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

Mohammed A. Hassan

Abstract — The design of footing on sand soils is often controlled by settlement 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 soil 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:

\[ s_1 = c_1 c_2 q_n z \Delta s \] ........................(1)

Where:

- \( c_1 \) = correction factor for embedment of foundation
- \( c_2 = 1 - 0.5 \) ...........................................................................(2)
- \( c_3 \) = correction factor to account for creep in soil

\[ c_3 = 1 + 0.2 \log \frac{t}{a} \] ........................(3)

time in years

\[ E_c = 2.5 q_n \] .............................(4) (for square and circular foundations)[5]

\[ E_c = 3.5 q_n \] ............................(5) (for strip foundations) [5]

\( q_n \) = cone penetration resistance

\[ c_0 = E_c \] .................................(6)[5]

\( E_c \) = Young's modulus of the elastic medium

\( s \) = strain influence factor

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

\[ q_n = q_n - \gamma D \] ..........................(7)

\( q_n \) = Stress at the level of the foundation

In order to obtain the strain influence factor, \( s \) 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
obtained by interpolating between square and strip footing [5].

The peak value of influence factor can be calculated by

\[ I_{z}^{(peak)} = 0.5 + 0.1 \left( \frac{3s}{s_{vo}} \right) \] ............ (8)

Where :

\( \sigma_{vo}^{'} \) : 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]

\[ I_{z} = 0.1 \text{ at depth}(z)=0 \]

\[ I_{z} = 0 \text{ at depth}(z)=2B \]

Maximum \( I_{z}^{(peak)} \) occurs at a depth of B/2 and has a value of:

\[ I_{z}^{(peak)} = 0.5 + 0.1 \left( \frac{3s}{s_{vo}} \right) \]

-For plane strain footings \((L/B \geq 1.0) \) [5]

\[ I_{z}^{(peak)} = 0.5 + 0.1 \left( \frac{3s}{s_{vo}} \right) \]

Maximum \( I_{z}^{(peak)} \) occurs at a depth of B and has a value of:

\[ I_{z}^{(peak)} = 0.5 + 0.1 \left( \frac{3s}{s_{vo}} \right) \]

For rectangular footings [5]

The following relations are suggested by Salgado (2008) for interpolation of \( I_{z} \) at depth \( (z) = 0 \), and \( I_{z}^{(peak)} \) for rectangular foundations[1].

\[ I_{z} = 0 \text{ at depth}(z)=z \]

\[ I_{z} = 0.1 + 0.0111 \left( \frac{L}{B} - 1 \right) \leq 0.2 \] ................. (9)

\[ I_{z} = 0 \text{ at depth}(z)=z \]

\[ I_{z} = 2 + 0.222 \left( \frac{L}{B} - 1 \right) \leq 4 \] ................. (10)

Maximum \( I_{z}^{(peak)} \) occurs at a depth of \( z=z_{1} \) and has a value of:

\[ I_{z}^{(peak)} = 0.5 + 0.1 \left( \frac{3s}{s_{vo}} \right) \]

\[ I_{z}^{(peak)} = 0.5 + 0.0555 \left( \frac{L}{B} - 1 \right) \leq 1 \] ................. (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 (Figure 2a).

Step 2. Plot the actual variation of \( E_{z} \) with depth (Figure 2b).

Step 3. Approximate the actual variation of \( E_{z} \), into a number of layers of soil having a constant \( E_{s} \), such as \( E_{s}(1), E_{s}(2) , \ldots , E_{s}(n) \) (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 \( E_{z} \) diagrams.

Step 5. Prepare a table to obtain \( \sum I_{z} E_{z} \)

Step 6. Calculate \( C_{1} \) and \( C_{2} \).

Step 7. Calculate \( S_{f} \) from Eq. (1).

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:

\[ s_{1} = c_{1}c_{2}q_{n} \sum I_{z} E_{z} d_{z} \] ................. (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](image)

-For square footing:

\[ I_{z} = \frac{z}{B} (I_{z}^{(peak)} - 0.1) + 0.1 \] ................. (13) for top line

\[ I_{z} = \frac{z}{B} (I_{z}^{(peak)} - 0.1) \] ................. (14) for bottom line

-For strip footing:

\[ I_{z} = \frac{z}{B} (I_{z}^{(peak)} - 0.1) + 0.2 \] ................. (15) for top line

\[ I_{z} = \frac{z}{B} (I_{z}^{(peak)} - 0.1) \] ................. (16) for bottom line

-For rectangular footing:

\[ I_{z} = \frac{z}{B} (I_{z}^{(peak)} - 0.1) + 0.1 \] ................. (17) for top line

\[ I_{z} = \frac{z}{B} (I_{z}^{(peak)} - 0.1) \] ................. (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 \( E_{z} \) with depth as shown in the Figure (2b).

Step 3. Approximate the actual variation of \( E_{z} \), into a number of layers of soil having a constant \( E_{s} \), such as \( E_{s}(1), E_{s}(2) , \ldots , E_{s}(n) \) 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 \( I_{z} \) and \( E_{z} \) 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 \( \sum I_{z} E_{z} d_{z} \)

Step 7. Calculate \( C_{1} \) and \( C_{2} \).

Step 8. Calculate \( S_{f} \) 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: \( \gamma = 17.5 \text{ kN/m}^3 \); \( q = 145 \text{ kN/m}^2 \), and the following approximated variation of \( (q_c) \) with (z) shown in table(1)[5]:

<table>
<thead>
<tr>
<th>Z(m)</th>
<th>( q_c ) (kN/m(^2))</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-0.5</td>
<td>2250</td>
</tr>
<tr>
<td>0.5-2.5</td>
<td>3430</td>
</tr>
<tr>
<td>2.5-5</td>
<td>2950</td>
</tr>
</tbody>
</table>

IV. UNITS

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

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

From Eq. (11)

\[ z = 0.5 + 0.0555 \left( \frac{L}{B} - 1 \right) \]

From Eq. (10)

\[ z = 2 + 0.222 \left( \frac{L}{B} - 1 \right) \]

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

\[ I_{z0} = 0.1 + 0.0111 \left( \frac{B}{L} - 1 \right) \]

\[ I_{z0} = 0.1 + 0.0111 \left( \frac{L}{B} - 1 \right) \]

\[ I_{z0} = 0.11 \]

\[ I_{z/p+2z0} = 0.5 + 0.1 \sqrt{\frac{3n}{\Delta z}} \]

\[ I_{z/p} = 0.5 + 0.1 \sqrt{\frac{145 - (126 \times 17.5)^2}{126 \times 17.5}} = 0.675 \]

\[ z = 2 + 0.222 \left( \frac{L}{B} - 1 \right) \]

\[ z = 2 + 0.222 \left( \frac{B}{L} - 1 \right) \]

\[ z = 2.22B = 4.44m \]

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

\[ I_{z0} = 0.1 + 0.0111 \left( \frac{L}{B} - 1 \right) \]

\[ I_{z0} = 0.1 + 0.0111 \left( \frac{B}{L} - 1 \right) \]

\[ I_{z0} = 0.11 \]

\[ I_{z/p+2z0} = 0.5 + 0.1 \sqrt{\frac{3n}{\Delta z}} \]

\[ I_{z/p} = 0.5 + 0.1 \sqrt{\frac{145 - (126 \times 17.5)^2}{126 \times 17.5}} = 0.675 \]

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

\[ E_s(\text{rect.}) = (1 + 0.4 \log \frac{L}{B}) \times 2.5q_c \]

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

The equation for settlement is

\[ S = c_1 c_2 q_n \sum_{z=0}^{2.22B} \frac{z}{E_s} \]

\[ c_1 = 1 - 0.5 \log \frac{L}{B} = 1 - 0.5 \times \frac{21}{145} = 0.915 \]

\[ c_2 = 1 + 0.2 \log \frac{L}{B} = 1 + 0.2 \log \frac{B}{L} = 1.4 \]

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 for calculating the term \( \frac{z}{E_s} \Delta z \).

<table>
<thead>
<tr>
<th>Layer No.</th>
<th>Dz (m)</th>
<th>( E_s ) (kPa)</th>
<th>( \frac{\int I_z dz}{E_s} \Delta z )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.5</td>
<td>6300</td>
<td>1.87 \times 10^{-5}</td>
</tr>
<tr>
<td>2</td>
<td>0.62</td>
<td>9604</td>
<td>3.35 \times 10^{-5}</td>
</tr>
<tr>
<td>3</td>
<td>1.38</td>
<td>9604</td>
<td>7.68 \times 10^{-5}</td>
</tr>
<tr>
<td>4</td>
<td>1.94</td>
<td>8260</td>
<td>4.62 \times 10^{-5}</td>
</tr>
</tbody>
</table>

\[ S = 0.915 \times 1.4 \times 124 \times 17.52 \times 10^{-5} \times 1000 = 27.83 \text{ mm} \]

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

\[ S = c_1 c_2 q_n \sum_{z=0}^{2.22B} \frac{z}{E_s} \]

- For rectangular footing:

\[ I_z = \frac{L}{E_s} \left( I_{z0} - I_{z0} + I_{z0} \right) \]

\[ I_z = \frac{L}{E_s} \left( I_{z0} + I_{z0} \right) \]

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

\[ I_{z0} = 0.1 + 0.0111 \left( \frac{L}{B} - 1 \right) \]

\[ I_{z0} = 0.1 + 0.0111 \left( \frac{B}{L} - 1 \right) \]

\[ I_{z0} = 0.11 \]

\[ I_{z/p+2z0} = 0.5 + 0.1 \sqrt{\frac{3n}{\Delta z}} \]

\[ I_{z/p} = 0.5 + 0.1 \sqrt{\frac{145 - (126 \times 17.5)^2}{126 \times 17.5}} = 0.675 \]

\[ z = 2 + 0.222 \left( \frac{L}{B} - 1 \right) \]

\[ z = 2 + 0.222 \left( \frac{B}{L} - 1 \right) \]

\[ z = 2.22B = 4.44m \]

\[ I_{z0} = 0.1 + 0.0111 \left( \frac{L}{B} - 1 \right) \]

\[ I_{z0} = 0.1 + 0.0111 \left( \frac{B}{L} - 1 \right) \]

\[ I_{z0} = 0.11 \]

\[ I_{z/p+2z0} = 0.5 + 0.1 \sqrt{\frac{3n}{\Delta z}} \]

\[ I_{z/p} = 0.5 + 0.1 \sqrt{\frac{145 - (126 \times 17.5)^2}{126 \times 17.5}} = 0.675 \]

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

\[ E_s(\text{rect.}) = (1 + 0.4 \log \frac{L}{B}) \times 2.5q_c \]

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

The equation for settlement is

\[ S = c_1 c_2 q_n \sum_{z=0}^{2.22B} \frac{z}{E_s} \]

\[ c_1 = 1 - 0.5 \log \frac{L}{B} = 1 - 0.5 \times \frac{21}{145} = 0.915 \]

\[ c_2 = 1 + 0.2 \log \frac{L}{B} = 1 + 0.2 \log \frac{B}{L} = 1.4 \]

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 for calculating the term \( \frac{z}{E_s} \Delta z \).

Table(3) The average of the influence factors for each of the layers[5]

<table>
<thead>
<tr>
<th>Layer No.</th>
<th>Dz (m)</th>
<th>( E_s ) (kPa)</th>
<th>( \frac{\int I_z dz}{E_s} \Delta z )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.5</td>
<td>6300</td>
<td>1.87 \times 10^{-5}</td>
</tr>
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<tr>
<td>4</td>
<td>1.94</td>
<td>8260</td>
<td>4.62 \times 10^{-5}</td>
</tr>
</tbody>
</table>

\[ S = 0.915 \times 1.4 \times 124 \times 17.52 \times 10^{-5} \times 1000 = 27.83 \text{ mm} \]
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 \( q_n = 120 \text{ kN/m}^2 \). Estimate the elastic settlement by Schmertmann’s method. Assume settlement is required at the end of a period of 3 years.

Solution using Schmertmann’s method(1978):
At the base of the foundation \( I_{z_0} = 0.1 \).

\[
I_z = 0.5 + \frac{0.1}{\sigma_{vo}} \Delta z
\]

\( q_n = 120 \text{ kN/m}^2 \)

\( \sigma_{vo} = 2 \times 16.5 + 4 \times 8.5 = 67 \text{ kN/m}^2 \).

\( I_{z_p} = 0.5 + 0.1 \frac{110}{67} = 0.63 \)

\( I_z = 0 \) at \( z = 16 \text{ m} \) below base level of the foundation. The distribution of \( I_z \) is given in figure(4). The equation for settlement is

\[
S_i = c_1c_2q_n \sum I_z \Delta z
\]

\( C_1 = 1 - 0.5 \frac{8a}{3} = 1 - 0.5 \times \frac{2 \times 16.5}{110} = 0.36 \)

\( C_2 = 1 + 0.2 \log_{0.1} 0.1 = 1 + 0.2 \log_{0.1} 3 = 1.3 \)

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 \( \sum I_z \frac{dS_i}{d\epsilon_i} \) as given in figure(5) and the results are tabulated along with the other calculations in table(4).

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

<table>
<thead>
<tr>
<th>Layer No.</th>
<th>( \Delta z ) (cm)</th>
<th>( q_n ) (MPa)</th>
<th>( E_s ) (MPa)</th>
<th>( E_0 ) (kPa)</th>
<th>( \sum I_z \frac{dS_i}{d\epsilon_i} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>300</td>
<td>3.6</td>
<td>14.4</td>
<td>0.3</td>
<td>6.25</td>
</tr>
<tr>
<td>2a</td>
<td>100</td>
<td>4.8</td>
<td>12.2</td>
<td>0.56</td>
<td>2.92</td>
</tr>
<tr>
<td>2b</td>
<td>500</td>
<td>4.8</td>
<td>12.2</td>
<td>0.56</td>
<td>15.02</td>
</tr>
<tr>
<td>3</td>
<td>700</td>
<td>6.8</td>
<td>27.2</td>
<td>0.18</td>
<td>4.63</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>26.82</strong></td>
</tr>
</tbody>
</table>

Substituting in the equation for settlement eq.(1)

\[
S_i = c_1c_2q_n \sum I_z \frac{dS_i}{d\epsilon_i}
\]

\( S_1 = 0.86 \times 1.3 \times 0.12 \times 26.82 = 3.6 \text{ cm} = 36 \text{ mm.} \)

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 \( \gamma = 115 \text{ lb/ft}^3 \) and the time = 10 years. Calculate the elastic settlement using strain influence factor.

Solution using Schmertmann’s method(1978)[7]
From Eq. (11)

\[
S_i = 0.5 + 0.0555 \frac{L}{B} - 1
\]

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

\( z_1 = 1 \times B = 8 \text{ ft} \)

From Eq. (10)

\[
S_i = 2 + 0.222 \frac{L}{B} - 1
\]

\( \frac{L}{B} = 2 + 0.222 (10 - 1) \)
From Eq. (9), at z = 0,
\[ I_{0z} = 0.1 + 0.0111 \left( \frac{L}{B} - 1 \right) \]
\[ I_{0z} = 0.1 + 0.0111(10 - 1) \]
\[ I_{0z} = 0.2 \]

The equation for settlement is
\[ I_{z[p=eq]} = 0.5 + 0.1 \frac{3n}{\sqrt{r_{eq}}} \]
\[ I_{z} = 0.5 + 0.1 \frac{4000 - (115x8)}{(5+5)x115} = 0.651 \]

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

![Diagram of soil layers](image)

**Figure(7) The plot of \( I_z \) versus depth \( (z) \) [7]**

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

<table>
<thead>
<tr>
<th>Layer No.</th>
<th>( \Delta z (ft) )</th>
<th>( E_s (lb/ft^2) )</th>
<th>( I, \text{at the middle of each layer} )</th>
<th>( \frac{\sum I_{0z}}{E_s \Delta z} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6</td>
<td>126000</td>
<td>0.309</td>
<td>1.757 \times 10^{-5}</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>250560</td>
<td>0.595</td>
<td>0.47467 \times 10^{-5}</td>
</tr>
<tr>
<td>3</td>
<td>12</td>
<td>250560</td>
<td>0.488</td>
<td>2.337 \times 10^{-5}</td>
</tr>
<tr>
<td>4</td>
<td>12</td>
<td>208000</td>
<td>0.163</td>
<td>0.937 \times 10^{-5}</td>
</tr>
</tbody>
</table>

\[ S_s = 0.916 \times 1.4 \times 3425 \times 5.506 \times 10^{-3} = 0.24183 \text{ft} \]

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

\[ S_i = c_1 c_2 q e \sum \frac{1}{z_1} \int E_s \Delta z \]

- For strip footing:
  \[ I_{z} = \frac{3n}{\sqrt{r_{eq}}} + 0.2 \quad \text{..............(15) for top line} \]
  \[ I_{z} = \frac{4B - z_1}{z_1} \quad \text{..............(16) for bottom line} \]

\[ z_1 = 0.5 + 0.0555 \left( \frac{L}{B} - 1 \right) \]
\[ B = 5 + 0.0555(10 - 1) \]
\[ z_1 = 1 \times B = 8 \text{ft} \]

From Eq. (10),
\[ z_2 = 0.5 + 0.0555 \left( \frac{L}{B} - 1 \right) \]
\[ z_2 = 2 + 0.222(10 - 1) \]
\[ z_2 = 4B = 32 \text{ft} \]

From Eq. (9), at \( z = 0 \),
\[ I_{z0} = 0.1 + 0.0111 \left( \frac{L}{B} - 1 \right) \]
\[ I_{z0} = 0.1 + 0.0111(10 - 1) \]
\[ I_{z0} = 0.2 \]

\[ I_{z[p=eq]} = 0.5 + 0.1 \frac{3n}{\sqrt{r_{eq}}} \]
\[ I_{zp} = 0.5 + 0.1 \frac{4000 - (115x8)}{(5+5)x115} = 0.651 \]

\[ C_1 = 1 - 0.5 \frac{L}{B} = 1 - 0.5 \frac{115x8}{4000 - (115x8)} = 0.916 \]
\[ C_2 = 1 + 0.2 \log \frac{z_1}{z_2} = 1 + 0.2 \log \frac{1}{4B} = 1.4 \]
\[ I_z = \frac{Z(4B - z_1)}{z_1} + 0.2 \]
\[ I_z = \frac{Z(4B - z_1)}{z_1} + 0.2 \]
\[ I_z = \frac{4B - z_2}{z_2} \]
\[ I_z = \frac{4B - z_2}{z_2} \]

\[ \sum I_{0z} \Delta z = 5.506 \times 10^{-5} \]

\[ S_s = 0.916 \times 1.4 \times 3425 \times 5.506 \times 10^{-3} = 0.24183 \text{ft} \]

**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 does not has error percentage and achived 100% accuracy.

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

**REFERENCES**


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


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