
Modified Dry Mixing (MDM)
a new possibility in Deep Mixing
LCTechnology
Hercules Grundläggning

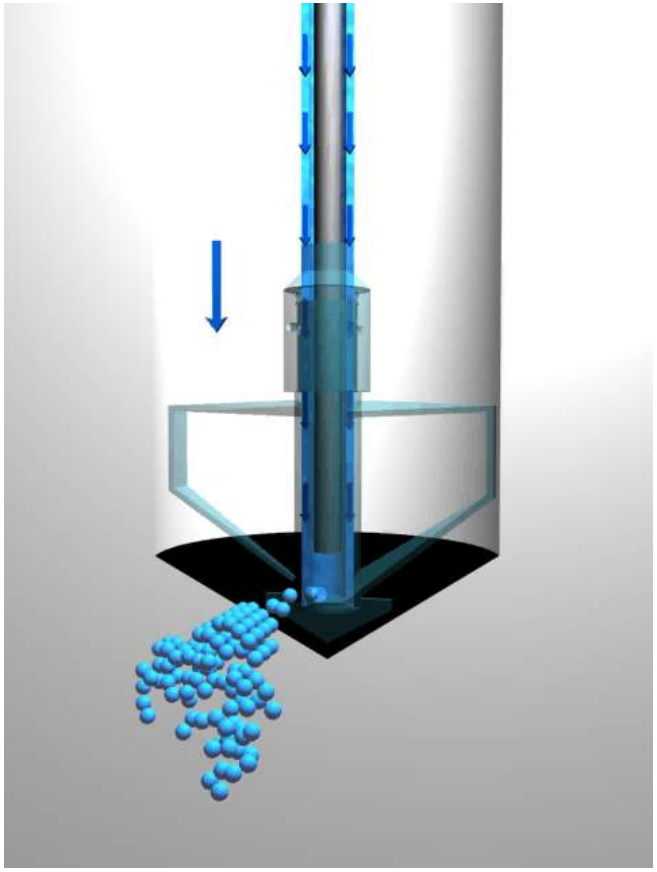
MDM – contribution

- Lower selling price
- 30 to 50% shorter installation time
- Investments
  - Increased shift costs
  - Increased assets
- Remaining measures
  - Introduction of binder during penetration
  - Revised control of binder outlet
- New applications
- Two equipments in one

The MDM Process - Purpose

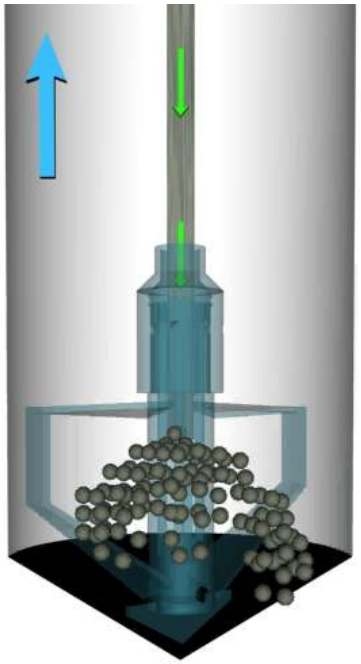
- Improve pre-mixing potential
  - Increase sensitivity
  - Increase liquidity index
- Fluidisation of soil
  - Mechanic
  - Hydraulic
- Introduction of binder
  - Penetration and/or retrieval
  - Binder quantities adjustable according to soil type
  - Zone program for water and binder
- Fully computer controlled process
  - Binder quantity
  - Mixing energy
  - Water flow/pressure

The MDM Process - Penetration



- Mechanical & hydraulic disaggregation
- Reduction of cohesion & friction by injection of water
- Introduction of binder and mixing with soil

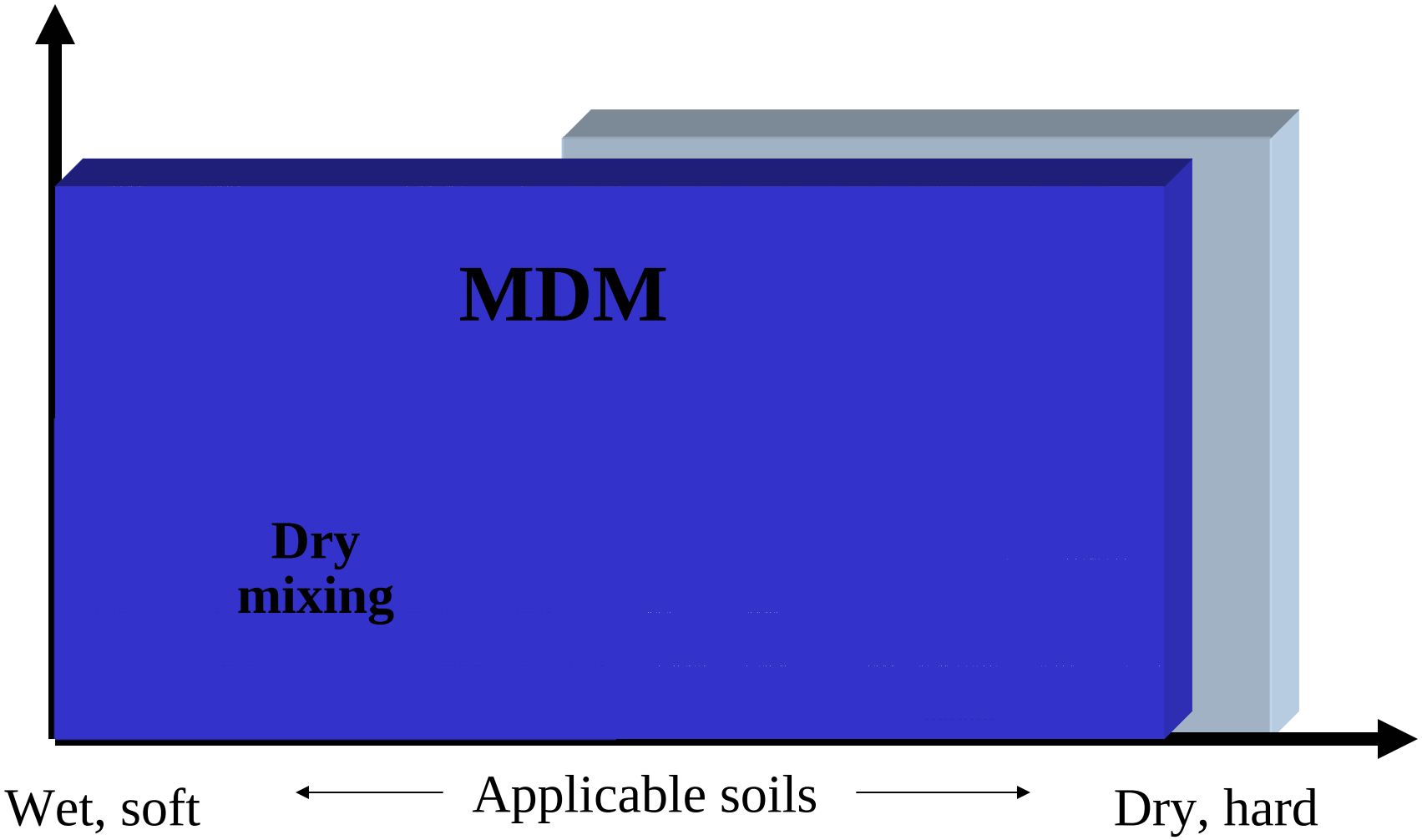
The MDM Process - Retrieval



- Reduction of cohesion & friction by injection of water
- Introduction of binder and mixing with soil

Column Strength

Versatility of MDM

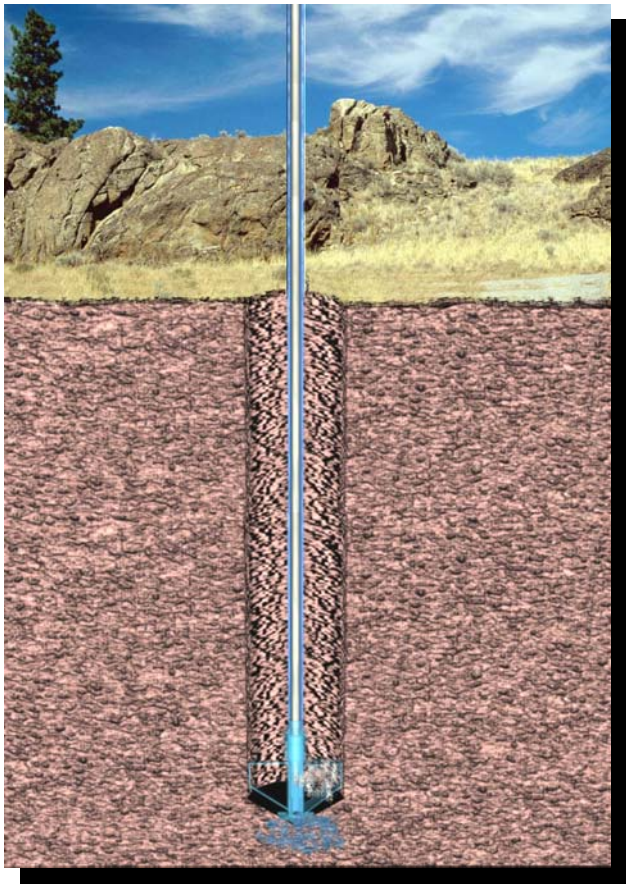


Deep Mixing Equipment

MDM

Wet **Dry**

The MDM system – new possibilities



- Combines the advantages from the wet and dry mixing
- Widens the range of applications using the same equipment

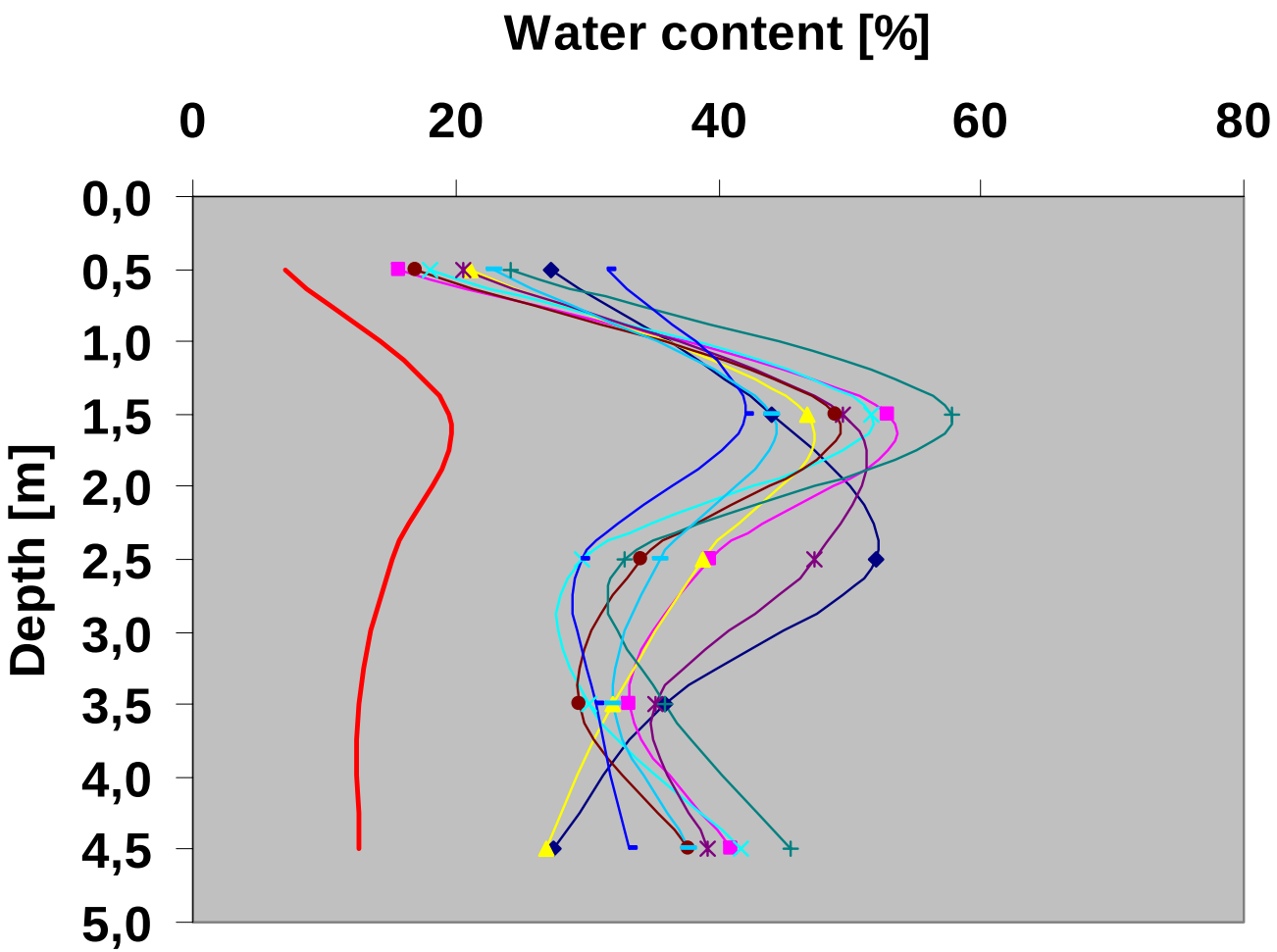
Major advantages

- Wide spectrum of soils
  - dry/wet
  - soft/stiff
- Tailor-made columns
  - Optimized water content
  - Optimized binder content
- No surface spoil
- Computerised process control
- Same equipment for wet & dry mixing

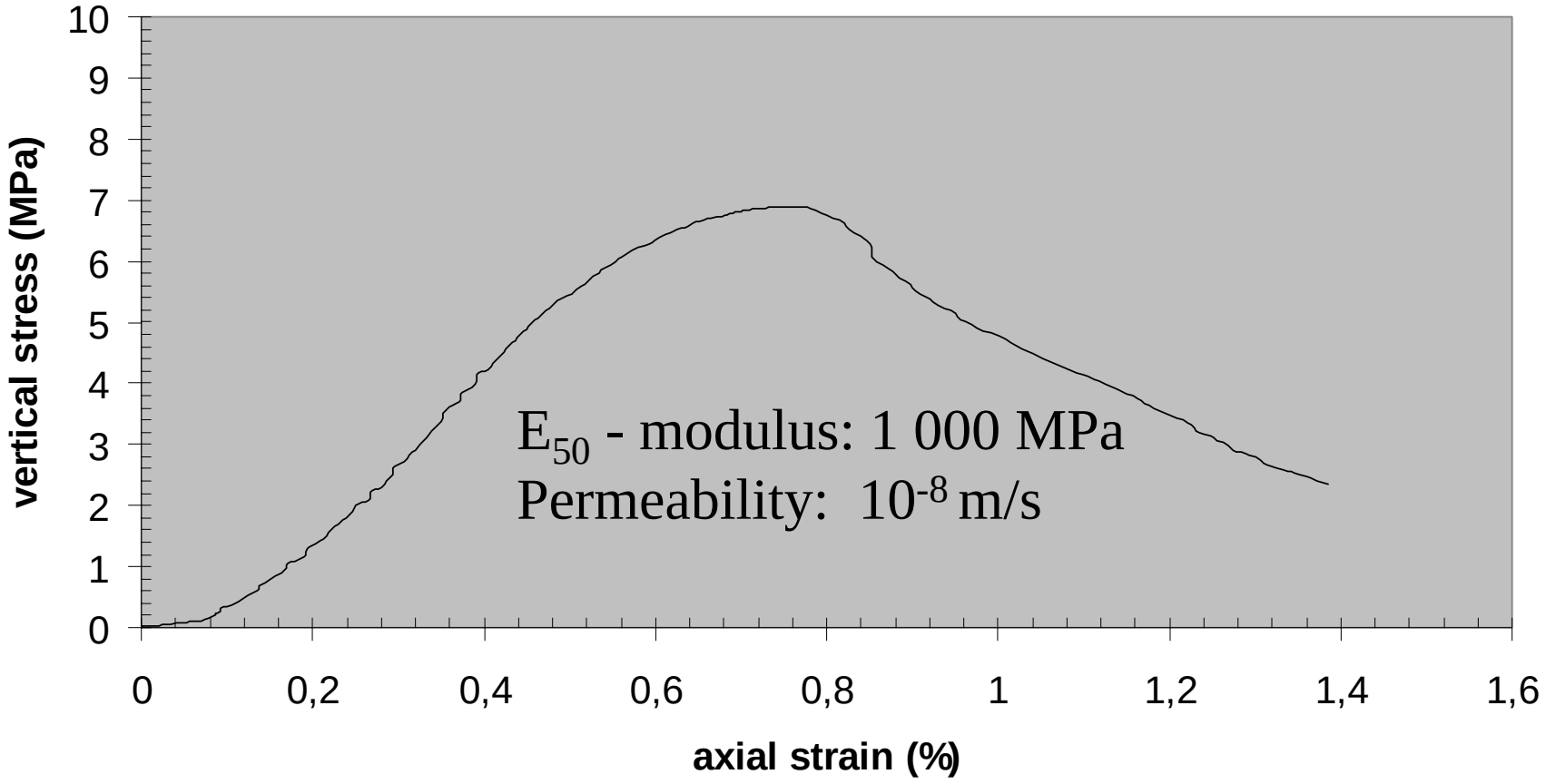
Field test in stiff “dry” sand, Tullinge

- Soil parameters
  - Fine to medium sand
  - q_c-value 20 – 30 MPa
  - water content 5 – 15%
- Column parameters
  - Diameter 800 mm
  - Length 10 m
  - Binder content 450 kg/m^3

Water content; before & after installation



Unconfined compression strength



Field test in very soft clay, Uppsala

- Soil parameters
  - Very soft clay
  - Shear strength: 20–35 kPa
  - Water content: 60–80%
  - Liquidity index: 0.6–1.1
- Column parameters
  - Diameter 600 mm
  - Length 10 m
  - Binder content 450 kg/m^3

Achieved results

- Improved homogeneity
  - Compared to dry mixing
- Coefficient of variation
  - 15 to 30%
- Compressive strength:
  - q=5.7 MPa

Result of mixing in competent dry crust

Dry Mixing - Crater

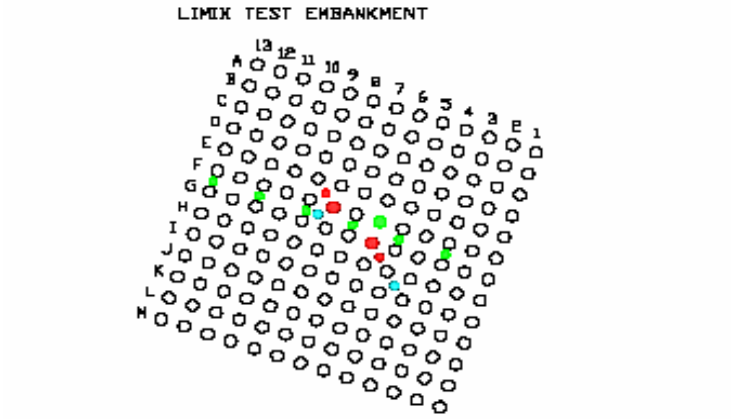
MDM – Good quality column

Test embankment at Torp, Uddevalla

- Behaviour of two test embankments
  - MDM
  - Dry Mixing (Limix)
- Control objectives
  - Settlement
  - Strength
  - Pore pressure
  - Chemical analysis (Ca)
  - Behaviour of geogrid (load transfer platform)

Soil parameters

Layout of MDM and Limix columns

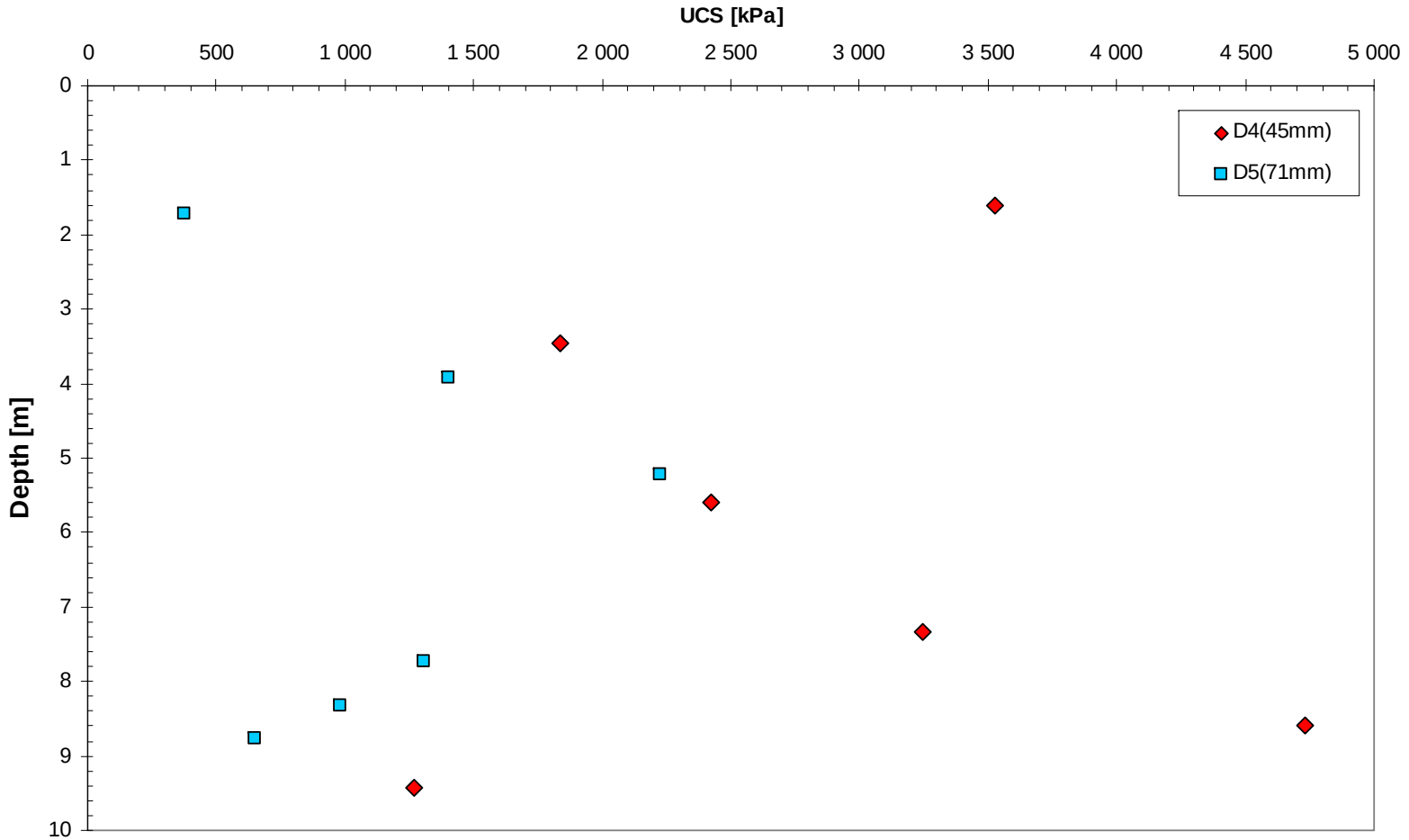


- MDM
  - Diameter ϕ600 mm
  - Length 10 m
  - Spacing 2.2 m
- Limix
  - Diameter ϕ600 mm
  - Length 14 m
  - Spacing 1.2 m

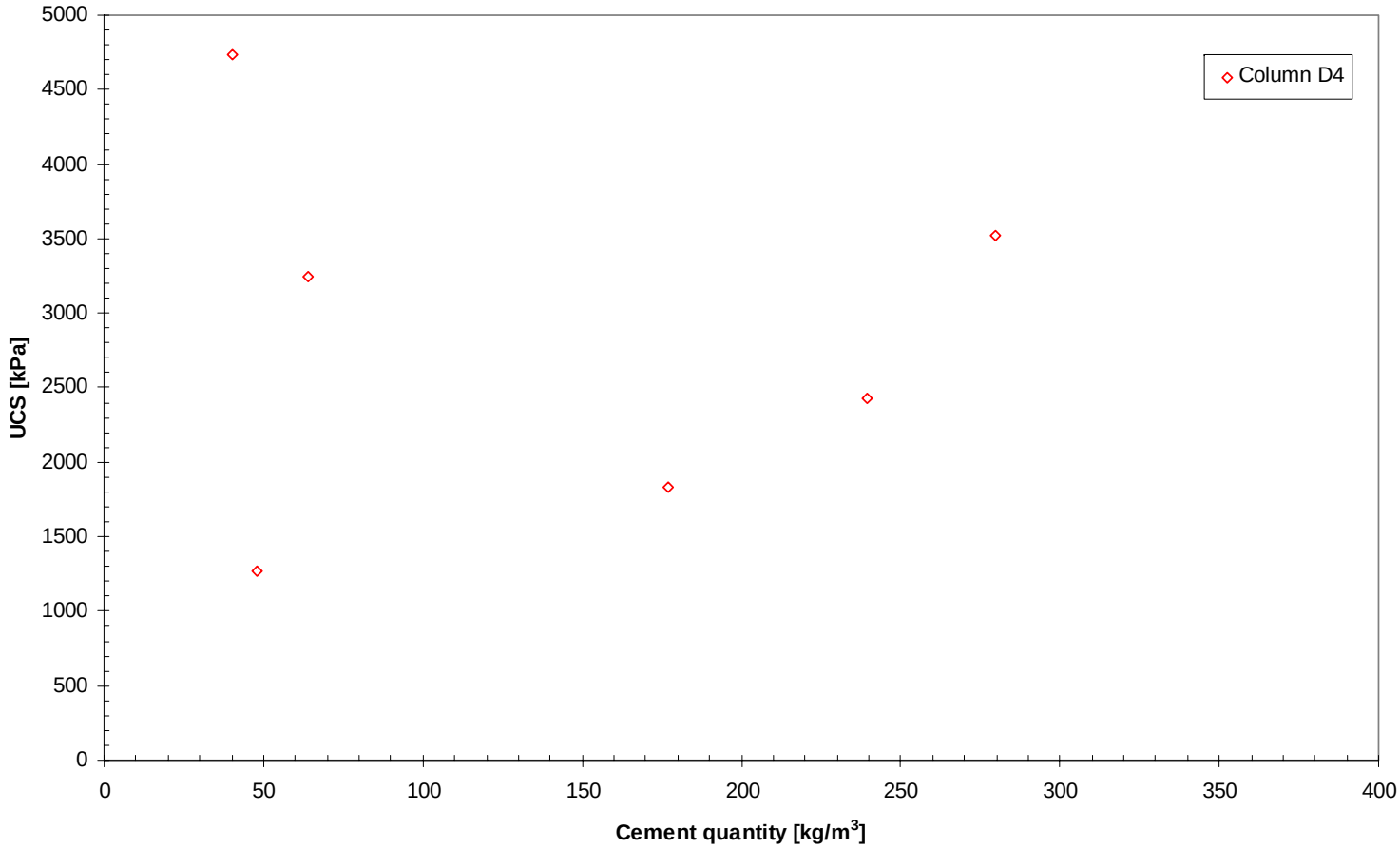
Core sampling – MDM columns

- Double barrel, split tube
  - Diameter ϕ45 and ϕ71 mm
  - Length 10 m
  - Columns D4 & D5

MDM columns – UCS on core samples



MDM Columns – UCS vs cement quantity



Full-scale (excavated) test columns

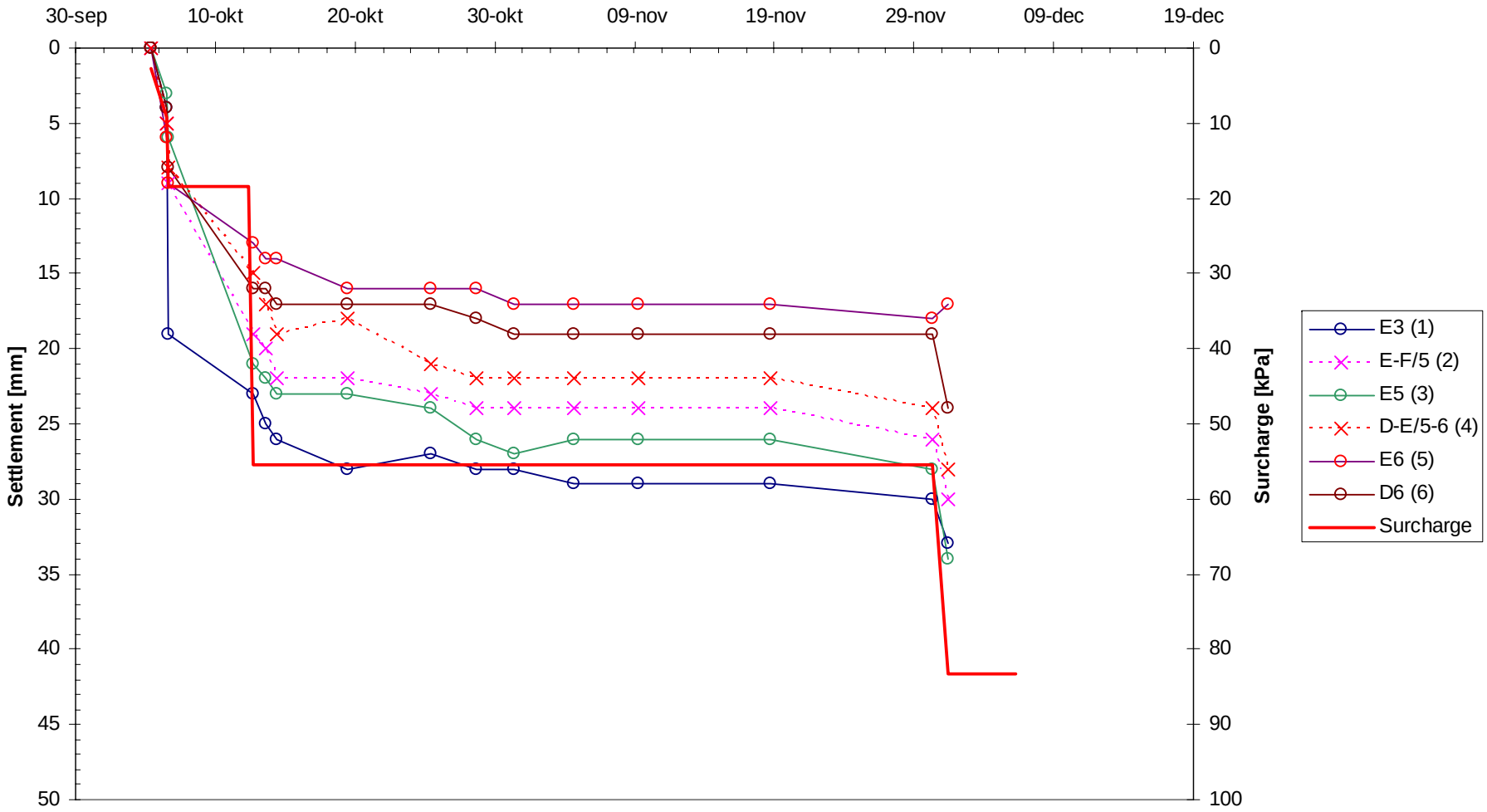
Construction & Instrumentation - MDM

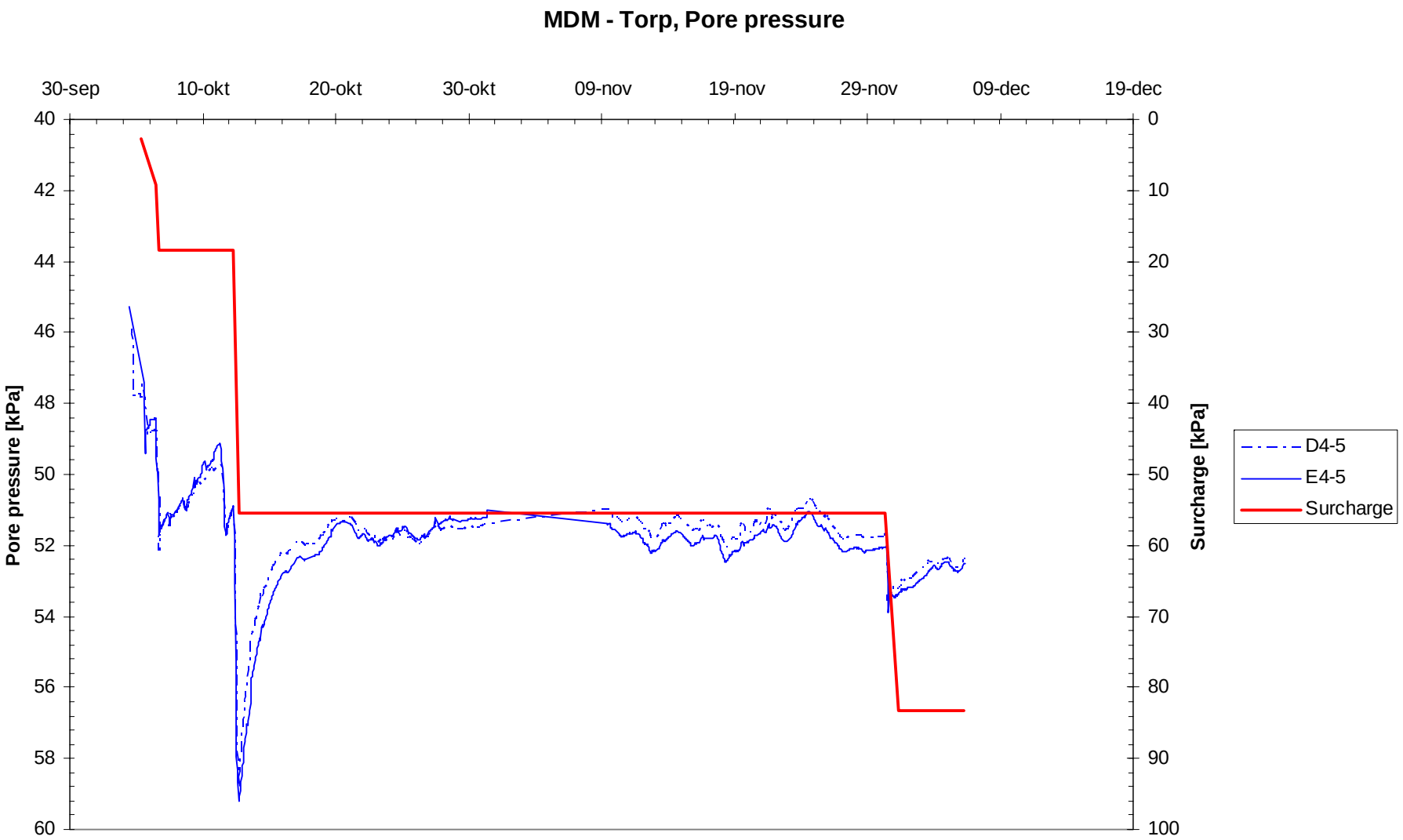
- Settlement gages
  - On top of columns
  - Between columns
- Pore pressure gages
  - Between columns
- Pressure cells
  - On top of columns
  - Between columns

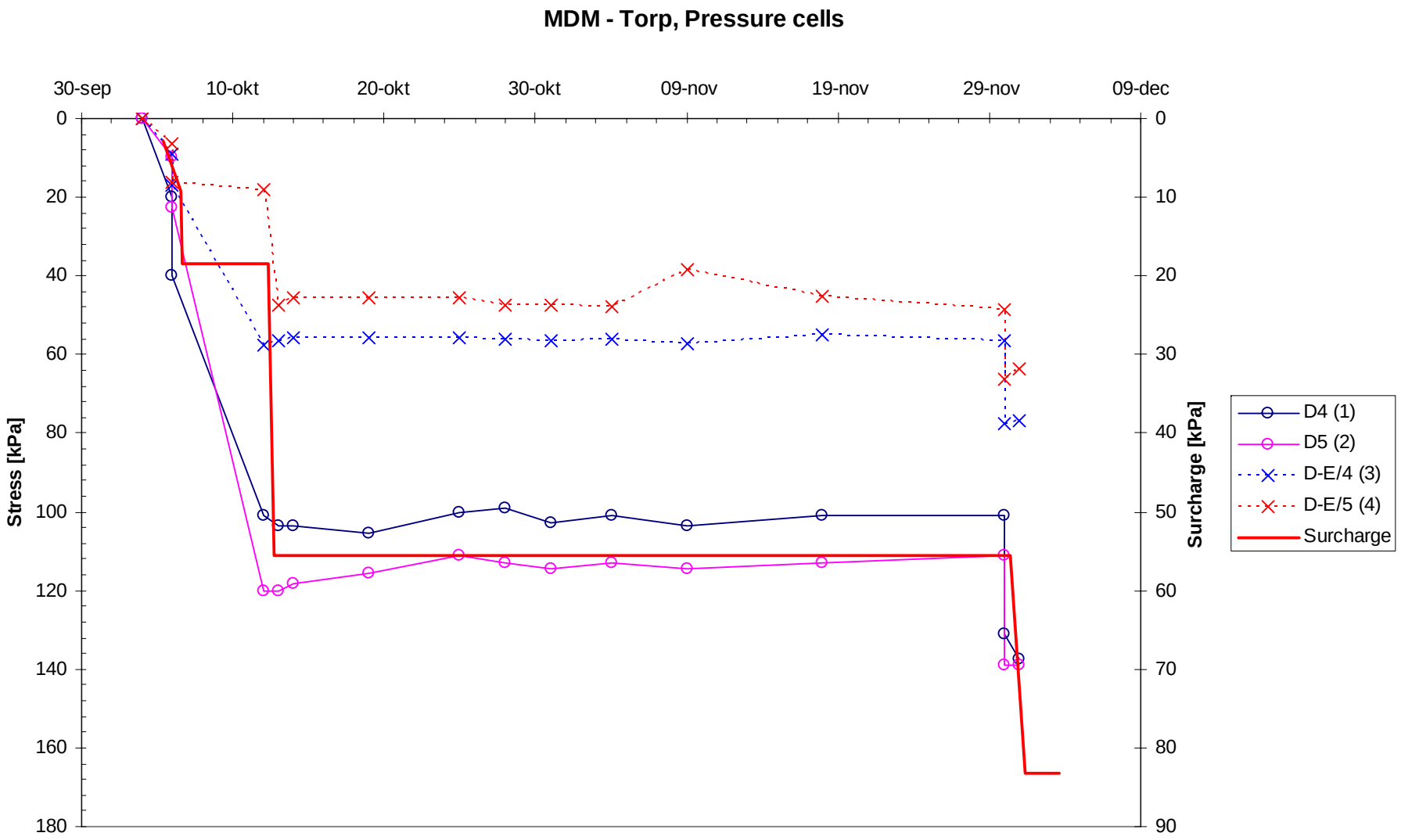
Construction & Instrumentation - Limix

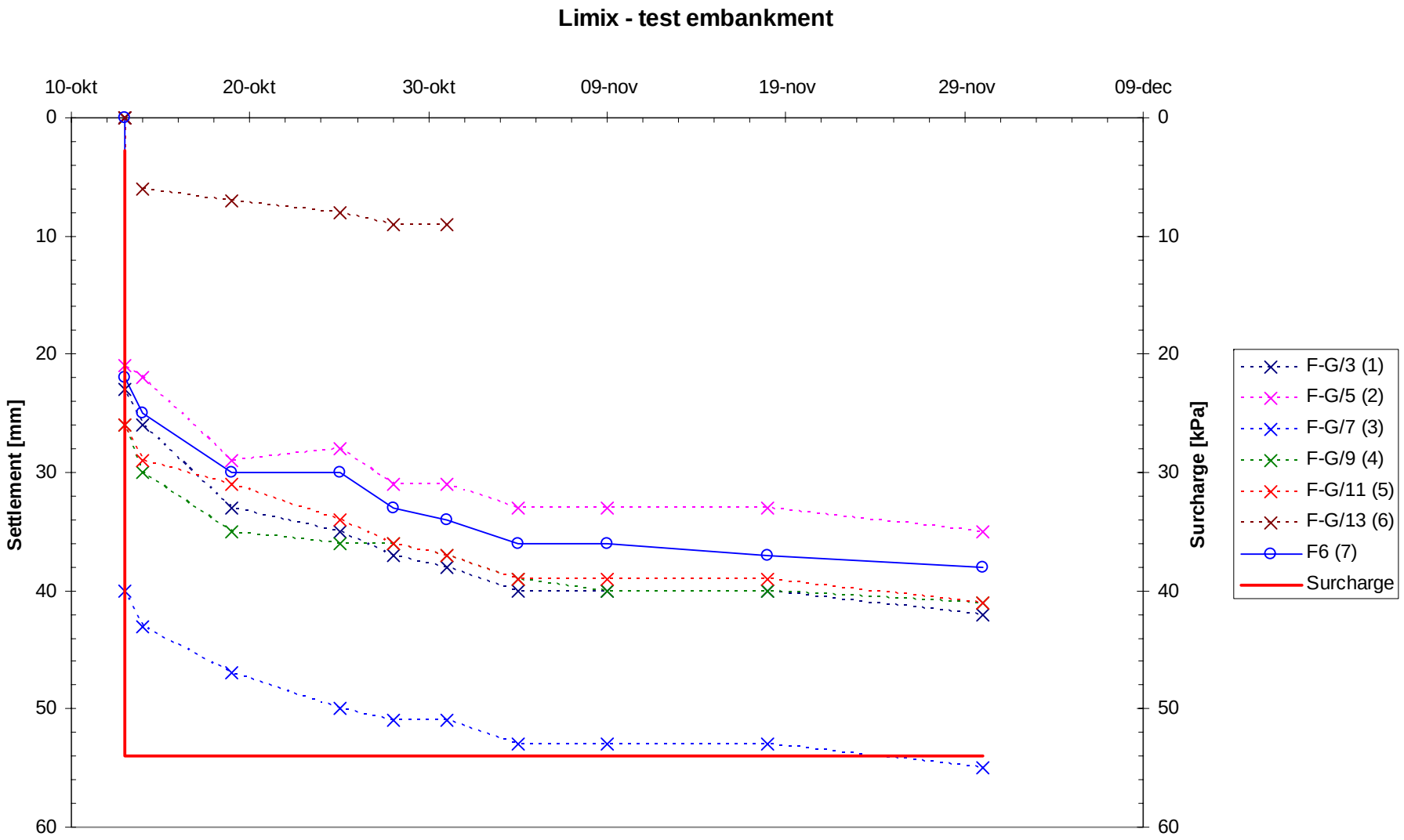
- Settlement gages
  - On top of columns
  - Between columns
- Pore pressure gages
  - Between columns

Test embankments – finished construction

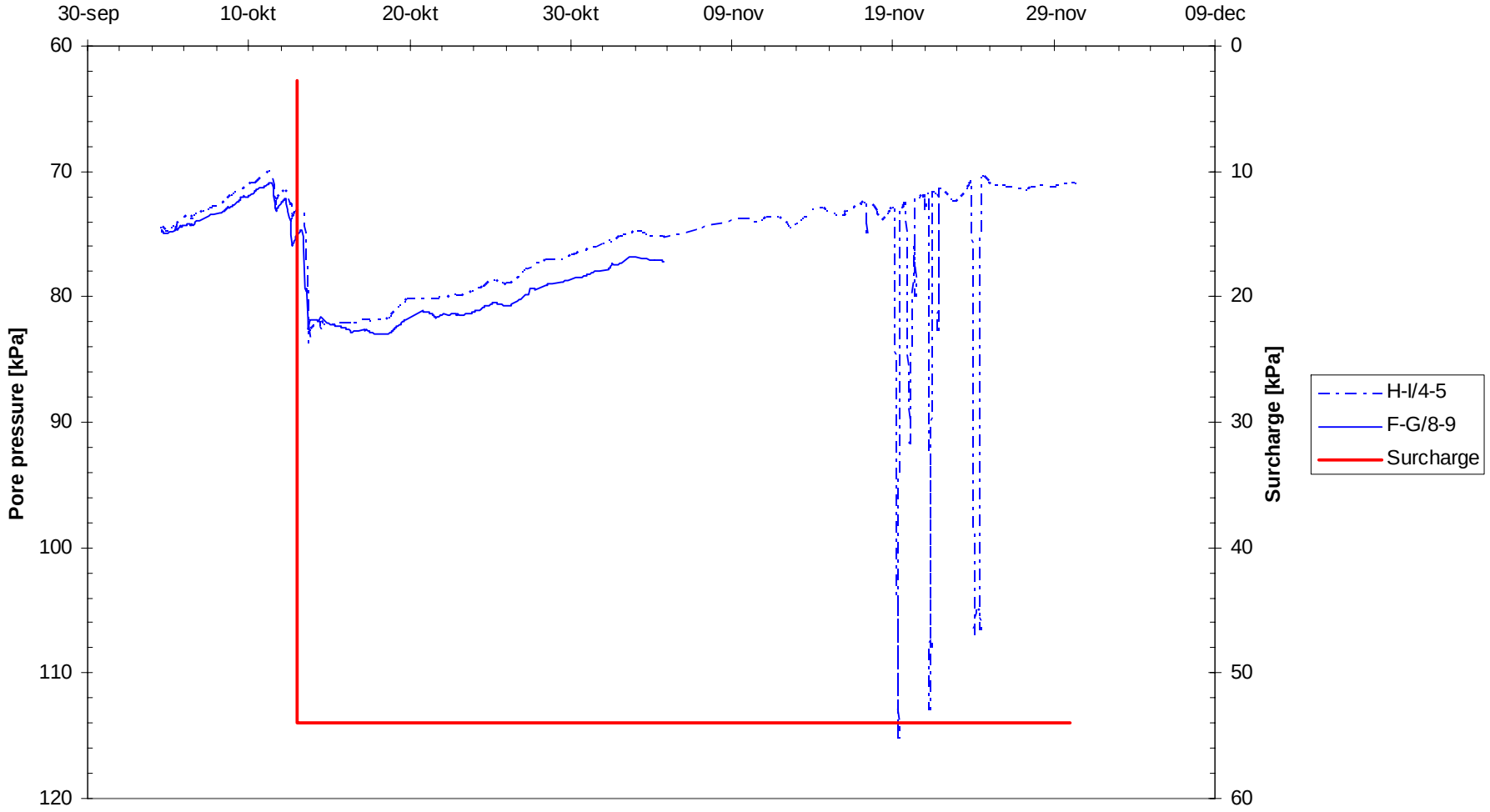

MDM - Torp, Settlements
30-sep
10-okt
20-okt
30-okt
09-nov
19-nov
29-nov
09-dec
19-dec
Settlement [mm]
Surcharge [kPa]
0
5
10
15
20
25
30
35
40
45
50
0
10
20
30
40
50
60
70
80
90
100
E3 (1)
E-F/5 (2)
E5 (3)
D-E/5-6 (4)
E6 (5)
D6 (6)
Surcharge


MDM - Torp, Pore pressure
30-sep
10-okt
20-okt
30-okt
09-nov
19-nov
29-nov
09-dec
19-dec
Pore pressure [kPa]
40
42
44
46
48
50
52
54
56
58
60
Surcharge [kPa]
0
10
20
30
40
50
60
70
80
90
100
D4-5
E4-5
Surcharge


MDM - Torp, Pressure cells
30-sep
10-okt
20-okt
30-okt
09-nov
19-nov
29-nov
09-dec
Stress [kPa]
Surcharge [kPa]
0
20
40
60
80
100
120
140
160
180
10
30
50
70
90
D4 (1)
D5 (2)
D-E/4 (3)
D-E/5 (4)
Surcharge


Limix - test embankment
10-okt
20-okt
30-okt
09-nov
19-nov
29-nov
09-dec
0
10
20
30
40
50
60
Settlement [mm]
Surcharge [kPa]
F-G/3 (1)
F-G/5 (2)
F-G/7 (3)
F-G/9 (4)
F-G/11 (5)
F-G/13 (6)
F6 (7)
Surcharge

Limix - test embankment



QC of MDM – columns

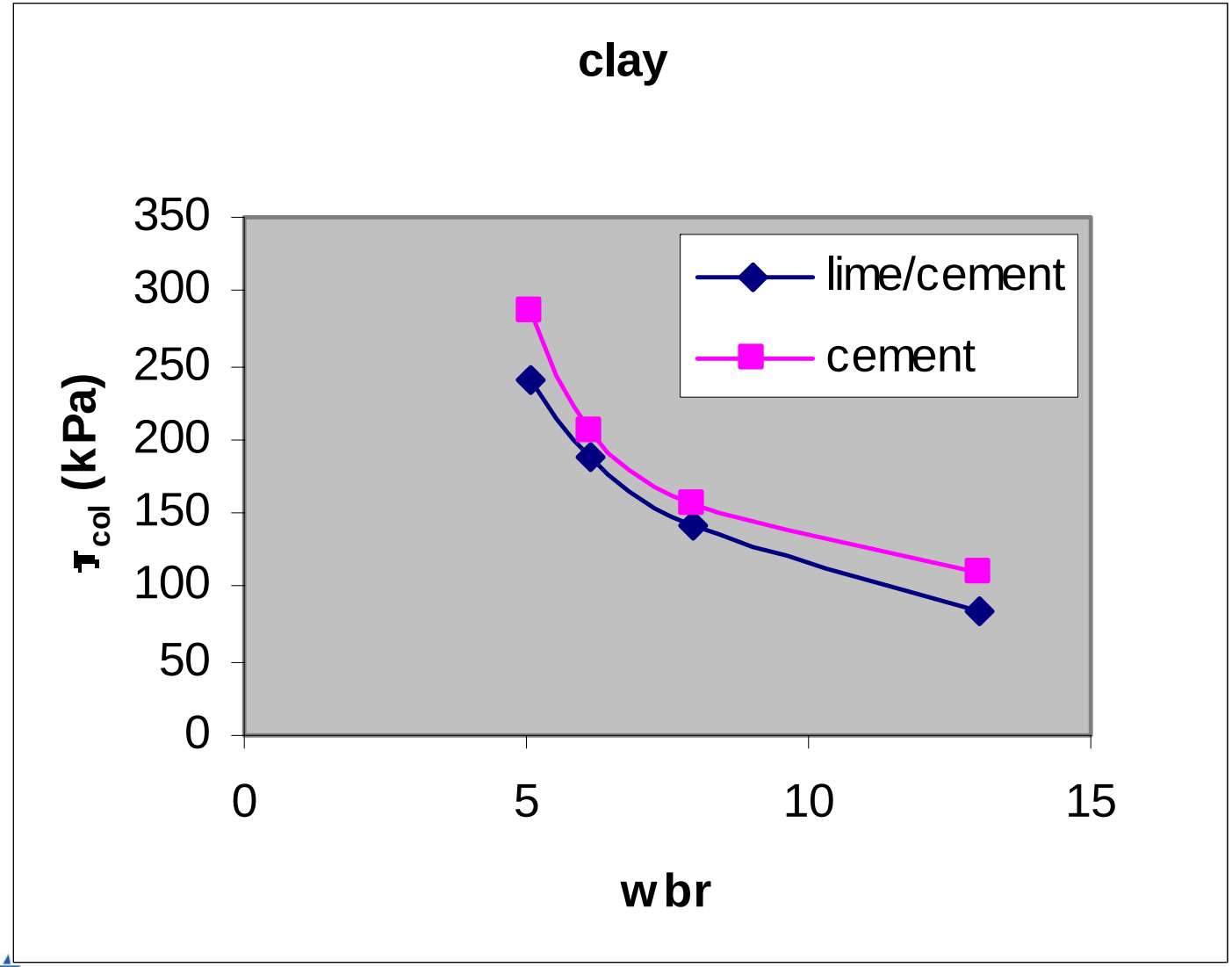
- Core sampling
- Load testing
- Pressure meter
- ICT® (Instant Core Testing, under development)
- Detailed recording of column properties

Applications

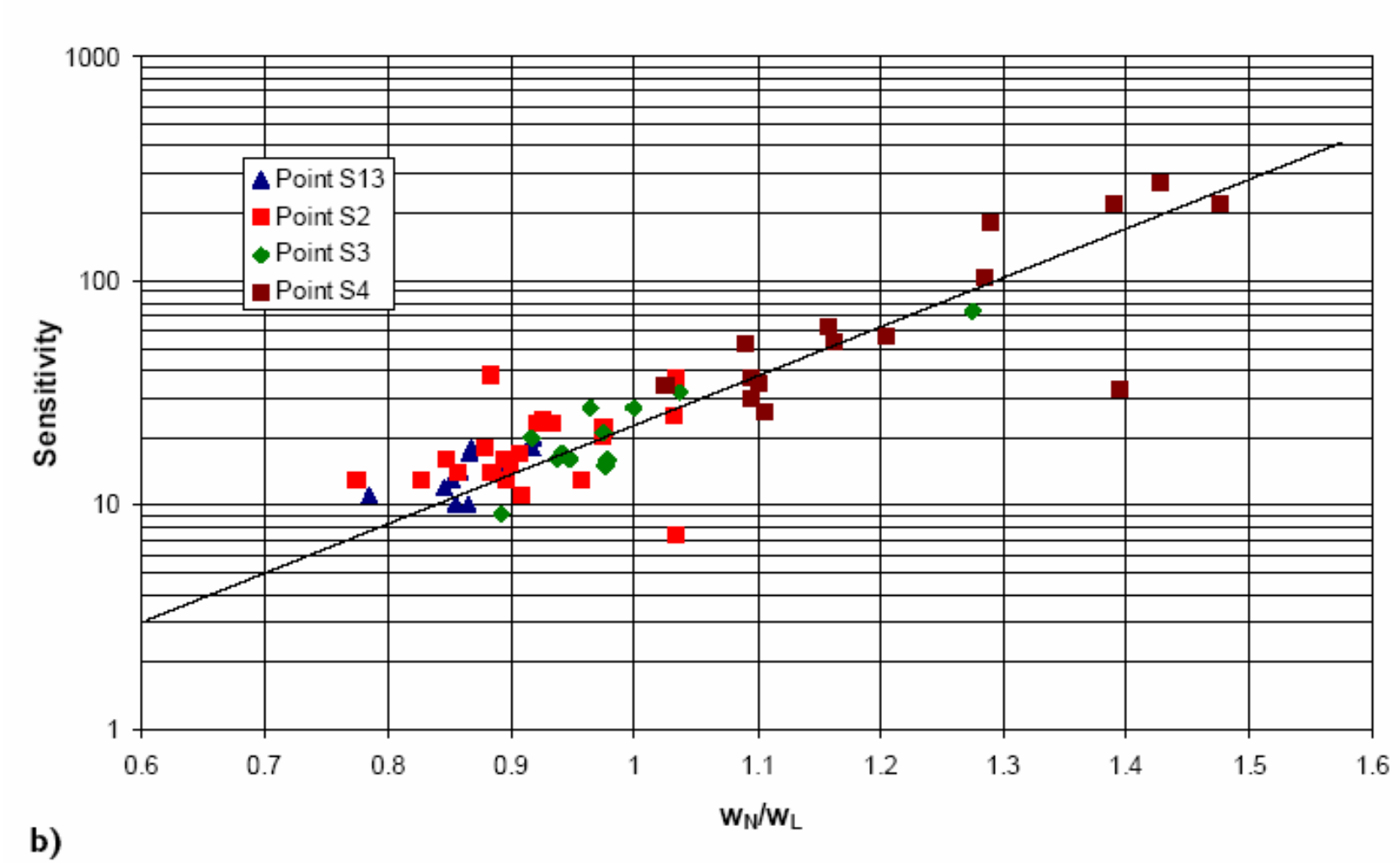
- Embankments
- **Levee walls**
- **Foundation**
- **Retaining walls**
- **Cut – off walls**

Some more applications

Strength vs water cement ratio



Sensitivity vs “liquidity index”



b)

Effect of mixing energy