CONCRETE DURABILITY

SHRINKAGE

JÜRGSCHLUMPF
SIKA SERVICES AG / TARGET MARKET CONCRETE
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
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
- ......
CONCRETE DURABILITY
SHRINKAGE

Loss of Humidity
CONCRETE DURABILITY

SHRINKAGE

Loss of Humidity
CONCRETE DURABILITY
SHRINKAGE

Why?

- wind, sunlight
- water loss, incomplete hydration
- low abrasion resistance
- shrinking, cracks
- macro pores, sensitivity to de-icing salts
CONCRETE DURABILITY
SHRINKAGE

Mechanism of curing aids

- **conventional Curing Agent**

- **Sika Curing Agent: Antisols**
  (due to emulsifier amount)

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

SHRINKAGE

Definition

- **Shrinkage compensation**
  Normal shrinkage process compensated by initial volume increase

- **Shrinkage reduction**
  Continuous shrinkage reduction from beginning of hardening
CONCRETE DURABILITY

SHRINKAGE

Hardening stages relevant for shrinkage

<table>
<thead>
<tr>
<th>Phases</th>
<th>Chemical Shrinkage</th>
<th>Plastic Shrinkage</th>
<th>Drying Shrinkage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase I</td>
<td>Re- compacting</td>
<td>Preventing loss of water</td>
<td>Providing curing treatment</td>
</tr>
<tr>
<td>Phase II</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase III</td>
<td></td>
<td></td>
<td>Shrinkage Reduction</td>
</tr>
</tbody>
</table>

4 - 6 h 1 N/mm²
CONCRETE DURABILITY

SHRINKAGE

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)
CONCRETE DURABILITY

SHRINKAGE

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
CONCRETE DURABILITY

SHRINKAGE

Shrinkage Reducing Admixtures: Testing

- **Shrinkage measurements**
  - Test specimen: 12 / 12 / 36 cm
    - or 4 / 4 / 16 cm
    - or φ100mm / 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 choose.
Mix Design:
0 / 32 mm
330 kg/m³ CEM II / A-L 32.5
W/C - ratio = 0.40

Conditions:
23 °C
50 % r. L.

Reference
Shrinkage-reduction: 36 %
Shrinkage-reduction: 22 %
Shrinkage-reduction: 10 %

SM-10 PLUS 1.2% ; Fro-V5-A 0.3%
SM-10 PLUS 1.2% ; Fro-V2-A 0.9% ; SikaControl-40 1.0%
SM-10 PLUS 1.2% ; Fro-V2-A 1.3% ; SikaControl-40 1.5%
SM-10 PLUS 1.2% ; Fro-V2-A 1.9% ; SikaControl-40 2.0%

Measuring 2 Years
CONCRETE DURABILITY
SHRINKAGE

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
CONCRETE DURABILITY

ETHZ: Check performance of SikaControl

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

<table>
<thead>
<tr>
<th>Mix</th>
<th>$f_{cw , 90d}$</th>
<th>$f_{bz , 90d}$</th>
<th>$f_{qz , 90d}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>M4 0.5 D0</td>
<td>58.7 N/mm²</td>
<td>9.9 N/mm²</td>
<td>4.1 N/mm²</td>
</tr>
<tr>
<td>M4 0.5 D1</td>
<td>53.5 N/mm²</td>
<td>9.3 N/mm²</td>
<td>3.6 N/mm²</td>
</tr>
<tr>
<td>M4 0.5 D2</td>
<td>51.8 N/mm²</td>
<td>8.9 N/mm²</td>
<td>3.4 N/mm²</td>
</tr>
</tbody>
</table>

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
CONCRETE DURABILITY

SHRINKAGE

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.
CONCRETE DURABILITY
SHRINKAGE

ETHZ: Check performance of SikaControl

Test specimen: 2 / 2 / 12 cm
CONCRETE DURABILITY

SHRINKAGE

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
CONCRETE DURABILITY
SHRINKAGE

Project reference: Birchi-Tunnel: MixDesign

- Concrete type: B 40/30 WUFT
- Aggregate: 0 / 32 mm
- Binder: 350 kg/m$^3$ 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)
CONCRETE DURABILITY
SHRINKAGE

Project reference: Birchi-Tunnel: Results

- Compressive strength: $fc_{w7d}$ 43.9 N/mm$^2$
  $fc_{w28d}$ 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  $\Delta S 100/10-60$ -0.223 %
FIBERS FOR DURABILITY
MICRO FIBERS FOR EARLY AGE SHRINKAGE CRACK CONTROL
FIBER TYPE DUE TO CONCRETE AGE

<table>
<thead>
<tr>
<th>Fiber Type</th>
<th>Time Period</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SikaFiber® Micro</td>
<td>~10hrs</td>
<td>Early age shrinkage crack reduction</td>
</tr>
<tr>
<td>SikaFiber® Micro</td>
<td>1-2days</td>
<td>Fire protection with micro PP-fibers</td>
</tr>
<tr>
<td>SikaFiber® Macro</td>
<td>28days</td>
<td>Increase of structural ductility / energy absorption</td>
</tr>
</tbody>
</table>

strength vs. time

~10hrs  1-2days  28days
## FIBER RANGE

<table>
<thead>
<tr>
<th>PP Micro Fibers (d&lt;0.30mm)</th>
<th>PP Macro Fibers</th>
<th>Steel fibers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduction of early age shrinkage cracks</td>
<td>Energy absorption for Shotcrete applications</td>
<td>Energy absorption for Shotcrete applications</td>
</tr>
<tr>
<td>Dosage: ~600g/m³</td>
<td>Dosage: 5-8kg/m³</td>
<td>Dosage: 25-40kg/m³</td>
</tr>
<tr>
<td>Fire protection</td>
<td>Crack bridging for slab on ground applications</td>
<td>Crack bridging for slab on ground applications</td>
</tr>
<tr>
<td>Dosage: ~2kg/m³</td>
<td>Dosage: 4-6kg/m³</td>
<td>Dosage: 20-30kg/m³</td>
</tr>
</tbody>
</table>
APPLICATION OF FIBERS

MICRO FIBERS
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).