Modification of End Bearing Equation

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End bearing equation.

Modifications:

- Reconciling differences between two papers.
  - Vesic, A., 1973, "Analysis of Ultimate Loads of Shallow Foundations", Journal of Soil Mechanics and Foundation Division.
  - Hansen, J. B. 1961, "A General Formula for Bearing Capacity", Bulletin 11, The Danish Geotechnical Institute.
- Adding depth factor.

End bearing equation. Typo Correction

FAD 5.2.2 and older

$$N_q = e^{\pi * \tan(\phi_{rad})} * \tan^2\left(\frac{\pi}{4} + \frac{\phi_{rad}}{2}\right)$$

Eq. 11 of Vesic (1973)

$$\xi_c = \xi_q - \frac{1 - \xi_q}{N_q \tan\phi}$$

$$\zeta_{cs} = 1 + \tan(\phi) + \frac{1}{N_q}$$

Table 5 in Vesic (1973)
Circle and Square

$$\zeta_{qs} = 1 + \tan(\phi)$$

Typo: It is not Nq but Nc

Correction now matches Table 5 in Vesic (1973) , while older FAD versions didn't match.

Correction

$$N_c = (N_q - 1) * \cot(\phi_{rad})$$

Eq. 13 of Hansen (1961)

$$i_c = i_q - \frac{1 - i_q}{N_c \tan\varphi}$$

Table 5 in Vesic (1973)
Circle and Square

$$\zeta_{cs} = 1 + \left(\frac{N_q}{N_c}\right)$$

End bearing equation.

Introducing Depth Factor

D/B<=1

Equations 10 and 12 Vesic (1973)

$$\begin{cases} \zeta_{qd} = 1 + 2 * \tan(\phi) * (1 - \sin(\phi))^2 * \frac{D}{B} \\ \zeta_{\gamma d} = 1 \\ \zeta_{cd} = (1 + 0.4 * \frac{D}{B}) \end{cases}$$

D/B>1

Equations 13 and 14 Vesic (1973)

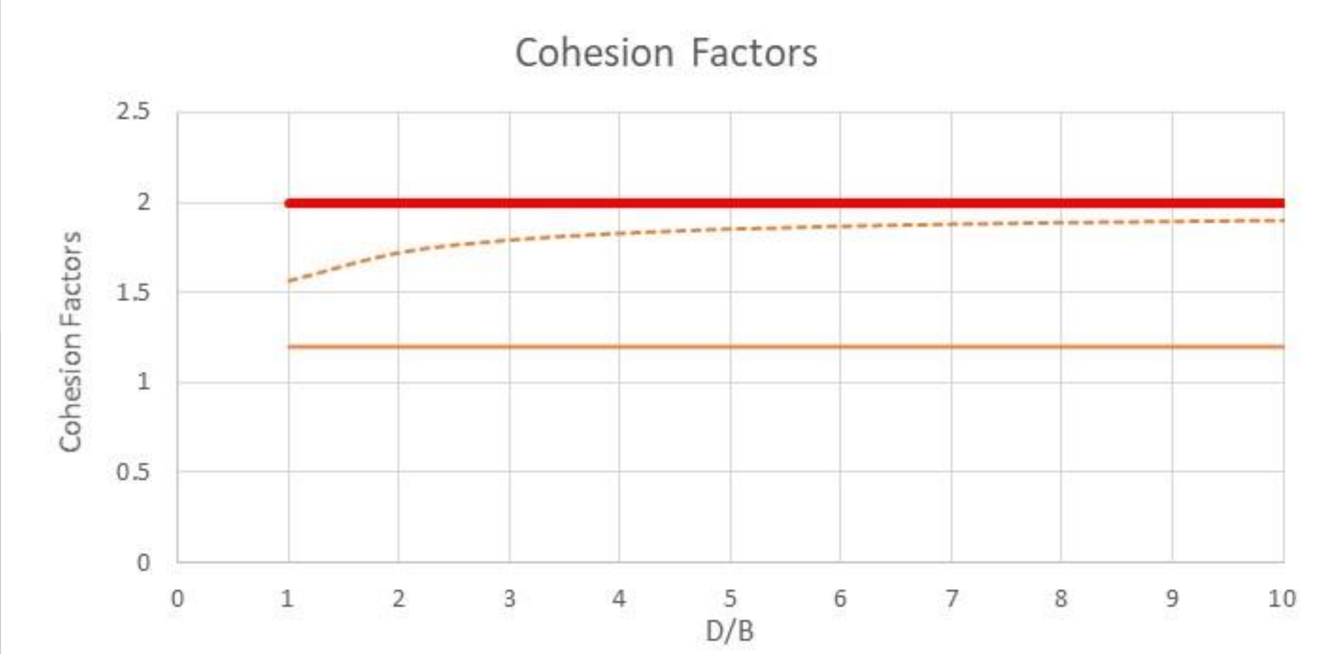
$$\begin{cases} \zeta_{qd} = 1 + 2 * \tan(\phi) * (1 - \sin(\phi))^2 * \\ tan^{-1}\left(\frac{D}{B}\right) \\ \zeta_{\gamma d} = 1 \\ \zeta_{cd} = \left(1 + 0.4 * tan^{-1}\left(\frac{D}{B}\right)\right) \end{cases}$$

End bearing equation.

Equation in FAD Code: $\zeta_{cs} = 1 + tan(\phi) + \frac{1}{N_q}$

Shape factor for cohesion: $\zeta_{cs} = 1 + \frac{N_q}{N_c}$

Shape factor for cohesion times depth factor: $\zeta_{cs} * \zeta_{cd} = (1 + \frac{N_q}{N_c})(1 + 0.4 * tan^{-1}\left(\frac{D}{B}\right))$

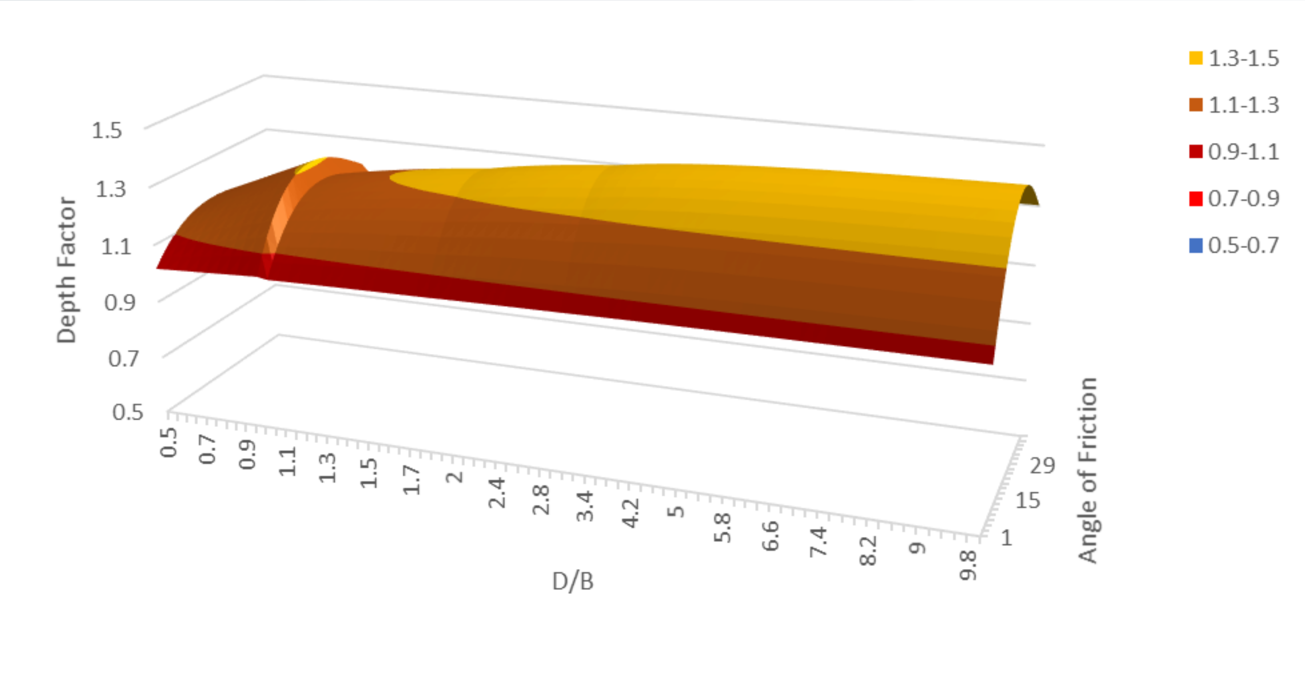


Greater depth of embedment could be obtained after this correction particularly for D/B < 3

End bearing equation.

$$\zeta_{qd} = 1 + 2\tan(\phi)\,(1 - \sin(\emptyset))^2 \frac{D}{B} \quad when \ \frac{D}{B} \le 1$$

$$\zeta_{qd} = 1 + 2\tan(\phi)\,(1 - \sin(\emptyset))^2 \, tan^{-1}\left(\frac{D}{B}\right) \quad when \ \frac{D}{B} > 1$$

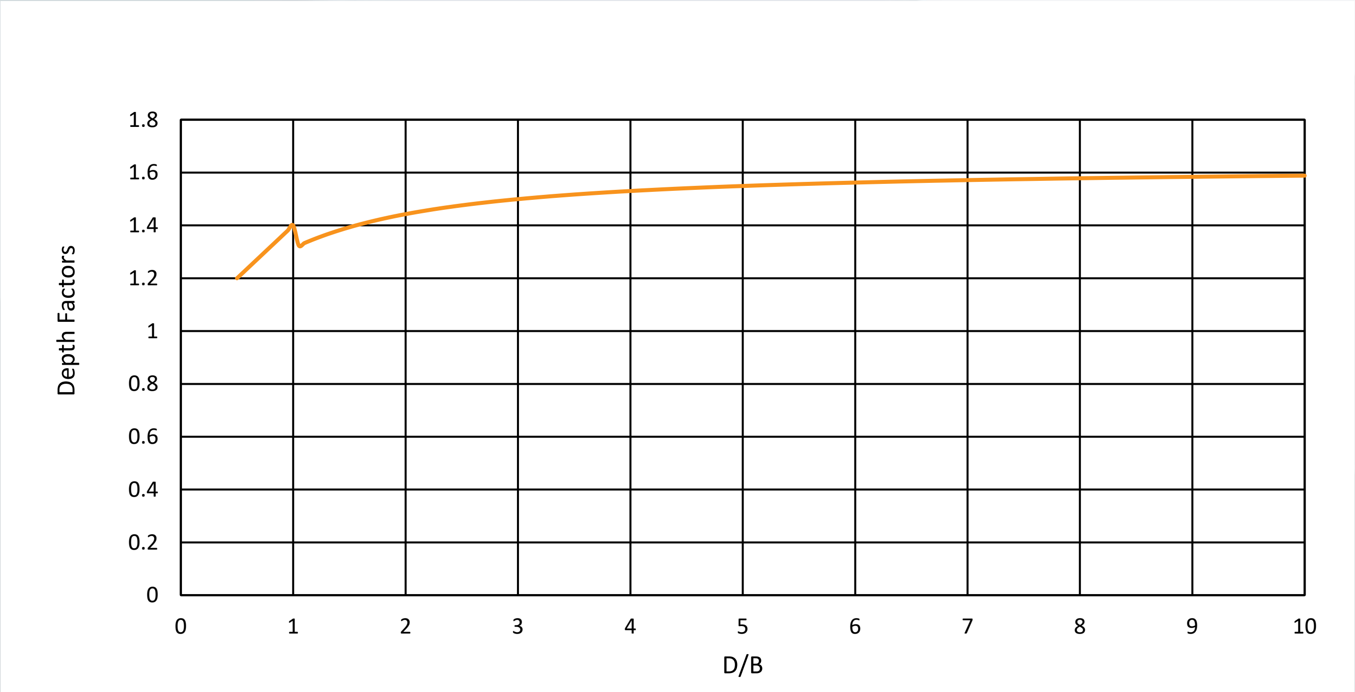


Lesser depth of embedment could be obtained after this correction

End bearing equation.

$$\zeta_{qd} = 1 + 2\tan(\phi)\,(1 - \sin(\emptyset))^2 \frac{\mathrm{D}}{B} \quad when \ \frac{\mathrm{D}}{B} \leq 1$$

$$\zeta_{qd} = 1 + 2\tan(\phi)\,(1 - \sin(\emptyset))^2\, tan^{-1}\left(\frac{D}{B}\right) \quad when \ \frac{\mathrm{D}}{B} > 1$$



Lesser depth of embedment could be after doing only this correction

Verification

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Verification

FAD Result (e.g., Input File)

Capacity Verification at Groundline

p of Shaft		Applied Load on Top of Shaft	Applied Load at Groundline	Nominal Capacity at Groundline	Design Capacity at Groundline
Axial [kips]	✓	1	1	34.85	20.64
Shear [kips]	✓	1	1	8.23	5.18
Moment [kip-ft]	✓	1	2	16.46	10.37
Axial [kips]	✓	1	1	220.16	100.4

Hand Calculation in excel

E	F	G	H	I	J	K	L
						Hand Calculation	
		Weight of the Caisson				3.30	
Total Force							
		Nominal				220.1625	kips
		Design				100.3995	kips

Parametric study

Parametric study available upon request.

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Impact

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Impact on Depth of Embedment

For cohesive soils and when compression loads control the design

D/B lesser than 2.

soft and medium stiff clay: Depth of embedment increases after the Vesic correction by approximately 50%.

For this relatively low D/B ratio, typically drilled shafts are designed using alternative methods rather than FAD Tools.

Very stiff clay: Depth of embedment can increase by up to 100% for D/B equal to 1 and large diameters (e.g. 5 to 10 ft).

Impact on Depth of Embedment

For cohesive soils and when compression loads control the design

D/B equal or greater than 2,

Soft and medium stiff clays : Depth of embedment increase is less than 10% for D/B greater than 4 regardless of the diameter;

Very stiff clays : Depth of embedment increase is approximately 10% .

Impact on Depth of Embedment

For sandy soils and when compression loads control the design.

- D/B lesser than 2. Depth of embedment decreases after Vesic correction by about 11 percent
  - For this relatively low D/B ratio, typically drilled shafts are designed using alternative methods rather than FAD Tools.
- D/B equal or greater than 2. Depth of embedment decreases by about 20 percent after correction.

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