(4) Precast elements and production technologies

TU Delft
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01 February 2013

Group Concrete Structures

Precast floor elements

Production of hollow core slabs

The long line casting technology.
Production of extruded hollow core slabs

The extrusion machine casting the concrete over a length of about 100m.

Marking recesses with a plotter

Cutting the slabs with a diamond saw to length

Production of extruded hollow core slabs

Lifting the slabs

Transport to the yard

Slab placement at the site

Hollow core slabs

Hollow core slabs have a considerable flexibility. Openings can easily be made during production. Large voids can be provided at the longitudinal joint to comfort reinforcing ties.
Ribbed soffit floors

There are three types of ribbed soffit floors: T-elements, TT-elements and U-elements. Span until 22m, with sectional depths between 150 and 800mm. Width e.g. 2400-3300mm. Good stability and high bearing capacity. U-shaped elements are covered with a shuttering slab unit and an in-situ topping is cast over the whole surface. High torsional stiffness. Overall depth 500-700mm. Maximum span 18m.

Reinforced composite floor plates

Production of precast plate units
Easy lifting and placement
Rough surface for better bond
Storage

These precast floor plates will be completed with in-situ concrete. The plate units are 0,6-2,4m wide and 40-100 thick. The lengths are adjusted to the floor spans. They can be reinforced or prestressed. The under side has a smooth finish. The plates are provided with protruding lattice girders. During transport and erection this reinforcement results in an improved stability and stiffness. The floor plates normally need propping during construction at a spacing of 1.5-3.5 m depending on the upper flange of the girder. The essential advantages of this system, compared to traditional cast-in-situ floors, are that, apart from the props, no moulds have to be used and most of the reinforcement is already incorporated in the prefabricated plank. However, self-weight is higher than for hollow core of ribbed floors.
Beam-block floors

Beam-block floors are made with the following components:
- Precast joists, placed at distances 0.4 to 0.8m
- Prefabricated infill blocks
- In-situ concrete filling

Elements for car parks

Precast frame and skeletal systems, with double T or hollow core elements for the floors are used to obtain large open spaces for parking.

Elements for sport arenas

Components used in different arenas include:
- Columns
- Ring beams
- Double T-elements
- Hollow core units
- Seating components
- Stairs
- Architectural Panels
- Special Elements
**Precast columns**

Columns may be continuous to the full height of the building or may be stepped back at an intermediate level to satisfy architectural demands.

Columns are commonly founded in pockets in in-situ concrete foundations, or on prepared pad foundations with projecting reinforcing bars or anchor bolts.

**Façade elements**

- Facade with polished and sandblasted surfaces
- Facade with smooth and water washed concrete
- Facade white concrete
- Example of two storey height facade units

Floor supported on facade panel

Connecting reinforcement cast in slab cut-outs

Wall to wall connection

Lateral floor connection
The revolution of concrete

Is concrete becoming too strong to test?

On the way to improved properties

Discovering concrete
Principle of Self-Compacting Concrete

Self compacting: a breakthrough in concrete technology

- How to treat SCC in codes?
- Potential?
- Significance of SCC in future

Concrete Tensile Strength of SCC
**Modulus of elasticity of SCC**

Young's Modulus [MPa]

![Graph showing Modulus of elasticity of SCC](image)

**DIN 1045-1**

Range for vibrated concrete

**Cube strength [MPa]**

<table>
<thead>
<tr>
<th>0</th>
<th>10000</th>
<th>20000</th>
<th>30000</th>
<th>40000</th>
<th>50000</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>20</td>
<td>40</td>
<td>60</td>
<td>80</td>
<td>100</td>
</tr>
</tbody>
</table>

**Bond of Ribbed Bars in SCC**

Relative bond strength

Bottom bar

Top bar

(Schulz, 2013)

**Treatment of (traditional) concrete consistency according to EN 206**

<table>
<thead>
<tr>
<th>Compaction</th>
<th>Slump</th>
<th>Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class</td>
<td>[mm]</td>
<td>Class [mm]</td>
</tr>
<tr>
<td>C0</td>
<td>≥ 1.46</td>
<td>F1 ≤ 340</td>
</tr>
<tr>
<td>C1</td>
<td>1.45-1.26</td>
<td>S1 (10-40)</td>
</tr>
<tr>
<td>C2</td>
<td>1.25-1.11</td>
<td>S2 50-90</td>
</tr>
<tr>
<td>C3</td>
<td>1.10-1.04</td>
<td>S3 100-150</td>
</tr>
<tr>
<td>C4</td>
<td>1.05-1.00</td>
<td>S4 (160-210)</td>
</tr>
<tr>
<td>C5</td>
<td>1.00-0.95</td>
<td>S5 (≥ 220)</td>
</tr>
<tr>
<td>C6</td>
<td>0.95-0.90</td>
<td>S6 (≥ 630)</td>
</tr>
<tr>
<td>C7</td>
<td>0.90-0.85</td>
<td>S7 280-330</td>
</tr>
<tr>
<td>C8</td>
<td>0.85-0.80</td>
<td>S8 330-380</td>
</tr>
<tr>
<td>C9</td>
<td>0.80-0.75</td>
<td>S9 380-430</td>
</tr>
<tr>
<td>C10</td>
<td>0.75-0.70</td>
<td>S10 430-480</td>
</tr>
<tr>
<td>C11</td>
<td>0.70-0.65</td>
<td>S11 480-530</td>
</tr>
<tr>
<td>C12</td>
<td>0.65-0.60</td>
<td>S12 530-580</td>
</tr>
<tr>
<td>C13</td>
<td>0.60-0.55</td>
<td>S13 580-630</td>
</tr>
<tr>
<td>C14</td>
<td>0.55-0.50</td>
<td>S14 630-680</td>
</tr>
<tr>
<td>C15</td>
<td>0.50-0.45</td>
<td>S15 680-730</td>
</tr>
<tr>
<td>C16</td>
<td>0.45-0.40</td>
<td>S16 730-780</td>
</tr>
<tr>
<td>C17</td>
<td>0.40-0.35</td>
<td>S17 780-830</td>
</tr>
<tr>
<td>C18</td>
<td>0.35-0.30</td>
<td>S18 830-880</td>
</tr>
<tr>
<td>C19</td>
<td>0.30-0.25</td>
<td>S19 880-930</td>
</tr>
<tr>
<td>C20</td>
<td>0.25-0.20</td>
<td>S20 930-980</td>
</tr>
<tr>
<td>C21</td>
<td>0.20-0.15</td>
<td>S21 980-1030</td>
</tr>
<tr>
<td>C22</td>
<td>0.15-0.10</td>
<td>S22 1030-1080</td>
</tr>
<tr>
<td>C23</td>
<td>0.10-0.05</td>
<td>S23 1080-1130</td>
</tr>
<tr>
<td>C24</td>
<td>0.05-0.00</td>
<td>S24 1130-1180</td>
</tr>
</tbody>
</table>

(Condition: bottom bar)

Bottom bar
Test methods for self compacting concrete

Demands on self compacting concrete
- Flowability
- Self leveling ability
- Segregation stability
- No blocking between rebars

Flowability properties:
- Yield value
- Plastic viscosity

Measuring the flowability of SCC
EN 12350-8: Flow diameter test

Class Flow diameter (mm)
SF1 550 – 650
SF2 660 – 750
SF3 760 - 850

Measuring the viscosity of SCC

V-funnel test (EN 1235-8)

<table>
<thead>
<tr>
<th>Class</th>
<th>V-funnel time (seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VF1</td>
<td>&lt; 9</td>
</tr>
<tr>
<td>VF2</td>
<td>9 - 25</td>
</tr>
</tbody>
</table>

$t_{500}$ test (EN 12350-8)

<table>
<thead>
<tr>
<th>Class</th>
<th>$t_{500}$ (seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>V91</td>
<td>&lt; 2</td>
</tr>
<tr>
<td>V92</td>
<td>3 – 6</td>
</tr>
<tr>
<td>V93</td>
<td>&gt; 6</td>
</tr>
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</table>
Measuring the segregation resistance of self compacting concrete

### Sieve segregation test

**EN 12350-11**

<table>
<thead>
<tr>
<th>Class</th>
<th>Segregation portion (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SR1</td>
<td>≤ 20</td>
</tr>
<tr>
<td>SR2</td>
<td>≤ 15</td>
</tr>
</tbody>
</table>

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Measuring the passing ability of SCC

**J-Ring EN 12350-12**

<table>
<thead>
<tr>
<th>Class</th>
<th>J-ring step (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PJ1</td>
<td>≤ 10 with 12 rebars</td>
</tr>
<tr>
<td>PJ2</td>
<td>≤ 10 with 16 rebars</td>
</tr>
</tbody>
</table>

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Measuring the passing ability of SCC (self leveling ability)

**L-Box EN 12350-10**

<table>
<thead>
<tr>
<th>Class</th>
<th>L-Box ratio (-)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PL1</td>
<td>≥ 0.80 with 2 rebars</td>
</tr>
<tr>
<td>PL2</td>
<td>≥ 0.80 with 3 rebars</td>
</tr>
</tbody>
</table>
Measuring rheological properties

The Japanese method

Consistency classes in EN 206 for traditional concrete (Dutch choice)

<table>
<thead>
<tr>
<th>Consistency</th>
<th>Compaction C</th>
<th>Slump S</th>
<th>Flow Diam. F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry</td>
<td>C0</td>
<td>± 1.46</td>
<td>S1</td>
</tr>
<tr>
<td>Earth dry</td>
<td>C1</td>
<td>1.45-1.28</td>
<td>S2</td>
</tr>
<tr>
<td>Semi plastic</td>
<td>C2</td>
<td>1.25-1.11</td>
<td>S3</td>
</tr>
<tr>
<td>Plastic</td>
<td>C3</td>
<td>1.10-1.04</td>
<td>S4</td>
</tr>
<tr>
<td>Very plastic</td>
<td></td>
<td></td>
<td>S5</td>
</tr>
<tr>
<td>Flowable</td>
<td></td>
<td></td>
<td>S6</td>
</tr>
<tr>
<td>Very flowable</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Extended Consistency Classes used by Dutch SCC producers
Advantages of self compacting concrete in the precast concrete industry

- No noise in the factory
- No dust
- Long service life of formwork
- Excellent quality of concrete
- Very good quality control
- Conditions perfect for relatively sensitive material SCC

Application of self-compacting concrete in the precast concrete industry

1. Casting a wall element
2. Equilizing the surface
3. Finishing the surface
4. Polishing the surface
5. Lifting the surface
6. Wall element with window and door
**SCC Bridge Beams**

Metro station Ajax
Amsterdam

**Particular applications of SCC**

Precast concrete arches

Cultural centre Mons, Belgium.

Arch length 65m from precast element 13 m

**New technologies for SCC: the "Upcrete technology", Reymann Germany**

Concrete Plant International 1-2009
On the way to concrete with higher strength

Hans Hendrik Bache, Denmark, 1986

CRC
Wcf: 0.13 – 0.18
Reinf. Ratio 5-20%
Fibrecontent: 5 – 10%
B150 – B300

Properties of concrete with ultra high strength

- Compressive strength: 150 – 200 Mpa
- Flexural tensile strength: 30 – 45 MPa
- Axial tensile strength: 10 – 15 MPa
- Post cracking strength: 10 MPa
- E-Modulus: 50 - 65 MPa
- Creep coefficient: 0,3-0,5
- Volume weight: 2500 kg/m³
Durability

Statistical distribution of pore-diameters for concrete of various strengths (Schmidt, University Kassel, 2005)

Fatigue (Lappa 2007)

Tests on various types of UHPFRC mixtures

BSL/Ceracem
\[ f_c = 220 \text{ N/mm}^2 \]
\[ V_f = 2.5 \text{ Vol.}\% \]

HSFRC
\[ f_c = 145 \text{ N/mm}^2 \]
\[ V_f = 1.6 \text{ Vol.}\% \]

Hybrid HSFRC
\[ f_c = 1.5 \text{ Vol.}\% \]
\[ V_f = 1.5\% \]

Synergy effects

Combination of short and long fibres to improve properties
Synergy effects

Flexural tensile strength for various fibre combinations

- 1%(60)
- 1%(13) + 0.5%(60)
- 2%(13)
- 1%(13) + 1%(40)
- 2%(6) + 1%(60)
- 2%(13) + 1%(60)
- 2%(6) + 2%(13)
- 4%(6) + 1%(40)

Optimization by fibre cocktails

Advantages as a structural material

- Light elements by high strength (fast assembly, slender structures)
- Self compacting properties (remote casting)
- Implicit reinforcement (no reinforcing works)
- High E-Modulus (favourable for strengthening of structures)
- High abrasion resistance
- Very durable (low maintenance costs)
- Interesting material for "Sustainability"
Mixture composition Bourg les Valence (2002)

- Cement: 1100 kg/m³
- Silicafume: 165 kg/m³
- Steel fibers 20x0.3mm: 235 kg/m³
- Superplasticizer: 40 kg/m³
- Water: 200 kg/m³

28-days strength: 175-210 MPa
Axial tensile strength: 8 MPa
E-Modulus: 64000 MPa
Specific weight: 2800 kg/m³

Ultra high-strength fiber concrete

Stairs of UHPFRC

Tuborg, Denmark
CRC Staircase Denmark

Canopy UHSFRC, The Netherlands

Dutch sanatorium: “De Zonnestraal”

Balconies Denmark

Foto B. Aarup
Hi-con
Denmarken
Balconies Poptahof Delft 2011

Proofloading 1500 kg/m³

New deck for Kaagbridges: heavily reinforced high strength fibre concrete

Challenge: take profit of architectural potential of UHSVB:
Glenmore/Legsby pedestrian bridge
Canada 2007

Span: 53 m
Suspended beams: 34 m (h = 1.1 m)
Crossing 8 traffic lanes

Important aspects:
- Assembly in 8 hours
- No intermediate support

Quarter centre Sedan
France

Facade panels: Ductal 4 x 2 m
Thickness: 45 mm

Architectonic applications France

Villa Enrico Navarra: Architect Rudy Ricciotti

20 elements
2 x 10 m
30 mm thick
Reconstruction stadium Jean Bouin, Parijs
- 20,000 m² precast concrete elements for hull
- Under construction 2012-2013

Stadium Jean Bouin, Parijs
1,900 elements for hull
1,600 elements for facade
l = 8.2 m
b = 2.4 m
d = 35 mm

MuCem Marseille
R. Ricciotti
(artist impression)
New runway Haneda Airport

Haneda Airport Tokyo
Expansion joint

New runway Haneda Airport
Platform for new runway Haneda Airport

Stainless steel pipes and titanium protection layer

Haneda Airport

Connecting deck elements made of UHPFRC by in-situ concrete
Runway Haneda Airport

Production and testing of deck-elements

Steps necessary to stimulate larger scale introduction of UHPC

- Generation of suitable international code recommendations
- Adoption of sustainability criteria
- Comparison of building cost on the project basis and not on the basis of the m³ cost of the concrete

GSE precast UHPFRC bridge at Haneda Tokyo Airport