OPEN PIT ELEMENTS AND THEIR CALCULATIONS

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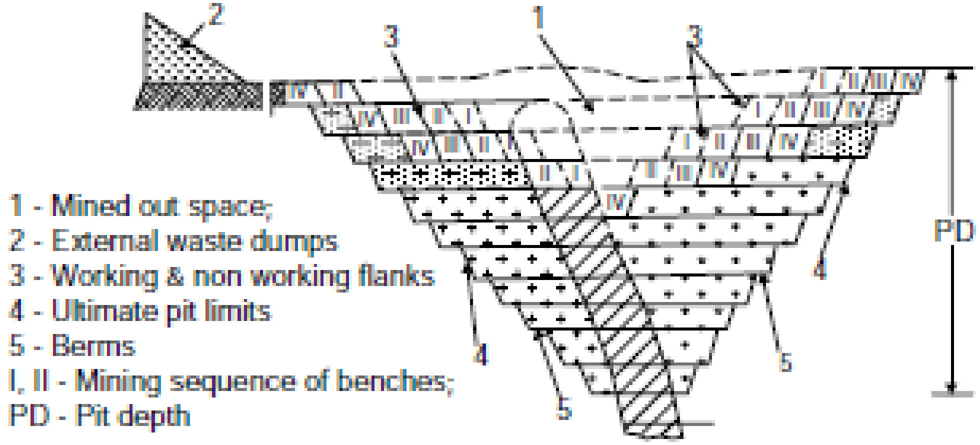
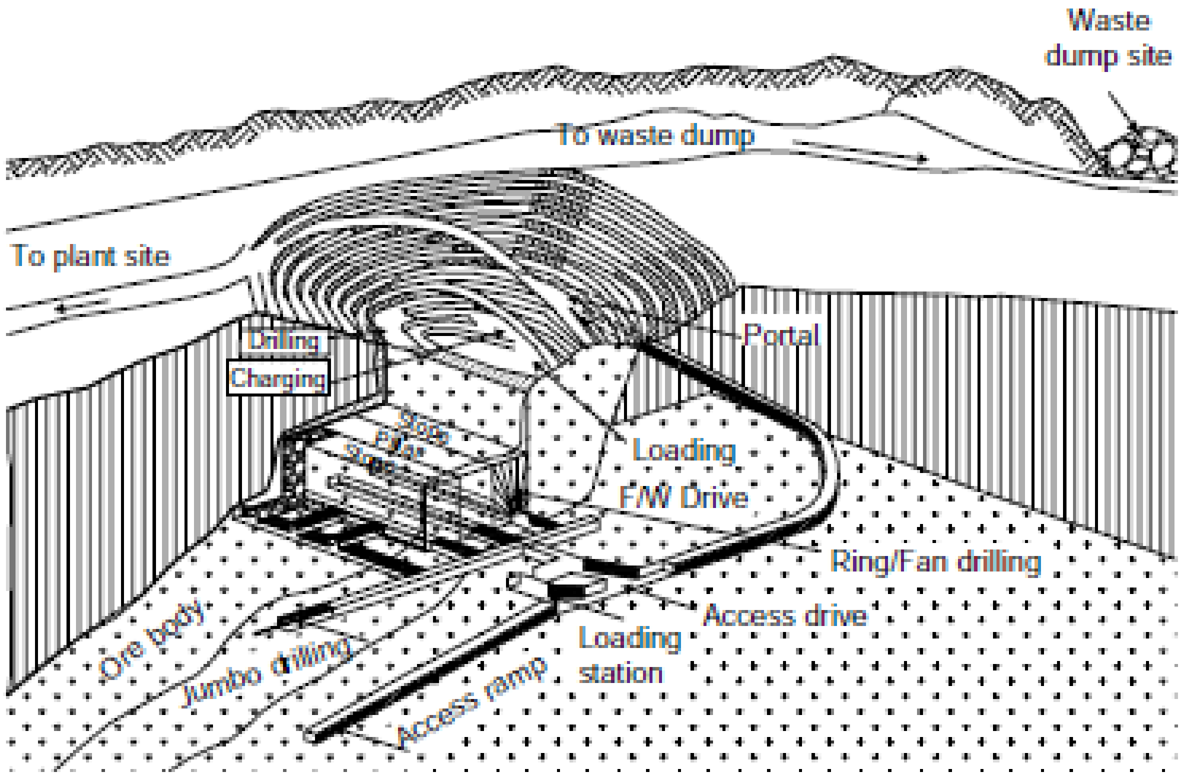
Open pit:
An excavation created to strip a deposit for the purpose of mining is called a pit and since this excavation is exposed to atmosphere; the resultant structure is known as open pit.
The rock masses on its hanging and footwall sides are termed as '*Hanging and Footwall Wastes'. But if the same orebody is located at a certain depth, then the rockmass* covering top of the orebody is known as '*Over-Burden'. Thus, to strip an orebody* suitable for open pit mining removal of hanging waste, footwall waste and the over burden is mandatory.

"Over All Pit Slope Angle', which can be defined as the angle formed while joining the Toe of the lowest bench (defined below) to the *Crest of the top most bench of a pit with horizontal,* when benches reach to their ultimate ends.

The amount of rocks need to strip the orebody increases as the depth is increased, and a situation arises when it becomes uneconomical to go beyond it. This is known as '*Break-Even Depth'. This is also a function of pit slope angle; lower the over all pit* slope angle lower would depth of pit and vise-versa.



(a) For steep orebodies a suitable pit slope angle at foot wall side is also essential



(b) Open pit mining followed by underground mining beyond break-even depth

Bench Height, Angle

- The waste that need to be stripped cannot be taken at a stretch but it need to be divided into convenient steps, which are safe and economical to be mined out, these steps so formed are called 'Benches'. *Bench Height is a function of:*
- ● *Ground competence i.e. ground could be hard, compact, loose, friable, soft, consolidated,* unconsolidated etc. In strata such as gravel, mourn, sand, alluvial soil, clay, running sand or any other similar strata, the bench height should not exceed 3 m.
- ● *Presence of water – the ground or strata could be dry, wet, porous, non porous,* above or below the water table etc.
- ● Presence of *geological disturbances such as fault, fold, joints, cleavage or bedding* planes etc.
- ● Height of the *boom or cutting height of the excavator to be deployed for loading,* mucking or excavation tasks.

In general, the Maximum allowable

Bench Height = Boom Height of Excavator + 3m

- *Bench angle or slope* It should be kept vertical but in practice it is difficult to maintain. Also it depends upon type of strata. Usually in practice it is kept to be 60°–80° to the horizontal for the working or active benches; and 45°–60° for non-working benches.

Minimum Bench Width = Working Berm Width + Non-Working Berm Width (17.2a)

Working berm width = 3 times the width of the truck/dumper to be operated on the bench. (17.2b)

Non-working berm width = 3 m (17.2c)

Thus, Bench Width = 3 x Truck Width (Or width of largest equipment operating) + 3 m (17.2d)

The Safety Berm is left when the bench reaches its '*ultimate end*'.

*Safety Berm = 0.2 x Berm Interval (i.e. bench height)** (17.3a)

*= (1/3) x Berm Interval (i.e. bench height)*** (17.3b)

(* – Minimum Safety berm width as per Russian Safety Regulation)[24]
(** – Minimum Safety berm width as per Hustrulid, Kuchta, 1998)[14]

OVERALL PIT SLOPE ANGLE

Calculation of overall pit slope angle:

$$OVERALL\ PITSLOPE\ (\ddot{o}) = \tan^{-1} \frac{N_B \times B_H}{\{(N_B - 1)B_W\} + \frac{N_B \times B_H}{\tan(B_A)} + (R_W)} \quad (17.4)$$

Whereas: φ – overall pit slope angle; degrees

N_B – number of benches

B_H – bench height in meters;

B_W – bench width in meters;

B_A – bench angle in degrees;

R_W – ramp width in meters (if intersected).

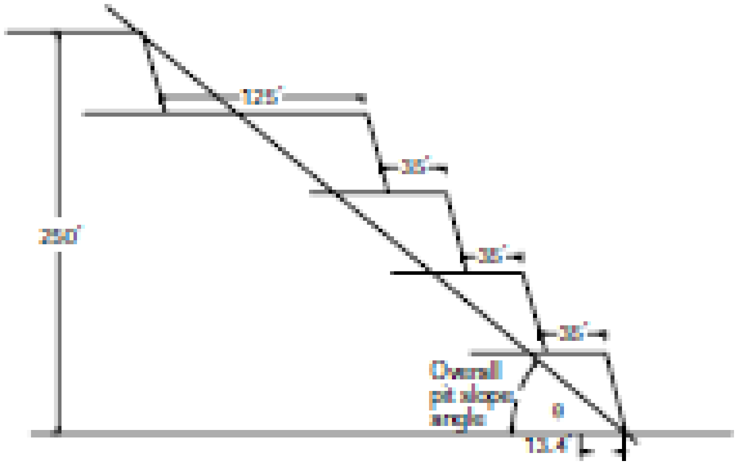
Given data: (i) $N_B = 5$; $B_H = 16$ m; $B_W = 12$ m; $B_A = 75°$; $R_W = 0$ m; (answer: 49°)

(ii) $N_B = 8$; $B_H = 10$ m; $B_W = 12$ m; $B_A = 75°$; $R_W = 0$ m; (answer: 37.2°)

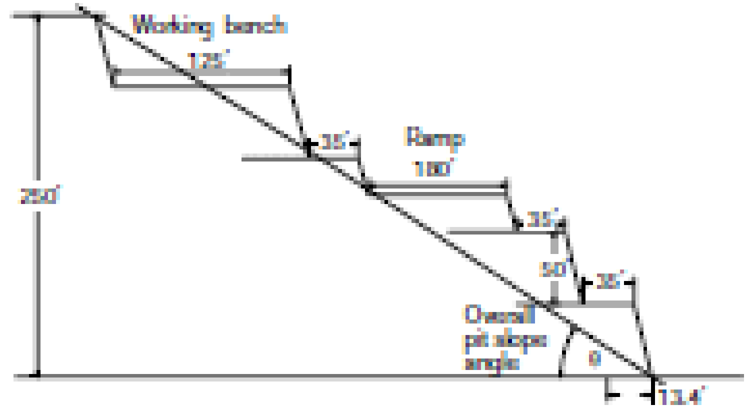
(iii) $N_B = 5$; $B_H = 16$ m; $B_W = 12$ m; $B_A = 75°$; $R_W = 30$ m; (answer: 38.8°)

(iv) $N_B = 5$; $B_H = 16\,m$; $B_W = 3.2\,m$; $B_A = 75°$; $R_W = 0\,m$; (answer: 66.8°)

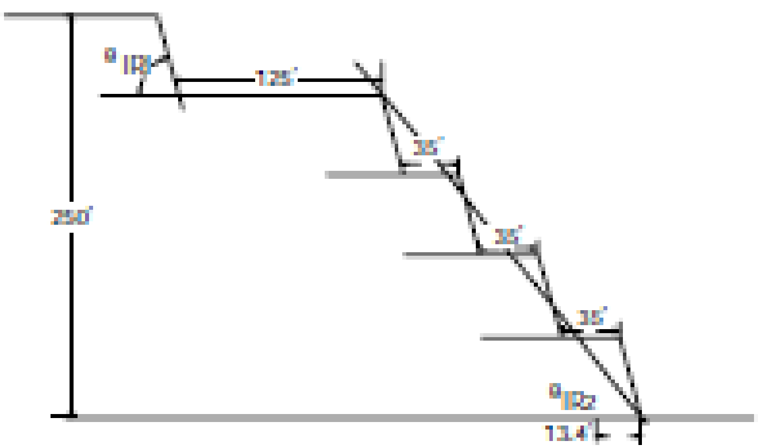
(v) $N_B = 5$; $B_H = 16\,m$; $B_W = 0\,m$; $B_A = 75°$; $R_W = 0\,m$; (answer: 75.0°)



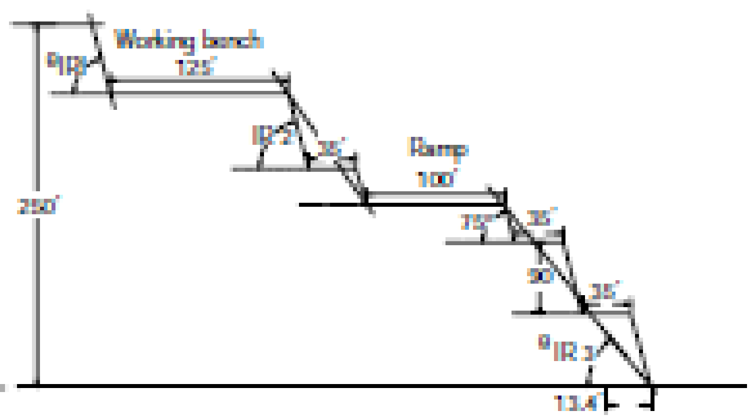
(a) Working pit slope angle is a function of number of benches and bench height



(c) Working pit slope angle is also influenced by the ramp traverse through it



(b) Working pit slope angle measured at two spots



(d) Working pit slope angle measured at three spots

Pit Slope Failure

- Reasons for pit slope failures
- ● Adopting a steep pit slope angle than appropriate.
- ● Presence of water and effective measures not taken to deal with it.
- ● Under-cutting of rock massif.
- ● Presence of geological disturbances

- Pattern of Pit Failures Commonly Known:6,11
- ● Slope failure (fig. (17.4(a))
- ● Base failure (fig. (17.4(b)).
- These failures have been illustrated in figure 17.4 & they include:12,14
- ● Raveling (17.4(c))
- ● Rotational shear (17.4(d))
- ● Plane shear (17.4(e))
- ● Step path (17.4(f))
- ● Step wedge (17.4(g))
- ● Simple wedge (17.4(h)).

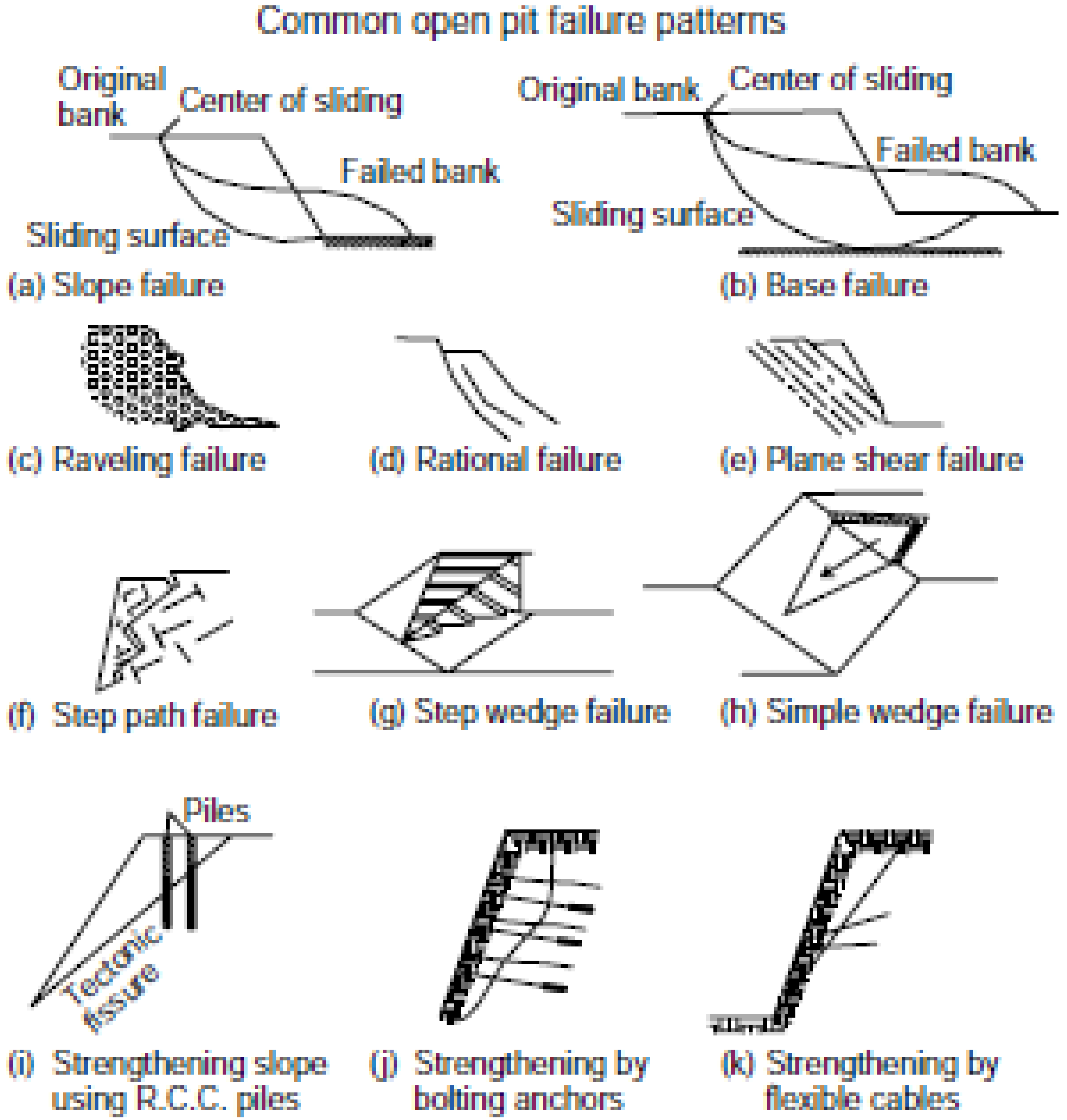


Figure 17.4 Open pits' common failure patterns (a to h), and common slope strengthening techniques (i to k).

Remedial Measures of Pit Slope failure

- 1. Flatten pit slope angle
- 2. Strengthening the slope with use of R.C.C. piles (fig. (17.4(i)); Anchors, Retaining
- walls, Bulkheads.
- 3. Strengthening slope by (i) Bolting (fig. 17.4(j)); (ii) Flexible cables (fig. 17.4(k)).
- 4. Rock consolidation – cementation, injection of consolidating polymer solutions,
- tar bonding
- 5. Protective coatings for strong-fissured rocks liable to weathering; or leaching with
- the use of shotcreting, guniting, or bituminous grouting
- 6. Combination of above techniques.

Haul Roads

Width and Number of Lanes:[23] (fig. 17.6(g))

$$Wr_1 = T_W + 2y, \quad Wr_2 = 2(T_W + y) + x,$$

Road Width; $Wr_2 \geq 4 \times T_W$

Whereas: Wr_1 = Road width for one lane traffic;
W_{r2} = Road width for two lane traffic;
T_W = truck width, m; $y = 0.5$;
$x = 0.5 + 0.005\,V$;
V is vehicle speed in km/hr.

Types and Natures of Haul Roads

- Based on service life; the haul-road may be Permanent, Semi-permanent, or Temporary.
- Permanent routes are established mostly at the non-working flanks of the surface mines and semi-permanent on the portion of the working flanks of the mines which have been out of operation for certain period.
- Temporary routes are prepared at the working benches or flanks of the surface mines.
- The Spiral (fig. 17.6(a)); and Switchback ((fig. 17.6(b)) are the two designs that are prevalent. Switchback is usually confined to Rail haulage and rarely used with automobile (Trucks) system. The spiral design follows the geometry of the pit and is run almost parallel to its longer axis, as shown in figure 17.6(f).20
- Sometimes a combination of two may be essential (fig. 17.6(d)) and 17.6(e)).24

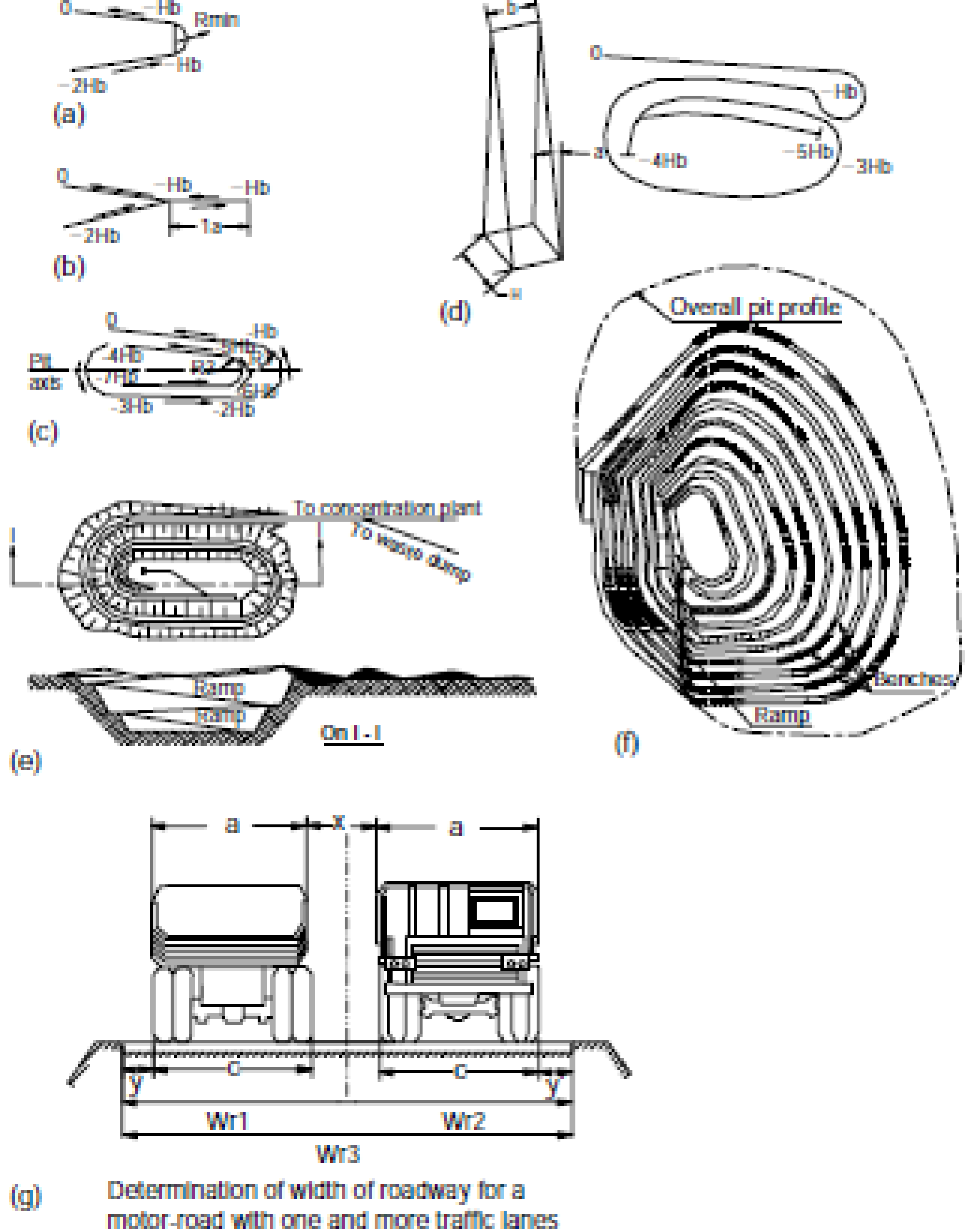


Figure 17.6 (a) to (e): Haul road's and ramp designs for surface mines. Ramp designs: Spiral, Shunt-back and, Combination. (g): Determination of haul-road width; a = T_W = truck width; Also a = c; c is out-to-out tyre width of truck.