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Temperature Effects on Atterberg Limits

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This study aims to investigate the effects of temperature on Atterberg limits of fine-grained soils with different mineralogies using fall cone tests. It is found in the literature that Atterberg limits are dependent on the clay mineralogy [1, 2] and are subjected to change upon an increase in temperature [3-5]. Measurements of liquid limit at different temperatures reveal sodium smectite is more sensitive to temperature than kaolinite. This observation is justified by relating the evolution of liquid limit to the initial changes of total specific surface areas associated with the physicochemical activity and inter-particle contacts [6]. Measurement of Atterberg limits using the conventional methods of Casagrande's cup and threading is not very practical when the impact of temperature on these parameters is investigated. The trial and error associated with this method and the time they take may hinder a robust estimation of the liquid and plastic limit. Various studies have shown that Atterberg limits measured using Cone Penetration Test are less subjective and more consistent compared to traditional ways [7-9]. For these reasons, utilizing a Fall Cone Test apparatus and a temperature control unit facilitates the investigation of the impact of temperature on Atterberg limits. In this study, first, the liquid limits measured at room temperature by Fall Cone and Casagrande's method are compared, and then Cone Penetration is utilized to investigate the evolution of liquid limit with temperature.

Rhassoul Clay (29.4% Illite, 0.10% Kaolinite, 70.5% montmorillonite) and Illite Clay are considered in this study. The measured penetration values of the cone against moisture content at room temperature for these two clays are plotted in Figure 1. The liquid limit is the water content at which the cone penetrates 20mm into the soil in the cup [10]. Accordingly, Table 1 lists the determined liquid fall cone test and their deviation for the measured Atterberg limits using Casagrande's cup. This comparison was performed to ensure that the difference between these two methods is not significant and the utilized device was accurate enough.

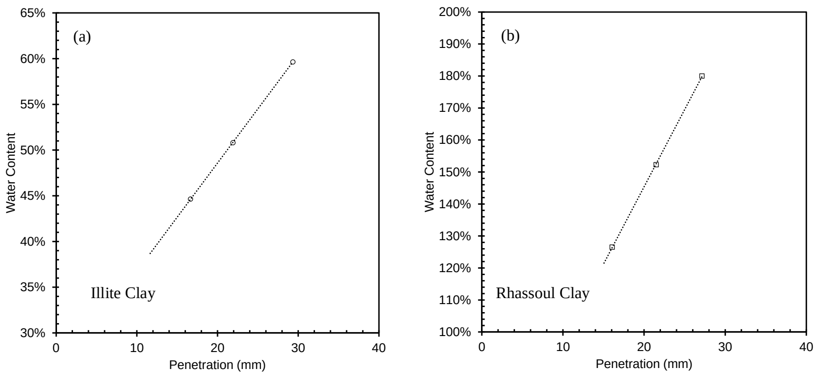

Figure 1 : Cone penetration at room temperature for a) Illite, and b) Rhassoul Clay.

Table 1 : Atterberg limits determined using Fall Cone vs. Casagrande's Cup at room temperature.

	LL		
Clay	**Casagrande's Cup**	**Fall Cone**	**% Difference**
Illite Clay	45	49	9%
Rhassoul Clay	138	142	3%

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To determine the Atterberg limits at higher temperatures (40 °C and 50 °C) and lower temperatures (10 °C), a temperature control unit is used to maintain the temperature of the soil sample during fall cone testing. For this purpose, first, the cup was filled with soil and then wrapped to avoid moisture migration in and out of the sample. The sample was then placed inside the temperature controller for an hour at the desired temperature. After one hour, the sample was swiftly unwrapped, and Cone Penetration test was performed. After the penetration a thermometer was used to measure the temperature at the center of the cup. This measurement showed that the alteration of temperature during the whole process is less than 1°C. Next, more water was added to the batch and then the same steps were followed until enough data points were obtained to estimate the liquid limit. The result of these tests allows for an assessment of temperature effects on Atterberg limits, which would be helpful in the understanding of the influence of temperature on different shear strength parameters of fine-grained soil with regards to their mineralogy.

Table 2 lists the measured liquid limit values for Rhassoul Clay and Illite clay at different temperatures. The results suggest that the liquid limit of Illite is temperature independent. On the other hand, Rhassoul clay liquid limits was more sensitive to elevated temperatures and did not change with cooling. As mentioned earlier, the liquid limit is directly associated with clay mineralogy and the thermal alteration of soil characteristics [11, 12]. Therefore, the observed thermally-induced change in liquid limit should be discussed with respect to mineralogy. According to Table 1, the Illite liquid limit is temperature independent. Furthermore, Rhassoul clay comprises 70.5% montmorillonite minerals and 29.4% Illite. Providing this and the observed sensitivity of Rhassoul clay to temperature change can be attributed to the montmorillonite constituent. This argument can be further supported by testing more clays with different percentages of montmorillonite and illite.

Table 2 : Liquid limit measured at different temperatures for Rhassoul and Illite clays.

Clay	**Temperature (°C)**			
	10	20	40	50
Rhassoul	145	142	150	157
Illite	49	49	48	48

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