Effective Composition of High Concentration Fly Ash-Bottom Ash Mixture Slurry for Efficient Disposal through Pipelines

P.K. Senapati[a*], B.K. Mishra[a], Aparajita Sahu[a], Vimal Kumar[b]

a Institute of Minerals and Materials Technology, Bhubaneswar 751 013, India
b Department of Science & Technology, Fly Ash Unit, New Merauli Road, New Delhi 110 016, India

* Corresponding author: pksenapati@immt.res.in
Fax: x91.674.2581160

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Abstract:
The composition of high concentration ash slurry requires careful selection of particle size distribution (PSD) to achieve the required rheological properties for efficient disposal through pipelines. In the present study, the maximum static settled concentration, $C_{W\text{-}max}$, tests and rheological measurements were carried out for a total eighteen nos. of ash samples (nine nos. of fly ash samples and nine nos. of fly ash–bottom ash mixture samples) in the concentration range of 60 – 70 wt%. It was observed that the $C_{W\text{-}max}$ value reached maximum for the composition of mixture slurry consisting of fly ash and bottom ash with d_{50} as 6.4 μm and 144 μm respectively at a fixed blend ratio (weight ratio of fly ash to bottom ash) of 4:1. This was attributed to the packing effect and was correlated to the ratio of surface to surface separation for the coarse bottom ash particles, β, to the average fly ash particle size, $d_{50\text{-}f}$, to achieve higher solids concentration. The rheological behaviour of the ash slurry samples were described by non-Newtonian power law model in the range of solids concentration studied. Also a substantial reduction in viscosity was observed for the same composition of mixture slurry sample which was attributed to the poly-dispersive characteristics of the ash particles. It was indicated that the slurry viscosity was very much influenced by particle size ratio ($\lambda = d_{large}/d_{small}$) and volume fraction of solids. The study revels that the blending of fly ash and bottom ash at a controlled PSD may be employed for preparation of high concentration ash mixture slurry for pipeline transport.

Zusammenfassung:
Die Formulierung von hochkonzentriertem Staubschlamm erfordert eine sorgfältige Auswahl der Partikelgrößenverteilung (PSD), um die rheologischen Eigenschaften für einen effektiven Transport durch Pipelines einzustellen. In der vorliegenden Arbeit, wurden die Bestimmung der maximalen statischen Sättigungskonzentration ($C_{W\text{-}max}$), und rheologische Messungen für achtzehn Staubproben (neun von Flugstaubproben) und neun von Bettasche-Schlammmischungen) im Konzentrationsbereich von 60-70 Gew.-% durchgeführt. Es wurde festgestellt, dass der $C_{W\text{-}max}$-Wert sein Maximum für eine Zusammensetzung einer Mischung aus Flug- und Bettasche mit einem d_{50} von 6.4 μm bzw. 144 μm bei einem konstanten Blendverhältnis (Gewichtsverhältnis von Flugstaub zu Bettasche) von 4:1 annimmt. Dieser Effekt wird der Packungsdichte zugeschrieben und wurde mit dem Verhältnis von Oberfläche zu Oberflächentrennung für die gröberen Bettasche-Partikel, β, und dem Durchschnittswert der Flugstaub-Partikelgröße $d_{50\text{-}f}$, in Beziehung gesetzt, um einen höheren Feststoffanteil zu erzielen. Das rheologische Verhalten der Staubschlammproben wurde mit dem nicht-Newtonschen Potenzgesetzmodell im Bereich der Feststoffkonzentrationen beschrieben. Darüber hinaus wurde eine wesentliche Reduktion der Viskosität bei derselben Konzentration der Mischstaubproben festgestellt, die der polydispersen Charakteristik der Staubproben zugeschrieben wird. Es wurde gezeigt, dass die Schlammviskosität sehr stark von dem Partikelverhältnis ($\lambda = d_{groß}/d_{klein}$) und dem Volumenanteil des Feststoffs beeinflusst wird. Diese Untersuchung zeigt, dass das Mischen von Flugstaub und Bettasche bei einer kontrollierten Partikelgrößenverteilung für die Herstellung von hochkonzentrierten Aschmischungen für den Transport durch Pipelines benutzt werden kann.

Résumé:
La composition des boues contenant de grandes concentrations de cendre requiert une sélection attentionnée de la distribution en tailles des particules (PSD), afin d'obtenir les propriétés rhéologiques requises pour l'épandage par tubage. Ici, la concentration statique établie et maximum, $C_{W\text{-}max}$, des mesures d'essais et des mesures rhéologiques ont été établies pour un total de 18 nos d'échantillons de cendre (neuf nos. d'échantillons de cendre volante et neuf nos. d'échantillons de mélanges de cendre volante et de fond) dans un régime de concentration allant de 60 à 70 % en poids. On a observé que la valeur de $C_{W\text{-}max}$ atteint un maximum pour la composition de boue mélangée faite de cendre volante et de fond avec un d_{50} de 6.4 μm et 144 μm, respectivement, et un ratio fixe de mélange (ratio en poids de cendre volante sur cendre de fond) de 4 :1. Ceci est attribué à un effet de remplissage et est corrélé avec le ratio de la surface de séparation pour les grosses particules de cendre de fond, β, sur la taille moyenne des particules de cendre volante, $d_{50\text{-}f}$, afin d'obtenir des concentrations en

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ash particles. The increase in $C_{W\text{-}max}$ values for the fly ash-bottom ash mixer samples S10, S11, S13, S14, S15, and S16 influenced by excluded volume effect was explained by the ratio of the surface to surface separation for the coarse bottom ash particle, β, to the average fine fly ash particle size, $d_{50\text{-}f}$, i.e. $\beta/d_{50\text{-}f}$. The rheological studies conducted for the eighteen ash samples indicated that the flow behaviour of ash slurry can be very well fitted to non-Newtonian power law model in the studied range of concentrations (60 – 70 %) by weight. The addition of coarse bottom ash particles to finer fly ash slurry affects the slurry viscosity at high solids concentration. An appreciable amount of reduction in viscosity in the order of 10 – 63.6 % was obtained for the samples S10, S11, S13, S14, S15, S16, and S17 in the slurry concentration range of 65 – 67.5 wt%.

The ash samples S3, S9, S11, S13 and S17 with size ratio in the range of 44.42 – 68 indicated lesser viscosity as compared to other samples at high solids concentration. The reduction in viscosity for the composition of mixture samples at a fixed blend ratio of 4:1 (weight ratio of fly ash to bottom ash) could be explained by correlating the viscosity to particle size ratio ($\lambda = d_{large}/d_{small}$) and volume fraction of solids. The distribution modulus, n_{farris}, values in the range of 0.15 – 0.2 computed for the ash samples indicated lower viscosities at high solids concentration. The ash sample S11 with n_{farris} value of 0.17 indicated near minimum viscosity and maximum packing density which is in reasonable agreement with the theoretical prediction of Farris. The results thus illustrates that the magnitude of viscosity reduction and maximum solids concentration can be achieved by controlling the diameter ratio and composition of fly ash-bottom ash mixture slurry. This will be beneficial for efficient disposal of high concentration ash slurry through pipelines by lowering the pumping costs.

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