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Performance Evaluation of Different Rheometric Shearing Techniques to Disperse Concentrated Cement Suspension

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Abstract:

Build-up of cement-based suspensions is a complex phenomenon affected by the mixture concentration and testing parameters as well as the shear history. Accurate measurements of build-up rely on the efficiency of the applied pre-shear regime to achieve an initial defined and dispersed structure to eliminate the shear history. This can therefore enable understanding mechanisms of build-up and quantifying the structuration of cement suspension from a reproducible dispersed state. Dispersing efficiency of various disruptive shear techniques, including rotational, oscillatory, and combination of both was evaluated. The initial and final states of suspension's structure were determined by applying small-amplitude oscillatory shear (SAOS). Test results showed that oscillatory shear has a greater effect on dispersing concentrated cement suspension than the rotational shear. Furthermore, the increase in shear strain in oscillatory technique enhanced the breakdown of suspension's structure until a critical point, after which thickening effects dominate. An effective dispersing method is then proposed. This consists in applying a rotational shear around the transitional value between shear-thinning and shear-thickening followed by an oscillatory shear at the crossover shear strain and high angular frequency of 100 rad/s.

Key words:

Build-up, concentrated cement suspension, dispersion, disruptive oscillatory shear, small amplitude oscillatory shear

1 INTRODUCTION

Cement-based suspensions are thixotropic materials [1–3]. Thixotropy, or the structural build-up at rest, refers to the change from liquid to solid-like states when cement suspension is left at rest (i.e. increase in static yield stress at rest) [4]. Flow performance, placement, and consolidation of cement-based materials are affected by their thixotropic properties [5–7]. For example, build-up of concrete has a great impact on its behavior in various applications, including multi-layer casting, cast in place concrete, and slip-form paving construction [6, 8, 9]. Furthermore, build-up kinetics affects the maximum lateral pressure exerted on formwork and its decay with time until cancellation [8, 10–12]. Lower build-up kinetics results in higher lateral pressure, hence increasing formwork costs and limiting the maximum allowable placement height [11]. On the other hand, using a highly thixotropic concrete in multi-layer casting will result in reducing the bond strength between the casted layers, hence resulting in poor mechanical performance for the structure. Indeed, in this case and due to the highly internal structure of the first casted layer, the stresses generated by the second layer may be not sufficient to re-initiate the flow in the first layer, thus preventing good bonding between the two layers [9].

Various studies have been conducted to investigate build-up of cement-based materials [13–17]. This phenomenon originates from the colloidal jamming due to particles flocculation and the chemical bridging resulting from cement hydration. Different techniques can be used to quantify build-up of cement-based materials [18–21]. Most of these techniques are based on assessing the structuration at rest after breaking down the internal network structure. The accuracy of measured build-up characteristics rely on the pre-shear regime and the shear stress applied during liquid-solid transition (i.e. flow stoppage) [22–25]. The applied pre-shear regime should be chosen to reproduce the application on hand. For example, rotational shear is probably the most suitable to reproduce the pumping, while in the case of vibration the oscillatory shear is the most suitable. However, for fundamental studies and in

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- For shear strains between 1 and 10 %, the application of a rotational shear of 150 or 225 s^{-1} before imposing the oscillatory shear resulted in comparable normalized storage modulus and damping factor. This indicates that applying disruptive oscillatory shear at strains around the crossover strain after rotational shear rate lower than the transition shear rate can compensate for the lower dispersion efficiency obtained at this shear rate.
- The application of LAOS before a rotational shear of 225 s^{-1} resulted in improving the normalized damping factor with no significant changes in the normalized storage modulus. Applying a rotational shear of 150 instead of 225 s^{-1} resulted in normalized structural parameters near unity. The application of rotational shear after LAOS can allow nucleation of CSH between dispersed cement particles, thus resulting in network strength similar to that obtained after rotational shear alone. The increase in network strength during the rotational shear may be related to the competition between breaking down due to shearing and build-up due to cement hydration [26]. These results suggest that applying LAOS before rotational shear does not result in significant improvement in the dispersion efficiency compared with the case of rotational shear followed by oscillatory one.

According to these observations, it is recommended to follow the traditional rotational disruptive technique with LAOS to ensure well dispersed systems before measuring the build-up. This combination showed higher efficiency to disperse concentrated suspension compared to rotational shear rate only. Moreover, this combination achieved a comparable reference state for various shear strains compared with LAOS which achieved different states depending on the strain value.

4 CONCLUSIONS

The effect of various disruptive shearing techniques including rotational, oscillatory, and rotational-oscillatory combinations on dispersion efficiency of 0.35 w/c suspensions (i.e. concentrated cement suspension) is investigated. Small amplitude oscillatory shear measurement technique was used to quantify the structure before (initial) and after (growth) applying the different disruptive shearing regimes. Based on the obtained results, the following conclusions can be pointed out:

- Large amplitude oscillatory shear at high frequency can be applied to disperse concentrated cement suspensions. This should be done at shear strain near the crossover value corresponding to the maximum damping factor (i.e. maximum liquid state).
- The oscillatory technique is more efficient than the rotational one to disperse concentrated cement suspensions. Oscillatory disruptive shear is shown to reduce viscosity by 70 times compared 5 times obtained with rotational shear.
- The dispersion efficiency of rotational shear performed at shear rates lower than the transitional value can be enhanced by applying a post-oscillatory shear at strain around the crossover value corresponding to the maximum damping factor.
- The application of rotational shear followed by an oscillatory shear is found to achieve a comparable dispersion degree for shear strain and shear rate values different than the optimum ones (i.e. cross over shear strain and transitional shear rate).
- The application of disruptive oscillatory shear before the rotational shear was not effective in enhancing the dispersion degree of concentrated cement suspension.
- An effective dispersion method for concentrated cement suspension is proposed. This consists in applying a rotational shear around the transitional value between shear-thinning and shear thickening followed by an oscillatory shear at the crossover shear strain and high angular frequency of 100 rad/s.

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