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Hard rock excavation without blasting for civil engineering and mining projects

In India, various mega infrastructure projects are upcoming for development and growth of the country. Most of these projects are in metros' or midsize cities. With huge population in the country, mega infrastructure civil engineering are in close proximity to community. Mining is also required to be carried out close to populated villages. Although blasting is most economical, adverse environmental impacts such as fly rock, ground vibration, air blast cannot be completely ignored and eliminated. This paper illustrates existing established technologies and various upcoming technologies which are blastfree and are environment friendly. At initial stage planning excavation, determining compressive strength, tensile strength, geological strength index are essential to decide type of excavation method. Surface miner for coal and limestone mines, ripper dozer, hydraulic rock breaker for secondary breaking are successful for more than two decades in India. Foam injection, plasma technology, chemical methods are emerging technologies. Impact hammer for primary breaking can be deployed in many mines in the country in the vicinity of local community. Excavation without blasting is the present need of technological requirement which is also well accepted as environment friendly.

1. Introduction

Excavation without blasting concept needs to be adopted in various civil engineering and mining projects for eco friendly and reducing the impact on local community surrounding the project [1-4]. Traditionally, hard rock excavation at civil engineering projects or opencast mining being site specific, requiring different size and frequency of blasting based on the production level. Mining causes invariable causing great environmental damage - land degradation, imbalance of ecosystem, noise-air and water pollution, disruption of water regimes, deforestation, landslides in hilly terrains, uprooting human habitant/ settlements, damage to sites of cultural, historical and scenic importance and the list can go on. The magnitude of these adverse environmental effects would vary depending upon the scale of operations, geological and geomorphologic settings, operation technology, and land use pattern of the natural resources system. Globally the mining industries have witnessed tremendous technology driven transitions from the past couple of decades and are strongly focused on the sustainable eco-friendly mining which will have least impact on the environment, flora fauna and the nearby communities. As per the conventional practices the breaking of the hard rocks are through the means of drilling and blasting process. 90% of limestone deposit in the country is of hardness beyond 50 MPa and uneconomical to mine by surface miners, ripper or even hydraulic breakers. However, various experimentation were carried out for developing techniques in mining without blasting due to certain unavoidable site constraints. Research efforts continued to develop mechanical excavation tools. Also many mining companies already adopted the state-of-the-art technologies as blast-free mining operation though the cost of the mining is prime concern in this regard, the detailed study on the rock characteristics and scale of mining decides the type of methodology to be adopted. There are many blast-free mining technologies available at present like mining through surface miner, primary rock breakers, bucket wheel excavators, vibratory rippers and mechanical impact breakers etc. Blasting causes invariable causing environmental impact due to - ground vibration, fly rock, airblast and dust, fumes which is given in Table 1.

Followings are certain advantages of using excavation without blasting concepts:

Productivity

- Continuous excavation operation without any blasting and associated clearance
- No stoppage for blasting
- Optimal yield from the approved mining volume
- Increase in primary crusher output
- More flexible planning

Cost reduction

- Reduction in the security requirement for explosives storage

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Table 1 Environmental hazards due to blasting [4,5]

Type of hazard	Possible impact	Common causes
• Fly-rock,	Property damage, serious injury, loss of life	Geological conditions, over charge of explosives, stemming length, back break
• Ground vibration	Annoyance to public, cracks in property	Exceeding max charge/ delay
• Air blast	Annoyance to public,	Use of detonating fuse, glass pane breakage
• Fumes, dust	Local hazard	Dry holes, improper initiation of ANFO

- Downsizing crushing equipment
- Completely dropping requirement of the primary crusher
- Systems which utilize continuous conveyor for transportation
- Simplification in procedures with authorities for obtaining statutory approval

Quality enhancement

- Reduction in percentage of fine size and meeting required coarser gradation of minerals and improving sales turnover
- Monitoring, controlling and reliability estimating distribution of gradation in different grain size
- Meeting quality standards with repeatable results
- The deposits can be mined selectively

Improvement in environment

- Elimination of emissions which may last for longer period
- Simplification in mining method for winning resources being utilized
- After closure of mining operation to restore for future utilzation
- Protection of the rockmass which is surrounded

Safety

- Elimination of environmental hazard such as flying rock
- Closing mining sites which are not essential

2. Selection of rock excavation process, machines

Fig.1 shows the process in which excavation process for blast-free mining is selected for a particular mining site during first stage objectives of excavation process are set. Selected process needs to be economical for sustained mining operation. Rock excavation process is adopted based on rock properties, geology, production volume, mine design consideration. Adverse climatic conditions are considered during planning stage to meet annual targets. Energy static and dynamic is shown. Energy source may be electrical, mechanical, pneumatic, thermal, chemical or mixed. Further various rock breaking systems are shown schematically.

3. Selection of surface miners

Two major parameters are considered while selecting surface miners. Most of the coal production in surface mines is through surface miners. Limestone mines relatively soft to medium hard where surface miner is deployed.

Geotechnical parameters which consist of (ucs-uniaxial compressive strength), tensile strength, percentage of moisture, abrasivity, brittleness, stickiness and percentage of silica.

Rock properties are determined through laboratory investigations consisting of (PLSI - point load strength index) with BEMEK tester and Schmidt hammer for Rebound Test for knowing strength of rock. Scan line survey is carried out at the face generated by the surface miner and the test to find out the discontinuity.

4. Rippability based on excavability index

The excavability index depends upon mass strength number, (RQD - rock quality designation), number of joint sets, relative ground structure number, joint roughness number, and joint alteration number (All with Q – system) [9].

(P Wave) which is compressional in nature is correlated by survey

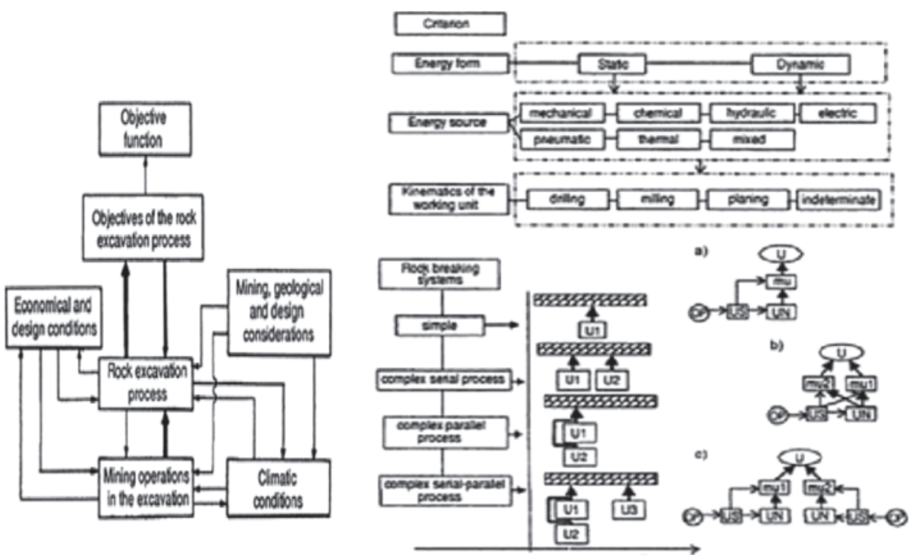

Fig.1 Selection of rock excavation process and machines, energy source and rock breaking system [6]

TABLE 2 FACTORS AFFECTINGABILITY OF SURFACE MINER TO CUT [7]

Rock/Rock Mass Parameters	Machine Configuration	Type of application
Moisture Content, Density, Brittleness, Unconfined Compressive Strength, Point Load Index, Young's Modulus, Fracture Energy, Toughness Index, Brazilian Tensile Strength, Sonic Velocity, Abrasivity (Schimazek-F,Cerchar) Volumetric Joint Count, Stickiness of Material, Specific Energy of Cuttability	Cutting Tool Configuration – Rake Angle, Attack Angle, Clearance Angle and Tip Angle, Pick Lacing, Type of Pick(point attack), Number of Picks, Tip Material; Drum Weight, Engine Power, Nature of Coolant for Tips etc.	Mode of Operation (Wind Rowing/ Conveyor Loading), Length and Width of Operating Area (Select Machine Travel Method), Operator Skill, Specific Requirements (Dry/Wet, Fragmentation Desired and Output)

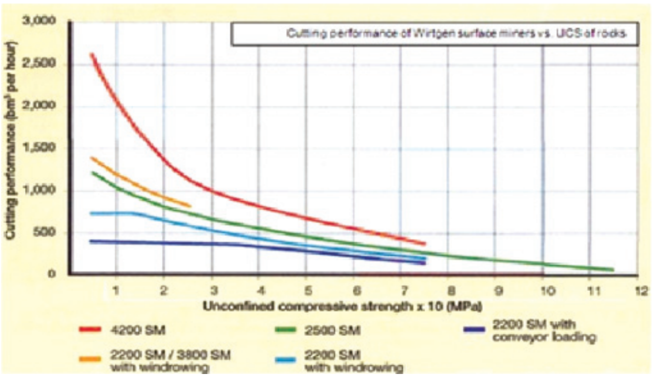

Fig.2 Unconfined compressive strength (UCS) Vs production rate of surface miner [8]

Assessment of rippability based on excavatability index (Kirsten, 1982)

Excavatability Index	Possibility of Ripping
1<N<10	Easy ripping
10<N<100	Hard ripping
100<N<1000	Very hard ripping
1000<N<10000	Extremely hard ripping advised blasting
N>10000	Blasting

Fig.3 Ripper dozer with excavability Index [9]

Fig.4 Application of hydraulic breaker

which is done through seismic refraction and this is recognized tool for selecting ripper dozer in many cases. In many R&D organizations with increase in instrumentation technology, selecting ripper dozer has become more scientific and any scientific study provides zones which can be marked for deployment of ripper dozer.

5. Hydraulic rock breaker

Various manufacturers are available for supplying hydraulic rock breakers mounting on back hoe excavators. Suitable application for breaking boulders to avoid secondary blasting. Output 100 to 200 Tph. Operating pressure is 300 Psi.

6. Controlled foam ejection

In this method, high-pressure foam starts to create pressure and propagates facture in the hard rock which is controlled. Smaller depth hole is drilled in a rock which is target for breaking. A barrel is inserted to meet sealing at the bottom of hole and the same is sealed. In this method, hole foam injection is carried out. The pressure created by this method inside hole is more than pressure created by small explosives.

Air blast and fly rock are reduced and thus allowing application in urban and environment sensitive area. Controlled foam injection (CFI) method uses as high as 83 MPa (12,000 psi) pressure when breaking a hard granite. Breakage efficiencies of 0.06 m^3 to 0.24 m^3 per break observed during trials [10,11].

7. Rock breaking using chemical method

Expansive Mortar which can fracture rock or concrete with expansive force of 15,000 psi (1034 kg/cm^2). Productivity of mechanical breakers is also increased by fracturing rock. Product can be used for pre-splitting rock in sensitive conditions. Expansive mortar can be used in dry and watery conditions hole diameter up to 76mm.

Application: For boulders, depth of hole is 65 to 70% height of boulder. 10 times hole diameter is distance between holes and holes are drilled in square or diamond pattern. Presplitting mortar is added to holes and after 6 hours, boulder or surface is cracked.

7. Plasma technology for rock breaking

A group of scientists at the Korea Institute of Geology, Mining and Materials established the plasma blasting method for rock fragmentation [13].

8. Impact hammer

The impactor breaker works on drop-ball method. The dead weight is lifted with the help of hydraulic cylinder and released/drop is by gravitational force. The movement of channelized/controlled in box frame. Excavator functions for placement only during hammering. During extraction/removal of broken material, the bucket cylinder function is used and the energy requirement is significantly low. The principle of

Fig.5 Rock breaking using plasma technology [14]

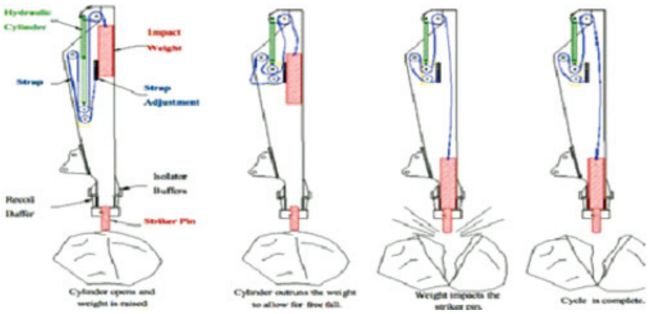

Fig.6 Principle of operation of impact hammer [15]

operation of impact hammer is explained in Fig.6.

Impactor breaker energy levels, number of blows per minute, class of excavator and size of bracket depends upon make and model. The details are given in Table 3 (fracturum, rockteck, surestrike, terminator).

Table 3: Comparison of technical specifications of impact hammers for primary breaking [15-19]

Particulars	Minimum	Maximum
Energy level (K Joules)	34	200
Number of blows per minute	7	16
Operating weight T	3.5	12
Operating pressure (kg/cm^2)	140	350
Excavator class T	18	80

Impact hammer specifications, uniaxial compressive strength and discontinuities in rock mass are useful in prediction of breaking rate of impact hammers. Rebound value of Schmidt hammer is a representative KPI (key performance indicator) of rock characteristics and provides important correlation with breaking rate (Bilgin et al., 2002). Geological conditions in hard rock deposit may vary from top weathered rock to compact rock at the bottom portion of the deposit. Information on RQD and uniaxial compressive is essential to select right model of impact hammer for delivering adequate power to break and desired productivity or breaking rate.

Uniaxial compressive strength and Schmidt hammer rebound value can be correlated for a given deposit. During operation stage, Schmidt hammer rebound value can be found easily based on field samples.

9. Conclusions

1. Blasting has fly-rock, ground vibration, air-blast, dust and fumes as hazards.
2. Various minerals produced in the country arelimestone, iron ore, coal, granites, basalts, quartzite, etc which may be close to community and require blast-free mining
3. In environmentally sensitive areas, various blast-free excavation technologies are being tried for more than two decades
4. Study of compressive strength, tensile strength, geological strength index for excavation are necessary to decide type of excavation method
5. Surface miners, hydraulic rock breaker, rippers are suitable for certain rock types with geological features (very blocky to disintegrated), for blast-free mining
6. Hydraulic rock breaker is used mainly for boulder breaking. Further development required for primary breaking.
7. Rock splitting mortar with hydraulic rock breaker can give advantage of rapid breaking and needs more R&D experimentation.
8. Impact hammer technology for primary breaking is suitable technology which is being used in some of limestone quarries. The same technology can be used for civil engineering projects which are close to community.

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SANDSTONE BODIES DISTRIBUTION IN SEQUENCE STRATIGRAPHIC FRAMEWORK OF JURASSIC SANGONGHE FORMATION IN MOXIZHUANG AREA, JUNGGAR BASIN

(Continued from page 226)

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