Management of sulfide soils in respect of environmental issues and climate change (MoSS)

Stabilization of Sulfide Soils with Binders

Impact of Portland Cement and Terra

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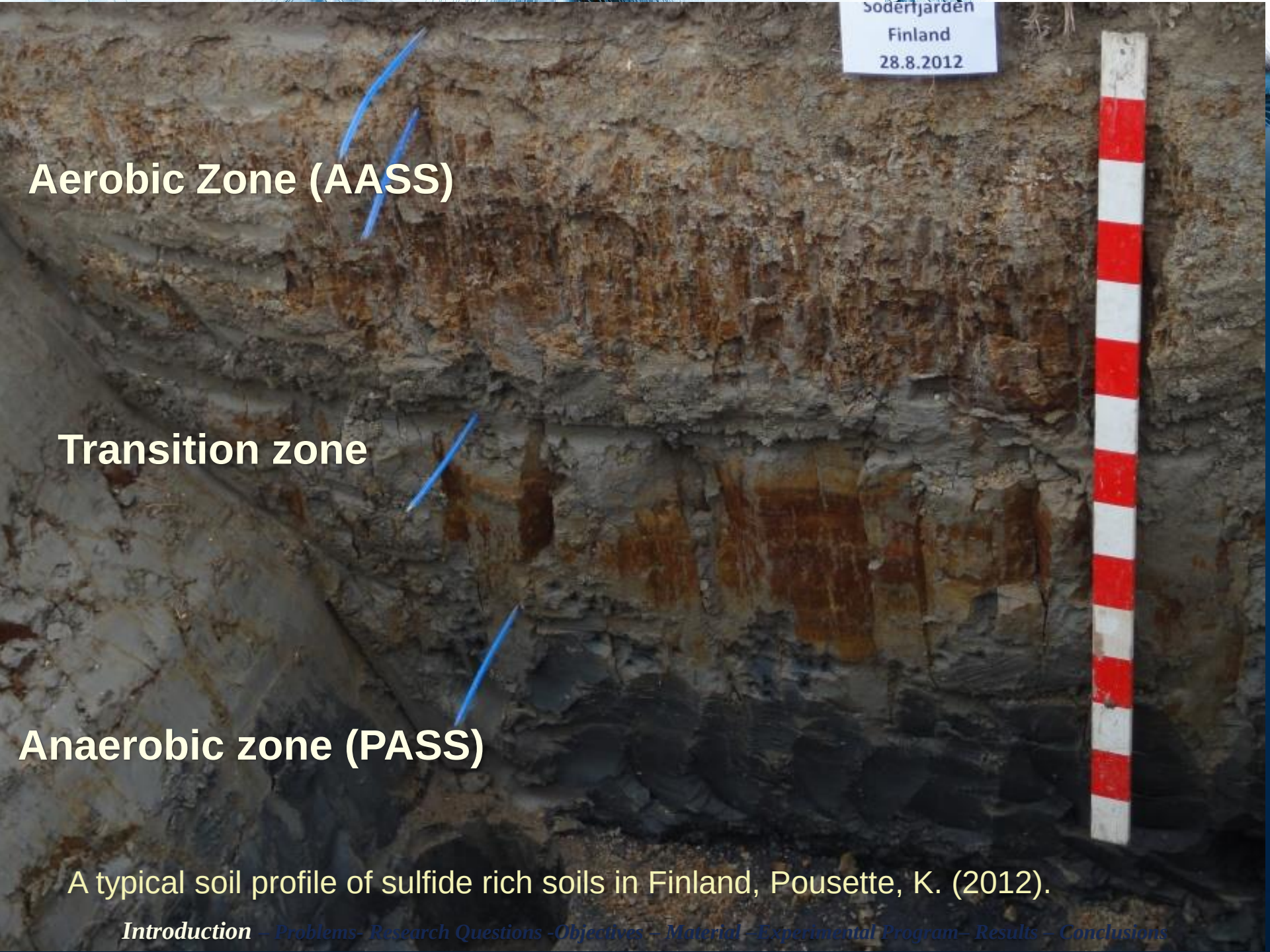
Outline

- *Introduction*
- *Problem Statement*
- *Objectives*
- *Materials (Sulfied Soil & Binders)*
- *Experimental program,sample preparation and testing*
- *Results*
- *Summary*

Sulfide rich soil

Sulfide rich soils are soils that contain elevated amount of iron sulfide minerals

- **Acid sulfate soils (ASS)- Oxidized (Aerobic)**
  - Have low pH (less than 4);
  - Vary in texture
  - A lighter color (from grey to brown)
  - Often contain jarosite (yellow/red mottles produced by the oxidation
- **Potential acid sulfate soils (PASS)- Unoxidized (Anaerobic)**
  - Have a pH (6.5-7.5)
  - Dark color (from grey to black)
  - Usually have a soft, sticky and water saturated texture



A typical soil profile of sulfide rich soils in Finland, Pousette, K. (2012).

Problem statement

- **Unsuitable for any Construction Project**
  - Low shear strength, stiffness and workability.
  - Highy compressiblty
- **Transportation and excavation**
- Environmental problems by releasing heavy toxic metals (such as iron, aluminum and arsenic)
- Contaminated soil and groundwater
- Sudden mass deaths of aquatic animals by consumes a large amount of oxygen during oxidation process,
- Environmental regulations and costs that associated with dumping the sulfied soil as waste in landfill

Main Objectives

Investigation the **Enhancement in sulfide soil strength and stiffness** in a **short and long term effects** due to adding various amounts of two different binder types (Cement and Terra)

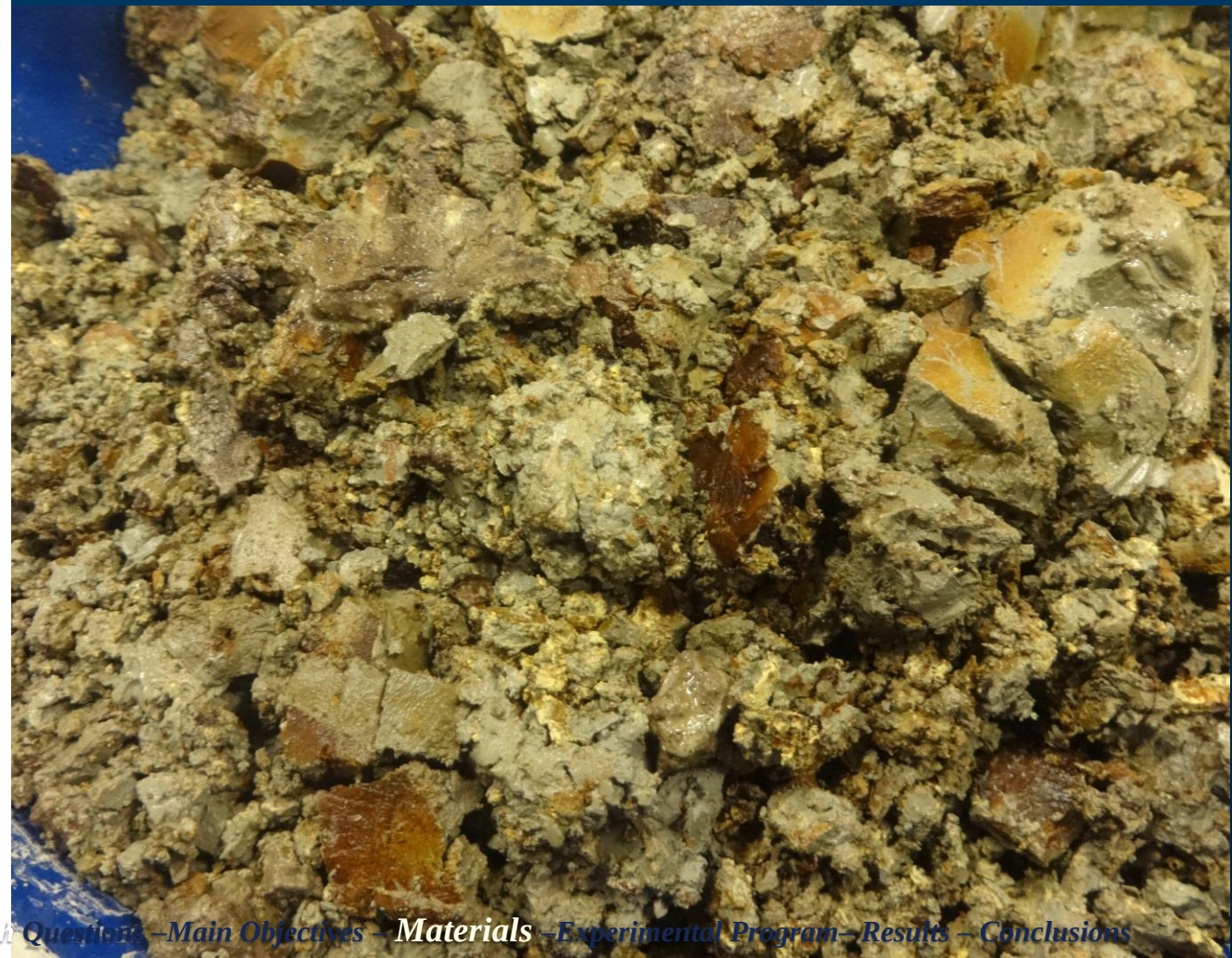
Materials

Sulfied Soils

Soils Location

▲ **Aerobic soil, Sunderbyn, S: 3400** mg/kgTS

0.3- 0.4 m



- **Anaerobic soil , Sunderbyn, S: 25000** mg/kgTS

Gray - black **1,8 m**

Anaerobic soil , Sunderbyn , S:8850 mg/kgTS

Black **2.1m – 2.5 m**

Anaerobic soil Umeå, S:2800 mg/kgTS

Gray - black **2.7 – 4.0 m**

Soils was stored inside a cooler at 6 C°

Binders

- **Portland cement** CEM II, Cementa Sweden AB.
  - Cementing potential ratio (CaO/SiO_2), **3.5**

- **Terra** , Nordkalk AB, Sweden
  - Cementing potential ratio (CaO/SiO_2): **2.6**

Portland cement

- Portland cement consist of:

C_3S , C_2S, C_3A and C_4AF

Alite, Belite, Aluminate and Ferrit

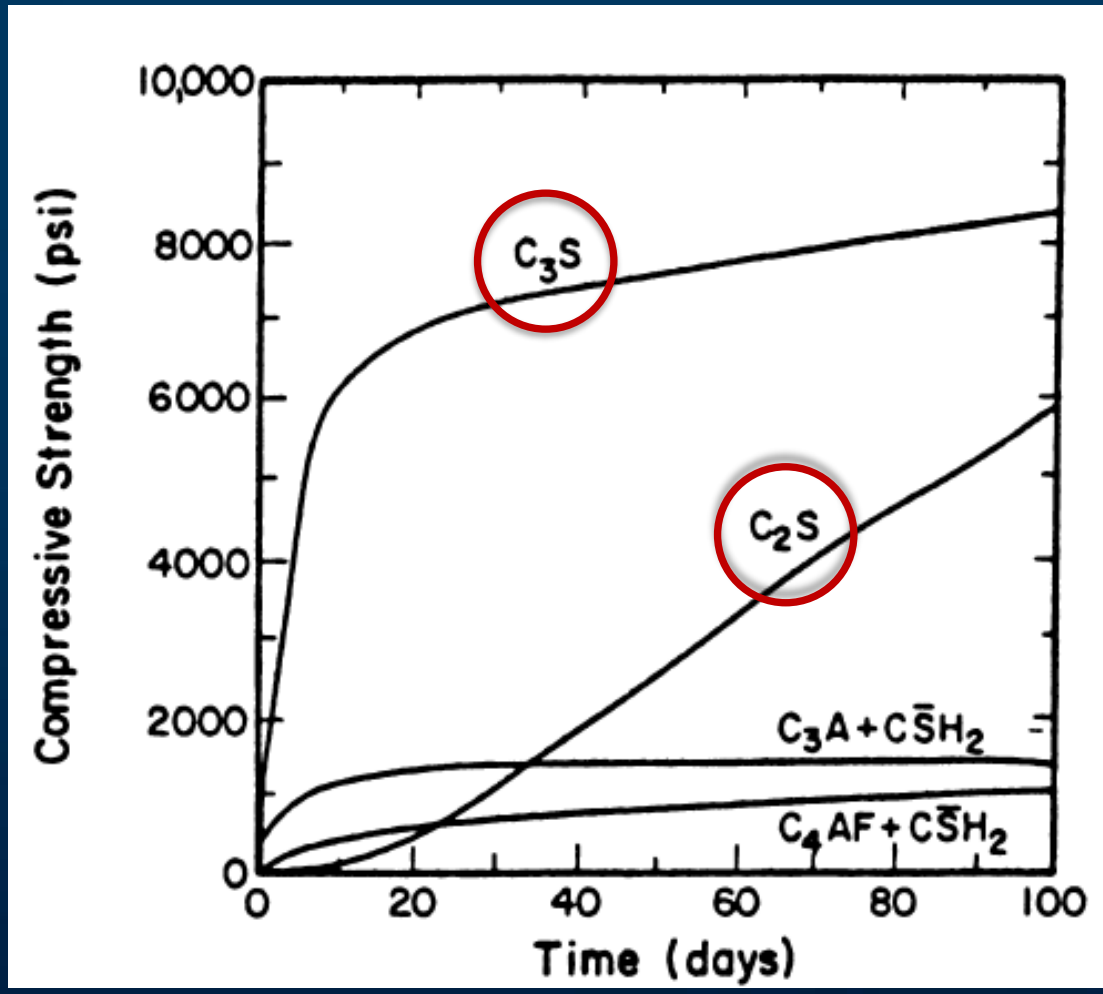
C: Calcium (CaO)

S: Silicate (SiO_2)

A: Aluminate (Al_2O_3)

H: Water (H_2O)

F: Iron (Fe_2O_3)

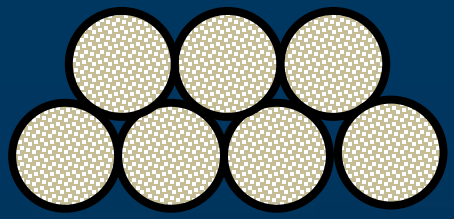


Soil Cement Reaction

Hydration Reaction → **Three Primary Cementing Components**

Calcium-Silicate Hydrate (CSH)

Calcium-Aluminate-Hydrate (CAH)



Bind soil particles together and produce strong hard mixture with time

Pozzolanic Reaction

Calcium Hydroxide

$Ca(OH)_2 + SiO_2 \Rightarrow$ (CSH) (Additional)

$Ca(OH)_2 + Al_2O_3 \Rightarrow$ (CAH) (Additional)

Experimental Program, Sample Preparation and Testing

Main Laboratory Tests

Before Treatment

Soil Basic Characterization

Identify basic soil properties

- Natural water content
- Loss of Ignition
- PSD
- Particle Density
- Plasticity tests
- Bulk Density

MRM Leaching Tests

Risk assessment for sulfide soil

- Immediately
- for continuous 10 days

After Treatment

Unconfined Compression Test (UCS)

Enhancement in soil strength and stiffness in short and long terms

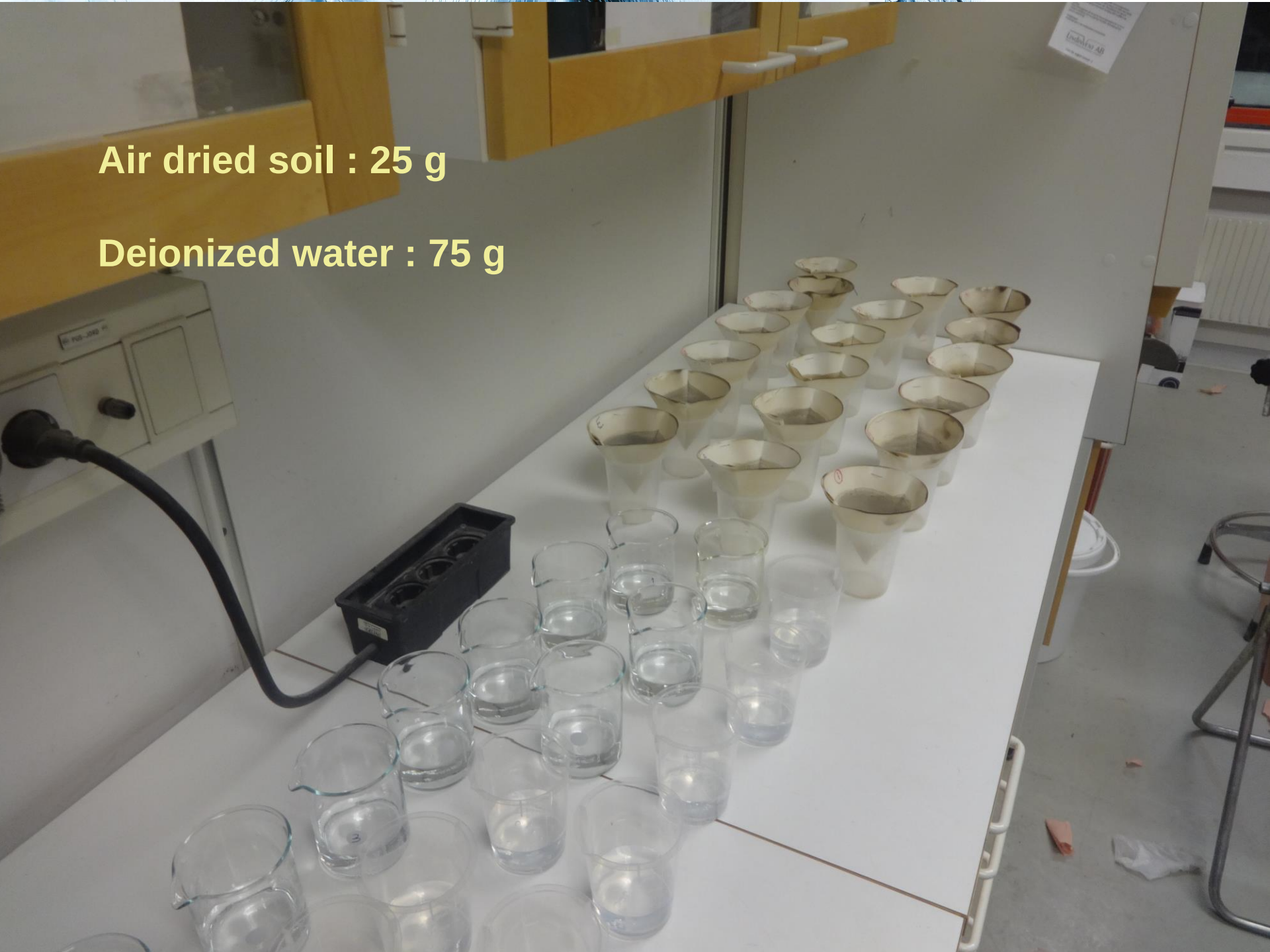
- Solidification
- Density
- pH value

Sample Preparation MRM Leaching Test

Fresh soil samples are cut into thin slices

Air-dryed soil samples

Dried soil sample is being ground and sieved through a 2 mm sieve


Air dried soil : 25 g
Deionized water : 75 g


1


1
ORP


8302BNUMD
40 ml
30
20
10


pH10
ORP15
CO30
200
150
100
3
1


Pulver

USC Sample Preparation

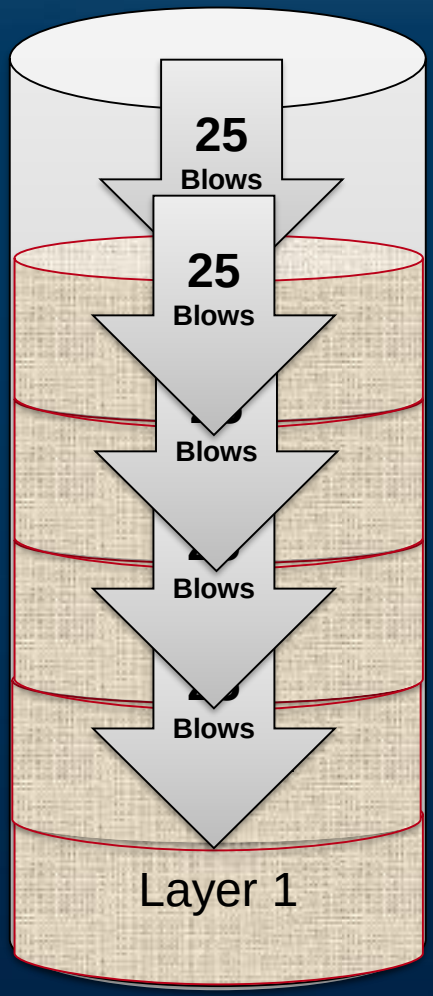
Homogenize the natural soil

Binder content:

- Cement : 1, 2, 4, 8%
- Terra: 1, 2, 4, 8 %

Mixing Time: 10 minutes.

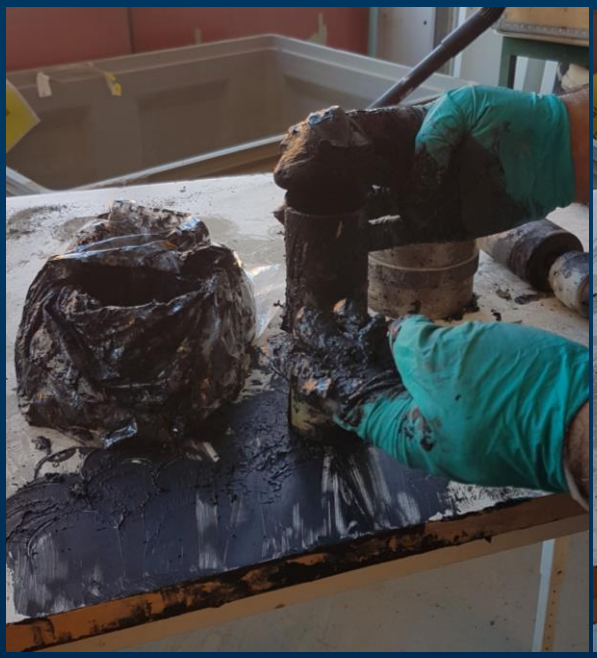
Compaction Efforts



- Cylindrical plastic tubes (170 x 50mm)
- Five soil layers
- Sample Height: 10 cm
- Sample Diameter: 5 cm
- Samples was prepared during one hour after mixing


Proctor Hammer

UCS sample preparation for Anaerobic soil , Sunderbyn



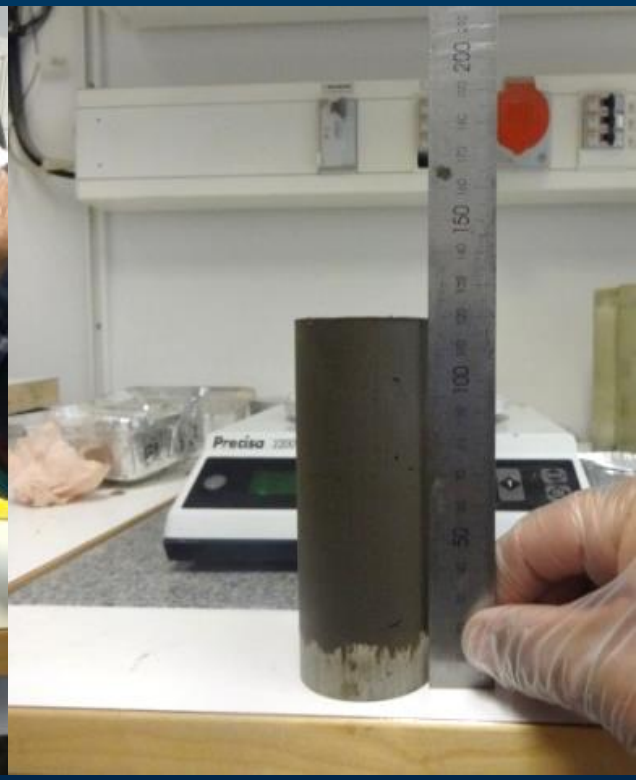
Curing Condition

- 7, 28, 90 and 360 days of curing
- No access to water
- Cured in controlled room temperature at 20° C
- Samples are surrounded by water

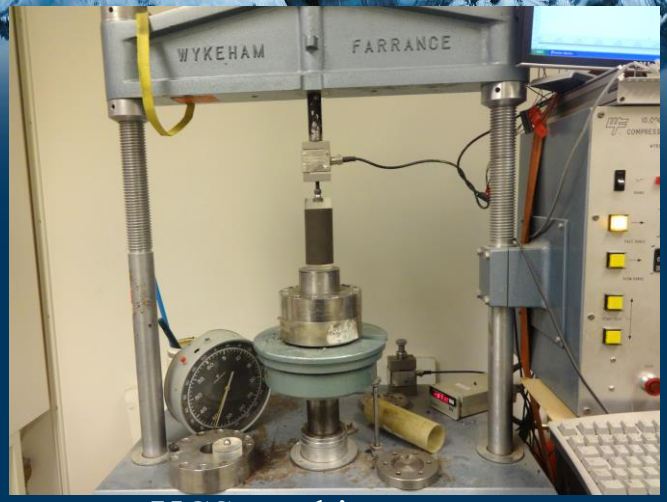
After Curing

- UCS Sample are removed from the tubes by using a mechanical jack

Measuring the density of UCS after curing period



Testing of UCS Samples



UCS machine test

Testing rate was 1 mm/minute until failure occurred

Before test **After test**

Development of USC sample during the test showing the cracks until failure

Results

Soil Basic Characterization

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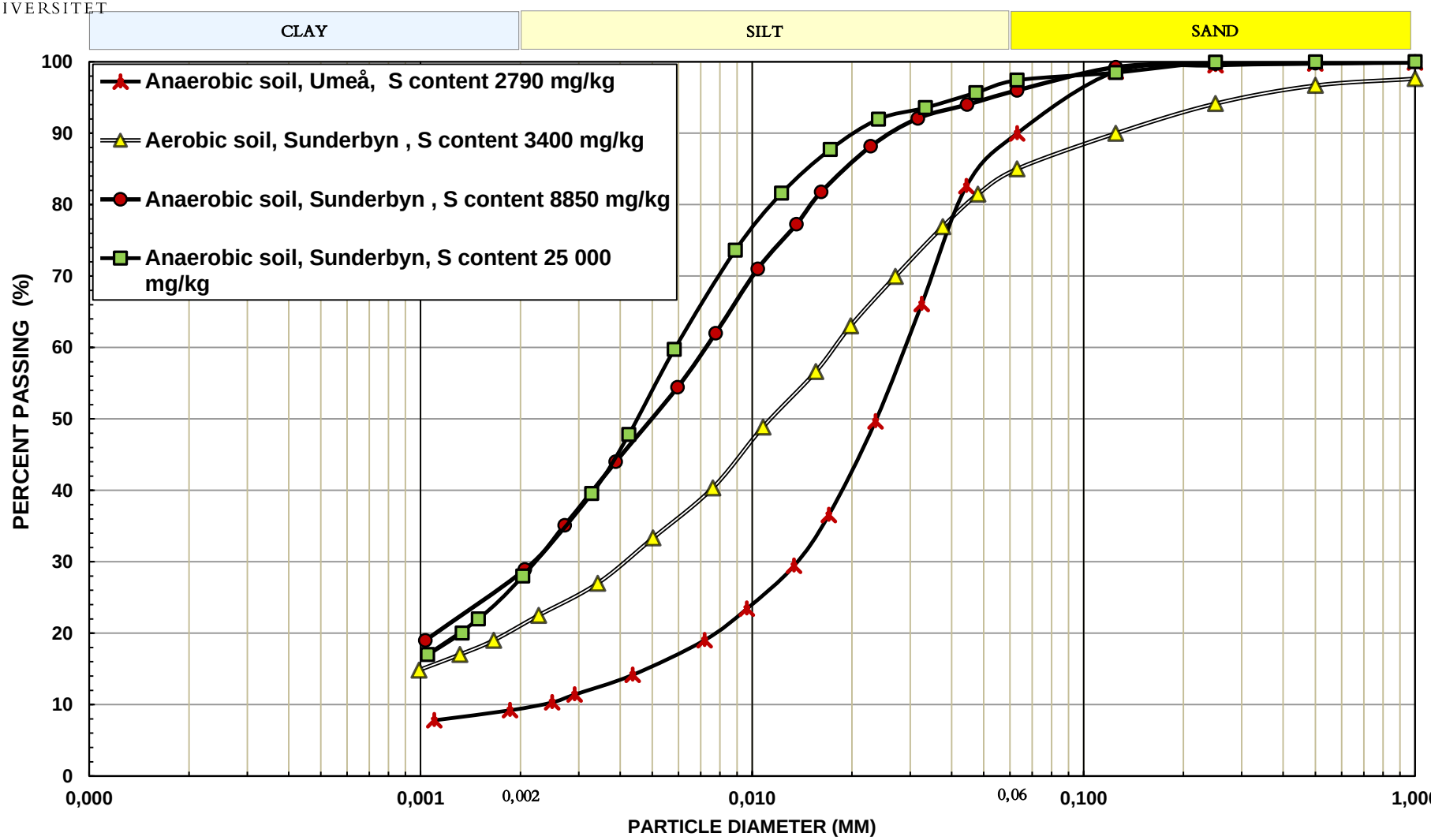
Particle size distribution of untreated Soils

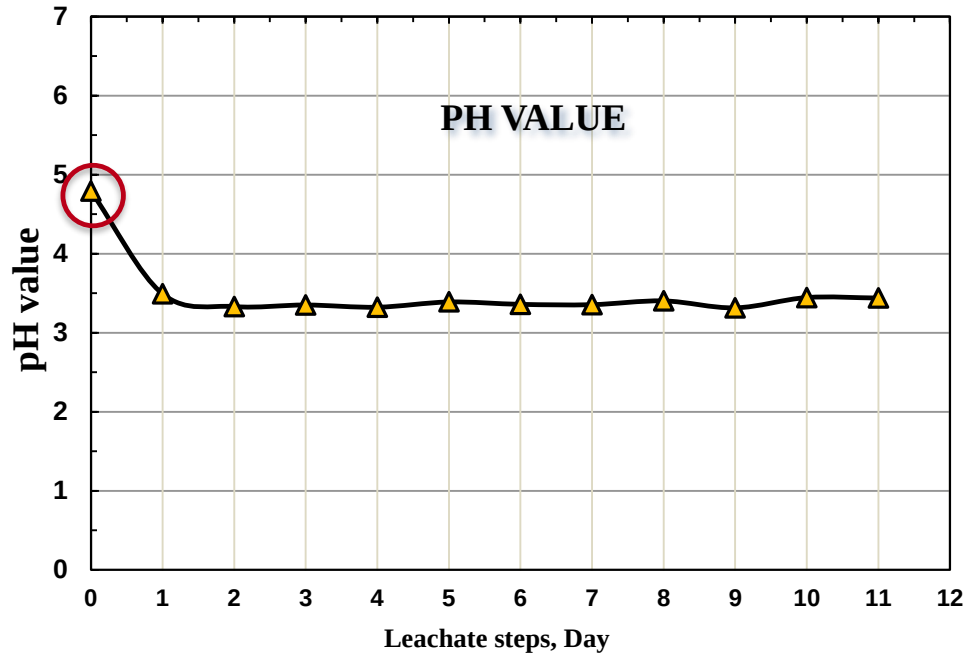


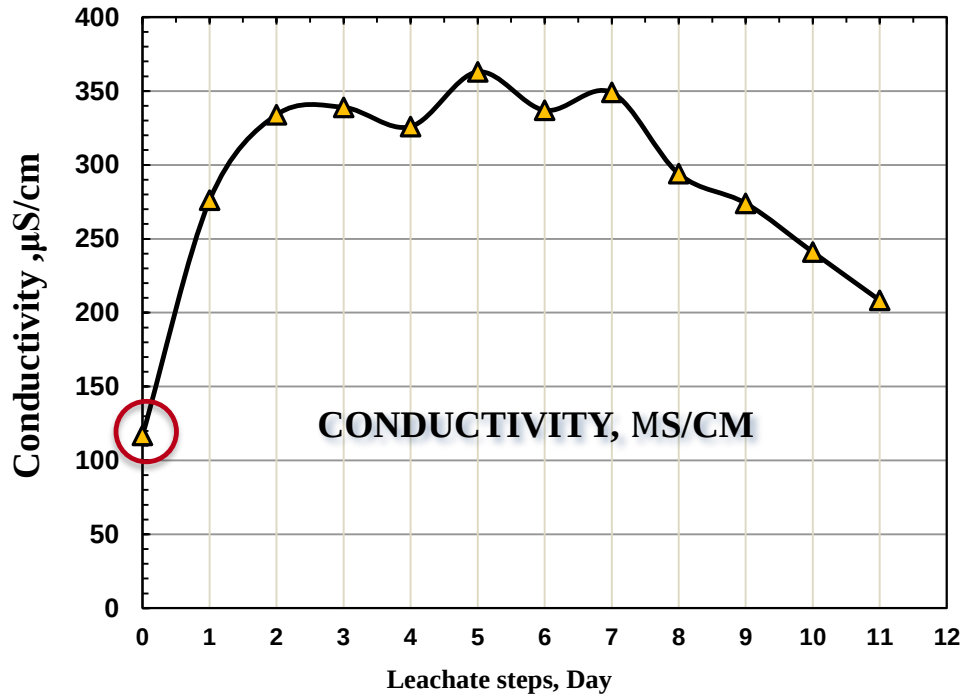
Parameter	Sunderbyn Soils			Anaerobic soil, Umeå, S: 2800
	Aerobic, S: 3400	Anaerobic, S: 25000	Anaerobic, S: 8850	
Silt, %	64	67	69	80
Liquid limit, %	46	95	113	56
Plasticity index, %	16	58	71	11
Loss of Ignition, %	4	6.75	6.1	2.5
Soil Classification				

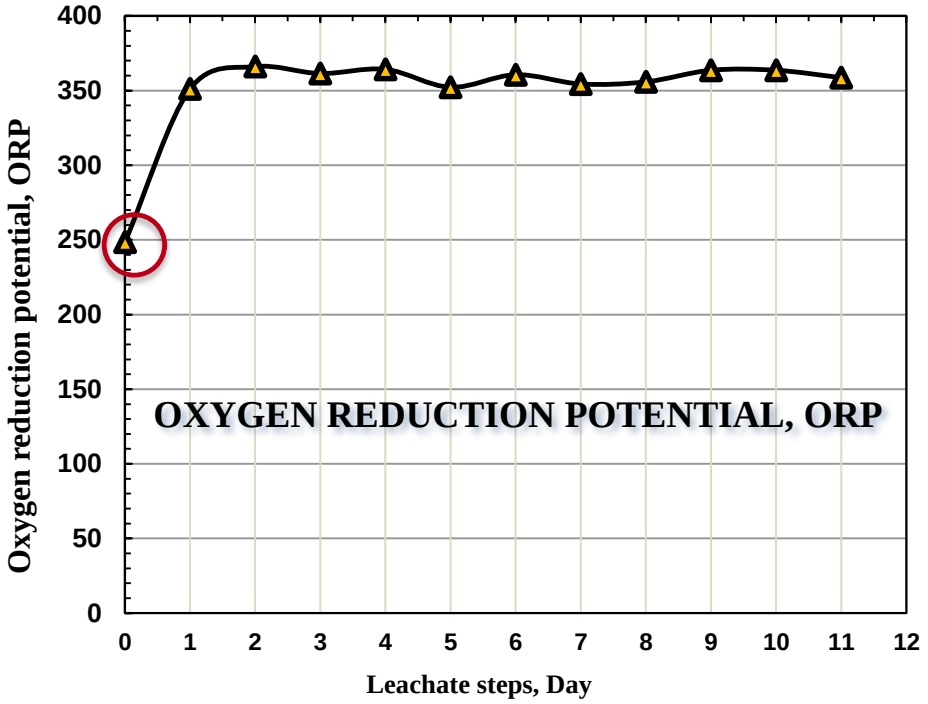
MRM Leaching Test

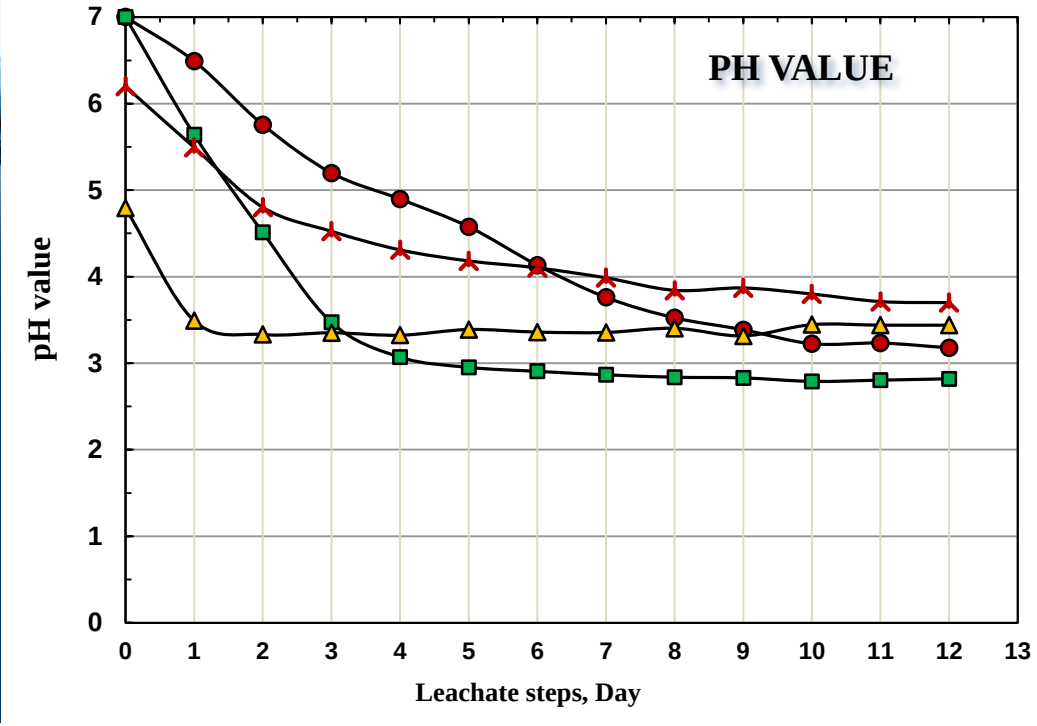
MRM Leaching Tests

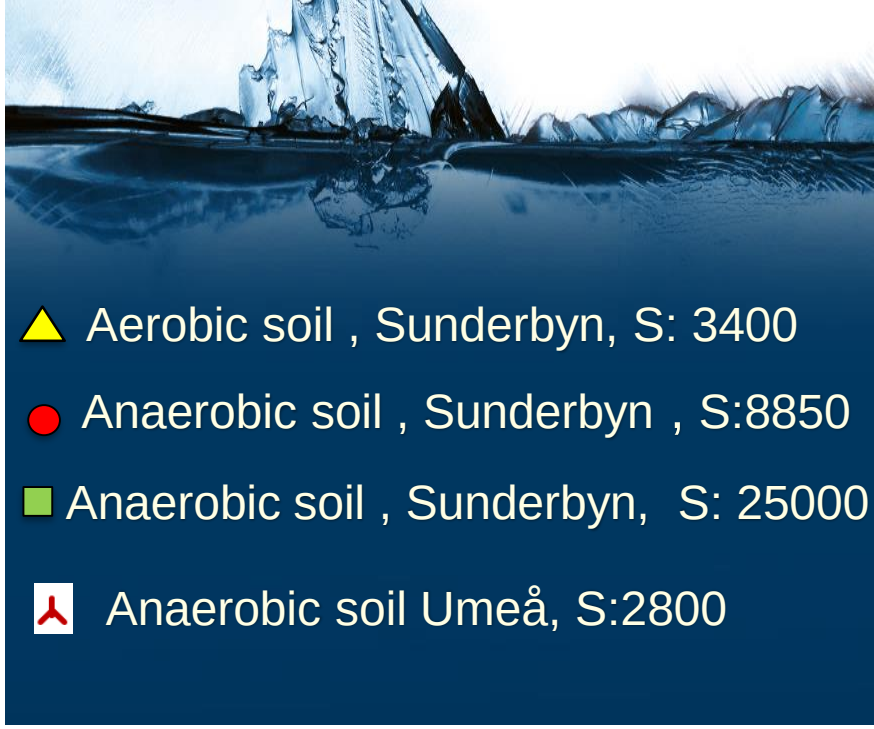
- *Aerobic soil , Sunderbyn, S: 3400*

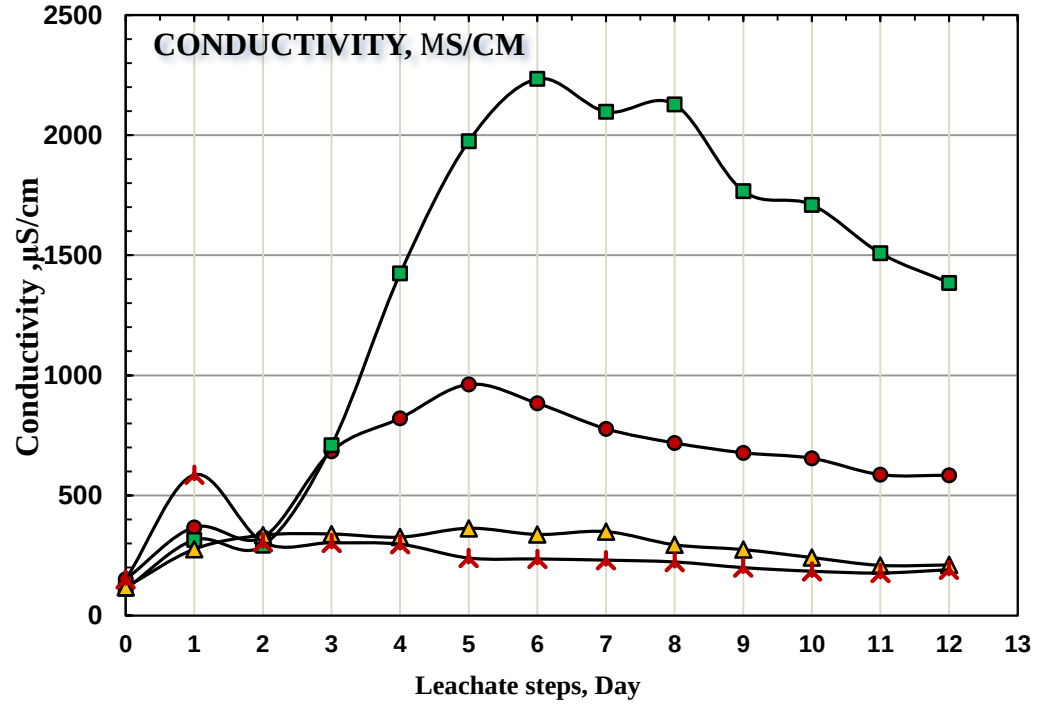


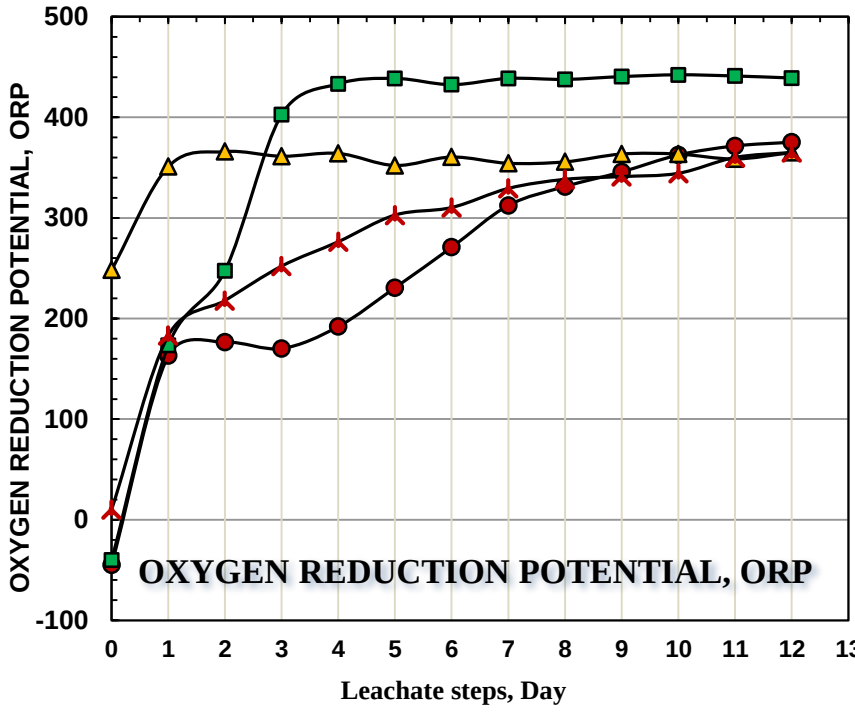




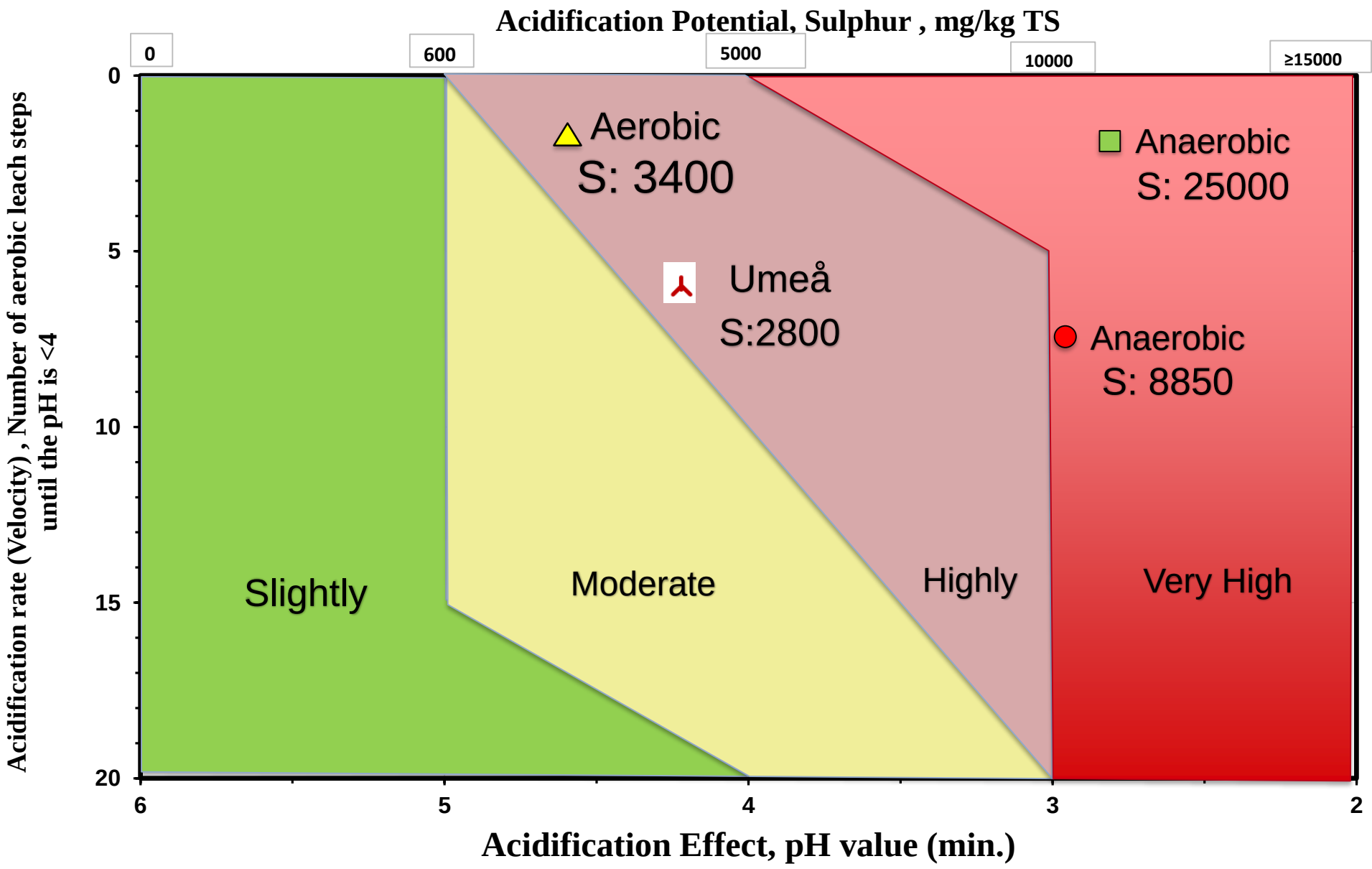

PH VALUE
pH value
Leachate steps, Day


Aerobic soil , Sunderbyn, S: 3400
Anaerobic soil , Sunderbyn , S:8850
Anaerobic soil , Sunderbyn, S: 25000
Anaerobic soil Umeå, S:2800


CONDUCTIVITY, MS/CM
Conductivity ,µS/cm
Leachate steps, Day

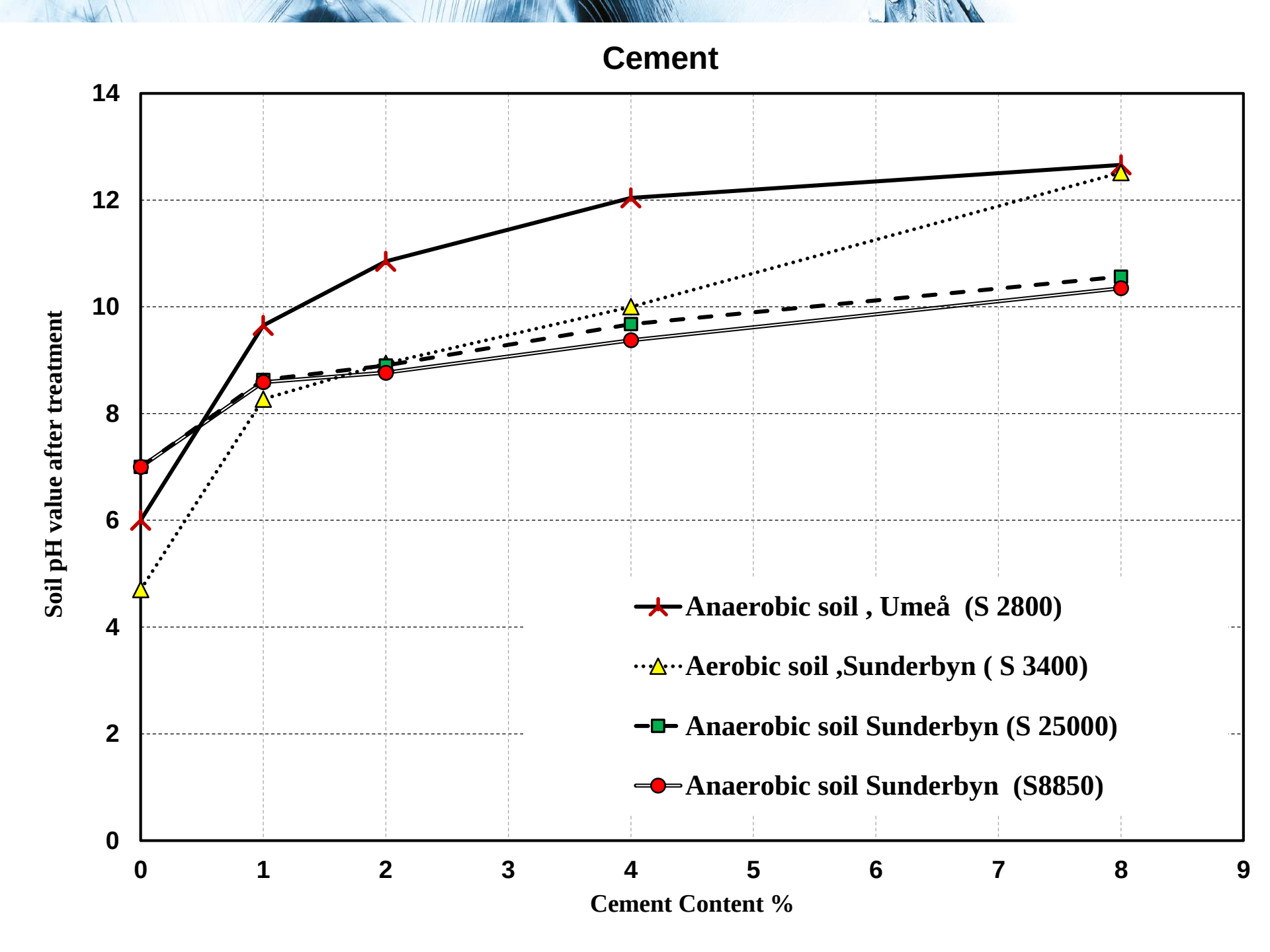

OXYGEN REDUCTION POTENTIAL, ORP
OXYGEN REDUCTION POTENTIAL, ORP
Leachate steps, Day

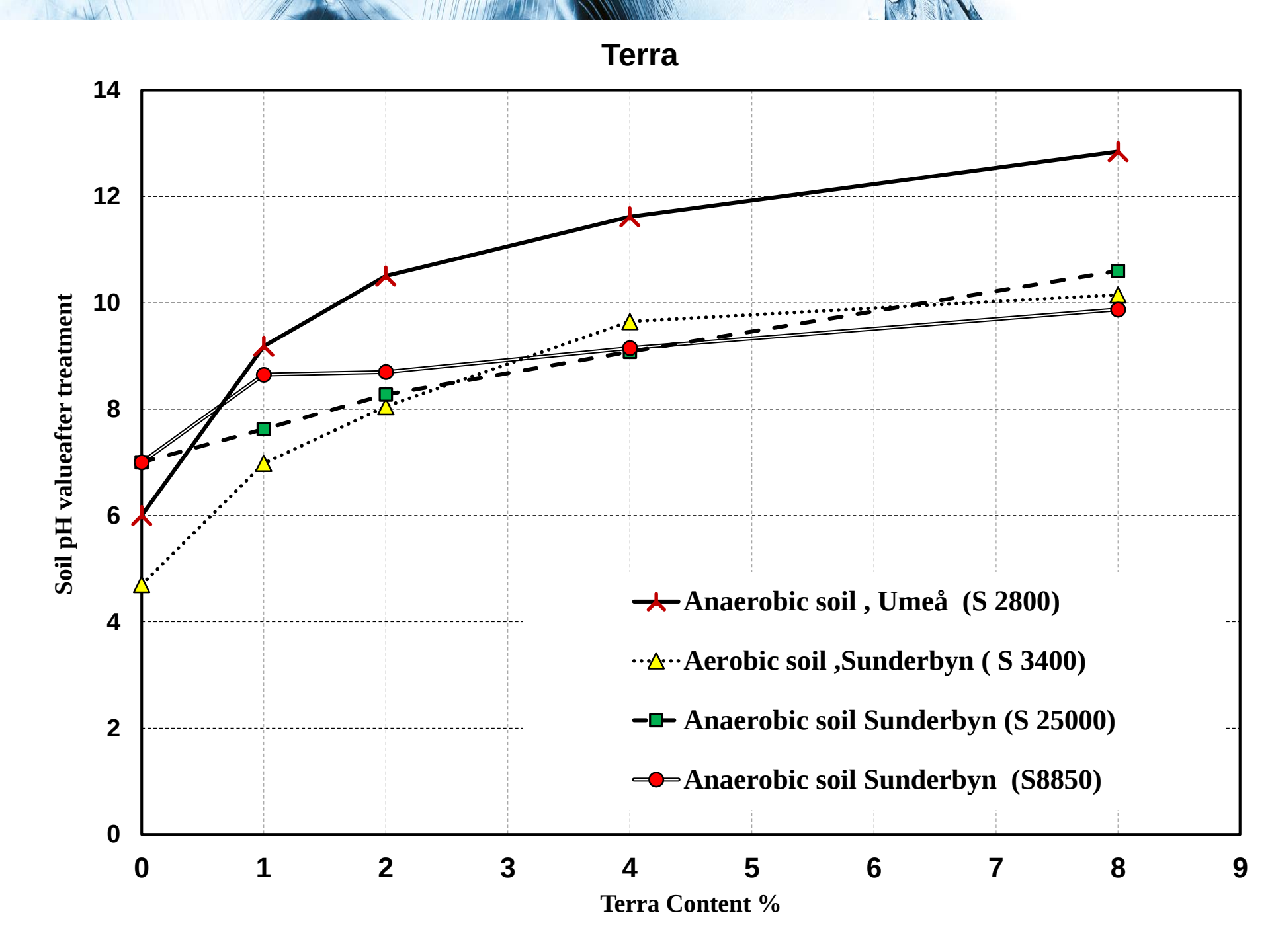
A typical soil profile of sulfide rich soils in Finland, Pousette, K. (2012).



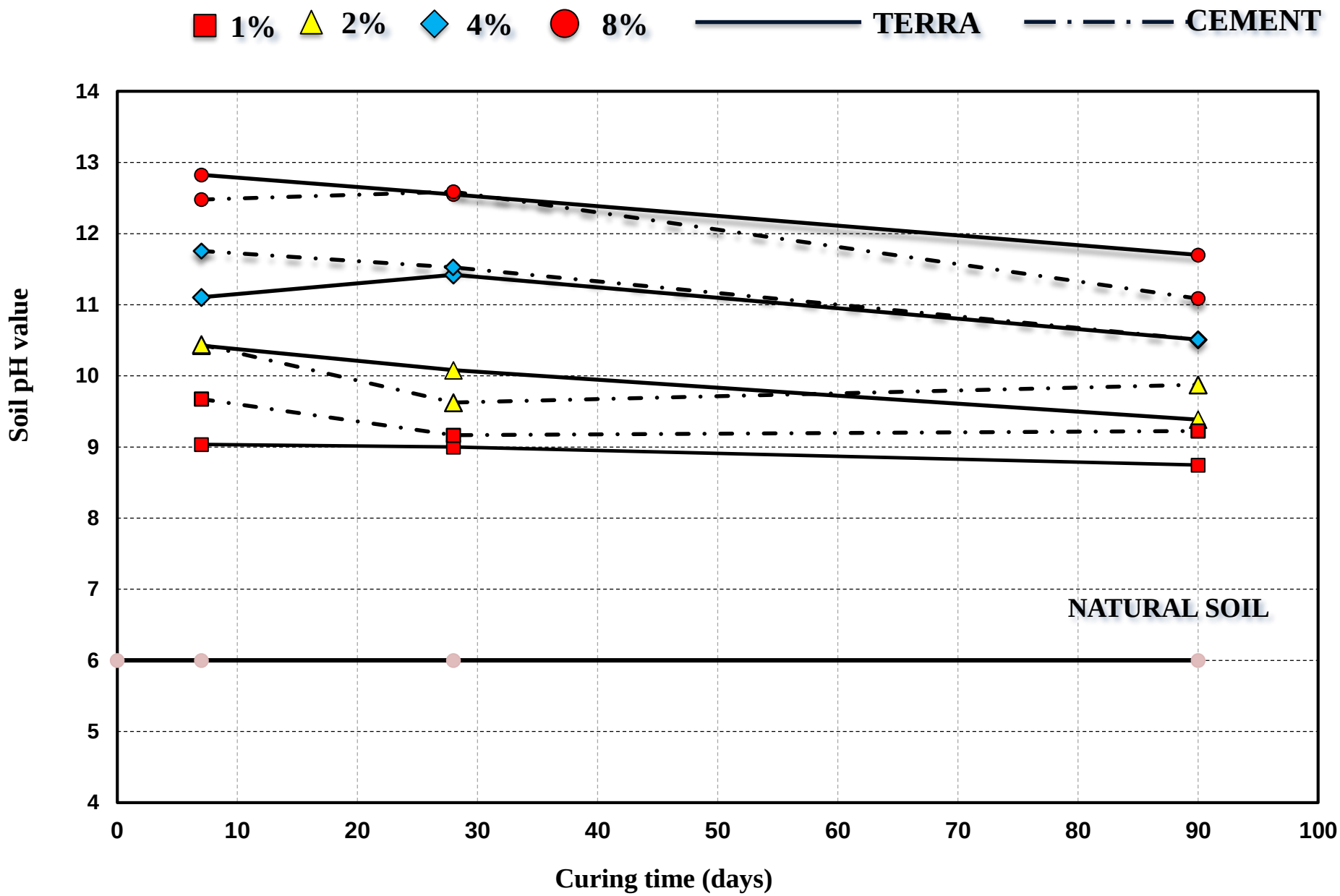
Stabilized soils

pH values after treatment

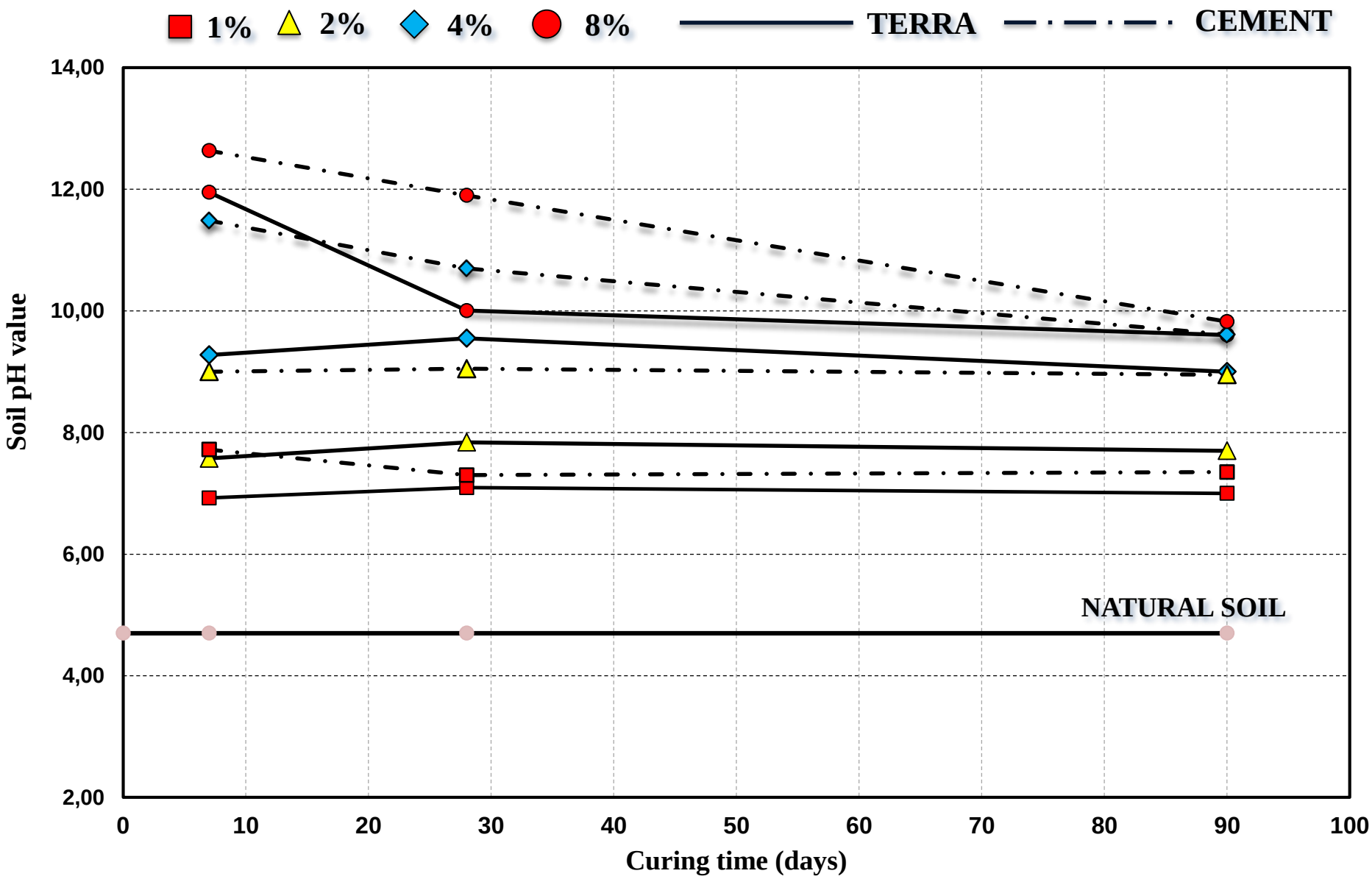

Cement
Soil pH value after treatment
Cement Content %
0
2
4
6
8
10
12
14
0
1
2
3
4
5
6
7
8
9
Anaerobic soil , Umeå (S 2800)
Aerobic soil ,Sunderbyn (S 3400)
Anaerobic soil Sunderbyn (S 25000)
Anaerobic soil Sunderbyn (S8850)

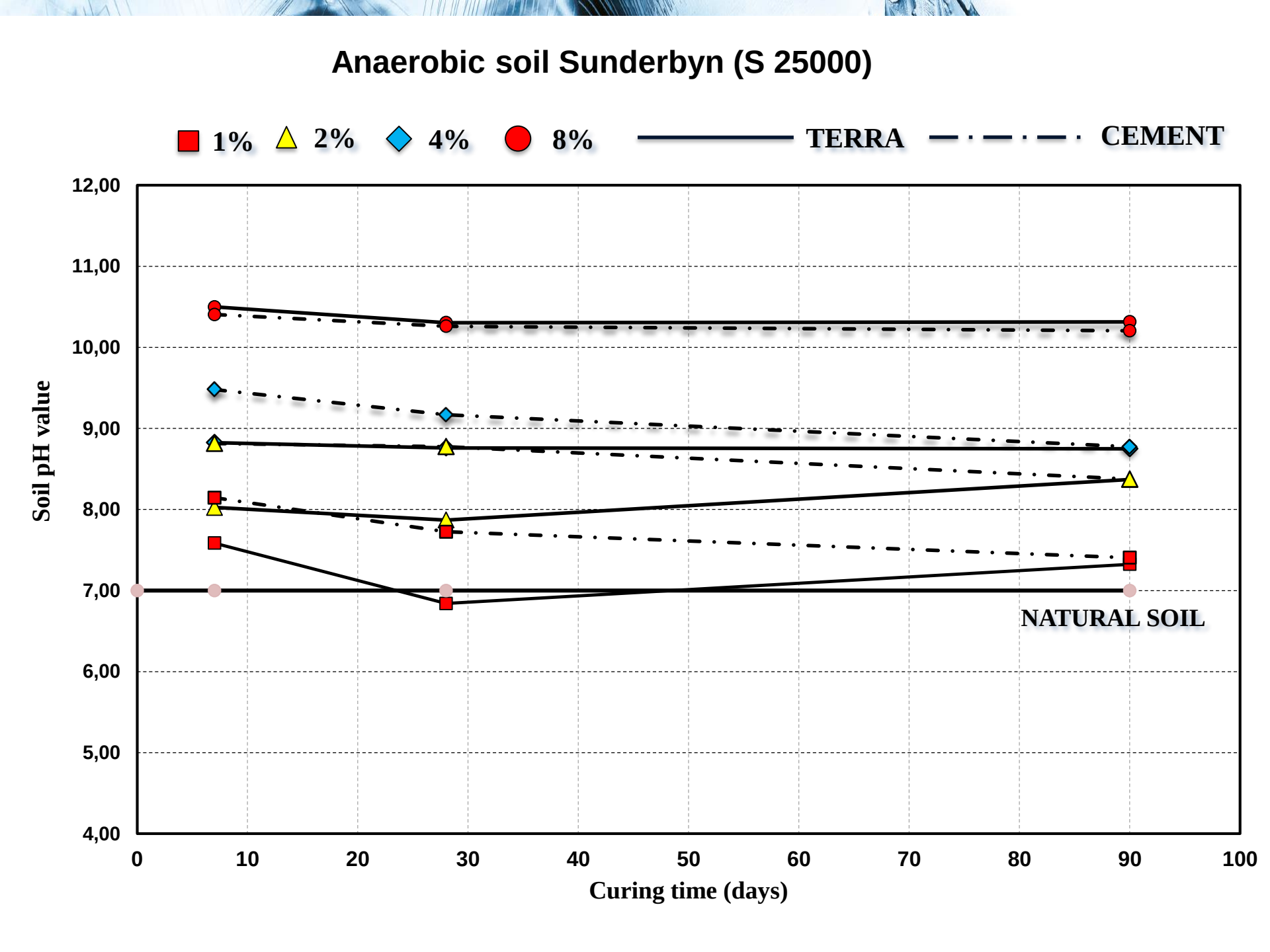

Terra
Soil pH valueafter treatment
Terra Content %
0
2
4
6
8
10
12
14
0
1
2
3
4
5
6
7
8
9
Anaerobic soil , Umeå (S 2800)
Aerobic soil ,Sunderbyn (S 3400)
Anaerobic soil Sunderbyn (S 25000)
Anaerobic soil Sunderbyn (S8850)

Anaerobic soil , Umeå (S 2800)

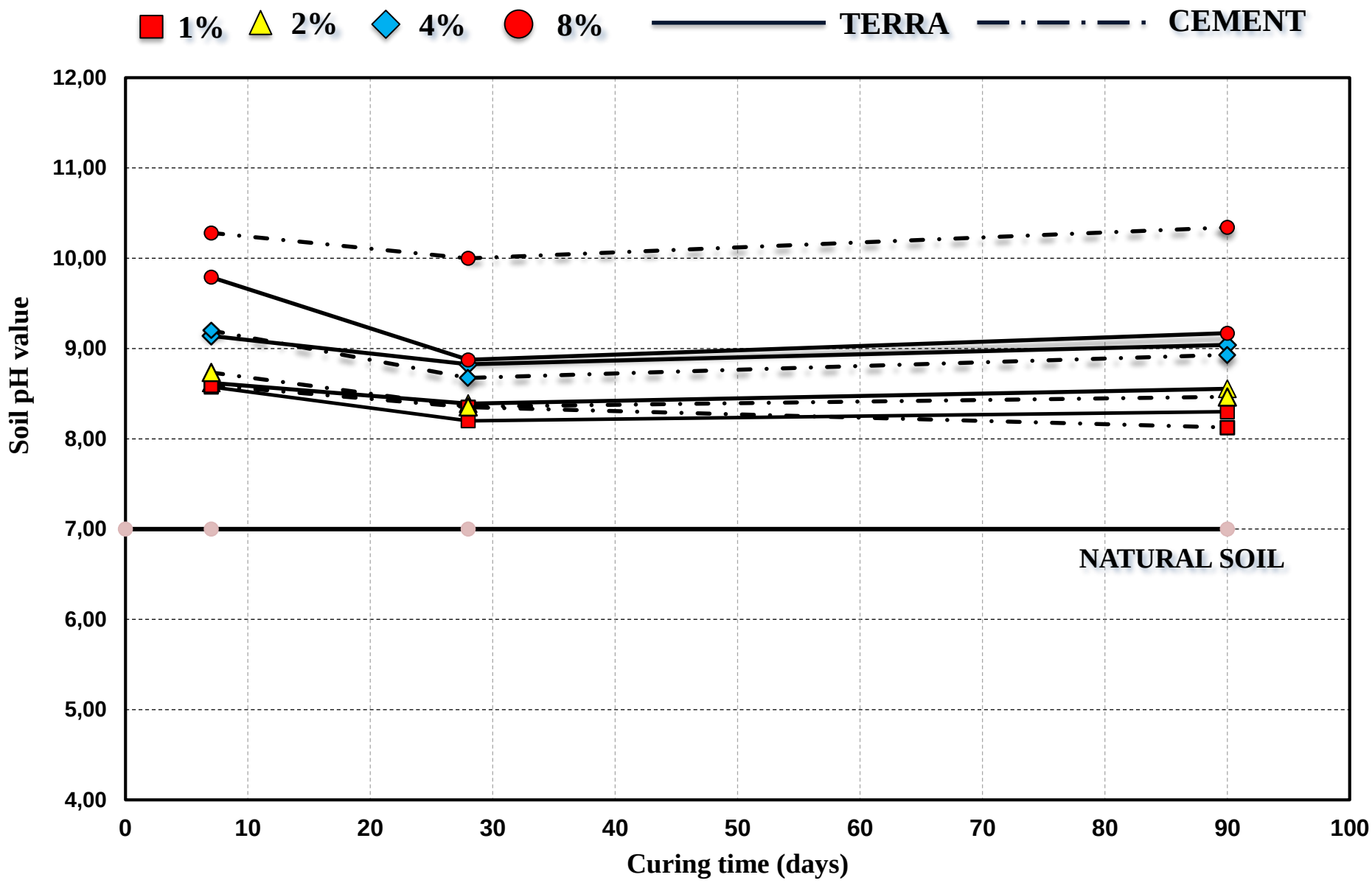


Aerobic soil ,Sunderbyn (S 3400)



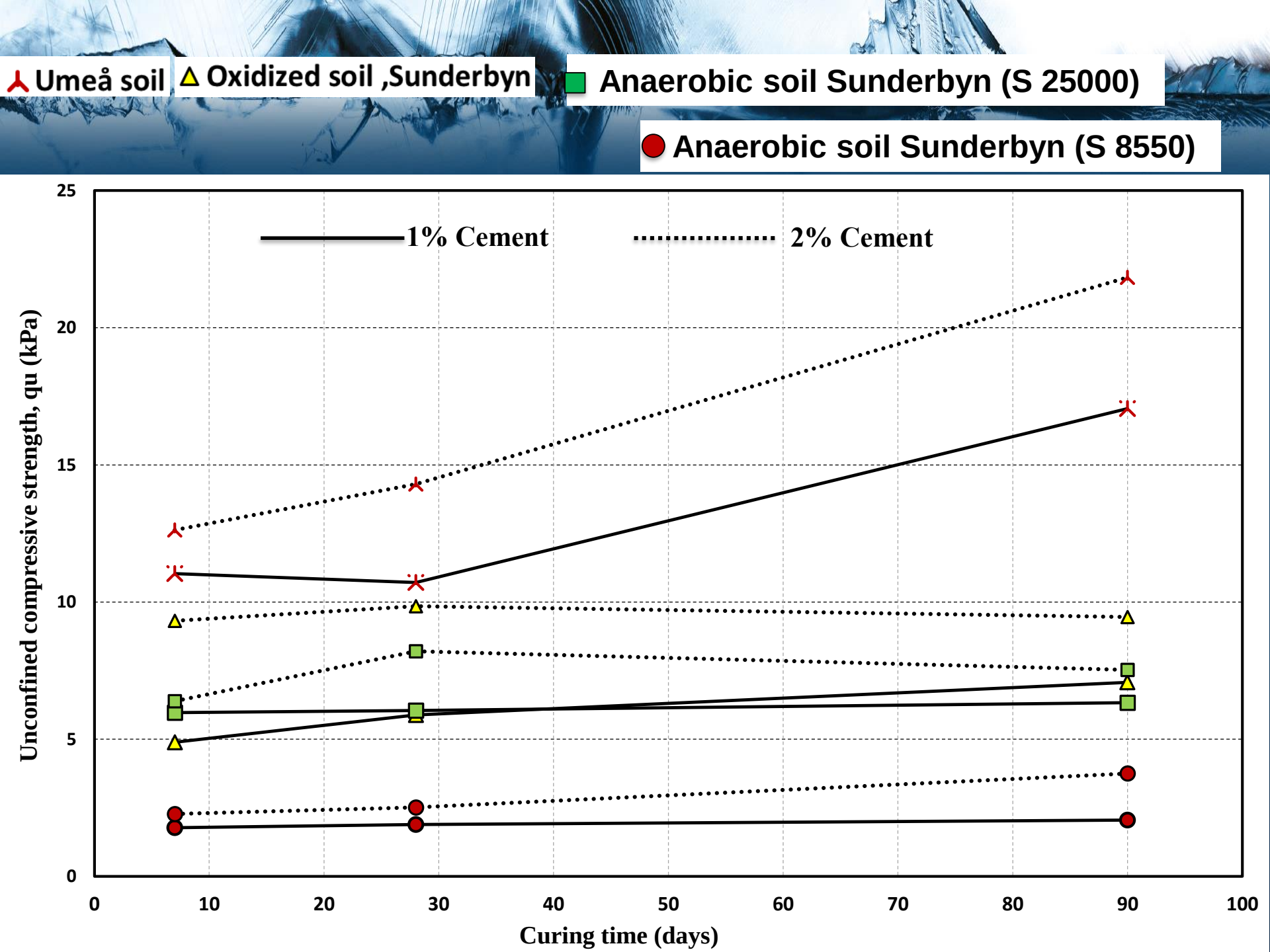

Anaerobic soil Sunderbyn (S 25000)
1%
2%
4%
8%
TERRA
CEMENT
12,00
11,00
10,00
9,00
8,00
7,00
6,00
5,00
4,00
Soil pH value
0
10
20
30
40
50
60
70
80
90
100
Curing time (days)
NATURAL SOIL

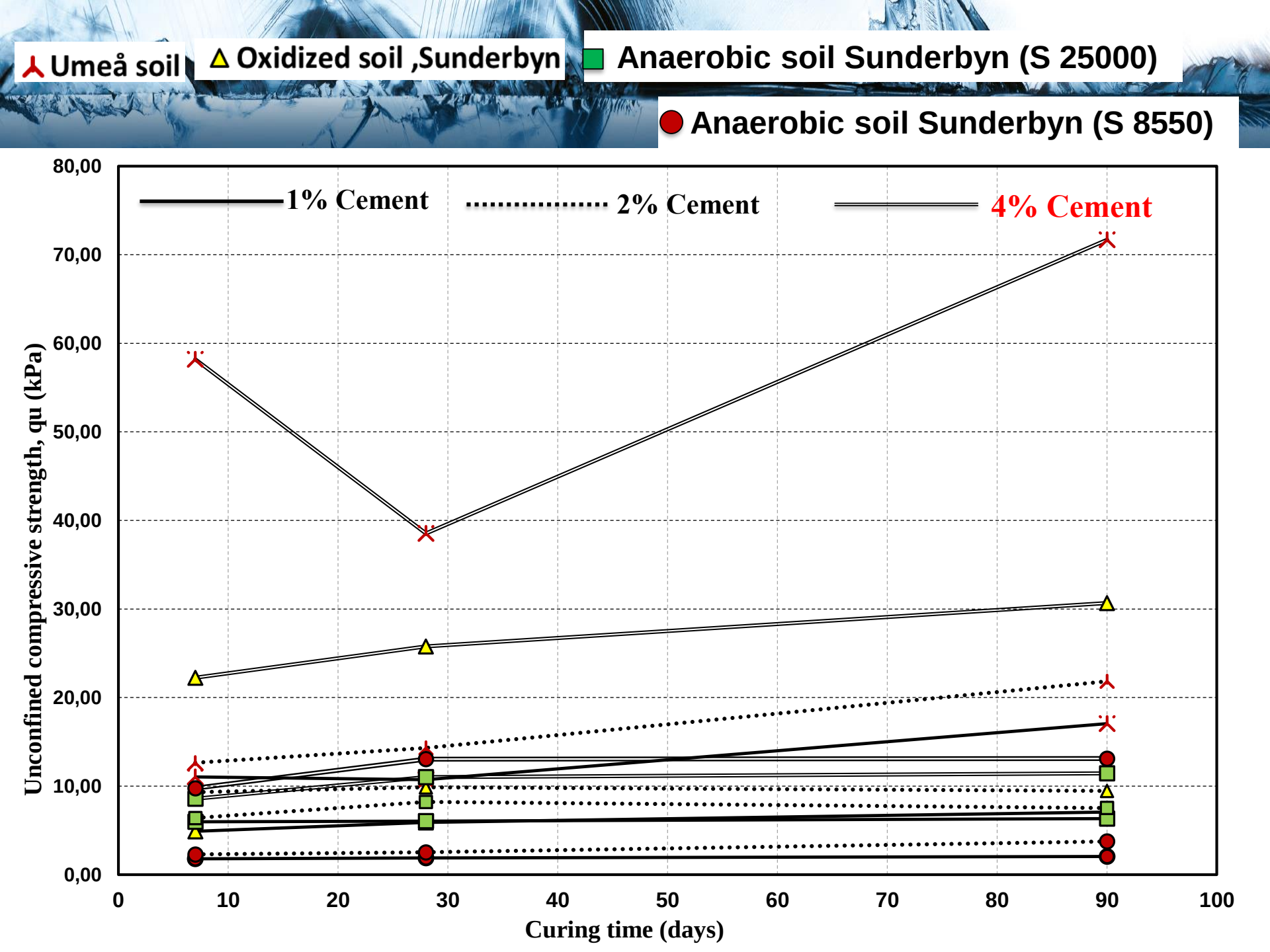
Anaerobic soil Sunderbyn (S 8850)



Stabilized soils

Enhancement in soil strength


Umeå soil
Oxidized soil ,Sunderbyn
Anaerobic soil Sunderbyn (S 25000)
Anaerobic soil Sunderbyn (S 8550)
1% Cement
2% Cement
Unconfined compressive strength, qu (kPa)
Curing time (days)
0
5
10
15
20
25
0
10
20
30
40
50
60
70
80
90
100

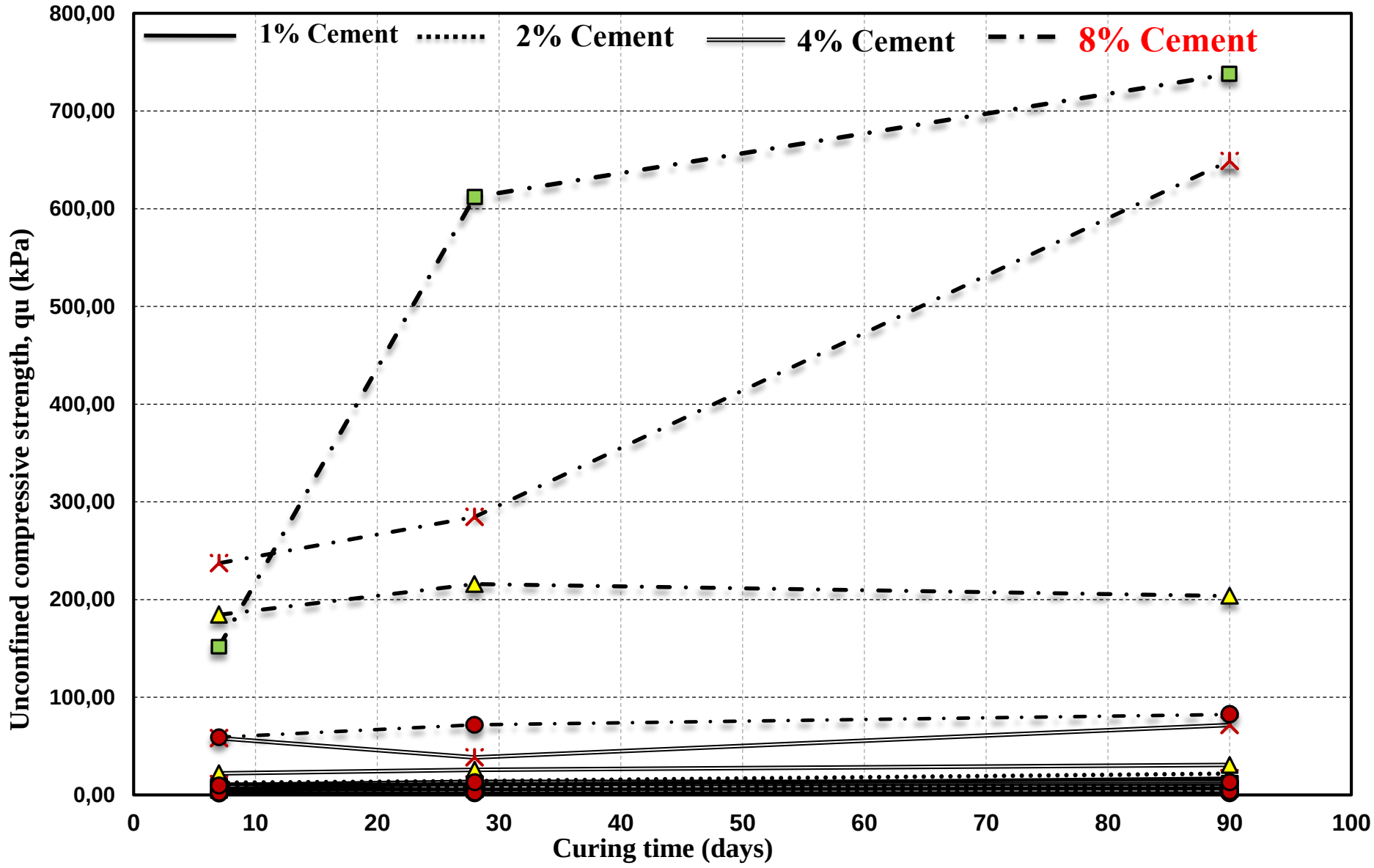

Umeå soil
Oxidized soil ,Sunderbyn
Anaerobic soil Sunderbyn (S 25000)
Anaerobic soil Sunderbyn (S 8550)
1% Cement
2% Cement
4% Cement
Unconfined compressive strength, qu (kPa)
80,00
70,00
60,00
50,00
40,00
30,00
20,00
10,00
0,00
0
10
20
30
40
50
60
70
80
90
100
Curing time (days)

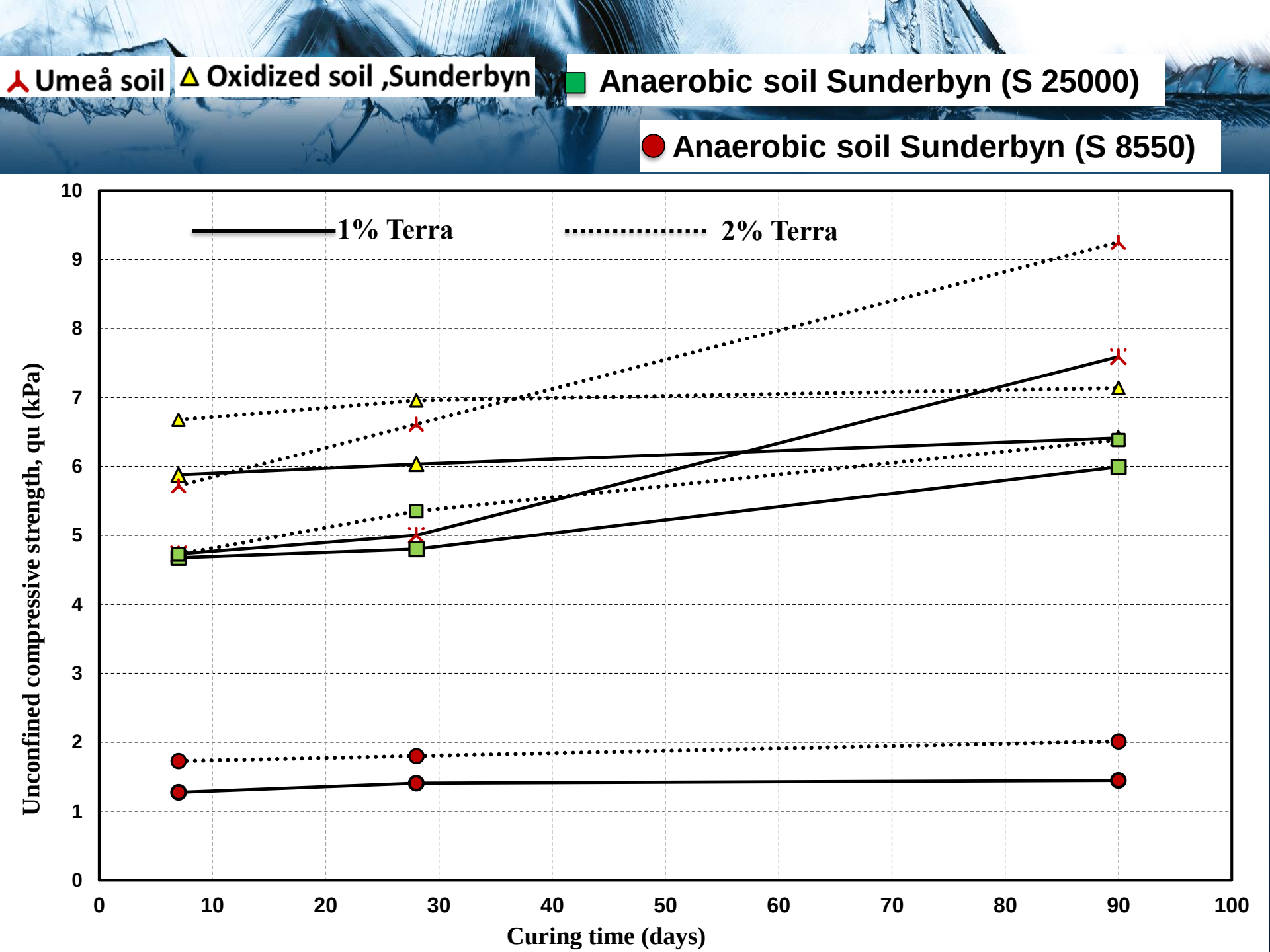
Umeå soil

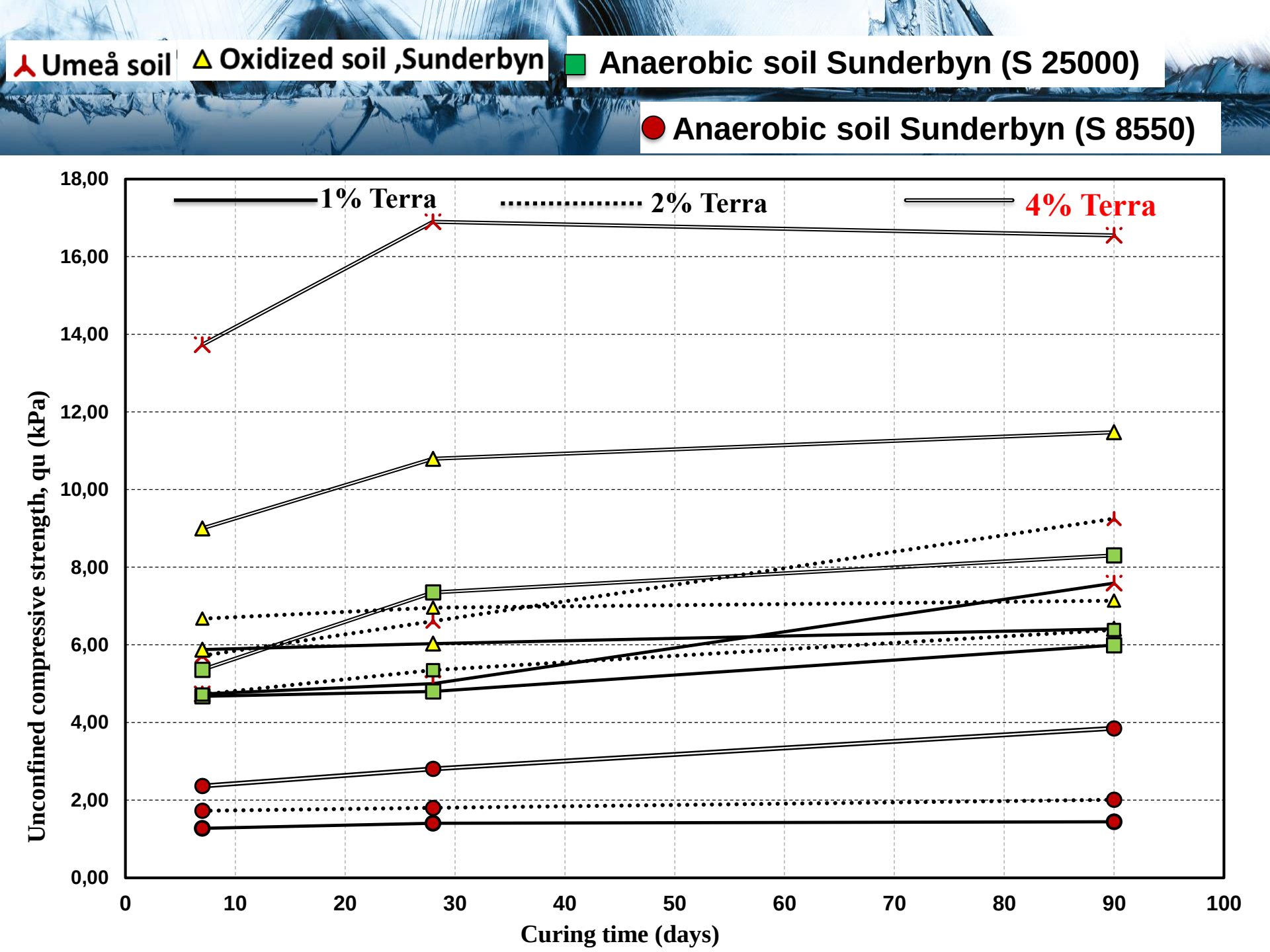
Oxidized soil ,Sunderbyn

Anaerobic soil Sunderbyn (S 25000)

Anaerobic soil Sunderbyn (S 8550)




Umeå soil
Oxidized soil ,Sunderbyn
Anaerobic soil Sunderbyn (S 25000)
Anaerobic soil Sunderbyn (S 8550)
1% Terra
2% Terra
Unconfined compressive strength, qu (kPa)
Curing time (days)
0
1
2
3
4
5
6
7
8
9
10
0
10
20
30
40
50
60
70
80
90
100

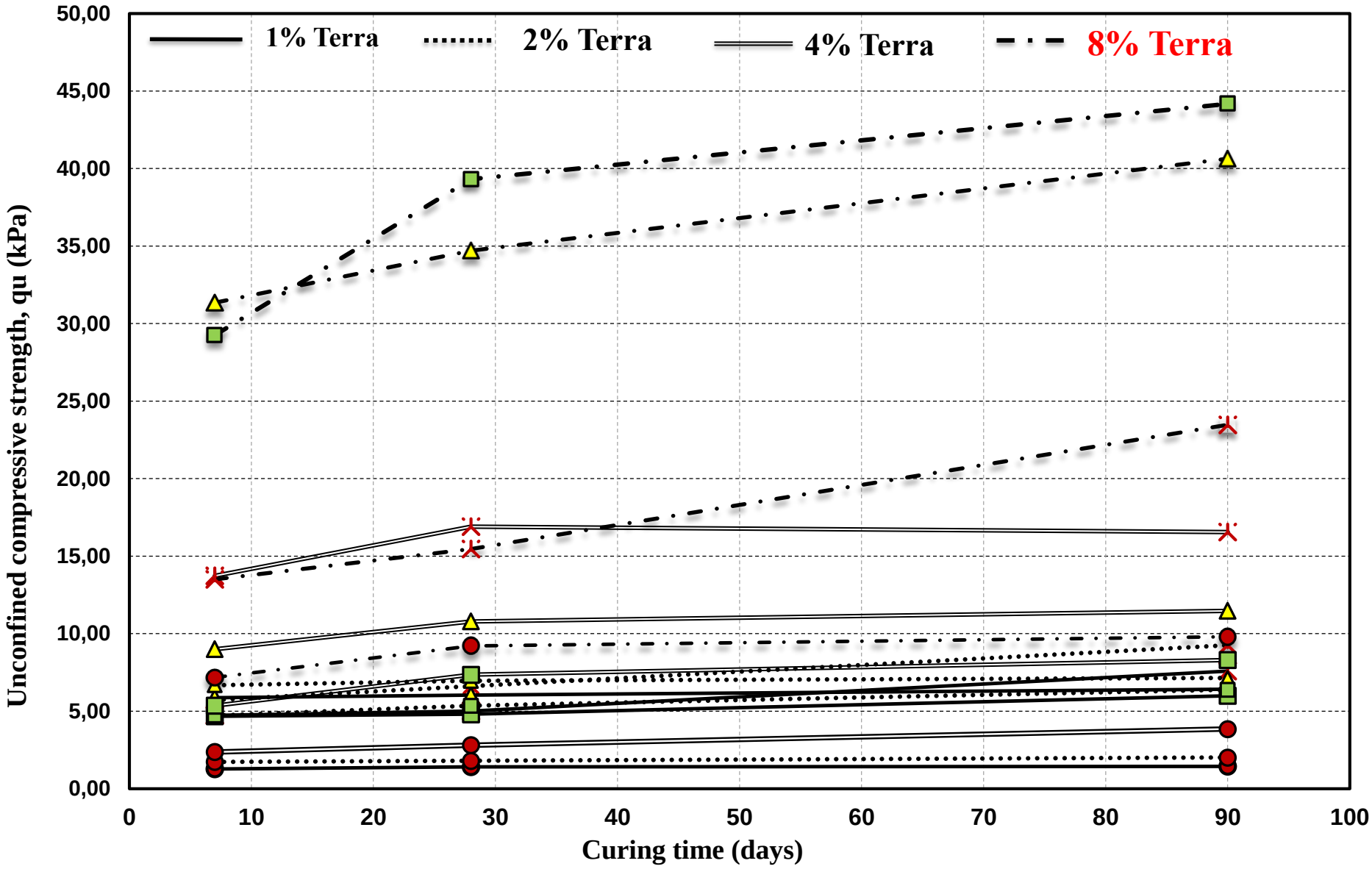

Umeå soil
Oxidized soil ,Sunderbyn
Anaerobic soil Sunderbyn (S 25000)
Anaerobic soil Sunderbyn (S 8550)
1% Terra
2% Terra
4% Terra
Unconfined compressive strength, qu (kPa)
Curing time (days)
18,00
16,00
14,00
12,00
10,00
8,00
6,00
4,00
2,00
0,00
0
10
20
30
40
50
60
70
80
90
100

Umeå soil

Oxidized soil ,Sunderbyn

Anaerobic soil Sunderbyn (S 25000)

Anaerobic soil Sunderbyn (S 8550)



Summary

- The addition of small binder amounts increase the strength and stiffness in short and long-term perspectives.
- Cement is more effective in improving strength properties comparing to Terra.
- The gain in soil strength is noticed for the anaerobic soil with high sulfide content (25000) comparing to other soil types.
- Both binder type have initial effect of increase the soil pH value to about 12.5 and 10 for Umea soil and sunderbyn soils respectively.
- Adding 1 % of both binder type has almost no effect on increase the soil pH value of the anaerobic soil with high sulfide content (25000)

Thank You

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Homogeneity of the Soil Samples after Treatment

1%Cement

2%Cement

4%Cement

8%Cement

Effect of pH value on the solubility of most soil minerals after (Loughnan, 1969)