable water ingresses and loosens soils below and samples obtained are not representative of soil mass.

END RESULTS



SPT Samples as obtained using proper boring methods



SPT samples as obtained from Wash bores