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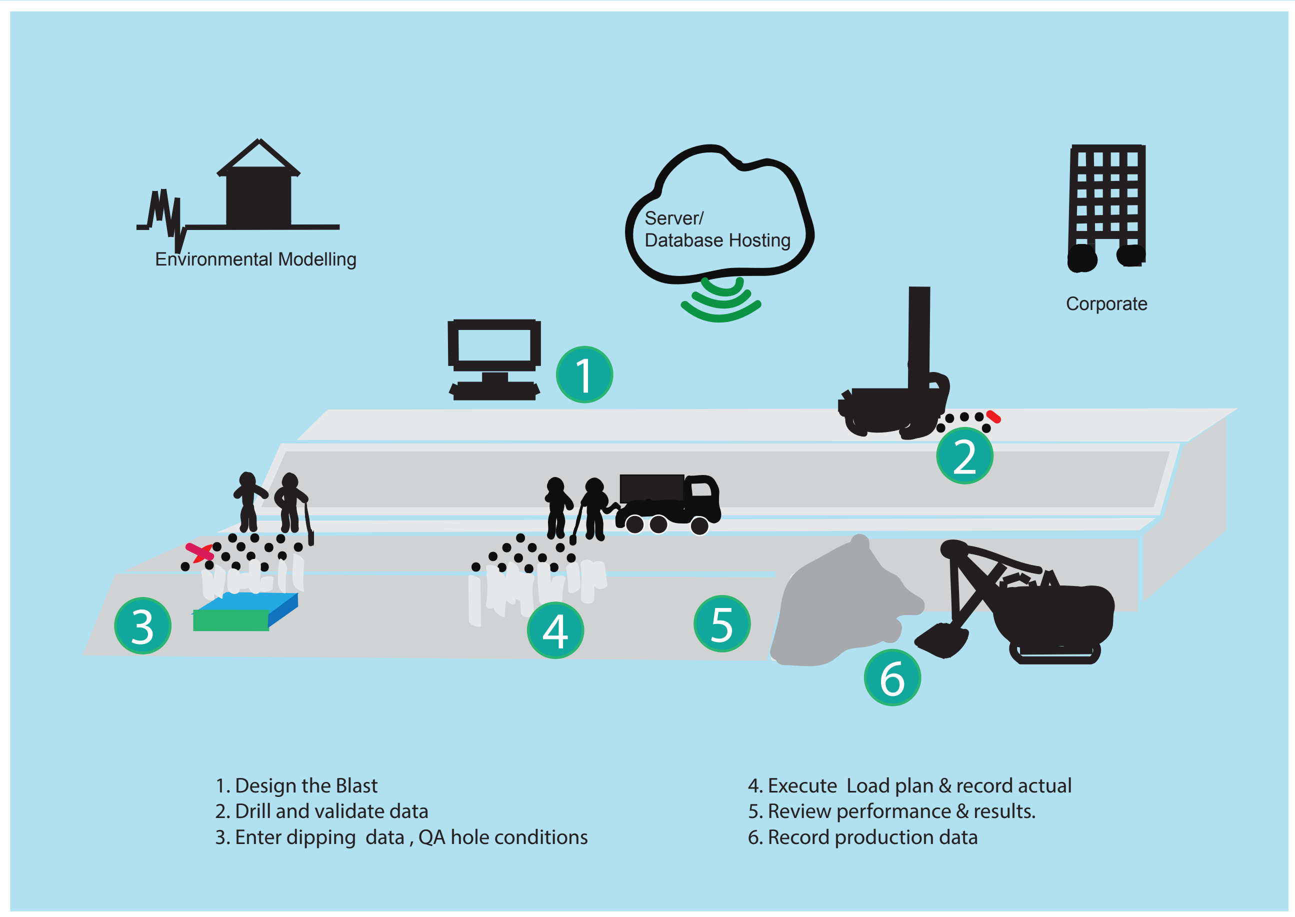
JOURNAL OF THE EXPLOSIVES SAFETY AND TECHNOLOGY SOCIETY (VISFOTAK) INDIA, DEALING WITH SAFETY AND TECHNOLOGICAL ASPECTS OF THE EXPLOSIVES INDUSTRY



Source : Maptek Blast- Logic.
(Instantly capture, analyse and share data at critical stages in drill and blast process ,thereby , increasing productivity , reducing costs , improving safety , and overall efficiency , with continuous improvement)

Cover Feature : Real-Time Digitalized Measurement and Monitoring of Blast Performance : An Over-View with Case-Studies !

MISSION STATEMENT

"To proactively establish a sustainable interface between all major constituents of the Explosives Industry : The Users, the Regulatory Bodies, the Manufacturers, the Academic and Research Institutions, et.al., in order to foster and promote modern concepts and practices, relating to Safety and Technology of Explosives."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Editorial...

" We are what we repeatedly do.Excellence then is not an act but a habit – Aristotle "

I am extremely grateful to all the members of the Editorial Board that despite Covid-19 pandemic, they unrelentingly provided their full support in the preparation of this edition; and not the least, to the authors who contributed articles and case studies !! Providentially, we live in the 'Digital Age', and been witness to the development of new sustainable core competency of organizations and governance developed through "*Convergence Innovation (CI) powered by the exponential fusion effect of the various objects, technologies, ideas, and strategies"* in order to combat the pandemic and its after math: 'the first digital health crisis in history' ! It immediately brings to mind the prophetic words of Bill Gates in his seminal book 'Business @ the Speed of Thought' – *"You are probably viewing hard ware and soft ware as a way to solve specific problems. But like a living organism, an organization functions best if it can rely on a nervous system that will instantly deliver to the parts that need it . In clear non-technical language 'Business @ the speed of Thought' shows you how a digital nervous system can unite all systems and processes under one common infrastructure, releasing rivers of information and allowing your company to make quantum leap in efficiency , growth and profit."* Make no mistake, we are witnessing a 'New Normal' in strategic planning of future businesses and Society at large !!!

The previous three editions as well as this edition of the Journal provide a global perspective on the progression of innovative electronics / digital technologies in commercial explosives business; and in particular, the last two decades have witnessed an evolutionary paradigm shift from the traditional focus on explosives products as saleable commodities, to new business offerings of 'Experience Economics' of 'Virtual Reality' of delivery and performance of marketable sets of explosive product systems and services, tailored to 'what a customer wants' !!! Consequentially, for the first time, the modern 'Rock Blasting Triad' comprising PLC operated blast hole drills with 'Measuring while Drilling systems', Digitized Blast Design Modeling and Simulation, and programmable Electronic Blast Initiation Systems, been integrated within one common infrastructure, thereby dynamically uniting all systems and processes of drilling and blasting enabling smart blasting solutions with precision and reliability.

Whereas, in comparison, the explosives industry and its major business constituents in India, appear to have merely scratched the surface, and singularly bereft of a 'Technology Vision' compatible with best global practices. The industry remains shackled in a 'commoditized business' syndrome which flies in the face of India's current ranking amongst the top five major producers of industrial explosives in the world. Attention is invited to the various recommendations contained in the previous three editions referred to above. It's about time that the industry and all its stakeholders collaboratively switch to 'Fast Forward' mode and address the challenge !

Best wishes for 2021

Ardaman Singh

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IITBHU	39	27	34
NITK	59	41	0
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Sentiment analysis of the vision statements of the institutes

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COVER FEATURE

‘Real-Time’ Digitalized Measurement and Monitoring of Blast Performance : An Over-View with Case Studies !

1. New technologies bring with them new regulatory challenges and if not met at the cusp then there are serious implications of ‘opportunity costs’ to the economy in terms of prospective financial benefits denied or foregone by not allocating resources towards superior technical specifications and operating procedures that fully take on board the best global developments / practices.

2. The ‘cover features’ of the three immediately preceding editions of the Journal serially dealt with significant developments in progressively digitalization of the explosives business ; the salient aspects are briefly recapped below for ready reference

2.1 It’s true , given the overwhelming primacy of ‘Safety and Security’’ above everything else, the explosives industryperforce been cautiously conservative; but significantly, nonetheless, been also a ‘ creative industry’ , through individual skills and innovations, readily adapting such emerging technologies at any given juncture that promised to deliver sustainable and improved safety and economic dividends. For example : the development of first automated continuous explosives manufacturing process, relate to the production of Nitroglycerin with the objective to reduce the number of personnel exposed to the hazardous process and to cut down on the amount of explosives present in the installation in the above context, it’s also appropriate to highlight a historically significant technological confluence , often missed out, and that is that , the advent of industrial electronics / digital technologies, had been almost contemporaneous with the development of a whole new genre of much safer, free flowing, bulk AN-Blasting Agents, fostering an extremely favorable industrial eco-system that enabled unprecedented advances in safety, performance and economy of the explosives business:-

2.2 Progressive Digitalization of Explosives business :

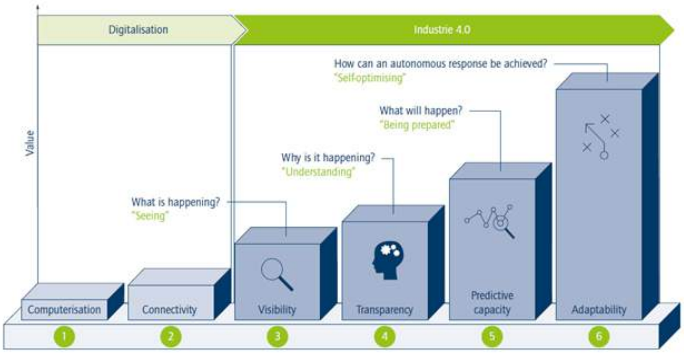
TABLE 1

The chronology of development is shown in Table-1 below :-

Period	Application
1970s	* Computer modelling of Blast Design * Electronic sequential Blasting Machine introduced . * First electronic seismograph devel oped by Dalls Instrument.
1980s	* Beginning of the development of programmable electronic delay detonators. * Lase profiling of benches for blast design and analysis developed in Britain.
1990s	* PLC operated drills for surface mining * GPS hole-spotting
2000s	* Commercial induction of Programmable Electronic Initiation System. * Digital Age of ‘Vitual Visualization of Drilling & Blasting Processes.

2.3 If one were to currently rate the explosive industry on the six-stage development ‘Maturity Index’ path of progressive digitalization, developed by the Academy of Science and Engineering (Acatec) , Germany , see Fig-1 , the outcome would be uneven depending upon the ‘Technology – Safety’ conundrum and the challenges uniquely associated with each of the operational domains of the explosives business briefly dealt below :

Figure 1: Stage in the Industrie 4.0 development path



(A six-stage development path of ‘Digitalization Maturity Index’ developed by the Academy of Science and Engineering (Acatec), Germany : the evolution from simple digitization (adopting industrial computers , programmable logic circuit controllers and connecting them on line) to being able to collect data , to understand what’s happening and why in real- time , to reaching a point of anticipating and predicting , to self – optimizing autonomous responses could be

a) Automation in manufacturing and handling processes :

The unique rheology of the modern genre of blasting agents , that is , the flow characteristics of solid and fluid ingredients under applied pressure or strains , has enabled modular designs for bulk manufacturing processes in a continuous flow easily adaptable for automation and digital control systems for optimization with complete safety including the

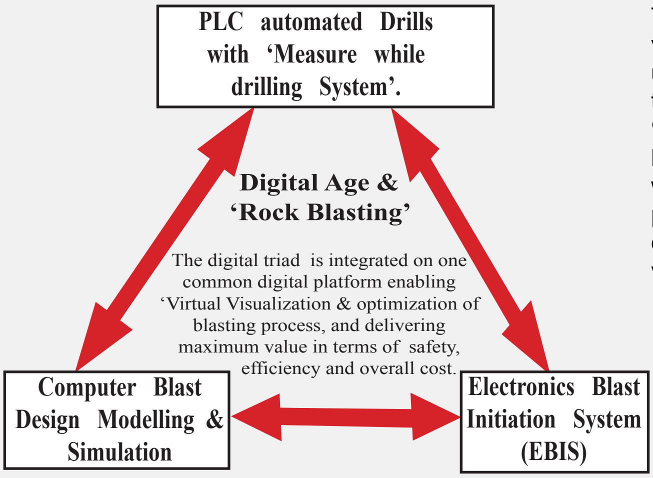
(The “Cover Feature” is an ‘In-House’ contribution, as part of the running serial on “Challenges and Issues” of the Explosives Industry - Editor)

capability to modify formulations on-line to match specific requirements. Further, unlike the traditional batch processes, the 'in-process ' volume of active formulations can be minimized and fully contained thereby significantly reducing the extent and severity of collateral damages to life and properties in the event of an accident during operations.

b) Smart Blasting Solutions with precision and Reliability :

For the first time , the Rock Blasting Triad of ' Drilling, Blast Design and Blast Initiation' could be brought on one integrated common digital platform , illustrated below (Box-1) , forever transforming the explosives business offerings of 'Product Systems and Services (PSS) to an enormously value adding virtual experience of delivery and performance specific to a customer's requirement, in order to deliver maximum value .

Digital Age & 'Rock Blasting' (Smart Blasting Solutions with Precision and Reliability) **Box - 1**



The programmable Electronic Blast Initiation System (EBIS) is the veritable 'linchpin' of the digital framework, endowing unique attributes of 'accuracy and precision' over a wide range of delays from 1ms to 10,000ms with increment of 1ms., within an accuracy range of 0.01 % of nominal delay. Thus, the available option to deploy small inter-hole delay has vastly opened up the scope for "practical use of wave propagation and dynamic fracturing of rock through overlapping, interaction and superposition of shock waves", and consequently enormous benefits across all the major operational domains, viz:-

- Improved environment impact control ;
- Accurate and consistent control over rock breakage viz, fragmentation, throw , swelling and loading out.
- Improvement in mining efficiency and productivity by enabling larger blasts than hitherto feasible; and not the least,
- Overall, resultant improved 'Cost Benefits'.

c) Digital Analytics as Key Value Drivers in Data Management :

Some data provides insight after the fact , what is known as 'Lagging Indicators', historical in nature and one can't go back and change it.! The other kind of data analysis uses predictive data by subjecting large numbers of real-time observations and incidents to data analysis, and making it possible to predict the likelihood of safety and other operational incidents with surprising accuracy, revealing factors which may not have been considered.

3. Real-Time digitalized Measurement and Monitoring systems of Blast Performance

3.1) Global Developments :

i) 3-D face profile, hole surveys and in-hole surveys to provide relevant geo spatial rock characteristics which are primarily affected by geological, geotechnical variations with spatial uncertainties, and duly factored in the blast design .

ii) On-site Bulk Explosive Analyzer : a real time game changer in explosives chemistry analysis assuring on-site quality control of explosives.

iii) In-hole Sensors for measurement of detonic characteristics of explosives used , viz, Velocity of Detonation ; Initiation-time / delay scatter / etc; - in-hole detonation pressure / near- field peak particle acceleration; making it feasible to quote performance parameters for explosives based on actual realistic field measurements than the theoretical values

iv) Blasting Seismographs with GPS Event Synchronization facility : to track the timing of sequential detonation in milliseconds to provide a detailed waveform showing where peak readings occur and then apply it to design appropriate solutions and delay pattern.

v) Rock breakage / Fragmentation Analysis System employing Digital video recording of a blast to measure fragmentation , duly assessed and evaluated with the help of soft ware packages developed for the purpose.

vi) Environmental control and safety :
Application of Drones enabling real time communication of blasting results from the stand point of environmental control and safety.

3.2) Developments in India :

Specifically addressing the Indian environment, a heterogeneous mix of small, medium and large operators, still early days, the progress has been lackadaisical, and the industry largely been shackled in the out-dated 'Commoditized Business Economics' with serious implications of huge 'Opportunity Costs '.

There are unique challenges ! Aside from making provision for requisite investment, new smart digitalized solutions would have to be developed to upgrade a variety of existing explosives manufacturing and handling processes / systems; and as importantly if not more, beside the challenges of 'Technology', it's also about people with relevant knowledge to make it work, and therefore, investing in appropriately qualified personnel is a critical component !

3.3) 'Case Studies' :

Following case-studies appear as 'Supplements' with the cover feature.

1. **Blast Performance Monitoring Using AI Powered Smart and Intelligent Sensors :**
   Dr. Ajay Kumar Jha, President, BioID GmbH, Germany , and Carlos Orlandi ,Director, TiramSpa,Chile

2. **Technical Ready Mining –Tata Steel's Perspective**
   Devraj Tiwari , Sr. Manager, Regulatory Affairs
   Bhaskar Bandyopadhyay, Head, IT Services
   Ankan Mitra, Head, Regulatory Affairs
   Pankaj Satija, Chief Regulatory Affairs Tata Steel Limited

3. **Improving Mining Efficiency with Application of Technology in Drilling & Blasting Operations**
   Dr. Sushil Bhandari, Formerly Professor of Mining, JNV University,Jodhpur and Amit Bhandari, Managing Director, MineExcellence, Melbourne

4. **Optimization Through Audit: Evaluating Rock Characteristics, Monitoring Explosive's Performance and Blast Outcomes**
   M.o. Sarathy (former Head of Technical Services , IDL Industries Limited, Hyderabad)

Editor

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1. How to Drive Mine Efficiency with Digital Drill and Blast Data, Maptek Blast Logic .(2020

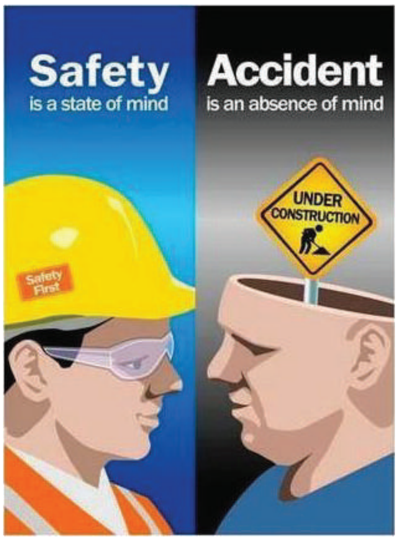
2 . Blast Performance Monitoring : Exchem Explosives, UK

3. Digitizing the blasting process: Aggregate Research.com (2020)

4. Advances in Rock Blasting Instrumentation: A Technical Note by Jagdeepak Sharma , Ultra-Enviro Systems , New Delhi.

5. How can Drill & Blast Opertations make Mining More Sustainable ?Jon Lawson, 2020

6. Blast monitoring instrumentation and analysis technIques , with an emphasis on field applications. By R. Frank Chiappetta



Blast Performance Monitoring Using AI Powered Smart and Intelligent Sensors

Dr. Ajay Kumar Jha
President, BioID GmbH, Germany

Carlos Orlandi
Director, TiramSpa,Chile

Abstract

Smart and intelligent instrumentation powered by Artificial Intelligence can play the role of a harbinger for achieving higher blast performance in any surface mine enhancing overall mine productivity and profitability significantly. The application of innovative technologies, real time productivity monitoring geared with advanced data analytics will result in safety, productivity and profitability advantages over conventional monitoring systems in the mining industry. It is an irony that many mining companies are still using the age old practice of powder factor (kg of explosives per cu m of rock blasted) or charge factor (cu m of rock blasted per kg of explosives) for blast performance evaluation, which must be replaced by scientific yardsticks. This paper discusses the use of intelligent sensors using artificial intelligence powered techniques for reliable, quantitative, technical and unbiased blast performance monitoring. The proposed real time methodology of real time blast performance depends on loading productivity, fill factor, digging time, non-digging time, diesel consumption during the digging cycle, diesel consumption during the non-digging cycle, idle time, no of dumpers loaded per hour, passes per dumper, dumper wait time near excavator, dumper loading time for each trip, dumper travel time for each trip and cost of excavation. The paper discusses the concept of AI based monitoring sensors and a use case in a limestone mine.

1.0 Introduction:

The use of powder factor as a performance metric for blast performance monitoring is scientifically and technically incorrect. Companies using normative or guaranteed powder factor for blast performance evaluation appears to be using a non-technical yardstick. Powder factor does not take the diggability rate or ease of digging, muck profile, heave, throw, fragment size distribution, muck pile tightness and overall cost of excavation into consideration. Technically speaking, defining an explosive product on the basis of other measurement metrics namely. "weight strength (absolute or relative), bulk strength (absolute or relative), specific energy (MJ/kg), energy density (MJ/L) is also scientifically inappropriate as they represent a theoretical number for comparison. Limited test facilities are available to determine the explosives energy of commercial explosives using the underwater test. Many of the companies estimate the explosive energy using software such as IDeX, Cheetah, BKW, TDS, Tigerwin, Vixen-I, which are essentially estimating the energy assuming the detonation as Ideal detonation of explosives (Jha et.al. 2013). Somesoftware namely DeNE has tried to estimate the explosive energy considering the detonation as non-ideal detonation of explosives (Neto, 2007). It may be notedthat all such software are estimating the explosive energy to quantify the blast performance as a theoretical estimate. As a result, blast performance on the basis of Energy Factor (kJ/m3) turns out also to be an estimate only.

Many large mining companies either procure or upgrade their Heavy Earth Moving Machineries (HEMMs) used for mineral extraction using Capex (Capital Expenditure) from the approved business plan. The other component Opex (Operating Expenditure) has two components – Fixed and Variable. For any mining project, the Capex and fixed component of Opex is fixed for any mining project and is a committed expenditure irrespective of mineral production. It may be generalized that the variable component of the Opex depends heavily on the cost of excavation i.e. drilling, blasting and loading cost, which influences the overall mine productivity and profitability significantly. On another hand, some of the large mining companies hire vendors by outsourcing the mineral extraction process to outside contractors, who deploy their own resources for mineral winning by entering into business contracts. Such vendors primarily estimate the cost of excavation i.e. variable cost as other components of cost of excavation involving HEMMs and other resources are reasonably constant to vendors also. The offered price by vendors heavily depends on the cost of excavation per m3 or per tonne or per hour. Commercially speaking, the cost of excavation per m3 or per tonne or per hour plays the most significant role for evolving the most suitable business model for any mining project and real time monitoring using smart instrumentation and advanced data analytics can catalyse such decision makings.

2.0 Mine Rock Mass Description:

The scientific study was conducted in one of the mines of UltraTech Cement Limited, the third largest cement manufacturer in the world with a consolidated capacity of 116.75 MTPA. The cement plant owns an integrated limestone mine to achieve the production capacity of 4.0 MTPA, manufacturing clinker and cement (OPC-43, OPC-53 and PPC grades).

2.1 Rock Mass Characterization

Ambrogeo 24 Channel engineering seismograph with HGS geophone was used to run the traverse with geophone spacing as 5m. A small diameter commercial explosive (25 mm diameter) was used to generate the stress waves. The rock impedance profile, density profile, seismic profile, VOD profile for limestone project are shown in Figure 1,2,3,4 respectively.

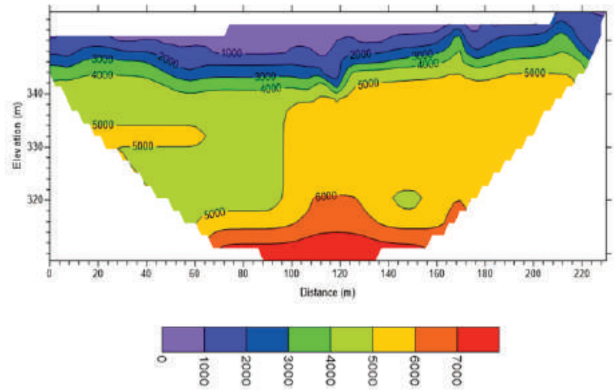


Figure 3 - Seismic Profile Spectrum Plot

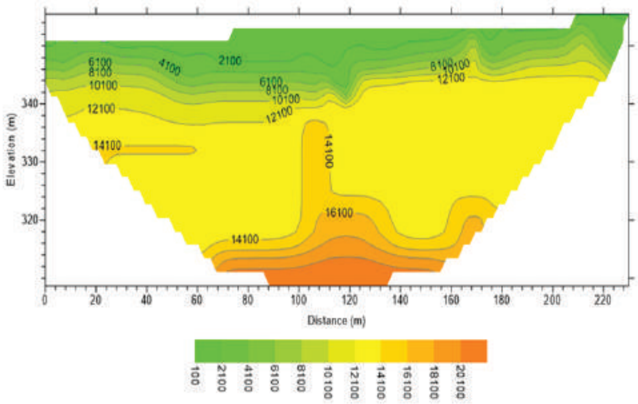


Figure 1 -Rock Impedance Plot

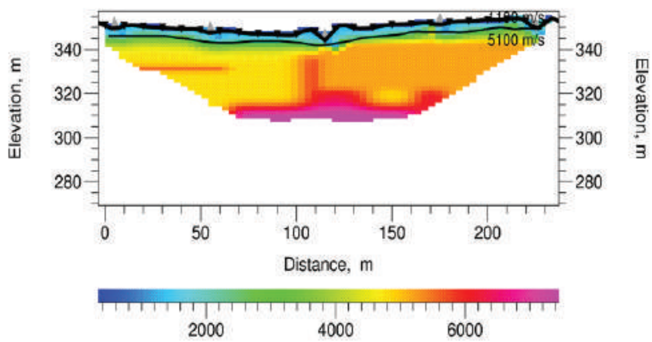


Figure 4 - Layer wise VOD Profile Plot

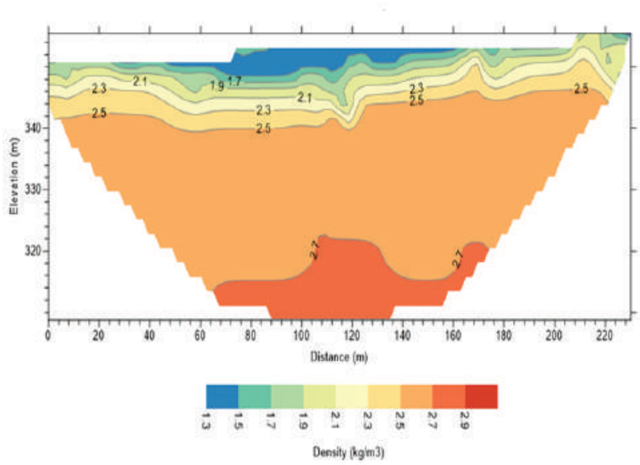


Figure 2 -Density Profile Plot

2.2 Dynamic Rock properties of the Rock mass under Blast Loading:

For dynamic uniaxial compressive strength tests (UCS), core samples of 25.4 mm in diameter should be cored from in-situ rock blocks (Mishra et.al. 2012). Core samples were saw and polished to 25.4 mm long cylinder. For dynamic tensile strength tests, core samples with 40 mm in diameter and 18 mm in thickness were cored from in-situ rock blocks. A notched semi-circular bend (NSCB) specimen was used for dynamic mode-I fracture test with 40 mm diameter core sample and 18 mm thick disk. A notch was subsequently machined to the semi-circular sample, located on the center of the original disk and perpendicular to the diametrical cut to conduct such tests. The details of rock samples and dynamic properties of the rock mass are shown in Table-1, which suggests that geological formation at the mine site was very hard and abrasive.

Table 1 : Details of Rock Sample and dynamic properties

Sample No.	Name of Formation	Stress Intensity Factor (MPa*m1/2)	Limiting Fracture Velocity (m/s)	Dynamic Constant (m)	Dynamic Constant (a) (MPa*m1/2)	Dynamic Constant (b) (s)
1	Dolomitic Limestone	3.56	1061	0.84	1.71	1.08E-04
2	Limestone	1.98	820	0.48	1.50	7.28E-05
3	Pegmatite	2.01	811	0.72	1.10	1.87E-04
4	Limestone	1.32	652	0.52	1.03	2.75E-04
5	Limestone	1.26	682	0.54	1.77	4.82E-05
6	Limestone	1.69	968	0.49	2.17	1.25E-04
7	Limestone	1.89	826	0.68	2.14	1.03E-04
8	Siliceous Limestone	1.99	796	0.62	1.95	7.11E-05
9	Limestone	1.75	825	0.61	0.44	5.31E-04
10	Dolomitic Limestone	1.02	1052	0.17	2.73	3.21E-05
11	Dolomitic Limestone	1.81	1500	0.23	2.52	8.27E-05
12	Limestone	1.31	651	0.51	1.04	2.74E-04
13	Limestone	1.23	679	0.52	1.79	4.85E-05
14	Limestone	1.71	979	0.51	2.19	1.24E-04
15	Limestone	1.90	825	0.67	2.15	1.06E-04
16	Limestone	1.96	818	0.47	1.48	7.26E-05
17	Limestone	1.28	649	0.49	1.06	2.68E-04
18	Limestone	1.27	690	0.525	1.80	4.78E-05
19	Limestone	1.76	984	0.52	2.21	1.27E-04
20	Limestone	1.98	834	0.69	2.18	1.13E-04
21	Limestone	1.88	811	0.45	1.47	7.21E-05
22	Limestone	1.81	988	0.54	2.23	1.21E-04
23	Limestone	1.95	830	0.66	2.17	1.09E-04
24	Siliceous Limestone	1.93	791	0.61	1.93	7.08E-05
25	Dolomitic Limestone	1.78	1482	0.22	2.51	8.23E-05

3.0 Instrumentation using Smart and Intelligent Sensors:

Real time monitoring of blast performance using smart and intelligent sensors, advanced analytics and Atificial Intelligence will be a game changer in blast performance monitoring (Pip 1980). The "Accuload" monitoring system is equipped with multiple non-evasive sensors which are easy to mount, robust in design and rugged in construction with all weather and mine environment compatibility. The intelligent microcontroller fetches data at a timestamp of 1s and sends it to software for real time data analytics. The system supports different data communication modules like Wi-Fi, 4G/3G modem with GPS. The 4G/5G modem with GPS option connects the system to cloud, so that data can be broadcasted and analyzed remotely. The "Accuload" system has a touch screen display which is very useful for parameter settings, viewing parameters online with recorded data. The touch screen display makes the in-cab user interface operator friendly. The specially developed sensors are fitt ed on the bucket, boom, arm, Chassis, hydraulic line, diesel supply line (intake and return) of Komatsu PC 1250 excavator as shown in Figure 5,6,7,8,9 respectively.

Figure 5-Sensors fitted on bucket at strategic location

Figure 6:Sensors fitted on arm and boom of Excavator

Figure 7 -Sensors fitted on Chassis of Excavator

Figure 8 - Sensors fitted on hydraulic pressure lines

Figure 9 - Sensors fitted in diesel supply line (intake and return)

The control unit and data acquisition system of “Accuload” system is connected to 24 V auxiliary port of the excavator to get power. The other salient details of the “Accuload” system is detailed below.

Communication

RS485: 1 Port for 3rd party interface
USB: Programming and data down loading
Ethernet 1 port /Wi-Fi adaptor optional
GSM/GPRS optional

Power Supply

Supply Voltage : 18-28 DC
Current Consumption : <1A
Protection : Reverse supply, Short-circuit

Physical and Environmetal Factors

Weight : 1 kg
Operating Temperature : -10°C to 55°C
IP Rating : IP66
Enclosure : ABS
Location : Driver cabin

The photograph of the load reading unit, control unit with the data acquisition system is shown in Figure 10&11 respectively.

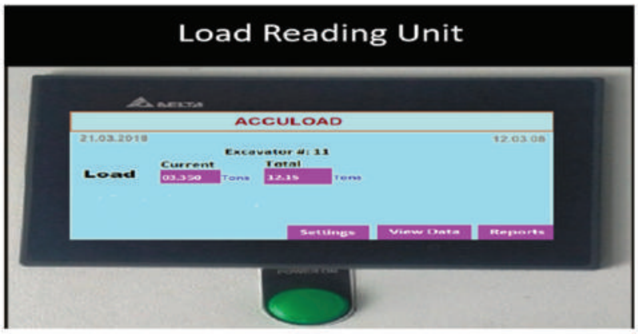


Figure 10-Photograph of the load reading unit

Figure 11-Photograph of the control unit

4.0 Results and Discussions:

The data acquisition system fetches the data from all 12 intelligent sensors at a timestamp of 1s, transmits to Client server using VPN or wi-fi or the internet. A typical format of the data is shown in Table 2.

Table 2: Raw data collected by the Accuload

Time	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
2019.02.20 20:20:16	74.7	57.5	15.8	36	87.66	23.2	43.9	117.7	123.1	178.7	125.3	53.4
2019.02.20 20:20:17	39.2	34.6	19.9	36.5	94.86	19	48.3	113.4	120.3	178.5	94.5	84
2019.02.20 20:20:18	52.6	49.8	13.2	70.2	90.66	35.4	72.5	202.2	122.8	178.3	145.4	32.9
2019.02.20 20:20:19	34.4	27.5	31.4	49.9	92.61	11.9	48.9	144.2	76.7	180.8	0	180.8
2019.02.20 20:20:20	47	39.2	26.6	83.9	81.36	72.8	64.5	106.6	51.7	178.7	106.2	72.5
2019.02.20 20:20:21	34	30	19.9	26.8	91.35	56.4	82.3	85.8	99.2	178.9	79.2	99.7
2019.02.20 20:20:22	45	39	12.4	30.2	89.58	222.9	326	84.2	130.9	180.2	95.3	84.9
2019.02.20 20:20:23	61	51.1	4	18.1	88.83	204.7	308.4	87.4	218.4	179.8	58.5	121.3
2019.02.20 20:20:25	67.1	58.1	0	4	91.83	105.9	143.5	84.4	146.5	178.7	82.2	96.5
2019.02.20 20:20:26	62.6	56.8	29.4	30.5	97.53	116.4	128.9	84.9	154.5	179.5	73.5	106
2019.02.20 20:20:27	85.6	74.7	5.2	10.3	91.5	213.8	299.8	85.6	259.7	178.1	40.5	137.6
2019.02.20 20:20:28	93.6	81.4	8.7	13.8	91.77	146.7	288.8	89.4	206.9	179.3	108.8	70.5
2019.02.20 20:20:29	133.9	123.4	0	0	87.39	119.1	217.1	81.4	218.8	178.1	103.1	75
2019.02.20 20:20:30	119.1	118.2	13.6	14.2	87.66	156.1	262.5	84.7	249.3	179.5	114	65.5
2019.02.20 20:20:31	115.8	98.2	16.3	11.5	86.85	119.3	229.4	82.2	232.3	180	80.9	99.1
2019.02.20 20:20:32	123.8	121.3	31.5	21.4	89.04	139.6	265.5	84.2	282.6	179.8	84.7	95.1
2019.02.20 20:20:33	144.4	135.8	21.5	11.9	92.31	119.1	147.9	73.2	230.1	179.5	102.1	77.4
2019.02.20 20:20:34	141.6	136.7	19.6	1.6	85.53	138.7	85	62.3	187.6	178.7	88	90.7
2019.02.20 20:20:35	159.7	154.6	30.2	11.9	90.21	219.3	60.8	69.6	188.5	178.3	106.7	71.6
2019.02.20 20:20:36	164.7	161.8	40.6	19	90.12	218.1	67.2	69.6	189.7	177.9	92	85.9
2019.02.20 20:20:37	169.9	165.9	43.6	22.3	90.96	216.8	71.3	70	195.2	178.9	34.6	144.3
2019.02.20 20:20:38	172.7	169.8	47.1	25.4	93.42	215.4	75	70	201.4	178.7	84.5	94.2
2019.02.20 20:20:39	174.6	173	52.6	30.1	90	214	78	70.7	203.9	178.9	83.8	95.1
2019.02.20 20:20:40	170.3	173.8	66.6	41.7	89.58	212.2	69.1	71.2	191	178.7	57.5	121.2

The software provided with the "Accuload" system at Client server analyzes the data automatically using deep learning based software. Accuload supports " Add on " to monitor the dumper also by integration using Tx-Rx sytem. This paper discusses the use of "Add on" system also.On the basis of intelligent real time monitoring and advanced analytics, the software provides various reports. Some of the important reports are discussed below.

i) Accuload displays the total loaded quantity, excavator productivity, fill factor, no of cycles, dig time, non dig time, idle time at any point of selected time period. A typical output for excavtor no. 31 is displayed here and on the next page.

Excavator Report

	From Event	2019.02.04	23.00.00
	To Event	2019.02.06	13.47.46

Excavator No. #	31
Total Loaded Quantity (ton)	8045.80
Productivity(tph)	423.11
Fill factor(avg)	0.71
Working time(s)	68457
No of Cycles	1296
Dig time(s)	38890
Non Dig time(s)	25683
Diesel consumption during digging	799.40
Diesel consumption during non digging	492.25
Dig time as percentage of total cycle time	56.81
Non dig time as percentage of total cycle time	37.52
Idle time(s)	3884
Idle time as percentage of total cycle time	5.67

Excavator Report

From Event 2019.02.04 23.00.00
To Event 2019.02.06 13.47.46

Average bucket load time(s)	31.8
Average swing loaded time(s)	6.4
Average dump time(s)	5.0
Average loader cycle time(s)	52.8
Average bucket load(ton)	6.21
Capacity utilization of Excavator(%)	47
Deviation in dig time from standard time(%)	211.76
Deviation in non dig time from standard time(%)	18.51
Cost of loading (INR/BCM)	21.48
Excavator effective time Utilization (%)	49.01

ii) It may be observed also that by making benchmarks/norms in respect of loader productivity/digging rate, capacity utlization of the excavtor can be continously investigated. Typically dig time should be 40-45% of the total cycle time. It may be noted that dig time percentage is more on account of tight muck pile or adverse blast fragmentation, which may be continuously improved by modifying the drilling and blast parameters, if dig time is monitored quantitatively, scientifically and for each blast.

iii) By monitoring diesel consumption during digging can help in optimization the drilling and blasting parameters with continuous improvement. The user can set the customized bench mark in this regard so that improved drill and blast parameters (with use of quality explosives and accessories) can optimize the diesel cost.

iv) By monitoring the non-dig time and diesel consumption during non-dig operation, the operator performance and efficiency can be measured. It can help in devising the proper training plan, incentive and motivational program for operators who are below the threshold set up by management. This will help in continuous improvement in operator performance with healthy competition among operators.

v) By monitoing the idle time, the dumper operator's performance, haul road condition, bench width, optimisation of lead and lift, tyre condition, dumper health can be indirectly investigated.

vi) By integrating "Accuload" with dumper monitoring system, the shovel dumper performance can be optimised.

Dumper Report

From Event 2019.02.04 23.00.00
To Event 2019.02.06 13.47.46

Average pass per truck	10.42
Average truck load time(min)	3.88
Average truck wait time(min)	5.14
Average trucks/hr	12.17
Average Tons/hr	423.11
Trucks Under loaded #	11
Trucks over loaded #	1

vii) "Accuload" supports mine digitization and provides output in form of csv or txt files, which can be made input to any ERP system.

viii) "Accuload" offers a global blast performance monitoring solution which is manufacturer independent as it can be fitted on small to high capacity machines of any make.

5.0 Conclusion:

It is found that "Accuload" based real time and digital productivity monitoring can be advantageous to any project by avoiding the over loading fines, reducing the haulage cost by avoiding the unnecessary trips caused by under loading, idle time monitoring, achieving consistent loading regardless of operator's experience and expertise, monitoring machine stress to schedule preventive maintenance, facilitate loading consistently by maximizing tons moved per day and tones per liter. Mine can make bench specific as well as location specific standards in terms of digging and non-digging time considering rock mass conditions to quantify and characterize blast performance scientifically and reliably. Accuload can help in minimizing the average bucket load time, dump time, swing empty time, cycle time to improve the machine productivity. Monitoring the digging time provides a scientific input to measure explosives and accessories performance and user can set site-specific norms suiting the rock mass condition.

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Technology Ready Mining - A TATA Steel's Perspective

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Abstract

Advances in Digital technology have made significant impact in the way customers are being served across industries. With increasing digital penetration in India & a booming technology demand, a combination of analytics and IoT could also create significant opportunities for the Mining industry. Some of the emerging trends of data visualization and optimised decision making, provide a scope for value creation & differentiation for mining businesses as the sector is resistant to adoption of technology.

Digitalisation in mines, including data collection, data transfer and data analysis, is key to improving productivity in the sector. In recent years, digitalised open platform systems have been developed to implement Internet of Things (IoT) technology and analysis of Big Data, as well as aid the use of automated vehicles and equipment, all with positive results for operational efficiency.

This paper tries to enlist the major initiatives implemented or are in various stages of implementation ranging from blasting to haulage to mineral processing at Tata Steel to get technology ready.

Introduction:

Mining companies are applying digital technology across the organization, but they are embracing it most heavily in mine operations, as opposed to areas such as exploration, mine development or marketing. Miners appear to be especially interested in getting the right data in the right time frame to help people to take the right actions and react quickly to changing situations. Some companies are applying digital technology in those areas to create connections across the value chain and link the mine to the market. Such integration can help mine operations be better informed about market needs and, conversely, help sales and marketing better understand what mine products are in the pipeline and available for customers.

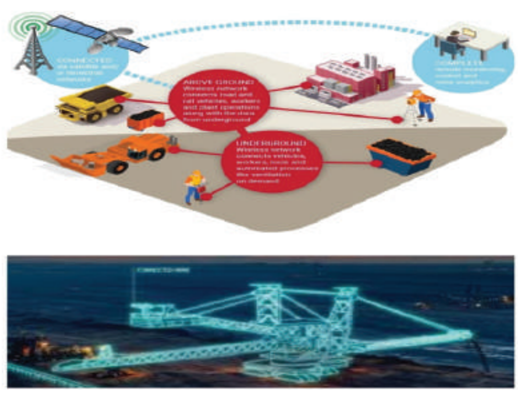


Figure1: Concept of Wireless connected

Digitalisation in mines, including data collection, data transfer and data analysis, is key to improving productivity in the sector. The concept of digital mine is shown in figure1. In recent years, digitalised open platform systems have been developed to implement Internet of Things (IoT) technology and analysis of Big Data, as well as aid the use of automated vehicles and equipment, all with positive results for operational efficiency.

Background

Tata Steel aspires to be the industry leader and one of the important levers to achieve this aspiration is technology leadership. This would include approach to collaborations, incubator channels, extent of open innovation, participation of start-ups, capability development, infrastructure etc.

In line with global trends, Tata Steel's Digital Value Acceleration Team (DVAT) & Information Technology Services(ITS) have started the digital transformation journey around a year back invarious opportunity areas, understanding customer decision journeys, understanding best practices across industry & identifying user hot button.

In view of above, the Umbrella idea of “Connected mines” was conceived, with three basic implementation pillars namely:

1) Connected Assets
2) Connected Processes
3) Connected People

The idea was implemented on three Vertical functions namely Mining,processing and Logistics and two of the horizontal functions, Safety and Maintenance.

The theme of Connected Assets consists of following implementation Strategies

A) Maintenance Technology Roadmap(MTR)

It includes Sensorization of the key components of the equipment and enabling the Real Time Asset Monitoring Mode. This provides a data backed updecision on whether a equipment should be taken for maintenance or maintenance can delayed based on the analysis of real time data received from the sensors.

Such strategic data driven decisions ramp up the life of the components of the equipment, thus bringing down the cost of maintenance.

B) Asset Management Tool(AMT)

This tool deals with the Life Cycle of Assets. It will holistically perform the Costing and Budgeting for Assets throughout the year and provides an analysed insight, in to whether to continue with the same asset or plan for a new one, thus enabling the user to take optimised decisions on its Assets Life Cycle. It provides a control on cost as well as performance of Assets.

C) Implementation of SAP PM

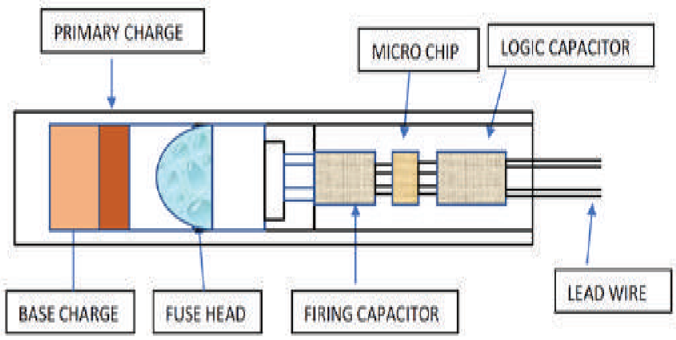
SAP PM (PlantMaintenance) is a functional module which handles the maintaining of equipments and Enables efficient planning of production and generation schedules and provides interfaces to process control and SCADA systems.The R/3 Plant Maintenance (PM) application component provides the user with a comprehensive software solution for all maintenance activities that are performed within a company. Supports cost-efficient maintenance methods, such as risk-based maintenance or preventive maintenance, and provides comprehensive outage planning and powerful work order management.

The theme of Connected Processes consists of following implementation Strategies

A)Technology infusion in Blasting

Blasting is said to be the base function of mining operations, effecting the entire value chain. Tata Steel have implemented the following advanced techniques in blasting:

Electronic Detonators: The electronic/ digital detonators use a microelectronic chip for providing delay instead of chemical or electricalcomponents.



Advantages of Electronic detonators:

* Reliability and exact verification of initiation network connection.
* Delay range of 1–16,000 millisecond with an increment of 1 millisecond.
* The precision of ±0.01 – 0.05% of designated/ programmed delay time.
* Better intrinsic safety features.
* Unique ID in each detonator avoids pilferage and misuse.
* Safety elements, including a unique fire control command enhancing safety.

Fragmentation Analysis Software: Fragmentation degree plays an important role in control and reduction of loading, transportation, and crushing expenses. Blasting is the first step to reduce rock size, which is followed by the crushing and grinding phases. The efficiency of these operations depends on size distribution of blasted rocks. Following the principle, Tata Steel has implemented the use of Fragmentation analysis software ‘Whipfrag’ at its mining locations.

B) Implementation of Fleet Management System(FMS)

Fleet Management System is a modern version of real time tracking of HEMMs in highly mechanized opencast mines. High precision Global Positioning System devices are installed in each HEMMs so that geo tracking of each HEMM can be obtained in real time basis as shown in Figure2.

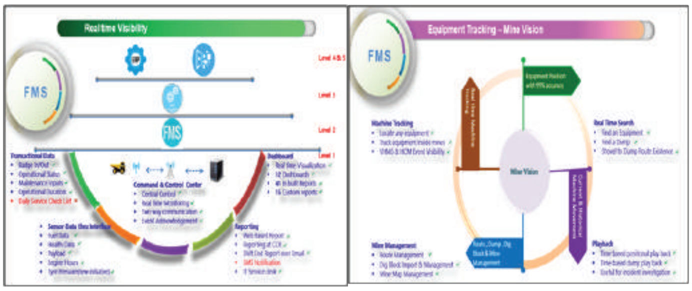


Figure 2: Concept of Real time visibility and Equipment Tracking in Mine Vision

Following prerequisites are required for the tracking of HEMM in fleet management system

>> Radio frequency signals (Through installation of fixed towers or movable rovers) in and around the geo-boundary of the concerned area
>> Data transmission through OEM interfaces in each machine Installation of fuel sensor in each machine (For real time fuel consumption tracking)
>> Import of dig blocks and slice plan for grade control
>> Installation of fleet management system in each HEMM and necessary networking.
>> Establishment of a control room with live displays
>> Communication system between dispatcher (who sits at control room) and HEMM operator.
>> Assigning boundaries of different destinations and creation of route map in line with haulage road assignments (To track movement in any undesired/unauthorized path)
>> Creation of time usage model specific to mine condition (To track the availability, utilization, detentions etc in real time condition)
>> Training to operators and dispatchers

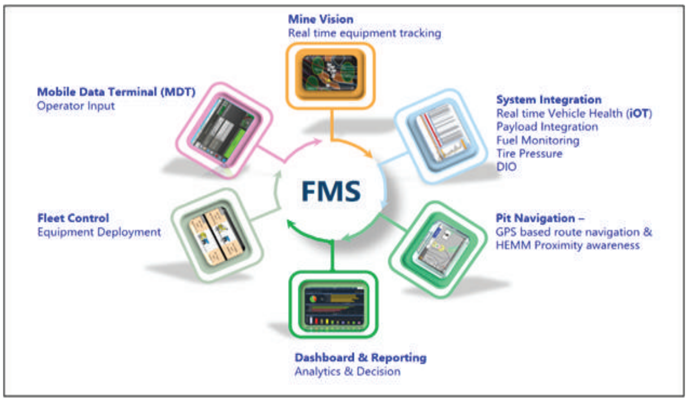


Figure 3: Components of Fleet Management System

The Fleet Management System has a feature of dynamic dispatch in which real time assignments to each Mobile unit(Dumper) is auto generated by the system based on the optimised calculations of the system. This feature ensures optimum utilisation of the mining machinery as per the constraints defined by the user in an automatic mode.

Advantages of fleet management system:

1. Improvement in OEE (Overall equipment effectiveness) of equipment.
2. Grade control and blend production.
3. Tracking of real time performance of each equipment and operator.
4. Integration of OEM interface with FMS to get the real-time health status of each equipment.
5. Maximizing the production and productivity based on optimization of site constraints.
6. Reduction in operational Cost by 10 to 15%

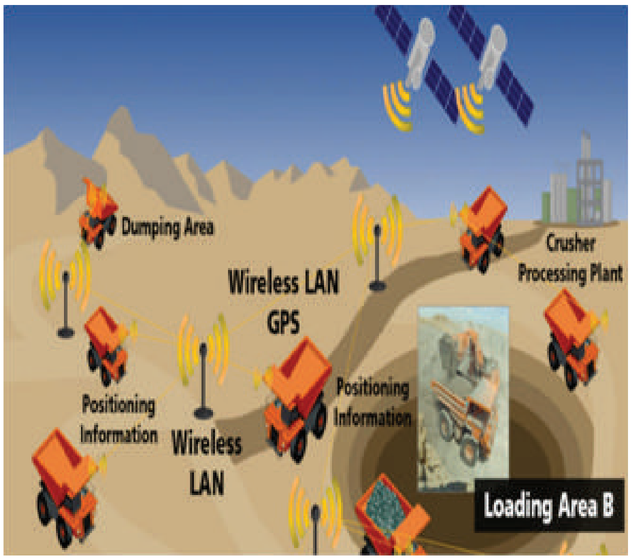


Figure 4: Working concept of FMS

Pre-& Post Implementation Comparison

Implementation of the Fleet Management System in the mines of Tata Steel has resulted in a better control over the mine operations on a real-time basis.The entire system ranging from manual system of manpower allocation to manual system of fuel consumption tracking have been replaced by digital modes through a system interface.Administrative control in managing the operator's performance is now data backed up.While utilization of machinery has reached anall-timehigh, materialhandling has increased to the tune of 10% since implementation of the system.

C) ReadyLine

It is said that unplanned downtime is 700% more costly than planned downtime. If a unit requires maintenance ahead of schedule, it creates chaos and sends costs skyrocketing.

Better planning and more predictable equipment availability starts with real-time access to the equipment health. ReadyLine streams OEM equipment sensor data and alarms directly to intelligent condition monitoring software to help manage equipment health in real-time.

ReadyLine expands the maintenance prevention capabilities beyond tires to every machine component of the fleet. It detects early maintenance indicators, such as engine misfires or high oil pressures, that signal more serious issues coming soon as shown in figure 5. ReadyLine also integrates with analytics systems, such as the Avoca business intelligence suite, and IoT platforms like Hitachi's Lumada. These integrations both broaden and deepen the data analysis, giving a stronger prediction capabilities for extending equipment life.

Figure 5: Data plotting in Readyline on continuous basis

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a) Monitors Sensor Data and Alerts

ReadyLine unearths the hidden data from Hitachi, Caterpillar, Komatsu, or others, letting the userto create its own virtual component sensors and alarms. This makes it possible to follow the components' condition and plan maintenance to increase operational life and improve safety.

b) Predict Condition, Prevent Failures

ReadyLine helps you get ahead of unplanned downtime events and catastrophic failures, identifying subtle changes in equipment performance long before problems occur. Real-time analytics give you the power to take preventive action and eliminate the costly burden and stress of unplanned downtime events.

c) More Insight from the Data

ReadyLine data can also be integrated with Hitachi Lumada and other IoT / machine learning platforms for deeper data analysis that enables prescriptive maintenance capabilities across multiple mines and locations. Sending on-site data into the cloud allows in-depth analysis across multiple mines and long-term

trending that scales through your entire enterprise. These solutions include: asset health condition monitoring, safety conditions monitoring, and failure mode and effects analysis (FMEA)
.

D) TireMax

TireMax enables early detection of changes in tire parameters, to prevent unexpected tire failures. The system assesses tire pressure, temperature, and work rate, then notifies the user if they show signs of concern. Most mines only use 65% of their available tire lifespan, even though tires form one their largest operating costs. TireMax presents a simple way to extend the value the usergets from these underused components.

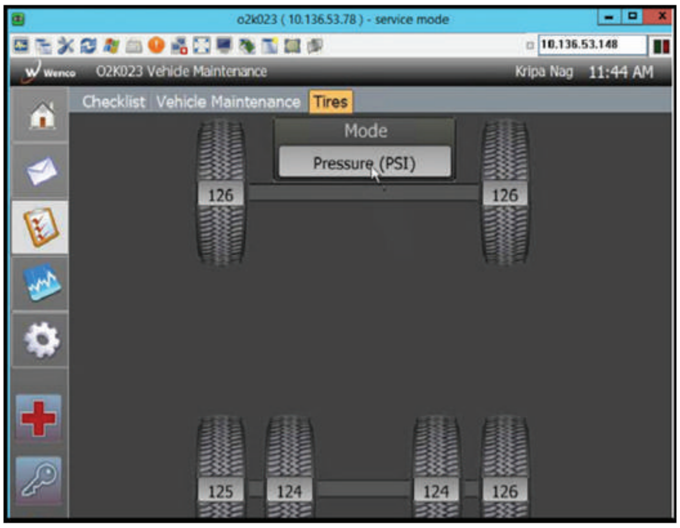

Figure 6: Display screen showing real time pressure in TireMax Application

E) Integration of Operator Attendance with FMS

This integration allows the Dispatcher/Shift In charge to have a real-time visibility of the Machine operator's attendance as they mark their attendance in the Biometric System. This enables them to manage the manpower and plan their operations in a much efficient manner.

F) Through process Quality

This project aims at reduction in the standard deviation of quality parameters which would have huge benefits at the blast furnace level. The implementation strategy consists of implementing:

a) BenchManager High Precision Drill

BenchManager Drill brings GNSS-powered precision to the blast hole drilling process. Finally, the operator can place holes at the right depth and location for smooth blasting and orderly fragmentation. A drill pattern is loaded into the onboard system and the Satellite guidance keeps the rig accurate to one-tenth of a degree, for blast holes that always match the designs.

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* Precise Drilling enables Precise Fragmentation

Efficient mining begins with regular, even fragmentation. BenchManager Drill enables us to create blastholes exactly as intended, so the blasting results in regular fragmentation with minimal throw.

* ROP Tracking for Improved Blast Plans

The instant, the drill breaks ground, BenchManager Drill tracks its rate of penetration, depth to target, elapsed time, and other key parameters. This real-time data works to uncover hard areas and other geological features so it can be adapted to blast plans accordingly.

* Drill Data, Integrated

BenchManager Drill integrates with other units and design software, synchronizing data across the entire suite of tools and technologies. All site personnel work from the same information, enabling greater efficiency and accuracy through the drill-and-blast process.


Figure 7: Bench Manager

b) Drill Navigation system

The Wenco Drill Navigation system fulfils this basic requirement by helping the machine operator to quickly and precisely move the drill to each hole location in the pattern. In doing so, the system eliminates the need for tedious field survey work and delays in laying out planned drill patterns. Setup of the drill is also faster, as the system provides real-time feedback about actual mast position and bearing during operation. The Wenco Drill Navigation system also automatically gathers as-drilled information and other operational information, which are extremely valuable for blasting personnel.

Inside the cab of the drill, the operator sees two main views on the Wenco Drill Navigation screen. The first view is the main navigation screen, as seen in this screenshot figure 8.

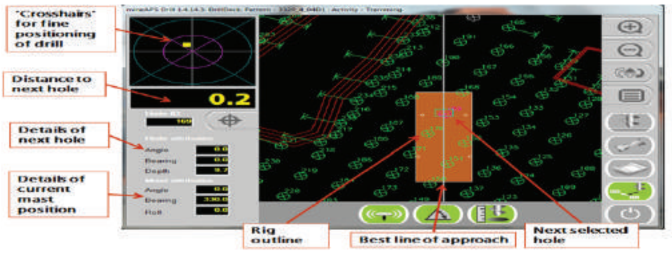

Figure 8: Main screen of the Drill Navigation system

Connected mobility, VR and AR technologies can be used to empower and monitor field workers. These employees can benefit from on-demand, real-time push and pull information and use mobile and wearable technologies (e.g. tablets, wearable glasses, watches, and vital trackers) to interact with sensors, robots and other systems around them. Connected worker technologies have numerous applications. For instance, equipping workers with connected, intelligent wearables and mobile devices allows mine and plant management to capture critical information in real time.

It also enables seamless communication; immediate, remote expert assistance, diagnosis and real-time guidance or access to instructions to repair faulty equipment; and "follow-complete document" workflows that can be carried out directly in the field. The theme of Connected People is implemented through Laura 1 Technology.Creation of a network of Laura Gateway and beckons tracks people carrying RFID Cards.

Future Projects

While, developing Application based mobility solution for controlling the Processing Plant parameters is already under implementation, there are plans for installing quality analysers at Belt Conveyors, Visualisation of Mine to Mill through integration of Fleet Management System(FMS), SAPetc., making pile quality visibility a reality etc.

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Conclusion

With traditional company information technology (IT) and operational technology (OT) becoming more integrated it will be interesting to view that how digital technology further advances in to the Mining Systems. At Tata Steel, integration of both these groups under a single governance umbrella has helped in getting the most out of IT-OT convergence. It has opened the door to practices such as real-time monitoring of the full range of operations, and the cloud-based, as-a-service delivery of operational activities such as alarm management and production accounting. It is also allowing Mining Engineers to bring together the combined, complementary strengths of both groups to focus on innovations that bring greater efficiency and effectiveness to operations.Acknowledging the fact that Innovation and Technology are the key strategic enablers for Mining companies in today's time, Indian mining companies will strive to achieve this

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Disclaimer- The views and opinions expressed in this article are those of the authors only and not of Tata Steel.

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Improving Mining Efficiency with Application of Technology in Drilling and Blasting Operations

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Amit Bhandari
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Melbourne

Abstract

Drilling and Blasting are core operations in a mine. They impact all the downstream operations and their costs. Digital technologies exist for optimizing both drilling and blasting for many years. However, these technologies have largely been non-integrated and non-real time. This gap results in sub-optimal drilling and blasting operations. Also traditionally focus has been on optimizing individual areas (drilling or blasting and subsequent subsystems). Industry has largely lacked real time or near real time integration available to the user in the field and in the office. In this paper, a case study is presented of a large global cement company using a cloud and mobile based platform across 17 of their mines consistently over a large number of users over a period of over two years. The use of a blast platform is detailed which include blast designs, blast data collection and the trends in terms of results. On the drilling side, this paper describes the ability to capture drill logs, plod reports etc. Also, actual drilling information in the field using a mobile device and its real time synchronization with a blast designer to provide visibility of expected fragmentation and vibration levels based on the drilling done. Key parameters such as hole ID, design depth, actual depth, hole status, designed and actual charge (length and weight), designed and actual stemming length are captured. The case study also highlights the challenges in technology adoption and implementation in mining in drilling and blasting. Making drill and blast results predictable should be the desired direction. Also digital technology tool adoption has been seen at the biggest miners – not so much in mid-sized miners or drill and blast contractors. Benefits of this platform on the safety side are highlighted including predictions on safety parameters and appropriate alerts if blast safety parameter / clearance zones are not met. The safety parameters are made available visually to the operator using maps and / or on drone images. Future possible improvements in the digital technology platform at the site are also highlighted including greater possible automation.

Introduction:

Mining differs from other industries in many ways. It is highly variable, starting with uncertainty about the nature of the resource being mined. Strains and stresses placed upon mining equipment by rocks of unpredictable geotechnical and geological characteristics result in frequent breakdowns. Intelligent planning and coordination of activities are required to mitigate variability caused by external forces. Accurate execution is needed to eliminate variability that miners create themselves.

Drilling-blasting are primary operations which impact on efficiency of entire downstream operations and result in poor image due to severe environmental impacts. A poor blast design or timing design, or poor execution of blast is likely to result in a bad blast.

An improper blast can change the balance sheet of a mine due to public litigation cases and payment of heavy compensation. Poor blasting design and execution not only has negative economic consequences but is also a safety and environmental hazard. Conventional blasting practices and techniques in mining and infrastructure construction industry are unable to improve efficiency and mitigate environmental hazards. The improper selection of blasting design will create problems with blasting results, such as rock fragmentation with a lot of boulders, flyrock, high ground vibrations, high air blasts, long digging time and high powder factor values. Based on the problems that arise, choosing the right blasting design will certainly be needed. Technology will be the cornerstone to overcome variability and productivity improvements. Most often smaller blasts are carried out because without the use of appropriate tools and techniques, larger blasts cannot be controlled.

These small drilling and blasting operations lead to huge loss of productivity and social issues. Efficient large blasting with reduced environmental effects requires suitable planning, good blast design, accurate drilling, the correct choice of explosives and initiation system, blast execution, adequate supervision and considerable attention to details.All these can be linked with integrated technology applications which provides tools and techniques for efficient drilling and blasting operations (Bhandari et al, 2015, Steve, 2018,

Integrated Platform for Drilling & Blasting

Software technology usage in blasting has been prevalent for many years (the use of blast designers and blast records in paper or excel is common) but it has not really been readily accessible to an average blaster. Integrated tools for blast data collection and blast performance analysis are largely missing from the industry. The tools that are available are not very easily accessible being confined to a desktop in the office. Many large geographies / developing countries are hardly using blasting software. Even the tier-1 mining companies in these geographies are not using any software for blasting. The software products that are available are too complicated for an average blaster – almost trying to showcase blasting knowledge rather than being user friendly. In other industries it is normal to have a cloud / mobile based platform – Why has this not happened in drilling and blasting?

The key reason being that software technology has not covered all aspects of blasting and at times has been too complicated for an average blaster.

Key Features

* Drilling & Blasting Lifecycle: The system covers the drilling & blasting lifecycle – not just design, but data collection, predictors, analytics, reporting etc.

* System for Drilling: It includes a system for drilling enabling things like drill logs, plod reports etc.

* Accessibility: Web and mobile nature makes it accessible by a lot of people. designs can be shared, reviewed and approved by multiple people.

* Geolocation: Significant integration with Maps, drone data etc. make it possible to take decisions at the site itself.

* Multi-Tenancy and Flexibility: Modular /Security Architecture ensures it can be used by blasting contractors as well as large enterprises cross all its users. Thus, every mine or organization has its separate and secure system.

* Mobility: The same solution is entirely available from a mobile device (both android and iPhone)

* Analytics and Reporting: Analytics and reporting plays a vary vital role in optimizing the blast, as it provides various insights into trends of previous blasts which can be used for analysis the problem points and optimize future blasts

* Management Portal: The management portal provides visibility to central mine management and supervisors across all the mines in a large organization, from the same central system. It enables assessment/comparison across all mines for important parameters (powder factor, costs, production, production per meter, downtime etc.).

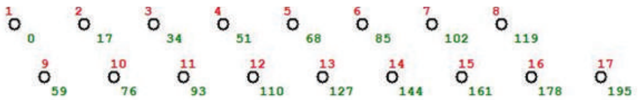
* Multi Tenancy: A crucial feature is the ability to be used across a number of mines within the same organization. This enables clear organization-wide visibility of the drilling &blasting function, whether it be design, drill &blast data collection, or a comparison of crucial parameters between mines.

* Process: The platform looks at the entire drill and blast process – Thus key functions and checklists can be digitized and stored centrally.

Blast Data Base

This system is helpful in storing important blast related data for generation of subsequent analytics and useful suggestions to the user regarding efficient conduction of future blasts. It is used to store, manage, document and retrieve drill and blast related information (Bhandari and Bhandari 2006,Bhandari, 2011). It can work in conjunction with other systems such as mine planning packages, ERP etc. All charging, initiation, decking, pre & post blast images and blasting block info regarding rock and location, face profile are stored. Searching functionality enables the user to precisely search for records in various manners such as according to vibration limits, according to face, explosive wise etc. Several reports can also be generated in the system as per user's requirements. Information about post-blast images, videos, accidents, misfires, fragmentation, displacement, can also be captured. It helps user maintain good records required for statutory purposes in an efficient manner as well. Data base for keeping blasting data has existed previously as well. Key features of the data include ability toimport from any blast design package, tools, significant analytics and reporting.

Row No.	Hole No.	Burden	Spacing	Hole Delay	Row Delay	Column Charge	Column Weight	Column Length	Column Cost	Base Charge	Base Weight	Base Length	Base Cost	Booster Charge
1	1	10	6.5	17	42	A.N.F.O.	32.96	3.97	26.39	Aquadyne	4.86	1	31.17	Cast Booster
1	2	8	6.5	34	42	A.N.F.O.	32.96	3.97	26.39	Aquadyne	4.86	1	31.17	Cast Booster
1	3	8	6.5	51	42	A.N.F.O.	32.96	3.97	26.39	Aquadyne	4.86	1	31.17	Cast Booster
1	4	8	6.5	68	42	A.N.F.O.	32.96	3.97	26.39	Aquadyne	4.86	1	31.17	Cast Booster



Theoretical Production(Volume)	3978 m^3	Theoretical Production(Tonnage)	10501.92 Ton
Total Base Charge	82.62 Kgs.	Total Explosive Consumed	643.11 Kgs.
Total Stemming Length	61.88 m	Theoretical Powder Factor	16.33 Ton/Kg
Total Drill Meterage	136 m	Actual Production(Tonnage)	3978 Ton

Fig 1. Pre-blast, during Blast and post Blast data stored in data base

Surface Blast Design Software

Blast Designer is used for the purpose of design, optimization and control of blast design. There is a unique possibility to implement different types of blasting scenarios such as production blasting, overburden removal, secondary blasting etc. The ability to plot irregular face profiles is helpful in correlating with the reality observed on-site. Blast location mapping is possible to be done using digital image, Google map and high definition drone imagery. Considering a few geological and geotechnical parameters, selecting the pattern details and targeted fragmentation size distribution outputs are provided in 5 different ways. They are mainly categorized as

1) Primary Design Parameters: Burden, Spacing, Depth, Charging Distribution, Powder Factor, Initiation

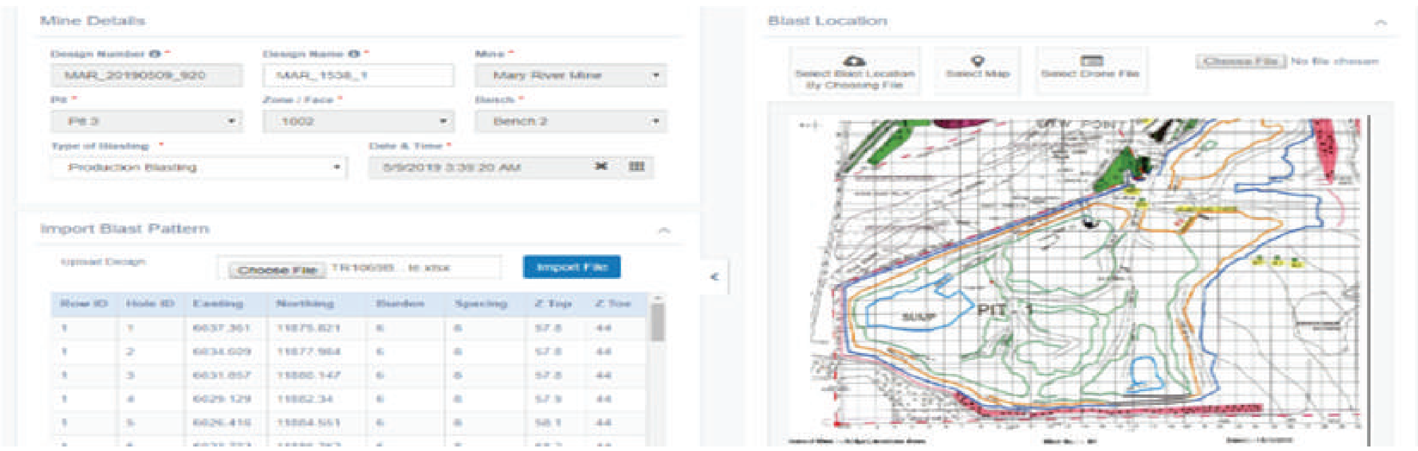


Fig 2: Primary Mine Info

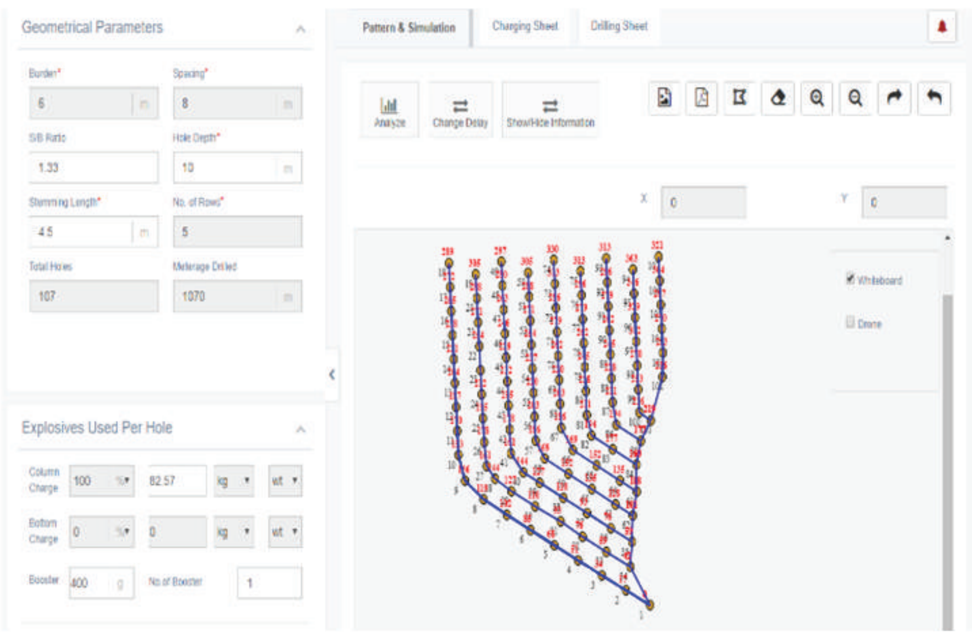


Fig 3: Primary Design

2) Fragmentation prediction based onKuz-Ram Model/KCO Model

3) Ground Vibration prediction

4) Air Blast Overpressure prediction

5) Blast Clearance prediction

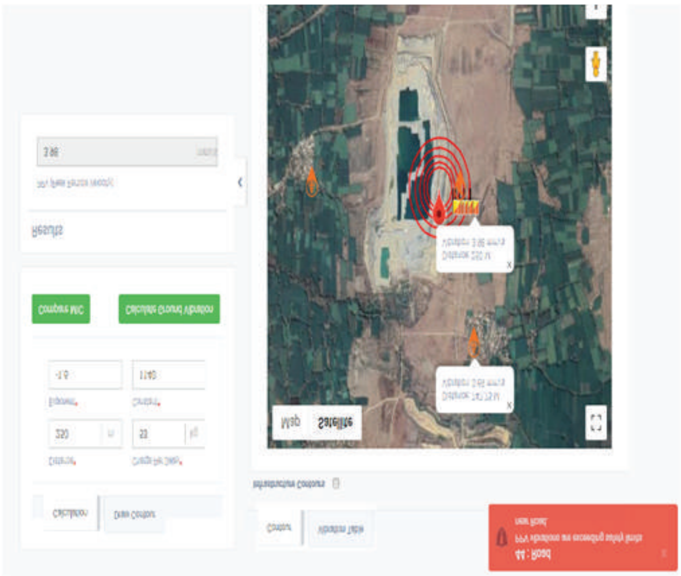
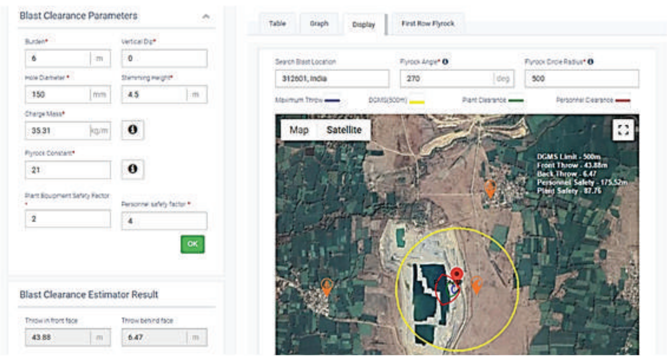


Fig 4: Ground Vibration PredictedContours



Uploading/ importing coordinates is also possible to be done in BLADES (handling complex patterns). There is an alerts/notifications tool to inform the user about deviation of expected results from the statutory/user defined limits (Figure 6).

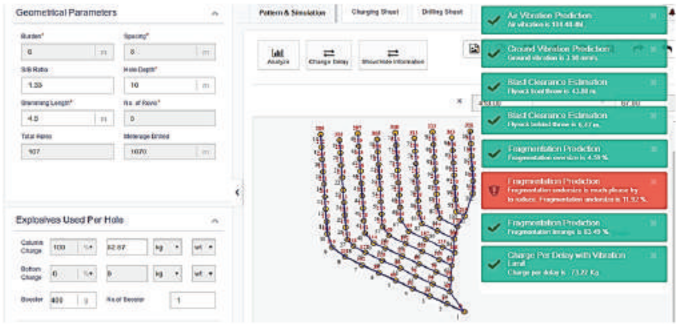


Figure6: Alerts generated for user-defined/statutory limits

The entire blast details including pattern and results can be synced directly with Blast Information Management System (BIMS). A capture of variation button has been provided to compare differences between actual and predicted blast results. Custom reports can also be generated by the user.
Design comparison for optimized blast – A blast is designed based on the required outcome. A person designing blast can change the parameters like burden, spacing etc. and compare the results like fragmentation, flyrock,vibrations, costs etc. and then choose the most optimized blast design to get optimum results.Table 1 (next page) is an example of comparison.

DrillingPlatform

Extensive information is now days available from the drill rig – this includes detailed information about the functions the drill rig operations or various aspects of productivity. However, a typical drilling activity is not operating in isolation. Things do not go as planned in the field; the information captured by the driller is required by downstream operations like for blast design. Drill design from blast designer is available in drilling platform via an automated feed in the field.It is a system for multiple aspects of the drilling eco-system. Key functions include plod reports, pre-starts, drill logs, drill status, safety checklists, invoicing, financial metrics, make my own checklist etc. Drillers uses the design and performs the drilling and collect data during drilling like actual drill depth, images, videos etc. which is again fed to blast designer to check that is based on actual drilling parameters, is the blast still in the safer limit and will produce desired outcome, if not then explosive quantity, initiation sequence and timing etc. can be changed to control the blast results and QA/QC operations are performed. The drilling platform also generates various useful analytics & reports like plod reports etc.

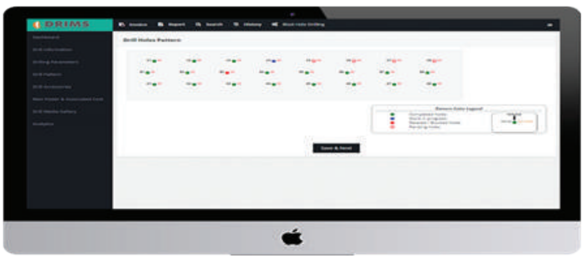


Fig 7: Main Input page in DRIMS

Table 1 :Blast Design Comparison to arrive at optimum parameters

Change Compare Mode		DESIGN 1	DESIGN 2	DESIGN 3	DESIGN 4
Geo Parameter	Burden (m)	4	4.5	5.5	6
	Spacing (m)	4.8	5.3	5.8	6.3
	Bench Height (m)	10	10	10	10
	S/B Ratio (m)	1.2	1.18	1.05	1.05
	Face Length (m)	33.33	74.07	60.6	55.55
	Hole Depth (m)	10	10	10	10
	Stemming Length (m)	3	3.38	4.13	4.5
	Total Holes	21.00	41.93	31.35	26.46
	Meterage Drilled (m)	208.33	419.29	313.48	264.55
Design Parameter	Bench Height (m)	10	10	10	10
	Hole Diameter (m)	115	115	115	115
Blast Cost	Total Explosive Cost (₹)	46744.13	89271.39	59558.98	47231.11
	Cost / Tonnes (₹)	4.78	3.65	2.45	1.94
	Total Initiating System Cost (₹)	11109.56	0	0	0
	Stemming Cost (₹)	0	0	0	0
	Total Drilling Cost (₹)	1041.67	2096.44	1567.4	1322.75
	Total Manpower Cost (₹)	2000	0	0	0
	Plant and Other Service (₹)	0	0	0	0
	Total Blasting Cost (₹)	60895.36	91367.83	61126.38	48553.86
Explosives Used Per Hole	Column Charge	61.77	58.46	51.84	48.53
	Bottom Charge	0.00	0	0	0
	Booster Charge	400.00	400	400	400
	Total Blasting Cost	62.17	58.86	52.24	48.93
Predicted Fragmentation Result	Blastability Index	3.18	3.78	3.78	3.78
	Uniformity Exponent	1.24	1.13	0.9	0.81
	Mean Fragment Size of Material (cm)	17.17	24.64	34.51	40.31
	Characteristic Size (m)	0.23	0.34	0.52	0.63
Predicted Fragmentation	Percent Oversize (%)	0.21	3.39	16.51	23.37
	Percent in Range (%)	69.84	74.42	63.2	56.47
	Percent Under Size (%)	29.95	22.19	20.29	20.16
Fragmentation Table Result		Size(m) / Percentage Passing(%)	Size(m) / Percentage Passing(%)	Size(m) / Percentage Passing(%)	Size(m) / Percentage Passing(%)

Fig 8: Drill Plod

Onsite Data Collection Using Mobile /Tablet

Mobility allows one to get easy access without having the limitations of network that is available, participate at any geographic location or be involved in, be the project office, or may be on site in front of the assets, or may be with the people at HQ, which has typically been, the place where the information resides. Innovative hand-held units allow field data to be captured and automatically down loaded when the unit is docked, eliminating human error during data transfer.

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The use of mobile devices makes it easier to collect data on-site and it is mainstream in many places where a mobile workforce is present. Use of these devices would be ideal in the field for drill and blast personnel. Though mobile devices are not being used appropriate rugged devices can be used 30 m/50 maway from a blast site during charging and blasting operations, thus they would get the required capability of collecting on-site blasting details. Smart Blasting App can be used to collect information on site and send the same to server (Fig. 9).

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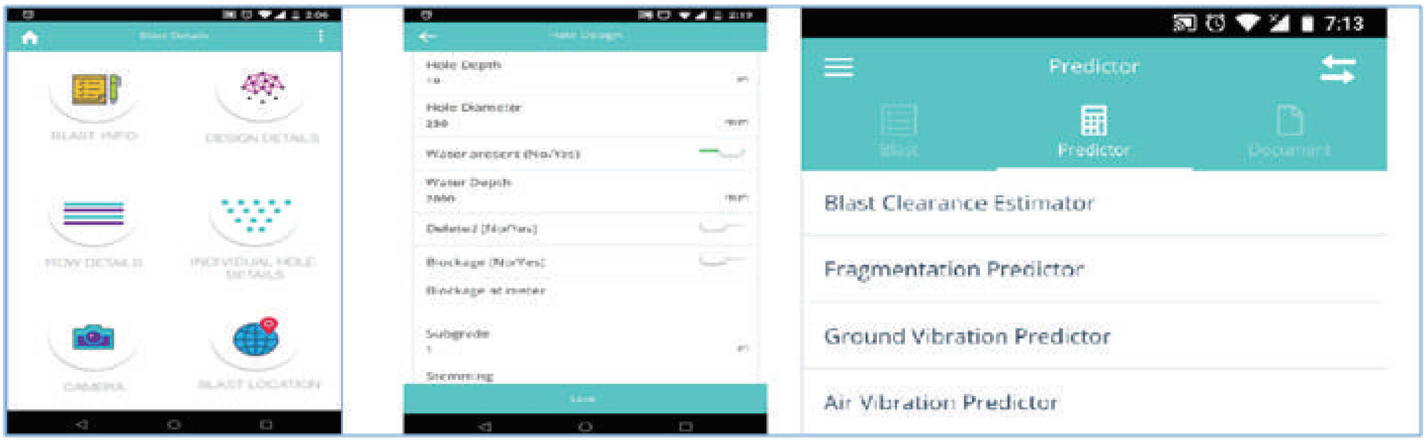

Figure 9: Blasting Data Collection on-site using Smart Blasting App

It helps in collecting data in the field and then transferring it to server or desktop computer. In addition to data collection; the SBlasting App also includes environmental predictors and can capture photos and videos.

Then drilling and blasting data is entered (as per design) pre-blast. Once the blasting is done, actual data is recorded to save it for future use. All parameters related to drilled holes and explosive charging, stemming, etc., can be collected. At this stage, the blaster can recheck predicted fragment size distribution, fly rock distance, ground and air vibration, fragment size, etc. and if there is variation from the designed blast and limits are exceeded, changes in charging, stemming, initiation devices and timing can be done before executing the blast. Photographs and videos can also be saved using the device. Data can be imported from other devices or tools such as vibration monitoring record. When mining personnel return from site, they can sync this data to the web version of the application and export it to the desktop because local storage of mobile devices cannot save large amounts of data.

QA/QC Analysis

Blasting patterns as designed are difficult to drill because of collaring errors, variable rock and operational difficulties. Deviation of holes can take place, collaring error, blockage of holes, under drilling or over drilling may occur. It is necessary to dip the holes for depth and inclination otherwise the overall outcome may beimpacted. Therefore, after drilling the pattern, hole dipping operations takes place and designer is again given the actual hole depth and inclination details. Decision regarding redrilling of under drilled holes or filling of over drilled holes can be taken. A comparison between designed drilling pattern and actuals drilled pattern helps indeciding charging and ignition sequence and timing.

Figure 10: QA/QC analysis

Case Study

The primary aim of the use of any software is to minimize human errors and enable faster and accurate computations. A case study is presented of the software usage at a group of mines belonging to one of the largest cement manufacturers in the world. This company has been using the platform simultaneously across 17 of their limestone mines in India for over a period of more than 2 years. They are continuing to use data collection and predictors. Apart from collecting data for blasting pattern,explosive charging details, initiation sequence and timing, vibration records, photographs, videosetc. are all recorded for each blast.Several of mines are also using the predictors for air, ground and flyrock prior to each blast. The simple act of making it easily accessible via cloud and mobile makes it a mass usage system. The software usage statistics are given in Table 2.

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				Key Statistics Report from 29-06-2019 To 28-07-2019									
				Important Statistics		Nice to have Statistics							
S.No.	Mine Name	Last Active Date and Time in BIMS	Number of blast records filled till date in BIMS	Cost Per Ton on Blasted Stone	Output Per kg of Explosive	Rock Blasted(Ton)	No. of hole Drilled	Total Drill Meterge	Total Explosive Consumed (kg)	Total ExpLosive Cost	Output Per Hole	Output Per Meter	Powder Factor (Theoretical)
1	Mine A	01/07/2019	456	2.82	10.6	18562.5	23	414	1751.32	52347	807.07	44.84	10.5991
2	Mine B	23/07/2019	505	5.42	6.97	2520	12	84	361.8	13658.4	210	30	NA
3	Mine C	21/05/2019	256	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4	Mine D	21/05/2019	457	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5	Mine E	24/07/2019	316	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
6	Mine F	12/07/2019	52	7.4	4.06	44950	80	4000	11064.4	332555	561.88	11.24	4.06258
7	Mine G	25/05/2019	76	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
8	Mine H	26/07/2019	498	10.57	3.57	149947	370	7929.5	41959.2	1584366	405.26	18.91	3.57365
9	Mine I	24/07/2019	275	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
10	Mine J			NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
11	Mine K			8.73	6.87	105023	302	4354	15279.3	916760	347.76	24.12	6.8735
12	Mine L	23/07/2019	635	2.87	11.34	230828	505	6465	20362.2	661706	457.09	35.7	11.3361
13	Mine M	11/07/2019	250	3.68	9.84	26400	77	704	2684	97086.4	342.86	37.5	9.83607
14	Mine N	24/06/2019	206	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
15	Mine O	21/05/2019	158	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
16	Mine P	28/07/2019	498	4.19	9.25	614935	526	9749	66513.9	2575392	1169.08	63.08	9.2452
17	Mine Q	15/06/2019	125	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
			4763										

Table 2. Blast records in software of 17 limestone mines

- Instantly capture, analyse & share data at critical stages in drill & blast process.

- Pre-blast, during blast and post blast data available anytime anywhere with no software and hardware needed at the site.

- Immediate access to data for making important decisions.

- Reduce incidents, control costs and increase performance.

- Access through cloud based server/ networked server through iPad, Android mobile App/ Tab.

- Mines are located in different parts of country, data can be viewed in corporate office, to seetrends for benchmarking and optimisation

The analytical graphs generated from the system can be used for comparison and performance assessment /benchmarking of each of the mine sites as well can be viewed by other authorised officials of the group. They are compiled to highlight the benefits of ongoing fine tuning of blasting activities to the user. Several types of analytical graphs can be obtained at click of button--blasting cost per ton, total explosive consumption, powder factor, vibration performance, burden &spacing and other parameters, production per meter/total meterage blasted, production per hole/total numberhole blasted and many others as per desire of the user. For example, if the user wants a comparative information about performance of different explosives or initiating system from different suppliers, this can be obtained at a click of button.Searching according to results of vibrations, fragmentation, explosives, face/zone/rock. This provides historical data for design of future blasts in the same block or with similar geological rock.

User is able to get reportsin pdf format or as excel for transmission to other mining software according to management requirement or according to regulatory requirements.

Datacan be imported from different equipment on the downstream side, mine planning software or from other analytical software or tools. Data can also be exported to other software.

15 mines are using 115mm hole diameter with two using 110 mm hole diameter holes. Bench heights are 6m to 10 m. Ten mines are using ANFO, 5 mines are using site-mixed emulsion explosives and two mines are usingcartridged explosives because of non-availability of site mixed explosives/blasting agent and watery conditions. Powder factor which is defined here as tonnes of rock broken per kg of explosives is mostly around 10 to 12 tonnes per kg with a couple of explosives less about 6 tonnes per kg. Three mines have reduced costs by change of parameters and have also improved rock per meter. The improvement has been obtained because of suggestions taken by the blasting professionals from the software. Some examples are as follows.

a) Blasting cost per tonreduced over a period of 2 years

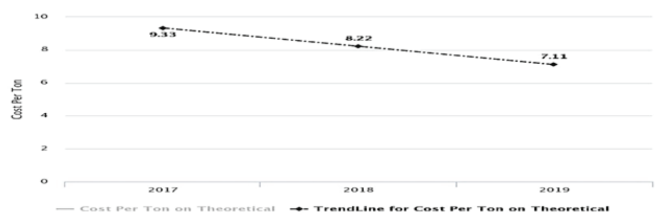

Fig 11: Cost per ton comparisons

A comparison of cost per ton and analyzing the general trends give a tool of monitoring can help determine the effect of changing blast parameters on cost.

b) Powder factor

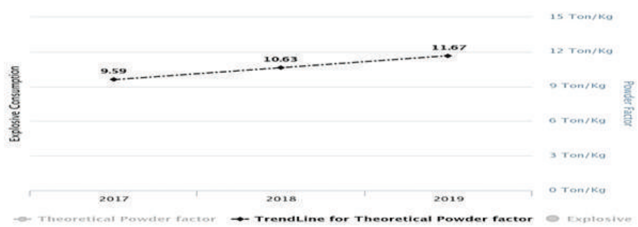

Fig 12: Powder Factor Variation

Powder factor is a key performance indicator for any mine. Hence any graph showing its variation over a specific time period can help the mine in figuring out their overall performance of blasts. For example, the above mine was able to increase their powder factor gradually over time as depicted from the corresponding trend line.

Blasting Parameter Variations: Three mines have changed blasting parameters during two-yearover periodand have reduced blasting and drilling costs by increasing spacing and not changing burden parameter.

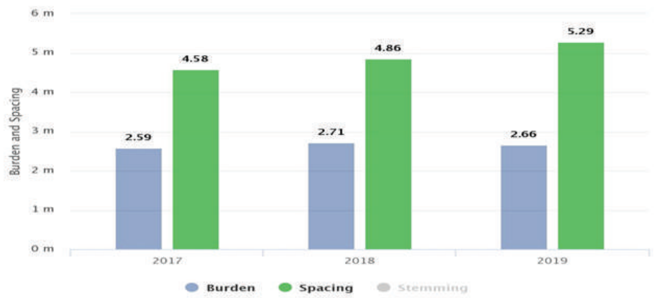

Fig 13: Burden and Spacing Variations

This type of graph can aid the mine in setting up proper primary blast parameters. These vary a lot with geology as well so if the mine considers their data properly, it is possible to generate an approximate correlation between blast parameters and geology/geotechnical parameters. Further based on historical data of each face gives possibility of improved blast design.

1) Production Data Variations

a) Drill Factor (Production/ Meter)

This graph is helpful in determining the variation of another important KPI w.r.t drilling and blasting activity i.e. production obtained per meter drilled.

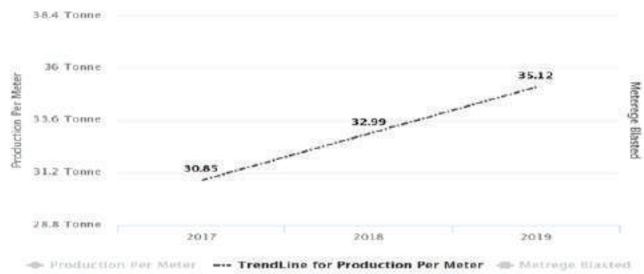

Fig 14: Drill Factor Comparisons

From the above graph it can be deduced that the overall production (in ton) per m of material drilled has increased. Production per hole determines the tonnage that can be obtained from each hole that is being blasted. This can help in determining whether to increase or decrease the total number of holes to be blasted per blast (size of the blast) considering that blast parameters have been fixed as per geological/geotechnical parameters (from previous benchmarking analysis)

Key Challenges in Implementation

There are several challenges in implementation. Different mines have a past record of keeping records in their own ways. It takes time to follow similar way across all the mines. This is important if data sources from drilling, blasting, loading, transportation and crushing are to be integrated. It takes time for a group of persons to get used to collect on site records.

Conclusions

Blasting operations needs to use innovative technology. Blast engineers are ideally trying to predict three outcomes in blast design: fragmentation (the size distribution of the blasted material), movement (where the grade and waste will end up), and environmental consequences. Use of digital technology for storing data, design, analysis and prediction of results helps in better control and optimization of mining operations. Data base helps to quickly respond to information and remain successful in today's competitive market place. By use of digital technology many projects can reduce complaints and can improve efficiency. It is worthwhile to look at some technologies which are being adopted in mining industry to make blasting operations efficient and reduce environmental impact.Mines using digital technology throughout mining life cycle in various mine operations are able to overcome this variability.

For a mine, an endless stream of data is available in the form of performance and condition data from sensors and monitoring devices on fixed and mobile assets through networks, servers, and services. This data can be processed and analyzed to spot trends, help predict events, and formulate reliability strategies as early as the design stage (e.g., reliability-centered design). This embedded intelligence can be used to optimize operational efficiency, increase asset availability and utilization, improve safety and environmental integrity, and maximize return on investment.

Development of Cloud Technology and Mobile Solutions has increased possibility of greater digital application in mining. Client server technology is not so user friendly and does not provide an integrated solution for the complete blasting lifecycle. In recent years, there is a growing convergence of "consumer" technologies that we are using every day on our iOS and Android devices such as camera, motion sensors, and GPS systems Mining industry has also adopted mobile technologies for innovative solutions to productivity improvements. Use of mobile devices makes it easier to collect data on site and it mainstream in many places where mobile workforce is present.

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Optimization Through Audit: Evaluating Rock Characteristics, Monitoring Explosive's Performance and Blast Outcomes

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Abstract

Blasting is the most efficient and economic method for excavations in mining and civil projects. Blast design inputs, performance of explosives and initiation systems influence blast outcomes such as fragmentation and muckpile characteristics which affect the efficiency of downstream operations and economics. Unwanted effects include rock mass damage, ground vibration, airblast, flyrock and misfires. Many parameters can be monitored for assessment during pre-blast, in-blast and post-blast stages which help in identifying the areas needing improvement so that corrective actions can be taken to achieve the desired results. This paper attempts to review various parameters that can be monitored for optimization through audit.

1.0 Introduction:

The concept of pre-blast, in-blast and post-blast monitoring was presented by the author in 1994 (Sarathy[19]). There have been significant developments of tools, techniques and instrumentation during the last three decades. It is essential to carry out technical audits through monitoring of blast outcomes because:

* It is required that actual performance of initiation systems and explosives during blasting is "as indicated" in the manufacturers' technical product data sheets.
* This is very essential since users mainly rely upon the data provided in the specifications for designing their blasts.
* Monitoring helps in identifying whether products are performing well and whether blast design and other inputs are meeting the users' objectives in totality.

Blast results are affected by the explosive system in use (properties, characteristics), distribution of explosive energy in space and time in the mass being blasted (blast geometry, drillhole pattern, initiation sequence), in-situ properties of material being blasted (mechanical properties and geologic structure) and effective confinement of explosive energy. Mines should systematically monitor operations within their capabilities on a regular basis which helps in identifying areas needing improvement. The 'mine-to-mill' concept is centered totally on holistic monitoring and audits at all stages of operations. It evaluates the inter-dependency of the various processes and cost centers on one another, beginning with drill-blast, downstream operations of loading, hauling, crushing, grinding and final extraction of metal or end product.

Technical audit can be segregated into three distinct stages of evaluation cum assessment activities, carried out both in the laboratory and in actual field conditions. They are 'pre-blast', 'in-blast' and 'post-blast'. While evaluation of rock characteristics is carried out before blast, it is preferable to monitor performance of explosive during the blast.

2. MONITORING PARAMETERS FOR BLAST DESIGNS

The mechanical and structural properties of the material being blasted have a more dominant control on blast results than the explosive characteristics. VOD of an explosive is the speed with which the detonation reaction travels through the explosive column and is a measure of the rate at which energy is released by the explosive. VOD increases with charge diameter, density, particle size and would be marginally higher under confinement than when measured in open. Explosive with high VOD generates higher shock energy (brisance) required for creating the radial cracks in high density, fine grained, hard rocks having high compressive strength. Coarse grained, low density soft to medium hard strata rocks absorb the shock energy and lower VOD explosive that generate higher heave energy perform better. Conventional slurry-emulsion products suitably modified to increase the heave by reducing the reaction rate and altering the shock-heave partition is also used. Tables 2 and 3 give details of explosive and rock characteristics considered in blasting operations.

Table-1 Monitoring of various parameters at different stages of blasting operations

PRE-BLAST MONITORING AND EVALUATION	IN-BLAST MONITORING AND EVALUATION	POST BLAST MONITORING AND EVALUATION
Rock Properties (Rock characterization) • Geophysical logging • Measure While Drilling • Watery drillholes ▸ Material Density ▸ Hardness ▸ Compressive Strength ▸ Tensile Strength ▸ Poisson's Ratio ▸ Bulk Modulus ▸ Young's Modulus ▸ Sonic / Compressive wave velocity Explosive Properties (Explosive characterization) ▸ Energy / Strength • Underwater Test • Computer Codes • Ballistic Mortar • Lead Block Expansion • Plate Dent Test ▸ Product Density ▸ Velocity of Detonation (Confined/Unconfined) ▸ Detonation Pressure ▸ Detonation Temperature ▸ Weight & Bulk strength Other Developments • Laser Profiling of Bench • Pre-blast survey of Structures • Laser alignment device for Drill mast • Borehole Video Camera • GPS based drilling and charging • Drones for survey • Blast Movement Monitor	High Speed Photography and Videography Quantitative ▸ Burden response ▸ Burden velocity ▸ Uplifting velocity ▸ Firing times of drillholes, firing out of sequence ▸ Venting velocity Qualitative ▸ Energy venting due to geology / discontinuities ▸ Stemming ejection ▸ Flyrock generation ▸ Missed drillholes (misfire) • Borehole pressure • Explosion Temperature • In-hole VOD • In-hole Detonation Pressure Other Developments ▸ Powerwave radar for measuring face velocity ▸ Infra-red sensor for recording firing times of initiators in drillholes ▸ In-situ strata damage • Monitoring gas pressure and ground vibrations behind blast ▸ Noxious fumes ▸ Dust generation ▸ Drones for photography during blast	Quantitative ▸ Muckpile Characteristics ▸ Fragment Size Analysis ▸ Shovel and Dragline performance monitoring ▸ Crusher performance ▸ Hauling productivity ▸ Boulder count ▸ Secondary Blasting ▸ Total cost evaluation Qualitative ▸ Misfires / Missed hole detection ▸ Flyrock source, cause and range ▸ Presence of 'Toe' ▸ Backbreak ▸ Overbreak / Side-tear ▸ Pit wall stability ▸ Damage to structures ▸ Damage Assessment • Core sample • Borehole Video Camera • Cross-borehole Seismiclogging • Permeability studies • Extensometers ▸ Aquifer course change ▸ Ore-Waste Delineation • Blast Movement Monitor (BMM) ▸ Migration • After-blast fumes • Dust generated in blast ▸ GHG / Carbon footprint ▸ Drones for muckpile survey

Table-2: Density and Velocity of Detonation of few explosive types (in large diameter)

Product Type (in Large Diameter)	Operating Density (g/cc)	Indicative VOD (m/s)	Detonation Pressure (kilobar)	Impedance Value
AN-FO	0.85 - 0.90	3500 - 4000	26 - 36	2.9 - 3.6
EMULSION-ANFO BLENDS*	1.05 - 1.18	3750 - 4500	37 - 59	3.9 - 5.3
SLURRY / WATERGEL	1.10 - 1.20	4000 - 4500	44 -60	4.4 - 5.4
STRAIGHT EMULSION	1.10 - 1.20	4500 - 5500	55 - 90	5.0 - 6.6
TRI NITRO TOLUENE (TNT)	1.60 - 1.65	6800 - 6950	185 - 199	10.8 - 11.5

(* - Emulsion-ANFO blends (various ratios), example: Heavy AN-FO, Doped Emulsions)

Table-3: Density, Compressive Strength and Longitudinal Wave Velocity of few rock types

ROCK / ORE TYPE	Density	UNIAXIAL COMPRESSIVE STRENGTH (UCS)36		SONIC VELOCITY	IMPEDANCE
	g/cc	kg/Sq cm	MPa	m/s	
BASALT	2.7 - 3.3	2500-4000	245-392	5500-6600	14.8 – 21.8
GABBRO	2.93	2826	272	5400-7000	15.8 – 20.5
GNEISS	2.6 - 3.0	1400-3000	137-294	4000-7600	10.4 – 22.8
GRANITE	2.5 - 2.8	2000-3600	196-353	4500-6200	11.3 – 17.4
LIMESTONE (Hard)	1.9 - 2.9	1300-2000	127-196	2800-7000	5.32 – 20.3
SANDSTONE	2.76	1600-2500	157-245	1400-4500	4.42 – 6.9
SHALE	2.81	2200	215	2000-4100	5.62 – 11.5
QUARTZITE	2.5 - 2.7	1600-2200	157-216	5000-5500	12.5 – 14.9
HARD IRON ORE	4.9 - 5.3	2039-5099	200-500	6000-6280	29.4 – 33.3
AIR	1.2	-	-	1000	1.2
WATER	1	Incompressible		4600-4900	4.6 – 4.9

Cratering Tests - Livingston Crater Theory

Crater theory was first put forth by C.W. Livingston and the earliest method used to compare relative strength of explosives. It is not much in use now. A vertical drillhole without a free face is charged with fixed quantity of explosive and blasted. Drill hole depths are varied and as the 'depth of burial' of the charge is increased, the crater volume increases progressively and reaches a maximum volume described as 'optimum depth of burial'. As the depth of burial is further increased, the crater volume progressively reduces and no crater is formed and only spalling is observed around the drill hole collar. This is defined as 'critical depth of burial'. For a given type of rock, the optimum depth of burial is established for various explosives under evaluation and is used for fixing the burden distance. The specific charge (kg/m^3) or powder factor (m^3/kg) at optimum depth of burial is used to calculate burden, spacing using empirical relationships.

Impedance Matching

Rock Impedance (Ri) is obtained by multiplying its density and longitudinal wave (sonic) velocity. Explosive impedance (Ei) is obtained by multiplying its density with VOD. It is generally considered that better results can be expected when explosive impedance matches the rock impedance viz Ei / Ri =1. It can be seen from Tables 2 and 3 that the maximum average density of commercial explosive is 1.20 g/cc and VOD is 5500 m/s, while the density of material being blasted can be 3.0-3.3 g/cc and sonic velocities as high as 6500-7600 m/s. Hence, impedance can be matched only in soft strata with low density and low wave velocities. Tri Nitro Toluene (TNT) with VOD of 6800-6950 m/s and density between 1.60-1.65 g/cc will generate impedance of 10.8-11.5 which is also much below the impedance of granite (11.7 - 17.4) and far below that of iron ore (29.4 -33.3). This method is not in use presently.

Schmidt Rebound Number

Schmidt Rebound Hammer Number (originally developed for testing uniaxial compressive strength (UCS) of concrete has been tried as an alternative method and investigators have attempted to find correlation between Schmidt Rebound Number, uniaxial compressive strength (UCS) and powder factor. Increasing rebound number implied increasing UCS of the material under test and requirement of higher specific charge (kg/m^3). Details of studies carried out are given below (Choudhary[6], Sawmliana et al[21]):

Table-3: Schmidt Rebound Number, UCS and Powder Factor

Investigator	Rock Type	Schmidt Number	UCS	PF (kg/m^3)
Choudhary[7]	Overburden	39-41	32-36	0.65-0.91
	Overburden	45-49	50-57	0.73-1.08
Sawmliana[21]	Overburden	15-45	-	0.28-0.65
	Ore / Mineral	26-60	-	0.25-1.05

Burden Response STUDIES

A field-oriented scientific monitoring method is to study the 'burden response' using high speed videography. This method accurately monitors the manner in which the burden reacts at the free face after detonation of explosive in the drillholes. The term 'burden' encompasses burden distance and material properties. After detonation which is considered as zero time, changes can be observed in the bench face after a certain lapse of time (time to initial movement T_{min}). Burden response studies help in selecting optimum burden and delay interval (inter-hole and inter-row) for the drillhole diameter and explosive-rock combination in use and eliminate the lengthy trials to optimize blast design parameters in a blast. The minimum response time can be decreased by reducing the burden distance, by using higher energy explosive or a combination of both.

EVALUATING Strength (ENERGY) OF EXPLOSIVES

With the advent of AN-FO and later development of AN-water based slurry/watergel and emulsion explosives, all strength comparisons are now made considering that of AN-FO as 100. While describing explosive strength (energy), two parameters are used namely weight strength (k.cal/kg) and bulk strength (k.cal/litre).

Several methods for measuring explosives energy have been developed which involve explosive quantities as small as 10 g to samples weighing kilograms. Qualitative methods include plate dent test, double pipe test, cylinder expansion and cylinder compression tests. Quantitative tests include Trauzl Lead Block, Ballistic Mortar and underwater (pond) test. The first two methods utilize just 10g of explosive and are suitable only for those products which detonate reliably in a small mass. Manufacturers in India adapted both for evaluating strength of slurry and emulsion explosives and it is often debated that these products do not detonate efficiently in such small mass and hence not suitable (Sarathy and Vidyasagar[20]).

Underwater Test (Pond Test)

This is a rather complex method requiring expertise on detonation physics and instrumentation. A known quantity of explosive is detonated underwater in a pond of adequate size and at a pre-determined depth. The size of the pond, its depth, the height of water in pond and the depth of burial of charge are critical. Same explosive tested in two different underwater environments may reveal different values and cannot be compared. Hence various products should be tested using a standard charge weight under identical conditions. This method uses tourmaline piezoelectric gauges and oscilloscope to measure (i) shock wave energy and (ii) bubble pulse energy. Shock energy is a direct measurement after detonation.
Detonation gases form a bubble expanding against the hydrostatic pressure of the surrounding water. When the momentum ceases, the hydrostatic pressure of the water causes the bubble to collapse which sends out a shock impulse which is recorded Bubble period is the time interval between detonation (first shock recorded) and the impulse generated at first bubble implosion, is considered in underwater measurements (Bjarnholt and Holmberg[1], ISEE[12]).

Partitioning of shock-heave energies: VOD controls the rate at which energy is released and consequently the ratio of shock and heave components. With high VOD, larger percentage will be shock energy while with low VOD (non-ideal detonations) heave energy would be larger. Modelling through thermo-chemical calculations has been carried out to ascertain the partitioning (ratios) of the two energies, but have not been quantified during blasting. Shock: Heave ratios for ANFO was 15:85 and 30:70 for AN-based explosives, as measured by underwater test (Mahadevan[15]).

Thermo-Chemical Calculations

This is an advanced technique of computing explosive energy, wherein the heat of explosion of the explosive formulation is calculated by assigning values to the individual ingredients used. The technique uses the 'equations of state' and computer programmes developed specially for the purpose. The sophistication of the programme, the equations used and values assigned by the developer of the programme to individual ingredients in the composition are the possible limitations of this technique. Energy calculated for the same formulation using two different computer programmes may yield different values. TIGER programme is popular and widely used by researchers and scientists for computing explosive energy (Sarathy and Vidyasagar[20]).

ROCK MASS DAMAGE MECHANISMS DUE TO BLASTING

In bench blasting, side break and back break occur due to wrong drillhole placement, improper blast design and initiation timing-sequence. Damage occurs due to excessive burdens, lack of free face for blasted rock to move into or due to geology - rock mass strength and structural integrity. Damage is caused when borehole pressure and blast induced stress exceeds the in-situ dynamic compressive strength of rock. Repeated blasting leads to reduction of shear strength and shear failure is controlled by shear strength of rock mass, duration of blast and blast vibration levels. Negative gas pressures in relation to atmospheric pressure upto -78 kPa have been recorded 1-3 burdens behind blast. In blasts having good free face (adequate relief), negative pressures are caused by volumetric increase of the air chamber (monitoring drillhole) due to opening up of new cracks and air gets sucked into the fractures. Positive pressures are recorded in confined shots as in crater blasts (Brent and Smith[3], Ouchterlony et al[17]). Negative pressures are also caused by forward burden movement which creates a huge void and expanding gases take the path of least resistance (Kanchibotla[13]).

Gas driven crack extension and block heaving - In jointed medium, separation of layers occur and gas driven crack extension behind the blast is a major cause of wall damage. High pressure gases wedge into structural discontinuities and separate them. Damage is controlled by the joint strength and

Block heaving occurs at the crest due to cratering effects caused by poor relief. Gas penetration dilation into blast generated fractures and natural joints 20-30 m behind blast has been recorded (McKenzie[16]).

Release of Load - In strata with discontinuities parallel to the last row of drillholes, behavior of rock behind the blast is similar to a heavy steel plate falling on a stack of thick rubber sheets. The heavy plate progressively compresses the layers till its momentum is exhausted. The compressed rubber sheets then expand and lift the plate upwards and the layers also separate from each other. Similar phenomenon occurs in strata and is observed as tension fractures when large multi-row blasts are fired using in-line pattern (row delay) where all the drillholes in the row fire simultaneously. Vertical parallel cracks upto 60m behind newly created open pit bench face in large multi-row blasts have been observed (Hagan and Morris[11]).

Blast Vibrations (Peak Particle Velocity PPV) - Ground vibrations of high order are known to cause damage to in-situ rock. Damage criteria suggested by various investigators is given below (Singh[22]):

Table-4: Peak Particle Velocity Vs Damage

Investigator	PPV in/s	PPV mm/s	Damage criteria
Calder	10	254	Safe - no cracks occur
	10-25	254-635	Minor tensile scabbing
	25-100	635-2540	Strong tensile and radial cracking
	100	> 2540	Break-up of rock mass
Langefors	12	305	Fall of rock in unlined tunnels
	24	610	Formation of new cracks
Oriard	> 25	> 635	Damage to rock

4. PRE-BLAST MONITORING

Evaluating rock characteristics

Mechanical properties such as density, hardness, compressive strength, tensile strength, Young's modulus, longitudinal wave velocity (sonic velocity) can be measured in the laboratory using drill cores. Sonic velocity is a parameter that can also be measured in the field. In this method two holes are drilled at a known distance apart and filled with water. One drillhole is charged with a small explosive charge primed with an instantaneous electric detonator and a sensor is placed inside the other drillhole (Figure-2). The sensor is activated at the same time firing current is delivered to the detonator. The time taken by the shock wave to reach the gauge after detonation of explosive is measured. The distance traversed and the time taken can be used to derive the sonic velocity of strata in field. A schematic of measurement is given below (Lang and Favreau[14]).

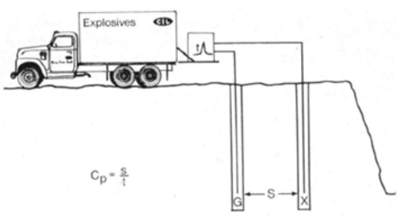


Figure-2: Measuring Sonic Velocity in the field
Cp = S/T
Cp = Sonic velocity
S = Distance between charge and gauge
T= Time recorded by Oscilloscope
G= Geophone/Gauge

Measure While Drilling (MWD)

MWD is not a new development. During mid-seventies, Bucyrus-Erie drills imported by Kudremukh Iron Ore Co Ltd came fitted with a module that displayed few performance parameters during drilling. With technology advancements, today's monitors are more accurate, reliable, rugged, with data storage and can be connected with satellite communication systems. The parameters monitored during MWD include drilled depth (m), penetration rate (m/s), rotary speed (RPM), pull down pressure (N), torque (Nm) and flushing pressure (kPa), bailing velocities (m/s) and drill vibrations. With MWD, the drilling and blasting engineers get information on the nature of strata being penetrated by the drill over the entire depth, such as hard-soft bands, presence of vughs, open fissures etc. by which appropriate selection of explosive, explosive charging techniques and placement of inert stemming decks at desired horizons can be adopted, as required.

GPS Based Drill Positioning, Drill Monitoring and Bulk ExplosivesCharging

Global Positioning System (GPS) technology has been adapted for drilling and blasting during the last few years. The system encompasses various operations including accurate positioning of drills, drilling the drillholes as per desired inclination and depth, monitoring the drilling using measure while drilling (MWD) and pass on the information through satellite communication to the blast designer who may be sitting several thousand kilometers away in front of his computer. The data from the drilling is analyzed and appropriate information is passed onto the bulk explosive loading pump trucks stationed at site. The on-board electronics accurately charges the drillholes with the desired quantity and the type of explosive commensurate to the strata conditions recorded by MWD.

ASCERTAINING DENSITY OF Explosive

The density of an explosive is useful for calculating detonation pressure, bulk strength and whether product would sink in watery drillholes or not. The simplest method of measuring density is to fill a measuring jar of known empty weight and volume, with explosive whose density is to be measured and ascertain its final weight (g).

$$\text{Density} = \frac{\text{Weight of jar with explosive (g) - Weight of empty jar (g)}}{\text{Weight of empty jar (cc)}}$$

The density of explosive in full cartridge form is ascertained by water displacement method, also known as immersion density method. An explosive cartridge is suspended from a spring balance and weighed (Wa). A suitable container is filled with water or any liquid whose density is known (dl). The explosive suspended from spring balance is fully immersed into the liquid and reading on spring balance is noted (Wl). Water can be used for products whose density is higher than that of water (Figure-3).

For products whose density is lower than 1 such as AN-FO whose density is 0.85-0.9 g/cc, then appropriate lower density liquid such as mineral oil whose density is 0.8 g/cc can be used (Vidyasagar[24]).

$$Density\ D = \frac{W_a}{W_a - W_b}(D_1 - D_a) + D_a$$

Where:
D- density of sample, g/cc
Da - density of air (=1.2 g/cc)
Dl - density of auxiliary liquid (=1 g/cc in case of water)
Wa- weight of sample in air
Wl- weight of sample in the auxiliary liquid

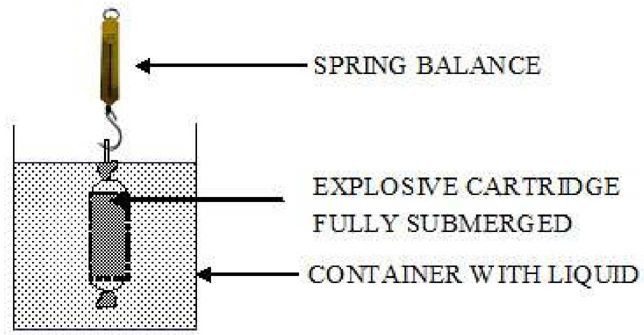


Figure-3: Method of measuring explosive cartridge density

IN-BLAST MONITORING

Velocity of Detonation (VOD)

VOD can be measured under different conditions, such as (a) unconfined - in open (b) partly confined in pipes of various materials and wall thickness (c) fully confined as in a stemmed borehole. However, for measurement of VOD inside a stemmed drillhole, continuous recording during detonation is preferable as it provides useful information such as:

- Sensitivity of explosive charged in the drill hole.
- Adequacy of booster (size and weight) for reliable initiation of explosive column.
- Overdrive - underdrive if any, steady state VOD, low order detonation, if any.
- Detonation stability, sudden drop in VOD, detonation failure.
- Deterioration of explosive due to extended sleeping times or charged into drillholes containing static/dynamic water.
- Explosive subjected to high hydrostatic pressure at the bottom of deep drillholes by explosive's own weight, stemming and water.
- Contamination of explosive due to drill cuttings flowing into drillholes during charging.
- Explosive charge separation caused by drillhole wall collapse or water (low density).

The classic D'Autriche method is a non-electric method and utilizes detonating cord of known VOD to measure VOD of the explosive under test. VOD is measured between two discrete points in an explosive column and this method is suitable for surface measurements only. VOD is also measured between two discrete points in an explosive column using ionization probes and 'start-stop' digital timer. The probes are simple to assemble and consist of two strands of thin insulated mono-core wires twisted and embedded in the explosives at a known distance apart. The detonation shorts the first probe which starts the timer and stops when the second probe gets shorted and the time interval is recorded in micro or milliseconds. Similar concept is possible with fiber optics-based timer which senses the light when detonation passes through. The above three methods can be used for measuring VOD on surface, either in the open or partly confined in pipes. The electric timer method can also be adapted for measuring VOD in-hole (point-to-point) with the probes designed as targets and multiple targets can be used with multi-core electric cable. Fiber optic ribbon cable can also be used. A timer using six-core cable (electric/fiber) enables recording 5 VOD readings across chosen inter target-fiber distances.

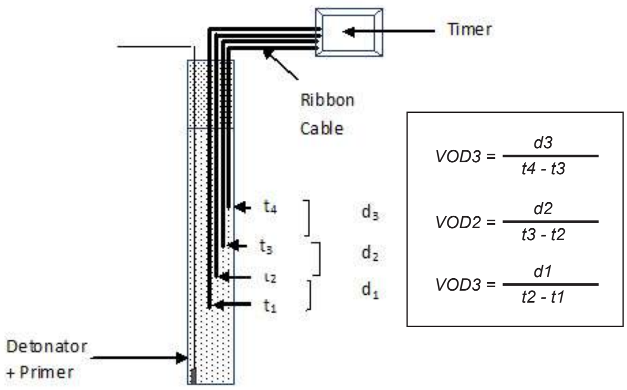


Figure-4: Measuring VOD between discrete points along explosive column

4.2.2.1 Spike technique: This technique uses shorting of wires or targets placed in the detonating explosive column. Multiple targets at pre-determined intervals are used. Upon shorting of the probe, capacitors in a circuit board get discharged and spikes are recorded in an oscilloscope. VOD is determined from the distance between spikes and actual distance between targets (Chiappetta and Vendenberg[9])

Continuous in-hole VOD measurements (Chiappetta and Vendenberg[9]):

4.2.2.2 Resistance wire method: This method uses two insulated twisted wires of known resistance per metre, a constant current generator and an oscilloscope. This is placed along the explosive column inside the drillhole. As detonation progresses, the cable gets shorted by ionization and as the length gets reduced, so does the resistance. The rate of change of resistance results in voltage drop which is proportional to shortening length of twisted wire (consumed during detonation) recorded by the oscilloscope and data used to deduce the VOD.

4.2.2.3 SLIFER (acronym for Shorted Location Indication by Frequency of Electrical Resonance):This method uses a shorted co-axial cable placed along the explosive column and an oscillator. Frequency of the cable is governed by its length. As the cable length gets shorter by the progressing detonation, frequency of oscillation increases. Rate of change of length of cable is determined by monitoring frequency as a function of time with the help of in-built electronics.

4.2.2.4 Time Domain Reflectometry (TDR) - CORRTEX VODR-1 system: System uses technique similar to radar, wherein a pulse of radio waves is sent out and a reflected pulse (echo) is returned. The system uses a co-axial cable and principle used is electric pulse getting reflected from the cable end, even if the cable is not shorted at the end. Reflection occurs wherever circular shape of cable is changed by the detonation and system works very reliably even when cable is not consumed as required in SLIFER or resistance wire method.

4.3 Detonation Pressure and detonation temperature

Detonation pressure is the pressure within a detonating column of explosive, behind the interphase of reacting and unreacted zones. Detonation pressure is a function of VOD and density of the explosive and implies that explosives with higher VOD and higher density would generate higher detonation pressure. Cavanough and Onederra[5] used carbon resistor gauge to measure detonation pressure inside drillholes. They also designed sensor to measure detonation temperature using photo-transistor. Measuring detonation temperature in-hole during detonation requires very rugged sensors that have to withstand high pressures and temperature, record and transmit the signals in a very short time before they get destroyed. (Figure-5).

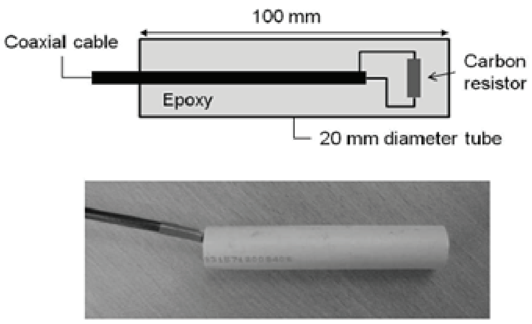
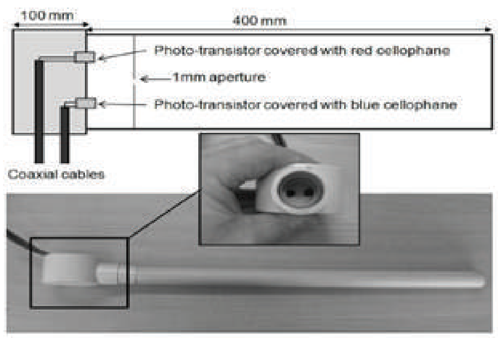


Figure-5: Sensors for measuring detonation pressure/temperature



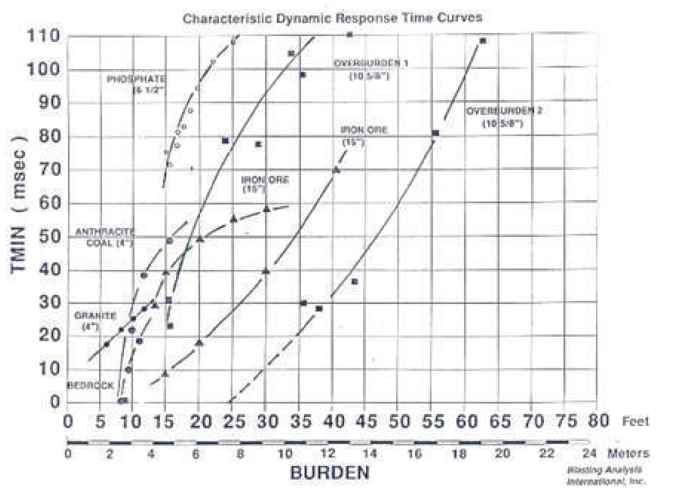
BOREHOLE PRESSURE, GAS VOLUME and WATER PROOFNESS

Borehole pressure is the pressure generated on the walls of the drillhole after detonation of explosive and is considered to be approximately 45-50% of detonation pressure. Gas volume liberated by different explosives is ascertained by thermo-chemical calculations or measurement by detonating explosive in specially constructed steel vessels or chambers excavated in rock. Commercial explosives are known to generate 800 - 950 liters of gas per kg of explosive as indicated in product data sheets of manufacturers.BIS Testing Standard IS 6609 Part II Section 1 describes test for water proofness of an explosive in cartridge form.

High-Speed Photography / Videography and Burden Response

High speed cameras are widely being used now-a-days as a diagnostic tool for optimization. Blasts are observed and results assessed both qualitatively and quantitatively. Blasts are picturized at speeds ranging from 400 to 1000 frames (pictures) per second. The resolution at 400 FPS would be 1 image per every 2.5 milliseconds while with 1000 FPS, it would be one image per every millisecond. Blasts are picturized at high speed and analyzed frame by frame using motion analyzers or similar equipment. Information obtained from studies are:

Qualitative	Quantitative
a) Drillholes firing out of sequence, timing accuracy related. b) Energy (gas) venting due to geology-through joints, mud seams, bedding planes. c) Blown out shots due to excess burden, ineffective stemming, watery drillholes. d) Misfires, if any.	a) Firing times of drillholes / initiators. b) Frontal burden movement velocity (face). c) Uplifting velocity from collar zone. d) Venting velocity (gas energy). e) Burden movement trajectory during overburden casting. f) Burden response.



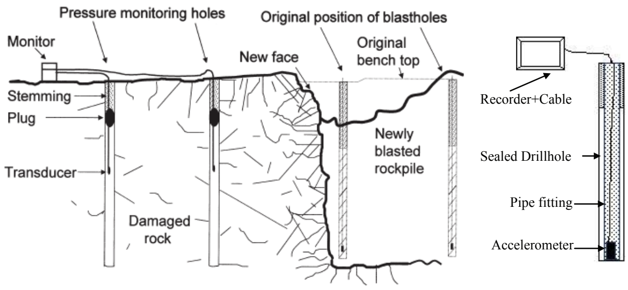
INFRA-RED DEVICE FOR MONITORING DRILL HOLE FIRING TIMES and BURDEN MOVEMENT

Infra-red sensing device has been tested for ascertaining firing times of individual drillholes and between rows.

Since blast progresses from front to back, the firing of drillholes at the back invariably get obscured by the stemming ejection, blast gases and dust generated by the drillholes firing in front. Infra-red sensor operates at a wave length approximately 10 times longer than the visible wavelengths. Longer the wave length, more efficient is the penetration through stemming ejection, escaping gases and dust. Infra-red device picks up the bright flash from detonating cord trunk lines or an upline taken from the explosive column and bundled on a stake embedded on the surface near the drillhole collar. Infra-red sensor gives an electric signal output and not a visual one (Blair and Little[2]).

MONITORING damage TO in-situ rock mass DURING BLASTING

Instrumented monitoring is carried out behind blast in dedicated sealed drillholes using vibration accelerometers and pressure transducers for measuring borehole air pressure (Figure-6). Commonly used gauges are carbon resistors, manganin gauges, piezo-electric type sensors, transducers and hydrophones (Brent et al[3,4], Ouchterlony et al[17]). Monitoring drillholes are filled with water and observed during blast using high speed photography to see effect of gas pressure on water columns in the drillholes.



Post-Blast Fragmentation Analysis

Fragmentation measurement is usually depicted as a size distribution curve with percentage passing of fragments vis-à-vis fragment size. Quantifying fragmentation is a means of determining blast performance vis-à-vis excavator bucket and crusher opening (grizzly) size. Qualitative visual analysis or 'eye-ball assessment' is the easiest and least expensive method, based on long experience of the blaster carrying out blasts regularly at site.According to Cunningham[10] the eye is not a good judge of mean size, especially for muckpiles with low uniformity. Sieving of entire blasted muck has been attempted for large production blasts. Boulder count, quantum of secondary blasting, bridging delays at crusher, excavator-dumper productivity studies are the other methods used. With advancements in image processing and computer graphics, fragment size analysis using photogrammetry has become accurate (Chiappetta[7]). WipFrag, Split Desktop, Shovel Metrics, Fraglyst4.0 (CIMFR), PowerSieve & FRAGTrack (ICI/Orica) are few references.

Monitoring Muckpile characteristics

Good fragmentation and muckpile characteristics are important parameters linked to efficient loading. They include (a) Muckpile profile suitable to the loading machine in use (b) Muckpile looseness (c) Swell factor (percentage) and void ratio (d) Uniformity index (e) Angle of repose (f) Centre of gravity of mass (g) Spread (h) Skewness (i) Moisture content in muckpile. Use of drones for carrying out survey of muckpile after blast is becoming popular.

Assessing Rock Damage – core DRILLING and BOREHOLE CAMERA

Monitoring damage to rock behind the blast is essential from final pit wall slope stability point of view. While gas pressures and particle velocities are measured behind the last row during in-blast, post-blast damage assessment is carried out by:

- Drilling cores at pre-determined locations both pre-blast and post blast and examining the cores for new cracks, damage.
- Visual examination of a dedicated array of empty drillholes behind a blast using borehole video camera, before and after a blast. Brent and Smith[4] observed many large horizontal open cracks and several large vertical cracks after blast (Figure-7), while no visible discontinuities or structures were observed before blast.
- Extensometers for ascertaining large shifting / movement of rock mass.
- High frequency cross borehole seismic logging for determining crack density.

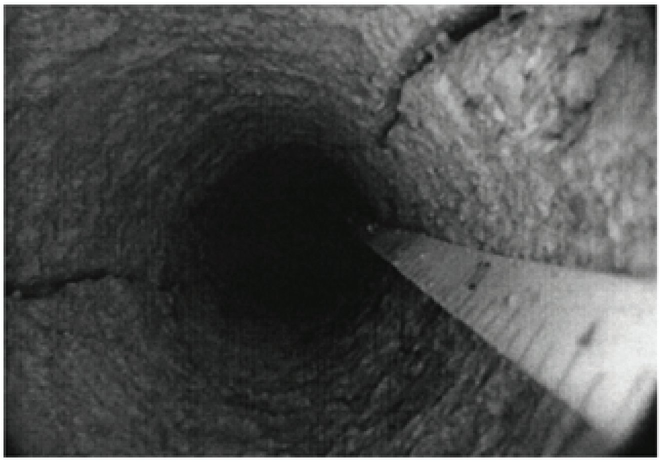


Figure-7 Damaged monitoring drillhole showing cracks (Brent and Smith4)

Monitoring Ore-Waste Rock BOUNDARIES IN MUCKPILE after Blast - USE OF Blast Movement Monitors (BMM)

In ore mining blasting, de-lineating ore-waste rock boundaries before blast (in-situ) and after blast (within muckpile) helps in 'selective excavation' by loading machines. Inaccurate post-blast delineation can lead to valuable ore erroneously going to the dumps and waste material miscategorized as ore sent for processing. Contamination of ore with waste rock can affect comminution costs for extraction of same quantity of metal. Earlier methods for delineation used physical objects (markers) such as wooden stake, coloured PVC pipe, chain, rope, coloured sand filled in bags.

The markers though of low cost and easy to adopt, have limitations such as poor recovery and become visible only during excavation. Another major drawback is their inability to measure sub-surface movement (Rogers and Kanchibotla[18]). Blast Movement Monitors (BMM) are Radio Frequency Identified (RFID) tags-based transmitters housed in strong shock resistant material moulded in the form of a sphere (Figure-8). In the block being blasted, a set of dedicated drillholes are drilled which are not charged (kept empty) and a BMM dropped into each one of them. The system consists of:

- Directional Transmitter.
- 'Activator' which switches on each transmitter and programs them as required.
- A special 'Detector' to locate each BMM in-situ.
- Dedicated software which calculates the movement of each BMM in 3-dimensions.

The BMMs after activation are dropped into the dedicated empty drillholes andpositions surveyed. After blast, their resting positions within the muckpile are located using the detector which processes the data using the dedicated software and information is stored for posterity. It takes 1-2 hours to process the entire data and to identify the in-situ ore-waste rock boundaries. The information is passed onto the excavator operator and for appropriate deployment of excavators. BMMs are recovered after blast from the muckpile and can be re-used. (Thornton[23])

Figure-8: Blast Movement Monitor
(image downloaded from google)

5. CONCLUSIONS

This paper reviewed the various monitoring techniques available for assessing performance of explosives systems and blast outcomes in large open pit mines and quarries. A complete technical audit during the three phases of activities namely pre-blast, in-blast and post-blast is essential in evaluation of explosives performance and blast results. Mines should explore the possibility of using various monitoring systems at different phases for scientific evaluation of blast designs and blast outcomes. If some of the instrumentations are not available with the mine, they can hire the services of consultants to identify operations needing improvement for optimization.

Acknowledgement

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SCIENTIFIC / TECHNICAL PAPER

ANALYSIS OF THE VISION STATEMENTS OF SEVEN LEADING MINING ENGINEERING INSTITUTES IN INDIA

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ABSTRACT

Seven leading mining engineering institutes were selected based on the 2020 national rankings of institutes/universities. Vision statements of these institutes were evaluated by performing content and sentiment analyses, and similarity checks using online tools. The readability analysis indicates that the vision statements of six institutes are difficult to comprehend, and the vision statements of two institutes are lengthy to communicate and remember. The sentiment score for six institutes is also low. Text similarity and grammatical mistakes were noted in some cases. After evaluating the vision statements, recommendations are made on how the vision statements of the institutes can be modified.

Keywords: Vision, Vision statement, Mining institute, Content analysis

1. Introduction

Vision and mission statements of an organisation are commonly found on the public facing websites. A vision or vision statement of an academic institute describes its long-term goal that it aspires to become in the future, normally within a defined timeframe. An effective vision is characterized by clarity, conciseness, ambitious, time bound, inspiring, achievable, consistent, imaginable (Kantabutra and Avery, 2010; Papulova, 2014; Wilson, 1992; Kirkpatrick, 2008). Six of these characteristics can be represented by an acronym VISION where the meaning of each letter is (Couch, 2014): V = Vivid (Clear); I = Inspiring; S = Succinct (concise); I = Intentional (Imaginable); O = Optimistic (positive/achievable) and N = Noteworthy (memorable).

A quick look at vision and mission statements of some academic institutes gave an impression that the vision statements are not written properly, clearly and concisely. This prompted the author to analyse the vision statements of the top seven mining institutes in India. To further narrow down the scope of the study, the vision statements in this paper are evaluated based on five parameters, namely readability, text statistics, sentiment, uniqueness and language efficiency. After identifying the deficiencies in the vision statements, some suggestions are provided for their modifications.

2. Methods

The top seven institutes that offer mining engineering degree courses were selected based on the 2020 rankings of National Institutional Ranking Framework (NIRF), Ministry of Human Resource Development (MHRD), Government of India (https://www.nirfindia.org/2020/EngineeringRanking.html). These institutes are: 1) IITK (Indian Institute of Technology Kharagpur), 2) IITISM (Indian Institute of Technology (ISM), Dhanbad), 3) IITBHU (Institute of Technology (BHU), Varanasi), 4) NITK (National Institute of Technology Karnataka, Surathkal), 5) VNIT (Visvesvaraya National Institute of Technology, Nagpur), 6) IIEST (Indian Institute of Engineering Science and Technology, Shibpur) and 7) NITR (National Institute of Technology Rourkela). The national ranks of IITK, IITBHU, IITISM, NITK, NITR, IIEST and VNIT are 5, 11, 12, 13, 16, 21 and 27, respectively. Vision statements, their websites, the latest rankings of the institutes are given in Table 1.

Powerful natural language processing and machine learning analytics were selected from the online survey of available tools. An online software tool (https://www.online-utility.org/) was used to compute six different readability indices, namely Gunning fog score, Coleman Liau index, Flesch Kincaid Grade Level, Automated Readability Index, SMOG and Flesch-Kincaid reading ease. The same tool was also used to compute text statistics of vision statements, which automatically counted the number of characters, sentences, words and complex words, percentage of complex words, number of words per sentence and average syllables per word. These attributes can measure the complexity of a text. Vision statements of the selected institutes were combined into a single text and keywords from this text were identified according to their frequencies of occurrences.

Microsoft Azure (https://azure.microsoft.com/en-in/services/cognitive-services/text-analytics was used to determine whether the sentiment score of the vision statement of each institute is positive, neutral or negative. Sentiment analysis is a proven tool in understanding customers' perceptions related to products and services (Farhadloo et al., 2016).

The vision statements were also checked for similarity or uniqueness of the content using online plagiarism checker. If a duplicate content was found, this tool displayed the link. Finally, vision statements of the institutes were also checked for grammatical errors.

Table 1 Selected institutes with their national rankings, websites and their vision statements

Rank-5: Indian Institute of Technology Kharagpur (IITK) http://www.iitkgp.ac.in/about-iitkgp -To be a centre of excellence in education and research, producing global leaders in science, technology and management -To be a hub of knowledge creation that prioritises the frontier areas of national and global importance -To improve the life of every citizen of the country.
Rank-12: Indian Institute of Technology IIT(ISM), Dhanbad https://www.iitism.ac.in/index.php/pages/vision To be a nationally and internationally acclaimed premier institution of higher technical and scientific education with social commitment having an ethos for intellectual excellence, where initiative is nurtured, where new ideas, research and scholarship flourish, where intellectual honesty is the norm and from which will emerge the leaders and innovators of tomorrow in the realm of technology. While serving as a catalyst in a developing society, its goal as one of the premier technology education institution in the country would be to intimately involve itself not just in the technological development of the Nation but indeed in its overall development.
Rank-11: Institute of Technology (BHU) (IITBHU), Varanasi https://www.iitbhu.ac.in/administration/vision The institute aspires to be a harbinger of modern interdisciplinary technological advancement in the country and at a forefront of imparting quality education by use of innovative pedagogy culminating traditional with contemporary methods. The institute also envisions building best in class infrastructure that not just attracts outstanding faculty, staff and students but also help institute to create an atmosphere for developing technologically astute professionals with a strong entrepreneurial spirit. - Pursuance of Value Based Excellence in Science & Technology Education and Research. - To serve Humanity through enlightened and morally sound human capital. - To contribute to the development of the nation by solving the problems of the nation and society at large.
Rank-13: National Institute of Technology Karnataka (NITK), Surathkal https://old.nitk.ac.in/general-info/our-vision-and-mission To facilitate transformation of students into good human beings, responsible citizens and competent professionals, focusing on assimilation, generation and dissemination of knowledge..
Rank-27: Visvesvarava National Institute of Technology (VNIT), Nagpur http://vnit.ac.in/vision-and-mission/ To contribute effectively to the national and international endeavor of producing quality human resource of world class standard by developing a sustainable technical education system to meet the changing technological needs of the country and the world incorporating relevant social concerns and to build an environment to create and propagate innovative technologies for the economic development of the Nation.
Rank-21: Indian Institute of Engineering Science and Technology (IIEST), Shibpur https://www.iiests.ac.in/IIEST/About To become one of the best Institutes in the world in providing the state-of-the art multi-disciplinary research ambience that will usher innovative world-class technologies developed towards realizing the goal of developed India.
Rank-16: National Institute of Technology Rourkela (NITR) https://www.nitrkl.ac.in/# To become an internationally acclaimed institution of higher learning that will serve as a source of knowledge and expertise for the society and be a preferred destination for undergraduate and graduate studies.

Note: Websites were accessed on 20 June 2020

3. RESULTS AND DISCUSSION

3.1 Content Analysis

The computed readability indices of vision statements of the institutes are shown in Figure 1. The readability indices of Gunning fog score, Coleman Liau index, Flesch Kincaid Grade Level, Automated Readability Index, SMOG vary from 10 to 37. Gunning Fog index indicates the number of years of formal education that a person requires to easily understand the text on the first reading. Coleman Liau index, Flesch Kincaid Grade level, Automated Readability Index and SMOG represents the U.S. grade level needed to comprehend the text. Basically, these readability indices represent the number of years of formal education needed to understand a text. Thus, the lower the index, the easier is the text to read, and conversely, the higher the index, the more difficult the text is to read. Although the basic purpose of all readability indices is the same, the calculated values differ due to the criteria used in counting various punctuations, texts and syllables (Zhou et al., 2017). The score of Flesch-Kincaid reading ease lies between 0 and 100, where 0 in contrast with other indices is 'extremely complicated', 100 is 'quite easy' to read, and negative values are assigned zero.

On the basis of the readability scores (Figure 1), the vision statement of IITK can be understood by a person having the education level of 12 standard while the vision statements of other six institutes are 'difficult' to 'very difficult' to understand and remember by most students and employees of the institutes. These institutes can improve the readability scores by cutting down lengthy sentences and replacing complex words with simpler ones.

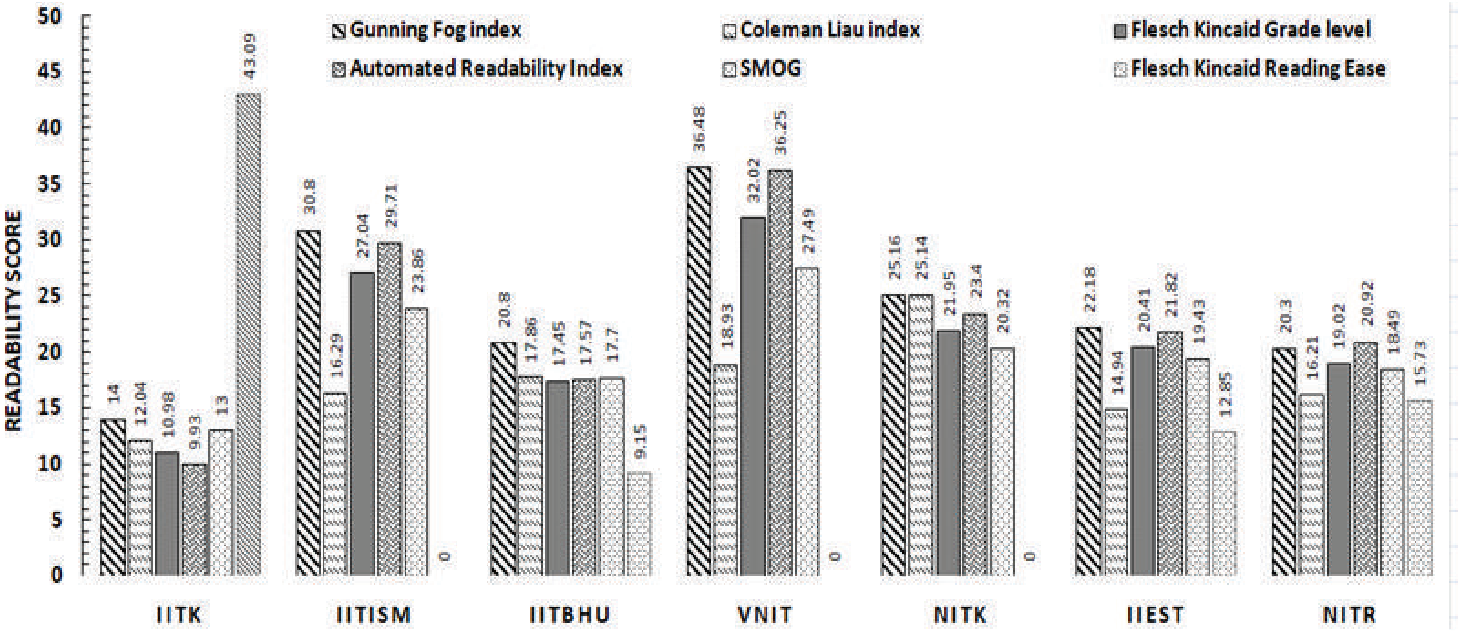

Figure 1. Readability indices for vision statements of the institutes

The overall text statistics of vision statements of seven institutes are presented in Figure 2. Judging by the number of words/characters, the vision statements of IITBHU and IITISM are lengthy. Therefore, these two institutes may rewrite their vision statements concisely, preferably limiting word counts to 50.

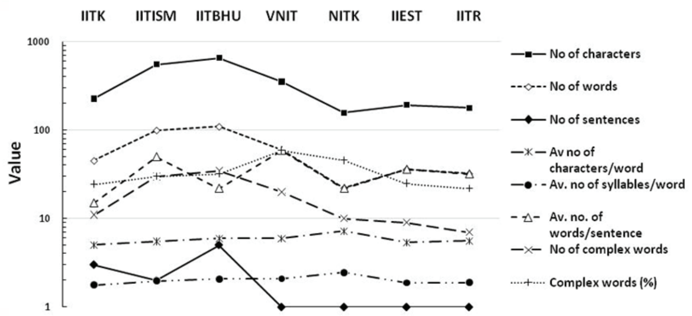

Figure 2 Text statistics of vision statements of the institutes

The keywords that occurred three or more times in the vision statements of the institutes are shown in Figure 3. The most common keywords are country/nation, education, technology/technologies, institute/institution and research.

3.2 Sentiment Analysis

The results of the sentiment analysis of the institutes' vision statements are given in Table 2. Highly positive values are considered to be emotionally charged. If the vision is emotionally charged, emotion acts as the driving force towards achieving the vision (Brătianu & Bălănescu, 2008). If a positive sentiment of 60% is considered desirable, the vision statements of six institutes lack adequate emotion to inspire and motivate the employees and students to work harder in order to achieve success.

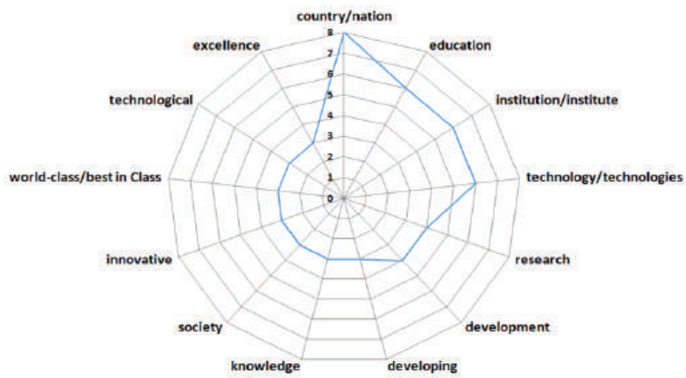

Figure 3 Most frequently used keywords in the vision statements of the institutes

Table 2 Sentiment analysis of the vision statements of the institutes

Institute	Sentiment		
	Positive, %	Neutral,%	Negative,%
IITK	69	30	1
IITISM	19	69	12
IITBHU	39	27	34
NITK	59	41	0
VNIT	5	95	0
IIEST	15	85	0
NITR	22	78	0

3.3 Text Similarity

An institute's vision should reflect uniqueness and originality in consistent with its objectives, values, strength and weakness. However, it was found that the vision statements of two institutes were identical with those of other institutes. The vision statement of NITK was similar to that of Takshila Institute, New Delhi. The vision statement of IITK was similar to that of the Indian Institute of Information Technology, Kalyani, West Bengal, and was also similar to that of the Government Polytechnic, Orissa. This study did not try to establish whether the vision statements of NITK and IITK were copied partly by other institutes.

3.4 Grammatical Issues

Simple grammatical mistakes can be noted in some vision statements (Table 1), indicating that vision statements were prepared casually and without involving people. It is suggested to rewrite the vision statements correctly.

3.5 Evaluation of the vision statements

A summary of evaluation of the vision statements of institutes using readability, conciseness, sentiment, uniqueness and grammatical correctness is given in Table 3

Table 3 Evaluation of vision statements of the institutes

Institute	Readability	Conciseness	Uniqueness	Positive sentiment score	Grammatically correct
IITK	Y	Y	?	Y	Y
IITISM	X	X	Y	X	X
IITBHU	X	X	Y	X	X
NITK	X	Y	?	X	X
VNIT	X	Y	Y	X	X
IIEST	X	Y	Y	X	X
NITR	X	Y	Y	X	Y

Note: y: the criterion is satisfied, x: not satisfied, and ?: doubtful

3.6 Some suggestions for modification

The following suggestions are put forward to overcome the deficiencies in the vision statements of the selected institutes.

Although the statement of IITK is acceptable, one of its elements "To be a hub of knowledge creation that prioritises the frontier areas of national and global importance" may be deleted because 'excellence in research" implies "knowledge creation in the frontier areas."

Looking at the competencies of other reputed institutes, it may not be realistic for IITK to achieve the number one position in the national rank in 3-5 years.

At the global level, Figure 4 shows IITK is not listed in the top-200 universities in any of the three major global rankings, namely Times Higher Education (THE), Academic Ranking of World Universities (ARWU), and QS World University Rankings. In this figure, the data of IITK for 2021 world rankings by 'THE' are missing as seven IITs, including Kharagpur did not participate in it because they were not convinced about the parameters and transparency of the ranking process. In its vision statement, this institute may include "to be one of the top 200 institutes in the world rankings". This goal is achievable by enhancing its international outlook through a significant increase both in international students and international faculty in the institute.

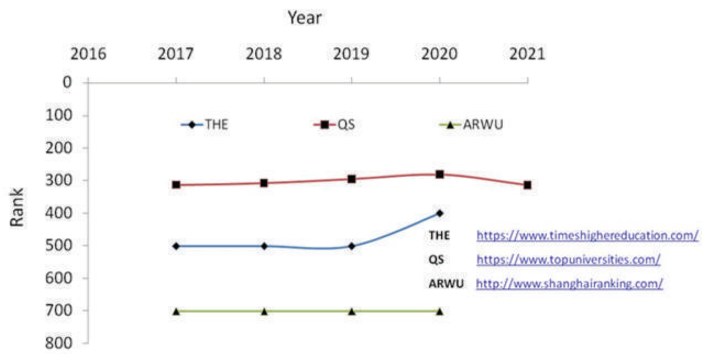

Figure 4 Global rank of IITK as per three popular global rankings

VNIT needs to improve the readability of its vision statement. It may include another element in its vision "to be a top-10 engineering college in India by 2025". The progress achieved by the college can be measured as per NIRF rankings which are published every year. The suggested vision statement is ambitious as it aims to attain a position within top-10 engineering institutes in India from its present rank of 27.

IITISM may rewrite its vision statement to make it concise and clear including the following elements:

- To be an internationally acclaimed institution of higher technical and scientific education with social commitment.
- To be one of the premier technology education institutions in the country from which will emerge the leaders and innovators of tomorrow in science and technology.

For conciseness, one of the elements of IITBHU's vision "The institute also envisions building … faculty, staff" may be deleted as it depends more on the availability of funds. Another element "by use of innovative pedagogy … traditional with contemporary methods" may also be deleted because a vision statement need not describe the plan to achieve the vision.

NITK is currently facilitating the transformation of students into good human beings, responsible citizens and competent professionals. It is also focusing on assimilation, generation and dissemination of knowledge. Therefore, readers are not able to visualize the image of what the institute desires to achieve over the next five years.

IIEST may modify its vision statement to improve the readability and sentiment scores. It need not specify "multi-disciplinary" research, which can be in a specific discipline or interdisciplinary, depending on the nature of the problem and the interest of the faculty and students. Further, the focus should be on research rather than “research ambience”.

With regard to the vision statement of NITR, it also needs to improve the readability and sentiment scores. In addition, it needs to find some ways to measure the progress and incorporate the time frame in its vision.

4.0 CONCLUSIONS

This study attempted to evaluate vision statements of the selected institutes based on five criteria such as readability, conciseness, sentiment score, text similarity and grammatical accuracy. As per the readability score, the vision statement of only one institute can be rated as clear and understandable while the vision statements of other institutes are “difficult to understand”. The analysis of text statistics shows that the vision statements of two institutes are not succinct and easy to remember. The vision statements of two institutes had similarity with those of some other institutes. The positive sentiment score of most of the institutes is too low to appeal to the hearts and minds of their employees and students. The recommendations made to rectify the observed deficiencies in the vision statements may be useful in modifying the vision statements of the selected institutes. While modifying the vision statements, these institutes should make their vision statements short and sweet or clear and concise that can be communicated and understood easily by the students, staff and faculty.

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Beyond the Maradu demolition: Abiding by the law

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ABSTRACT

The Petroleum and Explosives Safety Organisation (PESO), Ernakulam, Kerala monitored and supervised the entire demolition process supporting the offcials of Maradu Municipality who were appointed to implement the honourable Supreme Court order. The buildings were demolished by controlled demolition on Jan 11 and 12, 2020. In this paper, strategic planning of controlled demolition, placing of explosives material and timing of it's detonation are explained. The controlled demolition was conducted by experienced contractors and supervised by PESO.

1. Introduction

On 8th May 2019, the Honourable Supreme Court of India ordered five apartments in Maradu municipality in Kerala to be demolished within one month, for violation of Coastal Regulation Zone (CRZ) rules, however, only four of these apartments had been constructed. The four apartments already completed and occupied by the people were Jains Coral Cove (Jain Housing and Construction Ltd), H2O Holy Faith (Holy Faith Builders and Developers Pvt Ltd) and two blocks of Alfa Serene (Alfa Ventures Private Ltd) and Golden Kayaloram (KP Varkey & VS Builders).

The Apex Court stated that these apartments had been built on the shores of Vembanad wetland, renowned for its rich biodiversity. The wetland is a part of the strictly restricted zone for construction under the provisions of the CRZ notifcations, which aim to protect the ecology of the coast. Hence, the violations cannot be lightly condoned. The illegal constructions in Maradu might have hindered the natural water flow of Vembanad and resulted in severe natural calamities such as floods, which Kerala witnessed in 2018. Following the court order, residents, 335 families, started to protest.Despite this, the court gave strict instructions to the State government to speed-up the demolition process.

According to the Kerala Coastal Zone Management Authority, constructions had taken place in critically vulnerable coastal areas which are notified as CRZ-III, where no construction should be permitted except repairs of authorised structures. There were major administrative challenges in demolishing the apartments for the Maradu Municipality who has been authorised for the demolition by the State Government. Expert consultations had to take place, the public needed to be made aware of what was happening and a safe demolition strategy had to be drawn up.

Families in the neighbourhood, especially the families residing around Alfa Serene were anxious about their life and property. The safety of public assets such as roads, petroleum pipelines and bridges were also a concern. Besides, there were environmental costs of the demolition including air and noise pollution, contamination of t he lake, and safe disposal of the debris. The Government of Kerala appointed Fort Kochi Sub-Collector Mr. Snehil Kumar Singh as the special officer in charge of Maradu at Demolition.

2. Preparation for Controlled Demolition

2.1 Formation of Technical Committee

The Government of Kerala constituted a Technical Committee to assist and recommend the selection process of the agency for awarding the contract for conducting the demolition works of the four flats in Maradu Municipality. Members include demolition expert Shri. Sharad P Sarwate (First Class mining Manager) and members from Petroleum and Explosives Safety Organisation (PESO) under Government of India, Local self-government department (LSGD), Public Works Department (PWD), Kerala State Pollution Control Board (KSPCB) under Government of Kerala, Kochi Metro Rail Limited (KMRL) and the representative from Association of Structural and Geo-Technical Engineers.

2.2 Appointment of demolition contractors

The Technical Committee conducted meeting on 05.10.2019 and 11.10.2019 and selected two companies for the demolition of flats based on their technical expertise and experience in conducting such jobs.

The Technical Committee recommended for engaging M/s Edifice Engineering, Mumbai with technical partner M/s Jet Demolition (PTY) Limited for the demolishing work of Holy Faith H2O,. Jain Housing and Golden Kayaloram. And M/s Vijay Steels, Chennai with technical Partner Mr. Anand Sharma of M/s Quarry-tec, Jaipur for the demolishing works of two towers of Alfa Serene.

2.3 Blast Design

The first step was to examine the structural blueprints of the building. Then the demolition team inspected the building several times, held discussions with Structural Engineer about the support structure on each floor. After gathering the data, the team decided on the blast plan to decide which type of explosives were to be used, where to position them in the building and how to time their detonations. Each of these four buildings is constructed of different architecture.

PESO Ernakulam advised both the contractors to submit the blast design, implosion isochrone layout, drilling details, details of explosives intended to be used, blaster certificate, emergency plan, Hazard Identification and Risk assessment report and plan view of nearby structures and debris pile spread. M/s Jet Demolition (PTY) Limited and Mr. Anand Sharma presented the blast plan in several meetings with the PESO officials. Each of the activities were discussed in detail with special reference to pre-weakening of structure, drilling of charge holes, procurement of Explosives, quality control of explosives, Explosives blast design formula, Charging of explosives, barriers for containment of fragments, collapse footprint and sequence of detonation. PESO officers visited the site almost every 2 days inspecting the pre-weakening works, barriers positioning in containing fragmentation, drilling of holes and charging of explosives since 5th October. Instructions were given verbally and in writing for modifications required in several locations.

Implosion is defined as the designed collapse of a building using explosives within its own footprint [1]. Implosion involves difference between internal (lower) and external (higher) pressure, or inward and outward forces that are so large that the structure collapses inward into itself.

2.4 Footprint of Collapse

The footprint of the collapse is primarily determined by the trajectory of the fall of the building. For reinforced concrete columns, holes are first drilled in the column, the emulsion explosives are placed in the hole and stemmed to confine the charge. When the explosives detonate, the concrete in the column is fragmented leaving the reinforced bars bent. Almost all the explosives used in Maradu implosions are placed in columns. Columns at the lowest floor levels are the most important as that is where the stored potential energy is most effectively released [5].

3 Description of demolition

3.1 Pre-Weakening the Structures

The preparatory operation of demolition involved the weakening of the structures prior to implosion.The demolition companies' pre-removed certain non-load bearing partitions, walls and other elements on those floors of the structure where explosives were placed. This was done so that when these very small quantities of explosives were detonated inside these columns or wall supporting the structure, there were no partition walls or piping that might momentarily provide undesired support in the structure and prevent the desired failure sequence [6]

All the pre-weakening work of four flats was taken up simultaneously. Here, in this paper, the demolition of H2O Holy faith apartments is only considered because of the surrounding structures such as bridge, residential house and backwaters. Pre-weakening involves the removal of all non-loading bearing walls, fixtures, and fittings, mechanical equipment, plumbing and piping (electrical, water, sewage and communications), stairways and facades including all glazing from the building leaving intact the basic structural elements such as columns, beams and floors. In columns, which are drilled and loaded with explosives many that contain circular or rectangular steel stirrups or spirals that are tightly pitched were exposed and cut. Shear walls were pre-weakened mechanically by the removal of the concrete matrix around the steel reinforcing to make in effect plastic hinges that will operate to assist collapse when the implosion is activated.

3.2 Drilling of Holes

The key structural element that facilitates collapse is the column and so all columns are drilled to place explosives. Placing explosives on the face of columns lead to the explosive shock wave dissipating away from the column whereas if the explosive charge is placed into and central to the column the full extent of the shock wave produced by the detonation is impacted on the column. When explosives are placed in the drill holes for the pressure from detonation to be confined, stemming was provided using small bags filled with high-density foam.

The drilling of structural elements was done in such a manner to make the building fall to the predetermined direction based on the nature of building and immediate surroundings.

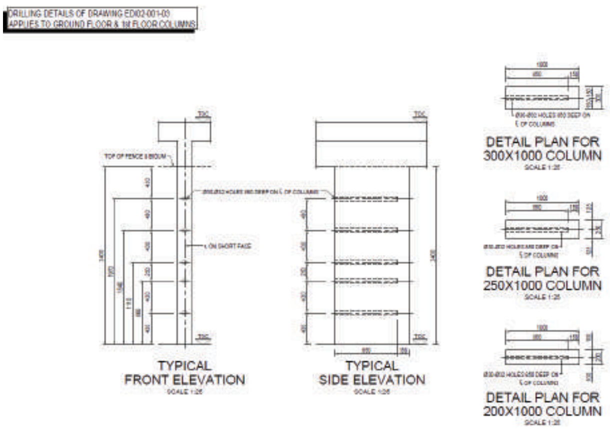

Figure 1: Drilling Details of Ground Floor and First Floor Columns

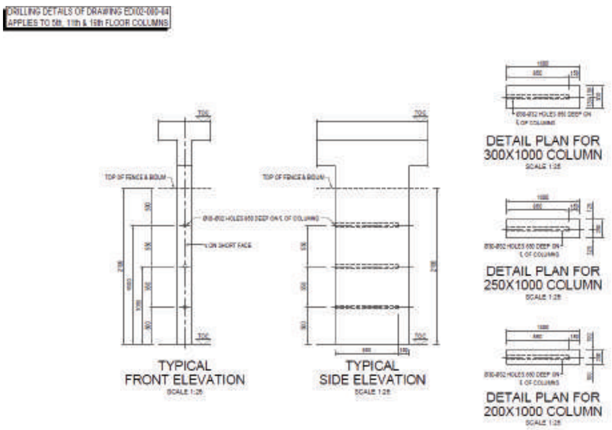

Figure 2: Drilling Details of 5th, 11th, and 16th Floor Columns

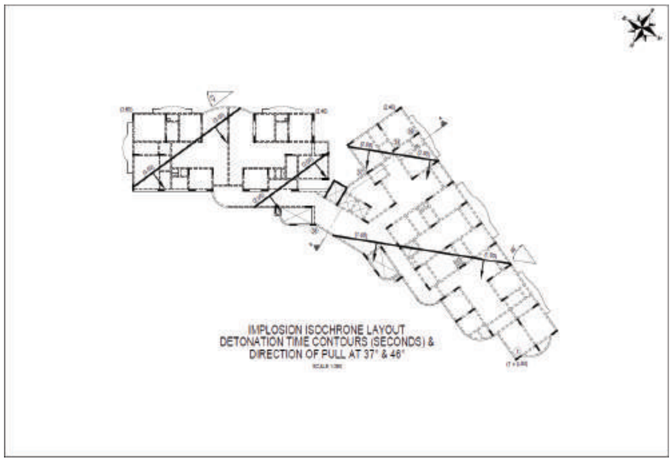

Figure 5: Implosion Isochrone Layout of H2O Holy Faith Apartment

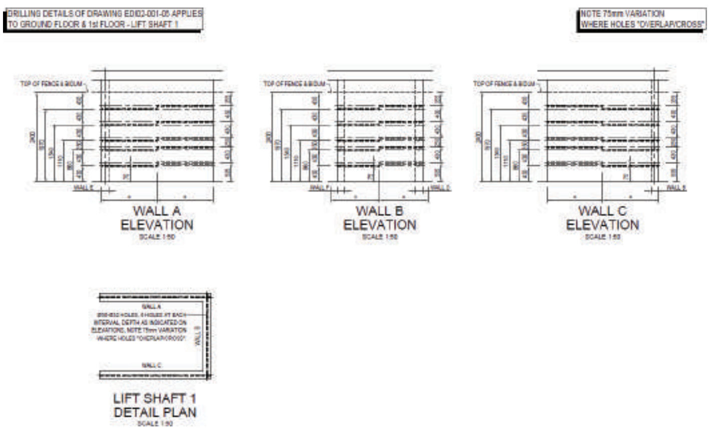

Figure 3: Drilling Details for Lift Shaft of Ground Floor and First Floor

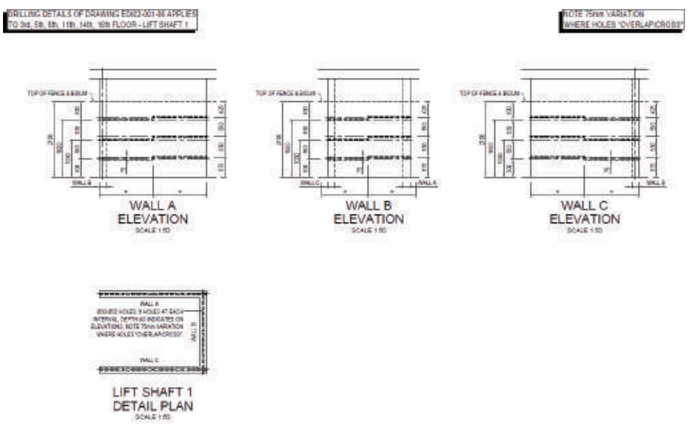

Figure 4: Drilling Details for Lift shaft of 3rd, 5th, 8th, 11th, 14th and 16th floor

3.3 Establishing Exclusion Zone

The design of the exclusion zone was carried out to identify the residence in and around or the inhabitants. An exclusion zone is identified to evacuate all residents, all inhabitants during the demolition. The exclusion zone was identified for each of the apartments to safeguard the public during the implosion of the flats.

3.3 Establishing Exclusion Zone

The exclusion zone was designed considering designed collapse mechanism, materials used in the structure, pre-weakening of the structure, quantity and type of explosives intended for use, topography and c ondition of t he site, extend of surrounding structures and whether they may need to be closures or public evacuation and the potential for noise, vibration and dust emissions. Everyone has been advised to be outside the exclusion zone at the time of the blast.

3.4 Sequence of Detonation

The theory that applied to a collapse timing is to collapse the building to the footprint. The columns at the bottom of the building are detonated first to make maximum amount of potential energy available immediately to get the progressive collapse. Column at the other floors are detonated in a few milliseconds to help fragment of the building debris and to control its fall direction and velocity. During this Maradu at demolition, the detonations are timed so that the alternate load path is created, the adjacent column line is detonated to allow continuity of the progressive failure. The individual explosive cartridges are primed with delay detonators. These delay detonators were wired together utilising the non-electric system. The system consists of detonating cord and emulsion cartridges. The entire system will be initiated with an instantaneous electric detonator. The electric detonator has two wires which will run to a capacitor discharge exploder (Blasting Machine). When the fire button is pressed, the exploder will pulse a charge of 600 volts, detonating the Nonel and beginning a chain reaction of small explosions throughout the structure.

3.5 Barriers for Containment of Fragments

To reduce ying debris, each column was wrapped with chain-link fencing and geo-textile fabric. The fence keeps large chunks of concrete from flying out, and the fabric catches most of the smaller bits. An extra net has also been wrapped outside of each floor i.e. loaded with explosives to contain any exploding debris that tears through the fabric around each individual column [7]. The loading of the column and wrapping of the column is shown in Figure 7.

Figure 7: Loading of column at Alfa Serene and wrapping of the column of H2O Holy Faith Apartments

3.6 Explosives used

The explosives used in Maradu demolition were Emulsion explosives, Non-electric detonators and Detonating fuse (DF). Water Gel and Emulsions consists of water-containing chemical mixtures that are either water gels or emulsions. Water gels contain oxidizing salts and fuels that are dissolved in water. Emulsions are fine droplets of oxidizing salts and water surrounded by a fuel mixture of wax and oil. These explosives are even more stable. The properties of emulsion explosives with regard to density, detonation pressure, fume characteristics, gas volume, sensitiveness, sensitivity, stability, strength, velocity of detonation (VOD) and water resistance.

The emulsion explosives are made by mixing fuel blend (FB) and oxidizer blend (OB) in the ratio 6 : 94. The fuel blend consists of microcrystalline wax, paraffin wax, paraffin oil etc. The oxidizer blend consists of Ammonium perchlorate. These salts are dissolved in water and made into a supersaturated solution at 90°C. The FB solution, consisting of the above-mentioned substances is heated to 85°C. The OB solution at 90 degrees centigrade and the FB solution at 85°C are transferred to a jet mixer in the ratio of 96 : 4 by means of mass ow meters. These solutions are subjected to high shearing action in the jet mixer in the presence of an emulsifier consisting of Sorbitan monoOleate (SMO) and Poly-isobutylene-Succinic-Anhydride (PIBSA). The SMO and PIBSA make up 1-1.5 % of the emulsion. In presence of these emulsifiers, the FB and the OB solutions in the jet mixer become emulsified and this emulsion is transferred to a KP machine after injecting the solution of Sodium Nitrite into the emulsion. Sodium Nitrite solution gives explosive characteristics to the emulsion and this process is called gassing of the emulsion. After gassing, the emulsion explosive is transferred to a KP packing machine and the emulsion is packed in polythene packs. The emulsion explosives have generally a VOD of 4000-4500 metres/sec and act as good explosives for blasting work. In the emulsion explosive, the FB is called as continuous phase and the OB is called as dispersed phase.

Non-electric detonators with various millisecond intervals were introduced for the initiation process, so as to ensure that the progressive collapse mechanism calculated ensued. The use of non-electric surface trunk line detonators ensured that there was less vibration transmission to the ground as there is less mass that simultaneously impacts, which leads to a reduction in the pressurised wave that comes from the detonation and maximises the stress increase due to bending. Moreover, the non-electrical initiation systems were used to avoid the risk of premature detonation by stray currents, external electromagnetic waves or radio frequencies.

Detonating fuse (DF) is also used as a blasting accessory to induce blasting in other explosives. DF is used for breaking steel rods in the beams and columns of the building. DF consists of PETN as the explosive material in the core of DF. This PETN is wound in a BOPP film (Bi-axial oriented polypropylene film) and BOPP film is then wound with PP yarn (polypropylene yarn). The DF at this stage is called as semi-fuse. This semi-fuse is coated with LDPE granules to give a coating of LDPE on the semi-fuse. This coating makes the semi-fuse water resistant. This coated semi-fuse is now crushed between brass rollers at a pressure of 75-80 kg. This crushing consolidates the loose PETN present in the BOPP film and PP yarn and increases the strength of the DF.

3.7 Charging of explosives

The criteria applied to the Maradu implosion design process is to use only minimum charge weight (kg) of explosives to successfully achieve the implosion as there are bridges, petroleum pipelines, residential buildings and backwaters around the buildings to be demolished. To achieve this, PESO advised to remove all necessary structural elements to lighten the structure and facilitate

The designed footprint was designated to collapse the structure within [4].

Explosives were placed in the lowest oor level and then were spaced out in the blast floors along the height of the building, closer together at lowest floors and more spread out at upper floors. The more gravity that is used during implosion process, the greater the debris i s pulverized. The explosive charges are calculated by the contracting companies and verified by PESO officials. The explosive charges are calculated simultaneously with the modelling and the pre-weakening processes being especially relevant its calculation as it is necessary to create the demolition belt, which can then cause the collapse mechanism and therefore the demolition to occur as predicted. The methods used by the demolition contracting companies for the calculation of the explosive charges is usually of an empiric nature based on the personal experience by them. The specific charge method, which is based on the concept of the specific charge (Qe), which represents an estimation of the weight of explosives that is necessary to fragment a cubic meter of the element to be demolished, in terms of the demolition belt that is to be used for each vertical element. The specific charge is distributed equitatively among each drilled space in the element [2].

The demolition contracting companies adopted different approaches in the method of calculation of explosive charges and charging of explosives. PESO verified the method of calculation of explosive charges and had discussions with the blasters with regard to quantity of explosives to be charged. Even though the quantity of explosives to be used was on the higher side, for e.g. the District Magistrate has granted NOC for use of 25 kg of Nitrate explosives for the demolition of Golden Kayaloram. But later, it was recalculated and there was only need of 14.8 kg. These calculations depend on the way which the building has to be demolished, to protect the nearby structures and the pre-weakening techniques used. PESO verified the quantity of explosives for use submitted by the contracting companies based on the Portuguese method for charge calculation and found tallying with the quantity of explosives to be used by the contracting companies. Portuguese method for charge calculation, developed by Gomes (2010), is a method which is based on older empirical expressions and tests on real models, and also results in an empirical formula.

Table 1: Quantity of Explosives permitted, charged and Collapse Time

Explosives	H_2O Holy Faith		Jain Coral cove		Golden Kayaloram		Alfa Serene	
	Permitted to Use	Actual Use	Permitted to Use	Actual Use	Permitted to Use	Actual Use	Permitted to Use	Actual Use
Emulsion explosives (kg)	215	212.4	312.5	372.8	125	14.8	600	343
Nonel (no's)	3050	2603	5105	4438	2091	1585	4104	3300
Detonating Fuse (m)	10100	10043	15500	15306	6200	5555	5000	10500
Electric Detonators (no's)	3	1	3	1	3	1	4	4
Collapse Time (s)	6		5		7		Tower 1 – 5 Tower 2 – 6	

Through this formula it is possible to calculate the charge necessary to fragment sections of stone or reinforced concrete, according to spacing between drill points, specific characteristics of elements (concrete resistance, reinforcement, among others) and the geometry of the section. As such, the following equation (1) is used to calculate the quantity of explosive necessary to fragment a section [3]:

$$Q = R^2 \text{ x } K \text{ x } L$$

Where,

Q Explosive charge per drill (kg) using TNT. This parameter does not take into account possible defects drill covers, considering it perfect, not taking any aggravating coefficient for this factor

R Width of th e gap chosen by the designer [m]. This usually corresponds to the distance from the centre of the drill to the exposed face (columns) or to half the space between drills in square grids, for example in solid concrete elements

K Coefficient that depends on the resistance and confining characteristics of the section (Table 2)

L Section length [m]

Table 2: Values for K for reinforced concrete columns and walls (Gomes, 2010)

K – Reinforced concrete columns and walls				
% of reinforcement	1%	2%	3%	4%
Hoops	Φ 8 // 25-30 cm	Φ 8 // 10-15 cm	Φ 8 // 10-15 cm	Φ 8 // 10 cm
Concrete Quality	Weak - Medium	Medium	Medium – Good	Good – Very Good
K	2.05	4.02	6	7.97
NOTES: The values for K can be reduced if the element hoops are lower than considered above, i.e. if spacing is greater than indicated. Excluded from this adjustment is the value of K (1%) that should not be optimised but possibly increased if the concrete is of good quality.				

4 Analysis of Collapse

In this paper, we consider the analysis of collapse of H2O Holy Faith apartments. The direction of pull as per the Implosion isochrone layout is 37° and 46°. This is considered as there are two 24" MS and HSD jetty pipelines traversing at a distance of 12.6 m from the building and the bridge is at 20 metres. The primary blast force as per the blast plan is lower ground floor, upper ground floor, fourth floor, tenth floor and fifteenth floor. The secondary blast as per the blast plan is second floor, seventh floor and thirteenth floor. The demolition work was recorded in detail. Information on the timing of the stage of collapse was also obtained from vibrometric records. The study of motion of the falling building has been on the no. of frames per picture taken from close to the long axis of the building. From the verification of the photo and video frames, it is noted that vertical force exchanged between the ground and the falling building during the fall. The pull of the building as designed by the blast plan was achieved without any damages to the pipelines nearby, the Kundanoor-Thevara bridge and the residential buildings. Some of the remnants fell into the nearby backwaters.

The dust generated by the implosion was entirely contingent on wind speed. The dust prevailed in the immediate area for approximately seven minutes and it dissipated fully in 15 minutes.

Figure 8: Demolition of Jain Coral Cove

Figure 9: Demolition of Golden Kayaloram

Figure 10: Demolition of Alfa Serene

Figure 11: Demolition of H2O Holy Faith

4.1 Piling of Debris

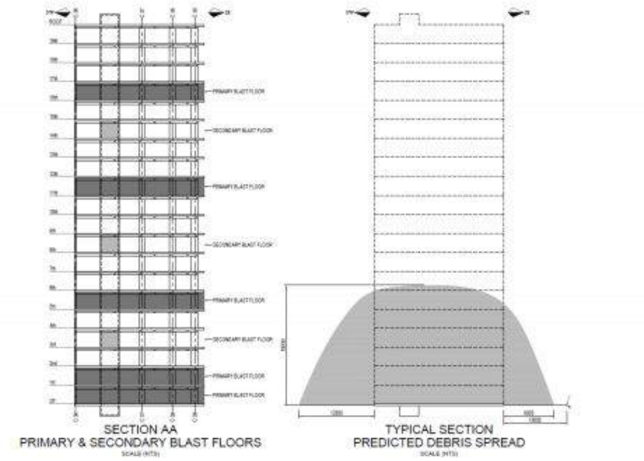

Figure 12: Primary and Secondary Blast Floor Section and Predicted Debris Spread of H2O Holy Faith Apartment

Figure 13: Debris piled after demolition of Alfa Serene

As per the blast plan of H2O Holy Faith apartment, the predicted debris spread was around 18 m high and the total quantity of demolished building was 21450 tonnes. The debris spread 12 m to the North-West direction and 8 m to the South-East direction. Total collected quantity of demolished building is 20450 tonne and spread of the same is as predicted in the blast plan.

Table 3: Debris Quantity Predicted and Collected from the Four Apartments

	Apartment name	Debris Quantity Predicted (Tonne)	Debris Quantity Collected (Tonne)
1	H_2O Holy Faith	21450	20450
2	Jain Coral Cove	26400	21575
3	Golden Kayaloram	7100	7206
4	Alfa Serene	21400	20375

Figure 14: Maradu Apartments after Implosion

5 Conclusion

The selection of the collapse mechanism in Maradu Demolitions were precise and evaluation of structures, surroundings and its environment which led to the determination of exclusion zones were intact. The calculation of explosive charges is not an exact process as there will be large no of parameters that will influence it. However, it is possible to assess the exact quantity required using trial fire test. The greater level of safety and greater precision in demolition was achieved due to the use of Nonel initiation system .The progressive collapse of the building was achieved through accurate and thorough assessment of the structure and its environment which lead to firing plan and impact control measures. In conclusion, the demolition by implosion using high explosives is the best method for demolition of high-rise buildings when compared to traditional mechanical demolition, if the safety protocols are ensured. It also necessitates the need for the production and publication of an Indian Standard for Controlled Demolitions.

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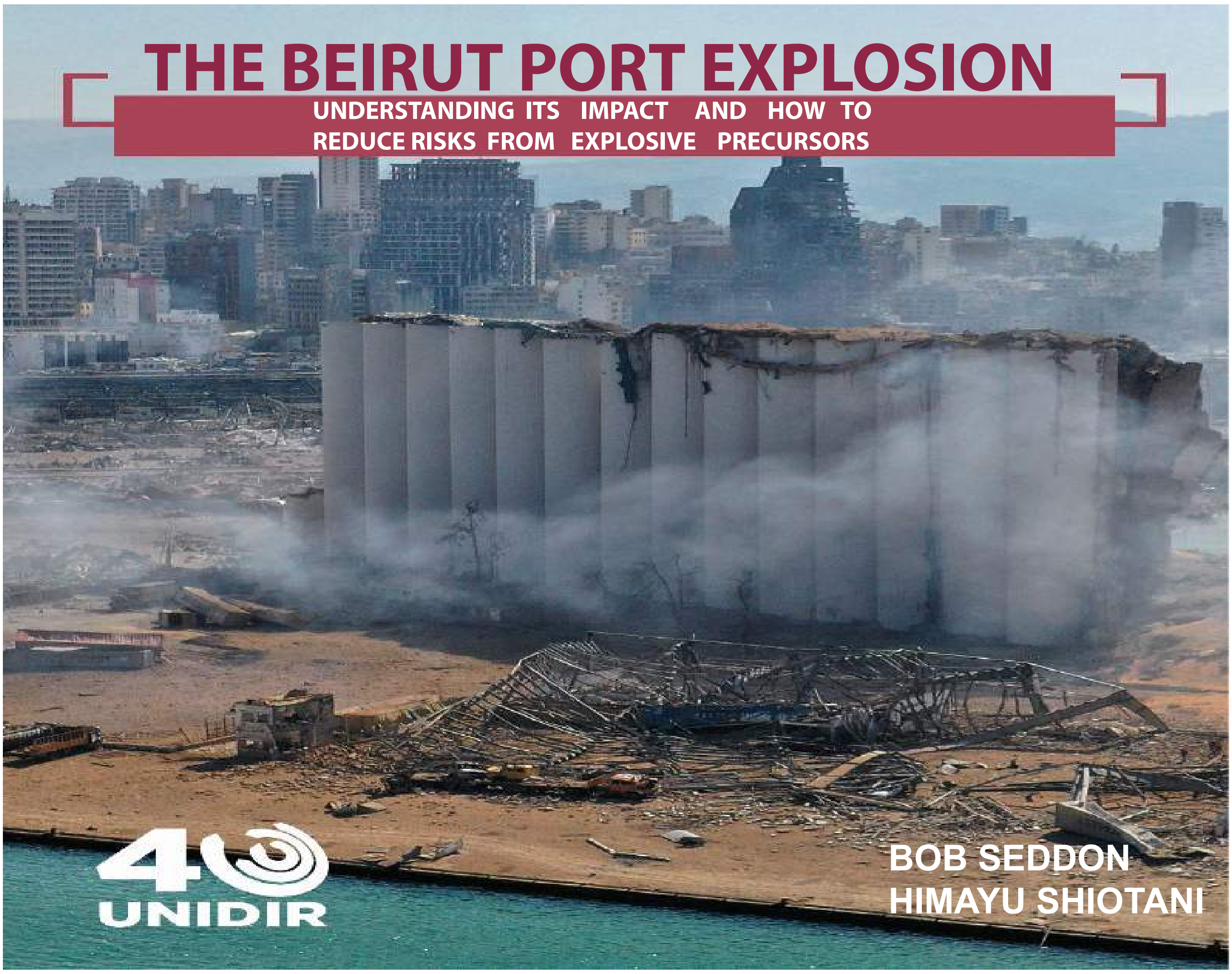
SPECIAL REPORT-1

1. The Beirut Port Explosion involving Ammonium Nitrate (Aug 04, 2020)

1.1 'Executive Summary' of the UNIDIR Report on Beirut Port Explosion (Aug.2020)



(The United Nations Institute for Disarmament Research (UNIDIR) is a voluntary funded autonomous institute within the United Nations)

On 4 August 2020, one of the biggest non-nuclear explosions in history – and the largest single explosion ever to occur in the Middle East – took place in the heavily populated city of Beirut, Lebanon. The explosion, caused by detonation of 2,750 tonnes of high-density ammonium nitrate (with an estimated TNT equivalent explosive effect of between 1.5 and 2 kilotons), had catastrophic consequences for the city of Beirut, its people and the urban ecosystem.

One month after the incident, the number of people killed had reached 190, and over 6,500 were injured. It is estimated that a total of 200,000 domestic dwellings were affected in Beirut; 40,000 buildings were damaged; and 3,000 housing structures received serious damage as a result of the explosion. It is further estimated that 300,000 people lost their homes, and over 15,000 establishments – approximately 50 per cent of Beirut's business and service sectors – were damaged, the majority in the wholesale, retail and hospitality sectors.

The post-blast consequences and the associated socio-economic risks for Lebanon in the future are considerable – the United Nations and the World Bank estimate that the cost of reconstruction may be in the range of several billion dollars. The explosion occurred at a time of severe economic crisis in Lebanon, where an estimated 1 million people live below the poverty line. Social tensions and associated risks have grown in Beirut and other parts of the country following the explosion, leading to the resignation of the Lebanese Government. Further compounding the recovery efforts is an observed increase in transmission of coronavirus 2019 (COVID-19) following the blast in Beirut, which is straining the country's already fragile health-care system. Beyond other immediate risks, such as disruption to the supply chain of food, medical and other essential supplies, the medium-to-long-term effects of the blast and the COVID-19-related lockdown are likely to have a significant impact on the psychological well-being of people in Beirut.The devastation caused by the Beirut explosion has renewed attention on the need for safe and secure through-life management – that is, production, acquisition, transportation, storage, handling and end use – of explosive precursors and other dangerous goods around the world. This incident also serves as an important reminder of the critical need to ensure that large quantities of explosive precursors are not stored and left unmanaged in built-up and populated areas, where unplanned or accidental explosions can cause catastrophic direct and indirect cumulative and long-term harm to people, their livelihood and the urban ecosystem.

The single most important lesson from the Beirut explosion is that the incident could have been prevented, and so there is an urgent need for States and relevant private sector and industry actors to take action to prevent similar future accidents. This report identifies a series of policy-relevant and technical recommendations to tackle and further reduce safety risks from explosive precursors and to strengthen oversight and governance to prevent accidental and unplanned explosions. Policy recommendations include:

• Clarify roles and responsibilities and strengthen national coordination and information exchange among and between national authorities and private sector and industry actors in the management of explosive precursors

.• Assess gaps and, where necessary, revise national regulatory frameworks to strengthen oversight and management of explosive precursors and the processes and capacities to enforce them

.• Assess and identify safety and security risks and vulnerabilities in the supply chain of explosive precursors and undertake mitigation measures throughout the life cycle of explosive precursors

.• Institute regulation and procedures for safe and secure storage, including safety distances, segregation, and removal or relocation of large quantities of explosives from populated areas.

• Raise awareness among both political leaders and industry actors downstream in the supply chain on the risks and potential impacts of poorly managed explosive precursors.

Technical recommendations include:

• For the purposes of storage and transport, high-density AN should be considered for reclassification as a Class 1 explosive with a Hazard Division of 1.1, that is, as a material capable of mass explosion

.• Review and, where necessary, update existing recommendations regarding the safe transport of dangerous cargo to reflect the mass explosion hazard associated with ammonium nitrate

.• Ensure that risks are as low as reasonably practicable (ALARP), and appropriate safety distances are applied to the storage of ammonium nitrate based on quantity risk assessment. "

1.2 An excerpt from the paper "AN- An overview of its safe storage and handling" by Francois LeDoux and Noel Hsu, with reference to Beirut Port Explosion (Source: Safex News Letter No. 73, Oct 2020)

"**Beirut (Fire and possibly Shock)**

On August 04, 2020 there was an explosion involving AN at the Beirut port. The mass involved was significantly higher –2,750 tonnes, and the explosion resulted in over 190 fatalities, injuring 6,000 and causing billions of dollars in damage. There was a preliminary explosion that was followed about 30 seconds later with the larger explosion that involved the AN stored in the port. According to the news and the official statements of the Lebanese authorities soon after the explosions, these 2750 tons of ammonium nitrate had been stored for six years in that warehouse.The Lebanese authorities are leading the investigation and are being supported with foreign experts including the FBI and French experts. From the information released to date, the most likely cause of ignition of the fire that preceded the first ex-plosion was welding that was carried out that day (New York Times, 2020). The article also stated that in the same warehouse there were 15 tons of fireworks, five miles of fuse on wooden spools, jugs of oil and kerosene, and hydrochloric acid.

Maritime transport and storage at Ports

Ammonium nitrate is internationally traded, and volumes moved by sea are in million tonnes per year. TGAN sea vessels will typically transport ~1,000 to ~10,000 tonnes while FGAN are commonly transported20,000 tonnes in a vessel.Over the decades this mode of transport has been carried out safely by following strict controls. Nevertheless, during its transport or in transient storage, if the controls are not in place the product may be exposed to threats that can result in a catastrophic event.Published information on the explosions at the Tianjin and Beirut ports indicate that there were failures of controls for thesafe storage of AN. In both events there were flammable, combustible, or pyrotechnic substances in proximity to the AN. These substances did accidentally ignite leading to a thermal insult to the AN. Since there were fireworks (New York Times, 2020), which are classified as Class 1 goods, co-located with the AN in the warehouse at the Beirut port, there may have been a shock insult as well.

Reminders and Lessons from the Recent Events

Ammonium nitrate manufacture and use has a long history, and as mentioned in a previous SAFEX newsletter, certain well-known accidents had practices from the past that are not comparable to those of today. Learnings and knowledge were gained and practices improved. The AN manufactured post-WW I or shortly after WW II is not the same product as today. Many of these products would be classified as explosives under today's UN safety regulations.

The following are reminders from the Beirut Port event:

1.Prohibition on the Co-storage of Flammable/Combustible, Explosive and Incompatible Materials

One of the principal controls when storing AN is that there should not be any flammable/combustible, explosives or incompatible materials in proximity to it. This becomes even more important when the product is entrusted to the carrier or stored under the jurisdiction of a third party, as was the case in the Beirut port.

2.Clear accountability and ownership

The Beirut event highlights the responsibility of care of all stakeholders: the supplier (AN manufacturers, who are aware of the product and its hazards), the buyer (explosive manufacturer, also aware of the product and its hazards) and the authorities. The supply chain actors will normally be less knowledgeable on the product, but they should not be less aware of the product and its safe handling. The supply chain must not be overlooked as it is of utmost importance with respect to transferring hazards knowledge to all stakeholders.

3.Compliance Checks

Auditing of operations against the SAFEX GPG or internal standards should be carried out to ensure strict compliance with segregation, safeguards, etc. This should also include assurance that the risk controls on the whole product lifecycle, product ownership and/or stewardship are in place.In summary, when storage conditions are neglected and AN characteristics are forgotten the AN storage can become unsafe. The subsequent probability of an event can be orders of magnitude higher and the TNT equivalent can be higher as well since the product may be degraded, contaminated, incorrectly co-stored, etc. In the case of the Beirut Port explosion, the news-feeds indicate that hot work may have initiated the fireworks and other combustible materials stored in the same warehouse as AN.When storage conditions are in conformance to either the GPG or appropriate internal standards, AN storage is safe."

SPECIAL REPORT

IME
Institute of makers of explosives
The safety and security of the commercial explosives industry since 1913

eDets FAQ for Regulators (Nov 2020)

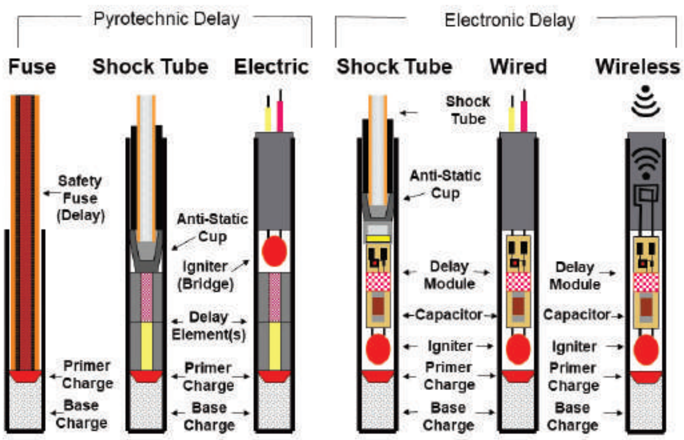
Electronic Blasting Initiation Systems (EBIS) Frequently Asked Questions for Regulators

What is an electronic detonator and how are they different than electric detonators?

A typical commercial electronic detonator can sometimes be confused with a commercial electric detonator since the construction of the detonator shell, bushings, and leads can be generally the same physical shape and size. A key difference between the two technologies is that in most all cases, an electronic detonator will incorporate a connector on the end of the wire leads to facilitate reliable connections as opposed to only stripped and shunted wires found on electric detonators.

Electronic detonators may use an aluminum shell or a copper alloy shell depending on the application or manufacturer, but the overall appearance will be similar to any commercial unit. The length of electronic detonators can vary from manufacturer to manufacture, but the outside diameters are generally the same as all other standard commercial detonators (electric and nonelectric).

The internal design and construction of an electronic detonator is what differentiates this technology from all others because the delay timing is provided by a circuit board and microchip technology versus a pyrotechnic delay composition which is generally jacketed in a steel or metal sleeve. The specific construction will differ from manufacturer-to-manufacturer, but one unifying characteristic of all electronic detonators is the existence of a circuit board populated with electronic components in addition to an application-specific integrated circuit (ASIC) or microchip/microprocessor.



Basic Detonator Construction

An electronic detonator typically has several different forms of protection built into the design, e.g. spark gaps devices, internal electronic shunts, input resistors, etc., in addition to the fact that a circuit board physically separates the leads from the "match head." Because of the built-in electronic protection devices and the physical separation of the match head from the external lead wires, electronic detonators are much less sensitive to extraneous energies. Generally, electronic detonators cannot be fired from common energy sources such as car batteries, wall circuits, static, stray current etc.

How are electronic detonators transported and stored?

As with any detonator or initiation technology, the same recommendations apply for the transportation and storage of electronic detonators.

Will radio frequency energy (RF) interfere with electronic detonators?

Although RF energy may interfere with the communication of these systems, extensive testing by the manufacturers and independent laboratories have verified that electronic initiation systems manufactured by IME member companies will "fail to a safe" mode even if exposed to RF levels that exceed levels typically experienced in mining, quarrying, and construction applications.

To help clarify risks associated with RF energy sources and detonator technologies, IME has developed a suggested warning for equipment manufacturers, i.e., that **electric detonators** are clearly at risk of premature initiation from RF energy sources, and users should recognize and apply safe distances outlined in SLP 20, Safety Guide for the Prevention of Radio Frequency Radiation Hazards in the Use of Commercial Electric Detonators (Blasting Caps). It is important to note that SLP 20 does **NOT apply to electronic detonator technologies.**

EBISs provide not only a high level of immunity from premature detonation due to their design and construction (as discussed above), but also provide a high level of resistance to potential interference sources. However, not all electronic systems use the same construction and design concepts to provide this protection. Users should read and understand all aspects of the system they use and follow the manufacturer's recommendations.

What precautions should be taken regarding use of electronic detonators during the approach and duration of electrical storms and lightning?

As with any detonator or initiation technology, the same recommendations apply for the approach of electrical storms and lightning.

How do you shunt electronic detonators?

In an electric detonator, the term "shunt" refers to a closed-loop circuit through the matchhead/fusehead. An electronic detonator typically has several different forms of protection built into the design, e.g. spark gaps devices, internal electronic shunts, input resistors, etc., in addition to the fact that a circuit board physically separates the leads from the "matchhead." It is inherently shunted internally through design of the ASIC or the integrated circuit (contained within the delay module illustrated above) and therefore much less sensitive to extraneous energies. All currently available electronic detonators manufactured by IME members and used in North America are shunted in this way.

How do you test electronic detonators?

Electronic and electric initiation system technologies vary significantly in the manner a detonator can be tested in the field prior to use. Users of electric detonators are familiar with the use of a "Blaster's Galvanometer" to test for continuity as well as the level of resistance for each detonator and branches and circuits that are used while tying in a blast.

The electronic bench testing unit which often may be called a "logger", "tagger", or "programmer" unit by individual manufactures, will provide the user with circuit tests to ensure communication with the detonator (wire breakage, leakage ranges, circuit board test protocols, match-head existence), as well as facilitating the programming of delay times and sequences of individual detonators. The methodology, sequence and type of communication varies between manufacturers due to proprietary technologies, but EBISs, using on bench testing and programming equipment ("on bench testers"), provide a much higher level of information and communication capability than conventional electric or nonelectric initiation systems.

It should be noted and understood by users that all on bench testers are designed so that that electronic detonator testing and communication is done at a voltage and current level that is below the level needed to charge and fire the detonator. The tester, by design, does not have the capability to produce or deliver a high enough energy to fire a blast or a single detonator. This design feature, as well as the other detonator design features, make electronic detonators nearly impossible to accidentally fire from extraneous electrical energy found in normal mining, quarrying and construction activities, and provides users of EISs the highest possible level of safety and security.

How do you fire electronic detonators?

Electronic detonator blasting machines are the only devices designed to provide password protection, programming capability, and the energy levels needed to charge the detonators in a circuit and send a fire command. It is the charging capability of the blasting machine that sets the units apart from all other field equipment used for electronic detonators. Users must ALWAYS clear the blast area of personnel, vehicles and equipment prior to hooking up to the firing device or blast controller. Refer to IME's SLP 4 for other electronic initiation system ALWAYS and NEVERS.

Many systems will require both password protected firmware and/or software interfaces for the user as well as a physical key or manual device to ensure no accidental firing can occur. As mentioned above, each system is specific to a manufacturer's design, and users must understand and follow all protocols to ensure reliable, safe and secure use of electronic blasting machines.

Where can I find out more about electronic detonators?

IME has developed and incorporated several references, guidelines, and recommendations for the safe use of electronic detonators for commercial blasting operations. Users of these products are encouraged to review, understand and, unless otherwise instructed by the system manufacturer, follow these recommendations. These recommendations can be found on-line at www.ime.org.

• "Electronic Blast Initiation Systems (EBIS) Guideline: General User Information for Mining, Quarrying and Construction Applications"
• SLP 3 "Suggested Code of Regulations for the Manufacture, Transportation, Storage, Sale. Possession and Use of Explosive Materials"
• SLP 4 "Warnings and Instructions for Consumers in Transporting, Storing, Handling and Using Explosive Materials"
• SLP 17 "Safety in the Transportation, Storage, Handling and Use of Explosive Materials"
• SLP 32 "Safety in the Transportation, Storage, Handling and Use of Oilfield Explosive Materials"

SPECIAL REPORT

SAFEX INTERNATIONAL

Safex International

Safex Incident Notices: October, 2018 to October 2020

Summary

Activity			No. Of Incidents
*	Fixed Plant Manufacturing:		
		HE	5
		Explosive Accessories	3
*	Mobile Manufacturing Unit (MMU):		-
*	Handling:	Within Plant Area	-
		Outside Plant Area	-
*	Storage:		-
*	Transportation:	Vans	-
		MMU	1
*	Waste / unused explosives disposal, etc.		1
		TOTAL	**10**

Almost all the incidents were due to human errors arising from lack of due diligence during supervision/lack of awareness.

-Editor

1 INCIDENT TITLE: Decomposition in Nitric Acid Separator Tank

When did it happen?	21:30 / 3rd shift, May 25, 2016
Who experienced it?	MAXAM Spain, S.L.
Where did it happen?	Paramo de Masa (Spain)
What material was involved?	Residual Nitric Acid from PETN Manufacturing Plant.
What happened?	The PETN plant has two separator tanks (41GF01A and 41GF01B), 600 litters each, working under vacuum and used to store temporary residual acid before is sent to one external tank. Usually only one tank is in operation. The tanks are equipped with temperature and level sensors. At 5:22 am the line connecting nitrators was cleaned with 98% nitric acid. Work Instruction says that the manual valve shall be open for several seconds. By mistake, the manual valve remained open for 8 minutes (estimated flow 3000 kg/h). The plant was stopped during the cleaning but later it was restarted. The extra acid entered to the filter and respectively to separator. Overflow of the filter was provoked and both separators were filled with acid having over 70% concentration. First separator 41GF01A remained with 70% acid in a stand-by mode and the second one 41GF01B was in operation during the day. Decomposition process has started in 41GF01A and it was speeded-up between 20:00 and 21:30 causing at the end its overpressure and destruction.

Why did it happen – theory?	Incident was the consequence of several contributing factors: -Higher concentration than normal of Nitric Acid, downstream of nitration. -Both separators were not designed as pressure equipment and it was not expected that overpressure could occur and therefore separators were not equipped with overpressure protection. -The cleaning operation of the overflow pipe from nitrator 1 to nitrator 2 was performed manually.

2 INCIDENT TITLE: Suspected contamination of emulsion with sodium nitrite

When did it happen?	26th November 2019
Who experienced it?	Mining Services Operation – South America
Where did it happen?	Salto de Pirapora, Brazil
What material was involved?	Bulk Emulsion (Division 5.1), Sodium Nitrite
What happened?	After loading emulsion into a transport vehicle, foaming was noted from the hatch after driving a short distance. The driver inspected the tank, and noticed a chemical reaction was occurring. Internal experts were consulted, water was added to the tank, and the vehicle parked in a safe location with the hatch open to prevent pressure build-up.
Why did it happen – theory?	Sodium nitrite contamination of the emulsion compartment was suspected, although no cause for the contamination could be determined.
What was the impact?	The load was discharged to waste.

3 INCIDENT TITLE: Detonators Explosion

When did it happen?	23 May 2020, 16:50 local time
	Filling & Pressing Building (D5) of Detonator Manufacturing Plant, Nagpur
	In the second shift, the plant was under normal operation for around 1.5 hours the operator opened the hatch of tumbling unit No.1 to remove the empty cap carrying plate from the holder of tumbling unit. An explosion took place in the tumbling unit which immediately spread to adjoining tumbling unit and both units exploded.

Immediate action taken	The emergency response plan was activated. Injured were rushed to the hospital in Nagpur. Other personnel from the plant were evacuated and personnel count taken. Regulatory authorities informed about the incident. All production activities of the site stopped. Families of injured informed about this incident. After cool-off time D5 building barricaded. Other buildings assessed for any damage.
What was the impact?	The tumbling operator got severely injured. Two persons who were carrying cap carrying plates with filled shells in their hands, in the vicinity of blast gas pressure, were severely injured. Three other nearby operator received minor injuries. The tumbling section and traverse behind demolished, concrete roof collapsed. No major impact on other buildings in plant.

4 INCIDENT TITLE: Truck brake fire while transporting emulsion

When did it happen?	16th June 2020
Who experienced it?	Mining Services Operation - Australia
Where did it happen?	Huntly, Western Australia
What material was involved?	Bulk Emulsion (Division 5.1)
What happened?	A bulk explosives transport vehicle sounded air and brake alarms after travelling from a depot for about 8 minutes. The driver pulled over after another 2 minutes and noticed a fire from between the rear wheels. The driver used two fire extinguishers and the on-board water storage to douse the flames.
Why did it happen – theory?	The most likely cause was a fault with a brake booster, resulting in the service brakes being applied during the trip.
What was the impact?	The prompt action of the driver prevented any serious impact. The

5 INCIDENT TITLE: Explosion at Austin Malaysia cartridge plant

When did it happen?	Wednesday, July 1, 2020 at 1:49 pm
Who experienced it?	Austin Powder Malaysia (APMY)
Where did it happen?	Cartridge emulsion plant at Batu Arang
What material was involved?	Sensitized emulsion for packaged product
What happened?	During the lunch break an explosion occurred in the cartridging building of the packaged emulsion plant. The plant is a semi batch plant with separation of buildings for emulsion mixing/blending, cartridging, cooling and packaging. Batches of sensitized emulsion in mobile hoppers (trolleys) are sent to the cartridging building for cartridging. The plant was in routine operation (standard commercial product, day shift) at the time of the incident.
Why did it happen – theory?	The cause of the incident is under investigation.
What was the impact?	There were no injuries or fatalities. The cartridging house (mounded structure) has been destroyed. There is limited damage to adjacent buildings and structures. No propagation to material in process (e.g. cooling bath) has occurred.

6 INCIDENT TITLE: Chemical Reaction in Emulsion waste bin

When did it happen?	24th September 2020
Who experienced it?	Mining Services Operation – South America
Where did it happen?	Maraba, Brazil
What material was involved?	Bulk Emulsion, Sodium Nitrite
What happened?	An operator noticed smoke/fumes coming from a waste drum at the emulsion pumping area. The operator applied water, and separated the materials in the bin.
Why did it happen – theory?	A sodium nitrite spill from a maintenance area had been cleaned up and the residues deposited into the emulsion/nitrate waste bin. The maintenance person was unaware of the incompatibility of the waste.
What was the impact?	The contaminated material was disposed of.

7 INCIDENT TITLE: PETN Burning Ground Explosion

When did it happen?	November 6, 2020 at 5:00 pm
Who experienced it?	Austin Star Detonator
Where did it happen?	Burning ground, Matamoros/Mexico
What material was involved?	Dry PETN waste
What happened?	Two detonations in quick succession occurred at the burning ground. An operator had placed dry PETN fines in two of the 4 bays; each bay containing approximately 2.5kg of PETN (Total of 5Kgs/10lbs). The PETN fines were generated from the drying and sieving explosive preparation process that supplies the base charge loading process. From a sheltered area approximately 30 meters away, the operator initiated the burn using pyrotechnics. According to the operator, two detonations occurred approximately 3-5 minutes after he had remotely initiated the bays and visually confirmed smoke arising from the bays. Debris such as cinder block fragments and parts of the bay galvanized metal roofs were ejected in the air directing westwards toward fallow land owned by the company. Debris was found up to 100 meters away.
Why did it happen – theory?	Recently, the main supplier of PETN had been switched and the new source produced significantly more fines than the previous supplier. The fines then became waste material for disposal (PETN had not been burned before). An operating procedure was then generated for the new waste stream. The procedure was drafted without including important details such as establishing a schedule to collect the fines on a regular basis, and institute explosive limits. The absence of details led the operator and others to create their own routine where dry PETN fines were collected on a weekly basis on Fridays (up to 4 – 5 kg). Methods for safe burning of PETN (mixing with sawdust) were neither reviewed nor implemented. It is assumed that, though the PETN was poured on a tray in an ‘S’ type pattern, there was variation of the PETN track in width and height that allowed the

8 INCIDENT TITLE: Chemical Reaction in Ammonium Nitrate waste bin

When did it happen?	26th November 2020
Who experienced it?	Mining Services Operation - Africa
Where did it happen?	Moatize, Mozambique
What material was involved?	Ammonium Nitrate prill
What happened?	While conducting housekeeping duties, an operator noticed white fumes issuing from a waste bin used for ammonium nitrate prill spills. Site staff did not evacuate, but approached the bin, and emptied it onto the ground, and the reaction ceased.
Why did it happen – theory?	The bin contents were contaminated with carbonaceous materials from the mine. The mine rock has also been shown to be reactive in some cases.
What was the impact?	The contaminated material was disposed of on-bench.

9 INCIDENT TITLE: Explosion of Detonator waste bin

When did it happen?	18 December at approximately 5:15 AM
Who experienced it?	AECI Mining Explosives, Modderfontein, South Africa
Where did it happen?	Initiating Systems Automated Plant– Detonator filling machine
What material was involved?	Lead Azide and PETN
What happened?	The waste bin is fitted to the detonator filling machine and all detonators that have been rejected by the machine are dispensed into the waste bin. Once a certain number of detonators is in the bin the bin is exchanged on the machine with an empty bin. The bins contain sawdust. An unintended detonation occurred whilst an operator was carrying an empty (presumed) detonator waste bin to the detonator filling machine.
Why did it happen – theory?	The waste bin that was being carried to the machine detonated before it could be fitted onto the detonator filling machine. It is presumed that the bin was dropped. Preliminary investigation showed that that the waste bin did contain explosives. It is suspected that a friction or impact event (or both) could have caused the explosion. The formal investigation is still ongoing.
What was the impact?	One operator was severely injured. Minor damage to the detonator filling machine. Minor damage to a table and chair. No other personnel were injured

10 INCIDENT TITLE: Flashing mixture initiation

When did it happen?	Jan 12, 2021
Who experienced it?	Anonymous
Where did it happen?	Safety fuse assembly plant
What material was involved?	60g of flashing mixture (Zarcon, Boron, Nitrocellulose and Ethyl Acetate.)
What happened?	The flashing mixture was prepared (mixed) and kept in a primary conductive pot that could hold up to 200g. The operator would take a small quantity on a secondary conductive pot for further handling. As the operator was removing the lid on the primary pot the flashing mixture initiated. When the incident occurred, there was approx. 60g of the mix in the pot.
Why did it happen – theory?	Friction
What was the impact?	Second degree burn to arms and first degree burn to face.

Explosives Safety & Technology Society

Secretariate Address :
Maimoon Chambers
Gandhibagh, Nagpur - 440032

Email : visfotak@yahoo.com

Website : www.visfotak.org

History :

The idea of "Visfotak" as a Scientific Society took birth in 1998, on the eve of the National Seminar on Explosives Safety and Technology *(Visfotak - 98),* when for the first time the three major constituents of the industry, viz, the Government Regulatory Bodies, the Manufacturers, and the Users respectively, were formally brought together on one platform to deliberate on common Concerns and Issues. Arising from the deliberations, a proposal to establish a Scientific Society exclusively dealing with the Safety & Technological aspects of the Explosives industry was unanimously endorsed.

Consequently, the Explosives Safety & Technology Society (Visfotak) was registered vide Certificate No. 410/99 (Nagpur) dated June 17th, 1999.

Objectives :

(a) To promote and develop modern concepts relating to safety and technology in manufacture, handling, and usage of explosives.
(b) To assist the Government of India through its appointed departments and officials in recommending, formulating policies pertaining to explosives manufacture, handling and usage.
(c) To hold seminars, workshops, conferences to promote interaction between the three constituents, viz. the Government regulatory bodies, the manufacturers of explosives and the users of Explosives, in the interest of the growth and health of the explosives industry.
(d) To collaborate with academic and research institutions in promoting the objectives mentioned above.
(e) To promote and strengthen affiliation with other world bodies / societies dealing with explosives safety and technology for exchange of information.
(f) To institute awards, fellowships and scholarships for the excellence in the field of explosives.

Governance :

The activities of the Society are overseen by a Governing Council, comprising of eminent professionals and technocrats, including nominees from the two major Regulatory Bodies, viz, the Office of the Chief Controllers of Explosives, and the Directorate General of Mines Safety, respectively.

Institutional Association :

- **'Institute Associate Member' of Safex International, e.f. 30 May, 2008**
  (Safex International is a global organization founded by the manufacturers of explosives and pyrotechnics, currently having 110 members in as many as 46 countries. For more details on Safex, visit www.safex-international.org)
- **'Liaison Member' of the Institute of Makers of Explosives (IME), e.f. Oct 29, 2014**
  (IME is the safety and security institute of the commercial explosives industry in USA since 1923. For more details on IME, visit www.ime.org)

Membership of the Society :

The membership application form is enclosed. The application form can also be accessed and down loaded from the society's web-site.

Student Chapter :

This is an initiative launched by the society to promote the mission of the society amongst the students and academics who are, directley or indirectly associated with the science and technology of explosives. The application form for membership of the student chapter is enclosed; it can also be accessed and downloaded from the society's web-site.

Visfotak being a Scientific Society, shall totally refrain from partisan activities of any manner or kind and shall not entertain tasks which are biased with commercial interest of its individual members.

ABOUT THE SOCIETY

INVITATION TO MEMBERSHIP

In its quest for interaction towards improved Safety & Technology in Explosives, Visfotak cordially invites concerned people to enrol as members.
Membership Categories comprise :

CORPORATE OR INSTITUTIONAL

Entrance Fee	***Membership for 5 years***
Rs. 2000/-	*Rs. 3000/-*
US $ 200	*US $ 300 - For Foreign Nationals*

INDIVIDUAL

Entrance Fee	***Membership for 5 years***
Rs. 1000/-	*Rs. 1000/-*
US $ 100	*US $ 300 - For Foreign Nationals*

STUDENT

Entrance Fee	***Membership for 5 years***
Rs. 50/-	*Rs. 200/-*

Application forms are enclosed with this journal for necessary action.

- Secretary General Visfotak

ORDER FORM

For Advertisement in Visfotak

To,
Secretary General
Explosives Safety and Technology Society (Visfotak)
Maimoon Chambers, Gandhi Bagh, Nagpur - 440032

1. Name & Address of the Organization.
2. Advertisement enclosed : Hard copy/Soft copy/Both solicited with the tariff as follows :

Full Page (170 mm x 258 mm)

Colour	Outer back cover	Rs.	50,000/-
	Inside front cover	Rs.	40,000/-
	Inside back cover	Rs.	40,000/-
	Inside Page	Rs.	25,000/-

Half Page (170 mm x 120 mm)

Black and White	Inside Page	Rs.	10,000/-
	Business Card	Rs.	5,000/-

Discount Offer : In case, advertisement is booked for four issues of the Journal at a time for one of the above categories, the concessional rates charged will be equal to three issues.

Payment is to be made through cheque / draft in the name of **"Visfotak", payable at Nagpur.**

SHARE YOUR ACHIEVEMENTS

Visfotak welcomes you to share highlights of your achievements and activities with other professionals through this journal.

Please send it to us through e-mail at : visfotak@yahoo.com
or write to
Secretary General
Visfotak : Explosives Safety and Technology Society, Maimoon Chambers, Gandhi Bagh, Nagpur - 440032, India

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Visfotak EXPLOSIVES SAFETY & TECHNOLOGY SOCIETY

REGISTERED UNDER SOCIETIES REGISTRATION ACT MAHARASHTRA NO. 410 / 99 NAGPUR (INDIA)

MEMBERSHIP APPLICATION FORM

(Registered members will be given a Certificate and they would be entitled to participate in all the events conducted by the Society, and receive the publications of the Society free of cost).

Category of Membership : (Please tick ✓) MEMBERSHIP FEE FOR FIVE YEARS ONLY

CORPORATE MEMBER ☐	INSTITUTIONAL MEMBER ☐	INDIVIDUAL MEMBER ☐
Entrance Fee Rs. 2,000/- (US $ 200)	Entrance Fee Rs. 2,000/- (US $ 200)	Entrance Fee Rs. 1,000/- (US $ 100)
Membership Fee Rs. 3,000/- (US $ 300)	Membership Fee Rs. 3,000/- (US $ 300)	Membership Fee Rs. 1,000/- (US $ 100)

Name of Corporate Body / Institution ____________________

Represented by (Head - Other) * ____________________

* NAME IN FULL ____________________
(First Name) (Middle Name) (Surname)

Date of Birth ______________ Designation / Current Status ____________________

Mailing Address ____________________

City __________ Pin Code ________ Country __________ E-mail ______________

Telephone (Office) __________ (Home) __________ (Mobile) ____________ (Fax) ________

Qualifications Educational ____________________ Professional ______________

Year of passing ______________ Institute / University ____________________

Nature of Industry (Explosives, Mining, Hydel Power, Cement, Highways, Irrigation, Academic / Research / Technical Services, Defence, Statutory Bodies, Other) (Please specify) ____________________

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Membership of Professional Bodies, Awards, Recognitions ____________________

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Professional Experience ____________________

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Areas of Specialization ____________________

Mode of Payment : Payments towards Membership fee may please be made by Cheque in favour of 'Visfotak' drawn on any Bank. Add Rs. 30/- for Outstation Cheques or send a Demand Draft payable on any bank in NAGPUR.

DD / Cheque No. ______________ Date ______________ For Rs. / US $ ______________

Drawn on ____________________ Bank ____________________

Please forward the above application along with Cheque / Demand Draft to the following address :

The Secretary General, Visfotak - Explosives Safety & Technology Society
Maimoon Chambers, Gandhibagh, Nagpur - 440 032 (India)

Tel. : 2768631 / 32 ▪ Fax : 0712 - 2768034 ▪ E-mail : visfotak@yahoo.com

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Place : ______________ Date : ______________ Signature ____________________

*** Please enclose a detailed BIO-DATA and a recent passport size PHOTOGRAPH.**
For Corporate and Institutional Members enclose Bio-data of the Head or Representative

Please send your detailed address, telephones / mobile numbers, fax and e-mail ID

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Visfotak EXPLOSIVES SAFETY & TECHNOLOGY SOCIETY

REGISTERED UNDER SOCIETIES REGISTRATION ACT MAHARASHTRA NO. 410 / 99 NAGPUR (INDIA)

MEMBERSHIP APPLICATION FORM FOR STUDENT

(Registered members will be given a Certificate and they would be entitled to participate in all the events conducted by the Society, and receive the publications of the Society free of cost).

Membership Fee : (Please tick ✓) MEMBERSHIP FEE FOR FIVE YEARS ONLY

ENTRANCE FEE ☐ Rs. 50/-

MEMBERSHIP FEE FOR FIVE YEARS ☐ Rs. 200/-

Name of Corporate Body / Institution * ______________________________

Represented by (Head - Other) ______________________________

* NAME IN FULL ______________________________
(First Name) (Middle Name) (Surname)

Date of Birth ______________________________

Name of Institution ______________________________

City ____________ Pin Code _________ Country ______________ E-mail ______________

Telephone (Office) ____________ (Home) ____________ (Mobile) ______________ (Fax) __________

Educational Qualification ______________________________

Academic Course being persued : ______________________________

Membership of Professional Bodies, Awards, Recognitions ______________________________

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Membership of Professional Bodies, Awards, Recognitions ______________________________

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Areas of Interest ______________________________

Mode of Payment : Payments towards Membership fee may please be made by Cheque in favour of 'Visfotak' drawn on any Bank. Add Rs. 30/- for Outstation Cheques or send a Demand Draft payable on any bank in NAGPUR.

DD / Cheque No. _________________ Date __________________ For Rs. / US $ ___________________

Drawn on ______________________________ Bank ______________________________

Please forward the above application along with Cheque / Demand Draft to the following address :

Dr. N.R. Thote, Assistant Professor
(Hony. Secretary, Student Chapter
Explosives Safety & Technology Society (Visfotak)
Department of Mining Engineering
Visveswaraya National Institute of Technology, Nagpur - 440 011

Place : _______________ Date : _______________ Signature ___________________________

*** Please enclose a detailed BIO-DATA and a recent passport size PHOTOGRAPH.**

Please send your detailed address, telephones / mobile numbers, fax and e-mail ID

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TATA STEEL
#WeAlsoMakeTomorrow
TATA
The Company targets to have
20%
Women Officers
in the workforce by 2025
BUILDING A MORE INCLUSIVE TOMORROW
TATA STEEL IS THE FIRST IN THE COUNTRY TO DEPLOY WOMEN IN ALL SHIFTS IN MINES
Tata Steel is the first company in India to deploy women in all shifts at Noamundi Iron Mine with effect from September 1, 2019. All norms stipulated by Directorate General of Mines Safety (DGMS) are being adhered to and prior consent from each woman employee is obtained. Adequate facilities and safeguards regarding occupational safety, security and health of the female employees working in the mines are of utmost importance to the company.
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TATA STEEL
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TATA
#SteelFact
Globally, extensive
afforestation
programmes are converting mines
into habitats for local wildlife
Source: World Steel Association
At Noamundi,
2.1 hectares of baby plantations
were set up in 2018
PLANTING
DOUBLE THE TREES
FOR A BETTER TOMORROW
BOTANICAL PARK, NOAMUNDI
We are ensuring that the natural ecosystem in our mining locations is preserved. We have progressively implemented Biodiversity Management Plans at all our raw material locations in order to ensure no net loss in biodiversity.
Sure, we make steel.
But #WeAlsoMakeTomorrow.
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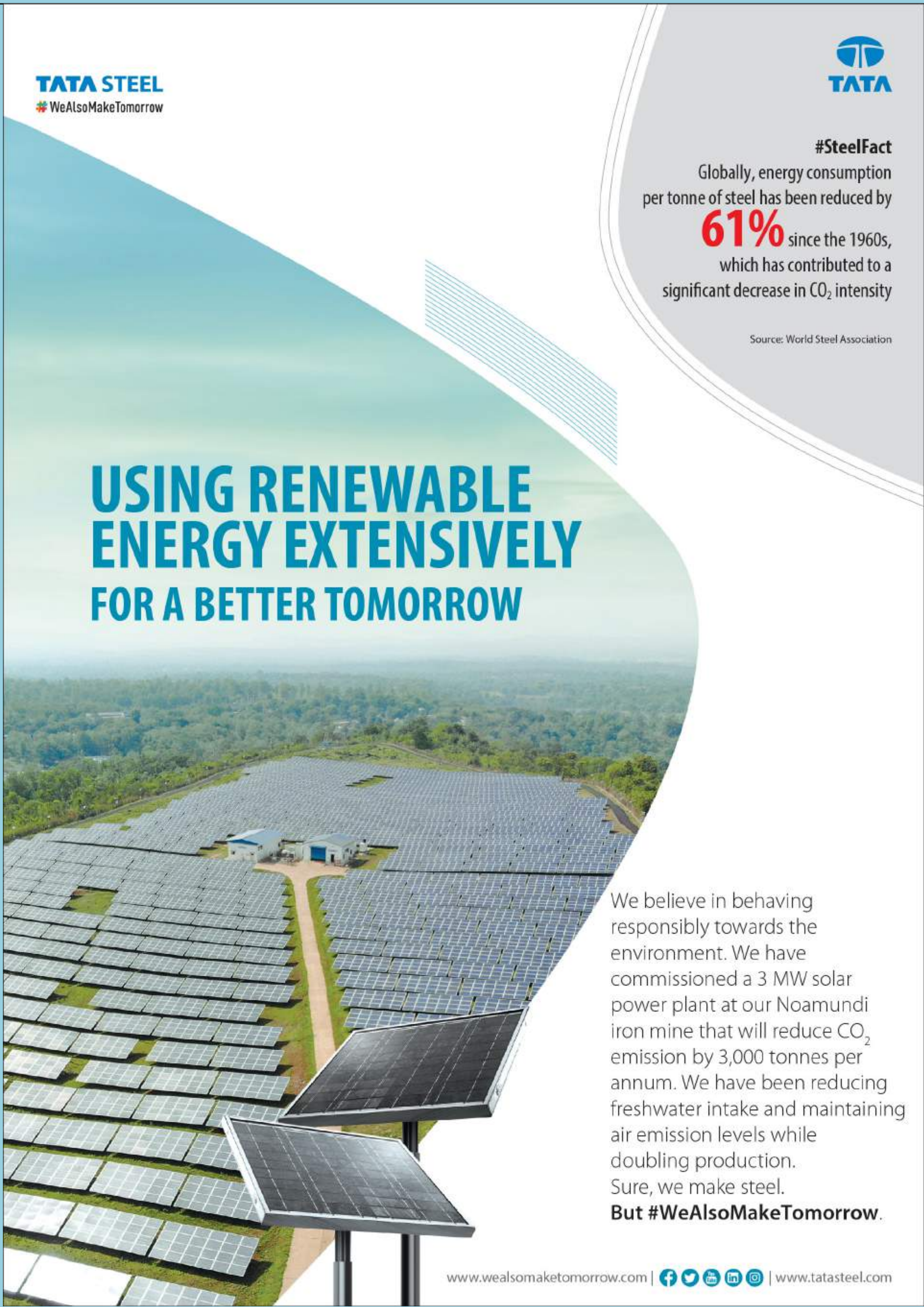
TATA STEEL
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#SteelFact
Globally, energy consumption per tonne of steel has been reduced by 61% since the 1960s, which has contributed to a significant decrease in CO_2 intensity
Source: World Steel Association
USING RENEWABLE ENERGY EXTENSIVELY
FOR A BETTER TOMORROW
We believe in behaving responsibly towards the environment. We have commissioned a 3 MW solar power plant at our Noamundi iron mine that will reduce CO_2 emission by 3,000 tonnes per annum. We have been reducing freshwater intake and maintaining air emission levels while doubling production.
Sure, we make steel.
But #WeAlsoMakeTomorrow.
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