Monday- 3

Analysis of Consolidation Test Data

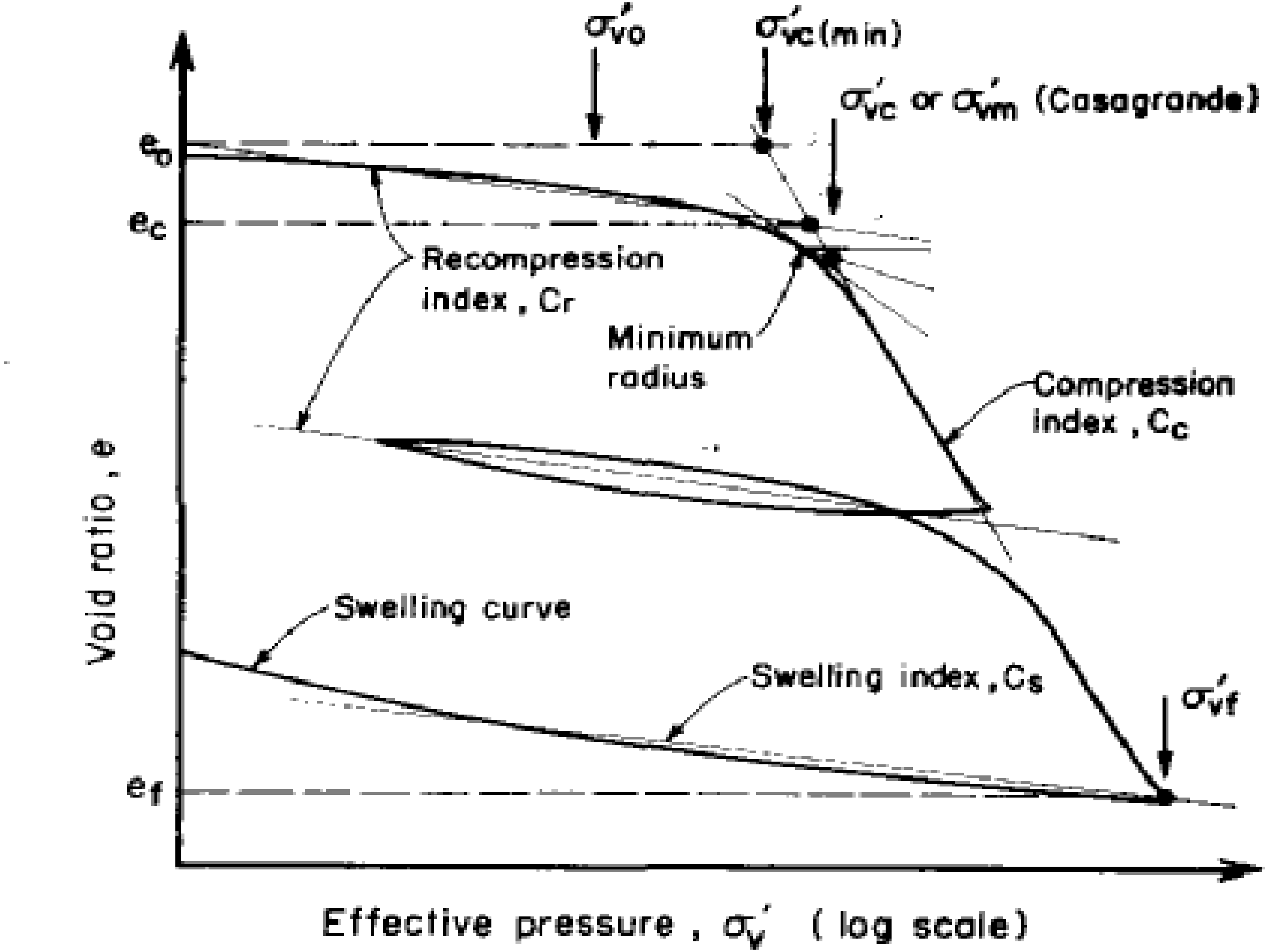
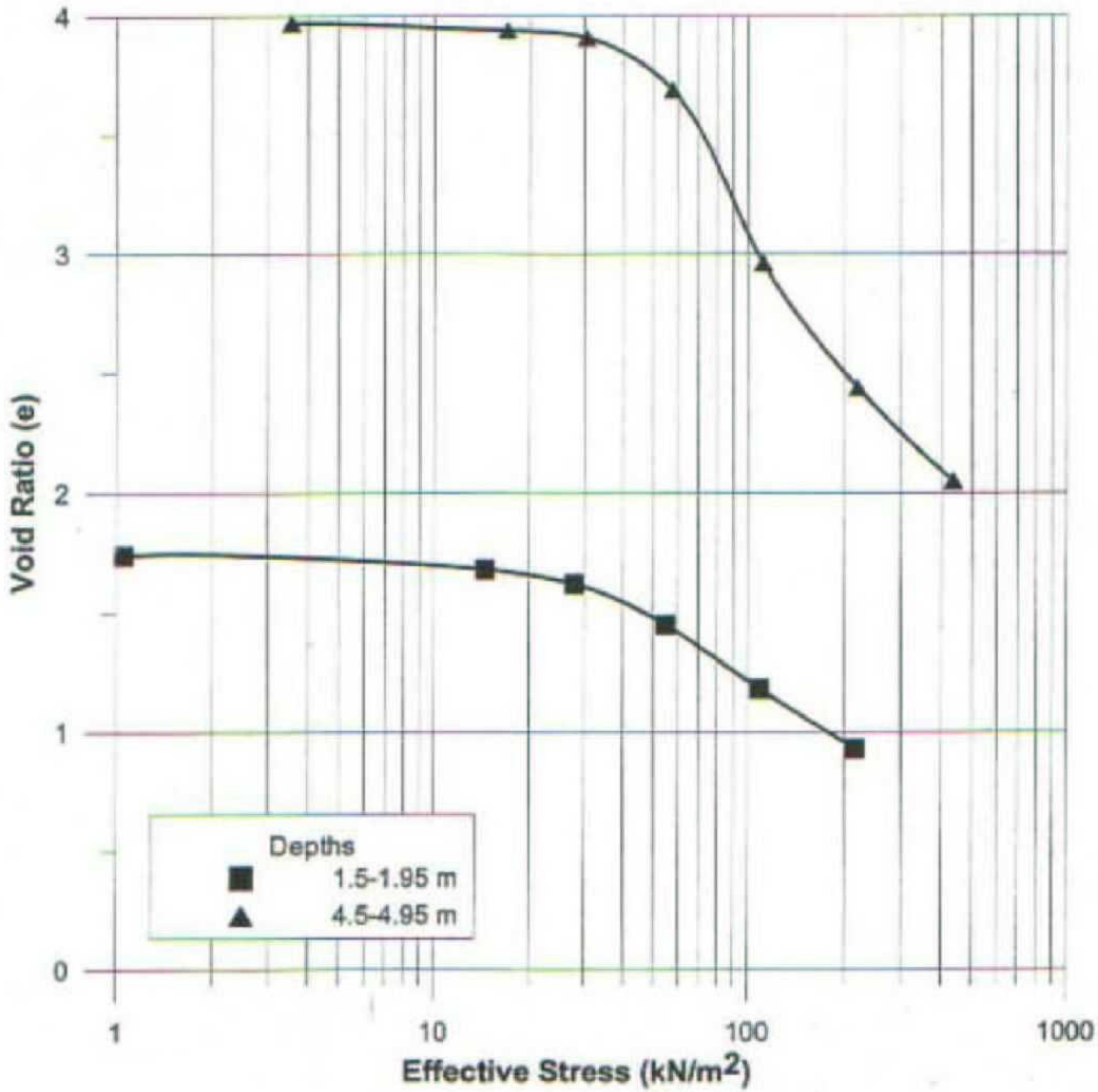


Fig. 7.4. Notation and terminology used for oedometer compression curves.

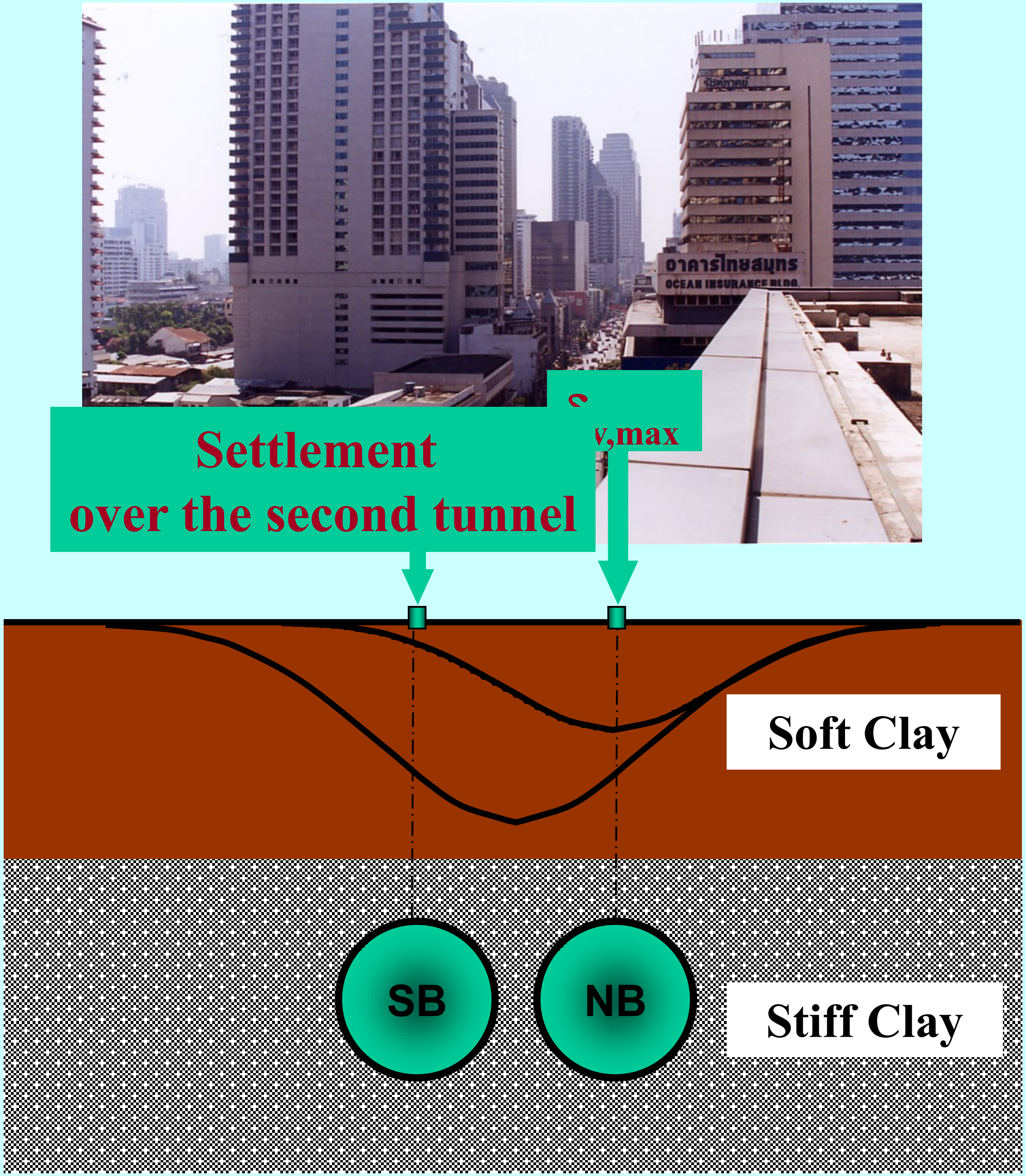

Void Ratio (e)
4
3
2
1
0
1
10
100
1000
Effective Stress (kN/m2)
Depths
1.5-1.95 m
4.5-4.95 m

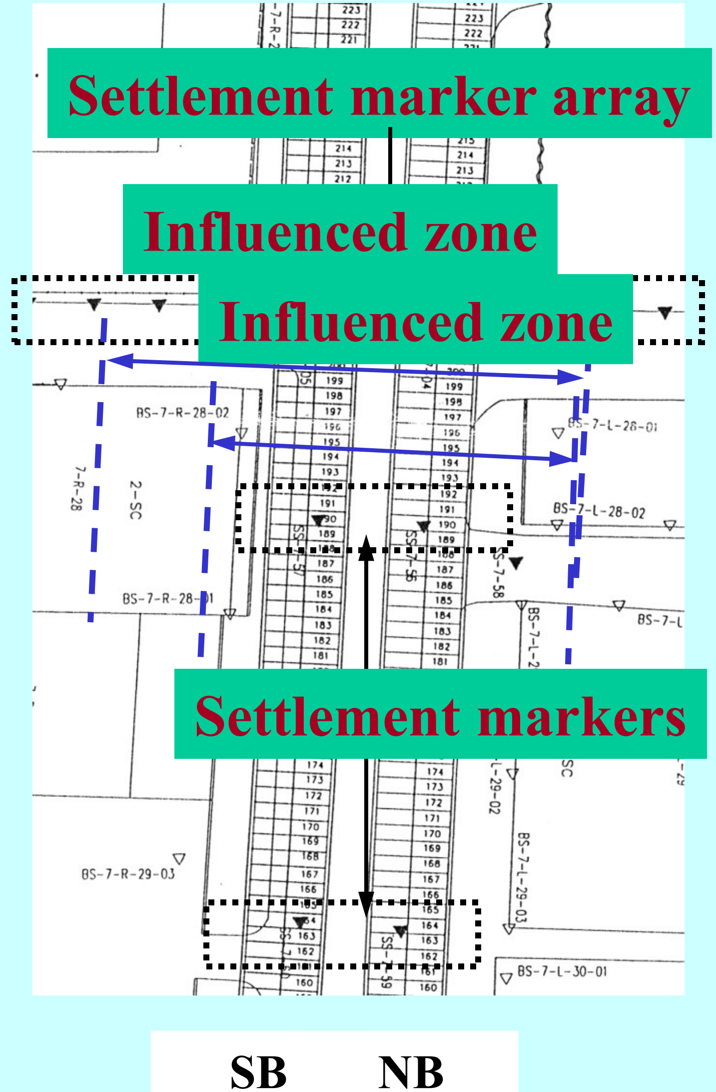
Odeometer type 1-D consolidation settlement

Settlement

Settlement of structures

Tunnelling in urban area





Settlement

- ❖ Definition of strain & settlement computation
- ❖ Stresses and stress increments
- ❖ Soil parameters: Moduli, Poisson's ratio; Consolidation parameters
- ❖ Settlement components & computations

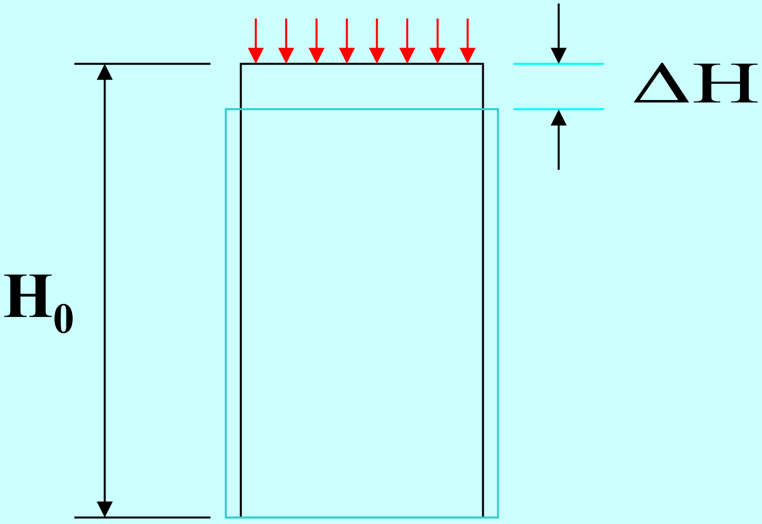


Fig. 2

$$\Delta\varepsilon_1 = -\frac{\Delta H}{H_0}$$

$$-\Delta H = \Delta\varepsilon_1 H$$

Settlement

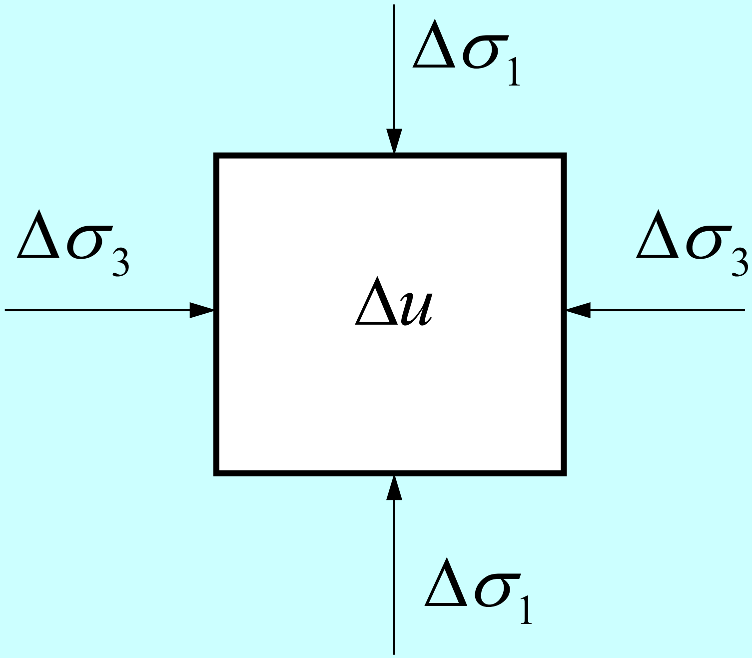


Fig. 3

Pore Pressure Coefficients

For saturated soil

$$\Delta u = \Delta\sigma_3 + A\left[\Delta\sigma_1 - \Delta\sigma_3\right]$$

A – pore pressure coefficient

Settlement

- **Definition of strain & settlement computation**
- **Stresses and stress increments**
- **Soil parameters: Moduli, Poisson's ratio; Consolidation parameters**
- **Settlement components & computations**

Settlement

- **Definition of strain & settlement computation**
- **Stresses and stress increments**
- **Soil parameters: Moduli, Poisson's ratio; Consolidation parameters**
- **Settlement components & computations**

Soil parameters for settlement analysis

Soil parameters related to theory of elasticity

1. Immediate Settlement (no volume change)

   Undrained modulus, $E_u\ (kN/m^2)$;

   Undrained Poisson's ratio, υ_u

2. Total settlement (undrained and consolidation)

   Drained modulus (kN/m^2), E';

   Drained Poisson's ratio, υ'

1-D consolidation settlement parametrs : soil parameters from Oedometer type of test

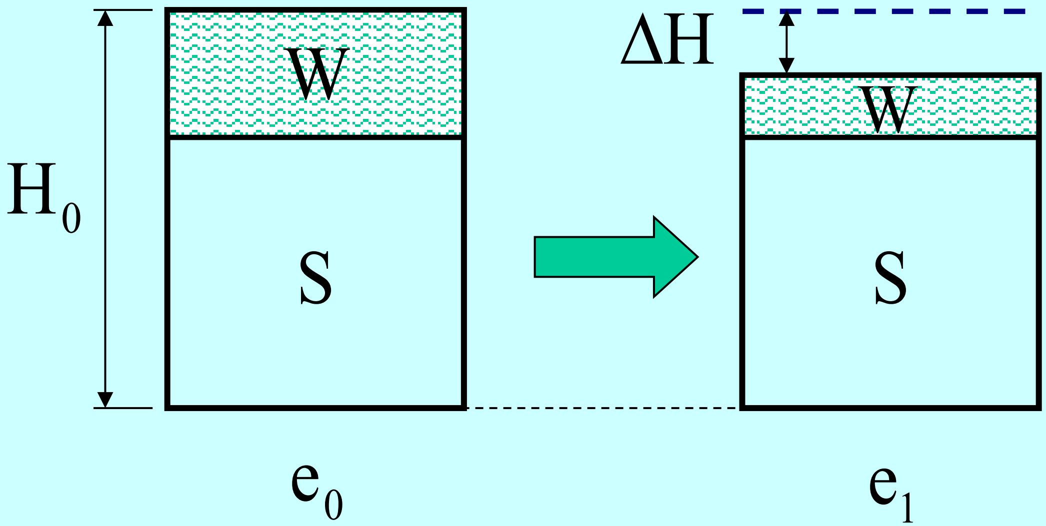
1. From (e, σ'_v) relation :
   - (a) Compression index, C_c
   - (b) Coefficient of volume decrease, $m_v\,(m^2/kN)$
   - (c) Constrained modulus, $D = \dfrac{1}{m_v}$ (kN/m^2)
   - (d) Maximum past pressure, $p_{max}\,(kN/m^2)$

2 From settlement - squarte root time plot or settlement log time plot, Coefficient of consolidation, $c_v\,(m^2/year)$

From settlement - log time plot: Coefficient of secondary consolidation, C_α

3. From, c_v, m_v, and γ_w determine, permeability, k

Consolidation – Reduction in pore space by expulsion of water only:



$$\Delta e = e_0 - e_1$$

$$\Delta \varepsilon_1 = \left(\frac{e_0 - e_1}{1 + e_0} \right)$$

Fig. 15

SECTION 8: ONE- DIMENSIONAL CONSOLIDATION

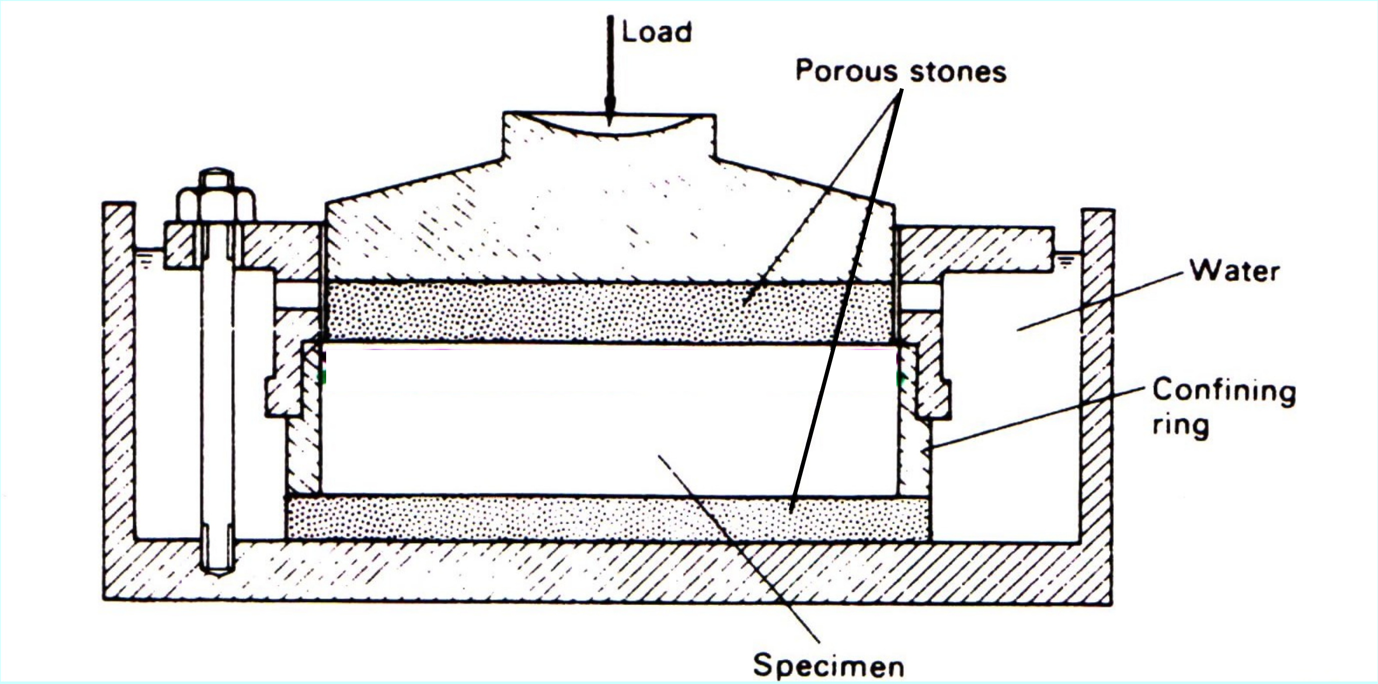


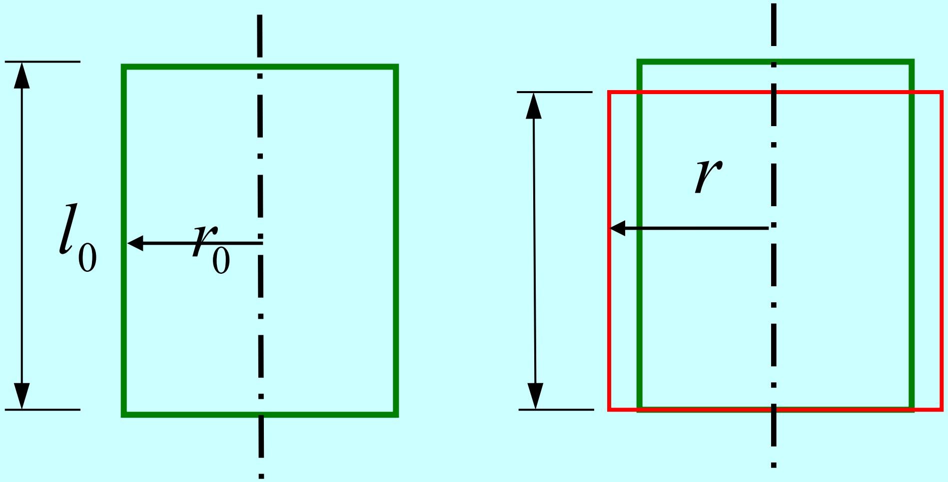
Fig 16. Consolidometer Oedometer

Undrained and Drained strains

1-D Consolidation

Theory of Elasticity for Strains

Consolidation Theory for Strains



$$\Delta\varepsilon_1 = \frac{l_0 - l}{l_0}$$

$$\Delta\varepsilon_3 = \frac{r_0 - r}{r_0}$$

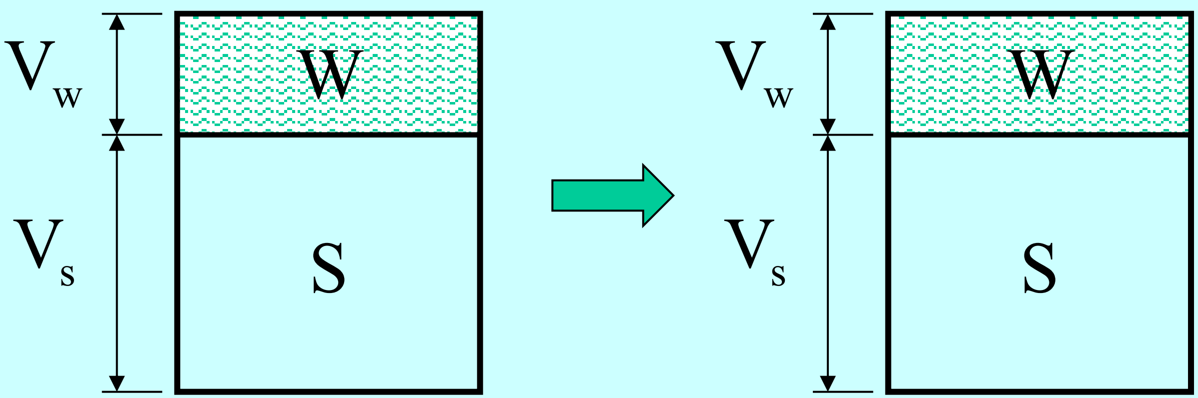


Fig.17

Undrained Deformation

Undrained Deformation

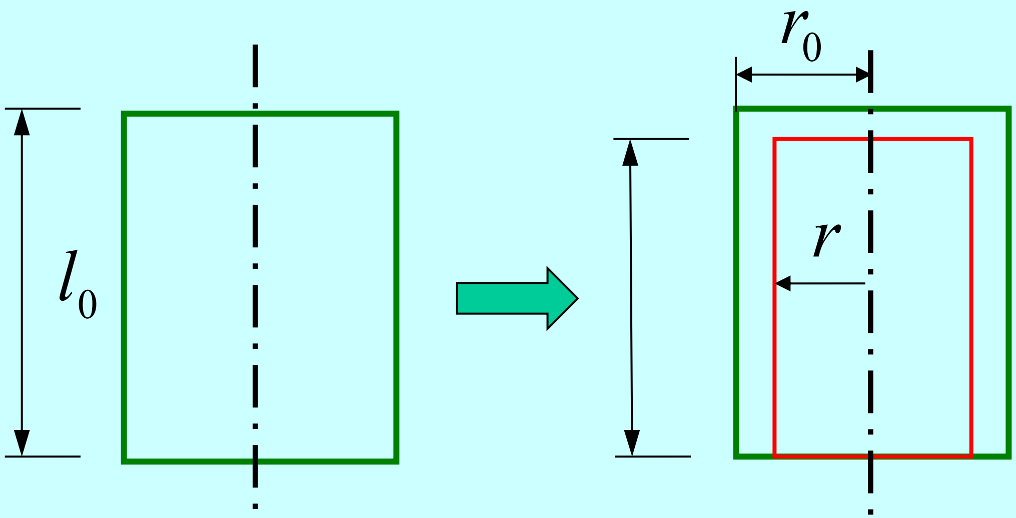
$$\Delta\varepsilon_1 = \frac{1}{E_u}\left[\Delta\sigma_1' - \upsilon_u(2\Delta\sigma_3')\right]$$

$$\Delta\varepsilon_3 = \frac{1}{E_u}\left[\Delta\sigma_3' - \upsilon_u(\Delta\sigma_1' + \Delta\sigma_3')\right]$$

E_u - Undrained Modulus

υ_u - Undrained Poisson's Ratio

$\upsilon_u = 0.5$



$$\Delta\varepsilon_1 = \frac{l_0 - l}{l_0} \qquad \Delta\varepsilon_3 = \frac{r_0 - r}{r_0}$$

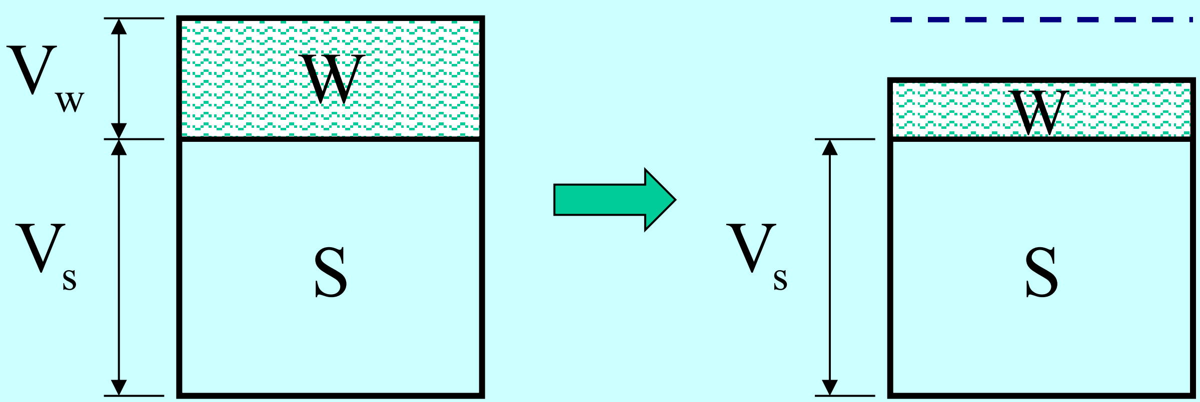


Fig. 18

Drained Deformation

Drained Deformation

$$\Delta\varepsilon_1 = \frac{1}{E'}\left[\Delta\sigma_1' - \nu'(2\Delta\sigma_3')\right]$$

$$\Delta\varepsilon_3 = \frac{1}{E'}\left[\Delta\sigma_3' - \nu'(\Delta\sigma_1' + \Delta\sigma_3')\right]$$

E' - Drained Modulus

ν' - Drained Poisson's Ratio

$= 0.2$ to 0.3

Consolidation Test Graphs & Parameters

1. For each increment

(a) Settlement - $\sqrt{t}$ Plot : c_v

(b) Settlement - Log t Plot : c_v and C_α

2. From several increments at equilibrium conditions with full dissipation of pore pressure

Voids ratio (e) - log efective vertical stress ($\bar{\sigma}_v$) Plot

$a_v, C_c, m_v, (\bar{\sigma}_v)_{max}$

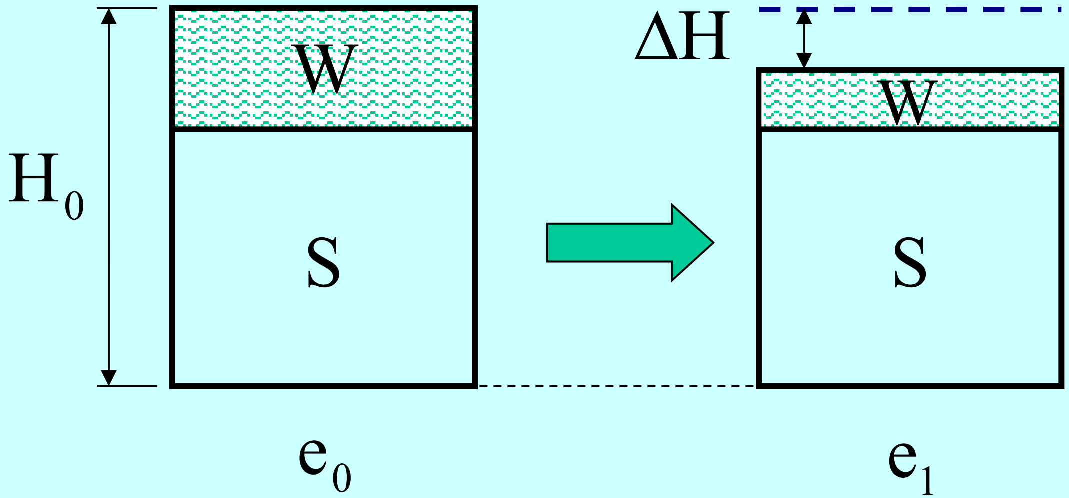
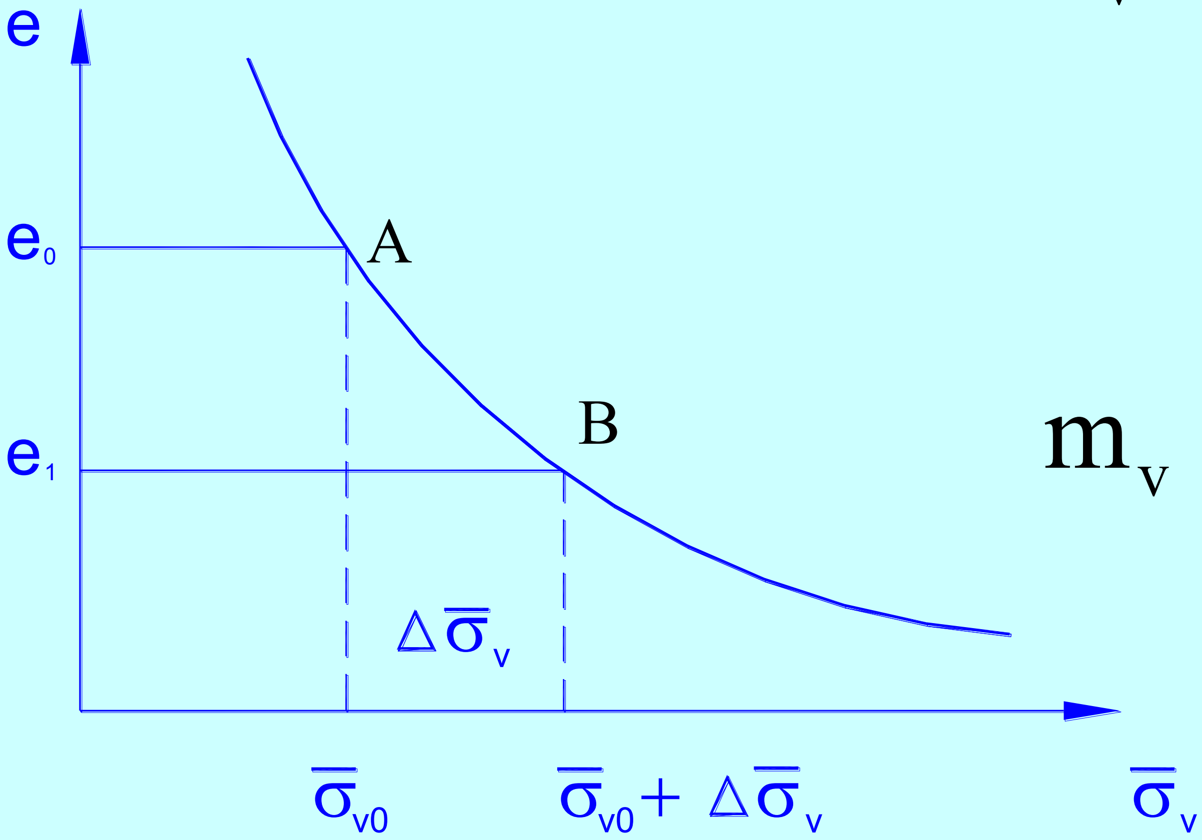


Fig. 19

$$\Delta e = e_0 - e_1$$

$$\Delta \varepsilon_1 = \left(\frac{e_0 - e_1}{1 + e_0} \right)$$

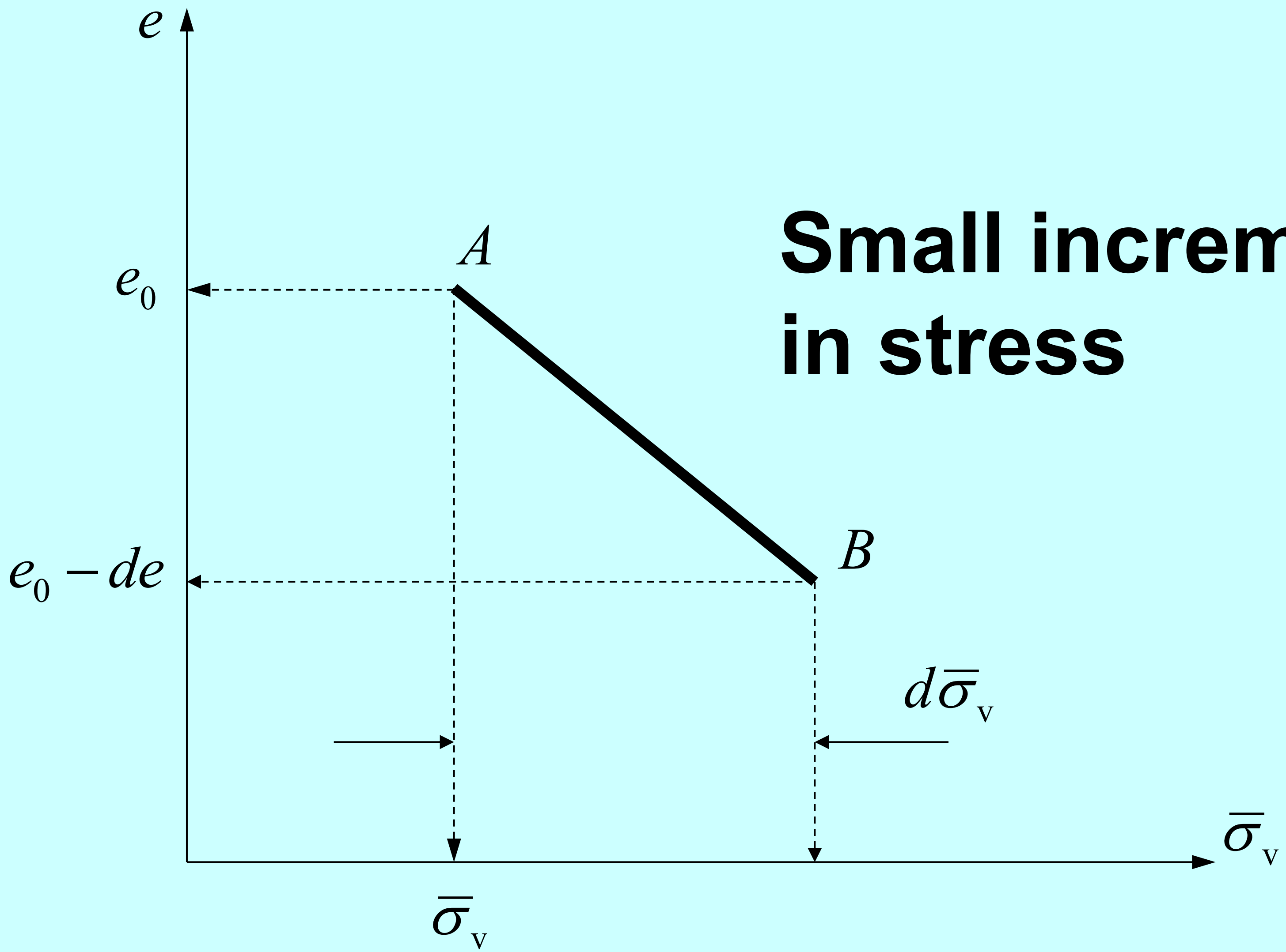
Voids ratio-Effective vertical stress relationship



$$a_v = \frac{e_0 - e_1}{\Delta \bar{\sigma}_v}$$

$$m_v = \frac{e_0 - e_1}{(1+e_0)\Delta \bar{\sigma}_v}$$

Fig. 20 Reduction of void ration with vertical effective stress

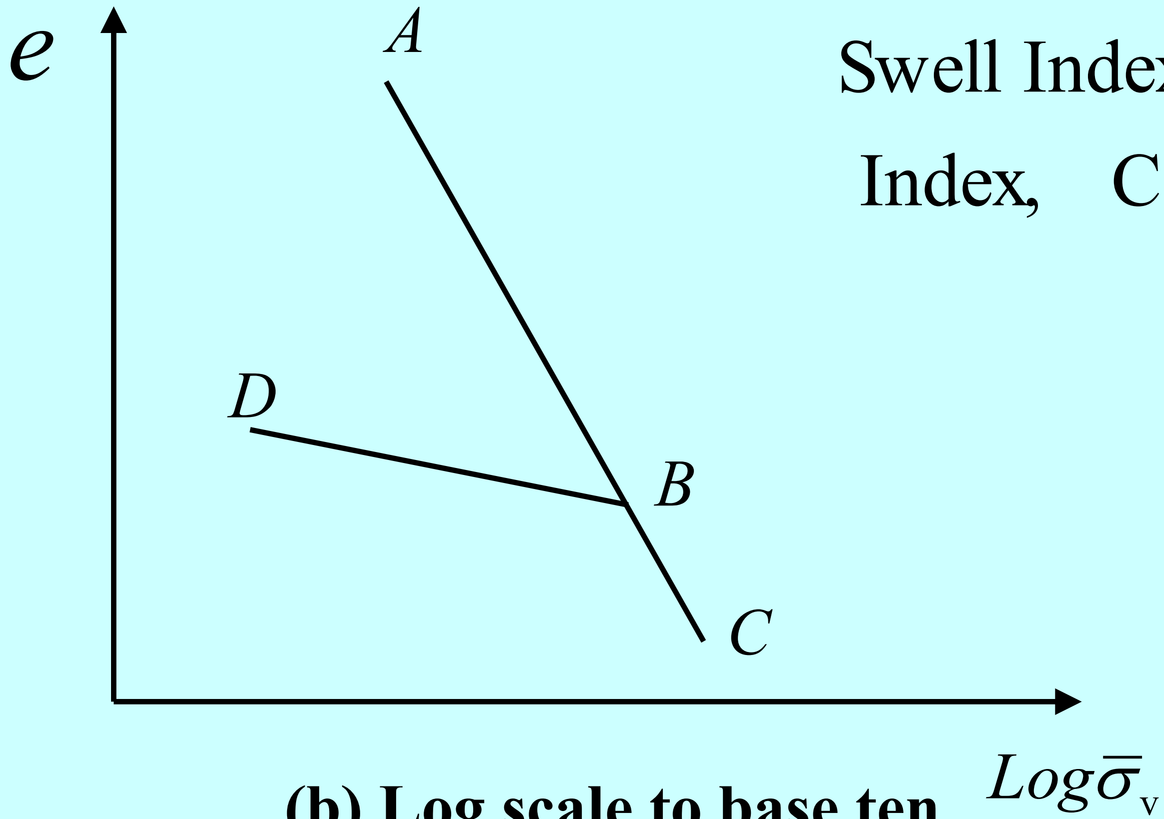


Small increment in stress

Fig. 21

1. Slope of line AC is Compression Index, C_c

2. Slope of line DB is Swell Index - Recompression Index, C_s



(b) Log scale to base ten

Fig. 22

Voids ratio – effective vertical stress plot

Maximum past pressure

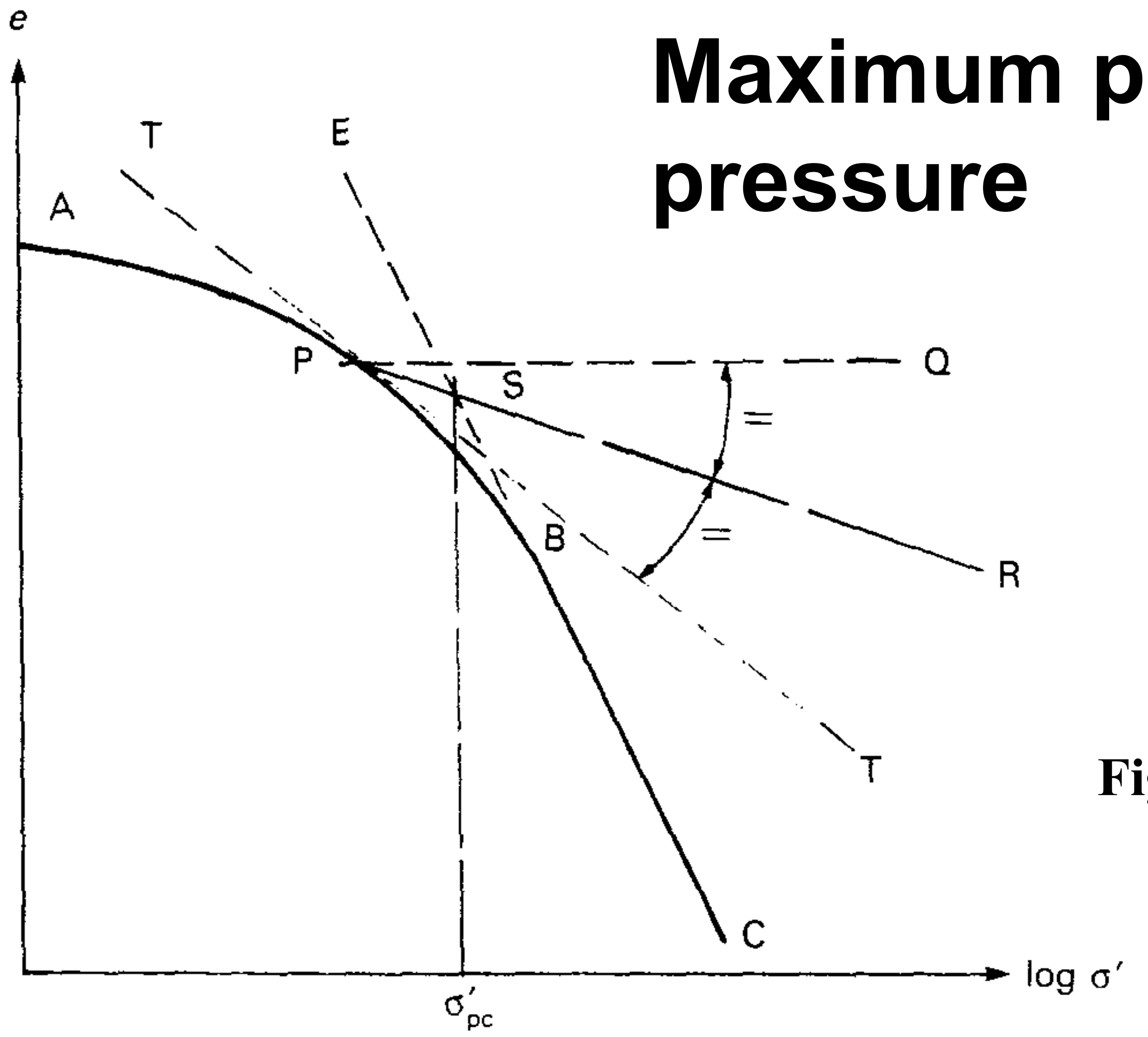


Fig. 23

Settlement –time plots

1. Settlement-square root time plot– Taylor's plot
2. Settlement log time plot

   Casagrande Method

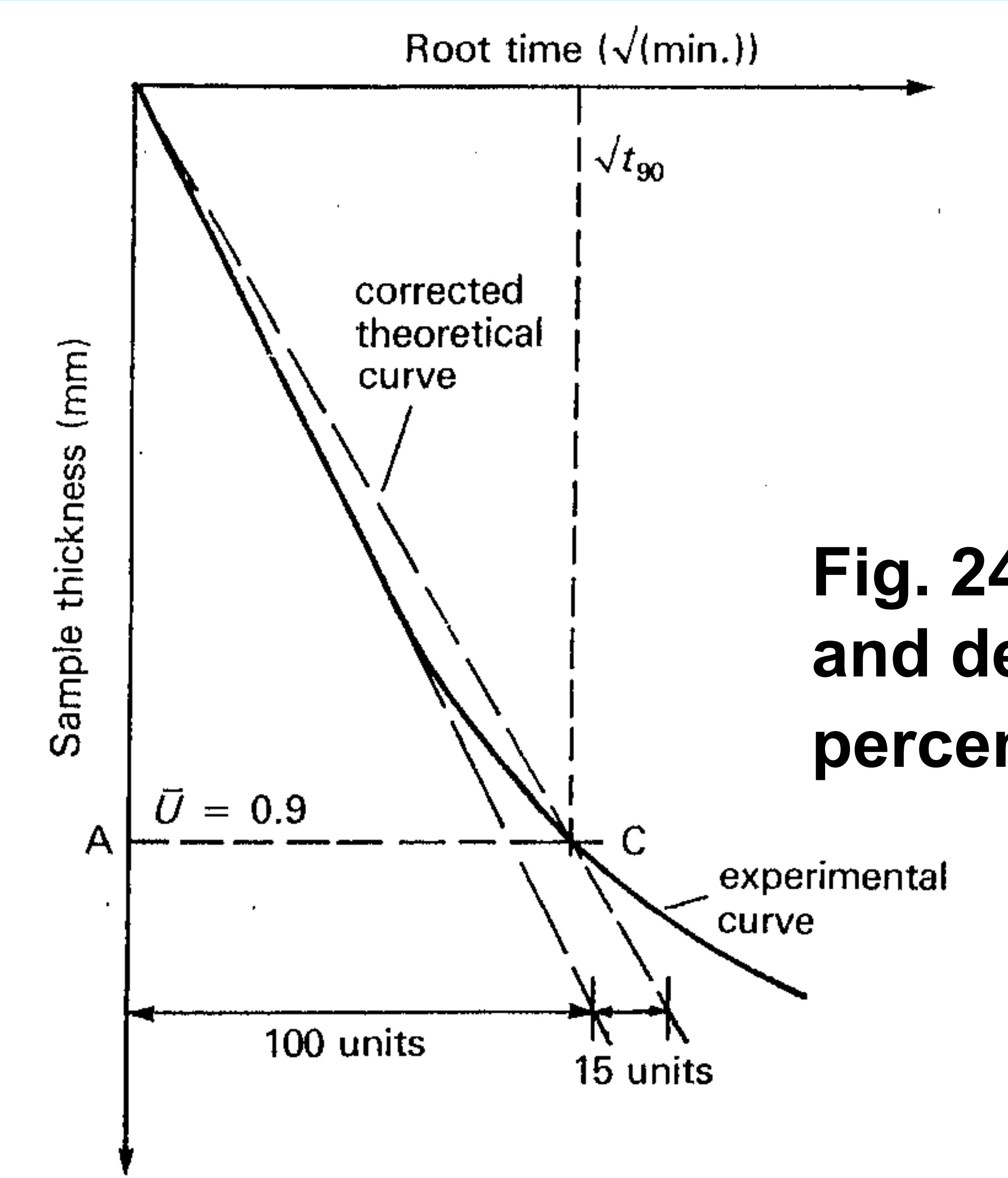


Fig. 24 Taylor's plot and determining 90 percent consolidation

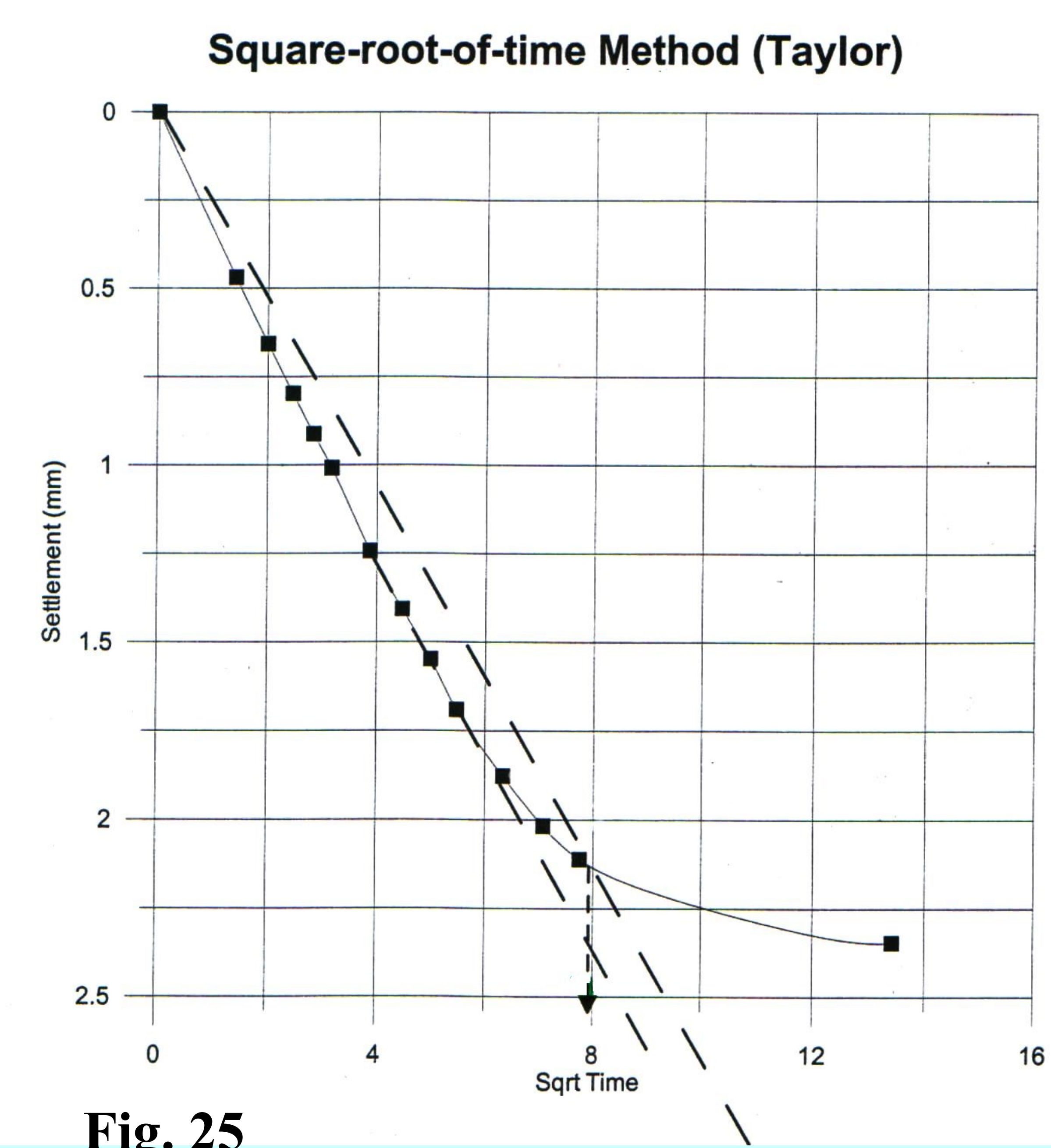
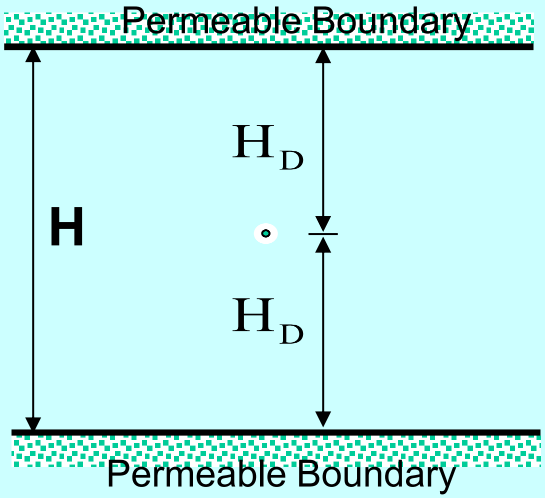
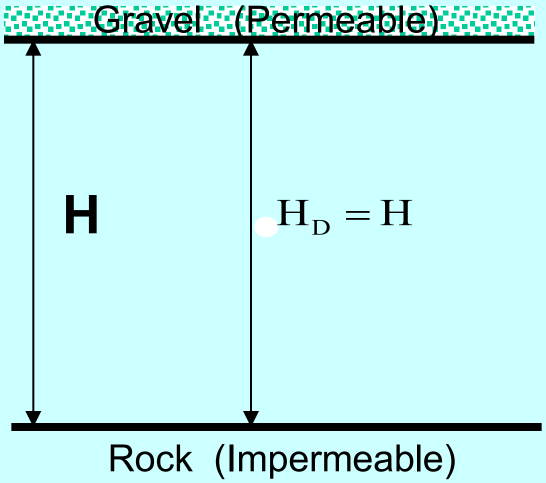


Fig. 25





$$\frac{c_v t_{90}}{H_D^2} = 0.85$$

Casagrande method-50 % consolidation

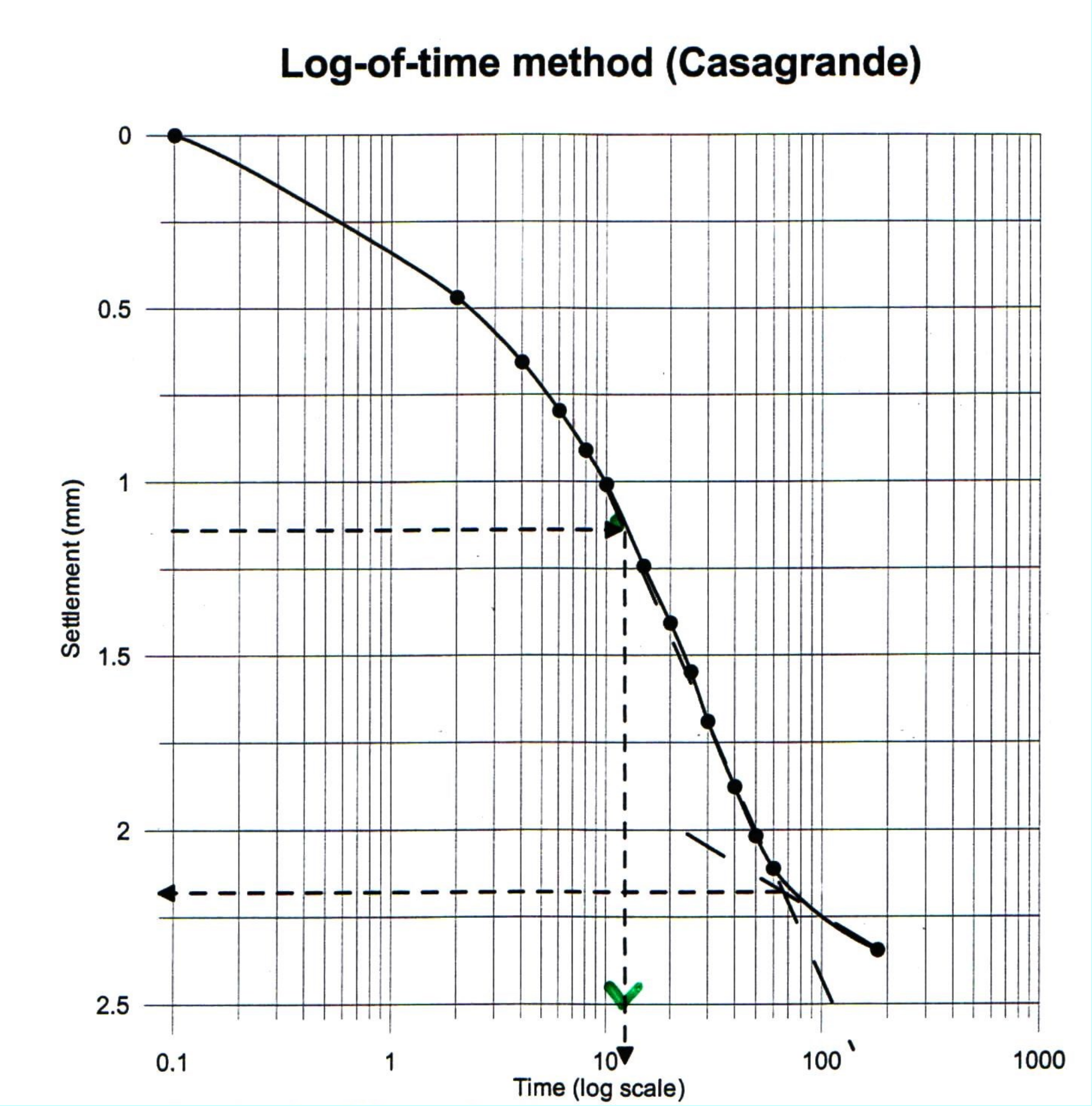
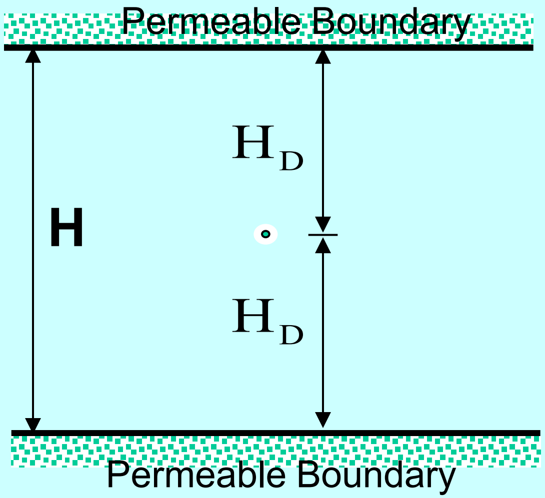
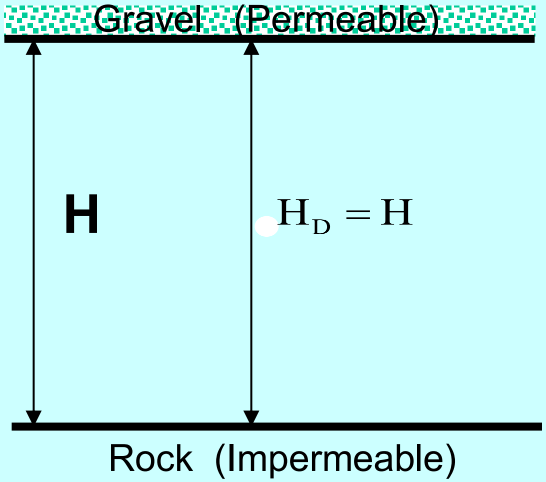
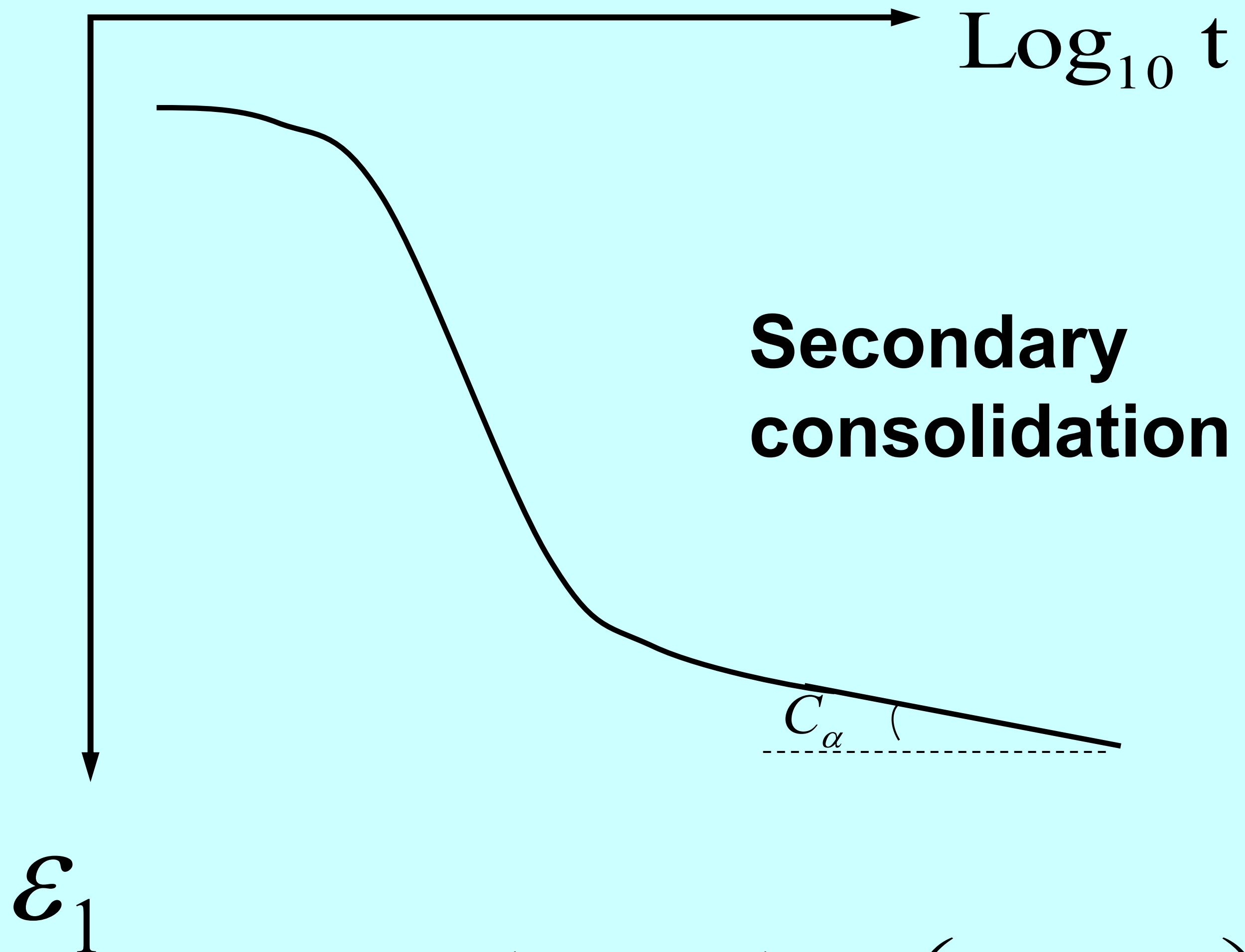


Fig. 26





$$c_v = \frac{0.195 H_D^{\;2}}{t_{50}}$$



$$\varepsilon_1 = \left(-\frac{\Delta H}{H}\right) = \left(\frac{e_0 - e_1}{1+e_0}\right)$$

Fig. 27

Consolidation Test Graphs & Parameters

1. For each increment

(a) Settlement - $\sqrt{t}$ Plot : c_v

(b) Settlement - Log t Plot : c_v and C_α

2. From several increments at equilibrium conditions with full dissipation of pore pressure

Voids ratio (e) - log efective vertical stress ($\bar{\sigma}_v$) Plot

$a_v, C_c, m_v, (\bar{\sigma}_v)_{max}$

Settlement

- Definition of strain & settlement computation
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$$\rho = \rho_{oed}$$

$$\rho = \rho_i + \rho_c$$

$$\rho = \rho_{oed} + \rho_s$$

$$\rho = \rho_i + \rho_c + \rho_{sc} + \rho_{creep}$$

$$\rho_c = \mu(\rho_{oed})$$

Immediate Settlement

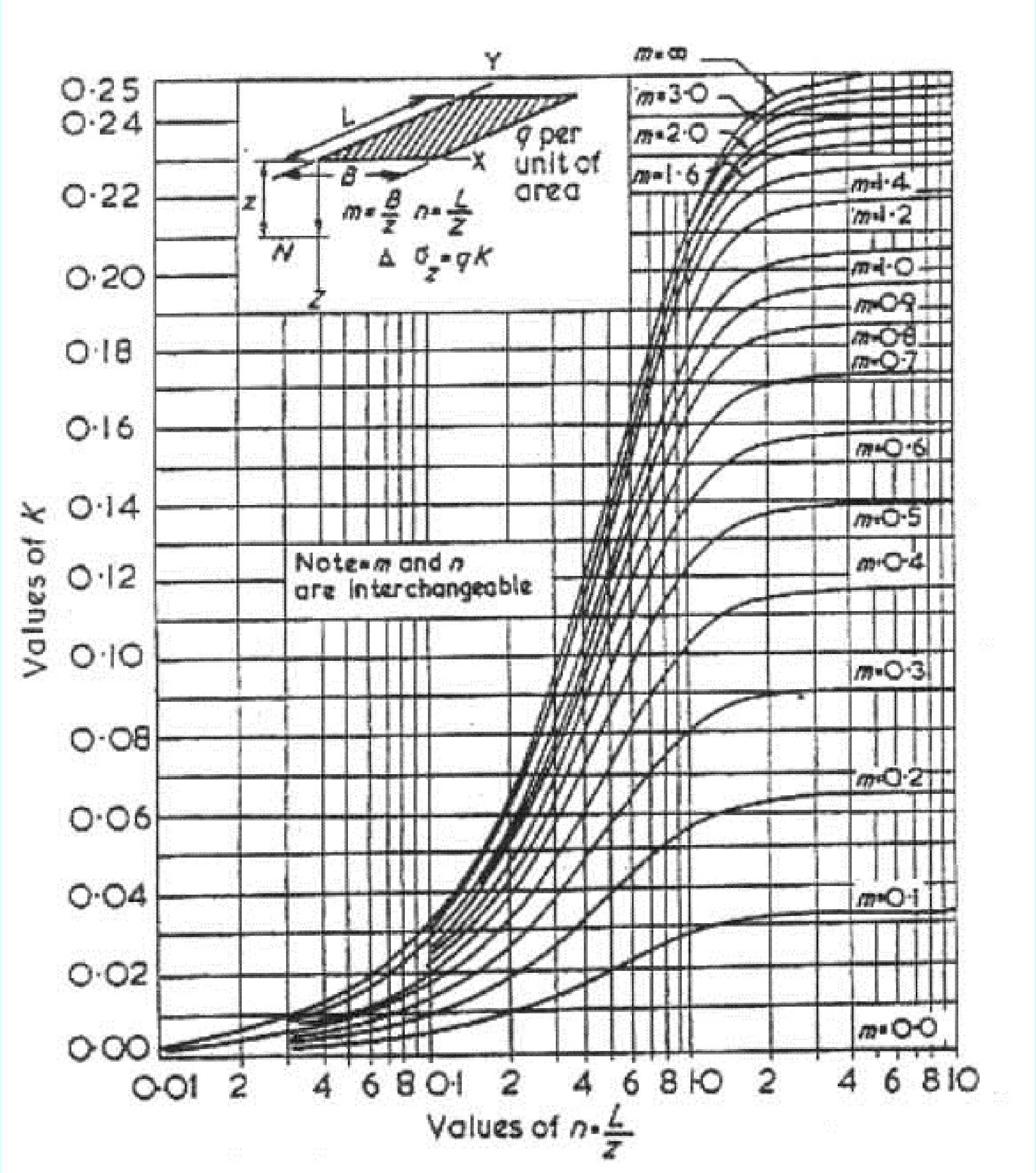
Y
L
q per
unit of
area
X
B
z
m = B/z n = L/z
N
Δ σz = qK
Z
m = ∞
m = 3·0
m = 2·0
m = 1·6
m = 1·4
m = 1·2
m = 1·0
m = 0·9
m = 0·8
m = 0·7
m = 0·6
m = 0·5
m = 0·4
m = 0·3
m = 0·2
m = 0·1
m = 0·0
Note = m and n
are interchangeable
Values of K
0·25
0·24
0·22
0·20
0·18
0·16
0·14
0·12
0·10
0·08
0·06
0·04
0·02
0·00
0·01 2 4 6 8 0·1 2 4 6 8 1·0 2 4 6 8 10
Values of n = L/z

Fig. 30

$$\rho = \int_0^h \frac{1}{E'}\left(\Delta\sigma_z - \nu'\{\Delta\sigma_x + \Delta\sigma_y\}\right)dz$$

$$\rho = \frac{qBI}{E} \qquad \rho_{ie} = \frac{qBI_u}{E_u}$$

Janbu, Bjerrum and Kjaernsli showed that I_u could be expressed as

$$I_u = \mu_0 \mu_1$$

$$\mu_0 = F_1\left(\frac{L}{B}, \frac{D}{B}\right) \qquad \mu_1 = F_2\left(\frac{L}{B}, \frac{H}{B}\right)$$

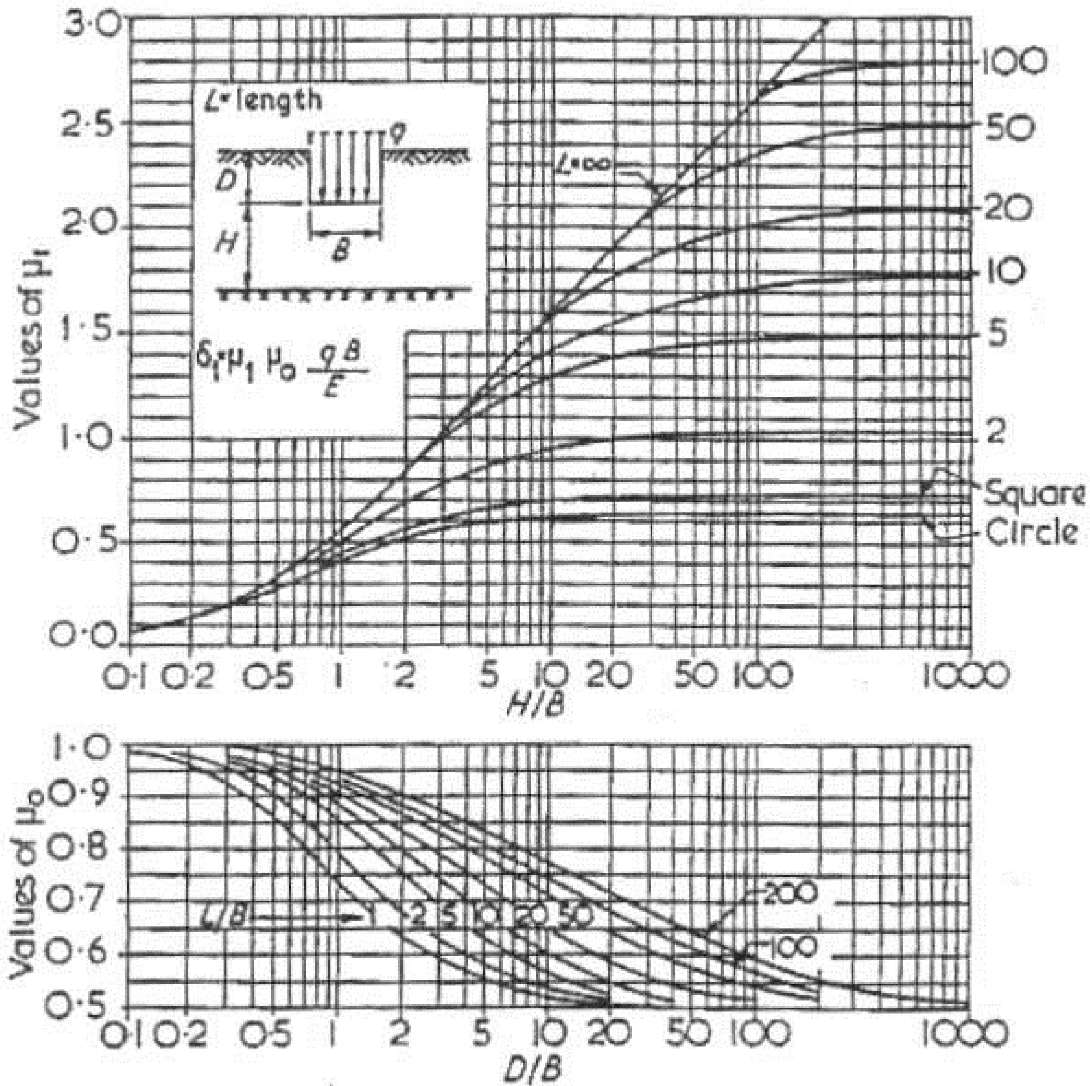

Fig. 31 Janbu, Bjerrum Kaernsli charts for μ_0, μ_1

$\frac{L}{B}$ **relates to the geometry of the loaded area.**

$\frac{D}{B}$ **is the ratio of the depth of the loaded area to the least width of the loaded area.**

$\frac{H}{B}$ **is the ratio of the thickness of compressible clay layer below the loaded area.**

Consolidation settlement

In this section, the traditional Odeometer type of 1-D settlement calculation, its modification by Skempton and Bjerrum's factor μ to obtain 3-D type of consolidation settlement will be discussed.

Odeometer type 1-D consolidation settlement

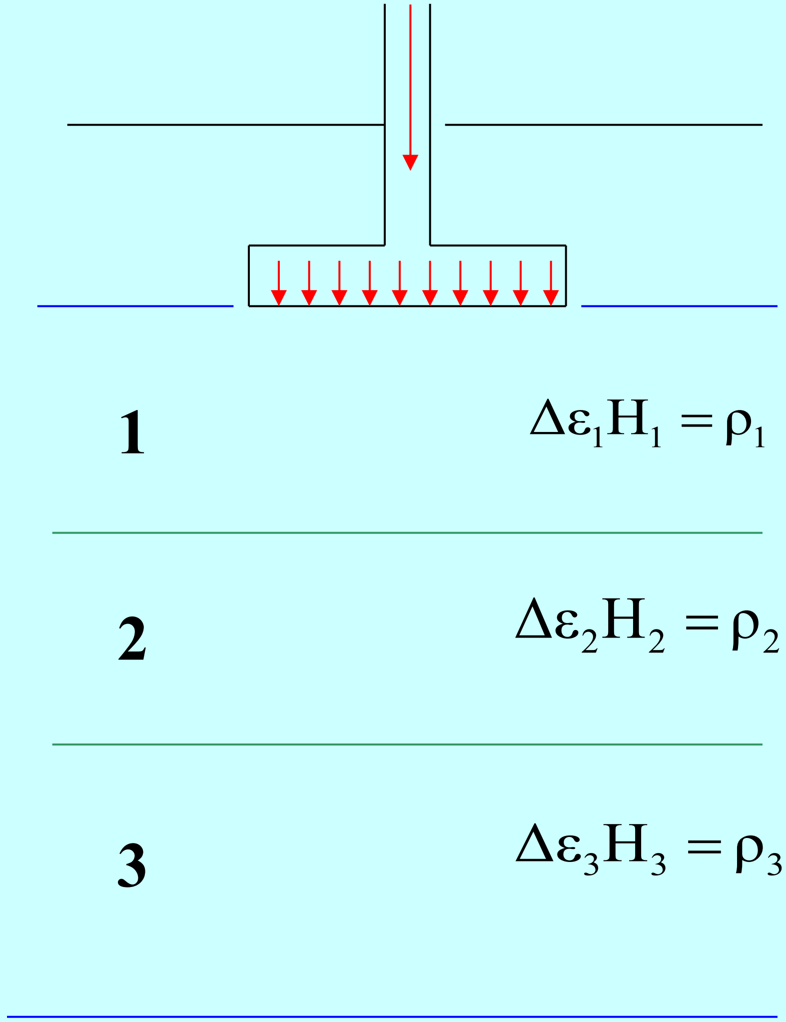

Fig. 33

$$\rho = \rho_1 + \rho_2 + \rho_3$$

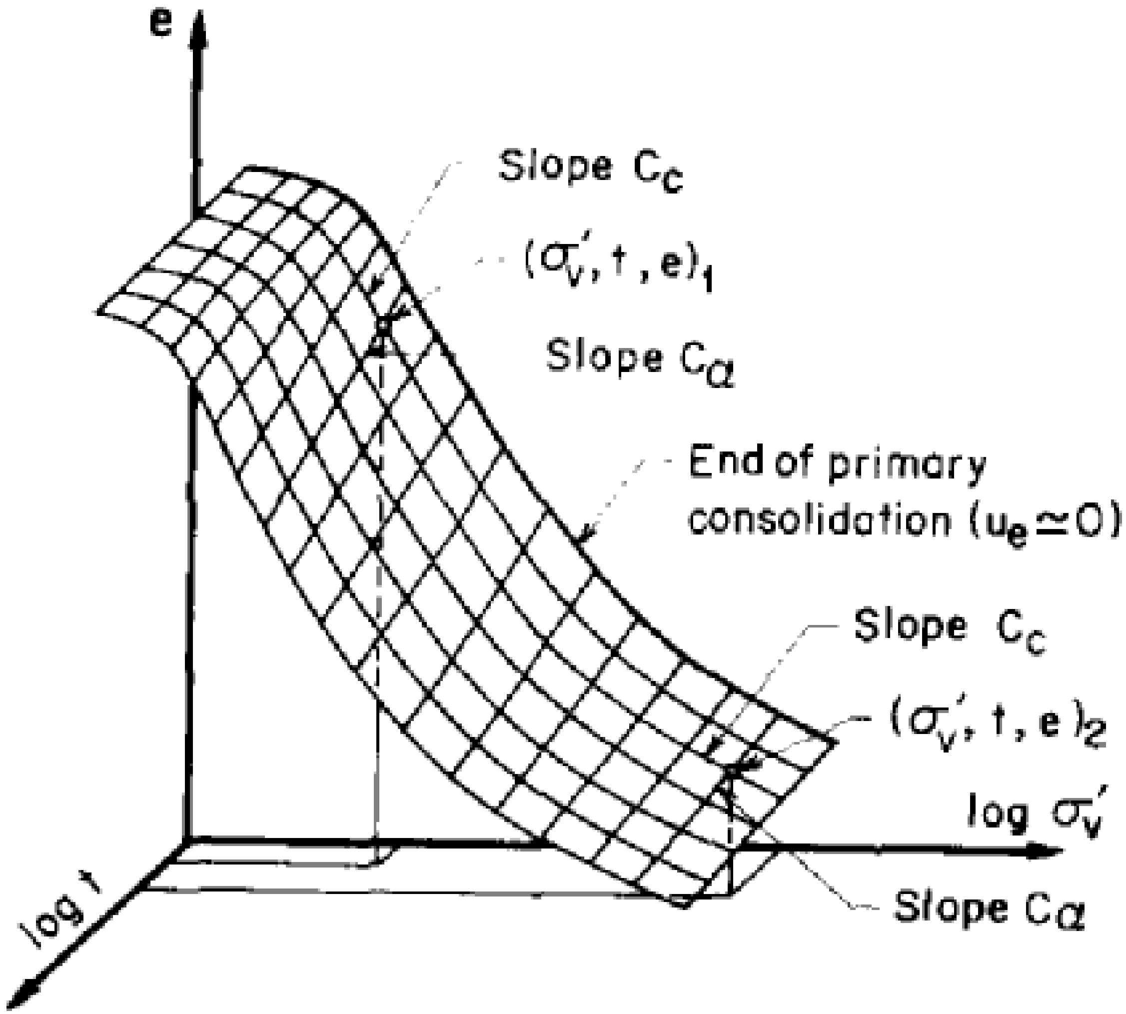

Fig. 7.37. Relationship between C_α and C_c during secondary compression in the e—log σ_v—log t space (Mesri & Godlewski, 1977).

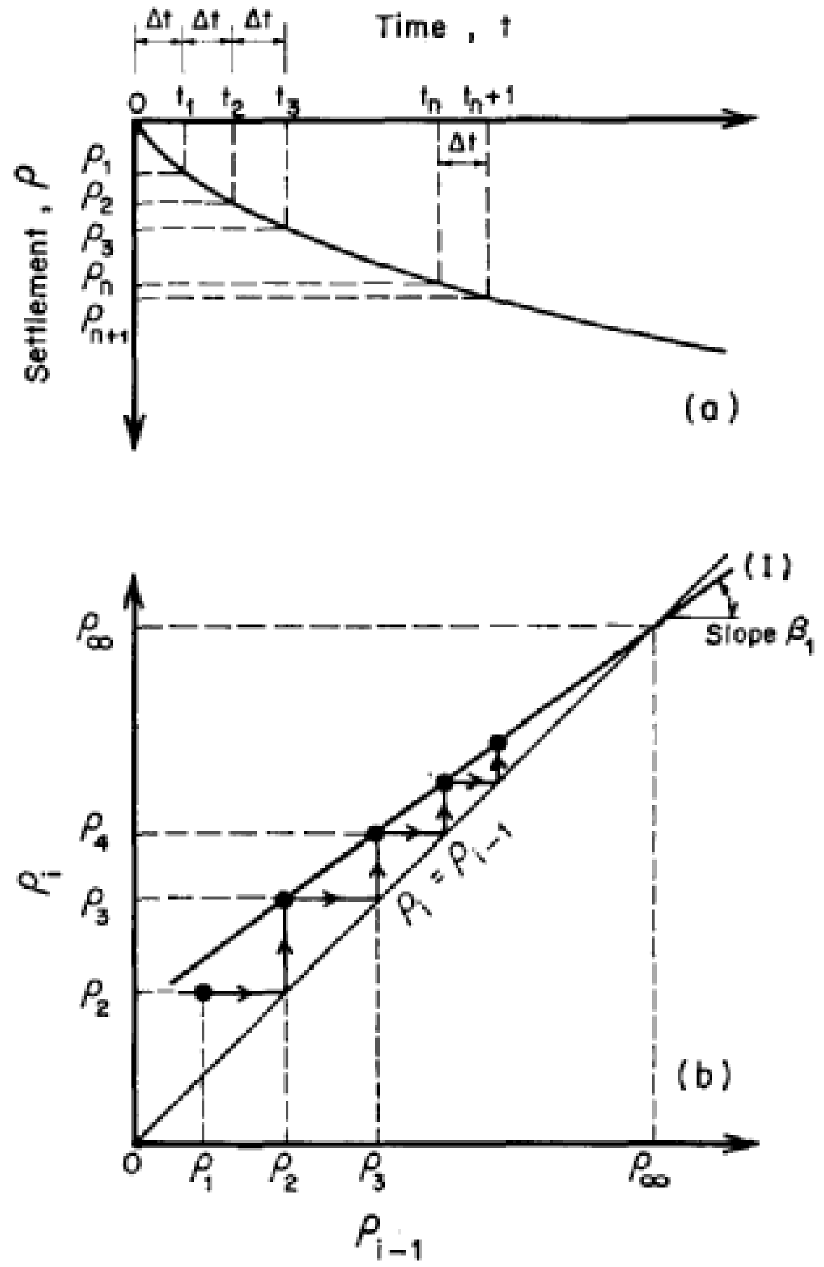

Fig. 7.24. Steps for the use of Asaoka's method: (a) partition of settlement record into equal time intervals, (b) plot of settlement values and fitting of straight line (Magnan & Deroy, 1980).

Settlement criteria in road embankment from motorways

1) **Maximum total settlement is 100 mm following practical embankment completion over 40 year period**

2) **Maximum differential settlement is 5mm at the interface between any structure and pavement**

3) **90 percent consolidation is deemed to be approximately full consolidation**

4) **Secondary compression (creep) is determined for a 40 year design life**