# Geotechnical Engineering–II

*BSc Civil Engineering – 5$^{th}$ Semester*

Lab # 6

*by*

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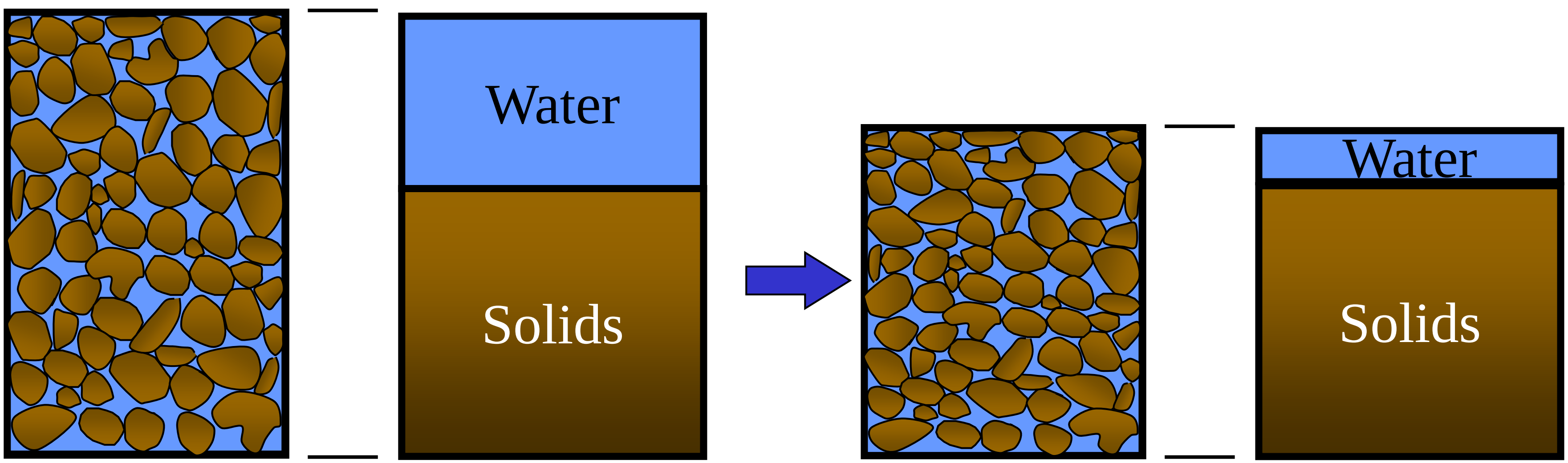
*Lecture Handouts: https://groups.google.com/forum/#!forum/geotech-ii*

# CONSOLIDATION OF SOIL

- Soil *volume reduction* due to *expulsion of water* upon application of *external load/stress.*
  - *fully saturated soil,* so all voids filled with water only *(no air)*

**Before Consolidation** **After Consolidation**



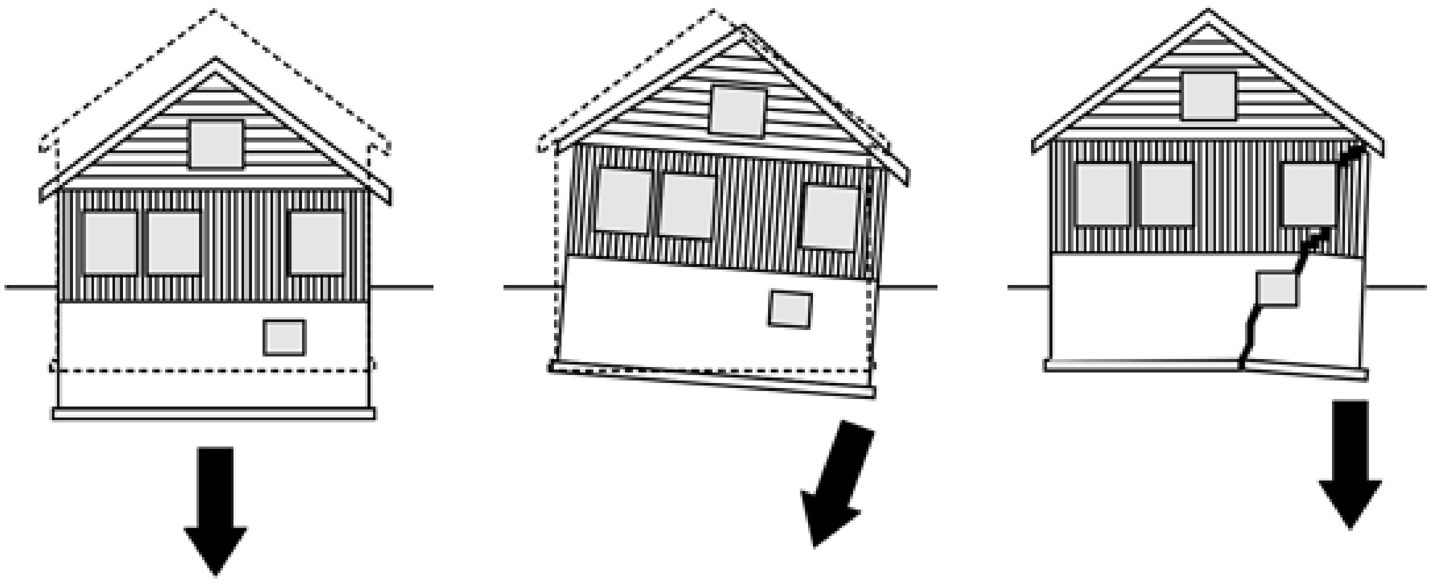

**Saturated Fine-grained Soil**

# Consolidation Damages

- Soil *volume reduction* due to *expulsion of water* upon application of *external load/stress.*

→ *Settlement* of structures

→ *Cracks* in walls, foundations, etc.



# CONSOLIDATION PARAMETERS

## *Magnitude of consolidation settlement*

dependent on *compressibility of soil*

- expressed in term of *compression index (Cc)*

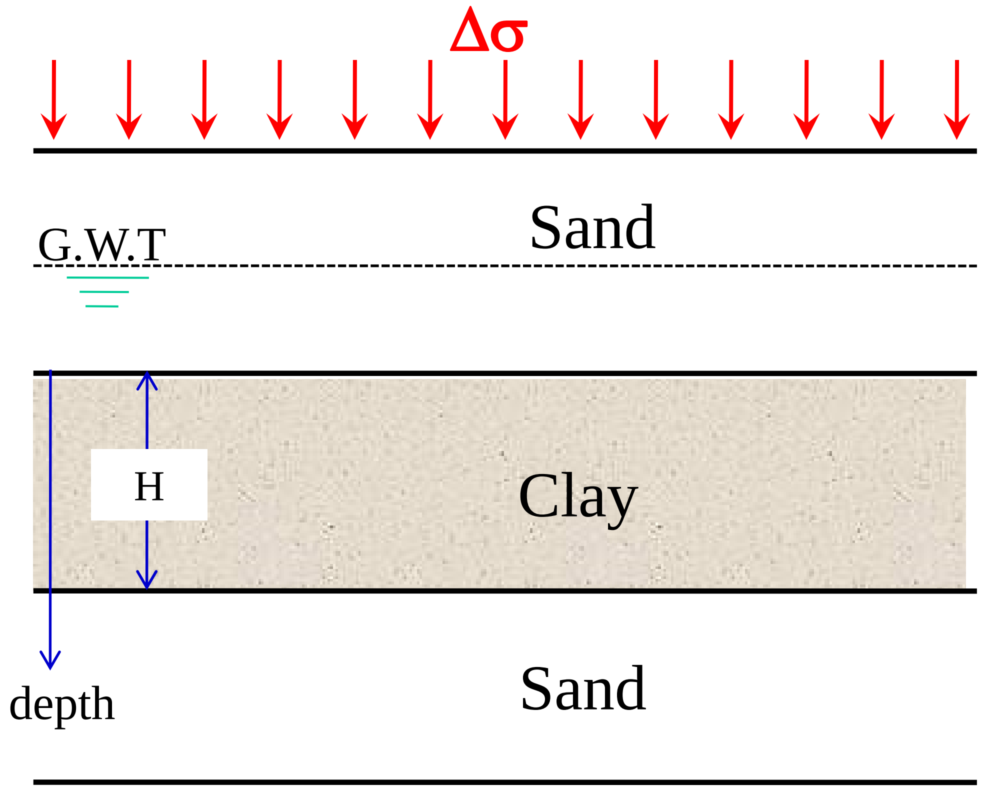
## *Rate of consolidation settlement*

dependent on

1. *permeability*, &
2. *compressibility* of soil.

- expressed in term of *co-efficient of consolidation (Cv)*

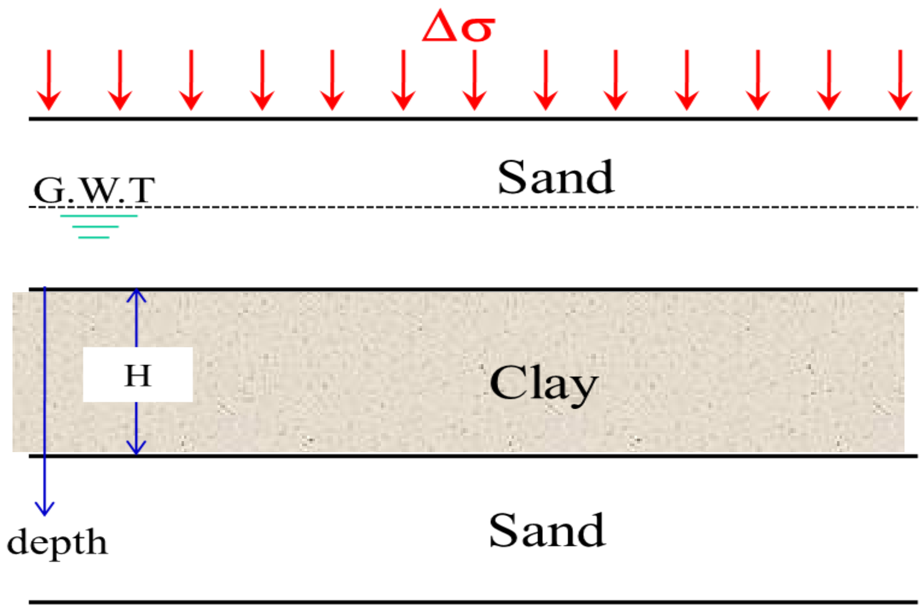
# Consolidation Settlement in the Field




External stress *(Δσ)* applied on a soil stratum in the field.

- SAND→ *Quick drainage* of water → *Immediate settlement*
- CLAY → *Slow drainage* → *Consolidation settlement* (time dependent)

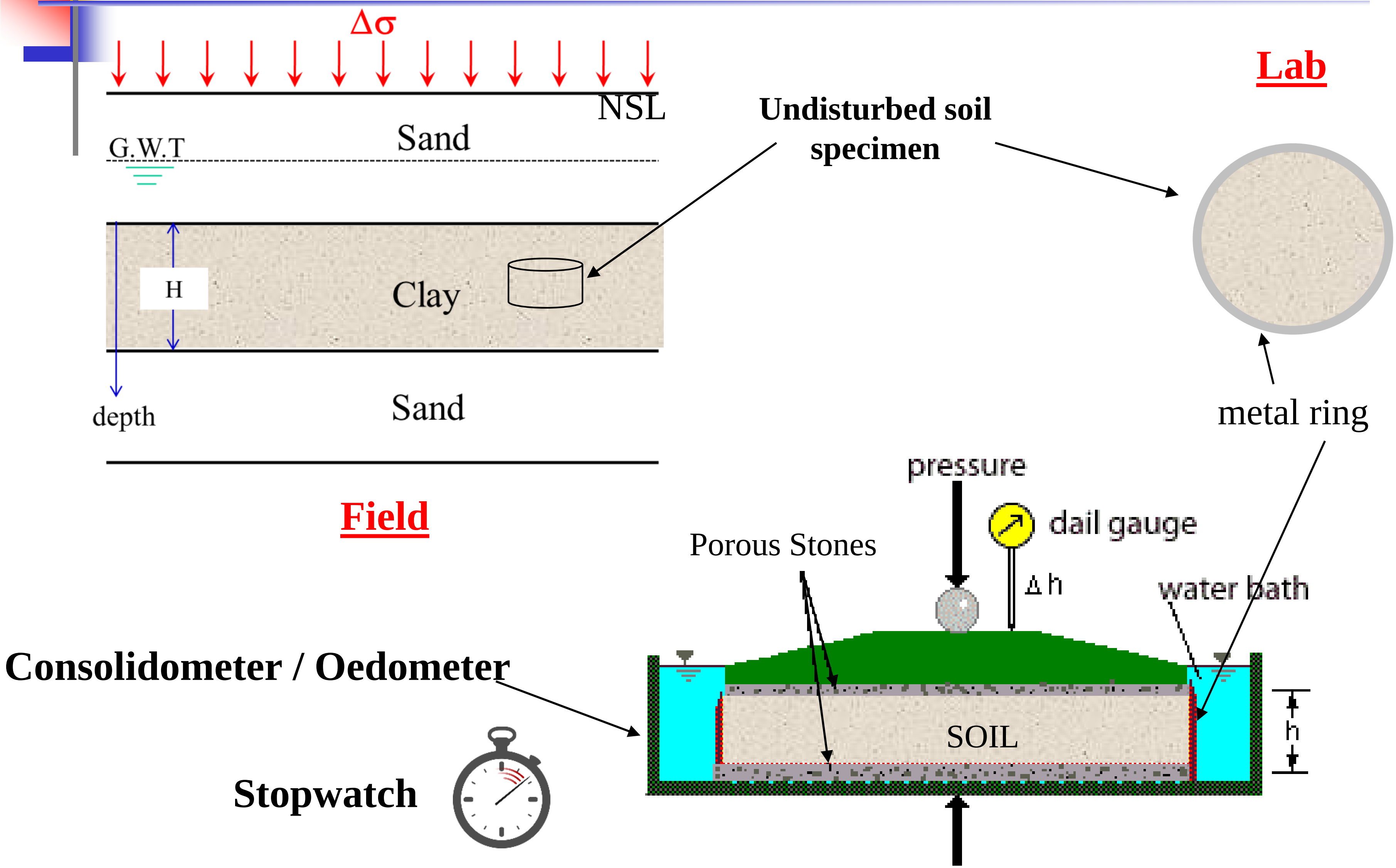
# One-Dimensional Consolidation




*Drainage* and *deformations* occur in *vertical direction only*.

A reasonable simplification for solving consolidation problems

# 1-D Lab Consolidation

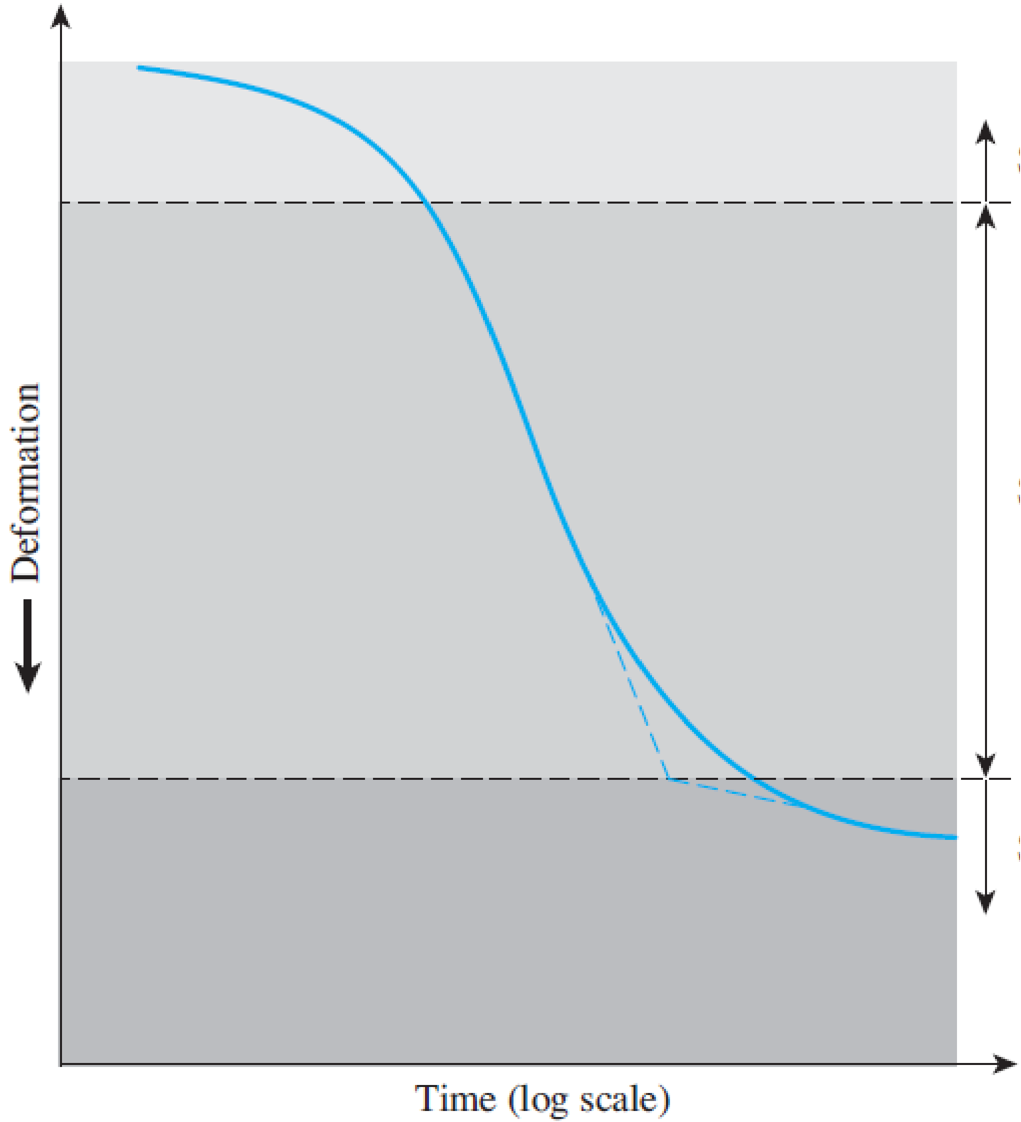


# CONSOLIDATION TEST
## - Observations -

Sample Observations

| Elapsed Time | Dial Gauge Readings | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Loading (lb) | | | | | | | |
| | 0 | 1.25 | 2.5 | 5 | 10 | 20 | 40 | 80 |
| 0 | 1000 | 1000 | 970 | 948 | 920.5 | 885 | 836 | 788.5 |
| 0.25 min | | 986.5 | 962 | 936 | 903 | 862 | 814 | 763 |
| 0.5 min | | 984 | 960.5 | 934.5 | 899 | 858 | 810 | 759 |
| 1 min | | 983.5 | 960 | 934 | 898 | 857.5 | 809 | 758 |
| 2 min | | 981 | 958.5 | 932 | 895.5 | 852 | 805 | 753 |
| 4 min | | 978.5 | 956.5 | 929.5 | 892 | 848 | 801 | 749 |
| 8 min | | 977 | 955 | 928.5 | 889 | 845 | 798 | 746 |
| 15 min | | 975 | 954 | 928 | 887.5 | 844 | 796 | 744.5 |
| 30 min | | 974 | 953.5 | 927.5 | 887 | 842 | 794 | 742.2 |
| 1 hr | | 972 | 953 | 926 | 886.5 | 841 | 793 | 740 |
| 2 hr | | 970 | 952 | 924 | 886 | 840 | 791.5 | 738 |
| 4 hr | | 970 | 952 | 923 | 885 | 8839 | 790 | 737 |
| 8 hr | | 970 | 9950 | 921 | 885 | 837 | 788.5 | 736 |
| 24 hr | | 970 | 948 | 920.5 | 885 | 836 | | 735 |
| **Unloading** | 750 | 722 | | 702 | | 674 | | |

# Deformation ~ Time Plot




Determination of *Cv*

- Casagrande’s Method
- Taylor’s Method

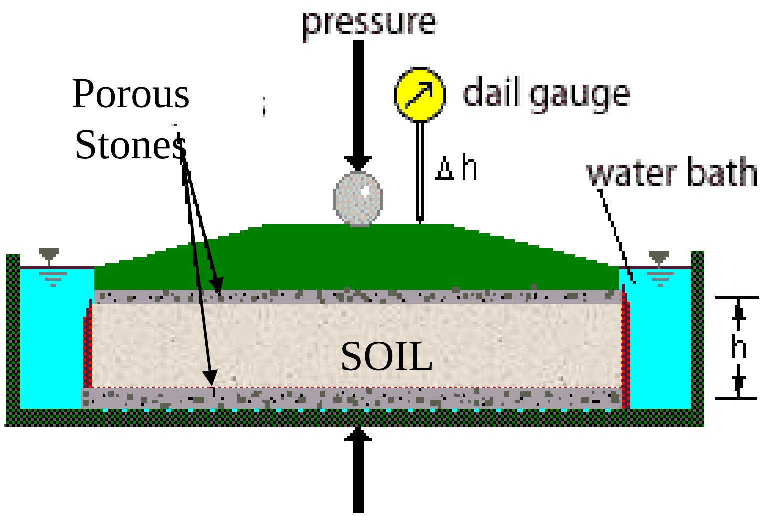
# CONSOLIDATION TEST

## - Interpretation of Test Results -

*Magnitude* of consolidation → compression index *(Cc)*

*Rate* of consolidation → co-efficient of consolidation *(Cv)*

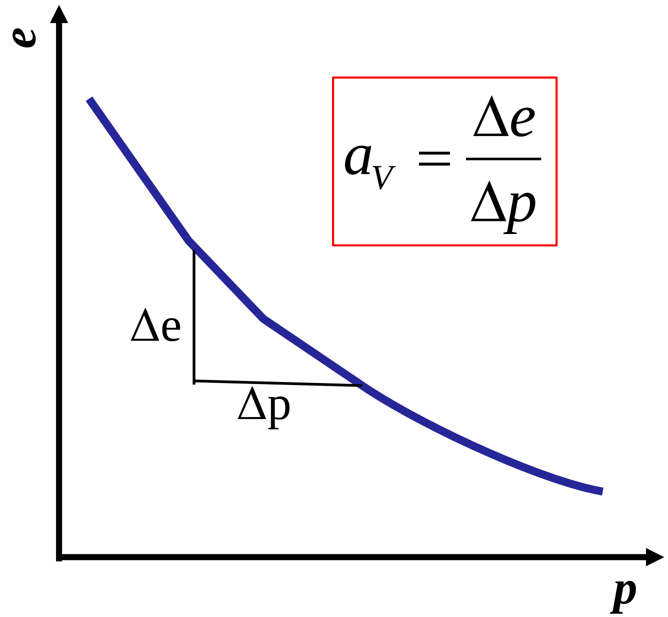
1. Time ~ Deformation curve
   - *i.* *Cv* (Coefficient of consolidation)
2. Pressure ~ Deformation curve
   - *i.* *Cc* (Compression index)
   - *ii.* *Cr* (Recompression index)
   - *iii.* $a_V$ (Coefficient of compressibility)
   - *iv.* $m_V$ (Coefficient of volume change)



# CONSOLIDATION TEST

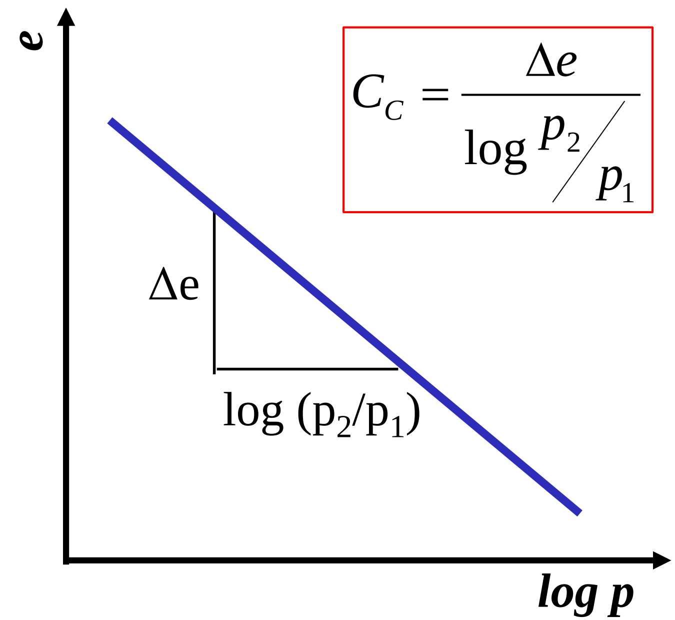
## Pressure ~ Deformation Curve

***e ~ p* plot**




$$a_V = \frac{\Delta e}{\Delta p}$$

***e ~ log p* plot**




$$C_C = \frac{\Delta e}{\log \frac{p_2}{p_1}}$$

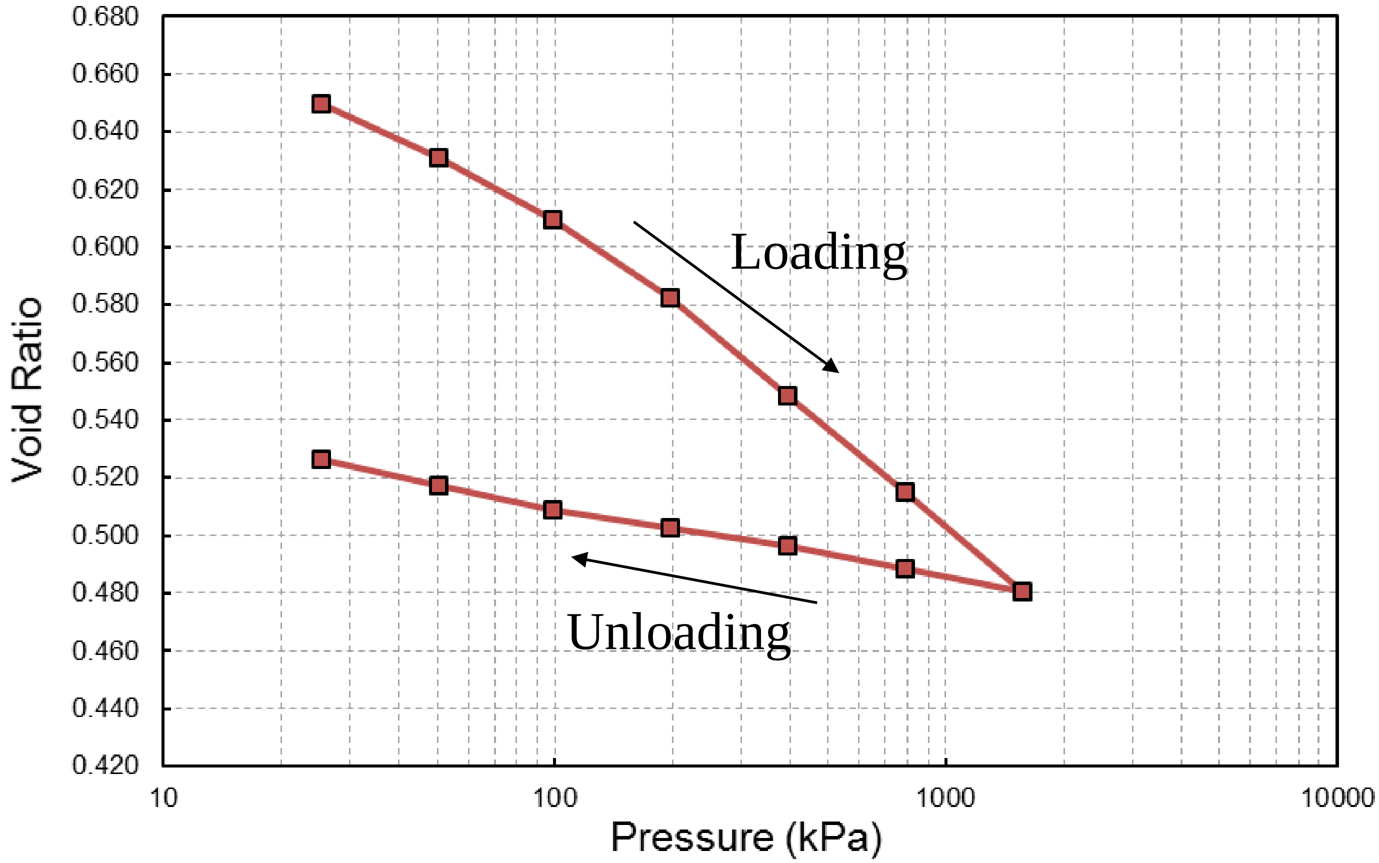
$a_V$ = coefficient of compressibility

Cc = compression index

$m_V$ = coefficient of volume change

$$m_V = \frac{a_V}{1+e}$$

# Pressure ~ Deformation Curve




Slope of loading part → Compression Index ($C_c$)

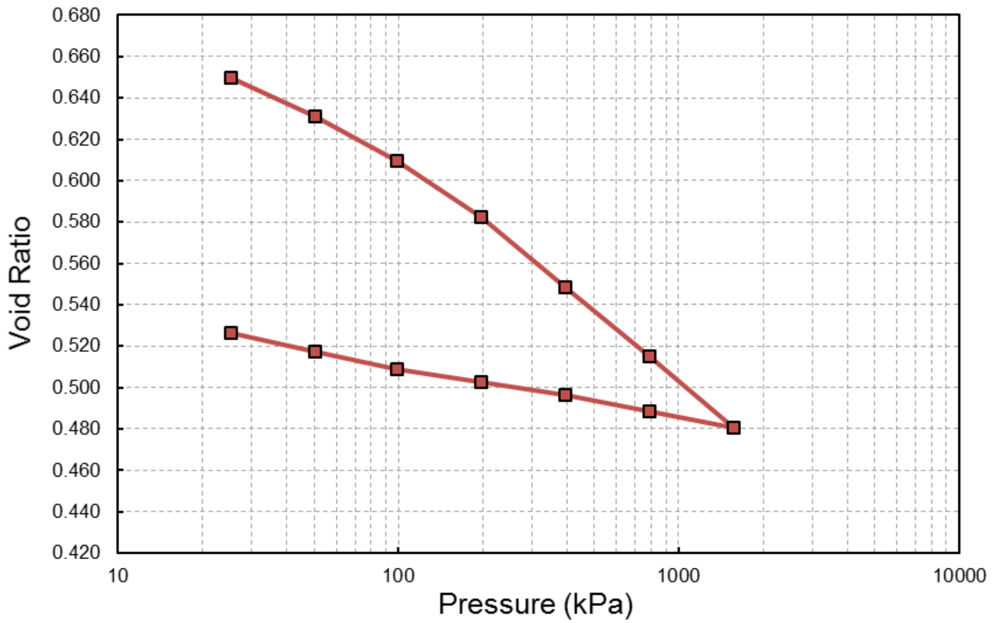
Slope of Unloading part → Recompression Index ($C_r$)

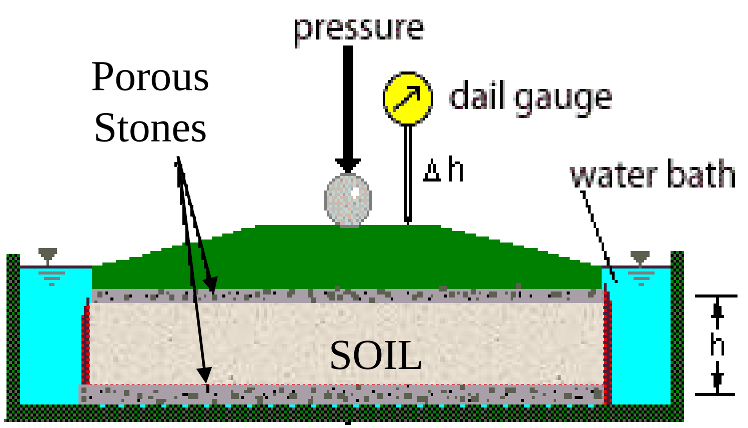
# CONSOLIDATION TEST

## Pressure ~ Void Ratio Curve

How to make *'e ~ log p'* graph?

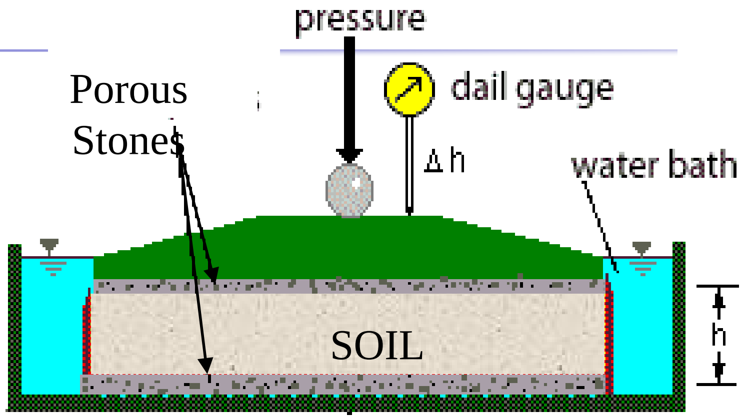
How to determine *'e'* at every loading increment?




# CONSOLIDATION TEST

## Pressure ~ Void Ratio Curve

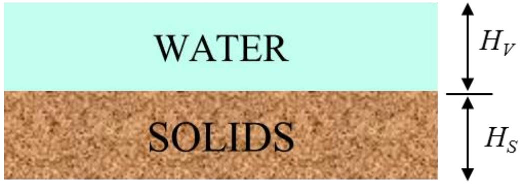



### Determination of $e_0$

$e_o$ = initial (or in-situ) void ratio

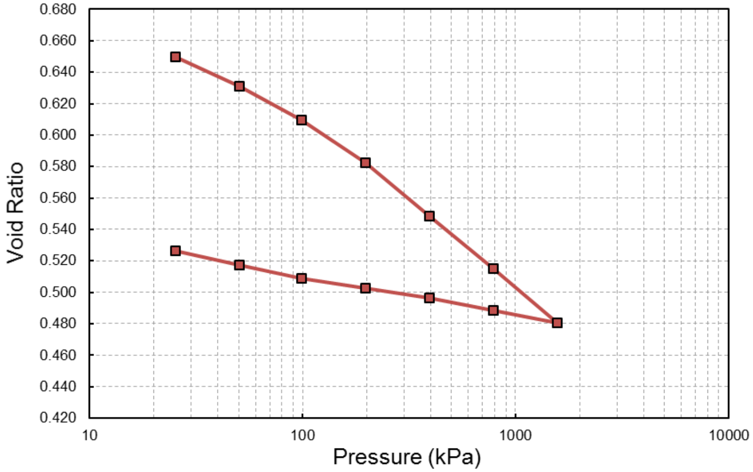
$$e_0 = \frac{V_V}{V_S} = \frac{A \cdot H_V}{A \cdot H_S} = \frac{H_V}{H_S}$$

$$e_0 = \frac{H - H_S}{H_S}$$




$$V_S = \frac{W_S}{G_S \cdot \gamma_w} \rightarrow A \cdot H_S = \frac{W_S}{G_S \cdot \gamma_w}$$

$$H_S = \frac{W_S}{G_S \cdot \gamma_w \cdot A}$$




*Ws = weight of soil solids* $W_S = \frac{W_T}{1 + w}$

*Determined from over drying the specimen at the end of consolidation test.*

# CONSOLIDATION TEST
## - Calculations -

Sample Calculations

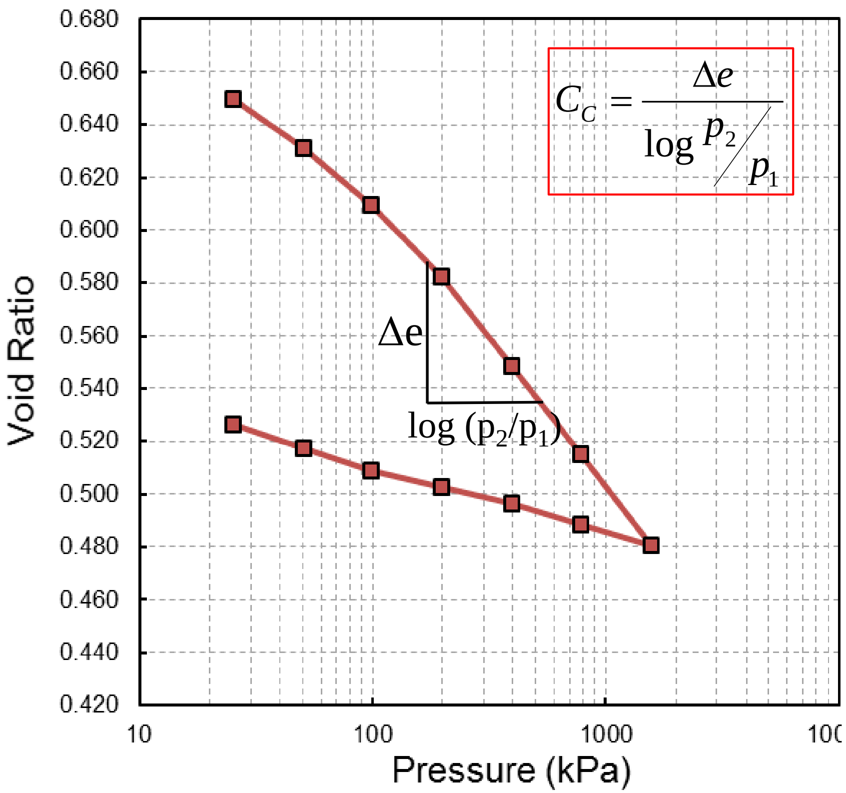
| | | |
|---|---|---|
| Ring Dia. , D | = | 6 cm |
| Ring Height, H | = | 2 cm |
| X-Area, A | = | 28.27 $cm^2$ |
| Initial Volume, V | = | 56.55 $cm^3$ |
| Wt. of Ring | = | 81 g |
| Wt. of Ring + Wet Soil | = | 183.8 g |
| Wt. of Wet Soil | = | 102.8 g |
| Initial Bulk Density | = | 1.82 $g/cm^3$ |
| | = | 17.83 $kN/m^3$ |

| | | |
|---|---|---|
| Gs | = | 2.65 |
| w | = | 15.3 % |
| Dry Density | = | 15.47 $kN/m^3$ |
| Wt. of Soil Solids | = | 89.16 g |
| Ht. of Soil Solids, Hs | = | 1.19 cm |
| Initial Void Ratio, $e_o$ | = | 0.675 |

| | | | | | $e_1=((Ho-\Delta H_1)-Hs)/Hs$ | |
|---|---|---|---|---|---|---|
| **Load** | **Applied Pressure** | **Final DGR** | **$\Delta H$ = DGR x LC** | **$\Delta H_{(cum)}$** | **Void Ratio, e** | **Strain, $\varepsilon$** |
| **(kg)** | **(kPa)** | | **(mm)** | | | **(%)** |
| 0 | 0.0 | 5000 | - | - | 0.67550 | |
| 0.05 | 1.91 | 4635 | 0.3650 | 0.365 | 0.64492 | 18.3 |
| 0.25 | 9.54 | 4412 | 0.2230 | 0.588 | 0.62624 | 29.4 |
| 1 | 38.17 | 4154 | 0.2580 | 0.846 | 0.60462 | 42.3 |
| 2 | 76.33 | 3831 | 0.3230 | 1.169 | 0.57757 | 58.5 |

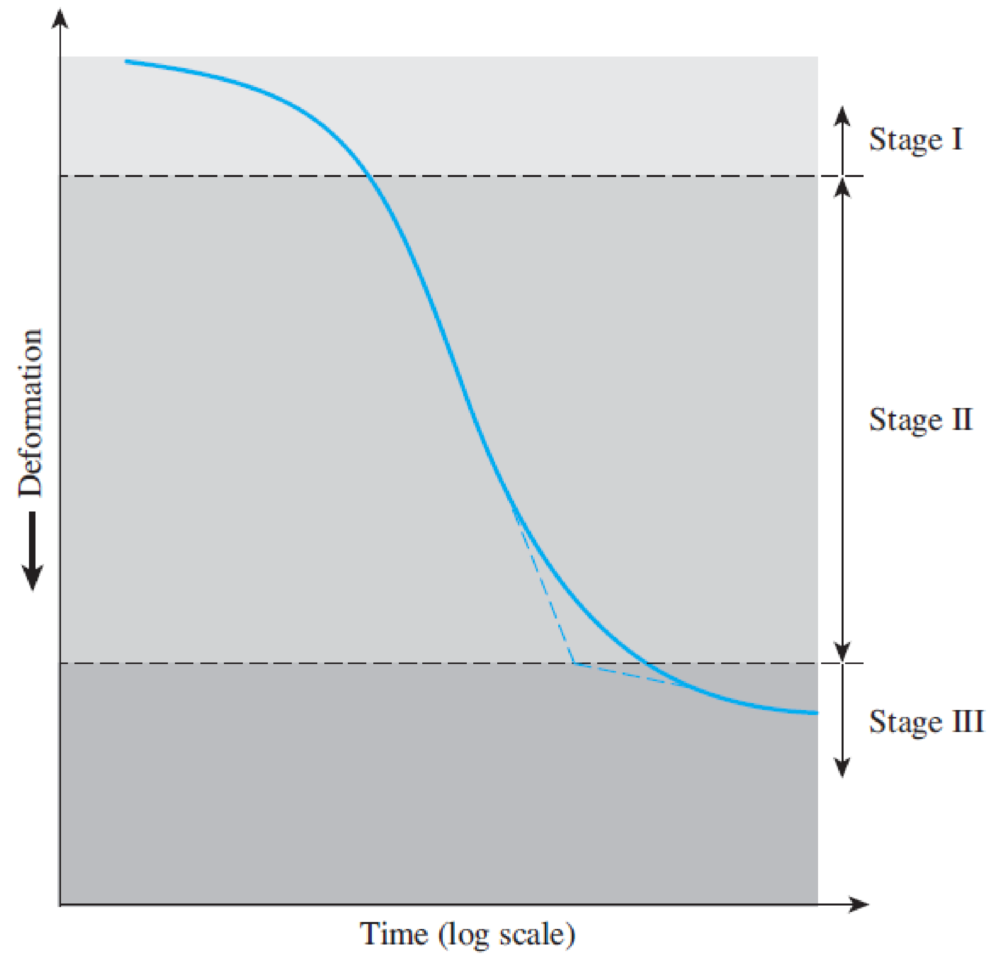
# CONSOLIDATION TEST
# - PLOTS -

## ***e ~ log p* plot**




For determination of *Cc*

## ***Deformation ~ Time* plot**




For determination of *Cv*

# CONCLUDED