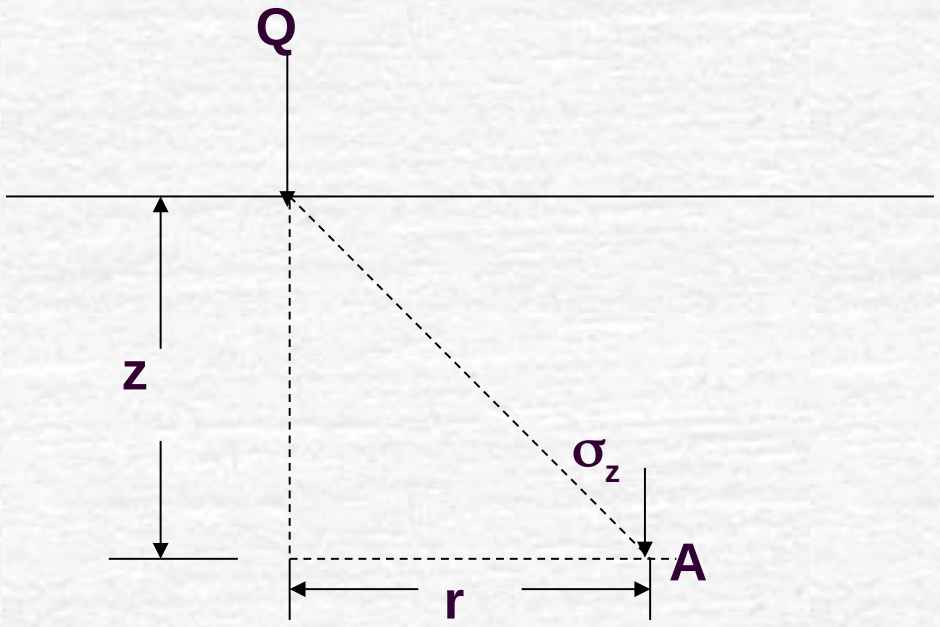
7. STRESS DISTRIBUTION IN SOILS AND SETTLEMENT ANALYSIS

STRESS DISTRIBUTION IN SOILS

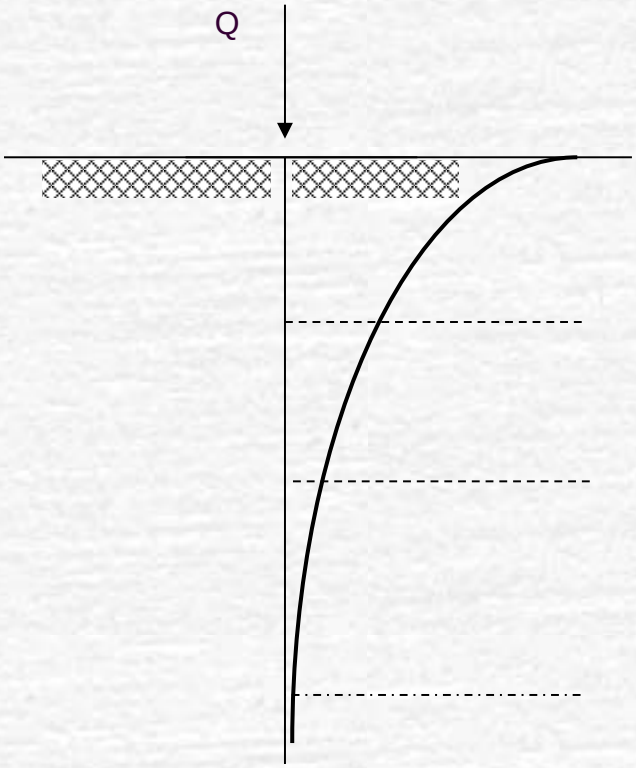
- When a load is placed on the surface of the ground or below the ground level, some stresses are transmitted to the deeper layers of the soil underneath. These stresses decrease with increasing depth and distance from the loaded area.
- An adequate knowledge of distribution of these stresses is essential for predicting the settlement of structures due to compression of layers of soil beneath the loaded surface.
- Equations have been developed to compute stresses at any point in a soil mass on the basis of the theory of elasticity.
- For the theory of elasticity to be applicable, the real requirement is not that the material necessarily be elastic, rather the stresses and the corresponding strains should be proportional.
- Therefore, in non-elastic soil masses, the elastic theory may be assumed to hold so long as the stresses induced in the soil mass are relatively small in comparison with the ultimate strength(shear strength) of the soil .
- Most widely used formula to calculate the stress distribution in the soil is the one which is developed by Boussinesq.

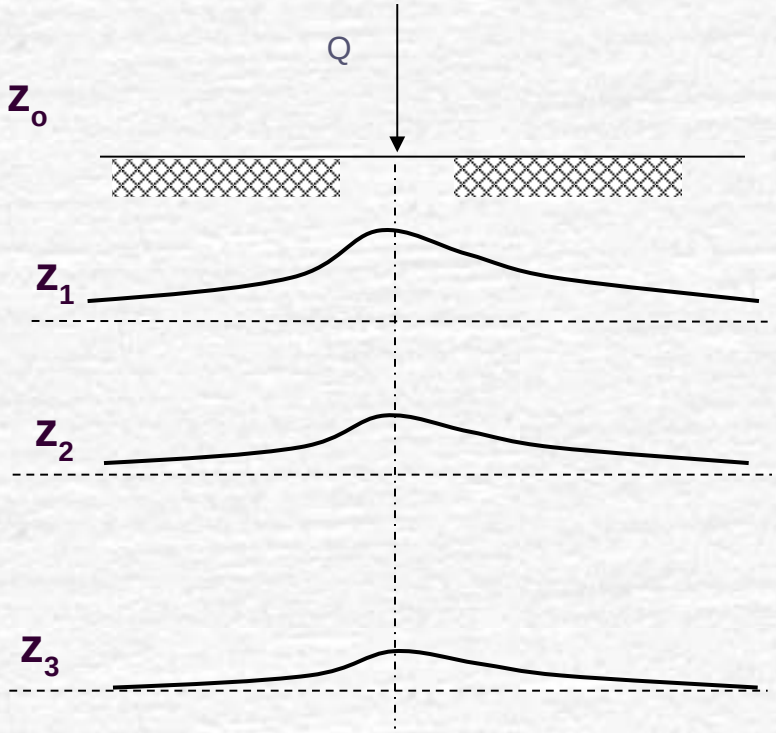
Boussinesq Equation for a Point Load

- **The state of stress at any point within an elastic, homogeneous and isotropic medium can be described by six components of stress- three of them being normal stresses and the other being shear stresses.**
- **For the purposes of settlement analysis, however, we are concerned with only the vertical normal stress, σ_z the whole of which would finally be taken by the soil grains as intergranular or effective pressure.**



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





a) Variation of stress with depth

b) Stress distribution on horizontal planes

Stress Due to Distributed Load

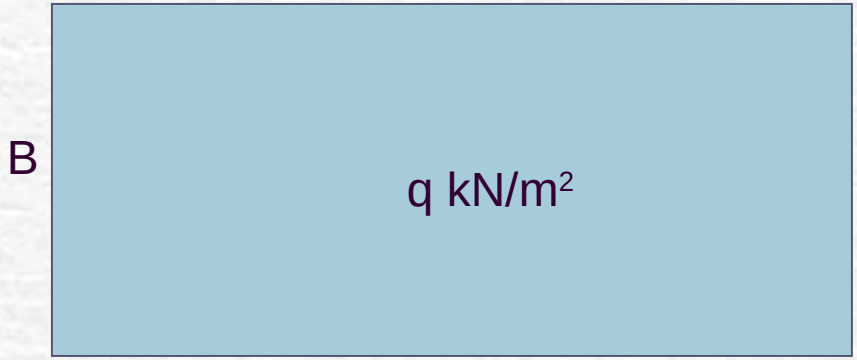
- **In actual structures, load is never applied at a point; it is spread over a certain area by the foundation structure. It is, therefore, necessary to determine the stress distribution in soil beneath loaded area.**

- **On the basis of Boussinesq's equation for point loads, there are two possible approaches to the problem.**

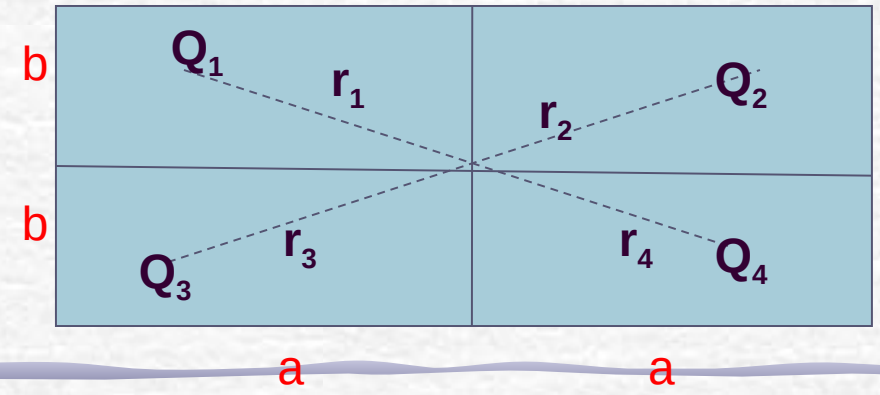
  - **Application of Point Load Formula**
  - **Newmark's Influence Diagram**

Application of Point Load Formula

- **Since loads occupy finite areas, point load formula may still be used if the loaded area is divided into smaller areas and a series of concentrated loads are assumed to act at the center of each smaller area.**



$$\frac{a}{z} \le \frac{1}{3}, \frac{b}{z} \le \frac{1}{3}$$



where

$Q_1=Q_2=Q_3=Q_4=q(ab)$

Newmark's Influence Diagram

- -Newmark's charts are based on subdivision of the loaded area into infinitesimal units and on integration of the effects of simulated point loads.

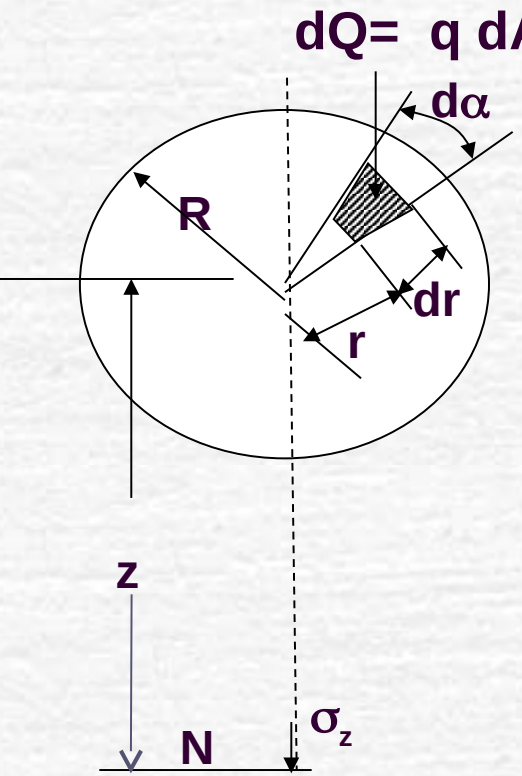
- That is, if an area on the surface of a very large mass carries a uniformly distributed load of intensity q, the intensity of the vertical stress at any point within the mass may be computed by dividing the loaded area into small parts dA, each of which supports a load

  $$dQ = q\,dA.$$

  This load is considered to be concentrated at the centroid of the elementary area dA

- **According to Boussinesq's equation, each concentrated load produces a vertical stress at point N, which is given by:**

$$d\sigma_z = \frac{dQ}{z^2}\frac{3/2\pi}{\left[1+\left(r/z\right)^2\right]^{\frac{5}{2}}} \Rightarrow d\sigma_z = \frac{3q}{2\pi z^2}\left[\frac{1}{\left[1+\left(r/z\right)^2\right]^{5/2}}\right]dA$$



- **The intensity of the vertical stress at point N due to the uniform loaded circular area is computed by integrating the above equation over the loaded area**

$$\int d\sigma_z = \int \frac{3q}{2\pi z^2}\left[\frac{1}{1+(r/z)^2}\right]^{5/2} dA$$

$$\Rightarrow \sigma_z = \int d\sigma_z = \int_0^{2\pi}\int_o^R \frac{3q}{2\pi z^2}\left[\frac{1}{1+(r/z)^2}\right]^{5/2} r\,d\alpha\,dr$$

After performing the integration and inserting the limits one can obtain the following equation

$$\sigma_z = q\left[1 - \left(\frac{1}{1+(R/z)^2}\right)^{3/2}\right] \Rightarrow \frac{\sigma_z}{q} = 1 - \left(\frac{1}{1+(R/z)^2}\right)^{3/2}$$

It may be seen from the above equation that when

$$\frac{R}{z} = \infty, \frac{\sigma_z}{q} = 1$$

that is $\sigma_z = q$

- **This indicates that if the loaded area extends to infinity the vertical stress in the semi-infinity solid at any depth z is the same as the unity load q at the surface.**

- **If the loaded area is limited to any given radius R it is possible to determine from the above equation the ratios R/z for which the ratio of σ_z/q may have any specified value. Table 6.1 shown on page 135 on the text gives the ratio of R/z for different values of σ_z/q**

- **The Table helps to compute the vertical stress σ_z at any depth z below the center of a circular loaded area of radius R and to draw Newmark's Influence Chart.**
- **. It is based on the following procedure. The vertical stress σ_z , below the center of a circular area of radius *R which carries uniformly distributed load q is determined per Eq. Above.***

Table 6.1 Values of R/z for different values of σ_z/q

σ_z/q	R/z	σ_z/q	R/z
0.00	0.000	0.80	1.387
0.10	0.270	0.90	1.908
0.20	0.401	0.92	2.094
0.30	0.518	0.94	2.351
0.40	0.637	0.96	2.748
0.50	0.766	0.98	3.546
0.60	0.917	1.00	∞
0.70	1.110	–	–

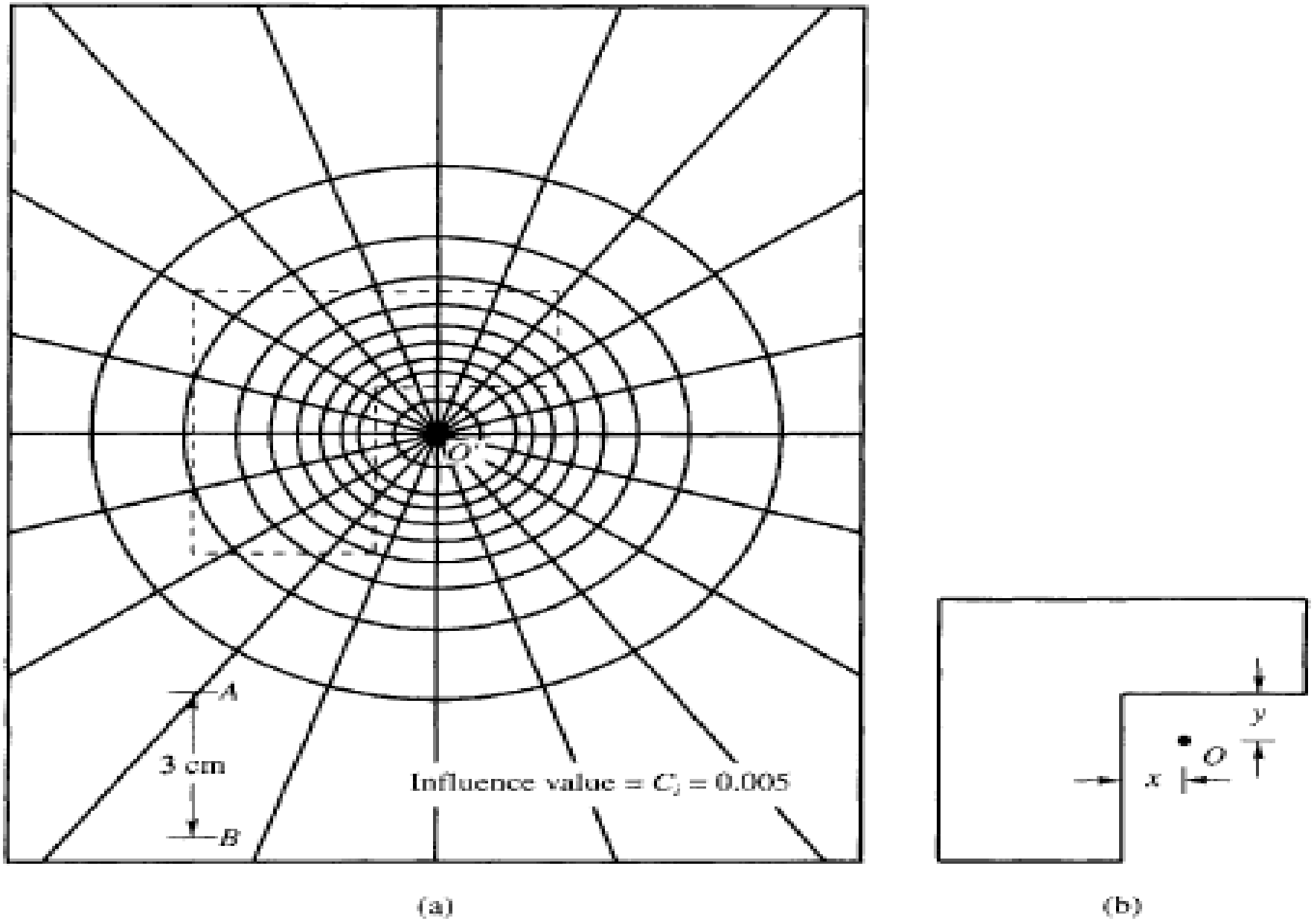


Figure 6.12 Newmark's influence chart

- **The procedure for obtaining vertical pressure at any point below a loaded area is as follows.**

1. **Draw the foundation plan on a tracing paper to such a scale that the depth z at which the stress σ_z is to be computed will be equal to distance AB of the chart.**
2. **Lay the tracing of the foundation plan over the chart in such a way that the surface point O beneath which the stress σ_z is to be computed coincides with the center of the chart.**
3. **Count the number of blocks covered by the foundation area.**
4. **Multiply the number of blocks found by the influence value(c_i) of the blocks and the distributed load . Thus, the product obtained gives the value σ_z for that particular point.**

$$\sigma_z = C_i N q$$

Two- to-One Load Distribution Method

- This method assumes that stress increment at successive depths beneath the footing is distributed uniformly over a finite area. The finite area is defined by planes descending at a

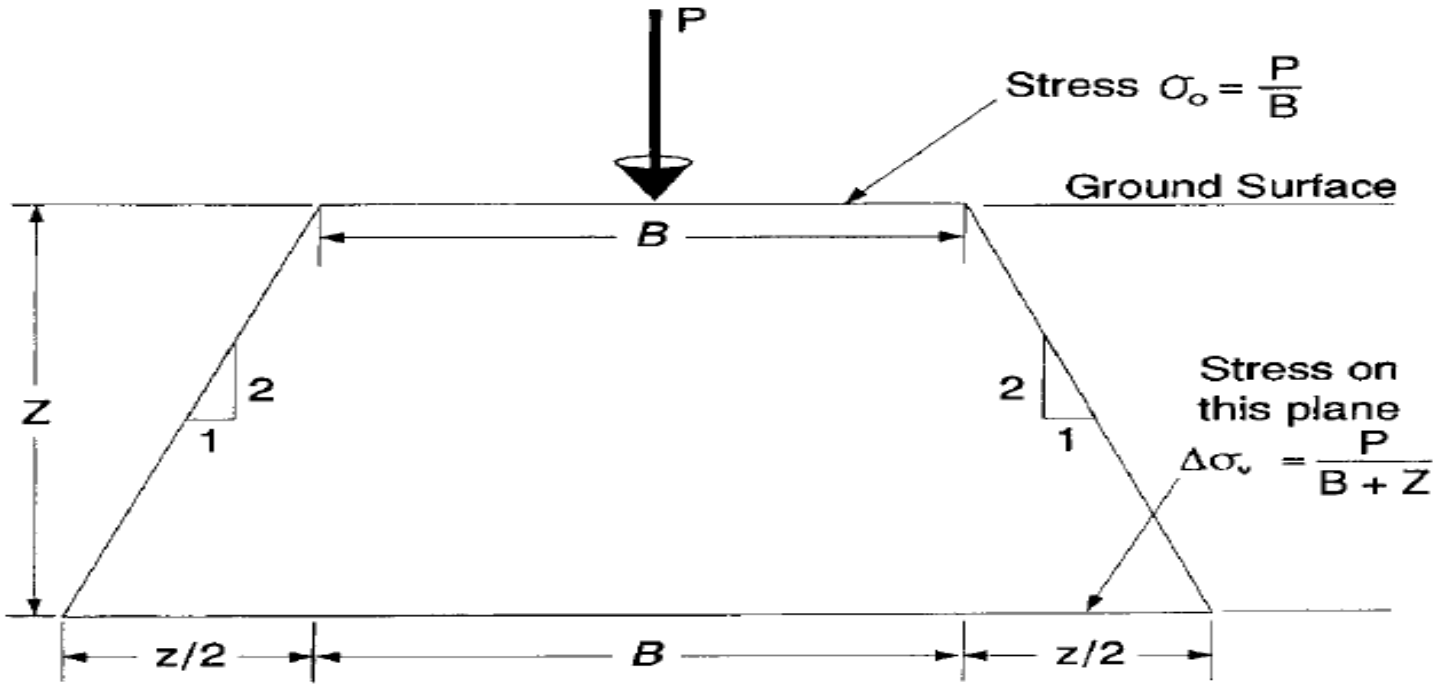


FIGURE 6.13 2:1 approximation for the calculation of the increase in vertical stress at depth due to an applied load (P).

SETTLEMENT ANALYSIS

- **The following are the necessary steps that one has to follow to predict the total settlement or to calculate the rate of settlement.**
  - **Soil Profile , Consolidation Test , Settlement Calculations**

The following steps may be adopted for settlement calculation

a) Determine the pre-loading pressure,

Po(avg) =1/6(Pt + 4Pm + Pb)

b) Determine stresses induced by column load (ΔP)

c) Tabulate final pressure analysis data

d) Comp

$$S = \frac{C_c H}{1 + e_o} \log \frac{(P_o + \Delta P)}{P_o}$$

e) Time settlement predictions:- Time settlement predictions are usually presented in the form of curves showing settlement in cm versus time in years.

Data needed to draw the curves

a) Ultimate settlement

b) Theoretical consolidation curve

c) The values of coefficient of consolidation, C_v

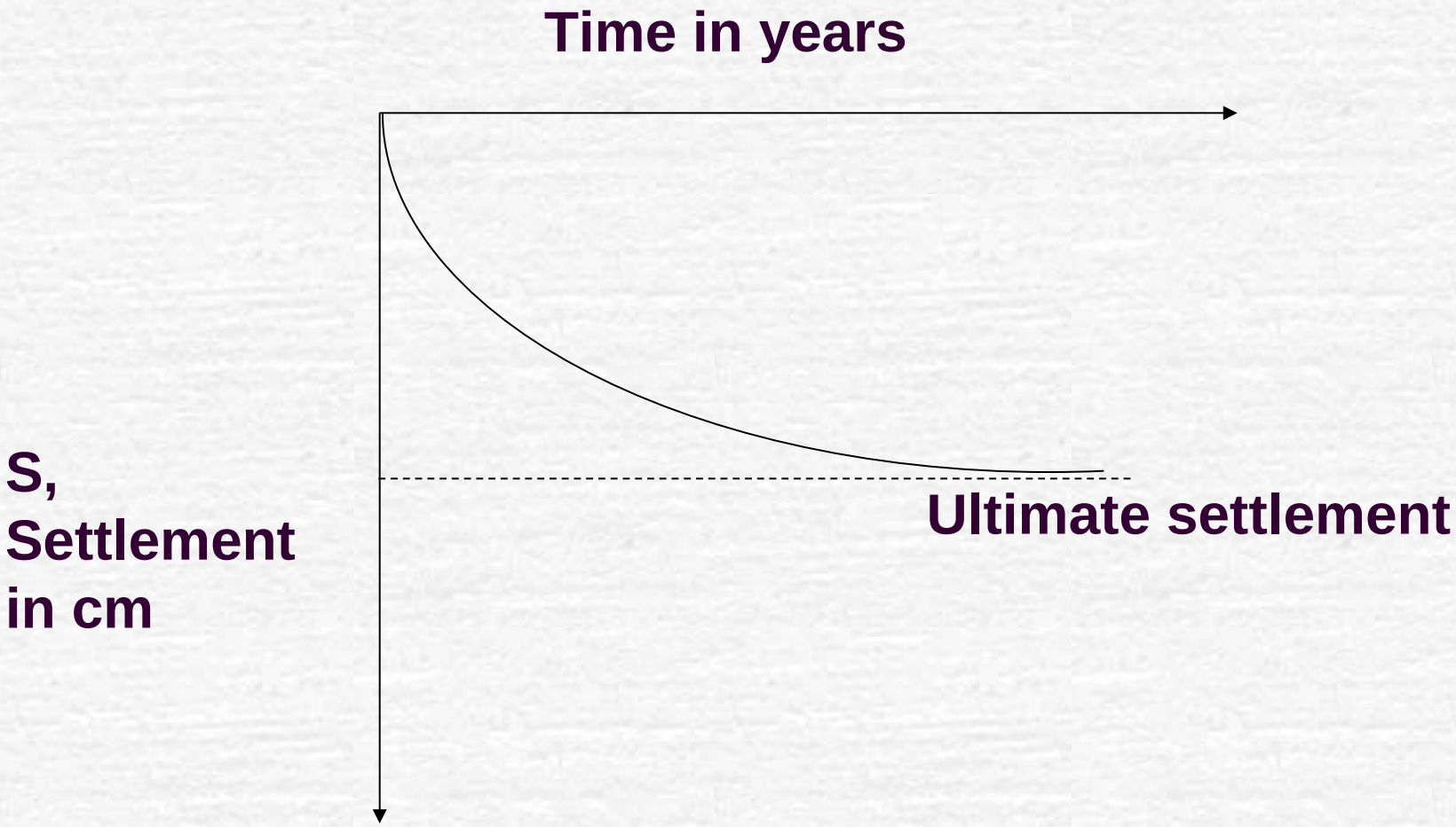
d) The thickness of the compressible stratum

e) Information on the drainage condition

- If S_t is the settlement at any time t after the imposition of load on the compressible layer, the degree of consolidation of the layer in time t may also be expressed as
  - $U\ \% = S_t / S * 100 \rightarrow S_t = S * U$

- Steps to draw the curve

1. For different values of U ,compute the corresponding values of settlement(S_t)using the above relationship.
2. From the theoretical cons. curve giving the relation b/n U and T . Find T for different degree of consolidation.
3. Compute the time t from equation $t = TH^2_{dr}/Cv$ for different values of T



Time settlement curve

Immediate Settlement

- **-Immediate or elastic settlement of foundation occurs immediately after the application of load without change of moisture content. The magnitude of the contact settlement depends on the flexibility of foundation and material on which it is resting.**
- **-Immediate settlement for foundations resting on elastic material can be calculated from equations derived by using the principle of the theory of elasticity, which is of the form**

$$S_i = qB\frac{(1-\mu^2)}{E_s}I_\omega$$

Where : Si =Immediate settlement
q =intensity of contact pressure
μ = Poisson's ratio
Es= Modulus of elasticity of soil
B = Least lateral dimension of foundation
I_ω= Non dimensional influence factor

- **For computation of Non dimensional influence factor,Iω, for corners of flexible footing Terzaghi used the following relationships**

$$I_\omega = \frac{1}{\pi}\left[m \log_e \left(\frac{1+\sqrt{m^2+1}}{m} \right) + \log_e \left(m + \sqrt{m^2+10} \right) \right]$$

where

$$m = \frac{(length\ of\ \ foundation)}{(width\ of\ \ foundation)}$$

CONSTRUCTION PERIOD CORRECTION

- The load due to a building or other structures is not applied instantaneously, but is spread over a certain period of time.
- First there is excavation for foundation that results in relief of pressure.
- This is followed by the construction of structure loading to gradual loading till the original pressure is reached and then exceed.

The following are the necessary procedures used to correct settlement for the construction period .

- 1.The time–settlement curve in the field is obtained based on the assumption that the settlement at the end of construction period (tf) is the same as that would have occurred in half as much time had the entire load been applied instantaneously (i.e. the actual settlement at time tf is equal to that at tf/2 due to instantaneous loading) .
- 2.The settlement on the corrected curve for any time t between t=o and t=tf can be obtained using the following procedure. The settlement ab at time t is obtained from the settlement EF at time t/2 ,but a correction is applied. A horizontal line EG is drawn to cut the vertical line at time tf at G then diagonal line is drawn from O which pass through G and this intersects the vertical ab at time t at point b . Thus, the actual settlement at time t is ab =EF(t/tf) not EF .

3. Points beyond the time tf are determined by displacing a horizontal distance equal to cd from the curve Si as shown in Fig. below. This is because the load after tf is equal to the full load.

