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Geotechnical properties of submarine soils, Oslofjorden and vicinity, Norway

by

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(c) Piston Coring with the Torpedo Sampler

(i) Description. This sampler was very briefly described by Andresen and others (1965). Prior to use the core barrel was entirely contained within the body of the sampler (Fig. 10A).

After sampling the corer was raised to the deck of the ship with the barrel protruding from the sampler (Fig. 10B). The external dimensions of the sampler are shown in Figure 11A. A diagrammetric method of operation is given in Figure 11B.

The propulsion units[4] contained three principal components : A time switch to close an electrical circuit (Fig. 11C) activates the igniter (Fig. 11D), which ignites the linear-burning, double.base, nitroglycerin-nitrocellulose, solid rocket propellant in the gas generator (Fig. 11E). The charge of propellant burns like a cigarette in the combustion chamber producing gas at a pressure of 55 atmospheres. This gas passes through an orifice to reduce its pressure to 25-30 atmospheres in the cylinder behind the movable piston, which pushes the sampling tube past a fixed piston (Fig. 11B) and out of the sampler. The gas pressure was self-adjusting to maintain a constant drive stroke because the rate of gas production was proportional to the pressure under which the charge burned. The system was selected so that varying soil resistance on the core barrel regulated the gas pressure by means of a feed-back mechanism. Only about 15 minutes was required to insert a new core barrel and re-arm the corer after the sampler was lowered to the deck of the ship.

(ii) Operation. The 500 kg Torpedo piston sampler was intended to utilize a free-fall release mechanism (Heezen, 1952) to reach the designed depth of 20 m below the water-soil interface (Fig. 13A). It was assumed that the maximum expected shear strength at this depth would be 3 metric tons/m^2 or less. Unfortunately, the winch on the H. U. Sverdrup did not have a level-wind mechanism. Wire wound unevenly on the winch drum and, as a result of the slippage of a loop of wire, a pre-trip of the free-fall mechanism occurred during the initial tests at sea and the corer dropped about 10 m. At the end of this free fall the wire broke and one of the two corers was irretrievably lost. Further use of the free-fall mechanism was discontinued. Subsequent operations were confined to lowering the sampler to about 10 m above the bottom and then varying the speed of the winch, or permitting it to free-wheel, to emplace the corer to the desired depth.

A dynamometer was used to register the approximate tension at the boom caused by the weight of the Torpedo, wire, and pullout force. The maximum pullout tension on the dynamometer for any core was 2600 kg for core OF 35, which was raised from the basin north of Rauøy from a water depth of about 250 m - the deepest water site at which a Torpedo corer was collected.

At the south Dramsfjorden site, where the maximum penetration into the bottom of the Torpedo occurred taking core DF 71, a pullout tension of only 2000 kg was recorded. The maximum pullout tension commonly was about this amount in collecting the Oslofjorden cores. The minimum was about 1400 kg for the Oslofjorden Torpedo sites and

[4] Information on the gas generating system was partly taken from an unpublished internal report written by Mr. J. T. Andresen, The Operation of a Closed Gas Generating system, Norwegian Defense Research Establishment, dated 26 July 1964.

about 1000 kg for the Dramsfjorden site.

All Torpedo operations, except explosives loading, were made under the direction of Mr. Arne Angvik. Mr. J. T. Andresen personally loaded the igniters and propellant charges when the ship was in port at night.

(iii) Penetration Distance. - Two methods were used to determine the depth of penetration by the Torpedo sampler below the water-soil interface during the 1963 Phase Three operations. Mr. Ivar Knoff suggested the use of a hollow metal ball (see Diericks and Hickling, 1967) 20 cm in diameter to serve as an acoustic reflector when attached a fixed distance above the corer by a carefully measured length of pre-stretched manila rope. The usual distance was 6.1 m from the center of the ball to the top of the sampler, and an additional 2.6 m to the top of the extruded core tube. This method was highly successful when used together with the SIMRAD BPS-X. Figure 12A shows the relationship of the reflector, Torpedo sampler, and bottom during the attainment of the deepest penetration at the South Dramsfjorden boring site. When estimating penetration distance the echo sounder was operated with a long pulse length to provide the maximum ease of identification of the corer and reflector; this is why the sub-bottom appears black in this echogram (Fig. 12A).

Figure 12A clearly shows how the corer was deeply emplaced by successive rapid raising and lowering prior to the actual sampling operation that was controlled by the time switch previously described. The echo sounder method was satisfactory for estimating the depth of penetration to about one meter. A refined method was employed for more accurate positioning.

Mr. Knoff adjusted the SIMRAD echo sounder to produce only a single short-pulsed ping upon command. The sub-bottom reflections were attenuated by the time-varied-gain circuit. He displayed the pulse-bottom relationship on a Tektronix 535A oscilloscope. The CRT was photographed on Polaroid type 42 or 47 film using a model C-12 oscilloscope camera. I believe that the positioning accuracy of the method was 0.1 m. Actual penetration distance is based on a sound velocity in water of 1.48 m/ms. A typical photograph of the calibrated cathode ray tube is shown in Figure 12B. At the South Dramsfjorden site, Figure 12C shows the reflector and sampler above the bottom. Only the reflector was located just above the bottom at the point of maximum penetration of the corer at this site (Fig. 12D).

(d) Incremental Sampling and Borings

Hvorslev (1949) cited a requirement for high quality sampling of fine-grained cohesive soils that a maximum safe barrel length should be less than about 20 times the core tube diameter. He added that the disturbance at the ends of piston core would be equivalent to about 3 diameters at the top and 1 diameter at the bottom. These relationships are diagrammatically shown in Figure 13B.

The Torpedo sampler was designed to take a length of core about 31 times the diameter; the actual barrel length was based on the requirement for reuse previously discussed. It was believed this was not an excessive length according to experience obtained using the Institute's 54 mm piston sampler.

Figure 13C shows the method of incremental sampling utilized by the Torpedo sampler. Geotechnical analysis of the piston cores indicated that the worst case of disturbance at the top and bottom of the core (Fig. 13B) was almost exactly that predicted by Hvorslev. Incremental sampling with suitable overlap (Fig. 13C) is a highly satisfactory, but time-consuming and expensive, method of obtaining essentially continuous samples of the highest quality. It was used in water depths to about 400 m.

Table 9 lists the locations of the major boring sites, which usually consisted of a gravity core and one or more piston cores collected using the incremental principle where time permitted.

	Cores in Primary Boring	Duplicate Cores	Cores in Primary Traverse, West to East	Duplicate Cores
Oslofjorden Axis				
East of Slemmestad	19, 21	20		
West of Hvitsten	14, 22-24	15, 16, 18		
East of Mølen	25, 27	26, 28		
North Bastøydjupet	29-32	33	79, 59, 57	78, 58, 56
North Rauøyrenna	34-37	38	45, 48	46, 47
South Rauøyrenna	72		76, 72, 74	
Oslofjorden, Other				
East of Holmestrand	10, 11, 13			
West of Sletter St.	39, 42-44	40-41		
North of Bevøya, Fault Axis	80	81		
North of Kollen, Fault Axis	54, 55	53		
North of Rauøy, Fault Axis	50-52	49		
West of Hanke, Fault Axis	74	73, 75		
Dramsfjorden				
South Dramsfjorden	65-71	60-62, 66		

Table 9. Principal Borings and Traverses

(e) Acoustic Reflection Depth

At only the South Dramsfjorden site was it possible to resolve near-bottom reflectors within the depth below the water-soil interface sampled by the Torpedo corer. (It should be recalled that the BPS-X had not been properly tuned before the SIMRAD personnel were asked to utilize the machine, as previously discussed.) Figure 7N (insert) shows the resolved layers that are listed in Table 10. The correlation with measured mass physical properties within the cores also is given in this table.

Reflection Number	Depth below Bottom, m *	Quality of Reflector in BPS Record	Geotechnical Change Description		Notes
			Grain Size	Water Content	
1	1.5	Weak	No change	Decrease	
2	3.0	Moderate	Decrease	Increase	Clay lumps present
3	4.1	Strong	Decrease	Increase	
4	12.8	Moderate			No core
5	14.0	Strong			No core

*Assuming sound speed of 1.5 m/ms. Depths given are approximate, having an estimated error of ± 5% of the given depth.

Table 10. Sonic Log of South Dramsfjorden Boring

(f) Sampling Data and Locations

All cores collected during the Project are listed in Table 11, in which the 1.7 m core tube length refers to the length below the attachment point (Fig. 16). All tubes were actually 1.8, not 1.7 m long. The difference being the attachment length of 0.1 m. The core length was measured in the laboratory. The geotechnical analysists were Ola Bruskeland and Adrian Richards, whose initials appear in Table 11. Almost every core was collected in duplicate. Most of the duplicate cores and a few of the primary cores of lesser importance were geotechnically analyzed by Mr. Bruskeland who also assisted in the analyses of some of the primary cores.

Locations (Table 11) of both gravity and piston cores were chosen after completion of the bathymetric and sub-bottom-profiling surveys. The most typical sites were selected from the results of these surveys, with particular regard to choosing locations at which underlying layers appeared to be within sampling depth. Each major basin (Table 4) was sampled and one or more traverses of gravity cores were made across most basins. The charted position of each core raised by the Project is given in Figure 14. In this figure, it should be noted that cores OF 35 and OF 36 probably were raised slightly to the west of their charted position.

Duplicate surface gravity-type cores were raised as closely as possible from the same geographic location. Most of the Torpedo piston cores at a boring site were raised when the ship was at anchor to minimize drift. The actual horizontal distance and azimuth the ship moved from any one core site to the next has not been determined. An estimate can be obtained from Figure 14 and Table 11. It must be kept in mind in the interpretation of the presented core data that duplicate cores and all cores in a given boring were not collected at identical geographic locations.

(g) Core Sealing and Transportation

All cores were handled as carefully as possible to reduce post-sampling disturbance.

The gravity cores were capped with a heavy-duty rubber cap and kept upright until the ends were waxed. The piston cores were removed from the Torpedo sampler when it was horizontal on the deck of the ship. The ends of the core tube were capped and stored in the ship's laboratory until the evening.

At the end of each day's sampling, beginning when the ship was returning to port for the night, first the top of the core tube and then the bottom of the core tube was waxed by Mr. Arne Angvik and his assistants to prevent movement of the soil during shipment by truck to the NGI. A very few of the gravity cores were not waxed, for example, core OF 84. These were very carefully transported to the Institute in a vertical position.

3. LABORATORY METHODS AND DATA

Core Storage and Extrusion

At the Institute, the cores were stored vertically at a temperature of about 9°C in the high humidity core storage locker. The time period in storage can be estimated by deducting about two weeks from the total number of days between the date the core was collected and the date it was extruded (Table 11).

The cores were tested in a vertical position. A make-shift core extruder,designed by NGI engineers, was constructed of wood and bolted to a bench in one corner of the geotechnical laboratory. The core tube was clamped into the device (Fig. 15A) and the core extruded by mechanically pushing a rubber stopper, having essentially the same diameter as that of the core tube, into the tube from the bottom (Fig. 15B) towards the top. Most cores were completely extruded by a single analyst in one long working day.

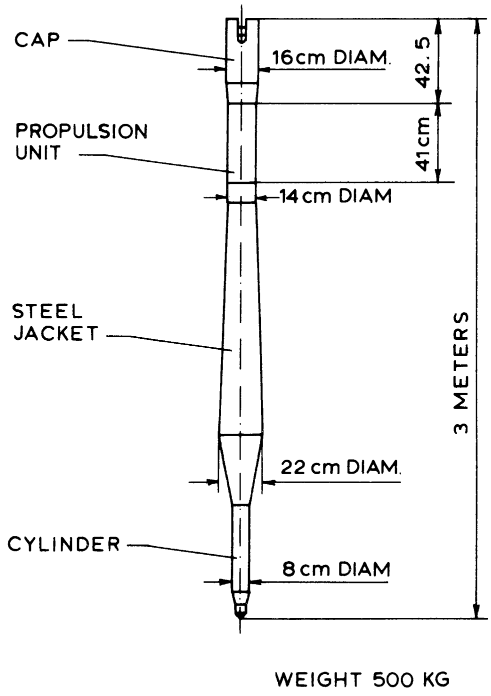
A basic testing interval of 0.1 m was selected. The approximate location within each core of all tests and analyses is shown in Figure 16. This figure also shows the relationship of a piston core having a length of 1.6 m contained within a piston core tube 1.8 m long.

Core Log, Color, and Specific Gravity

A symbolic method was developed to show the type of test and other information related to depth in the core for display in the log of the core. Abbreviations and symbols are listed in Table 12. The log description accompanies each Phase 3 core geotechnically investigated (Figs. 28A-28W).

Color information was taken at the surface of each 0.1 m test interval from a comparison of a smear of the soil on a spatula placed next to a Munsell color chip in the standard rock color chart prepared by The Rock-Color Chart Committee, E. N. Goddard Chairman, that is distributed by the Geological Society of America. The common Munsell colors were all grays: medium (N6), medium dark (N5), dark (N3-4), brownish (5YR 4/1), olive (5Y 4/1 or, occasionally, 5Y 3/2), and dark greenish (5GY 4/1, most commonly, to 5G 4/1, occasionally).

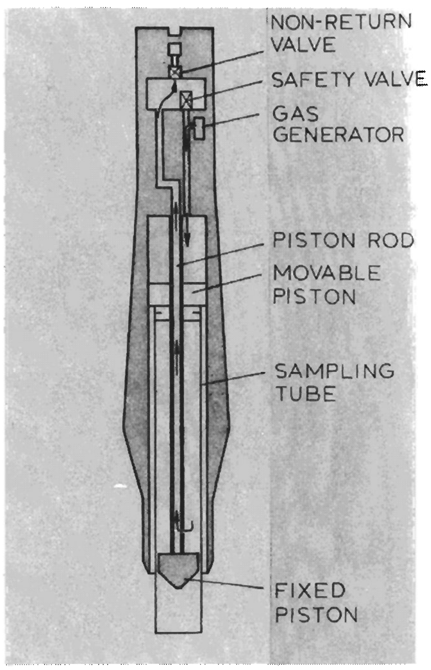
FIG. 11 A.



Components of Torpedo corer propulsion unit.

External dimensions of corer to scale.

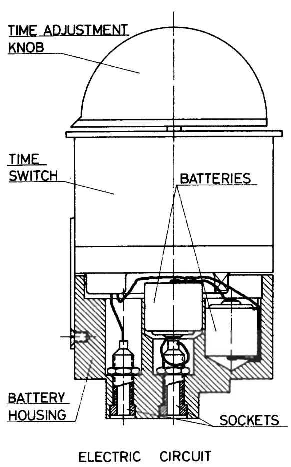
FIG. 11 B.



Components of Torpedo corer propulsion unit.

Diagrammatic view of internal parts showing flow of gas during operation. Not to scale.

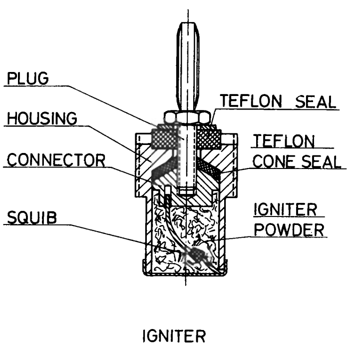
FIG. 11 C.



Components of Torpedo corer propulsion unit.

Arrangement of electrical circuit

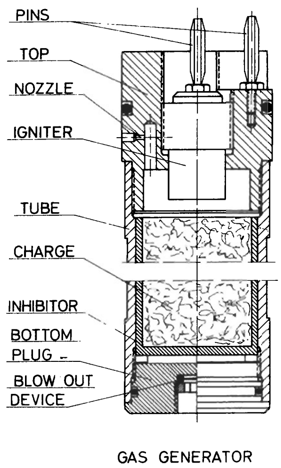
FIG. 11 D.



Components of Torpedo corer propulsion unit.

Arrangement of igniter, which fits within the gas generator.

FIG. 11 E.



Components of Torpedo corer propulsion unit.

Arrangement of gas generator.