1. Drilling and Charging

Following calculations are carried out within the module “Drilling and Charging”

1.1 Basic Formula to calculate Burden

Provided a Charge Concentration $l_b$ (kg/m) in the bottom part of the hole, Burden $B$ (m) and a Hole Spacing $S$ (m), maximum burden is calculated by using following geometrically correct formula:

$$B_{max} = \sqrt{\frac{l_b}{S \cdot B \cdot C}}$$

where the problem is to determine the Blasting Constant $C$ (kg/cu.m), which means how many kg of a certain explosive that is needed in the bottom part to break one cubic meter of the actual type of rock. Figures of $C$ for different types of rock, in combination with different types of explosives, are found on page 3 in the programme module “Drilling and Charging”. The figures have to be regarded as preliminary while waiting for more reliable methods. The figures shown are basic values $C_0$, valid for following conditions:

- Hole Inclination 5:1
- Charge Concentration $l_b$ covers the interval from $0.3 \times B_{max}$ below 0-level (bench bottom) up to $B_{max}$ above
- Number of rows in the blast are $< 6$

If these conditions are changed, the program automatically corrects the value according to $C = k_1 \times k_2 \times k_3 \times C_0$, where different values of $k$ is found below.

Please note that the burden is defined as the perpendicular distance between two rows of holes. For the first row it is the perpendicular distance to the face.
1.2 Correction with respect to Hole Inclination

\[ k_1 = \frac{3}{\tan \alpha} \cdot \frac{1}{1 + \frac{3}{\tan \alpha}} \cdot \frac{1}{0.94} \]  
\( \alpha = \) Hole inclination from vertical

resulting in following correction values:

<table>
<thead>
<tr>
<th>Vert</th>
<th>1.06</th>
</tr>
</thead>
<tbody>
<tr>
<td>5:1</td>
<td>1.00</td>
</tr>
<tr>
<td>3:1</td>
<td>0.96</td>
</tr>
<tr>
<td>2:1</td>
<td>0.91</td>
</tr>
<tr>
<td>1:1</td>
<td>0.80</td>
</tr>
</tbody>
</table>

1.3 Correction with respect to the location of the Charge

* Reduced length of Sub drilling, U:
  \[ k_2 = \frac{1}{0.67 + 0.33 \cdot \frac{U_{actual}}{0.3 \cdot B_{max}}} \]

* Increased length of Sub drilling, U:  No correction
* Reduced charge height above 0-level:  Correction as below
* Increased charge height above 0-level:  No correction

Correction due to reduced length of sub drilling may be "switched off" in the program by clicking "Options" and then "Technical Conditions". Note that the program automatically uses the correction and that if no correction is to be used it has to be switched off prior to each calculation, also when opening an existing file.

When the charge height above 0-level is to small, a correction of B_{max} is carried out by taking the charge geometry within the interval 0 to B_{max} into consideration, i.e. the location of the charge (or charges) and its concentration. The contribution to the breakage of the rock is then calculated with respect to the location, which means a decreasing contribution from maximum at bench bottom to a zero contribution at level B_{max} above grade. This method is used in all cases when full height of the bottom charge is not reached with one type of explosive, for instance at very low benches, when shorter height of the bottom charge is selected, large hole diameters in comparison to bench height, etc.

1.4 Correction when number of Rows > 5

When the number of rows exceeds 5, following correction is carried out:

\[ k_3 = 1 + \frac{1}{100} \cdot \text{(Number of rows)} \]

for example resulting in

<table>
<thead>
<tr>
<th>Rows</th>
<th>k</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>1.0</td>
</tr>
<tr>
<td>10</td>
<td>1.1</td>
</tr>
<tr>
<td>20</td>
<td>1.2</td>
</tr>
</tbody>
</table>

Correction due to number of rows exceeding 5 may be "switched off" in the program by clicking "Options" and then "Technical Conditions". Note that the program automatically uses the correction and that if no correction is to be used it has to be switched off prior to each calculation, also when opening an existing file.
1.5 Specific Drilling/Charge

Calculation of Specific Drilling and Specific Charge are in the program based on Rock Volume per Blast. In turn the Rock Volume is based on Width of the Blast, which means the distance between the first and last hole in a row, or between a free surface and the last hole in the row.

Please also note that Primers are not included in the amounts of explosives, which means that they do not affect the Specific Charge.

1.6 Mean Fragment Size

Estimation of Mean Fragment Size is carried out in both the module "Fragmentation Distribution" and in the module "Drilling and Charging". In the latter by estimating the resulting mean fragment size in a Charge calculation, or by adapting the hole pattern to a given demand on the mean fragment size. If the demand is higher than the calculated value, no change of the hole pattern is made.

Formulas to estimate mean fragment size are found in Fragmentation Distribution below.

1.7 Limitation with respect to relation Hole Diameter/Bench Height

In the program there is a limitation, which does not allow too small bench heights in relation to the hole diameter. Minimum accepted Bench Height (meter) is equal to Hole Diameter (mm) /100. For example, minimum bench height when using 76 mm drill holes is 0.76 m.

1.8 Hole Inclination when using "Row Types"

When using "Row Types", equal hole inclination has to be used for all types of rows. The reason for this is that the program requires all rows within one Row Type having equal hole inclination. This would not be the case if different hole inclinations were used for different Row Types. For example, if Row Type 1 has an other hole inclination than Row Type 2, this means that the first and second row within Row Type 2 have different rock volumes, burdens, etc.

1.9 Miscellaneous

Cautious Blasting can be used only for "Types of Blasts" or "Deck"

2. Fragmentation Distribution

Following calculations are used when estimating the mean fragment size in the modules "Drilling and Charging" and "Fragmentation Distribution".

2.1 Mean Fragment Size

\[ k_{50} = s^* FH^* e^{0.29* \ln(B^2 / \sqrt{s/B}) - 1.18* \ln C - 0.82} \]

where

- \( s = \) Rock Structure Constant
- \( FH = \) A relationship which takes the ratio between the uncharged part and the hole depth into consideration
- \( C = \) Mean value of the Blasting Constant (see Comments to the module "Drilling and Charging")
- \( B = \) Burden
- \( S = \) Hole Spacing
- \( q = \) Specific Charge

The mean fragment size, \( k_{50} \), is a figure which represents the screen size through which 50 % of the loosened rock would pass if screened.
2.2 Fragmentation distribution

The Rosin-Rammler size distribution function is used for the calculation of the fragmentation distribution. This is the most common function used in this field.

\[ y = 100 \times (1 - e^{-\left(\frac{x}{x_c}\right)^n}) \]

where  
\( y \) = weight-% passing the actual screen  
\( x \) = actual screen size  
\( x_c \) = characteristic screen size  
\( n \) = index of uniformity (the slope of the fragmentation distribution curve). Varies according to Cunningham between 0.75 - 1.5 for normal rock. Could be higher for very competent rock.

With this version of BLASTEC the n-value must be determined by the user before running the code. As a guideline: A high n-value gives uniform sizing (steep slope), while a low n-value gives higher proportions of both fines and coarse. Cunningham indicates following:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>n increases when</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burden/Hole Diameter</td>
<td>decreases</td>
</tr>
<tr>
<td>Drilling Accuracy</td>
<td>increases</td>
</tr>
<tr>
<td>Charge Length/Bench Height</td>
<td>increases</td>
</tr>
<tr>
<td>Spacing/Burden</td>
<td>increases</td>
</tr>
</tbody>
</table>

Normally high n-values are preferred to avoid too high proportions of fines and coarse.

3. Crack Zone

Crack zone estimation can be done in a separate module, "Crack Zone", or in the module "Drilling and Charging" when selecting Contour Blasting.

A set of formulas, according to the SveDeFo report DS 1978:6 by Roger Holmberg, are used when calculating the size of the crack zone.

According to the report, rock damage occurs when the peak particle velocity exceeds 700-1000 mm/s. Before running the code the user has to put in a suitable value. Other input parameters are charge concentration, charge height and vertical level of which the calculation of the crack zone is to be calculated.

Note that this code doesn’t take decoupling into consideration, which has a great importance on the size of the damage zone.

4. Vibrations

Vibration calculations are carried out in the module “Vibrations”.

4.1 Max Permitted Charge

Calculation of the max permitted charge can be done according to two different sets of formulas,
Method 1:

\[ Q = v^2 \frac{R^{3/2}}{K^2} \]

(Ref. "The Modern Techniques of Rock Blasting" by Langefors-Kihlström). The formula can be rewritten as:

\[ v = K^* \sqrt[3/2]{\frac{Q}{R}} \]

The constant k must be determined, preferably by test blasting.

Method 2:

\[ Q = k^2 a \times \frac{R^2}{v^2 a} \]

(Ref. Common in international literature). The formula can be rewritten as:

\[ v = k \left( \frac{R}{\sqrt[3/2]{Q}} \right)^a \]

The constants k and a must be determined, preferably by test blasting and regression analysis.

4.2 Swedish Standard

To calculate guidance levels for blast-induced vibrations in buildings, a Swedish Standard, SS 460 48 66, is developed. Calculations according to this standard can be carried out in the “Vibrations” module. For further information is referred to this standard.

4.3 Regression analyses

Regression analysis is a method to determine the constants k and α above by test blasting. The values from the test blasts are plotted in a log-log diagram where k is the intersection between the y-axis and a regression line. The constant α is the slope of the same line. In the module "Vibrations" three regression lines are calculated, 50 %, 84 % and 98 %, where for instance 50 % means that 50 % of the vibration values are expected to be below the limit.