STRENGTH BASED LIQUID LIMIT OF SOILS

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Introduction

Liquid limit is one of the major index properties for fine grained soils.

Attempts are made in the literature to study the shear strength at liquid limit water content.

The lowest value of shear strength at liquid limit reported in the literature is 0.2kPa (Locat and Demers 1988) and the highest value reported is 5.6kPa Wasti and Bezirci (1986).

Correlations relating the shear strength to the liquidity index of the sample are popular.

Nagaraj et al. (2012) and Haigh et al. (2013) concluded that the liquid and plastic limit cannot be associated with a unique value of shear strength. This is one of the reasons that earlier correlations are not found to be unique for all types of soils.

This has paved way for research in the field of strength based index properties.

Materials and Methods

- Ten fine grained soils of varying plasticity were used for the study.
- The following basic properties of the soils were determined in as per Indian Standard Specifications.
  - ✓ Liquid Limit
  - ✓ Plastic limit
  - ✓ Shrinkage Limit
  - ✓ Specific Gravity
  - ✓ Grain Size distribution
- The shear strength of the soil at liquid limit was determined using the vane shear apparatus.

Experimental Results

- The soils selected for the study have liquid limit ranging from 25 to 131.
- The position of soils on the plasticity chart is shown below

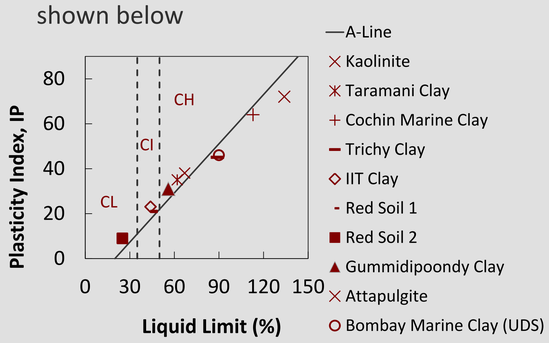

Figure 1. Position of soils in the Plasticity Chart as per Indian Standard Soil Classification System

- Table 1 gives the undrained shear strength (c_u) of the soils determined using the vane shear test.

Table 1 – Shear strength of soils at liquid limit

S.No.	Soil Designation	Shear Strength at Liquid Limit (kPa)	
		Casagrande	Fall Cone
1	Kaolinite	2.98	2.25
2	Taramani clay	1.59	1.39
3	Cochin Marine Clay	0.44	1.11
4	Trichy clay	2.13	2.02
5	IIT Clay	1.35	2.35
6	Red soil 1	1.25	1.71
7	Red soil 2	2.30	2.30
8	Gummidipoondy Clay	1.10	2.00
9	Attapulgite	0.90	1.80
10	Bombay marine clay UDS	0.75	1.22

- The fall cone factor '*K*' was determined for all soils and was found to vary from 0.50 to 1.22.
- Hence, the usage of a Standard *K* value of 1.33 in the prediction of shear strength of soils using equation $c_u d^2 = Kmg$ will either under predict or over predict the value of shear strength.

Thus, strength based liquid limit is expected to have better correlation with the shear strength of the soil

Proposed Strength based liquid limit

- Strength based liquid limit, as the name suggests, is identified on strength basis.
- Researchers have always tried to associate liquid limit to a unique shear strength.
  - ✓ Casagrande reported values of 2-3 kPa for soils tested in Harvard Laboratory.
  - ✓ Federico (1983) reported values between 1.7 and 2 kPa
  - ✓ ASTM D4318-10e1 suggests soil has strength of 2 kPa at liquid limit.
  - ✓ Several others suggested values of 2.2 to 2.3 kPa.

Water content at which the soil possesses shear strength of 2 kPa may be considered as Strength based Liquid Limit (LL_{sb})

- The strength based liquid limit is determined from a plot of water content versus shear strength as shown above.

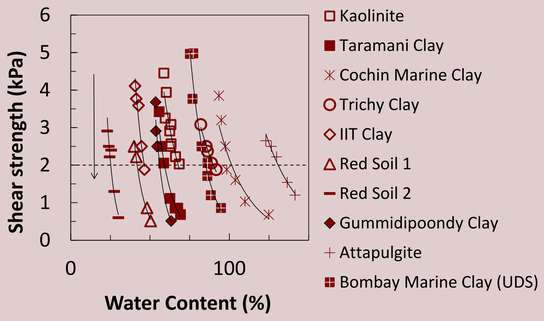

Figure 2. Variation of shear strength with water content

Results and Discussions

Comparison of strength based liquid limit and conventional liquid limit

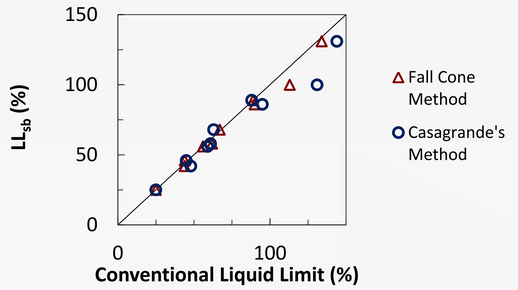

Figure 3. Comparison of strength based liquid limit and Casagrande's and fall cone liquid limit values

- There exists only a minor difference between the liquid limit determined by Casagrande and Fall cone method and strength based liquid limits for values less than about 100. (Fig.3)
- For soils with higher liquid limit, the strength based liquid limit gives lower value than the conventional methods.
- This difference is observed because of the fact that, with increase in the liquid limit, the shear strength at liquid limit is much lower.

Correlation with shear strength

- The shear strength predicted from extent of penetration in fall cone test using the factor 'K' has been found to be approximate.
- Shear strength is often correlated to Liquidity Index of samples.
- Kuriakose et al. (2017) suggested water content ratio, which is defined as the ratio of water content to the liquid limit of the soil, as an alternative to liquidity index.
- The correlation of undrained shear strength with the water content ratio for liquid limit determined by three methods is shown in the Fig.4 (a) and (b).

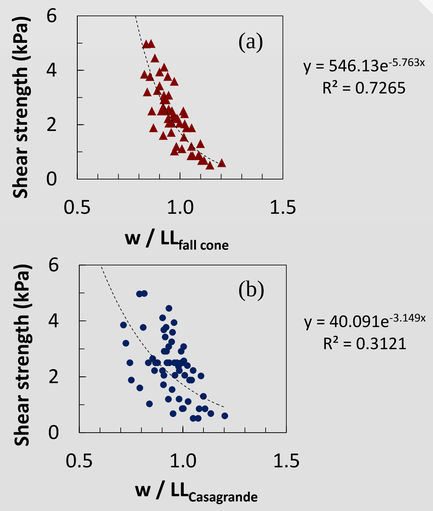

Figure 4. Shear strength versus water content ratio using (a) Fall Cone and (b) Casagrande's liquid limit

- A poor correlation coefficient observed for the Casagrande's method may be due to the larger variation in the shear strength of soils at this liquid limit (0.4kPa - 2.98kPa)
- In the case of fall cone liquid limit, the variation in shear strength lies in a narrow range of 1.1kPa to 2.35kPa, which in turn gives a better correlation coefficient.
- Fig. 5 shows a plot of the water content ratio using the strength based liquid limit versus the shear strength of all the soils.

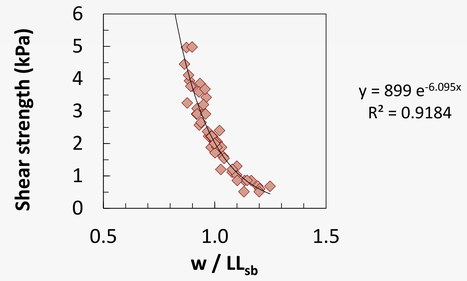

Figure 5. Shear strength versus water content ratio using strength based liquid limit

- The equation of the best fit obtained is given by :

$$c_u = 889 e^{-6.095(w/LL_{sb})} \quad \text{...[1]}$$

- An improvement of the correlation coefficient to 0.92 indicates that the strength based liquid limit is a better parameter for deducing correlations with engineering properties of soils.

Conclusion

- The fall cone factor K is not a constant and is found to vary for different types of soil. This might lead to the predicted shear strength using this method to be inaccurate.
- A strength based liquid limit is introduced, where the water content corresponding to shear strength of 2kPa is taken as the liquid limit.
- The water content ratio is a good replacement for the liquidity index in the prediction of shear strength of very soft soils.
- The strength based liquid limit is found to give a unique correlation despite wide variation in plasticity of soils considered. Hence Eqn. [1] is proposed for its prediction using the index property.
- It is expected that the strength based index property will have better correlations with the engineering properties of soils.

References

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