Construction Standard CS3:2013 – Aggregates for Concrete

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1. Background

Reasons


- Aggregates are local products

- Request for a local construction standard for aggregates by industry
1. Background

History

- SCCT agreed to form a drafting committee to develop a local construction standard for aggregates used in concrete (CS3) in October 2009.
- The membership of the working group (WG) for drafting of CS3 was confirmed and endorsed by SCCT in April 2010.
- The first WG meeting was held in June 2010 and the drafting works was completed in March 2013.
- SCCT endorsed the final version of CS3 in late March 2013.
1. Background

Membership of WG includes:

- Works Departments (CEDD, HyD, ArchSD, DSD and WSD)
- Housing Department
- Building Department
- Innovation and Technology Commission
1. Background

The following organizations that have contributed on the drafting of CS3 are:

- The Concrete Producers Association of Hong Kong Ltd.
- The Hong Kong Contract Quarry Association
- The Institute of Quarrying (Hong Kong Branch)
- The Import Aggregates Suppliers Association Ltd.
- The Association of Construction Materials Laboratories Ltd.
- The University of Hong Kong
1. Background

The Drafting Committee have reviewed the following specification, technical circular and standards:

- Section 16 of General Specification for Civil Engineering Works, 2006 Edition (GS 16)

- WBTC No. 12/2002 – Specifications Facilitating the Use of Recycled Aggregates (WBTC 12)
1. Background

- British Standards (BS)
  
  BS 882: 1992, incorporating amendment no. 1 *(BS 882)*
  BS 812: Part 2:1995
  BS 812: Part 100:1990
  BS 812: Part 102:1989
  BS 812: Section 103.1:1985
  BS 812: Section 105.1:1989
  BS 812: Section 105.2:1990
  BS 812: Part 109:1990
  BS 812: Part 111:1990
  BS 812: Part 112:1990
  BS 812: Part 117:1988
  BS 812: Part 118:1988
  BS 812: Part 120:1989
1. Background

- **British Standards (BS), cont’**
  
  BS 812: Part 121:1989
  BS 1881: Part 124:1988
  BS 7943:1999

- **European Standards adopted as British Standards (BS EN)**
  
  BS EN 12620: 2002+A1:2008 *(BS EN 12620)*
  BS EN 932-5:2000
  BS EN 933-9:2009
  BS EN 1015-4:1999
  BS EN 1015-11:1999
  BS EN 1744-1:2009
1. Background

- National Standard of the People’s Republic of China (GB)
  GB/T 14684-2011

- Réunion Internationale des Laboratoires et Experts des Materiaux, systèmes de construction et ouvrages (RILEM)
  RILEM AAR-1

- ASTM International Standards
  ASTM C131-96
  ASTM C294-12
  ASTM C295-08

- Building Research Establishment (BRE)
  BRE Digest 433
2. Contents

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Section 2 – Terms and definitions

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Section 3 – Geometrical requirements
Section 4 – Physical requirements
Section 5 – Chemical requirements
Section 6 – Quality control
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Section 7 – General requirements for common equipment and calibration
Section 8 – Methods for sampling

Petrographic Examination
Section 9 – Method for petrographic examination of aggregates
2. Contents

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Section 11 – Method for determination of flakiness index

Section 12 – Method for determination of elongation index

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2. Contents

Tests for Physical and Chemical Properties
Section 14 – Method for determination of Los Angeles Value
Section 15 – Methods for determination of aggregate impact value
Section 16 – Methods for determination of ten per cent fines value
Section 17 – Methods for determination of particle density and water absorption
Section 18 – Methods for determination of moisture content
Section 19 – Method for determination of soundness
2. Contents

Tests for Physical and Chemical Properties, cont’
Section 20 – Method for determination of drying shrinkage
Section 21 – Methods for determination of chemical properties
Section 22 – Method for determination of effect of organic substances by mortar method
3. Scope

- Specifies the property requirements, quality control requirements and testing methods of aggregates for use in production of concrete.

- Covers coarse and fine natural aggregates and coarse recycled aggregates having an oven-dried particle density not less than 2,000 kg/m³.

- Does not cover lightweight aggregates, heavyweight aggregates and all-in aggregates.

- Coarse recycled aggregate used in concrete in accordance with WBTC No. 12/2002
4. Geometrical Requirements

Grading of Coarse Aggregates

<table>
<thead>
<tr>
<th>Sieve size (mm)</th>
<th>Nominal size of graded aggregates (mm)</th>
<th>Nominal size of single-sized aggregate (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>40 to 5</td>
<td>20 to 5</td>
</tr>
<tr>
<td>50</td>
<td>100</td>
<td>-</td>
</tr>
<tr>
<td>37.5</td>
<td>90-100</td>
<td>100</td>
</tr>
<tr>
<td>20</td>
<td>35-70</td>
<td>90-100</td>
</tr>
<tr>
<td>14</td>
<td>25-55</td>
<td>40-80</td>
</tr>
<tr>
<td>10</td>
<td>10-40</td>
<td>30-60</td>
</tr>
<tr>
<td>5</td>
<td>0-5</td>
<td>0-10</td>
</tr>
<tr>
<td>2.36</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

NOTE: For coarse recycled 20 mm and 10 mm single-sized aggregates, the percentage by mass passing 4 mm test sieve shall not exceed 5%.
### 4. Geometrical Requirements

#### Grading of Fine Aggregates

<table>
<thead>
<tr>
<th>Sieve size</th>
<th>Overall limits</th>
<th>Percentage by mass passing test sieves (%)</th>
<th>Limits for declared grading</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td><strong>Percentage by mass passing test sieves (%)</strong></td>
<td><strong>Limits for declared grading</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Overall limits</strong></td>
<td><strong>Limits for declared grading</strong></td>
</tr>
<tr>
<td>10 mm</td>
<td>100</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>5 mm</td>
<td>89-100</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2.36 mm</td>
<td>60-100</td>
<td>60-100</td>
<td>65-100</td>
</tr>
<tr>
<td>1.18 mm</td>
<td>30-100</td>
<td>30-90</td>
<td>45-100</td>
</tr>
<tr>
<td>600 μm</td>
<td>15-100</td>
<td>15-54</td>
<td>25-80</td>
</tr>
<tr>
<td>300 μm</td>
<td>5-70</td>
<td>5-40</td>
<td>5-48</td>
</tr>
<tr>
<td>150 μm</td>
<td>0-20</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
4. Geometrical Requirements

Grading of Fine Aggregates, cont’

- The grading (i.e. C, M or F) of fine aggregates shall be declared and documented by the aggregate producer or supplier.

- The grading shall comply with both the overall limits and the limits for the declared grading in the table.

- Not more than one in ten consecutive samples shall have a grading outside the limit for the declared grading.
4. Geometrical Requirements

Shape of Coarse Aggregates

- Flakiness index
  - of coarse natural aggregate, $\leq 30$
  - of coarse recycled aggregate, $\leq 40$

- Elongation index
  - of coarse natural aggregate, $\leq 35$

Shell Content

- Free of shell
4. Geometrical Requirements

Fines Content

<table>
<thead>
<tr>
<th>Aggregate type</th>
<th>Maximum percentage by mass passing 75 μm test sieve (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse aggregates</td>
<td>4</td>
</tr>
<tr>
<td>Fine natural aggregate</td>
<td></td>
</tr>
<tr>
<td>Class I</td>
<td>10</td>
</tr>
<tr>
<td>Class II</td>
<td>&gt;10 and ≤14</td>
</tr>
</tbody>
</table>

NOTE:
1. For heavy duty floor finishes, Class I fine natural aggregate should be used.
2. For Class II fine natural aggregate, the methylene blue value, determined in accordance with Section 13 of this Standard, shall be ≤1.4.

The aggregate producer or supplier shall declare the class (i.e. Class I or II) of the fine natural aggregate.
4. Geometrical Requirements

Foreign Materials in Coarse Recycled Aggregate

<table>
<thead>
<tr>
<th>Type of foreign materials</th>
<th>Maximum percentage by mass (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood and other material less dense than water</td>
<td>0.5</td>
</tr>
<tr>
<td>Other foreign materials (e.g. metals, plastics, clay lumps, asphalt and tar, glass etc.)</td>
<td>1.0</td>
</tr>
</tbody>
</table>

The content of foreign materials shall be determined by manual sorting in accordance with BRE Digest 433.
5. Physical Requirements

Resistance to Fragmentation

- Los Angeles value of coarse natural aggregate, ≤ 30% loss
- Ten per cent fines value of coarse aggregates, ≥ 100 kN
- Aggregate impact value of coarse natural aggregate, ≤ 30%
5. Physical Requirements

Particle Density and Water Absorption

- Oven-dried particle density of aggregates, $\geq 2,000 \text{ kg/m}^3$

- Water absorption
  - of coarse natural aggregate, $\leq 0.8\%$
  - of coarse recycled aggregate, $\leq 10\%$
5. Physical Requirements

Durability

- Magnesium sulphate soundness value of coarse natural aggregate, $\geq 94\%$

- Drying shrinkage of natural aggregates, $\leq 0.075\%$

- Potential alkaline-reactivity of aggregates for mortar bar test, Table 10 of CS1 for concrete prism test, Table 13 of CS1
6. Chemical Requirements

Chlorides

- The chloride ion contents of combined natural aggregates for four categories of concrete

<table>
<thead>
<tr>
<th>Type and use of concrete</th>
<th>Chloride ion content expressed as percentage by mass of combined natural aggregates (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prestressed concrete and heat-cured concrete containing embedded metal</td>
<td>0.01</td>
</tr>
<tr>
<td>Concrete containing embedded metal and made with cement complying with BS 4027</td>
<td>0.03</td>
</tr>
<tr>
<td>Concrete containing embedded metal and made with cement complying with BS EN 197-1 or combinations with ground granulated blastfurnace slag (GGBS) or pulverized-fuel ash (PFA)</td>
<td>0.05</td>
</tr>
<tr>
<td>Other concrete</td>
<td>No limit</td>
</tr>
</tbody>
</table>
6. Chemical Requirements

Chlorides, cont’

- The chloride ion content of natural aggregates and coarse recycled aggregate when combined in use, \( \leq 0.05\% \) by mass

- The water-soluble chloride ion content shall be determined for natural aggregates and the acid-soluble chloride ion content shall be determined for coarse recycled aggregate.
6. Chemical Requirements

Suphur Containing Compounds

- Acid-soluble suphate content
  of natural aggregates, \( \leq 0.8\% \) by mass
  of coarse recycled aggregate, \( \leq 1\% \) by mass

- Total sulphur content
  of natural aggregates, \( \leq 1\% \) by mass
6. Chemical Requirements

Organic Substances

- The aggregate producer or supplier shall demonstrate that the supplied aggregate is free of organic substances or alternatively the presence of organic substances does not affect the stiffening or hardening of mortar.

- The presence of humus shall be determined by colour comparison method; if positive, its effect shall be assessed on the following:
  
  (i) the increase in stiffening time of mortar test specimens, $\leq 120$ min

  (ii) the decrease in 28-day compressive strength of mortar test specimens, $\leq 20\%$
7. Quality Control

Quality Control Under ISO 9001

- The aggregate producer and supplier shall establish and maintain a quality assurance system certified to ISO 9001 standard.

- The aggregate producer and supplier shall undertake routine control and laboratory testing to ensure that the aggregate product conforms to CS3 and is traceable throughout the process (production, supply, storage and delivery).

- All tests shall be performed by a HOKLAS accredited laboratory and the test results shall be presented in HOKLAS endorsed test reports.
7. Quality Control

Quality Control Under ISO 9001, cont’

- When requested, the aggregate producer or supplier shall provide the data including test results/certificates of aggregates.
Quality Control Under A Third Party Product Certification System (Alternative System)

- Quality assurance of the aggregate production and supply may rely on a third party certification of product conformity based on testing and continuous product surveillance and on the quality assurance system of the aggregate producer and supplier.

- A product certification scheme is required to be developed for Hong Kong to cover the production, supply, testing, handling, storage, transportation, etc. of the aggregate.
7. Quality Control

Quality Control Under A Third Party Product Certification System (Alternative System), cont’

- The certification scheme shall be reviewed by a certification body accredited by HKAS or its MLA partner(s) for product certification.
# 8. Comparison

## Geometrical Requirements

<table>
<thead>
<tr>
<th>Geometrical Requirements</th>
<th>CS3:2013</th>
<th>GS 16</th>
<th>WBTC 12</th>
<th>BS 882</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CNA</td>
<td>FNA</td>
<td>CRA</td>
<td>CNA</td>
</tr>
<tr>
<td>Grading</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Table 3.1 of CS3</td>
<td></td>
<td></td>
<td>Table 3.1 of CS3</td>
<td>(Table 3)</td>
</tr>
<tr>
<td>Flakiness index (max)</td>
<td>30</td>
<td>-</td>
<td>40</td>
<td>30</td>
</tr>
<tr>
<td>Elongation index (max)</td>
<td>35</td>
<td>-</td>
<td>-</td>
<td>35</td>
</tr>
<tr>
<td>Shell content</td>
<td>Free</td>
<td>-</td>
<td>-</td>
<td>Free</td>
</tr>
<tr>
<td>Fines content (max)</td>
<td>4%</td>
<td>10%  for Class I, &gt;10% and &lt;=14% for Class II</td>
<td>4%</td>
<td>(4%)</td>
</tr>
<tr>
<td>Sand content (max)</td>
<td>-</td>
<td>-</td>
<td>5% (&lt;4mm)</td>
<td>-</td>
</tr>
<tr>
<td>Foreign materials Content (max)</td>
<td>-</td>
<td>-</td>
<td>0.5% (&lt; water); 1.0% (&gt; water)</td>
<td>-</td>
</tr>
</tbody>
</table>

CNA = coarse natural aggregate, FNA = fine natural aggregate, CRA = coarse recycled aggregate
## 8. Comparison

### Physical Requirements

<table>
<thead>
<tr>
<th>Physical Requirements</th>
<th>CS3:2013</th>
<th>GS 16</th>
<th>WBTC 12</th>
<th>BS 882</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CNA</td>
<td>FNA</td>
<td>CRA</td>
<td>CNA</td>
</tr>
<tr>
<td>Los Angeles value</td>
<td>30% loss</td>
<td>-</td>
<td>-</td>
<td>30% loss</td>
</tr>
<tr>
<td>(max)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aggregate impact</td>
<td>30%</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>value (max)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ten per cent fines</td>
<td>100 kN</td>
<td>-</td>
<td>100 kN</td>
<td>100 kN</td>
</tr>
<tr>
<td>value (min)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ove-dried Particle</td>
<td>2,000 kg/m³</td>
<td>2,000 kg/m³</td>
<td>2,000 kg/m³</td>
<td>-</td>
</tr>
<tr>
<td>density (min)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water absorption</td>
<td>0.8%</td>
<td>-</td>
<td>10%</td>
<td>0.8%</td>
</tr>
<tr>
<td>(max)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Magnesium sulphate</td>
<td>94%</td>
<td>-</td>
<td>-</td>
<td>6% loss</td>
</tr>
<tr>
<td>soundness value</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(min)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drying shrinkage</td>
<td>0.075%</td>
<td>0.075%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(max)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alkali-silica</td>
<td>CS1</td>
<td>CS1</td>
<td>CS1</td>
<td>CS1</td>
</tr>
<tr>
<td>reactivity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CNA = coarse natural aggregate, FNA = fine natural aggregate, CRA = coarse recycled aggregate

2,000 kg/m³ and 0.075% from BS EN 12620
# 8. Comparison

## Chemical Requirements

<table>
<thead>
<tr>
<th>Chemical Requirements</th>
<th>CS3:2013</th>
<th>GS 16</th>
<th>WBTC 12</th>
<th>BS 882</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CRA</strong></td>
<td>CNA</td>
<td>FNA</td>
<td>CRA</td>
<td>CNA</td>
</tr>
<tr>
<td>Chloride ion content</td>
<td>0.01%(PresC), 0.03%(SulfRC), 0.05%(PC, GGBS, PFA)</td>
<td>-</td>
<td>[0.01%(PresC), 0.03%(SulfRC), 0.05%(PC, GGBS, PFA)]</td>
<td>-</td>
</tr>
<tr>
<td>(max, combined)*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acid-soluble chloride ion content (max, combined)</td>
<td>0.05%</td>
<td>-</td>
<td>0.05%</td>
<td>-</td>
</tr>
<tr>
<td>Acid-soluble sulphate content (max)</td>
<td>0.8%</td>
<td>0.8%</td>
<td>1%</td>
<td>-</td>
</tr>
<tr>
<td>Total sulphur content (max)</td>
<td>1%</td>
<td>1%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Organic materials</td>
<td>Free of hums; if not, use mortar test (i) increase in stiffening time ≤ 120min, (ii) decrease in 28-day compressive strength ≤ 20%</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

CNA = coarse natural aggregate, FNA = fine natural aggregate, CRA = coarse recycled aggregate

* - The water-soluble chloride ion content shall be determined for natural aggregates and the acid-soluble chloride ion content shall be determined for coarse recycled aggregate.

0.8%, 1% and organic materials from BS EN 12620
End of Presentation

Thank You