The influences of electrolyte on rheological properties of Poyang lake sand

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Abstract. The investigation on the influences of electrolyte and flow shear on rheological properties of highly-concentrated cohesive sediment suspension is an important subject in the context of sediment transport dynamics. By means of experiment measurement and theoretical analysis, this project studies the influence of electrolyte (valence of cation and concentration) on the rigidity (or viscosity) and yield stress of highly-concentrated cohesive sediment suspension under a static condition, then discusses a possible explanation involved in the role which is played by electrolyte in determinations of rigidity and yield stress of the suspension considering the influences of all factors such as electrolyte condition, primary sediment concentration, median size and size distribution of sediment particle.

1. Introduction
The dynamic characteristics of hyper-concentrated flow are different from that of the general sediment-laden flow, such as the ability to transport the hyper-concentrated flood in a certain water and sediment condition without particle separation[1]. It is worth noting that the hyper-concentrated flow is unstable, when sediment concentration of natural rivers is high, even if the upstream flow remains unchanged, the water level fluctuation also appears cyclical change which caused a great threat to flood control[2]. Therefore, the study on the characteristics of high sediment concentration water flow is an important subject in the study of the treatment and utilization of sediment-laden river in China[3].

The purpose of the study is to explore the influences of electrolyte and flow shear on rheological properties of highly-concentrated cohesive fine sediment suspension. The Poyang lake sand sample will be mentioned in this paper. Poyang Lake belong to the Yangtze River Basin, which lies in Jiangxi province, is the world's largest bird sanctuary. We chose the Poyang Lake sand sample to simulate the real environment, and in order to avoid the influence of mineral compositions on suspension and prepare a constant concentration of sediment suspensions with different combinations of electrolyte type and concentration. The rheological curve can be measured by the rheometer (viscometer). The corresponding rigidity coefficient and yield stress[4] can be calculated.

2. Experimental introduction
In this study, we selected the Poyang Lake sand sample with obvious flocculation characteristics and 3 different electrolytes: Sodium chloride, Calcium chloride, Aluminum nitrate nonahydrate (Nacl, Cacl2, Al(NO3)3•9H2O), to study the influence of the type of electrolyte, concentration, median particle size...
and particle size on the rheological parameters of high concentration suspension by using the control variable method.

We set the experience into 3 parts.

(1) Determine the particle size of Poyang Lake sand sample, according to the particle size determine the classification of Poyang Lake Sand

(2) The influence of sediment concentration on the rheological parameters of suspended sediment in pure water: measure the bulk density of sediment at first, then use RST-CC rheometer to measure the stiffness coefficient and yield stress, study the influence of initial sediment concentration on the high concentration of fine sediment suspension rheological parameters. Each measurement data are measured by a group of pure water as the control group.

(3) Influence of electrolyte (valence of cation and concentration) on rheological parameters of suspension: control the mass concentration of sand samples unchanged. We want to study the effects of type and concentration of electrolyte on the high concentration of fine sediment suspension rheological parameters. The above procedures for each measurement are a group of water measurement data as the control group.

3. Result and discussion

3.1. The particle size and classification of Poyang Lake sand.

We selected the Poyang Lake sand sample, using Marvin Granulator to determine their median size and size distribution of sediment particle.

The median size of the Poyang Lake sand sample is 146.325μm, which belongs to fine sand.

![Figure 1. The size distribution of sediment particle of Poyang Lake sand sample](image)

3.2. The influence of the concentration of the Poyang Lake sand on its rheological parameters

The initial sediment concentration (mass ratio) is set to , a total of 51 levels. We prepared the suspension according to the initial sediment concentration (under the electrolyte-free condition), and measured the stiffness coefficient and yield stress, wanted to study the effect of initial sediment concentration on the rheological parameters of high concentration viscous fine sediment.

Figure 2 shows the relative viscosity coefficient \( \eta_r \) ( \( \eta_r = \eta / \eta_0 \), \( \eta_0 \) represents the viscosity coefficient of pure water under this condition), \( S_v \) represents the sediment concentration of Poyang Lake sand (the sediment concentration of Poyang Lake sand= the volume of Poyang Lake sand / total volume of the sample).

After data analysis, we got the empirical formula:

\[
\eta_r = 1.0875 + k \frac{S_v}{S_{vm}}
\]

where \( S_{vm} \) represents the maximum sediment concentration of Poyang Lake sand sample (the volume fraction of the solid particles when the stiffness coefficient of the suspension reaches infinity), and \( k \) is the coefficient of correction of the solid concentration[5], which taking into account the impact of fine-grained film water, but also consider the closed network of free water.
Figure 2. The relationship between the relative viscosity and Poyang Lake sand and volume concentration in no electrolyte condition.

Figure 3. The relationship between yield stress and Poyang Lake sand volume concentration in no electrolyte condition.

Figure 3 shows the yield stress $\tau_B$, $S_v$ represents the sediment concentration of Poyang Lake sand. From Figure 3 we can infer that when the sediment concentration is small than 0.22, there is no yield, the fluid is Newtonian fluid, as the volume concentration is greater than or equal to 0.22, the sediment concentration appears, the fluid change into the Bingham fluid, and the sediment concentration increases exponentially with the increase of the volume concentration.

The experiment did not involve the sedimentation of sediment.

3.3. The influence of electrolyte (valence of cation and concentration) on the rigidity (or viscosity) and yield stress of highly-concentrated cohesive sediment suspension.

Figure 4. The relationship between relative viscosity and electrolyte concentration.
Figure 5. The relationship between relative yield coefficient stress and electrolyte concentration

Figure 4 shows the relative viscosity coefficient $\eta_r$ ($\eta_r = \eta / \eta_0$, $\eta_0$ represents the viscosity of pure water under this condition), $\Phi$ represents the cation concentration of the three electrolyte solutions. The graph of $z = 1$ represents the relationship between the relative viscosity of the sediment solution and the concentration of sodium ion, the graph of $z = 2$ represents the situation of bivalent calcium ion, the graph of $z = 3$ represents the situation of trivalent aluminum ion. Figure 5 shows the yield stress under the same condition, where $\Phi$ represents the cation concentration of the three electrolyte solutions, the series of $z=1,2,3$ have the same meaning of those are in Figure 4.

When the concentration of electrolyte solution is low, there was no significantly difference cross the effect of the three electrolytes on the relative viscosity coefficient of the sediment solution, as the concentration of the electrolyte solution continues to increase (when the solution concentration is same), the higher the cationic valence of the electrolyte is, the higher the viscosity coefficient of the sediment solution and the higher the shear stress of the sediment solution is.

We infer that a large number of sticky fine particles of sediment will quickly bond to each other to form a different size of the floc or filled with a regional space network structure, as the result the relative viscosity coefficient and the shear stress of the sediment solution increase.

4. Conclusion
When the electrolyte-free condition is maintained, the relative viscous coefficient increases slowly with the growth of the sediment concentration of Poyang Lake sand, and the yield stress increases exponentially with the increase of the volume concentration. As the concentration of the electrolyte solution continues to increase, the higher the cationic valence of the electrolyte is, the higher the viscosity coefficient of the sediment solution while the higher the yield stress of the sediment solution is.

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