EWCE 342

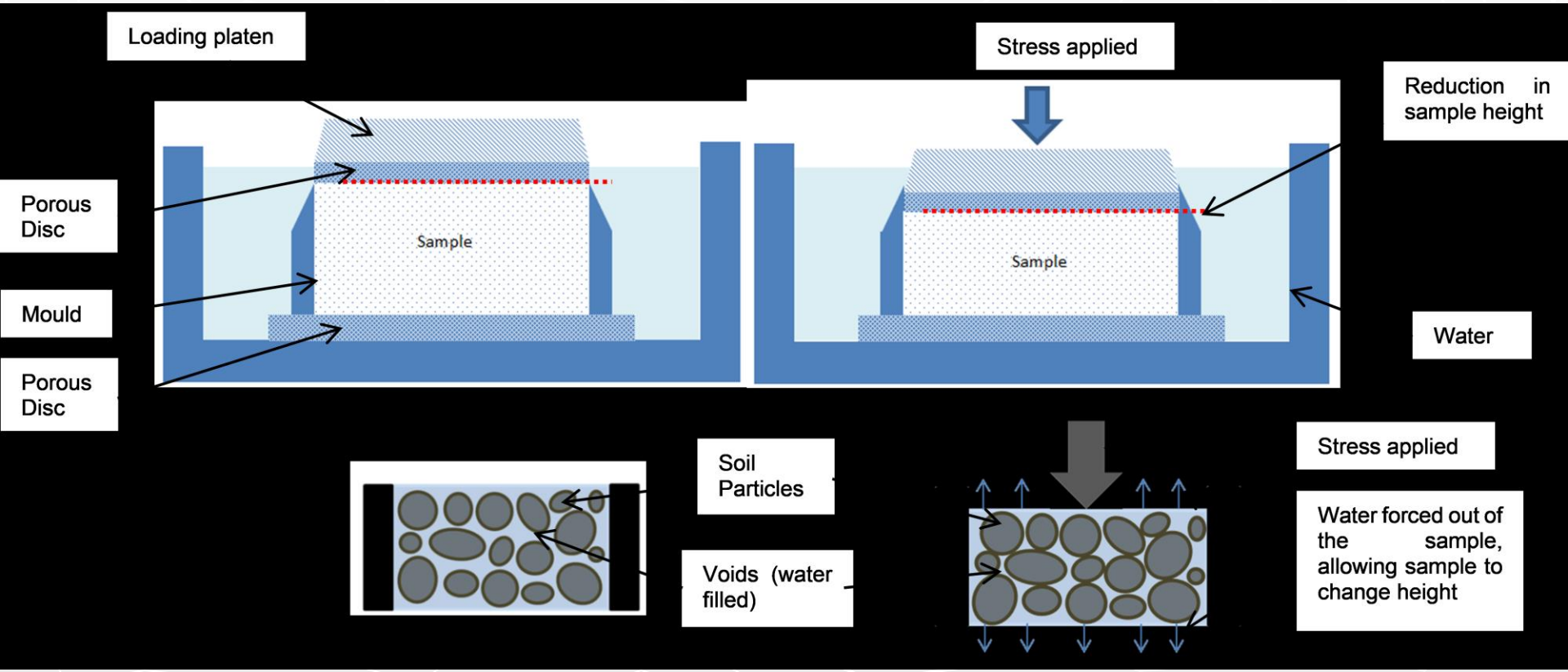
Soil Mechanics Sessional

EWCE 342

Name of Experiment: Consolidation Test

1D Consolidation Test

ASTM D4186-12



Consolidation Test

- Theory
- Preparation of specimen
- Preparation of Consolidation cell
- Loading in the Load Frame
- Data
- Calculation and graphs
- Result

Purpose/Objective:

- To **determine** of the **magnitude of compression** and **rate-of-consolidation** of **saturated cohesive soils** using **continuous controlled strained axial compression**.

Significance:

- Magnitude of compression and rate-of-consolidation of soil are **essential** in the **design of earth structure** and **earth supported**
- **structure.**

Compression Index: C_c

Re-compression Index: C_r

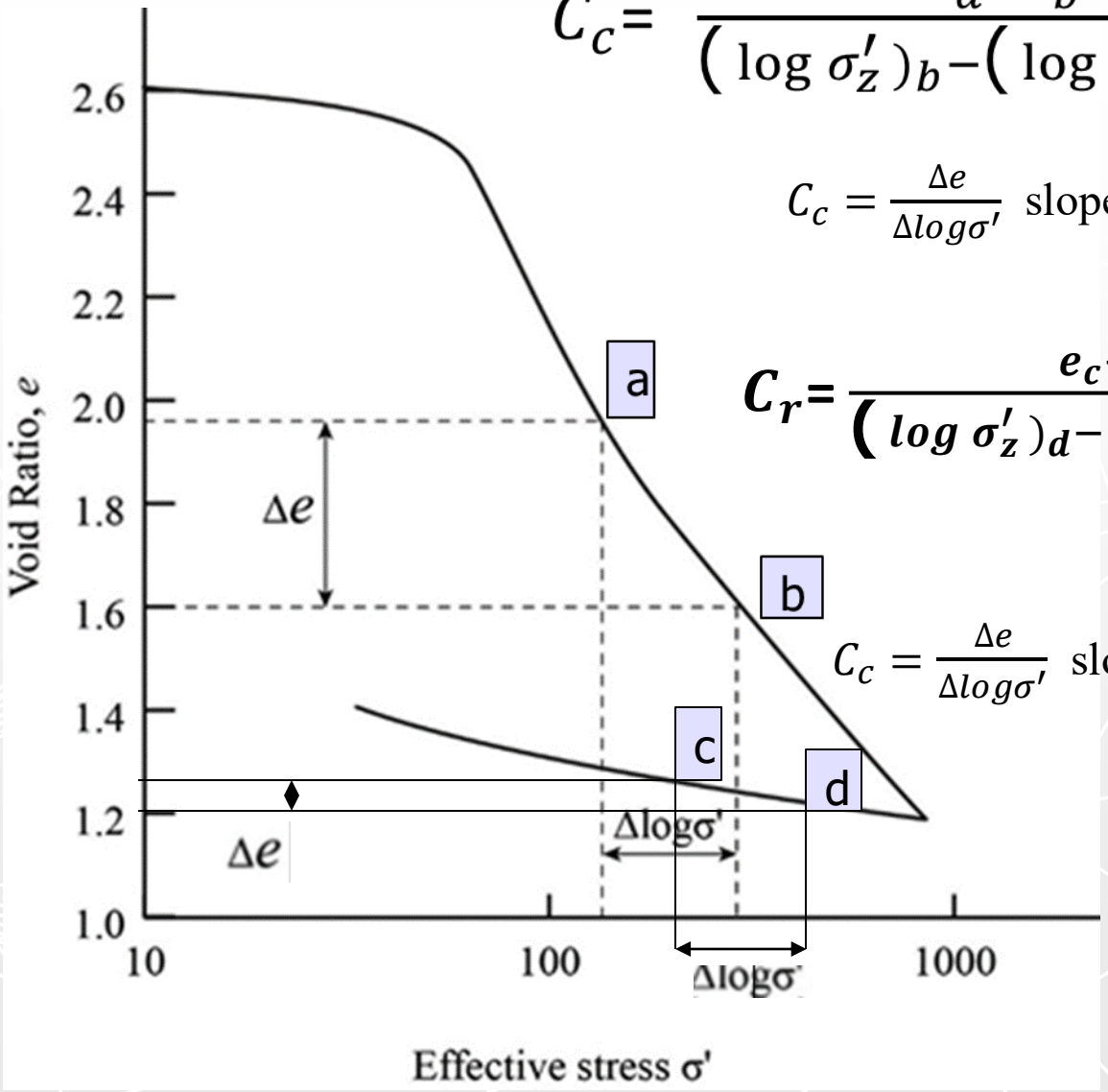
Pre-consolidation stress: σ'_z

Coefficient of consolidation C_v

$$C_c = \frac{e_a - e_b}{(\log \sigma'_z)_b - (\log \sigma'_z)_a}$$

$C_c = \frac{\Delta e}{\Delta log\sigma'}$ slope of virgin curve

$$C_r = \frac{e_c - e_d}{(log\ \sigma'_z)_d - (log\ \sigma'_z)_c}$$



$C_c = \frac{\Delta e}{\Delta log\sigma'}$ slope of virgin curve

N
NW
NE
E
S
SE

Soil	Compression index C_c
CL soft clay	0.34
CL hard clay	0.44
ML silt of low plasticity	0.16
CH clay of high plasticity	0.84
CH soft clay with silt layers	0.52

$$C_c = \frac{e_a - e_b}{(\log \sigma'_z)_b - (\log \sigma'_z)_a}$$

$$C_r = \frac{e_c - e_d}{(log\ \sigma'_z)_d - (log\ \sigma'_z)_c}$$

$$C_r \cong \frac{1}{5} \sim \frac{1}{10} C_c$$

Coefficient of consolidation (C_v):

- C_v **describes the rate** at which **saturated clay** or other soil **undergoes consolidation, when subjected to an increase in pressure.**

- C_v measures **1D consolidation**, or consolidation that occurs when soil experiences **no lateral strain.**

- Typical value, **stiff clay=0.002 in^2/min** and **fibrous peat soil is 0.1 in^2/min.**

- C_v **relates to how long,** it will take for an amount of consolidation to take.
- $\boldsymbol{C_v = \frac{T_v H^2}{t}}$, where

  $\boldsymbol{T_v}$**= time factor for 90%** consolidation at each increment= **0.848**

  $\boldsymbol{H}$**= maximum drainage path**

  =average drainage path, since the specimen is drained on both ends.

  $= \frac{H_{t_{av}}}{2}$

  t= **time for 90% consolidation at each** increment.

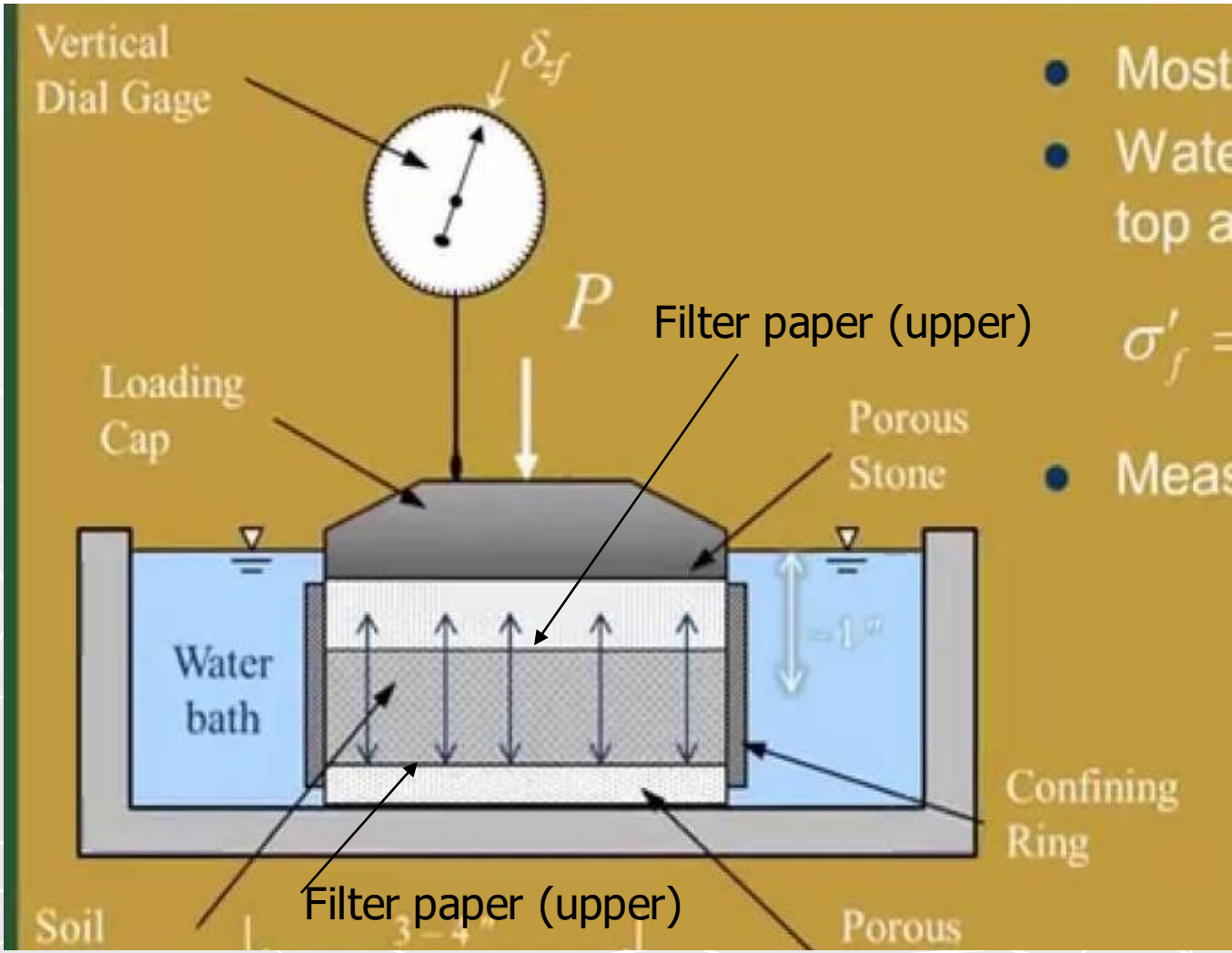
  t= $\boldsymbol{t_{90}}$

$$C_v = \frac{0.848 x H_{av}^2}{4 x t_{90}}$$

Equipment Used for the Test:

Equipment Used for the Test:

- Consolidometer and dial indicator.
- Loading frame (mechanically controlled)
- Timing device.



Loading Frame:






CONSOL
OEDOMETE

Apparatus:

1. Specimen Ring:

- Specimen is contained by a **relatively rigid ring**, thus compression and consolidation is ***one-dimensional***.

2. Porous Stones:

- There are ***porous stones*** **at the top and bottom** of the specimen so that **water can drain**, and thereby **dissipate** ***excess hydrostatic pressure.***

3. Filter Papers:

- **Filter papers** for preventing perculation soil particles with water.

4. Water bath:

- Specimen is surrounded by a **water bath** at all times to **prevent the specimen desiccating** (drying out).

6. Dial Indicator:

- **Dial indicator**, accurate to 0.0001inch or 0.025mm, **measures the change in height of specimen** after load has been applied.

7. **Load Multiplying System**:

- Because of **very large loads required** for typical consolidation tests, some type **load multiplying system** is commonly employed.

Main Components:

- Specimen ring
- Porous stones
- Filter papers
- Water bath
- Dial indicator



Procedures:

Following procedures need to be performed before the test:

Apparatus set up and ***specimen preparation***.

- **Specimen preparation** is an **extremely important** part of consolidation test.
- **Slight flows introduced in the specimen** during its preparation can severely affect the remainder of the test.
- Proper specimen preparation **takes much time** and usually **quite a bit of practice**.



(a) S1 (b) S2 (c) S3 (d) S4 (e) S6

Consolidation Test Calculation

General Information:

- Test No.
- Date Tested:
- Tested By:
- Project Name:
- Location:
- Sample Number:
- **Visual Classification**:
- Sample Depth:
- **Drainage Condition**: No impermeable layer (both sides drainage)

Consolidation Test
Calculation (cont..)

Ring Dimensions:

- **Diameter**: 2.5 inch
- **Area:** $\frac{\pi}{4} r^2$ = 4.91 sq. inch
- **Height**: 0.78 inch

Initial Data:

- **Specimen Height**: 0.78 inch
- **Specific Gravity of Soils, G_s**: 2.65

Consolidation Test
Calculation (cont..)

Initial Specimen Data:

- Mass of Specimen Ring:
- Mass of Paper:
- Ring + Paper + Wt. of Soils:
- Mass of Wt. of Soils:
- Initial Water Content, w%:
- Mass of Dry Soils (m_s) from Initial Water Content, w%:

$$m_s = \frac{W_{wei\,soil}}{1+w}$$

Consolidation Test
Calculation (cont..)

Final Water Content Determination:

- Mass of Dish:
- Mass of Ring + Dish+ Wet Soils:
- Mass of Ring + Dish + Dry Soils:
- Mass of Dry Soils:
- Mass of Water in Soils:
- Final Water Content, w_f %:

Consolidation Test Calculation

Soil Specimen:

- **Ring dimensions**: d=2.5 inch, h=0.78 inch

  $A=\frac{\pi}{4}d^2=\frac{\pi}{4}2.5^2=4.91$ sq inch

- **Initial ht. of specimen** = 0.78 inch

- $\boldsymbol{G_s}$ = 2.65

Initial water content:

- w_i= 24.65%

Final Water Content:

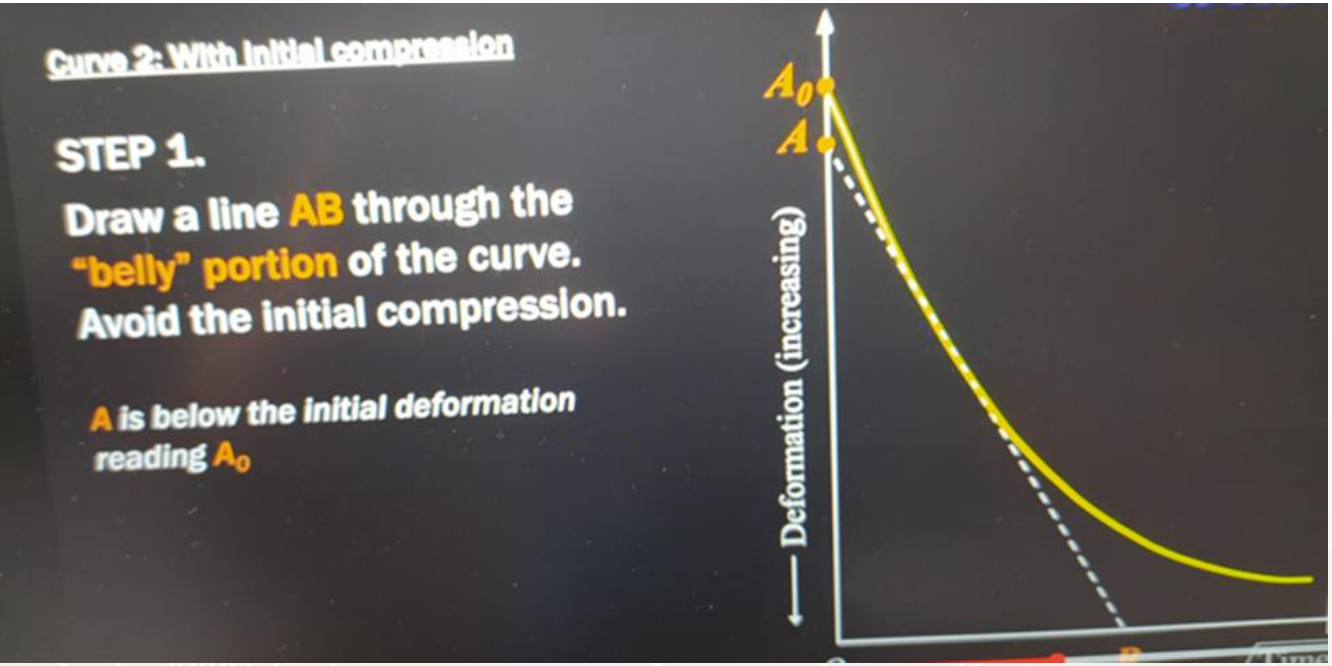
- **Mass of dry soil =** 110.6 gm
- Mass of water = 22.8 gm
- w_f= 11.32%

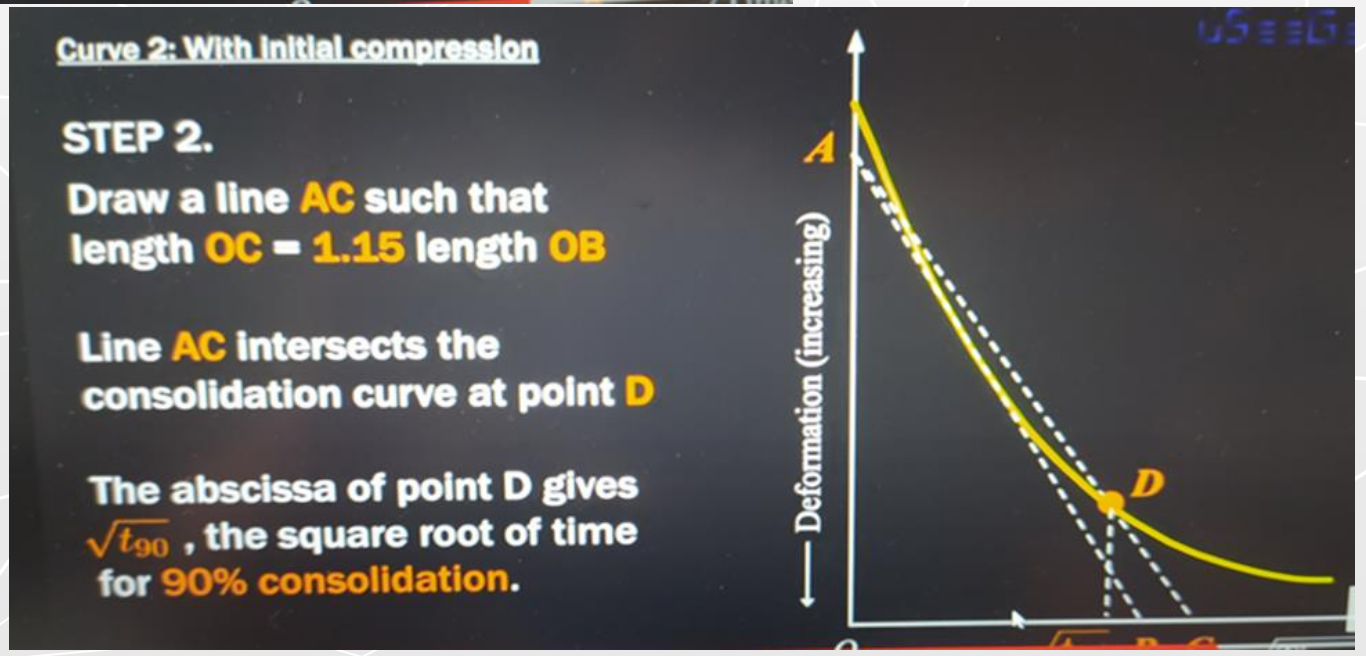
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Plot **Deformation vs.** $\sqrt{t}$ $\left(\sqrt{time}\right)$

- **To determine** $\sqrt{t}_{90}$
- **To determine** c_v

Determine $\sqrt{t_{90}}$:

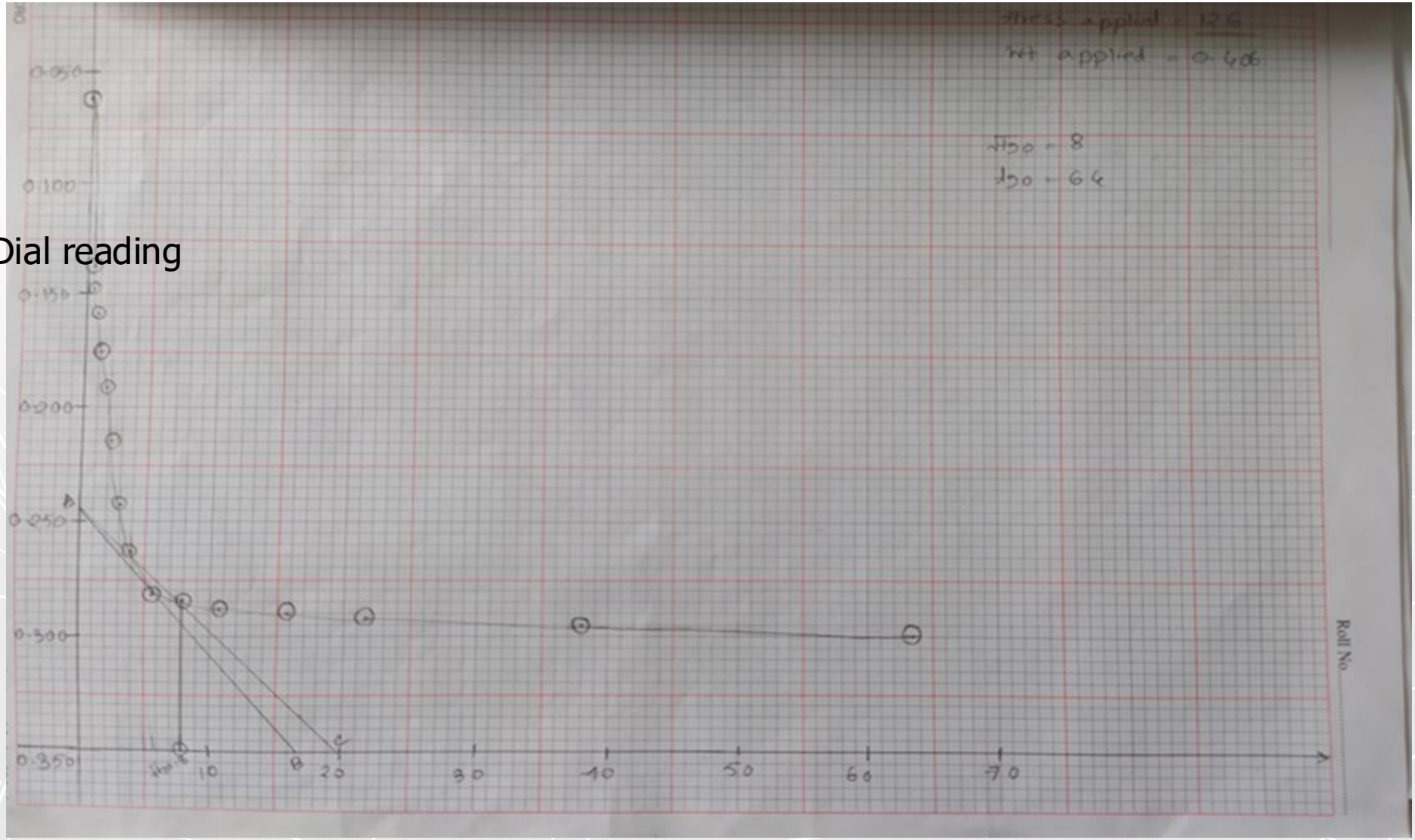




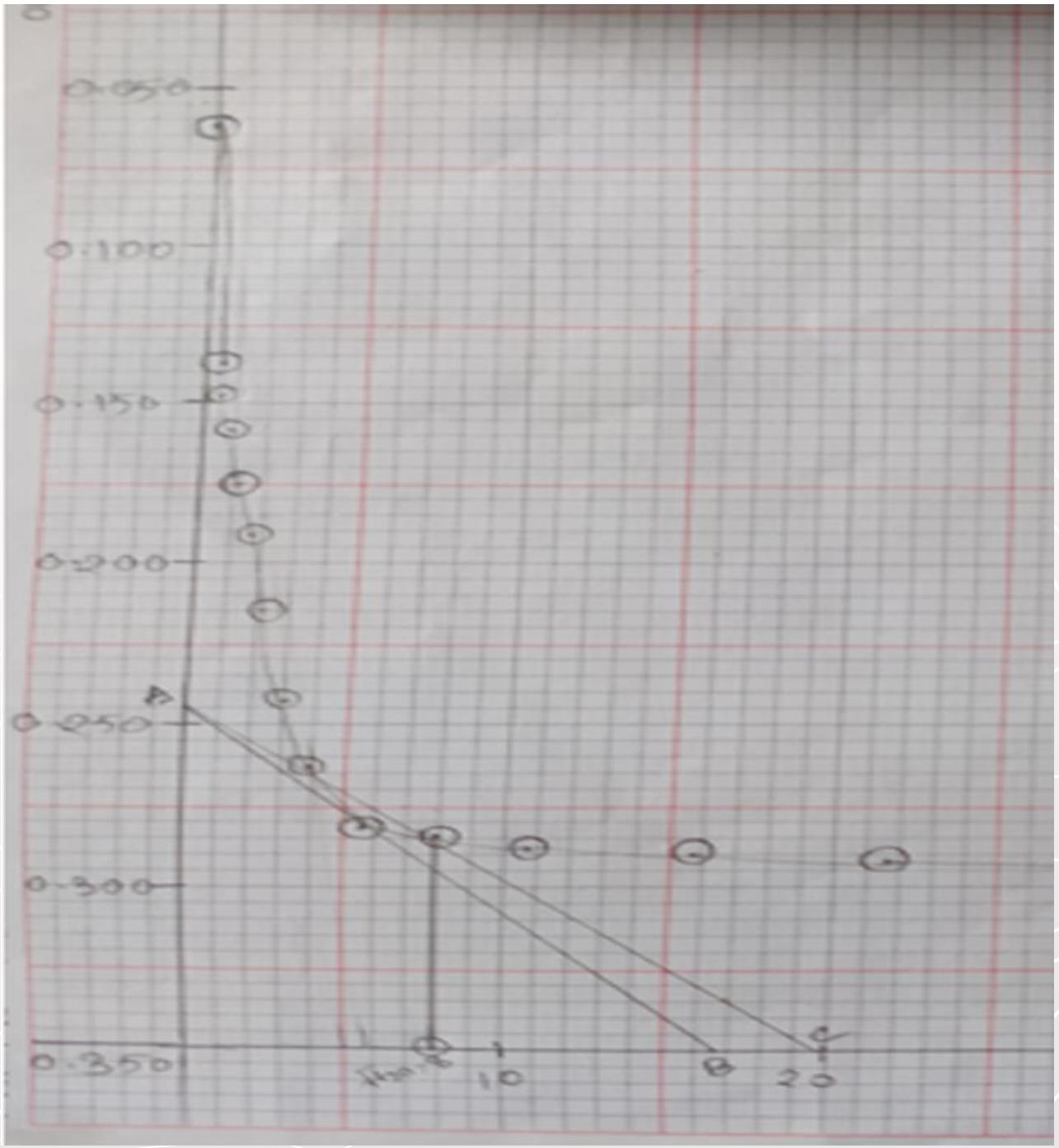
Loading Stage -0

Target Pressure (kPa)	12.607 kPa
Actual Applied Load (Kg)	*0.407*

Date	Time	Elapsed Time (min)	Square Root of Time ($\sqrt{min}$)	Dial Reading x 10^{-4} (inch)
29.01.21	0800	0	0	0
	0800	0.1	**0.316**	**0.139**
	0800	0.25	0.5	0.147
	0800	0.5	0.707	0.160
	0801	1	1	0.174
	0802	2	1.414	0.193
	0804	4	2	0.215
	0808	8	2.828	0.242
	0815	15	3.873	0.264
	0830	30	5.477	0.282
	0900	60	7.746	0.284
	1000	120	10.954	0.286
	1200	240	15.492	0.288
	1600	480	**21.908**	**0.291**
30.01.21	0800	1440	37.947	-


Dial reading
Square root of time in min

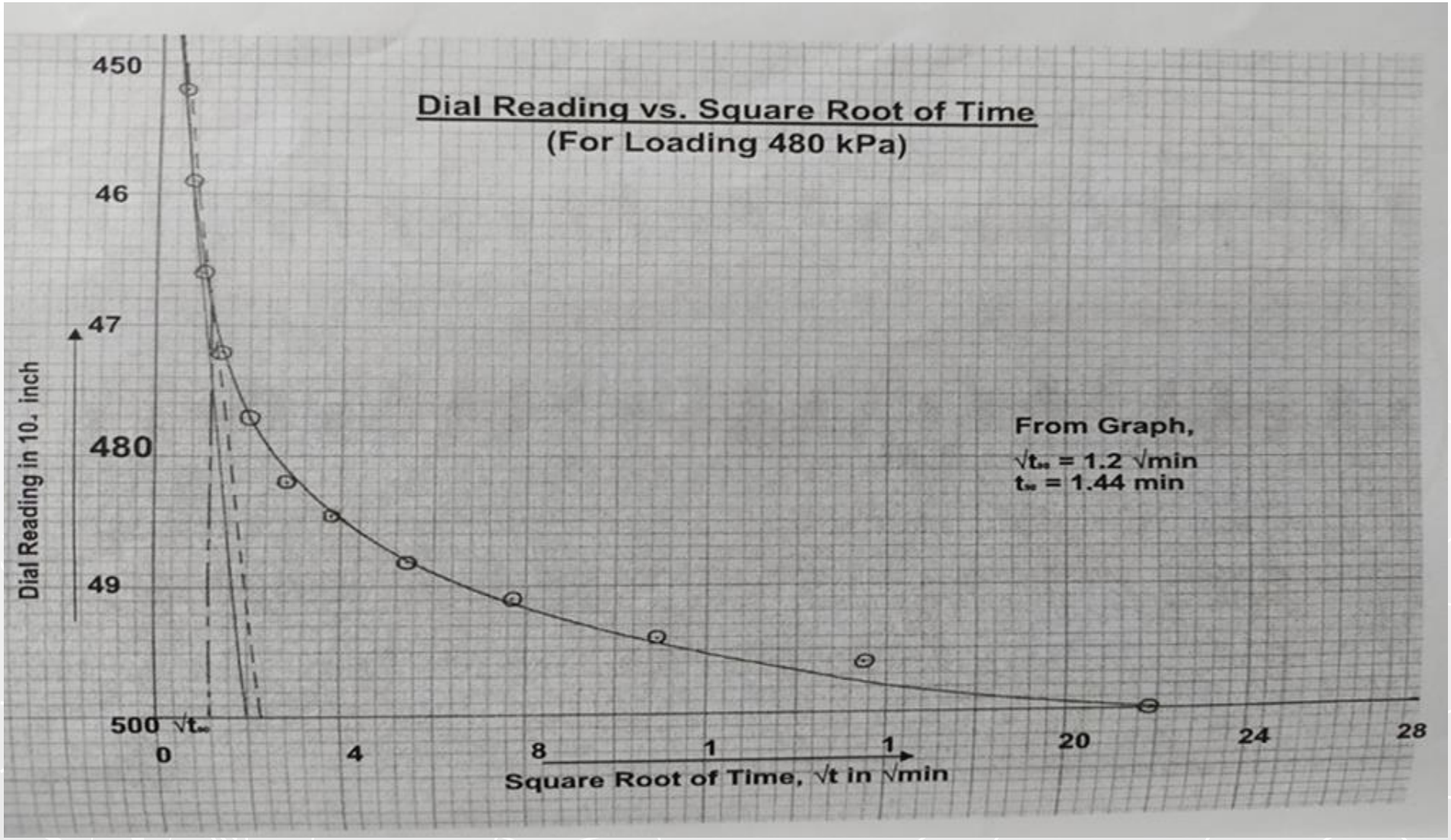
Square Root of Time ($\sqrt{min}$)	Dial Reading x 10^{-4} (inch)
0	0
0.316	**0.139**
0.5	0.147
0.707	0.160
1	0.174
1.414	0.193
2	0.215
2.828	0.242
3.873	0.264
5.477	0.282
7.746	0.284
10.954	0.286
15.492	0.288
21.908	0.291
37.947	-


0·050
0·100
0·150
0·200
0·250
0·300
0·350
A
B
C
10
20

- OB= 16.5 inch
- OC=1.15xOB = 1.15 x 16.5= 18.98 inch
- $\sqrt{\boldsymbol{t_{90}}}$= 8 min
- $\boldsymbol{t_{90}}$ = 64 min
- $\boldsymbol{c_v} = \frac{T_v H_{av}^2}{4x\boldsymbol{t_{90}}} = \frac{0.848xH_{av}^2}{4x\boldsymbol{t_{90}}}$

Loading Increment Data (Demo for calculation)

Target Pressure (kPa)				**480 kPa**
Actual Applied Load				16 Kg
Date	Time	Elapsed Time (min)	Square Root of Time ($\sqrt{min}$)	Dial Reading x 10^{-4} (inch)
03.02.21	0800	0	0	**318.5**
	0800	0.1	0.316	440
	0800	0.25	0.5	452
	0800	0.5	0.707	459
	0801	1	1	466
	0802	2	1.414	472
	0804	4	2	477
	0808	8	2.828	482
	0815	15	3.872	484.8
	0830	30	5.477	488.1
	0900	60	7.746	491
	1000	120	10.954	494


Dial Reading vs. Square Root of Time
(For Loading 480 kPa)
450
46
47
480
49
Dial Reading in 10⁻ inch
From Graph,
√t₉₀ = 1.2 √min
t₉₀ = 1.44 min
500 √t₉₀
0
4
8
1
1
20
24
28
Square Root of Time, √t in √min

Loading Increment Data (Demo for Calculation)

Target Pressure (kPa)	960 kPa
Actual Applied Load	32 Kg

Date	Time	Elapsed Time (min)	Square Root of Time ($\sqrt{min}$)	Dial Reading x 10^{-4} (inch)
04.02.21	0800	0	0	**503**
	0800	0.1	0.316	662
	0800	0.25	0.5	674
	0800	0.5	0.707	687
	0801	1	1	695
	0802	2	1.414	702
	0804	4	2	709
	0808	8	2.828	713
	0815	15	3.873	717
	0830	30	5.477	720
	0900	60	7.746	724
	1000	120	10.954	726

Cal of c_v for all the load increment:

Calculation of C_v for All Load Increment

pplied essure, kPa)	Final dial reading (inch)	Change in specimen height (inch	Final Specimen height (inch)	Void height H_v=0.78-H_s	Void ratio e=$\frac{H_v}{H_s}$	Average height during consolidation (inch)	Fitting time t_{90}	Coef consc C_v (
0	0.0	0.0	**0.78**	**0.26** (0.78-0.52)	**0.5** (0.26/0.52)	-	-	-
5								
)								
)								
20								
40 240			**0.7482**					
0 480	**0.0503**	**0.01845**	**0.72975**	**0.20975**	**0.4033**	**0.7390**	**1.44**	**0.020 0.0201**
0								
0								

Cal of c_v for all the load increment:

Applied P (kPa)	Final Dial (inch)	Change in Specimen ht (inch)	Final Specimen ht (inch)	Void ht (H_v) inch	Void Ratio (e)	Ave ht during Consolidation (inch)	Fitting Time (t_{90}) (min)	(C_v) ($inch^2/min$)
0	0	0	0.78	0.26	0.5	-	-	-
15	0.00133	0.00133(-)	0.7787	0.2587	0.498	0.7794	0.203	0.1586
30	0.00470	0.00337(-)	0.7753	0.2553	0.491	0.7770	1.103	0.0290
240			**0.7482**					
480	0.0503	0.01845	0.72975	0.20975	0.4033	0.7390	1.44	0.0201

Load Increment Data:

Target pressure: 15 kPa

Actual Applied Pressure: 500 gm

Elapsed Time	Dial Reading x 10^{-4}
0 (29 Jan)	**0**
0.1	**8**
0.25	**8.25**
0.5	**8.5**
1	**8.8**
2	**9.5**
4	11
8	12.25
15	12.5
30	12.8
60	12.9
120	12.95
240	13.0
480	13.25
1440 (30 Jan)	**13.25**

Load Increment Data:

Target pressure: 30 kPa

Actual Applied Pressure: 1000 gm (1 Kg)

Elapsed Time	Dial Reading x 10^{-4}
0 (30 Jan)	**13.25**
0.1	**43.5**
0.25	**43.75**
0.5	**44**
1	**44**
2	**44.75**
4	44.75
8	45
15	45.25
30	44.5
60	45.75
120	45.75
240	45.75
480	45.75
1440 (31 Jan)	**47.00**

Cal of c_v for all the load increment:

Cal of c_v for all the load increment:

Applied pressure Pressure=0

Final specimen height=**0.78** inch (original height)

Height of solid, H_s=0.52 inch

Void Height, H_v= 0.78 – 0.52= **0.26** inch

Void ration e=Initial void ration, e_0= H_v/H_s=**0.5**

Cal of c_v for all the load increment (0):

- **Ht. of Solids:** $H_s = \frac{m_s}{G_s \rho_w A_r}$
- m_s=mass of solid (dry mass of specimen)=110.6 gm

  G_s=Specific Gravity of soils=2.65 (given)

  ρ_w= Density of water= 1gm/cc = 16.38 gm/cubic inch

  A_r=Cross sectional area of ring= 4.91 sq. inch

$$H_s = \frac{110.6}{2.65x16.38x4.91} = 0.5189 = \textbf{0.52 inch}$$

Initial Void Ht. $H_{vo} = H_0 - H_s = 0.78 - 0.52 =$ **0.26 inch**

Initial Void Ratio, $e_0 = \frac{H_{vo}}{H_s} = \frac{0.26}{0.52} =$ **0.5**

Cal of c_v for all the load increment (15 kPa):

H_s=**0.52 inch**

Final Dial Reading (from load increment data) after 1440 min = 13.25 x10^{-4} inch = 0.001325 =**0.00133** inch

Change in specimen height = 0-0.00133= (-) 0.00133 inch

Final Specimen Height =0.78 –0.00133=0.77867=**0.7787** inch

Void Ht. H_v= 0.52 – 0.7787= **0.2587 inch**

Void Ratio, $e = \frac{H_v}{H_s} = \frac{0.2587}{0.52} = 0.4975$=**0.498**

Ave ht. during consolidation= $\frac{0.78+0.7787}{2}$**= 0.77935**

= 0.7794 inch

Coefficient of Consolidation, $C_v = \frac{0.848\,H_{av}^2}{4xt_{90}} = \frac{0.848\,x(\frac{07794}{2})^2}{4x0.203} = 0.15859$

$=0.1586\ inch^2/\text{min}$

Cal of c_v for all the load increment:

Sample calculation (For Applied Pressure 480 kPa)

H_s= Height of Solids,

$$H_s = \frac{m_s}{G_s \rho_w A_r}$$

Where, m_s=mass of dry soil=110.6gm

G_s= Specific Gravity of Soil=2.65

ρ_w=density of water=1 gm/cm^3

A_r= x-sectional area of the ring= 4.91 sq inch

$$H_s = \frac{110.6\ gm}{2.65\ [1x\ gm/cm^3]4.91\ inch^2}$$

$$= \frac{110.6\ gm}{2.65\ [16.38x\ gm/inch^3]4.91\ inch^2} = \mathbf{0.52\ inch}$$

H_0=Initial Height of the Specimen=0.78 inch

H_{v0}= Initial void height

= H_0- H_s=0.78- 0.52 =0.26 inch

Final dial reading (960 kPa, at start) = 0.00503 inch
Initial reading (480 kPa) =0.03185 inch

Change in Specimen height

H_I= 0.05030-0.03185=0.01845 inch

H_0= Final specimen height (from 240kPa) =0.7842 inch

Final Specimen height $H_{f.I}$= H_0 - H_I

=0.7842 – 0.01845=0.72975 inch

Height of voids $H_v = H_{f.I} - H_s = 0.72975 - 0.52$

$= \mathbf{0.20975}$ inch.

Void ratio, $e = \frac{H_v}{H_s} = \frac{0.20975}{0.52} = 0.4033$

Average height during consolidation,

H_{av} = Final specimen height of present applied pressure+ Previous specimen height of previous applied pressure= (0.72975+ 0.7482)/2=0.738975= 0.7390 inch.

For both side drainage condition,

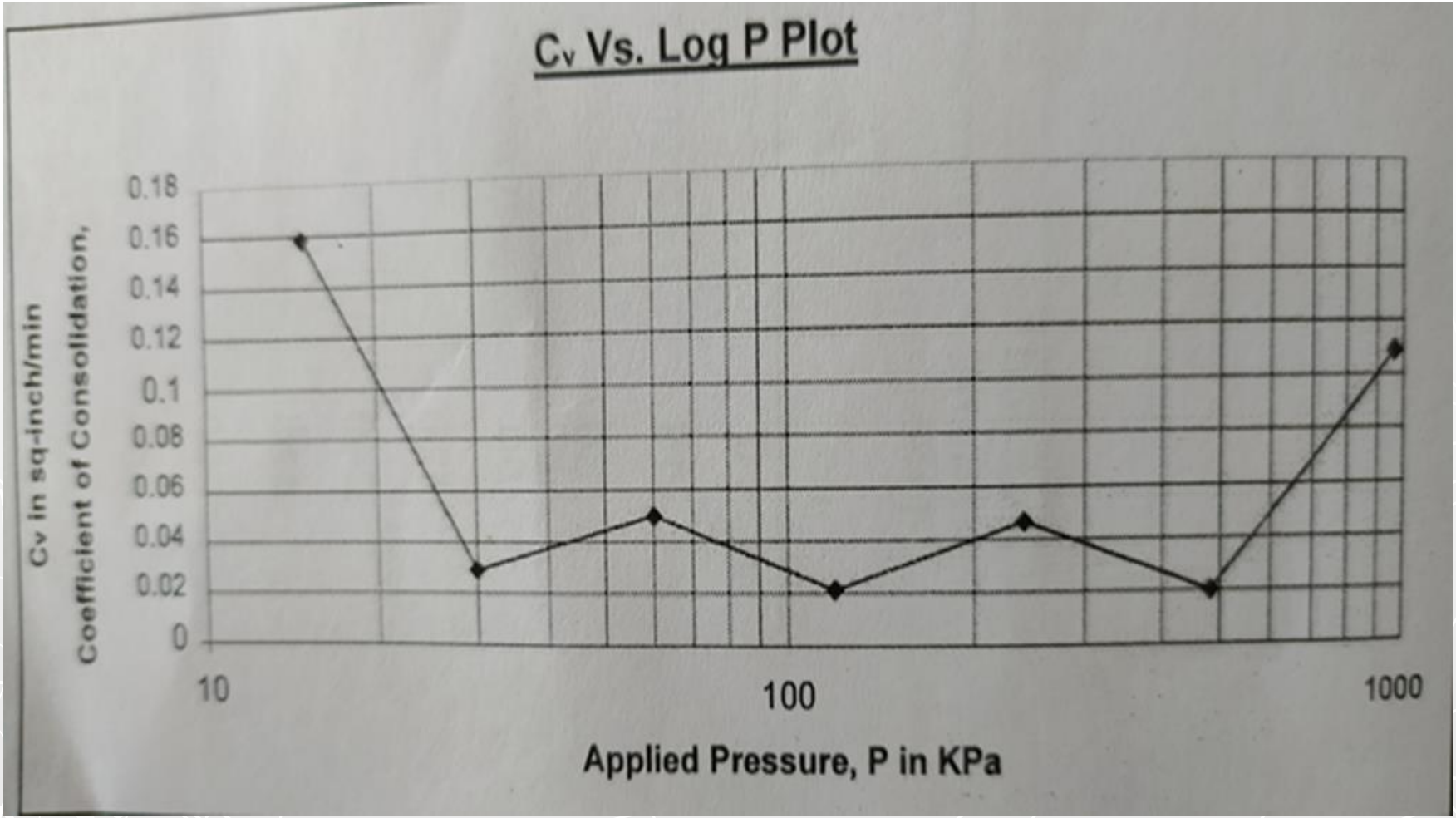
$$C_v = \frac{T_v(H_{av})^2}{4x\ t_{90}}$$

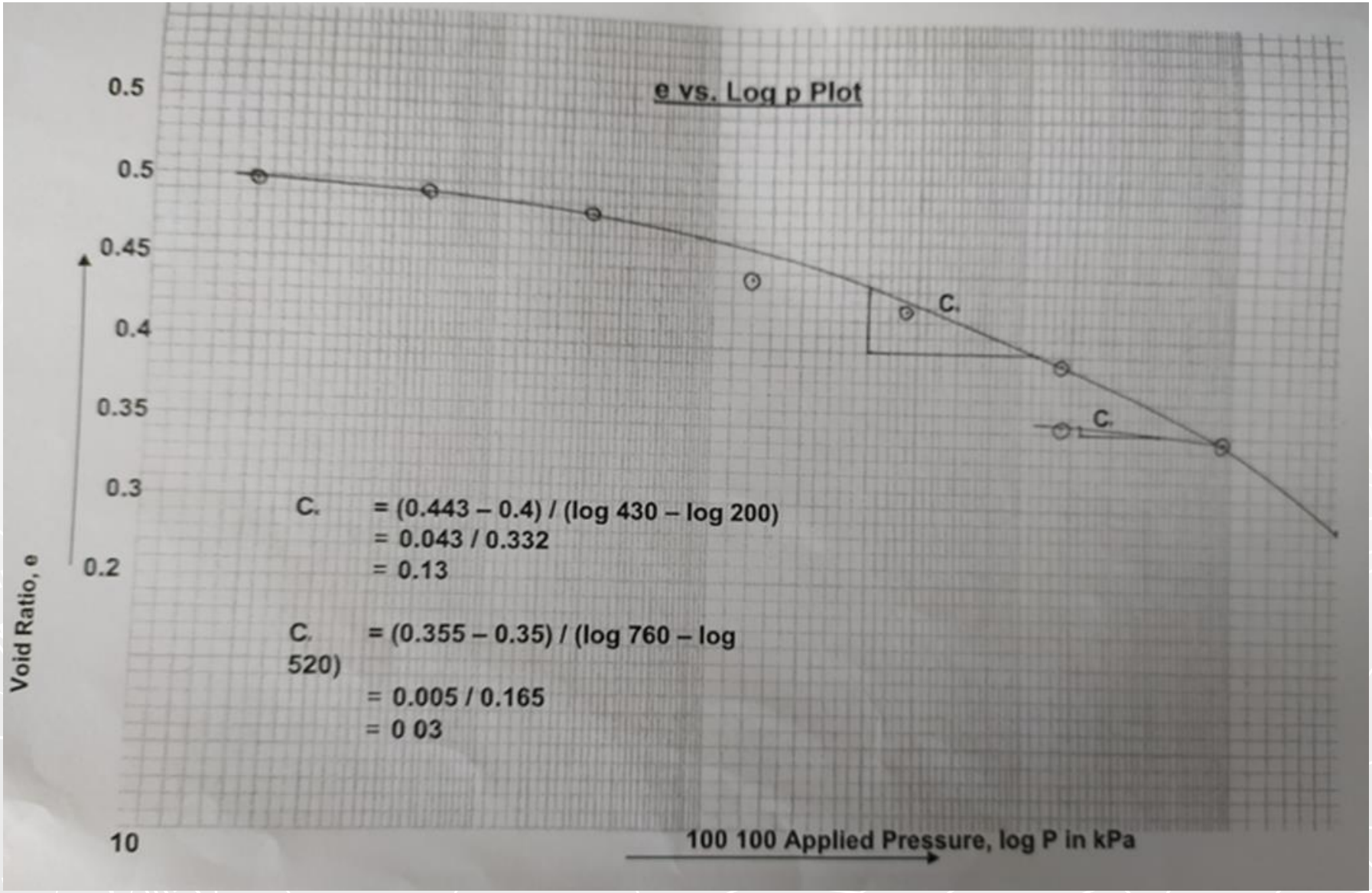
T_v for 90% consolidation = 0.848

H_{av} = **0.7390** inch

t_{90} = 1.44 min

$$C_v = \frac{0.848x\ (0.739/2)^2}{4x\ 1.44} = 0.0201 \text{ inch}^2/\text{min}$$


Cv Vs. Log P Plot
Cv in sq-inch/min
Coefficient of Consolidation,
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
10
100
1000
Applied Pressure, P in KPa


e vs. Log p Plot
0.5
0.5
0.45
0.4
0.35
0.3
0.2
Void Ratio, e
C.
C.
C. = (0.443 – 0.4) / (log 430 – log 200)
= 0.043 / 0.332
= 0.13
C. = (0.355 – 0.35) / (log 760 – log 520)
= 0.005 / 0.165
= 0 03
10
100 100 Applied Pressure, log P in kPa

Name of the Experiment: Consolidation Test

Objective of the Test:

i. To determine the coefficient of consolidation (c_v).

c_v –indicates the rate of compression for each load increment.

Thanks

ii. To determine the Compression Index (c_c).

c_c – indicates the compressibility of NC soils.

iii. To determine re-compression Index (c_r).

c_r - **indicates the compressibility of OC soils.**

iv. Pre-consolidation stress ($\sigma_c^{'}$) of soil sample from e log p graph.

$\sigma_c^{'}$ -

Significance:

Apparatus:

i. Consolidation Device
ii. Sample Extruder
iii. Sample trimming device
iv. Moisture can etc.

Plots/Graphs: As required

- As per number of loading and unloading stage- **Dial reading vs. $\sqrt{t_{90}}$,**
- **1x C_v vs. log $\sigma_z^{'}$**
- **1x e vs. log $\sigma_z^{'}$**

Table: As required

- **Data Sheet** – No. of Table will be as per the loading stage.
- **1x Calculation of C_v**

Results: C_c, C_r, $\sigma_c^{'}$

Discussion:

Thanks