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Influence of the Rheological Properties on the Fresh Concrete Pressure

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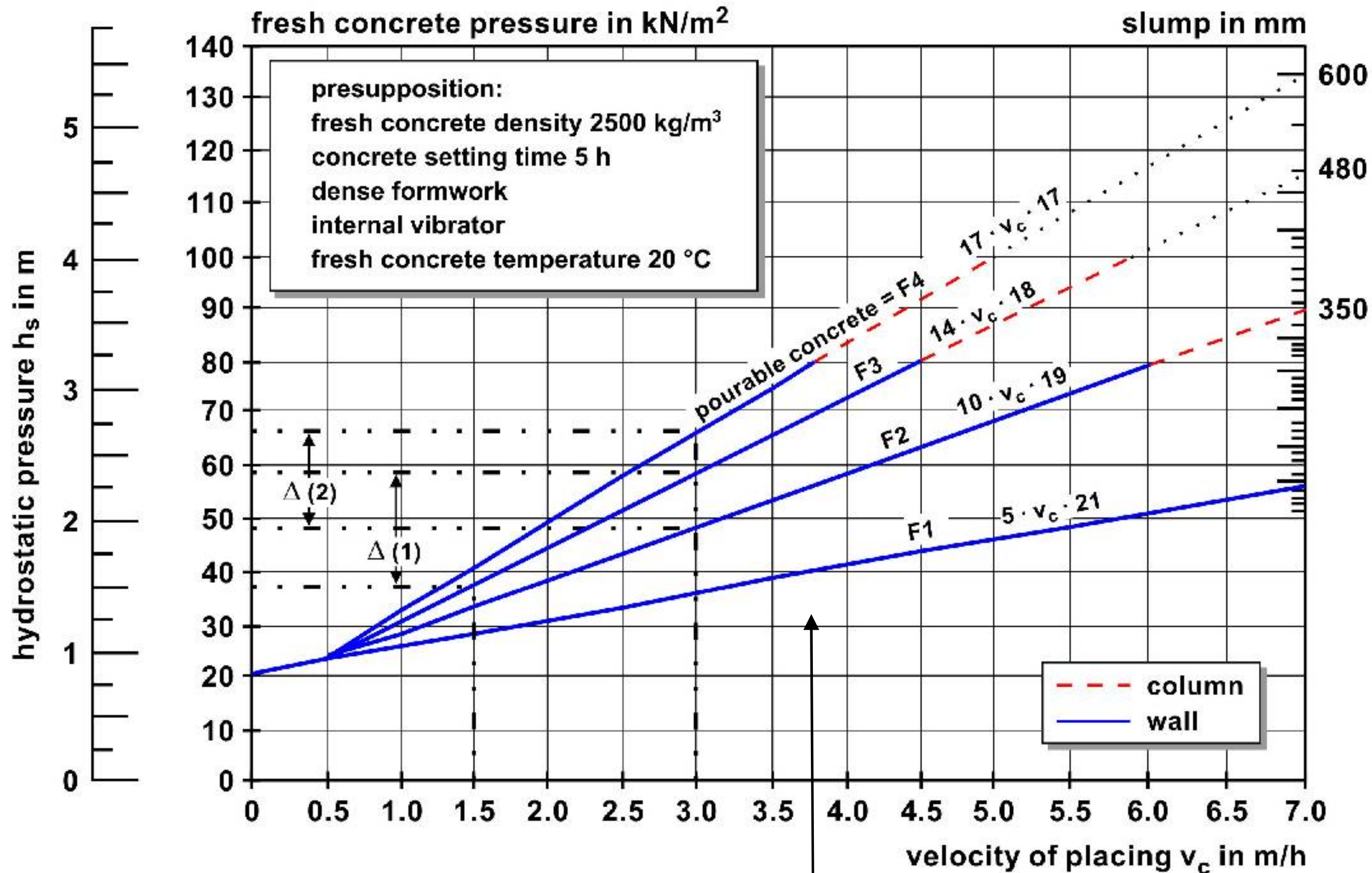
Outline

- Initial situation
- Rheological equations of state
- Research methods for the fresh concrete pressure
- Influence of the rheological properties on the fresh concrete pressure
- Summary

Fresh Concrete Pressure According to DIN 18 218



nonexistence of self-compacting and vibrated (F5 / F6) concretes

fresh concrete pressure depends on:
– velocity of placing
– consistency

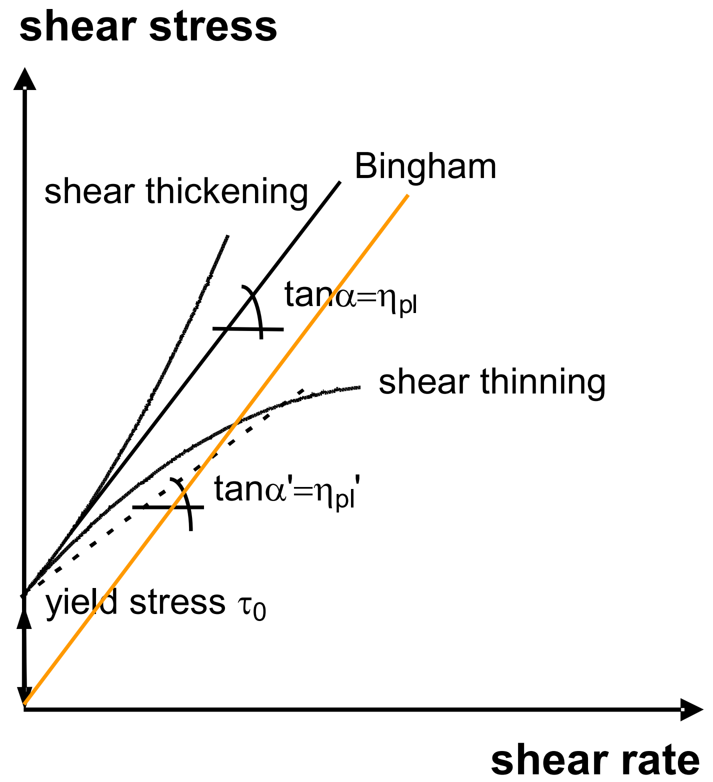
Influence Factors on the Fresh Concrete Pressure

Procedural factors	– consolidation of concrete – velocity of placing – pouring method
Concrete factors	– fresh concrete density – consistency / rheological properties – fresh concrete temperature – setting time
Specific formwork factors	– formwork geometry – formwork roughness – stiffness and density of the formwork – formwork height
Further factors	– ambient temperature – reinforcement

Flow Behaviour of Fluids and Ductile Materials

- **Newtonian flow behaviour**
  - **Newton:** $\tau = \eta \cdot \gamma$

- **Ductile flow behaviour**
  - **Bingham:** $\tau = \tau_0 + \eta_{pl} \cdot \gamma$
  - **Herschel-Bulkley:** $\tau = \tau_0 + k \cdot \gamma^n$



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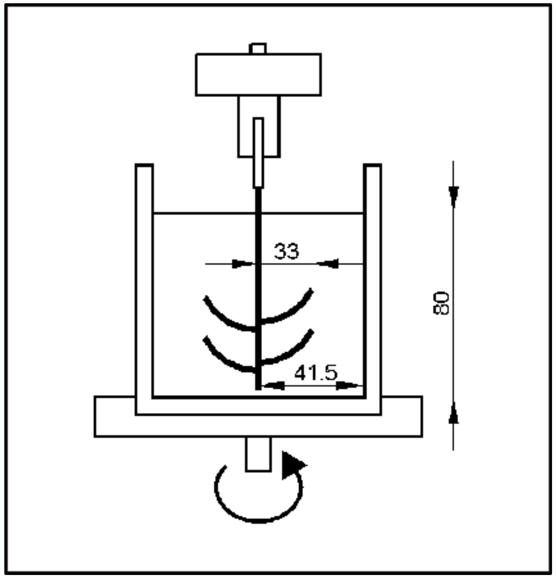
Determination of Momentum Curves

Viskomat NT



Bingham: T = g + h · N

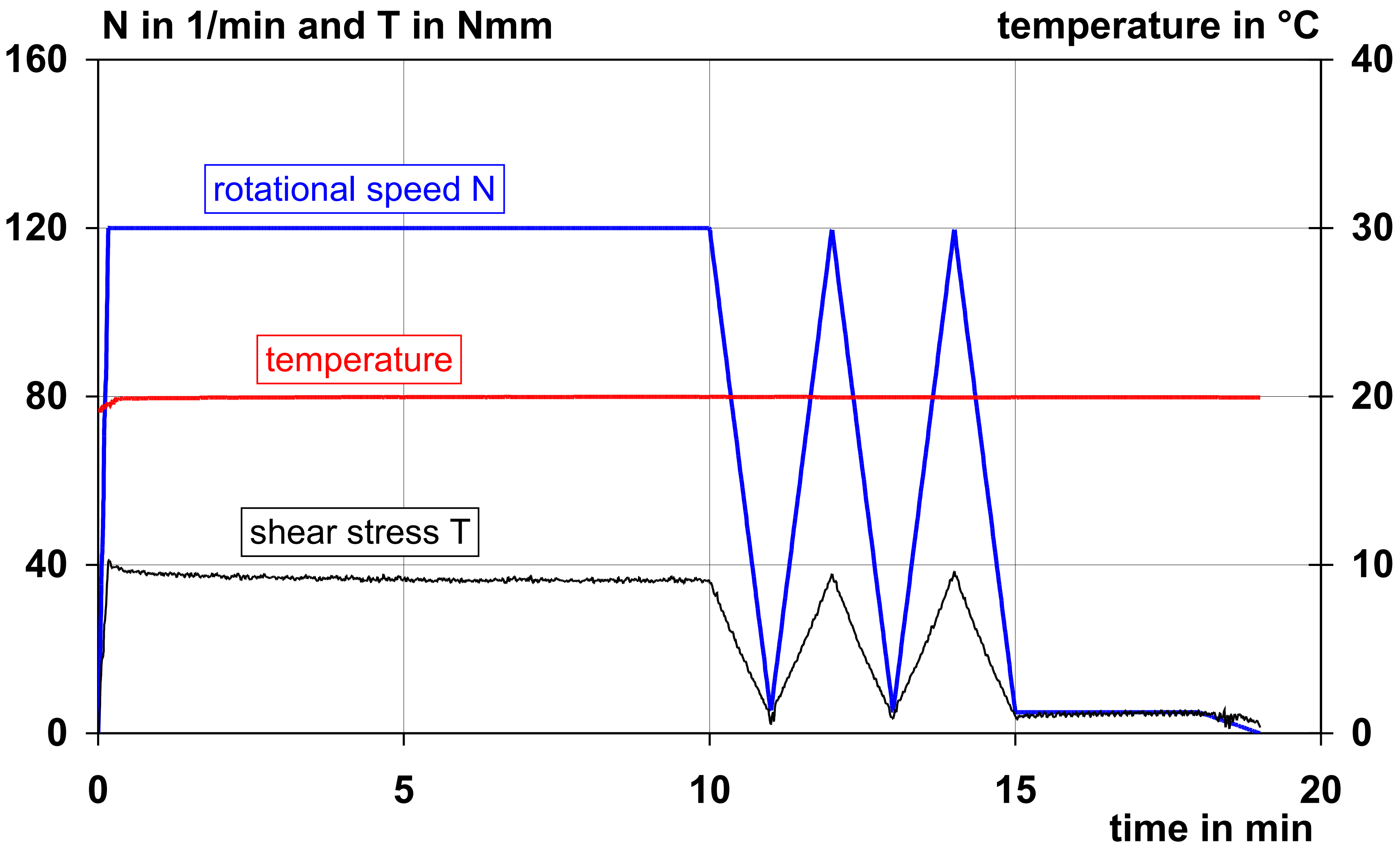
T: shear stress

N: rotational speed

g: relative yield stress

h: relative viscosity

Display of Relevant Data of the Viskomat NT



Approximation of Momentum Curves with Herschel-Bulkley

Herschel-Bulkley: $T = F + k \cdot N^n$

T: shear stress

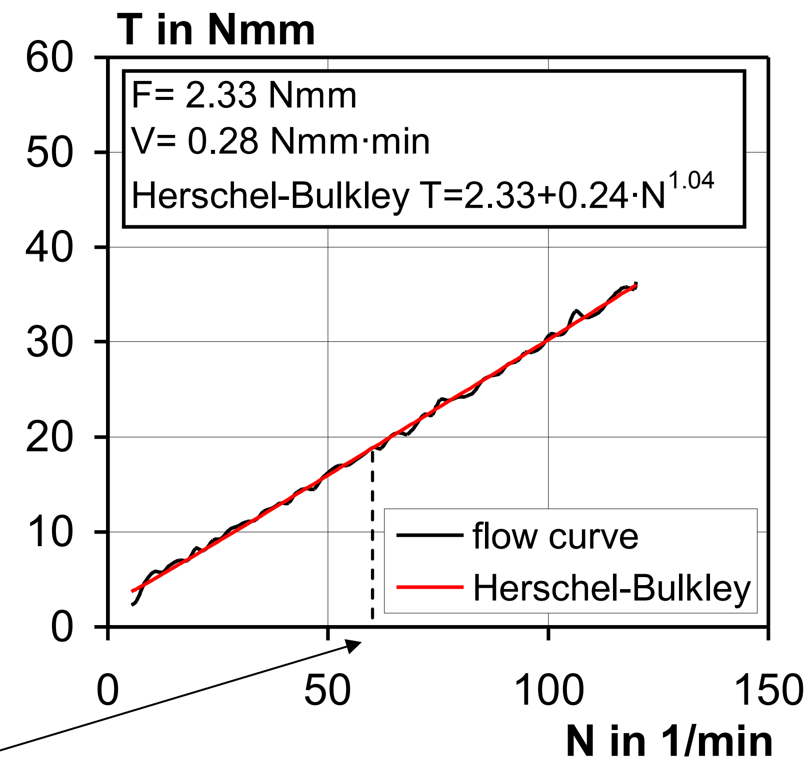
N: rotational speed

F: relative yield stress

k: slope factor

n: curve form factor

- **n > 1: shear thickening**
- **n < 1: shear thinning**
- **n = 1: Bingham**



V: relative average viscosity

(slope at N = 60 rpm)

Description of Concretes

- **Self-Compacting Concrete (SCC)**

SCC-PT-hv	PT: powder type
SCC-PT-lv	VAT: viscosity agent type
SCC-VAT-hv	hv: high viscosity
SCC-VAT-lv	lv: low viscosity

- **Vibrated Concrete (VC)**

  VC-F5
  VC-F6

Mix Design

material	unit	content/value					
		SCC PT-hv	SCC PT-lv	SCC VAT-hv	SCC VAT-lv	VC F5	VC F6
1	2	3	4	5	6	7	8
CEM II/A-LL 42.5 R	kg/m³	300		340		395	
fly ash		250		100		75	
water content		160	190	180	200	170	180
aggregate		1664	1584	1742	1689	1750	1723
superplasticizer	% per mass (binder)	3.9	2.1	2.7	1.7	1.2	1.5
stabilizer		1.0				-	1.0
air content	% per volume	1.5					
w/c_{eq}	-	0.47	0.56	0.47	0.52	0.4	0.42

Description of Mortars

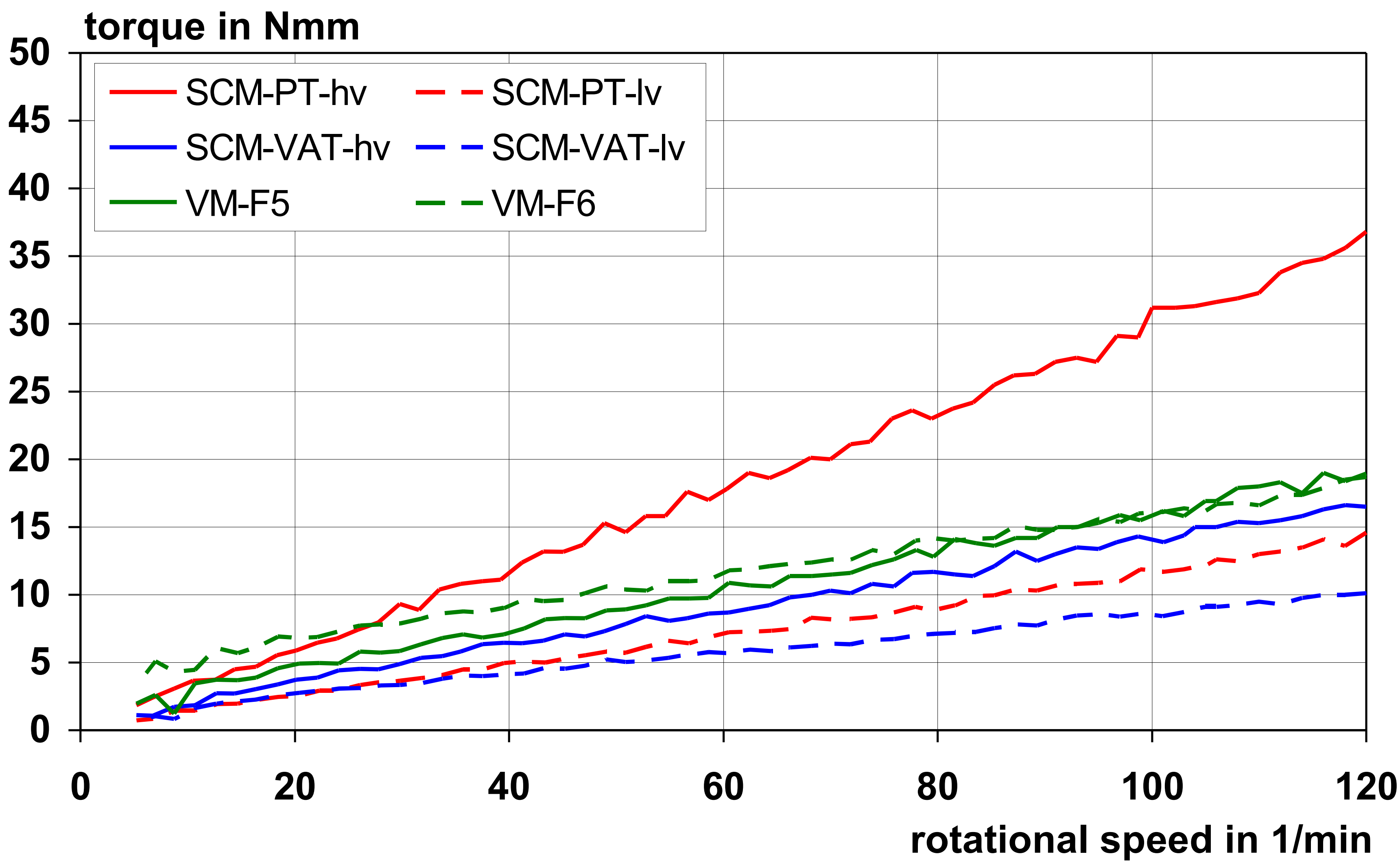
- **Self-Compacting Mortar (SCM)**

SCM-PT-hv	PT: powder type
SCM-PT-lv	VAT: viscosity agent type
SCM-VAT-hv	hv: high viscosity
SCM-VAT-lv	lv: low viscosity

- **Mortar of the Vibrated concrete (VM)**

  VM-F5
  VM-F6

Momentum Curves of Mortars



Herschel-Bulkley Approximation

- **Herschel-Bulkley: $T = F + k \cdot N^{n}$**

- **SCM-PT-hv: $T = 0.74 + 0.22 \cdot N^{1.06}$**

  SCM-PT-lv: $T = 0.02 + 0.13 \cdot N^{0.98}$

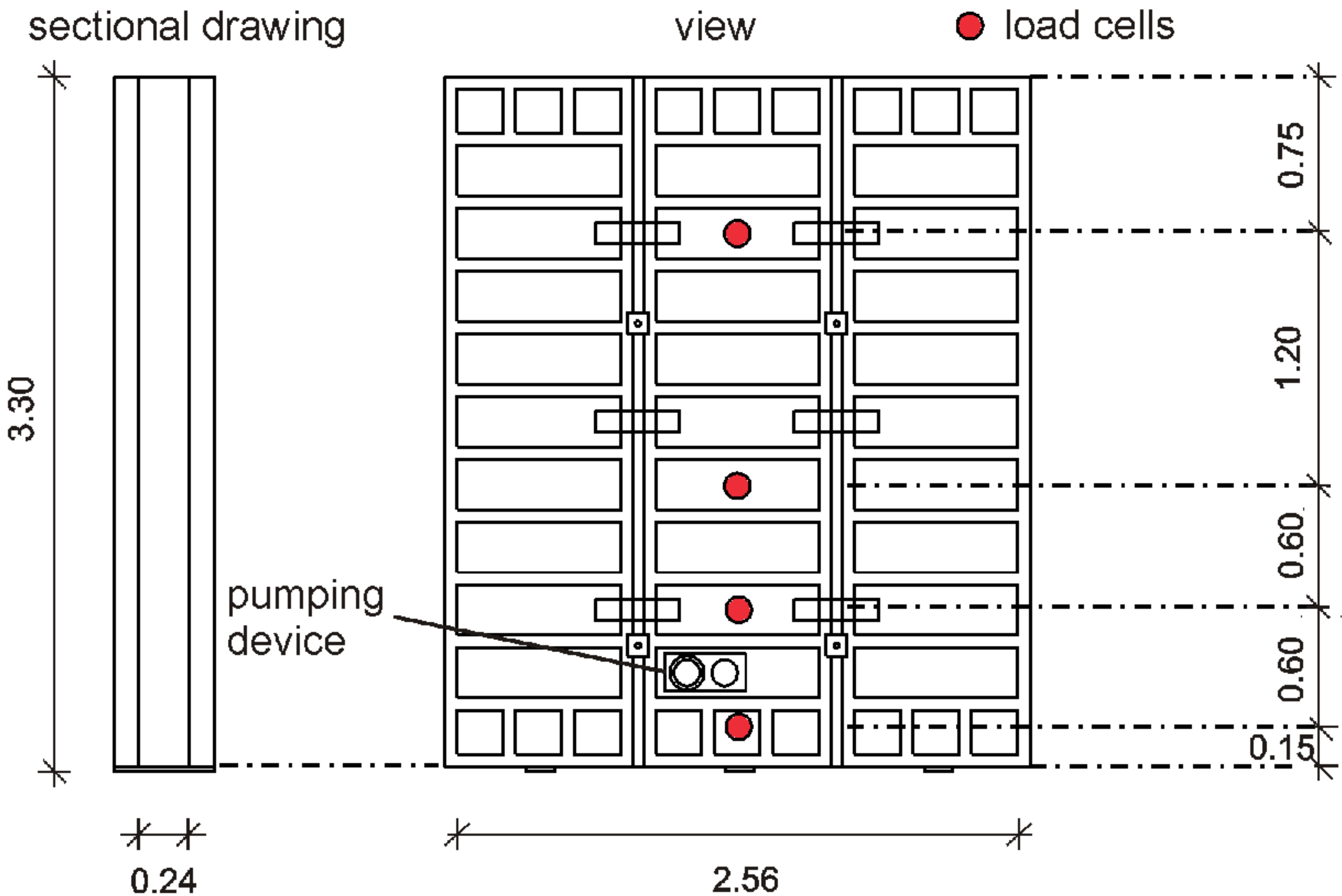
  SCM-VAT-hv: $T = 0.34 + 0.19 \cdot N^{0.93}$

  SCM-VAT-lv: $T = 0.00 + 0.24 \cdot N^{0.78}$

  VM-F5: $T = 1.34 + 0.17 \cdot N^{0.97}$

  VM-F6: $T = 3.07 + 0.30 \cdot N^{0.82}$

Experimental Set-Up for Pressure Measurements



Measurement Method of Fresh Concrete Pressure

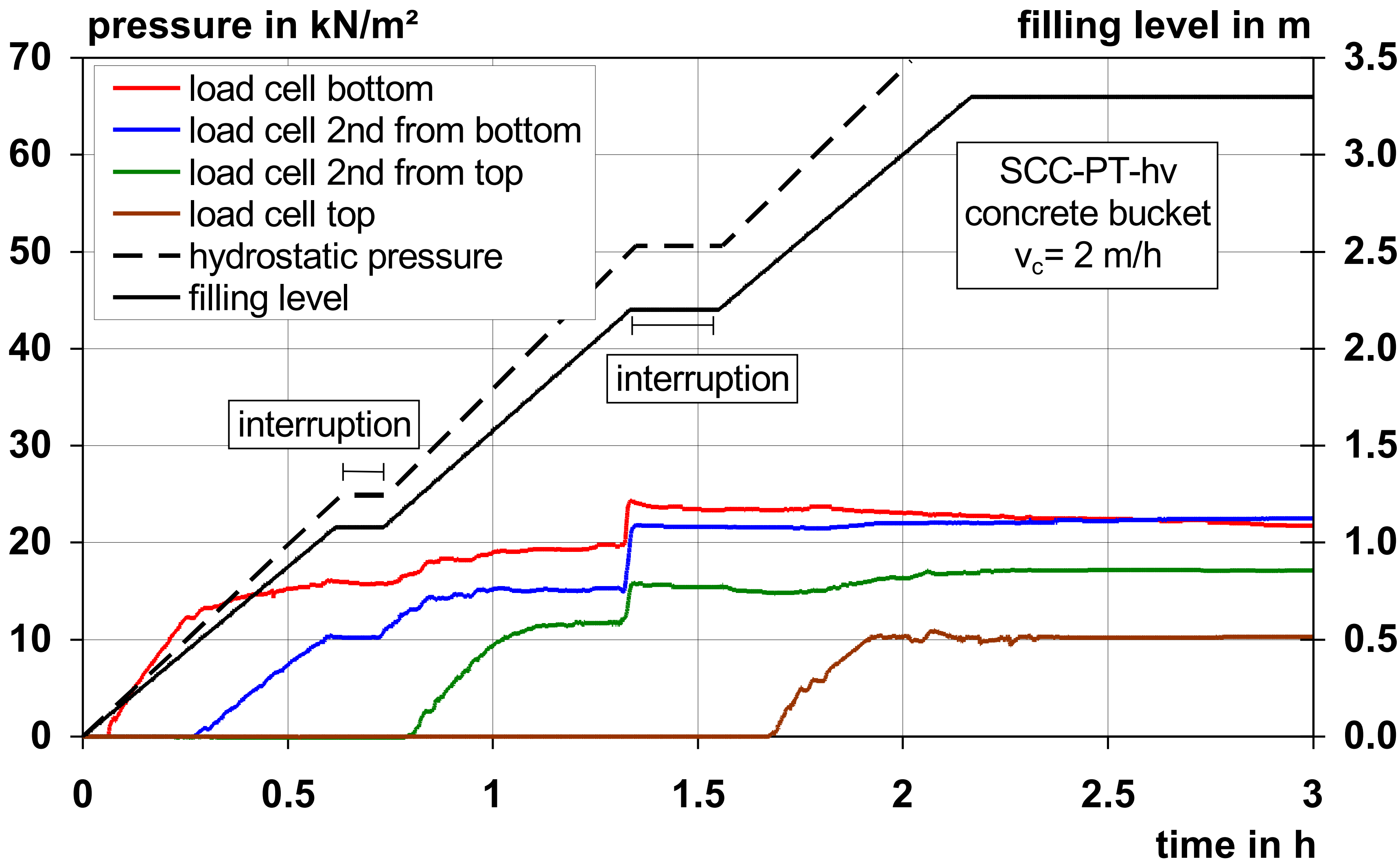
location load cells

detail load cell

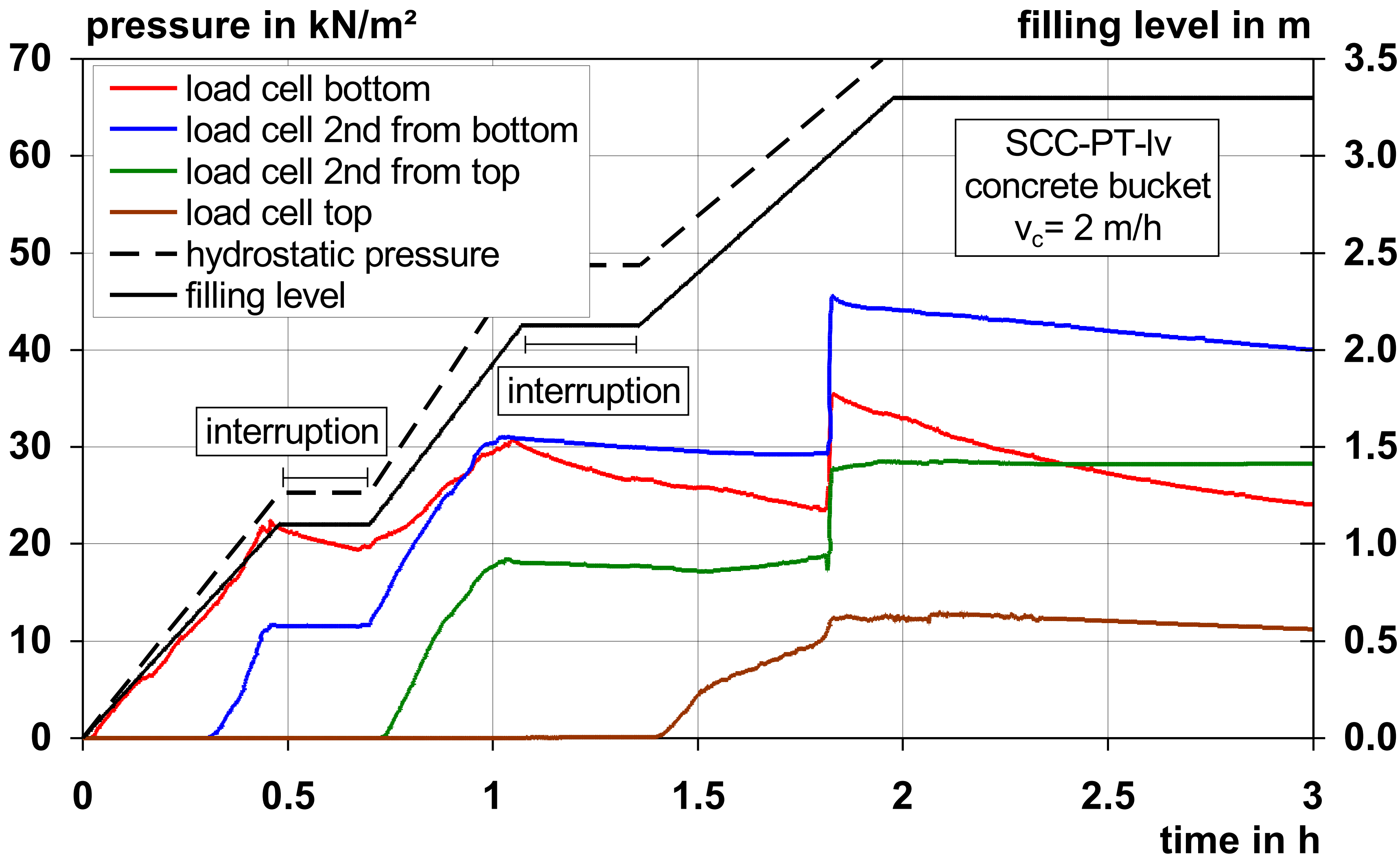
Research Program for Pressure Measurements

wall	concrete	pouring method	velocity of placing
1	2	3	4
1	SCC-PT-hv	concrete bucket	2.0 m/h
2	SCC-PT-lv		
3	SCC-VAT-hv		
4	SCC-VAT-lv		
5	VC-F5		
6	VC-F6		
7	SCC-PT-hv		10.0 m/h
8	SCC-PT-lv		
9	SCC-PT-hv	pump	2.0 m/h
10	SCC-PT-lv		
11	SCC-VAT-lv		

Pressure vs. Time – Wall 1



Pressure vs. Time – Wall 2



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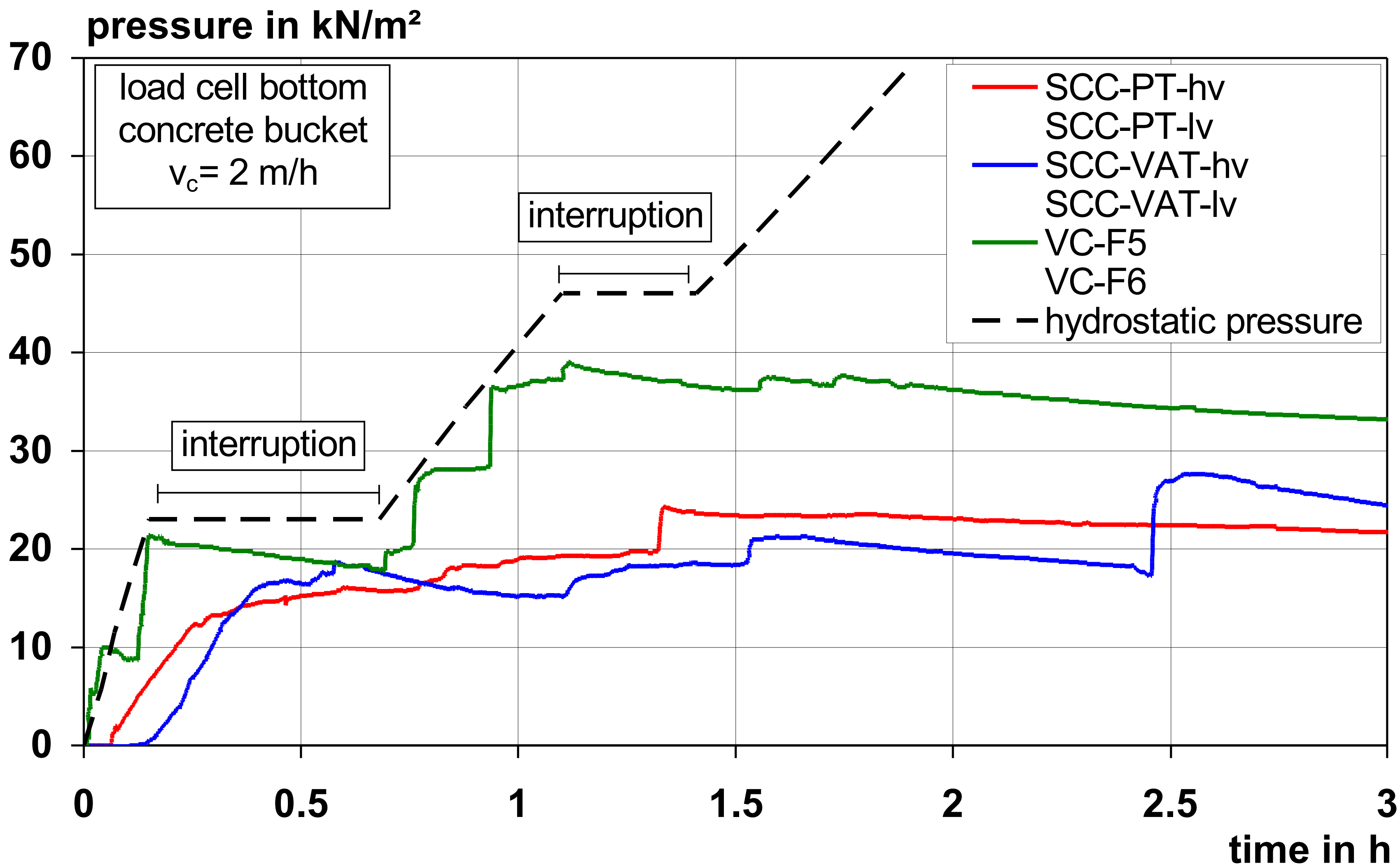
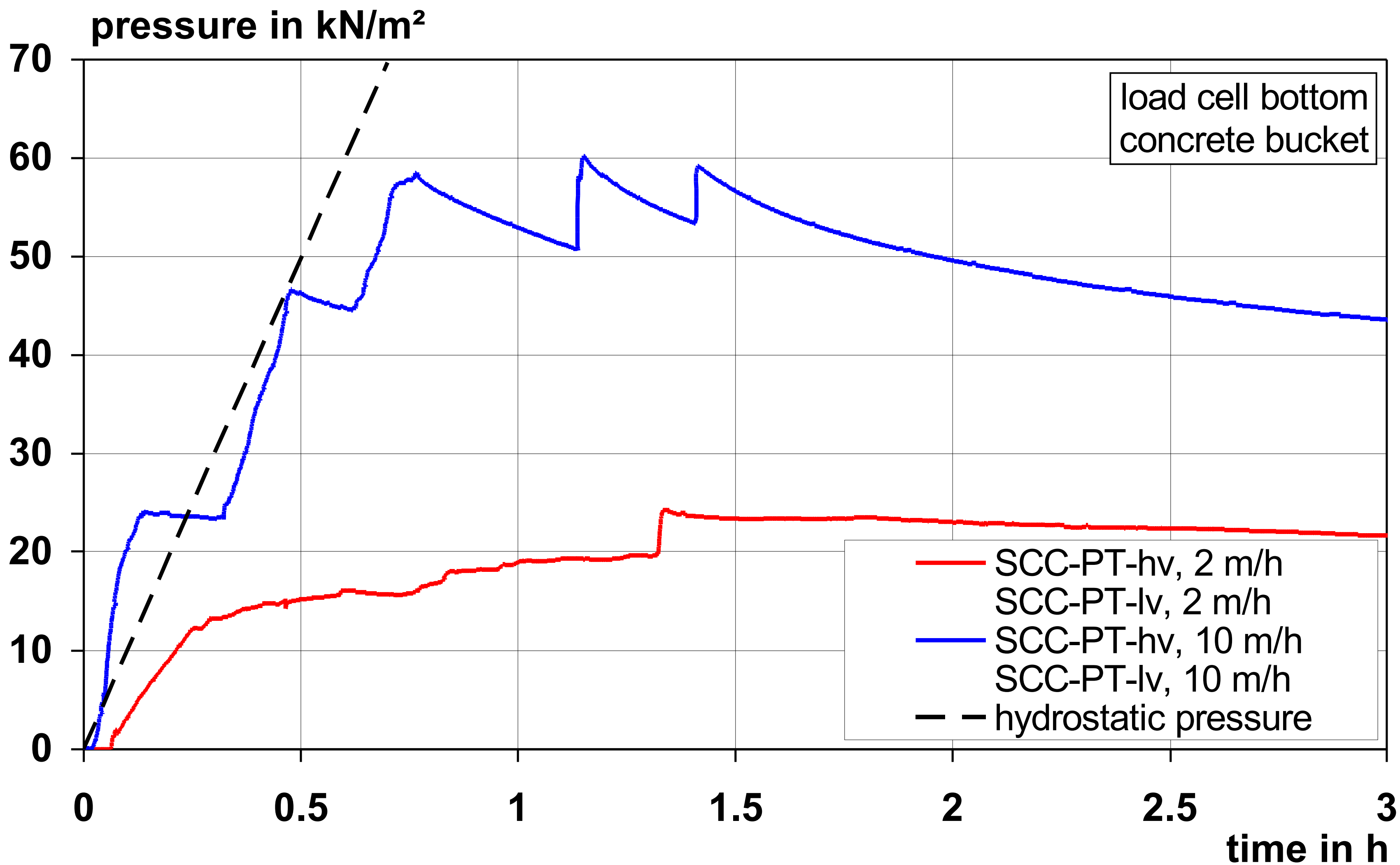
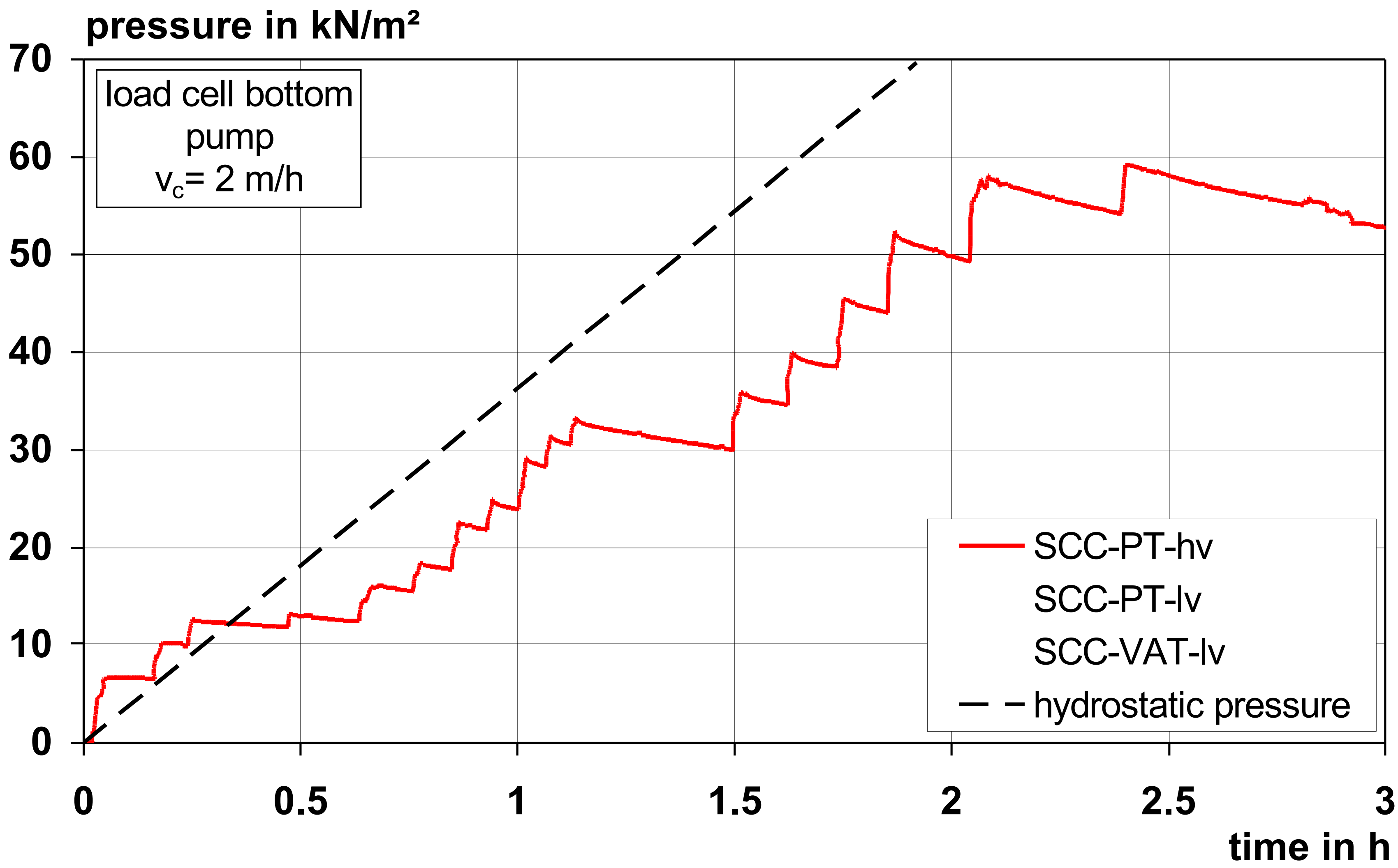
Pressure vs. Time – Wall 1 to 6



Pressure vs. Time – Wall 1, 2, 7 and 8



Pressure vs. Time – Wall 9, 10 and 11



Summary

- Low influence of SCC type on fresh concrete pressure
- Increasing pressure by decreasing the viscosity
- High influence on fresh concrete pressure by velocity of placing
- Low influence of rheological properties at higher velocity of placing or at pumping
- Hydrostatic pressure for formwork dimensioning at pumping
- Decrease of pressure at the bottom during interruption
- Fresh concrete pressure of SCC compared to VC significantly lower (concrete bucket, 2 m/h)