EFFECT OF SOLIDS AND DEFLOCCULANT CONTENT ON THE VISCOELASTIC BEHAVIOUR OF CLAY SUSPENSIONS

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1. INTRODUCTION

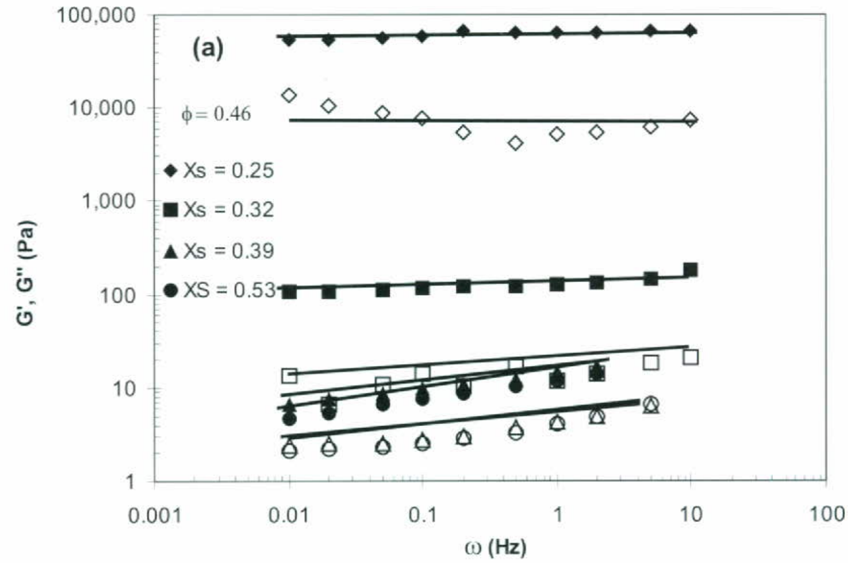
When concentrated clay suspensions are subjected to sufficiently small shear, they can exhibit viscoelastic behaviour, characterised by the simultaneous presence of viscous and elastic strains. Suspension viscoelastic behaviour is usually determined by dynamic oscillatory tests. These tests yield storage modulus, G', which describes the elastic component of the material's behaviour and loss modulus, G'', which quantifies the viscous component. The purpose of this work was to study the viscoelastic behaviour of different concentrated suspensions, obtained by modifying solids volume fraction, ϕ, and deflocculant content, Xs.

2. EXPERIMENTAL

More than 30 suspensions of a kaolinitic clay in distilled water were prepared, varying the solids volume fraction, ϕ, from 0.18 to 0.47, and the deflocculant-to-clay mass ratio, Xs, from 0.18 to 0.53 g deflocculant/100 g clay. G' and G'' were determined at different oscillation frequencies, ω. The dynamic oscillatory tests were preceded by vigorous stirring for 60 s, followed by a 300 s rest period. This protocol enables having suspensions with controlled, reproducible inner structure.

3. RESULTS AND DISCUSSION

Yield stress, σ_0, which limits the linear viscoelastic range, was found to rise with increasing solids content, ϕ, and decreasing deflocculant content, Xs. This is because suspension structure is more resistant with a greater number of interparticle bonds and higher bond strength.



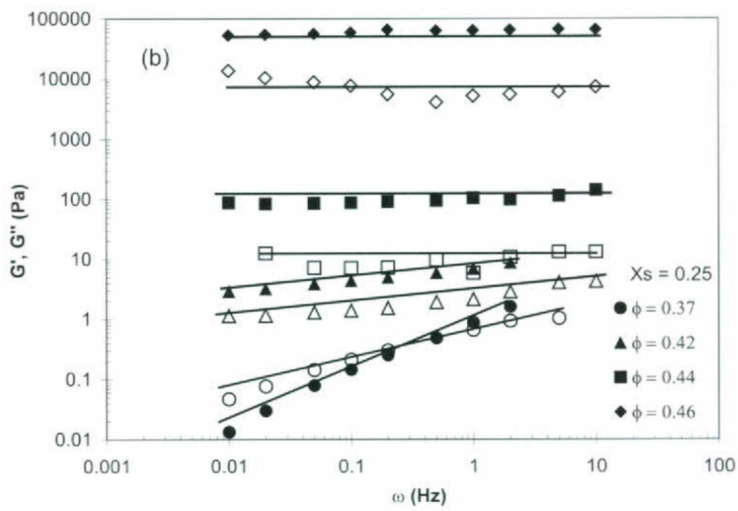


Figure 1. Variation of G′ and G″ with oscillation frequency, ω. (a) Experiments at ϕ=0.46. (b) Experiments at Xs=0.25. (G′ solid symbols, G″ empty symbols).

Figure 1.a plots the values of G′ and G″ versus frequency, ω, on a log-log scale for the suspensions prepared with ϕ=0.46. It can be observed that both G′ and G″ are practically independent of frequency. Furthermore, for each suspension, the value of G′ is

always much higher than that of G". This behaviour, which approaches the theoretical idealisation of a Kelvin viscoelastic solid, is typical of flocculated or gelled systems. It can similarly be observed that both G' and G" increase as deflocculant content decreases.

Figure 1.b plots the values of G' and G" versus frequency, ω, on a log-log scale for the suspensions prepared at a fixed deflocculant content, Xs=0.25. It can be observed that at values of $\phi \geq 0.42$, both G' and G" are practically independent of frequency, ω, and that G'>G". This behaviour clearly shows that these suspensions behave as a viscoelastic solid. At smaller solids contents, $\phi \leq 0.37$, the effect of frequency, ω, on G' and G" is considerable and G" is larger than G' at low frequencies. Both observations indicate that this suspension, and other more diluted ones, behave as a viscoelastic liquid.

Figure 2 plots the values of the ratio G'/G" versus solids volume fraction, φ, at different deflocculant contents, Xs. The values of G' and G" were found at a frequency of ω=1 Hz. It can be observed that this ratio increases as solids volume fraction, φ, increases, which indicates that the behaviour of the suspension approaches that of a viscoelastic solid ever more closely. The effect of deflocculant content, Xs, on this ratio rises as solids content increases and deflocculant content decreases.

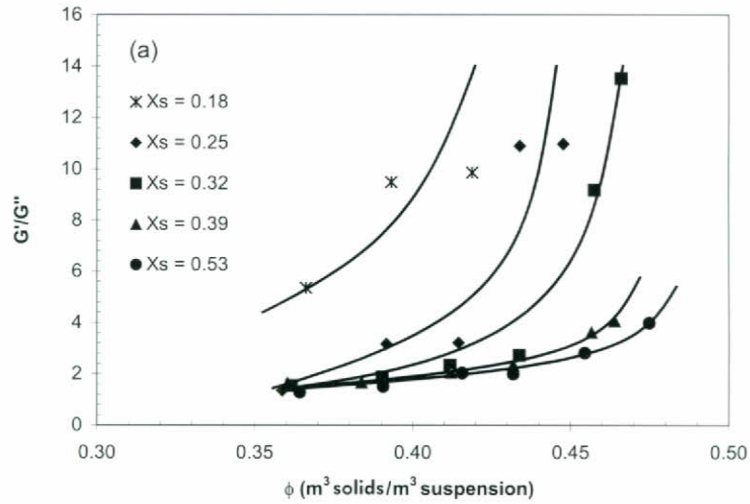


Figure 2. Effect of solids volume fraction, φ, and deflocculant content, Xs, on the ratio G'/G".

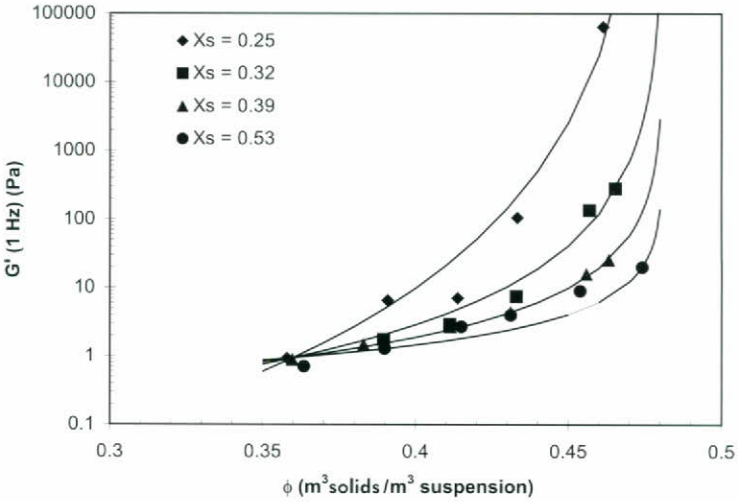


Figure 3. Relation between G' and φ. Verification of the proposed model.

To relate the value of storage modulus, G′, to solids volume content, the relative increase in the storage modulus, dG′/G′, with solids content dϕ, was assumed to depend inversely on the ratio: excess suspension water in respect of minimum volume / suspension volume, 1-ϕ/ϕ_{max}, which gave the starting relation, expressed in differential form:

$$\frac{dG'}{G'} = K \cdot \left(1 - \frac{\phi}{\phi_{max}}\right)^{-1} \cdot d\phi$$

The mathematical model found on integrating the differential equation satisfactorily describes the effect of ϕ on G′ at different values of Xs (Figure 3). K is found to decrease exponentially with the rise in deflocculant content. However ϕ_{max} can be considered constant.

4. REFERENCES

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[2] GREEN, M.A. *High Efficiency Silicon Solar Cells.* Switzerland : Trans Tech Publications, 1987.