CE 402:Geotechnical Engineering Lab

PROBLEM SOIL TESTING

What is problem soil?

- Problems from **engineering point** of view
- When problem soil form part of **embankment, superstructure** etc. influences the performances of structure (**stability** of embankment, **bearing capacity** and long term **settlements**)

Organic soil

Black cotton soil

Laterite soil

Liquefiable soil

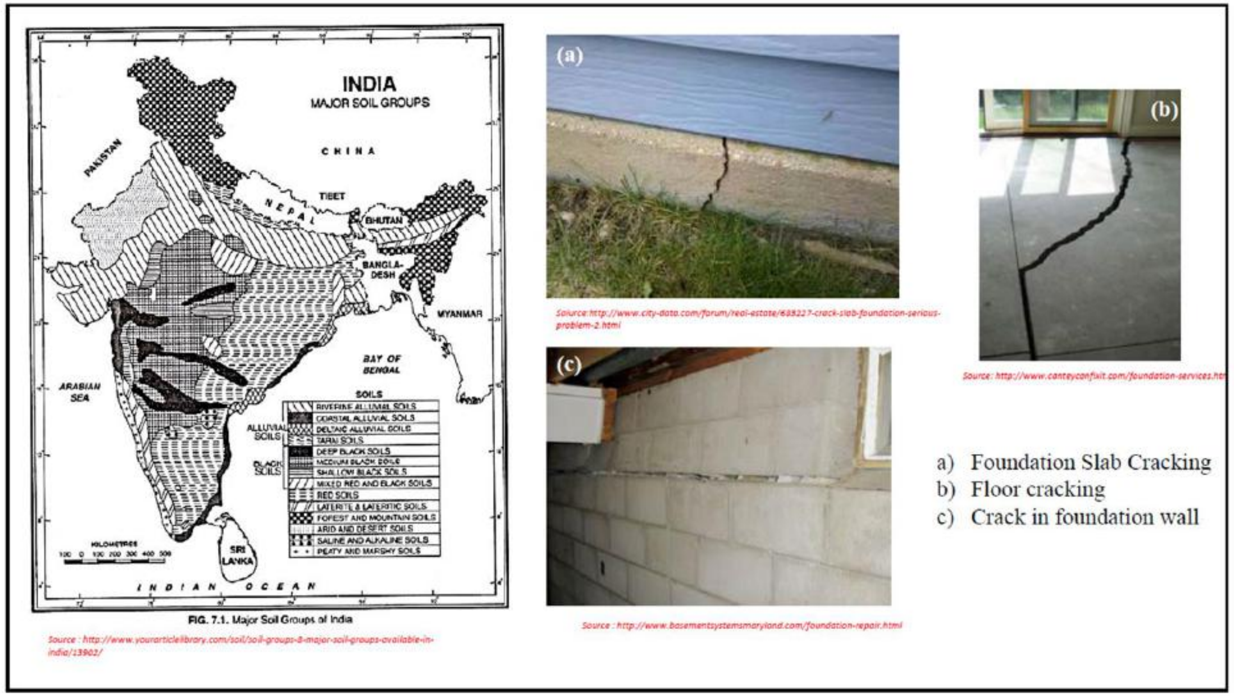
Marine deposits

Problem soil testing

- **Organic soil**: **Furnace test**
- **Expansive soil**: **DFSI** (differential free swell index), Swell pressure test (will be taught while performing oedometer test)
- **Dispersive soil**: **Crumb test**, Pin hole test, Double hydrometer test
- **Liquefiable soil**: Dynamic triaxial test (Analysis will be covered in tutorial portion)
- **Soft soil**: Compressibility (while performing oedometer test), Shear strength (Vane shear test)

Problem soil	Issues
Organic soil	High settlement
Expansive soil	• Swelling, shrinkage and desiccation cracking • Differential settlement
Laterite soil (known as red soil/yellow soil)	Dispersive in nature (only when wet)
Liquifiable soil	Zero shear strength and large deformations
Marine deposits/soft soil	• Low shear strength • High compressibility

Consequences of problem soil

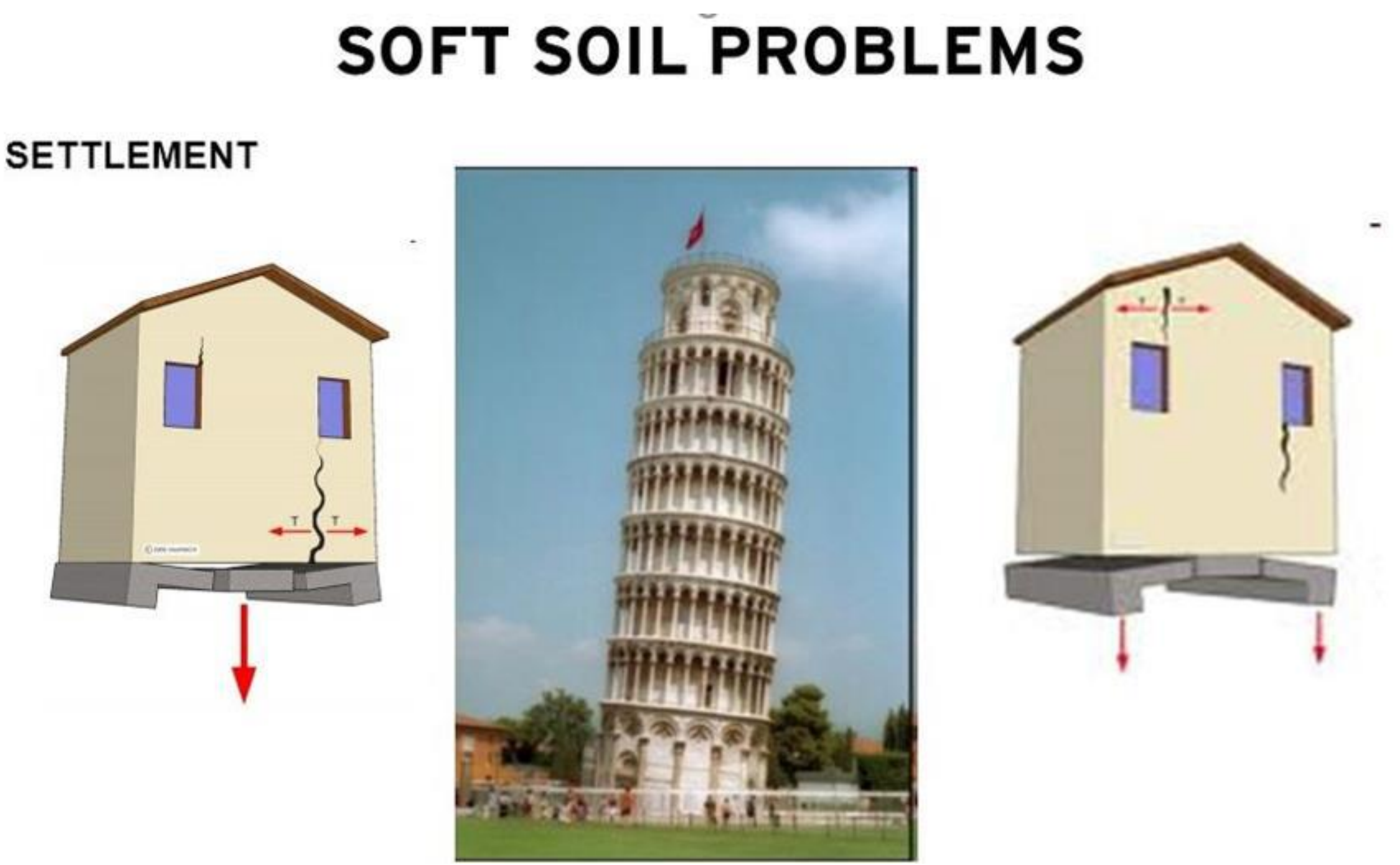


Raincuts due to erosion

Slope Failure

Source: https://cdn.iopscience.com/images/books/978-1-64327-078-4/live/bk978-1-64327-078-4ch10f1_online.jpg

Source: https://static.temblor.net/wp-content/uploads/2015/11/liquefaction-1024x597.jpg



Source: https://slideplayer.com/slide/3961117/12/images/5/SOFT+SOIL+PROBLEMS+SETTLEMENT+Bina+Nusantara.jpg

Not a problem soil?

Source: https://www.terre-armee.com/wp-content/uploads/sites/2/2020/01/M1-7-1.jpeg

Recommended: Cohesionless soil

If used locally available soil, problem of drainage

Poor design problem

Source: Meshida, 2006

Problems of micaceous soil:

Pot hole formation, rutting, peeling of asphalt layers, differential settlement

Problem for railway and highway embankment not for building

Dispersive soil

Methods to determine dispersiveness of soil

Test Name	ASTM Code	Remarks
Crumb Test	ASTM-6572-13	Qualitative
Pinhole Test	ASTM-D4647-93	Qualitative
Double Hydrometer Test	ASTM-D4221	Quantitative

Crumb test

(ASTM-6572-13)

- A cubical specimen of size 15 mm at in-situ density and in-situ water content is prepared to perform the crumb test.
- The specimen is carefully placed in 250 ml of distilled water.
- As the soil specimen begins to hydrate colloidal-sized particles tends to go into suspension.
- Turbidity of water is observed at timed intervals (2 min, 1 hour, 6 hours).
- According to turbidity of water, dispersiveness of soil is classified as follows:
  - **Grade-1 (Non Dispersive)**
  - **Grade-2 (Intermediate)**
  - **Grade-3 (Dispersive)**
  - **Grade-4 (Highly Dispersive)**

Dispersiveness of soil is classified in to different grades as follows (as per ASTM D6572-13):

11.9.1 *Grade 1 (Non-dispersive)*—No reaction; the soil may crumble, slake, diffuse, and spread out, but there is no turbid water created by colloids suspended in the water. All particles settle during the first hour.

11.9.2 *Grade 2 (Intermediate)*—Slight reaction; Grade 2 is the transition grade. A faint, barely visible colloidal suspension causes turbid water near portions of the soil crumb surface. If the cloud is easily visible, assign Grade 3. If the cloud is faintly seen in only one small area, assign Grade 1.

11.9.3 *Grade 3 (Dispersive)*—Moderate reaction; an easily visible cloud of suspended clay colloids is seen around the outside of the soil crumb surface. The cloud may extend up to 10 mm away from the soil crumb mass along the bottom of the dish.

11.9.4 *Grade 4 (Highly Dispersive)*—Strong reaction; a dense, profuse cloud of suspended clay colloids is seen around the entire bottom of the dish. Occasionally, the soil crumb dispersion is so extensive that it is difficult to determine the interface of the original soil crumb and the colloidal suspension. Often, the colloidal suspension is easily visible on the sides of the dish.

11.10 If a permanent record is desired, photograph the test specimen after the 6 hours ± 45 min reading.

12. Interpretation of Results

12.1 Use the following criteria to classify crumb test results:

12.1.1 *Grade 1*—Nondispersive.

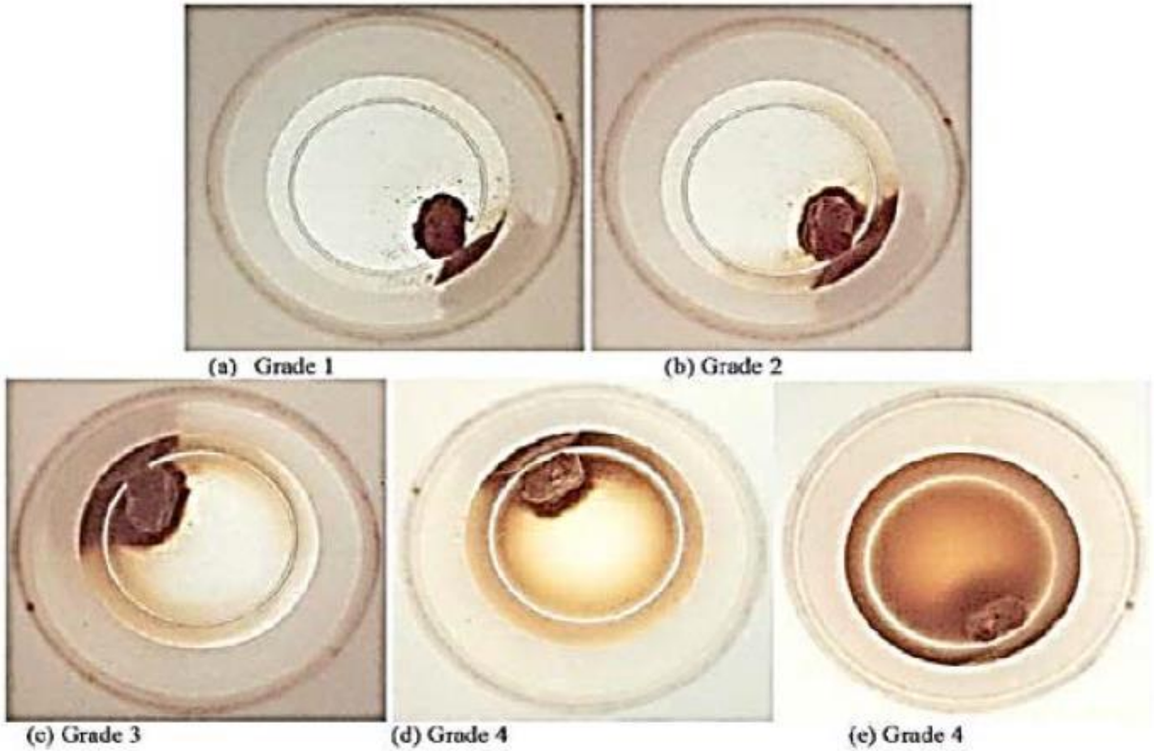
12.1.2 *Grade 2*—Intermediate.

12.1.3 *Grade 3*—Dispersive.

12.1.4 *Grade 4*—Highly Dispersive.

12.2 If the dispersive grade changed during the test, the 1 hour ± 8 min reading is normally used for the overall test evaluation. However, if the grade changes from 2 to 3 or from 3 to 4 between the 1 hour ± 8 min and 6 hours ± 45 min readings, use the 6 hours ± 45 min reading.

Deflocculation of colloidal particles with time



Soil crumb specimens and assigned dispersion grades (ASTM 6572-13)

Mould to make 15 mm cubical specimen for crumb test

Results from Crumb Test:

An example datasheet

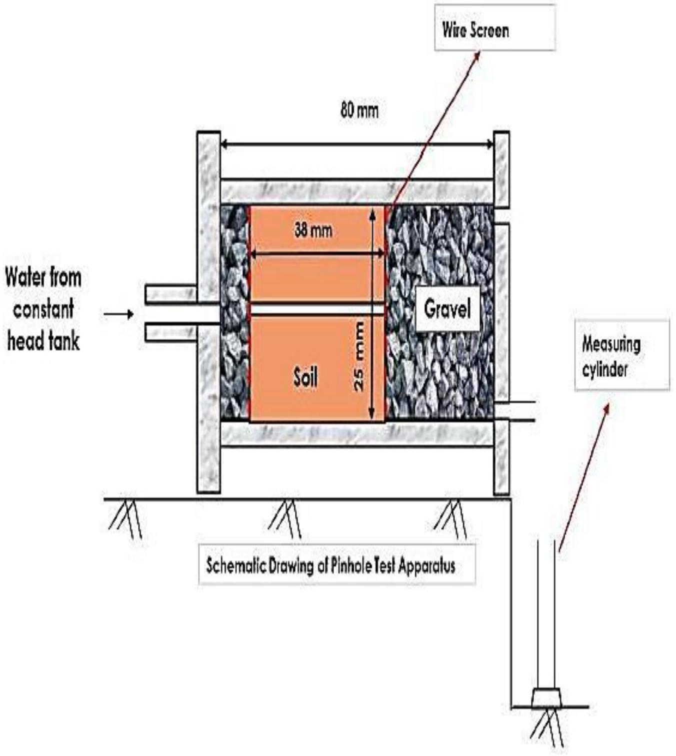
Start Time (hh:mm:ss): 10:30:00 AM				Start Time (hh:mm:ss): 10:35:00 AM				Start Time (hh:mm:ss): 10:40:00 AM			
Target Reading	Time Taken	Grade	Temp. (°C)	Target Reading	Time Taken	Grade	Temp. (°C)	Target Reading	Time Taken	Grade	Temp. (°C)
2 min ± 15 s	10:32:00	2	23.2	2 min ± 15 s	10:37:00	3	22.8	2 min ± 15 s	10:40:00	2	23.3
1 h ± 8 min	11:31 AM	2	22.9	1 h ± 8 min	11:33 AM	4	22.7	1 h ± 8 min	11:42 AM	3	23.0
6 h ± 45 min	4:15 PM	3	21.6	6 h ± 45 min	4:20 PM	4	22.5	6 h ± 45 min	4:25 PM	3	22.9
Dispersive Classification:	Dispersive			Dispersive Classification:	Highly dispersive			Dispersive Classification:	Dispersive		

Sample details:				Sample details:				Sample details:			
Start Time (hh:mm:ss):				Start Time (hh:mm:ss):				Start Time (hh:mm:ss):			
Target Reading	Time Taken	Grade	Temp. (°C)	Target Reading	Time Taken	Grade	Temp. (°C)	Target Reading	Time Taken	Grade	Temp. (°C)
2 min ± 15 s				2 min ± 15 s				2 min ± 15 s			
1 h ± 8 min				1 h ± 8 min				1 h ± 8 min			
6 h ± 45 min				6 h ± 45 min				6 h ± 45 min			
Dispersive Classification:				Dispersive Classification:				Dispersive Classification:			

Pinhole Test

(ASTM-D4647-93)

Schematic representation of pinhole test apparatus



- The prepared soil specimen is punched with a needle to make a **small hole of diameter 1 mm**.

- Water flows through the small hole in the specimen under hydraulic pressure head of 50 mm and the discharge through the specimen is observed to judge the dispersibility of the soil specimen.

- **Dispersive clays - distinctly dark flow** and the hole through the specimen enlarges rapidly with a resultant increase in the flow rate.

- **Slightly to moderately dispersive clays - slightly dark** with a constant hole size

- **Non-dispersive clays - completely clear** with no measurable increase in the hole size.

Double hydrometer test

(ASTM: D4221)

Two hydrometer tests are performed:

1. With using dispersing agent solution in hydrometer
2. Without using dispersing agent solution in hydrometer

$$\textbf{Percentage dispersion} = \frac{\%\ \textit{clay without dispersing agent}}{\%\ \textit{clay with dispersing agent}} * 100$$

Dispersive classification according to percent dispersion			
ASTM D 4221		*Sherard and Decker (1977)*	
% Dispersion	**Dispersive Classification**	**% Dispersion**	**Dispersive Classification**
< 30	Non Dispersive	< 35	No Dispersivity Problem
30 – 50	Intermediate	35 – 50	Probable Dispersivity
> 50	Dispersive	> 50	Problem of Dispersivity

DFSI test

Differential free swell index

(IS : 2720 (Part XL) – 1977, Reaffirmed 1997)

- **Objective :** Primary investigation to determine the swelling potential of the soil

- **Need and Scope:**

✓ To identify the **expansive nature** of the soil.

✓ Expansive soils are one of the problematic soils found in **arid and semi-arid** regions of the world.

✓ Black cotton soils found in India cover almost 20% of the total area.

✓ Expansive soils have tendency to **expand or swell** (increase in volume) in presence of water and shrink (decrease in volume) in dry conditions. This results in excessive differential settlement due to repetitive cycles of swelling and shrinkage resulting in significant damage to the foundation and super structure.

Procedure (IS : 2720 (Part XL) – 1977, Reaffirmed 1997)

1. Take three specimen of **10 g** of oven dried soil passing through **425-micron** IS Sieve.

2. Pour each soil specimen into a graduated glass cylinders of 100 ml capacity.

3. One cylinder shall then be filled with **kerosene** oil and the other two cylinders with **distilled** water up to the 100 ml .

4. Remove **entrapped air** by stirring with the glass rod. Allow the soils in all three cylinders allowed to settle.

5. Sufficient time (**not less than 24 h**) shall be allowed for the soil sample to attain equilibrium state of volume without any further change in the volume of the soils.

6. The **final volume** of soils in each of the cylinders shall be read out.

NOTE- In the case of highly swelling soils, such as sodium bentonites, the sample size may be 5 g or alternatively a cylinder of 250 ml capacity may be used.

Calculations

Differential free swell index (%) = ((V_d –V_k)/V_k) *100

where,

V_d= Volume of soil specimen read from the graduated cylinder containing **distilled water**

V_k = Volume of soil specimen read from the graduated cylinder containing **kerosene**

Degree of expansiveness	**DFSI (%)**
Low	Less Than 20
Moderate	20 to 35
High	35 to 50
Very high	Greater than 50

Source : Expansive soil classification based on DFSI (IS: 2911 part-III-1980), Design and Construction of Pile Foundation

Organic content determination test

Organic matter determination

(ASTM D 2974)

- **Objective:**

  To determine the organic content of soils

  Need and Scope:

- ✓Organic matter influences many of the **physical, chemical and biological properties** of soils. Some of the properties influenced by organic matter include **soil structure, soil compressibility and shear strength**. In addition, it also affects the water holding capacity, nutrient contributions, biological activity, and water and air infiltration rates.

- ✓Due to decomposition of organic matter in the soil with time leads to **excessive settlement** of soil.

Source:http://keywordsuggest.org/gallery/494028.html

Apparatus

- Muffle furnace
- Balance
- Porcelain dish
- Spatula
- Tongs

Source:http://civilblog.org/2015/12/03/how-to-determine-organic-matter-content-in-soil/

Procedure (ASTM D 2974)

- Determine and record the **mass of an empty**, clean, and dry **porcelain dish** ($\mathbf{M_P}$).
- Place a part of or the entire oven-dried test specimen from the moisture content experiment in the porcelain dish and determine and record the **mass of the dish and soil specimen** ($\mathbf{M_{PDS}}$).
- Place the dish in a **muffle furnace**. Gradually increase the temperature in the furnace to 440^0C. Leave the specimen in the furnace overnight.
- Remove carefully the porcelain dish using the tongs and allow it to cool to room temperature. Determine and record the **mass of the dish containing the ash (burned soil)** ($\mathbf{M_{PA}}$). Empty the dish and clean it.

Calculation

DATA ANALYSIS:

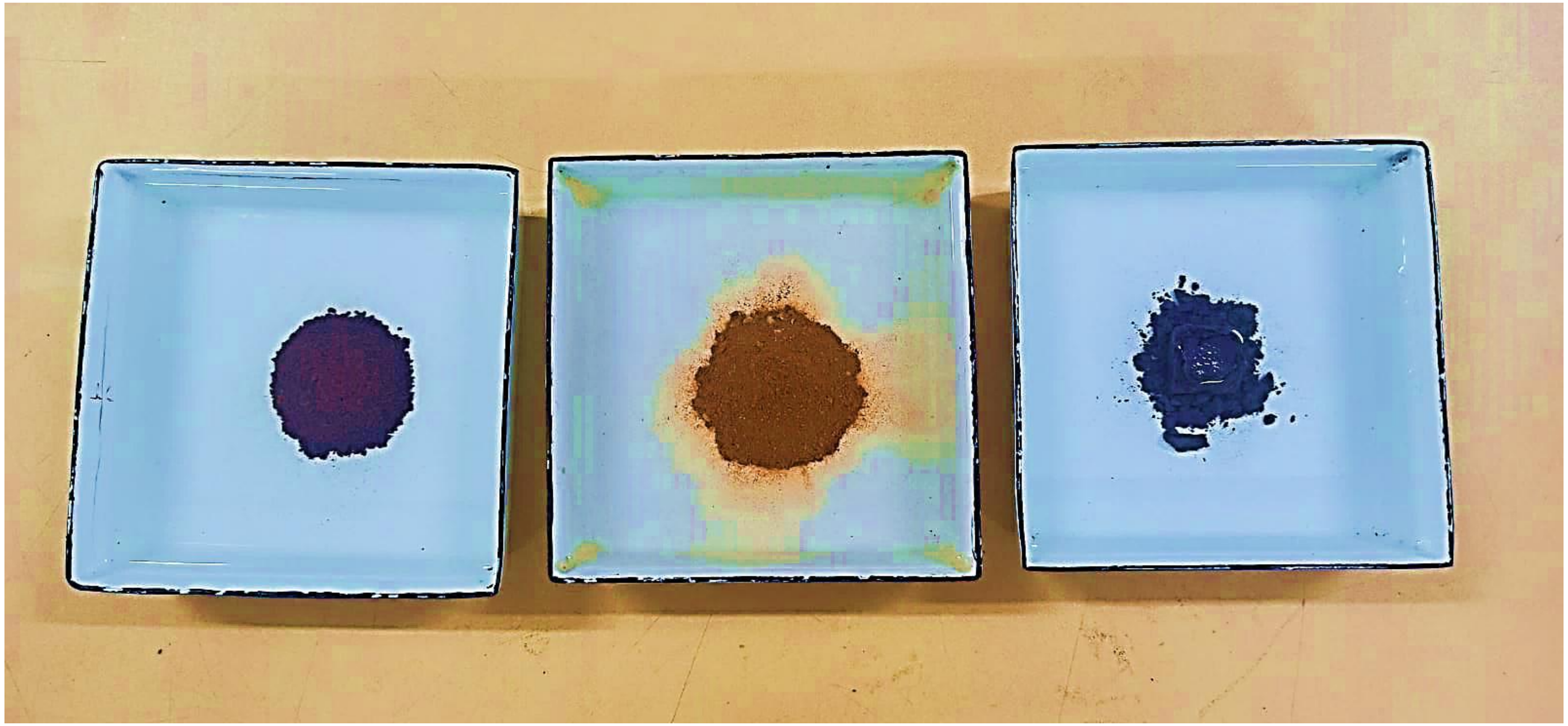
1. Determine the mass of the oven dry soil.
   $M_D = M_{PDS} - M_P$

2. Determine the mass of the ashed (burned) soil.
   $M_A = M_{PA} - M_P$

3. Determine the mass of organic matter
   $M_O = M_D - M_A$

4. Determine the organic matter (content).

$OM(\%) = (M_O/M_D)*100$



Determination of swelling pressure of soil from oedometer test (IS 2720- Part 41)

Time-swell response

IS : 2720 (Part XLI) - 1977

Dry density in g/ml

Moisture content in percent

Date

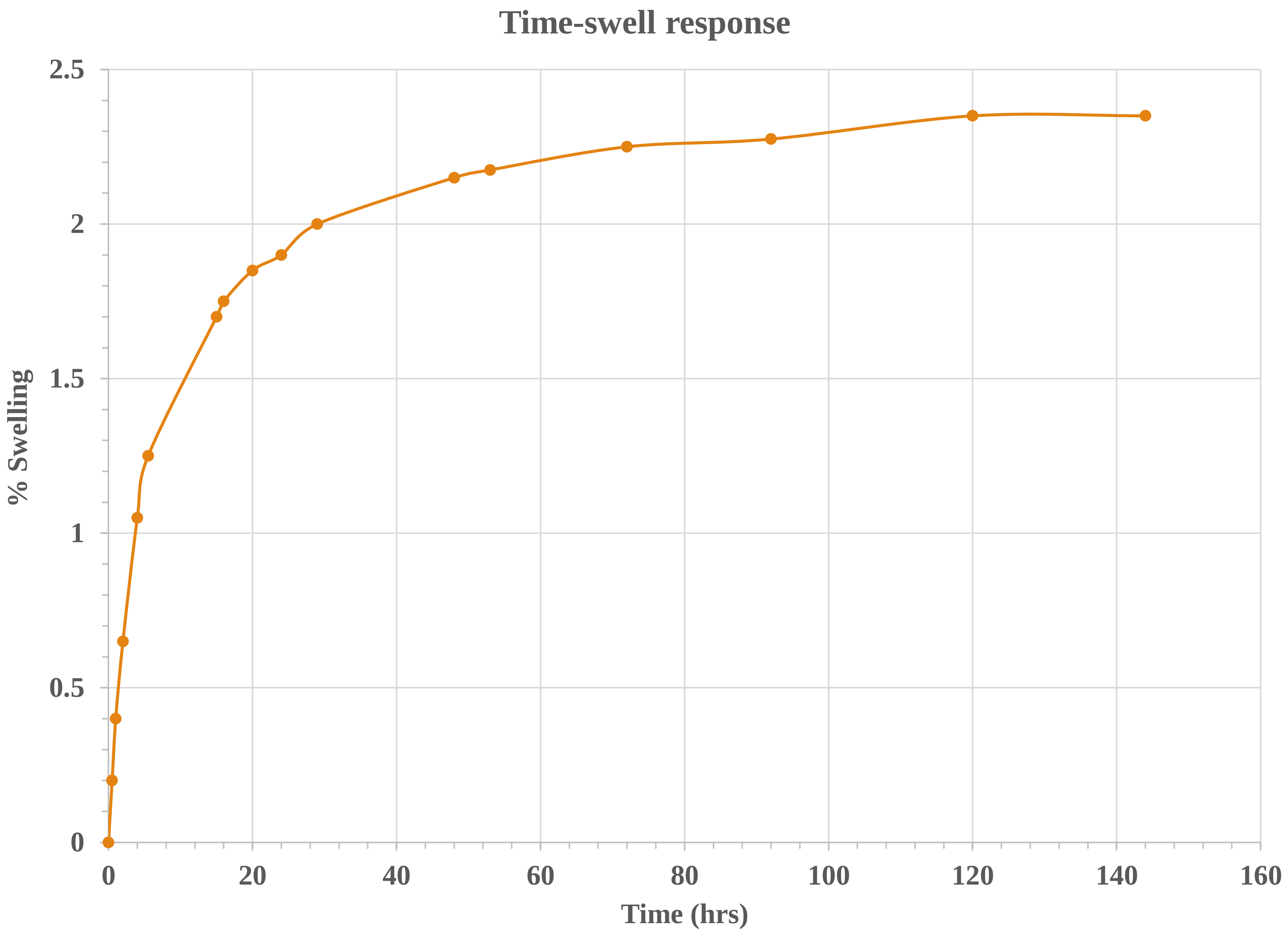
Time of starting

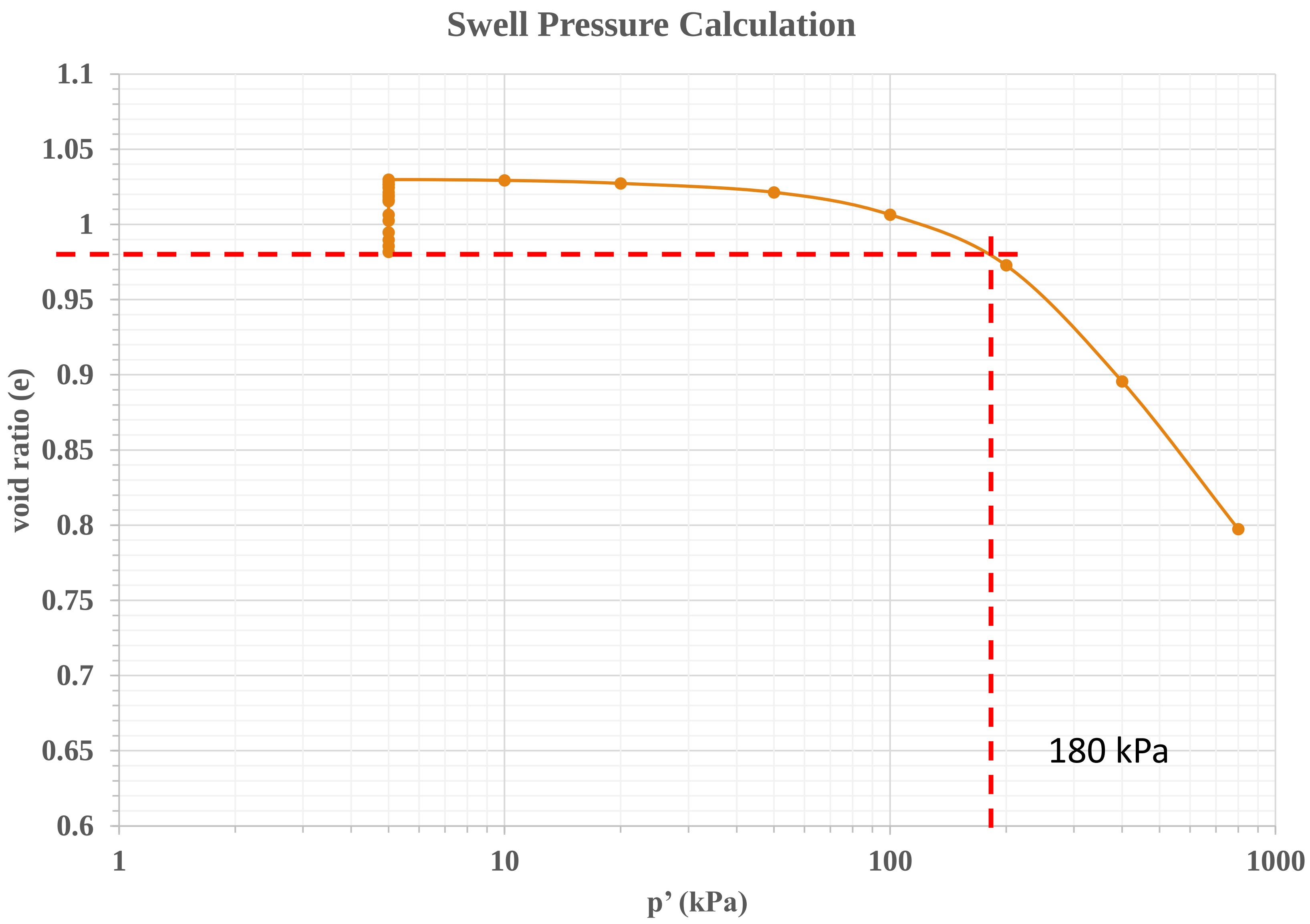
Elapsed time in hours	Swelling dial reading
0	
0·5	
1	
2	
4	
8	
12	
16	
20	
24	
36	
48	
60	
72	
96	
120	
144	

1-D Consolidation

Applied pressure (kg/cm^2)	Dial gauge reading
0.05*	
0.1	
0.2	
0.5	
1	
2	
4	
8	

* After completion of swelling


Time-swell response
% Swelling
Time (hrs)
2.5
2
1.5
1
0.5
0
0
20
40
60
80
100
120
140
160


Swell Pressure Calculation
void ratio (e)
p' (kPa)
1.1
1.05
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
1
10
100
1000
180 kPa