EP486.2 / EP486.3 - **Shallow Post and Pier Foundation Design**

EP486.2 is referenced by IBC 2015 & 2018, but the publisher (ASABE.org) considers it to be an out-of-date standard and I've only been able to find it at https://meganorms.com. The sections relevant to fence post footings appear to be the same as EP486.3 except for the Table 4 safety factors. Some formulas appear different, but they are just using different combinations of variables that have the same end result. The local building authority may allow the use of EP486.3 in lieu of the required EP486.2

Sections of the standard that are applicable to fence post footings:

3.2.2 – Foundation Depth, d_F	Depth of footing - Changed to D to correspond to FenceDesign.com deign guide variables
3.2.5 - Pier width, B	Width of footing - Changed to b to match design guide variables
3.3.9 – Soil Friction Angle, ϕ	This variable used for non-clay soils comes from either Table 1, or per 5.8.1 – 5.8.3 based on geotechnical data
3.3.12 – Undrained Shear Strength, S_U	This variable for clay soils comes from either Table 1, or per 5.7.1 – 5.7.4 based on geotechnical data

4 – Nomenclature

A	Footing bearing area – changed to A_f to match design guide variables
b	Diameter of post or pier – this is the same as b for fence post footing diameter in the design guide
B	Diameter of post footing – this is the same as b for fence post footing diameter in the design guide
d	Post embedment depth – this is the same as d_F for fence post footings – using D per design guide
d_w	Depth to the top of the water table - this affects the vertical bearing strength of non-clay soils
M_{ASD}	Maximum moment at ground level – changed to P½h to match design guide variables
P_{ASD}	Maximum vertical load – changed to D_{max} to match design guide variables
s_y	Shape factor for bearing strength f/ cohesionless soil – changed to s_z as it conflicts with s_y in the design guide for max bearing stress
γ	moist unit weight of soil = ρ g EP486.2 formulas use ρ g in place of γ EP486.3 uses γ so ρ g is replaced with γ in formulas below

5.4.1 - Soil test samples are to be taken at 1/3 of the expected post depth and at the full post depth + ½b. Determine this preliminarily from the table 1 values or the IBC §1807.3 procedure before having the samples taken if possible.

5.9 - If there is no geotechnical report available, Table 1 can be used for lateral and vertical soil strengths, but the required safety factors are higher, making the footings more expensive in labor & materials.

6.2 – Minimum allowable strength of the concrete to be used is 3,000 psi .

6.5.3 – Minimum footing diameter is 6" larger than largest post dimension vs 4" for the IBC procedure

8.4 – Simplified Method - Can be used if the soil is homogeneous for the entire embedment depth - no different layers of soil types within the depth of the footing. If there are different layers, the use of the universal procedure (8.3 – 8.3.4, 11.1 – 11.4 & Table 3) is required. Only the simplified Method for non-constrained posts is covered in detail below.

9.2 – For Risk Category I fences, Safety Factors for Lateral Forces, f_L and Axial Forces, f_B can be reduced 20%, limited to a minimum value of 1.5. These safety factors are shown in Tables 2 & 4.

10.2 – ASD Design - Allowable bearing stress vs maximum bearing stress $(q_B - \gamma\, d_F) / f_B \geq P_{ASD} / A$ is OK

$\gamma\, d_F$ in the EP486.2 formula is to address overburden of soil and does not apply to fence post footings so it is neglected. Formulas below rewritten to follow design guide variables.

Maximum bearing stress, $s_y = D_{max} / A_f$ per design guide

Allowable bearing stress, $S_y = q_B / f_B$ f_B is the safety factor per table 2
q_B is the Ultimate Bearing Capacity per 10.4.1, 10.4.2, 10.4.3 or 10.4.4

$s_y \leq S_y$ is OK Solve iteratively, changing D & b as needed

10.4 - Vertical bearing capacity, q_B Formulas per 10.4.1, 10.4.2, 10.4.3 or 10.4.4 depending on how soil values are determined. (see Table 2) Equations assume flat ground. Correction factors below used in q_B formulas for cohesionless soils (soil classes 3 & 4 – dirt, sand & gravel)

d_w = Depth to the top of the water table. This affects the vertical bearing strength of non-clay soils.

Correction factor, C_{w1}

- For $d_w \leq D$, $C_{w1} = 0.5$
- For $d_w \geq 1.5b + D$, $C_{w1} = 1.0$
- For $D < d_w < 1.5b + D$, $C_{w1} = 0.5 + (d_w - D) / 3b$

Correction factor, $C_{w2} = 0.5 + 0.5\, d_w / D \leq 1.0$

10.4.1 - Ultimate Soil Bearing Capacity, q_B when using Table 1 variables or when ϕ or S_U values come from geotechnical testing. (see Table 2)

For non-expansive, cohesive inorganic clay soils (soil class 5)

Cohesive Bearing Capacity Factor, $N_c = 5.14$

Shape Factor, $s_c = 1.2$ for square and round footings

Cohesive Depth Factor, $d_c = 1 + 0.2\, D / b \leq 1.5$ D used in place of d_f b used in place of B

$\rho g = \gamma$ = Moist Unit Weight in lbs / ft^3 - this is the soil density when wet. This needs to be divided by 12^3 to get lbs / in^3.

Ultimate Soil Bearing Capacity for Non-expansive, Cohesive Inorganic Clay Soils, $q_B = S_u N_c d_c s_c + \gamma D$

For cohesionless soils (soil classes 3 & 4 – dirt, sand & gravel)

Drained Soil Friction Angle in degrees, ϕ - this is only used for non-clay soils

Bearing Capacity Factor for Overburden, $N_q = e^{\pi \tan \phi} \tan^2(45 + \frac{1}{2}\phi)$

Bearing Capacity Factor for Soil Weight, $N_\gamma = 2(N_q + 1) \tan \phi$

Depth Factor f/ Bearing Strength, $d_q = 1 + 2 \tan \phi (1 - \sin \phi)^2 \tan^{-1}(D / b)$

Shape Factor f/ Bearing Strength, $s_q = 1 + \tan \phi$ for square & round footings

Values for $\tan \phi$, $1 - \sin \phi$, N_γ, N_q, s_q and d_q for different values of ϕ are given in Table 6 in lieu of calculating them by using the formulas above. (see EP486.2 or EP486.3 for Table 6)

Shape Factor for Bearing Strength, $s_z = 0.6$ for square & round footings. s_γ changed to s_z to avoid conflicting with the use of s_γ as the Maximum Vertical Pressure in the design guide.

Ultimate Soil Bearing Capacity for cohesionless soils, $q_B = \gamma(0.5\ b\ C_{w1}\ N_\gamma\ s_z + D\ C_{w2}\ N_q\ d_q\ s_q)$

For the sections below, see EP486.2, or EP486.3 if allowed by local building official

10.4.2 - Ultimate Soil Bearing Capacity, q_B from Standard Penetration Test (SPT) results

10.4.3 - Ultimate Soil Bearing Capacity, q_B from Cone Penetration Test (CPT) results

10.4.4 - Ultimate Soil Bearing Capacity, q_B from Pressure Meter Test (PMT) results

11.4 – Lateral Strength Checks for Simplified Method — Using design guide variables, $P\frac{1}{2}h \leq M_U / f_L$ is OK
Solve iteratively changing D & b as needed

11.4.1 – Non-constrained post in cohesionless soils (soil classes 3 & 4 – dirt, sand & gravel)

Coefficient of Passive Earth Pressure, $K_P = (1 + \sin \phi) / (1 - \sin \phi)$

Increase per Unit Depth in the Ultimate Lateral Force, $S_{LU} = 3\ b\ K_P\ \gamma$

Depth to Point of Post Rotation at Ultimate Load, $d_{RU} = (P\ f_L / S_{LU} + \frac{1}{2}D^2)^{0.5}$ — Safety Factor, f_L per Table 4

Ultimate moment, $M_U = S_{LU}(D^3 - 2d_{RU}^3) / 3$

11.4.2 – Non-constrained post in non-expansive, cohesive inorganic clay soils (soil class 5)

Depth to Point of Post Rotation at Ultimate Load, $d_{RU} = (64\,b^2 + 4P\,f_L / 3S_U + 12\,b\,D)^{0.5}$

For $d_{RU} < 4b$, Ultimate moment, $M_U = b\,S_U\,(4.5\,D^2 - 6\,d_{RU}^2 - d_{RU}^3 / 2\,b)$

Otherwise, $d_{RU} = P\,f_L / 18\,b\,S_U + ½D + ⅔b$ & Ultimate moment, $M_U = 9\,b\,S_U\,(½D^2 - d_{RU}^2 + 16\,b^2 / 9)$

For the sections below, see EP486.2, or EP486.3 if allowed by local building official

11.4.3 – Non-constrained post in any soil

11.4.4 – 11.4.6 – Constrained posts

Per EP486.2 & EP486.3 Table 1 - Presumptive Soil Properties

Soil Class	Soil Type	Unified Soil Classification	Consistency	Moist Unit Weight, γ	Drained Soil Friction Angle, ϕ	Undrained Soil Shear Strength, S_U
				lb / ft^3	Degrees	lb / in^2
Soil Class 5 Cohesive Soils	Homogeneous inorganic clay, sandy or silty clay	CL	soft	125	-	3.5
			medium to stiff	130	-	7
			very stiff to hard	135	-	14
	Homogeneous inorganic clay of high plasticity	CH	soft	110	-	3.5
			medium to stiff	115	-	7
			very stiff to hard	120	-	14
	Inorganic silt, sandy or clayey silt, varved silt-clay-fine sand of low plasticity	ML	soft	120	-	3.5
			medium to stiff		-	7
			very stiff to hard		-	14
	Inorganic silt, sandy or clayey silt, varved silt-clay-fine sand of high plasticity	MH	soft	105	-	3.5
			medium to stiff		-	7
			very stiff to hard		-	14
Soil Class 4 Cohesionless Soils	Silty or clayey fine to coarse sand	SM, SC, SP-SM, SP-SC, SW-SM, SW-SC	loose	105	30	-
			medium to dense	110	35	-
			very dense	115	40	-
	Clean sand with little gravel	SW, SP	loose	115	30	-
			medium to dense	120	35	-
			very dense	125	40	-
	Gravel, gravel-sand mixture, boulder-gravel mixtures	GW, GP	loose	135	35	-
			medium to dense		40	-
			very dense		45	-
	Well-graded mixture of fine- and coarse-grained soil: glacial till, hardpan, boulder clay	SW-GC, GC, SC	loose	120	35	-
			medium to dense	125	40	-
			very dense	130	45	-

Per EP486.2 & EP486.3 Table 2 - Safety Factors for Axial Loads							
Unified Soil Classification	Associated Clause	Method used to Determine q_B	ASD safety Factor, f_B	f_B at different ϕ values			
				@ ϕ = 30	@ ϕ = 35	@ ϕ = 40	@ ϕ = 45
Cohesionless Soils SP, SW, GP, GW, GW-GC, GC, SC, SM, SP-SM, SP-SC, SW-SM, SW-SC	10.4.1	Properties taken from Table 1 with no testing	1.4 / (0.58 - 0.01 ϕ)	5.00	6.09	7.78	10.77
		Properties taken from Table 1 - soil type verified by construction testing	1.4 / (0.77 - 0.01 ϕ)	2.98	3.33	3.78	4.38
		ϕ determined from laboratory direct shear or axial compression tests (5.8.1)	1.4 / (0.80 - 0.01 ϕ)	2.80	3.11	3.50	4.00
		ϕ determined from SPT data (5.8.2)	1.4 / (0.62 - 0.01 ϕ)	4.38	5.19	6.36	8.24
		ϕ determined from CPT data (5.8.3)	1.4 / (0.71 - 0.01 ϕ)	3.41	3.89	4.52	5.38
	10.4.2	q_B determined by Standard Penetration Test (SPT)	3.4	-	-	-	-
	10.4.3	q_B determined by Cone Penetration Test (CPT)	2.8	-	-	-	-
	10.4.4	q_B determined by Pressuremeter Test (PMT)	2.8	-	-	-	-
Cohesive Soils CL, CH, ML, MH	10.4.1	Properties taken from Table 1 with no testing	3.0	-	-	-	-
		Properties taken from Table 1 - soil type verified by construction testing	2.3	-	-	-	-
		S_U determined from laboratory compression tests (5.7.1)	2.3	-	-	-	-
		S_U determined from PBPMT data (5.7.2)	2.3	-	-	-	-
		S_U determined from CPT data (5.7.3)	2.3	-	-	-	-
		S_U determined from in-situ vane tests (5.7.4)	2.3	-	-	-	-
	10.4.3	q_B determined by Cone Penetration Test (CPT)	2.3	-	-	-	-
	10.4.4	q_B determined by Pressuremeter Test (PMT)	2.3	-	-	-	-

Per EP486.2 Table 4 - Safety Factors for Lateral Loads - Simplified Proceedure							
Unified Soil Classification	Required Property	Method used to Determine q_B	ASD safety Factor, f_B	f_B at different ϕ values			
				@ ϕ = 30	@ ϕ = 35	@ ϕ = 40	@ ϕ = 45
Cohesionless Soils SP, SW, GP, GW, GW-GC, GC, SC, SM, SW-SM, SP-SC, SW-SM, SW-SC	ϕ for 11.4.1 & 11.4.4	Properties taken from Table 1 with no testing	1.4 / (0.60 - 0.01 ϕ)	4.67	5.60	7.00	9.33
		Properties taken from Table 1 - soil type verified by construction testing	1.4 / (0.80 - 0.01 ϕ)	2.80	3.11	3.50	4.00
	ϕ for 11.4.1, 11.4.3, 11.4.4 & 11.4.6	ϕ determined from laboratory direct shear or axial compression tests (5.8.1)	1.4 / (0.83 - 0.01 ϕ)	2.64	2.92	3.26	3.68
		ϕ determined from SPT data (5.8.2)	1.4 / (0.64 - 0.01 ϕ)	4.12	4.83	5.83	7.37
		ϕ determined from CPT data (5.8.3)	1.4 / (0.73 - 0.01 ϕ)	3.26	3.68	4.24	5.00
Cohesive Soils CL, CH, ML, MH	S_U for 11.4.2 & 11.4.5	Properties taken from Table 1 with no testing	3.3	-	-	-	-
		Properties taken from Table 1 - soil type verified by construction testing	2.2	-	-	-	-
	S_U for 11.4.2, 11.4.3, 11.4.5 & 11.4.6	S_U determined from laboratory compression tests (5.7.1)	2.2	-	-	-	-
		S_U determined from PBPMT data (5.7.2)	2.2	-	-	-	-
		S_U determined from CPT data (5.7.3)	2.2	-	-	-	-
		S_U determined from in-situ vane tests (5.7.4)	2.2	-	-	-	-

Per EP486.3 Table 4 - Safety Factors for Lateral Loads - Simplified Proceedure - Numbers in Red are different than EP486.2							
Unified Soil Classification	Required Property	Method used to Determine q_B	ASD safety Factor, f_B	f_B at different ϕ values			
				@ ϕ = 30	@ ϕ = 35	@ ϕ = 40	@ ϕ = 45
Cohesionless Soils SP, SW, GP, GW, GW-GC, GC, SC, SM, SW-SM, SP-SC, SW-SM, SW-SC	ϕ for 11.4.1 & 11.4.4	Properties taken from Table 1 with no testing	1.4 / (0.61 - 0.01 ϕ)	4.52	5.38	6.67	8.75
		Properties taken from Table 1 - soil type verified by construction testing	1.4 / (0.82 - 0.01 ϕ)	2.69	2.98	3.33	3.78
	ϕ for 11.4.1, 11.4.3, 11.4.4 & 11.4.6	ϕ determined from laboratory direct shear or axial compression tests (5.8.1)	1.4 / (0.86 - 0.01 ϕ)	2.50	2.75	3.04	3.41
		ϕ determined from SPT data (5.8.2)	1.4 / (0.66 - 0.01 ϕ)	3.89	4.52	5.38	6.67
		ϕ determined from CPT data (5.8.3)	1.4 / (0.76 - 0.01 ϕ)	3.04	3.41	3.89	4.52
Cohesive Soils CL, CH, ML, MH	S_U for 11.4.2 & 11.4.5	Properties taken from Table 1 with no testing	2.6	-	-	-	-
		Properties taken from Table 1 - soil type verified by construction testing	2.1	-	-	-	-
	S_U for 11.4.2, 11.4.3, 11.4.5 & 11.4.6	S_U determined from laboratory compression tests (5.7.1)	2.1	-	-	-	-
		S_U determined from PBPMT data (5.7.2)	2.1	-	-	-	-
		S_U determined from CPT data (5.7.3)	2.1	-	-	-	-
		S_U determined from in-situ vane tests (5.7.4)	2.1	-	-	-	-