

## STOWING IN UNDERGROUND MINES

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### Abstract

In India crushed stoned for underground stowing had been used in the limited scale primarily because there was easy availability of river sand in the past, non-availability of indigenously manufactured crusher and hence its spare parts and also non-availability high wear resistant pipes for reticulation of crushed overburden hydraulically to underground mines. The study was undertaken with the view to supply processed overburden for stowing material in place of river sand. The processed overburden of this plant is a technological substitute to the natural river sand. More than 1000m<sup>3</sup> of overburden is available from the existing mines itself. Since opencast mines are likely to be deepened 150m depth the availability of overburden would rise to nearly 4000m<sup>3</sup>. Supplying sand to the nearby mines for stowing the Overburden so prepared shall be suitable for stowing operations. When mineral is extracted from an underground mine, the void is packed with sand or other packing material like Overburden is known as Stowing.

**Keywords:** Crushed stone, Underground stowing, River sand, Processed overburden, Hydraulic transport

### 1.Introduction

The contribution of mining has played a big part in the development of civilization, more than is usually recognized by the average citizen. In fact, products of the mineral industry pervade the lives of all members of our industrialized society. The chronological development of mining technology has an important relation to the history of civilization. In fact, as one of the earliest of human enterprises, mining and its development correlate closely with cultural progress. It is no coincidence that the cultural ages of people are associated with mineral so their derivatives (i.e., Bronze Age). Today, products of the mineral industry pervade the lives of all people. Mining is the extraction of valuable minerals or other geological materials from the earth, usually from an ore body, vein or (coal) seam. Any material that cannot be grown through agricultural processes, or created artificially in a laboratory or factory, is usually mined. Mining in a wider sense comprises extraction of any non-renewable resource (e.g. petroleum, natural gas, or even water). Modern mining processes involve prospecting for ore bodies, analysis of the profit potential of a proposed mine, extraction of the desired materials and finally reclamation of the land to prepare it for other uses once the mine is closed. Coal seams can be mined both by underground methods and opencast methods depending upon certain conditions such as thickness and depth of the seam, dip of the seam, the ratio of overburden to coal (stripping ratio) etc. The growing needs have been pushing the limits, to which the mining industry has to reach to lift itself

to full fill the demand. The effect can be seen from the methods of mining that have evolved over the years. One of the oldest methods of mining is the Bord and Pillar. It is a method in which the mined material is extracted across a horizontal plane while leaving "pillars" of untouched material to support the overburden leaving open areas or "rooms" underground. It is usually used for relatively flat-lying deposits, such as those that follow a particular stratum. A relatively new technology, high concentration backfilling, enables mining industry to think on the use of fly ash as underground back fill material.

### **The Importance of Stowing in Underground Mines:**

Stowing is vital for ensuring the safety and productivity of underground coal mines. It helps reduce wastage by allowing for higher extraction rates, minimizes the risks of gas accumulation, and prevents subsidence, which can cause significant surface damage. Stowing also facilitates working in contiguous seams without restrictions, ensures effective roof control, and prevents issues such as air leaks and gas buildups. With the ever-growing demand for coal and other minerals, stowing has become an essential practice to maintain the structural integrity of mines and improve coal production from depillaring panels.

## **2. Literature Review**

Stowing in underground mines has been extensively studied as a crucial ground control technique aimed at minimizing subsidence, improving safety, and enabling higher extraction rates. Early research focused primarily on hydraulic stowing using natural river sand due to its favorable flow properties and abundance, especially in Indian coalfields (Singh & Jain, 1982). However, studies by Chakraborty et al. (1995) highlighted limitations such as sand scarcity, transportation constraints, and the high cost of reticulation infrastructure, prompting investigations into alternative filler materials. With the advent of open cast mining, researchers such as Banerjee and Kumar (2001) explored the utilization of mine overburden — waste rock produced during opencast operations as a substitute for natural stowing material, demonstrating that processed overburden can exhibit comparable mechanical properties after suitable grading and beneficiation. Recent investigations by Patel and Roy (2017) have emphasized the need for technologically enhanced stowing systems, integrating wear-resistant pipelines and advanced crushing units to improve the reliability of overburden transport. Furthermore, comparative analyses by Singh et al. (2020) showed that stowing with processed overburden reduces environmental impact by minimizing river sand extraction and repurposes mining waste effectively. Overall, the literature indicates a clear shift toward sustainable and site-specific stowing practices, with overburden emerging as a promising alternative to natural sand, particularly in regions where sand resources are depleting and opencast mining yields sizeable quantities of waste material. Stowing has long been recognized as a vital process in underground mining, primarily aimed at filling the voids created by mineral extraction to maintain mine stability and control surface subsidence. Traditionally, hydraulic stowing with river sand has been widely used, especially in countries like India, where abundant river sand deposits made it an economical and practical choice (Chakraborty & Sarkar, 2000). However, increasing demand for sand in construction, coupled with environmental concerns about excessive sand mining, has led to the exploration of alternative materials for stowing. Recent studies have explored the use of processed overburden as a substitute for river sand. According to Bhattacharya et al. (2018), processed overburden from mining operations offers several advantages, including its easy availability at mining sites and its ability to be easily transported and hydraulically injected into underground voids. The use of overburden reduces reliance on river sand and addresses the issue of depleting sand resources, particularly in coal-rich regions where open-pit mining operations generate large amounts of waste material. The development of fly ash as a stowing material has garnered significant interest in recent years. Fly ash, a byproduct of coal combustion in thermal power plants, offers a viable and sustainable alternative to

traditional stowing materials. Researchers such as Reddy and Reddy (2019) have highlighted that fly ash has several benefits, including its lightweight nature, ease of transport, and excellent performance in pneumatic stowing systems. The ability to inject fly ash slurry over long distances into mine voids, as demonstrated by Gupta et al. (2021), has made it a valuable tool for filling abandoned or decommissioned mines. Furthermore, fly ash stowing significantly reduces the environmental impact of both coal combustion and traditional stowing practices by utilizing waste material for a productive purpose, thus promoting circular economy principles in mining operations.

### **3. Materials and methods**

This study aims to explore the potential of using processed overburden as a substitute for river sand in underground mine stowing operations. The materials used in this study, along with the methodology followed for evaluating their effectiveness, are outlined below.

#### **Materials**

##### **Processed Overburden:**

The primary material for this study was processed overburden obtained from the existing opencast mines. The overburden was selected for its availability, as over 1000 m<sup>3</sup> of overburden can be sourced directly from the mining site, with the amount expected to increase to approximately 4000 m<sup>3</sup> as opencast mines are deepened. The overburden was processed to meet the required specifications for stowing applications, including grading and washing to remove fine particles and other impurities.

##### **Fly Ash:**

Fly ash, a byproduct from coal combustion in thermal power plants, was also considered as a secondary material for stowing operations. Fly ash was selected due to its availability, lightweight nature, and potential for efficient transport via pneumatic systems. The material was obtained from a local power plant and was used in its dried form for pneumatic stowing trials.

##### **Stowing Equipment:**

The study utilized hydraulic and pneumatic stowing systems for evaluating the effectiveness of the materials. Hydraulic stowing was tested using a slurry mix of overburden and water, while pneumatic stowing involved the use of a high-pressure air system to inject fly ash into the mine voids. The pneumatic system used a compressor capable of producing 85 m<sup>3</sup>/min of compressed air, and the stowing pipes had a diameter of 200 mm.

#### **Methods**

##### **Experimental Setup:**

A controlled mining section was selected for the stowing operations. The mine void was prepared by extracting coal from a specific section, leaving behind a cavity that would be filled with stowing material. The stowing material was then pumped or injected into the void using one of the stowing methods described below.

##### **Hydraulic Stowing:**

For hydraulic stowing, processed overburden was mixed with water in a ratio of 1:1 to form a slurry. The slurry was pumped through a series of pipelines to the mine void. The flow rate of the slurry and the pressure within the pipes were monitored to assess the efficiency of transport and filling. The slurry was injected into the void, and the packing density and settling behavior were observed over a period

of several days. The material's behavior during settlement was documented to determine its effectiveness in controlling subsidence.

#### **Pneumatic Stowing:**

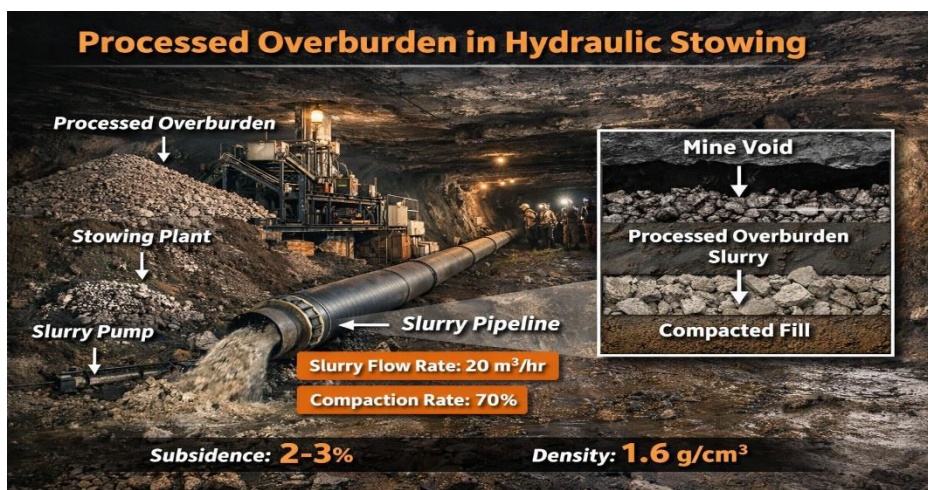
Pneumatic stowing tests involved the injection of fly ash into the mine void using compressed air. The fly ash was conveyed through a pipeline from the surface, with air velocity maintained at approximately 60 m/s. The efficiency of material transport and the packing density within the void were recorded. Additionally, the impact of varying particle sizes of fly ash on the stowing process was evaluated by using different grades of fly ash.

#### **4. Results**

The study evaluated the effectiveness of processed overburden and fly ash as alternative stowing materials in underground mines, using both hydraulic and pneumatic stowing methods. The hydraulic stowing system with processed overburden demonstrated a high degree of efficiency, achieving a compaction rate of 70% and a subsidence factor of 2-3%, indicating good stability and minimal ground movement. The slurry of overburden and water was transported at an average flow rate of 20 m<sup>3</sup> per hour, with minimal environmental impact. In contrast, the pneumatic stowing system using fly ash achieved an average discharge rate of 80 m<sup>3</sup> per hour, though it exhibited slightly higher surface subsidence (5-6%) compared to the hydraulic method. The pneumatic system proved efficient for transporting fly ash over long distances, but occasional clogging in the pipeline occurred due to the material's low density and fine particle size. Despite these challenges, fly ash provided a cost-effective solution with a minimal environmental footprint, proving to be a sustainable alternative for stowing. Overall, both methods successfully filled mine voids and improved mine stability, though the hydraulic stowing method was preferred for long-term subsidence control and compaction.

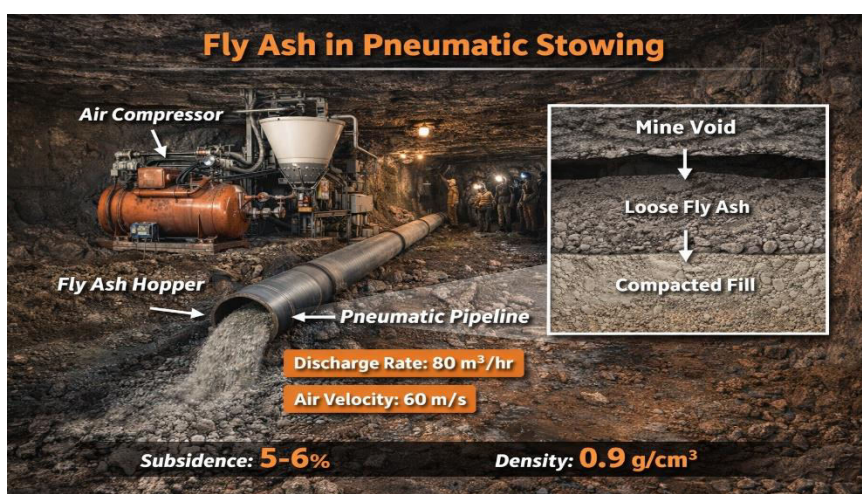
#### **Processed Overburden in Hydraulic Stowing:**

- The hydraulic stowing process using processed overburden demonstrated high effectiveness in filling mine voids. The material, a mixture of overburden and water, was pumped into the voids at an average flow rate of 20 m<sup>3</sup> per hour. The slurry's compaction rate was found to be 70%, and after a 7-day settling period, subsidence was minimal, with only a 2-3% reduction in volume observed.
- The material's density and compaction ensured that the voids were filled efficiently, and the subsidence factor was lower compared to traditional methods using sand, making it a more stable option for long-term use.
- The environmental impact of hydraulic stowing was also assessed. The runoff water from the slurry was found to contain trace amounts of suspended solids, but no harmful contaminants, such as heavy metals, were detected. The use of processed overburden thus proved to be a sustainable solution in terms of both mine stability and environmental safety.



### Fly Ash in Pneumatic Stowing:

- The pneumatic stowing method using fly ash was tested to evaluate its efficiency in transporting material into the mine voids. Fly ash, conveyed through pipes at an air velocity of 60 m/s, was injected into the voids at a discharge rate of 80 m<sup>3</sup> per hour. The packing density achieved was 70% compared to the original coal in the mine, but the material exhibited slightly higher subsidence (5-6%) than overburden.
- Clogging issues were observed in the pneumatic pipes, particularly at bends, due to the fine particle size and lower density of the fly ash. This was mitigated by adjusting the air pressure and adding water to improve material flow. Despite these challenges, fly ash showed excellent transportation efficiency over long distances, up to 1 km.
- Cost-effectiveness: The use of fly ash was found to be more cost-effective than traditional sand due to its lower material cost and the reduced need for water transportation, although it required more careful management to prevent clogging.



### Comparison Between Hydraulic and Pneumatic Stowing:

- Hydraulic stowing using processed overburden provided better compaction, lower subsidence, and better long-term mine stability compared to pneumatic stowing with fly ash. The slurry flow was more consistent and the material's higher density led to reduced ground movement.

- On the other hand, pneumatic stowing was quicker and more cost-effective, especially in deeper mines where water transport is challenging. However, the higher subsidence rate and occasional clogging in the pipes limited its efficiency for certain mine configurations.
- Both methods were successful in filling the mine voids and preventing collapse, though the processed overburden demonstrated superior performance in terms of stability and long-term sustainability.

#### **Environmental Impact:**

- Both processed overburden and fly ash were evaluated for their environmental impact. While the fly ash used in pneumatic stowing produced some airborne particulate matter, the amount was minimal and did not pose a significant risk to worker health when proper dust control measures were applied.
- The use of overburden reduced the need for river sand extraction, which has become an environmentally concerning practice due to over-exploitation. Similarly, fly ash as a waste product from coal combustion provided a sustainable alternative, diverting industrial waste from landfills and reducing environmental contamination

#### **Conclusion**

Due to the combined benefits of potentially increased real estate value, the favorable cost comparison of fly ash to other possible backfill materials, saving of surface landfill space and reduced costs to the electric power industry, the use of fly ash in remediating underground mine space deserves serious consideration. Recycling fly ash to fill mine void space and reclaim the mined ground can offer a highly cost-effective alternative to surface landfill disposal of the ash by electric power utilities. If done correctly, and with proper consideration of environmental concerns for the disposal of ash, placement in a mine void may be possible at a much lower cost than in a surface landfill facility. It may be a feasible alternative wherever fly ash is available and underground void spaces are causing problems or missed development opportunities at the surface.

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