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Effect of Testing Device Calibration on Liquid Limit Assessment

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Abstract**—**Liquid limit, which is used as a measure of soil strength, can be detected by Casagrande and fall-cone testing methods. The two methods majorly diverge from each other in terms of operator dependency. The Casagrande method that is applied according to ASTM D4318-17 standards may give misleading results, especially if the calibration process is not performed well. In this study, to reveal the effect of calibration for drop height and amount of soil paste placement in the Casagrande cup, a series of tests were carried out by multipoint method as it is specified in the ASTM standards. The tests include the combination of 6 mm, 8 mm, 10 mm, and 12 mm drop heights and under-filled, half-filled, and full-filled Casagrande cups by kaolin samples. It was observed that during successive tests, the drop height of the cup deteriorated; hence the device was recalibrated before and after each test to provide the accuracy of the results. Besides, the tests by under-filled and full-filled samples for higher drop heights revealed lower liquid limit values than the lower drop heights revealed. For the half-filled samples, it was clearly seen that the liquid limit values did not change at all as the drop height increased, and this explains the function of standard specifications.

Keywords**—**Calibration, Casagrande cup method, drop height, kaolin, liquid limit, placing form.

I. Introduction

IN geotechnical engineering, the soils are firstly classified according to their index properties and then analyzed for the strength parameters. For fine-grained soils, consistency limits are used to determine the water holding capacity between the solid, plastic, and liquid states of material. They were firstly determined by Atterberg [1] and later developed by Terzaghi [2], [3] and Casagrande [4], [5] for use of civil engineering applications. The consistency of soils is defined by shrinkage, liquid, and plastic limits. Due to mineralogical properties of clay and silt type soils, they have the potential to expand and shrink by holding the water inside their structures and losing it, respectively [6], [7]. Hence, liquid limit and plastic limit of soils should be determined well to detect the strength properties. In this study, testing procedure of liquid limit assessment by Casagrande method was evaluated and effect of testing device calibration was investigated.

Liquid limit assessment can be carried out by both Casagrande cup [5] and fall-cone [8] tests which are specified in AASHTO T89-13 [9] and ASTM D4318-17 [10] as standard measurement methods. Whereas the liquid limit attained by Casagrande cup method depends on the performance of operator, the fall-cone method presents more objective results using a digital test equipment. By the previous studies, liquid limit values obtained by each method diverge from each other. Sivapullaiah and Sridharan [11] studied on soil mixtures including bentonite, kaolinite, and sand of coarse grained, fine grained, rounded, and angular shaped grains by both Casagrande cup and fall-cone methods. The liquid limits obtained by fall-cone method were observed less than the ones obtained by Casagrande cup method. Kollaros [12] investigated the variation in liquid limit of high plastic soils stabilized by lime. The liquid limit of lime stabilized soil was obtained less for fall-cone method than the Casagrande cup method. Üyetürk and Huvaj [13] studied the performance of one-point Casagrande cup method and concluded that it has differed from the multi-point method with a rate of 2% which is proposed as an alternative for liquid limit determination. Karakan and Demir [14] investigated the liquid limit of different rated sand-clay mixtures by both Casagrande cup and fall-cone methods. They stated that liquid limit was obtained higher for high plastic clay-sand mixtures by Casagrande cup method, and it was obtained lower for low plastic clay-sand mixtures compared to fall-cone method for both. Niazi et al. [15] compared the liquid limit of 65 different soil samples by fall-cone and Casagrande cup method concluding that fall-cone method performed better for the determination of liquid limits than Casagrande cup method. According to the study of Jain et al. [16], Casagrande cup method yielded higher liquid limits for high plastic clays and lower liquid limits for low plastic clays when compared with the liquid limits obtained by fall-cone method. Karakan [17] used the fall-cone and Casagrande cup methods to investigate the relationship between liquid limit activity and clay fraction. It appears that each method has its own advantages; though the Casagrande cup method is widely preferable in many regions, the fall-cone method has been adopted as the main method for some regions as well [18]. However, for both methods, the calibration of the device is one of the major parameters affecting the liquid limits. Altıntas [19] investigated the penetration effect of different shaped, angled and weighed cones on high and low plastic clays for the liquid limit assessment by fall-cone test. Crevelin and Bicalho [20] studied the liquid limit assessment of different type clays by both fall-cone and Casagrande cup methods. They dropped the Casagrande percussion cup on the hard and soft base to see how the liquid limit values are affected. Considering the popular usage of the Casagrande cup method and calibration effect on

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the liquid limits, it is intended to investigate about the operator dependency of testing. For this purpose, the percussion cup was operated with four drop heights with under-filled, half-filled, and full-filled samples to reveal the variation in liquid limits.

II. Materials and Methods

To observe the calibration effect of Casagrande percussion cup on the liquid limits, it is preferred to study on a single soil type. The soil sample is originated from Ankara Province of Turkey, white in color and defined as low plasticity silt (i.e., ML) according to the Unified Soil Classification System (USCS) by the consistency limits obtained by the tests as specified in ASTM-D4318. The ML type soil sample includes 90% kaolin mineral as analyzed by XRD (X-Ray diffraction) method.

The multipoint liquid limit tests were carried out by Casagrande cup method depending on the ASTM-D4318-17 specifications. According to wet preparation method at least 200 gr of soil sample is sieved through ASTM No.40 sieve and mixed with distilled water until a homogeneous soil paste is obtained. The soil paste is kept in an airtight container for 24 hours in the room temperature to achieve the soil to be moistened well. Before placing the soil paste in the percussion cup, the Casagrande device is calibrated by means of drop height. The specifications recommend adjusting the cup to be dropped from 10 mm height filled with the portion of sample which is 10 mm thick in the deepest point of cup. As given in Fig. 1, the height of the point where the cup contacts the base in each drop is set to 10 mm by a height gauge.

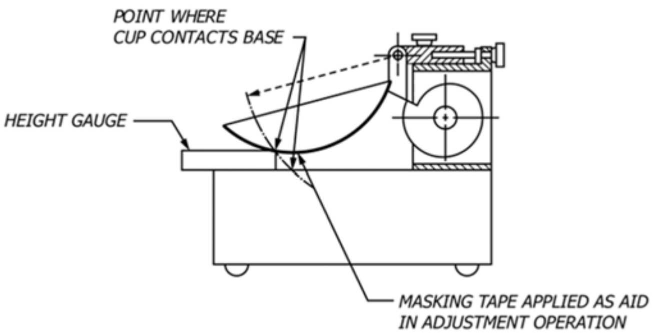

Fig. 1 Drop height calibration of the Casagrande cup by ASTM-D4318-17

The percussion cup should be nearly half full of the soil paste which has 10 mm height in the deepest point of the cup. The surface of the soil paste is formed to be parallel to the base of the device and then the paste is cut by the standard grooving tool by drawing a hyperbolic opening along the soil paste in one stroke. The crank of the Casagrande device is turned at a rate of two drops per second until the opening at the bottom of the cup is closed along a 13 mm line. The number of drops is counted until the opening is closed in each cycle. By increasing the water content of the soil paste, the test is repeated at least three times which enables to draw the liquid limit line. The data points are drawn on a semi-logarithmic coordinate system where the number of drops as the abscissas and water content as the ordinates. By intersecting the best-fitting line passing through these data points with the drop number of 25 on the x-axis, the liquid limit is defined as the water content on the y-axis. The test procedure is repeated on the same soil sample by changing the drop heights and amount of sample in the percussion cup by the stages of ASTM-D4318-17 followed in this study.

III. Experimental Studies

In the Casagrande cup method, the non-standard drop height adjustment and imprecise placing form of the soil paste in the percussion cup may cause to misleading results. Besides, the successive drop of percussion cup may yield distortions in the calibration of device as well. The motivation for the study arose at this point; multiple effects for the device calibration were tested by different combinations in the scope of this study. A series of liquid limit tests were carried out to investigate the effect of both drop height of percussion cup in each stroke on the base of device and amount of soil paste placed in the cup. For this intend, a total number of 12 combinations were tested by four different drop heights of the percussion cup as 6 mm, 8 mm, 10 mm, and 12 mm and three placing forms in the cup as under-filled, half-filled and full-filled.

For drop height adjustment of the percussion cup by 6 mm, 8 mm, 10 mm, and 12 mm, a digital caliper ruler was used manually (Fig. 2). The soil sample is moistened to form the soil paste and the soil paste is placed in the percussion cup by different filling types as under-filled, half-filled and full-filled as given in Figs. 3 (a), (b), and (c), respectively for the tests.

Fig. 2 Drop height calibration of the Casagrande device by a digital gauge

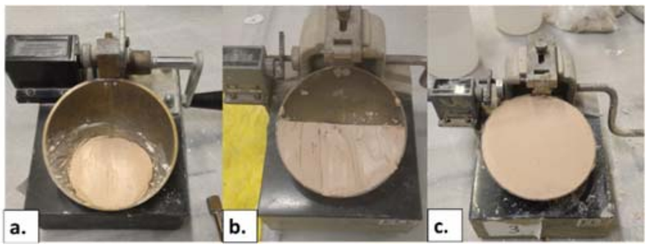

Fig. 3 Placement form of soil paste in the Casagrande cup: (a) under-filled, (b) half-filled, (c) full-filled

An opening is formed in the soil paste by the standard grooving tool (Figs. 4 (a)-(c)) and the percussion cup is dropped from different heights at a certain frequency until the groove is closed at the bottom of the cup along a 13 mm line (Figs. 5 (a)-(c)). The specimens are collected to determine the water content from both side of the closed groove covering a rectangular area as shown in Fig. 5.

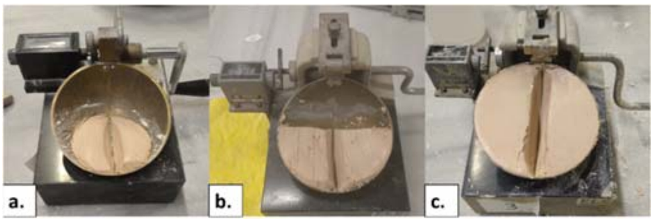

Fig. 4 Grooved soil paste for each placement form in the Casagrande cup: (a) under-filled, (b) half-filled, (c) full-filled

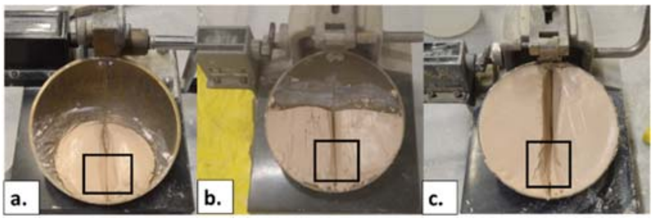

Fig. 5 Closed groove in the soil paste by the effect of strokes for each placement form: (a) under-filled, (b) half-filled, (c) full-filled

In the first set of experiments, the water content of the soil sample should be arranged to achieve a total stroke number higher than 25 to provide a closure in the groove. Attention must be paid on how much water should be added to the soil paste depending on the amount of soil sample (i.e., filling form) in the cup. The closure of the groove during strokes is directly related to water content of the soil sample, filling form and height of the cup. The samples of under-filled cups should be more wet than the samples of full-filled cups for the closure of gap in the first set of strokes. By the self-weight of sample and effect of gravity, the groove was closed more easily for full-filled cups at even below 25 strokes. As it comes to under-filled cups, the groove was closed at drop numbers above 80 for 6 mm drop height even though sufficient water was added to the soil sample.

When placing forms are evaluated, the application of half-filled form to the brass cup is easier than the other placing forms. More effort is needed to make the soil surface plain and to prepare enough homogenized and moistened sample for the full-filled cup. Besides, the water content should be higher for the soil pastes of under-filled cups, which makes it difficult to apply the sample to the brass bowl.

Another significant parameter affecting the closure of groove in soil specimen is the drop height of the percussion cup. The higher drop distance causes fast closure of the groove by less number of strokes. The flow lines are presented for under-filled, half-filled and full-filled cups including the results of four different drop heights (DH) separately in Figs. 6-8, respectively.

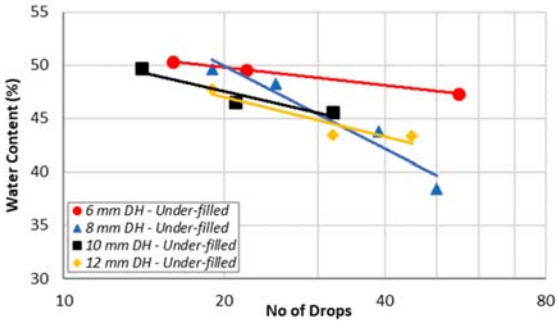

Fig. 6 Flow lines for the under-filled cups by different DH

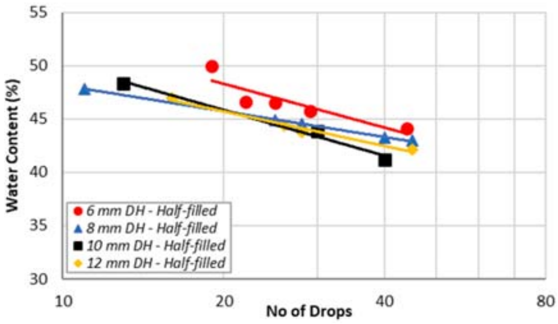

Fig. 7 Flow lines for the half-filled cups by different DH

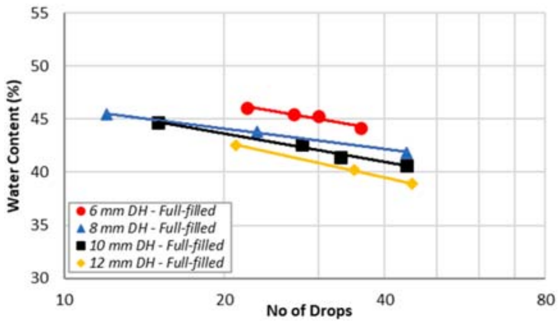

Fig. 8 Flow lines for the full-filled cups by different DH

The water contents intersecting the flow lines at 25 drops were noted as liquid limits (Table I). According to Figs. 6-8, as the placing form of cup switched to full-filled, the flow lines revealed lower liquid limits. Table I shows that the half-filled percussion cup reveals approximate liquid limit values for 8 mm, 10 mm, and 12 mm DHs, pointing out an optimum range (liquid limits between 44.5-45) for Casagrande cup method. However, the liquid limits diverge from each other considerably at each DH for the under-filled and full-filled cups. This finding supports the usage of standard DH (i.e., 10 mm) and filling form (i.e., half-filled) of the percussion cup since the half-filled cups dropped at 8 mm to 12 mm heights does not vary too much. The highest liquid limit value is obtained by under-filled cups at 6 mm DHs which is quite out of the optimum limits.

Due to discrepancies in the results that were realized, successive strokes of the percussion cup caused distortion in the DH calibration of the device. Hence, some of the experiments were repeated by checking the DH of the percussion cup and calibrating again after each set of strokes.

TABLE I
LIQUID LIMITS FOR DIFFERENT COMBINATIONS OF DH AND CUP FILLING FORMS

Filling Form	DH			
	6 mm	8 mm	10 mm	12 mm
Under-filled	49.26	47.43	46.43	45.80
Half-filled	46.99	44.96	44.47	44.67
Full-filled	45.72	43.49	42.78	41.75

IV. CONCLUSION

In this study, the calibration effect on liquid limit by Casagrande cup method was investigated. The DH and the filling form of the percussion cup are defined as the main parameters affecting the liquid limit. For this intend, 12 set of experiments were carried out by different combinations of DH and filling form of the percussion cup.

A single type of soil that is classified as kaolin was used to observe the effect of calibration parameters. The Casagrande cup method is tested by the combinations of under-filled, half-filled, and full-filled cups with 6 mm, 8 mm, 10 mm, and 12 mm DHs in addition to the standard half-filled cup with 10 mm DH specified in ASTM-D4318-17. By increasing the DH, the groove in the soil paste was closed more rapidly especially for under-filled and full-filled cups pointing out lower liquid limits. For half-filled cups, the tests revealed approximate liquid limits by increasing the DH. In addition, as the placing forms switched from under-filled to full-filled cups, the liquid limits decreased by the effect of self-weight and geometrical form of the soil paste in the cup.

These findings show that the placing form of the soil paste leads to significantly various results if it is not applied as half-filled. Besides, drop distance of 8 mm to 12 mm revealed approximate results for the half-filled cups. Therefore, it is recommended to use the standard placing form specified as half-filled in ASTM-D4318-17 and even if the device calibration is distorted by the successive strokes of the percussion cup, the liquid limit results are acceptable for the DH adjustment range of 8 mm to 12 mm.

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