Concrete Standards: a review of developments and refinements

Bryan Perrie

The Concrete Institute
Outline

• Introduction
• The way it was….
• Structural Design Codes
• Construction Specifications
• Material Specifications
• Test Methods
• Implications
• Conclusions
Why Standards and Specifications
• Control
• Protection
• Assessment
The way it was…
In Europe...
EN 206-1 Concrete

EN 1990 Basis for structural design

EN 1992 Design of concrete structures

EN 12350 Testing of fresh concrete

EN 12390 Testing of hardened concrete

BS 8500-1 Complimentary standard to EN 206-1 Method of specifying and guidance to the specifier

BS 8500-1 Complimentary standard to EN 206-1 Specification for constituent materials and concrete

ENV 13670-1 Execution of concrete structures

EN 197 Cement

EN 450 Fly ash

EN 13263 Silica fume

EN 15167 GGBS

EN 934 Admixtures

EN 12620 Aggregates

EN 1008 Water
Structural Design Codes
Reference Codes

- Codes reflect the customs from where they originate.
- Adopted codes may either be overly conservative, un-conservative, or irrelevant.
- Foreign reference codes are being withdrawn as European countries start adopting the Eurocode.
Current Revision Status

- Loading code and basis of design (2010)
- Concrete water retaining standard
- Concrete design standard
Loading Code

- Basis of design and actions for buildings and industrial structures - now based on EN-1990 and EN-1991. Extracted from Eurocode relevant sections for South Africa:
  - Where necessary, local requirements and conditions were allowed for.
  - SANS 10160 was issued in 2010

= ADAPTED Code
Design of Water Retaining Structures

• Project funded by Water Research Commission
• 2007-2010
• Reference standards:
  – BS8007
  – EN-1992-1-3
• DRAFT Standard completed in 2010:
  = ADAPTED Code (needs a concrete design code)
Adopting a Foreign Code

• Advantages of adopting foreign code:
  – Regular updates
  – Supporting material (manuals, software, graphs)
  – Time to implement

• Disadvantages of adopting a foreign code:
  – Materials
  – Local practice and procedures
  – Local standards
  – Local environment
Working Group Decision


• Process to *adopt* responsibly:
  – comparative calculations
  – review for local implications
  – identifying and motivating the choice of nationally determined parameters.
  – characterizing of South African material properties
Adopting EN 1992

• Time line:
  – Working group formed in August 2007
  – Review of relevant parts 2007 – 2010
  – Choose nationally determined parameters : 2011
  – Draft annexure(s) to National Annex (2012)
  – Draft code : END ????
Construction and Material Standards and Test Methods
Specifying Concrete
Traditional Approach

• Specify certain properties and actions
  • Aggregates
  • Concrete
  • Construction process
  • Quality control (strength)

• Prescriptive approach with some performance requirements
Traditional Approach

• Changes recently to add properties to control “covercrete”
• Specify those actual properties which prevent deterioration
• Move towards preventing
  • Ingress of chlorides
  • Ingress of CO$_2$
  • Poor curing
Traditional Approach

• Design structurally and then

• Determine how to make the structure durable
New Philosophy

• Determine environment and required longevity
• Determine required durability
• Choose an approach to achieve durability, and then

• Determine structural design
Changes to SA Concrete Standards and Specifications
Construction Specifications
SANS 10100-2

- Definitions
- Materials
- Plant
- Proportioning
- Production
- Reinforcement
- Formwork
- Placing

- Mass concrete
- Prestressing
- Precast
- Testing and acceptance
- Load tests
- Procedure in event of failure
SANS 10100-2  The Way Forward

• Adopting EN 206 *Concrete*
• Adopting EN 13670 *Execution of concrete structures*
• Developing two guidance documents (Parts A & B)
  – Same numbering
  – Incorporating a lot of current 10100-2
• By using guidance documents – compliance with 206 and 13670
SANS 10100-2 The Way Forward

• Two small committees working on different parts
• Circulate to large industry grouping
• Submission to SANS
SANS 2001 vs SANS 1200

• SANS 2001 series form part of the scope of the work

• Unlike SABS 1200, they contain:
  • No reference to measurement of quantities
  • No reference to payment items
  • No reference to who is responsible for work items or the management of the site
  • Requirements for the finished component of the works and work methods only where appropriate
SANS 2001 vs SANS 1200

• Debate at SABS on 24 July 2012
• SANS 2001 will be completed and 1200 series withdrawn

• 2001 CC--- will have to be revised once Part A and Part B finalised
Material Specifications
SANS 10160
Basis for structural design

SANS 10100-1
Structural use of concrete: Design

SANS 10100-2
Structural use of concrete: Materials and execution of work

SANS 2001 CC1/1200G
Concrete works

Various Methods for testing of fresh and hardened concrete

- SANS 50197
  Cement
- SANS 1491-1
  GGBS
- SANS 1491-2
  Fly ash
- SANS 1491-3
  Silica fume
- SANS 51008
  Water
- SANS 1083
  Aggregates
• Cement  SANS 50197 and SANS 50413

• GGBS  SANS 1491-1  SANS 55167 (EN 15167)
• Fly ash  SANS 1491-2  SANS 50450 (EN 450)
• Silica Fume  SANS 1491-3  SANS 53263 (EN 13263)

• Other metallurgical slags
• Admixtures SANS 50934 1-6 (EN 934)

• Water SANS 51008 (EN 1008)

• Aggregates SANS 1083 New WG

  – Revise 1083 to include
    • Natural aggregates
    • Non-natural aggregates
    • Recycled aggregates
Test Methods
EN 1990
Basis for structural design

EN 1992
Design of concrete structures

EN 206-1
Concrete

ENV 13670-1
Execution of concrete structures

EN 197
Cement

EN 450
Fly ash

EN 13263
Silica fume

EN 15167
GGBS

EN 934
Admixtures

EN 12620
Aggregates

EN 1008
Water

EN 12350
Testing of fresh concrete

EN 12390
Testing of hardened concrete
• Driven by SANRAL and TMH 1

• Homogenization of both

• Uniform numbering system

• SANS 3001 series
• Opted to look at EN methods
• Process driven by C&CI
• Hiatus with close of C&CI
• Restarting under SANS
• Restarted in 2013
• 3001 Bi  Bitumen
• 3001 So  Soils
• 3001 Gr  Gravels
• 3001 Agg Aggregate
• 3001 Co  Concrete
• 3001 Co 1 Parts 1- ?  Fresh Concrete
• 3001 Co 2 Parts 1- ?  Hardened Concrete
• 3001 Co 3 Parts 1- ?  Concrete in Structures
### Tests Carried Out on Fresh Concrete

<table>
<thead>
<tr>
<th>EXIST SANS</th>
<th>NEW SANS</th>
<th>TITLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>SANS 5861-1:2006</td>
<td>SANS 3001-CO1-1</td>
<td>Concrete tests — Mixing fresh concrete in the laboratory</td>
</tr>
<tr>
<td>SANS 5861-2:2006</td>
<td>SANS 3001-CO1-2</td>
<td>Concrete tests — Sampling of freshly mixed concrete</td>
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<td>SANS 3001-CO1-3</td>
<td>Concrete tests — Consistence of freshly mixed concrete — Slump test</td>
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<td>SANS 3001-CO1-4</td>
<td>Concrete tests — Consistence of freshly mixed concrete — Vebe test</td>
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<td>SANS 5862-4:2006</td>
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<td>Concrete tests — Consistence of freshly mixed concrete — Compacting factor and compaction index</td>
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<td>Concrete tests — Consistence of freshly mixed concrete — Flow test</td>
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<td>SANS 6250:2006</td>
<td>SANS 3001-CO1-7</td>
<td>Concrete tests — Density of compacted freshly mixed concrete</td>
</tr>
<tr>
<td>SANS 6252:2006</td>
<td>SANS 3001-CO1-8</td>
<td>Concrete tests — Air content of freshly mixed concrete — Pressure method</td>
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### Tests Carried Out on Hardened Concrete

<table>
<thead>
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<tbody>
<tr>
<td>SANS 5860:2006</td>
<td>SANS 3001-CO2-1</td>
<td>Concrete tests — Dimensions, tolerances and uses of cast test specimens</td>
</tr>
<tr>
<td>SANS 5861-3:2006</td>
<td>SANS 3001-CO2-2</td>
<td>Concrete tests — Making and curing of test specimens</td>
</tr>
<tr>
<td>SANS 5863:2006</td>
<td>SANS 3001-CO2-3</td>
<td>Concrete tests — Compressive strength of hardened concrete</td>
</tr>
<tr>
<td>SANS 6255</td>
<td>SANS 3001-CO2-3</td>
<td>Mortar tests — Compressive strength of mortar</td>
</tr>
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<td>SANS 3001-CO2-4</td>
<td>Concrete tests — Specification for testing machines for the measurement of the compressive strength of concrete</td>
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<td>SANS 5864:2006</td>
<td>SANS 3001-CO2-5</td>
<td>Concrete tests — Flexural strength of hardened concrete</td>
</tr>
<tr>
<td>SANS 6253:2006</td>
<td>SANS 3001-CO2-6</td>
<td>Concrete tests — Tensile splitting strength of hardened concrete</td>
</tr>
<tr>
<td>SANS 6085:2006</td>
<td>SANS 3001-CO2-7</td>
<td>Concrete tests — Initial drying shrinkage and wetting expansion of concrete</td>
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<tr>
<td>SANS 6254</td>
<td>SANS 3001-CO2-7</td>
<td>Mortar tests — Initial drying shrinkage and wetting expansion of mortar</td>
</tr>
<tr>
<td>SANS 6251:2006</td>
<td>SANS 3001-CO2-8</td>
<td>Concrete tests — Density of hardened concrete</td>
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### Tests Carried Out on Concrete Structures

<table>
<thead>
<tr>
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<th>NEW SANS</th>
<th>TITLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>SANS 3001-CO3-1</td>
<td>Concrete tests — DI Tests - Part 1: Preparation of test specimens</td>
<td></td>
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<tr>
<td>SANS 3001-CO3-2</td>
<td>Concrete tests — DI Tests - Part 2: Oxygen permeability test</td>
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<td>SANS 3001-CO3-3</td>
<td>Concrete tests — DI Tests - Part 3: Chloride conductivity test</td>
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<td>SANS 3001-CO3-4</td>
<td>Concrete tests — DI Tests - Part 4: Water sorptivity test</td>
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</tr>
<tr>
<td>SANS 5865:2006</td>
<td>SANS 3001-CO3-5</td>
<td>Concrete tests - The drilling, preparation, and testing for compressive strength of cores taken from hardened concrete</td>
</tr>
</tbody>
</table>
• WG for concrete methods
  – All complete
  – SCC methods to be added

• WG for aggregates methods
  – Starting
  – Check with roads committee work
Final Structure
Implications
New Environmental Classification

- New exposure classes
- Fresh and hardened properties classification
- New cover requirements
- Chloride content class
Prescribed Concrete

• Specifier (or SANS – for standardized) prescribes the composition of concrete

• Specifier (or SANS) responsible for ensuring that prescribed composition will satisfy all requirements

• Can be used for routine applications, primarily with low grade concretes (less than C20/25 or C25/30)
Designed Concrete

- Designer (concrete producer) decides composition of concrete – keeping strict adherence to limiting values in the table

- As long as concrete satisfies limiting values, it is deemed to satisfy the performance requirements
Exposure classes

<table>
<thead>
<tr>
<th>No risk of corrosion or attack</th>
<th>Carbonation induced corrosion</th>
<th>Chloride induced corrosion</th>
<th>Freeze thaw attack</th>
<th>Aggressive chemical environments</th>
</tr>
</thead>
<tbody>
<tr>
<td>X0</td>
<td>Carbonation induced corrosion</td>
<td>Chloride induced corrosion</td>
<td>Freeze thaw attack</td>
<td>Aggressive chemical environments</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sea water</td>
<td>Chloride other than</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>from sea water</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max w/c</td>
<td>X0</td>
<td>XC1</td>
<td>XC2</td>
<td>XC3</td>
</tr>
<tr>
<td></td>
<td>0.70</td>
<td>0.65</td>
<td>0.65</td>
<td>0.55</td>
</tr>
<tr>
<td>Minimum Strength Class</td>
<td>C20/25</td>
<td>C20/25</td>
<td>C20/3</td>
<td>C30/3</td>
</tr>
<tr>
<td></td>
<td>(a) 40</td>
<td>(b) 35</td>
<td>(a) 35</td>
<td>(a) 50</td>
</tr>
<tr>
<td>Air Content Range (%)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cement Type</td>
<td>Any</td>
<td>(a) I, IIA, IIB, SRPC</td>
<td>(a) I, IIA, IIB, SRPC</td>
<td>(a) I, IIA, IIB, SRPC</td>
</tr>
<tr>
<td></td>
<td>If IVB-V is used in XC3 or XC4</td>
<td>IIA, IIB, SRPC</td>
<td>IIA, IIB, SRPC</td>
<td>IIA, IIB, SRPC</td>
</tr>
<tr>
<td></td>
<td>increase minimum nominal cover to 40 mm</td>
<td>IIA, IIB, SRPC</td>
<td>IIA, IIB, SRPC</td>
<td>IIA, IIB, SRPC</td>
</tr>
<tr>
<td>Curing</td>
<td>To be performed until 70% of 28 day target mean strength is attained</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Performance Concrete

• This is an added category where additional requirements (over and above the designed concrete) may be proposed.

• This can cover performance requirements that are not specified for the designed concretes, such as (i) heat of hydration, (ii) water penetration (permeability), (iii) gas permeability, (iv) abrasion resistance, (v) Tensile strength, etc.

• Performance criteria to be agreed upon between specifier and producer.
Proprietary Concrete

- Special concretes such as Fibre Reinforced Concrete, Self Compacting Concrete etc. that have requirements other than the normal concretes
SANS 50206

- SANS 50206 covers:
  - Concrete mixed on site
  - Ready-mixed concrete
  - Concrete produced in a plant for precast
- SANS 50206 defines ready-mixed concrete as
  - Concrete delivered in a fresh state by a body who is not the user and includes
    - Concrete produced off site by the user
    - Concrete produced on site but not by the user
SANS 50206

• Exposure classes
  – X0 No Risk
  – XC 1 to 4 Corrosion induced by carbonation
  – XD 1 to 3 Corrosion induced by chlorides other than sea water
  – XS 1 to 3 Corrosion induced by chlorides from sea water
  – XF 1 to 4 Freeze/thaw attack
  – XA 1 to 3 Chemical attack
<table>
<thead>
<tr>
<th>Exposure classes</th>
<th>No risk of corrosion or attack</th>
<th>Carbonation induced corrosion</th>
<th>Chloride induced corrosion</th>
<th>Freeze thaw attack</th>
<th>Aggressive chemical environments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X0</td>
<td>XC1</td>
<td>XC2</td>
<td>XC3</td>
<td>XC4</td>
</tr>
<tr>
<td></td>
<td>X5</td>
<td>X5</td>
<td>X5</td>
<td>X5</td>
<td>X5</td>
</tr>
<tr>
<td>Max w/c</td>
<td>0.70</td>
<td>0.65</td>
<td>0.65</td>
<td>0.55</td>
<td>0.50</td>
</tr>
<tr>
<td>Minimum Strength Class</td>
<td>C20/25</td>
<td>C20/25</td>
<td>C20/25</td>
<td>C30/3</td>
<td>C30/3</td>
</tr>
<tr>
<td>Minimum nominal cover</td>
<td>15</td>
<td>15</td>
<td>25</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Air Content Range (%)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Any</td>
<td>Any</td>
<td>Any</td>
<td>Any</td>
<td>Any</td>
<td>Any</td>
</tr>
<tr>
<td>Curing</td>
<td>To be performed until 70% of 28 day target mean strength is attained</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
SANS 50206

- Consistence classes
  - By Slump
  - By Vebe
  - By Compaction
  - By Flow
### Table 3 – Slump classes

<table>
<thead>
<tr>
<th>Class</th>
<th>Slump in mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>10 to 40</td>
</tr>
<tr>
<td>S2</td>
<td>50 to 90</td>
</tr>
<tr>
<td>S3</td>
<td>100 to 150</td>
</tr>
<tr>
<td>S4</td>
<td>160 to 210</td>
</tr>
<tr>
<td>S5(^1)</td>
<td>≥ 220</td>
</tr>
</tbody>
</table>
# Table 4 – Vebe classes

<table>
<thead>
<tr>
<th>Class</th>
<th>Vebe time in seconds</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_0$</td>
<td>$\geq 31$</td>
</tr>
<tr>
<td>$V_1$</td>
<td>30 to 21</td>
</tr>
<tr>
<td>$V_2$</td>
<td>20 to 11</td>
</tr>
<tr>
<td>$V_3$</td>
<td>10 to 6</td>
</tr>
<tr>
<td>$V_4$</td>
<td>5 to 3</td>
</tr>
<tr>
<td>Class</td>
<td>Degree of compactability</td>
</tr>
<tr>
<td>-------</td>
<td>--------------------------</td>
</tr>
<tr>
<td>C0\textsuperscript{1)}</td>
<td>$\geq 1.46$</td>
</tr>
<tr>
<td>C1</td>
<td>1.45 to 1.26</td>
</tr>
<tr>
<td>C2</td>
<td>1.25 to 1.11</td>
</tr>
<tr>
<td>C3</td>
<td>1.10 to 1.04</td>
</tr>
<tr>
<td>Class</td>
<td>Flow diameter in mm</td>
</tr>
<tr>
<td>-------</td>
<td>---------------------</td>
</tr>
<tr>
<td>$F_1$</td>
<td>$\leq 340$</td>
</tr>
<tr>
<td>$F_2$</td>
<td>350 to 410</td>
</tr>
<tr>
<td>$F_3$</td>
<td>420 to 480</td>
</tr>
<tr>
<td>$F_4$</td>
<td>490 to 550</td>
</tr>
<tr>
<td>$F_5$</td>
<td>560 to 620</td>
</tr>
<tr>
<td>$F_6$</td>
<td>$\geq 630$</td>
</tr>
</tbody>
</table>
SANS 50206

- Strength classes
<table>
<thead>
<tr>
<th>Compressive strength class</th>
<th>Minimum characteristic cylinder strength $f_{ck, cyl}$ N/mm$^2$</th>
<th>Minimum characteristic cube strength $f_{ck, cube}$ N/mm$^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>C8/10</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>C12/15</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td>C16/20</td>
<td>16</td>
<td>20</td>
</tr>
<tr>
<td>C20/25</td>
<td>20</td>
<td>25</td>
</tr>
<tr>
<td>C25/30</td>
<td>25</td>
<td>30</td>
</tr>
<tr>
<td>C30/37</td>
<td>30</td>
<td>37</td>
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<tr>
<td>C35/45</td>
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<td>45</td>
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<td>C40/50</td>
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<td>C45/55</td>
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<td>C55/67</td>
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<td>C60/75</td>
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<td>85</td>
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<td>C80/95</td>
<td>80</td>
<td>95</td>
</tr>
<tr>
<td>C90/105</td>
<td>90</td>
<td>105</td>
</tr>
<tr>
<td>C100/115</td>
<td>100</td>
<td>115</td>
</tr>
</tbody>
</table>
Conclusions
Changes in approach with new standards:

• Determine environment and required longevity
• Determine required durability
• Choose an approach to achieve durability
• Determine structural design
Changes coming in:

- Design codes
- Standards
- Material specifications
- Test methods

Be Aware
We Need You

bryanp@theconcreteinstitute.org.za
george.evans@ppc.co.za