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MESSAGE

*I am happy to know that **'The Indian Mining & Engineering Journal'** published since 1961, has entered into the Diamond Jubilee year of its publication. Technical Journals are the flag bearers of news and views on various technological developments made in their respective field.*

Indian Mining Industry which had grown by leaps and bounds since 1960 with a plethora of developments and policy, changes from a controlled regime to a far more transparent and Sustainable industry. The coal sector has also seen developments in most areas like mechanization of mega opencast mines, more safe underground mining, infusion of in-house and indigenous R&D initiatives and a safe place to work.

At NCL, we have not only enhanced the production of coal maintaining highest standards of safety, productivity bust also caring the community in and around our mega projects. Our contribution to the 'energy security' of the nation is at the top of our agenda with infusion of new technologies in excavation, transportation and restoration of the mined out areas echoing with the slogan of 'Aatmanirbhar Bharat'.

At this occasion, I wish all the stakeholders associated with this Journal as readers, authors and editorial team members a successful year ahead.

(Prabhat Kumar Sinha)

THE INDIAN MINING & ENGINEERING JOURNAL

(Incorporating Mineral Markets: The Founder Publisher & Editor: J.F. De. Souza, Mumbai)

www.theimejournal.com

VOLUME 60: Number 02 **FEBRUARY 2021** ISSN 0019-5944

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 Published Monthly by IME Publications.
Annual Subscription : Rs.650/- (Incl. Postage)
Unit Price: Rs.50/-
FOREIGN: £ 75 OR US $ 150 (By Air Mail)
Payment by Cheque/Draft. Cheques drawn outside Bhubaneswar must include Rs.50/- (Overseas £1 or US$2) as bank charges and should be drawn in favour of
*"**The IM& E JOURNAL**" payable at Bhubaneswar*

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Prof.(Dr.) S. Jayanthu

Persons in the News

Anil Kumar Jha former Chairman-Coal India Limited, has been appointed as the Chairman of Jindal Power Limited (JPL), a subsidiary of Steel maker Jindal Steel & Power Limited (JSPL). Shri Jha is a mining Graduate, he also holds an M.Tech degree from Indian School of Mines, Dhanbad. He started his career with Coal India as a Junior Executive (Trainee) at Topa Colliery in Central Coalfields Limited (CCL) in 1983 and joined Mahanadi Coalfields Limited (MCL) as CMD on November 1, 2015.

COAL NEWS

INDIA'S COAL IMPORT DROPS 12 % TO 181 MT IN APRIL-JANUARY

India's coal import registered a drop of 11.59 per cent to 180.84 million tonnes (MT) in the first 10 months of the ongoing fiscal. The company had imported 204.55 MT of coal in April-January period of the previous fiscal year, according to provisional data compiled by mjunction services. mjunction -- a joint venture of Tata Steel and SAIL -- is a B2B e-commerce company and also publishes research reports on coal and steel verticals. However, India's coal imports in January increased to 20.05 MT as against 18.67 MT in year-ago period, it said.

Commenting on the coal import trend, mjunction MD and CEO Vinaya Varma said, "There was a drop in January volumes as compared to the previous month (December). This was mainly due to the firmness in seaborne prices. While there is steady demand in the market, the import trend will largely depend on the movements in international prices, freight rates and also domestic supply." Coal import was, however, 7.4 percent higher in January 2021 as compared to 18.67 MT in the year-ago period. Of the total imports in January 2021, non-coking coal was at 12.77 MT, while coking coal import was 5.62 MT.

During April-January 2020-21, non-coking coal import was at 119.84 MT as compared to 140.65 MT in the same period a year ago. Coking coal import was recorded at 39.16 MT, lower than 41.15 MT imported during the same period a year ago.

COAL INDIA, CENTRE FOR RAILWAY INFORMATION SYSTEMS SIGN MoU FOR RAKES DATA SHARING

Coal India entered a Memorandum of Understanding with Centre for Railway Information Systems (CRIS), a wing under Ministry of Railways for data sharing to rationalise coal supply matrix through rail mode. The access to data through Freight Operations Information System (FOIS) of Indian Railways would help Coal India monitor movement of coal laden rakes and coal despatch activity. The move would provide precise details of loading, weighment and unloading details along with turnaround time of rakes. The information would help minimise the instances of under loading and overloading of rakes and untangles the knots benefitting CIL, Railways and the consumers, an official said.

The information will also ease the way for faster billing and bill monitoring process replacing the manual entry of railway receipts with instantaneous online transfer. The data sets shared by CRIS provides CIL information on sanctioned coal and rake programmes, rake demand, rake detention and diversion details which helps the coal companies plan their supplies. CIL has developed a portal which helps in sharing the FOIS data with its subsidiary coal companies. “The pact assumes greater significance at a time when CIL is pushing for increased rail evacuation and gradually reduce the road movement of the dry fuel. The real time data helps us in better planning,” he said.

Till February 20 of the ongoing fiscal, CIL’s coal movement through rail mode from its own sidings, goods sheds and private washeries at 302.51 Million Tonnes (MTs) accounted for 61% of the total off-take quantity. When dovetailed with merry-go-round system, at 92.8 MTs, which is a dedicated rail mode transport, the percentage expands even higher to 79%. “We intend to raise it further,” said the executive. CIL and CRIS will collaborate for further improvement in data sharing with periodical reviews. The contract period of the MoU is one year with annual technical support, the official said.

CIL'S OVERALL EXPENDITURE DROPS TO RS 54,241 CRORE IN APR-DEC 2020 PERIOD

Coal India Ltd said its overall expenditure declined by 3.3 per cent to Rs 54,241 crore in the first nine months of the ongoing fiscal. In a statement, the company also said its composite open cast production increased by 16.1 per cent in the April-December period. "CIL's overall expenditure dropped to Rs 54,241 crore, during the referred period, from that of Rs 56,079 crore for the same period year ago," it said.

According to the statement, the company clocked 6.3 per cent output growth, 9.1 per cent surge in coal off-take and 17.3 per cent increase in Over Burden Removal (OBR) during the third quarter ended December 2020. In terms of expenditure, employee benefit expenses dropped by Rs 735 crore. These include salaries, performance-related pay of the executives, performance- linked reward of the non-executives and coal mines provident fund contributions. In recent years, CIL has seen superannuation of around 13,000 employees annually. The company's manpower stood at 2.72 lakh at the beginning of the current fiscal compared to 3.22 lakh employees four years ago. During the nine-month period of the current

fiscal, manpower reduced by 13,800. This reduction is expected to continue for few more years which would further shrink the employee benefit expenditure, which currently stands close to 50 per cent of CIL's overall revenue expenditure.

As per the statement, there was less provisioning for stripping activity of Rs 2,894 crore during the April-December 2020 period. Stripping activity is the quantity of OB removed for the required coal produced. OBR is one of the significant components of the expenditure.

MINING NEWS

HUTTI GOLD MINES TO TRIPLE PRODUCTION IN ONE-AND-HALF YEARS: KARNATAKA MINISTER MURUGESH NIRANI

Hutti Gold Mines plans to triple annual production of the yellow metal to 5,000 kgs in one-and-a-half years, according to Karnataka Mines and Geology Minister Murugesh R Nirani. Nirani, who completes one month in office as cabinet minister in the BJP-ruled Karnataka government, added that due to COVID-19, the revenue from mines auction so far in the current fiscal could reach only 85 per cent of the Rs 3,700 crore achieved in 2019-20. But in the next fiscal, it is expected to surpass the target of Rs 4,000 crore. The minister also highlighted the new policy measures the state government is working on to curb illegal mining and attract investment, including introducing a single-window clearance system and holding 'mining adalats' for addressing grievances, besides ramping up gold production in the state. Speaking to , the minister said Karnataka has the distinction of being the only gold ore producer in India. There are enough reserves, technology and market for gold, the price of which has soared to over Rs 47,000 per 10 grams now. Speaking to , the minister said Karnataka has the distinction of being the only gold ore producer in India. There are enough reserves, technology and market for gold, the price of which has soared to over Rs 47,000 per 10 grams now.

Hutti Gold Mines Company Limited (HGML), a Karnataka government undertaking, operates one unit each in Raichur and Chitradurga districts. "Currently, HGML is producing 1,700 kg per annum. Within 18 months, the plan is to increase gold production to 5,000 kg per annum. There are reserves, technology and markets. There is potential," Nirani said. According to the HGML website, the Chitradurga unit's operations for gold mining and processing ore have been temporarily suspended and the company has diversified into wind farm projects.

The Hutti Gold Unit (HGU) in Raichur district is a fully integrated facility with a capacity to produce 5,50,000 tonnes per annum. Asked about the number of mining assets to be auctioned in the 2021-22 fiscal, the minister said there are certain issues in mining because of which the proposals are pending at the central government level. Already, the state government has made a representation to the Union Mines Ministry which has assured clearance of pending proposals and paving the way for auctions in a transparent way, he said. On revenue earned from mines auction in 2020-21, Nirani said it has reached only 85 per cent of the Rs 3,700 crore achieved in the 2019-20 fiscal. "The revenue was lower this year because of lack of mining activities in the wake of COVID-19 pandemic. However for next fiscal, our target is to achieve Rs 4,000 crore. We expect to surpass this," he added.

Regarding the District Mineral Foundation (DMF) funds meant to be used in mining-affected areas, the minister said the state government has collected Rs 2,400 crore in the DMF till December 2020. However, only Rs 600 crore has been utilised so far. "Still we have Rs 1,800 crore. It has not been utilised as in some districts not a single meeting has been convened in the last two years," Nirani said. However, district collectors in mining areas have been directed to hold monthly meetings and warned of strict action for not utilising the DMF funds which are normally used for construction of roads and health infrastructure, among others, he added. As regards the policy changes the state government is mulling to make mining activities more transparent, the minister said permissions are required from seven-eight departments, from revenue to environment and transport, for carrying out any mining work. However, there are certain gaps in the current system due to which in some cases mining activity appears to be illegal. For example, a company is served with a notice for illegal mining work by the forest department two years after issuing a 'no objection certificate' (NOC) for the same project, he said.

Suppose a company has got permission to excavate from 'x' mine but due to non-recovery has excavated at 'y' place. Even this is termed as illegal but investors have a different view on this, he said, adding these gaps will be addressed. Nirani, who discussed these issues with Union Mines Minister Pralhad Joshi in the national capital, said the central government has assured it of support and cooperation on this issue. Further, he said the state government is planning to introduce a single window clearance system for mining projects. "Already, a draft is ready and very soon the policy will be announced. The idea is to fast-track the clearance and attract investment," he said. That apart, the government plans to hold 'mining adalats' in Mysuru, Belgaum, Gulbarga, Bengaluru and Mangalore on a fortnightly basis to address grievances

related to mining projects, he added.

BIRLA CARBON RECOGNIZED WITH THE FIFTH CONSECUTIVE GOLD RATING BY ECOVADIS FOR SUSTAINABILITY PRACTICES

Birla Carbon has been awarded a Gold level rating for the fifth consecutive year by EcoVadis, an independent sustainability rating agency. This recognition confirms Birla Carbon's position as an industry leader in advanced sustainability practices and reporting and places it in the top 3% of companies in its sector. The rating was provided after reviewing Birla Carbon's sustainability practices in its recently published eighth sustainability report, Bending Towards Circularity.

With many of Birla Carbon's customers utilizing the EcoVadis assessment to measure business sustainability performance, the rating is an important aspect in determining sustainability progress.

The overall performance rating by EcoVadis is based on the 21 criteria defined over four categories: environment, labor, and human rights, ethic, and sustainable procurement practices. With an overall score of 70, Birla Carbon is in the top 3% of all companies assessed in its category.

EcoVadis is the world's largest and most trusted provider of business sustainability ratings, and since its founding in 2007, to date, EcoVadis has rated over 75,000 trading partners worldwide, mitigating risk for global organizations for more than 300 leading multinationals worldwide. Combining People, Process, and Platform, EcoVadis has developed technology and a CSR assessment method covering 190 purchasing categories, 150 countries, and 21 CSR indicators. More than 55,000 companies use EcoVadis to reduce risks, drive innovation and foster transparency and trust between trading partners.

INOX AIR PRODUCTS ANNOUNCES INDIA'S LARGEST GREENFIELD INVESTMENT IN THE INDUSTRIAL GASES SECTOROF INR 2000 CR

Supporting theNation's revival journey through massive investments incore sectors like Manufacturing and Infrastructure as announced in Budget 2021, India's largest manufacturer of Industrial & Medical Gases, INOX Air Products(INOXAP) has laid out massive expansion plans of INR 2000 Croresto build eight new Air Separation Units across the country. This will be India's largest Greenfield investment plan ever witnessed in the Industrial Gases sector. With a combined capacity to manufacture more than 1500 Tons Per Day (TPD) of Liquid Gases, the expansion will take INOXAP's totalliquid gases production to 4800 TPD by 2024. Inspired by the Prime Minister's vision of *Make In India,* INOXAP's new plants will strengthen and promote inclusive growth in the existing and upcoming industrial corridors across the country. Complementing the critical boost provided in Budget 2021 to the Healthcare sector, INOXAP's expansion would also augment its Liquid Medical Oxygen (LMO) production capacity by 50%.

INOXAP's new plantswill be strategically located in proximity of high demand growth areasin the states ofGujarat, Maharashtra, Tamil Nadu, Madhya Pradesh, Uttar Pradesh, Andhra Pradesh and West Bengal. The plants will produce liquid oxygen, liquid nitrogen and liquid argon and will be commissioned during the course of FY22 to FY24.The bulk availability of industrial and medical gases will ensure constant supplies for electronic manufacturing, pharmaceutical sector, besides helping iron, steel and automobile industries to ramp up their production capacities.The projects will generate more than 1000 direct and indirect employment opportunities in their respective regions.

INOX AP currently manufactures 3300TPD of liquid gases across 44 locations in the country. During COVID, INOXAP has been catering to more than 60% of the total Medical Oxygen demand in the country. All INOXAP units have been running 24x7 to ensure a continuous production and uninterrupted supply of Medical Oxygen to more than 800 hospitals nationwide through a dedicated fleet of 550 transport tanks.With a massive 50% growth in the production of LMO, INOXAP would continue to fulfil its responsibilities in the Medical & Healthcare space.

AP CHOSES LIBERTY STEEL INDIA AS JV PARTNER FOR CONSTRUCTION OF YSR STEEL PLANT IN KADAPA

Andhra Pradesh government chose Liberty Steel India Limited as the joint venture partner for construction and development of YSR Steel Plant in Kadapa district. The state Cabinet, which met here under the chairmanship of Chief Minister Y S Jagan Mohan Reddy, also approved alienation of 3,148.68 acres of land in Jammalamadugu mandal for the integrated steel plant at the rate of Rs 1.65 lakh per acre, according to Information and Public Relations Minister Perni Venkataramaiah (Nani). The AP government established the YSR Steel Corporation Limited for development and operation of a new steel plant in Kadapa district and invited proposals in November last from renowned companies for inducting as a joint venture partner. The proposed steel plant will have a capacity of up to three million tonnes per annum for producing high grade steel products. The state government already

signed a memorandum of understanding with NMDC for supplying the required 4.5 million tonnes of iron ore every year for the proposed steel plant. The state government pooled 3,148.68 acres of land spread over two villages for the integrated steel plant, which would now be alienated to the YSR Steel Corporation for Rs 1.65 lakh an acre.

The YSR Steel Corporation set March 31, 2024 as the commercial operation date for phase-1 of the project, in which it has been targeted to produce one MTPA of crude steel finished products. The plant would use the latest green technologies in steel making to enable sustainable production, an official of the YSRSCL said. "Linkages for other raw materials like limestone, dolomite, quartzite, ferroalloys, are under progress and we will enter into contracts with suppliers before the scheduled commissioning of the project," the official added.

ENVIRONMENTAL MANAGEMENT WITH BEST PRACTICES FOR SUSTAINABLE MINING

NCL organized a seminar on Environmental Management with Best Practices for Sustainable Mining.

Coal Indian Subsidiaries, NCL WCL, MCL, and Ex-CMD Shri T K Nag shared their views in the event.

Northern Coalfields Limited, Singrauli Organized a seminar on Environmental Management with Best Practices for Sustainable Mining on Sunday at MDI in its Headquarters. Ex-CMD NCL Shri T K Nag, CMD, NCL Shri P K Sinha, Dir(Tech/Op), WCL Shri A K Chaudhary, Dir(Tech/P&P), MCL Shri Baban Singh, Director (Personnel), NCL Shri Bimlendu Kumar, Director (Tech/Op.), NCL Dr. Anindy Sinha, Dir. (Finance), NCL Shri R N Dubey, Ex-CGM NCL Shri R K Sharma General Managers from MCL and NCL and other official participated in the seminar.

Ex-CMD NCL Shri T K Nag shared his experience of the coal industry & put best global practices and their adaptability in Coal Indian Mines. He also expressed his views on the global and Indian Energy scenario. Detailing his Journey in Coal India, he also gave management lessons and wishes best to NCL for its growth in the future.

CMD NCL Sri Prabhat Kumar Sinha while speaking on the occasion stated that NCL is one of the best-performing Subsidiaries of Coal India. He recalled the series of strategic key decisions taken in the past which paved the path of remarkable progress & inclusive growth of the Company. He also emphasized the need for such experience and knowledge-sharing seminars for the adoption of best practices and to meet the challenges in the era of paradigm-shifting of the Energy sector.

Shri A K Chaudhary, Director (Technical/Operations) of Nagpur based Coal India Subsidiary and Shri Baban Singh, Director (Technical/Project and Planning) of Mahanadi Coalfields Limited presented the best practices in Environment Management and sustainability.

Utilization of Overburden material for sand, Mines water utilization, Eco-Tourism were presented by WCL while pollution mitigation measures using fog cannons and other steps for sustainability were presented by WCL. General Manager (Environment) Shri C S Tiwari Also present NCL's effort in direction of environment Management.

The Seminar was a Knowledge and experience sharing platform with interaction and learnings from Intra subsidiary and senior officials.

Notably, Coal India is the world's largest coal miner and NCL, WCL, MCL are it's 3 of 7 coal producing subsidiaries.

FIMI GOLDEN JUBILEE AWARD FOR NMDC MINES

In recognition of Excellence in mining safety, productivity & reducing environmental impact, NMDC BIOM Bacheli Complex has been awarded FIMI Golden Jubilee Award for Excellence in environmental management, social awareness, & safety performance by Shri Piyush Goyal, Hon'ble Union Minister for Commerce and Industry presented the award.

OPERATIONS AT NMDC DONIMALAI MINE TO IMPROVE DOMESTIC IRON ORE SUPPLY: EXPERTS

Resumption of mining operations at the Donimalai mine will improve iron ore supply in the country and help ease prices of the key steel making raw material, experts say. Mining at NMDC's 7-million tonnes per annum (MTPA) Donimalai mine in Karnataka resumed from Thursday. After remaining closed for over two years, the country's largest iron ore miner company was able to resume operations following the necessary permission and clearances from the Karnataka government.

Arnab Hazra, deputy secretary-general of the Indian Steel Association (ISA), the country's apex body that represents the interest of domestic steel industry, said Donimalai is an important mine in the southern region. It will help the mills in the Southern India with smooth supply of raw material. Anil Kumar Chaudhary, former CMD of the country's largest steel maker SAIL, said, "It has been

possible by the efforts taken by the steel ministry to resolve the issue." Resumption of mine will also help enhance NMDC in meeting its production targets. "This resumption of mining (at Donimalai) will increase supply of iron ore for steel making. Increased supply will lead to easing of prices of the raw material," R K Sharma, secratary general of miners' body Federation of Indian Mineral Industries (FIMI), told PTI.

Iron ore is a key raw material used for producing steel besides coking coal. To produce every 1 million tonne (MT) of steel, almost double amount of iron ore is required. NMDC former chairman and managing director (CMD) N Baijendra Kumar termed the development as "positive" for the domestic steel industry. Another 7 MT of iron ore will be back into the supply chain, he said adding that NMDC contributes about 18-20 per cent to India's total iron ore requirement annual. When asked for his comments, Jayanta Roy, senior vice-president and group head (corporate sector ratings) of ICRA, said, "This should be good for the industry, definitely."

This will also rectify the demand-supply balance. Besides, the production at Donimalai will replace the iron ore being brought into Karnataka from other states, Roy said. Further, the prices of iron ore are also expected to cool down, he said. As per industry data, the values for 62Fe (ore with 62 per cent iron content) reached about USD 172 per tonne by the middle of December. This level was last recorded in early 2013. NMDC, under the steel ministry, is the country's largest iron ore miner. The company, which has been in the business of mining iron ore for over six decades, produces about 35 MT iron ore from its three iron ore complexes in the country — one in Donimalai in Karnataka and two are in the Dantewada district of Chhattisgarh.

In 2018, NMDC suspended iron ore mining at the Donimalai mine following a decision of the state government to impose 80 per cent premium on the iron ore sales from the mine. The capacity of Donimalai mine is 7 MTPA. The mine has reserves of about 90-100 million tonne (MT) which may last for 15-20 years. NMDC aims to utilise 97 per cent of its production capacity to produce 35 million tonne (MT) of iron ore this fiscal and has set an ambitious target of producing 100 MT by 2030.

HIRING OF HEMM

A parliamentary panel has sought reasons behind hiring machinery worth Rs 859 crore in a year a move when its own equipment were not utilised fully in one of the CIL subsidiaries. The 22-member panel headed by BJP MP Meenakashi Lekhi while tabling its latest report on public undertakings has also suggested that the company may offer its machinery on hire if not used for fetching revenue.

The company spent Rs 859 crore on hiring of plant and equipment during 2018-19 while no independent study was undertaken to assess the comparative cost effectiveness in hiring of (heavy earth moving machinery) HEMMs or owning these equipment, the panel said.

“Keeping in view that such huge expenditure of Rs 859 crore was incurred in one year on hiring plant and equipment, especially when the departmental HEMM anbd equipment are not being utilised to the full extent in some cases as is evident that the utilisationof all HEMMs had been much less than 50 per cent of the norms prescribed during the year 2018-19, the committee recommend that detailed note be furnished to the committee explaining inter alia the reasons for hiring equipment when company -owned equipment were lying unutilised to a large extent,” the report said.

It also sought a note from the coal producing company on the comparative effectiveness of hiring in comparison to owning of HEMMs. The committee said that it observed that despite the availability of these equipment almost as per the norms, their actual utilisation was far short of prescribed norms in the year 2018-19.

“For instance, against the utilisation norms of 58 per cent, 50 per cent, 45 per cent 40 per cent for shovels, dumpers, dozers and drills, respectively, the actual utilisation was only 40.9 per cent, 35.4 per cent, 20.8 per cent and 28.2 per cent in 2018-19. The actual utilisation of dozers was less than 50 per cent of the norms and in case of other equipment, it was between 60-70 per cent only of the utilisation norms,” the report said. The panel observed that though availability of HEMMs is more or less as per the norms, their utilisation desires a lot to be improved.

“The committee would like to be apprised of the specific reasons for such low utilisation of HEMMs with the year-wise availability and utilisation of HEMMs during the last 5 years period and also the impact of such low utilisation of HEMMs on the production of the company,” the report said. It recommend that necessary measures need to taken to step up the utilization rates of various equipment of HEMMs.

“The committee also recommend that the machinery owned by the Co, if not needed by them during a particular period of time in a year, may be rented out to other users so that not only the machinery remains in use but also the Comppany earns some revenue from it,” it said. (Source ET).

The Indian Mining & Engineering Journal, Vol. 60, No.02, February 2021, pp.09-13
Printed in India, @ IME Publications, ISSN 0019-5944

Biodegradation Investigation of Polyhydroxybutyrate film by Soil Burial Method

Shreya Shah*

ABSTRACT

Conventional petroleum-based polymers lead to massive accumulation of non-degradable waste and therefore, it is needful to produce eco-friendly and degradable polymeric material. Bio-plastics, being biodegradable, act as an eco-friendly alternative to conventional plastics. Among all bio-plastics, the most popular and trending bio-plastic is polyhydroxybutyrate (PHB), which is degradable, water-insoluble, hydrophobic polymer synthesized and accumulated as granules by certain bacteria. This bio-polymer can be degraded by several soil dwelling microorganisms possessing the ability to secrete extracellular PHB depolymerase.

In the present work, we evaluated the degradability of PHB film by Soil Burial method. PHB used for producing film was biosynthesized by the bacteria Bacillus tropicus utilizing different carbon rich fermentation media. After 120 days of soil burial, average 20% of weight reduction was observed in PHB films. Scanning electron microscopic analysis depicted that PHB film became structurally distorted and more porous after 120 days of degradation. The biodegradability test of PHB bio-plastic confirmed its suitability as a green substitute of conventional petro-based plastics.

Keywords: Polyhydroxybutyrate, Biodegradation, PHB film, Soil burial method.

INTRODUCTION

The dominance of conventional petro-based plastics and its enormous use by the world population in every aspect of life has been perturbing the science world for the problem of its disposal owing to its non- degradability. Many of these conventional petro-based plastics such as poly (ethylene terephthalate), poly (vinyl chloride), polypropylene, polyethylene and polystyrene are non-degradable and their enhancing accretion in the environment has rendered a stern warning to our planet. It also increases carbon dioxide emissions and the production of other toxic residues [1]. To deal with these concerns, it is now considered globally to shift towards the use of renewable resource for the development of eco-friendly materials. In this regard, Biodegradable plastic is being seen as a promising solution due to their environment-friendly properties. Biodegradable plastics can be produced from renewable resources, thereby curbing emissions of harmful greenhouse gases [2].

Recent studies have revealed that due to migration from conventional to sustainable non petroleum-based polymers, manufacture of bio-degradable polymers is expected to increase thirteen percent annually for the next three years from the year 2020 [3]. Moreover, it is also reported in another study that by 2025 the top plastic packaging producers will be heading near a target of 100% recycled, re-useable or biodegradable plastics in their merchandises [4].

Presently, microbially produced Poly-3-hydroxybutyrate (PHB), is leading thermoplastic aliphatic polyesters and is getting abundant response as biodegradable alternative against non-degradable petro-based conventional plastics. On the contrary to the petroleum based plastics, microbes can easily assimilate biodegradable polymers such as PHB during their metabolism. Assimilation of PHB results in the generation of carbon dioxide, water, methane, some cellular components, some non-toxic products and sub-products [5-9]. Biodegradation process is a biological activity carried out by microorganisms which decomposes the complex organic compounds to simpler and lower molecular weight non-toxic residual products. The resultant residual products from biodegradation process can be used as a source of energy and raw materials for anabolic pathways of non-degrading microbes [10-12].

PHB exhibit a significant advantage against diverse biodegradable plastics because they do not require any specific environmental condition to get degraded. PHB degrading microorganisms are extensively present in various environments. These microbes can exhibit fast biodegradation of the bio-polymer under both aerobic as well as anaerobic environments, thus resolving the difficulty of vanishing landfill space [13].

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Numerous factors play effective role in the process of biodegradation such as activity of microbes, molecular weight, composition and crystallinity of the polymer. Some of the physical parameters such as temperature, pH, nutrient contents, moisture and oxygen also led an impact on biodegradation [14]. Additionally, researchers suggested that the rate of biodegradation significantly depends on the surface area of the polymeric compounds. It can be inferred that lesser surface area can hinder the growth of the microbes and vice-versa [15]. Degradation of the PHB films, *in vivo* resulted in production of nontoxic metabolites such as 3-hydroxybutyrate (3HB). 3HB is naturally present in blood, so, it can be suggested that PHB can exhibit biomedical applications such as implants, sutures, bone staplers etc. [16, 17]. Freier et al. [18] suggested that the addition of some plasticizers or polymers could probably accelerate the rate of degradation of PHB. On the other hand, using hydrophilic additives can result in high-water adsorption to the polymeric structure and eventually accelerates the hydrolysis of the polymer. Studies have been carried out on different formulations of polyhydroxybutyrate films and their biodegradation in soil [19-22].

One of the primary objectives of the present work was to seek the answer to the increasing problem of disposal of used/waste plastics which is proposed to be achieved through PHB produced from *Bacillus tropicus*. The *soil burial method* is an accepted method to test the degradability of bio-plastics by microorganisms present in the soil. Since, used conventional petro-based plastics wastes are carelessly being thrown away and gets accumulated in landfills, creates a major environmental pollution due to its non-degradability. Thus, the bio-polymer extracted through *Bacillus tropicus* was subjected to soil burial test to see its natural degradability capability.

MATERIALS AND METHODS
CHEMICALS

All the media components, salts and chemicals used in the experimental study were of high-quality analytical grade, bought from Hi-media, India.

PREPARATION OF PHB FILMS

For preparation of PHB films, the conventional solvent-cast technique was used [23]. A 0.3 g amount of extracted bio-polymeric PHB from *Bacillus tropicus* was dissolved in 30 ml of chloroform using a Schott bottle. The bottle was continuously magnetic stirred for 30 min resulting in the dissolution of PHB in chloroform. Thereafter, the dissolved mixture was casted on glass petri-plates (9 cm in diameter). Punctured aluminum sheets were used to cover the petri-plates. For complete evaporation of chloroform, plates were left in the dark for 24 h at 30°C. This resulted in formation of PHB films [24].

WEIGHT LOSS ANALYSIS OF THE PHB FILM BY SOIL BURIAL METHOD

The film made out of the extracted bio-polymeric PHB was used for soil burial bio-degradative analysis. Initially the film weighed 2.84 g and 0.6 mm thick. It was buried at a depth of 10 cm in the soil. The films were excavated every fortnight till 120 days. To remove any adhered soil residues, these were washed with sterile distilled water. Thereafter, these films were kept for twenty four hours at the room temperature and thereafter they were subjected under desiccator for one hour with an objective to achieve a stable weight. Thereafter, the reduction in weight was analyzed. The changes in the physical appearance, thickness and structure of the PHB films were also observed both by visual assessment and scanning electron microscopy.

Degradation percentage was measured based on its correlation to weight loss [24,25]:

Degradation%=[(W1"W2)/W1]*100
W1 was taken as the original weight of the film (before soil burial) and W2 as the final weight of the film after 120 days of bio-degradation.

STATISTICAL ANALYSIS

All the tests were conducted twice in triplicate. Standard deviation was determined. Also, all the data obtained were statistically analyzed by using one-way ANOVA in Microsoft excel software 2007 to determine the significance.

CHARACTERIZATION OF THE PHB FILM BY SCANNING ELECTRON MICROSCOPIC (SEM) ANALYSIS

The structural distortions and the alterations in morphology of the polymeric surface were observed by visual assessment as well as microscopic observation of surface changes of PHB film. The observation was made prior and post 120 days of burial in soil by Scanning Electron

Microscopic (SEM) technique (JEOL JSM 5600). Tungsten filament was the source of electron in the instrument. It is equipped with a secondary electron detector for topographic contrast imaging at an accelerating voltage of 5 kV. Each sample (5 mm × 5 mm) was fixed upon the eucentric goniometer specimen stage **[26].**

RESULTS AND DISCUSSION

DEGRADATION OF PHB BY MICROORGANISMS DWELLING IN SOIL

PHB films get primarily degraded by microbial activity in the soil. Whenever carbon deficient condition arises, PHB films serve as more readily available carbon source for bacteria, triggering their rapid disintegration [27,28]. Surface erosion mechanisms also play a role in degradative process of PHB films. Bacteria colonize on the porous surface area of the film and release depolymerase enzyme to catalyze the polymer [14]. On observation, it is evident that film had undergone significant reduction in terms of thickness, integrity and change in texture (Fig. 1). It was visible that the original film was uniform and strong in comparison to the recovered extracts of the film after 120 days which were now fragile and broken. On weight analysis after 120 days, it was seen that the weight was reduced around 20 % from 2.84 g to 2.25 g and the thickness reduced from 0.6 mm to 0.4 mm.

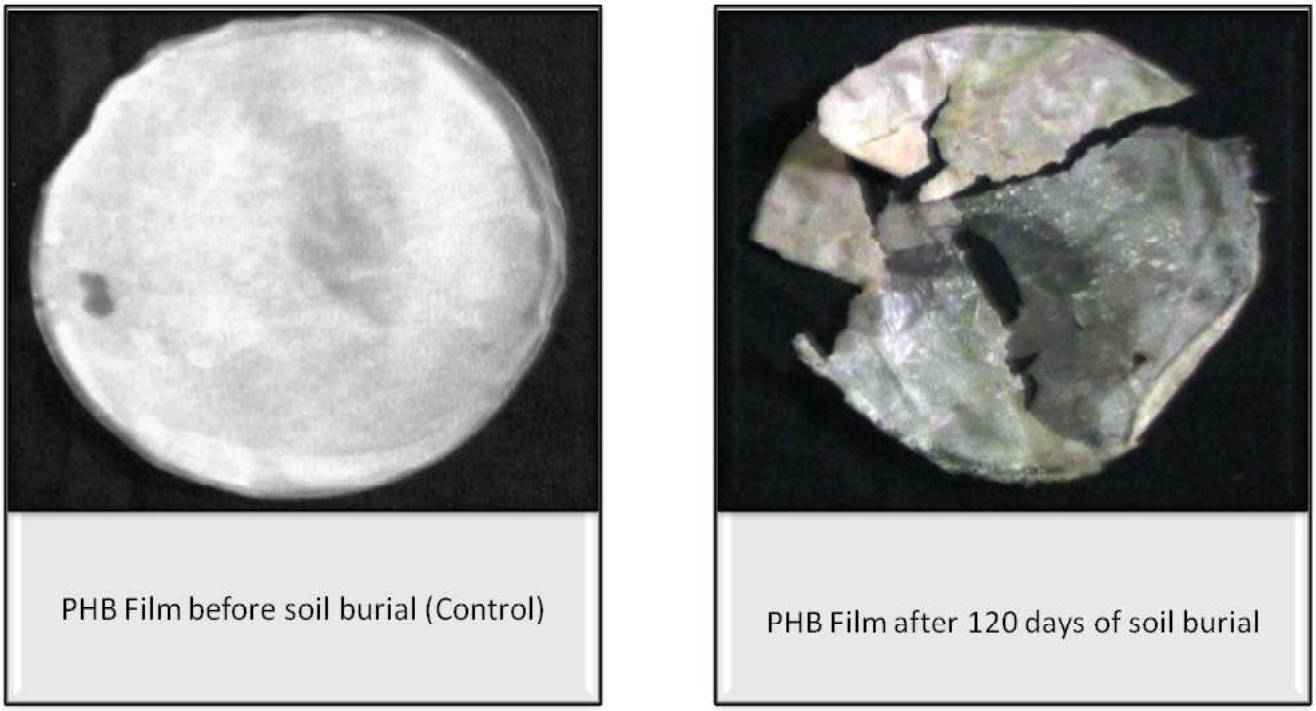

Fig. 1: Images of PHB film before and after the soil burial

Soil burial ultimately resulted in the reduction of the weight of the polymer which was clearly indicated by the weight loss analysis. Numerous non-biological (pH, temperature) and biological (micro-organisms) factors impact in the degradative process of the polymer. The degrading enzymes secreted by the soil dwelling microbes hydrolyze the ester bonds present in the biopolymer when exposed to different temperature conditions; convert the higher molecular weight PHB to lower molecular weight PHB. Earlier reports also reported similar results for PHB degradation in soil environments [29-31].

CHARACTERIZATION OF THE PHA FILM BY SEM ANALYSIS

The SEM micrographs depicted various changes in surface morphology such as increased porosity and appearance of grooves, cavity and incisions after 120 days burial in the soil (Fig. 2). These changes may be attributed due to the colonization and growth of microbes that released PHB depolymerase enzyme, and that eventually resulted in the bio-degradation of bio-polymeric films of PHB.

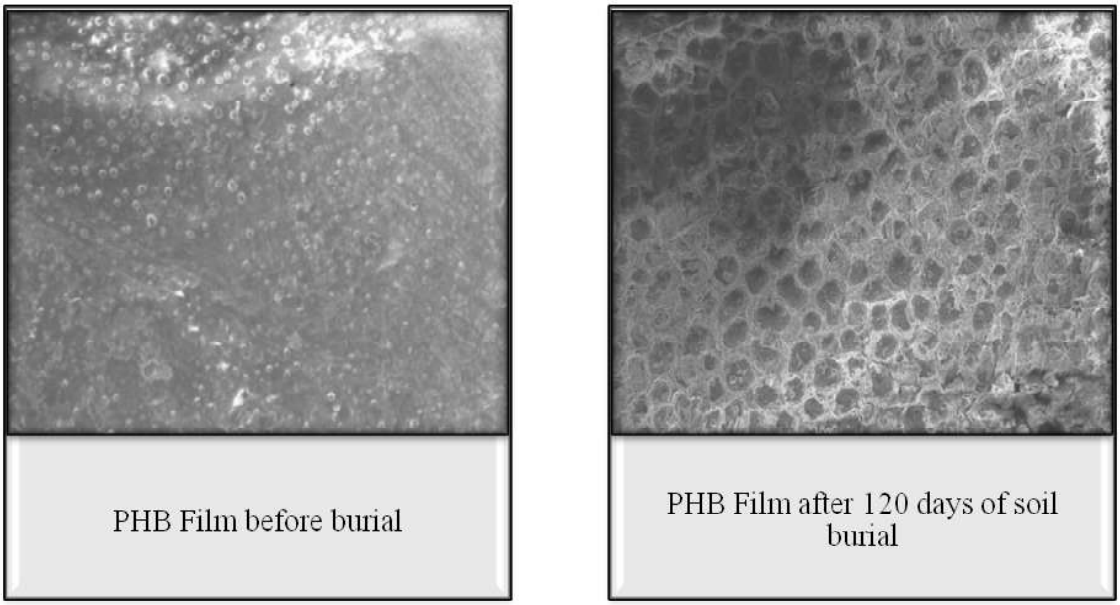

Fig. 2: SEM images of PHB film (before and after the burial)

Being degradable, the biopolymers benefit the society to cut-off the pollution problems accompanied with the single use petro-based plastics. From Fig. 2, it can be clearly seen that the soil degradation had induced the development of numerous holes on the film surface. This is indicative of the bio-degradation process that has occurred due to the action of microbes of the soil on the film surface.

Analysis of the PHB films using SEM (before and after degradation) indicated the following minor changes that took place on the surface in the course of degradation. The film showed highest reduction in weight as examined by SEM to study the surface modifications. The film after degradation showed numerous cracks on the surface when compared to the control film (before soil burial). Harshvardhan and Jha [26] also analyzed the plastic film through SEM and observed chemical changes in the surface topography of the film. The SEM images of control film (before degradation) showed smooth surface while, the images of the plastic films after degradation revealed the pits and cavities formation.

CONCLUSION

Among all the emerging new polymeric materials, biodegradable plastic has become a trending solution to cut off the plastic disposal problem. PHB is a biopolymer which is accumulated by various bacterial strains as carbon and energy reserve. Worldwide, this bio-polymer has attracted the researchers as well as industrials because it can be produced at a large scale by using cost-effective renewable resources. Best part of these polymers is that they can be biodegraded in all the environmental conditions without resulting in any toxic residue.

In the present study, the soil burial method of biodegradation for the film made up of biosynthesized polymer (PHB) was investigated. Weight loss analysis clearly revealed the reduction in the weight of the PHB film. The structural distortions were also observed and analyzed by SEM. It can be inferred that biopolymer extracted from *Bacillus tropicus* using different carbon substrates in fermentation medium, is biodegradable in nature. Owing to its biodegradable nature, PHB film can be used as agricultural mulch films etc. Plastic mulch produced from PHB has demonstrated potential to be a game changer in agriculture sector due to its twin properties of sustainability and easy degradability in soil. It is coupled with reduced labor costs for removal and disposal of mulches which would have been added to piling waste in landfills. Bio-degradable PHAs can also be used in agriculture sector for encapsulating seeds and fertilizers. Plastic films made from PHA are used to create facilities for protection of crops and making containers in greenhouses. These polymers can also be used as coating for herbicides and insecticides.

ACKNOWLEDGEMENTS

SS expresses gratitude to this University for the award of a Golden Jubilee Fellowship. Authors are grateful to the Head of the Department, School of Biotechnology, Devi Ahilya University, Indore to allow us to use the facilities of the Department for carrying out present work.

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The Indian Mining & Engineering Journal, Vol. 60, No.02, February 2021, pp.14-18
Printed in India, @ IME Publications, ISSN 0019-5944

Support for Underground Mineusing Waste Materials

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ABSTRACT

This paper is intended to encourage the mining industry to use waste materials produced in the mine for instance, tailings, fly ash, broken rocks (aggregates) during excavation of minerals to use during excavation of minerals to use them as underground support to make the mine safe, efficient and economical. The other advantages of using theses waste materials will be of course, control of environmental pollution save surface for other useful purposes such as farming land, h the souse construction etc. it is an emerging technology on trial in various parts of the world. So far, the results are encouraging. It also summarises the desirable properties of backfill materials and their relevance to backfill. The results of field trials at one of the copper mines in Zambia (Konkola Copper Mines, KCM) are reported.

Key words: tailings, aggregate, fly ash, backfill, hydrochloric fill,admixtures

INTRODUCTION

Underground miningcreates voids and in many cases roofs collapse and surfaces subside. It is therefore imperative to provide supports either by conventional type or strata reinforcement reinforcement using steel bolts/ dowels and paste (waste material mixed with additives). These materials are not necessarily of high strength having permeability and environmentally friendly.

In view of this, the research was initiated at Konkola Copper Mines (KCM) Zambia to develop a suitable material produced from the KCM mine tailings, fly ash, slag and aggregates which are at the mine surface.

Figure 1 Research site (Map of Zambia)

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The emphasis in developing such materials (research objectives) were:

- To develop a suitable material for mines with additional for increased strength and this must be cost effective.
- To determine the optional amount of binder to be added to the backfill material to achieve flow property (slumpproperty).
- To assess the environmental impact both at the surface and undergrounding

In pursuing this research the ….following questions were borne in mind:

- What are the basic considerations for success of a backfill em?
- What should engineering properties and flow characteristics of such materials so that continuous flow of material can be maintained?

Historically, whatever material was being used since the 1960s (past six decades).With adoption of bulk mining methods and increased use of cemented fill have become important as to suit as a support material. The understanding is required to ensure reliable and consistent fill performance as well as to optimize cost particularly where cemented fill is used. During the research, it was deemed essential to look at rheology modifiers, hydration modifiers and durability enhancers. Backfill materials researched were tailings, slags, aggregates, sand, cementand quality (saltier) water. The results of their suitability are reported in this paper.

The objectives of the research were:

- To develop a suitable martial for mine with addition of a binder of a binder for increased strength, and this must be safe and cost effective

- To determine the optimal amount of binder to be added to the backfill material to acieve ideal uniaxial compressive Strength flow property
- To assess the environmental impacts both at the surface and underground.

DEVELOPMENT IN SUPPRT TECHNOLOGY

Three principal methods of support of rock mass are didcussed which are mostly used in mines and also in civil engineering These are :

1. Strata reinforcement (rock bolt)
2. Pressure grout
3. Paste technology

Rock reinforcement is a method of adding strength to the rock in order to prevent failure. The most usual forms of reinforcement are rock bolts and stressed cables. These are used to load the in such a way that resistance to shear along planes of weakness is improved and some tensile strength is given to the rock mass.

Rock bolts have altogether different supporting actions compared to conventional type .of supports It works in three ways:
(a) Beam action ,(b) Suspension action and, ©Prevents lateral movements

All these actions are shown in Figure 2.

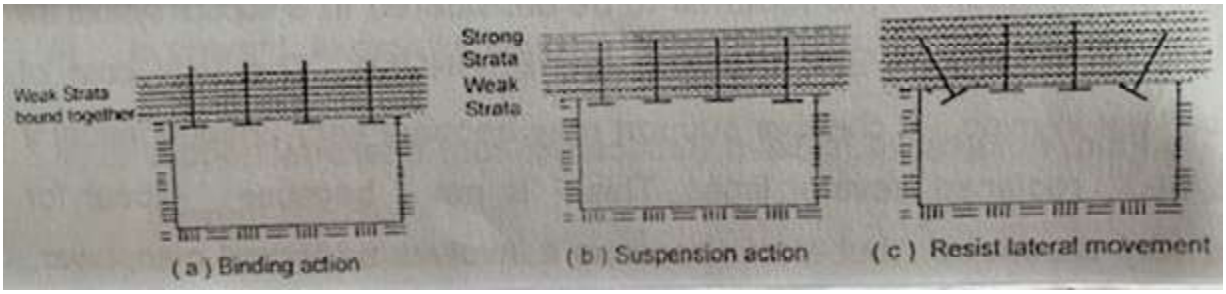


Figure 2: Principle of rock bolting

Pressure Grouting is the technique of injecting a fluid grout into the rock mass so that the air or watr in the fissures and cracks will be replaced by a set product which will inhibit leakage of water through the mass and may provide added strength.

The grout consists of a mixture of Portland cement and water, sand, clay, rock flour and other inert materials, for instance, bentonite, pozzolan are used as well.

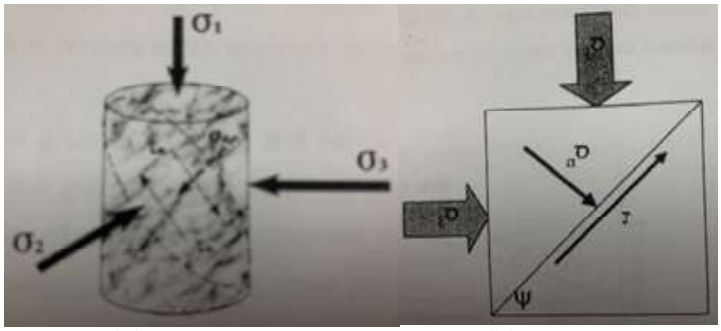
No doubt, the pressure grout has proved to be one of the most effective way to provide support to rock mass and the modern tendency is to use pressure corresponding to approximately twice the internal dynamic pressure in the roadway/ tunnel.

PASTE AS BACKFILL MATERIAL: A MATURING TECHNOLOGY

Mechanics of backfill materials and paste characteristics

Paste technology is founded on one basic concept: reduction of the water content of finally prepared backfill to an extent that it contains sufficient fluid to pump yet sufficiently stiff to gain quick stability.It is important to understand existing stress conditions within the rock of backfill masses in order that the stability of underground excavations can be adequately assessed.

In underground, three mutually perpendicular normal stress components i.e. principle stresses and shear plane development in the backfill areshown inFigure 3(a) and (b) respectively

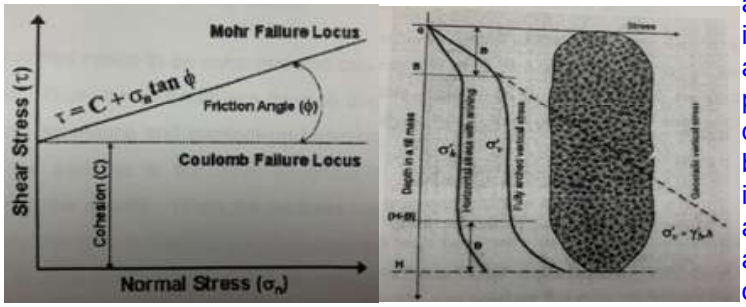


(a) (b)

Figure 3: (a) and (b) Principal and resultant stress upon a shear plane surface, respectively

Backfill strength is solely dependent on one, frictional forces that result from the interlocking of solid…and two, independent stress (free of moisture content). Cohesion (c) results from surface tension forces in pore water that disappears when the fill is fully dry or fully saturated.of

backfill and Mohr-Coulomb failure locus and vertical and horizontal stresses in backfill due to arching effect and horizontal tresses are shown in Figure 2 (a) and (b) respectively.



(a) (b)

Figures 4: (a) and (b) Mohr-Coulomb failure locus and vertical and horizontal stress distributions due to arching in back fill respectively

Potvin (2005) observed that unfermentedbackfill like hydraulic fill, cannot form a verticalface. Only cemented fill can form a vertical face. The fill goes deformation only when the particles start moving and rearranging to accommodate any changes in loading. The sliding and interlocking resistances are increased when the particles are pushed together perpendicular to the shearing plane.According to Terzaghi (1967) arching theory the downward movement of the backfill is partially resisted by the rock walls. Because of arching, the vertical stress in the fill masses are not geostatic.Figure 4shows arching and stress distribution in fill mass. Because of this arching, a fill of 500 kPaucs strength can withstand an explosion of over 100 min height. If arching were not present, such a condition would require over 2MPa strength fill which would in turn require more cement making cost of filling very high.

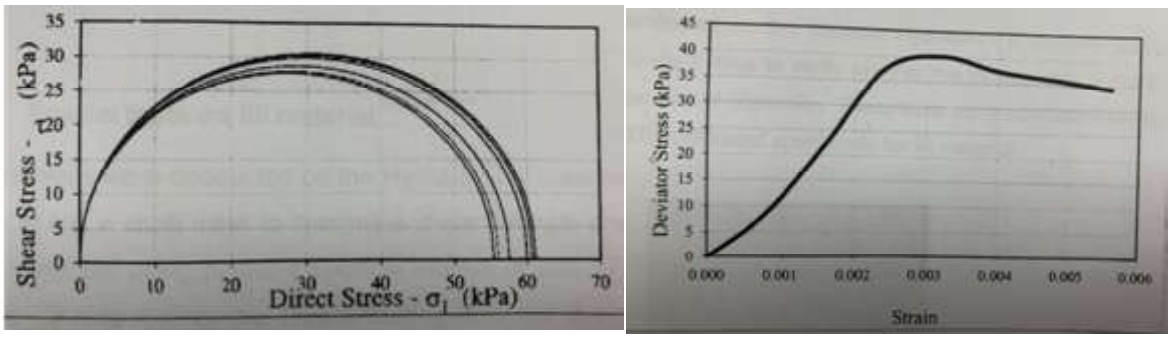
Table 1: Desirable properties of backfill material and their application in …mining

No.	Property	Brief description	Relevance
1.	Uniaxial compressive strength (UCS)	Maximum compressive strength that is mobilised by backfill material to resist failure	To ascertain whether the backfill material can flow
2.	Unit weight	If weight of back fill per unit of volume	For determining quantity of fill material required in a stope
3.	Permeability (K)	Rate of flow of water through backfill material	For determining how quickly transport water with drain from the backfill material in stope
4.	Internal angle of friction (Q)	Resistance to mobilised purely by interlocking	Whether backfill will remain free standing
5.	Cohesion (C)	Shows bonding forces of backfill material	Whether backfill will remain free and to determine the bearing of fill material
6.	Elastic modulas €	The relationship between backfill stress and strain	To determine deformability characteristics of backfill under various loading conditions.
7.	Void ratio (e)	To know ratio of voids to backfill material	To determine permeability affected by the particle size of fill
8.	Liquefaction potential	To know behaviour of backfill from solid state to liquefied state	To study the mechanical response of backfill material
9.	Particle size distribution	To know grading of backfill material	The strength and permeability is affected by the particle size.
10.	Mineralogical computation and chemical reactions	The different minerals the rocks as soil compressed	To study possible chemical reactions when additives are added to backfill
11.	Afterberg's limit	To know range of moisture content which will exhibit consistency	To understand the effect of water at different water content
12.	Slump	A measure of the quality of cemented backfill mixture	To determine the …and transportability of cemented backfill

Laboratory Tests and Analysis of Results on Backfill Material

Laboratory tests were undertaken on the backfill material composed **o**f mine waste materials available at Konkolala copper mine (KCM) in linewith the desirable properties of backfill material outlined in Table 1.

In cognizance of the main research objectives, which to develop a suitable backfill material for safe and economic ore production atKonkola mine. The first material to be analysed was uncommented fill material and the results are shown in 5.



(a) (b)

Figure 5 : (a) Uniaxial strength tests of uncommented material and (b)Stress-strain relationship for fill material

The results were statistically analysed to assess the reliability of the data and the average value of Uniaxial Compressive Strength (ucs) obtained was 58.4 kPa. The stress-strain graph from the above tests were plotted to derive the modulus of elasticity of fill material.

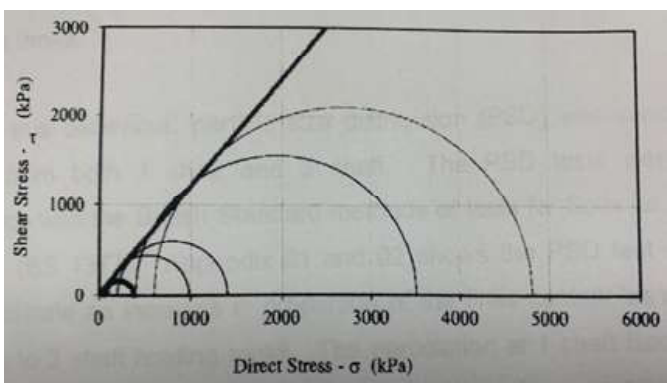
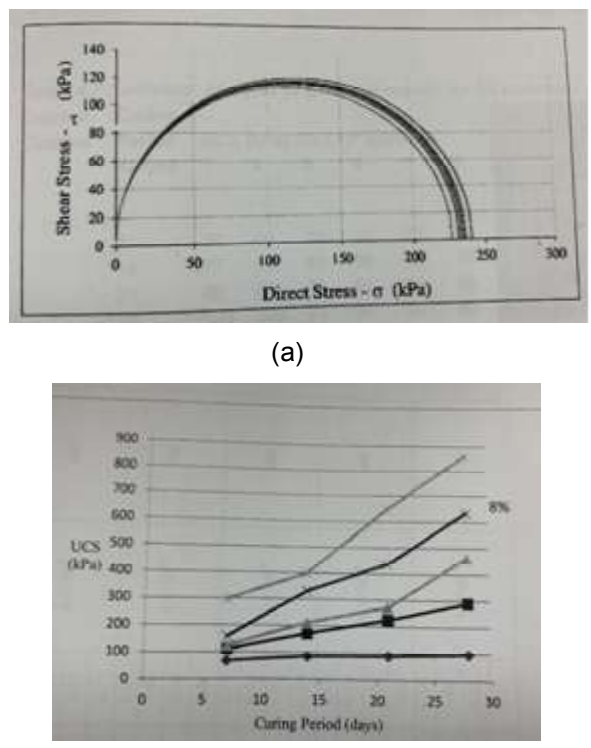


Figure 6: Mohr-Coulomb failure envelope for cemented fill material

Triaxial test w ere also conducted to determine the values of angle of internal friction and cohesive strength of the formartial under trial.

These tests were conducted using the backfill quality tester (BQT), calibrated specifically for this purpose. Also, , laboratory tests were conducted on unfermented hydraulic fills with 2 % and 4 % for different curing time; 7, 14, 21 and for 28) days, Figure 5 (a) and (b). Cement used was locally produced, Zambezi cement the curing period was 28 days, which yield maximum strengths.



(a)

(b)

Figure 7: (a0UCS test results using 4% of Zambian cement and (b) curing periodDays of 28

Slump tests were performed in orderto determine the pumpbility (transportability) characteristics of cemented back fill material.

Attterburg limits tests (shrinkage, water content test and plasticity were also performed to determine the range of moisture contents over which the material show consistency. The tests were performed using Casagrande apparatus.

The current hydraulic fill material with 65 % solid friction should blended with with maximum size of 2.83 mm in the ratio of 3:7respectively to produce a well graded dense back fill. It was observed that recent advantages in modelling can assist in designing a back fill for various stopes configurations.

CONCLUDING REMARKS

Mining companies worldwide are gaining the benefits from obtaining their waste materials disposal. This has temptedpaste technology which has a range of applications. The development of the deep cone thickener has revolutionised this maturing technology.

The research carried out at KCM, Zambia has highlighted some salient features on its successes and failures based on laboratory tests. A fill material with 65% of solid…when blended with aggregate of approximately 2.83 mm in the ratio of 3:7 produces a well graded dense back fill of adequate strength to hold the roof and sides of the excavation underground. Excess water must flow out of the drainage pipes and fill material must be kept saturated for not less than 28 days to ensure full hydration process of the material. Possibility of reducing cementing consumption can be achieved by different state/pillar configuration. Recent advances in numerical modelling can greatly assist in designing backfill for various stope/ pillars configurations.

Slag is believed to have very good pozzolonic properties as it has potential to eliminate completely cement requirements in backfill, which is a great breakthrough in paste technology. It is an emerging technology and has great potential to be used as backfill.

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The Indian Mining & Engineering Journal, Vol. 60, No.02, February 2021, pp.19-24
Printed in India, @ IME Publications, ISSN 0019-5944

Design of Illumination System in a Mechanized Opencast Coal Mine – A Case Study

Debi Prasad Tripathy* P.K. Rout**

ABSTRACT

In this paper, a detailed analysis of the illumination measurements carried out at different locations viz. haul road, dump roads, dump yards, overburden face, dumper parking yard etc. of the a mechanized coal mine, located in Korba districtof Chhattisgarhare presented. The illumination survey was conductedand it was found inadequate at the haul road, dump road, dump yard, dumper parking yard, overburden face etc. The illumination designs were carried out for different places which did not satisfy the minimum standards as per the DGMS.

Keywords:Illumination design; Opencast coal mine; DGMS; HPSV lamps

INTRODUCTION

Mine illumination system plays a great role in the productivity and safety of any mine. The controlling of the rate of accidents any mine is given the utmost priority as the outcome of any accident is always harmful. The adequacy of illumination system in different mines are eminent due to the persisting accident rates for the lack of lighting arrangements at some specified locations inside the mines. Especially at the night time, the need for appropriate lighting arrangements at the operational points and the roadways in the opencast mines must be satisfied, whereas for the underground mines, lighting arrangements are required for every working hour of the mines. The distribution of light might vary as various factors put an effect on it [1].Usually the illumination distributions depend on some basic lighting design parameters:level of illumination, nature of light,mounting height,spacing between the adjacent lamps and uniformity of the distributed light. In the present paper, investigations carried out comprised of the following objectives: (i)to conduct illumination survey atdifferent locations of the selected mechanized coal mine (ii) at working places of the Heavy Earth Moving Machineries. (iii)to compare the obtained survey data with the DGMS standards for illumination and prepare a report on the adequacy of illumination requirements for different places and (iv) to design/modify illumination designs of the places which does not satisfy the minimum standards specified by DGMS.

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BRIEF OVERVIEW OF PREVIOUS RESEARCH WORK

A number of researchers have been working on the theoretical and practical aspects of effects of illumination systems on safety and productivity of mines. The following studies reflect all the scientific research works carried out by different investigators. Mishra and Dixit (1978)carried out investigations in different Indian coal mines and finally concluded that 35% of all minor accidents happendue to the poor lighting conditions[2].

Odendaal (1996) carried out investigations in four different gold and platinum mines and concluded that around 88%-95% of the accidents were attributed due to the cap lamps [3]. Mayton (1991) carried out surveys in 15 metal mines and 7 coal mines and concluded that the illuminance measurements of different places and machineries varies from mine to mine and adequate lighting of the machineries can be obtained by replacing the lamps with higher luminous intensity [4].

Karmakar et al. (2005) suggested that mounting height is one of the very important aspects of illumination design and for road lightings, HPSV lamps are more suitable [5]. Das and Roul (2005) did an illumination study of a highly mechanized opencast bauxite mine of NALCO and design of haul road and auxiliary haul road illumination system were modified [6]. Tripathy and Chowdhury (2014) carried out different illumination survey reports in a highly mechanized opencast mine. Designs for haul road, dump road, coal face and overburden face were done by the DIALux software [7].

MINE ILLUMINATION STANDARDS IN INDIA

The minimum illumination standards as per DGMS are tabulated below in Table1.

Table 1: DGMS Standard for Opencast Lighting,2017[8]

Sl.No.	Places to be illuminated	Minimum illumination standards (in lux)
1	Work place of heavy machinery	15
2	Drilling operations	15
3	Places where manual works are done	15
4	Places where loading, unloading or transfer, loading of dumpers, trucks is carried out (including OB dump and coal stack yard)	15
5	Operators cabins of machines or machineries	50
6	Haul roads for trucks and dumpers	10
7	Rail haulage track in the pit	10
8	Roadways from bench to bench	10
9	Permanent paths for human use	10
10	In-pit crusher/Feeder breaker	40
11	Hand picking points	50
12	Conveyors	
	(i) Transfer points	40
	(ii) Along conveyor	20
13	Coal handling plant	
	(i) Places of crushing, screening, loading/unloading	40
	(ii) Operation points	50
	(iii) Other places	20
14	Pumping station	40
15	(i) Electrical sub-station	100
	(ii) Other places of operation of electrical equipment	20
16	First aid station	50
17	Rest shelter	30
18	Workshop	100
19	Parking yard	50
20	General working areas as determined by manager of the mine	10

ILLUMINATION MEASUREMENT METHODLOGY

The illumination measurements in the different places were carried out by using Metravi 1332 digital lux meter. The methodologies involved in the illumination study are listed below:

- Analyzation different designs of lighting system in opencast mines.
- Calculation of illuminance measurements at different working places of an opencast mines.
- Check if it satisfies the illuminance requirements as mentioned by the DGMS.
- Design different illumination arrangements for the required unsatisfactory areas.
- Reporting the results of the surveys and the illumination designs in the opencast mines.

STAUS OF ILLUMINATION SURVEY ATOPENCAST COAL MINING PROJECT

The selected mechanized opencast coal mine is located in the south – central part of Korba Coalfield in Korba district of Chhattisgarh. The mine had a production of around 30 MT per year and 14 years' life.

OBSERVATIONS OF ILLUMINATION SURVEY

When the illumination survey was taken, few observations were recorded and those are presented below:

Haul Road

There were 400 watts of HPSV lights installed on different poles. Some lamps were found to be defective while some poles did not have working lamps on it.

Dump Road

400 watts of HPSV lights were installed on different poles, which had lower values of luminous flux and one of the poles did not have a glowing lamp on it as at some places the light distributions were not uniform.

Road across Belt Conveyors

The roads across the belt conveyors were equipped with some 400 watts lights mounted on a pole. Heights of those pols were 10m. One of the road lighting was uniform throughout but the other road did not have the uniform distribution of light.

Dump Yard

The dump road was illuminated using some 400 watts and 1000 watts of HPSV lamps along the dump yard. The illuminance measurements were found to be low.

Dumper Parking Yard

The dumper parking yard was equipped with four 1000 watt lights installed on different poles with a spacing of 50m. It had a boom angle of 120°. The poles were kept at one side of the dumper parking yard.

Overburden Face

Three 400 watt lamps and one 1000-watt lamp were installed on four poles at the site of the overburden face. The illuminance measurement was found to be significantly low at this region.

The summary of illumination survey reports' is presented in Table 2.

Table 2: Summary of Survey Reports of Various Mining Working Environments

Location	Minimum Illuminance Standards (DGMS) (in lux)		Measured Illuminance (Average) (in lux)		Remarks
	Horizontal	Vertical	Horizontal	Vertical	
Haul Road	10	-	7.8	-	Not Satisfactory
Dump Road-1	10	-	5.4	-	Not Satisfactory
Dump Road-2	10	-	4.4	-	Not Satisfactory
Dump Road-3	10	-	4.1	-	Not Satisfactory
Dump Road-4	10	-	5.5	-	Not Satisfactory
OB Face	10	-	1.9	-	Not Satisfactory
Dump Yard-1	15	-	3.5	-	Not Satisfactory
Dump Yard-2	15	-	2.8	-	Not Satisfactory
Dump Yard-3	15	-	3.1	-	Not Satisfactory
Dump Yard-4	15	-	2.5	-	Not Satisfactory
Road across Belt Conveyor-1	10	-	15.2	-	Satisfactory
Road across Belt Conveyor-2	10	-	6.9	-	Not Satisfactory

DESIGN OF ILLUMINATION SYSTEMS ATMECHANIZED OPENCAST COAL MINE-A CASE STUDY

DESIGN OF ILLUMINATION SYSTEM FOR HAUL ROAD

For the designing of haul road, a design was simulated such that the average illuminance values satisfy the standards specified by the DGMS. HPSV lights of 400watts were used and the pole spacing was modified from 45m to 40m.Isolux diagram of haul road design is shown in Fig.1

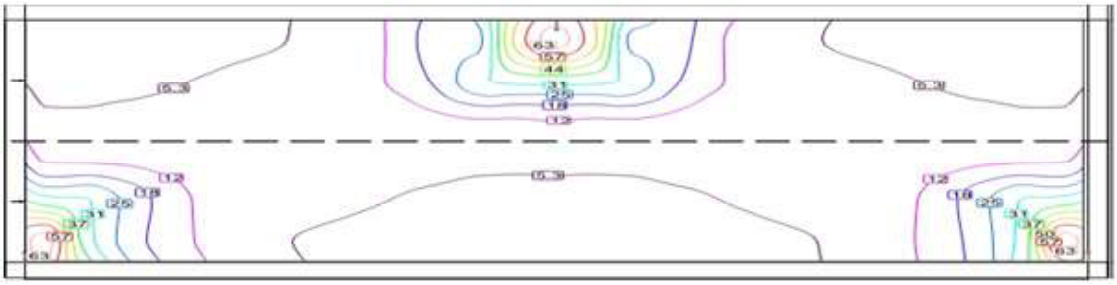

Figure 1: Isolux Diagram of Haul Road Illumination Design

DESIGN OF ILLUMINATION SYSTEM FOR DUMP ROAD

The design of the dump road illumination models was modified as the survey reports suggested that it did not satisfy the minimum standards prescribed by DGMS. The dump road had some lamps with lower luminous flux and needed a modification. The HPSV lights were put on one side of the dump road at a pole spacing of 40m. The isolux diagram of the lighting design is presented in Figure 2.

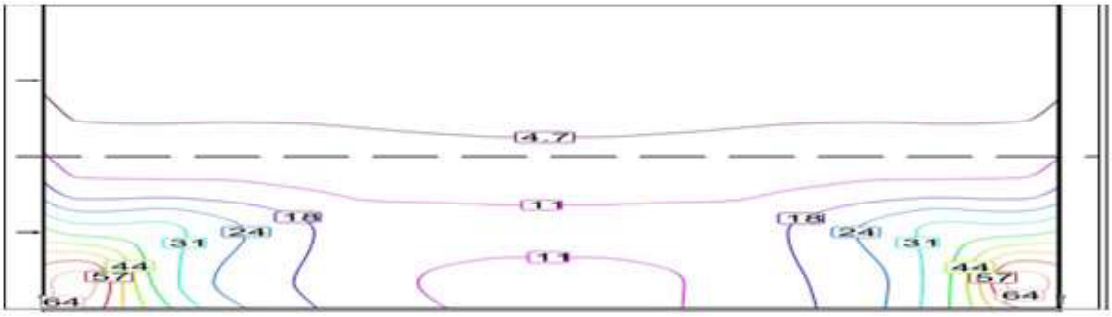

Figure 2: Isolux Diagram of Dump Road Illumination Design

DESIGN OF ILLUMINATION SYSTEM FOR ROAD ACROSS BELT CONVEYOR- 2

The illumination design for the road across belt conveyor-2 was modified as one of the lamps was not operating. The isolux diagrams for the illumination system is presented in Figure 3.

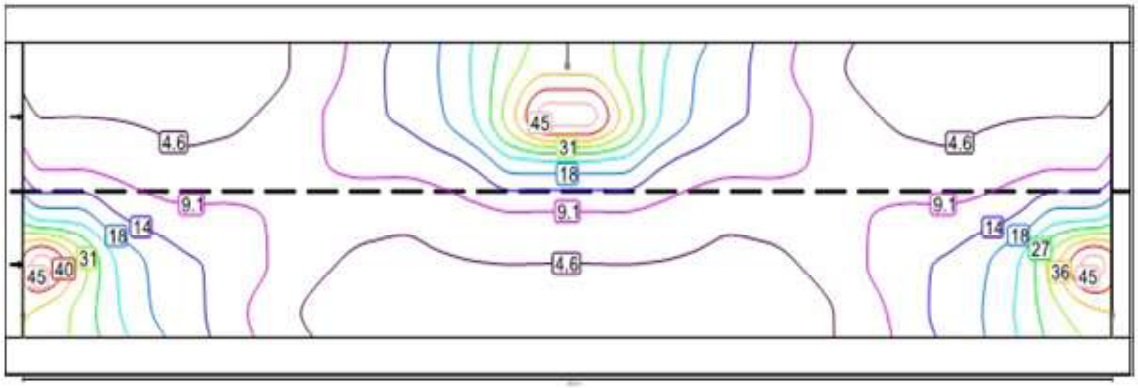

Figure 3: Isolux Diagram of Road across Belt Conveyor Illumination Design

DESIGN OF ILLUMINATION SYSTEM FOR DUMP YARD

The dump yard area was of 150m*100m. The illumination design was modified after the average illuminance measurements of the dump yard was found inadequate. The 3D CAD view of the design is shown in Figure 4.

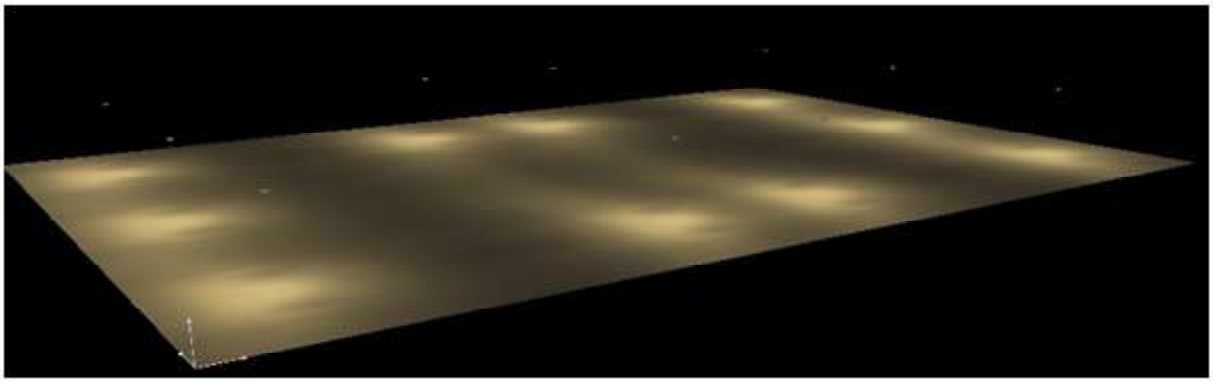

Figure 4: 3D CAD View of Dump Yard Design

DESIGN OF ILLUMINATION SYSTEM FOR OVERBURDEN FACE

The overburden face illumination measurements were found to be inadequate when compared with the DGMS guidelines and after designing an average illuminance value of 10 lux was obtained which satisfies the minimum standards. The 3D CAD view of the proposed model is presented in Figure 5.

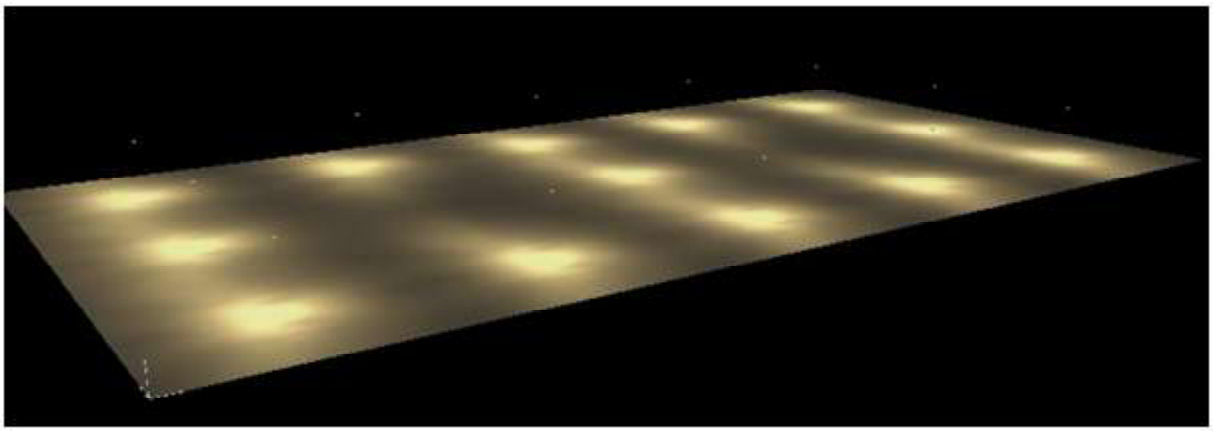

Figure 5: 3D CAD View of Overburden Face Design

CONCLUSIONS

The objectives of the paper were to properly study the illumination measurements of different places of selected opencast coal mine, thoroughly going through the illumination survey report and determine which areas does not have adequate illumination arrangements and finally to design illumination models for the areas which doesn't possess the required illuminance values. After the designing was done from the collected survey report, the following conclusions can be drawn:

- The average illuminance value in the haul road was found to be 7.8 lux which is less than the standard average value prescribed by DGMS which is 10 lux because there were some poles with defective lamps which needed repairing and some poles with no glowing lamps on them. In the design model, an average illuminance value of 11.2 lux was obtained which satisfies the DGMS standards for illumination measurements.
- An average illuminance valueof 4.1 lux was obtained throughout the dump road area which is less than the standard illuminance requirement specified by the DGMS of 10 luxas some of the lamps had lower luminous flux values. In the design model, an average illuminance value of 11.2 lux was obtained which

satisfies the DGMS standards for illumination measurements.

- The survey of the road across the belt conveyors gave an average illuminance value of 6.9 lux and 15.2 lux. As the minimum standard for the average illuminance values in these places is 10 lux, one side of the belt conveyor hence was declared to have an adequate illumination design when the other failed to do the same thing. After designing the road across the belt conveyor 2, an illuminance value of 16.2 lux was found, which satisfies the DGMS standards.
- As the average illuminance value required in the dump yard is 15 lux, the existing illumination model was declared to be not adequate as an average illuminance value of 3.1 lux was obtained. After designing an average illuminance value of 16 lux was obtained which proves the adequacy of the model.
- The average illuminance value recorded in the overburden face is of 1.9 lux which is less than the average standard illuminance requirement of 15 lux. The distribution of light at this area was deemed to be very low. Hence by the proposed illumination model, an average illuminance of 16 lux throughout the surface of the area is suggested.

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The Indian Mining & Engineering Journal, Vol. 60, No.02, February 2021, pp.25-30
Printed in India, @ IME Publications, ISSN 0019-5944

Analysis of Powder Factor in Limestone Mine- A Case Study

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ABSTRACT

In hard rock excavations, drilling and blasting is the cheapest method of rock breaking and it is widely used. The overall cost effectiveness of production operation is compatible with optimization of drilling and blasting. The blasting efficiency assesses in the form of rock fragmentation, powder factor and blast induced environmental nuisances. This research work is carried with the aim to analyse and improve of powder factor and rock fragmentation by blasting at JK cement Maliakhera limestone mine, Nimbahera, Chittorgarh. Fragmentation characteristics such as fragment size K25, K50, K98 and uniformity index were calculated by fraglyst software. Powder factor and rock fragmentation analysed for all baseline blasts and experimental blasts. In the analysis, powder factor was improved significantly in air deck blasting than solid deck blasting. Cost of explosives reduced by 9.12% in case of solid deck and 11.18% in air deck blasting. By decking, total charge per hole reduced, and rock fragmentation and powder factor improved.

Keyword: Rock, blasting, powder factor, fragmentation, deck.

INTRODUCTION

In hard rock excavations, drilling and blasting is the cheapest method of rock breaking and it is widely used. Drilling and blasting operation is one of trends to increase efficiency of excavation. Inspite of the best efforts to introduce mechanization in the opencast mines, blasting continue to dominate the production. Drilling and blasting cost in any project can be as high as 25% of the total production cost (Adhikari *et al.,* 1995). Therefore, to minimize the cost of production, optimal fragmentation from properly designed (explosive-rock mass interaction) blasting pattern has to be achieved. To optimize a blasting operation, it is necessary to understand the characteristics of blasting parameters.

An optimum blast is also associated with the most efficient utilization of explosive energy in the rock-breaking process. During blasting with explosive, a huge amount of energy in terms of pressure and temperature liberates. Only a part of explosive energy is actually used for the fragmentation and displacement, the rest of the energy is wasted, which creates a number of blast nuisances like ground vibration, air over pressure, flyrock, dust, fumes etc. These blasting nuisances cannot be completely eliminated but certainly minimized up to a permissible level to avoid damage to the surrounding and existing structures.

Blasting efficiency depends on controllable and non-controllable parameters. Controllable parameters are mainly related to blast hole geometry and explosive characteristics includes hole diameter, hole depth, sub drill depth, hole inclination, stemming length, stemming type, blast pattern, burden to spacing ratio, bench height to burden ratio and direction of blast, initiating system, initiating sequence, number of free faces, explosive types, explosive energy, explosive density, velocity of detonation, charge geometry, loading method etc. While non-controllable factors are geology of deposit, rock strength and properties, presence of water, joints and discontinuities in rock mass (Hagan,1983; Rustan,1983. Choudhary, 2013; Rai et al.,2010). After blasting the assessment of blast is important. These assessment parameters are fragmentation, blasting nuisances and powder factor. A correct fragmentation would optimize the cost and change the overall economics which is assessed in the form of powder factor (Bozic, 1998; Kemeny *et al*., 2015; Strelec,2011).

Powder factor is the ratio between the amounts of rock broken and total weight of explosive consumed (tonne/kg or m^3/kg) (Singh *et al*. 2016). It is taken tonne/kg in case of ore or coal and m^3/kg waste rock is broken. Reverse of powder factor known as specific charge kg/tonne or kg/m^3.It is an important parameter used to blast design, when it is referring to a pattern explosive or is expressed as energetic consumption (Jimeno *et al*., 1995). Powder factor is economic index for assessment of blastability of rock. Higher powder factor causes oversize and lower powder factor results into crushed rock. Powder factor can serve a variety of purpose, such as an indicator of how hard the rock is, or the cost of the explosive needed, or even as a guide to planning a blast.

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Powder factor is a blasting parameter for any opencast mines is depends on various parameter such as geology of rock, blast design including hole diameter, spacing, burden and bench height, size requirement of rock fragmentation, impedance matching, explosive energy output and its utilization etc.

STUDY AREA

Maliakhera limestone lease area is located near village Maliakhera, Tehsil-Nimbahera Chittorgarh, District of Rajasthan, India. The mining lease area lies approximately between the latitudes 24˚40'4.7" - 24°41'22.4" N, and longitudes 74°36'22.0" - 74°37'22.7"E. The lease area forms a part of the Survey of India toposheet no 45L/10.The lease area covers portions of 5 villages namely Maliakhera, Bansa, Piplia Gadia, Phalwa and Bhatt Kotri. The location map of this mine is shown in Figure 2.1

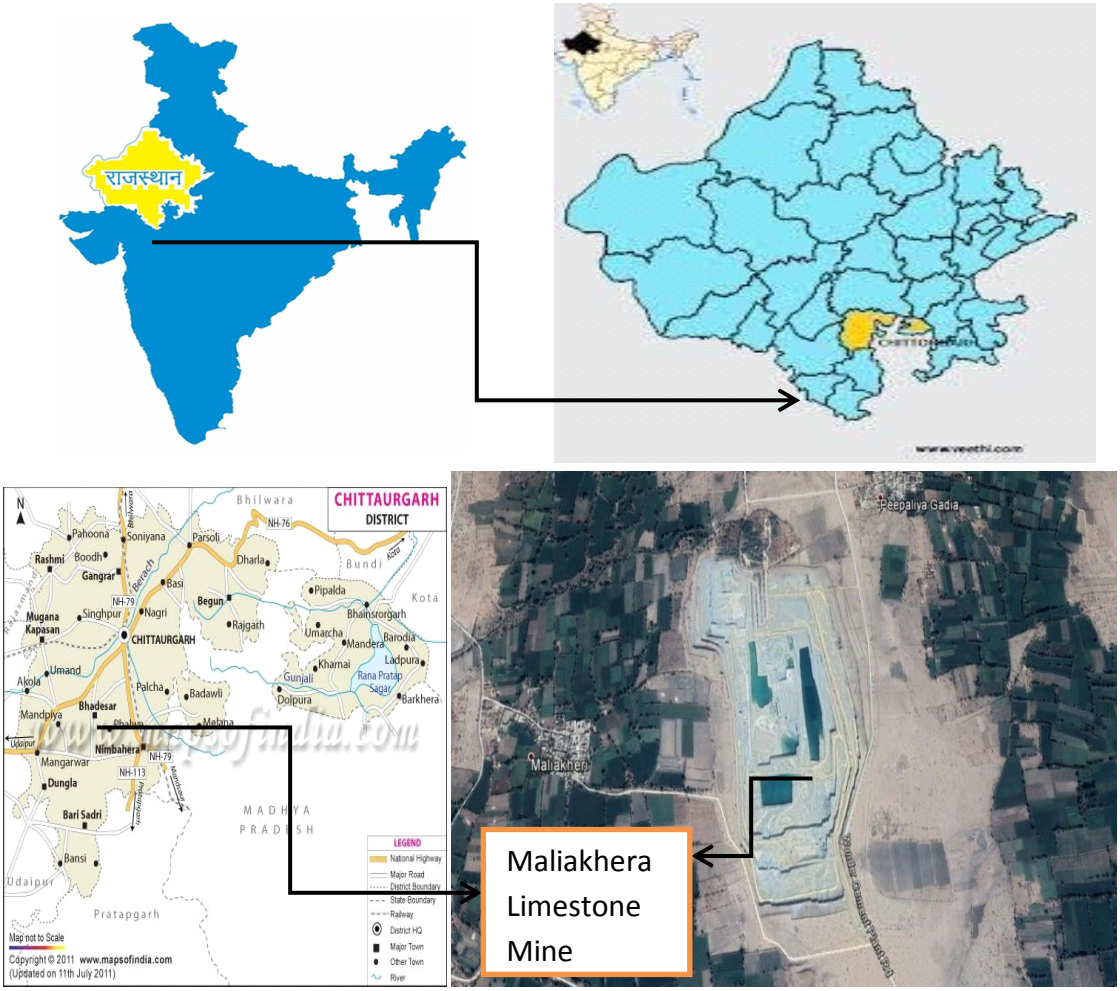

Fig. 2.1: Location map of JK cement Maliakhera limestone mine

METHOD OF MINING

The Maliakhera mines of JK cement works is fully mechanized and being worked by with deep hole drilling and blasting and subsystem adopting shovel- dumper combination for loading & hauling. The drilling is carried out in rectangular pattern using 115 mm diameter DTH drill machines with a burden 3 to 3.5m and spacing 4.5 to 5.5m. ANFO was used as column charge and Kelvex-600E, Kelvex- PE (83mm dia.) as booster charge and priming respectively. The number of holes varied between 8 and 16. The holes are drilled at angle 80˚-85˚. The sub grade drilling of 0.3 m was being followed at few locations where dip of foliation was against the free face. The blasts were initiated by shock tube system with DTH of 250ms,450 ms and trunk line delay(TLD) consisting of 17 ms,42

ms,65 ms were commonly used in blasting. Stemming column kept between 2.1m to 2.4 m. Drill cuttings were used as stemming material. Delay sequencing is shown in figure 3.2.

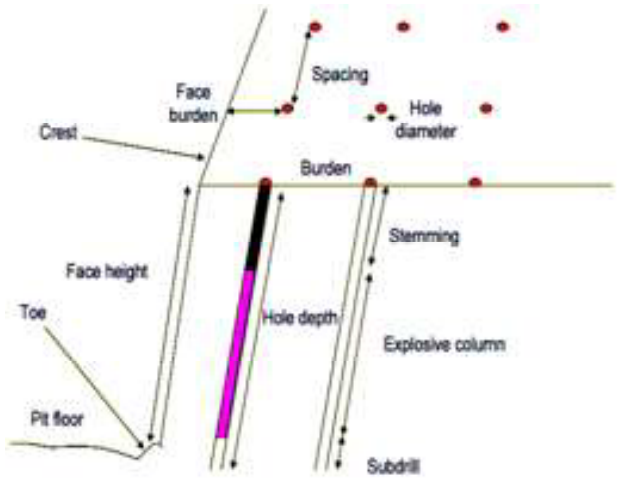

Fig. 3.1: Blast design parameters

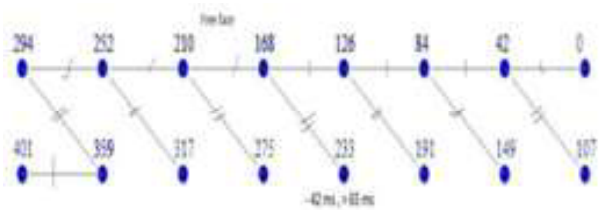

Fig.3.2: Firing pattern cummulative delay (ms)

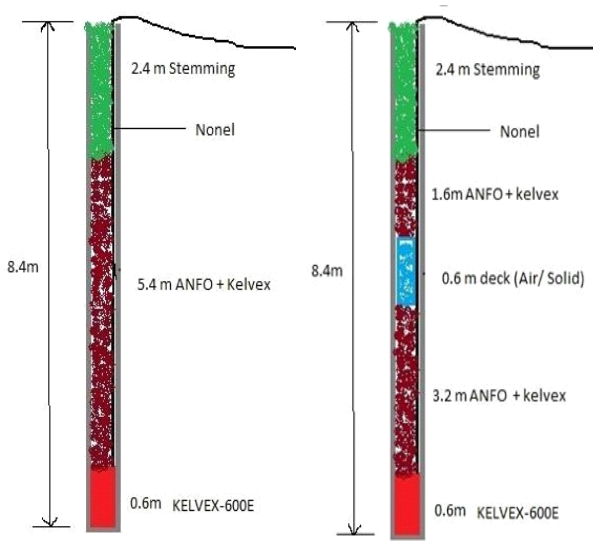

Fig.3.3: (a) Continuous charging (b) Deck charging

RESULTS AND DISCUSSIONS

On the basis of the study following results and discussions have been drawn.

Analyzed Fragmentation of Baseline Blasts and Experimental Blasts

To evaluate existing blasting, 16 blasts have conducted at Maliakhera limestone mine and bench height, burden, spacing, hole length, explosive consumption and blast hole data were collected during the blasts. After each blast, photographs were captured with scale and they were analyzed with WG-FRAGALYST 3.0. To appraise every blast 15 photos of blasted rock for each blast were analyzed. Photos were selected on the basis of good light conditions. For each image analyzed fragment size distribution curve was acquired with fragment size values of K25 to K98. Blasted block size distribution curve has been produced by the software on basis of Rosin-Rammler distribution. The curve will derive the size (mm) to cumulative passing % of the blasted fragments. The size K25 means 25 % fragments are finer and rests are coarser fragments. The primary crusher installed at JK cement accepts feed size as large as 1 m. Hence, optimum size of fragments should be in this criterion.

Analysis of mean fragment size K50

Figure 4.1 shows comparative fragment size distribution of blasted muckpile without deck, with solid deck and with air deck. Rock fragmentation size K50 is overall lowest in case of air decking.

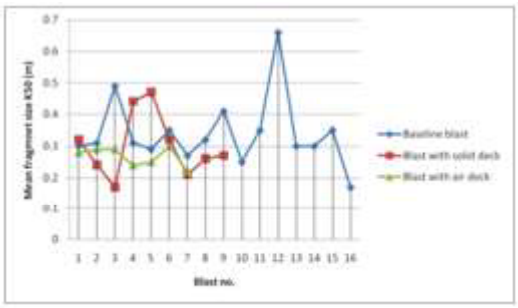

Fig.4.1: Analysis of mean fragment size (K50)

Decreasing K50 means the mean size of fragmentation decrease. Decreasing size of rock fragment is desired.

Analysis of oversize fragments

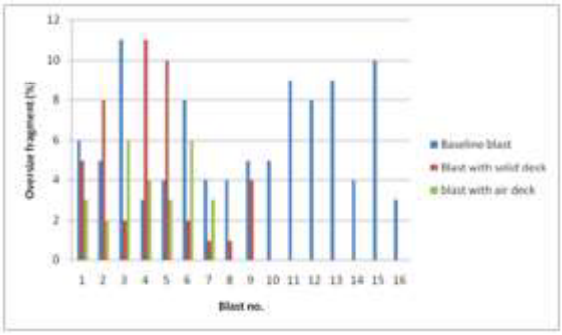

Fig.4.2: Analysis of oversize fragments (%)

It is evident from the fragmentation analysis that the oversize fragment generations are more in the case of without deck blasting. Size of rock fragments more than the primary crusher feed size is known as oversize. Oversize needs secondary breaking. The aim of any industry is produce minimum oversize so less need of secondary breaking. Figure 4.2 shows that the oversize produces without deck, with solid deck and with air deck. It was also observed that the oversize fragment (%) is least in case of air deck blasting.

Analysis of Powder Factor

Powder factor is the ratio between the amounts of rock broken and total weight of explosive consumed (tonne/kg or m^3/kg). Higher powder factor causes oversize and lower powder factor results into crushed rock. Fig.4.3 shows powder factor (tonne/kg) of each blast with different charging practices includes without deck, solid deck and air deck blasting.

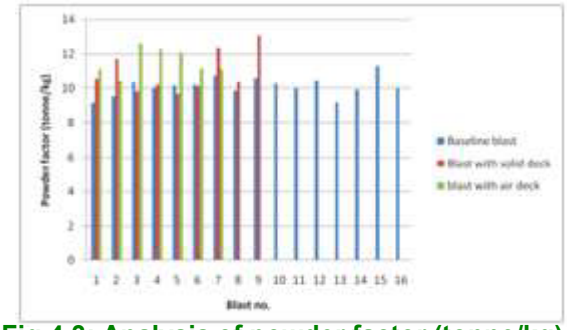

Fig.4.3: Analysis of powder factor (tonne/kg)

Fig.4.4 shows average powder factor without deck, with solid deck and deck provided with wooden spacers (Air deck). Powder factor is lower in solid deck blasting comparative to air deck blasting because in solid deck the column required more booster charge.

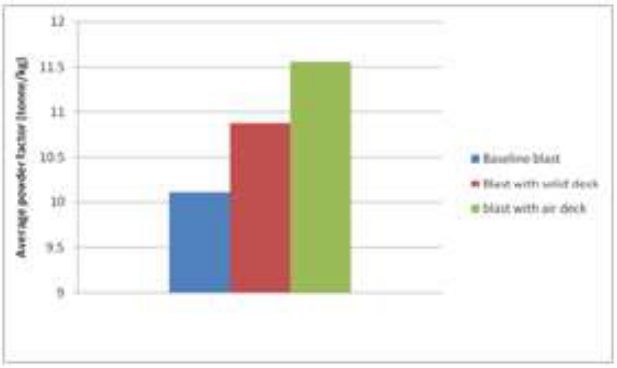

Fig.4.4: Analysis of average powder factor (tonne/kg)

Analysis of Energy Factor

Energy factor is the amount of the explosion energy required to break a unit weight or volume of material being blasted and expressed as MJ/t or MJ/m^3. This term is same as the powder factor, but explosives used other than ANFO has to be quantifying with energy factor. This factor fluctuates due to changes in type of explosives. It is representative of average explosive energy used per volume of rock.

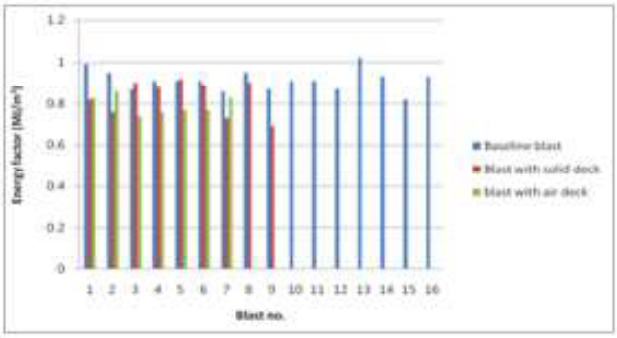

Fig.4.5: Analysis of energy factor (MJ/m^3)

Figure 4.5 shows energy factors for baseline and experimental blast. Fig.4.5 express that the amount of energy consumed per volume of rock in the baseline blast and deck blasts. Hence, this reduction in energy factor means improving utilisation of explosive energy.

Analysis of Cost

In rock excavation, cost plays important role. Increase in costing in blasting operation has adverse effect in the mining operation. In this research work, blasting cost of the blasts performed has been evaluated. Here, drilling cost consider constant for every blast.

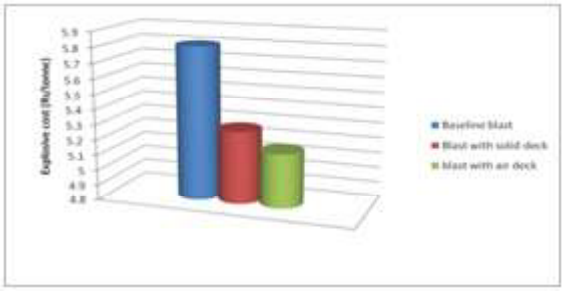

Fig.4.6: Analysis of cost (Rs/tonne)

As shown in Figure 4.6 cost of explosive (Rs/tonne) of rock broken used in blasting is lowest in case of air deck blasting followed by solid deck. By decking the total quantity of explosive used in a hole is reduced and improved charge distribution hence the cost of explosive in case of air deck is lower than other.

Results of Ground Vibration, Noise level and Flyrock

Ground vibration measurement is performed by seismograph called Minimate™ for 29 blasts conducted for this research work. Due to uncertain face condition and to maintain safe distance from the blast each recording distance has been changed in every blast. All the
reading has been taken from the back side of the blast. Table 4.1 gives the result of ground vibration for every blast.

Baseline blast					Experimental blast			
Blast No.	PVS (mm/s)	Noise Level (dB(L))	Distance (m)		Blast No.	PVS (mm/s)	Noise Level (dB(L))	Distance (m)
B-1	3.33	115.6	250		E-1	1.13	100.0	400
B-2	2.76	112.0	300		E-2	1.38	114.0	300
B-3	2.13	109.5	250		E-3	1.76	124.1	350
B-4	1.03	100.0	350		E-4	1.41	118.1	250
B-5	2.97	112.0	250		E-5	2.49	109.5	300
B-6	3.25	122.9	250		E-6	2.17	121.6	250
B-7	3.59	106.0	250		E-7	1.14	123.5	200
B-8	4.06	109.5	225		E-8	1.76	123.5	300
B-9	2.67	106.0	350		E-10	2.27	109.5	350
B-10	1.79	109.5	350		E-11	3.32	115.6	250
B-11	3.38	120.0	250		E-13	5.49	109.5	250
B-12	2.22	112.0	300		E-15	4.6	115.6	250
B-13	4.16	106.0	250					
B-14	3.29	121.6	300					
B-15	1.52	114.0	400					
B-16	1.25	100.0	400					

Table 4.1: Results of ground vibration and noise level

Table 4.1 shows peak vector sum (PVS) of every blast which is below the prescribed limit designated by DGMS. Though, in this research work all the blasts are under the permissible limit in the sense of ground vibration and noise level.

Excessive flyrock is rock that is projected beyond the normal blast-affected area. It is generated, when there is too much explosive energy for the amount of burden, when stemming is insufficient, or when the explosive energy is rapidly vented through a plane of weakness. The flyrock may take place from the bench face or bench top. Here, during this study the flyrock observed is between 32 m to 108 m from the blast face and it seems that flyrock are under control.

Analysis of blast vibration data

The ground vibration data including peak particle velocity (PPV), distance of monitoring, explosive charge per delay for various blasts were analyzed for understanding the effect of ground vibration induced by blast at Maliakhera limestone mine.

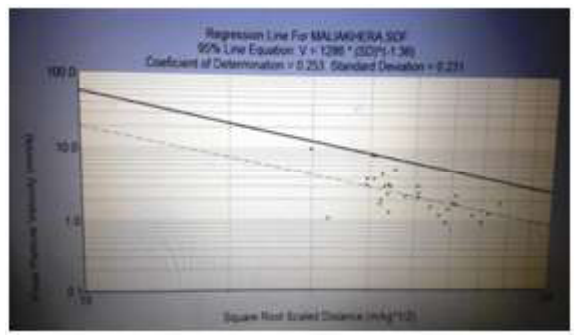

Fig.4.7: Peak particle velocity versus scaled distance

The prediction of particle velocity requires that the average and upper bound values be well known. The 50% average line is the line about which the recorded data is gathered. The 95% prediction limit line is a line generated from the standard error and data distribution curve as shown in the Figure 4.7.

The following predictor equation in terms of scaled distance and PPV is found to represent the data, and proposed for utilization of safe charge per delay to keep vibration level within safe limit for Maliakhera limestone mines.

$$V = 1286^{*} (\text{Scaled Distance})^{-0.1.36}$$

The ground vibration generated is related to the amount of charge per delay used in the blast holes. It has a critical value at which it gives the optimum output, amount more than that value will generate more ground vibration. This vibration generated can cause damage to the structures nearby. From the monitoring of ground vibration from a number of blasts the safe amount of charge per delay was determined. The safe charge per delay

recommended to keep the vibration level below 10 mm/sec at various distances from the blast site is given in below Table 4.2.

Table 4.2: Safe charge per delay at various distances

Distance (m)	Safe charge per delay (kg)
100	7.72
150	17.4
200	30.9
250	48.2
300	69.4
350	94.5
400	123.0
450	156.0
500	193.0

Analysis of Flyrock

Flyrock is caused by mismatch of the distribution of explosive energy, type of confinement of the explosive charge, and mechanical strength of rock. We conducted Blast videography of many blast to access the range of flyrock. For measuring distance, red flags was kept horizontally known distances. Flyrock measurement by blast videography and visual measurement the maximum flyrock lies in the range of 60 m to 140 m.

CONCLUSIONS

(i) Powder factor improved 7.61% and 14.34% in case of solid decking and air decking respectively compared to continuous column charge blasting method.

(ii) Improvement in size distribution of blasted rock was observed. Mean fragment size K50 decrease in experimental blasts. Reduction in oversize 19.67% and 37% in solid deck and air deck respectively. Secondary breaking has been reduced and ensures the normal efficiency of the shovel loading compared to baseline blasting.

(iii) Cost of explosive reduced in solid decking practices by 9.12% and in air deck 11.18%.

(iv) Reduction in energy factor 8.77% in solid deck blasting and 12.93% air deck blasting.

(v) Ground vibrations and noise level recorded during the blasts were under the permissible limit as prescribed by Directorate General of Mines Safety (DGMS), regulatory body of Government of India.

(vi) Flyrock measurement by blast videography and visual measurement the maximum flyrock lies in the range of 70 m to 140 m.

ACKNOWLEDGMENT

The authors are thankful to the management of Maliakhera Limestone Mine, JK cement works" for their support during field work.

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The Indian Mining & Engineering Journal, Vol. 60, No.02, February 2021, pp.31-36
Printed in India, @ IME Publications, ISSN 0019-5944

Assessment of Liquefaction Potential on Cemented Paste Backfill

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ABSTRACT

In the modern era, underground mines need such backfill schemes that can quickly deliver a backfill for the stability amelioration of underground mine openings. Cemented paste backfilling is one of these scheme which can quickly deliver cemented paste backfill (CPB) into underground stopes for supporting the underground structure. The CPBs need to be properly engineered and designed so that it can properly function once placed into the stopes. The liquefaction failure of an early age CPB due to its exposure to seismic events such as production blasts, rock burst and earthquakes has become the concern of geotechnical stability. This paper makes an attempt to apply knowledge of geotechnical earthquake engineering to examine the liquefaction susceptibility of a fresh CPB and a CPB which is cured for 28 days. The experimental investigations were undertaken on CPBs having pulp density of 79 to 81% (w/w) with 3%, 5%, and 7% cement dosages and slump ranging from 22.2 cm to 25.8 cm. The liquefaction analysis performed using horizontal shake table test infers that increase in cement content increases the time required for liquefaction failure of a given CPB for a given set of frequency and curing period. The Uniaxial Compression Strength and triaxial strength test results indicates that CPBs composed of 5% and 7% cement dosages are less likely to liquefy than CPB having 3 % cement dosage.

Keywords— tailings, binder, cemented paste backfill, uniaxial compression strength, liquefaction

INTRODUCTION

After the mine processing, a significant quantity of tailings are obtained. The tailings produced during the production of the ore are controlled through disposal into tailings dams, discharge into accessible deep sea areas, and re-fill into underground mine spaces. (David M Chambers, 2011) recorded globally finding more than 3,500 tailings dams. However, there have been a number of accidents involving the tailings reservoir, particularly between 1960–1980 and 1980–2011, which is an average of 2– 5 occurrences per year. These accidents have triggered human life loss, structural harm, industrial and forestry land destruction, and negative effects on the environment (such as water pollution). Deep-sea discharges are rarely used as the mine location needs to be very near to the ocean in order to provide an appropriate atmosphere for tailings disposal.

Cemented paste backfill is a combination of mill-tailings, water and binder agents used to fil subterranean opening that were earlier mined. Using backfill in a stope decreases the quantity of mine tailings to be stored on the ground and adds to the mine's stability.

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While long term stability is essential, the short term stability of fresh CPB, including its liquefaction resistance, is of prime concern.

In paste technology, the state of practice is to add a small quantity of cemented materials (i.e. binder agents) to mine tailings as backfill material to enhance short-term and long-term strengths. The 'thumb rule' used to regard backfill as resistant to liquefaction is to attain 100 kPa of unconfined compressive strength (UCS).

It has been demonstrated that the 100 kPa UCS can be achieved in a short time by adding a small amount of binder to CPB (le Roux, 2004) However, if the cement in CPB has not significantly hydrated, there may still be a risk of liquefaction in early ages.

Once CPB is prepared, it is then supplied at a monitored filling rate through pipelines to an earlier mined stope. Due to the hydration of cement binders, the filling rate relies on the consolidation and strength growth of CPB over time. The filling rate can be very slow in a lengthy, tight stope to avoid a barricade failure at the bottom of the stope.

Consequently, CPB's capacity to withstand static liquefaction owing to self-weight during stope filling is

essential owing to the safety and financial consequences connected with the prospective fill failure. Besides static liquefaction, CPB's dynamic response to an earthquake-induced liquefaction is of interest. In addition, it is essential to resist newly positioned CPB to liquefaction owing to blasting during the excavation of neighbouring stopes or rock bursts as unexpected seismic events in hard rock mining.

The word liquefaction was used in combination with a multitude of events involving soil deformation induced under undrained circumstances by monotonous, temporary, or cyclic loading of saturated soils. For example, the Geotechnical Engineering Division's Committee on Soil Dynamics, American Society of Civil Engineering (1978), has defined liquefaction as the process of transforming any substance into a liquid. In cohesion less soils, the transition is due to enhanced pore pressure and decreased efficient stress from a strong condition to a liquefied condition.

According to this concept, a main characteristic of liquefaction occurrences is the generation of surplus pore water pressure. Generally, when saturated soils under undrained circumstances are subjected to rapid loading, the contraction inclination leads surplus pore water pressures to rise and efficient stresses to reduce. In other words, generating surplus pore water pressure owing to static or dynamic loading may be adequate to take the earth to a stable state or a situation of zero effective deformation stress.

A soil or aggregate type must fulfil certain requirements for liquefaction to occur. The three primary conditions are: it must be saturated, it must be non-cohesive and it must be energized by an external load so as to reduce to zero the effective stress on the land ((Angemeer, Carlson, Stroud, & Kurzeme, 1975)). Paste backfill can be presumed to be saturated by definition, but with cement in place, it may not always be assumed to be cohesion less. Only when the CPB is freshly poured, and when the cement binder has not hydrated completely, it can be assumed to be cohesion less.

MATERIALS AND METHODS

A. Materials

The In this study, the tailing was collected from a Pb-Zn bearing ore processing mill located in Rajasthan, India. The tailings was preserved in sealed plastic containers. The other CPB components used in this study are tap water and ordinary Portland cement of 43 grade.

B. Methods

The experimental investigations were undertaken on CPBs having pulp density of 79 to 81% (w/w) with 3%, 5%, and 7% cement dosages and slump ranging from 22.2 cm to 25.8 cm.

C. Moisture content

The mill tailings obtained were examined for inherent moisture content according to IS 2720 part 2 1973. This allows us to know the amount of additional makeup water required to be added. In this study, five samples from different locations of the big tailings container were considered. The moisture content was determined using following expression.

$$w = \frac{w_2 - w_3}{w_2 - w_1} \times 100$$

D. Sample preparation and slump cone test

The moulds in which the samples were casted using PVC pipes with internal diameter 47 mm, cut into required lengths of L/D >2. The PVC moulds were made a slit so that the casted samples can be easily removed. Total 150 moulds were made. Figure 4-1 represents mouds made up of PVC pipe.

Cemented paste is designed considering 3%, 5% and 7% of cement content at a range of 79 to 81% pulp density. The mixed paste was checked for its consistency using Slump cone test according to IS 1199-1959. Figure 1 shows the slump cone testing over CPB.

Fig. 1: Slump cone test

The above activities were performed in a vibration-or shock-free location and within two minutes of sampling. The measured slump was reported during the experiment in terms of the specimen's millimeters of subsidence. The slump was experimented twice for the same composition and average values were taken and reported as slump value.

Now the mix was again made for preparation of samples. By fixing the pulp density to 79 to 81%, the amounts of each composition to be mixed was found out and a binder content of 3% with total solid content was taken in the first mix. The slit opened PVC pipes were plastered and sealed. The inner surface of the pipes were coated with grease. The mixture was put into moulds by putting in three equal layers each layer being tamped 25 blows with a tamping rod. The casted samples were opened after 24hrs and transferred into a specially arranged curing chamber. Since the casted mix is a paste and require sufficient time to attain strength, if the sample is cured in the conventional way the mix will be spoiled. Hence, a humidifier arrangement was made and sealed so that the mist formed is going to cure the casted samples.

Figures 2 and 3 shows the curing arrangement and casted CPB samples.

Fig. 2: Curing arrangement

Fig. 3: Casted CPB Samples

E. Uniaxial Compression Strength Test and undrained Unconsolidated triaxial test

The Uniaxial compression test was performed according to IS 2720 Part-10: 1991. Cylindrical tailings specimen were tested at a steady strain rate of 0.1 mm/min for failure in simple compression. The compressive force per unit area necessary to fail the specimen is called as unconfined compressive strength of the tailing. The sample prepared for UCS testing was a cylindrical sample with L/D ratio equal to 2. The uniaxial compression strength testing along with undrained unconfined triaxial tests were done at various curing periods of 7 days, 14 days and 28 days. The sample was trimmed on either side and the flatness was checked with a try-square. The dimensions including weights were noted.

The displacement strain gauges (LVDT sensor) were attached to determine deformations. The loading rod was released and the load was applied. The test was run till the failure takes place. The failure load (peak) divided by the area of cross-section of the specimen gives the unconfined compressive strength. The deformations which occur due to increased load were noted down. The deformations divided by their corresponding dimensions gives the strain values. The test was repeated over a minimum of three samples for the same composition and the average value was reported. Figure 4 represents the triaxial testing equipment over CPB sample.

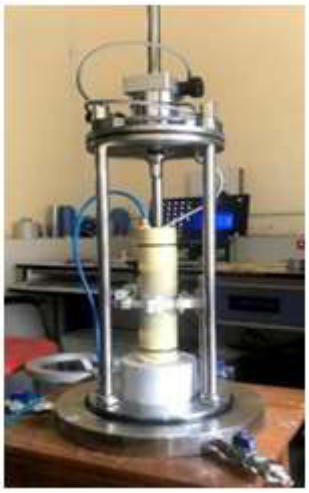

Fig. 4: Triaxial testing equipment

F. Liquefaction potential analysis

The liquefaction testing was done on Shake table apparatus. Shaking table experiments are one of the most significant earthquake design experiments that offered useful insight into soil- structure communication, liquefaction, and lateral dynamic soil stress and base response. A horizontal shake table with a load capacity 30 kilograms was used in liquefaction analysis. The operating frequency of the shake table is of the range 0 to 25 Hz. There is a provision of frequency control +/- 3%. The amplitude range is 0 to 10mm with a resolution of 1mm. The table size is 400 x 400 mm. A box is mounted a box of size 400mm x 300mm x 15mm. The CPB sample was made with the same proportions of mill tailings, cement dosage and water content. Tests were conducted on CPBs with varying cement proportion of 3%, 5%, 7%.

A mix of zero cement content was also made and comes out to be liquefied at a curing time of 9 hours. All the mixes were kept a constant curing time of 9 hours (Saebimoghaddam, 2010). The frequency of 10 Hz was also kept constant and the time taken for the each individual sample was counted. The occurrence of liquefaction was observed by placing two blocks of weight 1.54kgs, 3.22 kgs and dimensions 10 cm X 10 cm X 10cm and 10 cm X 10 cm X 20cm. Figure 5 represents the sinking of block structure due to dynamic loading in a shake table testing equipment and Figure 6 represents the frequency of shake table.

Fig. 5: Sinking of block structure due to dynamic loading in a shake table testing equipment

Fig. 6: Frequency of shake table

RESULTS AND DISCUSSIONS

A. Moisture content

The moisture content was measured for five samples, and the average of all the five samples represented as the inherent moisture content of the collected mill tailings. The readings of initial weights and final weights after keeping in oven at 105 degrees Celsius for 24 hours were taken. The below Table 1 represents the data from moisture content test.

Table. 1: Moisture content test results

S.No.	W1(gm)	W2(gm)	Water content (%)
1	64.601	60.096	7.496339
2	118.791	112.913	5.205778
3	102.722	97.741	5.096121
4	113.547	107.259	5.862445
5	104.407	98.197	6.324022
	Average		5.99

B. Slump cone test results

Slump cone test was performed on three samples for each composition of CPB. The average of the three values was denoted as the slump value of the samples. The gap between the mould's height and that of the specimen's lowest level being examined was represented as the slump value. The below Table 2 data represents the slump values of 3%, 5% and 7% cement dosage added CPBs.

Table. 2: Slump cone test results

Cement dosage in CPB%	Average slump Value(mm)
3	25.80
5	23.33
7	22.20

C. Unconfined comoression test results

The UCS tests were performed on a minimum of three different samples for every type of composition of 3%, 5% and 7% cement content of CPBs. The UCS tests were performed on 7 days, 14 days and 28 days of curing time. The 28 days strength was considered as final strength of the sample. Figure 7 represents the variation of UCS with days and cement dosage.

D. Undrained unconsolidated triaxial test results

The Unconsolidated undrained triaxial (UU) tests were performed on a minimum of three different CPB samples for three compositions of 3%, 5% and 7% cement content. The dimensions and weight of a 7% cement dosage at 28 days curing period is represented in Table 3.

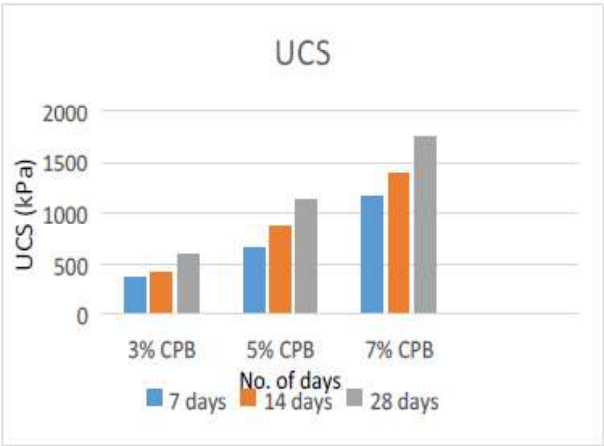

Fig. 7: Variation of UCS with days and cement dosage.

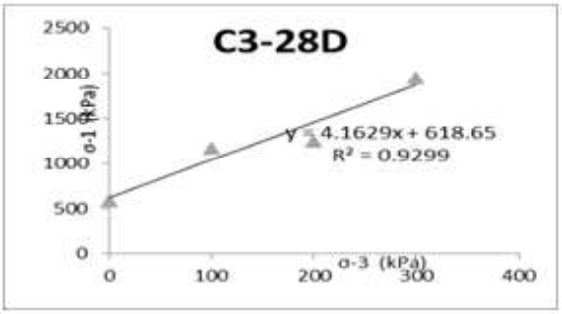

Fig. 8: Mohr-Coulomb failure envelope of PB with 3% cement and 28 days curing

Table. 3: Dimension and weight of 7% cement CPB sample cured for 28 days

Sample	Dia(mm)	L(mm)	Weight(g)
U1	46.57	105.66	394.8
U2	46.73	108.71	396.4
U3	47.17	111.89	429.5
U4	46.86	111.18	413.8
U5	46.62	100.81	375.7
T1	46.75	106.54	376.7
T2	47.04	108.63	378.3
T4	46.16	111.58	353.7
T5	46.49	111.83	419.3
T6	46.86	112.87	419.9

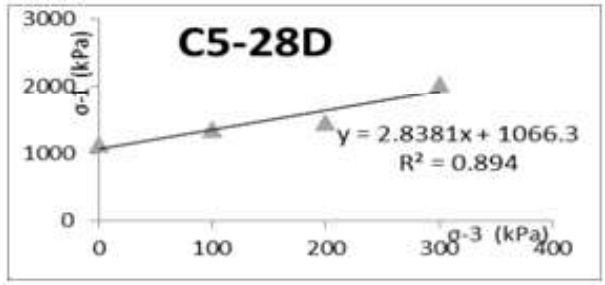

Fig. 9: Mohr-Coulomb failure envelope of PB with 5% cement and 28 days curing

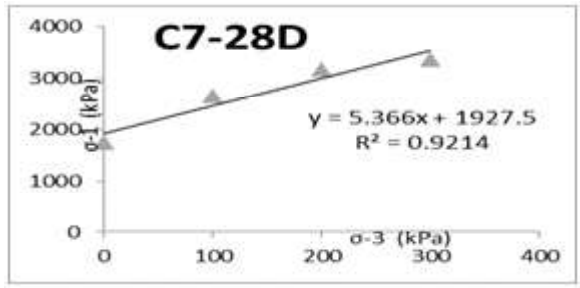

Fig. 10: Mohr-Coulomb failure envelope of PB with 7% cement and 28 days curing

E. Liquefaction test results

The liquefaction testing results which were performed on a horizontal shake table are detailed below. The frequency was kept 10 Hz for all tests and the curing period of all sample was kept 9 hrs. The time taken for initial liquefaction to occur and final liquefaction to occur were noted and are given below Table 5.

Table. 5: Liquefaction occurrence time of CPB sample

Cement content (%)	Frequency (Hz)	Initial liquefaction time(s)	Final liquefaction time(s)
0		Not feasible	
3	10	8	36
5	10	15	65
7	10	24	98

CONCLUSIONS

In this study geo-mechanical and liquefaction aspects of the CPB based on tailings and OPC were analyzed and following inferences were drawn. The results of geo-mechanical test substantiate that UCS and cohesion of CPBs increase with the increase in cement content, which increases the liquefaction potential of CPB over the curing period.

According to the thumb rule, UCS of 1 MPa for CPB after 28 days curing is sufficient for the CPB to resist liquefaction in underground stope filled with paste fill. In this study, the CPB having 3% cement, could not achieve UCS of 1 MPa after curing period of 28 days and hence, it may be prone to liquefaction when subjected to a blast induced or rock burst induced seismic wave with specific frequency and amplitude in underground mine. However, CPB having 5% and 7% cement dosage, cured for 28 days have achieved more than 1 MPa and hence these appeared to be less prone to liquefaction.

The shake table test infers that for a given frequency and curing period of a specific fresh CPB, the liquefaction occurrence time increases when cement dosage increases. The slump of developed CPBs is found to range from 25.8 to 22.2 cm which will ensure its flow ability with minimal pumping issues. Finally it can be deduced that the dosage of binder in the CPB is the most significant parameter which determines the liquefaction susceptibility of the CPB. Equations

ACKNOWLEDGEMENT

My profound thanks to Dr. Nikhil Sirdesai, Assistant Professor in Department of Mining Engineering, VNIT Nagpur for his valuable suggestions and help to carry out the work. The help in tailings sampling given by Dr. John Loui Porathur, Principal Scientist, CIMFR, Regional Centre, Nagpur and officials of Sindesar Khurd Mine deserve Acknowledgment. I thank Dr. Rakesh Kumar Assistant Professor, IIT Kharagpur for encouraging me in writing this paper. Finally I express my very profound gratitude to my parents and to my friends Sayali Ronghe, Shanmukha Srinivas and Manoj Kumar Woonna for providing me with unfailing support and encouragement.

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