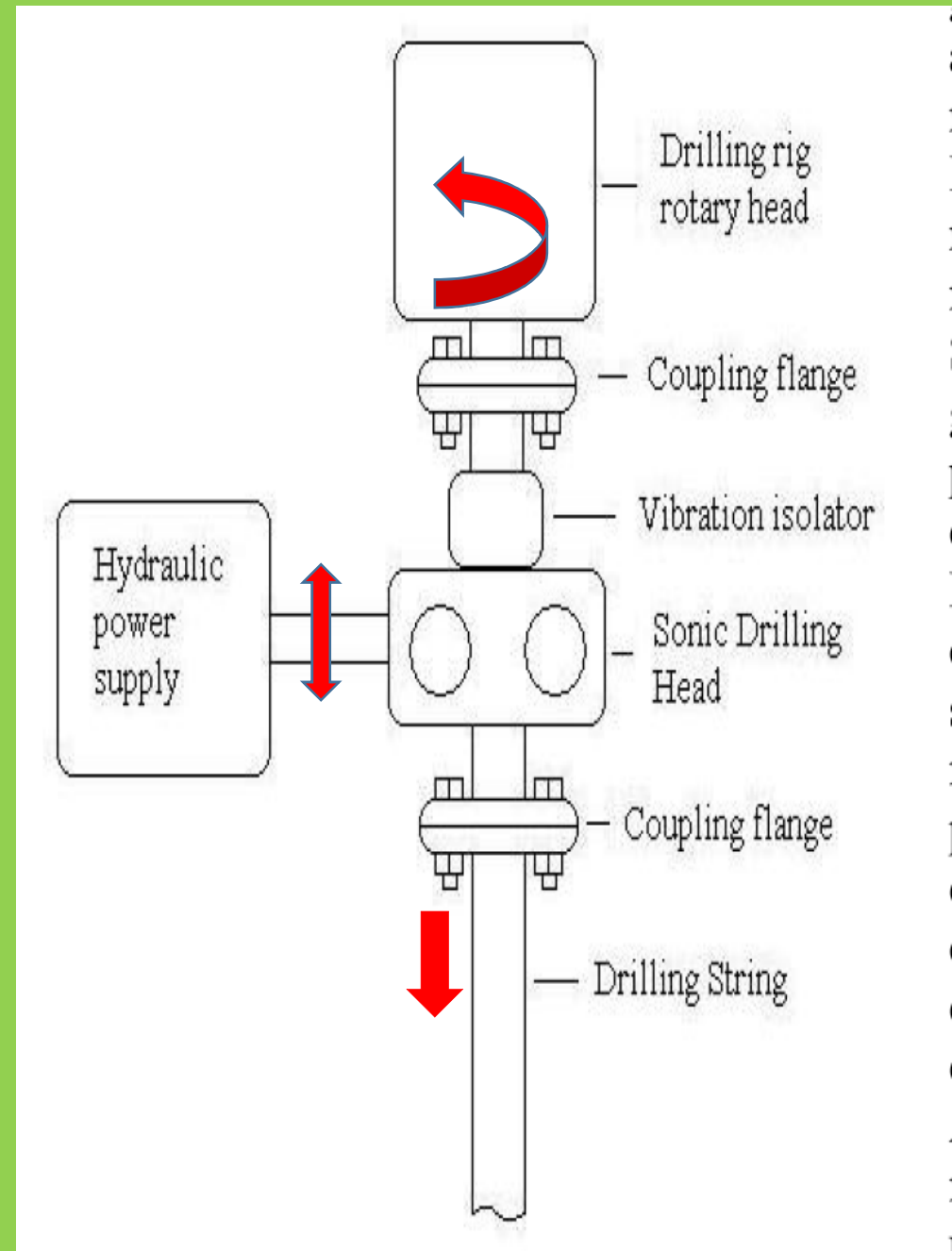


New Development -Sonic Drilling with Sampling



Three Forces on Drill Strings:

- Rotary force provides slow rotation to enhance vibrating effect
- Vertical oscillatory force provides localized displacement to shear and penetrate
- Vertical force from drill mast provides steady push or pull with advancement



Basic Equipment

- Hydraulic rig: better equipped with automatic drill rod or casing feeder device.
- Drilling String: typical 155 mm OD threaded casing.
- Drill bits: Crown-in bit; Crow-out bits; Rotary tricone bit; Full face bits
- Flushing Medium: Air rotary; Water ; mud fluid or even dry drill with small amount of water for cooling drill bits.

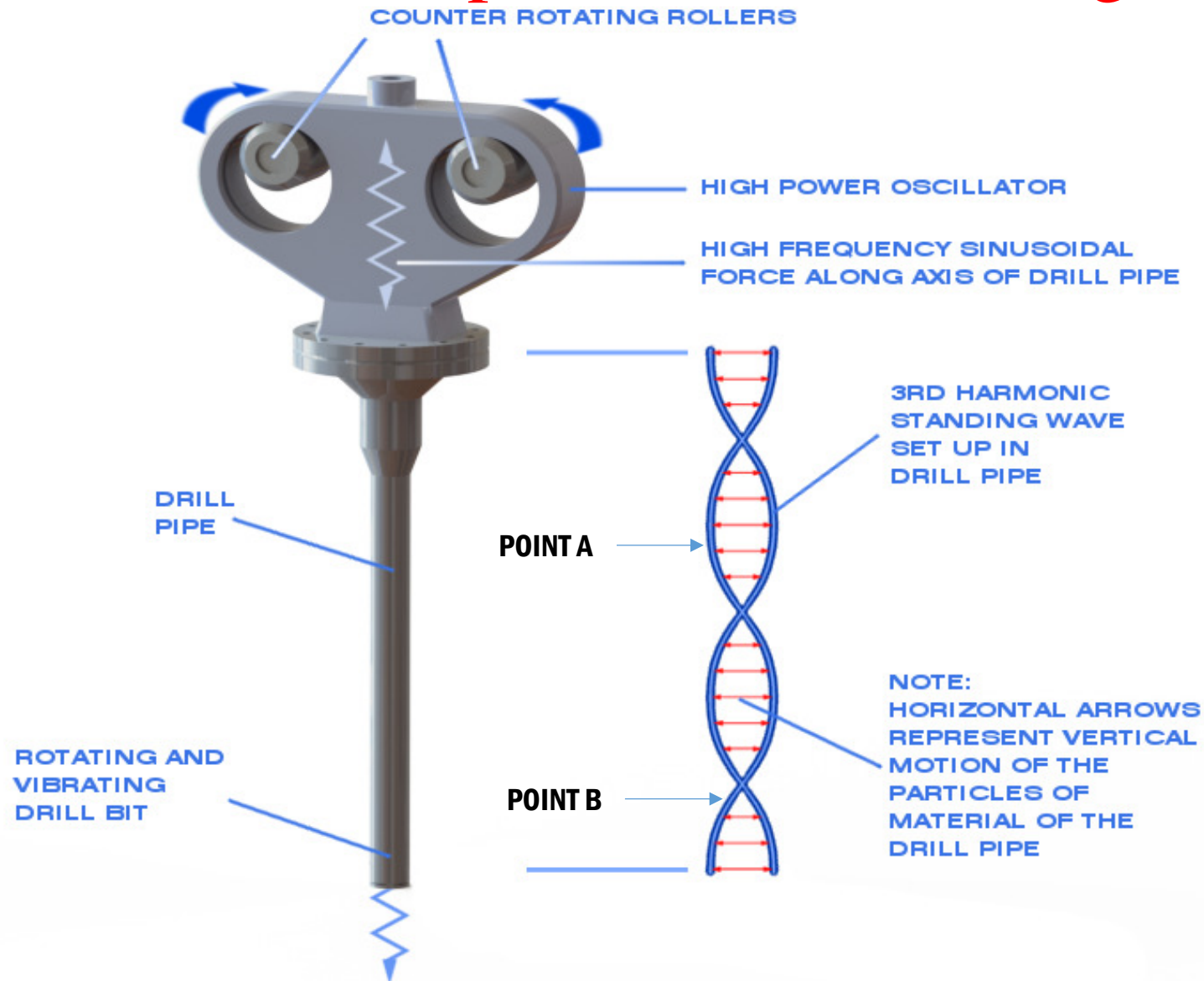
Sonic Drill

Oscillator

Rotary
Drill



Principle of Sonic Drilling



Principle of Sonic Drilling

- When the vibrations coincide with the natural frequency of the drill rod or casing a natural phenomenon called resonance occurs.
- The superimposition of the induced pressure wave and reflected pressure wave expanding and compressing the drill pipe
- The optimal condition generates the maximum energy is at the resonant condition
- Resonance magnifies the amplitude of the drill bit which fluidizes the soil particles at the bit face with fast penetration rate.

Principle of Sonic Drilling

- This drilling technique vibrates the entire drill strings and at a frequency between 50 and 150 cycles per second.
- The resonant frequency varies with the length of the pipe, and therefore, the driller has to adjust the vibration frequency of the oscillator from time to time.
- It combines rotation with high frequency vibration and suitable drill thrust at bit.

Principle of Sonic Drilling

- Point A- Antinode Location
 - Point of maximum strain in compression or expansion in molecular structures
- Point B- Node Location
 - Point of minimum strain in molecular structures
- The wave length and amplitude are varied with length of drill pipe

Sonic Drilling History in North America

Late 1940's	Development of sonic technology begins.
1946 to 1958	Funding for sonic research .
1957	Sonic drilling production found to be 3-20 times greater than conventional rates are reported.
1960's	Sonic prototype is developed.
1976 to 1983	Sonic prototype research continues, modern rotasonic head is built, patents received.
1985	North Star Drilling of Minnesota, USA begins using rotasonic for environmental drilling. First operator in the USA.
1990's	Rotasonic drilling becomes widely accepted in USA. North Star Drilling becomes a division of Boart Longyear Company .
2000's	Sonic applied to many new markets (geotechnical, construction, mining, etc.) and exported to Canada, Australia, Africa, South America and Europe.

Old and New Sonic Drilling Methods

	Rota-Sonic Drilling	Sonic Drilling
Drilling Method	Rotation, Sonic and axial/feed force	Sonic and linear/vertical down feed
Depth Capability	200 to 250m depending on ground conditions	Approximately 30m depending on ground conditions
Ground conditions	Anything! – can drill through obstructions which other methods refuse	Loose sands and gravels, soft clays, very weathered rock, will hit refusal on boulders and man made obstructions
Max BH Diameter	300mm (12 inches)	125mm (5 inches)
Max Sample size	254mm (10 inches)	102mm (4 inches)
Max Install Size	185mm OD	33mm OD or 42mm OD pre-pack screen

Terminology in Resonant Drilling

- Sonic Drilling
- Rotasonic Drilling
- Sonicore Drilling
- Rotosonic Drilling
- Resonant Drilling

They all refer to the same technology in resonant drilling method nowadays.

Purpose and Work Tasks

Destructive Drilling for:

- Hole for ground water monitoring device.
- Hole for well screen installation
- Grout hole for installation of TAM pipe.
- Hole for minipile purpose.
- For anchor installation.
- Installation of geotechnical instruments.
- Installation of geothermal sensors

Lost cones or bits for well installation, cold heat exchange system and seismic exploratory drilling.

Purpose and Work Tasks

Constructive Drilling for Geotechnical Investigation :

- Acquire soil and rock samples
- Drill hole without smear or severe overbreak such that soil testing and groundwater permeability tests can be performed
- Hole for ground water monitoring device.

Purpose and Work Tasks

Types of Constructive Drilling Works:

- Geothermal drilling with water sampling and permeability tests before installation of heat pump.
- Mine drilling for acquiring soil and rock samples for chemical analysis and logging.
- Geotechnical drilling with soil and rock samples, all related field tests and geotechnical instrumentation.

General Field Operation and Observation

- Drill string with intense vibration at the drill bit with resonant frequencies of 50 to 150 Hertz, which are audible and thus “Sonic”.
- Driller is trained to drill and adjust the bit force, oscillating speed and rotational speed (Three parameters) to achieve the resonant frequency for the drill string.
- Once the resonant frequency is reached, the drill string becomes likely less vibrating, and the penetration speed increases. A low booming sound from the drill string can be heard.

The driller can operate the hydraulic rig with a remote control panel



General Field Operation and Observation

- The driller can adjust the machine to achieve resonant frequency by the above feeling.
- Due to increase in length of casing, the natural frequency will be varied. The driller has to adjust the three parameters from time to time.

General Field Operation

Drilling Circulation Fluid

- Drilling with fresh water for stabilized formation with less caving.
- If caving or cutting to be too large to be removed, use mud fluid.

Volume of Drilling Fluid

- Excessive water will enlarge bored hole or cause collapse. Drill with minimum volume of fluid.

Uphole Velocity

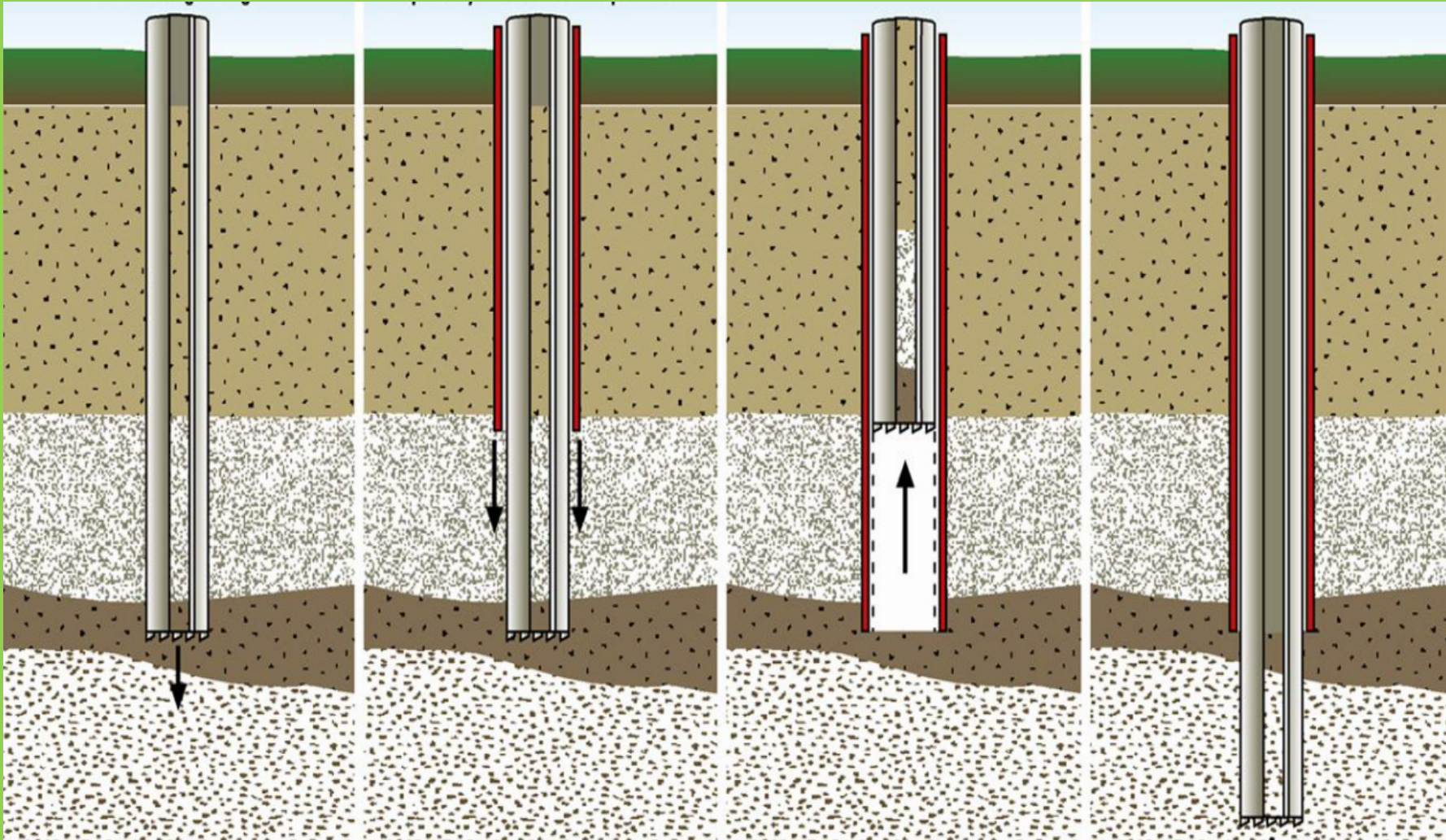
- 60 – 80 m/min for water and 30 to 40m/min for mud fluid.

General Field Operation

Weight on Drill Bit

- Lighter weight on bit than that of the conventional rotary method.
- Excessive weight may reduce the vibratory efficiency and result in decrease in penetration.
- Excessive weight may bend the hole and result in breakage of drill tools.

Continuous Soil Sampling (Dustman et al; 1992)



Taking soil sample
by core barrel

Drill outer casing

Extract soil sampler

Take soil sample at lower level

Thread
the
plastic
sleeve to
the core
barrel



Vibrate
the core
barrel to
let the
sand
sample to
go into the
plastic
sleeve.



Guide the
soil sample
to go
smoothly
into the
plastic
sleeve



Measure
the weight
of the soil
sample



Seal the soil
sample and
store in the
corebox



Inspect and
carry out
logging for the
soil sample



Extrusion of Soil Cores without Plastic Sleeve



Sonic Soil Sampler

It should be a “Thick Walled Piston Sampler” that can sustain for vibration force from the drill string

Sample with large area ratio!



Sonic Sample
Drill

Sonic Soil Sampler

- According to the standard, ISO 22475-1: 2006 Geotechnical Investigation, the core sample quality achievable is **A2/B3**, where Quality A1 being the quality of a pushed cutting ring, and C5 being fully disturbed.
- It is **not quite suitable to** carry out the compressibility test nor shear strength test.
- It **is achievable for** density, density index, porosity and permeability tests

Quality of Soil Samples - Table 3.1 Eurocode 7

Soil properties / quality class	1	2	3	4	5
Unchanged soil properties					
particle size	*	*	*	*	
water content	*	*	*		
density, density index, permeability	*	*			
compressibility, shear strength	*				
Properties that can be determined					
sequence of layers	*	*	*	*	*
boundaries of strata – broad	*	*	*	*	
boundaries of strata – fine	*	*			
Atterberg limits, particle density, organic content	*	*	*	*	
water content	*	*	*		
density, density index, porosity, permeability	*	*			
compressibility, shear strength	*				
Sampling category according to EN ISO 22475-1	A				
			B		
					C

3.4.2 Soil identification

Quality of Soil Samples

Rota-Sonic Sample Quality Class - BS EN 1997-2:2007

- Material Dependant
 - Sands and Gravels – Quality Class 3 (5)
 - Soft Clay, alluvium – Quality Class 3, Class 2 also achievable (4)
 - Stiff Clays – Quality Class 2 is achievable (4)
- Sample class B and A is also achievable (density, density index, Permeability, porosity)
- Utilise number of different drilling tools.

(5) = Quality Class/ Sampling Category in EN ISO 22475-1

Quality for Classification of Soil Sample – BS5930: 1999

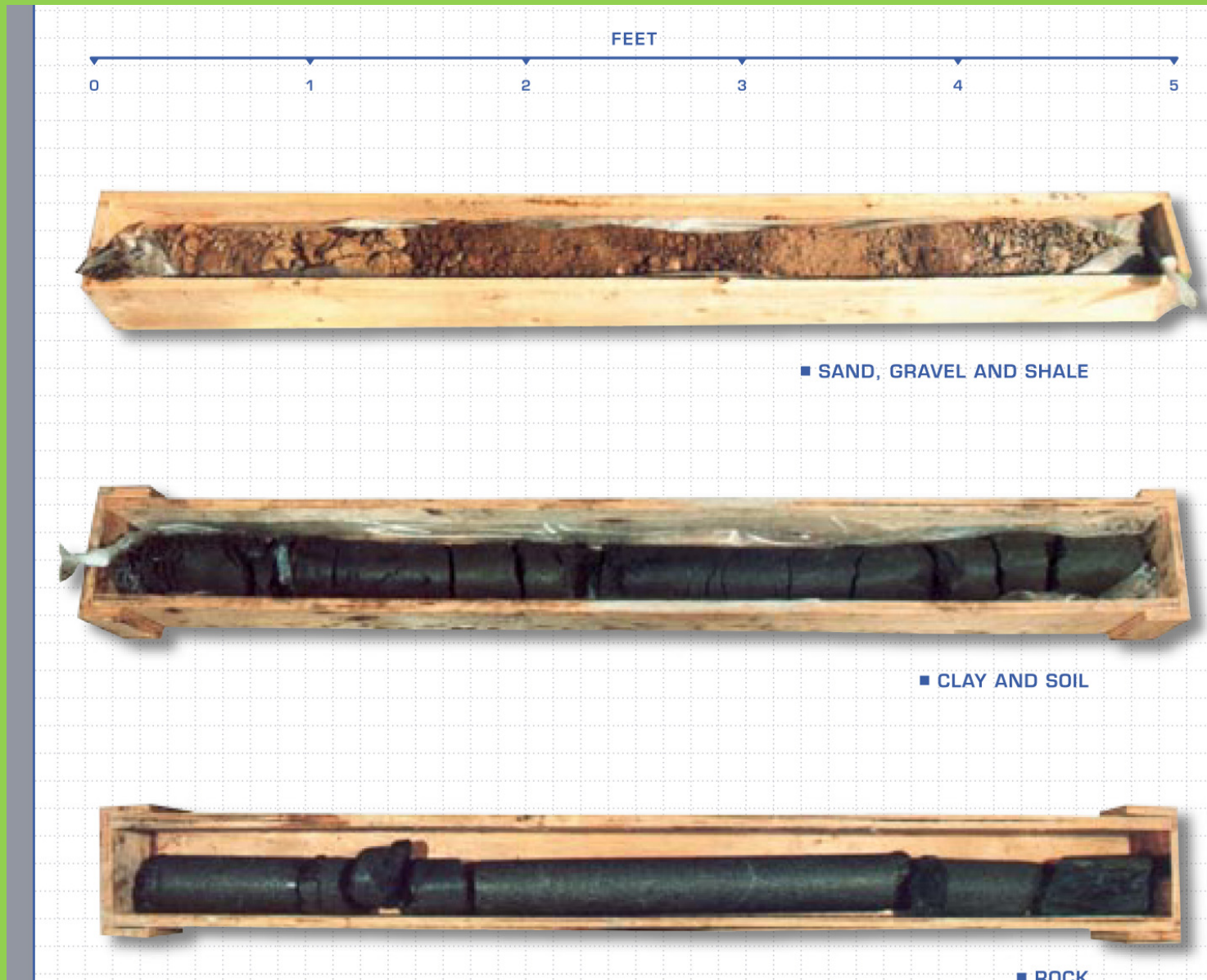
Quality	Properties that can be reliably determined
Class 1	Classification, moisture content, density, strength, deformation and consolidation characteristics
Class 2	Classification, moisture content, density
Class 3	Classification, moisture content
Class 4	Classification
Class 5	None (sequence of strata only)

A thin layer of disturbed soil against the inner wall is visible. It is believed that any of the triaxial or oedometer test from the sample should be handled with care.

Any improvement such that the two Above tests can be done?



Soil and Rock Samples



Extrusion of Soil Samples and Storage



- Continuous Core Sample
- Controlled extrusion of sample
- Safe handling for contaminated samples
- No dilution/cross-contamination of sample



- Engineers get to log the facts – Not interpret the losses
- Make decisions on borehole based on visual evidence



Continuous Soil Samples



Continuous Soil Samples in Clay



- Stiff Clay

- Easily Altered Geology



Rock cores with Sonic Core Barrels Used Overseas

Generally, the rockcore has been affected by the sonic vibration such that **more fractures** and segments are formed.

The **core recovery** may be higher and **RQD** may be lowered as compared with the conventional rotary coring method.



Selection of Drill Bits

There are two types of the tungsten carbide tips to be used for ring bits:

- House type : for sand, gravel and boulders
- Double conical type: For big boulders and hard formation



House type tip



Double conical type tip

Local Filed Observation for Bit Performance

Observation:

Rock pieces (Photo A) easily jammed inside the casing/ crown bit, time consuming to remove those rock pieces.

As cause of jamming problem, the size of crown deflated by less water flushing/ blocked, time consuming to ream by a new bit.

For trial should be.



Before Drilling:

Clay type ring bit
D=165mm

Local Field Observation for Bit Performance



After Drilling :
Ring Bit



Rock Piece (Photo A)

It was found that the performance for different bits like tricone, roller, full face, crown-in and crown-out bits **vary drastically**, and series of tests with different penetration rates and bit forces should be conducted.

Recovery of Steel Obstructions Reported Overseas



Steel train rail



Fused Slag

NOT SUBJECT TO REFUSAL

- Even in hard strata and difficult made ground

Is Sonic Drilling Cost Competitive?

Factors Cost Affecting Cost

- ❖ The cost for the plant investment and maintenance cost
- ❖ It should depends on requirements from contract and drilling method employed;
- ❖ Cost of investment in plant and rental rate estimated;
- ❖ Cost of waste disposal;
- ❖ Cost of remediation;
- ❖ Cost of second phase drilling due o insufficient data;
- ❖ Costs of skillful drillers and workers;
- ❖ Cost related to production rate;
- ❖ Cost for unforeseen ground conditions;
- ❖ Liquidated damage in project;

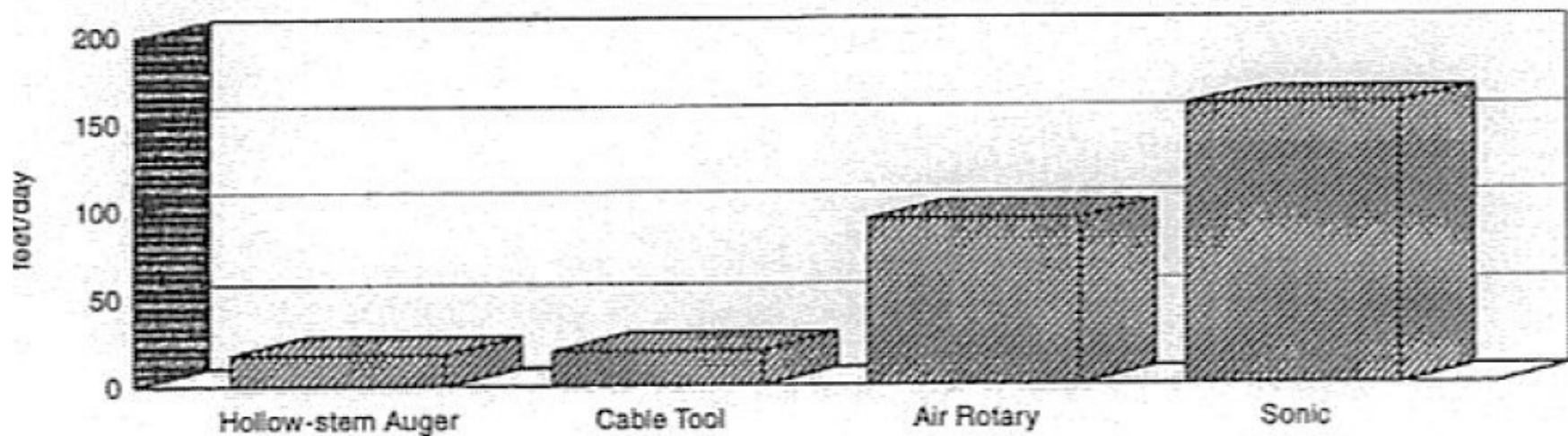
Is Sonic Drilling Cost Competitive?

Overview the Total Cost Against the Production

Cost Item	Sonic Drill Rig	Percussive Rig	Rotary Rig
Direct Cost			
Innovative Cost	High	Low	Low
Mobilization Cost	High	High	Low
Rig Daily Rental	High	High	Low
Rig Maintenance Cost	High	High	Low
Production Tool Maintenance Cost	Medium	Medium	Low
Consumable Cost	High	Medium	Low
Fuel Cost	High	High	Low
Water fee	Low	Medium	High
Mud Fee	Low	Low	High
Indirect Cost			
Cost for Abandoned Hole	Unlikely	Likely	Likely
Cost for Possible LD due to Slow Production	Low	High	High
Cost for Waste Disposal	Low	High	Medium

Comparison of Drilling Rates and Sample Methods (Dustman et al., 1982)

<u>Drilling Method</u>	<u>feet/day</u>	<u>Sample Method</u>
Hollow-stem Auger	18	Split-spoon (5 ft.)
Cable Tool	20	Bailer
Air Rotary	95	Split-spoon (10 ft.)
Sonic	160	Continuous Core

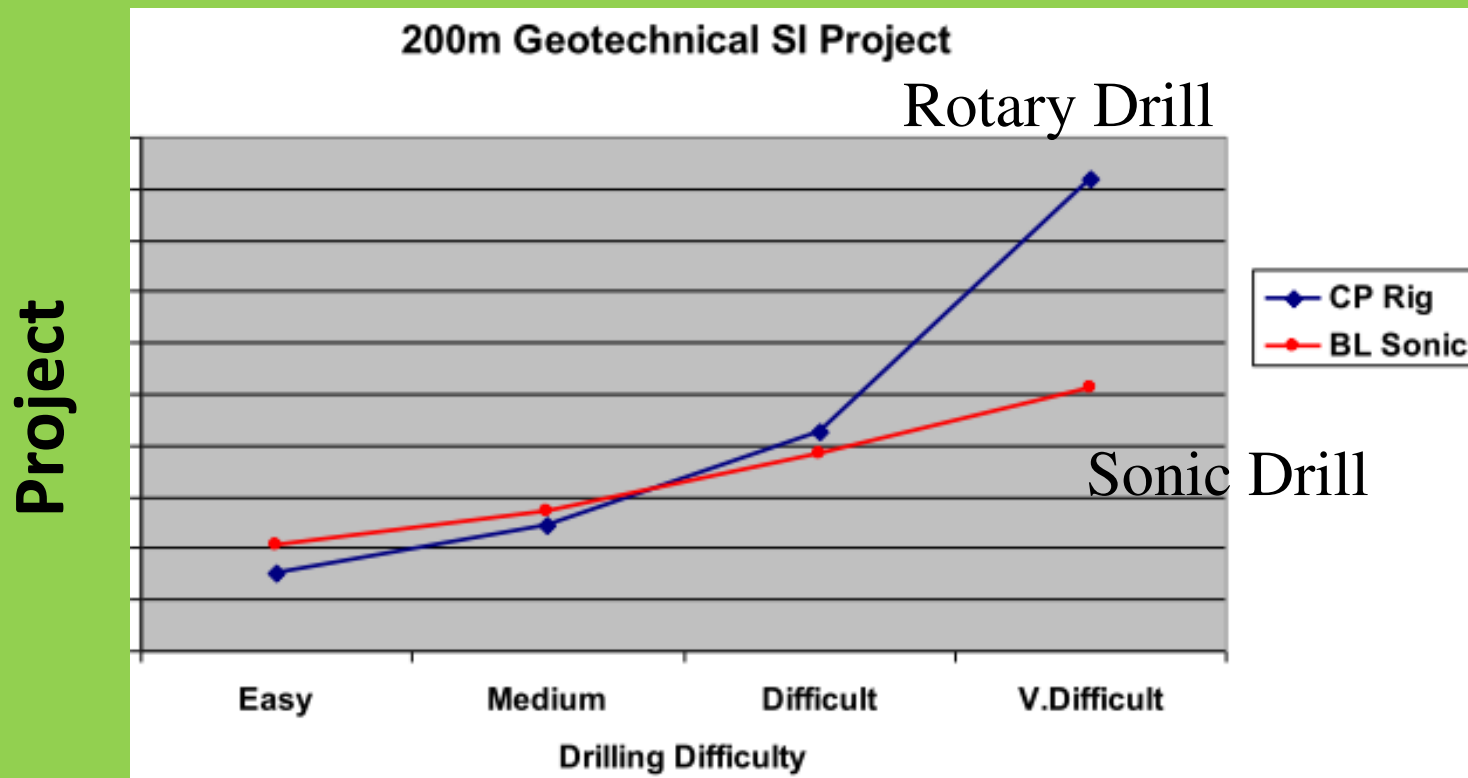


For rotary drilling method with SPT at 2m C/C, the production rate will around 15 to 18 m per shift.

Drilling Difficulty Definitions

- Easy- Soft, sandy clay
- Medium- Firm to stiff clay, medium dense sand and gravel with occasional cobbles
- Difficult – Glacial till, thick gravel bands, and made ground.
- Very Difficult – Large boulders, blowing sand, made ground with obstruction, reinforced concrete

Sonic Drilling Becomes cost Effective For Projects



Advantages for Sonic Drilling

- Penetration rate in soil is 3 to 5 times faster than rotary drilling.
- Drill effectively through mixed and adverse mixed ground condition like gravels, boulders, landfill, rock and even steel obstruction.
- No drilling refusal with abandoned hole.
- More cost effective for adverse ground conditions and deep hole.

Advantages of Sonic Drilling

- If required, the continuous core sample recovered provides a representative lithological column for review and analysis
- Accuracy and precision, with minimal deviation, even bored at angle. Drill string stay extremely straight
- Less wall smearing for geotechnical and environmental sampling and downhole testing.

Advantages of Sonic Drilling

- Eliminate problems associated with hydraulic fracturing and borehole erosion.
- Reduce drill cuttings and drilling waste water or mud for disposal.
- More clean site. It can generally be 70% less waste on highly polluted site.
- Ease of casing removal with vibration drill head.
- Low amplitude and high frequency for sonic energy limits impact to existing vulnerable structures

Advantages of Sonic Drilling

- Safe and ergonomic working method
- The statistical analysis found that sonic samples can acquire higher core recovery than conventional samples?
- Option to combine with Standard Penetration Test (BS EN ISO 22476-3, ASTM D1586 and Australian Standard AS 1289.6.3.1) with use of the automatic SPT device.

Disadvantages of Sonic Drilling

- Not cost effective for shallow boring, in easier drilling conditions or in hard rock.
- Vibration can disturb surrounding sensitive clayey formations.
- Soil sample quality cannot achieve the requirement for triaxial or oedometer tests.
- Rock cores will be slightly smaller than corresponding cores recovered by rotary method.

Disadvantages of Sonic Drilling

- The rock cores are more suitable for point load test than unconfined compressive strength test.
- The Standard Penetration Test can only be performed with the automatic trip hammer type.
- Heat generated may change moisture, or contaminant conditions despite it may be controlled using fluid.

Conclusion

- Raise the awareness of the new drilling method to be an option to others: Sonic Drilling
- The adoption of the method should be studied to fit your quality requirement and cost effective.
- For some projects, the advantages outweigh the cost effectiveness in consideration of adverse ground condition, program time and environmental aspect.
- There are more practices and experiences at overseas projects. But the technique just begins in trial and use in Hong Kong. It needs more practice and experience in order to get the optimal cost saving, and to improve the core quality with high production rate.