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Contents
Technical Papers

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Sandwich High Angle Conveyor

B. Fredrick Thomson*

INTRODUCTION

The Sandwich High Angle Conveyor will optimize the conveyor layout leading to cost saving and faster implementation of the project.

The Mobile Loading System will eliminate Over Loading and Under Loading of Wagons and Trucks.

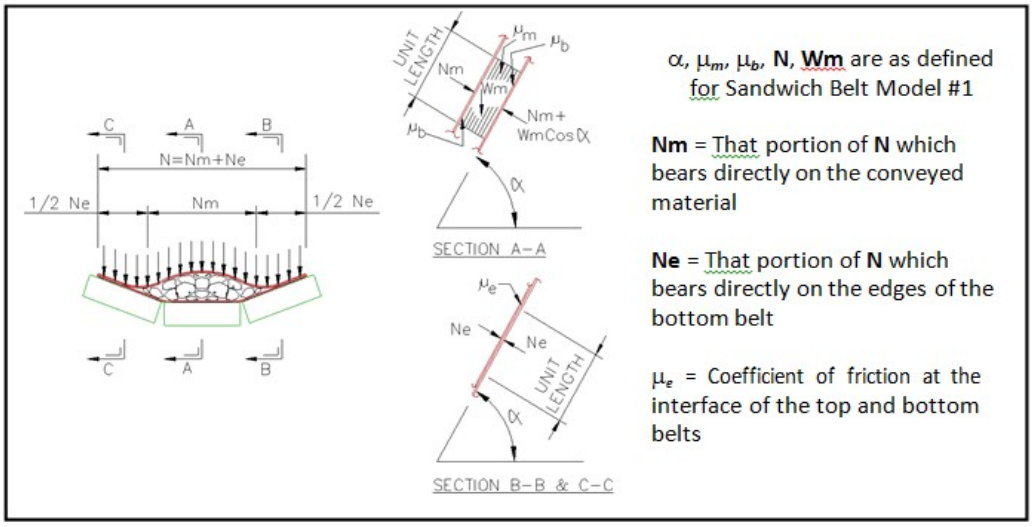
Keywords—Sandwich Conveyor, Under Loading, Over Loading, High Angle Conveyor etc.

BRIEF DESCRIPTION OF THE SYSTEM

Sandwich high angle conveyor has the ability to convey the bulk materials at high angles up to 90Deg.With this feature the length of the conveyor can be reduced.

WHAT IS HIGH ANGLE CONVEYOR (HAC)

SANDWICH BELT PRINCIPLE



Where: $\mu = \mu_m$ or $\mu = \mu_b$, whichever is the smaller

Hugging pressure N_m:

$$Nm \geq \frac{Wm}{2}\left(\frac{\sin\alpha}{\mu} - \cos\alpha\right)$$

HIGH ANGLE CONVEYOR (HAC) is sandwich belt employs two ordinary rubber belts which sandwich the conveyed material. Additional force on the belt provides hugging pressure to the conveyed material in order to develop sufficient friction at the material-to-belt and material-to-material interface. This prevent sliding back of material.

DSI Snake HAC system is later development by Joseph Santos, in which conveyors are passed through snake profile to maintain sufficient hugging pressure between top & bottom belt and without any need of additional spring loaded pressure arm. The wide use of long wall systems in the 1980s required upgrade or replacement of existing conveyor lines to keep up with production.

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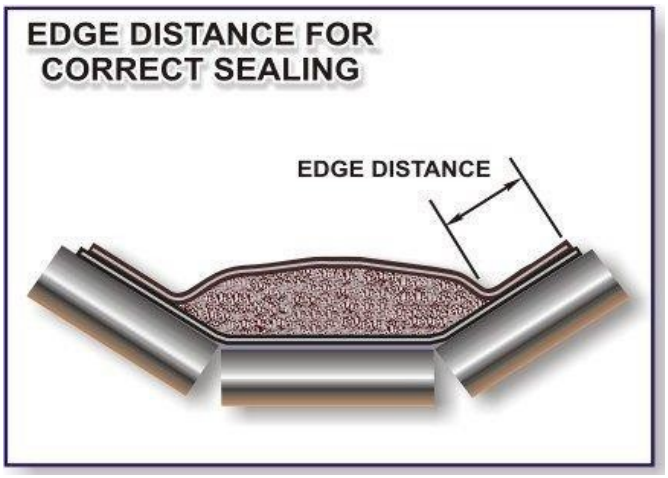
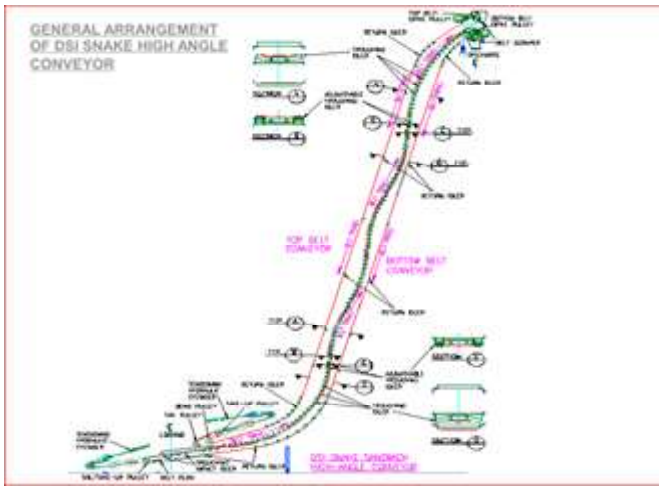


In deep coalmines this had resulted in choking at the main haulage shaft where existing skip hoists could not meet the increased production. This created great opportunities for high angle conveyors in the 1990s.



THERE CAN BE FOUR APPLICATIONS OF HIGH ANGLE CONVEYOR AS FOLLOWS:

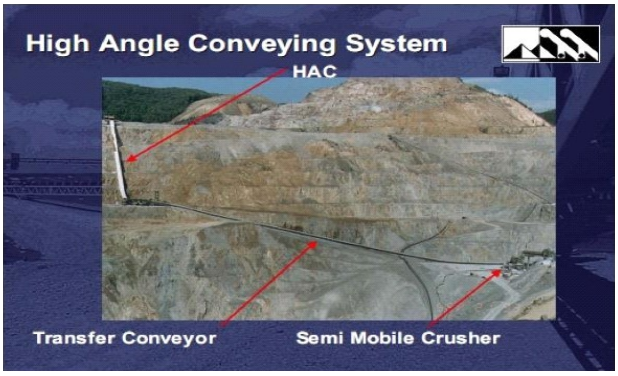
1. OPEN CAST MINE
2. UNDERGROUND MINE
3. DOWNHILL CONVEYOR
4. IN CHP FOR LOADING OF SILO

APPLICATION – I

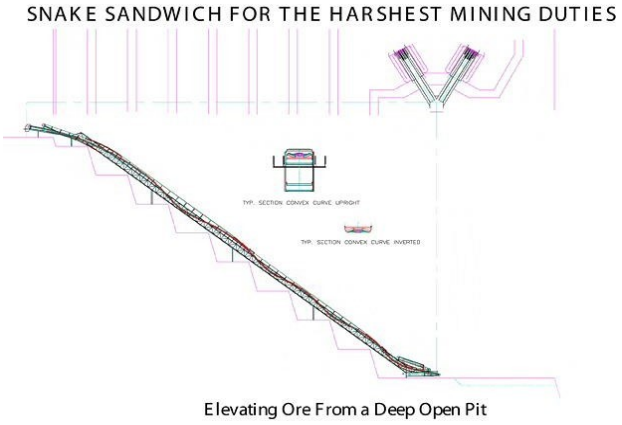
LAYOUT OF HAC ALONG SIDE WALL IN OPENCAST

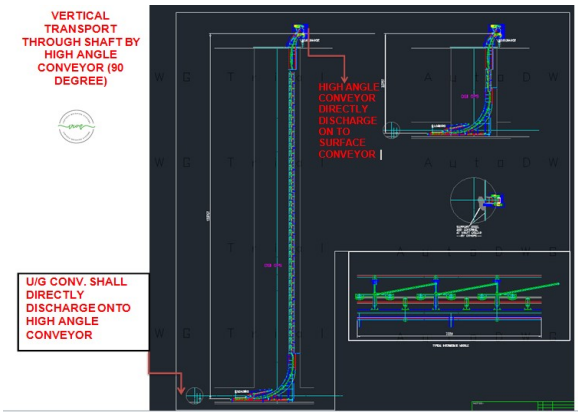
HAC IN OPERATION AT MAJDANPEK COPPER MINE, YUGOSLAVIA

CAPACITY – 4000 TPH, SLOPE – 35.5 DEGREE, LIFT – 93.5 M, LENGTH – 173.7 M, BELT WIDTH – 2000 MM, BELT SPEED –5.33 M/S, DRIVE – 450/900 kW (TOP/ BOTTOM)



SCHEMATIC LAYOUT OF DSI SNAKE CONVEYOR RECEIVING COAL FROM IN-PIT CRUSHER THROUGH BENCH CONVEYOR





APPLICATION – II HIGH ANGLE CONVEYOR IN SHAFT FOR UNDERGROUND MINE FOR VERTICAL TRANSPORT

Mobile Loading
Brief Description of the system

The system consists of 2 pre-weigh bins of around 80tons capacity each. The materials are loaded in the pre weigh bins by loaders continuously and the pre weigh bin will weigh each batch and it will discharge on the bottom conveyor. The bottom conveyor will discharge the materials in the wagon. The Loco has to pull or push each wagon for loading. During loading, each wagon will stop at the location of the loading conveyor and the loading conveyor will swing from left to right and load the wagon as per the capacity of the wagons.
In this option the system is mobile and it can be taken to different locations easily.

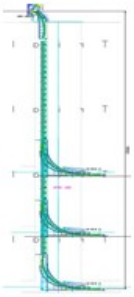
COMPARISON BETWEEN INCLINE & HAC SYSTEM

ALT I – DOG LEGGED INCLINE

TOTAL DEPTH – 230 M (UPTO BOTTOM SEAM)
LENGTH OF INCLINE IN 1 IN 5 GRADIANT (11.3 DEGREE) = 230 / 0.196 = 1180 M (ROUNDED)
COST OF INCLINE DRIVAGE @ 1.75 LAKH/M
= 1180 X 1.75 X 100000 = RS 21 CR (ROUNDED)
CONVEYOR COST FOR 1180 M (@2.5 LAKH/M) = RS 30 CR (ROUNDED)
CONVEYOR DRIVE POWER FOR 1000 MM WIDE & 250 TPH CAP = 365 KW
LIFE OF BELT = 3 YEARS
MANPOWER FOR CONVEYOR SYSTEM/SHIFT = 3 NOS
IN-EFFICIENT VENTILATION & LONGER CONSTRUCTION TIME

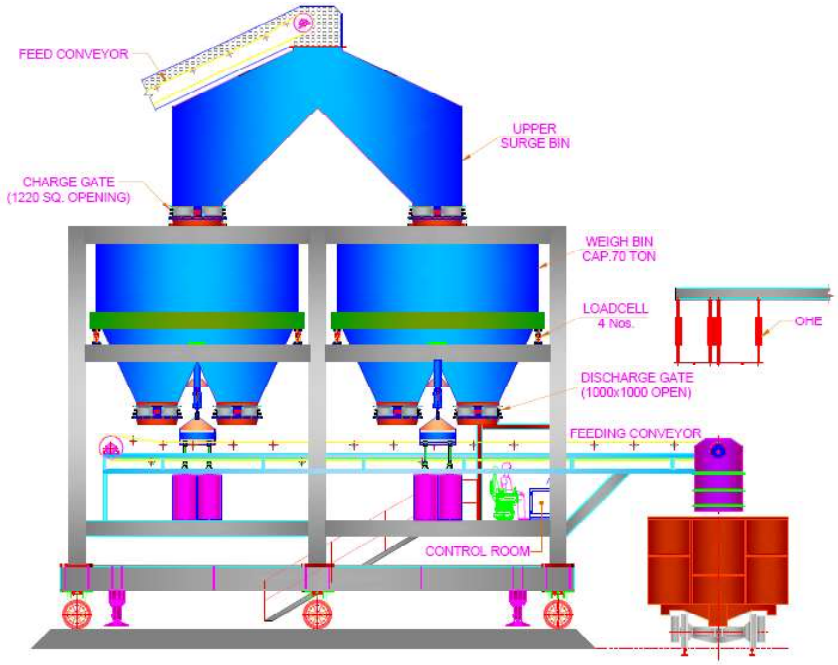
ALT II – HIGH ANGLE CONVEYOR THROUGH SHAFT

SHAFT DEPTH – 230 M
COST FOR SHAFT SINKING FOR 4.0 M DIA (@ 4.0 LAKH/M) = RS. 9.2 CR
HIGH ANGLE CONVEYOR COST = 230 X 10 =RS 23 CR
TOTAL DRIVE POWER FOR 230M = 300 KW
THE HIGH ANGLE CONVEYOR SHALL BE INSTALLED INITIALLY UPTO THE TOP SEAM. BOTH CAPITAL INVESTMENT & POWER SHALLBE LESS IN 1ST STAGE
LIFE OF BELT = 12 YEARS (DEPRECIATION COST SHALL BE ¼ TH OF ALT I)
MANPOWER FOR SYSTEM/SHIFT = 2 NOS
COST OF RACK & PINION CAGE = 30 LAKH
THE SHAFT CAN BE USED FOR MAN RIDING ALSO
EFFICIENT VENTILATION & LESS CONSTRUCTION TIME



Technical specification

1) Loading rate —1800TPH
2) Loading time for each train of 58 wagons —- Appr 2hrs 30mins
3) Loading accuracy for each wagon -+/- 0.2% (As per RDSO norms).
4) The system is suitable for FOIS connectivity.
5) We will provide weights and measures certificates for the weigh bins



MAJOR ADVANTAGES OF OUR MOBILE LOADING SYSTEM

- ✓ Low cost mobile loading system.
- ✓ Can be supplied and start loading in 4 months' time.
- ✓ No major civil works
- ✓ Very less power consumption.
- ✓ Can be shifted easily to a different location.
- ✓ Accurate weighing for each wagon +/- 0.1%
- ✓ Very easy and simple method of calibration.
- ✓ No over loading and under loading (Huge saving in cost)
- ✓ Approved by weights and measures and Railways.(As we are using pre-weighing).
- ✓ No need of any Rail in motion scale (Rail in motion scale is Very in accurate system +/-1%).
- ✓ System is offered on Rental basis no capital cost.
- ✓ System offered with O&M.
- ✓ We offered 2 options. One with loading system moving and another option of Train moving.
- ✓ With train moving the loading will be completed in 3hrs time and with loading systems moving the loading can be completed in 4hrs time.
- ✓ Can be loaded with OHE line. Our system is below OHE.
- ✓ Loading is safe and environmentally friendly.
- ✓ We can take back the equipment's after the expiry of contract

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Recent Trends in Blast Free Mining

Dr G.K.Pradhan* Ramesh Kant**

ABSTRACT

Blast free mining continues to expand in the recent years due several safety and environmental problems associated with blasting. Apart from safety it had getting application due to increase in the depth of opencast workings where slope stability has been an important area of concern. In India the blast free mining started with use of rippers followed by use of surface miners and rock breakers. While surface miners have been successfully used in coal mining where sized ore is produced cutting only coal and helping in effective quality control. In case of overburden or waste excavation the use of rippers are limited to Bauxite and in very few mines having compressive strength upto 20 to 30 MPa. In case of coal mines, MCL pioneered in the use of Exccentric Rippers to excavate overburden material. In few limestone mines very hard limestone was excavated by using splitters. Here holes at 2m grid are drilled of 110mm dia on a five to six m bench height towards free face. Each hole is split by the splitter. The cracked rock is handled by rock breakers and back home.

At Chittogarh limestone mines of Birla Corporation having compact strata, with compressive strength of 100-160 mpa. The rig-mounted hydraulic breakers of Epirock make HB10000 was deployed to produce in three shifts continuously more than 15,000 tons/day.The power generated in a single impact between piston and working tool corresponds to a weight force of around 760 metric tons and impact frequency up to 380 blows per minute.

Soundless chemical demolition agents or expansion Cement, are widely used where sensitive structures need to be protected from blasting effects. These agents are injected into drilled boreholes in the rock, where they expand and exert pressure until the rock fractures. An expansion cement type material this is safe and no regulation involved on its use.

In case of surface miners for hard rock excavation Tesmec, Vermeer and Trencor Make surface miners are best suited for UCS over 150 MPa which has the cutting drum in front of the machine unit. Vermeer unit was deployed at Nalco's Bauxite mine having more than 220 MPa UCS. The results were quite encouraging.

For coal measure strata overburden can be very well cut with Front drum surface miners for which the geotechnical data is required. In this presentation and overview of the blast free techniques will be presented.

INTRODUCTION

Blasting is the cheapest mode of breaking of hard to hardest rock. This is because of chemical energy release upon detonation is the cheapest option. In mining and quarrying operations, blasting has a significant role in view of its cost impact on the overall cost of excavation. DGMS had issued the blast induced ground vibration standards for Indian mines broadly covering the mine-owned and non-mine ownership installations/dwellings (Table 1). These standards have not only helped the blasting engineers to re-design blasting rounds, but also helped them to create a complaint free environment.

Table 1 : Permissible PPV(m/s) as per DGMS(Tech) (S&T) (Circular No. 7 of 1997)

Type of structure	Dominant excitation frequency, Hz		
	< 8 Hz	8–25 Hz	> 25 Hz
A) Buildings/ structures not belonging to the owner			
Domestic houses/ structures (Kuchha brick and cement)	5	10	15
Industrial Buildings (RCC and framed structures)	10	20	25
Objects of historical importance and sensitive structures	2	5	10
B. Buildings belonging to owner with limited span of life			
Domestic houses/ structures (Kuchha brick and cement)	10	15	25
Industrial buildings (RCC & framed structures)	15	25	50

*Prof. of Mining & Dean **Asst. Prof (Mining)
AKS University, Satna

ENVIRONMENTAL IMPACTS OF BLASTING IN MINING

Blasting is the principal method of rock breakage in mining and construction projects throughout the world. This may probably be due to its distinct advantages like economy, efficiency, convenience and ability to break the hardest of rocks. However, only a portion of the total energy of the explosives used in blasting is consumed in breaking rocks while the rest is dissipated. The dissipated energy creates environmental problems in the form of ground vibration, air overpressure and fly rock. With increasing mining and construction activities in areas close to human settlements, ground vibration has become a critical environmental issue as it can cause human annoyance and structural damage.

NOx is one of the pollutants predominantly present in most opencast mines due to mining. Use of dumpers contribute the maximum quantities, followed by blasting

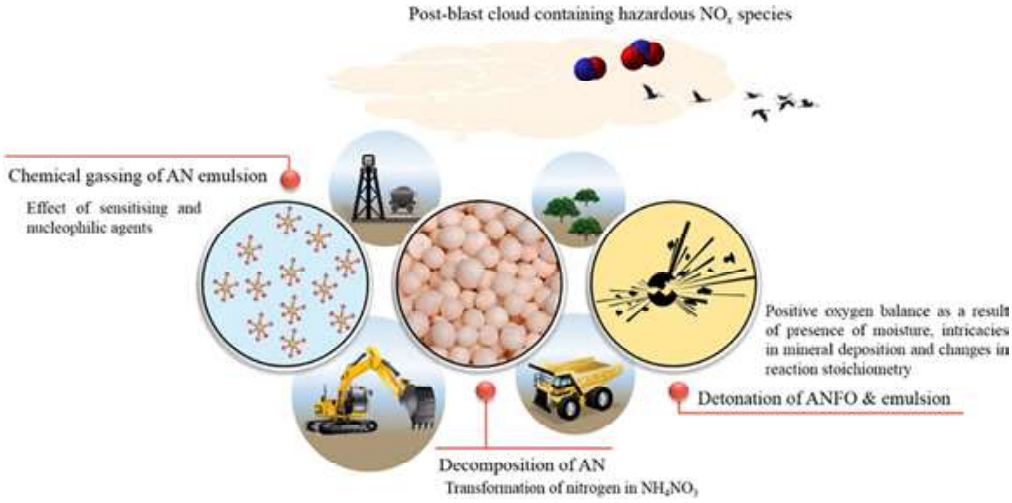


Figure 2 : Post Blast Impact of Blasting on the Environment

Oluwoye, I et el(2017), while studying the atmospheric emission of NOx from mining explosives (Figure 1) highlighted that - explosives engender environmental concerns, due to atmospheric pollution caused by emission of dust and nitrogen oxides (NO_x) from blasts, the latter characterised by the average emission factor of 5 kg (t AN explosive)$^{-1}$. This first-of-its-kind review provides a concise literature account of the formation of NO_x during blasting of AN-based explosives, employed in surface operations. We estimate the total NO_x emission rate from AN-based explosives as 0.05 Tg (i.e., 5×10^4 t) N per annum, compared to the total global annual anthropogenic NO_x emissions of 41.3×10^6 t N y^{-1}. Although minor in the global sense, the large localised plumes from blasting exhibit high NO_x concentration (500 ppm) exceeding up to 3000 times the international standards. This emission has profound consequences at mining sites and for adjacent atmospheric environment, necessitating expensive management of exclusion zones.

Use of surface miners in Indian coal mines not only helped in producing sized coal, coal with better calorific value, coal free from in-seam thin shale and sandstone partings etc. Sahu (2024) had reported about reduction of Total CO2 in entire MCL during 2023-24 by deploying surface miners has been estimated as 238465581 kgs. Similarly, most blast free excavations have contributed to reduction in CO2 and NOx emissions.

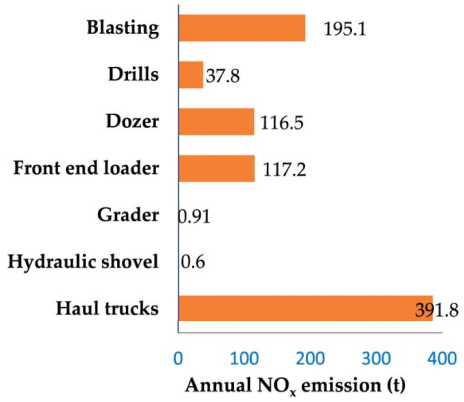


Figure 1 : NOx generation from various operations in Surface Mining

BLAST-FREE MINING TECHNIQUE

In mineral deposits and mines which are in the vicinity of human habitation and important structures (natural and/ or man made), the emphasis has been to avoid blasting. Besides, mines have also adopted blast-free mining keeping in view the incidence of thin coal seams, poor grade coal etc. Some of the blast free techniques currently in use are described in Figure 3.

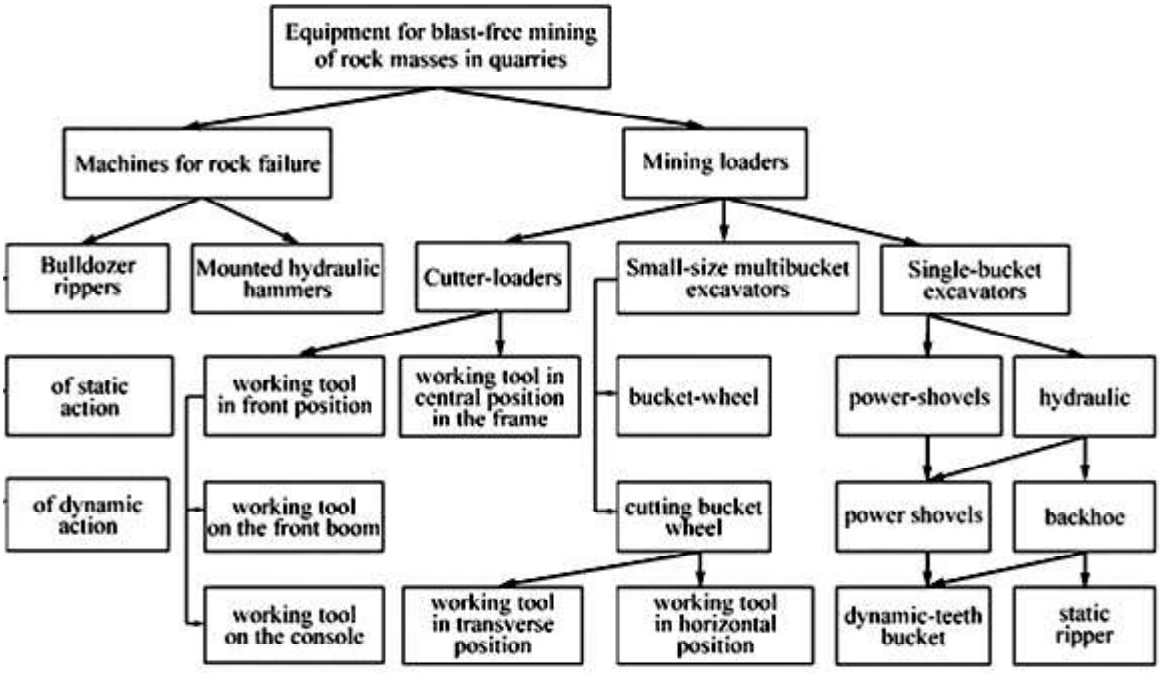


Figure 1 : Blast-free mining equipment & system

RIPPING WITH DOZER-CUM-RIPPER ATTACHMENT

The oldest practice of blast free mining is the use of dozers for removing and displacing soft rock formations, alluvium, top soil etc. However, with the increase in dozer engine capacity additional attachment like farmer's 'plough' in the dozer as an attachment had helped in removing medium hard to hard rocks. Dozer HP more than 400 HP are in use in several ripping operations. After studying the p-wave velocity, compressive strength of the rock strata ripping is introduced. Durgmanwadi Bauxite mines in Kolhapur district of Maharashtra, NALCO's Panchpatmali Bauxite Mine in Odisha, Belpahar OC coal mine of MCL are the best example. In all these mines ripping contribute to significant amount of production.

SURFACE MINER

Surface miners emerged as a clean mining system in India in 1980s for blast-free mining. This technology allows for continuous extraction of medium hard and hard minerals without blasting. With surface miners it is possible to mine in selective manner to avoid dilution of quality of in-situ coal. There are 3 different types of surface miners now available globally, cutting drum type, bucket wheel type and top down cutting type. These machines have been designed to handle limited capacity, owing to their restriction in cutting depth and cutting width. Surface Miners of Writgen, and L&T Make are quite successful in cutting soft to medium hard rocks/coal upto 50MPa. Today Coal India produces major quantities of coal by deployment of surface miners. Figure 3, different Models of Writgen which are operating in India designed to meet upto 80-MPa UCS.

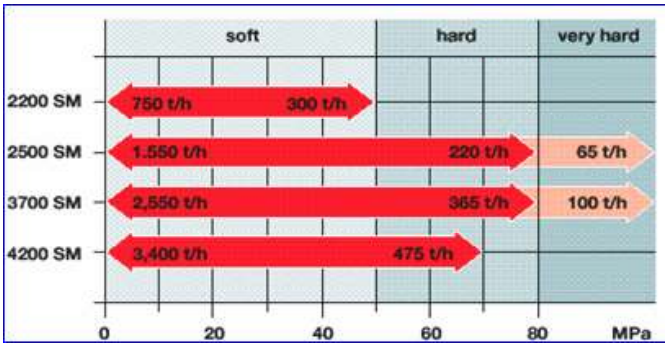


Figure 3 : Writgen Surface Miners operating in India in soft, hard & very hard rocks.

USE OF SURFACE MINERS IN HARD ROCK WASTE/ OVERBURDEN/ORE EXCAVATION

Continuous R&D input in drum and pick design had also made application of surface miners in hard rock excavation feasible. The present surface miners in use in Indian limestone and Coal mining are capable of handling rocks having compressive strength upto 50 MPa. There are other surface miners manufactured by Trencor, Vermeer, Krupp etc, to handle rock strength beyond 50MPa to as high as 120MPa. These machines are working on top down cutting principle to cut hard rock having the cutting drum in front of the machine. They are capable of excavating ore/rock type having UCS of over 120MPa and can produce 300 to 1600 tonnes per hour. Pradhan (2012) reported about the use of Vermeer surface miner at Bauxite mine of NALCO in the hard latrite waste rock and top bauxite strata.

ROCK BREAKERS

Originally meant for breaking oversize boulders and toe, is now adopted in many mines as a primary production unit, where blasting has been prohibited. At Chittogarh limestone mines of Birla Corporation having compact strata, with compressive strength of 100-160 MP. The rig-mounted hydraulic breakers of Epirock make HB10000 was deployed to produce in three shifts continuously more than 15,000 tons/day.The power generated in a single impact between piston and working tool corresponds to a weight force of around 760 metric tons and impact frequency up to 380 blows per minute.

VERTICAL RIPPERS

Initially it was used in some of the limestone mines, where the requirement was to replace blasting and create a stable crack free highwall at the mine boundary. With a stable slope Limestone Mines of Orient Cement, had not only increased the slope angle but also helped in better conservation. In the coal sector use of Eccentric Vertical Rippers were initiated by MCL to excavate overburden material.

Like Surface Miner adoption, MCL also has the credit to use Vibro Rippers for excavation of hard OB material at Kaniha. The results of MCL shows the techno-econo9mic benefits associated with is use, which had encouraged other mines of SECL and Tata Steel-West Bokaro to use them in their coal mines. consists of a vibration exciter, drag link mechanism, knife board, aseismic airbag bucker, teeth hydraulic motor and bedplate. The vibration exciter is arranged on the crushing mechanism and the static connection. The breaking plant and the drag link mechanism is the dynamic connection structure. The damping mechanism is arranged on the upper surface of the crushing mechanism mounting table. As shown in Fig. 4, presents the construction features of one such unit.. Kaile, W, et el(2014), had reported that this unit can easily work in n hardness and concentrated in the 3-8 Moh's hardness level of rock, these rocks completely could be broken in the range of the vibro ripper, when works on the rocks which the hardness below 5 level (the tensile strength below100Mpa), it can fracture quickly. With the hardness increasing, the efficiency of vibro ripper slowing down. The depth is about 50-70cm is the best each broken.

At Tata Steel in Quarry A-B, it was successfully used at the 7m thick OB benches having 30 to 80 MPa uniaxial compressive strength and Crechar Abrasivity Index of 0.48 to 0.90. Verma,P et el(2024) reported about the performance achieved with the use of Vibro Ripper of MaxBrio make Model No. BR55Initially the tooth life was very less but after cutting few layers it reported as high as 92 Hrs Tooth Life, with average tooth life of 50 Hrs. Average productivity reported from two shift operation has been 40 cubic m per hour for 1700rpm vibrations at the site.

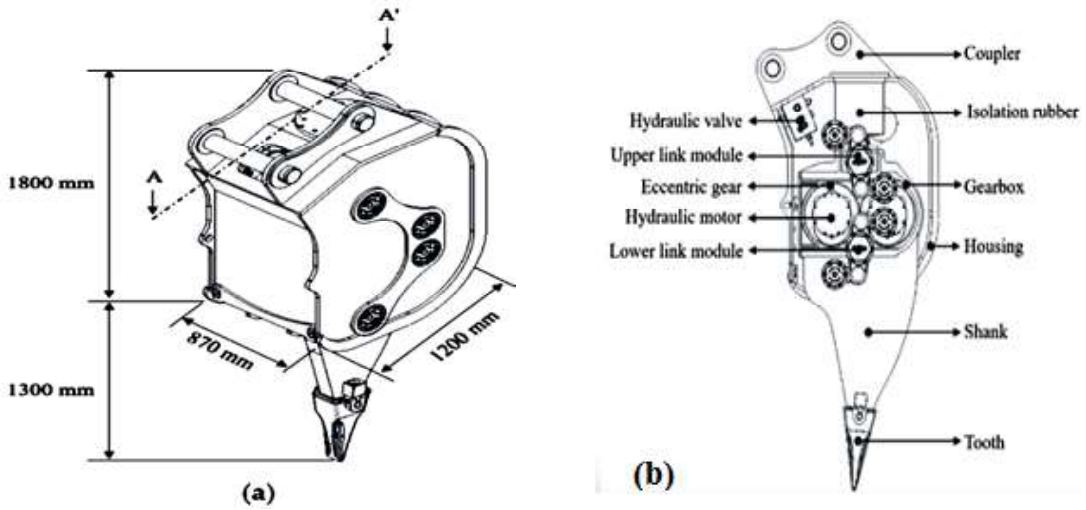


Figure 4 : (a) Schematic Features of a Vibro-Ripper iso-metric view, and (b) Cross-section A-A'.

SPLITTERS

The process begins by drilling a hole of appropriate depth(max 6m) and diameter (110 mm dia) into the rock. Burden and spacing is 20 to 25 times the hole diameter. Free face makes the handling and breakage better. A splitting insert, consisting of a central wedge and two counter wedges, is then placed into this hole. Hydraulic pressure is applied to push the central wedge between the counter wedges, forcing them apart. This generates immense splitting force, up to 1800 tons (17652 kN), which destroys the rock's internal structure in seconds, creating a controlled split. Figure 5, presents the splitting mechanism and Figure 6, field application.

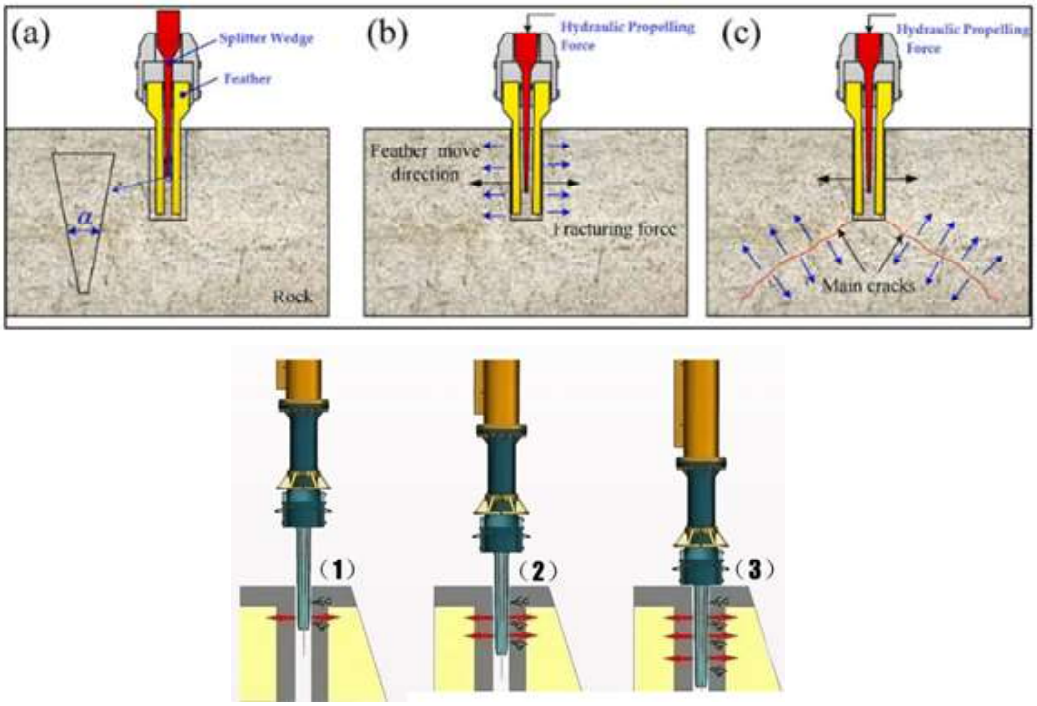


Figure 5 : (a) &(b) : Explains the Splitting Mechanism

Figure 6 : Shows field use of the splitting unit

In few limestone mines very hard limestone was excavated by using splitters. Here holes at 2m grid are drilled of 110mm dia on a five to six m bench height towards free face. Each hole is split by the splitter. The cracked rock is handled by rock breakers and back home. At Sagmania Limestone Mine of Birla Corporation, it was used successfully.

SOUNDLESS CHEMICAL DEMOLITION AGENTS OR EXPANSION CEMENT

These are widely used where sensitive structures need to be protected from blasting effects. These agents are injected into drilled boreholes in the rock, where they expand and exert pressure until the rock fractures. An expansion cement type material this is safe and no regulation involved on its use. Figure 7, explains its working mechanism.

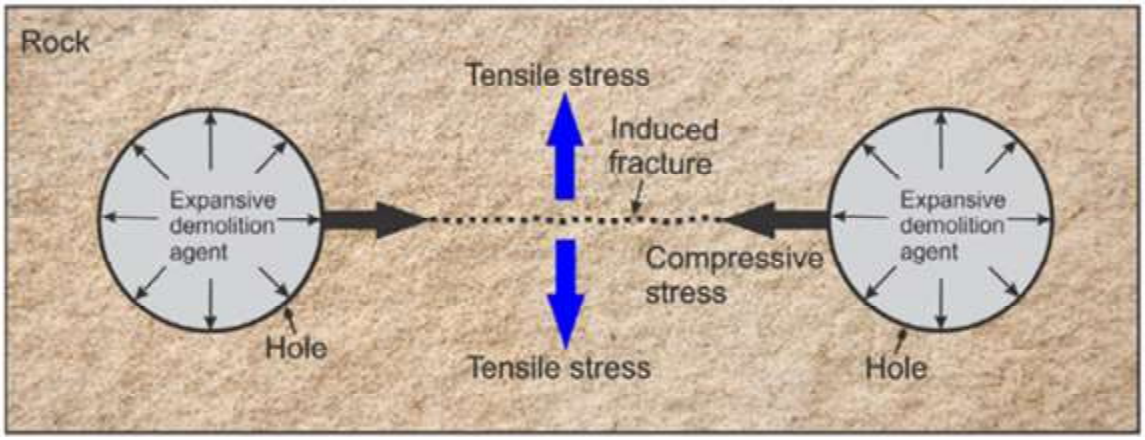


Figure 7 : Mechanism of rock breakage by expansion chemical agents

The composition comprises a principal component which is prepared by calcining a starting mixture comprising 100 parts by weight of quick lime and 1-20 parts by weight of calcium fluoride. When mixed with water at a fixed ratio and the thoroughly mixed aqueous slurry is poured into 32mm dia Jack Hammer dia drilled holes. The slurry spontaneously hydrate and set with development of expansion pressure.

Hole spacing and depth is decided based on the hardness, RQD and compressive strength of the rock. There are three different types of cracking powder available depending on the prevailing temperature of the site of use. The best results are obtained where the temperature is within 25 to 35 Degree Centigrade and within 3 to 4 hours cracks start developing.

Case study of NMDC Bailadila is presented in the paper. Cost of breaking one Cubic Meter by Chemical (excluding cost of drilling, manpower for charging, and excavation by rock breaker) is Rs. 1074.11. In some mines in BCCL this is regularly used for boulder cracking. Figure 8, shows the use of chemical demolition agents.

Figure 8 : Shows use of Chemical demolition of oversize boulders and breaking granite blocks in the granite quarry.

Liquid carbon dioxide fracturing device consists of a pneumatic valve, heating device, liquid storage pipe, energy-releasing sheet, sealing gaskets, and a releasing pipe; its structure is shown in Figure 9.

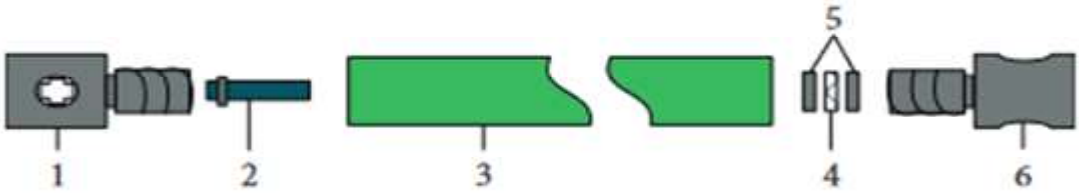


Figure 9(a) : Schematic diagram of a liquid carbon dioxide fracturing device. 1: pneumatic valve; 2: heating device; 3: liquid storage pipe; 4: energy-releasing sheet; 5: sealing gaskets; 6: releasing pipe.

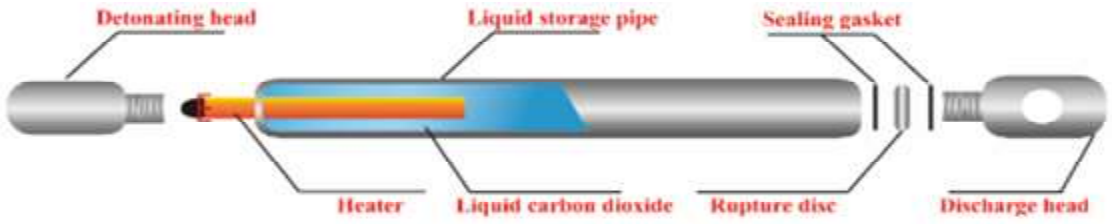
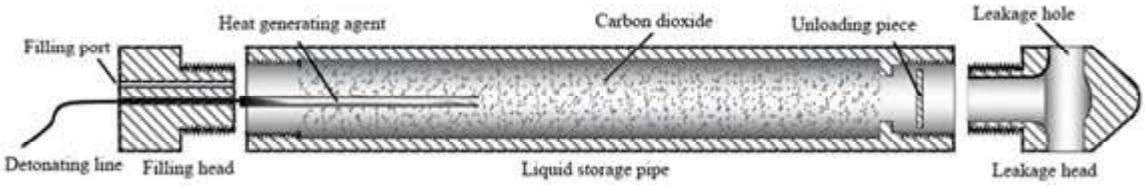
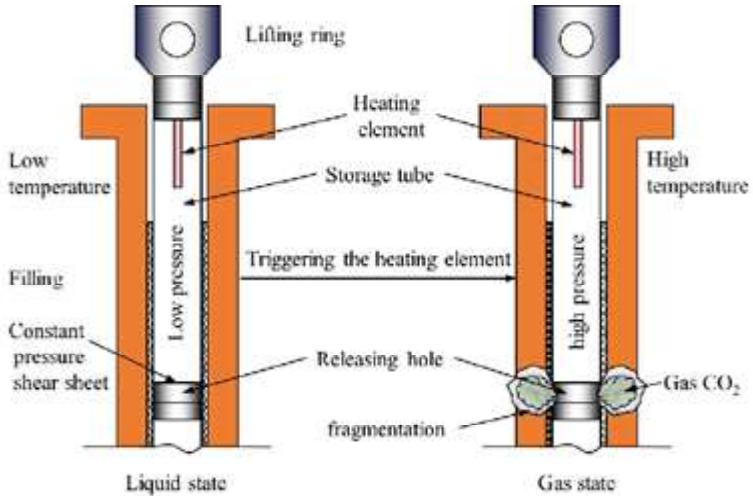


Figure 9(b) : Schematic diagram of Carbon Dioxide Phase Tansition Fracturing Pipe





The pneumatic valve is used to fill the liquid storage pipe with liquid carbon dioxide. The heating device provides the energy required to transform the liquid carbon dioxide. The liquid storage pipe is used to store liquid carbon dioxide. The energy-releasing sheet controls the maximum explosion pressure of the device. The sealing gasket prevents the leakage of carbon dioxide in the liquid storage pipe, and the releasing pipe controls the release direction of carbon di-oxide. When blasting, the heating device is detonated, heating the liquid carbon dioxide; the liquid carbon dioxide then becomes gasified, which increases the pressure in the liquid storage pipe. When the pressure exceeds its maximum shear strength, the energy-releasing sheet is destroyed, quickly releasing the gasified carbon dioxide from the re-leasing pipe towards the target rock.

PLASMA

It comprises Plasma capsules and a high voltage discharge device, upon discharge high voltage is passed through the capsules which initiates the formation of plasma which in turn initiates shock waves and pressure waves in the drilled holes resulting in fragmentation of rocks. The plasma capsules are composed of metal salt mixtures. Figure 10, shows the set up.

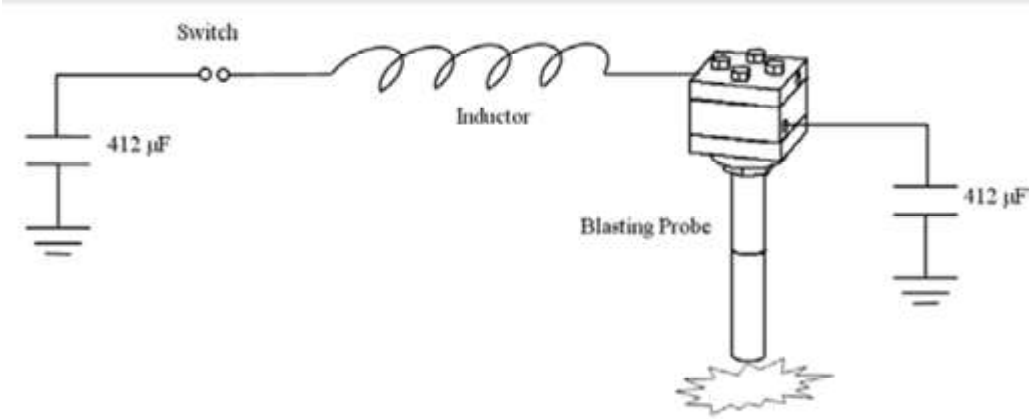


Figure 10 : Shows typical Plasma Blasting system configuration

At several civil engineering and mining sites they were used within less than 50 m from dwellings/installations. M/s Rock and Earth Projects, a Ranchi based company, completed major excavations near the Statue of Unity with proximity of less than 5 m from Dam Walls with a PPV of less than 5 mm/s and has carried out commercial orders for various critical sites including near railway structure, factory premises with less than 2.5 mm/s PPV. The PBT has been deployed at West Bokaro, TISCO premises, Birsa Chowk, Ranchi Railway Line Doubling works site, etc. which is within 50 meters of dwellings. The results obtained in vibration studies prove the safety aspects of rock excavation near dwellings etc.(Singh et el, 2024) & Singh, S.P(2023).

CONCLUSION

Blast-free mining techniques are fast emerging as an alternate to drill and blast system of primary production in Indian coal mines. With the success of surface miners in hard rock formations, Indian mines will have more such tailor made units to assist the mine to have better recovery of coal/ore in environmentally sensitive locations. However, there is a need for constant interaction of manufacturers, user and R&D establishment is required for improved productivity etc. Most blast free operations being energy efficient, to reduce Carbon footprint this technique offers lot of scope in the years to come.

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Sustainable Mining of Rare Earth Mineral at Orissa Sands Complex (OSCOM) in Ganjam District, Odisha

C V R Murty*

INTRODUCTION

Ore deposits associated with chemically evolved igneous rock suites have been the intense focus of research over the past several decades. Magmatic-associated mineral deposits are mineralogically and chemically diverse, occur in a range of geological settings, and have long been the target of the mineral industry. They host a wide array of precious and semi-precious metals including in (Sn), tungsten (W), lithium (Li), molybdenum (Mo), bismuth (Bi), iron (Fe), copper (Cu), and silver(Ag), and the rare earth elements (REEs) which includes the lanthanide series (Lanthanum (La) to lutetium (Lu) in addition to scandium (Sc) and yttrium (Y).The occurrence, distribution, and potential for economic extraction of the REEs have become the intense focus of world markets in recent years. This has been due to the extensive use of these elements in modern day technology, their criticality in supporting research throughout Medicine, Military-based Technologies, Space Technologies, Atomic Energy, Communication, Hi-tech Infrastructure and their role in the development of Clean Energy Technologies.

Rare-earth elements (REEs) include the lanthanides (atomic number 57-71), scandium (Sc, 21), and yttrium (Y, 39). REEs are classified in two distinct segments: Light rare-earth elements (LREE) and heavy rare-earth elements(HREE). LREE are the lower atomic weights elements, and include lanthanum(La, 57), cerium (Ce, 58), praseodymium (Pr, 59), neodymium (Nd, 60), promethium(Pm, 61) and samarium (Sm, 62). On the other hand, HREE include europium (Eu, 63), gadolinium (Gd, 64), terbium (Tb, 65), dysprosium (Dy, 66), holmium(Ho, 67), erbium (Er, 68), thulium (Th, 69), ytterbium (Yb, 70), lutetium (Lu, 71),and scandium (Sc, 21) &yttrium (Y, 39). Owing to their diverse nuclear, metallurgical, chemical, catalytic, electrical, magnetic, and optical properties, they are widely used in several civilian, military, and clean technologies. HREE are scarce and more expensive than LREE. Rare earths, such as Nd, Pr, Tb, Dy, Y, and Er are considered as critical, based on the importance of specific application, lack of comparable and reliable substitutes, geopolitical constraints, and their importance for the strategic sectors, and so on. The environmental concerns related to the extraction and processing of rare earth, supply vulnerability, and imbalance between supply and demand are the major challenges associated with the rare-earth industry.

In fact, the concentration of the rare earths in the earth's crust is as high as some other elements including that of copper. Rare earths are relatively abundant with the total average rare earth concentration ranging between 160–205 mg kg^{-1}. Among rare earths, cerium is the most abundant (66 ppm) while thulium (0.28ppm) is the least abundant. Rare earths do not occur as separate minerals amenable for easy exploration and mining and are widely distributed across the earth's surface. These elements do not occur naturally as metals like copper (Cu) or lead(Pb), instead being complexed in a wide array of different mineral types from carbonates to silicates to phosphates. Unlike base metals like iron, copper and aluminum, rare earths were not in use or in great demand throughout much of human existence, and hence not much attention was paid to their exploration, extraction and purification. In the recent period, Rare earths have risen in importance with their role in many important industries such as electronics, petroleum, clean-energy. Rare Earth Elements(REEs)are playing critical role in high-tech applications in the areas of Defense, Space and Atomic Energy sectors.

"Monazite" is the primary resource of REEs in India and occur in the beach sand mineral (BSM) deposits as an associated mineral along with Ilmenite, Rutile, Zircon, Sillimanite, Garnet and Leucoxene. Indian Monazite resources estimated as 13.15 million tons by AMD, Hyderabad. It contains about 57-58% of Rare Earth Oxides(REOs) predominant in LREEs. Further, mineable resources of "Monazite" in the country are less than 50% due to spread of dense habitation and infrastructure development over the BSM deposits in the coastal areas. In addition, re-classification of land use for the coastal areas as eco sensitivezones where BSM deposits exist further reducing mineable resources of Monazite. Four States out of twenty eight in the country viz; Odisha,

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Kerala, Tamilnadu and Andhra Pradesh contain 96% of Country's Monazite Resource. Out of total Monazite Resources in India, Andhra Pradesh contains 31%, Odisha contains 20%, Kerala contains 16%, West Bengal 10%, Tamilnadu contains 20.5% mt and others 2.5%. Further, the hard rock REE deposits are meager in India and identified in the States of Gujarat, Rajasthan, Tamilnadu, Assam, Meghalaya, Karnataka and Andhra Pradesh contribute rest 4% of RE resources. Towards protecting, conserving and meeting the future strategic requirement of REE for the infrastructure development of the Country, all the Beach Sand Mineral(BSM) deposits are presently reserved for Government Agencies towards undertaking mining and are regulated under the Atomic Mineral Concession Rules(AMCR) 2016 for grant of mineral concessions. Govt. of India notified Beach Sand Mineral (BSM) as "Atomic Minerals" under part-B of First Schedule of MMDR Act 1957.

Government of India has ambitious plans to increase nuclear power generation capacity by over 3 times in next7 years i.e. by 2031 (from 8180 MW to 21980 MW). The demand for REEs used in the permanent magnet is expected to dominate the global market by both volume and value. As phosphors contain a significant amount of heavy rare-earths, they are expected to dominate the global rare earth market by value after permanent magnets, despite their reducing market share by volume. Rare Earth Elements and their alloys are extensively used in non-conventional energy generations viz: Wind, Solar, Tidal, etc. Permanent magnets used in gear-free wind turbines contain 250 kg of rare earths per MW, motors in electric bikes contain 300 g/unit, magnetic resonance imaging (MRI) scanners contain 450 kg/unit, and a computer hard disk contains 4 g rare earths per unit. India has committed to a target of 500 GW of renewable energy capacity(non-fossil fuel based) by 2030 and meeting 50% of energy requirement from renewable sources by 2030. The commitment is not just towards sustainable energy but towards securing a greener tomorrow for the entire planet.

The paper attempts to present an over view of the sustainable mining operations undertaken by IREL (India) Limited in Odisha State towards winning the RE mineral "Monazite" from BSM Ore. Self-sufficiency in rare earths is vital and critical for the Indian strategic sectors; viz; Defense, Space, Atomic Energy, emerging non-conventional energy mission and other high-tech products. India has ambitious plans to become self-reliant in the field of Rare Earths. Atomic Mineral Directorate for Exploration and Research (AMD), Hyderabad, a Unit under the Department of Atomic Energy, Government of India is undertaking exploration extensively for BSM deposits across the country and estimating the availability of Monazite resources in the coastal tracts and inland areas.

IREL (INDIA) LIMITED

IREL (India) Limited, a Mini Ratna (Category-I) Central Public Sector Enterprise (CPSE) under the Administrative Control of the Department of Atomic Energy was established in August 1950. The first plant set up at Rare Earth Division (RED) in Aluva, Kerala started operations in the year 1952, with the mandate of producing compounds of strategic importance from Monazite. In order to ensure sustained supply of raw material required for monazite processing, IREL took over the operations of Travancore Minerals Limited in Chavara, Kerala and Manavalakurichi (MK), Tamil Nadu in 1965 and entered into the activities of mining, separation and beneficiation of the suite of seven beach sand minerals viz; Ilmenite, Rutile, Zircon, Monazite, Sillimanite, Garnet and Leucoxene. Subsequently, in order to augment its share in strategic and commercial sectors, IREL set up Orissa Sands Complex (OSCOM) in Chatrapur, Ganjam District, Odisha which is the largest mining and mineral separation unit in operation at present. The total installed mineral production capacity of all the above three plants is more than 9 lakh tons per annum (tpa).

IREL augmented the Monazite Processing operations by setting up a 10,000 tpa Rare Earth Extraction Plant (REEP) in its Unit at Odisha for production of Mixed rare earth chloride (MRCL), tri-sodium phosphate (TSP) and other compounds having a number of strategic and niche application. The plant facilities at RED, Aluva have been retrofitted to further process the Mixed Rare Earth Chloride (MRCL) produced in Odisha to produce separated high pure rare earths (HPRE) such as compounds of lanthanum, cerium neodymium-praseodymium, samarium etc.

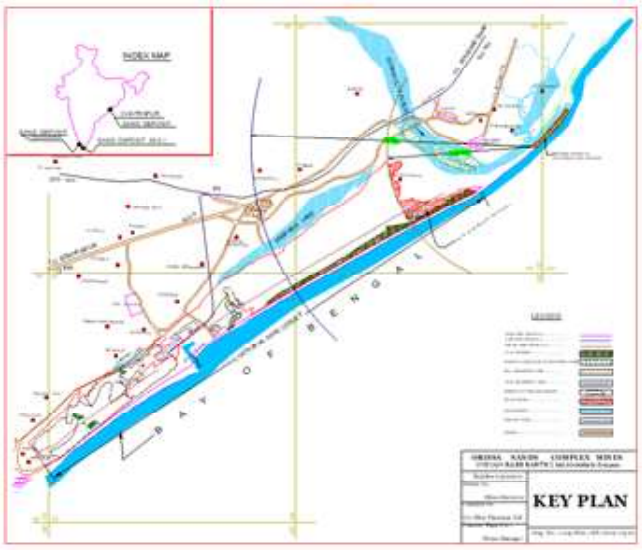
In addition to the above, IREL has undertaken and established number of products in the value chain of its mineral products through extensive in-house Research & Development (R&D) such as zirconium oxy-chloride,

nano zirconia, nano titania, lanthanum zirconate, etc.

IREL has the expertise and capabilities in a wide arena ranging from mining, separation and beneficiation of atomic minerals (BSM), besides establishing value chain in Rare Earths.

SUSTAINABLE MINING OF RARE EARTH MINERAL IN ORISSA SANDS COMPLEX(OSCOM) IREL (INDIA) LIMITED

Government of Odisha granted mining lease over an extent of 2877.76 Ha in favour of OSCOM, IREL in the year 1979 for mining of Beach Sand Minerals (BSM) viz; Ilmenite, Rutile, Zircon, Monazite (RE Mineral), Sillimanite and Garnet. These minerals are commonly known as "Heavy Minerals (HM)". The Mining Lease area is located near the town Chatrapur in Ganjam District of Odisha State. The suite of six minerals in the BSM Ore occur together in varying grades.



The mining lease area of OSCOM, IREL extends over a stretch of 18 km along Bay of Bengal with an average width of 1.5 km. Atomic Mineral Directorate for Exploration and Research (AMD) has explored OSCOM deposit and proven the availability of beach sand minerals. The exploration and geological report of AMD reveals the Heavy Mineral (HM) grade of OSCOM BSM deposit varies between 6% to 18%. The depth of the deposit ranges from 4 to 14 metres from the surface. The mining lease area of OSCOM, IREL is located over the toposheet nos: 74A/15 and 74E/3 and existing within coordinates : 19^0 21' 38''N, 85^0 03' 23''E and 19^0 15' 38''N, 84^0 55' 00''E. Rushikulya river flows at the northern side and the Gopalpur town is situated in the Southern end of the mining lease area. Operations of OSCOM continued as per the provisions of Approved Mining Plan, Environment Clearance, Consent to Operate from SPCB and Licences issued under the Atomic Energy Act 1962.

Government of Odisha renewed the mining lease over an extent of 2464.054 ha for a further period of 20 years w.e..f. 21.3.1999 to 20.3.2019. Subsequently the mining lease further extended from 21.3.2019 to 31.3.2047 under the provisions under Atomic Mineral Concession Rules 2016. Beach sand minerals notified as "Atomic Minerals" under Part-B of first schedule of MMDR Act 1957 w.e.f. 11.7.2016. The mining operations at OSCOM, IREL are continuing as per the approved mining plan in a sustainable manner.

FORMATION OF HEAVY MINERAL SAND PLACER DEPOSITS

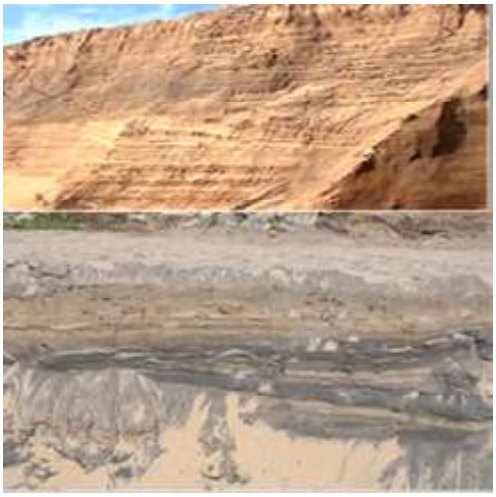
Heavy Mineral BSM deposits are sedimentary placer formations. Placers are mineral deposits that have been formed by the mechanical concentration of mineral particles from weathered parent rocks. They occur, in beaches, rivers, dunes, inland teris and offshore areas. The minerals that constitute the placer deposits are resistant to chemical breakdown and have high density and durability.

Beach placers: Such placers are formed by the interacton of the terrestrial processes with the coastal hydrodynamics. The heavy minerals among the sediments, that are contributed to the sea by various processes of transportation are selectively panned and

sorted and then deposited at suitable locations, by the action of waves and currents. The factors controlling the formation of beach placers are geomorphology of the area, climate, drainage pattern, coastal processes etc. The heavy minerals are concentrated by a combination of these processes in the upper part of the beach, where the action of the wind form heavy mineral rich coastal dune deposits.

Factors controlling the formation of beach placer Deposits :

Climate: Climate influences the weathering processes, which ultimately decomposes the rock matrix and liberate the minerals. Tropical to subtropical climate promotes chemical weathering, which has given rise to a decomposed stage of crystalline rocks called laterites. This could be considered as a pre-concentration process of the placer minerals. Most of the rich placer deposits of the world are in tropical regions.



Drainage Pattern: The alluvial processes act as a conduit of sediment transport from the source rock to the zone of concentration. In their youthful stages, the erosive power of rivers is strong and they release heavy minerals from the parent rock and transport them down stream.

Coastal processes: The beach deposits are essentially a result of the coastal hydrodynamics of rivers and currents. The waves sort out the heavy minerals and transport them onshore based on their size and specific gravity. The direction and strength of the coastal currents and the geomorphology of the coast determine the location of the deposit.

OSCOM deposit is primarily sourced from Eastern Ghats (comprising of khondalite, charnokites leptynites, granites, gneisses, pegmatites, anorthosites etc.) and

sediment transport drainage due to the action of perennial rivers viz; Rushikulya, Mahanadi, Bahuda etc.

The typical mineralogy of OSCOM BSM deposit :
Ilmenite : 5 to 8 % (Specific gravity : 4.54)
Rutile : 0.15 to 0.2% (Specific gravity : 4.2)
Zircon: 0.15 to 0.2% (Specific gravity : 4.7)
Monazite: 0.05 to 0.1% (Specific gravity : 5.25)
Sillimanite: 2.5 to 3.5% (Specific gravity : 3.25)
Garnet : 3 to 6% (Specific gravity : 4.1)

Monazite is a greenish – yellow phosphate Rare Earth mineral containing rare earth oxides (56 to 58% REOs). It is predominant in Light Rare Earth Elements. In BSM Ore deposits Monazite occurs in association with Ilmenite, Rutile, Zircon Sillimanite, Garnet etc.

Stratigraphically, the OSCOM BSM deposit is of Recent Age and its country rock belongs to Pleistocene Age. No fault planes, joints or geological disturbances exist in the deposit. The entire deposit is formed of beach sand having different grain size. The highest frequency distribution of BSM Ore is around 250 microns, while that of heavy mineral is confined to 149 microns. There is invariable increase of coarse fraction towards north as also to some extent to the depth. Depth wise, there is gradual decrease in the heavy mineral content.

GEOLOGICAL RESOURCES

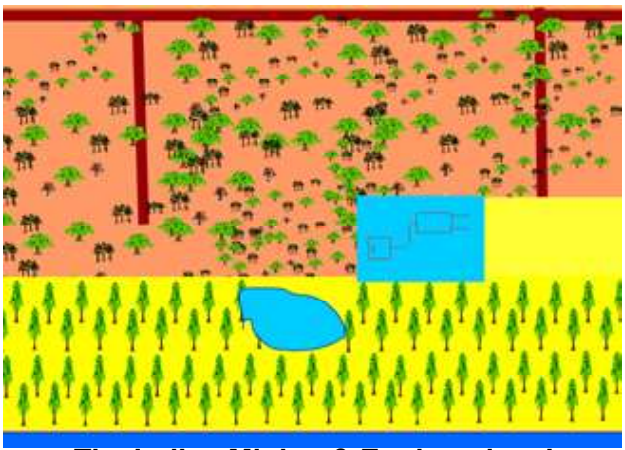
The mineralization of OSCOM deposit starts right from the surface and devoid of overburden & top soil. Being located near the sea OSCOM deposit does not have much vegetation. The surface of the deposit mostly having sparce growth of cashew-nut with casuarinas trees to some extent. After mining, the area is simultaneously backfilled, levelled and rehabilitated with plantation. Systematic Plantation is done on over the backfilled areas and lily ponds are left in the minedout areas for nurturing and maintenance of the plantation. The width of the deposit varies between 800 meters to 2200 meters and the depth/thickness ranges from 4 to 14 metres from the surface. The water table intercepts at a depth of 4 to 8 meters from surface, which flows from the landward side to seaward side.

As per the UNFC, the balance BSM Ore resources available within OSCOM deposit as on 31.3.2024 is about 170 million tons with an average HM grade of 14.80%.

PRODUCTION / MINING OPERATIONS

Mechanized mining operations in the beach mineral sand deposits have been continuing since more than four decades in our country. Geologically the beach mineral sand deposits are loose and less compact. At OSCOM dredging, tipper-excavator combination etc. are adopted as method of mining for extraction of BSM ore from the deposits followed by immediate mineral beneficiation.

Opencast Mining operations carried out at OSCOM utilizing a) Dredge & Wet Upgradation Plant (DWUP) and b) Dry Mining Plant deploying tipper-excavator combination. Based on the Geological report, the method of mining of BSM Ore is decided. Dredging method is undertaken in the areas sea-ward side where there is no hard strata / lenticular hard clay patches encounters at depth. Similarly, the areas away from beach in the landward side, where the clay patches / hard strata encounters occur, Dry mining method comprising of Tipper-excavator combination . Dredge moves in a pre-determined path over the deposit as per the approved mining plan for extraction of BSM Ore. Tipper-excavator Dry mining activities are conducted on the rear side of the OSCOM deposit.



Consent from the private land owners is always obtained on short term basis (1 to 3 years) prior to undertaking surface operations and the compensation is paid as per the agreed terms. After mining is completed, the backfilled areas are levelled and handed over to the concerned land owners with plantation. There is no permanent acquisition of private lands towards undertaking mining operations is practiced in OSCOM.

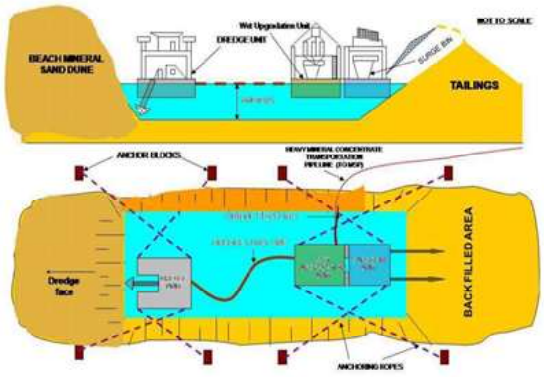
At present, five plants are in operation for mining of BSM Ore i.e. DWUP -1 no and Dry mining – 4 nos. The excavated BSM Ore is pre-processed with gravity spirals for recovering the heavy minerals present in the BSM Ore viz. Ilmenite, Rutile, Zircon, Monazite, Sillimanite and Garnet.

OSCOM has received the statutory clearances for excavation of 75 Lakh tons of BSM Ore per annum. DWUP is operated by employing a dredger having mining rate of 500 tonnes per hour of BSM Ore - excavates about 33 lakh tons per annum. Four Dry mining plants designed to pre-process the BSM Ore about 700 tons per hour – excavate about 30 to 35 lakh tons per annum.

DREDGE AND WET UPGRADATION PLANT (DWUP)

Extraction of BSM Ore at OSCOM is done by using a suction dredger, which floats in an artificially prepared pond. The dredger basically comprising of a gravel pump and a hydraulically operated cutter which cuts the BSM Ore and pumps it in the form of slurry for upgradation of heavy minerals. The Wet upgradation Plant which floats in the same pond receives the slurry from dredge concentrates the heavy minerals to a level of 88 to 90% HM and simultaneously backfills the minedout area with the tailings.

Diagrammatic Sketch of Dredge & Wet Upgradation Plant (DWUP)



DREDGE AND WET UP-GRADATION PLANT (DWUP)
TOP VIEW OF DWUP

DREDGE AND WET UP-GRADATION PLANT (DWUP)
WITH SIMULTANEOUS BACKFILLING

The mining and up gradation operation are carried out in three floating units, viz. Dredging unit, Head Feed Bin unit and Wet Upgradation unit. The above units float in pond. These floating units are anchored on the land with the wire ropes. The movements of these units are controlled by operating hydraulic winches installed on winch towers of their respective units.

The mining of raw mineral sand is carried out in a planned and pre-determined path which gives the specific details of face length, grade of raw mineral sand, R.L. of the water table and grade of heavy mineral along the path. A face length of 150 m is maintained for effective dredging operations at OSCOM. The dredger unit is provided with a cutter on its cutter ladder boom, cuts the BSM Ore, loosens it and keeps the sand particles in suspension enabling the suction pump to lift the sand in slurry form. The dredger can cut upto a depth of 6 meteres from the water surface as per the requirement. As the cutting face advances, the dredge and the wet Upgradation unit are advanced forward along the cutting path. The monthly

progress of the dredge face is around 85 to 100 metres and an average 1 km DWUP advances every year.

The BSM Ore mined by dredger unit is pumped in the form of slurry to Surge Bin through a rotating trommel screen. The trommel screen removes oversize pebbles, boulders and grass roots, etc. from the sand slurry. The screened under flow sand (-3mm) is collected in the Surge Bin known as Head Feed Bin. From the Head Feed Bin, the slurry is fed to spirals concentrators at a constant pulp density to Wet Upgradation unit for primary upgradation & separation of heavy minerals. The Wet Upgradation unit consists of spirals (gravity separators) which upgrades the heavy minerals from 12-14% HM to 88–90% HM. The mining output (88 to 90% HM) quantity so produced is transported to Mineral Separation Plant (MSP) for individual mineral separation. The tailings generated in the Wet Upgradation Plant comprises of 97 to 98% Quartz in its native state is simultaneously backfilled in the minedout areas. The backfilled area is dozed and leveled for development of vegetation. Trees like casurina, cashew, etc. are planted in the backfilled area to develop a green belt in the mined out area. Small ponds are left in the mined out areas for watering the plantation.

DRY MINING

Dry mining plants are working in the rear side of the deposit (landward side) as the main dredger of DWUP cannot access to these areas due to encountering of hard clay at shallow depth. It consists of 3 Units i.e Dry feeding bin unit, Head feed bin unit, Upgradation unit.

In this case, the BSM Ore is collected using excavator, loading into tippers, transporting to land based Upgradation unit. Sufficient quantity of BSM Ore is brought with the help of tippers from the active mining faces in the rear side of the deposit and is first stacked near the Upgradation unit. Temporary roads are laid for movement of tippers towards transportation of ROM from the mining faces.

Upgradation unit consisting of gravity spirals which is continuously operated. The excavated BSM Ore at the upgradation plant is first fed to a land based hopper using an excavator. A loader is engaged to push the Ore near to the face of the excavator.

The trommel screen mounted on the hopper bin removes the oversize pebbles, boulders and grass roots, etc and water is added to the bin to make the sand in slurry form. The sand in slurry form is fed to spirals of Upgradation unit. In spirals, heavy minerals are separated. The tailings generated are backfilled simultaneously in mined out areas. All the four dry mining plants are similar in operation.

The mining and backfilling activities go simultaneously hand in hand. There is no drilling & blasting activities practised during mining operations.

The mining output (HM concentrate) from DWUP and Dry Mining plants is transported to Mineral Separation Plant (MSP) where the individual minerals viz; Ilmenite, Rutile, Zircon, Monazite, Sillimanite and Garnet are separated. The HM grade of mining output transported to MSP varies from 88 to 90% HM which contain about 0.6 to 0.8% monazite (RE Mineral).

Plantation : The mining areas is mostly barren, does not contain much vegetation. After separation of heavy minerals, the mined out area is simultaneously back filled with the tailings which mostly consists of Quartz in its native state. The mined out area is leveled to original topography and left for one year for sand stabilization.

After one year, the area is planted with suitable species e.g. Casurina, Cashew nut etc. The growth of herbaceous trees/creepers further stabilizes the sand and the ecological conditions are restored back. The method of mining and pre-concentration of heavy minerals at OSCOM are diligently maintained as per the requirement and the minedout backfilled areas are levelled upto the natural topography. There is no water pollution, air pollution, soil pollution and noise pollution during the mining and pre-concentration of BSM Ore at OSCOM. Moreover removal of monazite from the BSM Ore deposit and backfilling the minedout areas with tailings devoid of monazite reduces the natural background. Simultaneous backfilling of minedout areas followed by thick plantation brings greenery to the area and improves the aesthetic look.

About 0.8 to 1.0 lakh saplings are planted every year over the backfilled areas. Local villagers are deployed for watering the plants. The survival rate is noticed to be 80 to 85%. After plantation, in case of private lands taken on short term period, the private rehabilitated areas are handed over to the concerned land owners.

Regular mineralogical analysis of tailings at DWUP and dry mining plants is carried to ascertain no loss of HM. In case of any leakage of HM in the tailings, spiral settings are immediately carried out to curb such loss and normalcy is ascertained. The quality control section of OSCOM always provides the timely HM analysis of Ore, Output concentrate and tailings every day.

MINERAL SEPARATION PLANT (MSP)

Heavies Upgradation Section (HUS)

The mining output from DWUP and Dry mining areas is transported to MSP where this material is further fed to Heavies Upgradation Section (HUS) which is comprising of gravity spirals, hydrosizers, WHIMS, centrifugal pumps which upgrade the HM grade from 88% to 96% HM. No chemicals are used in this operation. During HUS operation, three product fractions generated viz; a) HUS output comprising of 95-96% HM containing 0.9 to 1.1% monazite, b) Sillimanite rich fraction and c) Garnet rich fraction. The tailings generated from HUS contain significant quantities of heavy minerals and these tailings-mineral rich fraction(MRF) is stock piled in demarcated areas for future recovery. The HUS output is fed to Mineral Separation Plant for individual mineral separation. The sillimanite rich fraction generated at HUS is directly fed to sillimanite circuit through WHIMS. The Garnet rich fraction generated at HUS is directly fed to GeM (Garnet extraction Mill) for production of Garnet.

MINERAL SEPARATION PLANT

The 96 to 97% HM - HUP output is fed to Mineral Separation Plant for individual mineral separation. The Mineral Separation Plant comprises of series of Fluidized Bed dryers(FBD) to remove moisture, High Tension Separators, Magnetic Separators with varying intensities, Air tables, Wet tables, Spiral gravity separators, Rotary dryers, Hydrosizers etc. Depending upon the Electrical conductivity, Magnetic susceptibility, specific gravity, grain size and surface properties, the individual heavy minerals viz: Ilmenite, Rutile, Zircon, Monazite, Sillimanite and Garnet get separated. A number scavenging operations are carriedout towards achieving the individual mineral purity upto the desired level.

The feed intake capacity of MSP is about 100 tph (96% HM). The primary dryer is a 130 tph FBD makes the Feed material free from moisture and raises the temperature to 100^0C prior to feeding to the High Tension Separators. Intermittent shaft dryers are maintained to enhance the temperature of the feed material for better separation of minerals. The dryers are operated with Furnace Oil.

Minerals	Electrical Properties	Magnetic Properties
ILMENITE	CONDUCTING	MAGNETIC
RUTILE	CONDUCTING	NON-MAGNETIC
ZIRCON	NON-CONDUCTING	NON-MAGNETIC
MONAZITE	NON-CONDUCTING	FEEBLY MAGNETIC
SILLIMANITE	NON-CONDUCTING	NON-MAGNETIC
GARNET	NON-CONDUCTING	WEAKLY MAGNETIC

The output of the 130 tph FBD is fed to a series of High Tension Separators which separates Conducting and Non-conducting fractions. The conducting fraction is subsequently fed to a series of Rare Earth Drum Separators for separation of Ilmenite as Mag and Rutile as Non-mag. The non-conducting fraction is fed to Induced Roll Magnetic Separators(IRMS) which further separate Monazite & Garnet as Mag fraction whereas the Zircon & Sillimanite report in Non-Mag on fraction. The non-Mag fraction is further subjected to Wet-tabling, spiraling, Froth flotation and Airtable operations and Sillimanite and Zircon products are generated. The Mag fraction which contains Monazite & Garnet are subjected to a series of High Intensity Induced Roll Magnetic Separators (HIRMS) , Rare Earth Roll Magnetic Separators (RERMS) and separate Garnet product and Monazite Crude (45 to 55%).

After all the five minerals viz; Ilmenite, Rutile, Zircon, Sillimanite, Garnet separated in their own circuits, the balance material in MSP is the monazite crude fraction containing about 45 to 55% monazite is processed in the Monazite Upgradation Section (MUS). MUS comprises

of Spirals, Hydrosizers, FBD, Rare Earth Roll Magnetic Separators (RERMS), Induced Roll Magnetic Separators (IRMS) etc. MUS generates the Monazite product with a purity of +96% monazite. The monazite produced at OSCOM contains about 56 to 58% of Rare Earth Oxides (REOs) and the entire quantity is consumed for the captive purpose by Rare Earth Extraction Plant(REEP) located within OSCOM premises for the production of Mixed Rare Earth Chlorides (Concentrate of REOs), Trisodium Phosphate (TSP) and other strategic material.

Monazite Upgradation Section and scavenging operations in mineral separation of individual minerals activities are associated with Radioactivity due to presence of Monazite. Hence radiological safety measures are always taken asper the guide lines of AERB. An independent Health Physics Unit of BARC functions at OSCOM for maintaining the radiological safety.

The process overflow water from HUS and MSP wet operations is collected in a pond and after de-sliming again re-cycled for various process operations. The tailings generated out of MSP operations pre-dominant in Sillimanite and Garnet are stockpiled as Mineral rich fraction at demarcated locations for future recovery.

Radioactivity Control in BSM Ore mining, Pre-concentration and in separation of Monazite

The background radiation over the BSM Ore deposits at OSCOM is ranging from 1 to 2 mGy per hour due to presence of Monazite in the range of 0.08 to 0.1%. However, the background radiation is significantly reduced to below the detection levels when the minedout lands are backfilled with monazite free tailings consisting of mostly Quartz (97 to 98%) in its native state.

Since Monazite in these deposits available in its natural state, no significant radioactivity impact is observed on persons involved in Mining / excavation / pre-concentration of BSM Ore. AERB is exempting the regulatory controls in the excavation of BSM Ore. However, in Mineral Separation Plant, the grade of Monazite increases in Monazite Upgradation Section(MUS) and Scavenging operations. Towards ascertaining the safe exposures to the employees working in MUS and Mineral Separation Plant, they are provided with Thermo – Luminescence Dosimeter(TLD) badges for dose evaluation. Radiation symbols are displayed in Mineral Separation Plant and MUS areas and Monazite pits to avoid prolonged stay in those areas.

The TLD badges are to be periodically monitored by Radiological Safety Officer appointed in this regard for finding out the dosages of radiation received by each person employed in Mineral beneficiation activities. Based on the monitoring and evaluation, it shall be ensured that the radiation doses received by each employee are within the permissible limit set by the statutory authorities. Health Physics Unit of BARC functioning at OSCOM regularly monitors these activities and ensures the radiological safety in the operations.

OCCUPATIONAL HEALTH AND SAFETY MEASURES AT OSCOM

- All the persons engaged in the mining and mineral separation activities are given vocational training as the Mines VT Rules 1966 prior to commencement of work.
- The mining operations are carried out under the supervision of experienced mining engineers in line with the guidelines issued by DGMS.
- Traffic signals, speed breakers etc. are provided over the haul roads.

- ☞ Excavation / Mining activities are suspended during cloudy and rainy days to avoid thunder hazards .
- ☞ Audio Visual Reverse Alarms are mendatory for all the vehicles and loaders deployed in the mining and mineral separation plant areas.
- ☞ Life jackets are provided to the persons engaged in dredging operations. Lifebuoys are provided on the floating pontoons.
- ☞ Initial Medical Examination and Periodical medical examination for the persons employed in mining and mineral separation plant operations carried out as per the guide lines of DGMS.
- ☞ The inland minedout areas are simultaneously backfilled with mineral-free tailings
- ☞ TLD badges are provided for all the persons working in MUS plant and scavenging circuits of mineral separation plant. The evaluation of TLD badges is carried out quarterly once in order to find out the exposure dose and promote remedial measures.
- ☞ Persons exposed to high dose areas are periodically re-located and records are strictly maintained for preventive measures.
- ☞ Personal Protective Equipment (PPE) are ensured for all the persons working in mining and mineral separation plant operations
- ☞ Pit safety committee and sectional safety committees are formed to ensure and promote safety of all persons employed in the OSCOM mines.

STATUTORY COMPLIANCES MAINTAINED BY OSCOM FOR UNDERTAKING SUSTAINABLE MINING OF BSM ORE CONTAINING RE MINERAL (MONAZITE)

Monazite is declared as Atomic Mineral under Part-B of First Schedule of the Mines & Minerals (Development & Regulation) Act 1957 and Prescribed Substances under the Atomic Energy Act 1962.

Mining of BSM Ore and separation of Monazite & other associated minerals at OSCOM attract the following Acts and the Rules & the amendment Notifications made there under.

- The Mines and Minerals (Development and Regulation) Act, 1957
  - o The Atomic Mineral Concession Rules 2016
  - o The Mineral Conservation and Development Rules 2017
- The Atomic Energy Act 1962
  - o The Atomic Energy (Working of Mines, Minerals and Handling of Prescribed Substances) Rules, 1984
  - o The Atomic Energy (Radiation Protection) Rules, 2004
  - o The Atomic Energy (Safe Disposal of Radioactive Waste) Rules, 1987
- The Mines Act 1952
  - o The Mines Rules, 1955
  - o The Metaliferous Mines Regulations, 1961
  - o The Mines Vocational Training Rules, 1966
- The Air (Prevention and Control of Pollution) Act 1981
  - o The Air (Prevention and Control of Pollution) Rules 1982
- The Water (Prevention and Control of Pollution) Act 1974
  - o The Water (Prevention and Control of Pollution) Rules 1975
- The Environment (Protection) Act 1986
  - o The Environment (Protection) Rules 1986
  - o EIA 2006 notification / CRZ 2019 notification
  - o The Hazardous Wastes(Handling and Transboundary movement) Rules, 2008
- The Forest Conservation Act 1980
  - o The Forest Conservation Rules 2023

- ❖ Valid Mining Lease for undertaking mining of BSM Ore granted by Government of Odisha under the AMCR 2016. The Mining lease is valid upto March 2047.
- ❖ Approved mining plan obtained from Atomic Minerals Directorate for Exploration and Research, Hyderabad valid upto 2029.
- ❖ Environment Clearance obtained from MoEF as per EIA-2006 and/or CRZ-2011 notifications for mining of 75 lakh tons BSM Ore at OSCOM.
- ❖ Licence obtained from Dept. of Atomic Energy under Rule 3 of the Atomic Energy (Working of the Mines, Minerals and Handling of Prescribed Substances) Rules, 1984
- ❖ Licence for operation under Rule 3 of the Atomic Energy (Radiation Protection) Rules, 2004 from Atomic Energy Regulatory Board, Government of India
- ❖ Authorization for safe disposal / transfer of radioactive waste under the Atomic Energy (Safe Disposal of Radioactive Wastes) Rules 1987.
- ❖ Consent to Operate (CTO) for BSM Ore mining and mineral separation operations under the Air (P & C P) Act, 1981 and the Water (P & C P) Act, 1974 obtained from State Pollution Control Board.

- ❖ Permission from Competent Authority obtained for storing and use of Furnace Oil / Diesel / Other inflammables for mining and mineral separation operations.
- ❖ Stage-I and Stage-II Forest Clearances from MoEF & CC and Clearances from State Government.
- ❖ Permission from Directorate General of Mines Safety obtained under Regulation 106(2)(b) of Metaliferous Mines Regulation, 1961 and the Mines Act, 1952 for undertaking mechanized mining operations.
- ❖ NOC from the Chief Wildlife Warden obtained.
- ❖ Safety officer and Radiological Safety Officer appointed as per the Atomic Energy (Radiation Protection) Rules 2004 and AERB guidelines.
- ❖ Statutory returns submitted to Directorate General of Mines Safety, Atomic Mineral Directorate for Exploration and Research, Hyderabad, Atomic Energy Regulatory Board, Department of Atomic energy, State Government authorities

CSR & SUSTAINABILITY ACTIVITIES BY OSCOM, IREL

Corporate Social Responsibility (CSR) and sustainability is fundamentally a philosophy or vision about the relationship of business and society. It is the continuing commitment of business to behave ethically and contribute to economic development while improving the quality of life of the workforce and their families as well as of the local community and society at large. The concept of CSR and Sustainability goes beyond charity and requires the company to act beyond its legal obligations and to integrate social, environmental, and ethical concerns into the company's business process. IREL has been a major partner in the development of the community living near OSCOM operations, especially near its mining areas by its CSR initiatives. This CSR initiative has been taken by the company earlier to the formal notification by Government bringing out the guidelines and its implementation of CSR activities. Thus, IREL has been conscious of its CSR and Sustainability obligations and has been striving towards fulfillment of the same. IREL has been undertaking and implementing CSR and Sustainability activities for the welfare of the people and development falling within the periphery and close vicinity of its operational area.

The area of implementation of CSR & sustainability schemes are in and around the vicinity of mining sites and backward regions where the company has its operating units. Further, the CSR & Sustainability schemes are extended within the radius of 10 kms of plant locations. IREL has been taking up efforts for the development of the backward region - OSCOM having the potential of contributing significantly in the long run to socioeconomic growth in all its surrounding areas in the Ganjam District. The CSR activities are in principle governed by a Corporate Committee comprising of Directors and Independent Directors of the Company. About 7 to 8 Crores is spent by the Company towards CSR initiatives at OSCOM, IREL in various schemes specified under VII Schedule (Section 135) of the Companies Act 2013) every year; they are ;

- ➢ Preventive health care, Nutrition, water supply and sanitation
- ➢ Education, Empowerment, Enhancing skills
- ➢ Gender equality, empowering women
- ➢ Environment Sustainability
- ➢ Protection of culture heritage etc.
- ➢ Training to Promoting rural sports
- ➢ Rural Development Project

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Mineral Resources of Odisha

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INTRODUCTION

Odisha is endowed with vast reserves of mineral resources, the prominent ones being bauxite, iron ore, coal, Chromite, Manganese, Nickel, limestone and dolomite. Besides, the state has also large reserves of fire clay, china clay. graphite and also some reserves of base metal ore. Table 1, presnts the mineral production during 2023-24, which shows rise in the production of all major minerals. Chromite, Iron Ore and Graphite made a significant jump as compared to 2022-23.

Table 1 : Mineral Production in Odisha during 2023-24

Mineral	Unit	Quantity			Value in Rs '000		
		2023-24	% Share in India	% Change over 2022-23	2023-24	% share in India	% chage over 2022-23
Bauxite	Tonne	17591967	74	1.0	18498452	72	9.0
Chromite	Tonne	3147954	100	12.0	48499212	100	4.0
Graphite	Tonne	68054	40	140.0	145401	67	41.0
Iron Ore	Tonne	148965636	54	6.0	561982109	57	20
Limestone	Tonne	7923665	02	21.0	3530967	03	39.0
Manganese Ore	Tonne	650855	19	1.0	3223897	13	6.0
Coal	Million Tonnes	239.402	24	9.3	NA	NA	NA

(Source : Ministry of Mines, Govt. of India web sites)

RESOURCES

When compared with the all India resource potential, Odisha has 59% of the bauxite, 96% of chromite, 95% of nickel ore, 26% of iron ore, 29% of manganese ore, 67% of graphite, 25% of coal, 21% of fire clay, 16% of dolomite, 15% of limestone and 56% of vanadiferous and titaniferous magnetite. The graphite resources of Odisha have not yet been fully explored and it is the largest producer of graphite in India.

The distribution pattern of different mineral deposits in the state is controlled by the geological environment in which they occur. The southern and western districts namely Koraput, Rayagada, Kalahandi, Bolangir, Boudh and Phulbani, covering large parts of the granulite belt of Eastern Ghats, are large repositories of high-grade bauxite, graphite and manganese ore, beside the wide variety of gemstones, including dimond and gold (recently reported). On the other hand, the Precambrian supracrustals and the Gondwana SuperGroup lying in the northern districts, namely Kendujhar, Mayurbhanj, Sundargarh, Sambalpur, Dhenkanal and Cuttack, contain rich and large deposits of iron ore, chromite, manganese, coal, limestone, dolomite and a host of other minerals.

IRON ORE

Odisha has vast reserves of high grade iron-ore with average Fe content of over 60%. The State accounts for about 15.79% of iron ore production of the country Production-wise, Keonjhar district heads the list (61.66%) in the state, followed by Sundargarh (31 .37%), Cuttack (4:22%) and Mayurbhanj (2.74%) districts.

The state has a total iron ore reserve of 3360 million tonne of all grades varying from 55 to 66% Fe. In Keojhar district, important iron ore bearing areas are Thakurani Pahar, Sidhamat Parbat, Durga Parbat, Joda east and west, Banspani Pahar, Dal Pahar, north and west of Kurband, Jhiling Pahar, Longlota Pahar, Guali, Kiriburu, Kalta and Gandhamardan.

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In Sundargargarh district, the notable iron ore deposits are in Bonai range viz. Khandadhar, Malangtoli, Dandrahar Pahar, Taldih, Kalta, Basada Baliapahar, Badamgarh Pahar, Hitikuda, Rakmo, Daringburu and Barsuan. In Mayurbhanj district, iron ore deposits are located in Badampahar, Sulaipat and Gorumahisani areas over a stretch of 40km. Daitari hill is the only iron ore deposit adjacent to Jajpur district.

The chief iron ore which gives rise to iron ore deposits by supergene residual enrichment process is the banded haematite jasper/ quartzite of Precambrian age. They are found in two distinct geological associations namely (i) with the Badampahar Group of rocks in Badampahar belt, comprising highly metamorphosed volcanic rocks of mafic-ultramafic composition and metachert-quartzite and, (i) with the less metamorphosed rocks of the Koira-Noamundi Group. The former is chiefly found in Badampahar-Gorumahisani area in Mayurbhanj District and Daitari area in Kendujhar Dist District. The Iron ore formations of the Koira-Noamundi Group are associated with shales and tuffs which are exposed as a major low north plunging horse-shoe shaped synclinorium constituting the Bonai- Kendujhar belt. M/s SAIL,Tata Steel Ltd , JSW Steel Ltd Odisha, Jindal Steel Pvt Ltd., ArcelorMittal India Private Limited, ArcelorMittal Nippon Steel Limited.,Orissa Mining Corporation, M/s Rungta group of mines and several other merchant mines owner are operating iron mines in this area.

MANGANESE

Odisha accounts for one third of the country's annual production of manganese and possesses the second largest recoverable manganese reserve in the country i.e. 50.36 million tones of all grades, next only to that of Karnataka (64.55 million tones). The manganese deposits of Odisha, restricted to the Precambrian rocks, occur chiefly in four distinct geographic belts: (i) the Bonai - Kendujhar Belt in Sundargarh and Keonjhar districts, associated with chert-shale sequence and laterites, (i) Kuttinga - Nishikal - Ambadola - Patna belt in Koraput, Kalahandi and Bolangir districts, associated with Khondalite suite of rocks of the Eastern Ghats Supergroup, (i) Ghoriajhor belt (Gangpur Group) in Sundargarh district associated with Gonditic rocks and (iv) Bamra subdivision of Sambalpur district associated with laterite in the metasediments.

The grade of the ore is variable from deposit to deposit as also from body to body within the same deposit. High grade (above 45%Mn) and medium grade (35 to 44.99% Mn) ore constitute roughly 20% of the total reserve, although about 60% of the total reserve IS of marketable grade. The phosphorous content in the low- grade ore, ranges from 0.05% to 0.09%, which is always less than the clearance limit of 0.15%. In the higher grade ores the phosphorous content rises up to 0.19%. In some of the deposits of the belt, the ore contains high alumina while others contain high silic[1],. So, these are classed as high alumina siliceous ores."

Major manganese ore bodies occur as pockets and lenses, and veins within lateritoid rocks and lower lithomerge horizons in the core region of the Horse Shoe synclinorium. Manganese mineralization occurring within lower shale below the BIF is possibly of syngenetic origin. However for the most part, the Ore epigenetic The unique feature of the deposits are manganese ore deposits of Bonai Kendujhar belt is their very low phosphorous content.

BAUXITE

Odisha continues to be the leading state accounting for 59% of the total bauxite production of the country The bauxite deposits of Odisha may be broadly classified into five different categories based on their nature of the bedrock.

1. Relatively large cappings over khondalite/ khondalitic rocks of Eastern Ghats Supergroup in Koraput, Kalahandi, Phulbani. Bolangir and Sambalpur districts.

2. Cappings developed over charnockite, diorite / dioritic gneisses of Eastern Ghats Super- group in Koraput and Kalahandi districts.

3. Minor cappings over Chattishgarh Shale in Khariar highlands in Nuapada District.

4. Minor cappings over mafic volcanics and shale of Koira Group in Kendujhar and Sundargarh District.

5. Capping over Simlipal volcanic rocks in Mayurbhanj District.

The first two categories are by far the most important because of their large areal extent and greater thickness They constitute the well known East Coast Bauxite deposits of Odisha. These cappings generally occur in the elevation range of 900-1400 m.
The alumina content varies generally between 40 and 56%. A post Mio-Pliocene age has been assigned to these bauxite deposits. Apart from these major deposits, bauxite occurrences have also been recorded in several other areas of the state.

Bauxite with intercalated laterite cappings over metavolcanics occurs on the flat-topped hills, near Kuanr to the west of Kendujhar in the elevation range of 727m and 848m. The reserve is estimated at 10 million tonnes with Al2O3 content up to 49%.

Bauxite occurs as irregular pockets within ferruginous laterite capping on the ferruginous shale and chert of the Koira Group of rocks near Tantra_(22^0 53':85°10'), Kusumdihi, Jaldihi and San Indupur OF Sundergarh dist. It analyses up to 55% Al2O3. The reserves estimated are about 1 million tone.

Occurrences of bauxite associated with ferruginous laterite are found in a number of flat-topped hills around Kashipur, Kashinguda (19°15" : 83^{0}40'), Manjimali (19^{0}23' : 83^{0}4'), Pasangmali (19^{0}22' : 83^{0}7') in Rayagada district. The ore is derived from dioritic gneisses and khondalitic rocks.

CHROMITE

Odisha holds the first place in reserve position and production of chromite ore in the country, contributing to over 97% of the all India output. The deposit yielding metallurgical, refractory and chemical grade of ore, occurs within the chromiferous ultramafic rocks emplaced into the Archaean Badampahar Group of rocks. Although there are a number of ultramafic bodies located in this arcuate mafic-ultramafic belt stretching from Gorumahisani - Badampahar via Nilgiri Nuasahi to Sukinda and Malaygiri, only two areas, namely Sukinda and Nuasahi covering parts of Jajpur, Kendujhar and Dhenkanal districts contain commercially exploitable chromite lodes. Both Sukinda and Nuasahi areas are under exploitation by active mining for the last 30 to- 40 years and have been thoroughly investigated Y by GSI and other agencies.

The ultramafic field of Sukinda area falls mainly in Jajpur and partly in Dhenkanal districts and forms an E- W trending valley bounded by the Daitary hill ranges to the north and Mahagiri hill ranges towards the south. The valley is narrow at the eastern end and gradually opens up towards west. The general elevation of the valley is around 130m with several lateritic and chert mounds rising up to a maximum of 200m.

Different agencies exploiting chromite deposits of Sukinda area are Odisha Mining Corporation Ltd., Tata Iron and Steel Company, Ferro Alloys Corporation, Industrial Development Corporation, Indian Metals and Ferro Alloys, Balasore Alloys ltd & Jindal Stainless ltd.

The western part of Sukinda ultramafic complex extends into Dhekanal District. Towards south, beyond Mahagiri range, some chromite occurrences are also reported from around Bhuban area.

Nuasahi Belt (20°15': 86°18' to 20° 20': 86° 20'): The ultramafic rocks in the Nuasahi area in Kendujhar District have intruded a sequence of metasedimentariy lithounits of Iron Ore Supergroup. The later is folded into an anticline plunging NNE and the stratiform ultramafics occupy the outer part of this antiformal structure. The ultramafic body might have intruded as a sill and was later cofolded along with the host metasedimentary lithounits or may be a phacolith.

COAL

Odisha has 94.52 billion tonnes of coal which accounts to 24% of the total coal resource 378.21 billion tonnes of the country. This reserve has been estimated only in a part of the prognosticated coal bearing area of Talchir and Ib- river coalfields. Further exploration efforts are likely to substantially increase the reserve of coal in the state. The major coal bearing formations in both Talchir and Ib-river coalfields are Karharbari and Barakar. Coal seam has been established from Karharbari formation in both the coalfields, the Barakar Formation has Yielded 12 seams in Talchir and 4 Seams in Ib-River Coalfield. The Talchir coalfield mainly falls within Anugul district. It is characterized by east-west trending strike faults and in the process, repetition of coal seams has resulted quarriable increased potentiality. The basined structure of talchir coal field appears to be preserved distinctly in south and east.

Barakar coal seams are best developed in the southern part of the basin and deteriorate westward. The lowermost seam in this formation is the seam II (Jagannath seam) which is about 35 to 50 m thick. Seam- II in the western part of the area is not so persistent and even deteriorates in its quality. This seam is exploited in the Handidhua (now Talcher), Jagannath, Bharatpur and Nandira collieries.

The Ib river coalfield displays excellent development of coal seams in Sambalpur, Jharsuguda and Sundargarh Districts. The coalfield shows westerly plunging synclinal flexure which is like a half elliptical basin closed towards southeast and having an axial trend in NW-SE direction. Geological mapping of underground mines and opencast mines indicates that the coalfield is structurally much less disturbed. Four coal horizons, namely Rampur, Lajkura, Parkhani and Belpahar horizons, besides Ib seams, have been recognized in this coalfield.

The Ib seam is the only coal seam occurring in the Karharbari Formation of the basin. It varies in thickness from 2.29 to 10.3m. The Ib seam is being exploited in Orient and Rampur collieries at Belpahar by both underground and open cast mining.

The Rampur horizon, the lowermost coal seam in the Barakar Formation attains a thickness of (27-80m) in the area and comprises coal-shale alternations The lowermost part of this horizon is under exploitation in the Orient, Rampur and Belpahar area.

The overlying Lajkura horizon is highly interbanded and contains a number of major and minor shale/coal shale bands.

The uppermost coal horizon, the Belpahar horizon, is 24 to 30m thick and displays coal-shale laminations. The Parkhani and Belpahar horizons have not been developed in the Hemagiri (Hingir) sub-basin, located in the northern part of the Ib river coalfield.

GRAPHITE

Odisha continues to be the leading producer of graphite accounting for 67% (IBM) of the country's total production. Graphite is reported to have been produced as early as in 1937 in Lahakhan in the then Bolangir State (now. Bolangir district), Around that time, a beneficiation plant was set up at Titlagarh by the Patna State Graphite Mining Company. Sargipali mine in Sambalpur district, was developed in 1945. Today, there are 120 subsisting mining leases in the State covering a total area of 5705 hectares. Production-wise, Bolangir District heads the list with about 44% of the total production of the state followed by the districts of Sambalpur (26%) and Phulbani (23%). The total graphite resource of Odisha state is 2.46 million tonnes.

Almost the entire production of high grade graphite is contributed by Sargipalli underground mine in Baragarh District. Bulk of the production of graphite in the state is, however, of low grade containing less than 25% fixed carbon. The run of the mill ore is amenable to beneficiation upgrading the FC content to as high as 96%. There are as many as 24 beneficiation plants in the state distributed in the districts of Bolangir, Sambalpur, Kalahandi, Phulbani, Nayagarh, Puri. Rayagada and Dhenkanal.

GOLD

Gold occurrences of Odisha are confined to mainly placers, though there is evidence of old mining activity in the northern parts of Odisha, adjoining Bihar. Occurrence of alluvial gold has been recorded in almost all the districts of Odisha and panning of the stream sediments in the major rivers has yielded gold.

Washing for gold has been reported from Tikiria and Ouli rivers. River gravels near Katni, Dolia and Gundichanali are also washed for gold. Panning activity for gold in Ramiala and Betali streams are also on record.

Panning of the stream sediments in the 1s and 2ad order nalas draining the laterite crust capping, the metavolcanics of Iron Ore Group rocks in southern part of Bonai-Kendujhar belt around Kanjipani and Salaikana (21°25' ; 85°23') has shown incidence of gold.

Identification of palaeo-placer zone located at about 10 km north of Telkoi and 3km NNW of Salaikana appears to be a potential block for searching gold mineralization, Auriferous quartz veins are massive as well as brecciated, concordant to foliation and tend to occur in paralle] sets in schistose to phyllitic host rocks of both volcanogenic and sedimentary parentage.

Gold mineralisation has been suspected around Jashipur

(22°26': 86°12'), Suriagora (22°25': 86°15'), Gohaldongri (22°24': 86°20'), Ruansi, Munisahi Bijatola and Kalimati areas where there are evidences of old mining as well as local panning activity. A few old pits and shafts have been reported in the area. The area forms a part of Gorumahisani greenstone belt, which is the southern extension of gold-hosting Kunderkucha belt of Jharkhand.

GEMSTONES

The Eastern Ghats Granulite belt comprising mainly khondalite-charnockite suite of rocks and their variants intruded locally by mafic-ultramafic suites. anorthosites alkaline rocks, potassic granites, pegmatites and quartz. veins host most of the gemstone of the state Although resource potential of gemstone in Odisha is very high. no systematic assessment has been attempted yet in order to arrive at a reliable reserve estimate.

The best quality gems of Odisha have so far been recovered from several important gem tracts lying within this district. The 25km long Jilingdhar- Hinjilibahal belt is the most important for contributing the best quality ruby. It occurs in the eluvial zone of altered meta- pyroxenite particularly at its contact with granite gneiss marked by a zone of actinolite - tremolite — vermiculite being traversed by quartz vein. This ruby prospect is presently under active exploitation. The recovered ruby is mostly red to blood red in colour and is of excellent quality.

Several important gemstone tracts occurring withinthe Eastern Ghats granulite terrain of Bolangir district has yielded many good quality gems. Occurrences of emerald, topaz, heliodor and aquamarine associated with low-dipping unzoned pegmatites emplacing granite gneiss are known from Ghuchepara-Antarla sector.

CLAY

The state is endowed with a number of China clay and fire clay deposits.

CHINA CLAY

In Koraput Dist bedded clay occurrences have been reported from the localities mentioned below: Obuguda (18°45'; 82°45'), Doliambe ($18^0$30,: $82^0$52'), Turia ($18^0$36': $82^0$58'), Baipariguda (18°45': 82°25), Santhopur ($18^0$44': $82^0$24'), Kallaru ($18^0$37': 82°24), Saradaputti (18°34: 82°27'), Boipariguda ($18^0$34': $82^0$27'), Sorispadar ($19^0$03': $82^0$16') and Devandera ($19^0$04': $82^0$28). The total reserve of clay near Baipariguda, Kallaru and Ramagiri is estimated at 2800 tonnes. The beds are about 7m thick and the clay is white to greyish-white in colour and semi-plastic. The origin of clay is attributed to the weathering of shales. The Obuguda clay is slightly gritty, fairly plastic and pinkish white in colour. The linear shrinkage varies between 10- 15%. On burning, the colour of clay turns to dirty yellow and does not fuse at 1400°C. Clays derived from kaolinised gneiss are reported from Misoriguda ($18^0$52': $82^0$41'), Pukkili ($18^0$30': $82^0$54), Jodiguda (18°20: $82^0$46'), Nabgam (19°06':$82^0$30'), Madhupur ($19^0$53' : 83%28"), Lafhiponga (19°40' ; 83°30'), Pathibonda (18°11': 81°56') and Sirgarajnkonta (18°17'; 81°48').

Plastic and gritty kaolin derived from the decomposition of feldspars in gneisses is reported from south- west of Banrapal ($20^0$50: $85^0$23'). Gritty kaolin occurs at the foot of the Baideswar Hill ($20^0$28'; 85°34')in the district of Cuttack. The material is coloured, gritty and non-plastic. White clay, derived from decomposition of feldspathic gneisses intruded by pegmatites, occurs near Sibalopose ($20^0$56' ; $85^0$03')in Dhenkanal Dist. At places, it is yellowish at the top but white at depth.

FIRE CLAY

Bedded deposits of fire clay, mostly associated with coal measures of Gondwana Supergroup, are found in Cuttack, Dhenkanal, Puri, Sambalpur, Sundergarh and Koraput districts of Odisha.

The total reserve of fire clay in the state is of the order of 175.256 million tonnes .There are around 20 existing mines in the state which accounts for 16% of the total production of fire clay in the country.

Good quality of fire clay, occurring within the Gondwana rocks of Ib river coal field, is mined at Kiripsora, Gopapali, Kathpali, Khutijharia, Kurutoi, Juraboga, Girsuan, Jamakani etc. A good number of fire clay beds are recorded in and around Tencligad, Siarmai, Balinga, Benkibahal, Forkbahaj. Kiripsora, Garjanbehi, Khuntijheria, Dulunga, Khajurdihi and Jharpal and Girisuan areas of Sundergarh district. A total reserve of 618,000 tonnes of fire clay has been estimasted in the district. Workable deposits are located near Talbasta ($22^0$20': $85^0$35') and Chandiprasad ($20^0$26'; $85^0$48') of

cuttack district.

The Belpahar Refractories Limited had set up a modern and sophisticated refractory plant in the area primarily fed by the Jurabaga- Darilpali deposit. Abandoned fireclay workings are present in the Pajbira Khindia area to the east of the Ib river. At Talbira, the fire clay deposit occurring at the upper part of the Rampur horizon comprises two bands, grey to dark grey in colour and 2m in thickness. The clay analyses 19.76 to 25.30% Al2O3. An occurrence of 0.75m thick dark grey clay has been recorded in a coal quarry at Khindia. The clay is of inferior quality, containing about 18% Al2O3.

ASBESTOS

Tremolite-asbestos band have been reported from talc-tremolite-actinolite-chlorite schists of Bengpal Group occurring near Sanibahal Village (19°26': 82°51') in Kalahandi District. The bands vary in length from 1 to 16 m and the width from 20 to 30 cm. A tentative reserve of 0.4 million tones of asbestos is estimated for four such bands. The asbestos bands show sharp concordant as well as discordant contact with the enclosing schists.

BASE METALS

Odisha is relatively less endowed with basemetal ores. The deposits are associated with the Precambrian schists occurring in parts of north Odisha. Detailed exploration in recent past established a few promising sectors, especially for gold,copper and lead ores, at Kesarpur in Mayurbhanj District.Adash in Sambalpur District and Sargipalli in Sundargarh District respectively. The total reserves of lead and copper for Odisha have been estimated at 6.54 million tonnes and 6.42 million tonnes respectively.

LEAD & ZINC

Sargipalli (22°03':83°35') lead deposit is located between Lokdega (22°03': 83°50') and Bharatpur (22°03': 83°56') covering a stretch of 1600 m. The litho-units comprising dolomite, garnetiferous mica schist and quartzite belong to Gangpur Group and are intruded by granite, pegmatite and basic rock. The rocks are thoroughly metamorphosed and the host rock for mineralisation is the garnetiferous mica schist. 'The strike of the rock formation is WNW-ESE with dip varying between 30°-45° towards SSW. Mineralisation is confined to the southern limb of an easterly plunging syncline.

Closure of HZL UG mines was a very wrong decision from geo-mining view point. The infrastructure which were there could have helped the state in taking up various exploration activities, using underground space for developing UG Space, using tailings for recovery of metals etc. The campus could have been handed over to some Research Institutions for undertaking research in hard rock mining and mineral processing.

COPPER

Copper mineralization has been located in. Kesarpur-Kusumdihi area (22°07'; 85°41')of Mayurbhanj at a number of places in sheared metabasites. Stains of malachite, azurite and bornite with specks of chalcopyrite are seen in the altered basic rocks at the contact with sheared granite. Based on the evidence of old workings and subsequent details investigation three promising sector have been delineated at Kesarpur, Madansahi and Dudhiasol. Out of these, Kesarpur sector is most promising where strike extension of the mineralised zone is more than 3 km with nearly 1 km width. The copper mineralisation occurs in sheared metabasics belonging to the Iron Ore Supergroup. Copper ore is found as stringers, veins, disseminations and lenses. The ore zones occur as a series of discontinuous lenticular bodies disposed in an en-echelon Pattern, The ore minerals include sulphides like pyrite, pyrhotite and chalcopyrite associated with minor amounts of nickel and cobalt.

BEACH SAND MINERALS –RARE EARTH

The coastal tracts of Ganjam and Puri districts contain workable concentration of heavy minerals in the beach and dune sands, which include ilmenite, garnet, rutile, sillimanite, zircon and monazite. The heavy mineral concentration varies from 8.6 to 25% ilmenite constituting about 40% of the total heavies. The reserves/ resources of beach sand mineral in the coastal districts of Odisha have been estimated at 38.58 million tonnes of ilmenite, 25.39 million tonnes of garnet, 16.15 million tonnes of sillimanite, 1.62 million tonnes of rutile, 1.21 million tonnes of zircon and 0.87 million tonnes of monazite. A mineral processing plant of Indian Rare Earth Limited operating at Chhatrapur is producing 0.22 million tonnes of ilmenite, 0.01 million tonnes of rutile, 0.03 million tonnes sillimanite,

4000 tonnes of monazite and 2000 tonnes of zircon annually.

LIMESTONE AND DOLOMITE

Odisha is endowed with vast resources of limestone confined to three distinct geological settings viz; Gangpur Group, Chattishgarh Super Group and Eastern Ghats Super Group of rocks besides minor occurrences associated with Iron ore Supergroup rocks in Kendujhar district.

One of the most important Precambrian limestone and dolomite deposits of Odisha occurs associated with Gangpur Group of rocks in this district. The limestone band consists of an upper calcitic member and lower dolomitic member. The general structure is described as a synclinorium.

The major deposits are located at Biramitrapur. Hatibari, Purnapani in the northern limbs; Lanjiberna, Gomardiha, Khatkurbahal, Kutra in the Southern limb, and Dubkbera in the core of the synclinorium. Major cement manufacturer like ACC ltd., Dalmia cement, JSW ltd. operating their mines in this region.

The average width varies between 609 and 761 m of which dolomite forms 364m to 457m and limestone 245m to 300m. The limestone is fine to medium grained and grey in colour. The lime content in the rock varies from 30 to 52% while the insoluble and silica show variation from 30 to 35 % and magnesia upto 15%. Alumina and iron oxide contents never exceed 6 % and 8% respectively. About one third of the limestone resources is suitable for use as flux and cement manufacture.

The Biramitrapur formation hosts important horizons of limestone and dolomite extending over lengths of 50 km and 96km in the northern and southern limbs of the synclinorium respectively.

Lanjiberna deposit extends over a strike length of 12.50 km in an E-W direction from Lanjiberna to Amghats. The limestone is medium grained, grey to dark grey in colour. Dalmia cement (OCC) is operating their mines in Lanjiberna.

Purnapani Limestone band has an E-W strike length of 1.5 km with a southerly dip of 60° and an average width varying between 300m and 365m. The northern 180 m of this band is of good quality, owing to its low magnesia conten. SAIL RMD operating their mines in Purnapani.

In Baragarh Limestone occurs in a strip of plain country about 16 km long between Dungri(21° 42': 83° 34') and Banjipali(21°38':83°30') in form of an asymmetrical anticline plunging northwest. It is found interbedded along with shale, sandstone and quartzite. Previously IDC was operating their mines thereafter ACC Ltd. And now Ambuja Cement is operating Bargarh Limestone mines.

Steps should be taken to commence mining in Dinguri by undertaking detailed exploration and water management plans in association with Central Water Commission. With the availability of blast-free mining techniques, the limestone lying closer to Hirakud Dam water regime could have been undertaken safely.

NICKEL

Nickel ore occurs associated with limonitised and silicified ultrabasic rocks in the Sukinda area of Jajpur district and with the weathered zone of ultramafic differentiates of the Amjori sill emplaced in the Simlipal Group of rocks in the Simlipal area of Mayurbhanj district.

Several scientific studies have been undertakenin the past to extract Ni from the Sukinda bel in laboratory scale. The increase in the demand for Ni as a Critical Mineral, should be he sole criteria to infuse investment in Ni extraction from Sukinda.

PLATINUM

Presence of platinum has been reported from the ultramafic complexes of Sukinda and Nuasahi areas located at the trijunction of Kendujhar, Jajpur and Dhenkanal districts. Samples were drawn from the weathered ultramafics, limonitised/lateritic overburden as well as from chromitite horizons, for detection of platinum group of minerals (PGE). Layered differentiated ultramafic to mafic plutons emplaced in stable cratonic blocks of Late Archaean to early Proterozoic age are most potential for hosting orthomagmatic PGE deposits. Such rock associates are abundant in ultramafic complexes at Sukinda and Baula- Nuasahi and also over the Amjori sill of Simlipal Complex.

PYROPHYLLITE

Odisha, the second largest producer of pyrophylite in India is endowed with huge quantum of pyrophylite estimated at 8.4 million tonnes. In Odisha, pyrophyllite occurrences are found only in Keonjhar district Production of pyrophyllite is continuing in 3 mines having an estimated total reserve of 10 million tonnes. The pyrophyllite occurrences are associated with Singhbhum granite and Bonai granite.

QUARTZ/ QUARTZITE

The quartz and quartzite occurrences are found in almost all the districts of Odisha excepting the coastal plains. But they could not be plotted in the map due to limitation in scale size. Quartz occurs as a constituent of pegmatite and in the nature of veins.

DIMENSION STONE-GRANITE

Odisha had huge deposits of granite for the extraction of dimension stone. This area needs the support from the government and also special packages to be given to the mines for introducing state-of-the-art techniques to extract.

Dimension Stone Granite refers to all type of phanerocrystalline feldspathic igneous rocks of granitoid texture with or without gneissose structure ranging from granite (sensu stricto), granite-gneiss, migmatites, syenite, gabbro,anorthosite, charnockites,leptynites, pyroxene granulite,dolerite. pyroxenite,dunite etc. Granite is resistant to weathering and is found in a variety of pleasing colour. It is capable of retaining its polish fresh as in the original form for a long time. It is quite popular for use as tomb stone, paving and architecture material.

In the Koraput-Rayagada area mostly constitutes of Eastern Ghat Supergroup comprising Charnockite suite and Granitic suite of rocks, unclassified granites of Bastar Craton and Bengpal Group of meta sediments and basic dykes of gabbro-dolerite composition. The varieties identified are Red Pearl, White Wave, White Porphyry Black granite, Jeypur black and Pottangi Green etc.

Kalahandi-Bolangir-Nuapada Segment The rocks belonging to Cratonic granite, EGSG, Chhatishgarh Supergroup of sedimentaries and Gondwanas, alkaline syenites of Khariar area intrusive to EGSG and Anorthosites of Bolangir area are identified as the source rocks for DSG. The different varieties found are Pink Granite, Cats Eye, White Porphyry, Sea weed green, Midnight green Tiger skin etc.

The coloured granites are found occurring within Exterm Ghat Mobile Belt in the districts of Ganjam, Khurda,Nayagarh, Cuttack,Baudh, Phulbani, Koraput, Rayagada, Kalahandi, Nuapada, Bolangir, Dhenkanal, Angul and Sambalpur as well as the cratonic segments in the districts of Koraput, Kalahandi, Nuapada, Sambalpur, Deogarh, Sundergarh, Kendujhar, Mayurbhanj. Similarly black granites are identified in Koraput, Kendujhar, Mayurbhanj and Balasore districts.

OTHER MINERALS

Besides we have deposits of Glass Sand, Kyanite,Mica,Sillimanite,Soapstone,Vanadiferous Magnetit etc.

EMPLOYMENT

Employment of local population mostly belonging to tribal communities in the mineral bearing areas are for unskilled to semi-skilled categories. For skilled and supervisory level the dependence is more on other districts and on outside the state. Due to increase in number of seats in mining engineering in diploma level, there has been a rise in employment for local students under trainee and supervisory categories. However, the non-availability of proper teaching faculty members and laboratory facilities in majority of institutions is a cause of concern. Table 2, shows the annual growth of employment in mining. In the coal bearing areas the adoption of MDO concept and massive contractual activities had harmed local population to get unskilled jobs. Only jobs against land has been an encouraging step to get into well paid unskilled to semi-skilled category jobs. There is an urgent need to strictly implement minimum wages concept alongwith all facilities stated under Mines Act 1952.

CONCLUSION

Odisha with its vast reserves of ores/minerals, has the potential to make India Aatma Nirbhar (self reliance) in the field of iron ore, non-coking coal, manganese, chromite, dimension stone, graphite, beach sand etc. Geological exploration is needed to expedite massive effort to assess the so far discovered ore bodies.

Table 2 : The annual growth of employment in mining

year	*No. of employment*	*Annual growth of employment(percent)*
2000-01	52937	-
2001-02	45135	-14.73
2002-03	44167	-2.14
2003-04	43743	-0.95
2004-05	49837	13.93
2005-06	55764	11.89
2006-07	47376	-15.04
2007-08	49176	3.79
2008-09	44167	-10.18
2009-10	43705	-1.04
2010-11	51877	18.69
2011-12	48263	-6.96
2012-13	59417	23.11
2013-14	47370	-20.27
2014-15	47370	0
2015-16	49086	3.62
2016-17	52405	6.76
2017-18	55,940	6.74
2018-19	58,600	4.75
2019-20	59,636	1.76
CAGR		0.60

Source: Directorate of Mines, Odisha

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Advances in Sustainable Construction Materials-A Review

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ABSTRACT

Production and use of construction materials have a detrimental impact on the availability and quality of natural resources; this also has some serious environmental impacts like global warming and ozone layer depletion. Moreover, building materials directly correlate with energy consumption in buildings and, in turn, decide the severity of the energy consumed in that building. The objective for a sustainable future in building materials is the development of new environment-friendly materials and alternative, non-conventional building materials for construction.

For that, the Central Public Works Department report (CPWD, 2014) came up with 12 parameters to measure the sustainability index of construction materials. These parameters are Recycled content, Embodied Energy, Rapidly Renewable, locally available material, Functional Life Period, Capital cost, Maintenance cost, Construction Waste Management, Fly-ash content, Reduced Dead weight, Reduced Time of Construction, Toxicity/Indoor Air Quality/Safety. These parameters act as a yardstick to measure the suitability of the construction material in sustainable measure.

Furthermore, different work is going on alternative and non-conventional building materials, showing improved ranking in the sustainability index and advancement in their physical properties. This work covers the comparative study of different non-conventional construction materials, their properties, their impact on the environment, and the advances they undergo with time. For that, different non-conventional construction materials are selected, like Bamboo, which is known for flexibility, carbon-sinking properties, and economic sustainability. Others like cork as a building material with lightweight, waterproof, abrasion-resistant, and fire-retardant properties.

Similarly, another alternative material showing remarkable acceptability is Hempcrete, which has a concrete-like shape and strength but much lighter weight and primarily acts as an insulator. Building material under research like mycelium, which is a network of thin fungal strands called hyphae and is water, mold, and fire resistant; one of the studies shows that when mycelium combines with pasteurized sawdust, mycelium it transforms into almost any form. Other prominent materials under study are pre-cast concrete made off-site in a factory setting and ready-mix concrete poured and hardened on-site. In some places, Recycled glass is another primary material. It can replace natural aggregates like sand, gravel, and crushed stone, making it a great option for more sustainable cement varieties.

Non-conventional materials, which include Recycled plastic, can be used to create plastic sheets, concrete, bricks, lumber, pipes, roofs, floors, and PVC. Similarly, Terrazzo is a composite material used mainly for flooring, countertops, and stairways. It's made from marble, granite, quartz, glass, and other materials, usually bound with cement or epoxy resin.

All the above construction materials are at different stages of development; some are widely accepted and are used at full replacement level, and some are partially taken and are used along with other conventional construction materials. Some others are reinforced with other materials for improvement in their physical properties.

INTRODUCTION

The worldwide construction sector contributes significantly to economic growth and is essential to societal development and urbanisation. Concerns have been made regarding the traditional methods used in the manufacture and usage of building materials and their effects on the environment and natural resources. The world urgently needs to switch to sustainable building materials that can both meet the needs of infrastructure expansion and reduce their ecological imprint, given the problems posed by resource depletion and climate change. The most recent developments in ecologically friendly building materials are examined in this review

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article, which also looks at the approaches taken to assess the viability and impact of these alternatives.

The building industry has historically been linked to significant environmental problems, such as energy use, resource depletion, and emissions that fuel climate change. Traditional building materials' extraction, processing, and transportation all have a major impact on pollution, including carbon emissions. In addition, the world's fast urbanisation and population expansion increase the need for building supplies, which exacerbates their environmental impact.

A complete set of 12 metrics was created by the Central Public Works Department (CPWD) in 2014 to quantify the sustainability index of construction materials in recognition of these problems. These characteristics cover a wide range of factors, such as waste management, functional life duration, local availability, embodied energy, and recycled content. The CPWD programme promotes a more sustainable approach to infrastructure building by providing a crucial framework for assessing the environmental impact of construction materials.

The need to address environmental issues quickly has sparked innovation and research in the field of building materials. In order to give a thorough overview of these developments, this presentation will concentrate on the creation of non-traditional, alternative materials with superior physical attributes and sustainability indices.

This review's methodology entails a methodical evaluation of unconventional building materials using the CPWD's sustainability criteria. The comparative analysis takes into account a wide variety of materials at various phases of development and industrial adoption. This paper aims to present a nuanced understanding of the environmental impact, physical characteristics, and potential for widespread adoption of various materials, including Cork, Hempcrete, mycelium, pre-cast concrete, ready-mix concrete, recycled glass, recycled plastic, and Terrazzo. Analysis of these materials will be done critically.

Bamboo is a potential replacement for conventional building materials because of its adaptability, capacity to absorb carbon dioxide, and cost sustainability. Lightweight, waterproof, abrasion-resistant, and fire-resistant, cork is an excellent choice for a variety of applications. Hempcrete is a sustainable substitute and insulator that has strength comparable to concrete but a far lower weight. Mycelium is a network of fire-, mould-, and water-resistant fungal strands that can take on multiple forms when mixed with pasteurised sawdust.

Apart from the biological alternatives, the construction industry is also investigating ready-mix concrete that is poured and hardened on-site, as well as pre-cast concrete that is prepared off-site in factory settings. A viable alternative to natural aggregates like sand, gravel, and crushed stone is recycled glass, which presents a sustainable cement production method.

Recycled plastic is one of the non-traditional materials that offer potential for producing a variety of building goods, including PVC, sheets, concrete, bricks, lumber, pipes, roofs and flooring. Terrazzo is a composite material used for floors, worktops, and stairways. It is made of marble, granite, quartz, glass, and other elements linked together with cement or epoxy resin.

The materials under discussion are in varying phases of development; some are still in the experimental stage, while others have already gained widespread acceptance and are being utilised at full replacement levels. Certain materials are used in conjunction with more conventional building materials, while others are reinforced with different materials in order to improve their physical characteristics.

We will critically assess the environmental impact, physical characteristics, and present level of acceptance within the building industry as we delve into the comparative examination of various materials. The ultimate goal of the paper is to contribute to a more environmentally conscious and sustainable future for the construction industry by offering insights into the trajectory of sustainable construction materials, highlighting both triumphs and obstacles.

LITERATURE REVIEW

1. Sitepu, M. H., Matondang, A. R., & Tryana, M. (2020) "***Sustainability Assessment In Construction Industry Supply Network***":

This groundbreaking study offers a thorough summary of the approaches used in sustainability assessments of building materials. It presents a foundational

understanding of the opportunities and constraints related to sustainable construction materials by introducing a number of criteria, including as life cycle analysis, recycled content, and embodied energy. By defining important criteria for assessing the environmental impact of materials, the study lays the groundwork for further investigations. Our article incorporates the Central Public Works Department's (CPWD) sustainability standards for construction materials, building upon the seminal work in this paper. Although Smith et al. give a general review of sustainability assessment techniques, our work concentrates on these parameters in particular, providing a more focused and practical method of assessing how construction materials affect the environment. Furthermore, our review extends beyond assessment approaches to investigate the state of non-conventional materials and their improvements, offering a more dynamic viewpoint on sustainable building.[1]

2. Suhamad, D. A., & Martana, S. P. "*Sustainable Building Materials"*:

Suhamad, D. A., & Martana, S. P. explore new developments in environmentally friendly building materials, highlighting the need for creative solutions to pressing environmental issues. In order to evaluate alternative materials' potential to address sustainability concerns, the article evaluates a variety of materials, such as bamboo, recycled plastic, and mycelium. This work's comparative research provides insightful information about the wide range of sustainable building materials available. Emerging trends including bamboo, mycelium, and recycled plastic are highlighted. We build on this in our research by performing a comparison analysis that analyses and assesses these patterns in light of the CPWD sustainability criteria. Our assessment attempts to give a more thorough analysis of these materials' current status, taking into account their physical characteristics, acceptability level in the building sector, and influence on the environment.[2]

3. Di Capua, S. E., Paolotti, L., Moretti, E., Rocchi, L., & Boggia, A. *"Evaluation of the Environmental Sustainability of Hemp as a Building Material, through Life Cycle Assessment":*

The non-traditional material known as "Hempcrete," which is becoming more and more popular due to its sustainable qualities, is the subject of this study. This study's life cycle assessment compares the environmental effects of Hempcrete to more conventional materials like concrete. The results help to clarify Hempcrete's overall sustainability and offer a foundation for contrasting its environmental impact with that of other building materials. Although Gupta et al. concentrate primarily on Hempcrete, our paper expands the scope to encompass a wide variety of unconventional materials. We contrast Hempcrete with various materials including bamboo, mycelium, and recycled plastic in addition to evaluating its life cycle. This makes it possible to comprehend the relative sustainability of various non-traditional building materials more thoroughly.[3]

4. Lamba, P., Kaur, D., Raj, S., & Sorout, J. "*Recycling/reuse of plastic waste as construction material for sustainable development"*:

The review by Li et al. focuses on recycled plastic as an eco-friendly substitute for traditional building materials. In contrast to traditional materials, the qualities, robustness, and environmental impact of recycled plastic are evaluated severely in this research. The work adds to the expanding corpus of literature on the viability and difficulties of utilising recycled plastic in building by synthesising previous knowledge. The review of recycled plastic by Li et al. establishes the foundation for knowledge about its characteristics and effects on the environment. We expand on this conversation in our article by setting recycled plastic against a wider variety of substitute materials. Through contrasting recycled plastic with other materials such as bamboo and mycelium, we help to provide a more comprehensive knowledge of the benefits and drawbacks of utilising recycled plastic in sustainable building practices.[4]

5. Shams, S., Mahmud, K., & Al Amin, A. Q. "*A comparative analysis of building materials for sustainable construction with emphasis on CO_2 emissions":*

This study suggests adopting materials with reduced embodied energy and CO2 emissions for sustainable buildings, highlighting the construction industry's large contribution to CO2 emissions (40 percent). The study compares materials such as steel, aluminium, glass, and wood through a case study and comes to the following conclusion: The choice of building materials has a big impact on CO2 emissions. Steel and aluminium emit more

carbon dioxide than wood and glass combined. A building's carbon footprint can be decreased by using materials with fewer emissions, such as glass and wood. This study specifically delas with the issue of emission of C02 with respect to the building construction. [5]

6. Yadav, M., & Mathur, A. *"Bamboo as a sustainable material in the construction industry":*

In his paper, the author specifically dealt about how bamboo, which grows widely in India, is a flexible and sustainable substitute for traditional building materials like steel and wood. They examine the conventional and prospective applications of bamboo in many construction elements throughout India, emphasising the material's quick growth, durability, and ecological advantages. The purpose of the paper is to present bamboo as an environmentally acceptable and workable alternative for effective and conscientious building methods.[6] This aligns with our paper which discuss the use of sustainable construction material but this is very specific to the baboo whereas we have discussed on certain others materials as well.

COMPARATIVE ANALYSIS

Bamboo vs. Traditional Wood and Steel

Durability: Under some circumstances, bamboo's remarkable durability frequently surpasses that of typical wood. Because of its innate resilience to fungi and pests, it requires fewer chemical treatments than other building materials, making it a more environmentally responsible option.

Renewability: Bamboo can be harvested in three to five years, making it a fast renewable resource in contrast to typical wood, which may take decades to develop. This rapid turnover lessens the strain on trees and makes more sustainable harvesting methods possible.

Water Efficiency: Compared to conventional wood sources, bamboo often needs less water to thrive. For sustainable building, especially in areas where water shortage is an issue, this water efficiency is essential.

Low Energy Consumption: Compared to the production of steel or conventional wood, the processing and manufacturing of bamboo into construction materials usually requires less energy. Its overall environmentally friendly profile is bolstered by its lower energy use.

Biodiversity: Bamboo forests are home to a wide range of plant and animal species, contributing to their rich biodiversity. Using bamboo in building not only improves the environment but also preserves ecosystems.

Local Availability: Bamboo is readily available locally in many areas, which lessens the transportation sector's carbon footprint. Using resources that are sourced locally is essential to sustainable construction methods.

Waste Reduction: Because bamboo is so versatile, there is less waste produced throughout the manufacturing process. Its versatility in construction applications, ranging from structural components to finishing touches, optimises resource efficiency and minimises waste in the process. Bamboo is a good fit for the idea of a circular economy, which recycles, repurposes, and reuses materials. Because of its adaptability, it can be used in many life cycles, which gradually increases its sustainability.

Cork vs. Conventional Flooring Materials

Renewability: Cork is harvested without causing harm to cork oak trees, which means that the bark can regrow and be harvested once more. Compared to traditional flooring materials like hardwood, which frequently entail cutting down entire trees, leading to deforestation, this renewable harvesting approach is different.

Energy Efficiency in creation: Compared to the creation of some traditional flooring materials, including ceramic tiles or hardwood, the manufacturing process for cork flooring often uses less energy. This reduced energy usage makes the decision more environmentally responsible and sustainable.

Indoor Air Quality: Naturally occurring, cork emits few volatile organic compounds (VOCs). Choosing cork flooring over other traditional flooring materials that may eventually emit toxic chemicals can help improve indoor air quality and promote a healthier living environment.
Thermal Insulation: Buildings can benefit from an extra layer of energy efficiency thanks to cork's inherent thermal insulation qualities. Compared to other traditional flooring materials that could not give the same level of insulation, this might help lower heating and cooling expenses.

Recyclability: Cork flooring can be recycled or used for other purposes when its life cycle comes to an end. Compared to some conventional flooring materials that could wind up in landfills, this recyclability reduces the environmental effect associated with disposal, which is in line with the concepts of a circular economy.

Sustainable Forest Management: Cork oak tree plantations frequently adhere to sustainable forest management techniques in addition to being renewable. This includes preserving the ecosystem's overall health, stopping soil erosion, and preserving biodiversity—as opposed to certain traditional flooring materials that come from less environmentally friendly forestry operations.

Biodegradability: Over time, cork can naturally break down because it is a biodegradable substance. Because to this characteristic, it is a more environmentally responsible solution at the end of its life cycle than some conventional flooring materials, which have the potential to pollute the environment over time.

Hempcrete vs. Conventional Concrete

Carbon Sequestration: Hempcrete has a special capacity to gradually sequester carbon dioxide. The material's hemp fibres successfully offset the carbon emissions related to the creation of the lime binder by absorbing and retaining carbon dioxide during the hemp plant's growth phase. Because of its ability to sequester carbon, hempcrete is a carbon-negative building material that helps fight climate change.

Crop rotation and renewable resources: Hemp, the main ingredient of hempcrete, is a rapidly expanding renewable resource. Multiple crops can be produced in a year by cultivating and harvesting hemp plants in a single growing season. Crop rotation, which preserves soil health and lessens the need for synthetic fertilisers and pesticides, is another benefit of hemp farming.

Breathability: The breathable nature of hempcrete permits moisture to permeate the walls. By avoiding the growth of mould and mildew, this feature can help provide a healthier indoor atmosphere than many traditional concrete buildings that could trap moisture.

Temperature Control: The inherent insulating qualities of hempcrete help to control indoor temperature in addition to energy efficiency. A more sustainable and comfortable living area is made possible by the material's ability to collect and release moisture according on the surrounding conditions.

Elasticity and Versatility: Hempcrete provides a level of elasticity absent from traditional concrete. In earthquake-prone regions, where structures may need to absorb and disperse seismic pressures without suffering major damage, this flexibility can be advantageous.

Decreased trash: Hempcrete manufacture produces less trash than traditional concrete. On-site mixing of the material minimises the quantity of leftover material that frequently ends up in landfills during construction and eliminates the requirement for exact precast moulds.

Local Sourcing: It is frequently possible to grow hemp for hempcrete locally, which lowers carbon emissions associated with transportation. This local availability is consistent with sustainable construction methods, which give local materials priority.

Mycelium vs. Traditional Building Materials

Biodegradability: Mycelium decomposes naturally at the conclusion of its life cycle without harming the environment because it is a biodegradable material. On the other hand, conventional building materials, particularly those made of non-renewable resources, could result in waste and pollution over time.

Low Energy Input: Compared to the manufacturing procedures of conventional building materials like concrete or steel, the manufacture of materials based on myceliums usually needs minimum energy. This low energy consumption is consistent with sustainable building methods and helps reduce environmental impact.

Carbon Sequestration: During the growth phase, mycelium has the capacity to sequester carbon. As it consumes organic matter, carbon dioxide is taken up and stored. The environmental advantages of mycelium are enhanced by its carbon sequestration property, which helps slow down climate change.

Utilisation of Renewable Resources: Mycelium can be grown on a variety of organic waste products, including forestry and agricultural waste. By using renewable resources, traditional construction methods become less reliant on limited or non-sustainable building materials.

Mycelium-based materials possess a lightweight nature, rendering them appropriate for uses where a lower structural weight is desirable. Compared to many conventional building materials, this feature facilitates better handling and more effective transportation during construction.

Customisation and Growth: Mycelium is capable of being grown and moulded into precise shapes, which makes it possible to create elaborate architectural features and bespoke designs. It may be difficult to accomplish some creative possibilities with some traditional building materials, but this flexibility in shaping and moulding opens them up.

Sound Insulation: Materials made of mycelium have the ability to absorb sound, which improves indoor acoustics. When developing sustainably and prioritising the creation of aesthetically pleasing and energy-efficient structures, this can be a compelling feature.

Waste Reduction: By employing waste streams from other businesses, mycelium cultivation successfully upcycles materials that would otherwise burden the environment. This component of waste reduction emphasises the significance of reducing waste in the construction process, which is in line with the concepts of the circular economy. When these extra characteristics are taken into account, mycelium emerges as a particularly noteworthy sustainable building material. It has the inherent ability to withstand a variety of environmental problems, requires little energy, has the potential to sequester carbon, and can help reduce waste and use renewable resources.

Recycled Plastic vs. Conventional Plastic, Concrete, and Wood

trash Reduction: By keeping plastic trash out of landfills and the ocean, the use of recycled plastic in construction helps reduce waste and tackle the problem of plastic pollution worldwide. This component of waste reduction, which repurposes resources that could otherwise contribute to environmental harm, is in line with the ideas of a circular economy.

Weather Resistance and Durability: Recycled plastic materials are frequently weather resistant and durable, which can make them appropriate for a variety of construction applications. Recycled plastic has a longer lifespan under certain conditions because it is less prone to rot, decay, and disintegration than traditional materials like wood.

Lightweight Nature: Compared to other traditional materials, recycled plastic is typically lighter, making it simpler to handle and transport during construction. This characteristic may help improve logistics and lower carbon emissions associated with transportation.

Low upkeep: Compared to some standard materials, recycled plastic materials frequently require less upkeep. They might be resistant to decay, fungus, and pests, which would mean fewer chemical treatments and sporadic repairs are required.

Customisation and freedom in Design: Recycled plastic materials can be moulded into a variety of shapes, providing both freedom in design and customisation. This flexibility can be especially helpful in applications related to architecture and design when it is required to have distinctive shapes and forms.

Insulating qualities: Certain recycled plastic materials have the ability to insulate, which helps buildings use less energy. By regulating interior temperatures, this thermal insulation can lessen the demand for heating and cooling. Low Embodied Energy: Compared to the production methods of conventional materials like steel or concrete, the creation of recycled plastic often uses less energy. This low embodied energy is consistent with sustainable construction methods and helps reduce environmental impact.

Local Availability: Recycled plastic may be available locally, lowering carbon emissions associated with transportation, depending on the source. Using resources that are sourced locally is consistent with sustainable construction methods, which place an emphasis on reducing the transportation sector’s negative environmental effects.

Terrazzo vs. Traditional Flooring Materials

Recycled Content: By incorporating recycled aggregates like crushed glass or post-consumer recycled materials, Terrazzo can help promote the circular economy and lessen the need for new resources. Terrazzo is more sustainable than other flooring materials because it uses recycled content instead of only fresh raw materials.

Durability and longevity: Terrazzo has a reputation for being incredibly durable and long-lasting. Its tough, durable surface can endure high foot traffic and wear and tear, possibly outlasting certain conventional flooring materials. Because terrazzo lasts so long, fewer replacements may be required as often, which helps conserve resources.

Low Maintenance: Terrazzo is simple to clean and maintain due to its smooth, non-porous surface. Terrazzo's natural qualities make it a low-maintenance flooring alternative that requires less harsh cleaning agents and has a smaller environmental effect than certain standard flooring materials, which may need specific treatments or coatings for protection.

Reflectivity and Energy Efficiency: Terrazzo's reflective qualities can help distribute natural light more evenly, which may lessen the demand for artificial lighting in interior areas. This improved energy efficiency is in line with sustainable building techniques, resulting in a more economical and environmentally responsible structure.

Local Sourcing: Terrazzo materials are frequently available locally, which lowers carbon emissions associated with transportation. Using resources that are readily available locally is consistent with sustainable construction methods, which place an emphasis on reducing transportation's negative environmental effects and boosting local economies.

Minimal VOC Emissions: Terrazzo flooring materials can improve indoor air quality by having minimal or no volatile organic compound (VOC) emissions. When terrazzo is combined with this function, it becomes even more sustainable than some other traditional flooring materials that have the potential to discharge toxic chemicals into the air.

Recyclability: When terrazzo flooring reaches the end of its life cycle, it may be recycled or used for other purposes. Recycling choices include repurposing the old material by grinding it down or adding it to fresh terrazzo mixtures. This recyclability lessens the environmental impact of disposal and is consistent with the ideas of a circular economy.

Ready-Mix Concrete vs. Pre-Cast Concrete

Resource Efficiency: Because pre-cast concrete can be precisely measured and controlled in a factory setting, it is frequently more resource-efficient. Compared to ready-mix concrete, where overordering or on-site calculations may result in surplus material that is utilised, this efficiency can lead to reduced material waste.

Quality Control: Strict quality control procedures carried out in a regulated production environment are advantageous to pre-cast concrete. Consistent quality is achieved through meticulous monitoring of casting procedures, curing conditions, and proportions during the production process. Because it is mixed on-site, ready-mix concrete may be more prone to quality changes from things like weather or human error.

Impact on Transportation: By minimising the requirement for on-site concrete mixing and cutting down on the distance required to transport ready-mix concrete, pre-cast concrete can lower carbon emissions associated with transportation. This efficiency of transportation is in line with sustainable construction methods, which reduce the environmental effect of material transportation.

Energy Consumption: Compared to the on-site mixing and pouring involved in the manufacturing of ready-mix concrete, pre-cast concrete production might use less energy. Reduced overall carbon footprint is made possible by the controlled production environment, which optimises energy use and resource efficiency during the pre-casting process.

Local Sourcing: Using pre-cast components could help with local sourcing and manufacture, depending on the accessibility of pre-cast concrete facilities. By doing this, transportation distances are decreased, reducing the negative environmental effects of long-distance material transportation and boosting local economies.

Adaptability to Design: Ready-mix concrete offers greater flexibility in modifying the mix proportions, colour, or texture in accordance with project specifications, allowing for greater responsiveness to on-site design changes during construction. Even though pre-cast concrete allows for greater design flexibility, there can be drawbacks after the components are cast and cure.

Lifecycle Considerations: Over time, the sustainability of structures can be enhanced by the long lifespans of both ready-mix and pre-cast concrete. Though they can differ between the two approaches, factors including maintenance needs, reuse potential, and end-of-life recyclability should be assessed in the context of particular construction projects.

RESEARCH METHODOLOGY

Our study aims to identify any gaps in the literature that call for additional research by reviewing and analysing sustainable material use in the building industry supply network. A review of the literature is employed as the research approach to accomplish these goals. We reviewed papers that addressed sustainability evaluation in the building sector from various journals and sources. The research method is broken down into three parts in order to accomplish the goal of the study. The first step is to look through and choose journal articles. The construction sector and sustainability evaluation were the search and selection keywords. Different recognised database was used for the search. During the search process, further restrictions pertaining to the publication year of the paper between 2015 and 2024 were implemented. The second procedure focuses on categorising the papers according to where they are in the building industry.

The next step is to apply theme analysis to analyse those papers. There were four main topics that were used: assessment objects, assessment instruments, assessment indicators, and results presentation. The first theme is the object of assessment, which lists procedures, practices, or policies that have been evaluated in the literature. The second element is assessment tools, which show the concepts, techniques, and equipment utilised in the evaluation process. The third theme is “indicators for assessment,” which refers to the standards by which evaluations are made. The fourth subject is “presentation of assessment result,” which deals with how the results are made known and which conclusions they bolster.

ANALYSIS

Finding sustainable building materials for the construction industry can be accomplished through the exploration of non-traditional and alternative building materials. A thorough framework for assessing the sustainability index of building materials is offered by the Central Public Works Department’s 12 parameters, which take into account variables including recycled content, embodied energy, local availability, and environmental impact.

The materials that are being explored have a variety of qualities and environmental benefits. These materials include bamboo, cork, hempcrete, mycelium, pre-cast concrete, ready-mix concrete, recycled glass, recycled plastic, and terrazzo. Bamboo is unique because of its versatility, capacity to absorb carbon, and financial sustainability. Because of its fire-retardant, abrasion-resistant, waterproof, and lightweight characteristics, cork is a practical and environmentally beneficial material.

Hempcrete is a sustainable alternative to concrete that is strong enough and weighs a lot less. It also works well as an insulator. A fungal network called mycelium exhibits resilience to mould, fire, and water and can take on a variety of morphologies when coupled with pasteurised sawdust. The exploration of ready-mix and pre-cast concrete offers insights into off-site and on-site manufacturing techniques, each of which has benefits in terms of resource efficiency and construction time.

In the process of making cement, recycled glass shows to be a competitive substitute for natural aggregates, helping to create concrete types that are more environmentally friendly. Recycled plastic is a versatile material that can be found in many building materials, including lumber, concrete, bricks, and sheets. Terrazzo is a composite material that can be used for stairs, countertops, flooring, and other areas. It is made out of marble, granite, quartz, glass, and other materials.

The comparative analysis demonstrates how various materials have evolved and been adopted at different phases. While some, like cork and bamboo, are fully substituted and have achieved popular acceptability, others are still in the experimental stage or are used in

conjunction with traditional materials. This complex knowledge highlights how crucial it is for the construction sector to continue with research, innovation, and teamwork in order to fully realise the potential of sustainable materials.

CONCLUSION

The assessment emphasises how urgent and important it is to switch to sustainable building materials in order to address the environmental issues brought on by resource depletion and climate change. By offering a systematic method for assessing the environmental impact of building materials, the CPWD's 12 sustainability standards help steer the construction industry towards more environmentally friendly practices.

The materials covered offer a variety of characteristics and ecological advantages, offering choices for various building requirements. It is imperative to recognise that no material is a cure-all, and that the most sustainable solutions can come from a combination of these materials combined with thoughtful design and building techniques. Continuous investigation and advancement concerning non-traditional and alternative building materials show a dedication to discovering novel solutions. The building sector has the ability to drastically lessen its environmental impact and contribute to a more sustainable future as these materials improve and become more widely accepted.

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