Recommendations for High-Quality Field Sampling Procedures using the Dames & Moore (DM) Hydraulic Fixed-Piston Thin-Walled Tube Sampler

Prepared for:

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DISCLAIMER:

These guidelines describe "*good practices*" for field sampling using the Dames & Moore (DM) Hydraulic Fixed-Piston Thin-Walled Tube Sampler. Experienced users should follow these guidelines to ensure standardized practice within the geotechnical community, in pursuit of consistent high-quality sampling and testing.

These guidelines do not cover every scenario that may be encountered during field sampling and laboratory testing. The experienced user should exercise judgement in developing solutions for adverse conditions, with the goal of maintaining high-quality work. Alternative sampling methods and deviations from the prescribed specifications may be necessary, but care should be taken to minimize negative effects on the samples and specimens. Vibrations, rotations, and impact forces should be avoided.

These guidelines do not guarantee high-quality samples will be obtained and do not guarantee high-quality laboratory testing will be performed with those samples. Individual users are the primary variable in sampling and testing quality and repeatability.

These guidelines are not intended as a teaching tool for new users. It is hoped they will provide geotechnical practitioners with a general appreciation of the issues that need to be considered when undertaking high-quality sampling.

OBJECTIVES

These guidelines are provided to improve the likelihood of retrieving high quality samples using the Dames & Moore (DM) hydraulic fixed-piston thin-walled tube sampler in a cased mud-rotary boring. High quality samples are often referred to as "undisturbed" samples, although it is recognized that no sample can be retrieved without some minimal amount of disturbance. The aim of "undisturbed" sampling is to reduce sample disturbance effects to the point where they have a minor, trackable effect on the results of laboratory testing. Thus, the resulting sample disturbance effects are minor and can be assessed confidently while interpreting test results.

DM sampling is a highly specialized operation and requires an experienced drilling team that is familiar with the sampling equipment and procedures. The precise detail of this operation is beyond the scope of this document. The notes that follow have been prepared for use by engineers planning and undertaking geotechnical investigations. They are intended to provide information and guidance at key points to help improve the quality of the sampling operation.

DAMES & MOORE (DM) HYDRAULIC FIXED-PISTON THIN-WALLED TUBE SAMPLER

The DM hydraulic fixed-piston soil sampler is an Osterberg (1952)-type sampling device (Figure 1) that uses thin-walled, constant-inside-diameter, brass sample tubes with an outside cutting edge bevel of 60° to reduce disturbance during sampling. The nominal dimensions of the sampling tube are: OD = 63.5 mm, ID = 61.2 mm, and inside sampling length is 450 mm. Thus, when the sample tube is fully advanced, 100% recovery corresponds to a sample length of 450 mm.

Restricting the sample length to 450 mm and the use of smooth low-friction brass tubes reduces disturbance due to soil plugging. The DM brass tube area ratio (C_a) is 7.6%, which is defined by Hvorslev (1949) as $C_a = 100 \cdot (OD^2 - ID^2)/ID^2$, where OD is outside tube diameter and ID is inside tube diameter, and recommended to be less than 10-15%.

The sample tubes are secured to the sampler using grub screws which fit through two 10mm diameter holes in the sample tube, located 12.7 mm from the top. Removing the sample tube from the tool after sampling can be difficult due to the vacuum which exists between the bottom of the fixed piston and the top of the sample. To ease the removal process, a pair of 1mm diameter weep holes may be drilled through the tubes at a distance of 40 mm from the top. If weep holes are to be used, they must be created prior to sampling and then covered with several rounds of electrical tape before the tube is attached to the sampler.

In gravelly soil conditions that are prone to damaging brass tubes, stainless steel sample tubes are sometimes used with the DM sampler. However, stainless steel tubes are not equivalent to brass tubes and typically result in higher sample disturbance due to higher interface friction and typically higher C_a values. The DM hydraulic fixed-piston sampler is shown in Figures 2 & 3.

The DM hydraulic fixed-piston sampler was developed for clays and silts, and it has been shown to retrieve high quality samples of plastic fine-grained soils (e.g., Bray and Sancio 2006). Silty sands and fine sands with some silt have been successfully sampled with the DM sampler, and testing indicates high-quality samples can be retrieved in these soil types (e.g., Markham 2015, Markham et al. 2016). Medium dense sands have also been sampled successfully (meaning good recoveries were obtained; in situ shear wave velocities were preserved; measured relative densities compared favourably with CPT correlations; and lab-based cyclic resistance curves were similar to those from accepted field liquefaction triggering procedures; Markham et al. 2016). However, there is evidence that indicates loose sand samples (i.e., clean sand units with $q_{c1n} < 60$; Boulanger and Idriss 2014) were disturbed significantly during sampling by densification (Markham et al. 2016). The effectiveness of the DM sampler to retrieve "undisturbed" samples of dense sand has not been evaluated yet; significant sampling disturbance of dense soils would likely reduce their density.

PREPARATION FOR SAMPLING

- Sampling tubes should be inspected to ensure that there is no visible damage to the cutting edge at the base of the tube and that the tube has not been warped (i.e. oval cross section).
- Optional weep holes may be drilled at the top of the sample tube to assist in the removal of the sample tube from the tool after sampling. If used, the holes should be of small diameter (i.e. approx. 1mm diameter) and located such that they are slightly below the o-ring on the fixed piston. These holes should be covered with tape prior to sampling.
- Verify the length of the sample tube, as well as the stroke of the sampler to determine the expected length of core corresponding to 100% recovery.

DM FIELD SAMPLING PROCEDURE

- Mud-rotary borehole should be drilled out to the sampling depth using a side-discharge tri-cone roller bit (see Figure 4). Drilling fluid should consist of heavy "mud" created by adding bentonite or polymer additives to the drilling water. Drilling fluid should be appropriate for maintaining borehole stability and preventing mud loss.
- Conventional drilling will require casing with an inside diameter of at least 100 mm. Casing should be kept a minimum of 2 times the casing diameter (but no more than 1 m) above the bottom of the borehole to prevent borehole collapse, fall-in from shallower depths, and mud loss. Schematic for casing/sampling depths is shown in Figure 5. The final section of borehole between the bottom of the casing string and the target depth should be drilled after setting the casing. The roller bit should be advanced slowly, and once the target depth has been reached, the bit should be lifted 300 mm above the bottom of the hole and mud circulated to remove cuttings in the borehole. Do not leave roller bit at sampling depth too long, or it will erode the top of the sample.
- Measure depth to bottom of borehole prior to sampler insertion using a weighted tape.
- Attach D&M sampler to drill rods and carefully lower sampler to bottom of borehole using the rig's hoist and minimize contact of sampler/tube against the inner wall of casing and sides of borehole. Drillers should not slide the rods down the hole. Confirm sampler is at proper sampling depth based on drill rod stick-up.
- Use weight of rods to seat sampler to ensure its end is pushed through disturbed material (slough) at the bottom of the hole so that the top of retrieved specimen is firm.
    - If required, a small amount of steady pressure can be applied to push end of sampler through overly soft material in the bottom of the borehole. Do not over-push so that sampler causes a plug of soil below it to disturb the soil below the bottom of the borehole. If excessive force has to be applied to the sampler to get to target depth, then hole has not been sufficiently cleaned out or excessive fall in has occurred. The sampler should not be pushed past the depth that was confirmed using the weighted tape measure. If the soil is weak, it may be necessary to use the rig hoist to prevent the sampler from advancing past the start of the intended sampling zone.

- Record "seating" depth as sampler is pushed gently through any slough at bottom of borehole prior to retrieving a sample.
- Fill the drill rods with mud prior to connecting them to the rig's pumps.
- Ensure that rods are mechanically clamped in place to resist any upward movement of the drill rods during sampling.
- Advance sample tube with the drilling mud using a large capacity pump in a continuous stroke using moderate to high (if required) pressure. Record maximum pressure required.
    - Once the sampler has fully advanced, the drilling mud is able to escape the drill string via vent holes on the side of the sampler body and drilling mud returns should be visible at the surface.
    - At the instant that the sampler reaches full extension, the mud pressure will typically reduce suddenly at the instant when the vent holes become opened.
- With the drill rods mechanically clamped in place, turn off drill rig and leave the sampler in the borehole (at-depth) for a minimum of 5 minutes.
- After at least 5 minutes, rotate the rods/sampler through two full revolutions to shear the soil contact at the bottom of the sampler.
- Slowly remove the sampler and tube from the borehole using the rig hoist, keeping the borehole filled with mud at all times. Avoid contact between the sampler assembly and the casing or sides of the borehole.
    - Keep the sample tube vertical as it is removed from the borehole and detached from drill rods. Place a hand under the tube as it is removed from the borehole and drill rods to prevent slippage inside the tube.
    - If weep holes were pre-drilled in the top of the tube, remove the electrical tape to break the seal.
    - Do not shake or rock the tube back and forth during removal from the sampler. Gently move the tube backwards and forwards to break the suction at the piston interface.
    - Quickly inspect and if possible measure the distance between bottom of the sample tube and bottom of soil inside sample tube. Immediately place plastic cap on bottom of sample tube. If necessary, rags can be placed in the bottom of the sample tube (between soil and bottom cap) to support the soil inside sampling tube with less than 100% recovery. Use electrical tape to secure the caps to the tube after gently wiping the outside of the tube. Keep the sample tube vertical during this entire process.

AFTER SAMPLING

- Record distance of top/bottom of sample from top/bottom of tube and hence the length of the sample and record the percent recovery (i.e., sample length divided by 450 mm as a percentage). Note if surfaces were uneven.
- Weigh tube without any end caps or rags.
- The bottom end of the tube should be inspected to assess suitability of brass vs. stainless steel tubes. Brass tubes will be used unless they are damaged to the point where they no longer retrieve high quality undisturbed samples (e.g., dents, nicks in cutting edge). If stronger tubes are necessary, thin-walled, constant-inside-diameter, smooth stainless steel tubes may be used. Record the area ratio (C_a) of the tubes.
- Sample tubes should be appropriately labelled, and the top and bottom of the sample clearly identified.
- Electrical tape should be used to close weep holes (if used) and the attachment holes.
- After the sample tube has been removed, the sampler should be disassembled and washed in clean water to remove all soil and organic material. The split ring seal should be carefully removed and cleaned as part of this process (do not use sharp tools which can gouge the split ring).

- Anti-seize compound should be applied to all threads.
- Completely dry the sampler prior to storage.

SAMPLE TRANSPORTATION & STORAGE

The approach to sample transportation will vary depending on the type of soils being sampled, the distances over which they are being transported and the expected road conditions.

- Samples of clayey soil should be sealed at both ends using wax, before protecting with plastic end caps.
- Samples of sandy material which may be prone to liquefaction should be fitted with punctured end caps and allowed to drain on site (preferably overnight if a secure location is available) prior to transportation.
- If transporting samples by car, they should be placed vertically in a foam-padded box. Tubes should be secured in a vertical position, with additional padding between tubes. Empty spaces should be filled with additional padding to prevent movement of the tubes during transport.
- The sample box should be transported on a car seat – do not place transport the tubes in a car trunk or the footwell of a car.
- Once in the laboratory, samples should preferably be stored in a wet room, or beneath a tarpaulin with a humidifier.
- If transporting clean sands (<10% Fines Content) significant distances, it may be preferable to freeze the samples prior to transportation. The freezing process should be carried out in a uniaxial manner, freezing from the top down, while allowing the soil samples to continue to drain. Samples should remain in a frozen state until the time of testing. Additional handling procedures will be required to prepare frozen sampling for testing.

SAMPLE EXTRUSION (UNFROZEN SAMPLES)

- Extrusion length should be minimized by cutting tubes to the desired height. Before cutting brass tubes install stiffening rings on the tube above and below the location of the intended cut to prevent temporary distortion of the tube during cutting (Figure 6). When cutting through the tubes, the cutting element should be advanced gradually to avoid unnecessary radial deformations of the tube. Slowly rotate a large-diameter pipe cutter (with a material-appropriate cutting wheel) around the sample tube to cut it. Once the brass tube has been cut all the way around, smoothly slide a wire saw through the tube at the cut location to cut through the soil sample.
- Always extrude the specimen from the tube in the same direction as the soil first entered the tube using a manually-operated hydraulic jack (Figure 6). The upper portion of the exposed sample that is damaged during the deburring operation should be removed using a wire saw.
- Once the desired length has been extruded, the specimen should be cut at the bottom using a wire saw. The specimen should be hand lifted away from the sample tube by gently supporting the specimen over as much of its curved sides as possible, starting at the bottom of the specimen. Capillary stresses in most soils with fines are sufficient to temporarily maintain freestanding specimens.
- Visually inspect the extruded test specimen and record any features which might suggest disturbance to the specimen (e.g., visible cracks, twigs, gravels). Proceed immediately with test specimen preparation protocol, depending on the intended type of testing. Please refer to the guidelines for CTX testing for additional details related to sample preparation and laboratory testing.

REFERENCES

ASTM D6519-08. Standard Practice for Sampling of Soil Using the Hydraulically Operated Stationary Piston Sampler.

Boulanger, R. W., and Idriss, I. M. (2014). CPT and SPT Based Liquefaction Triggering Procedures. Report No. UCD/CGM-14/01, Center for Geotechnical Modeling, Department of Civil and Environmental Engineering, Univ. of California, Davis, CA, 134 pp.

Bray, J.D. and Sancio, R.B. (2006). Assessment of the Liquefaction Susceptibility of Fine-Grained Soils. *J. Geotech. Geoenviron. Eng.*, ASCE, V. 132, 1165-1177.

Hvorslev. M.J. (1949). Subsurface exploration and sampling of soils for civil engineering purposes. Waterways Experiment Station: Vicksburg, Mississippi.

Idriss, I.M. and Boulanger, R.W. (2008). Soil Liquefaction During Earthquakes. EERI Monograph MNO-12.

Markham, C. S. (2015). Response of Liquefiable Sites in the Central Business District of Christchurch, New Zealand. PhD Dissertation. Department of Civil and Environmental Engineering, Univ. of California, Berkeley, Berkeley, CA, 577 pp.

Markham, C.S., Bray, J.D., Riemer, M.F., and Cubrinovski, M. (2016). Characterization of Shallow Soils in the Central Business District of Christchurch, New Zealand. *Geotechnical Testing Journal*, ASTM, accepted for publication May 2016.

Osterberg, J.O. (1952). New Piston-type soil sampler. *Engineering News Record*, April 24, 1952.

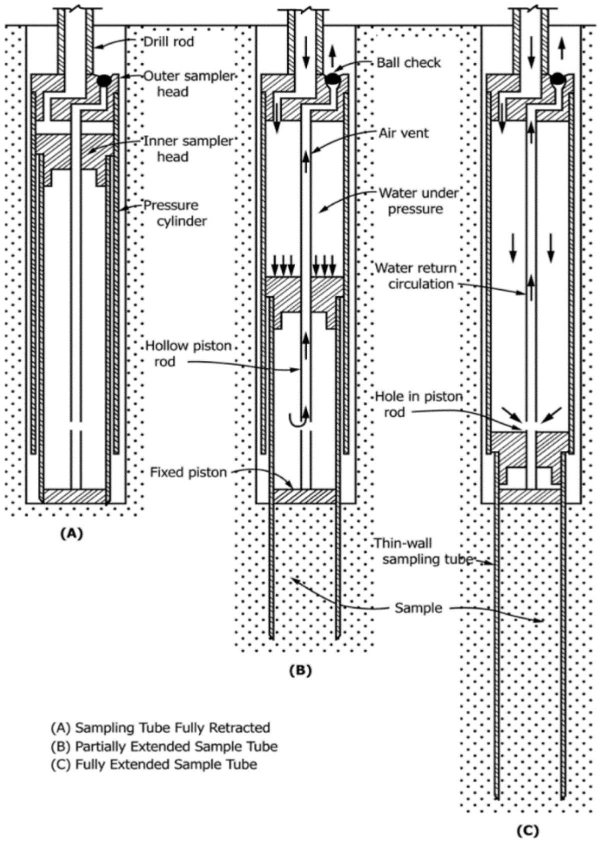

Figure 1: Schematic of hydraulic piston sampler operation using a thin-walled sampling tube (from ASTM D6519-08)

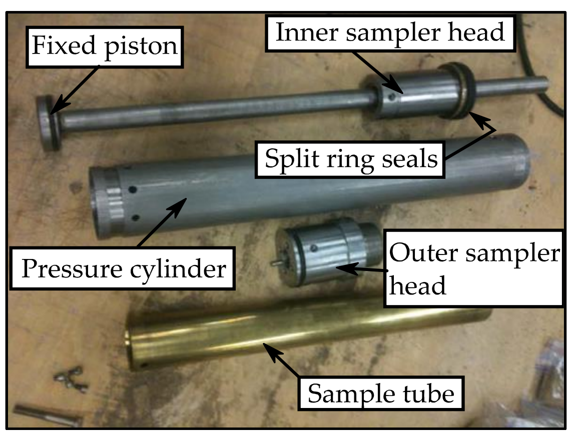

Figure 2: Fully and partially-disassembled DM Hydraulic Fixed-Piston Sampler with brass tube

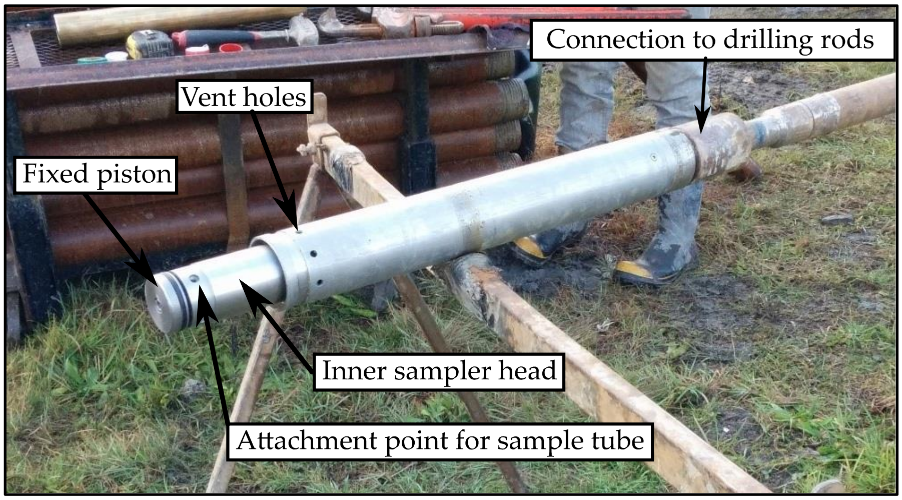

Figure 3. Fully-assembled DM Sampler (shown attached to drill rods, prior to sample tube placement)

Figure 4: Side-discharge tri-cone roller bit

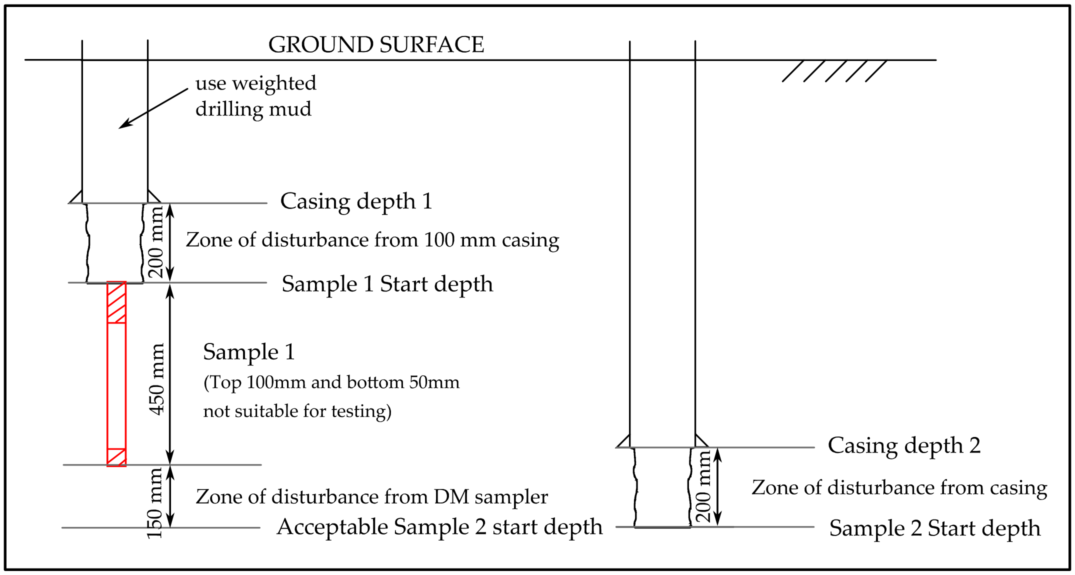

Figure 5: Drilling schematic – casing/sampling depths

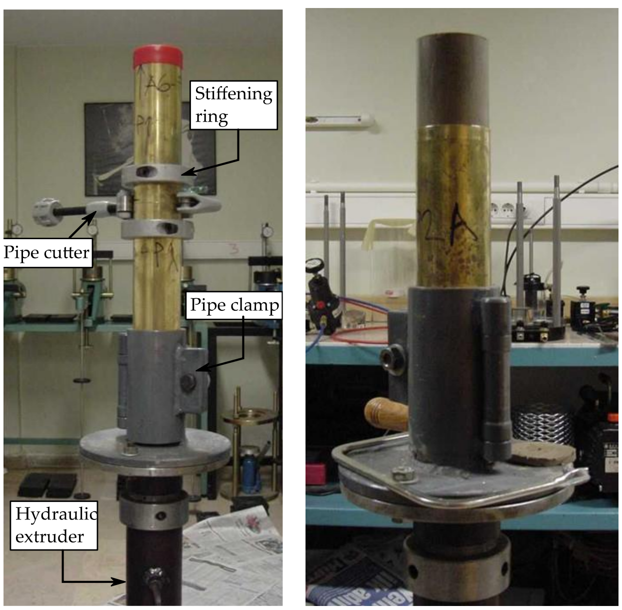

Figure 6: DM sample removal showing stiffening rings with pipe cutter and test specimen extrusion.