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Application of polymeric flocculant for enhancing settling of the pond ash particles and water drainage from hydraulically stowed pond ash

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ABSTRACT

Delayed settling of the ash particles and poor drainage of water from the pond ash are the major problems faced during the hydraulic stowing of pond ash. In this study the effect of polymeric flocculant on settling of the ash particles and drainage of water during pond ash stowing are investigated. In addition, the parameters, viz. drainage and absorption of water during pond ash stowing are quantified by stowing a mine goaf model with pond ash slurries of five different concentrations added with and without flocculant. The study revealed that addition of only 5×10^{-6} of Sodium Carboxymethyl Cellulose (Na-CMC) flocculant with the pond ash slurries during stowing offers best result in terms of quicker settling of the ash particles and enhanced water drainage from the hydraulically stowed pond ash. Besides, it resulted in drainage of more than 85% of the total water used in the initial 45 min of stowing. The improvement in drainage is caused due to coagulation and flocculation of the pond ash particles because of charge neutralization and particle–particle bridging. This study may provide a basis for estimating the drainage and absorption of water during the real pond ash stowing operation in underground mines.

1. Introduction

The fly ash generation in India is increasing day by day with the growing demand of electricity and currently it has reached to the level of 130 Mt per annum [1]. A small fraction of the total fly ash generation in India is utilized in different commercial applications, and disposal of the large quantity of unutilized fly ash requires vast area of land and causes significant economic and environmental problems [2]. The unused fly ash and bottom ash are sluiced together with water and disposed off into the ash ponds. The mixture of fly ash and bottom ash deposited in the ash ponds is known as pond ash. The ash ponds in India have occupied 113 million m^2 of valuable agricultural land [3].

It has been recognized that the use of fly ash in mine backfilling or stowing has got tremendous potential for its high volume utilization. Hydraulic stowing of pond ash in underground mines is gaining popularity over the conventional sand stowing and in near future, pond ash is expected to be a major alternative to the scarcely available river sand as a stowing material. In India, the trial of pond ash stowing was started in the underground mine PK-I of Singareni Collieries Company Ltd., Manuguru Area, where approximately 10,000 m^3 of pond ash was stowed in three phases. At GDK 6A Incline of Ramagundam Region, about 9000 m^3 of pond ash from NTPC, Ramagundam was stowed with satisfactory results [4,5]. Similar pond ash stowing was also undertaken at Durgapur Rayatwari Colliery of Western Coalfields Ltd. in a successive phased manner and it was observed that the pond ash of over 50 μm size is best suited for stowing which does not require any additive for the quicker settling of the ash particles [6].

The main problems encountered during fly ash and pond ash stowing are delayed settling of the ash particles, poor water drainage and escape of fines through the barricade, etc. [7]. For efficient stowing it is desired that the hydraulic fill should be free draining and water should readily drain out from the stowed area after stowing [8,9]. Quicker drainage not only prevents the buildup of hydrostatic pressure behind the barricade, but also helps in early settling, layer wise deposition and better consolidation of the stowing material. As a result, the consolidated stowed mass offers better support resistance to the overlying strata and prevents its subsequent subsidence. On the other hand, due to poor water drainage, the hydraulically stowed material remains in slurry form for a longer duration and thereby prolongs the stowing cycle. Besides, the escape of fines through the barricade produces mucks in the coal face and creates an unsuitable working condition.

Drainage of water from the stowing materials mainly depends on its particle size and permeability. Fly ash is predominantly a silt-size nonplastic material and between 60% and 90% of the fly ash particles are finer than 0.075 mm [10,11]. Therefore, it possesses low permeability than the river sand. Because of fineness and light in weight, the ash particles remain in suspension for a longer duration and settle very slowly after fly ash is stowed

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hydraulically. In addition, the fine ash particles block the filter medium (barricade) producing filter cake and offer high resistance to water drainage. The study carried out by the authors revealed that the coefficient of permeability of both the fly ash and pond ash of Talcher Thermal Power Station is in the range of 1.373×10^{-4}–1.4964×10^{-4} and 3.3507×10^{-4}–7.2272×10^{-4} cm/s, respectively, which is equivalent to the permeability of silts [12]. Due to coarser particle size and greater permeability, pond ash is considered more suitable for stowing than the fly ash [13].

Investigations are still on for enhancing water drainage from the hydraulically stowed pond ash for its effective use as a stowing material. Researchers have reported that addition of polymeric flocculants enables faster solid–liquid segregation and quicker settling of the ash particles in a water medium. Flocculants are mostly the water-soluble linear polymers of very high molecular weight that are sufficiently large to bridge between particles during the process of flocculation and coagulation. Coagulation is the induced destabilization through charge neutralization and the process of forming larger agglomerates of particles in suspension or of small agglomerates already formed as a result of coagulation is called flocculation. The settleable larger units of agglomerates formed in flocculation due to aggregation of the dispersed fine particles in liquid media are called flocs [14,15]. The performance of a flocculant is measured in terms of settling rate, clarity of supernatant liquid, sediment volume or flocculant consumption, and decided by the complex interplay between a number of factors, viz. slurry properties and physical properties of the flocculant [16]. The flocculant dose which gives the highest clarity of the supernatant liquid or the lowest number of fine particles in the suspension after flocculation is considered as the optimum dose.

Polymeric flocculants are progressively being used for enhancing the settling of fine suspended particles and dewatering due to their low dose, ease in handling, non-interference with pH of the suspensions and larger floc forming capability [15,17,18]. In mining industry, flocculants are used in processing of coal, iron ore, bauxite and uranium etc.; and the coal mining sector is the largest user of it [18]. Flocculants have been applied in gold mine industry to effectively aid dewatering of the fill, composed of hydraulically stowed tailings slurry of 0.4–0.6 kg/L solids concentration [19]. The usefulness of flocculant in hydraulic stowing of fly ash/pond ash is being realized and its application for quicker drainage of water from the stowed ash by enhancing settling of the ash particles has also been reported.

This research work examines the effect of polymeric flocculant on settling of the pond ash particles in a water medium and dewatering from the hydraulically stowed pond ash.

2. Materials

2.1. Pond ash

The pond ash of Talcher Thermal Power Station (TTPS), a subsidiary of National Thermal Power Corporation (NTPC) Ltd. located in the state of Odisha, India is used in this study for experimentation. The installed capacity of the thermal power station is 460 MW and it receives bituminous coal from Jagannath Opencast Mines of Mahanadi Coalfields Limited (MCL), Talcher for power generation. Grab samples of the pond ash are collected in airtight plastic bags from the nearby ash pond. Prior to conducting the experiments, the physico-chemical characterization of the pond ash is done and the results are presented in Section 4.1.

2.2. Polymeric flocculant

The Sodium Carboxymethyl Cellulose (Na-CMC) polymeric flocculant obtained from the Materials Science Centre of Indian Institute of Technology, Kharagpur with average molecular weight (M_w) of 90,000 and degree of substitution (DS) of 0.70 is used in this study for enhancing settling of the ash particles and improving water drainage from the stowed pond ash. Na-CMC (Molecular formula: $[C_6H_7O_2(OH)_x(OCH_2COONa)_y]_n$, an anionic water soluble polymer, has a wide range of applications in industry for flocculation and drag reduction. It is a derivative of natural products and produced from alkali cellulose (alkali salt of poly β-D-glucose) and monochloroacetic acid with degree of substitution in the range of 0.4–1.5 [18]. It has a number of sodium carboxymethyl groups (CH_2COONa), introduced into the cellulose molecule, which promote water solubility. This particular polymer has no acute health effects and chosen for this study because, amongst all the polysaccharides, it is easily available, cheap, eco-friendly in nature and relatively resistant both to biological and hydrolytic degradations [18,20].

3. Experimental

3.1. Set-ups

3.1.1. Jar test apparatus

The flocculation jar test apparatus consisting of six identical jars with stirrers and equipped with speed control arrangement is used for studying the settling of the pond ash. The stirrers are connected to a variable-speed motor through gear system to stir the pond ash–water slurries simultaneously at known speeds. The requirement of the variable rotation speed of the stirrers is that, a fast speed is used during flocculant addition and slow speeds for the flocculation phase. The apparatus is mounted on the top of a floc illuminator base consisting of fluorescent tube mounted below translucent plastic plate. The diffused cold light produced by the illuminator facilitates clear visual inspection of the flocs produced during the jar test.

3.1.2. Mine goaf model

A mine goaf model of dimension $30 \times 30 \times 12.7$ cm and made of transparent Perspex sheet is fabricated in the laboratory for conducting pond ash stowing. A rectangular funnel is attached to its top for feeding the pond ash–water slurry. The gradient of the model is maintained at 1 in 12.5 and its front side is attached with a removable barricade fitted with a cotton cloth and supported by wires for free drainage of water after stowing. The water drained out from the stowed pond ash is collected by a right angled flume attached to the bottom of the model and measured with a measuring cylinder.

3.2. Procedure

The experimental work is carried out in two stages. First, the settling characteristic of the pond ash used in stowing is studied using the jar test apparatus. The purpose of the jar test is to simulate the flocculation process in hydraulic pond ash stowing. In this test, the effect of flocculant on the settling of the suspended ash particles in a water medium is studied and the optimum flocculant dosage that can give maximum flocculation and least turbidity of the supernatant liquid of the pond ash–water suspension is determined. In the next stage, the mine goaf model is stowed with the pond ash slurries of five different solid concentrations added with the optimum flocculant dosage as determined from the jar test to observe its effect on drainage of water and compare the results with water drainage from the hydraulically stowed pond ash not added with flocculant.