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TECHNICAL REPORT

A COMPARISON OF ATTERBERG AND RIGIDENSE TESTS FOR THE MEASURE OF PLASTICITY

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ABSTRACT

A brief discussion is given of the Atterberg liquid and plastic limit test as compared to the Rigidense method of determining strength of bottom sediments. The relative merits of both methods are discussed. The U.S. Navy Hydrographic Office has adopted the Rigidense test as standard laboratory procedure.

FOREWORD

Elasticity is one of the properties of bottom sediments having an important bearing upon resistance to penetration. The measurement of plasticity is not a well-standardized procedure. Although both Atterberg and Rigidense tests are methods of quantitative measurement, the Rigidense method provides the more rapid analysis. This report describes both methods and compares the relative merits of each.

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A COMPARISON OF ATTERBERG AND RIGIDENSE TESTS FOR THE MEASURE OF PLASTICITY

I. Introduction

Plasticity is one of the properties of bottom sediments having an important bearing upon resistance to penetration. However, the measurement of plasticity is not a well-standardized procedure. It is usually reported qualitatively as high, medium, or low, and quantitatively as Atterberg limits (liquid and plastic). Recently the Chesapeake Bay Institute suggested a device (the Rigidense instrument) that indirectly would measure plasticity much more rapidly than the Atterberg test. The purpose of this investigation is to determine the relative merits of both tests.

II. Instrument Descriptions and Operations

The Atterberg liquid limit (LL) is a measure of the water content of a sediment at the boundary between the plastic state and the semiliquid state, whereas the Atterberg plastic limit (PL) is a measure of the water content of a sediment at the boundary between the plastic state and the semisolid state (fig. 1). The liquid and plastic limits

Figure 1. Schematic diagram indicating liquid and plastic limits

(Atterberg) are determined from that portion of the sediment fraction passing through the No. 40 (420 micron) sieve. The water content or moisture content is expressed as a percentage of the oven-dried weight of the sediment ($\frac{\text{Wt. of water}}{\text{Wt. of oven-dried sediment}} \times 100$).

LIQUID LIMIT DEVICE

CASAGRANDE GROOVING TOOL

FIGURE 2. LIQUID LIMIT DEVICE AND GROOVING TOOL

In the comparison of Atterberg and Rigidense tests the Atterberg liquid limit¹ was determined by using a liquid limit device. This instrument consists essentially of a brass cup, crank and cam mechanism, and carriage mounted on a hard rubber base (fig. 2). A standard grooving tool, made of 1/16 inch steel and having a cylindrical portion on the handle end, is also an essential part of the instrument. The cylindrical portion which serves to adjust the drop of the cup, has a diameter of 1 cm. A sediment sample of approximately 100 grams is placed in the brass cup and spread to form a smooth cake about 1/2 inch deep in the lower half of the cup (fig. 3). The sediment is then

Figure 3. Schematic diagram illustrating the sediment arrangement in cup prior to grooving

grooved and the instrument adjusted to permit a 1-cm. drop of the cup. The crank is turned, alternately lifting and allowing the cup to drop at the rate of 2 drops per second.

A "flow curve" representing the relation between the moisture contents and corresponding number of shocks required to make the two sides of the sample flow together for 1/2 inch along the bottom of the groove (fig. 4) are plotted on semilogarithmic paper (fig. 5). A minimum of three trials are performed on each sediment. The moisture content corresponding to the intersection of the flow curve and the 25-shock ordinate is taken as the liquid limit of the sediment sample.

¹ A more detailed description of this test procedure can be found in "Standard Specifications for Highway Materials and Methods of Sampling and Testing. Part II. Methods of Sampling and Testing." The American Association of State Highway Officials. 1947. pp. 198-291.

Figure 4. Schematic diagram illustrating the condition of a sample before and after the liquid limit test

Figure 5. Flow curve to determine liquid limit

The Atterberg plastic limit² (PL) is determined as the lowest water content at which a sediment sample of approximately 15 grams can be rolled to form a 1/8-inch thread of sediment without cracking, crumbling, or breaking into pieces (fig. 6). A sediment which cannot be rolled into a thread is recorded as nonplastic.

Figure 6. Schematic diagram illustrating a 15-gram sediment sample above and below the plastic limit

The Rigidense instrument is designed especially for use on sediment cores and consists essentially of a metal base and vertical bar, a hinged brass sample container, an adjustable brass base to support the container, and a steel-tipped aluminum cone with a vertex angle of 37 degrees fitted to the base of a lead penetrometer weight with attached millimeter scale (fig. 7). To determine the rigidense value of a sample, the cup is filled with a section of a core and placed on the adjustable base which is then raised until the penetrometer point just touches the surface of the core section. The penetrometer is then released, by pressing the penetrometer spring release, and allowed to settle for 2 minutes at which time a reading is taken. The critical features of the instrument are the total weight of the lead penetrometer, cone, and scale which must total 435 grams, and the vertex angle of the cone which must be 37 degrees.

III. Results

Seven sediment types were selected for this investigation. Each sample was analyzed for rigidense, Atterberg limits, water content, and the percent of sand, silt, and clay. The water content of each sample was varied three times and ten rigidense measurements made for each variation. A total of 230 rigidense measurements were made. For a given sample, the reproducibility of this test was within 10 percent. Only five of the seven sediment types contained a sufficient amount of material in the less than 420-micron range to perform Atterberg limit tests. Approximately 100 determinations were made on these five sediments. Reproducibility for the Atterberg tests generally was not within 20 percent.

² Ibid., pp. 202-203

FIGURE 7. RIGIDENSE INSTRUMENT

IV. Conclusions

The relative merits of both tests are compared below.

Factor	Rigidense	Atterberg
Applicability	Applies to total sample	Applies only to that portion of sample with grain size 420 microns
	Applies only to samples taken with coring devices	Applies to samples taken with any type sampling device.
	Applies to samples with natural water content retained (for valid interpretation)	Applies to all samples (water content may be varied)
Controllability	Less difficult	More difficult
Reproducibility	More accurate	Less accurate
Speed	Fast	Slow

Emphasis may be placed on the fact that the rigidense test applies to the total sample and as such is a more accurate measure of the compaction and bearing capacity of the sediment. On the other hand the primary shortcomings of the rigidense test are its dependence upon a sediment sample having natural water content for valid interpretation of test data and the fact that it may be applied only to cores. This investigation does not deal with the underlying causes for the results obtained. To do so would require a prohibitive number of man-hours and extremely elaborate equipment. Instead, an attempt was made to determine whether the faster rigidense method could replace the cumbersome Atterberg tests. It is well to remember that there is probably no substitute for an in situ measure of plasticity or penetration. However, at the present time no device for making such a measurement exists. Therefore, it is concluded that, as a relative measure of plasticity and penetration in the laboratory, the rigidense test is adequate and superior to the Atterberg tests. Samples which do not have natural water contents should be run through a range of rigidense measurements varying from low to high water content. Rigidense core analysis has been made a standard laboratory procedure at the Hydrographic Office.

It remains for a future investigation to determine what the relationship is between any laboratory measure of penetration and the actual penetration of static or dynamic loads placed on the ocean bottom.

U. S. Navy Hydrographic Office

1. Aterberg Test
2. Rigidity Test
3. Plasticity - Gilbert Jaffe and Frank W. Gaetano. April 1955. 7 p.
4. Submarine geology (H. O. TR-11)

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