Specifying Sustainable Concrete to BS 8500

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MSc MBA CEng MICE MIstructE

Guidance for concrete specification including:
• Reduction of ECO₂
• Use of recycled content
• Responsible sourcing
• Material efficiency

www.concretecentre.com/publications
Sustainability

*Sustainable development:*
'development which meets the needs of the present without compromising the ability of future generations to meet their own needs'

![Venn Diagram](image)

**Performance benefits of concrete**

<table>
<thead>
<tr>
<th></th>
<th>Social</th>
<th>Economic</th>
<th>Environmental</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Acoustics</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Flooding</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Robustness</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Thermal Mass</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Durability</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
</tbody>
</table>

...structural performance taken as read
Thermal mass to reduce OpCO₂

- Concrete has very useful role in energy efficient design strategies
- Use of thermal mass and night-time cooling to reduce energy loads necessary for heating and cooling

- Concrete on the inside
- Exposed soffit with night time ventilation to enhance passive cooling
- Exposed (or painted concrete) surface optimises thermal mass effect
Whole life CO\textsubscript{2}  

- Operational CO\textsubscript{2} + Embodied CO\textsubscript{2}  
  (Ratio depends on building type and life span)

EU carbon reduction plan:  
20% cut in emissions by 2020 compared to 1990

Energy Performance of Buildings  
Directive (EPBD)  
By 2020 all new buildings are ‘nearly zero-energy’

UK - Part L1A (2013) and SAP

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Embodied CO\textsubscript{2}

Research by Arup
Specifying concrete to BS8500

Exposure classification

XC: Corrosion induced by carbonation
XD: Corrosion induced by chlorides
XS: Corrosion induced by chlorides from sea
XF: Freeze-thaw attack
AC: Chemical attack
Exposure classification

XC: Corrosion induced by carbonation
XD: Corrosion induced by chlorides
XS: Corrosion induced by chlorides from sea
XF: Freeze-thaw attack
AC: Chemical attack

XC1: Dry or permanently wet
XC2: Wet, rarely dry
XC3: Moderate humidity
XC4: Cyclic wet and dry
**Exposure classification**

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
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<tbody>
<tr>
<td>XC</td>
<td>Corrosion induced by carbonation</td>
</tr>
<tr>
<td>XD</td>
<td>Corrosion induced by chlorides</td>
</tr>
<tr>
<td>XD1</td>
<td>Moderate humidity</td>
</tr>
<tr>
<td>XD2</td>
<td>Wet, rarely dry</td>
</tr>
<tr>
<td>XD3</td>
<td>Cyclic wet and dry</td>
</tr>
<tr>
<td>XS</td>
<td>Corrosion induced by chlorides from sea</td>
</tr>
<tr>
<td>XF</td>
<td>Freeze-thaw attack</td>
</tr>
<tr>
<td>AC</td>
<td>Chemical attack</td>
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</tr>
<tr>
<td>XD</td>
<td>Corrosion induced by chlorides</td>
</tr>
<tr>
<td>XS1</td>
<td>Exposed to airborne salt</td>
</tr>
<tr>
<td>XS2</td>
<td>Permanently submerged</td>
</tr>
<tr>
<td>XS3</td>
<td>Tidal, splash and spray zones</td>
</tr>
<tr>
<td>XS</td>
<td>Corrosion induced by chlorides from sea</td>
</tr>
<tr>
<td>XF</td>
<td>Freeze-thaw attack</td>
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<tr>
<td>AC</td>
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Exposure classification

XC: Corrosion induced by carbonation
XD: Corrosion induced by chlorides
XS: Corrosion induced by chlorides from sea
XF: Freeze-thaw attack
AC: Chemical attack

XF1: Moderate water saturation (no de-icing agent)
XF2: Moderate water saturation (de-icing agent)
XF3: High water saturation, (no de-icing agent)
XF4: High water saturation (de-icing agent)

Exposure classification

XC: Corrosion induced by carbonation
XD: Corrosion induced by chlorides
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XF: Freeze-thaw attack
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Methods of Specifying Concrete
BS 8500-1: 2015

a) Designated concrete

b) Designed concrete

c) Prescribed concrete

d) Standardized prescribed concrete

e) Proprietary concrete

Designated Concretes

Simple and reliable form of specification, widely used.
Specified by giving the designated name:

- FND
- GEN
- RC
- PAV
Designated Concretes

Basic specification requirements
• Concrete designation
• Max. aggregate size
• Consistence class

Other?
• Restriction / relaxation of cement type
• Special aggregate requirements
Designated Concrete

### BS 8500-2: 2015 (Table 5)

<table>
<thead>
<tr>
<th>Concrete designation</th>
<th>Min. strength class</th>
<th>Stamp class (A)</th>
<th>Min. w/c ratio</th>
<th>Max. cement or combination content (kg/m³) for max. aggregate size (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GEN0</td>
<td>C6/8</td>
<td>S3</td>
<td>—</td>
<td>120 120 120 120 120</td>
</tr>
<tr>
<td>GEN1</td>
<td>C8/10</td>
<td>S3</td>
<td>—</td>
<td>180 180 180 180 180</td>
</tr>
<tr>
<td>GEN2</td>
<td>C12/15</td>
<td>S3</td>
<td>—</td>
<td>200 200 200 200 200</td>
</tr>
<tr>
<td>GEN3</td>
<td>C16/20</td>
<td>S3</td>
<td>—</td>
<td>220 220 220 220 220</td>
</tr>
<tr>
<td>RC20/25</td>
<td>C20/25</td>
<td>S3</td>
<td>0.70</td>
<td>240 240 240 240 240</td>
</tr>
<tr>
<td>RC25/30</td>
<td>C25/30</td>
<td>S3</td>
<td>0.65</td>
<td>240 240 240 240 240</td>
</tr>
<tr>
<td>RC28/35</td>
<td>C28/35</td>
<td>S3</td>
<td>0.60</td>
<td>260 280 300 300 320</td>
</tr>
<tr>
<td>RC30/37</td>
<td>C30/37</td>
<td>S3</td>
<td>0.55</td>
<td>280 300 320 320 340</td>
</tr>
<tr>
<td>RC32/40</td>
<td>C32/40</td>
<td>S3</td>
<td>0.55</td>
<td>280 300 320 320 340</td>
</tr>
<tr>
<td>RC35/45</td>
<td>C35/45</td>
<td>S3</td>
<td>0.50</td>
<td>300 320 340 340 360</td>
</tr>
<tr>
<td>RC40/50</td>
<td>C40/50</td>
<td>S3</td>
<td>0.45</td>
<td>320 340 360 360 360</td>
</tr>
</tbody>
</table>

Cement and combination types:
- CEM I, II, III, IV, V
- CEM I, II, III, IV, V
- CEM I, II, III, IV, V
- CEM I, II, III, IV, V
- CEM I, II, III, IV, V
- CEM I, II, III, IV, V
- CEM I, II, III, IV, V
- CEM I, II, III, IV, V
- CEM I, II, III, IV, V
- CEM I, II, III, IV, V

### Designed Concretes

- Permits flexibility
- Suitable for most applications
- Strength, allowable cement types; water/cement ratios; use of recycled or secondary aggregates are specified
Designed Concrete

**Basic Specification Requirements**
- Strength class
- Max. W/C ratio
- Cement type and min. content
- Max. aggregate size
- Consistence class
- Chloride class
- Density class

**Additional Specification Options**
- Aggregate type, including use of recycled aggregate
- Fibres if used
- Air entrainment
- Temperature of the fresh concrete
- Heat development during hydration
Concrete constituents

Approx. proportions of A typical concrete mix
- Air 1.5%
- Cement 10%
- Water 18.5%
- Fine Aggregate (sand) 25%
- Course aggregate (stone/gravel) 45%

Specifying concrete - tips

1. Specify low carbon cements

- Portland cement contributes the majority of ECO₂ to concrete
- Carbon footprint of cement production has reduced by 55% since 1990.
- Use of cement replacements can reduce ECO₂ further eg: GGBS, fly ash
Concrete mix - ECO$_2$ of constituents

<table>
<thead>
<tr>
<th>Material</th>
<th>Embodied CO$_2$ (kg / tonne)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portland cement, CEM I</td>
<td>913</td>
</tr>
<tr>
<td>Addition or cement constituent</td>
<td></td>
</tr>
<tr>
<td>Ground granulated blastfurnace slag (ggbs)</td>
<td>67</td>
</tr>
<tr>
<td>Fly ash</td>
<td>4</td>
</tr>
<tr>
<td>Limestone</td>
<td>75</td>
</tr>
<tr>
<td>Aggregate</td>
<td>5</td>
</tr>
<tr>
<td>Reinforcement</td>
<td>427</td>
</tr>
</tbody>
</table>

Ref: Table 5: Embodied CO$_2$ for main constituents of reinforced concrete
Specifying Sustainable Concrete, The Concrete Centre, 2017

Define cements and combinations

<table>
<thead>
<tr>
<th>CEM</th>
<th>Addition</th>
<th>Portland cement replacement, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>–</td>
<td>0 - 5</td>
</tr>
<tr>
<td>IIA</td>
<td>Silica fume</td>
<td>6 - 10</td>
</tr>
<tr>
<td></td>
<td>Fly ash</td>
<td>6 - 20</td>
</tr>
<tr>
<td>IIB-V</td>
<td>Fly ash</td>
<td>21 - 35</td>
</tr>
<tr>
<td>IVB-V</td>
<td>Fly ash</td>
<td>36 - 55</td>
</tr>
<tr>
<td>IIB-S</td>
<td>Fly ash</td>
<td>21 - 35</td>
</tr>
<tr>
<td>IIIA</td>
<td>GGBS</td>
<td>36 - 65</td>
</tr>
<tr>
<td>IIIIB</td>
<td>GGBS</td>
<td>66 - 80</td>
</tr>
</tbody>
</table>

Approx. gen mix by volume

Based on BS 8500-1
### Embodied CO₂ of concrete

<table>
<thead>
<tr>
<th>Cement type</th>
<th>Strength class</th>
<th>CO₂ (kg/T)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEM I</td>
<td></td>
<td>153</td>
</tr>
<tr>
<td>CEM IIb-V (30% fly ash)</td>
<td><strong>C32/40</strong></td>
<td>130</td>
</tr>
<tr>
<td>CEM IIIa (50% GGBS)</td>
<td></td>
<td><strong>97</strong></td>
</tr>
</tbody>
</table>

40% less CO₂ than CEM I

### Strength Development

- CEM I at 3 days
- 70% GGBS and 30% FA at 3 days
- Same strength at 28 days
Sustainability specification tips for cement in concrete

1. Generally <40% GGBS for concrete soffits (unless programme can accommodate)

2. Maximise cementitious additions in footings or other locations where striking times are less critical. (e.g. ICF construction)

3. Allow some flexibility of % content for contractor to tailor mix to suit site conditions

Specifying Concrete - tips

2. Consider recycled or secondary aggregates

(if available locally or using low carbon transport)
Low carbon natural aggregates

- Inherently low carbon
- Mostly naturally occurring, local resource
- Potential self-sufficiency in UK aggregates for many thousands of years
- Recycled aggregates transported more than 15km by road are likely to have higher ECO₂ content than local primary aggregates

Use of recycled aggregates

- Recycled aggregates (RA) are already efficiently used e.g. as hardcore or in landscaping
- Very little (effectively none) goes into landfill
- Approx. a third of all aggregate in UK is recycled or secondary aggregate (three times more than the European average)
- Consistency of supply and source material are necessary for use in concrete
- Testing regimes for quality control is more rigorous than for natural/primary aggregates

Laban centre brown roof
Dusty Gedge photography

as brown roofs

in gabions
to create landscape
Coarse crushed concrete aggregate (CCA)

Crushed concrete used as aggregate: a form of RA with maximum 5% masonry content

- Fewer restrictions on use in concrete than RA
- Up to 20% is permitted to be supplied in ‘Designated’ reinforced concrete
- 100% coarse CCA possible in:
  - Lower grade concretes (GEN0, GEN1, GEN2, GEN3)
  - Strength classes up to C40/50 in exposure classes X0, XC1, XC2, XC3, XC4, XF1 & DC-1 (but are rarely supplied)

All RA tend to require more cement, change the mix relationships and add an element of risk

Secondary aggregates

Derived from by-products of other quarrying operations or industrial processes

- Recognised secondary aggregates available for concrete include:
  - China clay waste (known as stent aggregate, or granite aggregate and sands)
  - Fly ash (lightweight aggregate)
  - Air cooled blast-furnace slag aggregate
- Typically greater % in concrete possible than RA. Use depends upon properties of the aggregate.
Sustainable concrete specification tips for aggregates

1. Consider recycled or secondary aggregates, depending on:
   - Availability
   - Type of aggregate
   - Use of concrete
   - Local supply or low carbon transportation
   - Don’t rule out primary (virgin aggregates)

Specifying Concrete - tips

3. Specify responsible sourced concrete (BES 6001)

- Concrete is the leading construction material for responsible sourcing
- Around 90% all concrete production is BES 6001 accredited
Concrete is a local material

- Local manufacture and locally sourced raw materials
- Average delivery distance of ready-mixed concrete is less than 12km

Many quarries have on-site rail terminals enabling direct access to the rail network.

Sustainable concrete summary specification tips

When using BS 8500:

1. Specify low carbon cements
2. Consider recycled or secondary aggregates (if available locally or using low carbon transport)
3. Specify responsible sourced concrete (BES 6001)
Thank you

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