XII. SOME PHYSICAL PROPERTIES OF THE BOTTOM SEDIMENTS

Katsuya Tsurusaki and Toyohiko Hirota

Introduction

Some physical properties of the bottom sediments were measured on board for the purpose of obtaining data for manganese nodule mining. The measured properties were water content, vane shear strength, and cone penetrating resistance. Water content and vane shear strength were measured on 26 grab samples and 8 core samples, while cone penetrating resistance was measured on 16 grab samples and 8 core samples.

Some other physical and engineering properties such as specific gravity, grain size distribution, consistency, direct shear strength, and so on will be examined on the laboratory on land.

In this article the measuring method used on board and the results taken on board are described.

Instruments

To calculate the water content of sediment the dry and wet sample weight must be measured. The electrical weighing method was applied in order to remove the effects of vibration and sway of the ship. The instruments are composed of a small electrical load cell (cap. 1 kg), amplifier, electrical filter, and pen recorder. After two minutes recording the mean value was adopted as the sample weight.

The vane test has the advantage of ease of operation and the results most closely

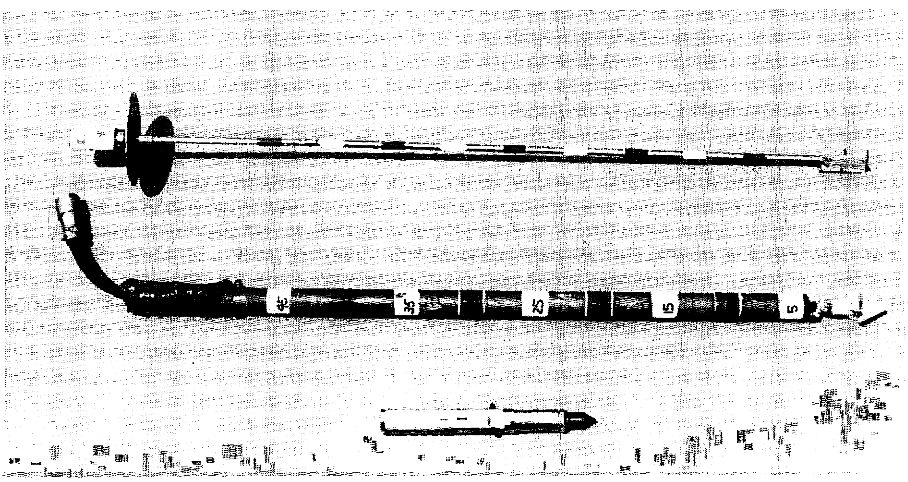

Fig. XII-1 Vane tester (upper figure), electrical cone tester (middle figure), and spring cone tester (lower figure).

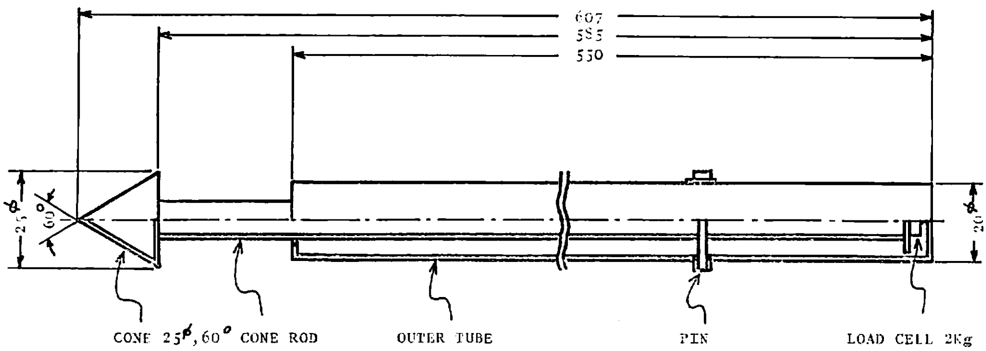

Fig. XII-2 Construction of electrical cone tester.

represent the undrain shear strength of the sediment. A small portable vane tester, shown in Fig. XII-1, was applied for measuring. It is a manually operated device using a torsional calibrated spring. The four blades were 4 cm in height and 2 cm in diameter and the length of the rod was 55 cm. The capacity of the torsional spring was 2 kg· cm. The vane tester was rotated by hand at a rate of about 2 rpm.

For measuring of cone penetrating resistance two types of cone testers (Fig. XII-1) were applied. One was for grab samples and the other for core samples. The former consisted of a penetrating cone, cone rod, miniature strain gauge type load cell, and loose pin (Fig. XII-2). It was designed with another tube to ignore the side friction which had an influence on the penetrating force. The angle of the cone is 60° and the diameter 2.5 cm. The length is 50 cm and the capacity 400 g/cm^2. The penetrating resistance is recorded on a pen recorder through a strain amplifier. A push button switch was set near the cone tester to indicate the penetrating depth on the record. The latter consisted essentially of the cone and calibrated compressive spring. The cone head is changeable with one of a different diameter of 1 cm, 2.5 cm, and 4 cm. The capacity of the spring is 600 g. Both cone testers were penetrated by hand with the rate of about 1 cm/sec.

Measuring procedure for grab samples

The Ocean-70 grab sampler was applied to obtain undisturbed samples of deep sea floor surface. Immediately after the Okean grab was recovered onto the deck photographs were taken to record the manganese nodules on the sediment surface and the temperature of the sediment was measured. The manganese nodules were then observed and described.

After removing the manganese nodules the vane tester was penetrated into the sediments. At first the upper end of the blades of the vane tester were kept at the surface of the sediments and the tester was rotated in order to measure the surficial shear strength. The shear strength was calculated from the maximum torque value through the following equation.

$$Sv = Tm/\left(\frac{\pi D^2 H}{2} + \frac{\pi D^3}{12}\right)$$

where Sv: Vane shear strength
Tm: Maximum torque value
D: Vane diameter
H: Vane height

Then, the blades were penetrated deeper into the sediments and at every 5 cm of penetration the inner vane shear torque was measured, and the shear strength was calculated through the following equation.

$$Sv = Tm/\left(\frac{\pi D^2 H}{2} + \frac{\pi D^3}{6}\right)$$

After measuring the vane shear strength the electrical cone tester was penetrated with the penetrating rate of about 1 cm/sec into the sediments near the vane tested point. The cone penetrating force was recorded continuously on the pen recorder and the pulse signal which was produced by pushing the button switch was also recorded at every 5 cm penetration for the reference of analysis. The penetrating resistance was the amount of penetrating force divided by the area of cone.

After those measurements a two-split thin wall tube, 5 cm in diameter, was pushed into the sediments and a cylindrical sample was resampled from the grab sample. Immediately after the cylindrical sample was carried into the wet laboratory on board, 2 cm thick sample cakes were taken from every several centimeters depth. From the cake small amount of sediments were picked up and sealed in a small phial for laboratory tests on land. The rest of the cake was used for measurement of its wet weight. After 24 hours drying under 105°C the dry weight was measured. The water content was calculated through the following equation.

$$W = \frac{Ww - Wd}{Wd} \times 100\ (\%)$$

where W: water content
Ww: wet weight
Wd: dry weight

Measuring procedure for core samples

After the piston corer was recovered onto the deck the core sample in the split inner tube which was coupled by cohesive tape was removed from the core barrel. Then the core sample was longitudinally split into two parts with a sharp core knife and was cut every 10 cm perpendicular to the axis. Because five kinds of studies such as pore water analysis, paleomagnetic investigation, etc. were to be completed on a core sample, the physical property tests were conducted every 50 cm. The diameter of the core sample was so small that the blades of the vane tester penetrated as deep as half their height. The vane shear strength was calculated through the following equation.

$$Sv = Tm/\left(\frac{\pi D^2 H}{4} + \frac{\pi D^3}{12}\right)$$

For measuring of the cone penetrating resistance the spring type cone tester, shown in Fig. XII-1, was penetrated into the cutting surface. 1 cm dia. and 2.5 cm dia. cone heads were mainly used. Following the vane and cone tests, 2 cm thick semicylindrical cakes were taken from the same parts for the measurement of the water content.

Results

Most of the grab samples were relatively undisturbed except at the very surface around the driving wire rope, inner wall side, and bottom in the Ocean grab. Therefore the vane and cone tests were conducted at the central part where evidence of surficial disturbance was least. The results of these tests are therefore considered to be fairly reasonable. The core samples were also undisturbed and the vane and cone tests were conducted on the splitting surface perpendicular to the core axis.

The results of measurement on every sample are shown in Figs. XII-3 in Chapter X, together with the other properties of the sediment. They suggest that as a general trend. water content decreases and the vane shear strength and cone penetrating resistance increase with an increase of sediment depth and that the physical properties can clearly indicate differences of sediment type. For example. the figure on the sample from St. 405

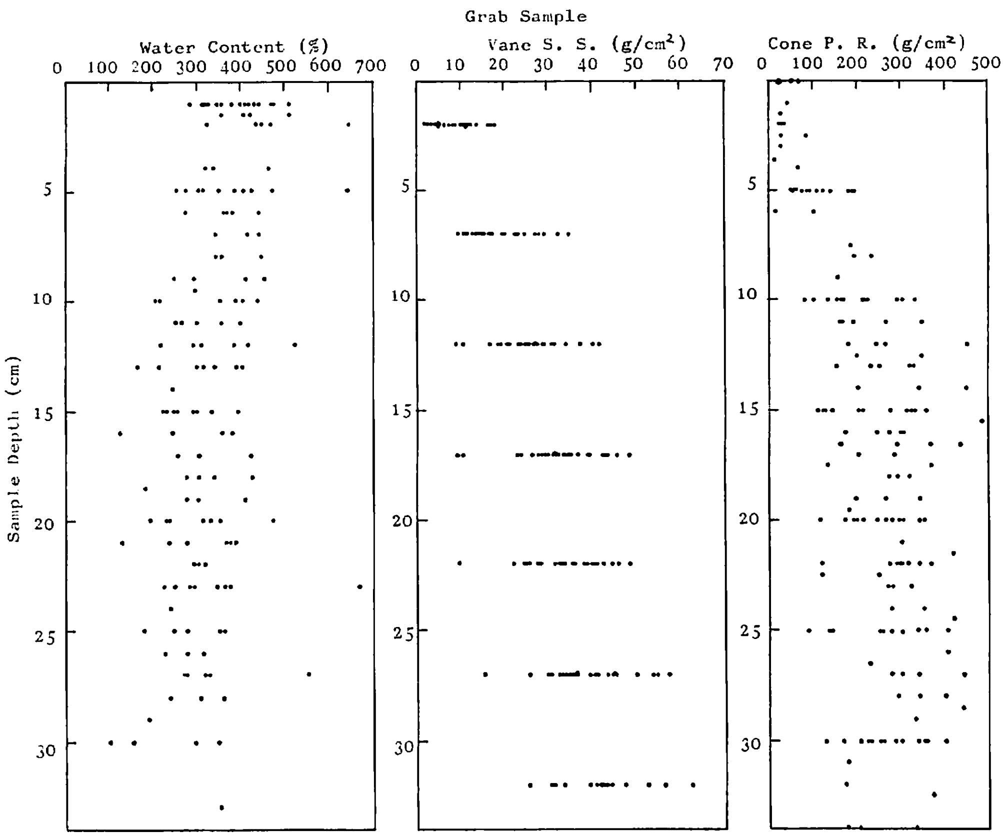

Fig. XII-3 Relationships between physical properties and sample columns of grab sample.

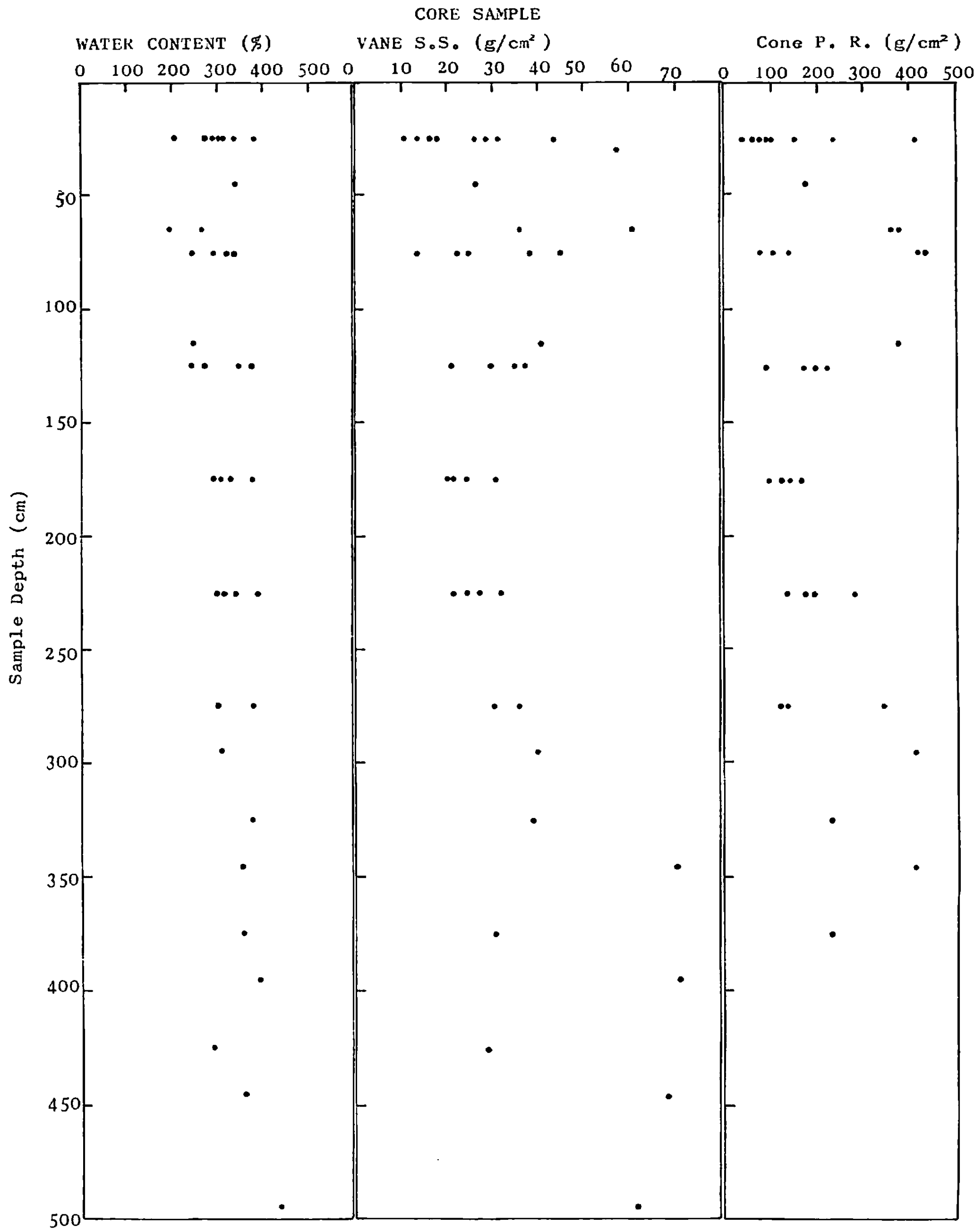

Fig. XII-4 Relationships between physical properties and sample columns of core sample.

(Fig. X-4 p. 106) shows that the surficial 10 cm part of the sample at the station is composed of siliceous clay, but the lower part is replaced by clay. The water content of this sample is around 450 % in the top 10 cm of the column, while it rapidly decreases downwards to less than 200 %. The cone penetrating resistance increases from 50 g/cm^2 to 200 g/cm^2 within the surficial 10 cm part and it keeps almost a constant value at the lower horizon. Thus the physical properties seem to indicate the difference of sediment type.

It is also suggested that the water content has a generally negative relationship with the vane shear strength and cone penetrating resistance.

The statistical relationship between the physical properties and sample column of the grab samples is shown in Fig. XII-3 and those of the core samples are shown in Fig. XII-4.

From the results the following facts become clear.

1) Water content at the very surface ranges from 300 % to 500 %, while it ranges from 150 % to 300 % in the part deeper than 20 cm. In the surficial 20 cm it clearly decreases down the sample columns, but there is no such clear tendency in the deeper part of several meters.

2) The vane shear strength increases linearly downwards within the sample columns. It ranges from 0 g/cm^2 to 20 g/cm^2 at very surface and from 30 g/cm^2 to 60 g/cm^2 at depth of 20 cm.

3) The cone penetrating resistance increases rapidly down the columns to a depth of 15 cm. It ranges from 0 g/cm^2 to 100 g/cm^2 at the surface and from 200 g/cm^2 to 350 g/cm^2 in parts lower than 15 cm. There is no such clear tendency in the lower part.

The relationships between other physical properties and the sediment column, between the sediment type and physical properties, and between each of the physical properties are not mentioned here. They are now under investigation, and the results shall be published elsewhere.