EWCE 343

Geotechnical and Foundation Engineering

Immediate Settlement

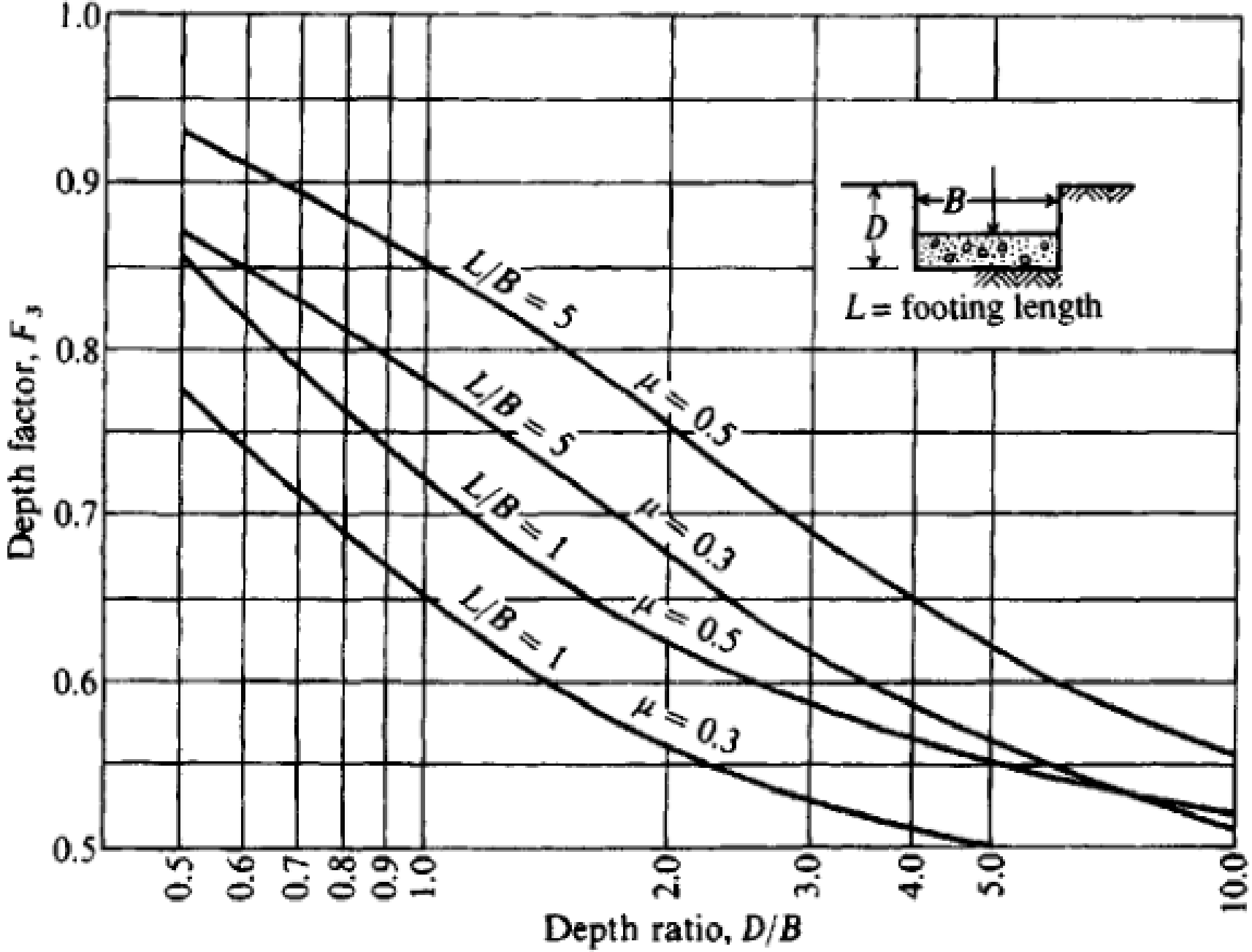

1.0
0.9
0.8
0.7
0.6
0.5
Depth factor, F_3
L/B = 5
μ = 0.5
L/B = 5
μ = 0.3
L/B = 1
μ = 0.5
L/B = 1
μ = 0.3
D
B
L = footing length
0.5
0.6
0.7
0.8
0.9
1.0
2.0
3.0
4.0
5.0
10.0
Depth ratio, D/B

TABLE 2-7

Values or value ranges for Poisson's ratio μ

Type of soil	μ
Clay, saturated	0.4–0.5
Clay, unsaturated	0.1–0.3
Sandy clay	0.2–0.3
Silt	0.3–0.35
Sand, gravelly sand	−0.1–1.00
commonly used	0.3–0.4
Rock	0.1–0.4 (depends somewhat on type of rock)
Loess	0.1–0.3
Ice	0.36
Concrete	0.15
Steel	0.33

TABLE 5-6

Equations for stress-strain modulus E_s by several test methods

E_s in kPa for SPT and units of q_c for CPT; divide kPa by 50 to obtain ksf. The N values should be estimated as N_{55} and not N_{70}. Refer also to Tables 2-7 and 2-8.

Soil	SPT	CPT
Sand (normally consolidated)	$E_s = 500(N + 15)$ $= 7000\sqrt{N}$ $= 6000N$ — — — ‡$E_s = (15\,000 \text{ to } 22\,000) \cdot \ln N$	$E_s = (2 \text{ to } 4)q_u$ $= 8000\sqrt{q_c}$ — — — $E_s = 1.2(3D_r^2 + 2)q_c$ *$E_s = (1 + D_r^2)q_c$
Sand (saturated)	$E_s = 250(N + 15)$	$E_s = Fq_c$ $e = 1.0 \quad F = 3.5$ $e = 0.6 \quad F = 7.0$
Sands, all (norm. consol.)	¶$E_s = (2600 \text{ to } 2900)N$	
Sand (overconsolidated)	†$E_s = 40\,000 + 1050N$ $E_{s(\text{OCR})} \approx E_{s,\text{nc}}\sqrt{\text{OCR}}$	$E_s = (6 \text{ to } 30)q_c$
Gravelly sand	$E_s = 1200(N + 6)$ $= 600(N + 6) \quad N \le 15$ $= 600(N + 6) + 2000 \quad N > 15$	
Clayey sand	$E_s = 320(N + 15)$	$E_s = (3 \text{ to } 6)q_c$
Silts, sandy silt, or clayey silt	$E_s = 300(N + 6)$ If $q_c < 2500$ kPa use $\quad$ $^{\$}E'_s = 2.5q_c$ $2500 < q_c < 5000$ use $\quad E'_s = 4q_c + 5000$ where E'_s = constrained modulus = $\dfrac{E_s(1-\mu)}{(1+\mu)(1-2\mu)} = \dfrac{1}{m_v}$	$E_s = (1 \text{ to } 2)q_c$
Soft clay or clayey silt		$E_s = (3 \text{ to } 8)q_c$

TABLE 5-2
Values of I_1 and I_2 to compute the Steinbrenner influence factor I_s for use in Eq. (5-16*a*) for several $N = H/B'$ and $M = L/B$ ratios

N		$M = 1.0$	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
0.2	$I_1 =$	0.009	0.008	0.008	0.008	0.008	0.008	0.007	0.007	0.007	0.007	0.007
	$I_2 =$	0.041	0.042	0.042	0.042	0.042	0.042	0.043	0.043	0.043	0.043	0.043
0.4		0.033	0.032	0.031	0.030	0.029	0.028	0.028	0.027	0.027	0.027	0.027
		0.066	0.068	0.069	0.070	0.070	0.071	0.071	0.072	0.072	0.073	0.073
0.6		0.066	0.064	0.063	0.061	0.060	0.059	0.058	0.057	0.056	0.056	0.055
		0.079	0.081	0.083	0.085	0.087	0.088	0.089	0.090	0.091	0.091	0.092
0.8		0.104	0.102	0.100	0.098	0.096	0.095	0.093	0.092	0.091	0.090	0.089
		0.083	0.087	0.090	0.093	0.095	0.097	0.098	0.100	0.101	0.102	0.103
1.0		0.142	0.140	0.138	0.136	0.134	0.132	0.130	0.129	0.127	0.126	0.125
		0.083	0.088	0.091	0.095	0.098	0.100	0.102	0.104	0.106	0.108	0.109
1.5		0.224	0.224	0.224	0.223	0.222	0.220	0.219	0.217	0.216	0.214	0.213
		0.075	0.080	0.084	0.089	0.093	0.096	0.099	0.102	0.105	0.108	0.110
2.0		0.285	0.288	0.290	0.292	0.292	0.292	0.292	0.292	0.291	0.290	0.289
		0.064	0.069	0.074	0.078	0.083	0.086	0.090	0.094	0.097	0.100	0.102
3.0		0.363	0.372	0.379	0.384	0.389	0.393	0.396	0.398	0.400	0.401	0.402
		0.048	0.052	0.056	0.060	0.064	0.068	0.071	0.075	0.078	0.081	0.084
4.0		0.408	0.421	0.431	0.440	0.448	0.455	0.460	0.465	0.469	0.473	0.476
		0.037	0.041	0.044	0.048	0.051	0.054	0.057	0.060	0.063	0.066	0.069
5.0		0.437	0.452	0.465	0.477	0.487	0.496	0.503	0.510	0.516	0.522	0.526
		0.031	0.034	0.036	0.039	0.042	0.045	0.048	0.050	0.053	0.055	0.058
6.0		0.457	0.474	0.489	0.502	0.514	0.524	0.534	0.542	0.550	0.557	0.563
		0.026	0.028	0.031	0.033	0.036	0.038	0.040	0.043	0.045	0.047	0.050
7.0		0.471	0.490	0.506	0.520	0.533	0.545	0.556	0.566	0.575	0.583	0.590
		0.022	0.024	0.027	0.029	0.031	0.033	0.035	0.037	0.039	0.041	0.043
8.0		0.482	0.502	0.519	0.534	0.549	0.561	0.573	0.584	0.594	0.602	0.611
		0.020	0.022	0.023	0.025	0.027	0.029	0.031	0.033	0.035	0.036	0.038
9.0		0.491	0.511	0.529	0.545	0.560	0.574	0.587	0.598	0.609	0.618	0.627
		0.017	0.019	0.021	0.023	0.024	0.026	0.028	0.029	0.031	0.033	0.034
10.0		0.498	0.519	0.537	0.554	0.570	0.584	0.597	0.610	0.621	0.631	0.641
		0.016	0.017	0.019	0.020	0.022	0.023	0.025	0.027	0.028	0.030	0.031
20.0		0.529	0.553	0.575	0.595	0.614	0.631	0.647	0.662	0.677	0.690	0.702
		0.008	0.009	0.010	0.010	0.011	0.012	0.013	0.013	0.014	0.015	0.016
500.0		**0.560**	0.587	0.612	0.635	0.656	0.677	0.696	0.714	0.731	0.748	0.763
		0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.001

TABLE 5-2
Values of I_1 and I_2 to compute the Steinbrenner influence factor I_s for use in Eq. (5-16*a*) for several $N = H/B'$ and $M = L/B$ ratios *(continued)*

N	M = 2.5	4.0	5.0	6.0	7.0	8.0	9.0	10.0	25.0	50.0	100.0
0.2	I_1 = 0.007	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
	I_2 = 0.043	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044
0.4	0.026	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024
	0.074	0.075	0.075	0.075	0.076	0.076	0.076	0.076	0.076	0.076	0.076
0.6	0.053	0.051	0.050	0.050	0.050	0.049	0.049	0.049	0.049	0.049	0.049
	0.094	0.097	0.097	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098
0.8	0.086	0.082	0.081	0.080	0.080	0.080	0.079	0.079	0.079	0.079	0.079
	0.107	0.111	0.112	0.113	0.113	0.113	0.113	0.114	0.114	0.114	0.114
1.0	0.121	0.115	0.113	0.112	0.112	0.112	0.111	0.111	0.110	0.110	0.110
	0.114	0.120	0.122	0.123	0.123	0.124	0.124	0.124	0.125	0.125	0.125
1.5	0.207	0.197	0.194	0.192	0.191	0.190	0.190	0.189	0.188	0.188	0.188
	0.118	0.130	0.134	0.136	0.137	0.138	0.138	0.139	0.140	0.140	0.140
2.0	0.284	0.271	0.267	0.264	0.262	0.261	0.260	0.259	0.257	0.256	0.256
	0.114	0.131	0.136	0.139	0.141	0.143	0.144	0.145	0.147	0.147	0.148
3.0	0.402	0.392	0.386	0.382	0.378	0.376	0.374	0.373	0.368	0.367	0.367
	0.097	0.122	0.131	0.137	0.141	0.144	0.145	0.147	0.152	0.153	0.154
4.0	0.484	0.484	0.479	0.474	0.470	0.466	0.464	0.462	0.453	0.451	0.451
	0.082	0.110	0.121	0.129	0.135	0.139	0.142	0.145	0.154	0.155	0.156
5.0	0.553	0.554	0.552	0.548	0.543	0.540	0.536	0.534	0.522	0.519	0.519
	0.070	0.098	0.111	0.120	0.128	0.133	0.137	0.140	0.154	0.156	0.157
6.0	0.585	0.609	0.610	0.608	0.604	0.601	0.598	0.595	0.579	0.576	0.575
	0.060	0.087	0.101	0.111	0.120	0.126	0.131	0.135	0.153	0.157	0.157
7.0	0.618	0.653	0.658	0.658	0.656	0.653	0.650	0.647	0.628	0.624	0.623
	0.053	0.078	0.092	0.103	0.112	0.119	0.125	0.129	0.152	0.157	0.158
8.0	0.643	0.688	0.697	0.700	0.700	0.698	0.695	0.692	0.672	0.666	0.665
	0.047	0.071	0.084	0.095	0.104	0.112	0.118	0.124	0.151	0.156	0.158
9.0	0.663	0.716	0.730	0.736	0.737	0.736	0.735	0.732	0.710	0.704	0.702
	0.042	0.064	0.077	0.088	0.097	0.105	0.112	0.118	0.149	0.156	0.158
10.0	0.679	0.740	0.758	0.766	0.770	0.770	0.770	0.768	0.745	0.738	0.735
	0.038	0.059	0.071	0.082	0.091	0.099	0.106	0.112	0.147	0.156	0.158
20.0	0.756	0.856	0.896	0.925	0.945	0.959	0.969	0.977	0.982	0.965	0.957
	0.020	0.031	0.039	0.046	0.053	0.059	0.065	0.071	0.124	0.148	0.156
500.0	0.832	0.977	1.046	1.102	1.150	1.191	1.227	1.259	1.532	1.721	1.879
	0.001	0.001	0.002	0.002	0.002	0.003	0.003	0.003	0.008	0.016	0.031

TABLE 5-6

Equations for stress-strain modulus E_s by several test methods

E_s in kPa for SPT and units of q_c for CPT; divide kPa by 50 to obtain ksf. The N values should be estimated as N_{55} and not N_{70}. Refer also to Tables 2-7 and 2-8.

Soil	SPT	CPT
Sand (normally consolidated)	$E_s = 500(N + 15)$ $= 7000\sqrt{N}$ $= 6000N$ — — — ‡$E_s = (15\,000 \text{ to } 22\,000) \cdot \ln N$	$E_s = (2 \text{ to } 4)q_u$ $= 8000\sqrt{q_c}$ — — — $E_s = 1.2(3D_r^2 + 2)q_c$ *$E_s = (1 + D_r^2)q_c$
Sand (saturated)	$E_s = 250(N + 15)$	$E_s = Fq_c$ $e = 1.0 \quad F = 3.5$ $e = 0.6 \quad F = 7.0$
Sands, all (norm. consol.)	¶$E_s = (2600 \text{ to } 2900)N$	
Sand (overconsolidated)	†$E_s = 40\,000 + 1050N$ $E_{s(\text{OCR})} \approx E_{s,\text{nc}}\sqrt{\text{OCR}}$	$E_s = (6 \text{ to } 30)q_c$
Gravelly sand	$E_s = 1200(N + 6)$ $= 600(N + 6) \quad N \le 15$ $= 600(N + 6) + 2000 \quad N > 15$	
Clayey sand	$E_s = 320(N + 15)$	$E_s = (3 \text{ to } 6)q_c$
Silts, sandy silt, or clayey silt	$E_s = 300(N + 6)$ If $q_c < 2500$ kPa use $\quad$ §$E'_s = 2.5q_c$ $2500 < q_c < 5000$ use $\quad E'_s = 4q_c + 5000$ where E'_s = constrained modulus $= \dfrac{E_s(1-\mu)}{(1+\mu)(1-2\mu)} = \dfrac{1}{m_v}$	$E_s = (1 \text{ to } 2)q_c$
Soft clay or clayey silt		$E_s = (3 \text{ to } 8)q_c$

Problem 1: Estimate the settlement of the raft (or mat) foundation for the "City Bank Building". Given data are as follows:

q_o= 134 kPa

B X L = 33.5 X 39.5m,

measured AH = about 18 mm

Soil is layered clays with one sand seam from ground surface to sandstone bedrock at - 14 m; mat at - 3 m.

E_s from 3 to 6 m = 42.5 MPa

E_s from 6 to 14 m = 60 MPa

E_s for sandstone > 500 MPa

Solution.

For clay, estimate μ = 0.35 (Table: 2-7).

Compute $E_{s.average}$= $\frac{3 \text{ x } 42.5 + 8 \text{ x } 60}{3+8}$= 55 Mpa

From base to sandstone H = 14- 3 = 11m. $B' = \frac{B}{2}=\frac{33.5}{2}$=16.75

B' = $\frac{33.5}{2}$= 16.75 m (for center of mat)

M=$\frac{L}{B} = \frac{39.5}{33.5} = 1.0$ $\frac{H}{B'} =\frac{11}{16.75}$ = 0.66 (use 0.7)

Interpolating in Table 5-2, we obtain I_1 = 0.0815; I_2 = 0.086:

$$I_s= I_1 + \frac{1-2\mu}{1-\mu} I_2 = 0.0815 + \frac{1-2x0.35}{1-0.35} 0.086=0.121$$

$\frac{L}{B} = \frac{39.5}{33.5} = 1.0$, μ =0.35 and $\frac{D}{B} =\frac{3}{33.5}$ = 0.089=0.1 from figure 5-7, I_F =0.95

With four contributing corners m = 4.

$$\Delta H = q_0 B' \frac{1-\mu^2}{E_s} m\, I_s I_F = 134(16.75)\frac{1-0.35^2}{55x1000}(4\ )(\ 0.121)(0.95)(1000) = 16.5 \text{ mm}$$

(The factor 1000 converts MPa to kPa and m to mm).

TABLE 2-7

Values or value ranges for Poisson's ratio μ

Type of soil	μ
Clay, saturated	0.4–0.5
Clay, unsaturated	0.1–0.3
Sandy clay	0.2–0.3
Silt	0.3–0.35
Sand, gravelly sand	– 0.1–1.00
commonly used	0.3–0.4
Rock	0.1–0.4 (depends somewhat on type of rock)
Loess	0.1–0.3
Ice	0.36
Concrete	0.15
Steel	0.33

Figure 5-7 Influence factor I_F for footing at a depth D. Use actual footing width and depth dimension for thi
D/B ratio. Use program FFACTOR for values to avoid interpolation.

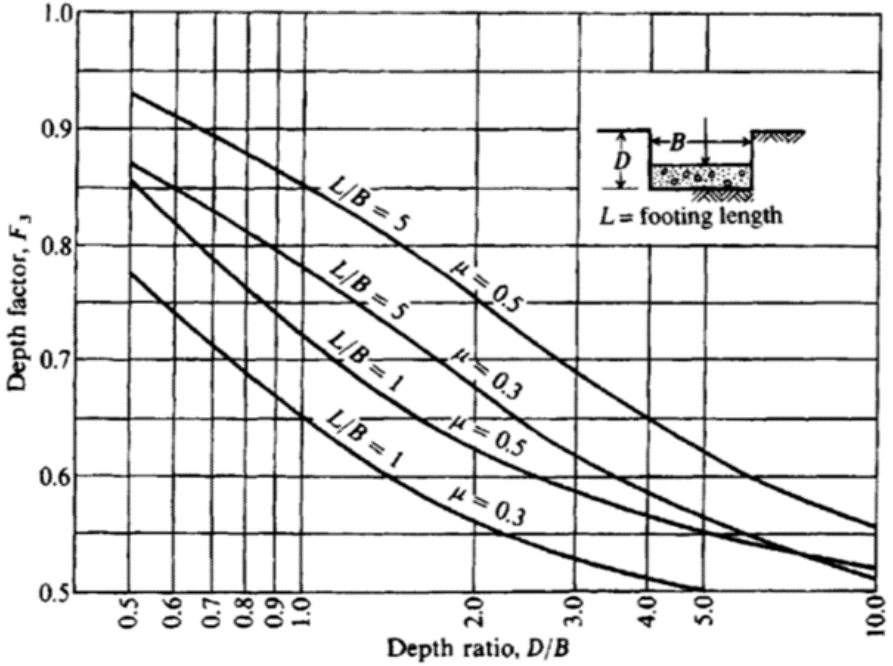


TABLE 5-2

Values of I_1 and I_2 to compute the Steinbrenner influence factor I_s for use in Eq. (5-16*a*) for several $N = H/B'$ and $M = L/B$ ratios

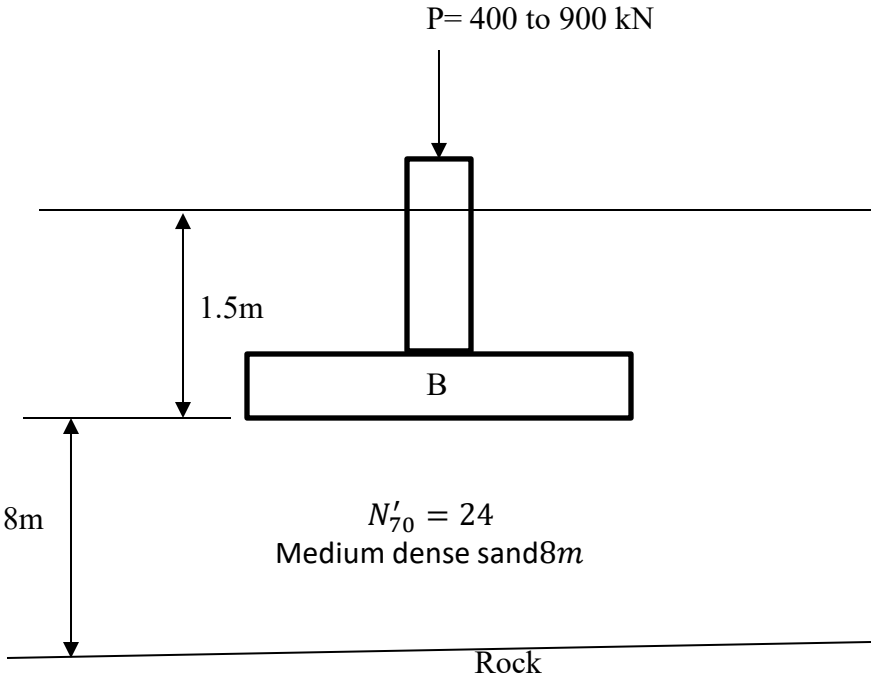
N		$M = 1.0$	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
0.2	I_1 =	0.009	0.008	0.008	0.008	0.008	0.008	0.007	0.007	0.007	0.007	0.007
	I_2 =	0.041	0.042	0.042	0.042	0.042	0.042	0.043	0.043	0.043	0.043	0.043
0.4		0.033	0.032	0.031	0.030	0.029	0.028	0.028	0.027	0.027	0.027	0.027
		0.066	0.068	0.069	0.070	0.070	0.071	0.071	0.072	0.072	0.073	0.073
0.6		0.066	0.064	0.063	0.061	0.060	0.059	0.058	0.057	0.056	0.056	0.055
		0.079	0.081	0.083	0.085	0.087	0.088	0.089	0.090	0.091	0.091	0.092
0.8		0.104	0.102	0.100	0.098	0.096	0.095	0.093	0.092	0.091	0.090	0.089
		0.083	0.087	0.090	0.093	0.095	0.097	0.098	0.100	0.101	0.102	0.103
1.0		0.142	0.140	0.138	0.136	0.134	0.132	0.130	0.129	0.127	0.126	0.125
		0.083	0.088	0.091	0.095	0.098	0.100	0.102	0.104	0.106	0.108	0.109
1.5		0.224	0.224	0.224	0.223	0.222	0.220	0.219	0.217	0.216	0.214	0.213
		0.075	0.080	0.084	0.089	0.093	0.096	0.099	0.102	0.105	0.108	0.110
2.0		0.285	0.288	0.290	0.292	0.292	0.292	0.292	0.292	0.291	0.290	0.289
		0.064	0.069	0.074	0.078	0.083	0.086	0.090	0.094	0.097	0.100	0.102
3.0		0.363	0.372	0.379	0.384	0.389	0.393	0.396	0.398	0.400	0.401	0.402
		0.048	0.052	0.056	0.060	0.064	0.068	0.071	0.075	0.078	0.081	0.084
4.0		0.408	0.421	0.431	0.440	0.448	0.455	0.460	0.465	0.469	0.473	0.476
		0.037	0.041	0.044	0.048	0.051	0.054	0.057	0.060	0.063	0.066	0.069
5.0		0.437	0.452	0.465	0.477	0.487	0.496	0.503	0.510	0.516	0.522	0.526
		0.031	0.034	0.036	0.039	0.042	0.045	0.048	0.050	0.053	0.055	0.058
6.0		0.457	0.474	0.489	0.502	0.514	0.524	0.534	0.542	0.550	0.557	0.563
		0.026	0.028	0.031	0.033	0.036	0.038	0.040	0.043	0.045	0.047	0.050
7.0		0.471	0.490	0.506	0.520	0.533	0.545	0.556	0.566	0.575	0.583	0.590
		0.022	0.024	0.027	0.029	0.031	0.033	0.035	0.037	0.039	0.041	0.043
8.0		0.482	0.502	0.519	0.534	0.549	0.561	0.573	0.584	0.594	0.602	0.611
		0.020	0.022	0.023	0.025	0.027	0.029	0.031	0.033	0.035	0.036	0.038
9.0		0.491	0.511	0.529	0.545	0.560	0.574	0.587	0.598	0.609	0.618	0.627
		0.017	0.019	0.021	0.023	0.024	0.026	0.028	0.029	0.031	0.033	0.034
10.0		0.498	0.519	0.537	0.554	0.570	0.584	0.597	0.610	0.621	0.631	0.641
		0.016	0.017	0.019	0.020	0.022	0.023	0.025	0.027	0.028	0.030	0.031
20.0		0.529	0.553	0.575	0.595	0.614	0.631	0.647	0.662	0.677	0.690	0.702
		0.008	0.009	0.010	0.010	0.011	0.012	0.013	0.013	0.014	0.015	0.016
500.0		**0.560**	0.587	0.612	0.635	0.656	0.677	0.696	0.714	0.731	0.748	0.763
		0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.001

TABLE 5-2

Values of I_1 and I_2 to compute the Steinbrenner influence factor I_s for use in Eq. (5-16*a*) for several $N = H/B'$ and $M = L/B$ ratios *(continued)*

N		$M = 2.5$	4.0	5.0	6.0	7.0	8.0	9.0	10.0	25.0	50.0	100.0
0.2	I_1 =	0.007	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
	I_2 =	0.043	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044
0.4		0.026	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024
		0.074	0.075	0.075	0.075	0.076	0.076	0.076	0.076	0.076	0.076	0.076
0.6		0.053	0.051	0.050	0.050	0.050	0.049	0.049	0.049	0.049	0.049	0.049
		0.094	0.097	0.097	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098
0.8		0.086	0.082	0.081	0.080	0.080	0.080	0.079	0.079	0.079	0.079	0.079
		0.107	0.111	0.112	0.113	0.113	0.113	0.113	0.114	0.114	0.114	0.114
1.0		0.121	0.115	0.113	0.112	0.112	0.112	0.111	0.111	0.110	0.110	0.110
		0.114	0.120	0.122	0.123	0.123	0.124	0.124	0.124	0.125	0.125	0.125
1.5		0.207	0.197	0.194	0.192	0.191	0.190	0.190	0.189	0.188	0.188	0.188
		0.118	0.130	0.134	0.136	0.137	0.138	0.138	0.139	0.140	0.140	0.140
2.0		0.284	0.271	0.267	0.264	0.262	0.261	0.260	0.259	0.257	0.256	0.256
		0.114	0.131	0.136	0.139	0.141	0.143	0.144	0.145	0.147	0.147	0.148
3.0		0.402	0.392	0.386	0.382	0.378	0.376	0.374	0.373	0.368	0.367	0.367
		0.097	0.122	0.131	0.137	0.141	0.144	0.145	0.147	0.152	0.153	0.154
4.0		0.484	0.484	0.479	0.474	0.470	0.466	0.464	0.462	0.453	0.451	0.451
		0.082	0.110	0.121	0.129	0.135	0.139	0.142	0.145	0.154	0.155	0.156
5.0		0.553	0.554	0.552	0.548	0.543	0.540	0.536	0.534	0.522	0.519	0.519
		0.070	0.098	0.111	0.120	0.128	0.133	0.137	0.140	0.154	0.156	0.157
6.0		0.585	0.609	0.610	0.608	0.604	0.601	0.598	0.595	0.579	0.576	0.575
		0.060	0.087	0.101	0.111	0.120	0.126	0.131	0.135	0.153	0.157	0.157
7.0		0.618	0.653	0.658	0.658	0.656	0.653	0.650	0.647	0.628	0.624	0.623
		0.053	0.078	0.092	0.103	0.112	0.119	0.125	0.129	0.152	0.157	0.158
8.0		0.643	0.688	0.697	0.700	0.700	0.698	0.695	0.692	0.672	0.666	0.665
		0.047	0.071	0.084	0.095	0.104	0.112	0.118	0.124	0.151	0.156	0.158
9.0		0.663	0.716	0.730	0.736	0.737	0.736	0.735	0.732	0.710	0.704	0.702
		0.042	0.064	0.077	0.088	0.097	0.105	0.112	0.118	0.149	0.156	0.158
10.0		0.679	0.740	0.758	0.766	0.770	0.770	0.770	0.768	0.745	0.738	0.735
		0.038	0.059	0.071	0.082	0.091	0.099	0.106	0.112	0.147	0.156	0.158
20.0		0.756	0.856	0.896	0.925	0.945	0.959	0.969	0.977	0.982	0.965	0.957
		0.020	0.031	0.039	0.046	0.053	0.059	0.065	0.071	0.124	0.148	0.156
500.0		0.832	0.977	1.046	1.102	1.150	1.191	1.227	1.259	1.532	1.721	1.879
		0.001	0.001	0.002	0.002	0.002	0.003	0.003	0.003	0.008	0.016	0.031

Problem 2: The geotechnical consultant on a foundation project has obtained the soil data and profile as shown on the following Figure. A best average of N values gave N'_{70} = 20. Column loads including dead and live loads are estimated in the range of 450 to 900 kN.



Required: Recommend q_a for this project so that ΔH is limited to not over 25 mm.

Solution.

Step-l:

Convert N_{70} *to* N_{55}, giving $N_{55} = 20(\frac{70}{55}) = 25.45$. Use $N_{55} = 25$.

$$q_a = (\frac{N_{55}}{0.08})(\frac{B+0.3}{B})(1 + 0.33\frac{D}{B}) \qquad \text{but } (1 + 0.33\frac{D}{B}) \leq 1.33$$

Solution:

B (m)	$1 + 0.33\frac{D}{B}$	q_a, kPa (rounded)
1.2	1.33	650 (probably no B< 1.5)
2.0	1.25	515
3.0	1.17	440

The actual soil pressure q for the given range of column loads and for B = 1.5 m is from

$q = \frac{P}{A} = \frac{450}{1.5x1.5} = 200$ kPa to $q = \frac{P}{A} = \frac{900}{1.5x1.5} = 400$ kPa.

Both of these soil pressures are much less than q_a in the foregoing table.

Tentatively recommend q_a = 250 kPa.

Maximum allowable soil pressure, as an approximate average of the three table values, is about 500 kPa (actual average = $\frac{650+515+440}{3} = 535$) with a maximum settlement ΔH ~ 25 mm.

Step 2. Check settlement for q_a = 250 kPa.

$B^2\ q_a = P_{av}$ $P_{av} = \frac{450+900}{2} = 675$ kPa

$B^2 = \frac{P_{av}}{q_a} = \frac{675}{250} = 2.7$

$B = \sqrt{(2.7)} = 1.6$m

For B x L = 1.6 X 1.6m, M=$\frac{L}{B}=\frac{1.6}{1.6}$=1.0 N=$\frac{H}{B'}$ $B'=\frac{B}{2}=\frac{1.6}{2}=0.8$ H=8m

N=$\frac{8}{0.8}$=10

Table 5-2 $\boldsymbol{I_1}$=0.498 I_2**=0.016**

Table 2-7: **C**ommonly used for sand, μ**=0.3**

I_s**=** $\boldsymbol{I_1}$ **+** $\frac{1-2\mu}{1-\mu}I_2$**= 0.498 +** $\frac{1-2x0.3}{1-0,3}$ 0.016**= 0.507**

Figure 5-7: $\frac{D}{B}=\frac{1.5}{1.6}$**=0.9** $\frac{L}{B}=\frac{1.6}{1.6}$=1.0 and μ**=0.3** I_F**=0.65**

From **Table 5-6** we estimate E_s for a normally consolidated sand as

E_s= 500(N + 15) = 500(25 + 15) = 20000 kPa (Note: use of N_{55})

Using E_s= 2600 N = 2600(25) = 65000 kPa (also N_{55})

Using E_s= 7000 √N, = 7000 W = 7000 √25 = 35000 kPa

From **Table 2-8** the value of 20 MPa appears reasonable (and conservative). Substituting values into
With four contributing corners m = 4.

ΔH = $q_0 B' \frac{1-\mu^2}{E_s} m\, I_s I_F$ = 250(0.8) $\frac{1-0.30^2}{20x1000}$(4)(0.507)(0.65)(1000) = 12 mm (for q_a=250 kPa and E_s=20000 kPa)

(The factor 1000 converts MPa to kPa and m to mm).

For E_s= 65000 kPa,

$\Delta H = 12(\frac{20}{65}) = 3.7$ mm

Here we can also obtain ΔH for maximum q_a=500kPa

$$\frac{\Delta H}{25} = \frac{q_{a.used}}{q_{a.max}}$$

$\Delta H = 25(\frac{250}{500}) = 12.5$mm

It would appear that in the range of B = 1.5 to 2.5 m the settlements will be well under 25 mm and differential settlements (difference in settlements between adjacent footings of different size) will be acceptable.

An 'averaged' E_s could have been used but was not needed as the minimum value gives acceptable AH and great computational refinement is not needed at this preliminary stage of design.

Recommend: q_a= 250 kPa

ΔH = under 25 mm

TABLE 5-6

Equations for stress-strain modulus E_s by several test methods

E_s in kPa for SPT and units of q_c for CPT; divide kPa by 50 to obtain ksf. The N values should be estimated as N_{55} and not N_{70}. Refer also to Tables 2-7 and 2-8.

Soil	SPT	CPT
Sand (normally consolidated)	$E_s = 500(N + 15)$ $= 7000\sqrt{N}$ $= 6000N$ — — — ‡$E_s = (15\,000 \text{ to } 22\,000) \cdot \ln N$	$E_s = (2 \text{ to } 4)q_u$ $= 8000\sqrt{q_c}$ — — — $E_s = 1.2(3D_r^2 + 2)q_c$ *$E_s = (1 + D_r^2)q_c$
Sand (saturated)	$E_s = 250(N + 15)$	$E_s = Fq_c$ $e = 1.0 \quad F = 3.5$ $e = 0.6 \quad F = 7.0$
Sands, all (norm. consol.)	¶$E_s = (2600 \text{ to } 2900)N$	
Sand (overconsolidated)	†$E_s = 40\,000 + 1050N$ $E_{s(\text{OCR})} \approx E_{s,\text{nc}}\sqrt{\text{OCR}}$	$E_s = (6 \text{ to } 30)q_c$
Gravelly sand	$E_s = 1200(N + 6)$ $= 600(N + 6) \quad N \le 15$ $= 600(N + 6) + 2000 \quad N > 15$	
Clayey sand	$E_s = 320(N + 15)$	$E_s = (3 \text{ to } 6)q_c$
Silts, sandy silt, or clayey silt	$E_s = 300(N + 6)$	$E_s = (1 \text{ to } 2)q_c$
	If $q_c < 2500$ kPa use $\quad$ $^{\$}E_s' = 2.5q_c$ $2500 < q_c < 5000$ use $\quad E_s' = 4q_c + 5000$ where E_s' = constrained modulus $= \dfrac{E_s(1-\mu)}{(1+\mu)(1-2\mu)} = \dfrac{1}{m_v}$	
Soft clay or clayey silt		$E_s = (3 \text{ to } 8)q_c$

TABLE 2-8

Value range* for the static stress-strain modulus E_s for selected soils (see also Table 5-6)

Field values depend on stress history, water content, density, and age of deposit

Soil	E_s, MPa
Clay	
Very soft	2–15
Soft	5–25
Medium	15–50
Hard	50–100
Sandy	25–250
Glacial till	
Loose	10–150
Dense	150–720
Very dense	500–1440
Loess	15–60
Sand	
Silty	5–20
Loose	10–25
Dense	50–81
Sand and gravel	
Loose	50–150
Dense	100–200
Shale	150–5000
Silt	2–20

*Value range is too large to use an "average" value for design.

Soils Settlement:

Soils Settlement:

Soils Settlement:

- SPT is widely used to obtain the bearing capacity of soils directly.

- One of the earliest published relationships was that of **Terzaghi and Peck** (1967).

- **Meyerhof** (1956, 1974) published equations for computing the allowable bearing capacity for a 25-mm settlement.

- Considering the accumulation of field observations and the stated opinions of the authors and others, this **author adjusted the Meyerhof equations** for an approximate 50 percent increase in allowable bearing capacity to obtain the following:

$$q_a = \frac{N}{F_1} k_d \qquad B \leq F_4 \qquad (1)$$

$$q_a = \frac{N}{F_2} \left(\frac{B+F_3}{B}\right)^2 k_d \qquad B > F_4 \qquad (2)$$

Where, q_a = allowable bearing pressure for ΔH_0= 25-mm or 1-in. settlement, kPa.

$$\boldsymbol{k_d}=\mathbf{1}+\mathbf{0.33}\frac{\boldsymbol{D}}{\boldsymbol{B}} \leq \mathbf{1.33} \text{ (Meyerhof)}$$

F factors as follows(SI Unit):

	N_{55}	N'_{70}
F_1	0.05	0.04
F_2	0.08	0.06
F_3	0.3	0.06
F_4	1.2	0.06

In these equations the allowable soil pressure is for an assumed 25-mm settlement. In general the allowable pressure for any settlement ΔH_j is:

$$\boldsymbol{q'_a}=\frac{\boldsymbol{\Delta H_j}}{\boldsymbol{\Delta H_0}}$$

Where, $\boldsymbol{\Delta H_0}$=25mm

$\boldsymbol{\Delta H_j}$=actual settlement that can be tolerated, in millimeters

Example: Find q_a from the diagram from the following data:

N_{70}= 24, Footing depth, D=1.0m footing width, B=3.0m

Solution:

Here, B=3.0 and F_4=1.2

since, B> F_4 use $q_a = \frac{N_{55}}{F_2}\left(\frac{B+F_3}{B}\right)^2 k_d$

F_2=0.08, F_3=0.3

$N_{55} = \frac{70}{55} N_{70} = \frac{70}{55} x24 = 30 > 24$

$\boldsymbol{k_d = 1 + 0.33\frac{D}{B} \leq 1.33}$

$\boldsymbol{k_d = 1 + 0.33\frac{1}{3} = 1.11 < 1.33}$

Substituting value in Following equation:

$$q_a = \frac{N_{55}}{F_2}\left(\frac{B+F_3}{B}\right)^2 k_d$$

$$= \frac{30}{0.08}\left(\frac{3.0+0.3}{3.0}\right)^2 1.11$$

$$= 503.66 \approx 500 \text{ kPa}$$

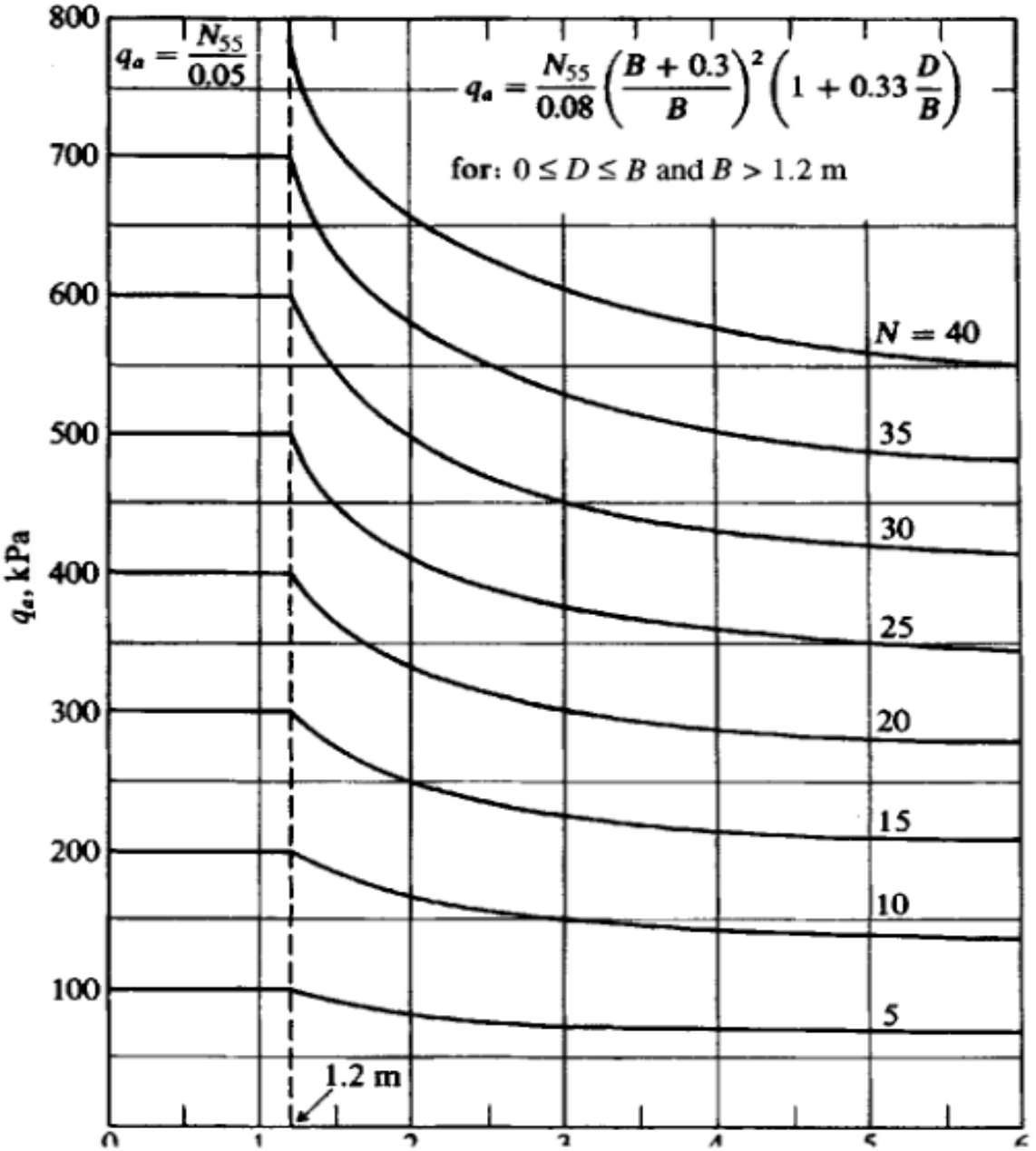


Figure 4-7 Allowable bearing capacity for **surface-loaded** footings with settlement limited to approximately 25 mm. Equation used is shown on figure.

Problem 4-8.

The average N'_{70}Nj0 blow count = 6 in the effective zone for a footing located at D = 1.6 m (blow count average in range from 1- to 4-m depth).

Required. What is the allowable bearing capacity for a 40-mm settlement?

Assume B> $\boldsymbol{F_4}$ where F_4=1.2

Use equation $\boldsymbol{q_a = \frac{N_{55}}{F_2}\left(\frac{B+F_3}{B}\right)^2 k_d}$

with **F2 = 0.08** and F3 = **0.30**

$$\boldsymbol{N_{55} = \frac{70}{55} N_{70} = \frac{70}{55} x6 = 9 > 6}$$

$$\boldsymbol{k_d = 1 + 0.33\frac{D}{B} \leq 1.33}$$

For 25mm settlement

Let B=1.5

$$q_a = \frac{N_{55}}{F_2}\left(\frac{B+F_3}{B}\right)^2 k_d \qquad k_d = 1 + 0.33\frac{1.6}{1.5} = 1.352 > 1.33$$

use k_d=1.33

$$q_a = \frac{9}{0.08}\left(\frac{1.5+0.3}{1.5}\right)^2 x\,1.33 = 215.46 \text{ kpa}$$

For **B=3.0**

$$q_a = \frac{N_{55}}{F_2}\left(\frac{B+F_3}{B}\right)^2 k_d \qquad k_d = 1 + 0.33\frac{1.6}{3.0} = 1.176 < 1.33 \text{ 0k}$$

$$q_a = \frac{N_{55}}{F_2}\left(\frac{B+F_3}{B}\right)^2 k_d$$

$$= \frac{9}{0.08}\left(\frac{3.0+0.3}{3}\right)^2 1.176 = \mathbf{160.083 \text{ kpa}}$$

Suggested $\boldsymbol{q_a}$=200 kPa for 25mm settlement

For 40mm settlement

$$\boldsymbol{q'_a}=\frac{\boldsymbol{\Delta H_j}}{\boldsymbol{\Delta H_0}} \text{ x } \boldsymbol{q_a}= \frac{\boldsymbol{40}}{\boldsymbol{25}}\text{x200=320 kpa}$$

Thanks