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Rheological Characteristics of Limestone water Suspension

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Abstract.

This research examines the rheological behavior of water-based slurries with high limestone concentration, focusing on the impact of bimodal particle size distributions. This research demonstrates that the intentional mixing of coarse and fine particle size may significantly alter the flow characteristics of unimodal suspensions. When there are more solids in suspension, they tend to be very viscous. This work studied the rheological behaviour of bi-modal limestone suspensions by blending fine (less than 53 μm) and coarse (75-106 μm) particles at limestone concentrations ranging from 35 - 65% by wt. Rheological behaviour studied at shear rates of 50 – 500 s^{-1} demonstrated that the flow resistance was significantly influenced by the size of the particulates. A blending concentration of 35% coarse particles was found to be best amount for lowering apparent viscosity for the fine limestone slurry. The results establish that controlled bimodal particle distribution is an effective strategy for improving the rheological performance of concentrated limestone suspensions.

Keywords. Limestone water slurry, Viscosity, Bi-modal slurry, Rheology Introduction

1. INTRODUCTION

Limestone is very important in many different fields, such as creating paper, steel, glass, fertilizers, cleaning products and treatment of water. Slurry transport via pipes is becoming more common in various industries [1,2]. This is because it is reliable, requires minimal maintenance, and has little influence on the environment [3,4]. In recent years, producing finely dispersed slurry in industrial systems has become increasingly important for enhancing solid concentration levels. As a result, it is important to characterize the slurry's rheological behaviour, particularly its yield stress and apparent viscosity to enable efficient pipeline transport while minimizing energy consumption. Within this transport system, dispersion, concentration, and particle size must all be appropriately assessed [5]. Generally, it is acknowledged that increasing the amount of solids in a suspension tends to make it appear more viscous. Additionally, expanding the PSD can notably minimize the overall viscosity of the slurry. Therefore, modifying the PSD is a good way to achieve large solid concentrations with a minimal viscosity [6-8]. It is observed that modifying the PSD is a great way to achieve higher solid concentrations without forgoing viscosity [9]. The flow

behaviour of Indian limestone samples was examined across a LWS in the solid concentration in the range of (40-70) % by wt, and the resulting viscosity values were evaluated against several established empirical model [10].

This research investigates the impact of different rheological properties on viscosity reduction using two limestone particle size samples. In the present work, optimum particle size distribution was determined to minimize viscosity. Specifically, it analyses how solids concentration and PSD influence the rheological properties of limestone–water slurries.

2. LIMESTONE SAMPLE COLLECTION AND PREPARATION

Limestone material has been obtained from a local seller in Jamshedpur, Jharkhand, India. The limestone powder sample was filtered through standard sieves, sizes below 53 μm (fine) and between 75 – 106 μm (coarse). Limestone was classified into two primary categories: S_1 (fine fraction, <53 μm) and S_2 (coarse fraction, 75–106 μm). Both of these fractions were used as the base material to prepare a bimodal mixture. After this, the mixed samples were prepared and labeled as S_3 – S_6 , where the number indicates the composition of the mixture, not the particle size fraction. four different bi-modals were produced by integrating 15, 25, 35, and 45% (by wt%) of S_2 samples mixed into S_1 limestone concentrate samples. The samples are labelled as S_3 , S_4 , S_5 , and S_6 . Table 2.1 illustrates how coarse and fine particulates are distributed among the different samples.

Table 2.1. Composition of unimodal (S_1 , S_2) and bimodal (S_3 – S_6) limestone samples

Samples	S_1	S_2	S_3	S_4	S_5	S_6
Fine Fraction (S_1) - wt. %	100	-	85	75	65	55
Coarse fraction (S_2) - wt. %	-	100	15	25	35	45

Distribution of Particle Sizes of the limestone samples was investigated with the help of a laser diffraction PSA 1190, from Anton Paar Austria. Laser diffraction is based on the principle of measuring the amount of space taken up by particles of less than a specified size. Each sample (S_1 – S_6) was 5-10g in weights and was sampled and examined in dry mode.

3. CHARACTERIZATION OF RHEOLOGICAL PROPERTIES

For the purpose of meeting industrial standards, suspension samples ready using tap water were utilized in the characterizations of rheology. The specified quantity of solid particles were mixed with tap water and agitated for a duration of 20 to 25 minutes to achieve homogeneity. The solid particle concentration, based on weight, ranged from 35 to 65% of the aggregate mass of the suspension. The samples were measured by using a Rheometer MCR 92, Anton Paar GmbH, Austria together with RheolabQC software. In this study, the method used involved a linear ramp shear test in steps, where the shear rate varied between 50 and 500 s^{-1} . The rheological experiments were conducted under certain conditions, the temperature was kept at 28°C.

4. RESULTS AND DISCUSSIONS

4.1. Distribution of particle sizes

Figure 4.1.1 presents particle size distributions of S1 and S2, both showing monomodal patterns. S1 has a modal diameter of 20 μm , while S2 measures 95 μm , with mean sizes of 16.1 and 93.4 μm , respectively.

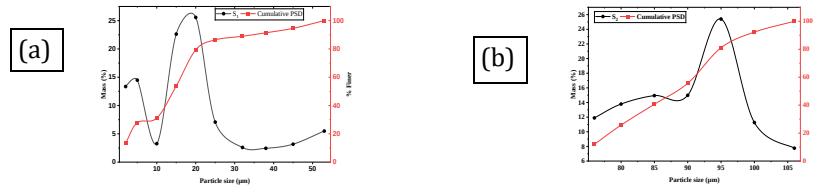


Figure 4.1.1. Distribution of sizes of particle for (a) S₁ and (b) S₂, with their corresponding cumulative curves

4.3. Rheological behaviour of the blended samples

Figure 4.3.1 presents rheological behavior of S₁ and mixed samples S₃–S₆. LWS shows Newtonian behavior at 35% solids and shear-thinning at 45–65%, with coarse particles reducing viscosity by 45–50%.

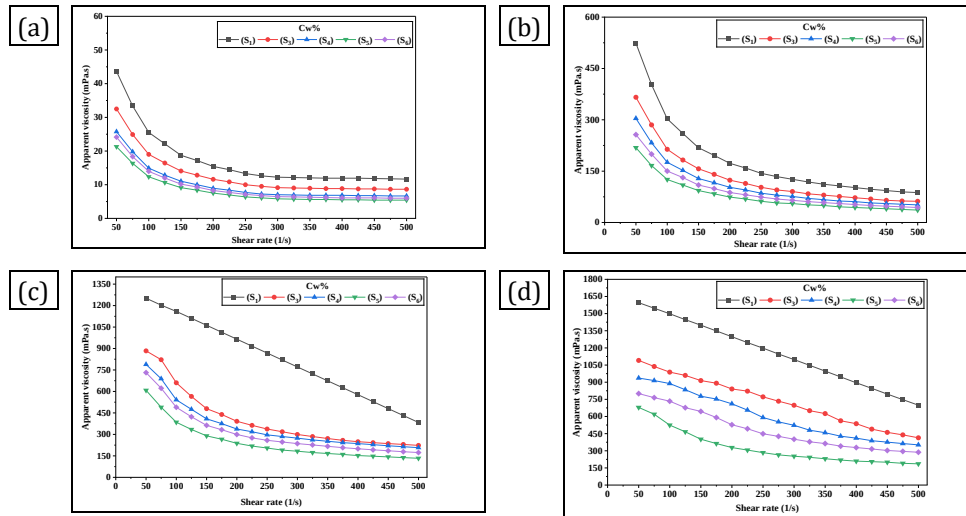


Figure 4.3.1. Rheological behaviour of blended samples at solid concentration of (a) 35%, (b) 45%, (c) 55%, and (d) 65% by weight

5. CONCLUSIONS

This study examined how a bimodal particle size distribution (PSD) affects the rheological properties of limestone–water slurries (LWS), with emphasis on apparent viscosity under varying solid concentrations and shear rates.

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