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Communication

The effect of water absorption and the role of fines on the yield stress of dense fly ash slurries

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Abstract

Fly ashes obtained from power stations burning Curragh and Tarong coal were aircyclosized into fractions of different particle sizes. The grading of fractions were done according to the percentage of fines (-10 μm at d_{32} [sauter diameter]). The fraction with maximum fines was mixed with the original fly ash samples in different proportions and water absorption determined. The yield stress of a slurry consisting of different proportions of fraction with maximum fines and the original fly ash was measured. In this work the effect of water absorption and the role of fines on yield stress is presented.

Keywords: Fly ash; Aircyclosizing; Water absorption; Fines; Yield stress

The disposal of fly ash as a dense slurry from coal-fired power stations is gaining popularity because it limits water usage and leaching of metals from fly ash particles into the environment. A slurry can be considered to consist of discrete coarse solids suspended in a "continuous" vehicle of water/fine solids as proposed by Hanks and Hanks [1]. In a slurry of C volume percent solids, the mass fraction at a particle size of 10 μm (d_{32} [sauter diameter]) is designated as β. The mass fraction at 10 μm (d_{32}) is chosen because interparticle forces operate below 10 μm for cement particles [2]. Because fly ash is analogous in composition to cement, it is appropriate to consider mass fraction of fly ash particles <10 μm (d_{32}) as fine fraction and mass fraction >10 μm (d_{32}) as coarse. An increase in β means that there is an increase in percentage of fines and a decrease in β means that there is an increase in percentage of coarse particles.

An effect that has been overlooked in interpreting flow behaviour is water absorption by fly ash particles. Investigators [3,4] of coal-water mixtures have shown that coal absorbs a significant amount of water. The absorbed water raises the effective volume fraction of solids and modifies the flow properties of concentrated coal-water slurries. The role of water-holding capacity in the flow properties of dense fly ash slurries has not been reported. Coal is hydrophobic, whereas fly ash is hydrophilic, which should confer the ability to absorb more water than coal. Both the fine and coarse fraction will absorb water with free water left to mobilise the mixture. With the inclusion of absorbed water, the effective volume fraction of solids increases from C to C_{eff}, as shown in Eq. (1).

$$C_{\mathrm{eff}} = \frac{V_s}{V_s + V_w - V_{ab}} \tag{1}$$

where V_s = volume of fly ash, V_w = total volume of water, and V_{ab} = volume of water absorbed by fly ash. Then on the basis of 100 kg of fly ash/water mixture [see Eq. (2)]

$$C_{\mathrm{eff}} = \frac{\dfrac{W}{\rho_s}}{\dfrac{W}{\rho_s} + 100 - W(1+\gamma)} \tag{2}$$

where W = weight of fly ash (kg), ρ_s = true density of fly ash (kg/m^3), and γ = water-holding capacity (kg kg^{-1}).

1. Experimental

1.1. Particle size

The particle size of the ashes used in this study was measured by laser diffraction analysis using a Malvern Mastersizer (E) (Malvern Instruments Ltd, Worchestire, England) with ultrasound to break aggregates. The mass fraction at 10 μm (d_{32}) from laser diffraction results was noted to demarcate the fine and coarse fractions.

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Table 1
β values of original and fraction with maximum fines

Sample	β	Weight percent (aircyclosized)
Original Curragh fly ash	0.2440	—
Original Tarong fly ash	0.0890	—
Fraction with maximum fines, Curragh fly ash	0.4400	23
Fraction with maximum fines, Tarong fly ash	0.8400	3

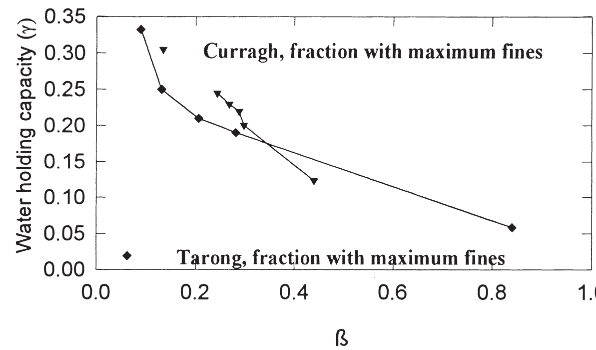

Fig. 2. The effect of mixing fraction with maximum fines on water-holding capacities of fly ash particles.

1.2. True density of fly ashes

The true density of fly ashes was measured by helium pycnometry.

1.3. Size separation

Size fractions were prepared in an aircyclosizer to separate the two fly ashes into seven fractions. Aircyclosizing of fly ash particles was done according to the procedure of Smith [5]. The seven fractions were analysed by laser diffraction to find the value of β and the percentage of fines were calculated as reported in an earlier study [6]. The fraction with the highest value of β was designated as the fraction with maximum fines.

1.4. Water-holding capacity (kg of water/kg of fly ash) of the original and the mixed fly ash particles

The water-holding capacity (γ) of both the fly ashes was measured by the method of Kaji [3,4]. Approximately 10 g of fly ash particles were soaked in distilled water for 4 hours at 22 ± 2°C. The supernatant liquid was then drained off and the external surface of the fly ash wiped with filter paper. The water-holding capacity was recorded as the loss in weight obtained on drying at 100°C to a constant weight (w ⩾3 hours). The average of three or four measurements was taken. Reproducibility of the data was within ±4%. The fraction with minimum and maximum fines was mixed with the original fly ashes and water absorption measured.

1.5. Yield stresses of dense fly ash slurries

Fractions with maximum fines of both Curragh and Tarong were added to the original fly ashes for yield stress measurements while keeping the solid concentration fixed (67 wt% Curragh, 63 wt% Tarong). A Haake RV-12 (Haake Mass Technik, Karlsruhe, Germany) rotational viscometer with the vane arrangement was used to measure the yield stress of dense slurries. The calculations for yield stress were based on the method of Boger and Nguyen [7].

2. Results and discussion

2.1. Size separation

The values of β, and the weight percentage of fraction with maximum fines and the original fly ashes is presented in Table 1. The results show that original Tarong fly ash has a very low percentage of fines compared to original Curragh fly ash. On aircyclosizing, the fraction with maximum fines has a higher percentage of fines for both Tarong and Curragh. The weight percentage obtained for a single batch of

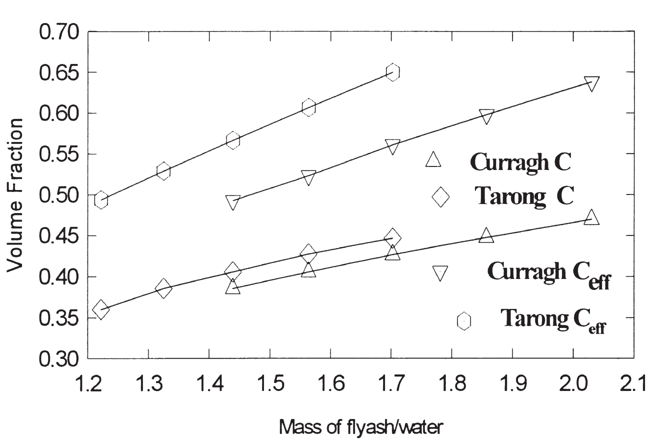

Fig. 1. Volume fraction of the fly ashes with allowance for water-holding capacity (kg kg^{-1}).

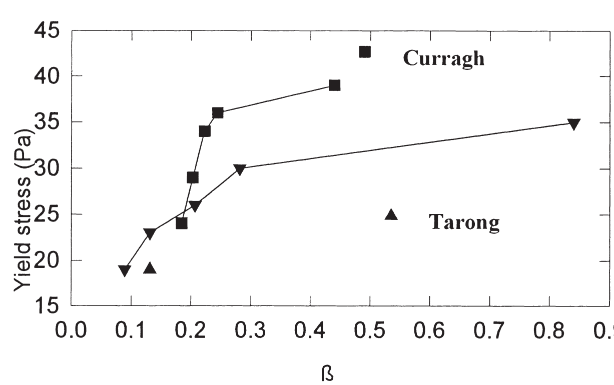

Fig. 3. Effect of β on yield stress.

400-g batch size of original fly ash was very low for Tarong (fraction with maximum fines). Several batches of both the fly ashes were aircyclosized to obtain sufficient quantities for water-holding capacity measurements and yield stress determination.

2.2. Effective volume fraction

The measured water holding capacity (γ) of original Curragh and Tarong fly ashes were 0.24 and 0.33, respectively. Water absorption increases the volume fraction (C_{eff}). This is presented in Fig. 1. Fly ashes have high water-holding capacities due to porous structure [8]. The true densities required to be inserted in Eq. (2) for C_{eff} were 2290 and 2110 kg/m^3 for Curragh and Tarong fly ash.

2.3. The effect of addition of fraction with maximum fines on water-holding capacity of original fly ash particles

The addition of fraction with maximum fines to the original fly ashes decreases water-holding capacity for both Curragh and Tarong. This is presented in Fig. 2.

2.4. The dependence of yield stress on percent fines, water-holding capacity

The addition of fraction with maximum fines to the original fly ash particles increases yield stress. This is presented in Fig. 3. An increase in β decreases water-holding capacity (Fig. 2). The results presented in Figs. 2 and 3 indicate that yield stress has an inverse relationship to water-holding capacity and a direct relationship to fines percentage.

3. Conclusions

1. Water absorption increases the volume fraction of a dense fly ash slurry.
2. Water absorption is a function of particle size. The addition of fraction with maximum fines to a dense fly ash slurry decreased water absorption.
3. Yield stress increases with an increase in fines.

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