Effect of Different Periods of Moist Curing on Near-Surface Drying and Ingress of Aggressive Fluids

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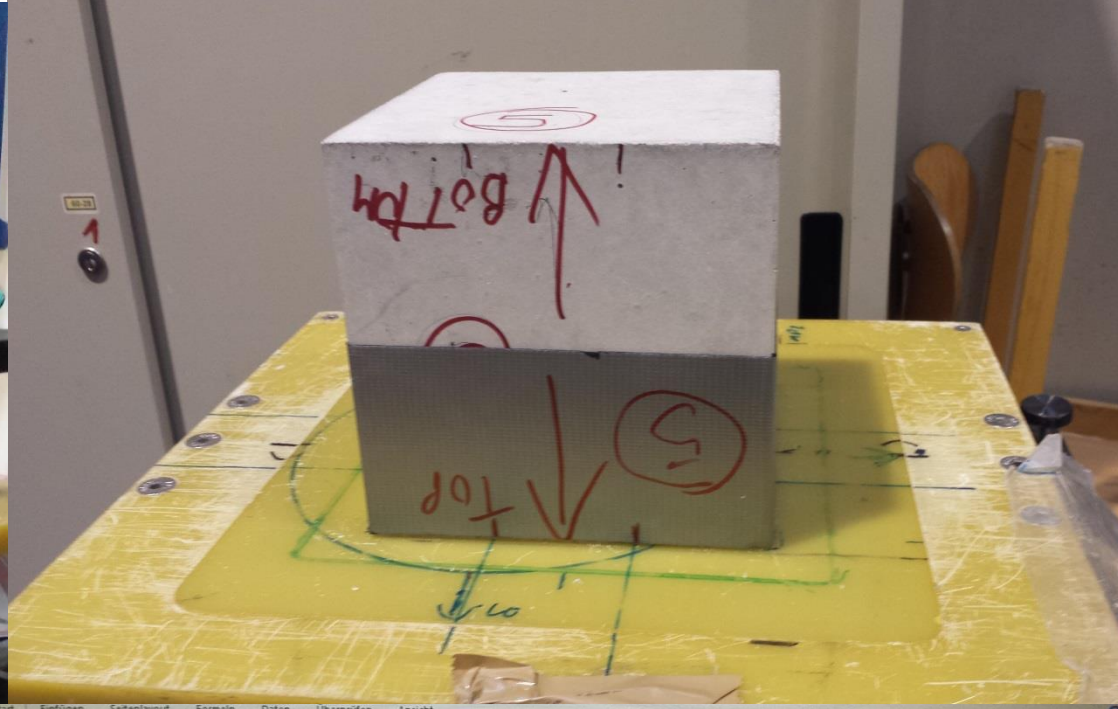
The NMR-Mouse

- Using device developed by RWTH, Aachen University and marketed by Magritek.
- Uses a permanent magnet to align protons in the concrete, therefore the amplitude of the relaxation time signal is proportional to water content (mainly from free water in the pores).
- Measures over an area of 50 x 50 mm with a resolution of 0.10 mm.
- Moisture contents were measured at 0.50 mm depth increments from 0 to 15 mm on 150mm cubes sealed on sides.


ACT GmbH
PM 25


bottom
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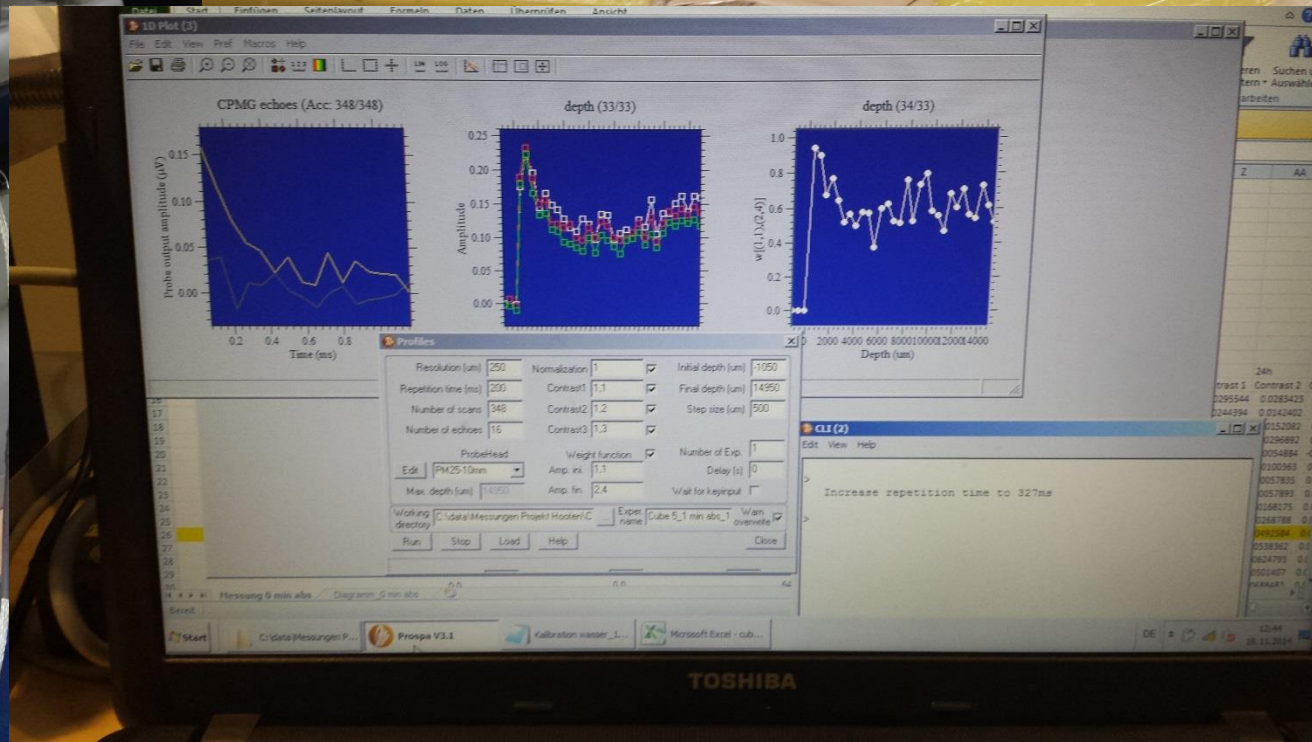
1D Plot (3)
CPMG echoes (Acc: 348/348)
depth (33/33)
depth (34/33)
Probe output amplitude (µV)
Amplitude
Time (ms)
Depth (um)
Profiles
Increase repetition time to 327ms
TOSHIBA

Different Types of Hydrogen (Water) in concrete

Reference

The Potential of Nuclear Magnetic Resonance (NMR) to Non-Destructively Characterize Early-Age Concrete by an One-Sided Access (OSA) Technique

By G. Dobmann1, M. Kroening1, N. Surkowa1, L. von Bernus2, B. Wolter1

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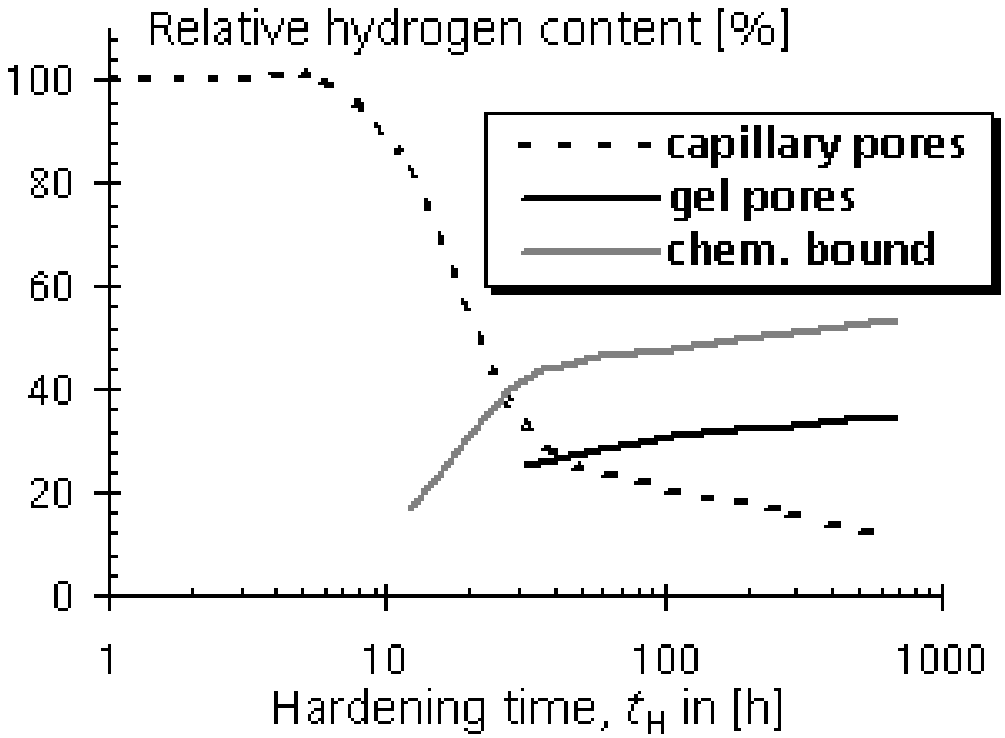
2 QNET - Quality Management GmbH, Altenkesseler Str. 17 B5, 66115 Saarbruecken, Germany



T1 proton relaxation times:
Chemically combined water $<10^{-4}$ s.
Gel water (adsorbed) 10^{-3} s
Free water 10^{-2} s

Concrete Properties

Typical German Highway Concrete Pavement Mixture

- 0.45 w/c
- CEM I 42.5, 360kg/m3
- 22mm greywacke aggregate
- Air-entrained: 5.4% at 10 minutes, 4.7% at 30 minutes
- Flow Table: 370 mm
- 28 days:
  - Cube strength: 43.5 MPa
  - ASTM C1202: 2430 coulombs
  - Bulk Resistivity: 9.8 kohm-cm

Three Types of Curing were used

150 mm cubes were left their molds for the curing and drying periods to get 1-D profiles.

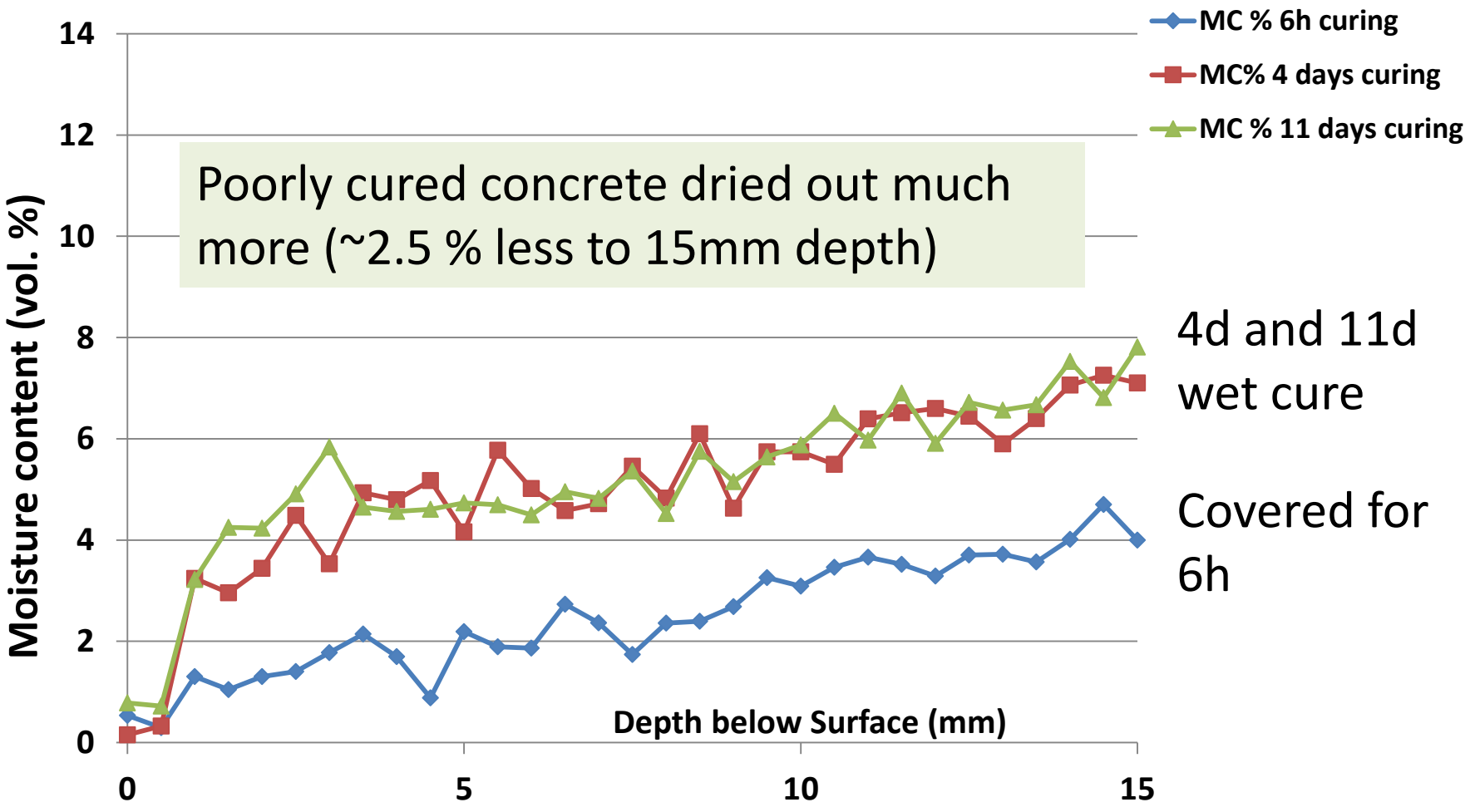
1. Covered with glass plate for 6 hours, then exposed to air at 50% rh at 23^{o}C.

2. Covered for 20 hours, then immersed in water to Day 4, then exposed to air at 50% rh at 23^{o}C.

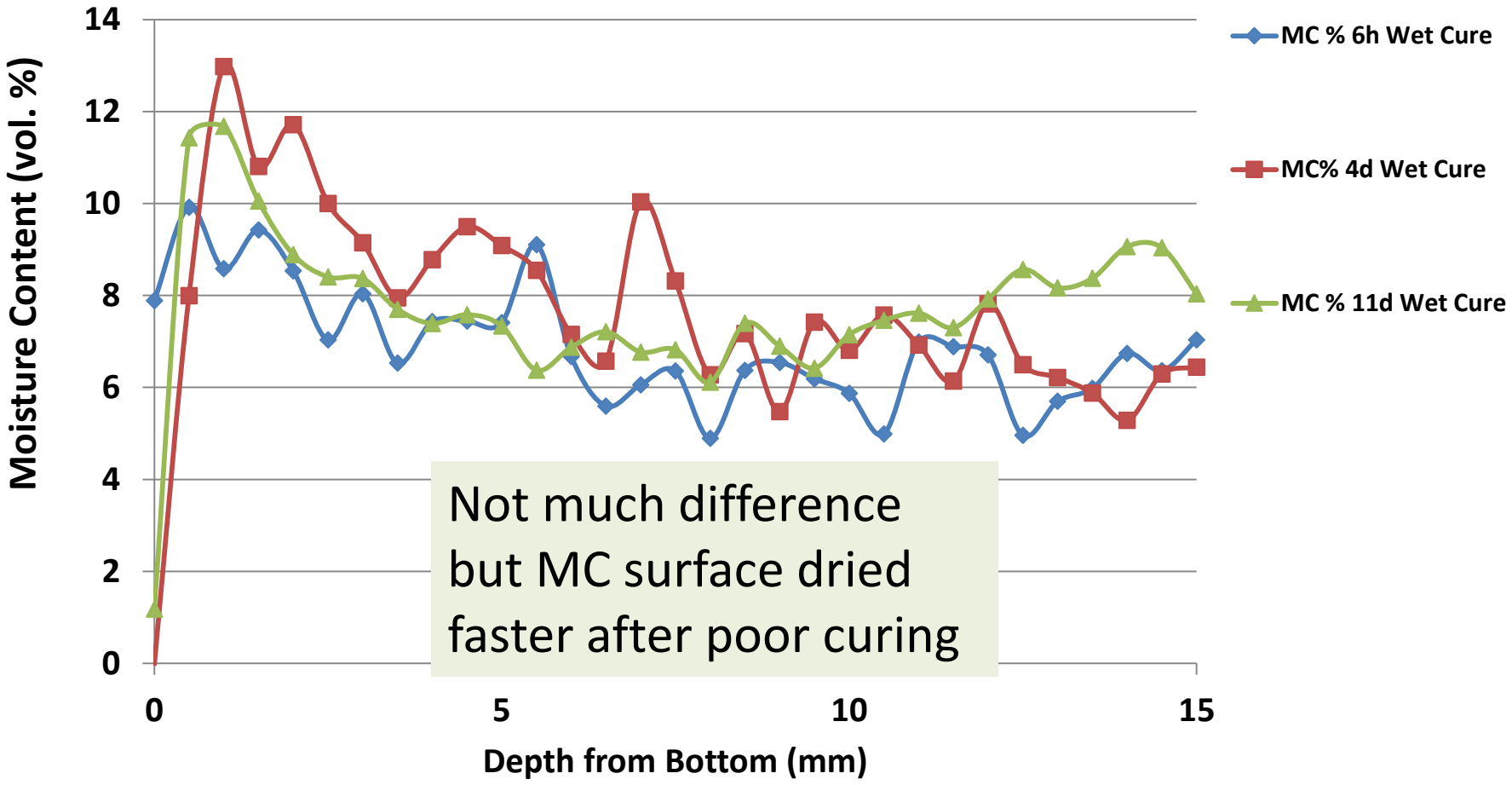
3. Covered for 20 hours, then immersed in water to Day11, then exposed to air at 50% rh at 23^{o}C.

Each 1-face **drying profile** was the average of 2 or 3 profiles at different locations

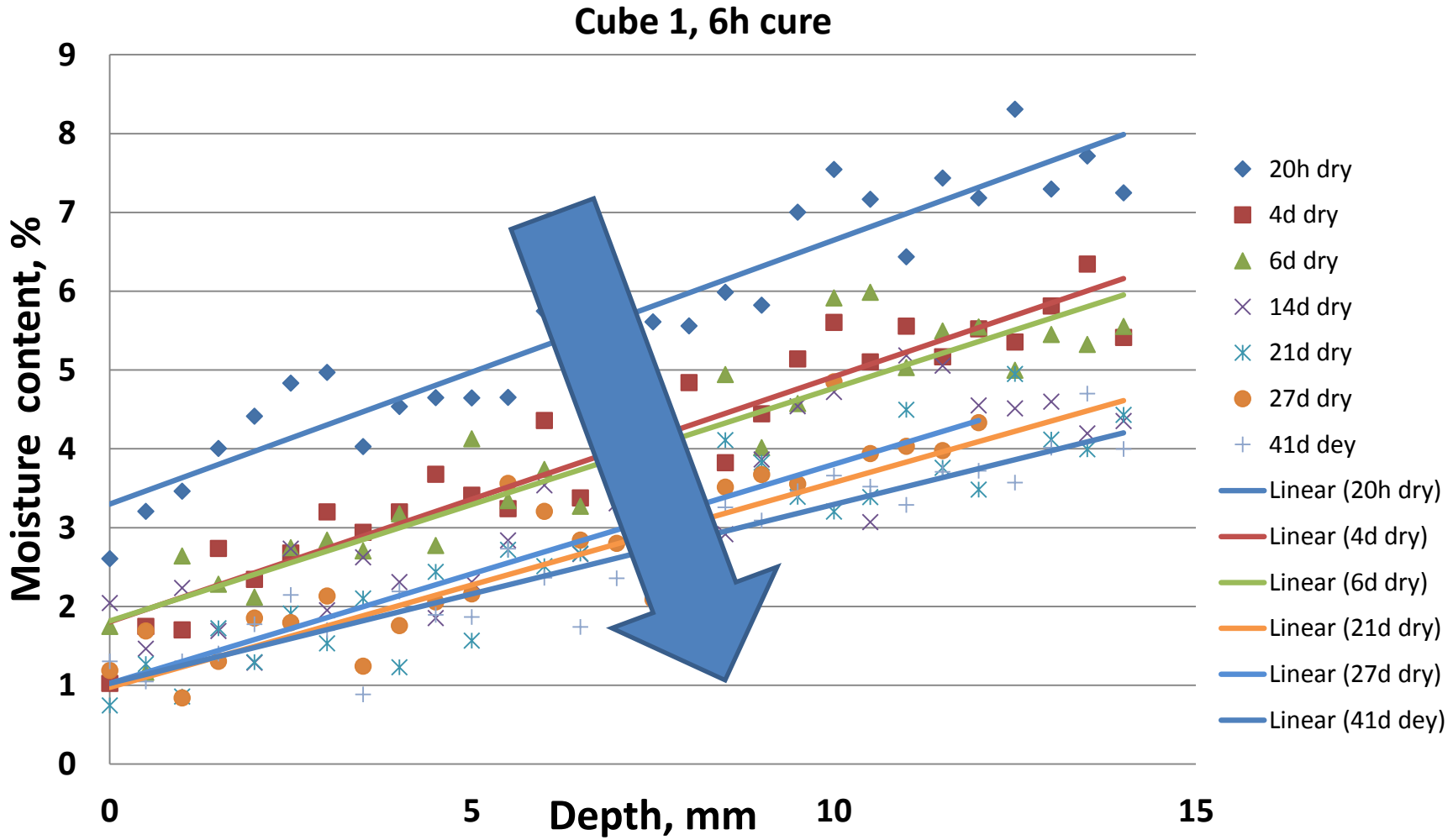
Top Finished Surface: Drying Profiles after 40 Days drying at 50% rh



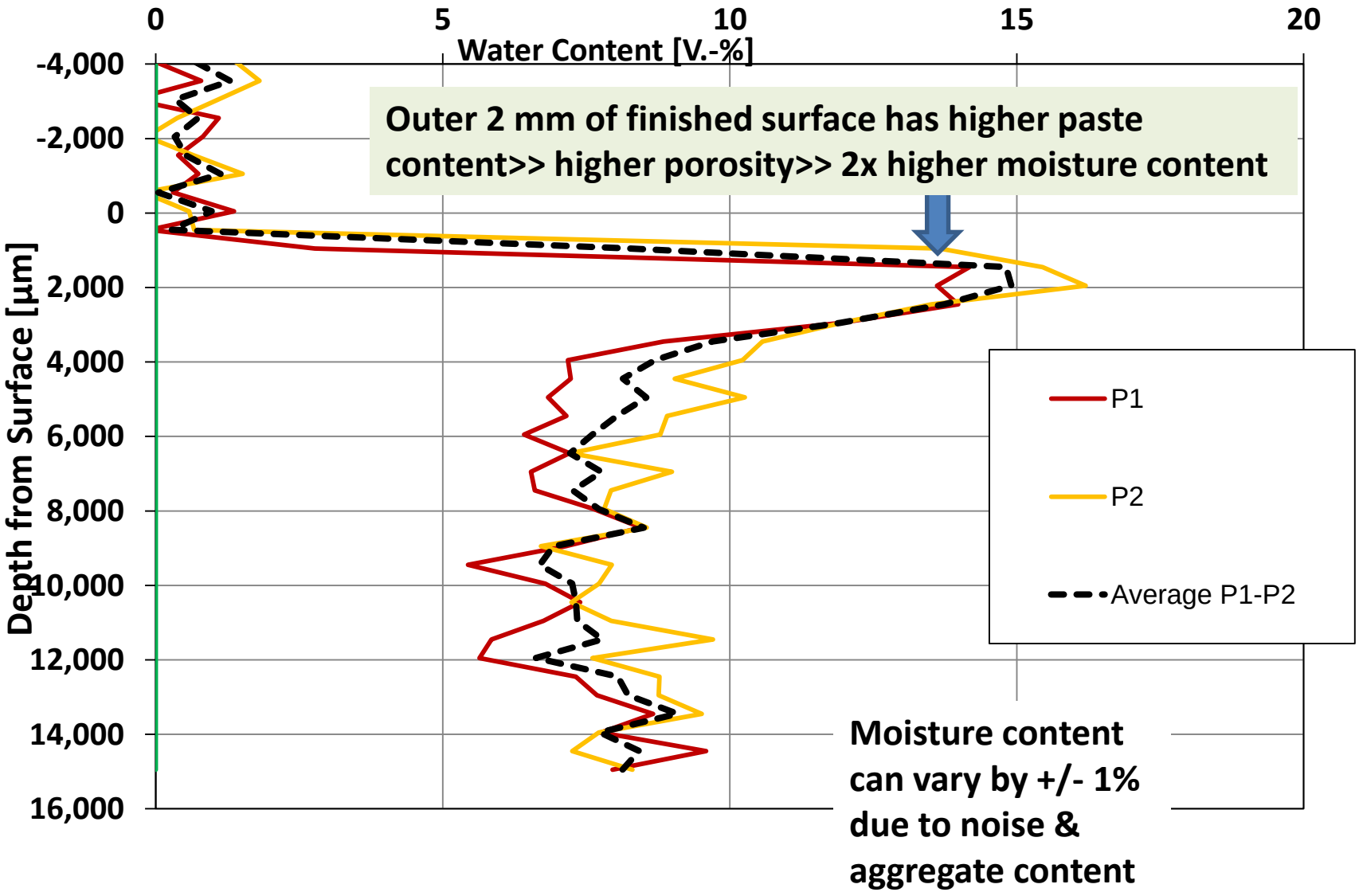
Moisture Profiles **from Bottom face** after 40 days drying (150mm below drying surface)



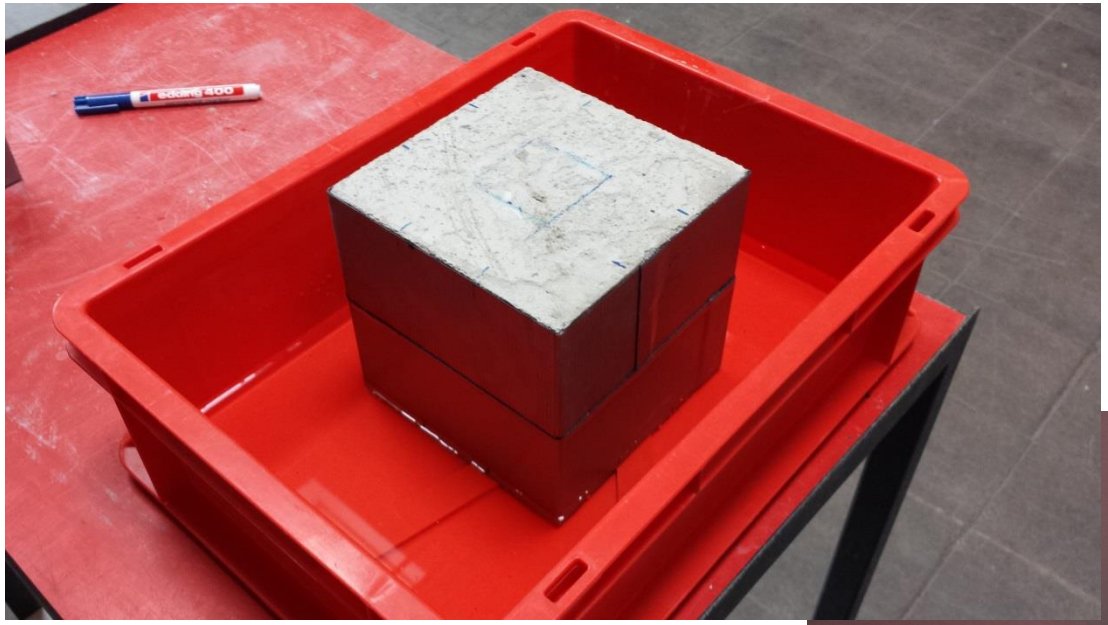
Rate of Drying after **0 days wet curing (covered for 6 hours)** then 1 to 41 days dried at 50% rh at 23°C



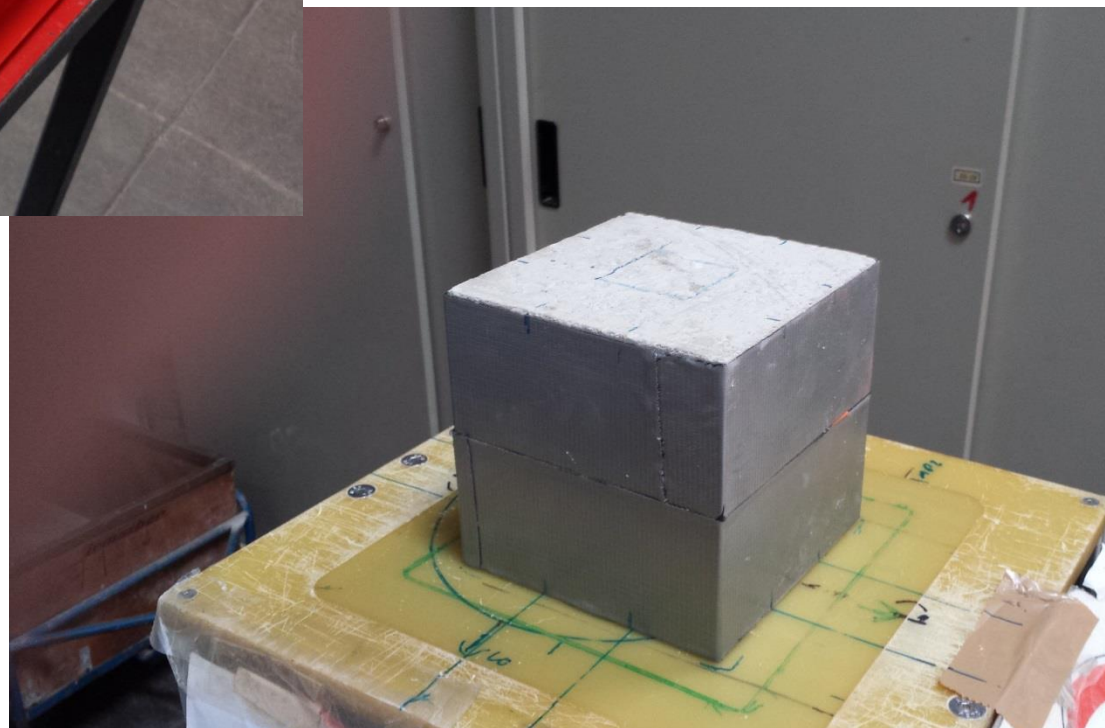
Noise & Surface Effects: Water Saturated for 14 days (2 profiles)



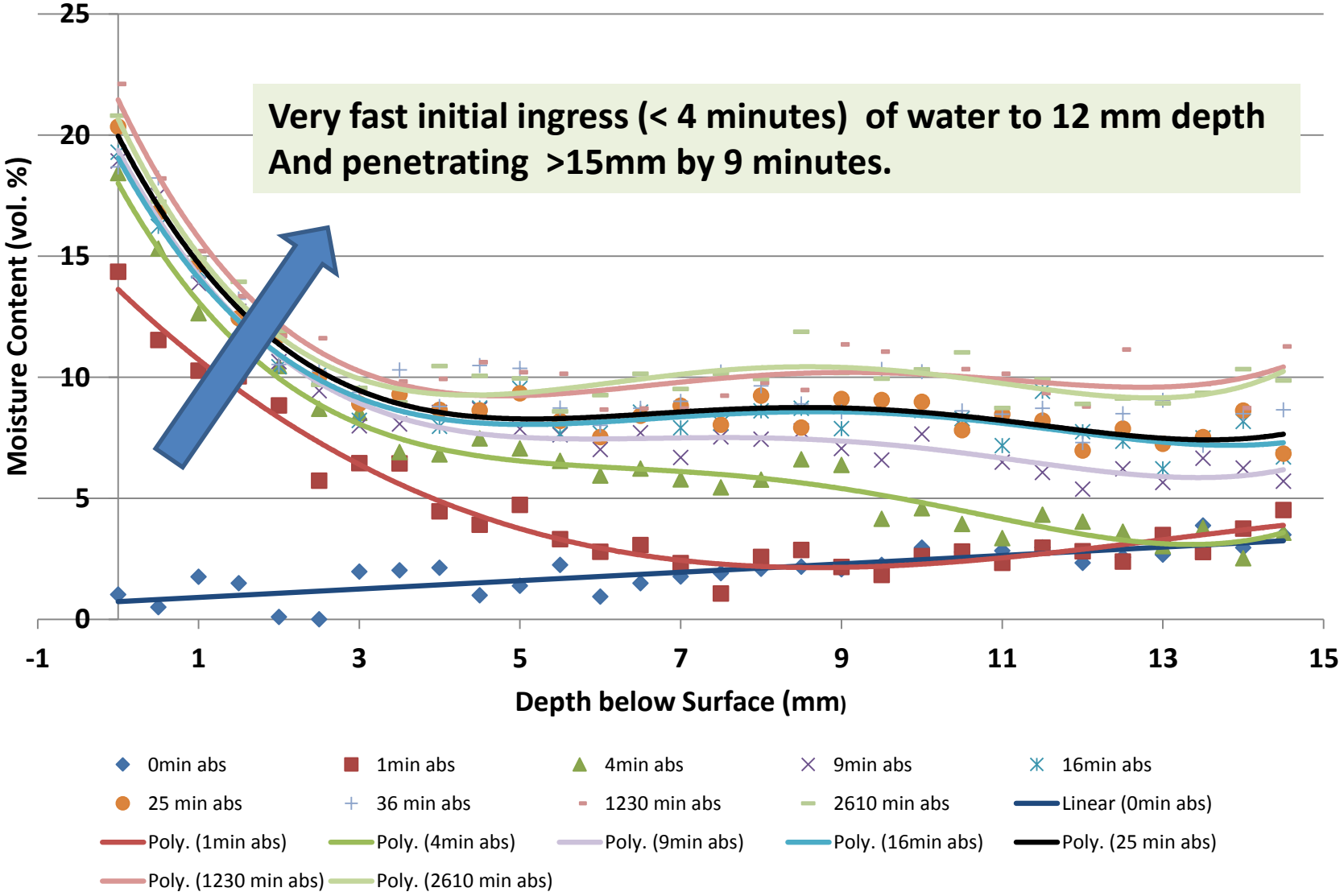
1-face, Rate of Absorption Tests



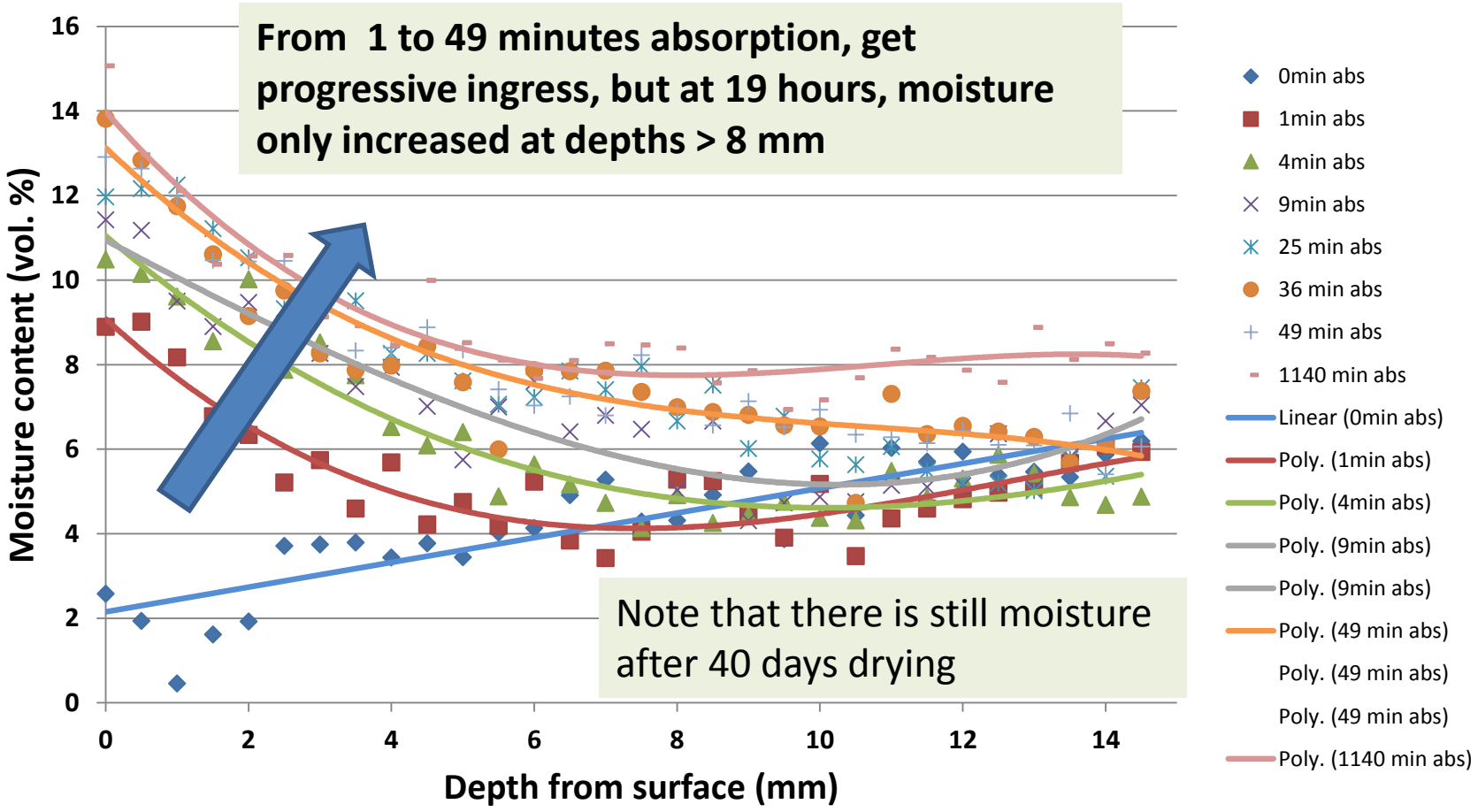
- One profile was measured for each absorption time in the centre of the exposed cube surface



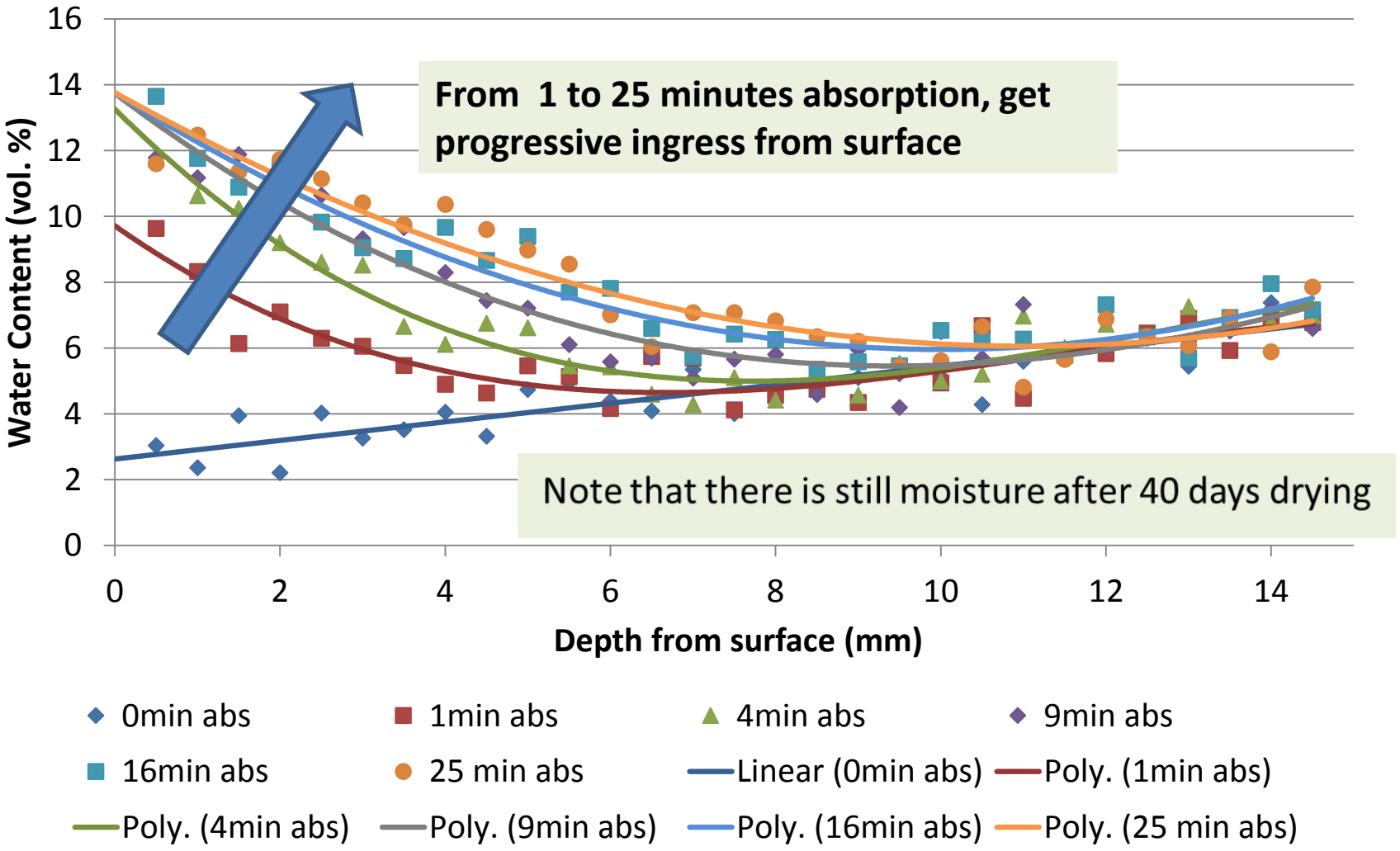
Rate of Absorption after **0 days wet curing (covered for 6 hours)** then 40 days dried at 50% rh, then 4d at 40°C



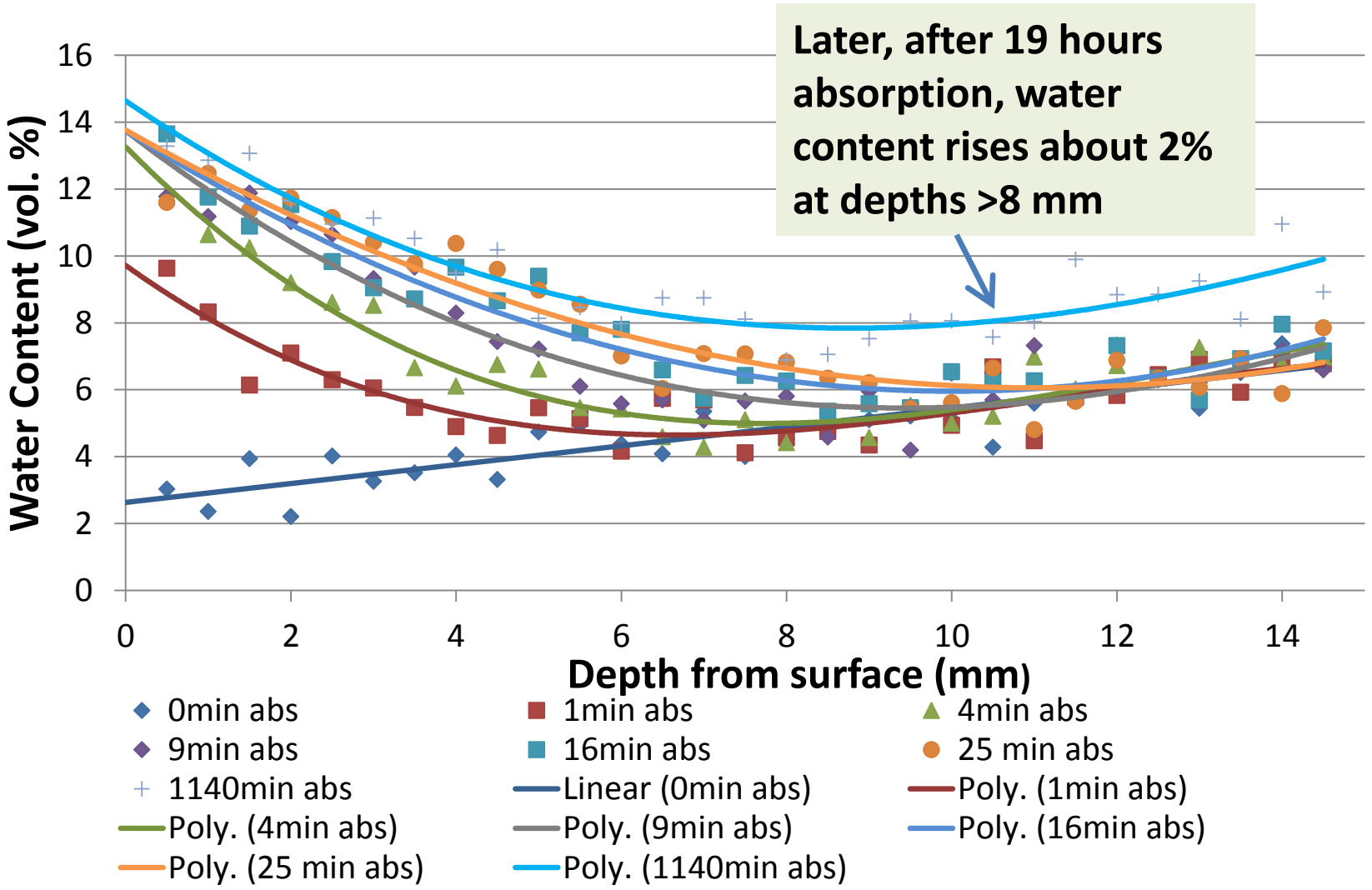
Rate of Absorption after **4 days wet curing** then 40 days dried at 50%rh, then 5 days at 40°C



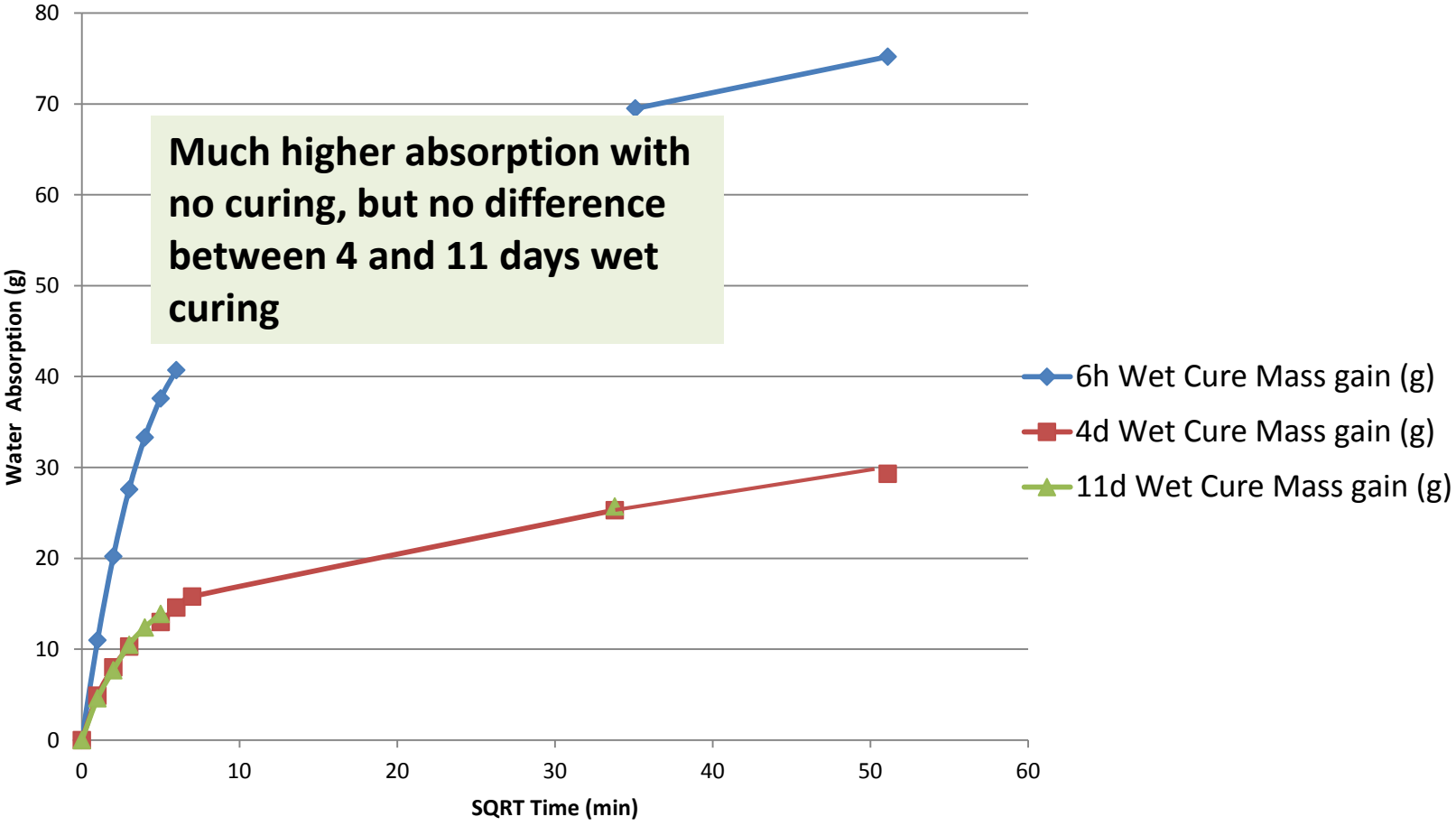
Rate of Absorption after **11 days wet curing** then 40 days dried at 50%rh, then 4 days at 40°C



Rate of Absorption after **11 days wet curing** then 40 days dried at 50%rh, then 4 days at 40°C



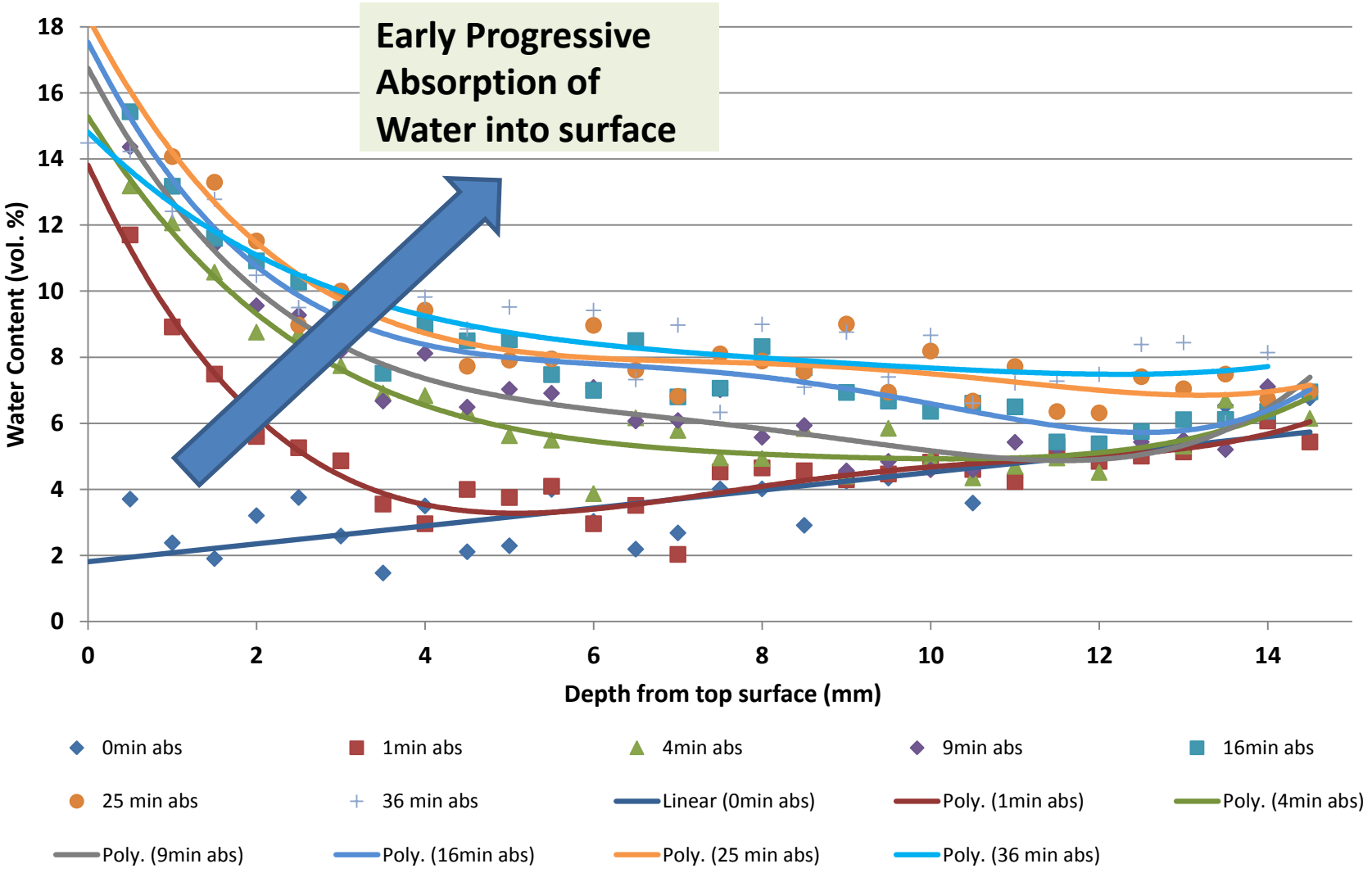
Rate of Absorption Mass Gain vs SQRT Time (min.) for Different curing



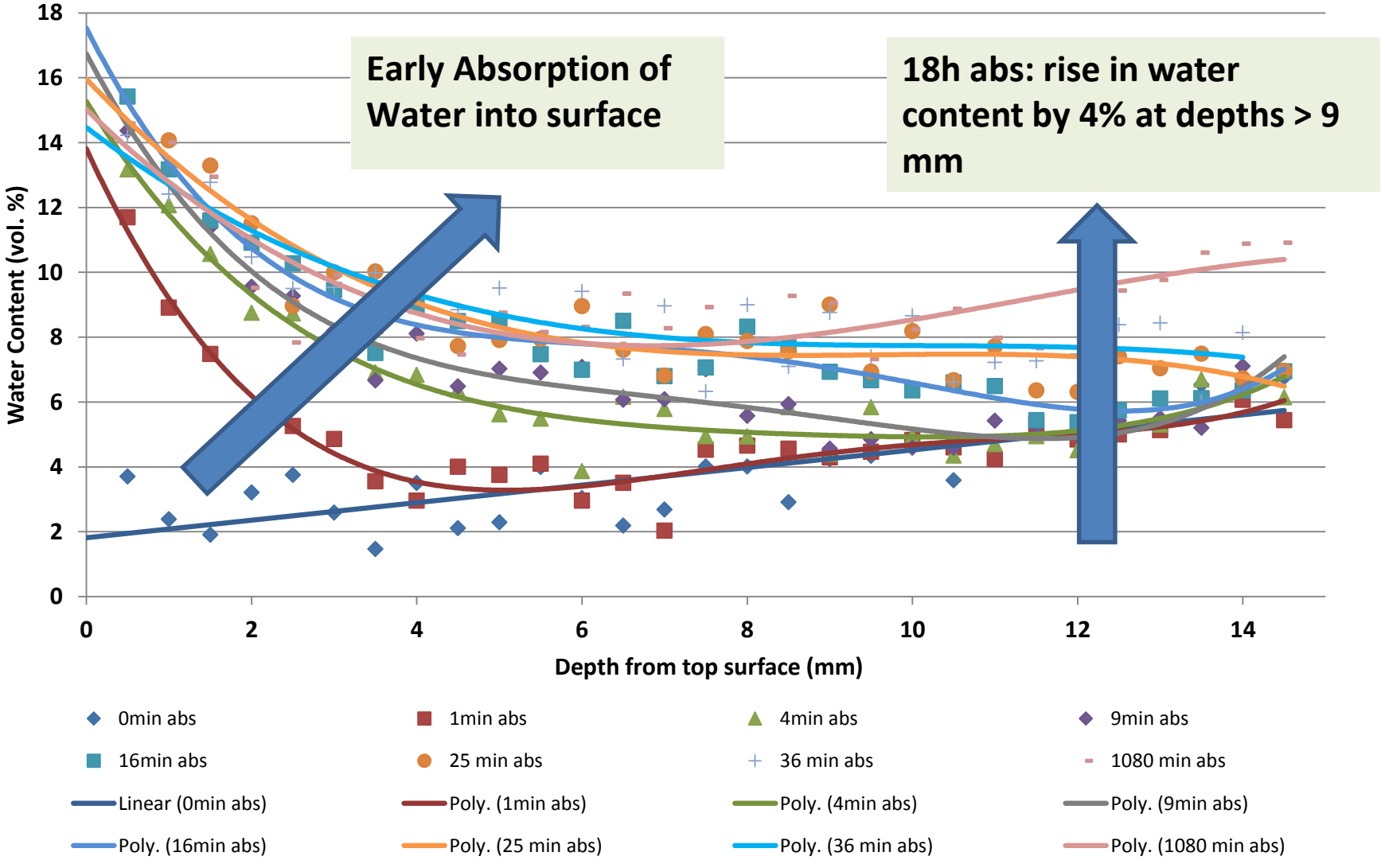
Effects of 40°C drying on Cube that was wet cured 14 days

- As follows:

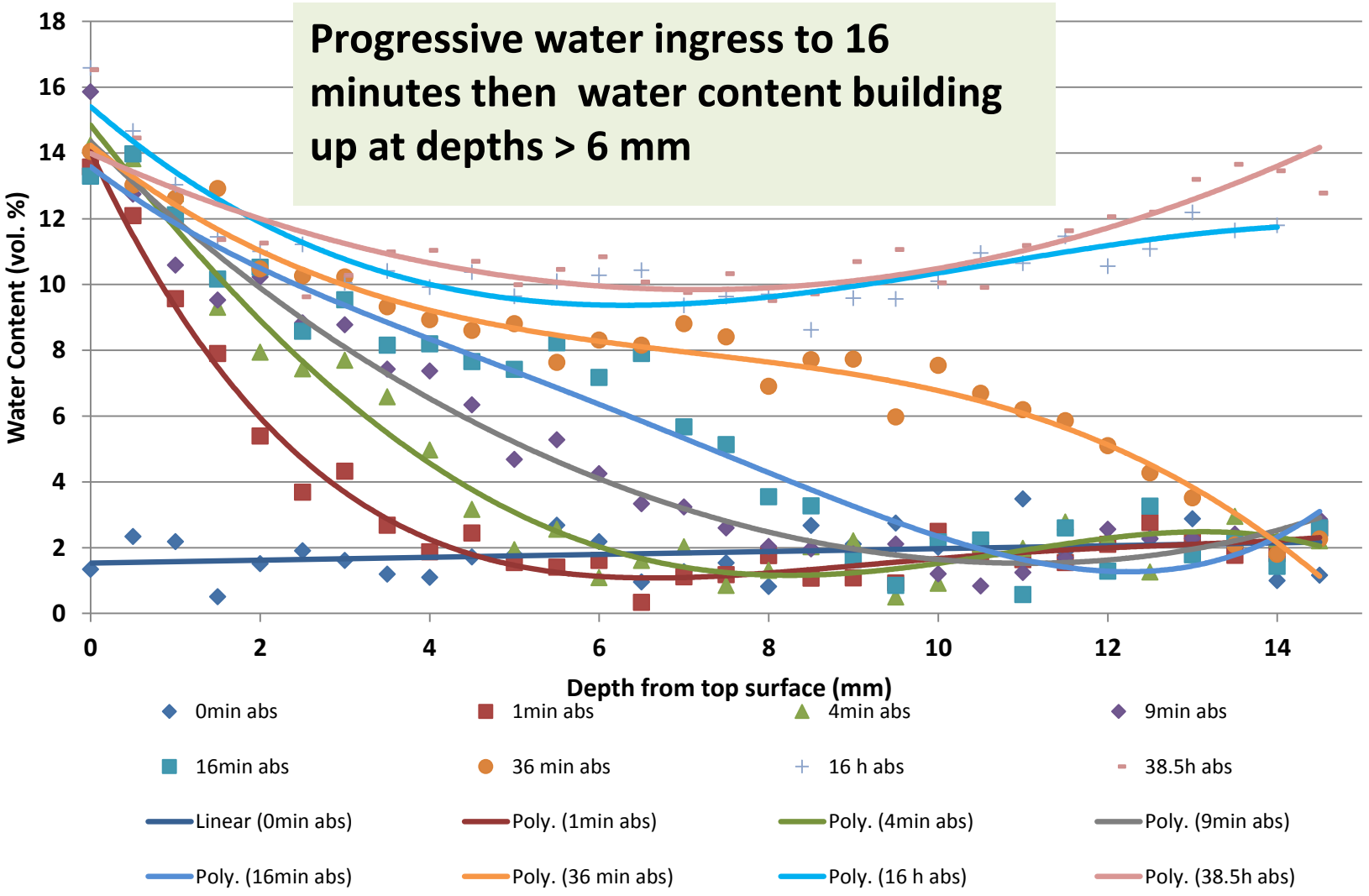
Rate of Absorption up to 36 minutes after **14 days wet curing** then 41 days dried at 40°C



Rate of Absorption to 18 hours after **14 days wet curing** then 41 days dried at 40°C

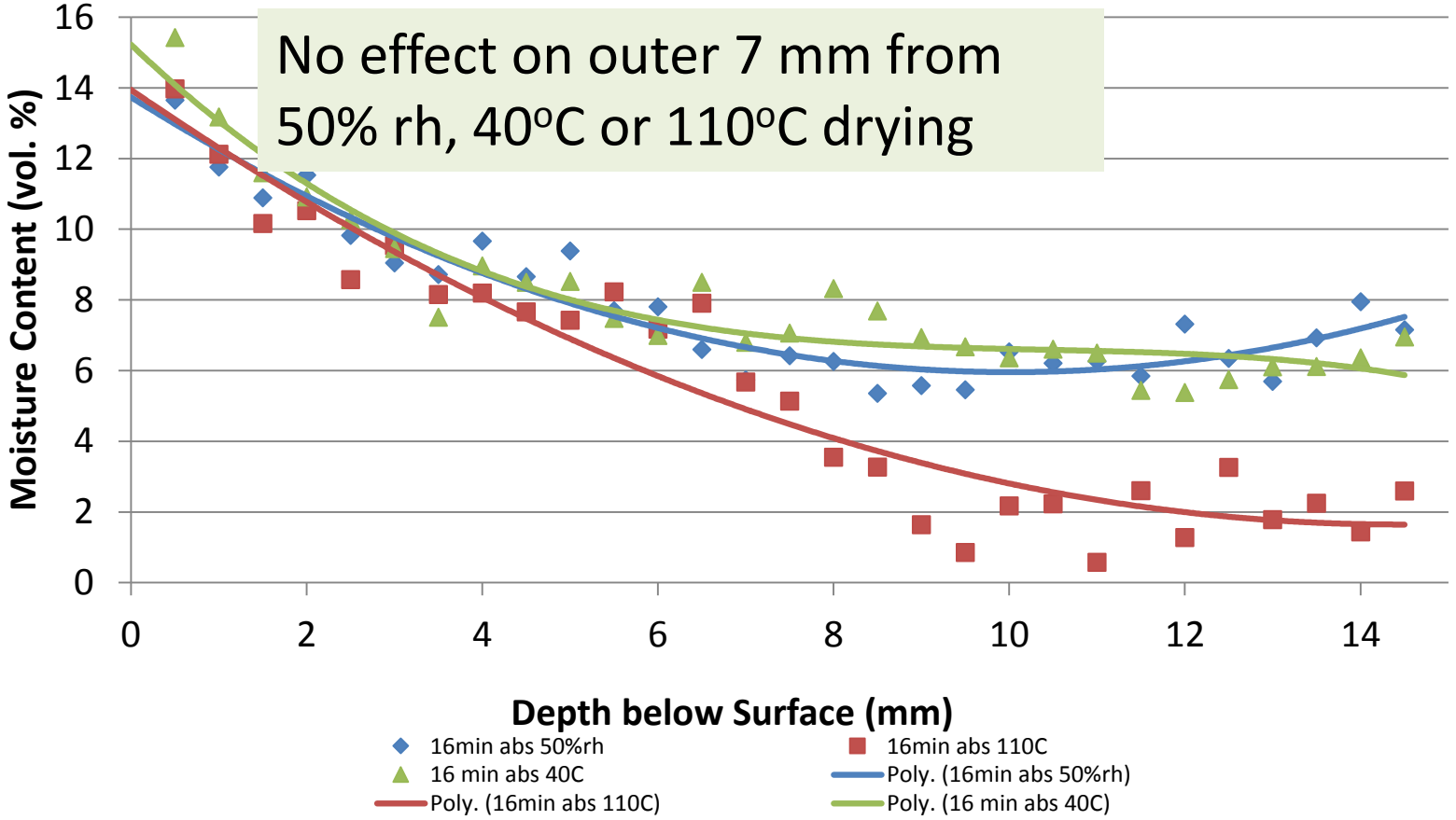


Rate of Absorption after **14 days wet curing** then dried at 110°C



Effect of Type of Drying on Water Absorption

Effect of Drying history on 16-minute Absorption (11 days wet curing)



We know 110°C drying damages concrete but does not appear to affect absorption profile relative to 40°C drying, except for different starting moisture content

Conclusions

1. The NMR-mouse provides moisture profiles down to 15 mm depth in concrete, but there is some noise—likely due to variable coarse aggregate content at any given depth.
2. During absorption tests, surface pores were rapidly saturated, then moisture contents increased at depth.
3. Provision of 4 days wet curing at 20^{o}C had a big impact on slowing drying and reducing absorption of water.
4. Wet curing beyond 4 days had little impact on drying or absorption rates (for the 0.45 w/c CEM I concrete cured at 20^{o}C).

Further Research

1. Research on the near-surface impacts of shorter wet curing periods and alternative curing procedures is needed.
2. Research on the impacts of blended cements on curing requirements is also needed.
3. Would be interesting to use the NMR to look at rate of water removal profiles using solvent exchange drying.

Other interesting things in Germany
2 m (6.5 ft) diameter pavement cores