Stress Distribution

- Geostatic stresses – Stress induced by self weight of soil
- Stresses due to loading
- Loading considered to be one dimensional, that is, 100% of the load influence is felt throughout the soil
  - Fill is large in areal extent e.g. filling a large area with several meters of selected compacted material referred to as ‘Areal Fill’
  - The width of loaded area is significantly greater than the thickness of the compressible layer e.g. one dimensional consolidation in lab
Different Types of Loading

Point load or concentrated load applied from column, wheel of machine e.g. Vertical load transferred to soil from an electric pole

Line load such as the load on Rail way and load from a long brick wall; load dimension ton/m:

Uniform load on an area, e.g., middle of an embankment load dimension ton/m²
Different Types of Loading

Triangular load such as applied from embankment, or from the dam, the load dimension is ton/m'

Oil or water storage tank

Circular uniform load
Boussinesq’s Method

• Appropriate for determining vertical stress in a homogenous isotropic medium

\[
\sigma_z = \frac{3P}{2\pi \left[1 + \left(\frac{r}{z}\right)^2\right]^{5/2}}z^2
\]

\[
\sigma_z = I_B \frac{P}{z^2}
\]

*I_B is Boussinesq Influence Factor*

Values of *I_B* can be obtained from plot or tables

• For a # of concentrated loads \(P_1, P_2, P_3\)

\[
\sigma_z = (I_B)_1 \frac{P_1}{z^2} + (I_B)_2 \frac{P_2}{z^2} + (I_B)_3 \frac{P_3}{z^2}
\]
Stresses from Point Loads

Boussinesq Influence Factor
Example 1

- A compressive load \( P = 60 \text{kN} \) is applied to the surface of a soil.
  - Find the vertical compressive stress at a point 2m below the surface at a distance of 1m away from the line of action of the force.
  - Plot the distribution of vertical compressive stress on the plane 2m (i.e. for \( z = 2 \text{m} \)) below the surface of the soil, for various radial distances up to 2m from the line of action of the force (i.e. \( r = 0, 1, 2 \)).
  - Plot the distribution of the vertical compressive stresses on various horizontal planes (i.e. for various values of \( z = 0.5, 1, 2 \)) along the vertical axis (i.e. at \( r = 0 \)).
Uniform Load over a Circular Area

FIGURE 6-6 Influence coefficients for uniformly loaded circular area [4].
Uniform Load over a Circular Area

- Uniform load on circular area
- \( \sigma_z = Iq_o \)
Example 2

- A circular area carrying a uniformly distributed load of 2000 lb/ft$^2$ is applied to the ground surface. The diameter of the circular area is 20ft. Determine the vertical stress due to this uniform load at a point 20ft below the edge of the circular area.
Uniform Load on a Rectangular Area

**FIGURE 6-8** Chart for use in determining vertical stresses below corners of loaded rectangular surface areas on elastic, isotropic material [4, 6].
# Uniform Load on a Rectangular Area

## Table 6-2

Influence Coefficients for Points under Uniformly Loaded Rectangular Areas [3, 5]

| m = A/z or n = B/z | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 | 1.2 | 1.5 | 2.0 | 2.5 | 3.0 | 5.0 | 10.0 | ∞  |
|---------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 0.1                 | 0.005 | 0.009 | 0.013 | 0.017 | 0.020 | 0.022 | 0.024 | 0.026 | 0.027 | 0.028 | 0.029 | 0.030 | 0.031 | 0.031 | 0.032 | 0.032 | 0.032 |
| 0.2                 | 0.009 | 0.018 | 0.026 | 0.033 | 0.039 | 0.043 | 0.047 | 0.050 | 0.053 | 0.055 | 0.057 | 0.059 | 0.061 | 0.062 | 0.062 | 0.062 | 0.062 |
| 0.3                 | 0.013 | 0.026 | 0.037 | 0.047 | 0.056 | 0.063 | 0.069 | 0.073 | 0.077 | 0.079 | 0.083 | 0.086 | 0.089 | 0.090 | 0.090 | 0.090 | 0.090 |
| 0.4                 | 0.017 | 0.033 | 0.047 | 0.060 | 0.071 | 0.080 | 0.087 | 0.093 | 0.098 | 0.101 | 0.106 | 0.110 | 0.113 | 0.115 | 0.115 | 0.115 | 0.115 |
| 0.5                 | 0.020 | 0.039 | 0.056 | 0.071 | 0.084 | 0.095 | 0.103 | 0.110 | 0.116 | 0.120 | 0.126 | 0.131 | 0.135 | 0.137 | 0.137 | 0.137 | 0.137 |
| 0.6                 | 0.022 | 0.043 | 0.063 | 0.080 | 0.095 | 0.107 | 0.117 | 0.125 | 0.131 | 0.136 | 0.143 | 0.149 | 0.153 | 0.155 | 0.156 | 0.156 | 0.156 |
| 0.7                 | 0.024 | 0.047 | 0.069 | 0.087 | 0.103 | 0.117 | 0.128 | 0.137 | 0.144 | 0.149 | 0.157 | 0.164 | 0.169 | 0.170 | 0.171 | 0.172 | 0.172 |
| 0.8                 | 0.026 | 0.050 | 0.073 | 0.093 | 0.110 | 0.125 | 0.137 | 0.146 | 0.154 | 0.160 | 0.168 | 0.176 | 0.181 | 0.183 | 0.184 | 0.185 | 0.185 |
| 0.9                 | 0.027 | 0.053 | 0.077 | 0.098 | 0.116 | 0.131 | 0.144 | 0.154 | 0.162 | 0.168 | 0.178 | 0.186 | 0.192 | 0.194 | 0.195 | 0.196 | 0.196 |
| 1.0                 | 0.028 | 0.055 | 0.079 | 0.101 | 0.120 | 0.136 | 0.149 | 0.160 | 0.168 | 0.175 | 0.185 | 0.193 | 0.200 | 0.202 | 0.204 | 0.205 | 0.205 |
| 1.2                 | 0.029 | 0.057 | 0.083 | 0.106 | 0.126 | 0.143 | 0.157 | 0.168 | 0.178 | 0.185 | 0.196 | 0.205 | 0.212 | 0.215 | 0.216 | 0.217 | 0.218 |
| 1.5                 | 0.030 | 0.059 | 0.086 | 0.110 | 0.131 | 0.149 | 0.164 | 0.176 | 0.186 | 0.193 | 0.205 | 0.215 | 0.223 | 0.226 | 0.228 | 0.230 | 0.230 |
| 2.0                 | 0.031 | 0.061 | 0.089 | 0.113 | 0.135 | 0.153 | 0.169 | 0.181 | 0.192 | 0.200 | 0.212 | 0.223 | 0.232 | 0.236 | 0.238 | 0.239 | 0.240 |
| 2.5                 | 0.031 | 0.062 | 0.090 | 0.115 | 0.137 | 0.155 | 0.170 | 0.183 | 0.194 | 0.202 | 0.215 | 0.226 | 0.236 | 0.240 | 0.242 | 0.244 | 0.244 |
| 3.0                 | 0.032 | 0.062 | 0.090 | 0.115 | 0.137 | 0.156 | 0.171 | 0.184 | 0.195 | 0.203 | 0.216 | 0.228 | 0.238 | 0.242 | 0.244 | 0.246 | 0.247 |
| 5.0                 | 0.032 | 0.062 | 0.090 | 0.115 | 0.137 | 0.156 | 0.172 | 0.185 | 0.196 | 0.204 | 0.217 | 0.229 | 0.239 | 0.244 | 0.246 | 0.249 | 0.249 |
| 10.0                | 0.032 | 0.062 | 0.090 | 0.115 | 0.137 | 0.156 | 0.172 | 0.185 | 0.196 | 0.205 | 0.218 | 0.230 | 0.240 | 0.244 | 0.247 | 0.249 | 0.250 |
| ∞                   | 0.032 | 0.062 | 0.090 | 0.115 | 0.137 | 0.156 | 0.172 | 0.185 | 0.196 | 0.205 | 0.218 | 0.230 | 0.240 | 0.244 | 0.247 | 0.249 | 0.250 |
Example 3

A 15ft by 20ft rectangular foundation carrying a uniform load of 4000lb/ft$^2$ is applied to the ground surface. Determine the vertical stress due to this uniform load at a point 10ft below the corner of the rectangular loaded area.
Westergaard’s Method

• Appropriate for determining vertical stress in layered stratum

• It may be solved in the same manner as the Boussinesq’s equation

\[ \sigma_z = I_w \frac{P}{Z^2} \]
2:1 Method (Approximate Method)

- Approximate method for determining the vertical stress at some depth due to loading
- It gives an average stress at a particular depth
- It is simple, quick and easy to use

\[ \sigma_z = \frac{P}{(B + z)(L + z)} \]
Example 4

A 10ft by 15ft rectangular platform carrying a uniform load of 5000lb/ft\(^2\) rests on the ground surface. Determine the vertical stress increment due to this load at a depth of 20ft below the ground surface by the approximate method.
Example 5

• A brown silty fill 5m thick was placed over a 15m thick layer of compressible gray silty clay. Underlying the clay layer is brown sandy gravel. The properties of the normally consolidated silty clay layer are:
  o Initial void ratio, $e_0 = 1.1$
  o Compression index, $C_c = 0.36$
  o Saturated density, $\gamma_s = 1.52 \text{Mg/m}^3$
  o Coefficient of consolidation, $C_v = 0.86 \text{m}^2/\text{yr}$

• The density of silty sand fill is $2.0 \text{Mg/m}^3$ and the groundwater table is at the interface of the fill and clay
  o Compute the consolidation settlement of the silty clay layer due to the weight of 5m of new fill
  o Determine time for which a settlement of 0.426m will occur
Example 6

- A circular tank, 8m high and 27m in diameter (q_o = 80kPa) is supported on a flexible mat foundation on a sand layer 9m thick that overlies a 30m thick layer of Clay. Below the clay is another layer of granular material. The groundwater table is 2m below the ground surface. Assume the tank with the foundation is on the ground surface. The average soil parameters and profile are given.

- Compute the change in stress at depth of 25m due to the foundation load at the center and edge of the tank

- Compute the settlement of the tank at the center and at the edge