Shear Stress-Strain Relationship Clay Filter Cake

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Abstract: The shear stress-strain relationship for clay cake formation is important to understand the cleaning of the borehole. Hence, experimental and analytical modeling was performed to quantify the stress-strain relationship for clay cake soil using 2% and 10% bentonite mud. Both clay cake soils have shown nonlinear stress-strain behavior. In addition; as the bentonite content increased from 2% to 10%, the peak stress and ultimate strain increased by 800% and 150% respectively.

1. Introduction:

In oil or gas drilling with a drilling fluid, mud cake is formed on the borehole wall when pressure within the wellbore is higher than the pore pressure in the rock. The filtrate enters the formation and leaves behind the deposit of solids that form the filter cake (Jiao and Sharma 1992, Parry 2006). The drill string can get stuck if it becomes embedded in the cake as rather high net forces acting on the drill string will push it against the wall. A further problem for mud-cake analysis in the wellbore is the sealing of different sections of the well by packers, the interaction of these packers with the cake, and the resulting sealing efficiency. Hence, studying the stress-strain relationship for soft clay cake is essential.

2. Objective:

The main objective was to experimentally develop and quantify the stress-strain relationship for filter cake with 2% and 10% bentonite.

3. Materials and Methods:

Water based drilling mud (WBM) with 2% and 10% of bentonite was used. The stress-strain relationship has been studied using modified vane shear device at room temperature. Laboratory modified vane shear device with schematic idealization for it can be seen in Figure 1.

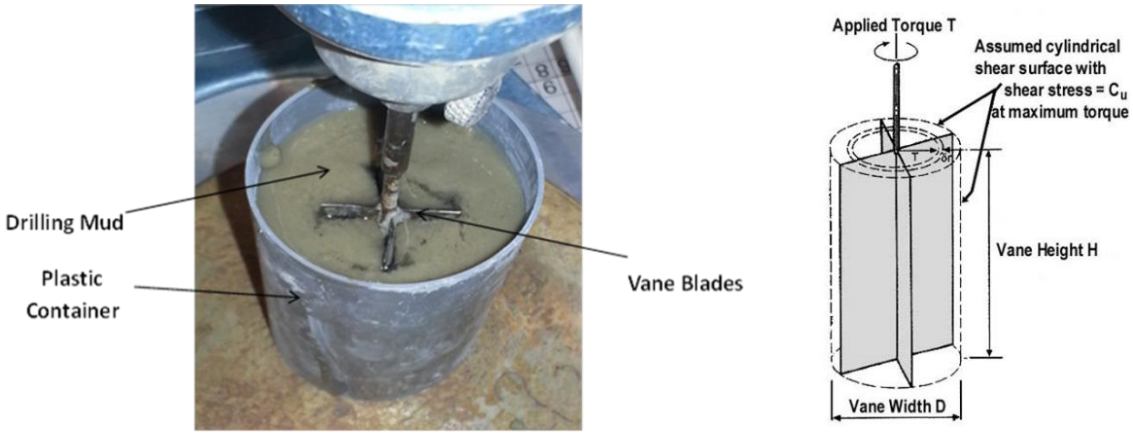

Figure 1. Laboratory Vane Shear Device with Schematic Idealization.

4. Hyperbolic Model:

The following mathematical model was used to predict the stress-strain relationship for both 2% and 10% bentonite ultra-soft soil:

$$\text{Shear Stress (kPa)} = \frac{\text{Strain}(\%)}{A + B * \text{Strain}(\%)} \quad (1)$$

Where: A and B are model parameters.

Table 1. showed model predication parameters for both 2% and 10% bentonite ultra-soft soil.

Table 1. Hyperbolic Model Predication for Stress-Strain Relationship.

Composition	Model Parameters		Accuracy Predication	
	A	**B**	**R^2**	**RMSE (kPa)**
2% Bentonite	**1000**	**25**	**0.98**	**0.0012**
10% Bentonite	**180**	**4**	**0.99**	**0.0048**

Note: R^2 is the coefficient of correlation, RMSE is root mean square error.

5. Results: It was indicated that as the bentonite content increased from 2% to 10%, the peak stress and ultimate strain increased by 800% and 150% respectively. The hyperbolic model predication showed a very good agreement with the experimental results.

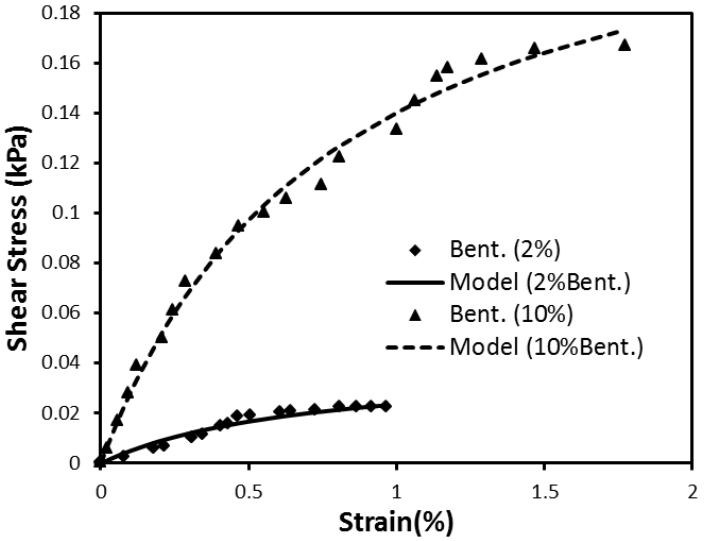

Figure 1. The Stress-Strain Relationship of Experimental and Model Predication of 2% and 10% Soft Clay Cake.

Table 2. Soft Clay Cake Properties

Comp.	**Density (gm/cm^3)**	**ρ_o (Ω.m)**	**ρ_f (Ω.m)**
2%Bent.	**1.013**	**4.39**	**43.8**
10%Bent.	**1.066**	**2.56**	**5.69**

Note:ρ_o: Initial resistivity, ρ_f: Failure resistivity.

6. Conclusion: Soft clay cake stress-strain relationship showed nonlinear behavior. Moreover; as the bentonite content increased from 2% to 10%, the peak stress and ultimate strain increased by 800% and 150% respectively

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8. References:

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