# APCOM 2007

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- It can be adapted and parameterized according to the reality of business where it is implemented, allowing free functionality,
- Standard data entry structure tool,
- Reports necessary for a proper blasting management can be obtained, and
- It can be housed equally in servers of the client's company or in a datacenter.

*BMS* is built on the interrelation with base data sources that need to be analyzed with the customer in order to determine its application in the models that they will use.

Specifically, the characteristics of the information sources and their integration are as shown below.

This system is capable of compiling and relating the information kept in other systems, no matter their format or native structure, as long as:

1. Information has a common denominator, which is a blasting identifier and,
2. In order to obtain the *base module* reports, the client must give the data structure according to what the system defines. Any modification or adaptation of the product must be analyzed together on the whole for its implementation.

Particularly for the *BMS*, the sources of base information considered are the following:

- Fragmentation measurement
- Dig Rate measurement
- Post-blasting analysis
- Blast design
- Real blasting
- Blasting cost
- Time control for auger trucks

## Advantages

A tool with the characteristics described above allows:

- Reuse of previous blast designs, and decision-making based on historical records,
- Study and optimize customer's processes,
- Associate the recorded information about conditions before and after a blast for analysis,
- Have access to updated and real data provided by Enaex and the customer,
- Become a source of knowledge for the application of better practices, and
- Be used by either Enaex or the customer's personnel.

# CONCLUSIONS

The Mining Process, when considered in its full context, consists of many separate stages or sub-processes such as drilling, blasting, loading, hauling, crushing, grinding, flotation, etc. These sub-processes make up the Production Chain, and each one of the stages of a chain is needed for the creation of the final product. Each one of these stages must contribute VALUE to the business. Optimization has to consider the value and profitability of the total business, and not a focus on each operating unit in an individualized way. This realization leads us to the Value Chain, and requires a greater knowledge of how the various sub-processes react to various changes in the nature of the material being processed. It also requires that we define and quantify Value, consistent with the strategic objectives of the business and in terms of dollars, at every stage in the Production Chain. Each stage of the process must be optimized not for itself, but rather to maximize its contribution of value to the Global Process.

Modern philosophies based on maximization of Global Value of the operations as a whole have created a new world of business opportunities for explosive manufacturers and blasting service providers. Based on the development of many communication platforms and specific ICT's applications for the mining industry, a full set of data is available to improve blasting efficiency to precondition the rock, ore or waste material, for the following stages of the mining process, allowing better understanding and managing of the leverage that blasting can generate to improve the business.

# DELPAT SOFTWARE SYSTEM FOR DESIGN OF DRILLING AND BLASTING OPERATIONS

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## ABSTRACT

Most mining operations include a chain of several processes such as drilling, blasting, loading, hauling, and crushing. Drilling and blasting, as the first element of the ore extraction process, have the main objective to fracture the *in situ* rock mass while maintaining safety and environmental standards. This sub-process needs to produce fragment size distributions that are tailored to minimize the production costs and energy consumption in downstream process including loading, hauling and crushing. This paper presents a part of new integrated computer-aided system called DelPat that can be used for design and planning of drilling and blasting operations. The stand-alone version, with both metric and English units, was developed in Microsoft Visual Basic programming language. The database was developed using Microsoft Access system and applies open database connectivity for storage and processing of drilling and blasting information. The case study of system application includes quarry operations in Turkey. The results obtained by DelPat are compared with actual costs incurred in the field. The results of this study, specifically the computerized software system, can be used by industry professionals to evaluate different drilling and blasting scenarios. This comprehensive and user-friendly system helps industry professionals to minimize design time and maximize the cost-effectiveness of drilling and blasting in mining projects.

## INTRODUCTION

The major thrusts in drilling and blasting operations are to maintain safety and minimize overall costs. Additionally, in road excavation projects special emphasis is placed on the final rock wall contours where smooth blasting or presplitting is commonly used. Drill holes are charged with special, light explosives to minimize the effect of shock waves and initiation is frequently performed by detonating cords. Pre-split holes are fired simultaneously ahead of the other holes, whereas, smooth blasting uses the highest number of detonator delay (Fernberg 2002).

Currently, there are a number of different drilling and blasting computer programs used in mining and civil engineering design projects. The application and effectiveness of specific software depend upon the number of factors including project site characteristics, input data available, the required output, skill, experience, and personal biases of the user.

Commonly, the graphical design of drilling and blasting patterns is preformed by 3-D Computer Aided Design (CAD) tools. The 3-D commercially available computer programs include MineScape Drill & Blast (Mincom 2004), Surpac Drill and Blast (Surpac Software International 2004), GEMS Blast Design (Gemcom Software International Inc. 2004), MineSight Blast Pattern Design (Mintec 2004), VULCAN V5 Drill and Blast Design Module (Maptek 2004), and Carlson Blasting Layout/Management Module (Carlson Software 2004). These sophisticated software have a powerful graphical interface, i.e. they provide design of 3-D virtual models of drilling and blasting patterns. However, they represent an integrated part of the larger, multi-purpose software packages that also include topographical interpretation, drillhole representation, geological, grade and solid modeling, volumetric calculation, bench design and planning, etc. These computer programs do not provide prediction of fragments distribution nor cost calculation related to drilling and blasting operations. They also require an extensive training which is very costly and time consuming (Stonce 2003).

Majority of drilling and blasting manufacturers such as Atlas Copco, Tamrock, Furukawa, P&H, Bucyrus, Swedala, Sandvik, Austin Powder, Dyno Nobel Inc., etc. have developed their own computer programs. It should be recognized that each company makes their recommendations of a particular piece of drilling equipment or type of explosive using not only numbers calculated according to the standard practice but often applying procedures or coefficients, which are part of the intellectual property of the given company. These hidden procedures and/or numbers are often the result of many years of experimentation, which need to be protected. The authors recognize this aspect of software ownership and any software developer can choose to display or to protect portions or types of information that are made available to others. By researching Dyno Nobel Inc. website the authors have learned that this company has the computer based simulation and analysis software named DynoConsult. This software has models that provide blast design, simulation and vibration analysis and can estimate fragmentation and damage (Dyno Nobel 2004). It is also indicated that "they work with their alliance partners to develop complex blast models to predict blast movement, and muck-pile profile". Additional computer programs by Dyno Nobel include productivity analysis, blast costing models, profiling software and explosive thermodynamic codes. Also, the authors learned that software called SABREX by ICI Explosives gives practical and graphical information about fragmentation, muck-pile, damage and costs (Kirby et al. 1987; Paine et al. 1987). No additional information was available on the web site at the time of paper writing. The most detailed description of manufacturer-developed computer program is given by the Ingersoll-Rand (Drake 2002). This company has developed Drill Cost Estimation (DCE) software to assist users to select the proper drilling equipment, and to calculate operating and ownership costs of such equipment.

Drilling and blasting computer programs that are commercially available on the market include JKSimBlast (JK Tech Pty Ltd 2004), GoldSize (Golder Associates 2004), Blast Optimisation (Rockmate 2004), Blast Layout (DBS 2004), and MBD-MineBlastData (Reeves 2004). The Precision Blasting Services (PBS) has developed several modules that incorporate blast designer, blast report database, blasting cost, and blasting plan designer (PBS 2004). Most of these computer programs are conceptually similar to each other.

Based upon the previous research related to the development of computer programs for drilling and blasting operations, a new user-friendly software called DelPat is developed to help industry professionals to minimize design time and maximize the cost-effectiveness of drilling and blasting projects. The major novelty of DelPat software is integration of fragmentation and costs analysis. The text that follows describes the application of DelPat system at the excavation project in Turkey, and the costs obtained by the software are compared with actual costs incurred in the field.

## CASE STUDY

Drilling and blasting operations were based on 4.8 million or rock materials to be excavated annually including 4 non-working days per month, 10 working hours per shift and 2 shifts per day (Figure 1). Drilling machine utilization was designed at the rate of 67.5 %.

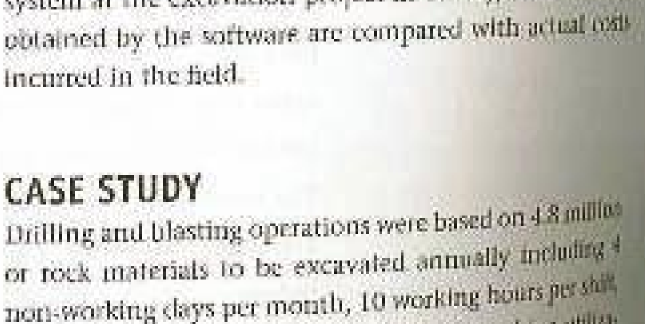

Figure 1: Planning of drilling and blasting operations.

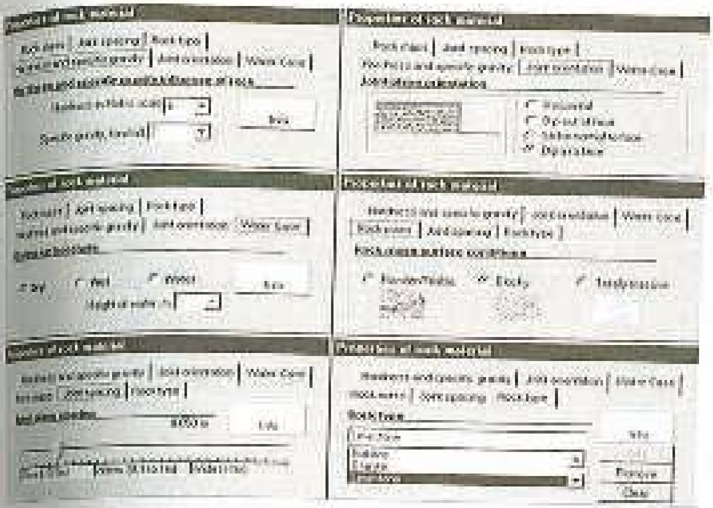

Figure 2: Properties of rock material.

All the rock properties are selected based upon the geological conditions in the field. Rock material was limestone with hardness in Moh's scale of 6 and specific gravity of 2 t/m³. DelPat enables selection of Rock mass surface condition as Powder/Friable, Blocky or Totally massive. Joint plane orientation can be selected as either Horizontal, Dip out of face, Strike normal to face or Dip into face. Borehole case can be Dry, Wet, or with appropriate level of the Water. Joint plane spacing can be selected as Close (< 0.1 m), Intermediate (0.1 to 1 m), or Wide (> 1 m). Based on the geological conditions in the field, the Rock mass surface condition was selected as a Blocky, i.e. well interlocked undisturbed rock mass consisting of cubical blocks and intersecting discontinuity sets. The Joint plane orientation was selected as a Dip into face, borehole case was as Dry, while the Joint plane spacing value was 0.05 m. All the input parameters are presented in Figure 2 through Figure 5.

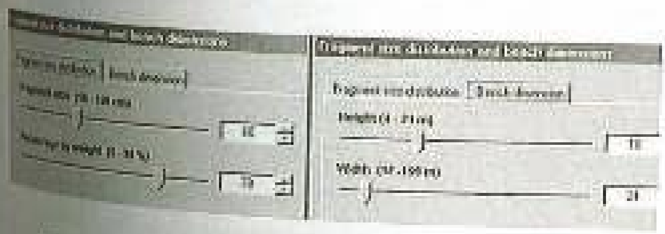

Figure 3: Fragment size distribution and bench dimensions.

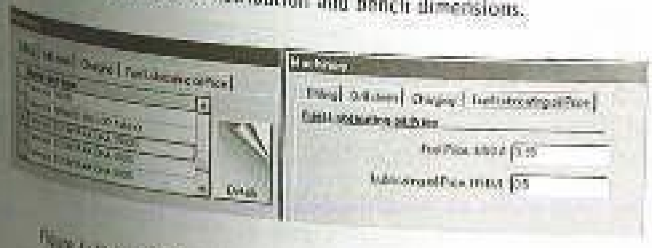

Figure 4: Machine selection.

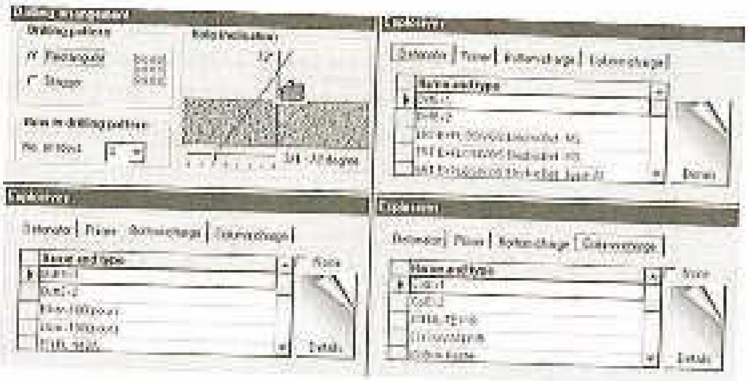

Figure 5: Selection of drilling arrangements and explosives.

Based upon the input parameters, the various alternatives such as different hole diameters, burden, and spacing were considered. Figure 6 shows calculated values for burden, spacing, stemming, column and bottom charge, hole depth and sub-drilling for hole diameter of 89 mm.

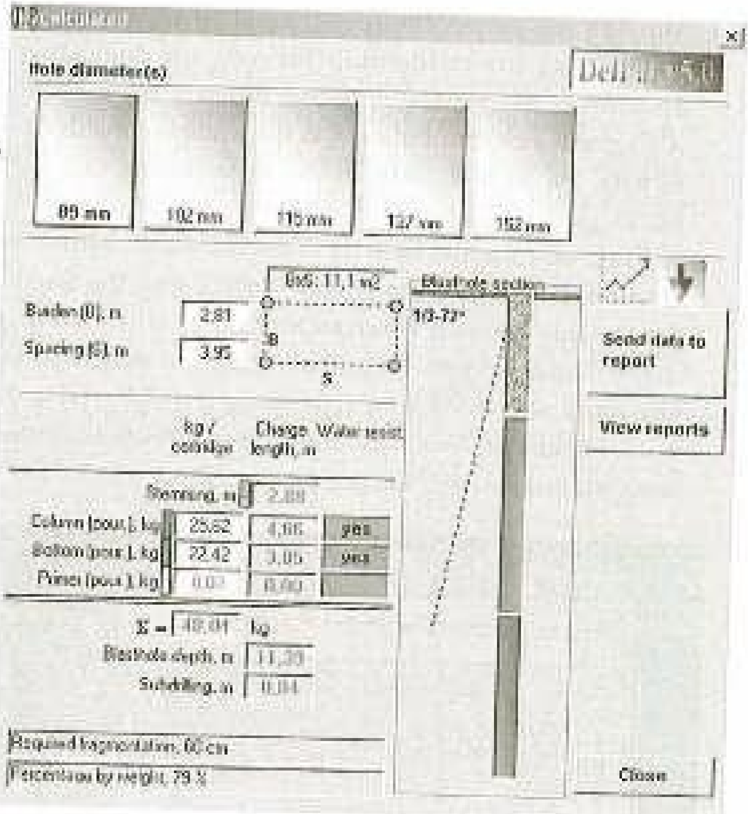


Figure 6: Calculated values for hole diameter of 89 mm.

Table 1 shows column and bottom charge for various hole diameters applied in the project, while Table 2 presents specific drilling, yield, and specific charge.

Table 1: Column and bottom charge for different hole diameters.

| Hole diameter (mm) | Column charge | | | | | Bottom charge | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Burden(m) | Spacing(m) | Stemming(m) | Column(kg) | Column(m) | Column(kg) | Column(m) | Hole depth(m) | Sub-drilling(m) |
| 89 | 2.81 | 3.95 | 2.88 | 25.62 | 4.66 | 22.42 | 3.85 | 11.39 | 0.84 |
| 102 | 3.04 | 4.49 | 3.10 | 30.39 | 4.21 | 31.73 | 4.15 | 11.46 | 0.93 |
| 115 | 3.24 | 5.03 | 3.36 | 33.31 | 3.63 | 44.09 | 4.53 | 11.52 | 0.97 |
| 127 | 4.21 | 4.45 | 3.83 | 35.39 | 3.16 | 57.38 | 4.84 | 11.83 | 1.26 |
| 152 | 4.51 | 5.38 | 4.01 | 32.22 | 2.01 | 95.09 | 5.60 | 11.92 | 1.36 |

Table 2: Specific drilling, yield, and specific charge for various hole diameters.

| Hole diameter (mm) | Bench height (m) | Hole length (m) | Specific drilling ($m/m^3$) | Yield ($m^3/m$) | Yield ($m^3$/hole) | Total charge (kg) | Specific charge ($kg/m^3$) |
|---|---|---|---|---|---|---|---|
| 89 | 10 | 11.39 | 0.103 | 9.75 | 110.99 | 48.04 | 0.433 |
| 102 | 10 | 11.46 | 0.084 | 11.91 | 136.42 | 62.12 | 0.455 |
| 115 | 10 | 11.52 | 0.071 | 14.13 | 162.81 | 77.36 | 0.475 |
| 127 | 10 | 11.83 | 0.063 | 15.86 | 187.53 | 92.77 | 0.495 |
| 152 | 10 | 11.92 | 0.049 | 20.34 | 242.45 | 127.32 | 0.525 |

Through the project the special emphasizes was placed on studying the relationship between the cumulative amounts of fragments (%) passing different meshes size. A fragment size distribution was quantified by mesh sizes with 10, 50 and 100% of the mass passing ($S_{10}$, $S_{50}$, and $S_{100}$). The prediction of fragment size distributions is based on formulas such as Kuznetsov-Rosin-Rammler (Kuznetsov 1973), Cunningham (1987), and the Swedish Detonic Research Foundation formula (Ouchterlony 1980). Figure 7 shows cumulative graph of weight passing block size in 89 mm hole diameter while Table 3 shows fragment size distribution for various hole diameters studied through the project.

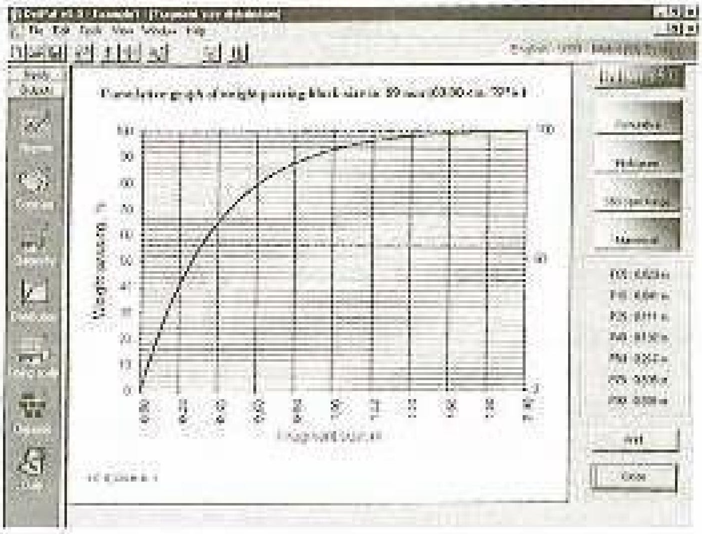

Figure 7: Cumulative graph of weight passing block size in 89 mm hole diameter.

The mesh sizes obtained in the project are as follows:

- The mesh sizes with 5% of the mass passing as block size (P05) is 0,020 m
- The mesh sizes with 10% of the mass passing as block size (P10) is 0,041 m
- The mesh sizes with 25% of the mass passing as block size (P25) is 0,111 m
- The mesh sizes with 40% of the mass passing as block size (P40) is 0,197 m
- The mesh sizes with 50% of the mass passing as block size (P50) is 0,267 m
- The mesh sizes with 75% of the mass passing as block size (P75) is 0,535 m
- The mesh sizes with 90% of the mass passing as block size (P90) is 0,888 m

Table 3: Fragment size distribution for various hole diameters.

| Hole diameter (mm) | Burden (m) | Spacing (m) | Fragmentation size (mm) | Percentage by weight | S50 (m) | Ratio Spacing |
|---|---|---|---|---|---|---|
| 89 | 2.81 | 3.95 | 60 | 79 | 0.266 | 1.41 |
| 102 | 3.04 | 4.49 | 60 | 79 | 0.268 | 1.48 |
| 115 | 3.24 | 5.03 | 60 | 79 | 0.266 | [illegible] |
| 127 | 4.21 | 4.45 | 60 | 79 | 0.266 | [illegible] |
| 152 | 4.51 | 5.38 | 60 | 79 | 0.268 | [illegible] |

Table 4: Values of S50 and specific charge for various hole diameters.

| Hole diameter (mm) | 102 | 115 | 127 | 152 |
|---|---|---|---|---|
| S50s (cm) | 21.25 | 22.14 | 23.23 | [illegible] |
| S50f (cm) | 26.62 | 26.64 | 26.56 | [illegible] |
| SCs ($kg/m^3$) | 0.60 | 0.60 | 0.58 | [illegible] |
| SCf ($kg/m^3$) | 0.46 | 0.48 | 0.49 | [illegible] |

The histogram of weight passing – block size for 89 mm hole diameter is shown in Figure 8, while Figure 9 shows calculation of S50 according to block size. Table 4 shows these values for various hole diameters where S50s is start value of S50, S50f is end value of S50, SCs is start value of specific charge, and SCf is end value of specific charge.

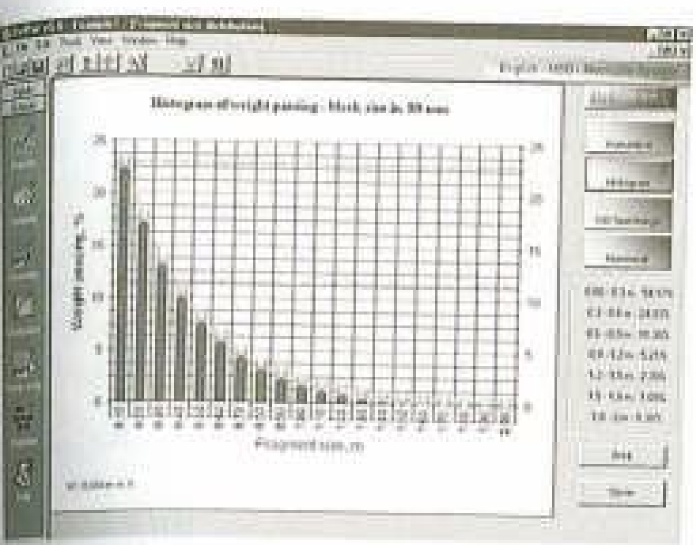

Figure 8: The histogram of weight passing – block size for 89 mm hole diameter.

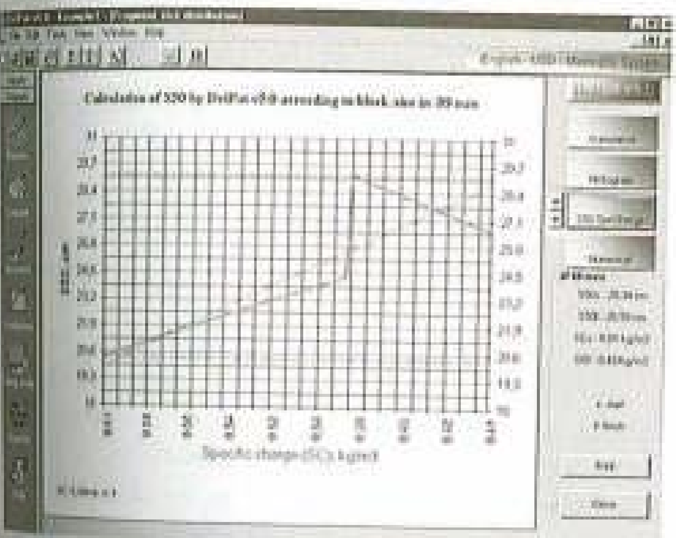

Figure 9: Calculation of 550 according to block size for 89 mm hole diameter.

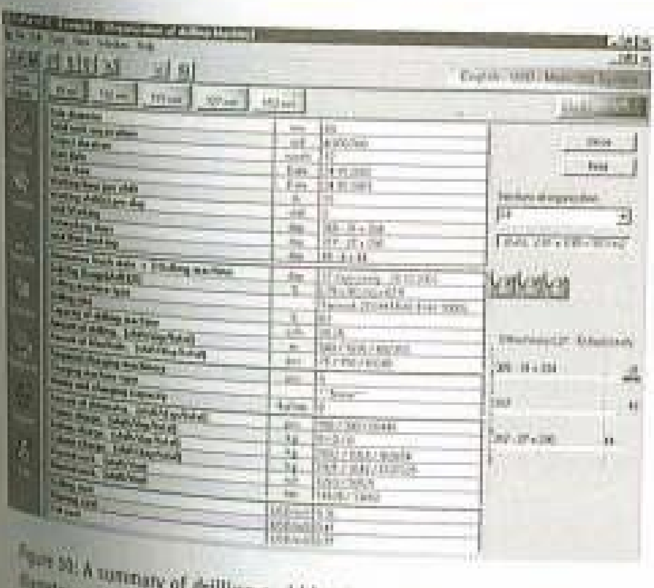

Figure 10: A summary of drilling and blasting costs for 89 mm hole diameter.

Analysis of costs associated with drilling and blasting operations was performed for various hole diameters, and rectangular blasting patterns. Figure 10 presents a summary of drilling and blasting data for hole diameter of 89 mm while Table 5 shows blasting cost report for various hole diameters.

Table 5: Blasting cost report for various hole diameters.

| Hole diameter (mm) | Detonator costs ($) | Primer costs($) | Bottom charge costs ($) | Column charge costs($) | Blasting costs ($/m3) |
|---|---|---|---|---|---|
| 89 | 294,067.31 | 0 | 1,115,103 | 553,912.33 | 0.42 |
| 102 | 239,261.11 | 0 | 1,283,993 | 534,603.20 | 0.44 |
| 115 | 200,479.09 | 0 | 1,493,408 | 491,085.40 | 0.46 |
| 127 | 174,053.36 | 0 | 1,689,055 | 452,940.57 | 0.49 |
| 152 | 134,625.68 | 0 | 2,165,077 | 318,992.47 | 0.55 |

In order to evaluate the accuracy of the DelPat computer program, the program output values are compared with the results obtained in the field. Table 6 summarizes designed costs by DelPat vs. actual costs obtained in the field. As can be seen from Table 6, the actual costs incurred in the field were 0.15 $/m³ less than costs predicted by DelPat computer program. This difference incurred because of change in the following parameters: burden, spacing, hole depth, sub drilling, drilling rate, capacity of drilling machine, and specific charge (Table 7).

Table 6: Designed vs. actual drilling and blasting costs.

| Cost elements | Designed costs by DelPat | Actual costs |
|---|---|---|
| Drilling machine investment ($/m³) | 0.270 | 0.150 |
| Maintenance ($/m³) | 0.047 | 0.040 |
| Fuel ($/m³) | 0.034 | 0.050 |
| Drilling-Labor ($/m³) | 0.009 | 0.010 |
| Drill steel ($/m³) | 0.027 | 0.020 |
| **Total drilling ($/m³)** | **0.390** | **0.270** |
| Detonator ($/m³) | 0.036 | 0.030 |
| Primer ($/m³) | 0.000 | 0.000 |
| Bottom ($/m³) | 0.351 | 0.330 |
| Column ($/m³) | 0.094 | 0.090 |
| Blasting-Labor ($/m³) | 0.010 | 0.010 |
| **Total blasting ($/m³)** | **0.490** | **0.460** |
| **Total drilling and blasting ($/m³)** | **0.880** | **0.730** |

Table 7: Difference between designed and actual drilling and blasting parameters.

| Drilling and blasting parameters | Designed by DelPat | Actual |
|---|---|---|
| Burden (m) | 4.21 | 4.00 |
| Spacing (m) | 4.45 | 5.00 |
| Hole depth (m) | 11.83 | 11.76 |
| Sub drilling (m) | 1.26 | 1.20 |
| Drilling rate (%) | 60.00 | 67.00 |
| Capacity of drilling machine (m/h) | 15.38 | 17.17 |
| Specific charge (kg/m³) | 0.49 | 0.46 |

The set of graphs included in the DelPat software allows for conveying two important messages. First, the graphs in a combined fashion allow the operator to see the relative contribution of each cost element to the overall cost. Secondly, they permit the user to concentrate on improving performance in these areas that have the largest weight in the overall cost, thus making their efforts more effective.

## CONCLUSIONS

Drilling and blasting operations are critical in any rock excavation process. The various factors should be considered in trying to achieve a reliable cost estimation including a knowledge of rock properties, selection of appropriate explosives and drilling machinery, pattern arrangement, fragment size distribution, time schedule and labor management.

A new computer program called DelPat integrates drilling and blasting costs with fragmentation analysis helps industry professionals to minimize design time and maximize the cost-effectiveness.

The time required to learn software is becoming an important issue as software grows in functionality and sophistication and the need to follow changes made in subsequent updates becomes a full-time occupation. The expense involved with hiring personnel designated to learn and operate these complex programs can be costly. In this process smaller operators are at a disadvantage. Obtaining answers even to simple questions requires involvement of experts, who are both expensive and seldom readily available. The DelPat software is designed to fulfill such needs by being applicable in any type of operation, especially those smaller in size. This self-contained package is designed to address a specific need, and it can be used quickly and effectively with modest training.

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