OPTIMIZATION AND DETERMINATION OF BLAST DESIGN PARAMETERS FOR AN OPENCAST MINE

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Abstract
According to the study of performance analysis of various unit operations on opencast mines, transporting and excavating equipments are primarily dependent upon the blast results, most importantly to controlling the fly rock, fragmentation, stress distribution, rock factor etc. Therefore, real life blast configuration is a fundamental factor that influences the cost of entire mining activities. As we know blasting and drilling are the most important unit operations in opencast mining, blasting still holds to rule the production of a mine. Consequently to cut down the cost of production and get most suitable fragmentation of rock, coal or any mineral from any opencast mine appropriate blasting design is an essential component of mine design principles. The proper method of blasting and drilling can make a contribution extensively in the direction of benefit and subsequently improvement of these parameters is essential. In this paper an attempt is made mainly to deal with uncontrollable and controllable parameters, which have a significant effect on opencast blast design. The Mine excellence software model which is developed by Dr. Sushil Bhandari is being tried for this model too. The developed optimization model is tested for three different coal mines and is found that some changes are required in blast design parameters. Software was used to optimize the fly rock which is in result helped in the optimization of fragmentation of coal. After optimization suitable parameters found, was used for developing the computational approach optimization Model. It can predict the blasting parameters and also compare the given details and give best results according to cost parameter. This paper gives examples of predicted parameters and changes which can be made before blasting to control adverse environmental impacts too.

1. Introduction

Drilling and blasting are the maximum cost-efficient strategies used to excavate the minerals like ores, coal, and limestone etc. from the earth's crust. It takes a huge amount of energy to break the rock. The Energy which is required in a blast, which isn't utilized for rock breakage, is squandered as clean scattering, fly rock, ground vibration, noise, back break, air blast etc. But blasting optimization is extremely essential as the fracture got in this way affect the cost of the entire range of interrelated mining activities, for example, blasting, loading, drilling, crushing and hauling, & to some extent grinding. So Appropriate selection of blasting and drilling can make contribution notably towards profitability and therefore optimizations of parameters like the burden, spacing, bench height etc. are more important. Choice of blasting pattern is a completely critical challenge for mining project. The choice is made according to many important criteria; hence, mine to mine, there may be a big variant within the decided blasting pattern. The most dominant factors are yearly mine production, required geotechnical characteristics of the area, rock fragmentation, ground water condition and physico-mechanical and geological properties of surrounding coal. The determination of blasting parameters along with the whole mining process is performed both economically and technically and the explosive energy might now not totally eat up favourably in displacement of coal or rock and fragmentation. The other most important blasting operation side effect is fly rock. It can be described as uncontrollable throw of the blasted rocks beyond the blast surface area. Preparing the working site susceptible, appearance of this phenomenon also shows that the explosive energy isn't always completely carried out for the close goal objective of displacement of rocks blasting and fragmentation. From ancient data, we found that the most of the accidents happened related blasting are in reference to flyrock and most of the reports details available on hazards for both equipment and personnel. Workman and safety officers of mines concluded that on the basis of pervious hazards that insufficient burden, inadequate stemming, unfavourable geological conditions, high powder factor, improper delay timing, drilling deviation, and existence of much more back break are the most crucial factors in generating flyrock.

2. Aim of Blasting Optimization

Optimization implies desired objective to get the better result i.e. to accomplish minimum or maximum value of the operating parameters. Blast Optimization is reliant on a large group of complex factors identified with explosive, the rock, drill-hole parameters, initiation, and their design. The significant targets are:

- Efficient utilization of blasting energy, less throw of materials
- Reduced blasting cost
    - ✓ By less explosive consumption
    - ✓ By less wastage of explosive energy
- Reduction in blast vibration leading to stability to the nearby structures
- Greater degree of safety

2.1. Classification of Basic Parameters of Blasting

a. Explosive parameters

a. VOD of explosive, Density, Characteristics impedance, Energy output
b. Explosive type (Special gelatin, NG based, Gun powder, Slurry explosive, ANFO, Emulsion)

b. Geo-mechanical parameters of rock mass

a. P-wave velocity, b. Density of rock mass, c. S-wave velocity
d. Tensile strength, e. Compressive strength, f. RQD
g. Q (Rock quality factor), h. Dip direction and Dip amount

c. Blast geometry parameters

a. Spacing, b. Burden, c. Bench height, d. Depth of hole
e. Diameter of hole, f. Stemming length and type, g. Loading density
h. Length vs. area, i. Charge factor

d. Parameters related to initiation pattern

a. Delay pattern or connection, b. Delay interval

2.2. Blast Design

Blast design is most important parameter that not only influence blasting cost but also influences fragmentation, vibration and air blast etc. The blast design parameters are hole diameter, burden, stemming height, bench height, spacing, etc.

2.2.1 Blast Hole Diameter

The factors that are considered at the time of selecting blast hole diameter are: Rock mass properties, Rock pile characteristics, Bench height, Explosive distribution, and Relative economics of different type of drilling equipment.

2.2.2 Bench Height

Bench height is defined as vertical separation between the upper and lower surface of each bench called bench height. Bench height should not be more than 62 times the hole diameter. Because the use of large diameter blast holes in shallow faces prevents the efficient charge distribution while small diameter blast holes in high faces can be ineffective due to effect of blast hole deviation.

2.2.3 Burden

It may be defined as the shortest distance to relief at the time the hole is detonated in any blasting operation. It is the most critical parameter because of the following:

- If the burden is very small, then the rock will be thrown to a considerable distance from the face, air blast level will be high and excessive fine will be produced.
- Excess burden will produce severe back break and shattering on the back wall.

2.2.4. Spacing

It is the distance between boreholes or charges in the same row. Spacing should be determined in relation to burden, joints of rocks and hole depth. The following formulae may be used as a broad guideline for the determination of spacing: S= (1.2-1.5) B.

In some opencast mines it has been noticed that S/B ratio of 3 also work well.

- S<B is used in cast blasting, smooth blasting and cushion blasting and in places where the specific requirement is to get bigger size boulders.
- Very small spacing may cause excessive crushing amongst charges and shallow pit breakage, huge blocks in front of the blast hole would occur and the issue can't be overruled.

2.2.5 Stemming

This is essential in blasting in order to check emission of gas, reduce air shock waves, increase of blasting efficiency or dampen any open flames. The stemming length (S_t) varies from twelve times of the bore hole diameter for hard competent rock to 30 times of the diameter for soft competent rock.

2.2.6 Sub-drilling (J_m)

When sub-drilling is used there will be a larger zone of maximum tension and it will occur close to the floor level which must be sheared for good breakage. Sub-drilling may be used as per the following relation, **J_m = 0.1 to 0.25** times the burden (B).

2.2.7. Powder Factor

Powder factor is defined as volume of rock broken (m^3) per unit charge amount (kg) consumption and depends on parameters as volume of rock, charge amount, explosive strength, drilling diameter, rock type, geological weaknesses, etc. Specific charge is just reciprocal of powder factor. Powder factor depends upon rock type, explosive strength, degree of mechanization, drill hole diameter, pattern of drilling, explosive density etc.

2.2.8. Hole Inclination & Drilling

It is always advisable to drill blast holes making some angle usually 5 to 10 degree with vertical and as much as to avoid some clearly visible fracture lines.

2.2.9. Delay Interval

The following guidelines should be observed for fruitful blast results. The delay interval should be such that the burden from previously fired holes has enough time to move out to make next row to have adequate relief. Insufficient relief will result in fly rock and back breaks.

- As a general guideline the delay interval between consecutive rows may be chosen as 6-12 ms of the burden.
- Delay neither should be too short nor be too long which may lead to bad fragmentation. But it should be optimum to get the desired results.

3. Blast Design in SURPAC

3.1. Requirements of Software to Blast Design: SURPAC 6.3.2

GEOVIA Surpac™ is the world's most well-known geography and mine planning software, supporting open pit and underground tasks and exploration or investigation project in excess of 120 Nations. The software delivers effectiveness and precision through convenience, capable of 3-D graphics and work process automation that can be adjusted to organization of particular procedures and information streams. Surpac tends to every one of the necessities of surveyors, geologists and mining engineers in the resource area and is sufficiently adaptable and reasonable for each ore body, mining technique and commodity. Its multilingual capacities enable worldwide organizations to help a common solution across their operations.

SURPAC System

This Surpac System is used for

- Resource estimation, Drill hole data management, Block modeling
- Mine planning , Geological modeling , Geo-statistics , Mine design

3.2. Sample Details Collected

- It is an opencast mine, Rock type: laterite
- Burden: 4 m , Spacing: 6m
- Hole depth= bench height+ sub drill = 9+1.5=10.5 m
- Stemming length : 1.5 m
- Explosive used: ANFO 0.8 and ANFO 0.9
- Detonator: Excel LP , Booster: AZOMEX G
- Delay: 200 ms , Blast pattern: Diagonal And V-Pattern

3.3. Drilling pattern for blasting

a. Create the ore body and mine boundary using string function and then save it
b. Bring the "blast design" menu bar
c. Create a "blast database" where all the information will be stored
d. Apply the "drill and blast settings" which contains information about drilling, charging, rock type and firing
e. Display the ore body in the graphics
f. "Create blast pattern" over the ore body and give required information i.e. burden, spacing, blasting pattern, sub-drill, collar and bottom elevation
g. After creation of pattern upload this into the blast database

3.4. Charging & Firing

a. Display the ore body by dragging into the graphics.
b. "Download the blast hole data" from database.
c. "Charge all the holes" by giving certain information such as stemming length, explosive type, detonator type, booster type & delay time.
d. Give the "firing sequence".
e. Again "upload the charging data" into the blast database.

3.5. Blasting

a. Before blasting create a "blast boundary" which will resist the movement of rock beyond this.
b. Then generate the "blast solid" which will show you the blasted volume of rock and save this as DTM file.

3.6. Report generation

a. Generate a "blast summary report" by selecting the DTM file created in above step. This report will generate all the information i.e. amount of explosive used per hole as well as total drilling cost, blasting cost, powder factor etc.
b. A "work order" can also be generated which will give order to the shot firer about where and when to blast and how will be the charge pattern.

3.7. Results

Table 1: Results on the basis of above sample details

SL. No.	Details	ANFO (0.8 Kg)	ANFO (0.9 Kg)
1	Blasted volume	175403.82 m3	175403.82 m3
2	Blasted mass	385888414.34kg	385888414.34kg
3	No. of Blasted Holes	490	490
4	Powder factor	0.100 kg/m^3	0.113 kg/m^3
5	Total drilling cost	89011.44	89011.44
6	Total explosive cost	13411.26	15933.92
7	Total detonator cost	1470.00	17515
8	Total drilling and blasting cost	103892.70	106660.36
9	Cost per unit drill length	29.45	30.23

4. Optimization of Blasting Parameter on Collected Field Data

Optimization implies desired objective to get the best results i.e. to accomplish minimum and maximum value of the operating parameters. Blast optimization is reliant on a large group of complex factors identified with explosive, the rock, initiation, drill-hole parameters and their design. The significant targets are: Less throw of materials, Greater degree of safety, Stability to the nearby structures.

4.1. Analysis of Flyrock by Using Mine Excellence Software

Fly-rocks are the undesirable ejection of rock particles projected beyond the normal blast area. A few blasts generated fly-rock in vertical upward direction because of improper stemming and water in the blast hole; however it was confined to blasting patch itself. The detailed experimentation proved that the stemming length to burden (S_L/B) ratio greater than 1.0 would efficiently reduce the extent of fly-rocks. With this observation in hand, it was planned to maintain S_L/B ratio greater than 1.0 and consequently fly-rock could not be observed.

4.2. Mine excellence Software (Or Smart Blast App.)

Mine Excellence software is building up itself as a worldwide pioneer blasting and drilling software innovation space. It has an online and mobile based stage which gives all insight into the hands of normal blasters, senior mine administration, and blast supervisor. The innovation enhances and optimizes the blasting which can bring about huge advantages operationally and dispose of potential dangers/issues amid blasting. Web/Mobile based innovation stage for blasting which covers blasting lifecycle in a coordinated way useable across all locales. It looks for blasting lifecycle - blast data collection, Blast Design, and advanced analysis, optimizers (fragmentation, air/ground vibration, pattern simulation), and blast data collection, explosive inventory management etc. Mobile APP works without internet access and has significant capability. Versatile APP works without web get and have a significant capacity.

4.3. Sample Detail, Calculation and Results

Table 2 – Calculation and Results of Bharatpur Opencast Mine on Flyrock analysis

Bharatpur Opencast Mine	
General Details of Mine To calculate the charge mass	
bench height=12 m,	hole diameter=160 mm
hole angle =45	burden=4.5
Sub-grade=0.45 m	stemming height = 1.9 m
explosive density = 1.35 kg/m^3	charge mass = 27.14 kg/m

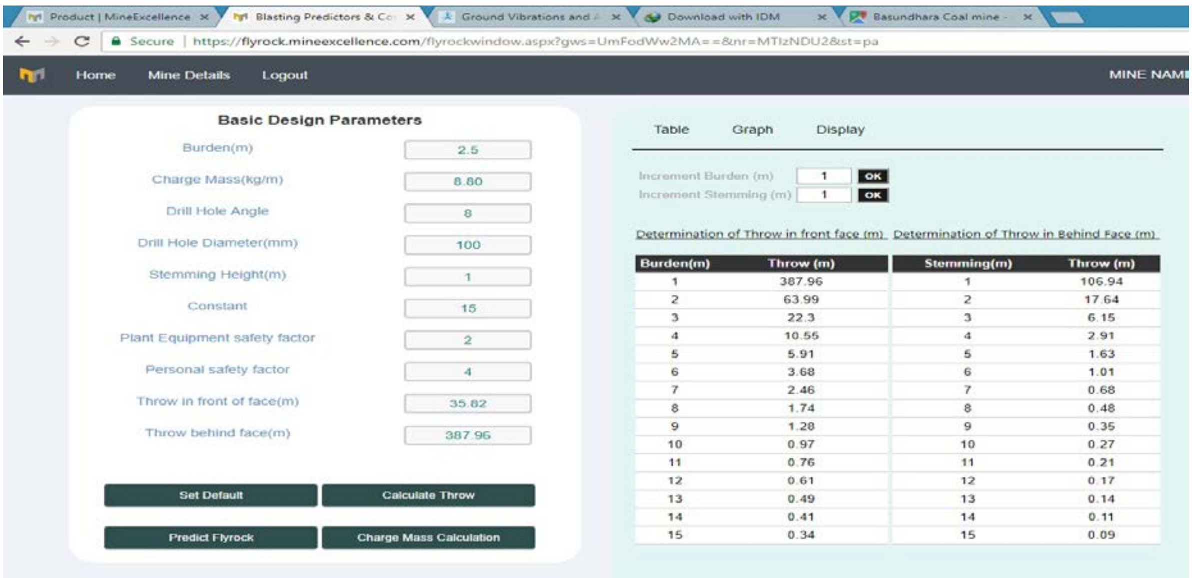


Figure 1: Sample Figure of Calculation Using Mine excellence Software

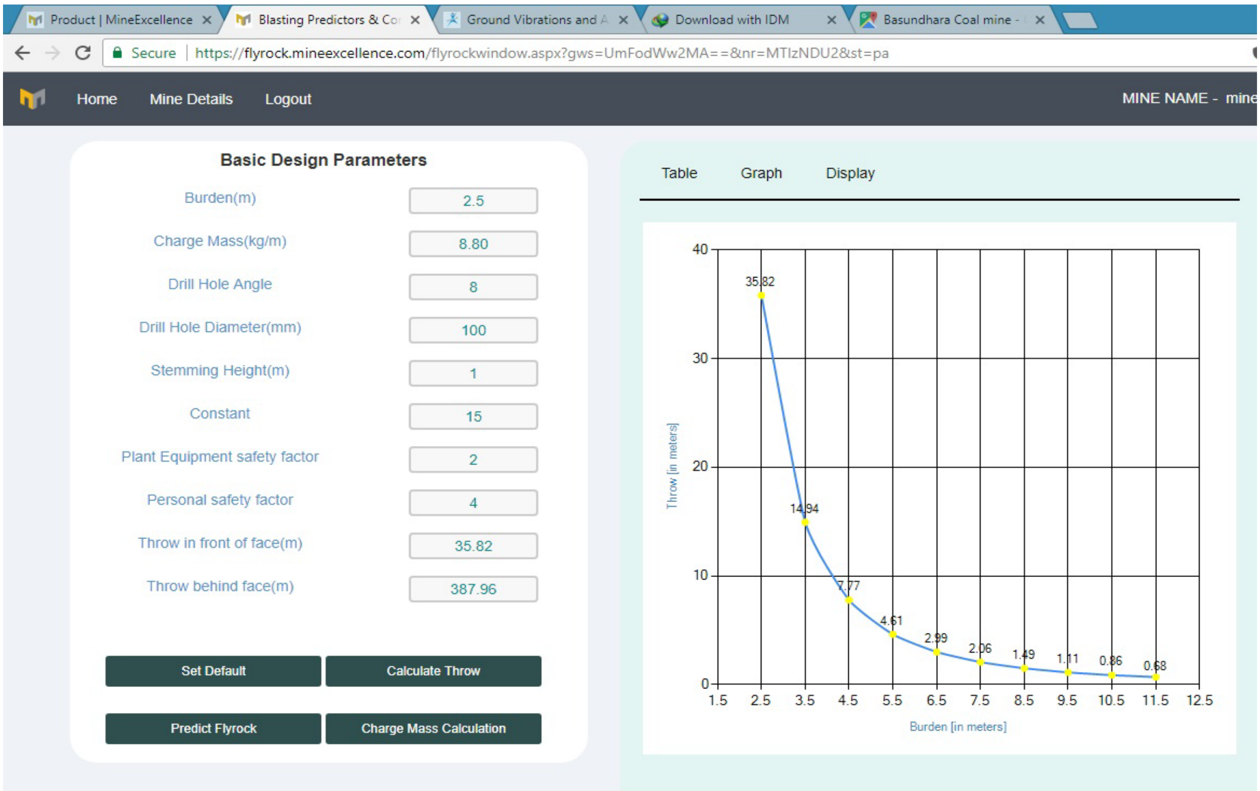


Figure 2: Sample Figure of Calculation Using Mine excellence Software

Table 3: Basic Design Parameter

By changing burden parameter:-

Burden (m)	Charge mass	Drill hole angle	Drill hole diameter(mm)	Stemming Height(m)	Constant	Plant Equipment Saftey factor	Personal Safety Factor	Throw in front of face(m)	Throw behind face(m)
3	27.14	8	160	1.9	10	2	4	42.85	140.51
3.5	27.14	8	160	1.9	10	2	4	28.7	140.51
4	27.14	8	160	1.9	10	2	4	20.28	140.51
4.5	27.14	8	160	1.9	10	2	4	14.93	140.51
5	27.14	8	160	1.9	10	2	4	11.35	140.51
5.5	27.14	8	160	1.9	10	2	4	8.86	140.51
6	27.14	8	160	1.9	10	2	4	7.07	140.51

By changing stemming Height:-

Burden (m)	Charge mass	Drill hole angle	Drill hole diameter(mm)	Stemming Height(m)	Constant	Plant Equipment Saftey factor	Personal Safety Factor	Throw in front of face(m)	Throw behind face(m)
3	27.14	8	160	1.8	10	2	4	42.85	161.72
3.5	27.14	8	160	2.1	10	2	4	28.7	108.32
4	27.14	8	160	2.4	10	2	4	20.28	76.55
4.5	27.14	8	160	2.7	10	2	4	14.93	15.54
5	27.14	8	160	3	10	2	4	11.35	11.82
5.5	27.14	8	160	3.3	10	2	4	8.86	9.22
6	27.14	8	160	3.6	10	2	4	7.07	7.36

By changing Constant value:-

Burden (m)	Charge mass	Drill hole angle	Drill hole diameter(mm)	Stemming Height(m)	Constant	Plant equipment saftey factor	Personal safety factor	Throw in front of face(m)	Throw behind face(m)
4.5	27.14	8	160	2.7	8	2	4	9.56	9.95
4.5	27.14	8	160	2.7	10	2	4	14.93	15.54
4.5	27.14	8	160	2.7	12	2	4	21.5	22.38
4.5	27.14	8	160	2.7	14	2	4	29.27	30.46
4.5	27.14	8	160	2.7	16	2	4	38.23	39.78
4.5	27.14	8	160	2.7	18	2	4	48.38	50.35
4.5	27.14	8	160	2.7	20	2	4	59.73	62.16

So Best result for this mine: - Burden should be 4.5m, Stemming height – 2.7m, Constant value – 12.

Table 4 – Calculation and Results of Basundhara Opencast Mine on Flyrock analysis

Basundhara Opencast Mine	
General Details of Mine To calculate the charge mass	
bench height=6 m	hole diameter=100mm
Burden = 2.5m	hole angle =45
subgrade=0.25 m	stemming height = 1 m
explosive density = 1.12 kg/m^3	**Charge mass = 8.80 kg/m**

By changing burden parameter: - **Table 5: Basic Design Parameter**

Burden (m)	Charge mass	Drill hole angle	Drill hole diameter(mm)	Stemming Height(m)	Constant	Plant Equipment Saftey factor	Personal Safety Factor	Throw in front of face(m)	Throw behind face(m)
2.5	8.8	8	100	1	15	2	4	35.82	387.96
3	8.8	8	100	1	15	2	4	22.3	387.96
3.5	8.8	8	100	1	15	2	4	14.94	387.96
4	8.8	8	100	1	15	2	4	10.55	387.96
4.5	8.8	8	100	1	15	2	4	7.77	387.96
5	8.8	8	100	1	15	2	4	5.91	387.96
5.5	8.8	8	100	1	15	2	4	4.61	387.96

By changing Constant value:-

Burden (m)	Charge mass	Drill hole angle	Drill hole diameter(mm)	Stemming Height(m)	Constant	Plant Equipment Saftey factor	Personal Safety Factor	Throw in front of face(m)	Throw behind face(m)
4	8.8	8	100	1	10	2	4	4.69	172.43
4	8.8	8	100	1	12	2	4	6.75	248.29
4	8.8	8	100	1	14	2	4	9.19	337.95
4	8.8	8	100	1	16	2	4	12.01	441.41
4	8.8	8	100	1	18	2	4	15.2	558.66
4	8.8	8	100	1	20	2	4	18.76	689.7

Anyone we can choose but the least throw behind face is first one. But according to this software if we choose constant 20 then it will give the best result.

By changing stemming Height:-

Burden (m)	Charge mass	Drill hole angle	Drill hole diameter(mm)	Stemming Height(m)	Constant	Plant Equipment Saftey factor	Personal Safety Factor	Throw in front of face(m)	Throw behind face(m)
4	8.8	8	100	1	20	2	4	18.76	689.7
4	8.8	8	100	1.5	20	2	4	18.76	240.34
4	8.8	8	100	2	20	2	4	18.76	31.37
4	8.8	8	100	2.5	20	2	4	18.76	17.56
4	8.8	8	100	3	20	2	4	18.76	10.93
4	8.8	8	100	3.5	20	2	4	18.76	7.32

So Best result for this mine: - Burden should be 4 m, Stemming height – 2.5 m, Constant value – 20.

Table 6 – Calculation and Results of Anant Opencast Mine on Flyrock analysis

Ananta Opencast Mine	
General Details of Mine To calculate the charge mass	
bench height=7 m	hole diameter=160 mm
hole angle =45	burden = 4
Sub-grade=1.4 m	stemming height = 4.5 m
explosive density = 1.14 kg/m^3	**charge mass = 22.92 kg/m**

Table 7: Basis Design Parameter

By changing burden parameter:-

Burden (m)	Charge mass	Drill hole angle	Drill hole diameter (mm)	Stemming Height(m)	Constant	Plant Equipment Saftey factor	Personal Safety Factor	Throw in front of face(m)	Throw behind face(m)
3	22.92	6	160	4.5	10	2	4	34.4	3.31
3.5	22.92	6	160	4.5	10	2	4	23.04	3.31
4	22.92	6	160	4.5	10	2	4	16.28	3.31
4.5	22.92	6	160	4.5	10	2	4	11.99	3.31
5	22.92	6	160	4.5	10	2	4	9.11	3.31
5.5	22.92	6	160	4.5	10	2	4	7.11	3.31
6	22.92	6	160	4.5	10	2	4	5.67	3.31

Both of them are good. By changing stemming Height:-

Burden (m)	Charge mass	Drill hole angle	Drill hole diameter (mm)	Stemming Height(m)	Constant	Plant Equipment Saftey factor	Personal Safety Factor	Throw in front of face(m)	Throw behind face(m)
3	22.92	6	160	1.8	10	2	4	34.4	129.82
3.5	22.92	6	160	2.1	10	2	4	23.04	86.95
4	22.92	6	160	2.4	10	2	4	16.28	61.45
4.5	22.92	6	160	2.7	10	2	4	11.99	12.47
5	22.92	6	160	3	10	2	4	9.11	7.15
5.5	22.92	6	160	3.3	10	2	4	7.11	5.58
6	22.92	6	160	3.6	10	2	4	5.67	4.45

Both of them are good. But according to the cost cutting factor, less waste of coal,Out of both, the best one is having burden 4.5m.

By changing Constant value:-

Burden (m)	Charge mass	Drill hole angle	Drill hole diameter (mm)	Stemming Height(m)	Constant	Plant Equipment Saftey factor	Personal Safety Factor	Throw in front of face(m)	Throw behind face(m)
4.5	22.92	6	160	2.7	8	2	4	9.82	10.24
4.5	22.92	6	160	2.7	10	2	4	11.99	12.47
4.5	22.92	6	160	2.7	12	2	4	16.28	19.36
4.5	22.92	6	160	2.7	14	2	4	11.99	14.96
4.5	22.92	6	160	2.7	16	2	4	9.11	13.12
4.5	22.92	6	160	2.7	18	2	4	7.11	10.24
4.5	22.92	6	160	2.7	20	2	4	5.67	8.67

Anyone we can choose but the least throw behind face is first one. But according to this software if we choose constant 20 then it will give the best result. So Best result for this mine:- Burden should be 4.5 m, Stemming height – 2.7 m, Constant value – 20.

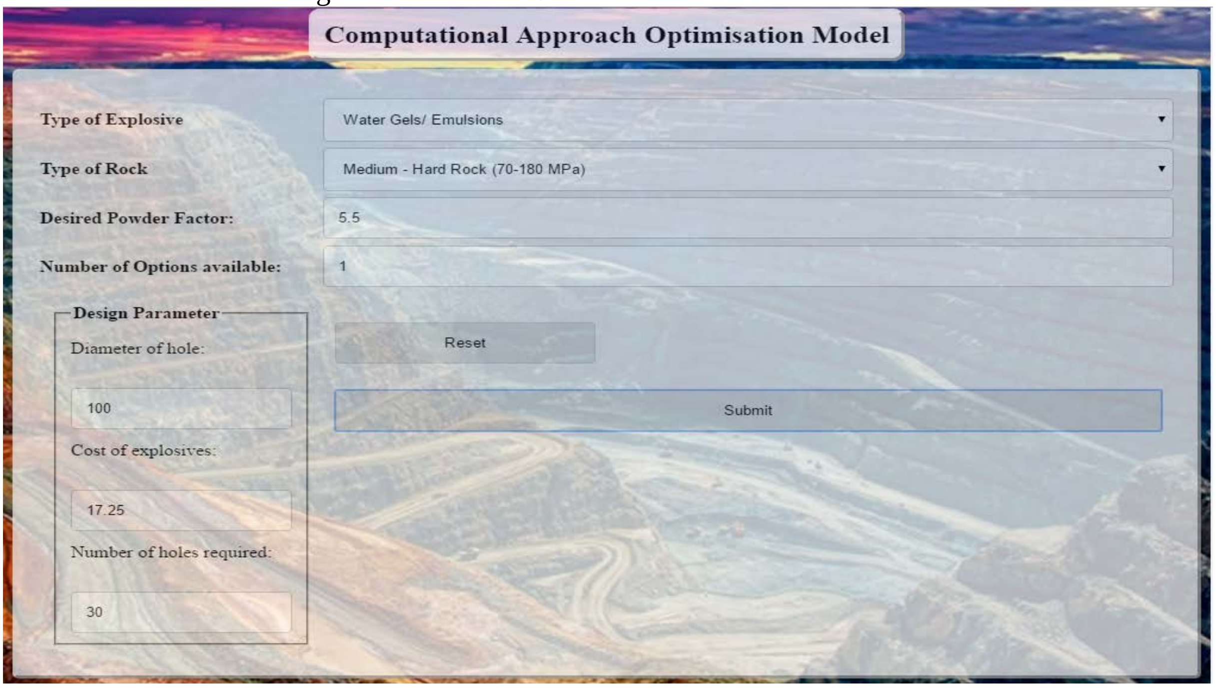
4.4. Optimization Methodology

In the proposed method performed in the current project work, the need is given to the explosive type, the number of holes, rock factors, and the desired powder factor. These factors combinedly consider the energy result of the explosive, the explosive types and density used. The principal significance here is to the cost optimization with the desired production. The equation expressed for the optimization is from the fundamental information available from the mines and the best combination and according to the ideal guidelines. In the present case, since the drill holes are settled and can't be differed as they rely upon the accessible drill machines, this is taken as an input to the procedure. According to the client's requirements, the fragmentation estimate should be steady which differs by the powder factor, so that powder factor is made constant or input information. The explosive cost which is the driving information is likewise to be considered as information. According to the optimization models observed till now; the spacing, the length of the hole, burden, and height of bench can be effortlessly related with the diameter of the drill hole by some simple derivation and equations. From all the past information the total cost of the configuration and the charge per hole can be determined. The constants utilized as a part of the equation are expressed from the field information available from some Indian coal mines and some optimized equation officially applied in coal and metal mines**.** The input parameters are that accessible explosive information from the coal mines in India. The prepared model programme was written using visual basic on PHP platform. Some sample presentation of the input and output parameters are as shown below:

Starting Screen:

In the starting page, the user have to enter value for type of explosive, rock types, powder factors, basic parameters (Drill hole diameter, Cost of explosive and No. of holes) & further calculation.

Input Page:
In this page user can enter as much as number of data to find best value among all the input value given. So you have to enter some number of option available boxes to find the best one. After that this software will calculate them according to given input data then it will compare among all the calculated data then it will give the best result.



Output Page:
In the output page, after calculation, it will show the important parameter value for blast design. The important parameters are Bench height, burden, sub drilling, spacing, stemming, hole length, explosives used, volume of rock blasted, fragmentation size, charged per hole and total cost of blasting. It's also giving the best results among all multiple given data.

4.5. Case Study

The developed model has been tested in three mines i.e. Basundhara OCP, Bharatpur OCP, Ananta OCP. Some of the important parameters are matching and also there are some changes required according to prepared computational approach optimization model.

Table 8: Mines details which is necessary for prepared optimization model

Sl. No.	Mines Name	Type of Explosive	Type of Rock Factor	Blasting Pattern	Powder factor (m^3/kg)	Diameter of hole (mm)	Cost of Explosive per Kg (Rs./kg)	No. of Holes
1	Basundhara OCP	Slurry Explosive	Medium-Hard	Square	5.5 (OB), 5.6 (Coal)	100(OB), 160 (Coal)	17.25	30
2	Bharatpur OCP	Power Gel B	Medium-Hard	Square	2.2 (OB), 4.6 (Coal)	160	14	40
3	Ananta OCP	emulsions	Medium-Hard	Square	2.78 (OB), 4.96 (Coal)	259(OB), 160 (Coal)	14	30

Table 9: Desired Blasting Design parameter value for Basundhara OCP mine

Parameters	Power factors and Diameter Of Drill hole	
	Over Burden(5.5m3/Kg) and 100mm Dia	Coal(5.6m3/Kg) and 160mm Dia
Bench Height(m)	5.2	8.32
Burden(m)	3.8	6.08
Spacing(m)	4.5	7.2
Stemming Height(m)	2.28 , 3.8	3.65 , 6.08
Sub Drilling(If Required)	1.14	1.82
Length Of hole(m)	6.34 , 7	10.144 , 11.2
Fragmentation Size(cm)	47.63	60.96
Cost Of Explosive(Rs/Kg)	17.25	17.25
Charged per Hole (kg)	1.655	4.765
No. of Holes	30	30
Total Cost of blasting(Rs)	856.57	2465.87

Table 10: Desired Blasting Design parameter value for Bharatpur OCP mine

Parameters	Power factors and Diameter Of Drill hole	
	Over Burden(2.2 m3/Kg) and 160mm Dia	Coal(4.6m3/Kg) and 160mm Dia
Bench Height(m)	8.32	8.32
Burden(m)	6.08	6.08
Spacing(m)	7.2	7.2
Stemming Height(m)	3.648	3.648
Sub Drilling(If Required) (m)	1.824 , 2.88	1.824 , 2.88
Length Of hole(m)	10.144, 11.2	10.144, 11.2
Fragmentation Size(cm)	33.74	53.825
Cost Of Explosive(Rs/Kg)	14	14
Charged per Hole (kg)	9.689	5.532
No. of Holes	40	40
Total Cost of blasting(Rs)	5425.83	3098.42

Table 11: Desired Blasting Design parameter value for Ananta OCP mine

Parameters	Power factors and Diameter Of Drill hole	
	Over Burden(2.78 m^3/Kg) and 259 mm Dia	Coal(4.96 m^3/Kg) and 160mm Dia
Bench Height(m)	13.468	8.32
Burden(m)	9.842	6.08
Spacing(m)	11.655	7.2
Stemming Height(m)	5.91	3.645
Sub Drilling(If Required) (m)	2.95 , 4.662	1.824 , 2.88
Length Of hole(m)	16.42 , 18.13	10.144 , 11.2
Fragmentation Size(cm)	49.81	56.455
Cost Of Explosive(Rs/Kg)	14	14
Charged per Hole (kg)	24.31	5.225
No. of Holes	30	30
Total Cost of blasting(Rs)	10209.74	2194.54

As we know that, in opencast mine desired powder factors varies from 0.33 to 0.55 kg/m3 (1.82 to 2.86 m^3/kg) and diameter varies from 100mm to 381mm. Therefore on the basis of present details, we prepared some results by varying the parameters i.e. type of explosive, rock types, powder factors and diameters. Then we can compare them among given details to know the least blasting cost. Here, in the below table type of explosive taken ANFO and Rock types taken soft rock (<70MPa).

Table 12: Desired Blasting Design parameter value for powder factor 1.8 m^3/kg

Parameters	Power factors (1.8 m^3/kg) and Diameter Of Drill hole					
	100mm	160mm	200mm	250mm	311mm	381mm
Bench Height(m)	5.2	8.32	10.4	13	16.172	19.812
Burden(m)	3.8	6.08	7.6	9.5	11.818	14.478
Spacing(m)	4.5	7.2	9	11.25	13.995	17.145
Stemming Height(m)	2.28 , 3.8	3.65 , 6.08	4.56,7.6	5.7,9.5	7.09,11.82	8.68,14.48
Sub Drilling(If Required)	1.14,1.8	1.82,2.88	2.28,3.6	2.85,4.5	3.55,5.59	4.34,6.85
Length Of hole(m)	6.34 , 7	10.144 , 11.2	12.68,14	15.85,17.5	19.717,22	24.155,27
Fragmentation Size(cm)	23.48	29.72	33.235	37.167	41.46	45.9
Cost Of Explosive(Rs/Kg)	23.50	22	20	22	17	17.5
Charged per Hole (kg)	3.867	11.284	18.76	31.2	51.31	81.496
No. of Holes	40	40	30	30	30	30
Total Cost of blasting(Rs)	3634.6	9930.26	11258.16	20592.01	26169.88	42785.86

Table 13: Desired Blasting Design parameter value for powder factor 2 m^3/kg

Parameters	Power factors(2 m^3/kg) and Diameter Of Drill hole					
	100mm	160mm	200mm	250mm	311mm	381mm
Bench Height(m)	5.2	8.32	10.4	13	16.172	19.812
Burden(m)	3.8	6.08	7.6	9.5	11.818	14.478
Spacing(m)	4.5	7.2	9	11.25	13.995	17.145
Stemming Height(m)	2.28 , 3.8	3.65 , 6.08	4.56,7.6	5.7,9.5	7.09,11.82	8.68,14.48
Sub Drilling(If Required)	1.14,1.8	1.82,2.88	2.28,3.6	2.85,4.5	3.55,5.59	4.34,6.85
Length Of hole(m)	6.34 , 7	10.144 , 11.2	12.68,14	15.85,17.5	19.717,22	24.155,27
Fragmentation Size(cm)	25.104	31.769	35.527	39.73	44.323	49.068
Cost Of Explosive(Rs/Kg)	23.50	22	20	22	17	17.5
Charged per Hole (kg)	3.569	10.416	17.320	28.8	47.367	75.229
No. of Holes	40	40	30	30	30	30
Total Cost of blasting(Rs)	3355.05	9166.49	10392.26	19008.22	24152.07	39495.07

Table 14: Desired Blasting Design parameter value for powder factor 2.5 m^3/kg

Parameters	Power factors(2.5 m^3/kg) and Diameter Of Drill hole					
	100mm	160mm	200mm	250mm	311mm	381mm
Bench Height(m)	5.2	8.32	10.4	13	16.172	19.812
Burden(m)	3.8	6.08	7.6	9.5	11.818	14.478
Spacing(m)	4.5	7.2	9	11.25	13.995	17.145
Stemming Height(m)	2.28 , 3.8	3.65 , 6.08	4.56,7.6	5.7,9.5	7.09,11.82	8.68,14.48
Sub Drilling(If Required)	1.14,1.8	1.82,2.88	2.28,3.6	2.85,4.5	3.55,5.59	4.34,6.85
Length Of hole(m)	6.34 , 7	10.144 , 11.2	12.68,14	15.85,17.5	19.717,22	24.155,27
Fragmentation Size(cm)	28.913	36.589	40.917	45.758	51.046	56.512
Cost Of Explosive(Rs/Kg)	23.50	22	20	22	17	17.5
Charged per Hole (kg)	3.013	8.792	14.62	24.31	39.981	63.499
No. of Holes	40	40	30	30	30	30
Total Cost of blasting(Rs)	2831.96	77.7.31	8771.97	16044.59	20390.67	33337.27

5. Conclusion

The developed model is easy to understand and simple to use. One can also modify with the developed model by changing parameters like blasting and drilling pattern and new explosives and so on according to their requirement. In this study we first carried out blast design using SURPAC software to know the basic blasting detail like powder factors and the cost estimation. Then, we carried out fly rock analysis using MINEEXCELLENCE software from where we could find some clues for optimization of some parameters like burden, stemming height and appropriate constant value which is required for the software. MINEEXCELLENCE software has been tested on three different mines i.e. Basundhara OCP, Bharatpur OCP, Ananta OCP. After that, blast design model has been created with simple methodologies which can be easily used by any mining industry to analyse the explosive expenses and accomplish better blasting results. This model considers the regular explosives used by large opencast mines which in turn are chosen by valuable parameters like rock parameter, explosives parameter and in addition powder factor and other related parameters. The model created is an easy to use one, since by keeping type of explosive, the powder factor, type of rocks, and number of choices of explosives details available as constant and by differing the parameters like number of holes, drill hole diameter and cost of explosives one can compare the explosive performance and accordingly take a choice to choose the best possible kind of explosives for blasting. The performance of the developed model can be improved with the collection of information from a large number of mines. We are sure this model will give some help to the blasting engineers and mine operators to accomplish the best results with a less cost of blasting.

6. References

1. Roy, P.P. (2017): Best practiced drilling and blasting operations for Indian surface and underground mining, seminar at NIT Rourkela during MINARE 2017.
2. Nanda, N.K. (2003): Optimization of mine production system through operation research techniques, 19th World Mining Congress, New Delhi, November, pp.583-595.
3. Roy, P.P. (2005): Terms and parameters influencing mine and ground excavations, Rock blasting effects and operations, pp. 17-22.
4. Roy, P.P. (2005): Rock blasting effects and operations, 1st Edition (2005), pp:1-2,17-21,102-109, 131-142.
5. Rout, M. and Parida, C.K. (2007): Thesis on optimization of blasting parameters in open cast mines, D-space, NIT Rourkela.
6. Pradhan, S.K. and Das, A. (2007): Thesis on evaluation of explosive using ground vibration criterion, D-space, NIT Rourkela.
7. Choudhury, S.S.K. and Ranjan, R. (2014): Thesis on blast vibration in opencast mines, D-space, NIT Rourkela.
8. Kujur, B.K. (2010): Thesis on blast vibration in opencast mines, D-space, NIT Rourkela.
9. Armstrong, L.W. (2001): Evaluation of parameters affecting blast induced vibrations, Thesis work of University of Wollong.
10. https://www.researchgate.net/profile/Mohan_Yellishetty/publication/220677847_Application_of_soft_computing_to_predict_blast_induced_ground_vibration/links/0f317533fd875b5f57000000.pdf
11. Sethi, N.N. and Dey, N.C. (2004): A simulated studies on blast design operation in open cast iron ore mine, The Indian Mining & Engineering Journal, January, pp.17-23.
12. Bhandari, A. (2004): Indian mining industry: need for adoption of technology for better future, The Indian Mining & Engineering Journal, December, pp.40-49.
13. Adhikari, G.R. and Venkatesh, H.S. (1995): An approach for optimizing a blast design for surface mines", The Indian Mining & Engineering Journal, February, pp.25-28.
14. Majhi, H. (2008): Development of a Module for End Break and Back Break in Surface Blasting, unpublished B. Tech Project, NIT Rourkela, pp.4-8,24-27
15. https://www.leg.state.mn.us/docs/2015/other/150681/.../Dyno%20Nobel%202010.pdf
16. Sharma P.D. (1979): Empirical Equations Supporting Blast Designs, Available on - https://www.scribd.com/document/76869143/Empirical-Equations-Supporting-Blast-Designs-Discussion-on-Design-Parameters-and-Related-Matters, last visit: 02-05-2018