# Technical Justification: Settlement Analysis of Transmission Towers


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**Abstract**

This document covers a presentation related to a technical justification in determining the total settlements of transmission towers in Smelter Ferronickel Kolaka, a project handled by PT. PP (Persero) Tbk. This document will not present a detail data used in the project, but rather demonstrates the methodology and framework for the task. A key innovation employed by the author is the use of machine learning (ML) algorithm for interpolating the depth factor for immediate settlements. In addition, this document is intended as a portfolio that demonstrates the competency and experience of the author in the corresponding problem solving.


## Contents



# 1 Introduction

In project Smelter Ferronickel Kolaka held by PT. PP, there are transmission towers which distribute powers for the Smelter from its source a few kilometers apart. The engineering design of the transmission towers were conducted by a engineering consulting company hired by PT. PP. However, after the engineering team in the internal body of PT. PP performed a review on the calculation, there were missing technical components to be analysed. These components are the consolidation settlements. Hence, I was tasked on producing a technical justification for evaluating the total settlements of the transmission towers.

In this document, we will only highlight the methodology used for evaluating the settlements as well as the result. We do not disclose sensitive data related to the project such as the soil investigation data, etc. It is also worth noted that this document only serves as a portfolio of the author in demonstrating the depth of the knowledge in the corresponding problem as well as the approach offered by the author to solve such cases.

## 2 Methodology and Theoretical Framework

In geotechnical engineering, settlements of soils can be defined as the change in the thickness of soil layers due to compressions to the soil surfaces by applied loads such as existence of buildings, infrastructures or any civil engineering constructions (Das and Sobhan, 2012a). In practices, settlements shall be controlled in order to maintain the integrity of the buildings above the ground since uncontrolled settlements could damage the buildings.

Settlements of shallow foundations are basically divided into three components (Das and Sobhan, 2012a), namely immediate settlement (or elastic settlement), consolidation settlement (or primary settlement) and secondary consolidation settlement. Immediate settlement of foundations is the settlement which occurs directly after the application of a load without a change in the moisture content of the soil (Das and Sobhan, 2012b). Consolidation settlement refers to the vertical deformation or settlement that occurs in a soil layer when it undergoes consolidation under applied loads (Das and Sobhan, 2012a). While Secondary consolidation settlement is the settlement which occurs at the end of the primary settlement due to the plastic adjustment of soil fabrics (Das and Sobhan, 2012c). And the total settlement is defined as the sums of these three settlements (Das and Sobhan, 2012a). In a formal expression, the total settlement can be given by

$$S := S_i + S_c + S_s \,, \tag{1}$$

where $S_i$ is the immediate settlement, $S_c$ is the consolidation settlement and $S_s$ is the secondary consolidation settlement. Note that all the values in the expression above are magnitudes, hence $S, S_i, S_c, S_s \in [0, \infty)$.

Throughout this section, we will use a shallow foundation as the geotechnical object associated with settlements. In addition, the units to be used throughout the discussion are meters (m) for length and distance measures, kilo Newtons (kN) for forces and loads and the combinations of these two initial units for other soil mechanical properties such as kN/m$^2$ for stresses as well as Young's modulus, kN/m$^3$ for unit weights, etc., unless otherwise stated. Then let us suppose a rectangular shallow foundation with horizontal dimensions $B \times L$ such that $B, L \in (0, \infty)$ with $B \leq L$.

### 2.1 Immediate Settlement

For a foundation that is perfectly flexible in theory, the immediate settlement of the foundation (Das and Sobhan, 2012d) is given by

$$S_i = \Delta\sigma(\alpha B')\frac{1 - \mu_s^2}{E_s} I_s I_f \,. \tag{2}$$

The components of equation 2 above are presented as follows:

I. $\Delta\sigma$ is the applied pressure on the foundation. Suppose $P$ is the gravitational applied load on the foundation, then

$$\Delta\sigma = \frac{P}{BL} \,. \tag{3}$$

II. $\alpha$ is a factor regarding the position of the settlement to be considered, and is given by

$$\alpha := \begin{cases} 4 & : \text{ for centre of foundation} \\ 1 & : \text{ for corner of foundation} \end{cases} \,. \tag{4}$$

III. $B'$ is the effective width of the foundation (Das and Sobhan, 2012d), defined by

$$B' := \begin{cases} B/2 & : \text{ for centre of foundation} \\ B & : \text{ for corner of foundation} \end{cases} \tag{5}$$

IV. $\mu_s$ is the Poisson's ratio of soil (Das and Sobhan, 2012d).

V. $E_s$ is the Young's modulus of soil (Das and Sobhan, 2012d).

VI. $I_s$ is the shape factor (Steinbrenner, 1934), given by

$$I_s = F_1 + \frac{1 - 2\mu_s}{1 - \mu_s} F_2 \,. \tag{6}$$

And the components in the expression above is given by

$$F_1 = \frac{1}{\pi}(A_0 + A_1) \tag{7}$$

$$F_2 = \frac{n'}{2\pi} \tan^{-1} A_2 \tag{8}$$

$$A_0 = m' \ln \frac{1 + \sqrt{m'^2 + n'^2 + 1}}{m'(1 + \sqrt{m'^2 + n'^2 + 1}} \tag{9}$$

$$A_1 = \ln \frac{\left(m' + \sqrt{m'^2 + 1}\right) \sqrt{1 + n'^2}}{m' + \sqrt{m'^2 + n'^2 + 1}} \tag{10}$$

$$A_2 = \frac{m'}{n' \sqrt{m'^2 + n'^2 + 1}} \,, \tag{11}$$

with

$$m' := \frac{L}{B} \quad \text{, and } n' := \begin{cases} 2H/B & : \text{ for centre of foundation} \\ H/B & : \text{ for corner of foundation} \end{cases} .$$

VII. $I_f$ is the depth factor. And several values of depth factors are given in table 1 (Das and Sobhan, 2012e). In case the values of parameters for $I_f$ do not present in table 1, $I_f$ is determined by

Table 1: Parameters for depth factor (Das and Sobhan, 2012e)

| $L/B$ | $D_f/B$ | $I_f$ $\mu_s = 0.3$ | $\mu_s = 0.4$ | $\mu_s = 0.5$ |
|---|---|---|---|---|
| 1 | 0.50 | 0.77 | 0.82 | 0.85 |
| | 0.75 | 0.69 | 0.74 | 0.77 |
| | 1.00 | 0.65 | 0.69 | 0.72 |
| 2 | 0.50 | 0.82 | 0.86 | 0.89 |
| | 0.75 | 0.75 | 0.79 | 0.83 |
| | 1.00 | 0.71 | 0.75 | 0.79 |
| 5 | 0.50 | 0.87 | 0.91 | 0.93 |
| | 0.75 | 0.81 | 0.86 | 0.89 |
| | 1.00 | 0.78 | 0.82 | 0.85 |

linear interpolations on the nearby parameters. However, for multidimensional hyper parameters such as those of table 1, it will be very difficult to conduct a accurate linear interpolation. In exchange, we developed a Machine Learning (ML) model to execute this task by making use of `LinearRegression()` from the `Python` (van Rossum, 2018) library `sklearn` (Pedregosa et al., 2011). From the ML model, we obtain the following equation for $I_f$;

$$I_f = \sum_{k=0}^{3} \beta_k x_k \,, \tag{12}$$

with the additional pararmeters given on table 2. The detail development of the ML model and the model itself can be accessed on (Purnawan, 2024).

The rigidity of foundations also affects the settlement profile (Das and Sobhan, 2012f). For rigid foundations, the settlement can be estimated in accordance with (Das and Sobhan, 2012g) by

$$S_{i,r} \approx 0.93 S_i \,, \tag{13}$$

where $S_i \in (0, \infty)$ is the settlement for perfectly flexible foundations.

Table 2: A function from ML model for $I_f$

| $k$ | $x_k$ | $\beta_k$ |
|---|---|---|
| 0 | | 0.739085 |
| 1 | $L/B$ | 0.025799 |
| 2 | $D_f/B$ | -0.198381 |
| 3 | $\mu_s$ | 0.353371 |

## 2.2 Consolidation Settlement

Consolidation settlement is a time-dependent process that happens in saturated or nearly saturated soils. The formula for consolidation settlement is given by

$$S_c = \begin{cases} \frac{C_c H}{1+e_0} \log\left(\frac{\sigma_0'+\Delta\sigma'}{\sigma_0'}\right) & : \text{ for normally consolidated clays} \\ \frac{C_s H}{1+e_0} \log\left(\frac{\sigma_0'+\Delta\sigma'}{\sigma_0'}\right) & : \text{ for overconsolidated clays with } \sigma_0' + \Delta\sigma' \leq \sigma_c' \\ \frac{C_s H}{1+e_0} \log\left(\frac{\sigma_c'}{\sigma_0'}\right) + \frac{C_c H}{1+e_0} \log\left(\frac{\sigma_0'+\Delta\sigma'}{\sigma_0'}\right) & : \text{ for overconsolidated clays with } \sigma_0' + \Delta\sigma' > \sigma_c' \end{cases} . \tag{14}$$

The components in equation 14 above is descrived as follows:

I. $C_c$ is the compression index, given in accordance with (Rendond-Herrero, 1983) by

$$C_c = 0.141 G_s^{1.2} \left(\frac{1+e_0}{G_s}\right)^{2.38} , \tag{15}$$

where $G_s$ is the specific gravity of soils.

II. $C_s$ is the swell index, taken as (Das and Sobhan, 2012h)

$$C_s = \frac{C_c}{r} \tag{16}$$

with $r \in [5, 10]$.

III. $\sigma_0'$ is the maximum effective initial pressure of soil before the current settlement occurs, and is given by

$$\sigma_0' = \frac{\gamma' H}{2} , \tag{17}$$

where $\gamma'$ is the effective unit weight of soil. In case the soil is normally consolidated, then $\sigma_0' = \sigma_c'$, where $\sigma_c'$ is the effective precosolidation pressure. Otherwise, $\sigma_c'$ is given in accordance with (Mayne, 1988) by

$$\sigma_c' = 0.243 q_c^{0.96} , \tag{18}$$

where $q_c$ is the tip resistance of cone penetration test (CPT) at the depth of interest.

IV. $\Delta\sigma'$ is the net applied pressure, given as the pressure experienced at the depth of interest due to the load on the foundation. Follows from (Fang, 1975), using the method proposed by (Harr, 1977), it is given by

$$\Delta\sigma' = q\psi\left(\frac{B}{\kappa z\sqrt{K}}\right)\psi\left(\frac{L}{\kappa z\sqrt{K}}\right) , \tag{19}$$

where $q$ is the pressure from the foundation, and $\kappa$ is given by

$$\kappa := \begin{cases} 1 & : \text{ for consolidation at the edge of foundation} \\ 2 & : \text{ for consolidation at the centre of foundation} \end{cases} ,$$

and $K$ is coefficient of lateral earth pressure, and $\psi : \mathbb{R} \to \mathbb{R}$ is the probability density function proposed by (Harr, 1977) and is given by

$$\forall z \in \mathbb{R} , \ \psi(z) := \frac{1}{\sqrt{2\pi}} \int_0^z \frac{\mathrm{d}U}{\sqrt{e^{U^2}}} .$$

We can approximate $\psi : \mathbb{R} \to \mathbb{R}$ by estimating the error function (Andrews, 1998). We will show that $\psi$ can be expressed in terms of error function as follows:

Note that

$$\psi(z) = \frac{1}{\sqrt{2\pi}} \int_0^z \frac{\mathrm{d}U}{\sqrt{e^{U^2}}} = \frac{1}{\sqrt{2\pi}} \int_0^z e^{-U^2/2} \, \mathrm{d}U \,.$$

Assuming $t := \frac{U}{\sqrt{2}}$, thus $\mathrm{d}U = \sqrt{2}\mathrm{d}t$. Thus we have

$$\psi\left(z\sqrt{2}\right) = \frac{1}{\sqrt{2\pi}} \int_0^z \sqrt{2} e^{-t^2} \, \mathrm{d}t = \frac{1}{\sqrt{\pi}} \int_0^z e^{-t^2} \, \mathrm{d}t = \frac{\operatorname{erf} z}{2} \,,$$

which shows that

$$\psi(z) = \frac{\operatorname{erf}\left(\frac{z}{\sqrt{2}}\right)}{2} \,.$$

We can use an approximation to erf given in the form of Bürmann's series (Schöp and Supancic, 2014), as given by

$$\begin{aligned}
\psi(z) &\approx \frac{1}{2}\left(\frac{2}{\sqrt{\pi}} \operatorname{sgn}\left(\frac{z}{\sqrt{2}}\right) \sqrt{1 - e^{-\frac{z^2}{2}}} \left(\frac{\sqrt{\pi}}{2} + \frac{31}{200} e^{-\frac{z^2}{2}} - \frac{341}{8000} e^{-\frac{2z^2}{2}}\right)\right) \\
&= \frac{1}{\sqrt{\pi}} \operatorname{sgn}\left(\frac{z}{\sqrt{2}}\right) \sqrt{1 - e^{-\frac{z^2}{2}}} \left(\frac{\sqrt{\pi}}{2} + \frac{31}{200} e^{-\frac{z^2}{2}} - \frac{341}{8000} e^{-z^2}\right) .
\end{aligned}$$

Since $z > 0$, then $\operatorname{sgn}(z/\sqrt{2}) = 1$, thus

$$\psi(z) \approx \frac{1}{\sqrt{\pi}} \sqrt{1 - e^{-\frac{z^2}{2}}} \left(\frac{\sqrt{\pi}}{2} + \frac{31}{200} e^{-\frac{z^2}{2}} - \frac{341}{8000} e^{-z^2}\right) . \tag{20}$$

Coefficient of lateral earth pressure $K$ is allowed to be taken as the coefficient of active earth pressure (Fang, 1975). Thus,

$$K := \tan^2\left(45 - \frac{\phi'}{2}\right) , \tag{21}$$

where $\phi'$ is the effective friction angle.

## 2.3 Time-Rate Consolidation Settlement

In the time-rate consolidation settlement, consolidation can be described as a function of time. Obtaining information about the time when the primary consolidation ends is crucial for computing secondary consolidation settlement. The first theory describing time-rate consolidation settlement was proposed by Terzaghi (Das and Sobhan, 2012i). Terzaghi modelled the problem into a partial differential equation (PDE) (Kreyszig, 2011)

$$\frac{\partial u}{\partial t} = c_v \frac{\partial^2 u}{\partial z^2} \,,$$

where $u(t, x, y, z)$ is the function of pore water pressure and $c_v$ is the coefficient of consolidation. A set of boundary conditions is given;

$$\begin{aligned}
z = 0 &\implies u = 0 \\
z = 2H_{dr} &\implies u = 0 \\
t = 0 &\implies u = u_0 \,.
\end{aligned}$$

The solution is given in a form of Fourier series

$$u = \sum_{m=0}^{\infty} \frac{2u_0}{M} \sin\left(\frac{Mz}{H_{dr}}\right) e^{-M^2 T_v} \,, \tag{22}$$

where

| | | |
|---|---|---|
| $u_0$ | | is the initial excess pore water pressure, |
| $M$ | | $= \frac{\pi(2m+1)}{2}$, |
| $T_v$ | | $= \frac{c_v t}{H_{dr}^2}$ (time factor), |
| $H_{dr}$ | | is the maximum vertical drainage path. |

The degree of consolidation is given by

$$U = 1 - \frac{1}{u_0 2H_{dr}} \int_0^{2H_{dr}} u \, \mathrm{d}z = 1 - \sum_{m=0}^{\infty} \frac{2}{M^2} e^{-M^2 T_v} . \tag{23}$$

If we can find the invers of $U$ from equation 23 above, we can treat $T_v$ as a function $T_v : U \mapsto T_v(U)$. However, posing the question whether the equation above is invertible is another serious question in mathematics. Moreover, the equation above does not seem to have a closed form solution. Thus, it is very inconvenience for computing $T_v$ from the equation above. An approximation to the function is given in accordance with (Das and Sobhan, 2012j) by

$$T_v = \begin{cases} \frac{\pi U^2}{4} & : U \leq 0.6 \\ 1.781 - 0.933 \log\left(100(1-U)\right) & : U > 0.6 \end{cases} . \tag{24}$$

Note that $U \in [0, 1]$ along this discussion.

The time in which the primary consolidation is considered ending is the time in which the consolidation has reached 95% (Fang, 1975). Thus, the time in which the primary consolidation ends is given by

$$t_1 := \frac{T_v(0.95) H_{dr}^2}{c_v} . \tag{25}$$

### 2.4 Secondary Consolidation Settlement

The secondary consolidation settlement is given by (Das and Sobhan, 2012c)

$$S_s = \frac{C_\alpha H}{1 + e_p} \log\left(\frac{t_2}{t_1}\right) , \tag{26}$$

where $t_1$ is the time in which the primary consolidation ends (given by equation 25), $t_2$ is the time in which the secondary consolidation is expected to occur –thus, $t_1 < t_2$ necessarily hold, $e_p$ is the void ratio right after the primary consolidation settlement, given by

$$e_p = e_0 - \Delta e , \tag{27}$$

and $C_\alpha$ is the secondary compression index, given by (Das and Sobhan, 2012c)

$$C_\alpha = \frac{\Delta e}{\log\left(t_2/t_1\right)} . \tag{28}$$

And $\Delta e$ is the change in void ratio, which is given by (Das and Sobhan, 2012k)

$$\Delta e = C \log\left(\frac{\sigma_0' + \Delta\sigma'}{\sigma_0'}\right) , \tag{29}$$

where

$$C := \begin{cases} C_c & : \text{ for normally consolidated clays} \\ C_s & : \text{ for overconsolidated clays} \end{cases} .$$

## 3 Settlements of Transmission Towers Foundations

The detail calculation sheets for the settlements of the transmission towers are given in the attachment. The summary of the analysis result is given in table 3.

Table 3: Summary of the computation results

| Tower | $S_i$ (mm) | $S_c$ (mm) | $S_s$ (mm) | $S$ (mm) |
|---|---|---|---|---|
| T01 | 6.822 | 5.231 | 3.179 | 15.232 |
| T02 | 3.774 | 6.530 | 3.724 | 14.028 |
| T03 | 9.580 | 5.777 | 4.318 | 19.675 |
| T04 | 10.233 | 4.973 | 4.619 | 19.825 |
| T05 | 8.560 | 8.194 | 8.455 | 25.208 |
| T06 | 18.941 | 7.401 | 5.682 | 32.025 |
| T07 | 12.886 | 4.518 | 3.981 | 21.385 |
| T08 | 6.288 | 4.826 | 5.274 | 16.388 |
| T09 | 7.226 | 4.360 | 5.104 | 16.691 |
| T10 | 7.567 | 4.088 | 5.264 | 16.918 |
| T11 | 7.153 | 4.358 | 4.723 | 16.233 |
| T12 | 12.829 | 5.955 | 5.194 | 23.978 |
| T13 | 12.694 | 5.277 | 4.670 | 22.640 |
| T14 | 12.963 | 4.761 | 4.034 | 21.758 |

# 4 Conclusion

We have presented the theoretical framework for evaluating settlements of shallow foundations, and in this case, the foundations of transmission towers in Smelter Ferronickel Kolaka. From the computation as presentd in table 3, the largest settlement occurs at tower T06 with a total settlement of 32.025 mm. And most towers have total settlements below 25 mm.

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# ATTACHMENT

# SETTLEMENT OF FOUNDATION T01

## GENERAL SOIL MECHANICAL PROPERTIES

| | | | |
|---|---|---|---|
| Young's modulus | $E_s$ = | 35,561.300 | kN/m$^2$ |
| Poisson's ratio | $\mu_s$ = | 0.300 | |
| Unit Weight | $\gamma$ = | 16.300 | kN/m$^3$ |
| Existence of water | | TRUE | |
| Effective unit weight | $\gamma'$ = | 6.490 | kN/m$^3$ |
| Water content | w = | 0.069 | |
| Dry unit weight | $\gamma_d$ = | 15.251 | kN/m$^3$ |
| Specific gravity | $G_s$ = | 2.530 | |

## FOUNDATION PROPERTIES

| | | | |
|---|---|---|---|
| Length of the foundation | L = | 22.000 | m |
| Breadth of the foundation | B = | 22.000 | m |
| Depth of foundation | $D_f$ = | 3.400 | m |
| Thickness of soil layer | H = | 4.000 | m |
| Maximum dranage path | $H_{dr}$ = | 2.000 | m |

## COMPUTING NET APPLIED PRESSURE

| | | | | |
|---|---|---|---|---|
| Applied pressure | | $\Delta\sigma$ = | 21.386 | kN/m$^2$ |
| Internal angle of friction | | $\phi'$ = | 0.000 | |
| Coefficient of lateral earth pressure | (Eq. 21) | K = | 1.000 | |
| Depth of interest | | z = | 2.000 | |
| Density input-1 | | Z1 = | 5.500 | |
| Density input-2 | | Z2 = | 5.500 | |
| Probability density-1 (Harr, 1977) | (Eq. 20) | $\psi$(Z1) = | 0.484 | |
| Probability density-2 (Harr, 1977) | (Eq. 20) | $\psi$(Z2) = | 0.484 | |
| Net applied pressure | (Eq. 19) | $\Delta\sigma'$ = | 5.005 | kN/m$^2$ |

## SETTLEMENT

### Immediate Settlement

***A. At the Center***

| | | | | |
|---|---|---|---|---|
| Effective width | (Eq. 5) | B' = | 11.000 | m |
| Location factor | (Eq. 4) | $\alpha$ = | 4.000 | |
| Computing shape factor | | | | |
| | | m' = | 1.000 | |

| | | | | |
|---|---|---|---|---|
| | | $n'$ = | 0.364 | |
| | (Eq. 9) | $A_0$ = | 0.466 | |
| | (Eq. 10) | $A_1$ = | 0.540 | |
| | (Eq. 11) | $A_2$ = | 1.372 | |
| | (Eq. 7) | $F_1$ = | 0.320 | |
| | (Eq. 8) | $F_2$ = | 0.070 | |
| Shape factor | (Eq. 6) | $I_s$ = | 0.360 | |
| Depth factor | (Eq. 12) | $I_f$ = | 0.846 | |
| Immediate settlement | (Eq. 2) | $S_i$ = | 6.822 | mm |

***B. At the Corner***

| | | | | |
|---|---|---|---|---|
| Effective width | (Eq. 5) | $B'$ = | 22.000 | m |
| Location factor | (Eq. 4) | $\alpha$ = | 1.000 | |
| Computing shape factor | | | | |
| | | $m'$ = | 1.000 | |
| | | $n'$ = | 0.182 | |
| | (Eq. 9) | $A_0$ = | 0.462 | |
| | (Eq. 10) | $A_1$ = | 0.536 | |
| | (Eq. 11) | $A_2$ = | 1.964 | |
| | (Eq. 7) | $F_1$ = | 0.318 | |
| | (Eq. 8) | $F_2$ = | 0.081 | |
| Shape factor | (Eq. 6) | $I_s$ = | 0.364 | |
| Depth factor | (Eq. 12) | $I_f$ = | 0.846 | |
| Immediate settlement | (Eq. 2) | $S_i$ = | 3.450 | mm |

**Primary Consolidation Settlement**

| | | | | |
|---|---|---|---|---|
| Pressure of initial state | (Eq. 17) | $\sigma_0'$ = | 12.980 | $kN/m^2$ |
| Void ratio of initial state | | $e_0$ = | 0.627 | |
| Compression index | (Eq. 15) | $C_c$ = | 0.150 | |
| Swell index | (Eq. 16) | $C_s$ = | 0.030 | |
| Corresponding cone tip resistance | | $q_c$ = | 1,078.732 | $kN/m^2$ |
| Preconsolidation pressure | (Eq. 18) | $\sigma_c'$ = | 198.245 | $kN/m^2$ |
| Consolidation status | | | Overconsolidated | |
| Change of void ratio | (Eq. 29) | $\Delta e$ = | 0.004 | |
| Consolidation settlement | (Eq. 14) | $S_c$ = | 5.231 | mm |

**Secondary Consolidation Settlement**

| | | | | |
|---|---|---|---|---|
| Void ratio at the end of primary consolidation | (Eq. 27) | $e_p$ = | 0.623 | |

Computing the time in which the primary consolidation ends (assumed to be 95% consolidation):

| | | | | |
|---|---|---|---|---|
| Time factor | (Eq. 24) | $T_v$ = | 1.129 | |
| Coefficient of consolidation | | $c_v$ = | 2.78E-06 | $m^2$/min |
| Drainage path | | $H_{dr}$ = | 2.000 | m |
| Time at the end of primary consolidation | (Eq. 25) | $t_1$ = | 3.129 | years |
| The time considered for secondary consolidation | | $t_2'$ = | 2.000 | years |
| | | $t_1 + t_2' =: t_2$ = | 5.129 | years |
| Empirical value for $C_\alpha/C_c$ | | $C_\alpha/C_c$ = | 0.040 | |
| Secondary compression index | | $C_\alpha$ = | 0.006 | |
| Secondary consolidation settlement | (Eq. 26) | $S_s$ = | 3.179 | mm |
| | | | | |
| **Total Settlement** | (Eq. 1) | **S =** | **15.232** | **mm** |

# SETTLEMENT OF FOUNDATION T02

**GENERAL SOIL MECHANICAL PROPERTIES**

| | | | | |
|---|---|---|---|---|
| Young's modulus | | $E_s$ = | 41,414.190 | $kN/m^2$ |
| Poisson's ratio | | $\mu_s$ = | 0.500 | |
| Unit Weight | | $\gamma$ = | 15.600 | $kN/m^3$ |
| Existence of water | | | FALSE | |
| Effective unit weight | | $\gamma'$ = | 15.600 | $kN/m^3$ |
| Water content | | w = | 0.257 | |
| Dry unit weight | | $\gamma_d$ = | 12.413 | $kN/m^3$ |
| Specific gravity | | $G_s$ = | 2.560 | |

**FOUNDATION PROPERTIES**

| | | | | |
|---|---|---|---|---|
| Length of the foundation | | L = | 7.200 | m |
| Breadth of the foundation | | B = | 7.200 | m |
| Depth of foundation | | $D_f$ = | 3.400 | m |
| Thickness of soil layer | | H = | 4.900 | m |
| Maximum dranage path | | $H_{dr}$ = | 2.450 | m |

**COMPUTING NET APPLIED PRESSURE**

| | | | | |
|---|---|---|---|---|
| Weight of pedestal | | $W_p$ = | 4.320 | Ton |
| Weight of footing | | $W_f$ = | 87.091 | Ton |
| Force on the foundation | | F = | 195.870 | Ton |
| Total force | | P = | 2,818.229 | kN |
| Applied pressure | | $\Delta\sigma$ = | 54.364 | $kN/m^2$ |
| Internal angle of friction | | $\phi'$ = | 40.280 | |
| Coefficient of lateral earth pressure | (Eq. 21) | K = | 0.215 | |
| Depth of interest | | z = | 2.450 | |
| Density input-1 | | Z1 = | 3.171 | |
| Density input-2 | | Z2 = | 3.171 | |
| Probability density-1 (Harr, 1977) | (Eq. 20) | $\psi$(Z1) = | 0.446 | |
| Probability density-2 (Harr, 1977) | (Eq. 20) | $\psi$(Z2) = | 0.446 | |
| Net applied pressure | (Eq. 19) | $\Delta\sigma'$ = | 10.832 | $kN/m^2$ |

**SETTLEMENT**

**Immediate Settlement**

***A. At the Center***

| | | | | |
|---|---|---|---|---|
| Effective width | (Eq. 5) | $B'$ = | 3.600 | m |
| Location factor | (Eq. 4) | $\alpha$ = | 4.000 | |
| Computing shape factor | | | | |
| | | $m'$ = | 1.000 | |
| | | $n'$ = | 1.361 | |
| | (Eq. 9) | $A_0$ = | 0.508 | |
| | (Eq. 10) | $A_1$ = | 0.546 | |
| | (Eq. 11) | $A_2$ = | 0.612 | |
| | (Eq. 7) | $F_1$ = | 0.336 | |
| | (Eq. 8) | $F_2$ = | 0.044 | |
| Shape factor | (Eq. 6) | $I_s$ = | 0.336 | |
| Depth factor | (Eq. 12) | $I_f$ = | 0.853 | |
| Immediate settlement | (Eq. 2) | $S_i$ = | 3.774 | mm |

***B. At the Corner***

| | | | | |
|---|---|---|---|---|
| Effective width | (Eq. 5) | $B'$ = | 7.200 | m |
| Location factor | (Eq. 4) | $\alpha$ = | 1.000 | |
| Computing shape factor | | | | |
| | | $m'$ = | 1.000 | |
| | | $n'$ = | 0.681 | |
| | (Eq. 9) | $A_0$ = | 0.477 | |
| | (Eq. 10) | $A_1$ = | 0.546 | |
| | (Eq. 11) | $A_2$ = | 0.968 | |
| | (Eq. 7) | $F_1$ = | 0.326 | |
| | (Eq. 8) | $F_2$ = | 0.058 | |
| Shape factor | (Eq. 6) | $I_s$ = | 0.326 | |
| Depth factor | (Eq. 12) | $I_f$ = | 0.853 | |
| Immediate settlement | (Eq. 2) | $S_i$ = | 1.831 | mm |

**Primary Consolidation Settlement**

| | | | | |
|---|---|---|---|---|
| Pressure of initial state | (Eq. 17) | $\sigma_0'$ = | 38.220 | $kN/m^2$ |
| Void ratio of initial state | | $e_0$ = | 1.023 | |
| Compression index | (Eq. 15) | $C_c$ = | 0.249 | |
| Swell index | (Eq. 16) | $C_s$ = | 0.050 | |
| Corresponding cone tip resistance | | $q_c$ = | 1,961.330 | $kN/m^2$ |
| Preconsolidation pressure | (Eq. 18) | $\sigma_c'$ = | 351.929 | $kN/m^2$ |
| Consolidation status | | | Overconsolidated | |
| Change of void ratio | (Eq. 29) | $\Delta e$ = | 0.005 | |

| | | | | |
|---|---|---|---|---|
| Consolidation settlement | (Eq. 14) | $S_c$ = | 6.530 | mm |

**Secondary Consolidation Settlement**

| | | | | |
|---|---|---|---|---|
| Void ratio at the end of primary consolidation | (Eq. 27) | $e_p$ = | 1.018 | |
| Computing the time in which the primary consolidation ends (assumed to be 95% consolidation): | | | | |
| Time factor | (Eq. 24) | $T_v$ = | 1.129 | |
| Coefficient of consolidation | | $c_v$ = | 2.78E-06 | $m^2$/min |
| Drainage path | | $H_{dr}$ = | 2.450 | m |
| Time at the end of primary consolidation | (Eq. 25) | $t_1$ = | 4.695 | years |
| The time considered for secondary consolidation | | $t_2'$ = | 2.000 | years |
| | | $t_1 + t_2' =: t_2$ = | 6.695 | years |
| Empirical value for $C_\alpha/C_c$ | | $C_\alpha/C_c$ = | 0.040 | |
| Secondary compression index | | $C_\alpha$ = | 0.010 | |
| Secondary consolidation settlement | (Eq. 26) | $S_s$ = | 3.724 | mm |

| | | | | |
|---|---|---|---|---|
| **Total Settlement** | (Eq. 1) | **S =** | **14.028** | **mm** |

# SETTLEMENT OF FOUNDATION T03

**GENERAL SOIL MECHANICAL PROPERTIES**

| | | | | |
|---|---|---|---|---|
| Young's modulus | | $E_s$ = | 14,715.000 | $kN/m^2$ |
| Poisson's ratio | | $\mu_s$ = | 0.300 | |
| Unit Weight | | $\gamma$ = | 14.800 | $kN/m^3$ |
| Existence of water | | | FALSE | |
| Effective unit weight | | $\gamma'$ = | 14.800 | $kN/m^3$ |
| Water content | | w = | 0.336 | |
| Dry unit weight | | $\gamma_d$ = | 11.080 | $kN/m^3$ |
| Specific gravity | | $G_s$ = | 2.450 | |

**FOUNDATION PROPERTIES**

| | | | | |
|---|---|---|---|---|
| Length of the foundation | | L = | 7.400 | m |
| Breadth of the foundation | | B = | 7.400 | m |
| Depth of foundation | | $D_f$ = | 3.400 | m |
| Thickness of soil layer | | H = | 4.900 | m |
| Maximum dranage path | | $H_{dr}$ = | 2.450 | m |

**COMPUTING NET APPLIED PRESSURE**

| | | | | |
|---|---|---|---|---|
| Weight of pedestal | | $W_p$ = | 2.535 | Ton |
| Weight of footing | | $W_f$ = | 65.712 | Ton |
| Force on the foundation | | F = | 154.530 | Ton |
| Total force | | P = | 2,185.442 | kN |
| Applied pressure | | $\Delta\sigma$ = | 39.909 | $kN/m^2$ |
| Internal angle of friction | | $\phi'$ = | 33.870 | |
| Coefficient of lateral earth pressure | (Eq. 21) | K = | 0.284 | |
| Depth of interest | | z = | 2.450 | |
| Density input-1 | | Z1 = | 2.833 | |
| Density input-2 | | Z2 = | 2.833 | |
| Probability density-1 (Harr, 1977) | (Eq. 20) | $\psi$(Z1) = | 0.437 | |
| Probability density-2 (Harr, 1977) | (Eq. 20) | $\psi$(Z2) = | 0.437 | |
| Net applied pressure | (Eq. 19) | $\Delta\sigma'$ = | 7.604 | $kN/m^2$ |

**SETTLEMENT**

**Immediate Settlement**

***A. At the Center***

| | | | | |
|---|---|---|---|---|
| Effective width | (Eq. 5) | $B' =$ | 3.700 | m |
| Location factor | (Eq. 4) | $\alpha =$ | 4.000 | |
| Computing shape factor | | | | |
| | | $m' =$ | 1.000 | |
| | | $n' =$ | 1.324 | |
| | (Eq. 9) | $A_0 =$ | 0.507 | |
| | (Eq. 10) | $A_1 =$ | 0.547 | |
| | (Eq. 11) | $A_2 =$ | 0.624 | |
| | (Eq. 7) | $F_1 =$ | 0.335 | |
| | (Eq. 8) | $F_2 =$ | 0.045 | |
| Shape factor | (Eq. 6) | $I_s =$ | 0.361 | |
| Depth factor | (Eq. 12) | $I_f =$ | 0.781 | |
| Immediate settlement | (Eq. 2) | $S_i =$ | 9.580 | mm |

***B. At the Corner***

| | | | | |
|---|---|---|---|---|
| Effective width | (Eq. 5) | $B' =$ | 7.400 | m |
| Location factor | (Eq. 4) | $\alpha =$ | 1.000 | |
| Computing shape factor | | | | |
| | | $m' =$ | 1.000 | |
| | | $n' =$ | 0.662 | |
| | (Eq. 9) | $A_0 =$ | 0.476 | |
| | (Eq. 10) | $A_1 =$ | 0.546 | |
| | (Eq. 11) | $A_2 =$ | 0.983 | |
| | (Eq. 7) | $F_1 =$ | 0.325 | |
| | (Eq. 8) | $F_2 =$ | 0.059 | |
| Shape factor | (Eq. 6) | $I_s =$ | 0.359 | |
| Depth factor | (Eq. 12) | $I_f =$ | 0.781 | |
| Immediate settlement | (Eq. 2) | $S_i =$ | 4.764 | mm |

**Primary Consolidation Settlement**

| | | | | |
|---|---|---|---|---|
| Pressure of initial state | (Eq. 17) | $\sigma_0' =$ | 36.260 | $kN/m^2$ |
| Void ratio of initial state | | $e_0 =$ | 1.169 | |
| Compression index | (Eq. 15) | $C_c =$ | 0.309 | |
| Swell index | (Eq. 16) | $C_s =$ | 0.062 | |
| Corresponding cone tip resistance | | $q_c =$ | 2,255.530 | $kN/m^2$ |
| Preconsolidation pressure | (Eq. 18) | $\sigma_c' =$ | 402.462 | $kN/m^2$ |
| Consolidation status | | | Overconsolidated | |
| Change of void ratio | (Eq. 29) | $\Delta e =$ | 0.005 | |

| | | | | |
|---|---|---|---|---|
| Consolidation settlement | (Eq. 14) | $S_c$ = | 5.777 | mm |

**Secondary Consolidation Settlement**

| | | | | |
|---|---|---|---|---|
| Void ratio at the end of primary consolidation | (Eq. 27) | $e_p$ = | 1.164 | |
| Computing the time in which the primary consolidation ends (assumed to be 95% consolidation): | | | | |
| Time factor | (Eq. 24) | $T_v$ = | 1.129 | |
| Coefficient of consolidation | | $c_v$ = | 2.78E-06 | $m^2$/min |
| Drainage path | | $H_{dr}$ = | 2.450 | m |
| Time at the end of primary consolidation | (Eq. 25) | $t_1$ = | 4.695 | years |
| The time considered for secondary consolidation | | $t_2'$ = | 2.000 | years |
| | | $t_1 + t_2' =: t_2$ = | 6.695 | years |
| Empirical value for $C_\alpha/C_c$ | | $C_\alpha/C_c$ = | 0.040 | |
| Secondary compression index | | $C_\alpha$ = | 0.012 | |
| Secondary consolidation settlement | (Eq. 26) | $S_s$ = | 4.318 | mm |

| | | | | |
|---|---|---|---|---|
| **Total Settlement** | (Eq. 1) | **S =** | **19.675** | **mm** |

# SETTLEMENT OF FOUNDATION T04

## GENERAL SOIL MECHANICAL PROPERTIES

| | | | |
|---|---|---|---|
| Young's modulus | $E_s$ = | 14,715.000 | kN/m$^2$ |
| Poisson's ratio | $\mu_s$ = | 0.300 | |
| Unit Weight | $\gamma$ = | 16.800 | kN/m$^3$ |
| Existence of water | | FALSE | |
| Effective unit weight | $\gamma'$ = | 16.800 | kN/m$^3$ |
| Water content | w = | 0.327 | |
| Dry unit weight | $\gamma_d$ = | 12.658 | kN/m$^3$ |
| Specific gravity | $G_s$ = | 2.550 | |

## FOUNDATION PROPERTIES

| | | | |
|---|---|---|---|
| Length of the foundation | L = | 7.100 | m |
| Breadth of the foundation | B = | 7.100 | m |
| Depth of foundation | $D_f$ = | 2.500 | m |
| Thickness of soil layer | H = | 3.200 | m |
| Maximum dranage path | $H_{dr}$ = | 1.600 | m |

## COMPUTING NET APPLIED PRESSURE

| | | | | |
|---|---|---|---|---|
| Weight of pedestal | | $W_p$ = | 2.535 | Ton |
| Weight of footing | | $W_f$ = | 60.492 | Ton |
| Force on the foundation | | F = | 159.510 | Ton |
| Total force | | P = | 2,183.088 | kN |
| Applied pressure | | $\Delta\sigma$ = | 43.307 | kN/m$^2$ |
| Internal angle of friction | | $\phi'$ = | 32.150 | |
| Coefficient of lateral earth pressure | (Eq. 21) | K = | 0.305 | |
| Depth of interest | | z = | 1.600 | |
| Density input-1 | | Z1 = | 4.015 | |
| Density input-2 | | Z2 = | 4.015 | |
| Probability density-1 (Harr, 1977) | (Eq. 20) | $\psi$(Z1) = | 0.465 | |
| Probability density-2 (Harr, 1977) | (Eq. 20) | $\psi$(Z2) = | 0.465 | |
| Net applied pressure | (Eq. 19) | $\Delta\sigma'$ = | 9.374 | kN/m$^2$ |

## SETTLEMENT

### Immediate Settlement

***A. At the Center***

| | | | | |
|---|---|---|---|---|
| Effective width | (Eq. 5) | B' = | 3.550 | m |
| Location factor | (Eq. 4) | $\alpha$ = | 4.000 | |
| Computing shape factor | | | | |
| | | m' = | 1.000 | |
| | | n' = | 0.901 | |
| | (Eq. 9) | $A_0$ = | 0.486 | |
| | (Eq. 10) | $A_1$ = | 0.549 | |
| | (Eq. 11) | $A_2$ = | 0.813 | |
| | (Eq. 7) | $F_1$ = | 0.330 | |
| | (Eq. 8) | $F_2$ = | 0.053 | |
| Shape factor | (Eq. 6) | $I_s$ = | 0.360 | |
| Depth factor | (Eq. 12) | $I_f$ = | 0.804 | |
| Immediate settlement | (Eq. 2) | $S_i$ = | 10.233 | mm |

***B. At the Corner***

| | | | | |
|---|---|---|---|---|
| Effective width | (Eq. 5) | B' = | 7.100 | m |
| Location factor | (Eq. 4) | $\alpha$ = | 1.000 | |
| Computing shape factor | | | | |
| | | m' = | 1.000 | |
| | | n' = | 0.451 | |
| | (Eq. 9) | $A_0$ = | 0.468 | |
| | (Eq. 10) | $A_1$ = | 0.542 | |
| | (Eq. 11) | $A_2$ = | 1.223 | |
| | (Eq. 7) | $F_1$ = | 0.322 | |
| | (Eq. 8) | $F_2$ = | 0.066 | |
| Shape factor | (Eq. 6) | $I_s$ = | 0.359 | |
| Depth factor | (Eq. 12) | $I_f$ = | 0.804 | |
| Immediate settlement | (Eq. 2) | $S_i$ = | 5.108 | mm |

**Primary Consolidation Settlement**

| | | | | |
|---|---|---|---|---|
| Pressure of initial state | (Eq. 17) | $\sigma_0'$ = | 26.880 | $kN/m^2$ |
| Void ratio of initial state | | $e_0$ = | 0.976 | |
| Compression index | (Eq. 15) | $C_c$ = | 0.236 | |
| Swell index | (Eq. 16) | $C_s$ = | 0.047 | |
| Corresponding cone tip resistance | | $q_c$ = | 2,451.663 | $kN/m^2$ |
| Preconsolidation pressure | (Eq. 18) | $\sigma_c'$ = | 436.002 | $kN/m^2$ |
| Consolidation status | | | Overconsolidated | |
| Change of void ratio | (Eq. 29) | $\Delta e$ = | 0.006 | |

| | | | | |
|---|---|---|---|---|
| Consolidation settlement | (Eq. 14) | $S_c$ = | 4.973 | mm |

**Secondary Consolidation Settlement**

| | | | | |
|---|---|---|---|---|
| Void ratio at the end of primary consolidation | (Eq. 27) | $e_p$ = | 0.970 | |
| Computing the time in which the primary consolidation ends (assumed to be 95% consolidation): | | | | |
| Time factor | (Eq. 24) | $T_v$ = | 1.129 | |
| Coefficient of consolidation | | $c_v$ = | 2.78E-06 | $m^2$/min |
| Drainage path | | $H_{dr}$ = | 1.600 | m |
| Time at the end of primary consolidation | (Eq. 25) | $t_1$ = | 2.002 | years |
| The time considered for secondary consolidation | | $t_2'$ = | 2.000 | years |
| | | $t_1 + t_2' =: t_2$ = | 4.002 | years |
| Empirical value for $C_\alpha/C_c$ | | $C_\alpha/C_c$ = | 0.040 | |
| Secondary compression index | | $C_\alpha$ = | 0.009 | |
| Secondary consolidation settlement | (Eq. 26) | $S_s$ = | 4.619 | mm |

| | | | | |
|---|---|---|---|---|
| **Total Settlement** | (Eq. 1) | **S =** | **19.825** | **mm** |

# SETTLEMENT OF FOUNDATION T05

## GENERAL SOIL MECHANICAL PROPERTIES

| | | | |
|---|---|---|---|
| Young's modulus | $E_s$ = | 14,715.000 | $kN/m^2$ |
| Poisson's ratio | $\mu_s$ = | 0.300 | |
| Unit Weight | $\gamma$ = | 16.700 | $kN/m^3$ |
| Existence of water | | FALSE | |
| Effective unit weight | $\gamma'$ = | 16.700 | $kN/m^3$ |
| Water content | w = | 0.359 | |
| Dry unit weight | $\gamma_d$ = | 12.290 | $kN/m^3$ |
| Specific gravity | $G_s$ = | 25.400 | |

## FOUNDATION PROPERTIES

| | | | |
|---|---|---|---|
| Length of the foundation | L = | 5.900 | m |
| Breadth of the foundation | B = | 5.900 | m |
| Depth of foundation | $D_f$ = | 2.500 | m |
| Thickness of soil layer | H = | 2.400 | m |
| Maximum dranage path | $H_{dr}$ = | 1.200 | m |

## COMPUTING NET APPLIED PRESSURE

| | | | | |
|---|---|---|---|---|
| Weight of pedestal | | $W_p$ = | 2.203 | Ton |
| Weight of footing | | $W_f$ = | 37.595 | Ton |
| Force on the foundation | | F = | 118.030 | Ton |
| Total force | | P = | 1,548.293 | kN |
| Applied pressure | | $\Delta\sigma$ = | 44.478 | $kN/m^2$ |
| Internal angle of friction | | $\phi'$ = | 30.230 | |
| Coefficient of lateral earth pressure | (Eq. 21) | K = | 0.330 | |
| Depth of interest | | z = | 1.200 | |
| Density input-1 | | Z1 = | 4.278 | |
| Density input-2 | | Z2 = | 4.278 | |
| Probability density-1 (Harr, 1977) | (Eq. 20) | $\psi$(Z1) = | 0.470 | |
| Probability density-2 (Harr, 1977) | (Eq. 20) | $\psi$(Z2) = | 0.470 | |
| Net applied pressure | (Eq. 19) | $\Delta\sigma'$ = | 9.810 | $kN/m^2$ |

## SETTLEMENT

**Immediate Settlement**

***A. At the Center***

| | | | | |
|---|---|---|---|---|
| Effective width | (Eq. 5) | $B'$ = | 2.950 | m |
| Location factor | (Eq. 4) | $\alpha$ = | 4.000 | |
| Computing shape factor | | | | |
| | | $m'$ = | 1.000 | |
| | | $n'$ = | 0.814 | |
| | (Eq. 9) | $A_0$ = | 0.482 | |
| | (Eq. 10) | $A_1$ = | 0.548 | |
| | (Eq. 11) | $A_2$ = | 0.868 | |
| | (Eq. 7) | $F_1$ = | 0.328 | |
| | (Eq. 8) | $F_2$ = | 0.055 | |
| Shape factor | (Eq. 6) | $I_s$ = | 0.359 | |
| Depth factor | (Eq. 12) | $I_f$ = | 0.789 | |
| Immediate settlement | (Eq. 2) | $S_i$ = | 8.560 | mm |

***B. At the Corner***

| | | | | |
|---|---|---|---|---|
| Effective width | (Eq. 5) | $B'$ = | 5.900 | m |
| Location factor | (Eq. 4) | $\alpha$ = | 1.000 | |
| Computing shape factor | | | | |
| | | $m'$ = | 1.000 | |
| | | $n'$ = | 0.407 | |
| | (Eq. 9) | $A_0$ = | 0.467 | |
| | (Eq. 10) | $A_1$ = | 0.541 | |
| | (Eq. 11) | $A_2$ = | 1.293 | |
| | (Eq. 7) | $F_1$ = | 0.321 | |
| | (Eq. 8) | $F_2$ = | 0.068 | |
| Shape factor | (Eq. 6) | $I_s$ = | 0.360 | |
| Depth factor | (Eq. 12) | $I_f$ = | 0.789 | |
| Immediate settlement | (Eq. 2) | $S_i$ = | 4.281 | mm |

**Primary Consolidation Settlement**

| | | | | |
|---|---|---|---|---|
| Pressure of initial state | (Eq. 17) | $\sigma_0'$ = | 20.040 | kN/m$^2$ |
| Void ratio of initial state | | $e_0$ = | 19.274 | |
| Compression index | (Eq. 15) | $C_c$ = | 4.000 | |
| Swell index | (Eq. 16) | $C_s$ = | 0.800 | |
| Corresponding cone tip resistance | | $q_c$ = | 784.532 | kN/m$^2$ |
| Preconsolidation pressure | (Eq. 18) | $\sigma_c'$ = | 146.027 | kN/m$^2$ |
| Consolidation status | | | Overconsolidated | |
| Change of void ratio | (Eq. 29) | $\Delta e$ = | 0.138 | |

| | | | | |
|---|---|---|---|---|
| Consolidation settlement | (Eq. 14) | $S_c$ = | 8.194 | mm |

**Secondary Consolidation Settlement**

| | | | | |
|---|---|---|---|---|
| Void ratio at the end of primary consolidation | (Eq. 27) | $e_p$ = | 19.136 | |
| Computing the time in which the primary consolidation ends (assumed to be 95% consolidation): | | | | |
| Time factor | (Eq. 24) | $T_v$ = | 1.129 | |
| Coefficient of consolidation | | $c_v$ = | 2.78E-06 | $m^2$/min |
| Drainage path | | $H_{dr}$ = | 1.200 | m |
| Time at the end of primary consolidation | (Eq. 25) | $t_1$ = | 1.126 | years |
| The time considered for secondary consolidation | | $t_2'$ = | 2.000 | years |
| | | $t_1 + t_2' =: t_2$ = | 3.126 | years |
| Empirical value for $C_\alpha/C_c$ | | $C_\alpha/C_c$ = | 0.040 | |
| Secondary compression index | | $C_\alpha$ = | 0.160 | |
| Secondary consolidation settlement | (Eq. 26) | $S_s$ = | 8.455 | mm |

| | | | | |
|---|---|---|---|---|
| **Total Settlement** | (Eq. 1) | **S =** | **25.208** | **mm** |

# SETTLEMENT OF FOUNDATION T06

**GENERAL SOIL MECHANICAL PROPERTIES**

| | | | | |
|---|---|---|---|---|
| Young's modulus | | $E_s$ = | 14,715.000 | $kN/m^2$ |
| Poisson's ratio | | $\mu_s$ = | 0.300 | |
| Unit Weight | | $\gamma$ = | 16.000 | $kN/m^3$ |
| Existence of water | | | FALSE | |
| Effective unit weight | | $\gamma'$ = | 16.000 | $kN/m^3$ |
| Water content | | w = | 0.329 | |
| Dry unit weight | | $\gamma_d$ = | 12.042 | $kN/m^3$ |
| Specific gravity | | $G_s$ = | 2.530 | |

**FOUNDATION PROPERTIES**

| | | | | |
|---|---|---|---|---|
| Length of the foundation | | L = | 9.300 | m |
| Breadth of the foundation | | B = | 9.300 | m |
| Depth of foundation | | $D_f$ = | 3.400 | m |
| Thickness of soil layer | | H = | 2.000 | m |
| Maximum dranage path | | $H_{dr}$ = | 1.000 | m |

**COMPUTING NET APPLIED PRESSURE**

| | | | | |
|---|---|---|---|---|
| Weight of pedestal | | $W_p$ = | 4.685 | Ton |
| Weight of footing | | $W_f$ = | 176.440 | Ton |
| Force on the foundation | | F = | 361.040 | Ton |
| Total force | | P = | 5,318.633 | kN |
| Applied pressure | | $\Delta\sigma$ = | 61.494 | $kN/m^2$ |
| Internal angle of friction | | $\phi'$ = | 32.150 | |
| Coefficient of lateral earth pressure | (Eq. 21) | K = | 0.305 | |
| Depth of interest | | z = | 1.000 | |
| Density input-1 | | Z1 = | 8.415 | |
| Density input-2 | | Z2 = | 8.415 | |
| Probability density-1 (Harr, 1977) | (Eq. 20) | $\psi$(Z1) = | 0.496 | |
| Probability density-2 (Harr, 1977) | (Eq. 20) | $\psi$(Z2) = | 0.496 | |
| Net applied pressure | (Eq. 19) | $\Delta\sigma'$ = | 15.145 | $kN/m^2$ |

**SETTLEMENT**

**Immediate Settlement**

***A. At the Center***

| | | | | |
|---|---|---|---|---|
| Effective width | (Eq. 5) | $B'$ = | 4.650 | m |
| Location factor | (Eq. 4) | $\alpha$ = | 4.000 | |
| Computing shape factor | | | | |
| | | $m'$ = | 1.000 | |
| | | $n'$ = | 0.430 | |
| | (Eq. 9) | $A_0$ = | 0.468 | |
| | (Eq. 10) | $A_1$ = | 0.541 | |
| | (Eq. 11) | $A_2$ = | 1.254 | |
| | (Eq. 7) | $F_1$ = | 0.321 | |
| | (Eq. 8) | $F_2$ = | 0.067 | |
| Shape factor | (Eq. 6) | $I_s$ = | 0.359 | |
| Depth factor | (Eq. 12) | $I_f$ = | 0.801 | |
| Immediate settlement | (Eq. 2) | $S_i$ = | 18.941 | mm |

***B. At the Corner***

| | | | | |
|---|---|---|---|---|
| Effective width | (Eq. 5) | $B'$ = | 9.300 | m |
| Location factor | (Eq. 4) | $\alpha$ = | 1.000 | |
| Computing shape factor | | | | |
| | | $m'$ = | 1.000 | |
| | | $n'$ = | 0.215 | |
| | (Eq. 9) | $A_0$ = | 0.463 | |
| | (Eq. 10) | $A_1$ = | 0.537 | |
| | (Eq. 11) | $A_2$ = | 1.803 | |
| | (Eq. 7) | $F_1$ = | 0.318 | |
| | (Eq. 8) | $F_2$ = | 0.078 | |
| Shape factor | (Eq. 6) | $I_s$ = | 0.363 | |
| Depth factor | (Eq. 12) | $I_f$ = | 0.801 | |
| Immediate settlement | (Eq. 2) | $S_i$ = | 9.566 | mm |

**Primary Consolidation Settlement**

| | | | | |
|---|---|---|---|---|
| Pressure of initial state | (Eq. 17) | $\sigma_0'$ = | 16.000 | $kN/m^2$ |
| Void ratio of initial state | | $e_0$ = | 1.061 | |
| Compression index | (Eq. 15) | $C_c$ = | 0.264 | |
| Swell index | (Eq. 16) | $C_s$ = | 0.053 | |
| Corresponding cone tip resistance | | $q_c$ = | 2,451.663 | $kN/m^2$ |
| Preconsolidation pressure | (Eq. 18) | $\sigma_c'$ = | 436.002 | $kN/m^2$ |
| Consolidation status | | | Overconsolidated | |
| Change of void ratio | (Eq. 29) | $\Delta e$ = | 0.015 | |

| | | | | |
|---|---|---|---|---|
| Consolidation settlement | (Eq. 14) | $S_c$ = | 7.401 | mm |

**Secondary Consolidation Settlement**

| | | | | |
|---|---|---|---|---|
| Void ratio at the end of primary consolidation | (Eq. 27) | $e_p$ = | 1.046 | |
| Computing the time in which the primary consolidation ends (assumed to be 95% consolidation): | | | | |
| Time factor | (Eq. 24) | $T_v$ = | 1.129 | |
| Coefficient of consolidation | | $c_v$ = | 2.78E-06 | $m^2$/min |
| Drainage path | | $H_{dr}$ = | 1.000 | m |
| Time at the end of primary consolidation | (Eq. 25) | $t_1$ = | 0.782 | years |
| The time considered for secondary consolidation | | $t_2'$ = | 2.000 | years |
| | | $t_1 + t_2' =: t_2$ = | 2.782 | years |
| Empirical value for $C_\alpha/C_c$ | | $C_\alpha/C_c$ = | 0.040 | |
| Secondary compression index | | $C_\alpha$ = | 0.011 | |
| Secondary consolidation settlement | (Eq. 26) | $S_s$ = | 5.682 | mm |

| | | | | |
|---|---|---|---|---|
| **Total Settlement** | (Eq. 1) | **S =** | **32.025** | **mm** |

# SETTLEMENT OF FOUNDATION T07

## GENERAL SOIL MECHANICAL PROPERTIES

| | | | | |
|---|---|---|---|---|
| Young's modulus | | $E_s$ = | 14,715.000 | $kN/m^2$ |
| Poisson's ratio | | $\mu_s$ = | 0.300 | |
| Unit Weight | | $\gamma$ = | 18.800 | $kN/m^3$ |
| Existence of water | | | FALSE | |
| Effective unit weight | | $\gamma'$ = | 18.800 | $kN/m^3$ |
| Water content | | w = | 0.237 | |
| Dry unit weight | | $\gamma_d$ = | 15.196 | $kN/m^3$ |
| Specific gravity | | $G_s$ = | 2.580 | |

## FOUNDATION PROPERTIES

| | | | | |
|---|---|---|---|---|
| Length of the foundation | | L = | 6.800 | m |
| Breadth of the foundation | | B = | 6.800 | m |
| Depth of foundation | | $D_f$ = | 3.000 | m |
| Thickness of soil layer | | H = | 2.400 | m |
| Maximum dranage path | | $H_{dr}$ = | 1.200 | m |

## COMPUTING NET APPLIED PRESSURE

| | | | | |
|---|---|---|---|---|
| Weight of pedestal | | $W_p$ = | 2.839 | Ton |
| Weight of footing | | $W_f$ = | 77.683 | Ton |
| Force on the foundation | | F = | 194.890 | Ton |
| Total force | | P = | 2,701.796 | kN |
| Applied pressure | | $\Delta\sigma$ = | 58.430 | $kN/m^2$ |
| Internal angle of friction | | $\phi'$ = | 30.230 | |
| Coefficient of lateral earth pressure | (Eq. 21) | K = | 0.330 | |
| Depth of interest | | z = | 1.200 | |
| Density input-1 | | Z1 = | 4.930 | |
| Density input-2 | | Z2 = | 4.930 | |
| Probability density-1 (Harr, 1977) | (Eq. 20) | $\psi$(Z1) = | 0.478 | |
| Probability density-2 (Harr, 1977) | (Eq. 20) | $\psi$(Z2) = | 0.478 | |
| Net applied pressure | (Eq. 19) | $\Delta\sigma'$ = | 13.366 | $kN/m^2$ |

## SETTLEMENT

### Immediate Settlement

***A. At the Center***

| | | | | |
|---|---|---|---|---|
| Effective width | (Eq. 5) | $B'$ = | 3.400 | m |
| Location factor | (Eq. 4) | $\alpha$ = | 4.000 | |
| Computing shape factor | | | | |
| | | $m'$ = | 1.000 | |
| | | $n'$ = | 0.706 | |
| | (Eq. 9) | $A_0$ = | 0.478 | |
| | (Eq. 10) | $A_1$ = | 0.547 | |
| | (Eq. 11) | $A_2$ = | 0.947 | |
| | (Eq. 7) | $F_1$ = | 0.326 | |
| | (Eq. 8) | $F_2$ = | 0.058 | |
| Shape factor | (Eq. 6) | $I_s$ = | 0.359 | |
| Depth factor | (Eq. 12) | $I_f$ = | 0.785 | |
| Immediate settlement | (Eq. 2) | $S_i$ = | 12.886 | mm |

***B. At the Corner***

| | | | | |
|---|---|---|---|---|
| Effective width | (Eq. 5) | $B'$ = | 6.800 | m |
| Location factor | (Eq. 4) | $\alpha$ = | 1.000 | |
| Computing shape factor | | | | |
| | | $m'$ = | 1.000 | |
| | | $n'$ = | 0.353 | |
| | (Eq. 9) | $A_0$ = | 0.466 | |
| | (Eq. 10) | $A_1$ = | 0.539 | |
| | (Eq. 11) | $A_2$ = | 1.394 | |
| | (Eq. 7) | $F_1$ = | 0.320 | |
| | (Eq. 8) | $F_2$ = | 0.070 | |
| Shape factor | (Eq. 6) | $I_s$ = | 0.360 | |
| Depth factor | (Eq. 12) | $I_f$ = | 0.785 | |
| Immediate settlement | (Eq. 2) | $S_i$ = | 6.461 | mm |

**Primary Consolidation Settlement**

| | | | | |
|---|---|---|---|---|
| Pressure of initial state | (Eq. 17) | $\sigma_0'$ = | 22.560 | $kN/m^2$ |
| Void ratio of initial state | | $e_0$ = | 0.666 | |
| Compression index | (Eq. 15) | $C_c$ = | 0.155 | |
| Swell index | (Eq. 16) | $C_s$ = | 0.031 | |
| Corresponding cone tip resistance | | $q_c$ = | 5,393.658 | $kN/m^2$ |
| Preconsolidation pressure | (Eq. 18) | $\sigma_c'$ = | 929.425 | $kN/m^2$ |
| Consolidation status | | | Overconsolidated | |
| Change of void ratio | (Eq. 29) | $\Delta e$ = | 0.006 | |

| | | | | |
|---|---|---|---|---|
| Consolidation settlement | (Eq. 14) | $S_c$ = | 4.518 | mm |

**Secondary Consolidation Settlement**

| | | | | |
|---|---|---|---|---|
| Void ratio at the end of primary consolidation | (Eq. 27) | $e_p$ = | 0.659 | |
| Computing the time in which the primary consolidation ends (assumed to be 95% consolidation): | | | | |
| Time factor | (Eq. 24) | $T_v$ = | 1.129 | |
| Coefficient of consolidation | | $c_v$ = | 2.78E-06 | $m^2$/min |
| Drainage path | | $H_{dr}$ = | 1.200 | m |
| Time at the end of primary consolidation | (Eq. 25) | $t_1$ = | 1.126 | years |
| The time considered for secondary consolidation | | $t_2'$ = | 2.000 | years |
| | | $t_1 + t_2' =: t_2$ = | 3.126 | years |
| Empirical value for $C_\alpha/C_c$ | | $C_\alpha/C_c$ = | 0.040 | |
| Secondary compression index | | $C_\alpha$ = | 0.006 | |
| Secondary consolidation settlement | (Eq. 26) | $S_s$ = | 3.981 | mm |

| | | | | |
|---|---|---|---|---|
| **Total Settlement** | (Eq. 1) | **S =** | **21.385** | **mm** |

# SETTLEMENT OF FOUNDATION T08

## GENERAL SOIL MECHANICAL PROPERTIES

| | | | |
|---|---|---|---|
| Young's modulus | $E_s$ = | 14,715.000 | $kN/m^2$ |
| Poisson's ratio | $\mu_s$ = | 0.300 | |
| Unit Weight | $\gamma$ = | 17.300 | $kN/m^3$ |
| Existence of water | | FALSE | |
| Effective unit weight | $\gamma'$ = | 17.300 | $kN/m^3$ |
| Water content | w = | 0.364 | |
| Dry unit weight | $\gamma_d$ = | 12.686 | $kN/m^3$ |
| Specific gravity | $G_s$ = | 2.530 | |

## FOUNDATION PROPERTIES

| | | | |
|---|---|---|---|
| Length of the foundation | L = | 4.100 | m |
| Breadth of the foundation | B = | 4.100 | m |
| Depth of foundation | $D_f$ = | 2.500 | m |
| Thickness of soil layer | H = | 2.000 | m |
| Maximum dranage path | $H_{dr}$ = | 1.000 | m |

## COMPUTING NET APPLIED PRESSURE

| | | | | |
|---|---|---|---|---|
| Weight of pedestal | | $W_p$ = | 2.203 | Ton |
| Weight of footing | | $W_f$ = | 18.155 | Ton |
| Force on the foundation | | F = | 64.340 | Ton |
| Total force | | P = | 830.887 | kN |
| Applied pressure | | $\Delta\sigma$ = | 49.428 | $kN/m^2$ |
| Internal angle of friction | | $\phi'$ = | 30.230 | |
| Coefficient of lateral earth pressure | (Eq. 21) | K = | 0.330 | |
| Depth of interest | | z = | 1.000 | |
| Density input-1 | | Z1 = | 3.567 | |
| Density input-2 | | Z2 = | 3.567 | |
| Probability density-1 (Harr, 1977) | (Eq. 20) | $\psi$(Z1) = | 0.456 | |
| Probability density-2 (Harr, 1977) | (Eq. 20) | $\psi$(Z2) = | 0.456 | |
| Net applied pressure | (Eq. 19) | $\Delta\sigma'$ = | 10.287 | $kN/m^2$ |

## SETTLEMENT

### Immediate Settlement

***A. At the Center***

| | | | | |
|---|---|---|---|---|
| Effective width | (Eq. 5) | $B'$ = | 2.050 | m |
| Location factor | (Eq. 4) | $\alpha$ = | 4.000 | |
| Computing shape factor | | | | |
| | | $m'$ = | 1.000 | |
| | | $n'$ = | 0.976 | |
| | (Eq. 9) | $A_0$ = | 0.490 | |
| | (Eq. 10) | $A_1$ = | 0.549 | |
| | (Eq. 11) | $A_2$ = | 0.772 | |
| | (Eq. 7) | $F_1$ = | 0.331 | |
| | (Eq. 8) | $F_2$ = | 0.051 | |
| Shape factor | (Eq. 6) | $I_s$ = | 0.360 | |
| Depth factor | (Eq. 12) | $I_f$ = | 0.749 | |
| Immediate settlement | (Eq. 2) | $S_i$ = | 6.288 | mm |

***B. At the Corner***

| | | | | |
|---|---|---|---|---|
| Effective width | (Eq. 5) | $B'$ = | 4.100 | m |
| Location factor | (Eq. 4) | $\alpha$ = | 1.000 | |
| Computing shape factor | | | | |
| | | $m'$ = | 1.000 | |
| | | $n'$ = | 0.488 | |
| | (Eq. 9) | $A_0$ = | 0.470 | |
| | (Eq. 10) | $A_1$ = | 0.542 | |
| | (Eq. 11) | $A_2$ = | 1.171 | |
| | (Eq. 7) | $F_1$ = | 0.322 | |
| | (Eq. 8) | $F_2$ = | 0.065 | |
| Shape factor | (Eq. 6) | $I_s$ = | 0.359 | |
| Depth factor | (Eq. 12) | $I_f$ = | 0.749 | |
| Immediate settlement | (Eq. 2) | $S_i$ = | 3.135 | mm |

**Primary Consolidation Settlement**

| | | | | |
|---|---|---|---|---|
| Pressure of initial state | (Eq. 17) | $\sigma_0'$ = | 17.300 | $kN/m^2$ |
| Void ratio of initial state | | $e_0$ = | 0.956 | |
| Compression index | (Eq. 15) | $C_c$ = | 0.233 | |
| Swell index | (Eq. 16) | $C_s$ = | 0.047 | |
| Corresponding cone tip resistance | | $q_c$ = | 5,393.658 | $kN/m^2$ |
| Preconsolidation pressure | (Eq. 18) | $\sigma_c'$ = | 929.425 | $kN/m^2$ |
| Consolidation status | | | Overconsolidated | |
| Change of void ratio | (Eq. 29) | $\Delta e$ = | 0.009 | |

| | | | | |
|---|---|---|---|---|
| Consolidation settlement | (Eq. 14) | $S_c$ = | 4.826 | mm |

**Secondary Consolidation Settlement**

| | | | | |
|---|---|---|---|---|
| Void ratio at the end of primary consolidation | (Eq. 27) | $e_p$ = | 0.947 | |
| Computing the time in which the primary consolidation ends (assumed to be 95% consolidation): | | | | |
| Time factor | (Eq. 24) | $T_v$ = | 1.129 | |
| Coefficient of consolidation | | $c_v$ = | 2.78E-06 | $m^2$/min |
| Drainage path | | $H_{dr}$ = | 1.000 | m |
| Time at the end of primary consolidation | (Eq. 25) | $t_1$ = | 0.782 | years |
| The time considered for secondary consolidation | | $t_2'$ = | 2.000 | years |
| | | $t_1 + t_2' =: t_2$ = | 2.782 | years |
| Empirical value for $C_\alpha/C_c$ | | $C_\alpha/C_c$ = | 0.040 | |
| Secondary compression index | | $C_\alpha$ = | 0.009 | |
| Secondary consolidation settlement | (Eq. 26) | $S_s$ = | 5.274 | mm |

| | | | | |
|---|---|---|---|---|
| **Total Settlement** | (Eq. 1) | **S =** | **16.388** | **mm** |

# SETTLEMENT OF FOUNDATION T09

## GENERAL SOIL MECHANICAL PROPERTIES

| | | | | |
|---|---|---|---|---|
| Young's modulus | | $E_s$ = | 14,715.000 | $kN/m^2$ |
| Poisson's ratio | | $\mu_s$ = | 0.300 | |
| Unit Weight | | $\gamma$ = | 17.900 | $kN/m^3$ |
| Existence of water | | | FALSE | |
| Effective unit weight | | $\gamma'$ = | 17.900 | $kN/m^3$ |
| Water content | | w = | 0.416 | |
| Dry unit weight | | $\gamma_d$ = | 12.646 | $kN/m^3$ |
| Specific gravity | | $G_s$ = | 2.520 | |

## FOUNDATION PROPERTIES

| | | | | |
|---|---|---|---|---|
| Length of the foundation | | L = | 4.600 | m |
| Breadth of the foundation | | B = | 4.600 | m |
| Depth of foundation | | $D_f$ = | 2.500 | m |
| Thickness of soil layer | | H = | 2.400 | m |
| Maximum dranage path | | $H_{dr}$ = | 1.200 | m |

## COMPUTING NET APPLIED PRESSURE

| | | | | |
|---|---|---|---|---|
| Weight of pedestal | | $W_p$ = | 2.203 | Ton |
| Weight of footing | | $W_f$ = | 22.853 | Ton |
| Force on the foundation | | F = | 82.050 | Ton |
| Total force | | P = | 1,050.710 | kN |
| Applied pressure | | $\Delta\sigma$ = | 49.655 | $kN/m^2$ |
| Internal angle of friction | | $\phi'$ = | 15.230 | |
| Coefficient of lateral earth pressure | (Eq. 21) | K = | 0.584 | |
| Depth of interest | | z = | 1.200 | |
| Density input-1 | | Z1 = | 2.508 | |
| Density input-2 | | Z2 = | 2.508 | |
| Probability density-1 (Harr, 1977) | (Eq. 20) | $\psi(Z1)$ = | 0.426 | |
| Probability density-2 (Harr, 1977) | (Eq. 20) | $\psi(Z2)$ = | 0.426 | |
| Net applied pressure | (Eq. 19) | $\Delta\sigma'$ = | 9.004 | $kN/m^2$ |

## SETTLEMENT

### Immediate Settlement

***A. At the Center***

| | | | | |
|---|---|---|---|---|
| Effective width | (Eq. 5) | $B'$ = | 2.300 | m |
| Location factor | (Eq. 4) | $\alpha$ = | 4.000 | |
| Computing shape factor | | | | |
| | | $m'$ = | 1.000 | |
| | | $n'$ = | 1.043 | |
| | (Eq. 9) | $A_0$ = | 0.493 | |
| | (Eq. 10) | $A_1$ = | 0.549 | |
| | (Eq. 11) | $A_2$ = | 0.738 | |
| | (Eq. 7) | $F_1$ = | 0.332 | |
| | (Eq. 8) | $F_2$ = | 0.050 | |
| Shape factor | (Eq. 6) | $I_s$ = | 0.360 | |
| Depth factor | (Eq. 12) | $I_f$ = | 0.763 | |
| Immediate settlement | (Eq. 2) | $S_i$ = | 7.226 | mm |

***B. At the Corner***

| | | | | |
|---|---|---|---|---|
| Effective width | (Eq. 5) | $B'$ = | 4.600 | m |
| Location factor | (Eq. 4) | $\alpha$ = | 1.000 | |
| Computing shape factor | | | | |
| | | $m'$ = | 1.000 | |
| | | $n'$ = | 0.522 | |
| | (Eq. 9) | $A_0$ = | 0.471 | |
| | (Eq. 10) | $A_1$ = | 0.543 | |
| | (Eq. 11) | $A_2$ = | 1.128 | |
| | (Eq. 7) | $F_1$ = | 0.323 | |
| | (Eq. 8) | $F_2$ = | 0.063 | |
| Shape factor | (Eq. 6) | $I_s$ = | 0.359 | |
| Depth factor | (Eq. 12) | $I_f$ = | 0.763 | |
| Immediate settlement | (Eq. 2) | $S_i$ = | 3.599 | mm |

**Primary Consolidation Settlement**

| | | | | |
|---|---|---|---|---|
| Pressure of initial state | (Eq. 17) | $\sigma_0'$ = | 21.480 | $kN/m^2$ |
| Void ratio of initial state | | $e_0$ = | 0.955 | |
| Compression index | (Eq. 15) | $C_c$ = | 0.234 | |
| Swell index | (Eq. 16) | $C_s$ = | 0.047 | |
| Corresponding cone tip resistance | | $q_c$ = | 2,451.663 | $kN/m^2$ |
| Preconsolidation pressure | (Eq. 18) | $\sigma_c'$ = | 436.002 | $kN/m^2$ |
| Consolidation status | | | Overconsolidated | |
| Change of void ratio | (Eq. 29) | $\Delta e$ = | 0.007 | |

| | | | | |
|---|---|---|---|---|
| Consolidation settlement | (Eq. 14) | $S_c$ = | 4.360 | mm |

**Secondary Consolidation Settlement**

| | | | | |
|---|---|---|---|---|
| Void ratio at the end of primary consolidation | (Eq. 27) | $e_p$ = | 0.948 | |

Computing the time in which the primary consolidation ends (assumed to be 95% consolidation):

| | | | | |
|---|---|---|---|---|
| Time factor | (Eq. 24) | $T_v$ = | 1.129 | |
| Coefficient of consolidation | | $c_v$ = | 2.78E-06 | $m^2$/min |
| Drainage path | | $H_{dr}$ = | 1.200 | m |
| Time at the end of primary consolidation | (Eq. 25) | $t_1$ = | 1.126 | years |
| The time considered for secondary consolidation | | $t_2'$ = | 2.000 | years |
| | | $t_1 + t_2' =: t_2$ = | 3.126 | years |
| Empirical value for $C_\alpha/C_c$ | | $C_\alpha/C_c$ = | 0.040 | |
| Secondary compression index | | $C_\alpha$ = | 0.009 | |
| Secondary consolidation settlement | (Eq. 26) | $S_s$ = | 5.104 | mm |

| | | | | |
|---|---|---|---|---|
| **Total Settlement** | (Eq. 1) | **S =** | **16.691** | **mm** |

# SETTLEMENT OF FOUNDATION T10

## GENERAL SOIL MECHANICAL PROPERTIES

| | | | | |
|---|---|---|---|---|
| Young's modulus | | $E_s$ = | 14,715.000 | $kN/m^2$ |
| Poisson's ratio | | $\mu_s$ = | 0.300 | |
| Unit Weight | | $\gamma$ = | 18.000 | $kN/m^3$ |
| Existence of water | | | FALSE | |
| Effective unit weight | | $\gamma'$ = | 18.000 | $kN/m^3$ |
| Water content | | w = | 0.418 | |
| Dry unit weight | | $\gamma_d$ = | 12.690 | $kN/m^3$ |
| Specific gravity | | $G_s$ = | 2.520 | |

## FOUNDATION PROPERTIES

| | | | | |
|---|---|---|---|---|
| Length of the foundation | | L = | 5.200 | m |
| Breadth of the foundation | | B = | 5.200 | m |
| Depth of foundation | | $D_f$ = | 2.500 | m |
| Thickness of soil layer | | H = | 2.000 | m |
| Maximum dranage path | | $H_{dr}$ = | 1.000 | m |

## COMPUTING NET APPLIED PRESSURE

| | | | | |
|---|---|---|---|---|
| Weight of pedestal | | $W_p$ = | 2.117 | Ton |
| Weight of footing | | $W_f$ = | 35.693 | Ton |
| Force on the foundation | | F = | 87.140 | Ton |
| Total force | | P = | 1,225.756 | kN |
| Applied pressure | | $\Delta\sigma$ = | 45.331 | $kN/m^2$ |
| Internal angle of friction | | $\phi'$ = | 6.570 | |
| Coefficient of lateral earth pressure | (Eq. 21) | K = | 0.795 | |
| Depth of interest | | z = | 1.000 | |
| Density input-1 | | Z1 = | 2.917 | |
| Density input-2 | | Z2 = | 2.917 | |
| Probability density-1 (Harr, 1977) | (Eq. 20) | $\psi$(Z1) = | 0.439 | |
| Probability density-2 (Harr, 1977) | (Eq. 20) | $\psi$(Z2) = | 0.439 | |
| Net applied pressure | (Eq. 19) | $\Delta\sigma'$ = | 8.740 | $kN/m^2$ |

## SETTLEMENT

### Immediate Settlement

***A. At the Center***

| | | | | |
|---|---|---|---|---|
| Effective width | (Eq. 5) | $B'$ = | 2.600 | m |
| Location factor | (Eq. 4) | $\alpha$ = | 4.000 | |
| Computing shape factor | | | | |
| | | $m'$ = | 1.000 | |
| | | $n'$ = | 0.769 | |
| | (Eq. 9) | $A_0$ = | 0.480 | |
| | (Eq. 10) | $A_1$ = | 0.548 | |
| | (Eq. 11) | $A_2$ = | 0.899 | |
| | (Eq. 7) | $F_1$ = | 0.327 | |
| | (Eq. 8) | $F_2$ = | 0.056 | |
| Shape factor | (Eq. 6) | $I_s$ = | 0.359 | |
| Depth factor | (Eq. 12) | $I_f$ = | 0.777 | |
| Immediate settlement | (Eq. 2) | $S_i$ = | 7.567 | mm |

***B. At the Corner***

| | | | | |
|---|---|---|---|---|
| Effective width | (Eq. 5) | $B'$ = | 5.200 | m |
| Location factor | (Eq. 4) | $\alpha$ = | 1.000 | |
| Computing shape factor | | | | |
| | | $m'$ = | 1.000 | |
| | | $n'$ = | 0.385 | |
| | (Eq. 9) | $A_0$ = | 0.467 | |
| | (Eq. 10) | $A_1$ = | 0.540 | |
| | (Eq. 11) | $A_2$ = | 1.332 | |
| | (Eq. 7) | $F_1$ = | 0.320 | |
| | (Eq. 8) | $F_2$ = | 0.069 | |
| Shape factor | (Eq. 6) | $I_s$ = | 0.360 | |
| Depth factor | (Eq. 12) | $I_f$ = | 0.777 | |
| Immediate settlement | (Eq. 2) | $S_i$ = | 3.788 | mm |

**Primary Consolidation Settlement**

| | | | | |
|---|---|---|---|---|
| Pressure of initial state | (Eq. 17) | $\sigma_0'$ = | 18.000 | $kN/m^2$ |
| Void ratio of initial state | | $e_0$ = | 0.948 | |
| Compression index | (Eq. 15) | $C_c$ = | 0.232 | |
| Swell index | (Eq. 16) | $C_s$ = | 0.046 | |
| Corresponding cone tip resistance | | $q_c$ = | 980.665 | $kN/m^2$ |
| Preconsolidation pressure | (Eq. 18) | $\sigma_c'$ = | 180.911 | $kN/m^2$ |
| Consolidation status | | | Overconsolidated | |
| Change of void ratio | (Eq. 29) | $\Delta e$ = | 0.008 | |

| | | | | |
|---|---|---|---|---|
| Consolidation settlement | (Eq. 14) | $S_c$ = | 4.088 | mm |

**Secondary Consolidation Settlement**

| | | | | |
|---|---|---|---|---|
| Void ratio at the end of primary consolidation | (Eq. 27) | $e_p$ = | 0.940 | |
| Computing the time in which the primary consolidation ends (assumed to be 95% consolidation): | | | | |
| Time factor | (Eq. 24) | $T_v$ = | 1.129 | |
| Coefficient of consolidation | | $c_v$ = | 2.78E-06 | $m^2$/min |
| Drainage path | | $H_{dr}$ = | 1.000 | m |
| Time at the end of primary consolidation | (Eq. 25) | $t_1$ = | 0.782 | years |
| The time considered for secondary consolidation | | $t_2'$ = | 2.000 | years |
| | | $t_1 + t_2' =: t_2$ = | 2.782 | years |
| Empirical value for $C_\alpha/C_c$ | | $C_\alpha/C_c$ = | 0.040 | |
| Secondary compression index | | $C_\alpha$ = | 0.009 | |
| Secondary consolidation settlement | (Eq. 26) | $S_s$ = | 5.264 | mm |

| | | | | |
|---|---|---|---|---|
| **Total Settlement** | (Eq. 1) | **S =** | **16.918** | **mm** |

# SETTLEMENT OF FOUNDATION T11

## GENERAL SOIL MECHANICAL PROPERTIES

| | | | | |
|---|---|---|---|---|
| Young's modulus | | $E_s$ = | 14,715.000 | $kN/m^2$ |
| Poisson's ratio | | $\mu_s$ = | 0.300 | |
| Unit Weight | | $\gamma$ = | 18.100 | $kN/m^3$ |
| Existence of water | | | FALSE | |
| Effective unit weight | | $\gamma'$ = | 18.100 | $kN/m^3$ |
| Water content | | w = | 0.425 | |
| Dry unit weight | | $\gamma_d$ = | 12.703 | $kN/m^3$ |
| Specific gravity | | $G_s$ = | 2.550 | |

## FOUNDATION PROPERTIES

| | | | | |
|---|---|---|---|---|
| Length of the foundation | | L = | 4.500 | m |
| Breadth of the foundation | | B = | 4.500 | m |
| Depth of foundation | | $D_f$ = | 2.500 | m |
| Thickness of soil layer | | H = | 3.000 | m |
| Maximum dranage path | | $H_{dr}$ = | 1.500 | m |

## COMPUTING NET APPLIED PRESSURE

| | | | | |
|---|---|---|---|---|
| Weight of pedestal | | $W_p$ = | 2.203 | Ton |
| Weight of footing | | $W_f$ = | 21.870 | Ton |
| Force on the foundation | | F = | 79.800 | Ton |
| Total force | | P = | 1,018.996 | kN |
| Applied pressure | | $\Delta\sigma$ = | 50.321 | $kN/m^2$ |
| Internal angle of friction | | $\phi'$ = | 23.800 | |
| Coefficient of lateral earth pressure | (Eq. 21) | K = | 0.425 | |
| Depth of interest | | z = | 1.500 | |
| Density input-1 | | Z1 = | 2.301 | |
| Density input-2 | | Z2 = | 2.301 | |
| Probability density-1 (Harr, 1977) | (Eq. 20) | $\psi$(Z1) = | 0.418 | |
| Probability density-2 (Harr, 1977) | (Eq. 20) | $\psi$(Z2) = | 0.418 | |
| Net applied pressure | (Eq. 19) | $\Delta\sigma'$ = | 8.809 | $kN/m^2$ |

## SETTLEMENT

### Immediate Settlement

***A. At the Center***

| | | | | |
|---|---|---|---|---|
| Effective width | (Eq. 5) | $B'$ = | 2.250 | m |
| Location factor | (Eq. 4) | $\alpha$ = | 4.000 | |
| Computing shape factor | | | | |
| | | $m'$ = | 1.000 | |
| | | $n'$ = | 1.333 | |
| | (Eq. 9) | $A_0$ = | 0.507 | |
| | (Eq. 10) | $A_1$ = | 0.546 | |
| | (Eq. 11) | $A_2$ = | 0.621 | |
| | (Eq. 7) | $F_1$ = | 0.335 | |
| | (Eq. 8) | $F_2$ = | 0.045 | |
| Shape factor | (Eq. 6) | $I_s$ = | 0.361 | |
| Depth factor | (Eq. 12) | $I_f$ = | 0.761 | |
| Immediate settlement | (Eq. 2) | $S_i$ = | 7.153 | mm |

***B. At the Corner***

| | | | | |
|---|---|---|---|---|
| Effective width | (Eq. 5) | $B'$ = | 4.500 | m |
| Location factor | (Eq. 4) | $\alpha$ = | 1.000 | |
| Computing shape factor | | | | |
| | | $m'$ = | 1.000 | |
| | | $n'$ = | 0.667 | |
| | (Eq. 9) | $A_0$ = | 0.476 | |
| | (Eq. 10) | $A_1$ = | 0.546 | |
| | (Eq. 11) | $A_2$ = | 0.979 | |
| | (Eq. 7) | $F_1$ = | 0.325 | |
| | (Eq. 8) | $F_2$ = | 0.059 | |
| Shape factor | (Eq. 6) | $I_s$ = | 0.359 | |
| Depth factor | (Eq. 12) | $I_f$ = | 0.761 | |
| Immediate settlement | (Eq. 2) | $S_i$ = | 3.557 | mm |

**Primary Consolidation Settlement**

| | | | | |
|---|---|---|---|---|
| Pressure of initial state | (Eq. 17) | $\sigma_0'$ = | 27.150 | kN/m$^2$ |
| Void ratio of initial state | | $e_0$ = | 0.969 | |
| Compression index | (Eq. 15) | $C_c$ = | 0.234 | |
| Swell index | (Eq. 16) | $C_s$ = | 0.047 | |
| Corresponding cone tip resistance | | $q_c$ = | 2,451.663 | kN/m$^2$ |
| Preconsolidation pressure | (Eq. 18) | $\sigma_c'$ = | 436.002 | kN/m$^2$ |
| Consolidation status | | | Overconsolidated | |
| Change of void ratio | (Eq. 29) | $\Delta e$ = | 0.006 | |

| | | | | |
|---|---|---|---|---|
| Consolidation settlement | (Eq. 14) | $S_c$ = | 4.358 | mm |

**Secondary Consolidation Settlement**

| | | | | |
|---|---|---|---|---|
| Void ratio at the end of primary consolidation | (Eq. 27) | $e_p$ = | 0.964 | |
| Computing the time in which the primary consolidation ends (assumed to be 95% consolidation): | | | | |
| Time factor | (Eq. 24) | $T_v$ = | 1.129 | |
| Coefficient of consolidation | | $c_v$ = | 2.78E-06 | $m^2$/min |
| Drainage path | | $H_{dr}$ = | 1.500 | m |
| Time at the end of primary consolidation | (Eq. 25) | $t_1$ = | 1.760 | years |
| The time considered for secondary consolidation | | $t_2'$ = | 2.000 | years |
| | | $t_1 + t_2' =: t_2$ = | 3.760 | years |
| Empirical value for $C_\alpha/C_c$ | | $C_\alpha/C_c$ = | 0.040 | |
| Secondary compression index | | $C_\alpha$ = | 0.009 | |
| Secondary consolidation settlement | (Eq. 26) | $S_s$ = | 4.723 | mm |

| | | | | |
|---|---|---|---|---|
| **Total Settlement** | (Eq. 1) | **S =** | **16.233** | **mm** |

# SETTLEMENT OF FOUNDATION T12

## GENERAL SOIL MECHANICAL PROPERTIES

| | | | | |
|---|---|---|---|---|
| Young's modulus | | $E_s$ = | 14,715.000 | $kN/m^2$ |
| Poisson's ratio | | $\mu_s$ = | 0.300 | |
| Unit Weight | | $\gamma$ = | 17.900 | $kN/m^3$ |
| Existence of water | | | FALSE | |
| Effective unit weight | | $\gamma'$ = | 17.900 | $kN/m^3$ |
| Water content | | w = | 0.395 | |
| Dry unit weight | | $\gamma_d$ = | 12.832 | $kN/m^3$ |
| Specific gravity | | $G_s$ = | 2.520 | |

## FOUNDATION PROPERTIES

| | | | | |
|---|---|---|---|---|
| Length of the foundation | | L = | 6.300 | m |
| Breadth of the foundation | | B = | 6.300 | m |
| Depth of foundation | | $D_f$ = | 3.400 | m |
| Thickness of soil layer | | H = | 2.000 | m |
| Maximum dranage path | | $H_{dr}$ = | 1.000 | m |

## COMPUTING NET APPLIED PRESSURE

| | | | | |
|---|---|---|---|---|
| Weight of pedestal | | $W_p$ = | 5.549 | Ton |
| Weight of footing | | $W_f$ = | 66.679 | Ton |
| Force on the foundation | | F = | 188.910 | Ton |
| Total force | | P = | 2,561.764 | kN |
| Applied pressure | | $\Delta\sigma$ = | 64.544 | $kN/m^2$ |
| Internal angle of friction | | $\phi'$ = | 17.390 | |
| Coefficient of lateral earth pressure | (Eq. 21) | K = | 0.540 | |
| Depth of interest | | z = | 1.000 | |
| Density input-1 | | Z1 = | 4.287 | |
| Density input-2 | | Z2 = | 4.287 | |
| Probability density-1 (Harr, 1977) | (Eq. 20) | $\psi$(Z1) = | 0.470 | |
| Probability density-2 (Harr, 1977) | (Eq. 20) | $\psi$(Z2) = | 0.470 | |
| Net applied pressure | (Eq. 19) | $\Delta\sigma'$ = | 14.245 | $kN/m^2$ |

## SETTLEMENT

### Immediate Settlement

***A. At the Center***

| | | | | |
|---|---|---|---|---|
| Effective width | (Eq. 5) | $B'$ = | 3.150 | m |
| Location factor | (Eq. 4) | $\alpha$ = | 4.000 | |
| Computing shape factor | | | | |
| | | $m'$ = | 1.000 | |
| | | $n'$ = | 0.635 | |
| | (Eq. 9) | $A_0$ = | 0.475 | |
| | (Eq. 10) | $A_1$ = | 0.546 | |
| | (Eq. 11) | $A_2$ = | 1.008 | |
| | (Eq. 7) | $F_1$ = | 0.325 | |
| | (Eq. 8) | $F_2$ = | 0.060 | |
| Shape factor | (Eq. 6) | $I_s$ = | 0.359 | |
| Depth factor | (Eq. 12) | $I_f$ = | 0.764 | |
| Immediate settlement | (Eq. 2) | $S_i$ = | 12.829 | mm |

***B. At the Corner***

| | | | | |
|---|---|---|---|---|
| Effective width | (Eq. 5) | $B'$ = | 6.300 | m |
| Location factor | (Eq. 4) | $\alpha$ = | 1.000 | |
| Computing shape factor | | | | |
| | | $m'$ = | 1.000 | |
| | | $n'$ = | 0.317 | |
| | (Eq. 9) | $A_0$ = | 0.465 | |
| | (Eq. 10) | $A_1$ = | 0.539 | |
| | (Eq. 11) | $A_2$ = | 1.474 | |
| | (Eq. 7) | $F_1$ = | 0.319 | |
| | (Eq. 8) | $F_2$ = | 0.072 | |
| Shape factor | (Eq. 6) | $I_s$ = | 0.361 | |
| Depth factor | (Eq. 12) | $I_f$ = | 0.764 | |
| Immediate settlement | (Eq. 2) | $S_i$ = | 6.444 | mm |

**Primary Consolidation Settlement**

| | | | | |
|---|---|---|---|---|
| Pressure of initial state | (Eq. 17) | $\sigma_0'$ = | 17.900 | $kN/m^2$ |
| Void ratio of initial state | | $e_0$ = | 0.927 | |
| Compression index | (Eq. 15) | $C_c$ = | 0.226 | |
| Swell index | (Eq. 16) | $C_s$ = | 0.045 | |
| Corresponding cone tip resistance | | $q_c$ = | 1,667.131 | $kN/m^2$ |
| Preconsolidation pressure | (Eq. 18) | $\sigma_c'$ = | 301.091 | $kN/m^2$ |
| Consolidation status | | | Overconsolidated | |
| Change of void ratio | (Eq. 29) | $\Delta e$ = | 0.011 | |

| | | | | |
|---|---|---|---|---|
| Consolidation settlement | (Eq. 14) | $S_c$ = | 5.955 | mm |

**Secondary Consolidation Settlement**

| | | | | |
|---|---|---|---|---|
| Void ratio at the end of primary consolidation | (Eq. 27) | $e_p$ = | 0.915 | |
| Computing the time in which the primary consolidation ends (assumed to be 95% consolidation): | | | | |
| Time factor | (Eq. 24) | $T_v$ = | 1.129 | |
| Coefficient of consolidation | | $c_v$ = | 2.78E-06 | $m^2$/min |
| Drainage path | | $H_{dr}$ = | 1.000 | m |
| Time at the end of primary consolidation | (Eq. 25) | $t_1$ = | 0.782 | years |
| The time considered for secondary consolidation | | $t_2'$ = | 2.000 | years |
| | | $t_1 + t_2' =: t_2$ = | 2.782 | years |
| Empirical value for $C_\alpha/C_c$ | | $C_\alpha/C_c$ = | 0.040 | |
| Secondary compression index | | $C_\alpha$ = | 0.009 | |
| Secondary consolidation settlement | (Eq. 26) | $S_s$ = | 5.194 | mm |

| | | | | |
|---|---|---|---|---|
| **Total Settlement** | (Eq. 1) | **S =** | **23.978** | **mm** |

# SETTLEMENT OF FOUNDATION T13

**GENERAL SOIL MECHANICAL PROPERTIES**

| | | | | |
|---|---|---|---|---|
| Young's modulus | | $E_s$ = | 14,715.000 | $kN/m^2$ |
| Poisson's ratio | | $\mu_s$ = | 0.300 | |
| Unit Weight | | $\gamma$ = | 18.200 | $kN/m^3$ |
| Existence of water | | | FALSE | |
| Effective unit weight | | $\gamma'$ = | 18.200 | $kN/m^3$ |
| Water content | | w = | 0.453 | |
| Dry unit weight | | $\gamma_d$ = | 12.524 | $kN/m^3$ |
| Specific gravity | | $G_s$ = | 2.500 | |

**FOUNDATION PROPERTIES**

| | | | | |
|---|---|---|---|---|
| Length of the foundation | | L = | 6.200 | m |
| Breadth of the foundation | | B = | 6.200 | m |
| Depth of foundation | | $D_f$ = | 3.400 | m |
| Thickness of soil layer | | H = | 3.200 | m |
| Maximum dranage path | | $H_{dr}$ = | 1.600 | m |

**COMPUTING NET APPLIED PRESSURE**

| | | | | |
|---|---|---|---|---|
| Weight of pedestal | | $W_p$ = | 5.549 | Ton |
| Weight of footing | | $W_f$ = | 64.579 | Ton |
| Force on the foundation | | F = | 183.840 | Ton |
| Total force | | P = | 2,491.426 | kN |
| Applied pressure | | $\Delta\sigma$ = | 64.813 | $kN/m^2$ |
| Internal angle of friction | | $\phi'$ = | 2.200 | |
| Coefficient of lateral earth pressure | (Eq. 21) | K = | 0.926 | |
| Depth of interest | | z = | 1.600 | |
| Density input-1 | | Z1 = | 2.013 | |
| Density input-2 | | Z2 = | 2.013 | |
| Probability density-1 (Harr, 1977) | (Eq. 20) | $\psi$(Z1) = | 0.407 | |
| Probability density-2 (Harr, 1977) | (Eq. 20) | $\psi$(Z2) = | 0.407 | |
| Net applied pressure | (Eq. 19) | $\Delta\sigma'$ = | 10.744 | $kN/m^2$ |

**SETTLEMENT**

**Immediate Settlement**

***A. At the Center***

| | | | | |
|---|---|---|---|---|
| Effective width | (Eq. 5) | $B'$ = | 3.100 | m |
| Location factor | (Eq. 4) | $\alpha$ = | 4.000 | |
| Computing shape factor | | | | |
| | | $m'$ = | 1.000 | |
| | | $n'$ = | 1.032 | |
| | (Eq. 9) | $A_0$ = | 0.493 | |
| | (Eq. 10) | $A_1$ = | 0.549 | |
| | (Eq. 11) | $A_2$ = | 0.744 | |
| | (Eq. 7) | $F_1$ = | 0.332 | |
| | (Eq. 8) | $F_2$ = | 0.050 | |
| Shape factor | (Eq. 6) | $I_s$ = | 0.360 | |
| Depth factor | (Eq. 12) | $I_f$ = | 0.762 | |
| Immediate settlement | (Eq. 2) | $S_i$ = | 12.694 | mm |

***B. At the Corner***

| | | | | |
|---|---|---|---|---|
| Effective width | (Eq. 5) | $B'$ = | 6.200 | m |
| Location factor | (Eq. 4) | $\alpha$ = | 1.000 | |
| Computing shape factor | | | | |
| | | $m'$ = | 1.000 | |
| | | $n'$ = | 0.516 | |
| | (Eq. 9) | $A_0$ = | 0.471 | |
| | (Eq. 10) | $A_1$ = | 0.543 | |
| | (Eq. 11) | $A_2$ = | 1.134 | |
| | (Eq. 7) | $F_1$ = | 0.323 | |
| | (Eq. 8) | $F_2$ = | 0.064 | |
| Shape factor | (Eq. 6) | $I_s$ = | 0.359 | |
| Depth factor | (Eq. 12) | $I_f$ = | 0.762 | |
| Immediate settlement | (Eq. 2) | $S_i$ = | 6.324 | mm |

**Primary Consolidation Settlement**

| | | | | |
|---|---|---|---|---|
| Pressure of initial state | (Eq. 17) | $\sigma_0'$ = | 29.120 | $kN/m^2$ |
| Void ratio of initial state | | $e_0$ = | 0.958 | |
| Compression index | (Eq. 15) | $C_c$ = | 0.237 | |
| Swell index | (Eq. 16) | $C_s$ = | 0.047 | |
| Corresponding cone tip resistance | | $q_c$ = | 2,549.729 | $kN/m^2$ |
| Preconsolidation pressure | (Eq. 18) | $\sigma_c'$ = | 452.731 | $kN/m^2$ |
| Consolidation status | | | Overconsolidated | |
| Change of void ratio | (Eq. 29) | $\Delta e$ = | 0.006 | |

| | | | | |
|---|---|---|---|---|
| Consolidation settlement | (Eq. 14) | $S_c$ = | 5.277 | mm |

**Secondary Consolidation Settlement**

| | | | | |
|---|---|---|---|---|
| Void ratio at the end of primary consolidation | (Eq. 27) | $e_p$ = | 0.952 | |
| Computing the time in which the primary consolidation ends (assumed to be 95% consolidation): | | | | |
| Time factor | (Eq. 24) | $T_v$ = | 1.129 | |
| Coefficient of consolidation | | $c_v$ = | 2.78E-06 | $m^2$/min |
| Drainage path | | $H_{dr}$ = | 1.600 | m |
| Time at the end of primary consolidation | (Eq. 25) | $t_1$ = | 2.002 | years |
| The time considered for secondary consolidation | | $t_2'$ = | 2.000 | years |
| | | $t_1 + t_2' =: t_2$ = | 4.002 | years |
| Empirical value for $C_\alpha/C_c$ | | $C_\alpha/C_c$ = | 0.040 | |
| Secondary compression index | | $C_\alpha$ = | 0.009 | |
| Secondary consolidation settlement | (Eq. 26) | $S_s$ = | 4.670 | mm |

| | | | | |
|---|---|---|---|---|
| **Total Settlement** | (Eq. 1) | **S =** | **22.640** | **mm** |

# SETTLEMENT OF FOUNDATION T14

## GENERAL SOIL MECHANICAL PROPERTIES

| | | | | |
|---|---|---|---|---|
| Young's modulus | | $E_s$ = | 14,715.000 | kN/m$^2$ |
| Poisson's ratio | | $\mu_s$ = | 0.300 | |
| Unit Weight | | $\gamma$ = | 18.500 | kN/m$^3$ |
| Existence of water | | | FALSE | |
| Effective unit weight | | $\gamma'$ = | 18.500 | kN/m$^3$ |
| Water content | | w = | 0.438 | |
| Dry unit weight | | $\gamma_d$ = | 12.869 | kN/m$^3$ |
| Specific gravity | | $G_s$ = | 2.580 | |

## FOUNDATION PROPERTIES

| | | | | |
|---|---|---|---|---|
| Length of the foundation | | L = | 7.600 | m |
| Breadth of the foundation | | B = | 7.600 | m |
| Depth of foundation | | $D_f$ = | 3.500 | m |
| Thickness of soil layer | | H = | 4.000 | m |
| Maximum dranage path | | $H_{dr}$ = | 2.000 | m |

## COMPUTING NET APPLIED PRESSURE

| | | | | |
|---|---|---|---|---|
| Weight of pedestal | | $W_p$ = | 4.915 | Ton |
| Weight of footing | | $W_f$ = | 110.899 | Ton |
| Force on the foundation | | F = | 194.420 | Ton |
| Total force | | P = | 3,043.399 | kN |
| Applied pressure | | $\Delta\sigma$ = | 52.690 | kN/m$^2$ |
| Internal angle of friction | | $\phi'$ = | 18.390 | |
| Coefficient of lateral earth pressure | (Eq. 21) | K = | 0.520 | |
| Depth of interest | | z = | 2.000 | |
| Density input-1 | | Z1 = | 2.634 | |
| Density input-2 | | Z2 = | 2.634 | |
| Probability density-1 (Harr, 1977) | (Eq. 20) | $\psi$(Z1) = | 0.430 | |
| Probability density-2 (Harr, 1977) | (Eq. 20) | $\psi$(Z2) = | 0.430 | |
| Net applied pressure | (Eq. 19) | $\Delta\sigma'$ = | 9.748 | kN/m$^2$ |

## SETTLEMENT

### Immediate Settlement

***A. At the Center***

| | | | | |
|---|---|---|---|---|
| Effective width | (Eq. 5) | $B'$ = | 3.800 | m |
| Location factor | (Eq. 4) | $\alpha$ = | 4.000 | |
| Computing shape factor | | | | |
| | | $m'$ = | 1.000 | |
| | | $n'$ = | 1.053 | |
| | (Eq. 9) | $A_0$ = | 0.494 | |
| | (Eq. 10) | $A_1$ = | 0.549 | |
| | (Eq. 11) | $A_2$ = | 0.734 | |
| | (Eq. 7) | $F_1$ = | 0.332 | |
| | (Eq. 8) | $F_2$ = | 0.050 | |
| Shape factor | (Eq. 6) | $I_s$ = | 0.360 | |
| Depth factor | (Eq. 12) | $I_f$ = | 0.781 | |
| Immediate settlement | (Eq. 2) | $S_i$ = | 12.963 | mm |

***B. At the Corner***

| | | | | |
|---|---|---|---|---|
| Effective width | (Eq. 5) | $B'$ = | 7.600 | m |
| Location factor | (Eq. 4) | $\alpha$ = | 1.000 | |
| Computing shape factor | | | | |
| | | $m'$ = | 1.000 | |
| | | $n'$ = | 0.526 | |
| | (Eq. 9) | $A_0$ = | 0.471 | |
| | (Eq. 10) | $A_1$ = | 0.543 | |
| | (Eq. 11) | $A_2$ = | 1.122 | |
| | (Eq. 7) | $F_1$ = | 0.323 | |
| | (Eq. 8) | $F_2$ = | 0.063 | |
| Shape factor | (Eq. 6) | $I_s$ = | 0.359 | |
| Depth factor | (Eq. 12) | $I_f$ = | 0.781 | |
| Immediate settlement | (Eq. 2) | $S_i$ = | 6.457 | mm |

**Primary Consolidation Settlement**

| | | | | |
|---|---|---|---|---|
| Pressure of initial state | (Eq. 17) | $\sigma_0'$ = | 37.000 | $kN/m^2$ |
| Void ratio of initial state | | $e_0$ = | 0.967 | |
| Compression index | (Eq. 15) | $C_c$ = | 0.230 | |
| Swell index | (Eq. 16) | $C_s$ = | 0.046 | |
| Corresponding cone tip resistance | | $q_c$ = | 1,765.197 | $kN/m^2$ |
| Preconsolidation pressure | (Eq. 18) | $\sigma_c'$ = | 318.074 | $kN/m^2$ |
| Consolidation status | | | Overconsolidated | |
| Change of void ratio | (Eq. 29) | $\Delta e$ = | 0.005 | |

| | | | | |
|---|---|---|---|---|
| Consolidation settlement | (Eq. 14) | $S_c$ = | 4.761 | mm |

**Secondary Consolidation Settlement**

| | | | | |
|---|---|---|---|---|
| Void ratio at the end of primary consolidation | (Eq. 27) | $e_p$ = | 0.962 | |
| Computing the time in which the primary consolidation ends (assumed to be 95% consolidation): | | | | |
| Time factor | (Eq. 24) | $T_v$ = | 1.129 | |
| Coefficient of consolidation | | $c_v$ = | 2.78E-06 | $m^2$/min |
| Drainage path | | $H_{dr}$ = | 2.000 | m |
| Time at the end of primary consolidation | (Eq. 25) | $t_1$ = | 3.129 | years |
| The time considered for secondary consolidation | | $t_2'$ = | 2.000 | years |
| | | $t_1 + t_2' =: t_2$ = | 5.129 | years |
| Empirical value for $C_\alpha/C_c$ | | $C_\alpha/C_c$ = | 0.040 | |
| Secondary compression index | | $C_\alpha$ = | 0.009 | |
| Secondary consolidation settlement | (Eq. 26) | $S_s$ = | 4.034 | mm |

| | | | | |
|---|---|---|---|---|
| **Total Settlement** | (Eq. 1) | **S =** | **21.758** | **mm** |