



CONCRETE DURABILITY SHRINKAGE

JÜRIG SCHLUMPF
SIKA SERVICES AG / TARGET MARKET CONCRETE

BUILDING TRUST



CONCRETE DURABILITY

SHRINKAGE

Mix Design Actions

- Reduction of w/c increases paste density & improve quality
- Reduced Portland clinker part to reduce shrinkage
- Proper use of HRWR (Sikament / Viscocrete) to achieve w/c
- Therefore the use of HRWR increases durability of concrete
- And of course proper mix design to guarantee homogeneous concrete without segregation is necessary

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But:

If the structure remains intact, everything is o.k. now! But:

The biggest problem are

Causes of cracks:

- Not professional pouring
- Not complete compacting
- Improper curing
- Drying shrinkage
- Freeze-thaw damage
-



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Loss of Humidity



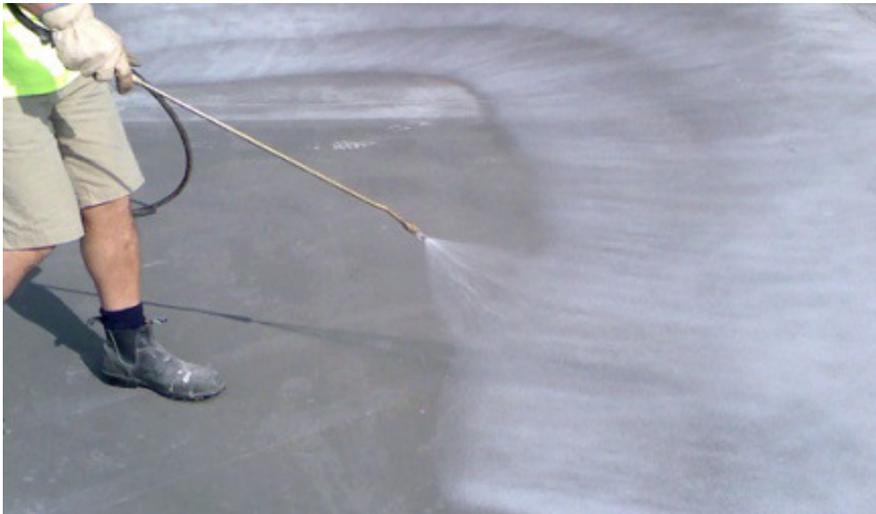
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Loss of Humidity



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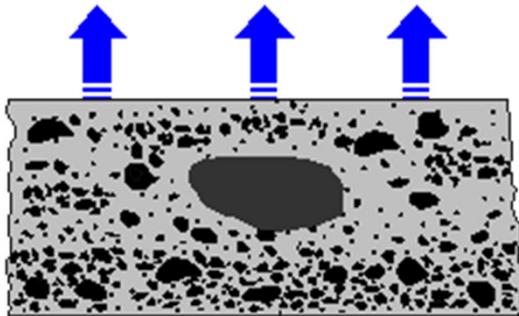
Curing



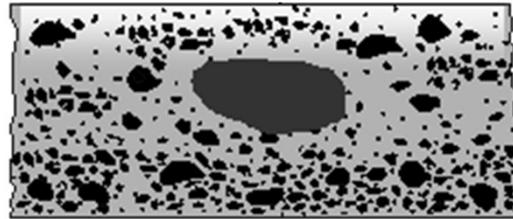
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Why?



water loss,
incomplete hydration



low abrasion
resistance



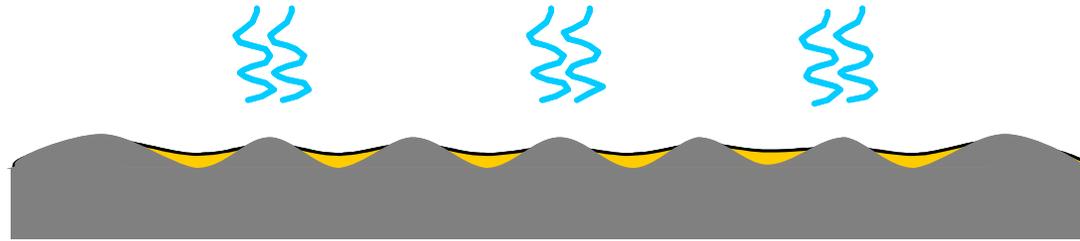
shrinking,
cracks



macro pores,
sensitivity to
de-icing salts

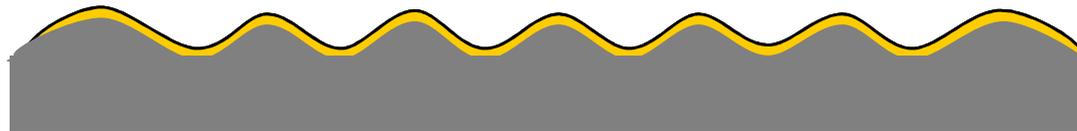
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Mechanism of curing aids



conventional
Curing Agent

- Concrete
- Curing Agent



Sika Curing Agent:

Antisols

(due to emulsifier amount)

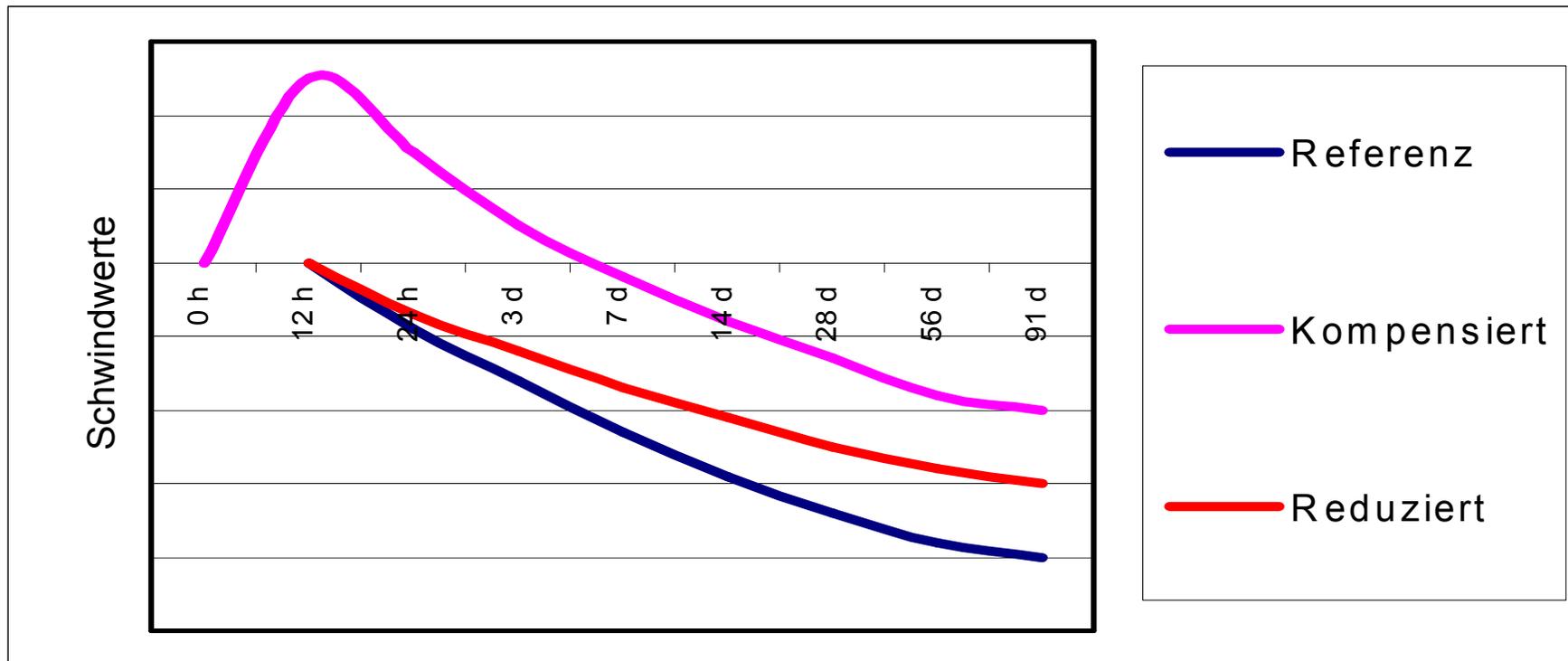
Curing effectiveness (Barrier values) of 100 % can be obtained

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Definition

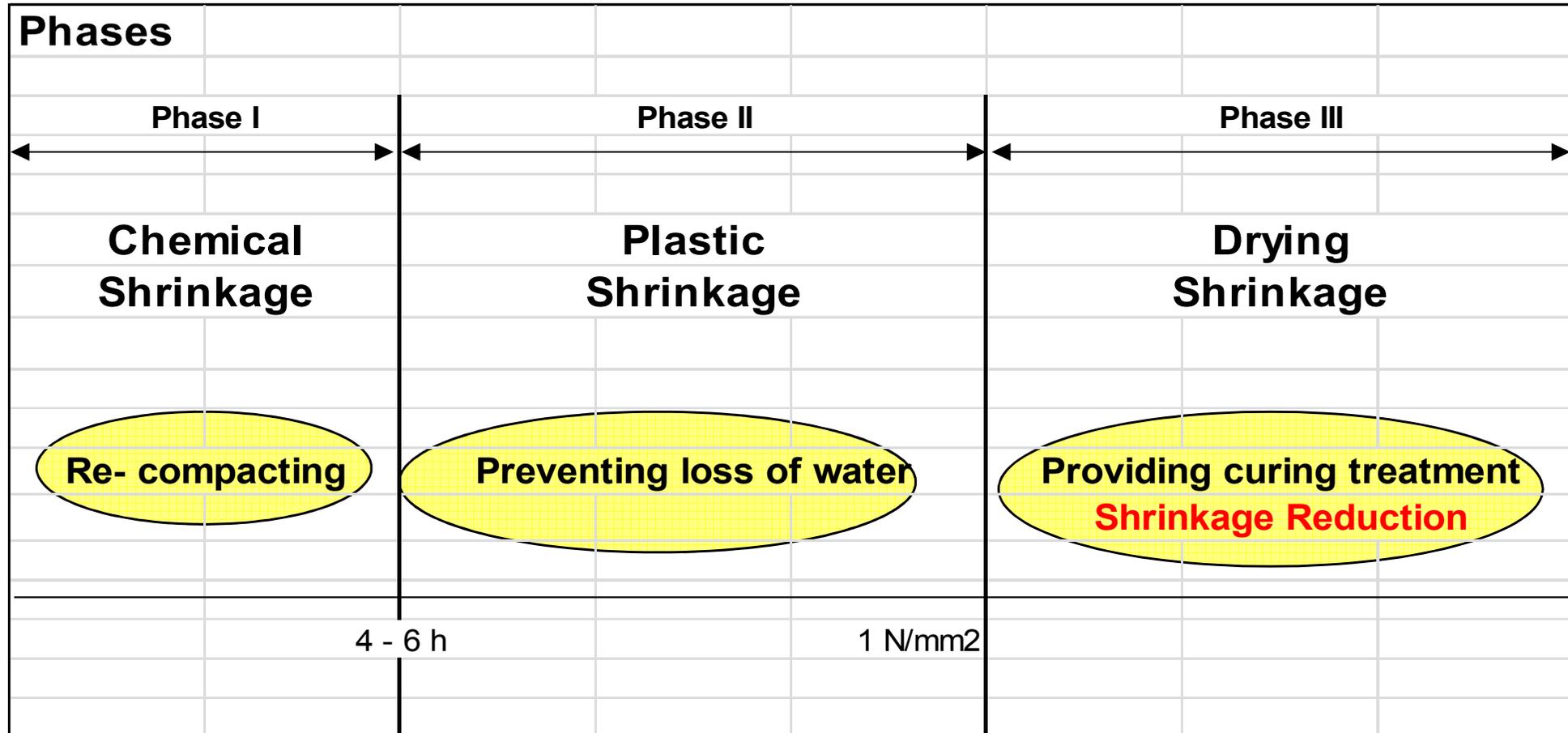
- **Shrinkage compensation**
Normal shrinkage process compensated by initial volume increase
- **Shrinkage reduction**
Continuous shrinkage reduction from beginning of hardening



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Hardening stages relevant for shrinkage



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Shrinkage Reducing Admixtures: how it works

The shrinkage reduction produced by **SikaControl** is based on physical and chemical effects:

- Surfactants decrease the surface tensions
(direct shrinkage reduction)

and

- Special substances reduce the formation of cement phases
(mainly aluminates und ferrites)

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Shrinkage Reducing Admixtures: Performance of SikaControl

- Shrinkage reduction up to 40 %
(depending on conditions: cement, dosage)
- Compatible with air entrainers
Freeze thaw resistance can be achieved
- Dosage 1 - 3 %
- Compatible with HRWR
- even slight increase in initial flow

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Shrinkage Reducing Admixtures: Testing

- **Shrinkage measurements**

Test specimen

12 / 12 / 36 cm
or 4 / 4 / 16 cm
or \varnothing 100mm / L = 300 mm

Temperature

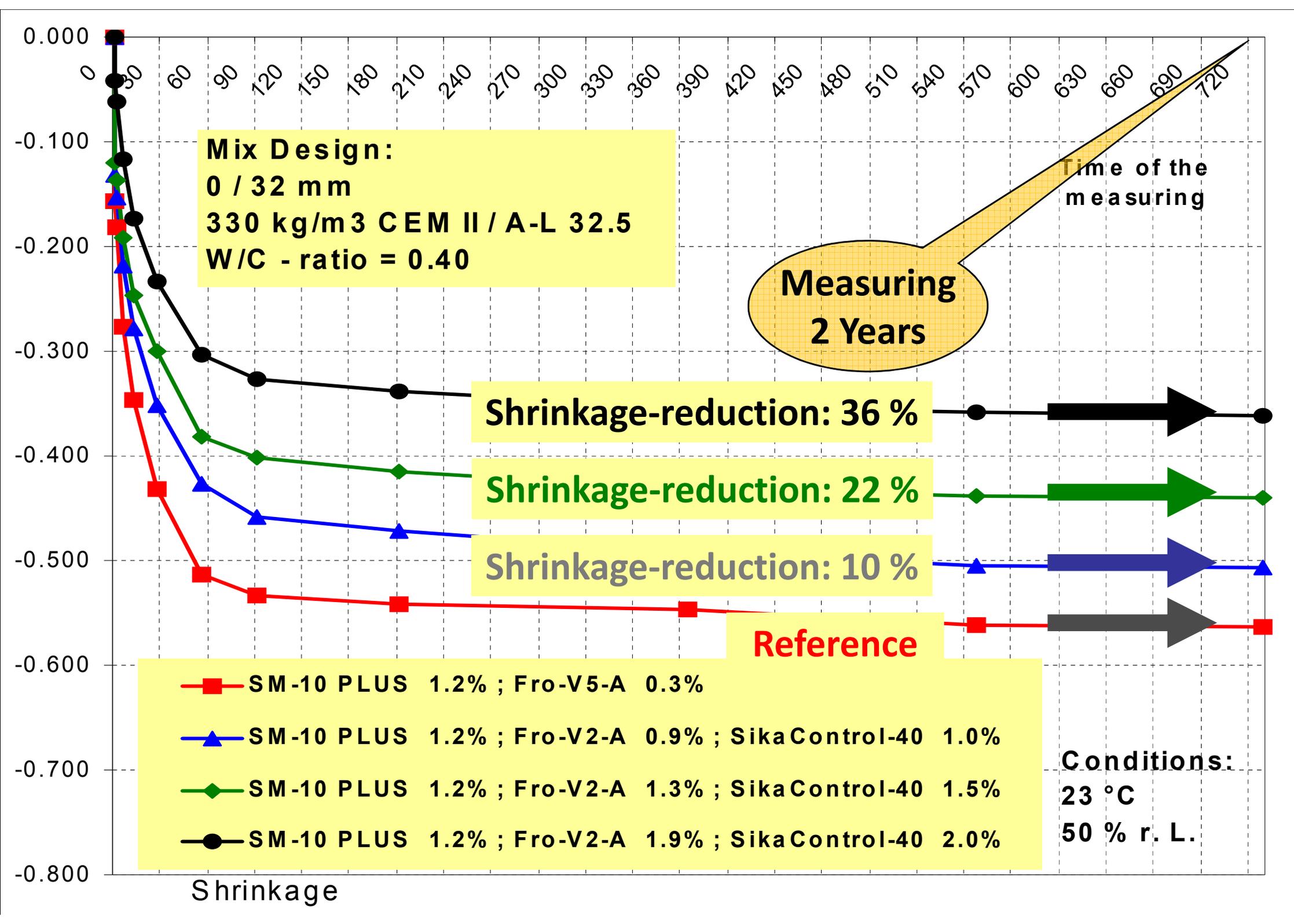
20 ° C / 23 ° C

Rel. air hum. conditions

50 % / 70 %

- **SIA 162/1 Nr. 4**

SIA Standards specify precision and beginning of the measurements.
Climatic conditions and test specimen size are free to chose.



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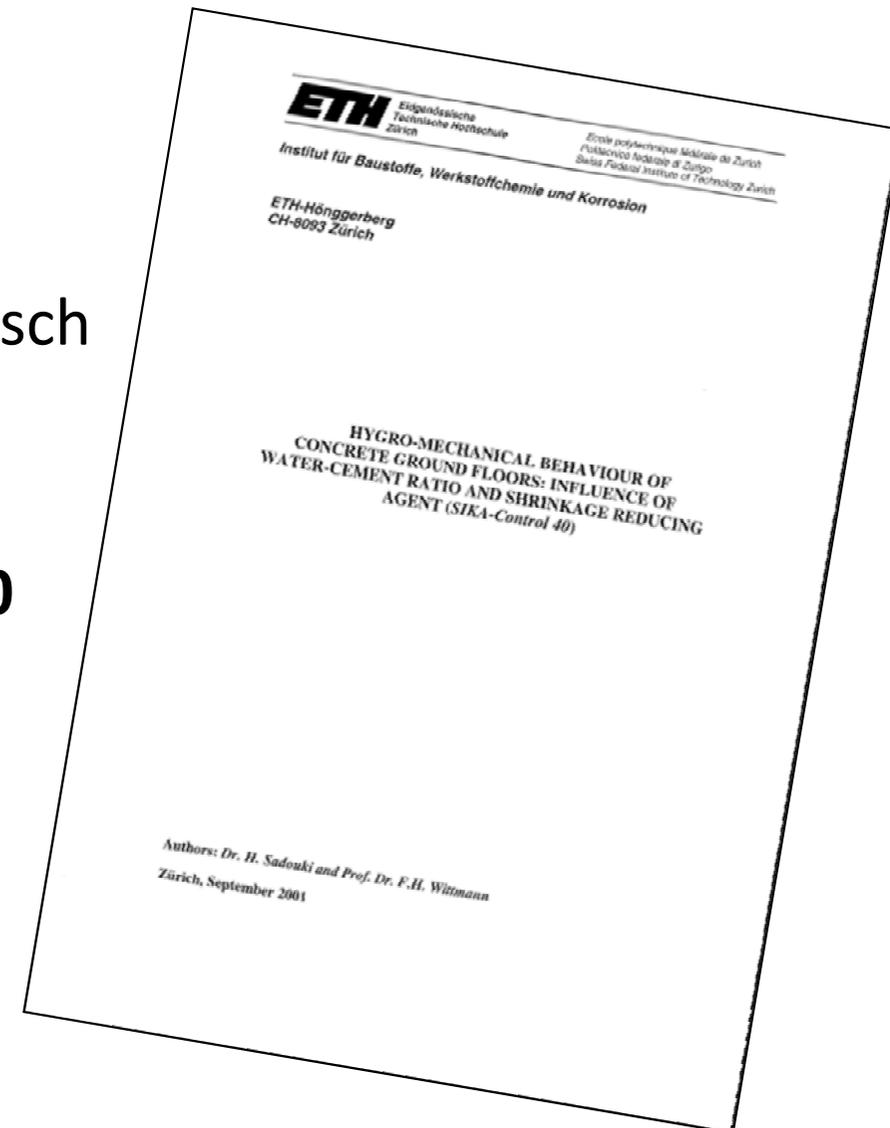
ETHZ: Check performance of SikaControl

- SFITZ Prof. Dr. F.H. Wittmann / Mr. L. Trausch
- **Research report on the efficiency of the**
- **Shrinkage Reduction Agent SikaControl-40**

Humidity-related behaviour of the mixes

Mechanical properties of the mixes

Hygro-mechanical behaviour



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ETHZ: Check performance of SikaControl

- Mortar 0/4 mm with 500 kg/m³ CEM I 42.5 w/c-ratio 0.50

Reference	(M4 0.5 D0)	no SikaControl-40
2nd mix	(M4 0.5 D1)	1.0% SikaControl-40
3rd mix	(M4 0.5 D2)	2.0% SikaControl-40

- Mechanical properties

Mix	f_{cw} 90d	f_{bz} 90d	f_{qz} 90d
M4 0.5 D0	58.7 N/mm ²	9.9 N/mm ²	4.1 N/mm ²
M4 0.5 D1	53.5 N/mm ²	9.3 N/mm ²	3.6 N/mm ²
M4 0.5 D2	51.8 N/mm ²	8.9 N/mm ²	3.4 N/mm ²

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ETHZ: Check performance of SikaControl

- A mortar ring is poured around the steel ring
- Strain gauges fixed onto the steel ring
 ,measure stress and detect stress drop (cracks)
- The test is performed at 45% rel. air hum.

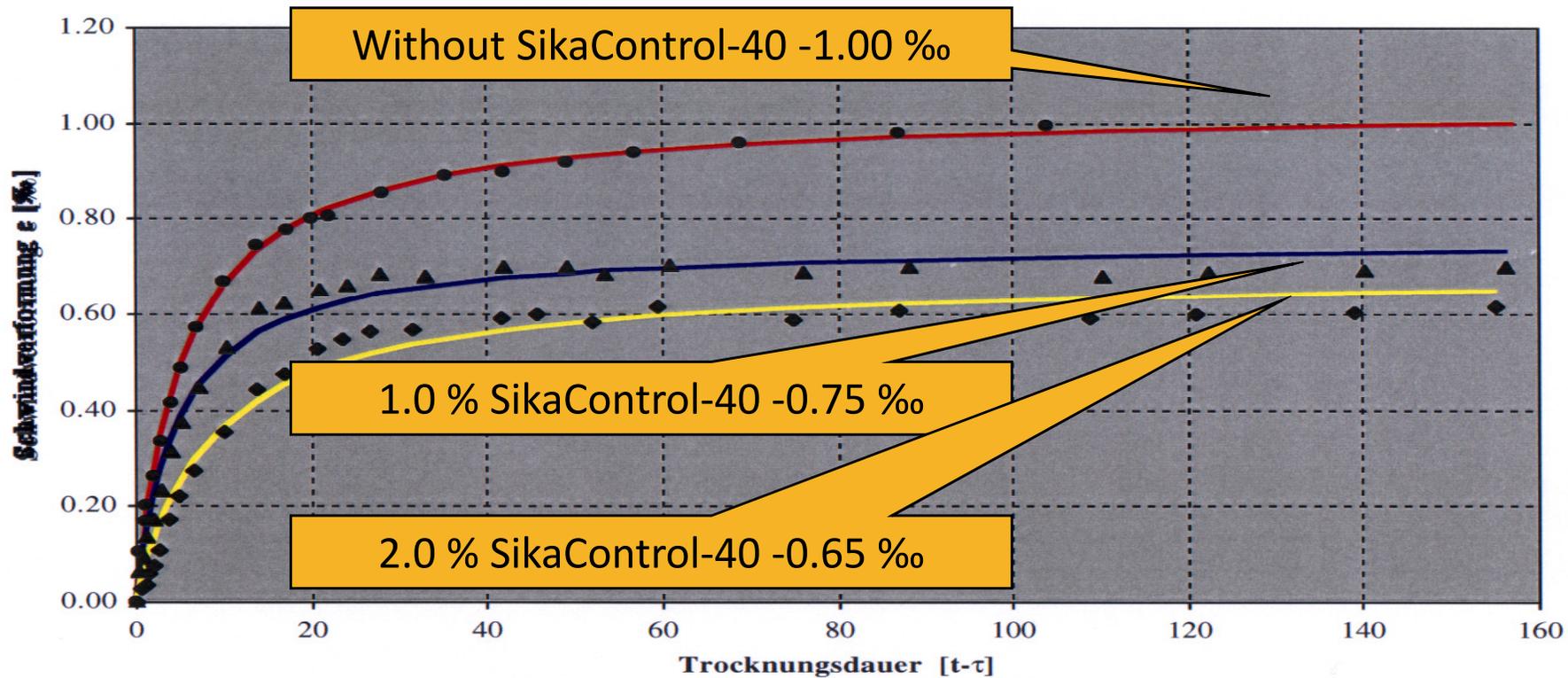


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ETHZ: Check performance of SikaControl

Schwindverformung bei 60% relative Luftfeuchte M4, M4 D1, M4 D2



Test specimen: 2 / 2 / 12 cm

IBWK/ETHZ

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Project reference: Birchi-Tunnel: Requirements

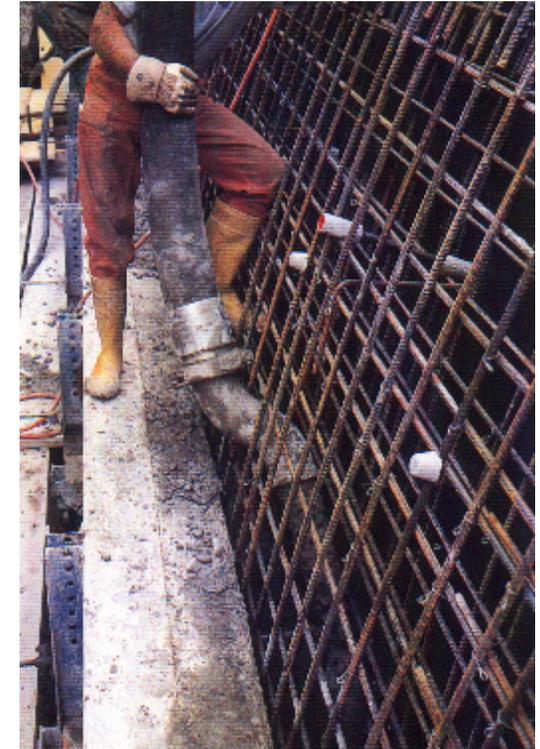
- Min. cement content 300 kg/m³
- Max. allowable w/c-ratio 0.42
- Max. allowable shrinkage 0.25 ‰
tested to ΔS 100/10-60
- For Watertight Concrete:
Test N° 5 SIA 162/1
- For freeze/thaw/de-icing salt resistant concrete:
HIE-FT Test

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Project reference: Birchi-Tunnel: MixDesign

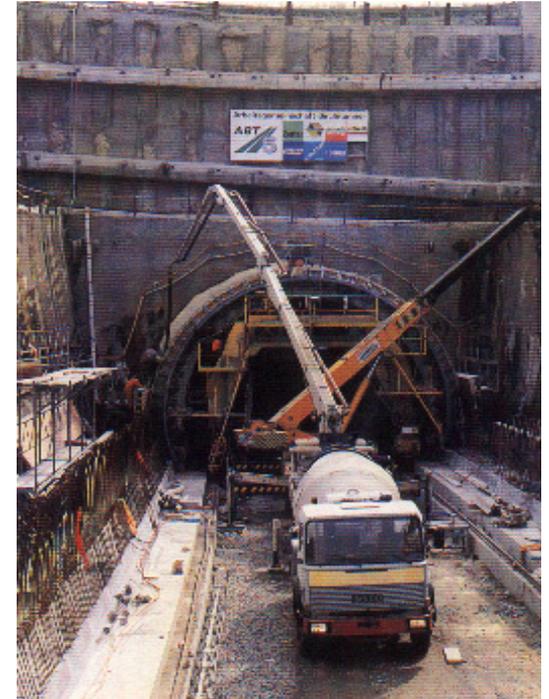
- Concrete type: B 40/30 WUFT
- Aggregate: 0 / 32 mm
- Binder: 350 kg/m³ CEM II / A - L 32.5
- Admixtures:
 - 1.20 % Sikament-10 TOP (HRWR)
 - 0.80 % Sika Fro-V5-A (AEA)
 - 1.00 % SikaControl-40 (SRA)



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Project reference: Birchi-Tunnel: Results

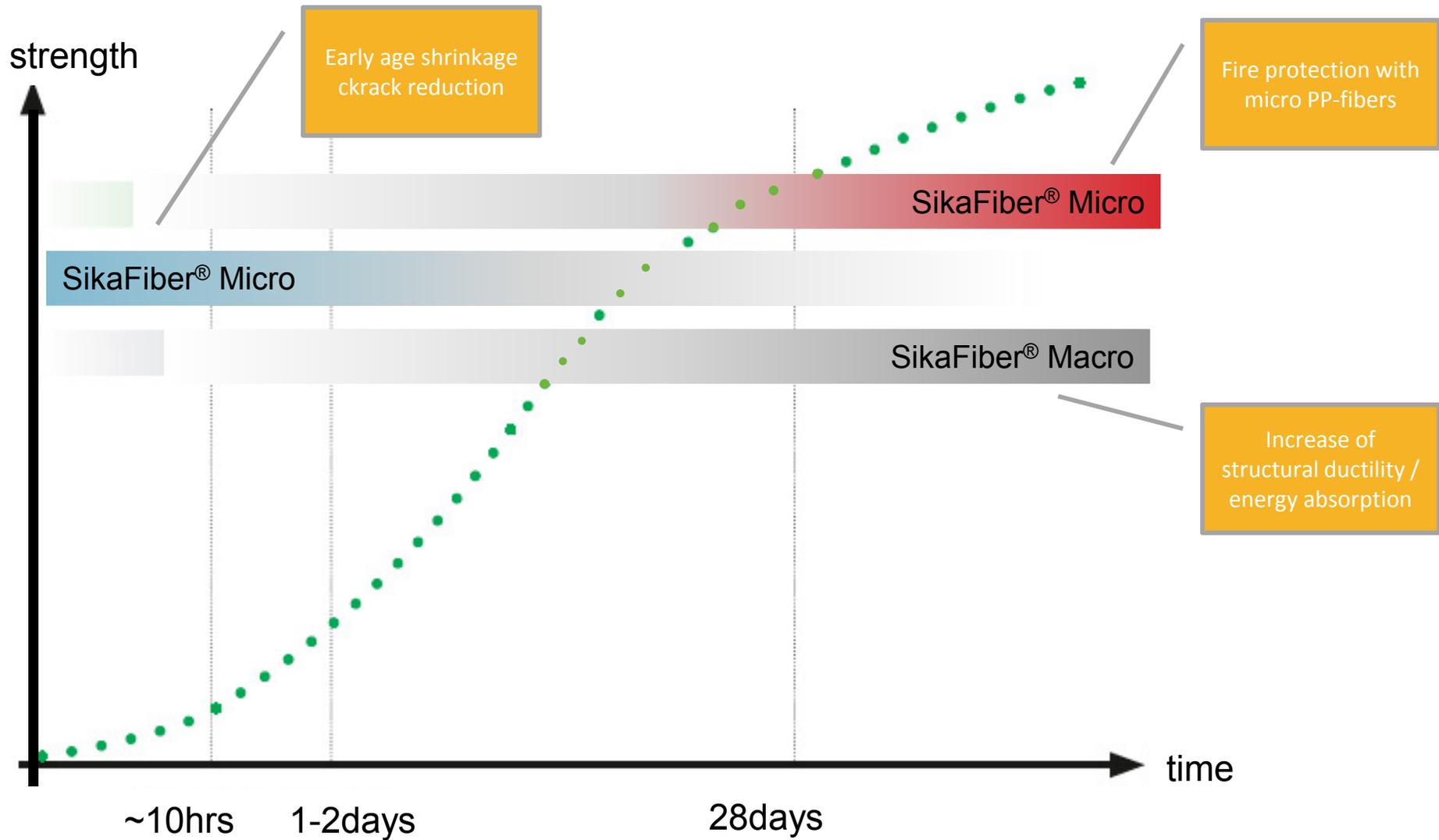
■ Compressive strength:	fcw_{7d}	43.9 N/mm ²
	fcw_{28d}	52.5 N/mm ²
	Density	2390 kg/m ³
■ Water permeability	SIA 162/1 Nr.5	3.312 g/m ² h
■ Freeze/thaw/de-icing salt resistance	FT N ₅₀	176 cycles
■ Shrinkage	ΔS 100/10-60	-0.223 ‰



FIBERS FOR DURABILITY

MICRO FIBERS FOR EARLY AGE SHRINKAGE CRACK CONTROL

FIBER TYPE DUE TO CONCRETE AGE



FIBER RANGE

PP Micro Fibers (d<0.30mm)	PP Macro Fibers	Steel fibers
Reduction of early age shrinkage cracks Dosage: ~600g/m ³	Energy absorption for Shotcrete applications Dosage: 5-8kg/m ³	Energy absorption for Shotcrete applications Dosage: 25-40kg/m ³
Fire protection Dosage: ~2kg/m ³	Crack bridging for slab on ground applications Dosage: 4-6kg/m ³	Crack bridging for slab on ground applications Dosage: 20-30kg/m ³

APPLICATION OF FIBERS

MICRO FIBERS

APPLICATION OF FIBERS

MICRO FIBERS - REDUCTION OF EARLY AGE CRACKS

- The addition of micro fibers has no influence on the shrinkage itself
- **BUT:** The cracks resulting of early age settling and plastic shrinkage can be reduced
 - The fibers enhance the cohesion of the concrete
 - → less settling and plastic deformation of the concrete
- **Due to the low strength of the concrete at early ages, the polypropylen fibers can bridge the cracks and distribute them**
 - → no large visible cracks, but more smaller cracks, which are less deep
 - → larger crack free cross-section
 - → salts and other harming substances are hindered in penetrating the concrete

APPLICATION OF FIBERS

MICRO FIBERS - REDUCTION OF EARLY AGE CRACKS

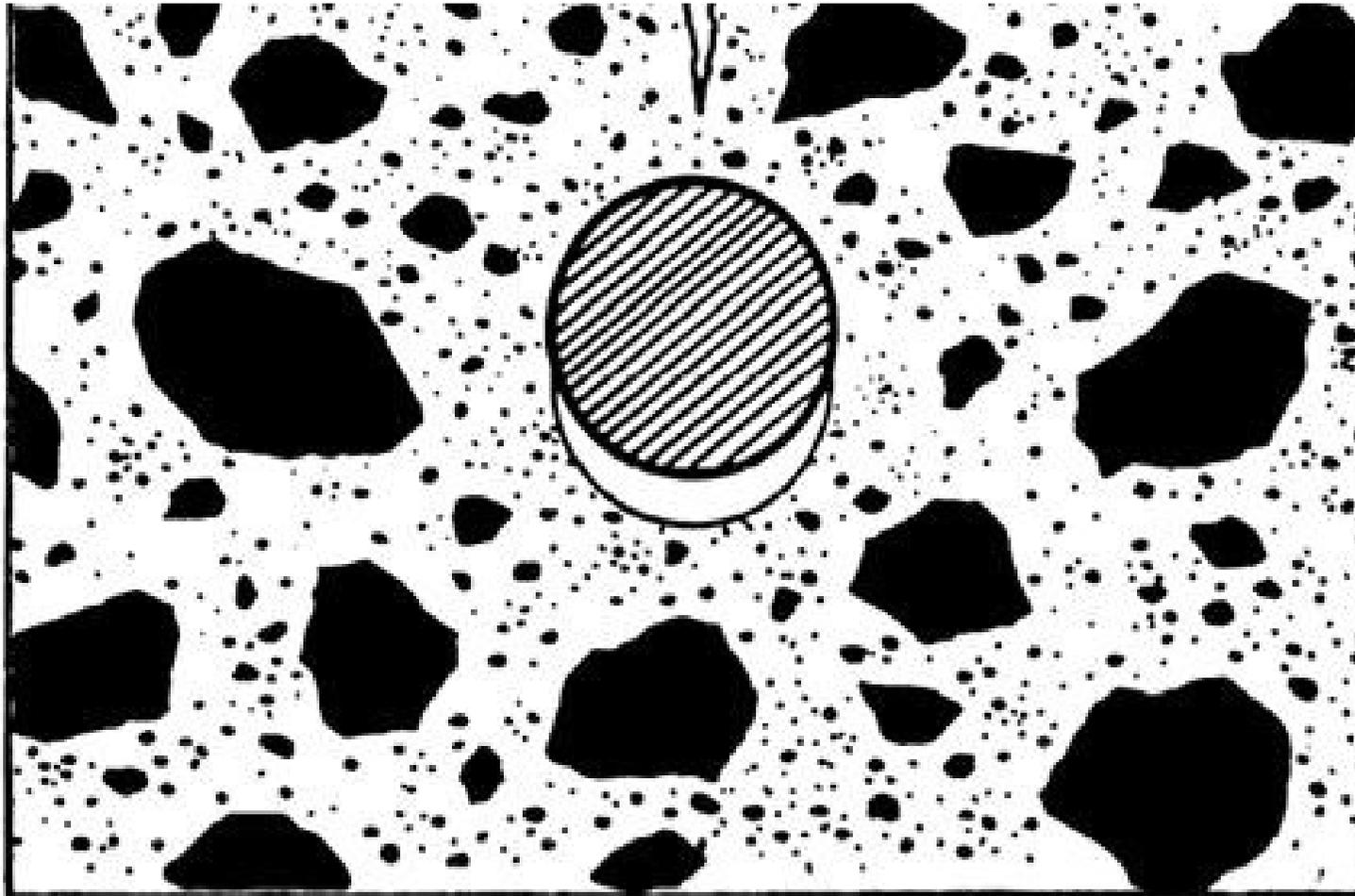
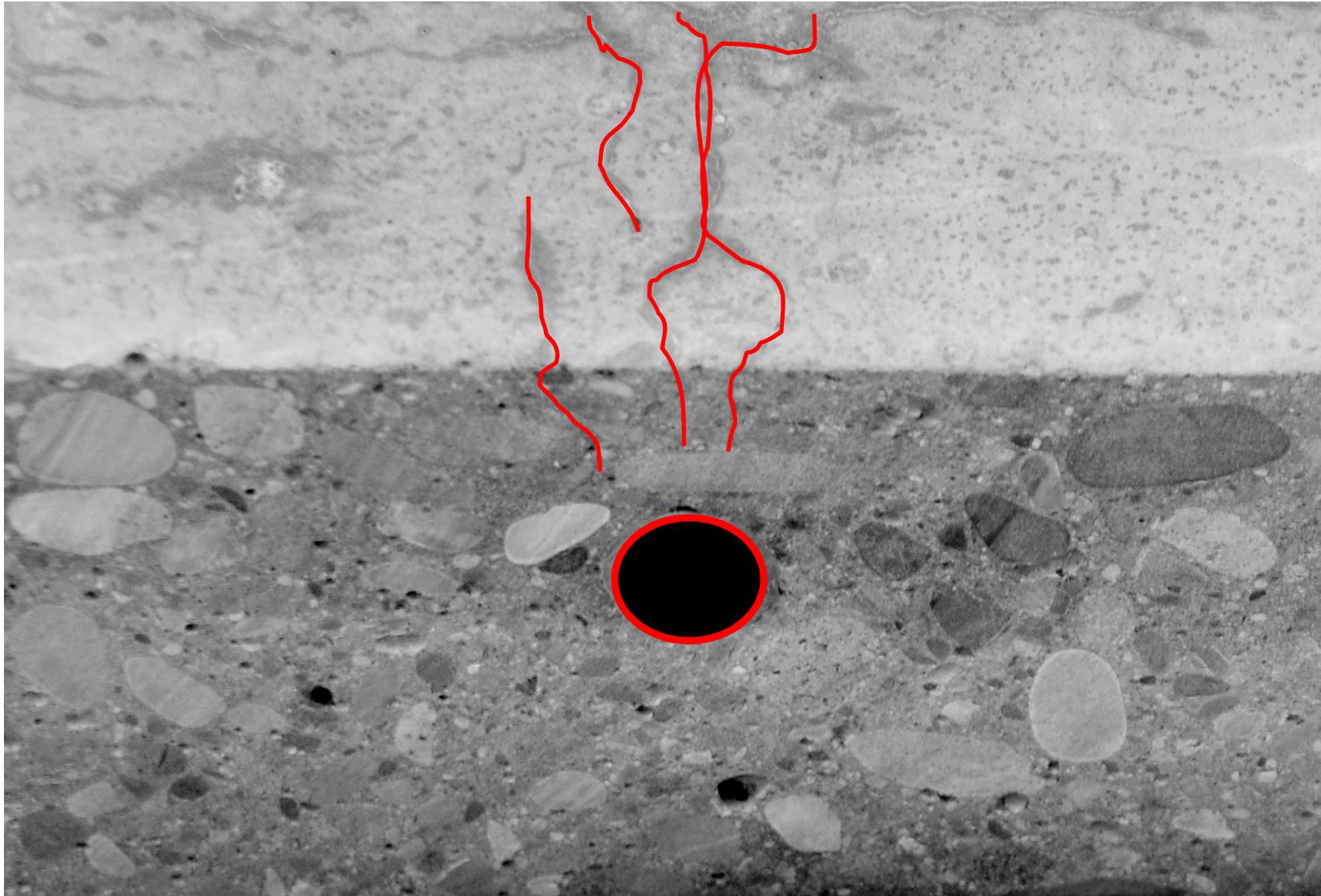


Fig. 1.2-Crack formed due to obstructed settlement (Price 1982)

APPLICATION OF FIBERS

MICRO FIBERS - REDUCTION OF EARLY AGE CRACKS



APPLICATION OF FIBERS

MICRO FIBERS - REDUCTION OF EARLY AGE CRACKS

- With plastic shrinkage or early age settling cracks tend to occur above the steel reinforcement, which needs to be protected for durability
- Less wide and deep cracks result in a more durable structure as the reinforcement is better protected
- Larger crack-free cross-section results in higher strength of the structural element
 - → higher resistance against loads and external influences
- Microfibers: For example 12mm length, 34 microns diameter,
 - Typical Dosage: 600g/m³ (provided in watersoluble bags)