STUDY ON HIGH CONCENTRATION FLY ASH SLURRY DISPOSAL THROUGH PIPELINE

by

ABHAI KUMAR VERMA

Department of Applied Mechanics

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CERTIFICATE

This is to certify that the thesis entitled **"STUDY ON HIGH CONCENTRATION FLY ASH SLURRY DISPOSAL THROUGH PIPELINE"** being submitted by **ABHAI KUMAR VERMA** to the **Indian Institute of Technology Delhi (India)** for the award of the **Degree of Doctor of Philosophy in Applied Mechanics** is a record of bonafide research work carried out by him under our supervision and guidance. The thesis in our opinion has reached the requisite standard fulfilling the requirement of Doctor of Philosophy Degree.

The research report and the results presented in this thesis have not been submitted in part or in full to any other University or Institute for the award of any degree or diploma.

Singh
(S. N. Singh) 25/6/04

Professor

Department of Applied Mechanics

Indian Institute of Technology Delhi

New Delhi –110016

V Seshadri
(V. Seshadri) 25-6-2004.

Professor

Department of Applied Mechanics

Indian Institute of Technology Delhi

New Delhi -110016

To

My Wife

Rashmi

&

My Daughters

Eipsa and Eisha

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ABSTRACT

Slurry pipelines are commonly used for transportation of particulate materials like mineral ores, coal, fly ash, tailings etc. For transportation of such materials in bulk quantities over considerable distances, these pipelines are commonly designed for operation at low to medium solid concentrations. Though the design procedure involves the use of pilot plant loop test data and semi empirical correlations developed over the years, it has to ensure operational reliability and flexibility. However, in recent years, the emphasis is more on energy efficiency and conservation of water, which is being used as carrier fluid. Thus, the recent trend is to increase the solid concentration to as high a level as possible.

Thermal power constitutes more than half of the world's electric power generation and millions of tonnes of coal are burnt in thermal power plants across the world. Large quantity of coal ash (Fly ash and Bottom ash) is thereby produced whose properties vary over a wide range from one plant to other. With such a high production rate of ash having hardly any commercial value, it is essential that the material be quickly, reliably and efficiently removed from the plant. The ever-increasing requirement of fly ash removal has caught the attention of the investigators and the slurry pipeline designers across the world, because transportation of coal ash from the plant to the ash ponds is generally done through pipelines in slurry form in the thermal power stations. The properties of coal ash vary from one plant to the other depending on the coal used. In India, the quality of coal used is of poor grade and as such it contains 35 to 45% of ash. Presently approximately 100 million tonnes of coal ash is produced in India out of which

about 80% is fly ash and the rest is bottom ash. The concentrations used for transportation lie between 10 to 20% by weight making the whole system highly uneconomical and energy intensive. The fly ash produced is very fine where as bottom ash is coarse and many a times same pipe line is used for disposal of both materials. Hence the design requires a planned study to generate data, which will be useful for the pipeline designers.

The present day knowledge about hydraulic design of slurry pipelines is far from being complete which compels the designers to resort to the expensive, time consuming and material-specific pilot plant studies. Hence, the need arises to carry out extensive study to generate a basic data covering all aspects of slurry pipeline design to make it an optimum design methodology. Pressure drop besides having the complex dependence on the flow and geometrical parameters is also dependent on the different components used in the pipeline network. The in-depth review of the literature reveals that there is still a large gap in the knowledge for selection of optimised values of hydraulic parameters and hence the present study is aimed to generate some experimental data for the solid-liquid flow in horizontal straight pipelines and bends. Looking into the recent trend for the design of the slurry pipelines, the entire emphasis of the present work is given towards the slurry flow through pipelines especially at higher range of solid concentrations i.e. C_w>50%, by weight. Fly ash has been chosen as the material due to its relevance in Indian context.

The knowledge of slurry rheology is very much vital particularly in the dense phase slurry conveying system for the design of slurry pipeline. The rheological behaviour of the suspension depends on a large number of parameters and for fly ash slurry at any concentration has a marked dependence on particle size distribution. Five groups of fly ash samples having different particle size distribution are prepared by wet sieving to simulate the fly ash collected from different fields of Electro-static Precipitator (ESP) hoppers. Six suspensions of different solid concentrations in the range of 40-70% (by weight) are prepared from each sample to study the effect of solid concentration on the rheological parameters. The study shows that the fly ash slurries above a solid concentration of 40% by weight are non-Newtonian and that the experimental data fits a simple Bingham plastic model. It further shows that the rheological parameters increase monotonically with the solid concentration and have higher values for finer particulate suspensions. These rheological parameters can be used to predict the pressure drop in pipelines based on some suitable rheological model of the slurry.

In order to carry out in-depth study on pressure drop characteristics for fly ash slurry flow through straight pipeline, basic data for pressure drop is generated in a 50 mm NB pilot plant test loop as a function of velocity at concentration 'C_w' ranging in the higher concentration range from 50-65 % (by weight). The study is mainly oriented towards understanding the flow behaviour for multi-sized particulate fly ash slurries and an attempt has been made to correlate the effect of efflux concentration on pressure drop characteristics. This pressure drop data for non-Newtonian fly ash slurries at high concentrations have been compared with the results obtained from analytical approach which involves the choice of semi-empirical pressure drop correlations based on rheometric data in quantitative terms. The deviations in the results are within the reasonable limits (± 20%). Hence the analytical approach can be adopted by the slurry pipeline designers instead of resorting to the extensive pilot plant tests, which is tedious, time consuming, uneconomical and complex in nature.

In the present study, the direct methods for slurry viscosity reduction by adding deflocculants, which disperse flocculated slurries and soap addition (wetting agent), at concentrations in the range 0.1 to 0.4 % by total mixture weight have been studied. The slurry rheological parameters get modified and even in some cases the behavior of the slurry changes from non-Newtonian behavior to Newtonian behavior. The analysis of data has shown that at any selected velocity there is a substantial decrease in the pressure drop, the average reduction being around 30%. This highlights a net saving of approximately one-third of the total energy consumption.

In order to carry out the study on ageing effect, fly ash slurry was allowed to flow for 10 hours of run continuously, and observation showed that practically there was no attrition of particles. So the fly ash slurries are found to be free from the ageing effect.

Pipe bends are an integral part of any pipeline system and they involve additional losses. The study is carried out for the effect of bend in the slurry pipeline in terms of relative pressure drop, bend loss coefficient, and permanent pressure loss coefficient for the flow of fly ash slurries at higher concentration range (50-65%, by weight). The results show that the effect of pipe bend on it down-stream side does not persist for a long distance and fully developed flow is achieved much earlier, as compared to the slurry flow at low concentrations. This phenomena even reduces the over all pressure losses.

Thickened tailing disposal system through slurry pipelines has also been investigated for tailing material from a Uranium ore processing plant in India in terms of rheological properties and pressure drop characteristics at higher concentrations range and the utility of the single pipeline for transporting both pre and post hydro-cyclone materials has been established.

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