Specification for Concrete

SINGAPORE STANDARD
SS EN 206-1 : 2009
(ICS 91.100.30)

SPECIFICATION FOR
Concrete
SS EN 206-1 : 2009

• This Singapore Standard is the result of the review of:
  – SS 289 : Parts 1 to 4 : 2000

• This standard is identical to European Standards EN 206-1.

• CP 65 is replaced.
Relationships between SS EN 206-1 and Standards
Shrinkage

• As concrete hardens there is a reduction in volume.

• This shrinkage is liable to cause cracking of the concrete.

• It also has the beneficial effect of strengthening the bond between the concrete and the steel reinforcement.
Thermal Expansion

- Day-to-day thermal expansion of concrete can be greater than the movements caused by shrinkage.

- When the tensile stresses caused by shrinkage or thermal movement exceed the strength of concrete, cracking will occur.

- To control the crack widths, steel reinforcement must be provided close to the concrete surface.
Workability & Consistency

It is desirable that freshly mixed concrete be relatively easy to transport, place, compact and finish without harmful segregation. A concrete mix satisfying these conditions is said to be workable.

It is determined to a large extent by measuring the “consistency” of the mix. Consistency is the fluidity or degree of wetness of concrete.
Factors Affecting Workability

• Method and duration of transportation
• Quantity and characteristics of cementing materials
• Aggregate grading, shape and surface texture
• Quantity and characteristics of chemical admixtures
• Amount of water
• Amount of entrained air
• Concrete & ambient air temperature
Bleeding

- Bleeding is the tendency of water to rise to the surface of freshly placed concrete.
- It is caused by the inability of solid constituents of the mix to hold all of the mixing water as they settle down.
Working Life of Concrete Structure

For a given quality of concrete

More of onsite concreting practices

Workability, Compaction & Curing

Long-term performance

Strength

Durability
Limit State Design

• The **design of an engineering structure** must ensure that:

  – Under the worst loadings, the structure is safe, and

  – During normal working conditions the deformation of the members does not detract from the appearance, durability and performance of the structure.
Limit States

The purpose of design is to achieve acceptable probabilities that a structure will not become unfit for its intended use.

The two principal types of limit state are:
1. Ultimate Limit State
2. Serviceability Limit State
Test Methods

Methods for measuring consistency / workability:

- Slump test (most widely used)
- Compaction factor test: measures degree of compaction
- Vebe test: measures time required for full compaction
- Flow table test: measures the amount of flow
- Slump flow test: measures flow value
Slump Test

• Slump Test is related with the ease with which concrete flows during placement (ASTM C 143)
Slump Test

- The slump cone is filled one-quarter full and rod it thoroughly 25 times.
- Then put in more concrete to about half-way up and rod it another 25 times.
- Finally fill the cone up, rod 25 times again and smooth off the top.
Measuring the Slump

- Very carefully, lift the cone off and put it down beside the mound of concrete on the plate.
- As soon as the mould comes off, the concrete will collapse.
- The rod is rested on the cone and the distance from the underside of the rod to the top of the concrete is measured.
Three Kinds of Slump

1. Natural or True Slump
2. Shear Slump
3. Collapsed Slump

\[ s = \text{slump} \]
\[ h = \text{measured height} \]
Natural or True Slump

• The concrete mould simply sinks, keeping its shape more or less.
Shear Slump

• The concrete mould falls away sideways.
Collapsed Slump

• The mould collapses completely.
Compaction of Concrete

- Fresh concrete contains entrapped air in the form of voids.

- The objective of compaction is to remove the unwanted entrapped air.

- The amount of entrapped air is related to the workability.
Vibration

• The most effective way of compacting concrete is by use of vibration which can be applied either internally or externally.

• Vibrating machines are mainly of two types:
  – Internal vibrator, submerged directly into the concrete
  – External vibrator, attached to pre-selected positions on the form
Internal Vibration

- The proper and knowledgeable handling of an internal vibrator is very important.
- place vibrator into centre of mix
  - push rapidly to bottom of form
  - withdraw vibrator slowly at about 25mm per second
  - avoid vibrating the rebars or strands intentionally.
Poker Vibrator
Systematic Vibration

- **CORRECT**
  - Vertical penetration a few inches into previous lift (which should not yet be rigid) of systematic regular intervals will give adequate consolidation.

- **INCORRECT**
  - Haphazard random penetration of the vibrator at all angles and spacing without sufficient depth will not assure intimate combination of the two layers.
Don’ts in Vibration

• Avoid handling the poker vibrator too fast and in an irregular pattern. Vibrating too fast will cause over-vibration and result in honey-combing and reduction of strength.

• Avoid leaving the vibrator in the concrete for too long as this will cause over vibration.

• Avoid using the vibrator to move or distribute concrete.
Curing of Concrete

- Curing is the procedure used for promoting the hydration of cement and consists of a control of temperature and the moisture movement from and into the concrete.

- Therefore curing is the process of keeping freshly laid concrete moist during the initial hardening of concrete.
Proper Curing

• Proper curing increases concrete strength, durability and resistance to abrasion and watertightness. If concrete is not cured properly and dries out too quickly, cracks will appear on the surface, resulting in reduction of strength and loss of durability.

• Therefore, well cured concrete is good concrete.
Methods of Curing

- **Ponding or Spraying**
  - the concrete is kept continuously wet by ponding or spraying

- **Covering of Concrete**
  - Leaving the formwork in place but top exposed surface must be kept wet

- **Steam Curing**
  - Steam curing is common in the precasting industry to obtain high strength early
Curing Times

• Curing should begin as soon as the initial setting commences, which is from 15 to 45 minutes after placing.

• Curing time is the minimum period during which the concrete is kept moist.

• Continuous curing for three to four days is generally applicable.
Concrete Mix Design

- Principle – requires the selection of the correct proportions of cement, fine & coarse aggregate and water to meet specified properties.

- Many properties can be specified but the most usual are:
  
  Workability / Consistency
  Compressive strength
  Durability
Basic Concept of Mix Design

- Due to variability of quality of concrete, a mix must be designed to have a considerably higher mean strength than that specified.

\[
f_m = f_c + ks
\]

Target Mean = Characteristic Strength + Margin Strength
Parameters for Concrete Mix Design

- Determine the job parameters
  - Compressive strength
  - Durability requirements
  - Slump
  - Aggregate properties

- Design and mix proportions
  - Cement, water, aggregates, admixtures, etc

- Calculate batch weights

- Adjusting to the batch weight based on trial mix
### Mix Design Sample

**1. Concrete Grade**
- 1.1 Concrete Grade (SS EN 206): 40 N/mm²
- 1.2 Strength Class (SS EN 206): C32/40
- 1.3 Slump Class (SS EN 206): S3 (125±25 mm)
- 1.4 Exposure Class (SS EN 206): XC4, XD3, XS3, XA1
- 1.5 Chloride Content Class (SS EN 206): Cl 0.10

**2. Characteristic Strength**
- 2.1 Characteristic Strength: 40N/mm² at 28 days below which 5% of test results may be expected to fall.
- 2.2 Designed Standard Deviation: 4.57 N/mm²
- 2.3 Designed Margin: 1.64 x 4.57 N/mm² = 7.50 N/mm²
- 2.4 Target Mean Strength: 40 + 7.50 N/mm² = 47.50 N/mm²
- 2.5 Water/Cement Ratio: 0.44

**3. Material Details**

<table>
<thead>
<tr>
<th>Material Type</th>
<th>Description</th>
<th>Source</th>
<th>S.G.</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1 Cement</td>
<td>OPC</td>
<td>SS/BS EN 197-1</td>
<td>3.15</td>
</tr>
<tr>
<td>3.2 Fine Aggregate</td>
<td>Natural Sand/Manufactured Sand</td>
<td>SS/BS EN 12620</td>
<td>2.59</td>
</tr>
<tr>
<td>3.3 Coarse Aggregate</td>
<td>Crushed Granite</td>
<td>SS/BS EN 12620</td>
<td>2.62</td>
</tr>
<tr>
<td>3.4 Water</td>
<td>BS EN 1008</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.5 Admixture</td>
<td>85 RA SS/BS EN 934-2</td>
<td>400 ml/100kg of cement (Plasticizer &amp; Retarder)</td>
<td></td>
</tr>
<tr>
<td>3.6 Reagent</td>
<td>M150 SS/BS EN 934-2</td>
<td>500 ml/100kg of cement (Superplasticizer)</td>
<td></td>
</tr>
</tbody>
</table>

**4. Physical Properties**
- 4.1 Cement Content: 385 kg/m³
- 4.2 Water Content: 171 kg/m³
- 4.3 Concrete Density: 2348 kg/m³
- 4.4 Proportion of Fine Aggregate: 43.5 %
- 4.5 Air Content: 2%

**5. Summary (kg/m³)**

<table>
<thead>
<tr>
<th>Material Type</th>
<th>Water</th>
<th>Fine Aggregate</th>
<th>Coarse Aggregate</th>
<th>Admixture</th>
<th>Reagent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>385</td>
<td>171</td>
<td>778</td>
<td>1010</td>
<td>1.74</td>
</tr>
<tr>
<td>Water/Cement Ratio</td>
<td>0.44</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Percentage of Fine Aggregate:** 43.5%

**6. Remarks:**
1. The characteristic strength shall conform to SS EN 206
2. This design mix is done under surface dry and saturated conditions.
3. Trial mix should be conducted to confirm suitability with specified requirements.
4. The cement content can be adjusted without notice in accordance with and subject to the limits specified in SS EN 197-1
Mix Design Sample

MIX DESIGN: Precast Concrete for Tunnel Segments (Type db)

PROJECT:

CONTRACTOR:

1.1 Characteristic Strength at 28 days
1.2 Slump
1.3 Standard Deviation
1.4 Margin
1.5 Target Mean Strength
1.6 Free-Water/Cement ratio

2.1 Cement Type
2.2 Cementitious Material
2.3 Fine Aggregate Type
2.4 Coarse Aggregate Type
2.5 Admixture 1
   Dosage Rate
2.6 Constituent Material 1
   Dosage Rate
2.7 Constituent Material 2
   Dosage Rate

PBFC(70%GGBFS)
Silica Fume
Uncrushed/Crushed Granite
Mapefluid N200
2200.00 ml per 100 kg cement
Steel Fibres
40.00 kg per m³
Synthetic Fibres
1.00 kg per m³

CONCRETE CLASS: C60

DATE:

MIX REF NO: SFRC60_BF

\[ 70 \pm 20 \] (75 \pm 25 mm)

60 N/mm²
6 N/mm²
10 N/mm²
70 N/mm²
0.33
Mix Design EN 206 Classifications

• Fresh Concrete
  – Consistence classes
  – Classes related to maximum aggregate size

• Hardened Concrete
  – Compressive strength classes
  – Density classes for light-weight concrete

• Exposure Classes
  – Related to environmental actions
Consistence Classes

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>S5¹)</td>
<td>≥ 220</td>
</tr>
</tbody>
</table>

• Earlier slump ranges in Singapore
  • Normal Mix          -  75±25 mm  -  ~S2
  • Pump Mix            -  100±25 mm
  • High Pump or Dry Mix-  125±25 mm  -  ~S3
  • High Slump Mix      -  150±25 mm
  • Tremie Mix          -  175±25 mm  -  ~S4
  • High Tremie Mix     -  200±25 mm
# Consistence Classes

### Table 4 — Vebe classes

<table>
<thead>
<tr>
<th>Class</th>
<th>Vebe time in seconds</th>
</tr>
</thead>
<tbody>
<tr>
<td>V0(^1)</td>
<td>≥ 31</td>
</tr>
<tr>
<td>V1</td>
<td>30 to 21</td>
</tr>
<tr>
<td>V2</td>
<td>20 to 11</td>
</tr>
<tr>
<td>V3</td>
<td>10 to 6</td>
</tr>
<tr>
<td>V4(^1)</td>
<td>5 to 3</td>
</tr>
</tbody>
</table>

### Table 5 — Compaction classes

<table>
<thead>
<tr>
<th>Class</th>
<th>Degree of compactability</th>
</tr>
</thead>
<tbody>
<tr>
<td>C0(^1)</td>
<td>≥ 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>C4(^3)</td>
<td>≤ 1,04 (A(^1))</td>
</tr>
</tbody>
</table>

\(^3\) C4 applies only to light-weight concrete.
# EN 206 Consistence Classes

## Table 18 — Conformity criteria for consistence

<table>
<thead>
<tr>
<th>Test method</th>
<th>Minimum number of samples or determinations</th>
<th>Acceptance number</th>
<th>Maximum allowed deviation of single test results from the limits of the specified class or from the tolerance on the specified target value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Lower value</td>
</tr>
<tr>
<td>Visual inspection</td>
<td>Comparison of the appearance with the normal appearance of concrete with the specified consistence</td>
<td>Each batch; for vehicle deliveries, each load</td>
<td>—</td>
</tr>
<tr>
<td>Slump</td>
<td>EN 12350-2</td>
<td>i) frequency as given in Table 13 for compressive strength ii) when testing air content iii) in case of doubt following visual inspection</td>
<td>see Table 19b</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>–20 mm b</td>
</tr>
<tr>
<td>Vebe time</td>
<td>EN 12350-3</td>
<td>see Table 19b</td>
<td>–2 sec</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>–4 sec b</td>
</tr>
<tr>
<td>Degree of compactability</td>
<td>EN 12350-4</td>
<td>see Table 19b</td>
<td>–0,03</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>–0,05 b</td>
</tr>
<tr>
<td>Flow</td>
<td>EN 12350-5</td>
<td>see Table 19b</td>
<td>–20 mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>–30 mm b</td>
</tr>
</tbody>
</table>

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a Where there is no lower or upper limit in the relevant consistence class, these deviations do not apply.
b Only applicable for consistence testing from initial discharge from truck mixer (see 5.4.1).
Aggregate Reactivity

Field History
Is there a proven history of satisfactory field performance?
- Yes
- No

Petrographic Examination
Is the aggregate potentially reactive?
- Yes
- No

Chemical Composition
CSA A23.2-6A
Is composition potentially alkali-carbonate reactive?
- Yes
- No

Concrete Prism Test ASTM C1105
Expansion < limits
- Yes
- No

Accelerated Mortar Bar Test, ASTM C1260
Is 14-day expansion > 0.10%?
- Yes
- No

Concrete Prism Test ASTM C1293
Is 1-year expansion > 0.04%?
- Yes
- No

Type of Reaction
Is the expansion due to ACR or ASR?
- ASR
- ACR

Alkali-Silica Reactive
Take preventive measures or do not use

Alkali-Carbonate Reactive
Avoid reactive components or do not use.

Non-Reactive
Accept for use
No precautionary measures necessary
Currently, the Sixth Schedule of the Building Control Regulations prohibits the use of aggregates that have potential for ASR in structural concrete works. To prepare for a wider choice of supply of aggregates for our construction sector in the long run, BCA will be introducing control measures in the production of structural concrete which will allow the use of aggregates with marginal reactivity to ASR. These aggregates with marginal reactivity are defined as having expansion not greater than 0.2% when evaluated using ASTM C1260b (Mortar-Bar Method). The measures listed in paragraph 4 below will take effect from 1 Jan 2009. Consequently, aggregates with marginal reactivity will also be allowed for use in structural concrete. Reactive aggregates with expansion greater than 0.2% in the Mortar-Bar Method, or having potential for Alkali-Carbonate Reaction (ACR), or aggregates deriving from volcanic rocks will still be prohibited.