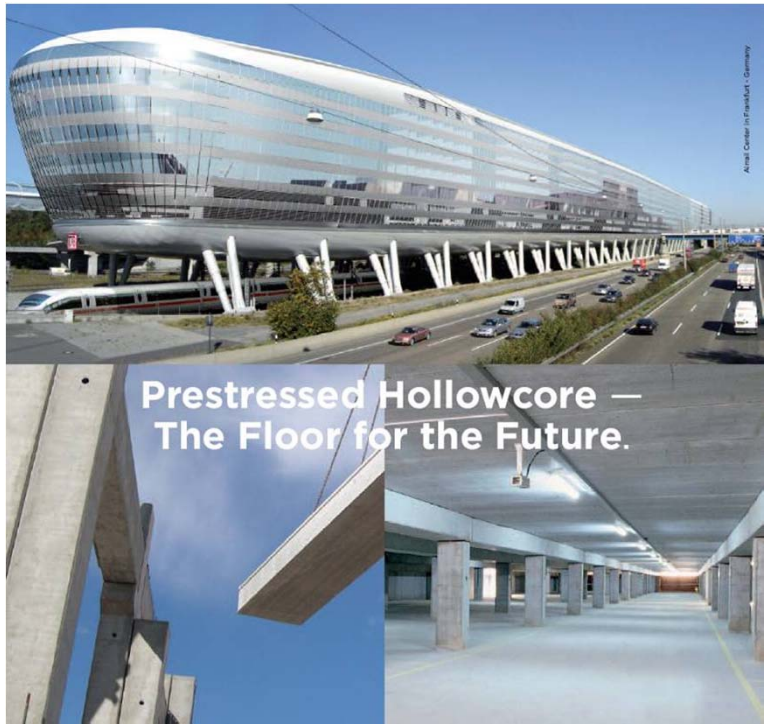
INTERNATIONAL PRESTRESSED HOLLOWCORE ASSOCIATION

Test methods for HC materials



Stef MAAS

IPHA Technical Seminar

October 26th – 27th 2011

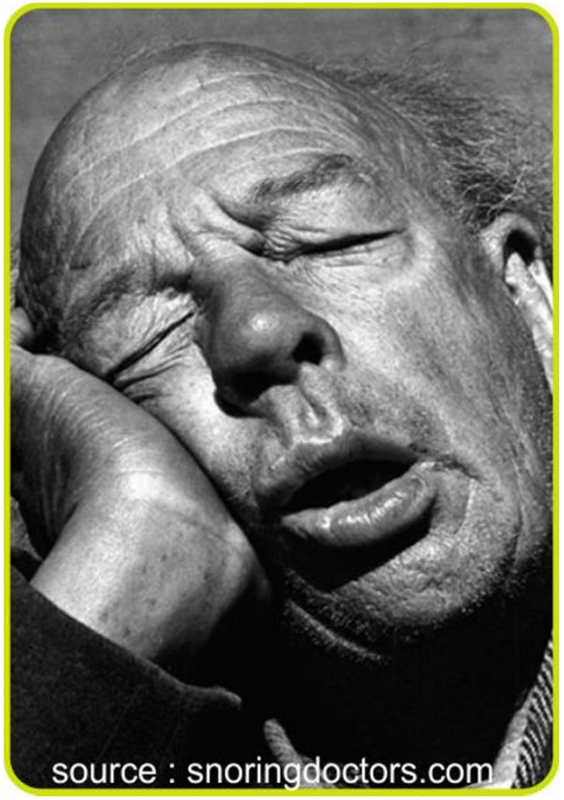
Aachen (GE)

Why this presentation?

- During the latest annual meeting (Oslo May 7th -10th) 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…

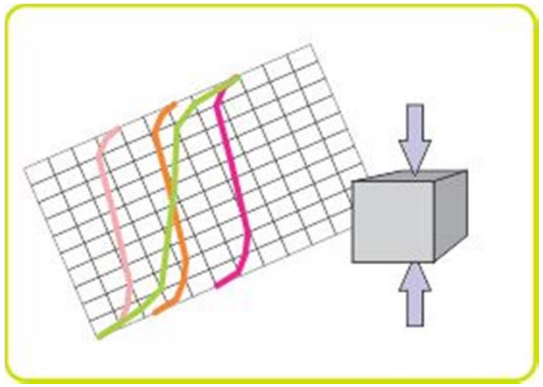
- You are allowed to sleep;
- This presentation takes 30 minutes,
- Please don’t snore!!



Inventory

- 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)

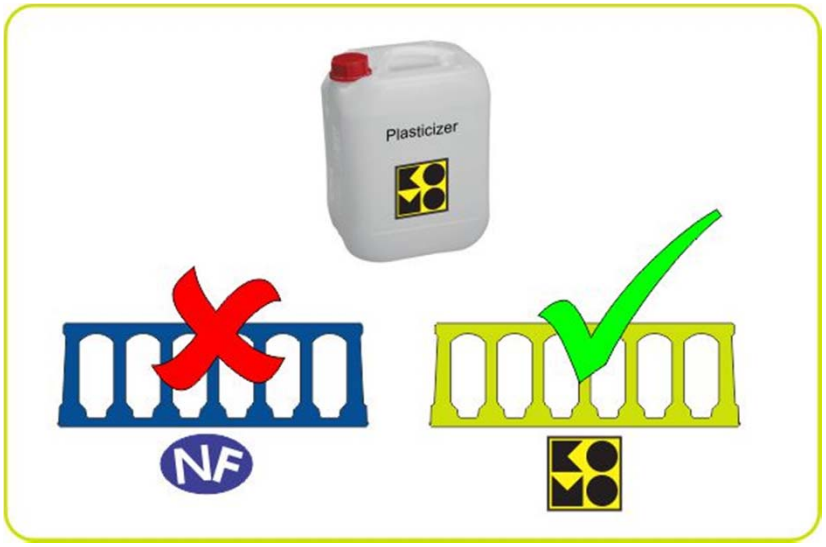
- To ascertain that the consignment is as ordered and from the correct source, at each delivery, delivery ticket and/or label on the package will be inspected, prior to discharge.

- Materials submitted to an assessment of conformity before delivery, don’t require further testing, if the considered property is assessed.

Materials inspection

General statements (2)

- 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 :

Subject	Purpose	Method	Frequency
Cement and other cementitious materials	Conformity with requirements	Appropriate test methods	Each delivery

- Appropriate test methods ??
  - Requirements : EN 197-…
  - Test methods : EN 196-…
  - Most of these test 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:

Subject	Property	Method	Remark
Methods of testing cement	Strength	EN 196-1:2005	
	Chemical composition	EN 196-2:2005	
	Setting times and soundness	EN 196-3:2005+A1:2008	
	Pozzolanicity	EN 196-5:2005	For pozzolanic cements
	Fineness	EN 196-6:2010	
	Sampling	EN 196-7:2007	
	Hydration heat	EN 196-8:2003	Solution method
	Hydration heat	EN 196-8:2010	Solution method
	Hydration heat	EN 196-9:2003	Semi-adiabatic method
	Hydration heat	EN 196-9:2010	Semi-adiabatic method
	Water soluble chromium (VI) content	EN 196-10:2006	
Conformity	Composition, specifications and conformity criteria for common cements	EN 197-1:2000	
	Conformity evaluation	EN 197-2:2000	
	Composition, specifications and conformity criteria for low early strength blastfurnace cements	EN 197-4:2004	

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)


Source : Matest


Source : CBR


Source : CBR

Materials inspection : aggregates

Materials NOT submitted to an assessment of conformity before delivery

Subject	Purpose	Method	Frequency
Aggregate *could also be imposed for recycled concrete aggregates*	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

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

Materials inspection : aggregates

Materials NOT submitted to an assessment of conformity before delivery

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

- Hint : evaluate sand by “Stokes Law”

Materials inspection : admixtures

Materials NOT submitted to an assessment of conformity before delivery

- General :

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

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

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

Subject	Property	Method	Remark
Pigments	Specifications and methods of test	EN 12878:2005	
Flyash	Definition, specifications and conformity criteria	EN 450-1:2005+A1:2007	
	Conformity evaluation	EN 450-2:2005	
Ground granulated blast furnace slag	Definitions, specifications and conformity criteria	EN 15167-1:2006	
	Conformity evaluation	EN 15167-2:2006	
Silica fume	Definitions, requirements and conformity criteria	EN 13263-1:2005+A1:2009	
	Conformity evaluation	EN 13263-2:2005+A1:2009	
Recycled slurry	Density	Producer	Only from own plant!!

Materials inspection : water

Materials NOT submitted to an assessment of conformity before delivery

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

Subject	Purpose	Method	Frequency
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;

Subject	Purpose	Method	Frequency
Recycled water	Check for solid content and contaminants (see 4.1.2)	Visual inspection	Weekly
		Test to prEN 1008	In case of doubt

- 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

Subject	Purpose	Method	Frequency
Steel	Conformity with requirements (see 4.1.3 and 4.1.4)[a]	Visual inspection	Each delivery
		Appropriate test method	Each delivery

Subject	Property	Method	Remark
Prestressing steel	prEN 10138-1:2009	EN ISO 15630-3:2010	General requirements
	prEN 10138-2:2009	EN ISO 15630-3:2010	Wire
	prEN 10138-3:2009	EN ISO 15630-3:2010	Strand
	prEN 10138-4:2009	EN ISO 15630-3:2010	Bar

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

Materials inspection : inserts

Materials NOT submitted to an assessment of conformity before delivery

Subject	Purpose	Method	Frequency
Inserts and connections	Conformity with requirements (see 4.1.5)	Manufacturers method	Each delivery

- 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

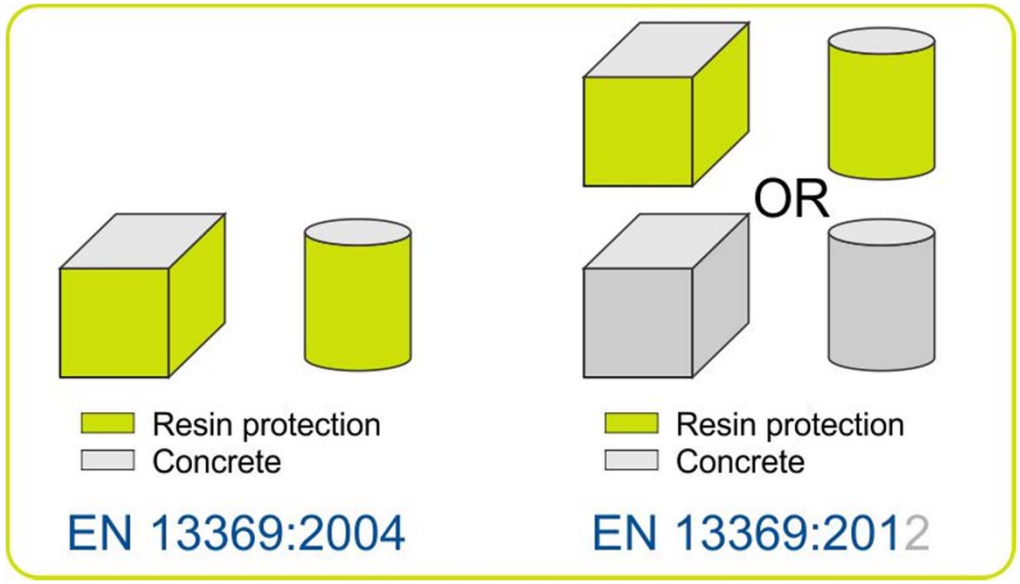
Hardened and fresh

- Water absorption;
  - EN 13369 old/new.
- Tensile strength;
  - On cylinders;
  - Alternative.
- Consistency;
  - Common procedures;
  - Alternative.
- Full scale test.
  - Why?

Concrete (hardened)

Water absorption

- EN 13369:2004 +A1:2006+AC:2007
  - 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)

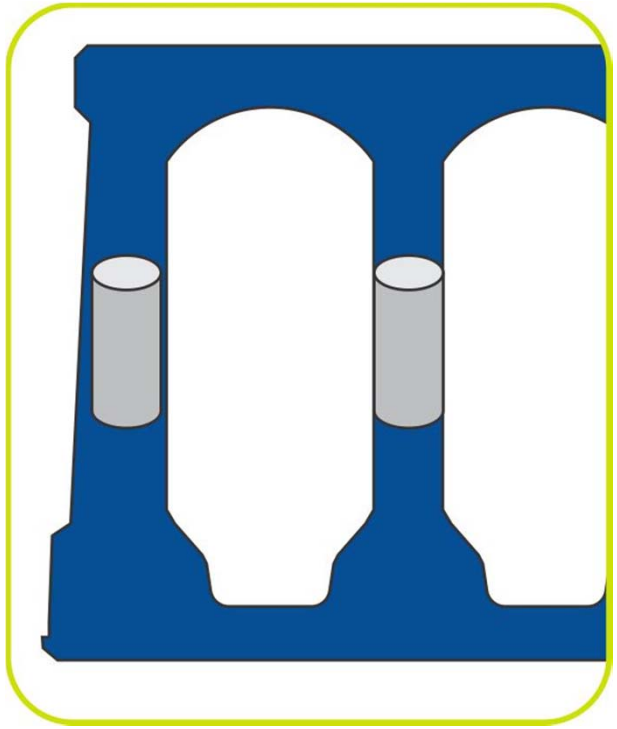
Potential versus structural strength (1)

- 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)

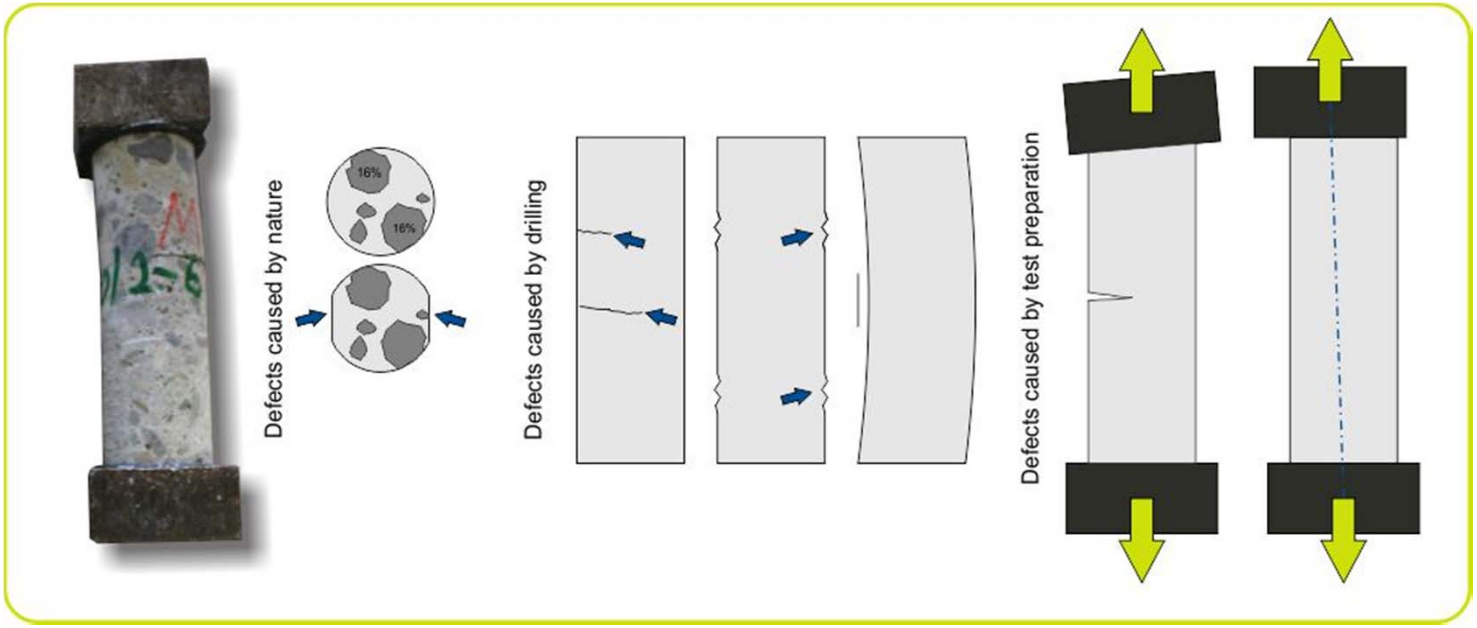
Potential versus structural strength (2)

- 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.



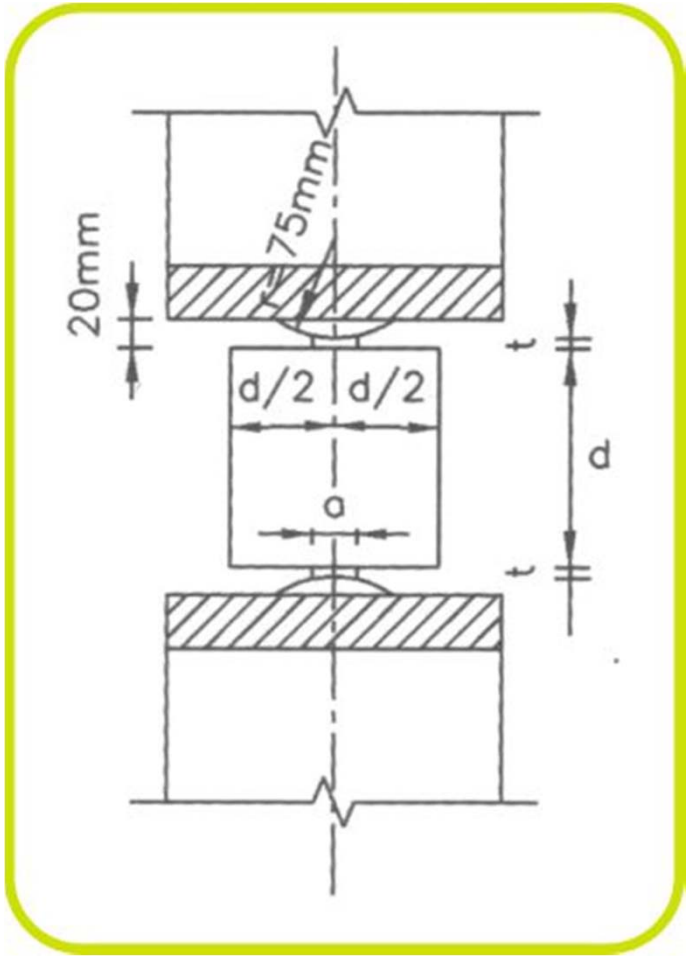
Concrete (hardened)
Tensile strength (1)

- 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 : $f_{ck,\ is} = 0{,}85\ f_{ck}$
- 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 test 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 need better procedures