Comparison between Casagrande method and Cone penetrometer method for determination of liquid limit of soil

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Abstract. The liquid limit is an essential property of soil due to its relationship with other properties and behaviour of soil directly or indirectly. The two methods for determining the liquid limit are widely used viz., Casagrande method and Cone penetrometer method. This paper presents a comparison of the liquid limit of soils determined by performing both experiments. The result demonstrates that the liquid limit value obtained from Casagrande method is a little higher than those obtained from cone penetrometer in high plastic soil. In low plastic soils, cone penetrometer gives the higher values of liquid limit. However, in medium plastic soil it is difficult to make any conclusion.

Keywords: Casagrande method, Cone penetrometer method, Cohesive soil, Liquid limit, Plasticity

1 Introduction

Liquid limit of soil is the minimum water content at which soil changes its state from plastic state to liquid state with least shearing strength. Determination of liquid limit is important as it is one of the essential properties of soil, which uses to classify the soil and assess the soil behaviour. The liquid limit not only used to calculate the activity of clays, plasticity index and toughness index of soil but also used to predict the allowable bearing capacity of soil and settlement of soil. There are two methods to determine the liquid limit of soil, namely, Casagrande method and Cone penetrometer method (IS 2720-V). As both the methods are used for determination of the same property of soil there are chances of getting different results. The cone penetrometer method imposes the slow static shear deformation, while the Casagrande method imposes a sudden deformation of soil. A number of studies explored the relationship between limit values determined using Casagrande and Cone penetrometer methods [1]. However, in India, most of the studies use the Casagrande apparatus to determine the liquid limit of plastic soil.

The soft base Casagrande apparatus always gives higher liquid limits than those from the hard base of the Casagrande apparatus. The difference between soft and hard base Casagrande apparatus can be about 5% for soils with a liquid limit greater than 40%. In another study, Ozer [3] observed that Casagrande apparatus gives higher liquid limits than those determined from the cone penetration apparatus. The difference in values depends on the clay contents and types of mineral contents in the soil. Christaras [2] and Di Matteo [4] found the liquid limit value, determined by the Casagrande apparatus systematically 2-3% lower than the penetrometer values for soils with lower clay contents. The difference between the two methods is reduced with the decrease in the liquid limit, clay fraction, and free swelling capacity of the bentonite present in the mixture. Similarly, the difference in the liquid limit values obtained by both these methods is reduced with an increase in salt concentration [5]. A correlation based on the results were also developed for standards clays and compared with other correlations from other studies. The similar correlation was developed by Spagnoli [6]. For a constant depth of penetration of 20 mm, it was observed by Hrubesovaa et al. [7] that Standard cone penetrometer test (20 mm penetration) gives significantly lower value of liquid limit in comparison to Casagrande cup method for high plasticity soils. In another study carried out by El-Shinawi [9], shows that the liquid limit values determined by the Casagrande apparatus were generally lower than those obtained by the Russian cone apparatus. Based on the experimental results, Karakan et al. [10] concluded the liquid limit values obtained from the fall cone and Casagrande tests are consistent and close to each other. It was also observed that fall cone test is more useful and powerful tool for the practical soil classification test. The study of Letícia Garcia Crevelin et al. [11], reveals that the linear correlation exists between results of a relatively harder base Casagrande apparatus and cone penetrometer as compared to a softer base apparatus.

The number of studies has been explored the correlation between Casagrande apparatus and the cone penetrometer apparatus. Most of the studies are mostly carried out for soils found in other countries and found that the relationship between both the methods depends on soil properties. However, the studies on Indian soils are missing in the literature. Therefore, the experimental studies were carried out to find out the comparison between the liquid limit of different soils found in Gujarat, India.

2 The material used in the study

The soil sample collected are from different regions in Gujarat as shown in Fig. 1. The locations of sample are Adalaj (Latitude 23.17, Longitude 72.14) (soil A), Bhavnagar (Latitude 21.76, Longitude 72.14) (soil B), Ahmedabad location 1 (Latitude 23.15, Longitude 72.54) (soil C), Ahmedabad location 2 (Latitude 23.16, Longitude 72.54) (soil D). The type of soil A dry alluvial soil, soil B is black cotton soil while soil C is low plastic sandy soil and soil D is plastic dark brown soil. The collected soil samples are shown in Fig. 2.

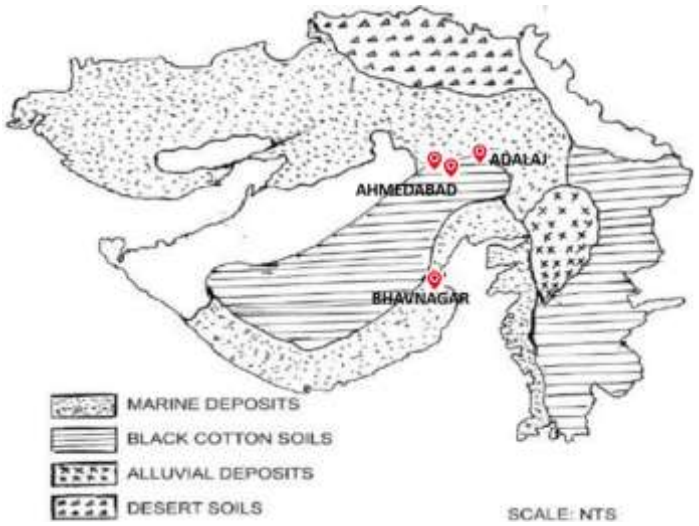


Fig .1 Loacation of sites

(a) (b)

(a) (b)

Fig. 2 Collected soil samples used in the testing: (a) Adalaj Soil (Soil A), (b) Bhavnagar Soil (Soil B), (c) Ahmedabad Location-1 (Soil C), (d) Ahmedabad Location-2 (Soil D)

3 Methodology and apparatus used in the study

The liquid limit of soil is determined by the procedure described in the Indian standard method of test for soils, Part 5 Determination of liquid and plastic limit. The detailed procedure of both the methods is discussed separately in sections, namely, "3.1 Casagrande method" and "3.2 Cone penetrometer method".

3.1 Casagrande method

In this experiment, about 120 gm of air-dried soil passing from 425 microns I.S sieve is taken in mixing dish, and distilled water is mixed to form a uniform paste. A portion of the soil water paste is placed in the cup of Casagrande device and spread into portion with few strokes of a spatula. Then groove is made with a grooving tool at the center of cup as shown in Fig.3. Lift and drop the cup by turning crank at the rate of two revolutions per second until the two halves of soil cake come in contact with each other for a length of about 1 cm by flow only. The number of blows shall be recorded, and this should be carried out with different moisture content for blows between 10 and 40.

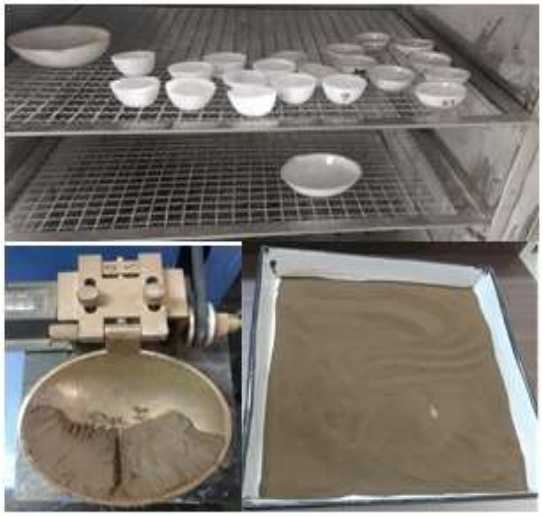


Fig. 3 Performing Casagrande test

3.2 Cone penetrometer method

In this experiment, about 150 gm. of air-dried soil passing from 425-micron Indian standard sieve is taken in mixing dish, and distilled water is mixed to form a uniform

paste. Then the wet soil paste is transferred to the cylindrical cup of cone penetrometer apparatus, with no air trapped and placed on the base of the cone penetrometer apparatus. The penetrometer is so adjusted that the cone point touches the surface of the soil paste in the cup, and the initial ready is to be taken. The vertical clamp is then released, allowing the cone to penetrate soil paste under its weight for 5 seconds and reading is noted. The test is repeated with different water contents for values of penetration in the range of 15 to 25 mm. Cone Penetrometer test apparatus used in the present is shown in Fig. 4.

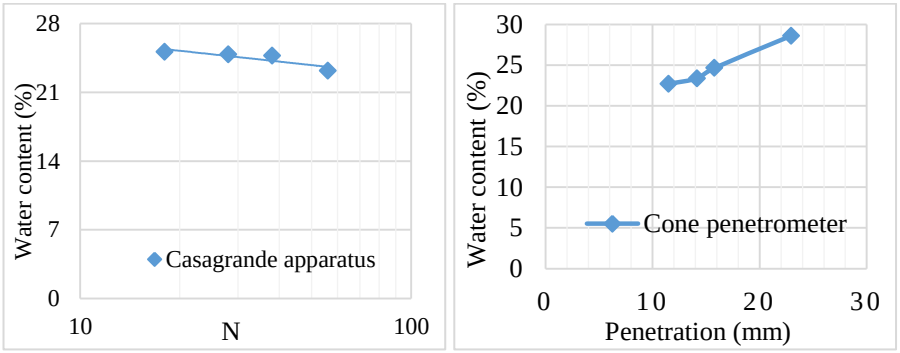
Fig. 4 Cone Penetrometer apparatus used in testing

4 Results and discussion

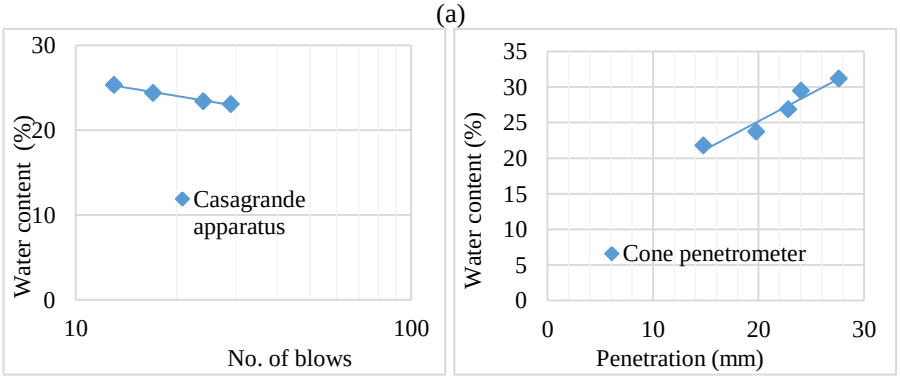
All the five soils were tested for a number of times to ensure the repeatability of tests. A large number of experiments were carried out on soil samples. However, only some typical tests are presented here. In Casagrande method, the liquid limit is obtained at the value of water content to 25 blows from the graph while in cone penetrometer the liquid limit is obtained at the value of water content corresponding to 20mm penetration from chart. The results are presented separately for low plastic soils and medium to highly plastic clays.

4.1 Low plastic soils

The results of liquid limit tests carried out in low plastic soil (liquid limit >35%) is shown in Fig. 5. The left and right parts in each figure represent the liquid limit test results obtained by Casagrande and the cone penetrometer apparatus. It shows that the liquid limit is minimum for soil A and increases higher for soils B and C in chronical order. Though soil B is black cotton soil, it is having alkaline nature. Therefore, liquid is found to be relatively small as compared to normal expansive soils. It is also observed that flow index (slope of flow line) increases with an increase in liquid limit of soil. For soils A, B and C the liquid limit determined by Casagrande apparatus is found to be lower than those determined by Cone penetrometer apparatus.



(a)



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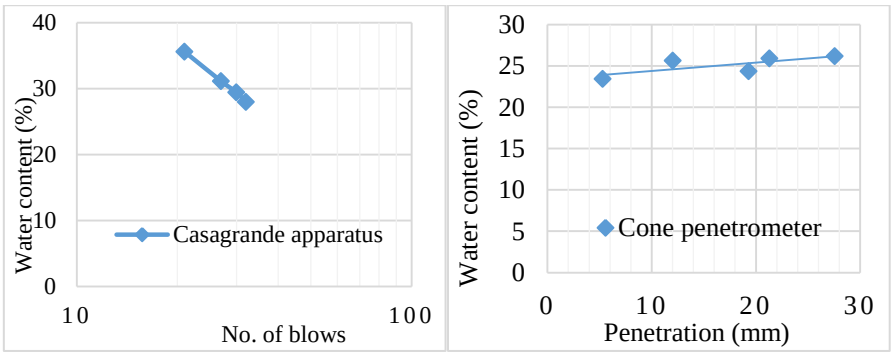
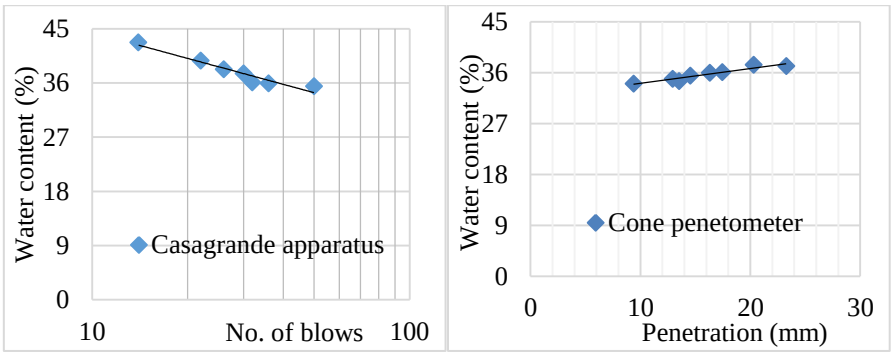


(c)

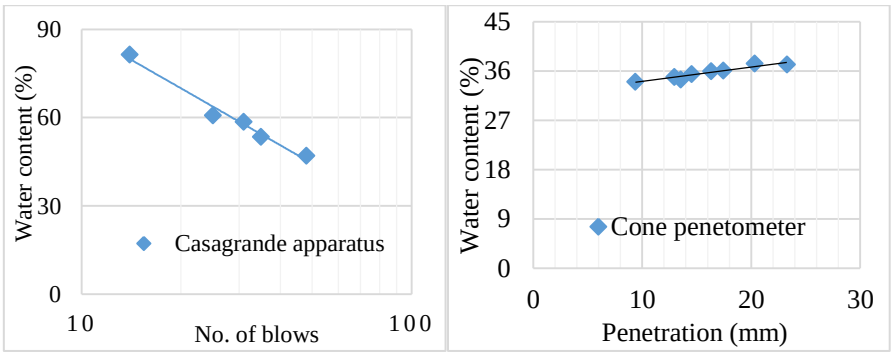
Fig. 5. Liquid limit determination for low plastic soils: (a) Soil A, (b) Soil B, (c) Soil C

4.2 Medium to high plastic soils

The results of liquid limit tests carried out in soils (soils D and E) with medium to high plastic soils is shown in Fig. 6. Similar to Fig. 5, the left and right parts in each figure represent the liquid limit test results obtained by Casagrande and the cone penetrometer apparatus. The slope of curves in Casagrande apparatus is relatively higher than the slope of the curve in Cone penetrometer test. It indicates that the effect of change in the water content is relatively more in case of Casagrande apparatus compared to the Cone penetrometer apparatus. The Casagrande method imposes sudden deformation of soil. Therefore, the Casagrande method might have been more sensitive to change in water content.



(a)



(b)

Fig. 6. Liquid limit determination for high plastic soils: (a) Soil D, (b) Soil E

The comparison of the values of liquid limit obtained for a different type of soils is shown in Fig.7. It shows that the difference in the liquid limit is varying with the types of soils. As per Indian standard, the soils are classified as low plastic soil if the liquid limit is below 35%. For soils with liquid limit less than 30%, the Casagrande apparatus estimates the lower value of the liquid limit.

The soils can be classified as medium plastic soils if the liquid limit is varying between 35% to 50%. However, no information is provided in the Indian standard about transition state, from low plastic to medium plastic state. It is difficult to come out with any correlation between Casagrande apparatus, and the cone penetrometer results in soils with plasticity higher than 30% and less than 40%. This range is close to the boundary differentiating between low and medium plastic soil. A very small number of tests have been carried out for the soil with a liquid limit of 30-40%. Therefore, it is required to carry out a large number of tests on soils with liquid limit falling in this range. The liquid limit determined by Casagrande apparatus is found to higher than those determined by the Cone penetrometer apparatus for highly plastic soil (soil E). The similar observation has been made in the earlier published studies for highly plastic soils (Christaras, 1991; Ozer, 2009; Matteo, 2011)

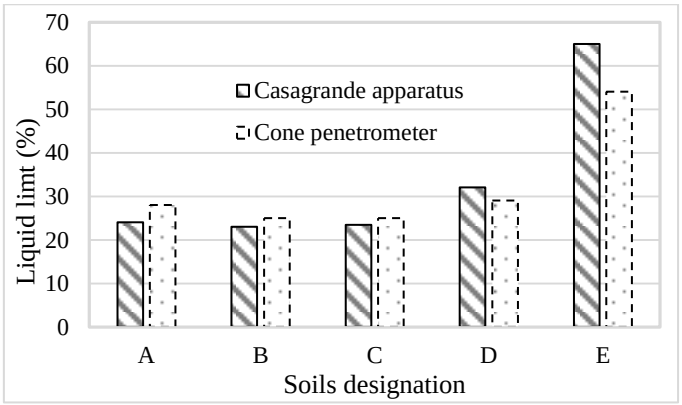


Fig. 7. Comparison of results of Casagrande and Cone Penetrometer test

5 Conclusions

The liquid limit was determined for low, medium and highly plastic soils found in Gujrat, India using Casagrande method and the cone penetrometer method. The liquid limit of low plastic soil determined by cone penetrometer is higher than those obtained by Casagrande. For highly plastic soils, the opposite trends have been observed. The relationship between both the methods is clear for low plastic and high plastic soils. However, it is difficult to make any conclusion for soil with liquid limit ranging from 30%-40%. Therefore, it is required to carry out a large number of tests to make any conclusion regarding the soils close to the boundary of low to medium plastic.

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