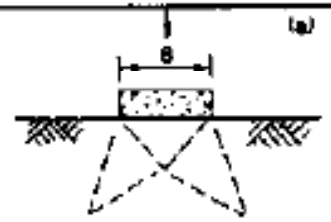
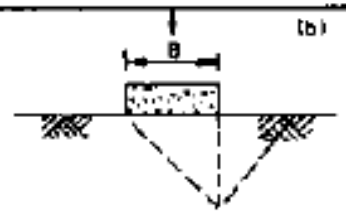
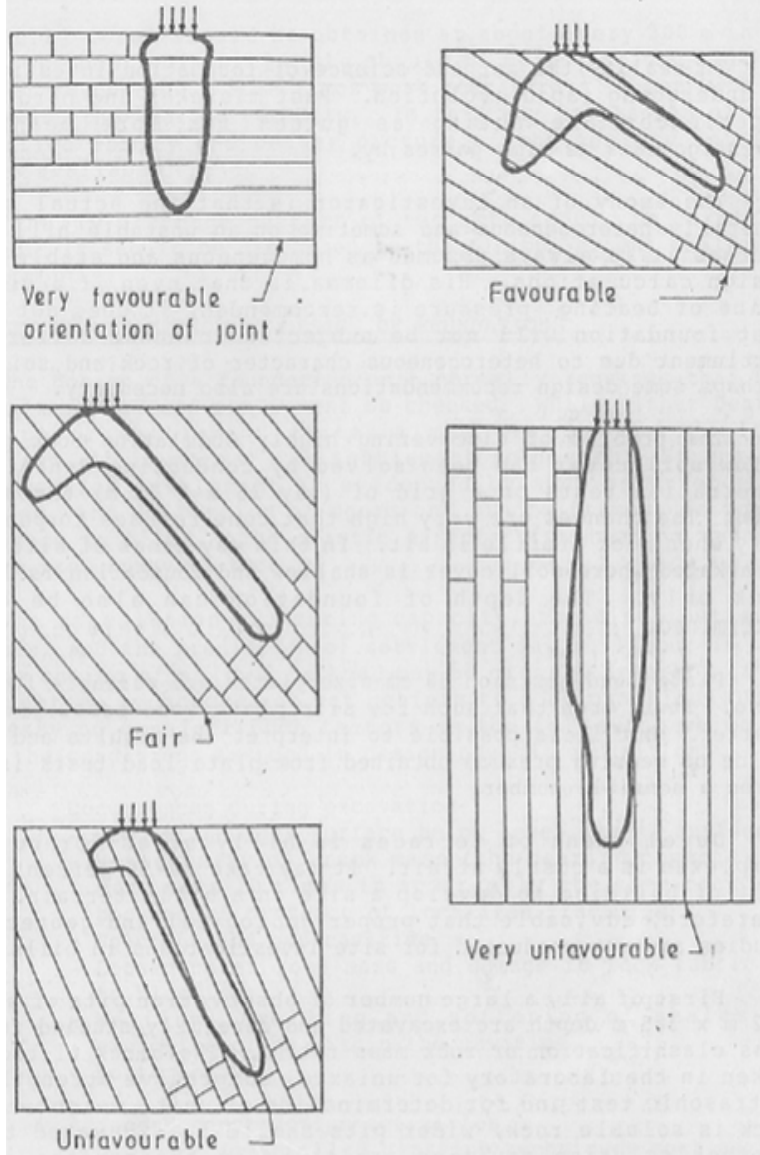
Bearing Capacity of Rocks

Intact Rock Mass

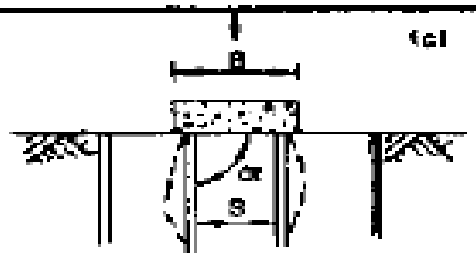
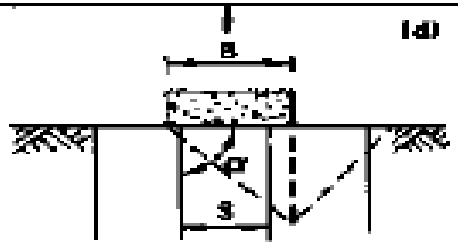
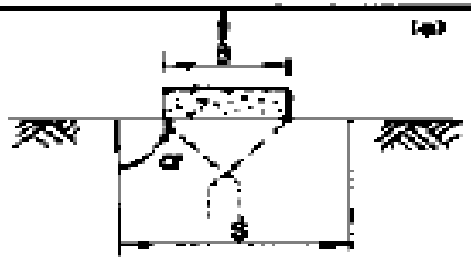
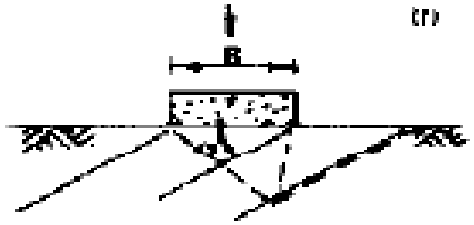
A rock mass with joint spacing greater than 4 to 5 times the width of the footing. Local and General shear failure is associated to brittle and ductile rock respectively.

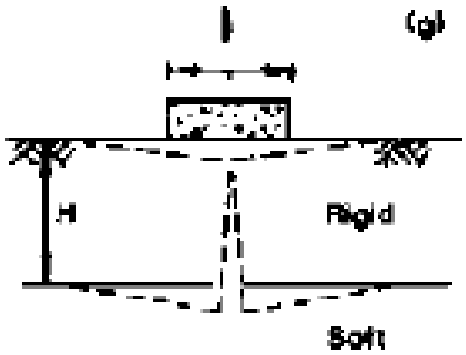
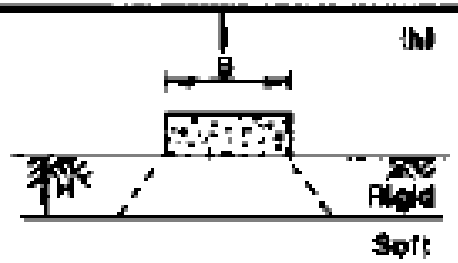
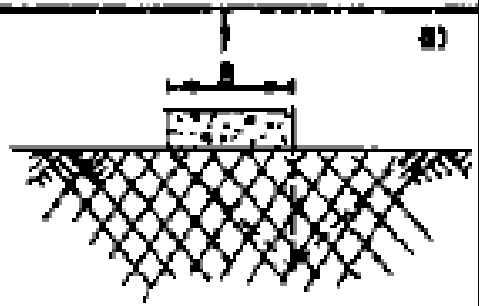
Rock Mass Conditions			Failure		Bearing Capacity Equation No.
	Joint Dip	Joint Spacing	Illustration	Mode	
INTACT	N/A	S>>B		Brittle Rock: Local shear failure caused by localized brittle fracture.	Eq. 6.4
				Ductile Rock: General shear failure along well defined failure surfaces.	Eq. 6.1



1. Theoretical pressure bulbs (10% intensity) below strip load on a medium of rock mass having low shear modulus.

Jointed Rock Mass

STEEPLY DIPPING JOINTS	70° < α > 90°	S < B	 (c)	Open Joints: Compressive failure of individual rock columns. Near vertical joints set(s)	Eq. 6.5
			 (d)	Closed Joints: General shear failure along well defined failure surfaces. Near vertical joint(s).	Eq. 6.1
		S > B	 (e)	Open or Closed Joints: Failure initiated by splitting leading to general shear failure. Near vertical joint set(s).	Eq. 6.6
JOINTED	20° < α < 70°	S < B or S > B if failure wedge can develop along joints	 (f)	General shear failure with potential for failure along joints. Moderately dipping joint set(s).	Eq. 6.3

LAYERED	$0 < \alpha < 20$	Limiting Values of H with respect to B is dependent upon material properties	(g) 	Thin Rigid Upper Layer: Failure is initiated by tensile failure caused by flexure of thin rigid upper layer.	N/A
			(h) 	Thin Upper Rigid Layer: Failure is initiated by punching tensile failure of the thin rigid upper layer.	N/A
FRACTURED	N/A	$S << B$	(i) 	General shear failure with irregular failure surface through rock mass. Two or more closely spaced joint sets.	Eq. 6.3

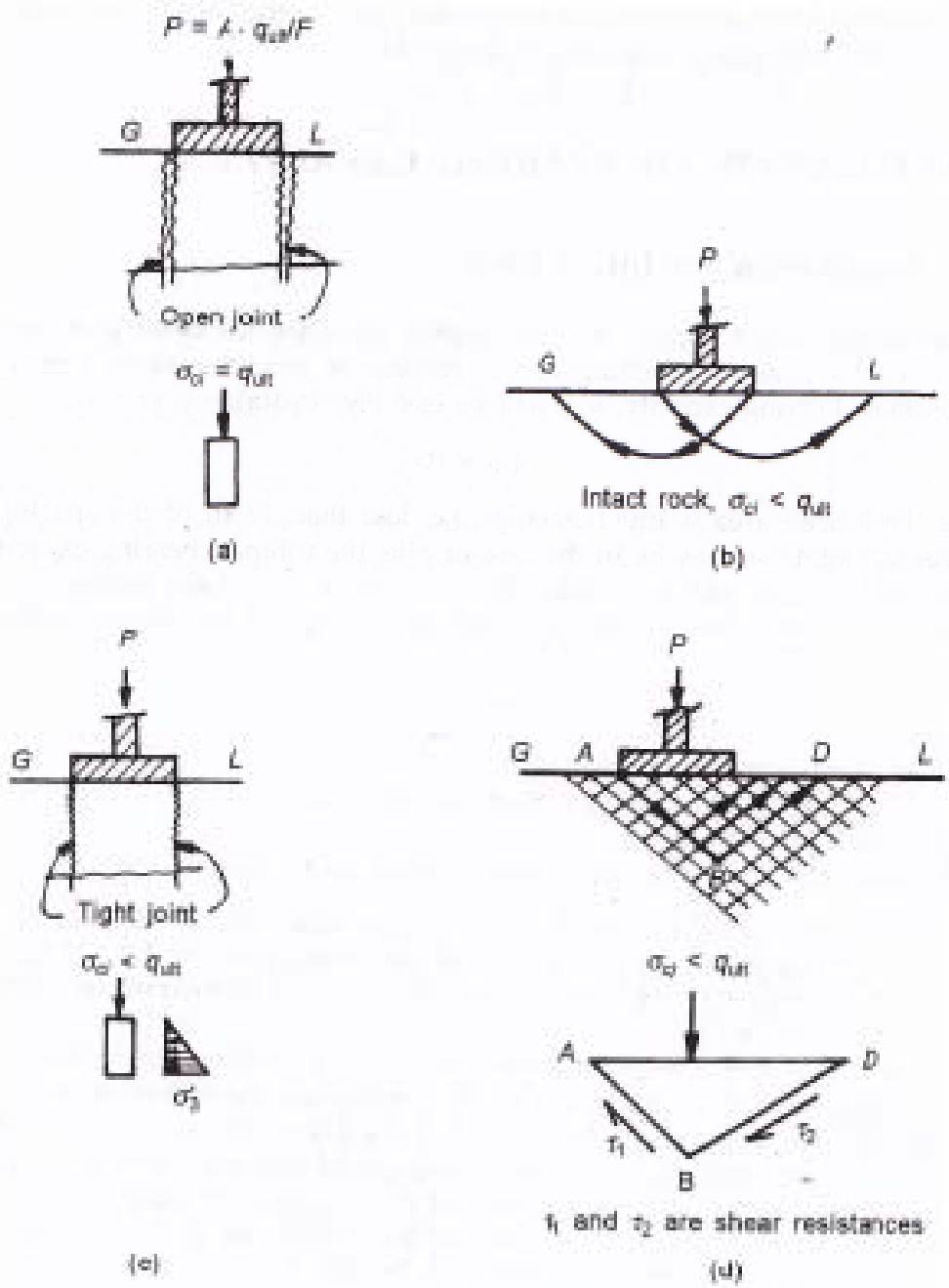


FIGURE 16.1 Contd.

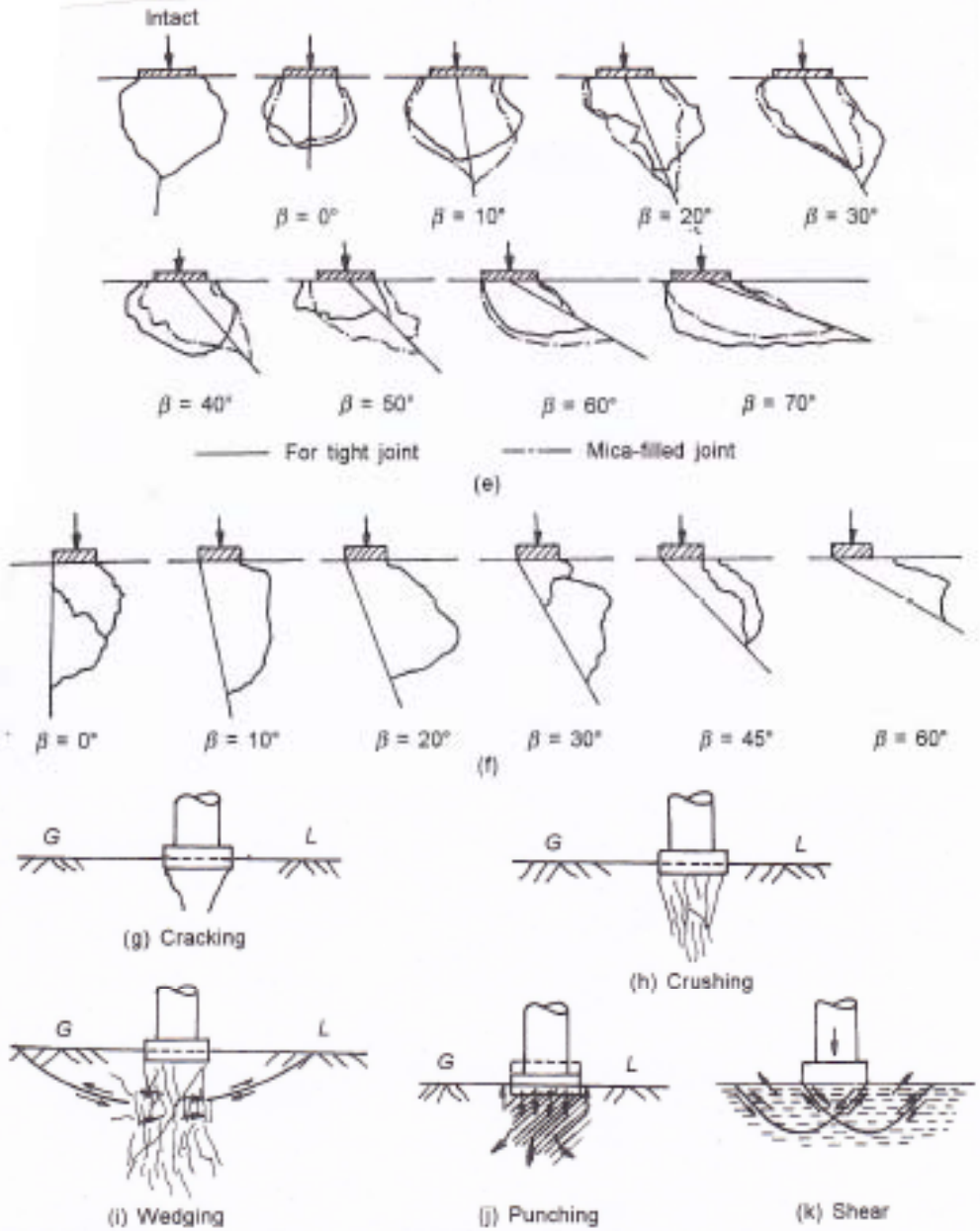


FIGURE 16.1 Surface footing—ultimate bearing capacity in case of: (a) open vertical joints, (b) intact rock, (c) tight vertical joints and (d) inclined set of tight joints, development of rupture zones with inclination of, (e) centrally located joint, (f) joint located at the edge of footing; other possible modes of failure of foundation rock (g) to (k), [Goodman (1989)].

General Shear Failure

$$q_{ult} = cN_c + 0.5\ \gamma BN_\gamma + \gamma DN_q \qquad (6\text{-}12)$$

where

q_{ult} = the ultimate bearing capacity

γ = effective unit weight (i.e. submerged unit wt. if below water table) of the rock mass

B = width of foundation

D = depth of foundation below ground surface

c = the cohesion intercepts for the rock mass

Local Shear Failure

$$q_{ult} = cN_c + 0.5\gamma BN_\gamma$$

- Compressive Failure:

  A case characterized by poorly constrained columns of poor rock.

$$q_{qult} = 2\ c\ \tan\ (45\ +\ \phi/2)$$

Splitting Failure

For widely spaced and vertically oriented discontinuities, failure generally initiates by splitting beneath the foundation.

- The ultimate bearing capacity is given by:

For circular foundations

$$q_{ult} = JcN_{cr} \qquad (6\text{-}6a)$$

For square foundations

$$q = 0.85JcN_{cr} \qquad (6\text{-}6b)$$

For continuous strip foundations for L/B ≤ 32

$$q_{ult} = JcN_{cr}/(2.2 + 0.18\ L/B) \qquad (6\text{-}6c)$$

where

J = correction factor dependent upon thickness of the foundation rock and width of foundation.

L = length of the foundation

The bearing capacity factor N_{cr} is given by:

$$N_{cr} = \frac{2N_{\phi}^{2}}{1+N_{\phi}} \quad (\cot\phi)\,(S/B) \left(1 - \frac{1}{N_{\phi}}\right) \qquad (6\text{-}6d)$$

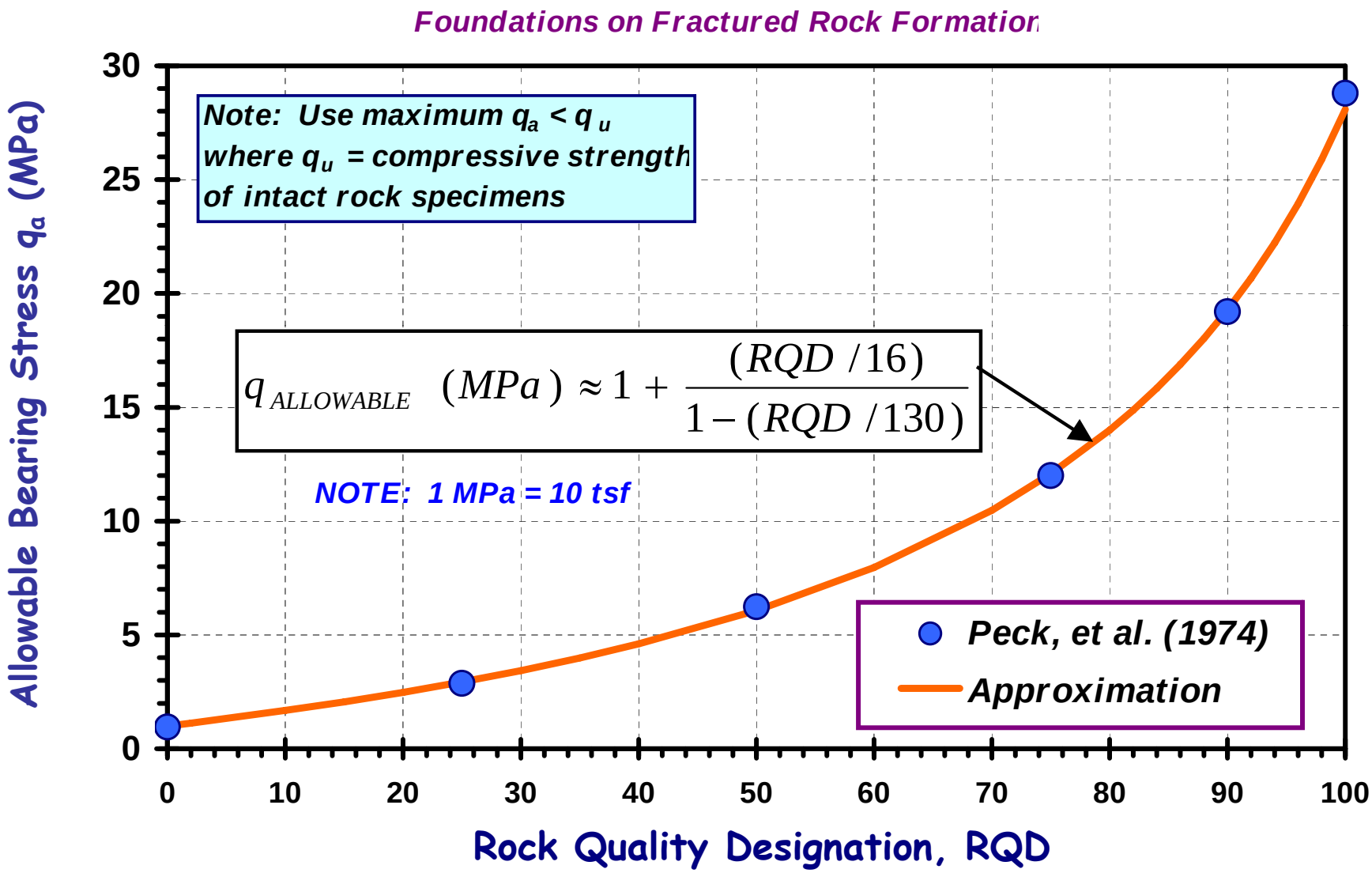
$$- N\phi\ (\cot\phi) + 2N\phi^{1/2}$$

Guideline properties of Rock Mass Classes

Guideline Properties of Rock Mass Classes

Class	I	II	III	IV	V
Description	very good rock	good rock	fair rock	poor rock	very poor rock
RMR	80–100	60–80	40–60	20–40	< 20
Q Value	> 40	10–40	4–10	1–4	<1
Friction angle ϕ (°)	> 45	35–45	25–35	15–25	<15
Cohesion (kPa)	> 400	300–400	200–300	100–200	< 100
SBP (MPa)	10	4–6	1–2	0·5	< 0·2
Safe cut slope (°)	> 70	65	55	45	< 40
Tunnel support	none	spot bolts	pattern bolts	bolts + shotcrete	steel ribs
Stand up time for span	20 yr for 15 m	1 yr for 10 m	1 wk for 5 m	12 h for 2 m	30 min for 1 m

Allowable Bearing Stresses on Rock Masses



In case of rock mass with favorable discontinuities, the net allowable bearing pressure may be estimated from:

$q_a = q_c * N_j$

Where q_c = average uniaxial compressive strength of rock cores

N_j = empirical coefficient depending on the spacing of the discontinuities

$$= \frac{3 + S/B}{10\sqrt{[1 + 300(\delta/S)]}}$$

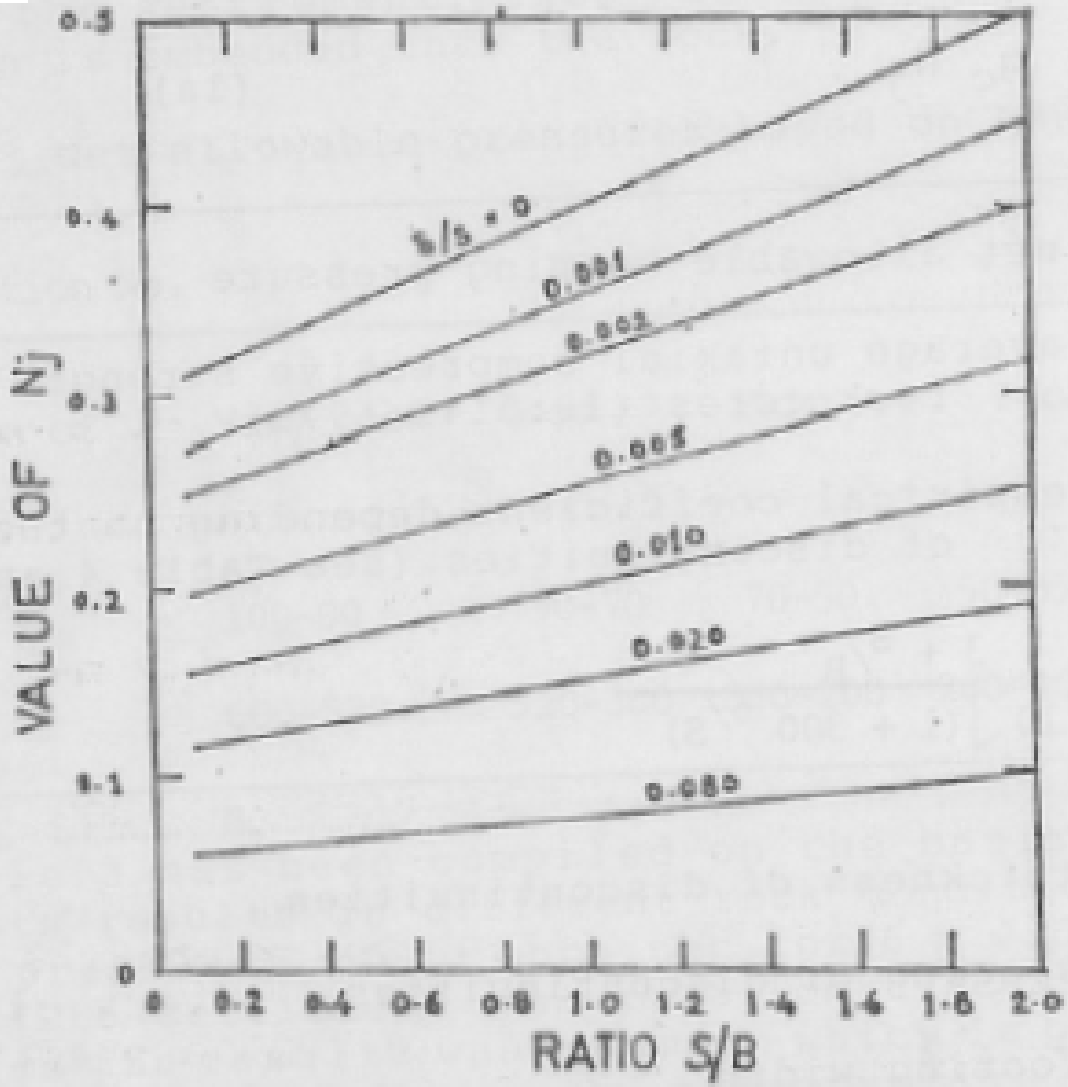
δ = thickness of discontinuity

S = spacing of discontinuities

B = width of footing

The above relationship is valid for a rock mass with spacing of continuities > 0.3 m, δ < 10 mm (15 mm if filled with soil) and

B >0.3 m.



$$N_j = \frac{3 + S/B}{10\sqrt{1 + 300\ s/S}}$$

FIG. 2 - BEARING PRESSURE COEFFICIENT Nj

Pile Foundations:

The allowable bearing capacity of socketed piles is given by:

$q_a = q_c * N_j * \mathbf{N_d}$

Where

$\mathbf{N_d = 0.8 + 0.2\ h/d}$

h = depth of socket in rock

d = diameter of socket

Determination of Net Allowable Bearing Pressure from Pressuremeter Test:

$$q_a = \frac{1}{3}\left[\gamma D_f + K_d (P_l - \gamma D_f)\right]$$

Where q_a = allowable bearing pressure in t/m^2

P_l = limit pressure determined by the Pressuremeter in t/m^2

γD_f = overburden pressure in t/m^2

Values of K_d

Depth of footing	K_d
Load at rock surface	0.8
Load at radius/width of foundation unit	2.0
Load at 4 times radius/width of foundation unit	3.6
Load at 10 times radius/width of foundation unit	5.0

Plate Load Test

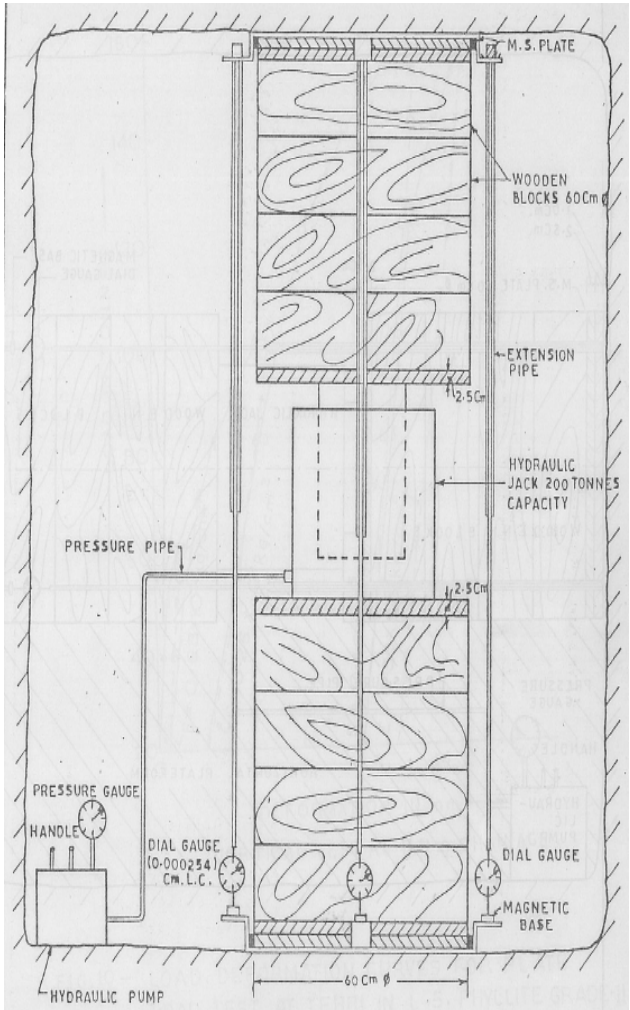


FIG.8.-ASSEMBLY FOR VERTICAL PLATE LOAD TESTS, USED AT TEHRI DAM SITE, UTTAR PRADESH.

Correction Factors : (Not required for RMR)

- Ground Water Table:
  - (a) Rock with discontinuous joints with opening less than 1mm wide – 0.75
  - (b) Rock with continuous joints with opening 1 to 5 mm wide filled with gouge – 0.7 to 0.5
  - (c) Limestone/ Dolomite deposit with major cavities filled with soil – 0.66 to 0.5.
- Cavities: Major cavities inside limestone - 0.5
- Slope and orientation of joints:
  - (a) Fair orientation of continuous joints in the slope – 1 to 0.5
  - (b) Unfavorable orientation of continuous joints in slope – 0.5 to 0.33.

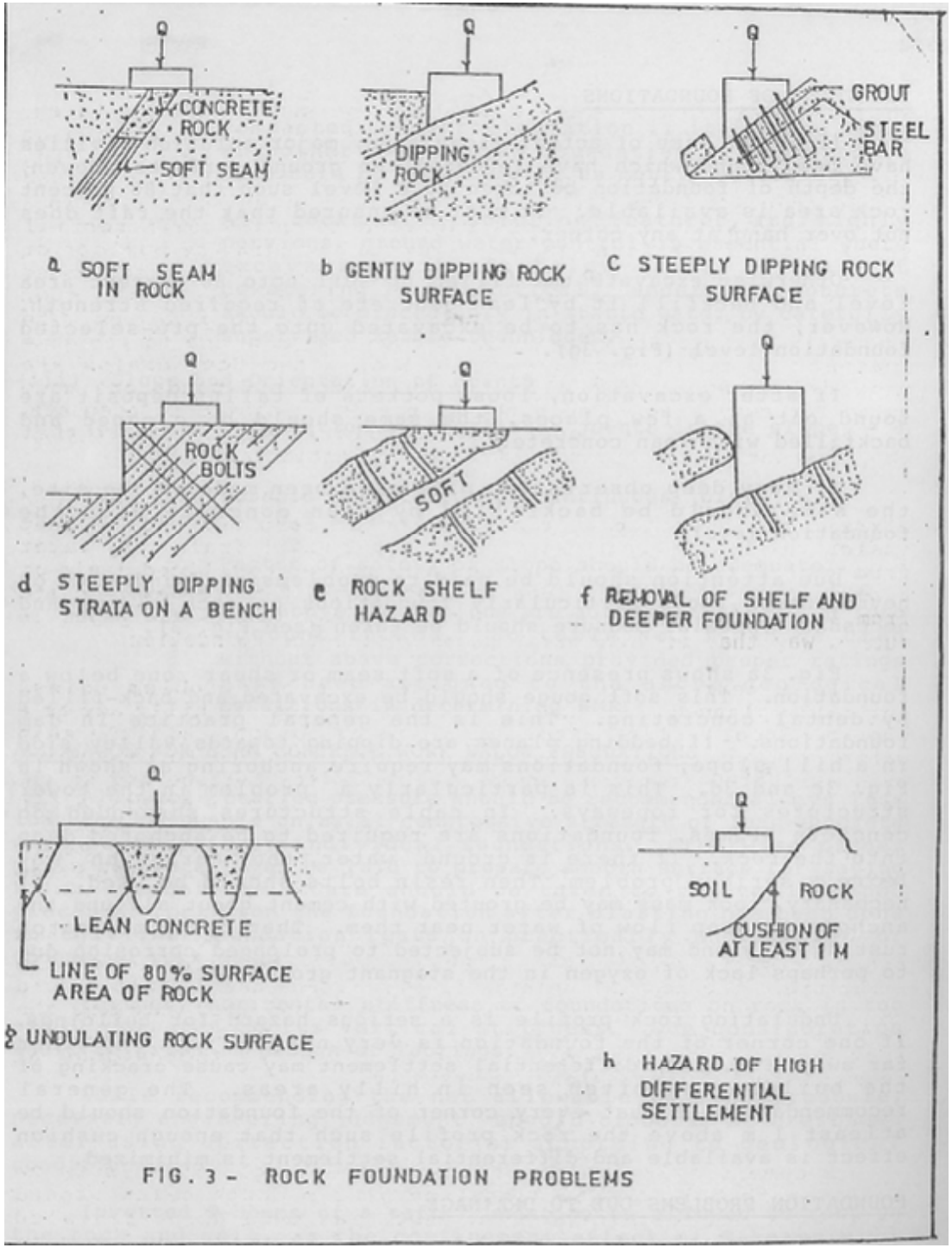


FIG. 3 - ROCK FOUNDATION PROBLEMS