Four-Section Parallel Hole Cut Model (Swedish method) for Tunnel Blast Design

Four-section cut, perhaps a model of Swedish method, is an empirical method for blasting design in underground excavations and tunnels. This method, often, has been used in excavating tunnels with cross section area of more than 10m$^2$.

The four-section cut is basically based on the parallel hole cut. This model started with Langefors and Kihlstrom (1963) and has been further developed afterwards. Holmberg published the complete blast design model in 1982 (Holmberg, 1982) and was later updated by Persson et al (2001).

The method suggests the experimental equations listed in Table 1. In this Table, E and X are drilling error and length of each quadrangle sides respectively. Due to relative easiness and precision in drilling of direct cutting holes E is taken as zero. The value of E for stopping and perimeter holes is calculated by the Equation (Konya, 1995), “$E = \alpha H + \beta$”.

Where; $E$ = drilling error, $H$ = blast hole depth, $\alpha$ = angular deviation and $\beta$ = collaring error.

In this Swedish model, the holes in the face are divided into separate sections as

- Cutting holes,
- Stopping holes,
- Perimeter (roof, floor and wall) holes.

![Different tunnel sections](image)

Fig-1

Four-section cut method includes an empty hole in the centre. If the number of empty holes is more than one, equivalent diameter is calculated by the equation(Konya, 1995), ”$\Phi_{eq} = (N)^{1/2} \Phi_e$”.

Where; $\Phi_e$ = Empty hole diameter and $\Phi_{eq}$ = Equivalent diameter of empty holes.
This model suggests that the diameter of empty hole to be more than 75 mm.

The type of Explosives that must be charged into cut holes is determined by Equation (Jimno et al, 1995):

$$q = \frac{55\phi_n}{PRP_{ANFO}} \left[ \frac{B_1}{\phi_{e2}} \right]^2 \left( B_1 - \frac{\phi_{e2}}{2} \right) \left( \frac{C}{0.4} \right)$$
Where: \( q = \) Lineal charge concentration (kg/m), \( \Phi_h = \) drilling diameter (m), \( \Phi_{e2} = \) equal diameter of empty holes, \( B_1 = \) Maximum distance between empty hole and holes in the first cutting quadrangle (m), \( C = \) Rock constant, \( PRP_{ANFO} = \) Relative weight strength of explosive with respect to ANFO.

It's obvious that quantity of ‘q’ for stopping holes is less than that of cut holes and quantity of ‘q’ for roof and wall holes is less than that of stopping holes. Also, the quantity of q for floor holes is more than those of the roof and wall holes.

**Advance:** The advance of tunnelling excavation is restricted by the diameter of empty hole and hole deviation for smaller diameter holes. As long as deviation is maintained within 2%, the advance is assumed to be 95% of the blast-hole depth. The depth of blast-holes depends on empty hole diameter.

As discussed above, when more holes are used instead of only one large diameter drill-hole, equivalent diameter must be used in the calculation.

**Cut Hole:** The distance between central blast-hole and those of the first section should not be more than 1.7\( \Phi \) to obtain fragmentation and a satisfactory movement of rock, where \( \Phi \) is the empty hole diameter.

To utilize the explosives in the best manner, a burden of 1.5\( \Phi \) for a drilling deviation of 0.5 to 1% should be used. If deviation is more than 1%, practical burden is calculated by subtracting the drilling error from maximum burden.

There are two conditions that burden should fulfil them. These conditions are for preventing plastic deformation and reducing aperture angle to less than 90.

A rule of thumb to determine the number of sections is the side length of the last section should be less than the square root of the advance. The stemming length of the cut holes is 10 times drill-hole diameter.

**Lifters:** The burden for lifters in a round are in principle calculated with the same formula as for bench blasting. The bench height is simply replaced by the advance, and a higher fixation factor \( (f=1.45) \) is used due to gravitational effect and to a greater time interval holes. The burden should comply with the following condition: \( B \leq 0.6L \), where ‘L’ is drill-hole length. The relationship between spacing and burden \( (S/B) \) is usually considered equal to one.

**Stoping:** The method for calculating the stoping holes (in section B and C of fig-1) does not differ much from calculation of lifters. Only different fixation factor \( (f=1.45 \text{ for section B and } f=1.2 \text{ for section C}) \) and Spacing/Burden ratio \( (S/B) \) of 1.25 for both the sections should be used.

**Contour Holes:** If smooth blasting is not necessary, pattern is calculated as for lifters with the values: “\( f = 1.2 \), ”\( S/B = 1.25 \)”. The column charge concentration will be half the bottom charge concentration.

If smooth blasting is to carried out, the spacing burden between blast-holes is calculated from: \( S = Kd \), where \( K \) varies between 15 and 16 and \( d \) is blast-hole diameter. A \( S/B \) ratio of 0.8 should be used. The lineal charge concentration is function with drilling diameter. With the blast-holes of calibre lower than 155mm the equation used is: \( \text{Charge concentration} = 90d^2 \), where \( d \) is expressed in m.

**References:**


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