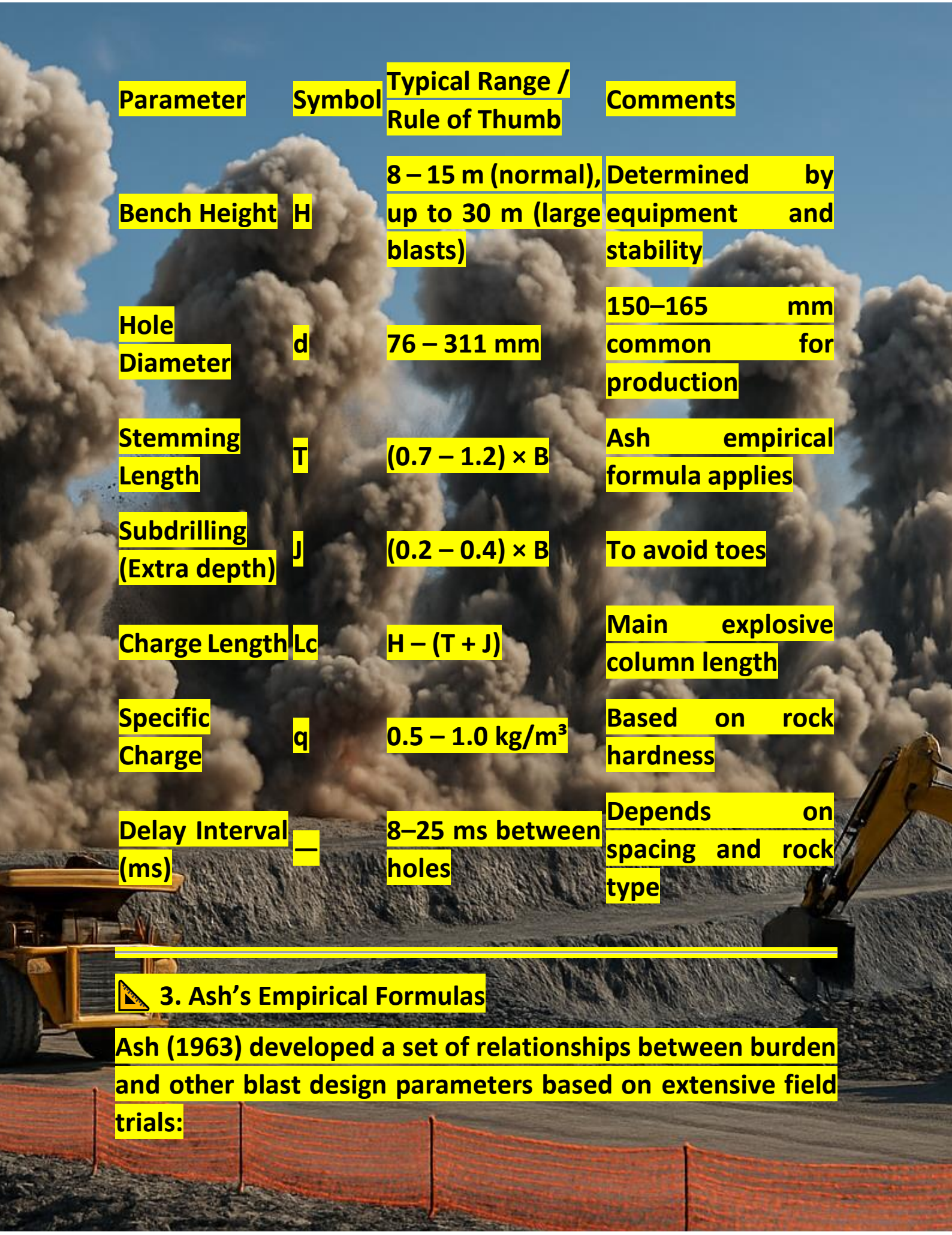
# Thumb rules and Ash's empirical formulas for drilling and blasting in opencast mines

## 1. Objectives of Drilling and Blasting Optimization

- Achieve uniform fragmentation for efficient loading & hauling.
- Minimize powder factor (kg explosive per $m^3$ of rock).
- Reduce fly rock, ground vibration, air blast, and back break.
- Improve drill utilization, explosive performance, and cost efficiency.

## 2. Key Parameters and Thumb Rules

| Parameter | Symbol | Typical Range / Rule of Thumb | Comments |
|---|---|---|---|
| Burden | B | (20 – 40) × hole diameter (d) | 25–35×d is common in hard rock |
| Spacing | S | 1.15B – 1.5B | Larger spacing for free faces |



| Parameter | Symbol | Typical Range / Rule of Thumb | Comments |
|---|---|---|---|
| Bench Height | H | 8 – 15 m (normal), up to 30 m (large blasts) | Determined by equipment and stability |
| Hole Diameter | d | 76 – 311 mm | 150–165 mm common for production |
| Stemming Length | T | (0.7 – 1.2) × B | Ash empirical formula applies |
| Subdrilling (Extra depth) | J | (0.2 – 0.4) × B | To avoid toes |
| Charge Length | Lc | H – (T + J) | Main explosive column length |
| Specific Charge | q | 0.5 – 1.0 kg/m³ | Based on rock hardness |
| Delay Interval (ms) | — | 8–25 ms between holes | Depends on spacing and rock type |

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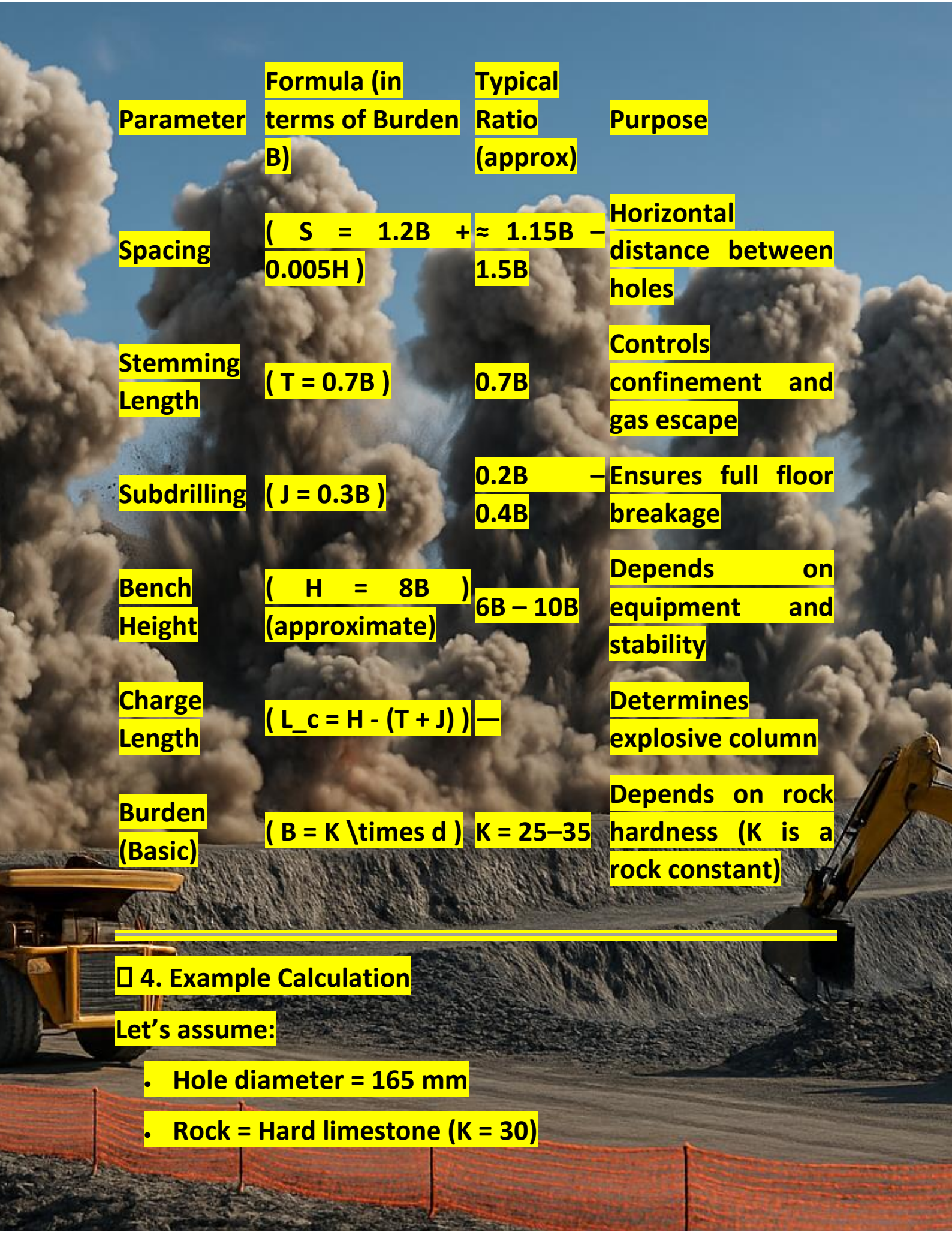
## 📐 3. Ash's Empirical Formulas

Ash (1963) developed a set of relationships between burden and other blast design parameters based on extensive field trials:



| Parameter | Formula (in terms of Burden B) | Typical Ratio (approx) | Purpose |
|---|---|---|---|
| Spacing | ( S = 1.2B + 0.005H ) | ≈ 1.15B – 1.5B | Horizontal distance between holes |
| Stemming Length | ( T = 0.7B ) | 0.7B | Controls confinement and gas escape |
| Subdrilling | ( J = 0.3B ) | 0.2B – 0.4B | Ensures full floor breakage |
| Bench Height | ( H = 8B ) (approximate) | 6B – 10B | Depends on equipment and stability |
| Charge Length | ( L_c = H - (T + J) ) | — | Determines explosive column |
| Burden (Basic) | ( B = K \times d ) | K = 25–35 | Depends on rock hardness (K is a rock constant) |

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## 4. Example Calculation

Let’s assume:

- Hole diameter = 165 mm
- Rock = Hard limestone (K = 30)

Then:

- Burden ( B = 30 × 0.165 = 4.95 , m )
- Spacing ( S = 1.25 × 4.95 = 6.19 , m )
- Stemming ( T = 0.7 × 4.95 = 3.47 , m )
- Subdrilling ( J = 0.3 × 4.95 = 1.49 , m )
- Bench height ( H ≈ 8 × 4.95 = 39.6 , m ) (usually truncated to 12–15 m for equipment)
- Charge length ( L_c = 15 – (3.47 + 1.49) = 10.04 , m )

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## 🔥 5. Thumb Rules for Explosive Energy and Delay

| Aspect | Rule of Thumb |
|---|---|
| Powder Factor | 0.4–0.8 kg/m³ (hard rock), 0.2–0.4 kg/m³ (soft rock) |
| Explosive per Hole (Q) | ( $Q = \pi/4 \times d^2 \times L_c \times \rho \times R_f$ ) |
| Charge per Delay | Should not exceed safe vibration limit (check with OSM/ DGMS guidelines) |
| Delay Timing | 8–25 ms between holes; 25–65 ms between rows |
| Stemming Material | Coarse angular chips or crushed stone (not drill cuttings) |

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## ⚙️ 6. Optimization Techniques

1. Use of Empirical Design + Simulation Software
    - e.g., *JKSimBlast, Blastware, ShotPlus, RocBlast, i-Blast, Vistablast.*
2. Fragmentation Analysis through drone or digital imaging (e.g. WipFrag).
3. Vibration Monitoring using seismographs and models (USBM, Ambraseys-Hendron).
4. Controlled Blasting Techniques — pre-splitting, cushion blasting.
5. Blast Pattern Trials — optimize burden & spacing by monitoring fragmentation.
6. Explosive Energy Distribution Optimization — use column decking or air decking.
7. Delay Timing Optimization — modern electronic detonators allow millisecond precision.

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## 📊 7. Quick Field Guidelines Summary

| Parameter | Ratio to Burden (B) | Field Range |
|---|---|---|
| Spacing (S) | 1.15B – 1.5B | 5 – 8 m |
| Stemming (T) | 0.7B | 3 – 4 m |
| Subdrilling (J) | 0.2B – 0.4B | 1 – 2 m |
| Bench Height (H) | 6B – 10B | 10 – 15 m |
| Powder Factor | — | 0.4 – 1.0 kg/m³ |

## 8. DRILL HOLE DIAMETER (D) SELECTION

| Bench Height (m) | Hole Diameter (mm) | Typical Application |
|---|---|---|
| 6 – 8 | 100 – 115 | Small limestone, coal OB |
| 10 – 12 | 150 – 165 | Iron ore, manganese ore |
| 15 – 20 | 200 – 250 | Hard rock / deep benches |
| >20 | 270 – 310 | Large surface mines (coal OB, metal) |

👉 Thumb Rule:

[
D (\text{mm}) = 6 \times \text{Bench Height (m)} \ \text{to} \ 15 \times \text{Bench Height (m)}
]

## 📏 9 BURDEN (B)

The most critical parameter — affects fragmentation, throw, and ground vibration.

Thumb Rules:

1. ( B = (25 \text{ to } 40) \times D )
2. ( B = K_1 \times D ), where ( K_1 ) = 25–40 (empirical constant depending on rock strength).

3. For hard rock → 30 × D

4. For medium rock → 35 × D

5. For soft rock → 40 × D

**Example:**
For 165 mm hole → B = 165 × 0.03 = 4.95 m (≈5 m)

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## 📐 10. SPACING (S)

Spacing = distance between adjacent holes (in same row).

**Thumb Rules:**

1. ( S = (1.15 \text{ to } 1.5) \times B )

2. Use 1.15 × B for hard rock, 1.4 × B for soft rock.

3. For staggered pattern → S ≈ 1.15 × B

4. For square pattern → S ≈ 1.25 × B

**Example:**
If B = 5 m → S = 5.5 – 7.0 m

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## 🧱 11. STEMMING (T)

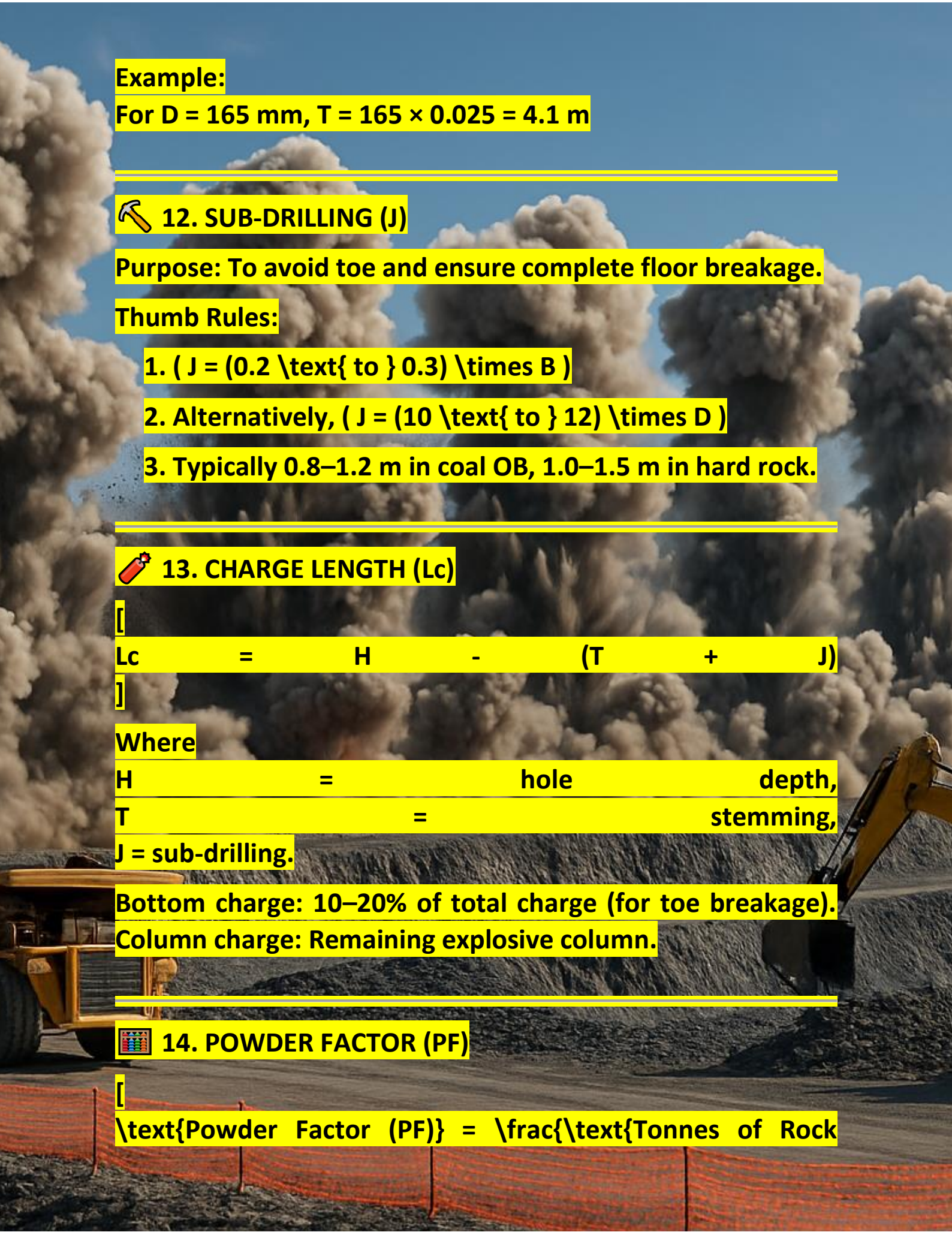
**Purpose:** Confinement of gases and efficient energy utilization.

**Thumb Rules:**

1. ( T = 0.7 \times B )

2. Alternatively, ( T = (20 \text{ to } 30) \times D )

3. Minimum stemming length = 25–30% of hole depth.



Example:

For D = 165 mm, T = 165 × 0.025 = 4.1 m

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## 🔨 12. SUB-DRILLING (J)

Purpose: To avoid toe and ensure complete floor breakage.

Thumb Rules:

1. ( J = (0.2 \text{ to } 0.3) \times B )
2. Alternatively, ( J = (10 \text{ to } 12) \times D )
3. Typically 0.8–1.2 m in coal OB, 1.0–1.5 m in hard rock.

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## 🧨 13. CHARGE LENGTH (Lc)

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Lc = H - (T + J)

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Where

H = hole depth,

T = stemming,

J = sub-drilling.

Bottom charge: 10–20% of total charge (for toe breakage).

Column charge: Remaining explosive column.

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## 🧮 14. POWDER FACTOR (PF)

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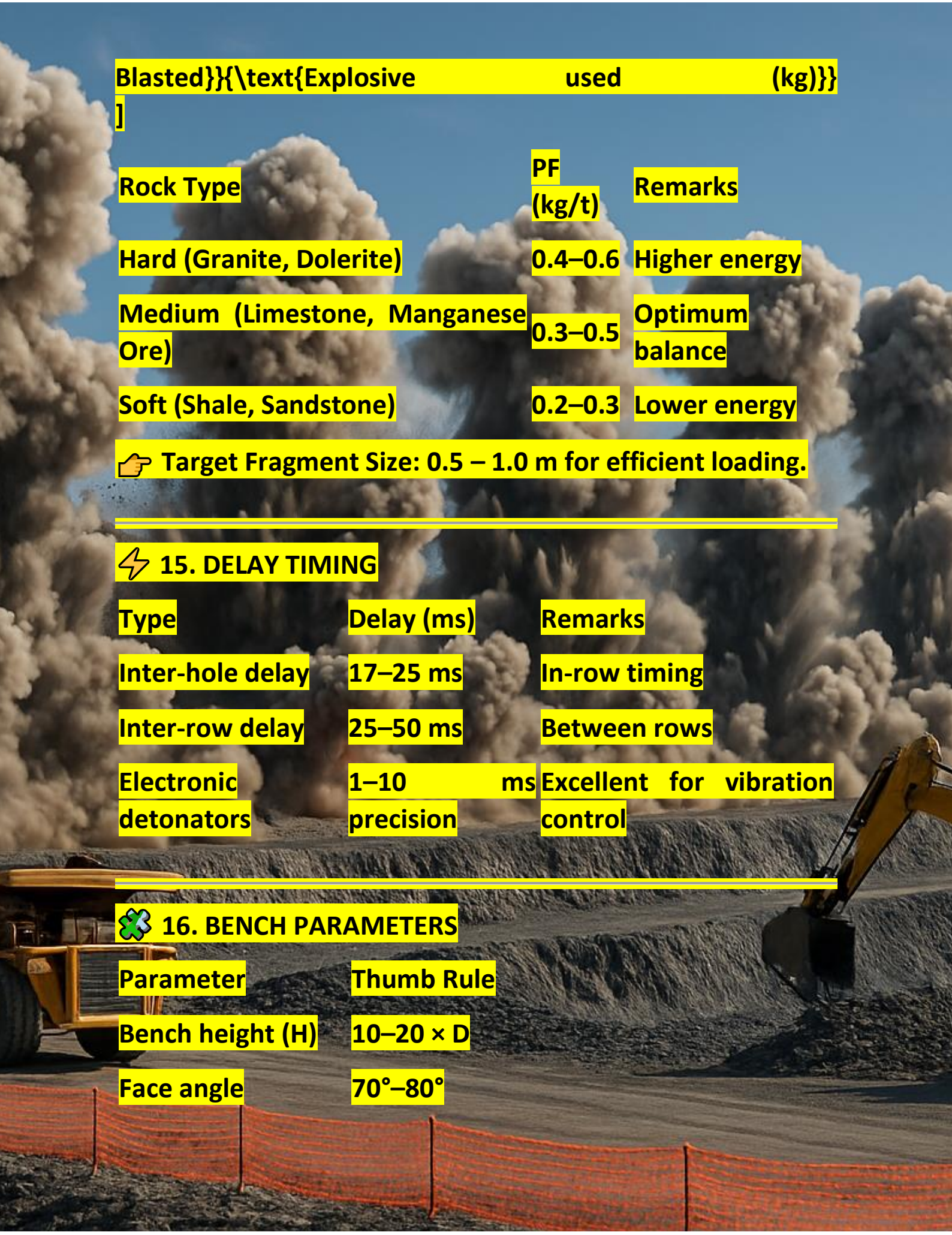
\text{Powder Factor (PF)} = \frac{\text{Tonnes of Rock



Blasted}}{\text{Explosive used (kg)}}
]

| Rock Type | PF (kg/t) | Remarks |
|---|---|---|
| Hard (Granite, Dolerite) | 0.4–0.6 | Higher energy |
| Medium (Limestone, Manganese Ore) | 0.3–0.5 | Optimum balance |
| Soft (Shale, Sandstone) | 0.2–0.3 | Lower energy |

👉 Target Fragment Size: 0.5 – 1.0 m for efficient loading.

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## ⚡ 15. DELAY TIMING

| Type | Delay (ms) | Remarks |
|---|---|---|
| Inter-hole delay | 17–25 ms | In-row timing |
| Inter-row delay | 25–50 ms | Between rows |
| Electronic detonators | 1–10 ms precision | Excellent for vibration control |

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## 🧩 16. BENCH PARAMETERS

| Parameter | Thumb Rule |
|---|---|
| Bench height (H) | 10–20 × D |
| Face angle | 70°–80° |

| Parameter | Thumb Rule |
| --- | --- |
| Bench width (safety) | ≥ 3 × bench height (for machinery movement) |

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## 📊 17. FRAGMENTATION SIZE (Cunningham Formula)

$$
X_{50} = A \times (B^{0.8}) \times (Q^{1/6}) \times (115/D)^{0.5}
$$

Where:

- ( X_{50} ): mean fragment size (m)
- ( B ): burden (m)
- ( Q ): charge per hole (kg)
- ( D ): hole diameter (mm)
- ( A ): rock factor (ranges 0.6–1.8)

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## 🧠 18. ENERGY DISTRIBUTION

| Parameter | Thumb Rule |
| --- | --- |
| Bottom charge | 15–25% total charge |
| Column charge | 75–85% total charge |

| Parameter | Thumb Rule |
|---|---|
| Decking | Used in weak strata or water-bearing zones |
| Explosive VOD | Match with rock strength (4,000–6,000 m/s typical for ANFO & emulsion) |

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## 🚜 19. DRILLING PRODUCTIVITY

| Drill Type | Hole Dia (mm) | Avg. Output (m/h) |
|---|---|---|
| DTH 115 mm | 15–25 | |
| DTH 150 mm | 20–30 | |
| Rotary 250 mm | 30–45 | |

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## 🌐 20. COST OPTIMIZATION RELATION

$$
\text{Total Cost per tonne} = \text{Drilling Cost} + \text{Explosive Cost} + \text{Secondary Breakage} + \text{Crushing Cost}
$$

**Rule of Thumb:**

- 5% increase in drilling & blasting cost can reduce overall mining cost by 15–25% if fragmentation improves.

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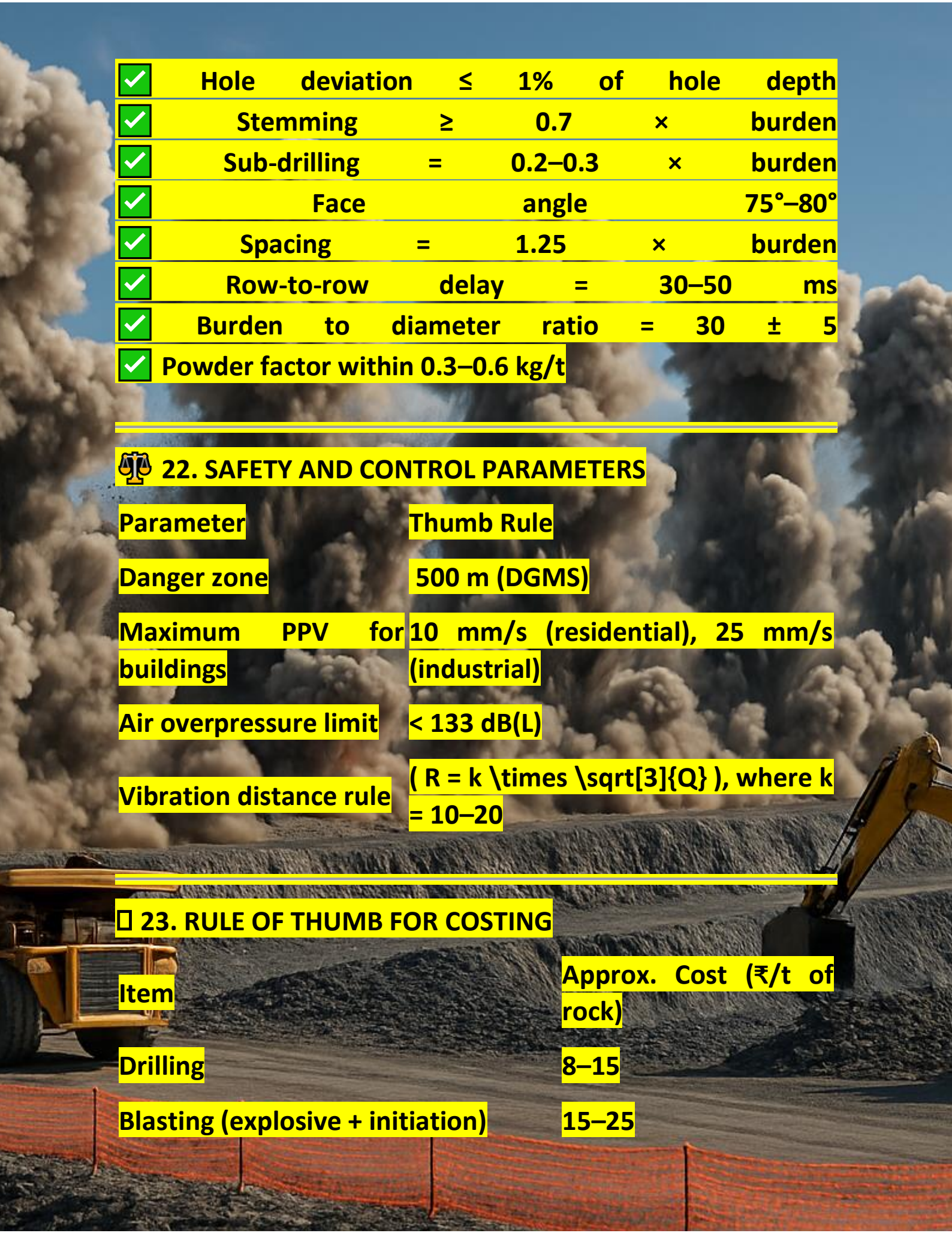
## 🧰 21. FIELD THUMB RULE CHECKLIST



- ✅ Hole deviation ≤ 1% of hole depth
- ✅ Stemming ≥ 0.7 × burden
- ✅ Sub-drilling = 0.2–0.3 × burden
- ✅ Face angle 75°–80°
- ✅ Spacing = 1.25 × burden
- ✅ Row-to-row delay = 30–50 ms
- ✅ Burden to diameter ratio = 30 ± 5
- ✅ Powder factor within 0.3–0.6 kg/t

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## ⚖️ 22. SAFETY AND CONTROL PARAMETERS

| Parameter | Thumb Rule |
|---|---|
| Danger zone | 500 m (DGMS) |
| Maximum PPV for buildings | 10 mm/s (residential), 25 mm/s (industrial) |
| Air overpressure limit | < 133 dB(L) |
| Vibration distance rule | ( R = k \times \sqrt[3]{Q} ), where k = 10–20 |

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## 23. RULE OF THUMB FOR COSTING

| Item | Approx. Cost (₹/t of rock) |
|---|---|
| Drilling | 8–15 |
| Blasting (explosive + initiation) | 15–25 |

| Item | Approx. Cost (₹/t of rock) |
| --- | --- |
| Total D&B cost | 25–35 |
| Crushing & Handling (influenced by blast) | 30–50 |

## 🔧 19. INTEGRATION WITH MACHINE PERFORMANCE

- Loader bucket capacity should be ≈ 0.8–1.2 × mean fragment size.
- Crusher feed opening ≈ 1.5 × $X_{50}$ of blasted rock.
- Maintain fragmentation uniformity index ($\sigma/X_{50}$) < 0.7.

## 📈 24. OPTIMIZATION WORKFLOW

Rock Mass Characterization

→ Hole Design (D, B, S, T, J)

→ Explosive Selection (VOD, RWS)

→ Delay Timing Design

→ Simulation (Software)

→ Field Trial Blast

→ Fragmentation Analysis

→ Feedback & Adjustment


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