Test methods for HC materials

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IPHA Technical Seminar
October 26th – 27th 2011
Aachen (GE)
Why this presentation?

- During the latest annual meeting (Oslo May 7\textsuperscript{th} -10\textsuperscript{th}) the technical committee received several questions related to the way hollowcore materials are tested.
- Obviously, our engineers are well familiar with HC and test procedures for HC but less with test procedures for raw materials and concrete.
- Aim : overview of most important standards related to testing of raw materials.
If you are responsible for quality control…

- You are allowed to sleep;
- This presentation takes 30 minutes,
- Please don’t snore!!
This inventory is based on:

- Documents related to CE-Marking
  - EN 13369
  - EN 1168
  - EN 206-1
- Documents related to private quality-marks
  - BENOR (conformity with Belgian prescriptions);
  - KOMO (conformity with Dutch prescriptions);
  - NF (conformity with French prescriptions);
  - Ü (conformity with German prescriptions);
Classification of tests

- Tests can be classified in 4 groups
  1. Inspection of equipment:
     - Testing and measuring equipment;
     - Storage and production;
  2. Materials inspection:
     - General;
     - Materials submitted to an assessment of conformity before delivery;
     - Materials not submitted to an assessment of conformity before delivery;
  3. Process inspection:
     - Concrete;
     - Other subjects;
  4. Finished product inspection.

In this presentation we’ll have a closer look at (2) and (3).
Materials inspection
General statements (1)

- To ascertain that the consignment is as ordered and from the correct source, at each delivery, delivery ticket and/or label on the package will be inspected, prior to discharge.

- Materials submitted to an assessment of conformity before delivery, don’t require further testing, if the considered property is assessed.
However, private quality marks can restrict the use of materials. Some examples:

- HC under NF-certification requires NF-plasticizers;
- HC under Ü-certification requires Ü-steel;
- HC under KOMO-certification requires KOMO-granulates
Materials inspection
General statements (3)

- When a private quality mark is required, other certified products could be allowed if the equivalence can be demonstrated:
  - Two levels;
    - Product characteristics;
    - Test procedures
      - Type of tests;
      - Frequency.
  - Hard to demonstrate full equivalence!
Materials inspection
Materials NOT submitted to an assessment of conformity before delivery

- Cement;
- Aggregates;
- Admixtures;
- Additions;
- Water;
- Recycled water;
- Steel;
- Inserts;
Materials inspection: cement

Materials NOT submitted to an assessment of conformity before delivery

- Cement in Europe: attestation level CE 1+
  The levels of Attestation of Conformity are identified as 1+, 1, 2+, 2, 3 and 4. The highest level is -1 and the lowest is 4.

- Producers task:
  - factory production control
  - further testing of samples according prescribed test plan

- Notified body (third party), certification based on
  - initial type-testing of the product
  - initial inspection of factory and of factory production control
  - continuous surveillance, assessment
  - approval of factory production control

- In EU: generally, cement is assessed before delivery.
Materials inspection: cement

Materials NOT submitted to an assessment of conformity before delivery

- If assessment is needed:

<table>
<thead>
<tr>
<th>Subject</th>
<th>Purpose</th>
<th>Method</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement and other cementitious materials</td>
<td>Conformity with requirements</td>
<td>Appropriate test methods</td>
<td>Each delivery</td>
</tr>
</tbody>
</table>

- Appropriate test methods ??
  - Requirements: EN 197-…
  - Test methods: EN 196-…
  - Most of these tests are hard to do in a factory environment.

Note: blue text parts are taken from EN13369:2004
Materials inspection: cement
Materials NOT submitted to an assessment of conformity before delivery

- Requirements and tests, an overview:

<table>
<thead>
<tr>
<th>Subject</th>
<th>Property</th>
<th>Method</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methods of testing cement</td>
<td>Strength</td>
<td>EN 196-1:2005</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Chemical composition</td>
<td>EN 196-2:2005</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pozzolanicity</td>
<td>EN 196-5:2005</td>
<td>For pozzolanic cements</td>
</tr>
<tr>
<td></td>
<td>Fineness</td>
<td>EN 196-6:2010</td>
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<tr>
<td></td>
<td>Sampling</td>
<td>EN 196-7:2007</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hydration heat</td>
<td>EN 196-8:2003</td>
<td>Solution method</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EN 196-8:2010</td>
<td>Solution method</td>
</tr>
<tr>
<td></td>
<td>Hydration heat</td>
<td>EN 196-9:2003</td>
<td>Semi-adiabatic method</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EN 196-9:2010</td>
<td>Semi-adiabatic method</td>
</tr>
<tr>
<td></td>
<td>Water soluble chromium (VI) content</td>
<td>EN 196-10:2006</td>
<td></td>
</tr>
<tr>
<td>Conformity</td>
<td>Composition, specifications and conformity criteria for common cements</td>
<td>EN 197-1:2000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Conformity evaluation</td>
<td>EN 197-2:2000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Composition, specifications and conformity criteria for low early strength blastfurnace cements</td>
<td>EN 197-4:2004</td>
<td></td>
</tr>
</tbody>
</table>
Materials inspection: cement
Materials NOT submitted to an assessment of conformity before delivery

- Tests that allow to follow the continuity of cement:
  - RILEM prism (1, 7, 28 days)
    - Compressive strength;
    - Flexure tensile strength;
    - Temperature bed can be considered.
  - Blaine (fineness);
  - Start setting (Vicat)
## Materials inspection: aggregates

Materials NOT submitted to an assessment of conformity before delivery

<table>
<thead>
<tr>
<th>Subject</th>
<th>Purpose</th>
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</tr>
</thead>
</table>
| Aggregate | Conformity with requirements (is also valid for recycled concrete and filler) | Visual inspection prior to discharge with respect to the grading shape and impurities (include smell) | - Each delivery  
- When delivery is by belt conveyor and from the same source, periodically depending on local or delivery conditions |
| | Compliance with agreed grading | Sieve analysis according to EN 933-1 | - 1st delivery from source  
- In case of doubt, following visual inspection  
- Periodically depending on local or delivery conditions |
| | Assessment of impurities or contamination | Appropriate test method | - 1st delivery from source  
- In case of doubt, following visual inspection  
- Periodically depending on local or delivery conditions |
| | Assessment of effective water content of concrete (see EN 206-1:2000, 5.4.2) | Test for water absorption according to EN 1097-6 | - 1st delivery from source  
- In case of doubt, following visual inspection |
**Materials inspection: aggregates**

Materials NOT submitted to an assessment of conformity before delivery

<table>
<thead>
<tr>
<th>Subject</th>
<th>Property</th>
<th>Method</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>General properties</strong></td>
<td>Grading</td>
<td>EN 933-1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>EN 933-10</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Shape of coarse aggregate</td>
<td>EN 933-3</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>EN 933-4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fines content</td>
<td>EN 933-1</td>
<td>Fine aggregate (sand)</td>
</tr>
<tr>
<td></td>
<td>Fines quality</td>
<td>EN 933-8</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>EN 933-9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Particle density and water absorption</td>
<td>EN 1097-6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Alkali-silica reactivity</td>
<td>NONE</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Petrographic description</td>
<td>EN 932-3</td>
<td></td>
</tr>
<tr>
<td><strong>Properties specific to end use</strong></td>
<td>Resistance to fragmentation</td>
<td>EN 1097-2</td>
<td>For high strength concrete</td>
</tr>
<tr>
<td></td>
<td>Resistance to wear</td>
<td>EN 1097-1</td>
<td>Aggregates for surface courses only</td>
</tr>
<tr>
<td></td>
<td>Polishing resistance</td>
<td>EN 1097-8</td>
<td>Aggregates for surface courses only</td>
</tr>
<tr>
<td></td>
<td>Resistance to surface abrasion</td>
<td>EN 1097-8:1999, annex A</td>
<td>Aggregates for surface courses only</td>
</tr>
<tr>
<td></td>
<td>Freezing and thawing</td>
<td>EN 1367-1 or EN 1367-2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Chloride content</td>
<td>EN 1744-1:1998, clause 7</td>
<td>For marine aggregates</td>
</tr>
<tr>
<td></td>
<td>Calcium carbonate content</td>
<td>EN 1744-1:1998, 12.3</td>
<td>Fine aggregate for concrete surface courses</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EN 196-21:1989, clause 5</td>
<td></td>
</tr>
</tbody>
</table>

**Note:**
- EN = European Standard
- NONE indicates no specific test method is required.
- Details of properties specific to end use are provided for aggregates used in specific applications.
Materials inspection: aggregates
Materials NOT submitted to an assessment of conformity before delivery

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<th>Subject</th>
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</thead>
<tbody>
<tr>
<td>Properties related to the source</td>
<td>Shell content</td>
<td>EN 933-7</td>
<td>Coarse aggregates of marine origin</td>
</tr>
<tr>
<td></td>
<td>Volume stability - Drying shrinkage</td>
<td>EN 1367-4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Chloride content</td>
<td>EN 1744-1:1998, Clause 7</td>
<td>Aggregates of marine origin</td>
</tr>
<tr>
<td></td>
<td>Sulfur containing compounds</td>
<td>EN 1744-1:1998, Clause 12</td>
<td></td>
</tr>
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<td></td>
<td>Organic substances:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- humus content</td>
<td>EN 1744-1:1998, 15.1</td>
<td>Fine aggregate (sand)</td>
</tr>
<tr>
<td></td>
<td>- fulvo acid</td>
<td>EN 1744-1:1998, 15.2</td>
<td>when indicated humus content is high</td>
</tr>
<tr>
<td></td>
<td>- comparative strength test - stiffening time</td>
<td>EN 1744-1:1998, 15.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- lightweight organic contaminants</td>
<td>EN 1744-1:1998, 14.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dicalcium silicate disintegration</td>
<td>EN 1744-1:1998, 19.1</td>
<td>Blastfurnace slag only</td>
</tr>
<tr>
<td></td>
<td>Iron disintegration</td>
<td>EN 1744-1:1998, 19.2</td>
<td>Blastfurnace slag only</td>
</tr>
</tbody>
</table>

- **Hint**: evaluate sand by “Stokes Law”
Materials inspection: admixtures
Materials NOT submitted to an assessment of conformity before delivery

- General:

<table>
<thead>
<tr>
<th>Subject</th>
<th>Purpose</th>
<th>Method</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Admixtures</td>
<td>Conformity with normal appearance</td>
<td>Visual inspection</td>
<td>Each delivery</td>
</tr>
<tr>
<td>Uniformity of density</td>
<td></td>
<td>Test to EN 934-2</td>
<td>Each delivery</td>
</tr>
<tr>
<td>Conformity with suppliers stated data</td>
<td>Tests for identification according to EN 934-2, e.g. density, infrared etc.</td>
<td>In case of doubt</td>
<td></td>
</tr>
</tbody>
</table>

Note: pay attention to chloride content of admixtures

- Tests according EN 934-2 should be done in specialised laboratory;

- Easy to do (at delivery)
  - Colour;
  - Density;
Materials inspection : additions
Materials NOT submitted to an assessment of conformity before delivery

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<tr>
<th>Subject</th>
<th>Purpose</th>
<th>Method</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Additions/pigments</td>
<td>Conformity with normal appearance</td>
<td>Visual inspection</td>
<td>- Each delivery</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Periodically during production of concrete</td>
</tr>
<tr>
<td>Uniformity of density</td>
<td></td>
<td>Appropriate test method</td>
<td>- Each delivery</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Periodically during production of concrete</td>
</tr>
<tr>
<td>Identification of changes in carbon content which may affect air entrained concrete</td>
<td>Test of loss of ignition</td>
<td>Each delivery to be used for air-entrained concrete</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Subject</th>
<th>Property</th>
<th>Method</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pigments</td>
<td>Specifications and methods of test</td>
<td>EN 12878:2005</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Conformity evaluation</td>
<td>EN 450-2:2005</td>
<td></td>
</tr>
<tr>
<td>Ground granulated blast furnace slag</td>
<td>Definitions, specifications and conformity criteria</td>
<td>EN 15167-1:2006</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Conformity evaluation</td>
<td>EN 15167-2:2006</td>
<td></td>
</tr>
<tr>
<td>Silica fume</td>
<td>Definitions, requirements and conformity criteria</td>
<td>EN 13263-1:2005+A1:2009</td>
<td></td>
</tr>
<tr>
<td>Recycled slurry</td>
<td>Density</td>
<td>Producer</td>
<td>Only from own plant!!</td>
</tr>
</tbody>
</table>
Materials inspection: water
Materials NOT submitted to an assessment of conformity before delivery

- Consider tap water as assessed water, however, check chloride content;
- Other:

<table>
<thead>
<tr>
<th>Subject</th>
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<th>Method</th>
<th>Frequency</th>
</tr>
</thead>
</table>
| Water not taken from a public distribution system | To ascertain that the water is free from harmful constituents | Test according to EN 1008 | - 1st use of new source
- Water from open water course: 3 times a year, or more depending on local conditions
- Other sources: once a year
- In case of doubt |

- EN 1008:2002 has 2 (of 3) very useful annexes:
  - Testing scheme for mixing water for concrete (informative);
  - Requirements for the use of water recovered from processes in the concrete industry (normative).
Materials inspection: recycled water
Materials NOT submitted to an assessment of conformity before delivery

- General: only use water recovered from proper production;

<table>
<thead>
<tr>
<th>Subject</th>
<th>Purpose</th>
<th>Method</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recycled water</td>
<td>Check for solid content and contaminants (see 4.1.2)</td>
<td>Visual inspection</td>
<td>Weekly</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Test to prEN 1008</td>
<td>In case of doubt</td>
</tr>
</tbody>
</table>

- Annex A of EN1008 can be used to calculate the maximum density of recycled slurry.
- Hint: Use “Stokes Law” + density check.
## Materials inspection: steel

Materials NOT submitted to an assessment of conformity before delivery

<table>
<thead>
<tr>
<th>Subject</th>
<th>Purpose</th>
<th>Method</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel</td>
<td>Conformity with requirements (see 4.1.3 and 4.1.4)*</td>
<td>Visual inspection</td>
<td>Each delivery</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Appropriate test method</td>
<td>Each delivery</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Subject</th>
<th>Property</th>
<th>Method</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prestressing steel</td>
<td>prEN 10138-1:2009</td>
<td>EN ISO 15630-3:2010</td>
<td>General requirements</td>
</tr>
<tr>
<td>prEN 10138-2:2009</td>
<td>EN ISO 15630-3:2010</td>
<td>Wire</td>
<td></td>
</tr>
<tr>
<td>prEN 10138-3:2009</td>
<td>EN ISO 15630-3:2010</td>
<td>Strand</td>
<td></td>
</tr>
<tr>
<td>prEN 10138-4:2009</td>
<td>EN ISO 15630-3:2010</td>
<td>Bar</td>
<td></td>
</tr>
</tbody>
</table>

- In practice: local standards and test methods are still used.
Materials inspection: inserts

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<table>
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<tr>
<th>Subject</th>
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<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inserts and connections</td>
<td>Conformity with requirements (see 4.1.5)</td>
<td>Manufacturers method</td>
<td>Each delivery</td>
</tr>
</tbody>
</table>

- Integrated lifting devices should be assessed similarly;
  - In practice: every country has own procedure for testing and for demonstrating conformity;
    - Safety factors: national determined!!
  - CEN/TR 15728 still under discussion;
  - EC 0, Chapter D7 gives good guidelines for evaluation of conformity.
Concrete
Hardened and fresh

- Water absorption;
  - EN 13369 old/new.

- Tensile strength;
  - On cylinders;
  - Alternative.

- Consistency;
  - Common procedures;
  - Alternative.

- Full scale test.
  - Why?
Concrete (hardened)
Water absorption

  - Annex G : French method;
  - Resin protection to be applied;
  - Method is rather complex and time consuming.

- Next version:
  - Easier method;
  - No resin;
  - Considered as “equal”.
Concrete (hardened)
Potential versus structural strength (1)

Definitions:

- Potential strength:
  - concrete strength derived from tests on cubes or cylinders conforming to EN 12390-3 made and cured in laboratory conditions in accordance with EN 12390-2;

- Structural strength:
  - concrete strength derived from tests on specimens (drilled cores or cut prisms) extracted from the finished product (direct structural strength) or deduced from tests on standard specimens (as for potential strength) but cured in factory conditions as close as possible to the structural product (indirect structural strength)
Concrete (hardened)
Potential versus structural strength (2)

- In case of direct structural strength:
  - Consult EN 13791: Assessment of in-situ compressive strength in structures and precast concrete components;
  - Table 1: $f_{ck, is} = 0.85 \ f_{ck}$
  - Benefit is rarely used.
  - HC producers should discuss this topic with notified body.
  - Background documents are available.
Concrete (hardened)
Tensile strength (1)

- Tensile test on cylinders is subject to large scatter;
  - Defects caused by nature;
  - Defects caused by drilling;
  - Defects caused by testing.
Concrete (hardened)
Tensile strength (2)

- Possible answer: Tensile splitting strength
  - EN 12390-6
  - Preliminary tests: less scatter;
  - Easy to convert to tensile strength (0.9);
  - Samples can be cut from HC;
  - Extra investment is rather low if press can be calibrated in lower range.
Concrete (hardened)
Compressive strength (on cylinders)

- Direct structural strength: $f_{\text{ck, is}} = 0.85 f_{\text{ck}}$
- Calculation from (small) cylinders towards cubes
  - Do not use factors from (local) standards
  - Determine factors by comparing:
    - Compressive strength on cylinders drilled out of cubes;
    - Compressive strength on cubes.
Concrete (fresh)
Consistency

- Recognised methods:
  - EN 12350-2 (Slump)
  - EN 12350-5 (Flow/Shock-table)
  - EN 12350-3 (Vebe)
  - EN 12350-4 (Walz)

- Concrete used for HC
  - Determination of consistency is imposed by (local) standards;
  - Only VeBe and Walz can be considered;
  - Test don’t have required “resolution”
Concrete (fresh)
Consistency

- Alternative: Gyratory compactor
  - The precession of the die compacts the concrete;
  - Compactability of the concrete is measured by the number of cycles for a desired raw density of concrete;
  - The lower the number of cycles is, the better is the compactability
Concrete (hardened)
Full scale test (EN1168 – Annex J)

- Further full scale type testing according to Annex J shall be performed if there is a major change in the design of the cross sections, in concrete strength, in the type or operating principal of the production machine or if there is another change which could significantly affect shear resistance.

- The change of concrete compressive strength by more than 1 class shall be considered as a major change of concrete strength.
Concrete (hardened)
Full scale test (EN1168 – Annex J)

- Annex J test gives good insights;
- Test should be done by producers on a voluntary base;
- Only HC is submitted to destructive testing;
  - Most tested construction product in the world;
  - Are other products more reliable (e.g. beam and blocks)
- Other methods are available evaluate HC in case of changes in concrete strength, compaction method,....
- EN 1168 should not impose annex J test?
- Your opinion please?
Summary

- A large number of tests is available and well documented in (European standards);
- Private quality marks can make life much easier;
- HC is one of the best tested construction materials in the world;
  - Start looking for benefits in the standard;
  - Sometimes, the best product just needs better procedures.