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Modified Schmertmann's Method (1978)for Calculating Settlement In Sand Soils By Using Integration

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***Abstract*— The design of footing on sand soils is often controlled by settl-ment rather than bearing capacity. Therefore, settlement predictions are essential in the design of shallow foundations. Schmertmann's (1970) method is one of the most rational methods for computing settlements of footings in granular soils, and commonly used world-wide. In order to consider the effect of footing shape on foundation settlement, Schmertmann's method relies on a strain influence factor that varies with depth. Schmertmann's (1978) proposed separate strain influence factors for axi-symmetric and plane strain loading situations representing square, rectangular and strip footings, respectively. The procedure for calculating elastic settlement using Schmertmann's method (1978) is numerical solution depends on plotting variation of the strain influence factor diagram with depth to same scale. The strain influence factor diagram is divided into layers ,and the strain influence factor is calculated at the center of each layer. In this paper, a new modified equation for Schmertmann's method (1978) is presented by using the integration. The new modified equation is depending on mathematical solution that eliminate the necessity of plotting variation of the strain influence factor diagram with depth to same scale to calculate the settlement. The new modified equation can be used for more cases for square, rectangular and strip footings. A numerical problem has been solved by using both methods, the basic Schmertmann,s method1978 and the presented new modified equation to examine the validity of the new approach and achieve a comparison between the two procedures .The results shows that for the cases of square, rectangular and strip footings, using the new modified Schmertmann's method provides accurate solution. It has been concluded that the new approach is suitable for calculating the settlement in granular soils for square, rectangular and strip footings.**

***Index Terms*—Settlement in sand soils, Modified Schmertmann's Method (1978) by using integration.**

I. INTRODUCTION

To design shallow foundation the bearing capacity must be satisfied as well as the settlement [1]. settlement criterion is more dominant due to the type of the structure [2]. When the settlement limit is above the maximum limit, one of the following parameters must be revised, firstly the foundation dimension and geometry, secondly the soil condition, which can be reinforced [3]. Schmertmann's (1970) proposed a procedure for calculating the settlement for shallow foundation on sandy soils be dividing the soil beneath the foundation into separate layers and then calculating the settlement of each layer, the summation of the settlements of all layer represent the total settlement of the soil. The mentioned procedure is applicable for the compressible layer only [4]. The method is based on assumed vertical strain distribution that develops beneath the footing [4].Schmertmann's (1970) shows that, this method is also referred to "2B- 0.6" method, where B is the width of the foundation, which shows the approximation for the strain influence diagram developed by Schmertmann's to calculate settlements over an area of influence that equal to 2B beneath the foundation [4]. Many studies showed that this method need for subtle modification to the strain influence diagram in order to increase the applicable parameters for the shapes and load, this method is referred to as the " Schmertmann's (1970)" method that uses the improved strain influence diagrams presented by Schmertmann's (1978) [4]. Figure(1) shows a comparison between the two methods, the original and the modified one [4].

The settlement is calculated from the expression:

$s_i = c_1 c_2 q_n \sum_{i=1}^{i=n} \frac{I_z}{E_s} \Delta z$ ....(1)

Where:

C_1=correction factor for embedment of foundation

$C_1 = 1 - 0.5\frac{q_o}{q_n}$ ………………(2)

C_2=correction factor to account for creep in soil

$C_2 = 1 + 0.2 log\frac{t}{0.1}$ ……………(3)

t=time in years

$E_s = 2.5 q_c$ …………(4) (for square and circular foundations)[5]

$E_s = 3.5 q_c$ …………(5) (for strip foundations)[5]

q_c= cone penetration resistance

$E_{s(rectangle)} = (1 + 0.4 log\frac{L}{B}) \times E_{s(square)}$.......(6)[5]

E_s=Young's modulus of the elastic medium

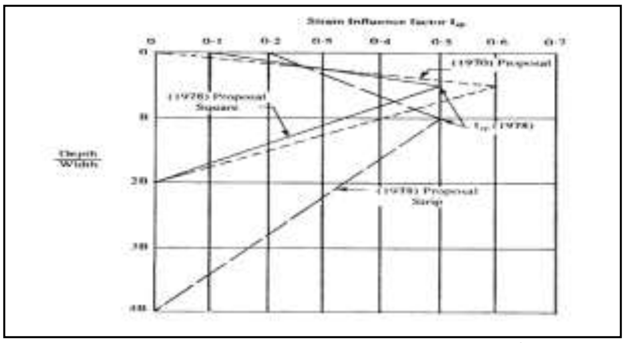
I_z =strain influence factor

q_n = The intensity of the uniformly distributed load at the base of the foundation.

$q_n = q_u - \gamma D_f$ ....(7)

q_u =Stress at the level of the foundation

In order to obtain the strain influence factor, I_z at the midpoint of each soil layer, it is necessary to construct the strain influence diagram.



Figure(1) comparison between the original and the modified strain influence diagrams [4]

The influence factor diagram for a rectangular foundation can be

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obtained by interpolating between square and strip footing [5].
The peak value of influence factor can be calculated by

$$I_{z(peak)} = 0.5 + 0.1\sqrt{\frac{q_n}{\sigma'_{vo}}} \text{..............(8)}$$

Where :
σ'_{vo} : overburden pressure at the depth where peak occurs.
To construct the strain influence diagram for a particular case
-For axisymmetric footings (square and round)[5]
I_{zo}=0.1 at depth(z)=0
I_z = 0 at depth(z) = 2B
Maximum I_{zp} occurs at a depth of B/2 and has a value of:

$$I_{z(peak)} = 0.5 + 0.1\sqrt{\frac{q_n}{\sigma'_{vo}}}.$$

-For plane strain footings (L/B $\geq$ 1 0) [5]
I_{zo} = 0.2 at depth(z)= 0
I_z= 0 at depth(z) = 4B
Maximum I_{zp} occurs at a depth of B and has a value of:

$$I_{z(peak)} = 0.5 + 0.1\sqrt{\frac{q_n}{\sigma'_{vo}}}.$$

For rectangular footings [5]
The following relations are suggested by Salgado (2008) for interpolation of I_z at depth (z) = 0, $\frac{z_1}{B}$, and $\frac{z_2}{B}$ for rectangular foundations[1].

-I_{zo} at depth(z) = 0

$$I_{zo} = 0.1 + 0.0111\left(\frac{L}{B} - 1\right) \leq 0.2 \text{ .... (9)}$$

I_z = 0 at depth(z) = z_2

$$\frac{z_2}{B} = 2 + 0.222\left(\frac{L}{B} - 1\right) \leq 4. \text{ .... (10)}$$

Maximum I_{zp} occurs at a depth of z=z_1 and has a value of:

$$I_{z(peak)} = 0.5 + 0.1\sqrt{\frac{q_n}{\sigma'_{vo}}}.$$

$$\frac{z_1}{B} = 0.5 + 0.0555\left(\frac{L}{B} - 1\right) \leq 1. \text{ .... (11)}$$

Where: L=Length of footing ,B=Width of footing.
The procedure for calculating elastic settlement using Eq. (1) is given in the below steps and shown in figure (2) [5].
Step 1. Plot the foundation and the variation of I_z with depth to scale (Figure 2a).
Step 2. Plot the actual variation of E_s with depth(Figure 2b).
Step 3. Approximate the actual variation of E_s into a number of layers of soil having a constant E_s, such as $E_{s(1)}$,$E_{s(2)}$, . . , $E_{s(i)}$,. . . $E_{s(n)}$ (Figure 2b).
Step 4. Divide the soil layer from z = 0 to z = z_2 into a number of layers by drawing horizontal lines. The number of layers will depend on the break in continuity in the I_z and E_s diagrams.
Step 5. Prepare a table to obtain $\sum_{i=1}^{i=n}\frac{I_z \Delta_z}{E_s}$
Step 6. Calculate C_1 and C_2.
Step 7. Calculate S_i from Eq. (1).

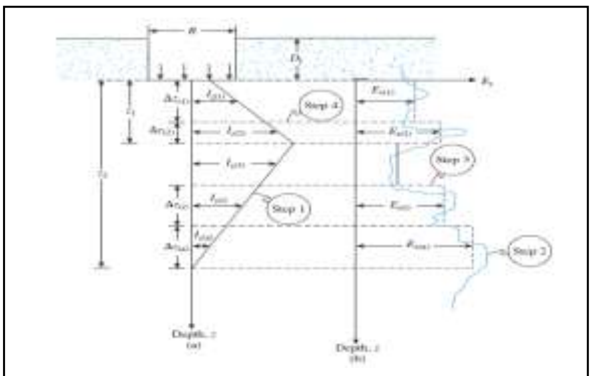


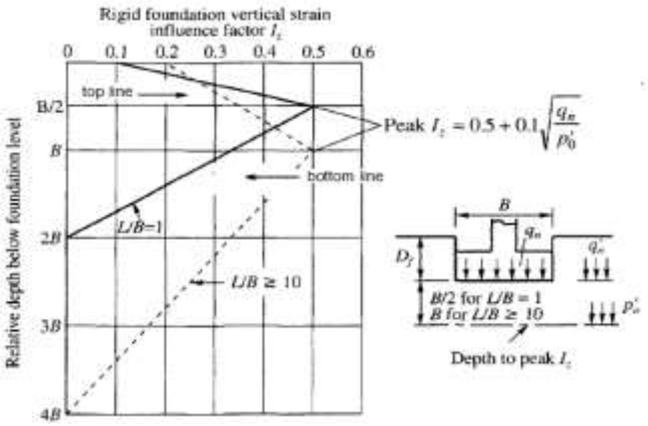
Figure (2) Procedure for calculation of Si using the strain influence factor[5]

II. MODIFIED SCHMERTMANN'S METHOD(1978).

In this paper, a new modified equation for Schmertmann's method(1978) is presented by using the integration. The new modified equation is depending on a mathematical solution, *the modified equation* for Schmertmann's(1978) can be expressed as:

$$s_i = c_1 c_2 q_n \sum_{i=1}^{i=n}\int_a^b \frac{I_z}{E_s}\,dz \text{ ....(12)}$$

In this modified equation, the term of integration need equations of (I_z),the equations of(I_z)can be found from the figure(3) and can be expressed as flows for square , strip and rectangular foundation:



Figure(3)Equation of I_z for top and bottom lines

-For square footing:

$$I_z = \frac{2Z}{B}(I_{zp} - 0.1) + 0.1 \text{ ....(13) for top line}$$

$$I_z = \frac{2B - Z}{1.5B} I_{zp}. \text{ ....(14) for bottom line}$$

-For strip footing:

$$I_z = \frac{Z(I_{zp} - 0.2)}{B} + 0.2 \text{ ....(15) for top line}$$

$$I_z = \frac{4B - Z}{3B} I_{zp} \text{ ....(16) for bottom line}$$

-For rectangular footing:

$$I_z = \frac{Z}{z_1}(I_{zp} - I_{zo}) + I_{zo} \text{ ....(17) for top line}$$

$$I_z = \frac{Z - z_2}{z_1 - z_2} I_{zp}. \text{ ....(18) for bottom line}$$

The procedure for calculating elastic settlement using Eq. (12) is given below.
Step 1. Plot the foundation and the variation of I_z with depth not to scale as shown in the Figure(2a).
Step 2. Plot the actual variation of E_s with depth as shown in the Figure(2b).
Step 3. Approximate the actual variation of E_s into a number of layers of soil having a constant E_s, such as $E_{s(1)}$,$E_{s(2)}$, . . , $E_{s(i)}$,. . . $E_{s(n)}$ as shown in the Figure(2b).
Step 4. Divide the soil layer from z = 0 to z = z_2 into a number of layers by drawing horizontal lines. The number of layers will depend on the break in continuity in the Iz and E_s diagrams.
Step 5.Find equation of I_z for the top line and bottom line as shown in the figure(3).
Step 6. Prepare a table to obtain $\sum_{i=1}^{i=n}\int_a^b \frac{I_z}{E_s}dz$
Step 7. Calculate C_1 and C_2.
Step 8. Calculate S_i from Eq. (12).

III. NUMERICAL EXAMPLE

Example 1[5]:.

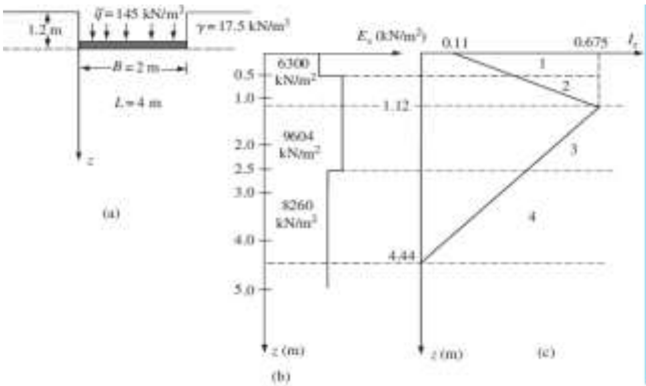
Consider a rectangular foundation 2 m x 4 m in the plan at a depth of 1.2 m in a sand deposit, as shown in Figure (4). Given: γ =17.5 kN/m^3; q'= 145 kN/m^2, and the following approximated variation of (q_c) with (z) shown in table(1)[5]:

Table(1) Relation between (q_c)and depth(z)

Z(m)	q_c(kN/m^2)
0-0.5	2250
0.5-2.5	3430
2.5-5	2950

IV. UNITS

Estimate the elastic settlement of the foundation using the strain influence factor method.



Figure(4)The plot of (Es) versus depth(z) and (Iz) versus (z) [5]

Solution using Schmertmann's method(1978)[5]

From Eq. (11)

$$\frac{z_1}{B} = 0.5 + 0.0555(\frac{L}{B} - 1)$$

$$\frac{z_1}{2} = 0.5 + 0.0555(\frac{4}{2} - 1)$$

$$z_1 = 0.56 \times B = 0.56B = 1.12m$$

From Eq. (10)

$$\frac{z_2}{B} = 2 + 0.222(\frac{L}{B} - 1)$$

$$\frac{z_2}{2} = 2 + 0.222(\frac{4}{2} - 1)$$

$$z_2 = 2.22B = 4.44m$$

From Eq. (9), at z = 0,

$$I_{zo} = 0.1 + 0.0111(\frac{L}{B} - 1)$$

$$I_{zo} = 0.1 + 0.0111(\frac{4}{2} - 1)$$

$$I_{zo} = 0.11$$

$$I_{z(peak)} = 0.5 + 0.1\sqrt{\frac{q_n}{\sigma'_{vo}}}$$

$$I_{zp} = 0.5 + 0.1\sqrt{\frac{145-(1.2\times17.5)}{(1.2+1.12)\times17.5}} = 0.675$$

$$E_s(\text{rect.}) = (1 + 0.4\log\frac{L}{B}) \times E_s(\text{square})$$

$$E_s(\text{rect.}) = (1 + 0.4\log\frac{4}{2}) \times 2.5q_c$$

$$E_s(\text{rect.}) = 2.8q_c$$

The equation for settlement is

$$S_i = c_1 c_2 q_n \sum_0^{2.22z} \frac{I_z}{E_s}\Delta_z$$

$$C_1 = 1 - 0.5\frac{q'_0}{q_n} = 1 - 0.5 \times \frac{21}{145-21} = 0.915$$

$$C_2 = 1 + 0.2\log\frac{t}{0.1} = 1 + 0.2\log\frac{10}{0.1} = 1.4$$

The soil layer is divided into four layers as shown in Figure(4.b) and Figure(4. C). Now the following table(2) can be prepared for calculating the term $\frac{I_z}{E_s}\Delta_z$.

Table(2) The average of the influence factors for each of the layers[5]

Layer no.	Δz (m)	E_s (kN/m^2)	I_z at middle of layer	$\frac{I_z}{E_s}\Delta z$ (m^3/ kN)
1	0.50	6300	0.236	1.87×10^{-5}
2	0.62	9604	0.519	3.35×10^{-5}
3	1.38	9604	0.535	7.68×10^{-5}
4	1.94	8260	0.197	4.62×10^{-5}
				$\Sigma 17.52 \times 10^{-5}$

S_i=0.915*1.4*124*17.52$\times 10^{-5} \times 1000$=27.83mm

Solution using the modified Schmertmann's method(1978):

$$S_i = c_1 c_2 q_n \sum_{i=1}^{i=n} \int_a^b \frac{I_z}{E_s} dz$$

-For rectangular footing:

$$I_z = \frac{z}{z_1}(I_{zp} - I_{zo}) + I_{zo} \quad \text{..................(17) for top line}$$

$$I_z = \frac{z - z_2}{z_1 - z_2} I_{zp}. \quad \text{.................(18) for bottom line}$$

From Eq. (9), at z = 0,

$$I_{zo} = 0.1 + 0.0111(\frac{L}{B} - 1)$$

$$I_{zo} = 0.1 + 0.0111(\frac{4}{2} - 1)$$

$$I_{zo} = 0.11$$

$$I_{z(peak)} = 0.5 + 0.1\sqrt{\frac{q_n}{\sigma'_{vo}}}$$

$$I_{zp} = 0.5 + 0.1\sqrt{\frac{145-(1.2\times17.5)}{(1.2+1.12)\times17.5}} = 0.675$$

$$\frac{z_2}{B} = 2 + 0.222(\frac{L}{B} - 1)$$

$$\frac{z_2}{2} = 2 + 0.222(\frac{4}{2} - 1)$$

$$z_2 = 2.22B = 4.44m$$

$$\frac{z_1}{B} = 0.5 + 0.0555(\frac{L}{B} - 1)$$

$$\frac{z_1}{2} = 0.5 + 0.0555(\frac{4}{2} - 1)$$

$$z_1 = 0.56 \times B = 0.56B = 1.12m$$

$$I_z = \frac{z}{z_1}(I_{zp} - I_{zo}) + I_{zo}$$

$$I_z = \frac{z}{1.12}(0.675 - 0.11) + 0.11$$

$$I_z = \frac{113z}{224} + 0.11 \quad \text{(for top line)}$$

$$I_z = \frac{z - z_2}{z_1 - z_2} I_{zp}$$

$$I_z = \frac{z - 4.44}{1.12 - 4.44} \times 0.675$$

$$I_z = \frac{135\,(4.44 - z)}{664} \quad \text{(for bottom line)}$$

The soil layer is divided into four layers as shown in Figure(4.b) and Figure(4. C). Now the following table(3) can be prepared.

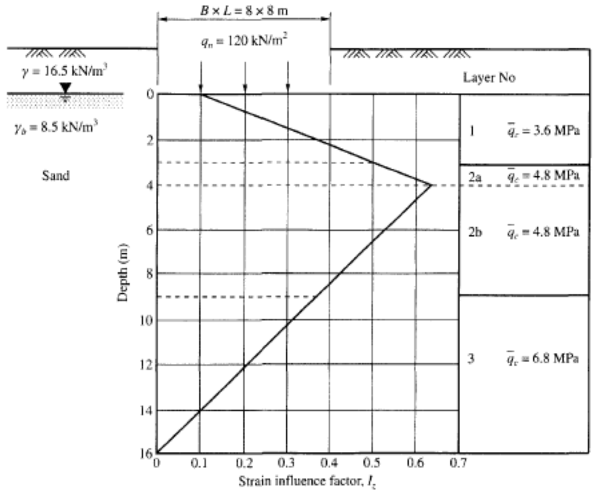
Table(3) Calculation of the influence factors $\sum \int_a^b \frac{I_z}{E_s} dz$ for each of the layers

Layer No.	Dz (m)	Es (kPa)	$\sum \int_a^b \frac{I_z}{E_s} dz$
1	0.5	6300	$\int_0^{0.5} \frac{\frac{113z}{224}+0.11}{6300} dz$ =1.87$\times 10^{-5}$
2	0.62	9604	$\int_{0.5}^{1.12} \frac{\frac{113z}{224}+0.11}{9604} dz$ =3.34$\times 10^{-5}$
3	1.38	9604	$\int_{1.12}^{2.5} \frac{\frac{135(4.44-z)}{664}}{9604} dz$ =7.68$\times 10^{-5}$
4	1.94	8260	$\int_{2.5}^{4.44} \frac{\frac{135(4.44-z)}{664}}{8260} dz$ =4.63$\times 10^{-5}$
			$\sum \int_a^b \frac{I_z}{E_s} dz$ =17.52$\times 10^{-5}$

S_i=0.915*1.4*124*17.52$\times 10^{-5} \times 1000$=27.83mm

Example 2[6]:

A square footing of size 8 x 8 m as shown in the figure(5) is founded at a depth of 2 m below the ground surface in loose to medium dense sand with q_n = 120 kN/m^2. Estimate the elastic settlement by Schmertmann's method. Assume settlement is required at the end of a period of 3 years.



Figure(5) The plot of (Iz) versus depth (z) [6]

Solution using Schmertmann's method(1978):

At the base of the foundation I_{zo} = 0 . 1

$$I_{z(peak)} = 0.5 + 0.1\sqrt{\frac{q_n}{\sigma'_{vo}}}$$

q_n = 120 kN/m^2

σ'_{vo}= 2x 16.5 + 4x8.5 = 67 kN/m^2.

$$I_{zp} = 0.5 + 0.1\sqrt{\frac{120}{67}} = 0.63$$

I_z= 0 a t z = 16m below base level of the foundation. The distribution of I_z is given in figure(4). The equation for settlement is

$$S_i = c_1 c_2 q_n \sum_0^{2z} \frac{I_z}{E_s} \Delta_z$$

$$C_1 = 1 - 0.5\frac{q_0}{q_n} = 1 - 0.5 \times \frac{2\times16.5}{120} = 0.86$$

$$C_2 = 1 + 0.2\log\frac{t}{0.1} = 1 + 0.2\log\frac{3}{0.1} = 1.3$$

Layer (2) is divided into sublayers (2a) and (2b) for computing I_z. The average of the influence factors for each of the layers given in figure(5) are tabulated along with the other calculations in table(4).

Table(4) The average of the influence factors for each of the layers [6]

Layer No.	Δz (cm)	$\bar{q}_c$ (MPa)	E_s (MPa)	I_z (av)	$\frac{I_z \Delta z}{E_s}$
1	300	3.6	14.4	0.3	6.25
2a	100	4.8	19.2	0.56	2.92
2b	500	4.8	19.2	0.50	13.02
3	700	6.8	27.2	0.18	4.63
				Total	26.82

Substituting in the equation for settlement eq.(1)

$$S_i = c_1 c_2 q_n \sum_0^{2z} \frac{I_z}{E_s} \Delta_z$$

S_i=0.86x1.3x0.12x26.82=3.6cm =36 mm.

Solution using the modified Schmertmann's method(1978):

$$s_i = c_1 c_2 q_n \sum_{i=1}^{i=n} \int_a^b \frac{I_z}{E_s} dz$$

-For square footing:

$I_z = \frac{2Z}{B}(I_{zp} - 0.1)+0.1$ ....(13) for top line

$I_z = \frac{2B-Z}{1.5B} I_{zp}$. ....(14) for bottom line

$I_z = \frac{2Z}{8}(0.63 - 0.1)+0.1$

$I_z = 0.1325Z + 0.1$ (for top line)

$I_z = \frac{2x8-Z}{1.5x8}x0.63$.

$I_z = 0.0525\,(16 - z)$ (for bottom line)

Layer (2) is divided into sublayers (2a) and (2b) for computing I_z. The equations of the influence factors for each of the layers are presented as above and can use the integration to calculated$\sum \int_a^b \frac{I_z}{E_s} dz$ as given in figure(5) and the results are tabulated along with the other calculations in table (5).

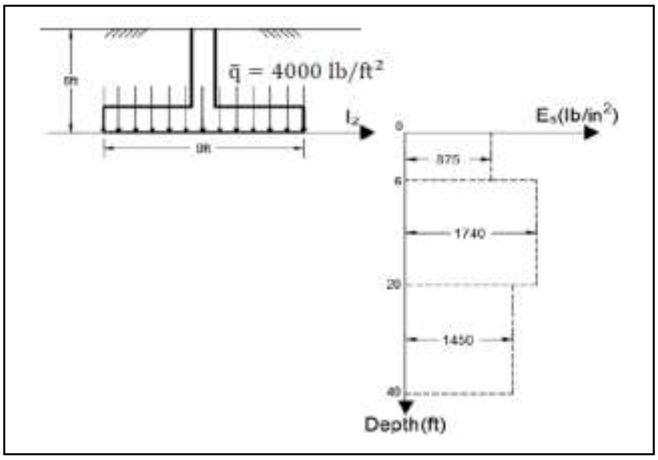
Table(5) Calculation of the influence factors$\sum \int_a^b \frac{I_z}{E_s} dz$ for each of the layers

Layer No.	dz(m)	q'_c (MPa)	E_s (MPa)	E_s (kPa)	$\sum \int_a^b \frac{I_z}{E_s} dz$
1	3	3.6	14.4	14400	$\int_0^3 \frac{0.1325Z+0.1}{14400} dz$=6.2× 10^{-5}
2a	1	4.8	19.2	19200	$\int_3^4 \frac{0.1325Z+0.1}{19200} dz$=2.93× 10^{-5}
2b	5	4.8	19.2	19200	$\int_4^9 \frac{0.0525(16-z)}{19200} dz$=12.98× 10^{-5}
3	7	6.8	27.2	27200	$\int_9^{16} \frac{0.0525(16-z)}{27200} dz$=4.71× 10^{-5}
					$\sum \int_a^b \frac{I_z}{E_s} dz$=26.82× 10^{-5}

S_i=0.86x1.3x0.12x26.82=3.6cm =36 mm.

Example 3[7]:

A continuous foundation resting on a deposit of sand layer is shown in the figure (6), along with the variation of the modulus of elasticity of soil (E_s). Assuming γ=115 Ib/ft^3 and the time = 10 years. Calculate the elastic settlement using strain influence factor.



Figure(6) The plot of (Es) versus depth(z) [7]

Solution using Schmertmann's method(1978)[7]

From Eq. (11)

$\frac{z_1}{B} = 0.5 + 0.0555(\frac{L}{B} - 1)$

$\frac{z_1}{B} = 0.5 + 0.0555(10 - 1)$

$z_1 = 1 \times B = 8ft$

From Eq. (10)

$\frac{z_2}{B} = 2 + 0.222(\frac{L}{B} - 1)$

$\frac{z_2}{B} = 2 + 0.222(10 - 1)$

$z_2 = 4B = 32ft$

From Eq. (9), at z = 0,

$I_{zo} = 0.1 + 0.0111\,(\frac{L}{B} - 1)$

$I_{zo} = 0.1 + 0.0111\,(10 - 1)$

$I_{zo} = 0.2$

$I_{z(peak)} = 0.5 + 0.1\sqrt{\frac{q_n}{\sigma'_{vo}}}$

$I_{zp} = 0.5 + 0.1\sqrt{\frac{4000-(115x5)}{(5+8)x115}} = 0.651$

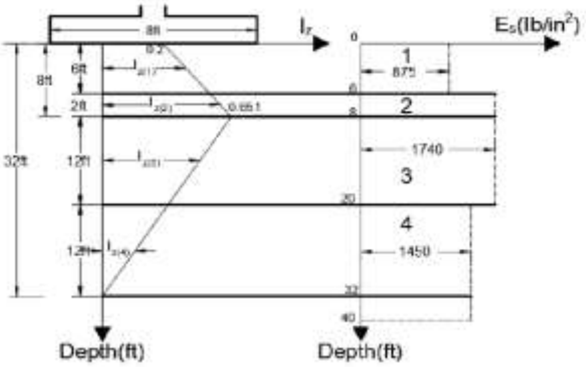
The equation for settlement is

$S_i = c_1 c_2 q_n \sum_0^{4z} \frac{I_z}{E_s} \Delta_z$

$C_1 = 1 - 0.5\frac{q'_o}{q_n} = 1 - 0.5 \times \frac{115x5}{4000-(115x5)} = 0.916$

$C_2 = 1 + 0.2\log\frac{t}{0.1} = 1 + 0.2\log\frac{10}{0.1} = 1.4$

The soil layer is divided into four layers as shown in Figure(7) . Now the following table(6) can be prepared.



Figure(7) The plot of (Iz) versus depth (z) [7]

Table(6) The average of the influence factors for each of the layers

Layer No.	Δz(ft)	E_s(lb/ft²)	I_z at the middle of each layer	$\frac{I_z}{E_s}\Delta z$
1	6	126000	0.369	1.757×10^{-5}
2	2	250560	0.595	$0.474637x10^{-5}$
3	12	250560	0.488	2.337×10^{-5}
4	12	208800	0.163	0.937×10^{-5}
				$\sum_0^{z_2} \frac{I_z}{E_s}\Delta z = 5.506x10^{-5}$

S_i=0.916x1.4x3425x5.506x10^{-5}=0.24183ft

Solution using the modified Schmertmann's method(1978):

$s_i = c_1 c_2 q_n \sum_{i=1}^{i=n} \int_a^b \frac{I_z}{E_s} dz$

-For strip footing:

$I_z = \frac{Z(I_{zp}-0.2)}{B} + 0.2$ ....(15) for top line

$I_z = \frac{4B-Z}{3B} I_{zp}$ ....(16) for bottom line

$\frac{z_1}{B} = 0.5 + 0.0555\,(\frac{L}{B} - 1)$

$\frac{z_1}{B} = 0.5 + 0.0555\,(10 - 1)$

$z_1 = 1 \times B = 8ft$

From Eq. (10)

$\frac{z_2}{B} = 2 + 0.222\,(\frac{L}{B} - 1)$

$\frac{z_2}{B} = 2 + 0.222\,(10 - 1)$

$z_2 = 4B = 32ft$

From Eq. (9), at z = 0,

$I_{zo} = 0.1 + 0.0111\,(\frac{L}{B} - 1)$

$I_{zo} = 0.1 + 0.0111\,(10 - 1)$

$I_{zo} = 0.2$

$I_{z(peak)} = 0.5 + 0.1\sqrt{\frac{q_n}{\sigma'_{vo}}}$

$I_{zp} = 0.5 + 0.1\sqrt{\frac{4000-(115x5)}{(5+8)x115}} = 0.651$

$C_1 = 1 - 0.5\frac{q'_o}{q_n} = 1 - 0.5 \times \frac{115x5}{4000-(115x5)} = 0.916$

$C_2 = 1 + 0.2\log\frac{t}{0.1} = 1 + 0.2\log\frac{10}{0.1} = 1.4$

$I_z = \frac{Z(I_{zp}-0.2)}{B} + 0.2$

$I_z = \frac{Z(0.651-0.2)}{8} + 0.2$

$I_z = \frac{451z}{8000} + 0.2$ for top line

$I_z = \frac{4B-Z}{3B} I_{zp}$

$I_z = \frac{4x8-Z}{3x8} x0.651$

$I_z = \frac{217(32-Z)}{8000}$ for bottom line

The soil layer is divided into four layers as shown in Figure(7) . Now the following table(7) can be prepared.

Table(7) Calculation of the influence factors $\sum\int_a^b \frac{I_z}{E_s} dz$ for each of the layers

Layer No.	dz(ft)	E_s (lb/ft²)	$\sum\int_a^b \frac{I_z}{E_s} dz$
1	6	126000	$\int_0^6 \frac{(\frac{451}{8000}z+0.2)}{126000} dz = 1.75774 \times 10^{-5}$
2	2	250560	$\int_6^8 \frac{(\frac{451}{8000}z+0.2)}{250560} dz = 4.74637 \times 10^{-6}$
3	12	250560	$\int_8^{20} \frac{217(32-z)}{8000x250560} dz = 2.33837 \times 10^{-5}$
4	12	208800	$\int_{20}^{32} \frac{217(32-z)}{8000x208800} dz = 9.35345 \times 10^{-6}$
			$\sum\int_a^b \frac{I_z}{E_s} dz = 5.506 \times 10^{-6}$

S_i=0.916x1.4x3425x5.506x10^{-5}=0.24183ft

V. CONCLUSION

1) The modified Schmertmann's method 1978 for calculating elastic settlement of sandy soils by using integration is very accurate and it may be used as an alternative to Schmertmann's method 1978.

2) The modified Schmertmann's method 1978 uses on a mathematical solution that does not depends on plotting variation of the strain influence factor diagram with depth to same scale ,while Schmertmann,s method(1978) is a numerical solution that depends on plotting variation of the strain influence factor diagram with depth to same scale.

3) Schmertmann's method(1978) is a numerical solution that may has a percentage of error because it depends on a graphical solution ,while the modified Schmertmann's method 1978 that presented in this paper is uses a mathematical solution that dose not has error percentage and achived 100% accurcy.

4) The presented modified Schmertmann's method 1978 can be used for more cases for square , rectangular and strip footings.

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