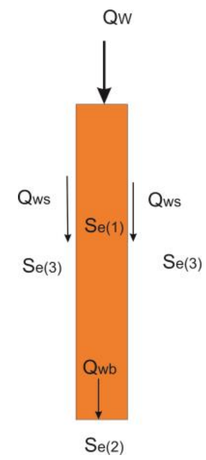
Total settlement of pile



The total settlement of a pile under a vertical working load Q_W is given by:

$S_e = S_{e(1)} + S_{e(2)} + S_{e(3)}$

$S_{e(1)}$: Elastic settlement of pile

$S_{e(2)}$: Settlement of pile caused by the load at the pile tip

$S_{e(3)}$: Settlement of pile caused by the load transmitted along the pile shaft

If the pile material is assumed to be elastic, the deformation of the pile shaft can be evaluated, in accordance with the fundamental principles of mechanics of materials, as

$$S_{e(1)} = \frac{(Q_{Wb} + \xi Q_{WS})L}{A_b E_P}$$

Q_{Wb}: Working load at the pile base
Q_{WS} : load carried by frictional (skin) resistance under working load condition
A_P: Area of cross section of pile.
L: length of pile
E_P: modulus of elasticity of the pile material
The magnitude of varies between 0.5 and 0.67 and will depend on the nature of the distribution of the unit friction (skin) resistance f along the pile shaft.
The settlement of a pile caused by the load carried at the pile end may be expressed in the form:

$$S_{e(2)} = \frac{q_{Wb} D}{E_S}(1 - \mu_S^2) I_{Wb}$$

Where:
D: width or diameter of pile.
q_{Wb}: Base load per unit area $= \frac{Q_{Wb}}{A_b}$
E_S: Modulus of elasticity of the soil at or under the base
μ_S: Poisson's ratio of soil.
I_{Wb}: Influence factor$\approx$ 0.85
The settlement of a pile caused by the load carried by the pile shaft is given by a relation

$$S_{e(3)} = \left(\frac{Q_{Ws}}{PL}\right)\frac{D}{E_S}(1 - \mu_S^2) I_{WS}$$

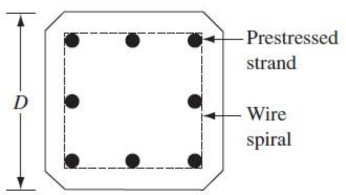
Where
I_{WS}: is influence factor.

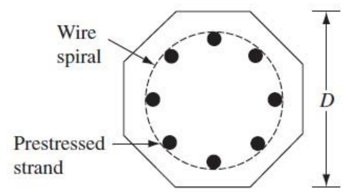
$$I_{WS} = 2 + 0.35\sqrt{\frac{L}{D}}$$

Table 1 Typical prestressed concrete pile in use

Pile shape[a]	D (mm)	Area of cross section (cm^2)	Perimeter (mm)	Number of strands: 12.7-mm diameter	Number of strands: 11.1-mm diameter	Minimum effective prestress force (kN)	Section modulus (m^3 × 10^{-3})	Design bearing capacity (kN), Strength of concrete (MN/m^2): 34.5	Design bearing capacity (kN), Strength of concrete (MN/m^2): 41.4
S	254	645	1016	4	4	312	2.737	556	778
O	254	536	838	4	4	258	1.786	462	555
S	305	929	1219	5	6	449	4.719	801	962
O	305	768	1016	4	5	369	3.097	662	795
S	356	1265	1422	6	8	610	7.489	1091	1310
O	356	1045	1168	5	7	503	4.916	901	1082
S	406	1652	1626	8	11	796	11.192	1425	1710
O	406	1368	1346	7	9	658	7.341	1180	1416
S	457	2090	1829	10	13	1010	15.928	1803	2163
O	457	1729	1524	8	11	836	10.455	1491	1790
S	508	2581	2032	12	16	1245	21.844	2226	2672
O	508	2136	1677	10	14	1032	14.355	1842	2239
S	559	3123	2235	15	20	1508	29.087	2694	3232
O	559	2587	1854	12	16	1250	19.107	2231	2678
S	610	3658	2438	18	23	1793	37.756	3155	3786
O	610	3078	2032	15	19	1486	34.794	2655	3186

[a]S = square section; O = octagonal section





Example:

The allowable working load on a prestressed concrete pile 21-m long that has been driven into sand is 502 kN. The pile is octagonal in shape with D= 356 mm. Skin resistance carries 350 kN of the allowable load, and point bearing carries the rest. Use $E_P = 21 * \frac{10^6\ KN}{m2}$, $E_s = 25 * 10^3 KN/m2$, $\mu_s = 0.35$ and $\xi = 0.65$. Determine the settlement of the pile.

Ans:

$$\boldsymbol{S_{e(1)} = \frac{(Q_{Wb} + \xi Q_{WS})L}{A_b E_P}}$$

For D = 356 mm2, $A_b = 1045mm2$, P = 1.168m

$Q_u = 502KN, and\ \ Q_{ws} = 350KN,\ therefore\ Q_{wb} = 152KN$

$$\boldsymbol{S_{e(1)} = \frac{(Q_{Wb} + \xi Q_{WS})L}{A_b E_P} = \frac{(152 + 0.65 * 350)21m}{0.1045 * 21 * 10^6 KN/m2} = 3.63mm}$$

$$\boldsymbol{S_{e(2)} = \frac{q_{Wb} D}{E_S}(1 - \mu_S^2) I_{Wb}}$$

$q_{wb} = \frac{Q_{wb}}{A_b} = \frac{152KN}{0.1045M2} = 1454.5KN/m2$, $I_{wb} = 0.85$

$$\boldsymbol{S_{e(2)} = \frac{1454.5 * 0.356}{25 * 10^3}(1 - 0.35^2)0.85 = 15.5\text{mm}}$$

$$\boldsymbol{S_{e(3)} = (\frac{Q_{Ws}}{PL})\frac{D}{E_S}(1 - \mu_S^2) I_{WS}}$$

$I_{WS} = 2 + 0.35\sqrt{\frac{L}{D}} = 2 + 0.35\sum\frac{21}{0.356} = 4.688$

$$\boldsymbol{S_{e(3)} = \left(\frac{350}{1.168*21}\right)\frac{0.356}{25*10^3}(1-0.35^2)4.688 = 0.83mm}$$

$\mathbf{S_e = S_{e(1)} + S_{e(2)} + S_{e(3)}}$

$\mathbf{S_e = 3.63 + 15.5 + 0.83}$ **= 19.96 > 25mm ok**

Problems:

Problem1:

A concrete pile is 18 m long and has a cross section of 0.406 m * 0.406 m. The pile is embedded in a sand having γ =16 kN/m3 and $\emptyset$ = 37°. The allowable working load is 900 kN. If 600 kN are contributed by the frictional resistance and 300 kN are from the base load, determine the elastic settlement of the pile. Given: $E_P = 2.1 * \frac{10^6\,KN}{m2}$, $E_s = 30 * 10^3 KN/m2$, $\mu_s = 0.38$ and $\xi = 0.57$.

Problem2:

Solve Problem 1 with the following: length of pile = 15 m, pile cross section = 0.305 m * 0.305 m, allowable working load = 338 kN, contribution of frictional resistance to working load = 280 kN, E_p = 21 *10^6 KN/m2, E_s = 30,000 KN/m2. $\mu_s = 0.3$ and $\xi = 0.62$.