

VIBROCORING AS AN EFFECTIVE COMBINED GEOTECHNICAL, GEOCHEMICAL AND ASS INVESTIGATION TOOL

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ABSTRACT

Vibrocoring has been conventionally conducted by many practitioners using aluminium tube of 50 mm to 80 mm diameter, requiring multiple holes to achieve 'combined' investigation sampling targets. Apart from the vibrocorer head itself, the penetration of the vibrocore tubes can be limited by the strength and diameter of the tubes, as well as the ability of the tube cross-section to effectively transmit the vibration energy. The length of the sample tubes is typically limited to a 6 m 'standard'. GHD has worked together with MDS on a variety of projects, using 100 mm diameter steel vibrocoring tubes, to penetrate up to 9 m depth, through sands of up to medium dense/dense relative density and has been able to penetrate into stiff/very stiff clays for up to approximately 1 m (below other sediments). The use of steel tubes allows penetration where aluminium tubes will buckle, it also provides a more effective transfer of vibration energy (less damped) than for aluminium tubes and the wider diameter makes the sample significantly less prone to jamming on shells or blocking within coarser sediments, which effectively stops further penetration/sample collection. A number of case studies are presented, where geochemical, geotechnical and Acid Sulphate Soils (ASS) samples have been obtained from the same core, and where sophisticated geotechnical tests, including staged triaxial with pore pressure measurement, were possible on the firm to very stiff cohesive materials recovered.

1 VIBROCORING OVERVIEW

1.1 SAMPLING AND RECOVERY

The vibrocorer uses a range of vibrating amplitude and frequency, plus 'head weight' in order to advance thin wall tubes through generally loose to medium dense sands and very soft to firm muds (silt and clay). Mostly the tubes so advanced comprise 50 mm to 80 mm diameter, up to 6 m length aluminium tube. The vibrocorer is traditionally used for sampling very soft to soft/very loose to loose sediments, but with the use of steel tubes can be adapted for stronger strata.



Figure 1: 9 m Steel Vibrocore ready to deploy



Figure 2: Recovered Vibrocore with Sealed ends on Deck

In the sampling exercise, the tube with vibrocorer head attached (as shown on Figure 1 above), is lowered to the seabed from a deck crane; the vibrocorer is started and slack given to allow penetration of the corer until either refusal or full penetration of the tube length attached. The vibrocorer is switched off and the tube recovered by

winching out of the seabed, through the water cover and laid onto the deck of the vibrocoring barge (as shown on Figure 2 above). It is usually a quick process (minutes) to penetrate the normally very soft to firm or very loose to loose sediments being targeted, but can sometimes take up to about 20 minutes if dense sands or firm to stiff clays are being cored. In stiff/very stiff clays the penetration is usually limited to about 1-1.5 m. In sands, silty sands and very soft to soft materials some sample may be lost through the base of the tube on lifting from the seabed and onto the barge. Hence this operation is normally expedited as much as is practical. Firm (or better) clays usually 'plug' the end of the vibrocore tube.

There are many variations that can affect reliability of logging and sampling using vibrocoring techniques. The main such variables include:

- *Seabed level.* This can be obtained from DGPS/tidal records combined with a measurement to the seabed using a weighted tape, echo sounder, divers depth gauge etc., all with varying degrees of accuracy. The recording of the depth to seabed has the greatest potential for error from both equipment accuracy, wave/swell error and drift of the measuring tape due to currents (resulting in deeper readings). Typically +/- about 0.5 m.
- *Grid Co-Ordinates.* The grid co-ordinates are usually taken from DGPS or autonomous GPS, depending on accuracy requirements.
- *Depth Penetrated.* The vibrocore depth penetrated can be measured by marker flags on a line attached to the head (typically at 1 m intervals), by observation using divers to tape around the tube at the seabed level (refer Figure 3), or in the case of shallow water by observation and direct measurement to the vibrocorer head. This is regarded as the most variable of the measurements, unless observed directly and marked by divers, as the string line length submerged will be affected by the distance from the vessel and by any non-verticality of the tube. In particular, a vibrocore tube that has tilted significantly could record a significant penetration, when only a shallow depth was penetrated. In some cases tower frames are deployed, to assist in maintaining verticality (assuming a flat seabed).



Figure 3: Recovered Core Taped at Seabed



Figure 4: Cutting the Core Tubes

- *Recovery.* The recovery can be one of the most misinterpreted aspects of vibrocoring. Often the sample length recovered is factored up to match the depth penetrated (or close to it) by claiming 'compression' of the core. While compression can occur in very loose to loose sands, it is generally up to no more than about 10% of the core length. The writer has witnessed cores where there is a gap in the middle of the recovered core as a result of the lower section of core sliding down the tube with core having been being lost out the base of the tube, where up to 30% compression has been logged in order to match recovered length to that penetrated! A variety of core catchers can be used to assist in retaining sample, but these must be used with caution, as the core catcher 'fingers' dampen the energy transmitted to the soil and provide a (thin) obstruction layer around the inside of the tube just behind the cutting edge. This can cause the sample to jam, blocking off further sample ingress and causing early refusal. Generally the writer only attempts recovery using core fingers if difficulties are experienced in the recovery of materials in up to fine to medium grained sand size. The core recovery is usually (but not

always) less than the length penetrated and an assessment must be made on how much of this is compression and how much is core loss. Since most core loss occurs in lifting the vibrocore tube from the seabed to the barge, the use of divers to seal the base of the tube on emergence from the seabed can significantly improve recovery.

1.2 THE USE OF DIVERS IN SAMPLING AND RECOVERY

Divers are not essential when vibrocoring. However, the use of professional certified divers facilitates the vibrocoring operation because the divers can:

- Provide rapid feedback on the nature of the seabed and the progress of the vibrocorer into the seabed
- Seal the end of the vibrocorer tube rapidly on extraction, in order to prevent loss of material from the bottom of the tube
- Give confirmation that the core has penetrated vertically and that the exact depth of penetration has been recorded
- Inspect the inside of the tube while it is embedded, after removing the vibrocorer head in order to check the degree of compression.

While the use of divers is very convenient when operating a vibrocorer, they are not essential and in some situations their use may be unsafe or impractical. For example if the water is too deep for them to be deployed, or if diving conditions are hazardous due to toxins in the water or dangerous marine creatures. The risks/costs of every diving operation needs to be assessed against the potential benefits. An alternative to divers is the use of a fixed underwater camera on the vibrocorer frame, and/or the use of a Remotely Operated Vehicle (ROV).

1.3 LOGGING AND PROCESSING THE CORES

The vibrocore tube is usually cut into manageable lengths (up to 3 m) and transported from the barge for processing, or processed on the barge (refer Figure 4 above). The processing comprises splitting the core tube longitudinally while avoiding cutting into the sample, logging, photographing and sub-sampling. It is noted that some practitioners have been known to support the tube vertically from the crane and ‘vibrate’ the sample into a plastic ‘sock’. This method of extraction is not recommended, due to sample mixing and disturbance. A series of some exposed cores is shown in Figures 5-7 below.



Figure 5: Recovered Core Tube Split



Figure 6: Sand



Figure 7: Very Stiff Fissured Clay

In the case of the smaller diameter tubes, most of the sample at any given depth/material range will be utilised for either ASS/geochemical or geotechnical (classification) testing. However, for the 100 mm diameter tube, there is normally sufficient sample to do both. Moreover, with the larger diameter tube, material volumes suitable for compaction tests or for sluicing of fines to provide sufficient material for simulation test modelling

of dredge deposition can normally be achieved. While multiple samples of the smaller diameter vibrocore tubes can be taken at each location, this can double/treble the sampling and processing time and also provides samples that are more 'disturbed'.

Once the sub-samples have been removed, the remaining core is normally wrapped in plastic film, labelled and stored at a location of convenience for future reference, e.g. by dredging contractors etc. Alternatively it can be disposed of under normal industry protocols.

2 CASE STUDIES

2.1 PORT CONSTRUCTION, SYDNEY, NSW

For this project steel vibrocores from 6 m – 9 m in length were used successfully to investigate ASS, geochemical and geotechnical aspects of a proposed dredging operation.

The water depths encountered ranged from about 6m to some 20 m.

Divers with radio transmitters were deployed from the barge. This enabled the verticality of the vibrocores to be confirmed, the penetration depths to be marked by tape on the tubes, data on the rate of penetration in dense sand/stiff to very stiff clay to be relayed and incorporated in the sampling record, and the base of the vibrocore tubes to be sealed on emergence from the seabed. Recovery ranged from near complete to some 5% greater than the recorded penetration. The latter result was attributed to dilation within the medium dense to dense sand creating an expansion of the recovered volume.

The vibrocore tubes recovered were geotechnically logged and photographed, then sampled for geochemical, ASS and geotechnical purposes. The testing conducted included a contaminant suite, ASS indicator/SPOCAS/Chromium Reducible Sulphur suite and geotechnical testing comprising particle size with hydrometer, Atterberg limits, moisture contents, shear box, shear vane and staged Consolidated Undrained triaxial with Pore Pressure measurements ('undisturbed' sample).

A model was prepared based on the vibrocoring results (refer Figure 8). The results of the laboratory testing: enabled the dredged material to be relocated elsewhere within the bay being investigated, were able to demonstrate the appropriate dredge methodology to be used and allowed stability assessment of dredged slopes, albeit with some assumptions required as regards the relative density of the sands encountered.

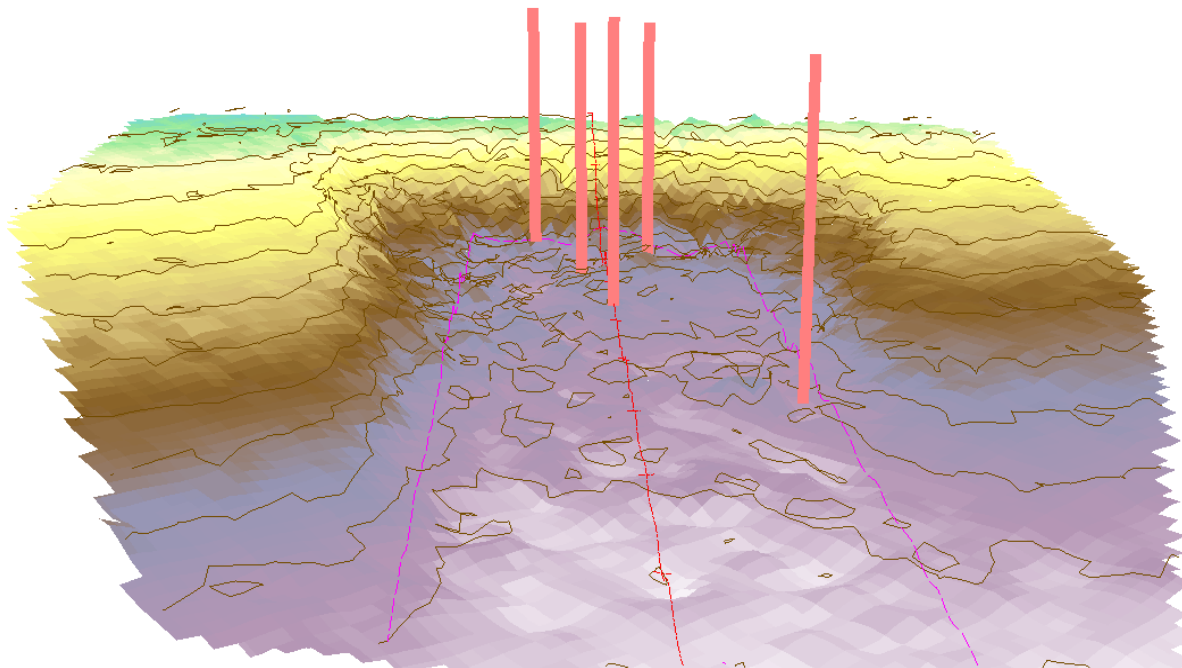


Figure 8: Idealised Ground Model

Some issues that were encountered during the work included delays due to port traffic, and standby due to inclement weather (always an issue with overwater investigations).

2.2 PORT DEVELOPMENT, QLD

Overwater investigations for this development comprised vibrocores obtained using a motorised barge and CPTu/ cored boreholes conducted from jack-up drilling platforms.

For this project steel vibrocores from 6 m – 9 m in length were used successfully as part of the investigation for ASS and geotechnical aspects of a proposed dredging/reclamation. The water depths encountered ranged from less than 2 m to some 20 m.

Loss of time due to inclement weather was similar for the vibrocore barge and the jack up platforms, as the allowable wave height, wave period and wind conditions applied to barge operations for both the vibrocoring and for access onto/off the jack up platforms.

Divers with voice communications to the surface were deployed from the barge. This enabled the verticality of the vibrocores to be confirmed, the penetration depths to be marked by tape on the tubes, data on the rate of penetration in dense sand/stiff to very stiff clay to be relayed and incorporated in the sampling record and the base of the vibrocore tubes to be sealed on emergence from the seabed. Recovery ranged from near complete to some 30% loss. The higher loss figures were recorded mainly on the longer (9 m) cores, due to the unusual presence of a very loose silty stratum (accounting in general for the loss) beneath a more competent (partially cemented) sand. The use of core fingers in this application usually resulted in refusal within the sand.

The vibrocore tubes recovered were geotechnically logged and photographed, then sampled for ASS and geotechnical purposes. The testing conducted included, ASS indicator/SPOCAS/Chromium Reducible Sulphur suite and geotechnical testing comprising: particle size with hydrometer, Atterberg limits, moisture contents, shear box, angle of repose, shear vane, staged Consolidated Undrained triaxial with Pore Pressure measurements and oedometer ('undisturbed' samples), compaction tests, relative density, quartz content, carbonate content, soil abrasion, petrographic assessment and dredge deposition simulation testing.

The value of the vibrocoring contribution was in enabling bulk sampling of the top 6-9 m of material, thus allowing a much more comprehensive laboratory test programme than would otherwise have been possible from just the boreholes. Moreover, the ease of sampling and the much faster production rate than boreholes meant that the sample volume was recovered at a fraction of the cost of overwater boreholes.

3 CONCLUSIONS

It can be stated that it is a misconception that vibrocoring is essentially only a geochemical and ASS investigation methodology.

It is recognised that for very soft to soft conditions and for cohesionless materials, the sample will be mainly useful for 'disturbed' geotechnical testing. However, for firm to very stiff cohesive strata, the recovered sample may be largely unaffected, as the disturbance is localised around the edges of the 100 mm diameter steel tube. Such samples are now being tested in CUPP triaxial and oedometer apparatus.

The use of vibrocoring, as part of an overwater geotechnical investigation, enables a rapid and relatively inexpensive data base of geotechnical material properties to be obtained from continuous large diameter samples, taken to depths of up to 6-9 m using steel tubes (depending on the ground conditions). Jack up barges are not normally utilised.

Technical limitations for the steel vibrocore tube include: the typical 6-9 m penetration restriction for 100 mm diameter steel tube (up to 6 m for aluminium and smaller diameter tube), the need for careful interpretation of the 'recovery' lengths, the lack of 'hard' data on relative density and the 'disturbed' nature of very soft to soft materials on extraction from the vibrocore tube. Therefore CPTu is used to obtain a continuous depth profile of inferred relative density/consistency, as correlated to borehole data. However, the CPTu returns no sample and the boreholes return only limited sample within the sands and very soft to firm clays (even if conducted using continuous coring techniques).

Overall, vibrocoring forms an important part of an overwater investigation, rapidly providing a significant quantity of geotechnical, geochemical and ASS data on the materials investigated, subject to the limitations stated above. It is enhanced by the use of steel tubes to achieve greater depths of penetration, particularly into medium dense/dense sands and stiff to very stiff clays.

