SUITABLE NO. OF CLAY LAYER SUB DIVISIONS TO ESTIMATE MAXIMUM CONSOLIDATION SETTLEMENT

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Abstract

The consolidation settlement of the soil is one of the important settlement components, which are included immediate, consolidation, and secondary settlement. The consolidation settlement, depending on time, has significant effects on the stability of structures.

The accuracy in calculations of consolidation settlement affects the whole analysis and design of structures founded on clayey soils that in the condition of very slow water dissipation (low permeability). The accuracy increases (increasing in consolidation settlement) with dividing the clay layer into small sub divisions then the consolidation is calculated for each sub division separately, the total final settlement is equal to the summation of settlement of the sub divisions.

This research presents a study about selecting the suitable number of clay layer sub divisions, for different clay layer parameters and loading values, to estimate the maximum consolidation settlement.

Symbols

ΔV: change in volume
V_o: initial volume
e_o: initial void ratio
e_f: final void ratio
σ'_o : initial effective stress
dSc: differential consolidation settlement
Sc: total consolidation settlement
m_v: coefficient of volume change from (e-σ') diagram, (m^2/kN)
a_v: coefficient of compressibility from (e-σ') diagram, (cm^2/kg)
H: total clay layer thickness
Cc: compression index from (e-log σ') diagram
σ'_f : final effective stress

1-Introduction

Foundation settlement must be assessed as accurately as possible for most structures including buildings, bridges, towers, power plants, etc. it is often necessary to obtain an indications of the probable magnitude of settlement for other structures such as fills, dams, braced sheeting, and retaining walls.

Generally, the settlement of foundation may be regarded as consisting of three components of settlement, giving: -

$$S = Si + Sc + Ss \quad ...(1)\ [5]$$

Where:

S = total settlement,
Si= immediate settlement, or those which take place as soon (0 to less than about 7 days) as the load is applied.
Sc= consolidation settlement (which is time - dependent).
Ss= secondary settlement or creep (which is also time - dependent).

"Immediate settlement analyses are appropriate for all fine - grained soils (silts and clays) with a degree of saturation less than about 90 %. All soils with a large coefficient of permeability (rapid draining under a hydraulic gradient) including all cohesionless soils undergo immediate settlement"[5].

"Consolidation settlement analyses are appropriate, for all saturated, or nearly saturated, fine - grained soil deposits (k on the order of 10^{-6} m/sec or less). Consolidation settlement analyses are actually a modified form of elasticity computations. They are done in the alternative form, however, because in the development of the "elastic constant" Ce, one also obtains a time - rate constant (the coefficient of consolidation Cv) so that one obtains estimates of both amount of settlement and time duration"[5].

The settlement at the end of construction is sometimes taken as being equal to the initial settlement (immediate) but, even if the construction period is short, this will include some part of the primary consolidation settlement.

Secondary settlement also, considered to be the settlement occurring after changes in effective stress have taken place, will also develop during the primary consolidation period as the pore - water pressure dissipates and the effective stresses.

2- Calculations Of Consolidation Settlement

The reduction in volume per unit volume of clay:

$$\frac{\Delta V}{V_0} = \frac{(e_0 - e_1)}{(1 + e_0)} \qquad \ldots(2)$$

Assuming the condition of no lateral strain, $\Delta\sigma = \Delta\sigma'$ after complete the consolidation, this will cause a reduction (dSc):

$$dS_c = \frac{(e_0 - e_1)}{(1 + e_0)} dz * \frac{(\sigma'_1 - \sigma'_0)}{(\sigma'_1 - \sigma'_0)} \qquad \ldots(3)$$

$$dS_c = \frac{(e_0 - e_1)}{(\sigma'_1 - \sigma'_0)} * \frac{(\sigma'_1 - \sigma'_0)}{(1 + e_0)} dz \qquad \ldots(4)$$

$$dS_c = m_v * \Delta\sigma' * dz \qquad \ldots(5)$$

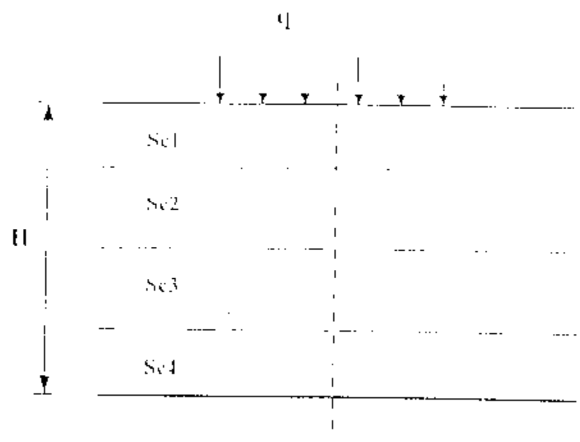


Figure (1): Consolidation Settlement Calculations

$$S_c = \int_0^H m_v * \Delta\sigma' * dz \qquad \ldots(6)$$

If (m_v) and ($\Delta\sigma'$) assumed constant with depth, then: -

$$Sc = m_v * \Delta\sigma' * H \quad \ldots(7)$$

$$\text{Or} \quad S_c = \frac{(e_o - e_1)}{(1 + e_o)} * H \quad \ldots(8)$$

There is other equation depending on idealization of (e-σ') diagram by the (e-log σ') diagram, then: -

$$\text{Or} \quad S_c = \frac{C_c * H}{(1 + e_o)} * \log\left(\frac{\sigma'_f}{\sigma_o}\right) \quad \ldots(9)$$

Where:

$$\sigma'_f = \sigma'_o + \Delta\sigma' \quad \ldots(10)$$

Eq. (9) was considered to estimate the consolidation settlement in this paper.

3- Load And Soil Specifications

Fig. (2) shows the examined soil profile and the variables used in research.. Table (1) shows the studied cases in the research with variable properties of load and soil. Table (2) shows the constant properties used in investigation.

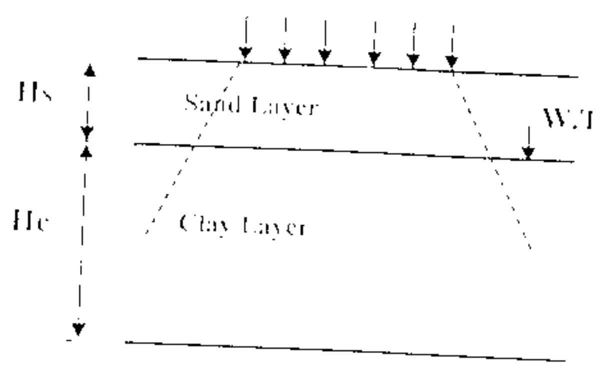


Figure (2): Soil Profile

Table (1): Studied Cases.

Clay Thickness (Hc), m	*Fill Stress (q) kN/m²*	*Void Ratio (e_o)*
10	100	0.8, 0.9, 1.0, 1.1
10	150	0.8, 0.9, 1.1
10	200	0.8, 0.9, 1.1
15	100	0.8, 0.9, 1.1
15	150	0.8, 0.9, 1.1
15	200	0.8, 0.9, 1.1
25	100	0.8, 0.9, 1.1
25	150	0.8, 0.9, 1.1
25	200	0.8, 0.9, 1.1

Table (2): Constant Properties of Soil.

Clay Unit Weight, kN/m	*Sand Unit Weight, kN/m'*	*Sand Layer Thickness (Hs), m*	*Compression Index (Cc)*
20	18	5	0.3

3-Presentation of Results

3-1 Total Clay Layer Thickness = 10 m

Fig. (3) shows the results for clay layer thickness (10 m) and for different values of fill stress and different void ratios.

Fig. (3a), the fill stress = 100 kN/m^2, shows a high difference between value of settlement calculated from whole clay layer and the value of settlement that calculated by dividing the clay layer into (2) layers for different void ratios. The results show a small increase in values of settlement, for different void ratios, after increasing of divided layers more than two. This fact is obviously repeated for fill stress (150 & 200) kN/m^2, Figs. (3b) & (3c) respectively.

3-2 Total Clay Layer Thickness = 15 m

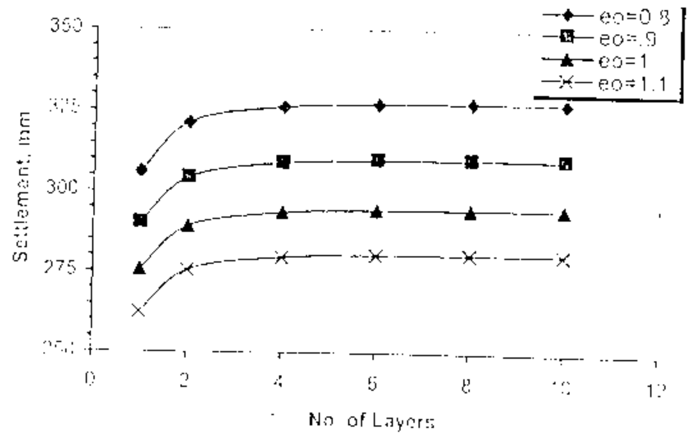
Fig. (4) shows the results for clay layer thickness (15 m) and for different values of fill stress and different void ratios.

Fig. (4a), the fill stress = 100 kN/m^2, shows a high difference between value of settlement calculated from whole clay layer and the value of settlement that calculated by dividing the clay layer into (4) layers for different void ratios. The results show a small increase in values of settlement, for different void ratios, after increasing of divided layers more than four. This fact is obviously repeated for fill stress (150 & 200) kN/m^2, Figs. (4b) & (4c) respectively.

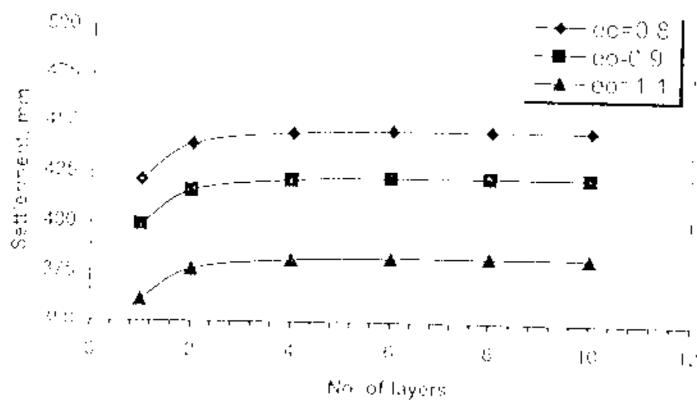
3-3 Total Clay Layer Thickness = 25 m

Fig. (5) shows the results for clay layer thickness (25 m) and for different values of fill stress and different void ratios.

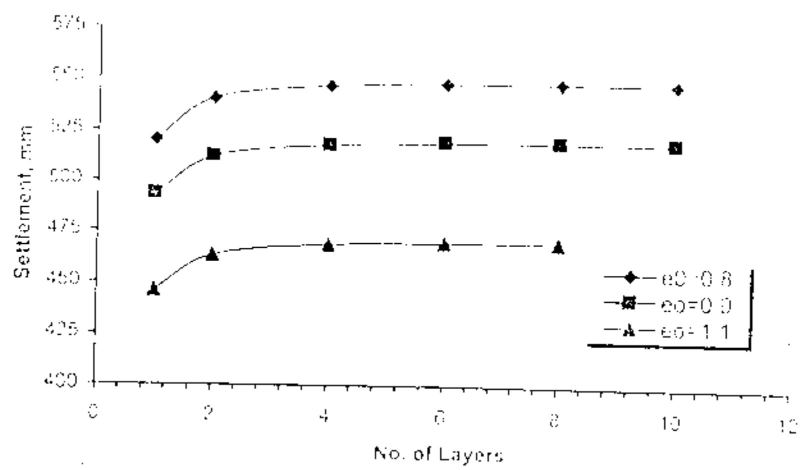
Fig. (5a), the fill stress = 100 kN/m^2, shows a high difference between value of settlement calculated from whole clay layer and the value of settlement that calculated by dividing the clay layer into (6) layers for different void ratios. The results show a small increase in values of settlement, for different void ratios, after increasing of divided layers more than six. This fact is obviously repeated for fill stress (150 & 200) kN/m^2, Figs. (5b) & (5c) respectively.



a) Fill Stress = 100 kN/m²

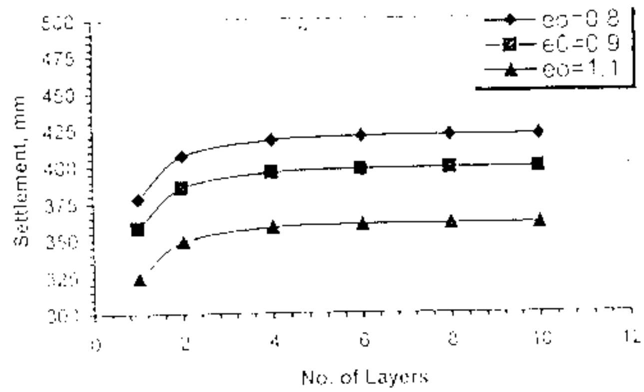


b) Fill Stress = 150 kN/m²

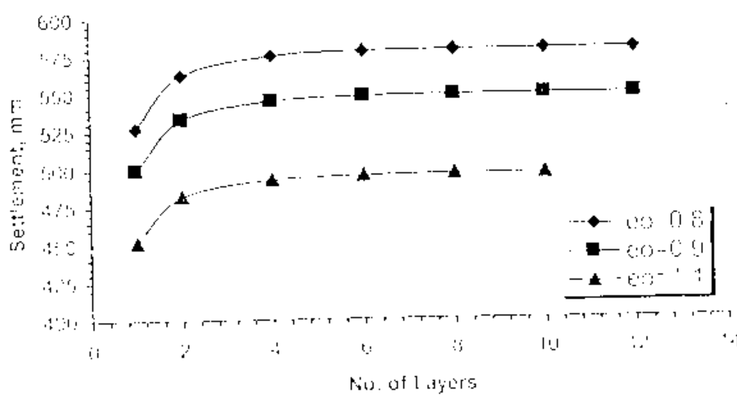


c) Fill Stress = 200 kN/m²

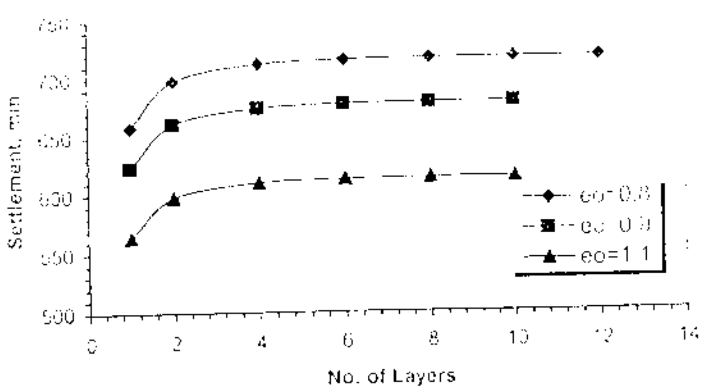
Figure (3): Relationship Between The No. of Layers (Divisions) and Settlement For Clay Layer Thickness Equal to (10 m).



a) Fill Stress = 100 kN/m^2

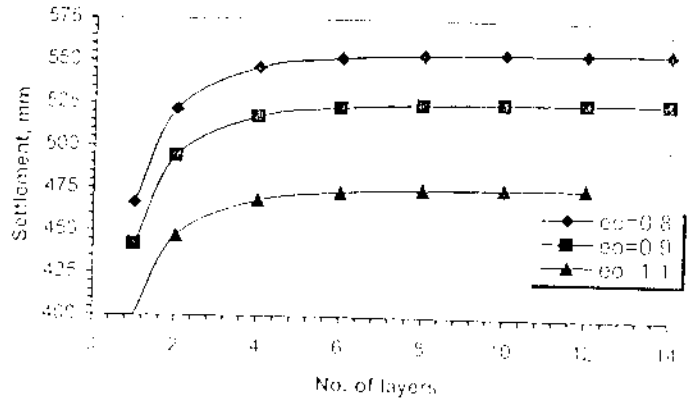


b) Fill Stress = 150 kN/m

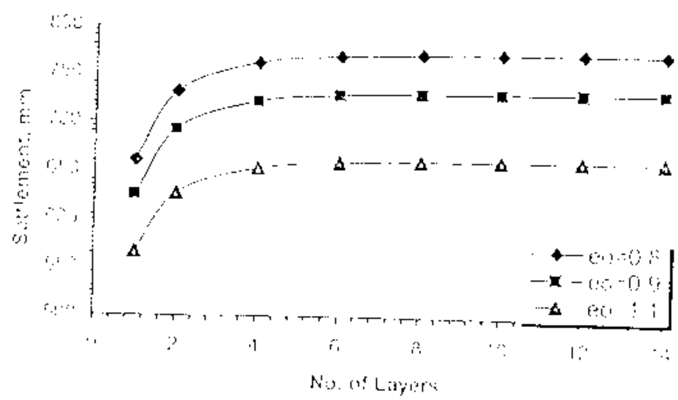


c) Fill Stress = 200 kN/m^2

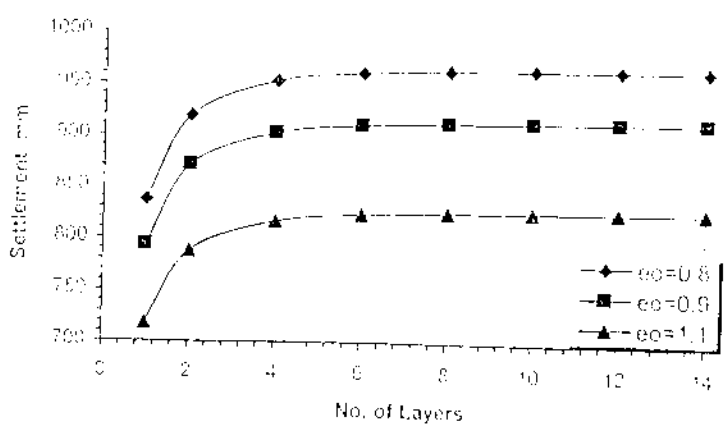
Figure (4): Relationship between the No. of Layers (Divisions) and Settlement for Clay Layer Thickness Equal to (15 m).



a) Fill Stress = 100 kN/m²



b) Fill Stress = 150 kN/m²



c) Fill Stress = 200 kN/m²

Figure (5): Relationship between the No. of Layers (Divisions) and Settlement for Clay Layer Thickness Equal to (25 m).

4- Regression Analysis

As a result from previous data. Fig. (6) shows the estimated number of divisions for each clay layer thickness (10, 15. and 25 m), a regression analysis was made to investigate an equation correlates the variables. Eq. (11) correlates the number of divisions with clay layer thickness with R^2=0.9956. As in Fig. (6). the equation gives good agreement with estimated data.

$$N = 4.3463 * \ln(Hc) - 3.9226 \quad ...(11)$$

where:

N=No. of divisions

Hc = Clay layer thickness

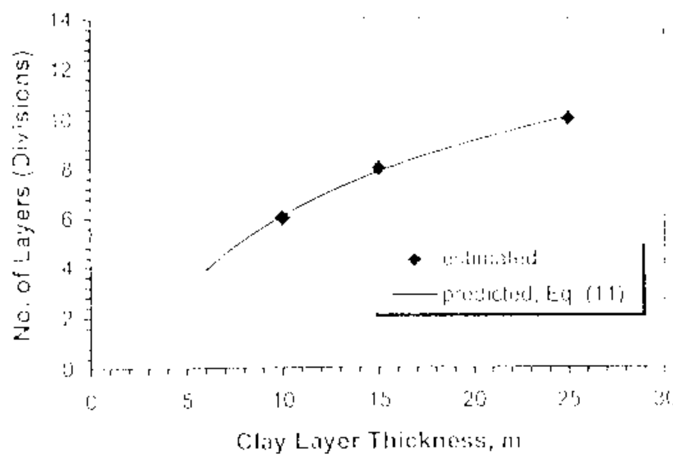


Figure (6): Relationship between the Clay Layer Thickness and No. of Divisions

Conclusions

From the results, one can state the followings: -

1- For clay layer thickness = 10, the results show a small increase in values of settlement, for different fill stresses and different void ratios, after increasing of the sub divided layers more than two, and the suitable number of sub divisions = 6 to give maximum and economic consolidation settlement.

2- For clay layer thickness = 15, the results show a small increase in values of settlement, for different fill stress and different void ratios, after increasing of the sub divided layers more than four, and the suitable number of sub divisions = 8.

3- For clay layer thickness = 25, the results show a small increase in values of settlement, for different fill stress and different void ratios, after increasing of the sub divided layers more than six, and the suitable number of sub divisions = 10.

4- A good agreement data obtained from Eq. (11) with that estimated from research

Recommendations

For the future such work, we recommended the following: -

1- investigate the effect of other soil parameters, such as unit weight, water table, and compression index (Cc), on the selection of suitable clay layer divisions to estimate the maximum consolidation settlement.

2- Investigate the effect of other types of additional loading, such as square, cicular, and strip footing, to achieve the certain purpose.

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عدد التقسيمات الثانوية لطبقة الطين المناسب

لتخمين اكبر هبوط انضمام

الخلاصة

ان هبوط الانضمام واحدا من أهم مركبات الهبوط، والتي تشمل على الهبوط الآني، هبوط الانضمام، وفي المرحلة المتأخرة الأخيرة الانضغاط الثانوي. ان هبوط الانضمام، مع الزمن، له تأثير كبير على استقرارية المنشآت.

ان الدقة في حساب هبوط الانضمام الكلي له أهمية كبيرة في تحليل وتصميم تلك المنشآت خاصة الموضوعة منها على تربة طينية مشبعة وذات تصريف ضئيل للماء (قابلية النفاذية). وتزداد قيمة هبوط الانضمام بزيادة التقسيمات الثانوية لطبقة الطين، ثم يحسب الهبوط لكل تقسيم على حدة، ويكون الهبوط الكلي هو مجموع هبوط التقسيمات الثانوية.

يقدم هذا البحث دراسة حول الاختيار المناسب لعدد التقسيمات الثانوية – ولمختلف خصائص الطبقة الطينية ومقدار التحميل والذي سيمكننا من تخمين هبوط الانضمام الأكبر للطبقة الطينية.