IJNRD.ORG ISSN : 2456-4184
INTERNATIONAL JOURNAL OF NOVEL RESEARCH AND DEVELOPMENT (IJNRD) | IJNRD.ORG
An International Open Access, Peer-reviewed, Refereed Journal

IMPACT OF SOLID CONCENTRATIONS ON THE RHEOLOGICAL BEHAVIOUR OF FLY ASH-WATER SUSPENSION

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ABSTRACT: Almost every country uses coal as its primary energy source. The rising usage of coal in the manufacturing process causes ash output to rise in line with energy consumption. The goal of this research is to investigate the rheological, chemical, and physical properties of fly ash in combination with water in order to build a slurry transport system. Fly ash is mostly composed of silica and alumina. The rheological investigation shows that the slurry behaves non-Newtonian at larger concentrations (40-60%) and Newtonian at lower values (10-30%). By applying rheological properties to the slurry in a horizontal conduit, one may predict its flow characteristics.

1. INTRODUCTION

Coal is the only stable fuel known on Earth, and it holds the most energy squeezed into a small space by nature. Despite its uneven distribution around the globe, coal remains the dominant energy source in every country. According to government reports, coal-fired power plants meet around 59.2% of India's energy needs. Approximately 40% of India's coal reserves are made up of low-quality, high-ash coal that is largely new. A substantial number of research institutions in India are currently working to determine the most efficient techniques of ash resource exploitation. Rheology is the scientific study of how substances change shape and flow under shear pressures. The rheological qualities of a solid-liquid slurry dictate how it flows through a slurry tunnel. When developing ways for transporting slurries, it is necessary to consider the suspension's rheological properties. Significant research has been conducted to examine the rheological properties of slurry suspensions made of various components. When the solid percentage of fly ash slurry exceeds 30%, the rheological characteristics change significantly. Ash's qualities vary depending on its geographical location, reflecting the specific characteristics of the coal in which it is encountered. There is currently no empirical correlation that can be used to estimate the rheological parameters of an ash-water suspension. A slurry's rheological properties are governed by a number of physical elements, including its chemical composition, pH level, wetting capability, particle size and form. The relationship between pressure drop and flow rate can be used to quantify the head loss of a solid-liquid mixture being transported via a conduit. This study seeks precise data on the physical properties, chemical content, and flow characteristics of fly ash and its precipitate. This data will be used to create a more efficient slurry transportation system.

2. EXPERIMENTAL PROCEDURE

A fly ash sample was submitted by a Nabha Power ash disposal facility in Rajpura. Standardized tests are used to examine the physical properties of fly ash. The PSD is calculated using a typical sieve shaker with filter thicknesses ranging from 1000 microns to 53 microns. A specific amount of sample is placed into the upper sieve, and then a lid is installed. After 20 minutes, deactivate the agitator and examine the sieves. Following that, the mass of the sample in each sieve is determined. A certain measurement known as the middle diameter (d50) determines whether 50% of the particles are finer or coarser by weight. The PSD is used to determine this.

The concentration of fly ash that settles in a stable state is determined using gravity settling. The test is conducted using a graded cylinder with a capacity of 100 ml. The slurry, which has a capacity of 100 ml, is made by weighing 30 percent fly ash and 70 percent water. In this case, 100 milliliters of slurry are added first. Consistently, the volume of the settled slurry is measured for fifteen minutes before being increased several times.

The JOEL JSM-6510LV scanning electron microscopy (SEM) model examines ash particle morphology using a high-resolution camera. When the low vacuum electron detector receives the particles' dispersed electron beam, it produces an image. The technique is only used in carefully regulated settings, such as a vacuum, to ensure that no particulates hinder the analysis. Fly ash particles are initially coated with gold due to their low electrical conductivity. Using a 500x magnification lens, the particles under research in this study are visible. EDS is used to evaluate the minerals and chemicals in fly ash. Fly ash is made up of component components that reflect X-rays in different ways, resulting in a range of frequencies and energies. An energy source is provided to a pre-established spectroscope, which is linked to a known pure chemical. This study uses a small sample of fly ash to determine its makeup. The pH test is designed to identify the chemical components of the sediment in response to a change in solids content. A conventional pH meter is used to determine the pH of the slurry solution. Initially, water is used to calibrate the meter; the water's pH is supposed to be 7. The pH of the fly ash slurry is then measured using a calibrated pH meter. The pH meter's digital display indicates the pH value.

An research into the rheological properties of a solution containing water fly ash. The approach uses a fly ash sample whose particle size distribution is shown in Table 1. To make the slurry, use a glass stick to blend 100 ml of water and the required amount of charcoal. To prevent particle loss, the stirring technique is carried out gradually. The result of Cw, which represents concentration, indicated that the weight percentage of the sediment ranged from 10% to 60%. Scientists investigate rheology with the Anton-Paar RheolabQC rheometer, which uses the Searle principle. To estimate the rheological parameters, the related shear stress is determined using shear rate variations ranging from 0 to 500 s-1. In this inquiry, the revolving bob and cup design is used. The produced slurry is then put to the cup, shaped like a cylinder, and attached to the bob. The air is kept at 33 degrees Celsius throughout the rheological measurement. The experiment lasts three minutes and ten seconds, with a ten-second break to allow sediment to settle and limit the possibility of a mistake during the analysis.

3. RESULTS AND DISCUSSION

Physical and chemical properties of fly ash

Table 1 shows the dispersion of fly ash particles. Particle size distribution: 61.2% are less than 75²m in diameter, while 20.7% are less than 53²m. 25% of particles are between 75 and 150 µm in size, whereas 14% are larger than 150 µm. The sample contains just 1.4% of particles larger than 250µm. The sample's median size (d50) is determined to be 68.1±m. A static settling concentration test is performed for 1200 minutes, as any settling that occurs beyond that time is considered insignificant. Table 2 displays the percentage of cases settled over time. Particles with higher initial potential energy settle more quickly. Particles increasingly slow down as their potential energy decreases during fall. Over time, the rate of settlement slows. To improve slurry mobility, keep the solid concentration five to ten percent lower than the maximum stable settled concentration. Table 2 shows that the fly ash slurry has the highest static settled concentration (Css) at 60.2%. The ash particles were rounded, as evidenced by the x500-magnification scanning electron microscopy (SEM) study in Figure 1. A scanning electron microscope (SEM) image shows a very small number of cenospheres, which are spherical voids. The cenosphere is made up of agglomerates, which are groups of bigger particles. The mineral composition of fly ash can be measured using energy dispersive X-ray spectroscopy (EDS). Figure 2 shows that the fly ash contains a high concentration of silica (SiO2) and alumina (Al2O3). Silica and alumina account for 81% of the mass of the ash. The ASTM-311 standard can be used to quantify the loss of ignition (LOI) fraction for unburned carbon. The percentage is 1.32 percent. Table 3 and Figure 3 describe the specimen's specific mineral composition. The slurry's pH is measured using an automated pH meter. The pH profile of the fly ash slurry was almost neutral at all solid concentrations examined. This is seen in Figure 4 and Table 4. The pH value for 10% solids is 6.15, and for 60% solids, it is 6.67, as stated. This suggests that the ash contains a higher concentration of less reactive and acidic chemicals.

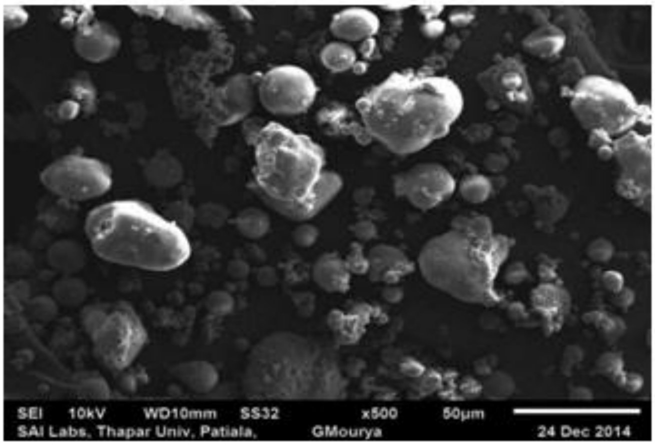


Figure 1 Figure 1 depicts fly ash using a SEM

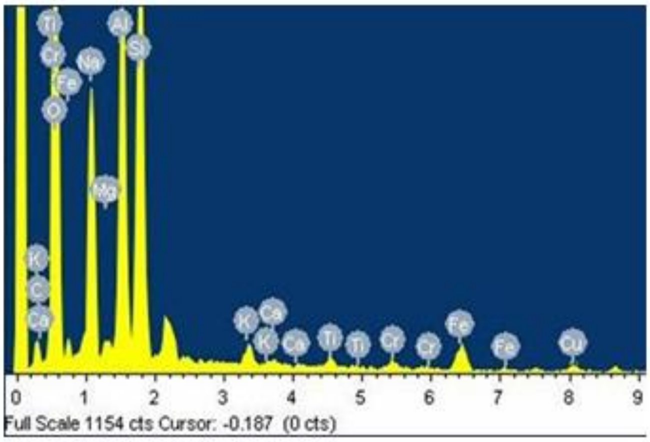


Figure 2 The EDS spectra of the fly ash sample is shown in.

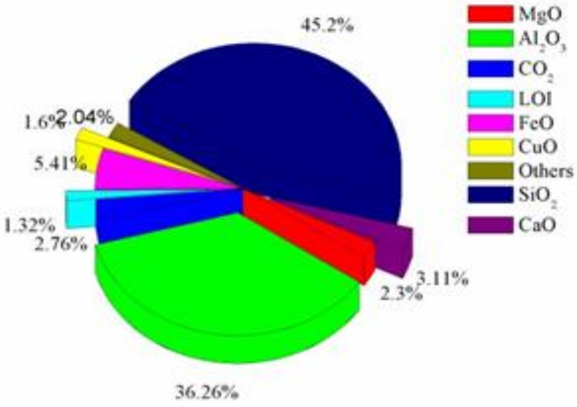


Figure 3 illustrates the components of fly ash.

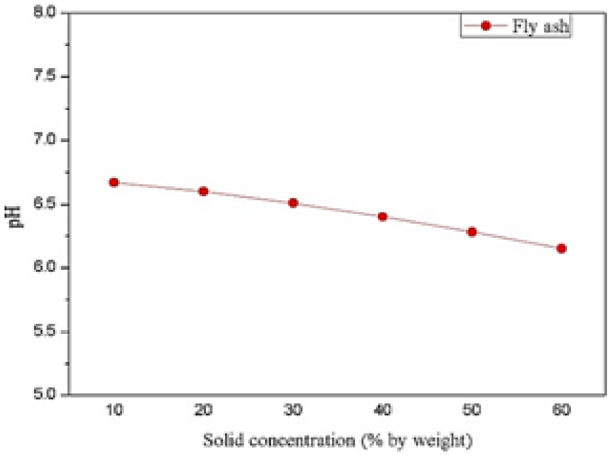


Figure 4 depicts the measured pH of the fly ash mixture.

Previous research by [researcher's name] has shown a direct link between the hydrophobic qualities of the particles dispersed in the slurry and its acidic properties. Ash particles are hydrophobic, which prevents water molecules from reaching their pores. This means that water predominates in the area around the particle. As a result, the slurry's viscosity drops. The fact that the pH of the slurry remains reasonably steady and approaches normal suggests that it has minimal effect on the suspension's rheological qualities.

Rheological characteristics

Scholars explore the rheological properties of various amounts of fly ash subjected to different stress rates. When the slurry is concentrated to 10%, 20%, or 30%, it exhibits Newtonian behavior. The observed shear stress correlates positively with the solids concentration.

Table 1 shows the distribution of different particle dimensions.

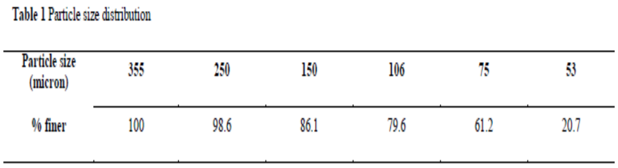


Table 1 Particle size distribution

Particle size (micron)	355	250	150	106	75	53
% finer	100	98.6	86.1	79.6	61.2	20.7

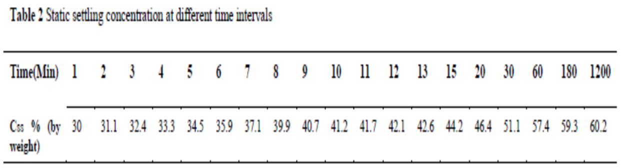


Table 2 Static settling concentration at different time intervals

Time(Min)	1	2	3	4	5	6	7	8	9	10	11	12	13	15	20	30	60	180	1200
C_{ss} % (by weight)	30	31.1	32.4	33.3	34.5	35.9	37.1	39.9	40.7	41.2	41.7	42.1	42.6	44.2	46.4	51.1	57.4	59.3	60.2

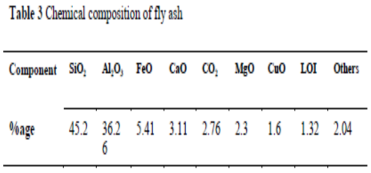


Table 3 Chemical composition of fly ash

Component	SiO_2	Al_2O_3	FeO	CaO	CO_2	MgO	CuO	LOI	Others
%age	45.2	36.26	5.41	3.11	2.76	2.3	1.6	1.32	2.04

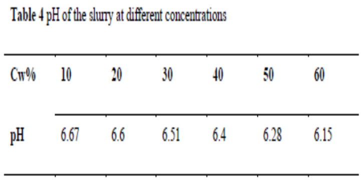


Table 4 pH of the slurry at different concentrations

Cw%	10	20	30	40	50	60
pH	6.67	6.6	6.51	6.4	6.28	6.15

Without a doubt, Figure 5 shows that the rheological behavior of the slurry changes dramatically as the quantity surpasses 30%. Specifically, the fluid's behavior is no longer Newtonian. This occurs because an increase in the number of solid particles causes increased stickiness, which intensifies the drag between two layers of particles. The sediment's flow properties qualify it as a Bingham plastic non-Newtonian fluid.

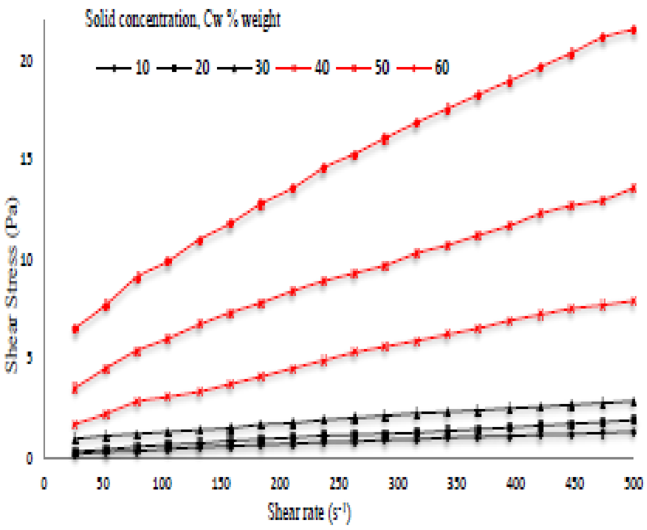
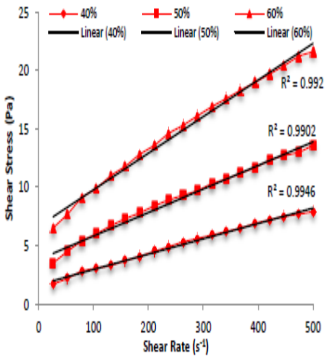


Figure 5 shows the relationship between shear stress, shear strain, and the amount of solid fly ash in the leachate.



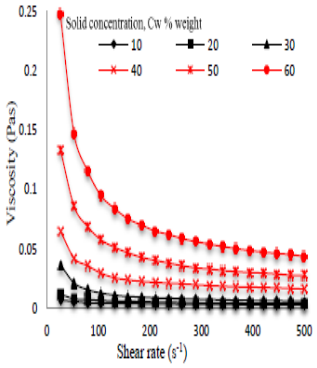
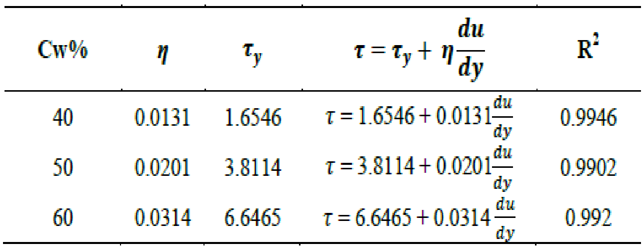


Figure 6 shows the lines that represent the tendencies in the test findings. Figure 7 depicts the relationship between the shear rate and viscosity of a fly ash water slurry with variable solid content.

The aforementioned action can be mathematically expressed by the following formula.

$$\tau = \tau_y + \eta \frac{du}{dy} \;;$$

This study focuses on shear rate, Bingham viscosity, shear stress, and Bingham yield stress. Table 5 shows the yield stress and Bingham viscosity values at various solid concentrations.



Cw%	η	τ_y	$\tau = \tau_y + \eta \frac{du}{dy}$	R^2
40	0.0131	1.6546	$\tau = 1.6546 + 0.0131\frac{du}{dy}$	0.9946
50	0.0201	3.8114	$\tau = 3.8114 + 0.0201\frac{du}{dy}$	0.9902
60	0.0314	6.6465	$\tau = 6.6465 + 0.0314\frac{du}{dy}$	0.992

When the above computation is performed on a

Newtonian fluid, the yield stress is assumed to be zero. When Bingham polymers are used, the shear rate and fluid viscosity are found to be inversely related. Based on this, we may predict that shear will occur as the flow velocity increases. As a result, shear will reduce the viscosity of the slurry, reducing the degree of the pressure decrease. Table 5 shows how the Bingham yield stress values fluctuate according to the amount of solid present. Using different linear equations, one can generate a variety of concentrations.

This enables for predictions of what will happen at higher shear rates. The association between shear stress and shear strain follows patterns similar to those found by Kumar et al. (2014) and Kumar et al. (2016). Figure 6 depicts the trend lines generated from the previously presented data. R2 values of 0.99 or above suggest that all lines are interconnected. Figure 7 illustrates the relationship between strain and shear rate. When the solid concentration is low, Newtonian behavior requires that the viscosity stay roughly constant at shear rates greater than 60 s-1. In contrast, due to non-Newtonian behavior, viscosity is substantially stronger at larger volumes and decreases as the shear rate increases. The initial viscosity of the immobile high density slurry is high due to the significant adhesion force. In opposition to this force, a significant shear stress is necessary, commonly known as the yield stress or Bingham yield stress. Throughout this experiment, a high association was found between the solid concentration and the yield stress value. The number of particles in a liquid correlates positively with its viscosity.

4. CONCLUSIONS

The goal of this study is to get a better understanding of the unique properties of fly ash and fly ash slurry in order to design a hydraulic delivery system. The following conclusions were derived from this inquiry:

At its highest level, 59.34% of the fly ash slurry has been sedimentated. Various amounts of sediment were employed to determine its pH, and the results showed that it was neutral. The fly ash samples are mostly composed of alumina (Al2O3) and silica (SiO2). There are also trace amounts of CaO, MgO, and MnO, as well as Fe2O3. Fly ash is widely used in geotechnical applications, cement material production, storage, and civil construction. This is due to its high silica and alumina content, which contribute to its strength, as well as its CaO concentration, which improves its cementing properties.

When the solid content is less than 30%, the fly ash slurry behaves similarly to a Newtonian fluid, but when the solid content surpasses 30%, it deviates from this behavior. The sample containing 60% solid has a maximum viscosity of 0.2471 Pa s. The sample contains 60% solids and has the highest yield stress of 6.6465 Pa..

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