STEEL MATERIAL SELECTION AND COMPLIANCE WITH STRUCTURAL EUROCODES

Chiew Sing Ping
Professor and Programme Director of Civil Engineering
SINGAPORE INSTITUTE OF TECHNOLOGY

23 February 2017
Use of Chinese Guobiao Steel in Singapore
Scope of Presentation

1. Why Material Selection is important?
2. Steel Construction in Singapore
   - Overall framework
   - Consistent quality assurance
   - Interface to bridge material and design
Steel Construction in Singapore (from 1 April 2015)

Design
BS EN1993

Material
BS ENs only

Execution
BS EN1090
Uniquely Singapore!

- **Design**: BS EN1993
- **Material**: BS ENs & Non-BS ENs (GB/JIS/ASTM/AS/NZS)
- **Execution**: BS EN 1090
Uniquely Singapore!

- **Design**: BS EN1993
- **Material**: BS ENs & Non-BS ENs (GB/JIS/ASTM/AS/NZS)
- **Execution**: BS EN 1090

Guide to bridge Material and Design
Steel Construction in Singapore

• Sustainability, Productivity & Resiliency in the industry:
  – Disruption in sand & granite supply
  – Increase productivity / Reduce migrant workers
• BS5950/EC3 design codes
  – Only covers BS/EN materials by default
• For e.g. BS5950/EC3 + Chinese GB Steel = ???
Alternative Steel Materials

‘Alternative’ in Singapore’s context…

• not manufactured to BS/EN
• not covered in BS5950/EC3 by default
• easily available (GB, JIS, ASTM, AS/NZS)
• use to BS5950/EC3 ⇒ design guide needed
Singapore Steel Market (2013)

• Import of structural steel sections (plates, H & I sections, channels, angles, hollow sections)
  - China  588K Tonnes
  - Ukraine 488K Tonnes
  - Japan 472K Tonnes
  - Others  371K Tonnes
    (Korea, Thailand, Taiwan, Malaysia)

• Export (Indonesia) 639K Tonnes

TOTAL STRUCTURAL STEEL ≈ 1.3M Tonnes
TOTAL REINFORCING STEEL ≈ 1.5M Tonnes
Singapore imports fabricated structural steelwork from the following countries in 2013:

- China, S$313M
- Japan, S$284M
- Malaysia, S$156M (subsidiaries of Singapore companies operating in Malaysia)
- Germany, S$53M
- Korea, S$50M

**TOTAL = S$856M**
Local trends
- Cheaper steel
- Higher strength
- Higher labour cost
  - lower MYEs, higher levies
- National productivity drive
- BCA’s push for sustainability
  – i.e. Green Mark 2015

Source: IESingapore
Some Basic Considerations

• Steel material production standards are substantial documents covering mechanical, chemical, physical and other delivery conditions
• One piece of steel is not necessary the same as another although they may look the same
• We are not the only ones using steel
• We never buy steel by weight
• Testing a batch of steel from different ‘parents’ is meaningless
• Material failure can be sudden and disastrous
Structural Performance Requirements

- **Strength** – ability to carry load
- **Ductility** – ability to sustain permanent deformation without loss of strength
- **Toughness** – ability to absorb damage without fracture
- **Weldability** – ability to transfer load
Grand Challenge – Balance Performance!

- Strength
- Ductility
- Toughness
- Weldability
Material Selection & Compliance

BC 1: 2008 - Design Guide on use of Alternative Steel Materials to BS5950

(Approved Document under Singapore’s Building Regulations and enforced by BCA of Singapore)

BC 1: 2012 - Design Guide on use of Alternative Structural Steel to BS5950 and Eurocode 3

(Approved Document under Singapore’s Building Regulations and enforced by BCA of Singapore)
Selection of Equivalent Steel Materials – Hong Kong & Macau

(Industrial Guide for Best Construction Practice in Hong Kong and Macau)
BC 1 - Objectives

- Allow a wider choice of steel materials to achieve greater economy and sustainability
- Ensure product conformity, quality and traceability in materials from various sources

Deliverables:
- Use only adequate & reliable alternative materials to ensure public safety
- Optimize usage of alternative materials (eg. use full design strength) for more competitive design
- Address long-standing material problems facing the steel construction sector
BC 1 – Overall Framework

Two Major Issues

- Adequacy?
  - Material performance requirements
- Reliability?
  - Quality assurance requirements
BC 1 – Overall Framework

BS EN, ASTM, AS/NZS, JIS & GB

Steel materials

For e.g. IS, KS, API

Not common route!!

Reliability assessment
(see 4.2)

Class 1

by certification
(see 4.1.1)

Adequacy assessment
(see 4.1)

Class 3

by material testing
(see 4.1.2)

Reliability assessment
(see 4.2)

Class 2

“special case”
(see 4.4)

Key:
Pass
Fail

Not common route!!
## Eurocodes Material Requirements

Trend is towards use of higher grade steel but more stringent performances are required.

<table>
<thead>
<tr>
<th></th>
<th>Reinforcing Steel</th>
<th>Structural Steel</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td><strong>Yield strength</strong>&lt;br&gt;(MPa)</td>
<td>400 to 600</td>
<td></td>
</tr>
<tr>
<td><strong>Modulus of elasticity</strong>&lt;br&gt;(GPa)</td>
<td>200</td>
<td></td>
</tr>
<tr>
<td><strong>f_t/f_y or f_u/f_y</strong></td>
<td>≥ 1.05</td>
<td>≥ 1.08</td>
</tr>
<tr>
<td><strong>Elongation (%)</strong></td>
<td>≥ 2.5</td>
<td>≥ 5.0</td>
</tr>
<tr>
<td><strong>Ultimate strain</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Current Design Issues
and Bridging the gaps with BC1
## Column Buckling Curves in EC3

<table>
<thead>
<tr>
<th>Cross-section</th>
<th>Limits</th>
<th>Buckling about axis</th>
<th>Buckling curve</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>S235</td>
</tr>
<tr>
<td>Rolled I-sections</td>
<td>h/b &gt; 1.2</td>
<td>t_f ≤ 40 mm</td>
<td>y - y</td>
</tr>
<tr>
<td></td>
<td></td>
<td>40 mm &lt; t_f ≤ 100 mm</td>
<td>y - y</td>
</tr>
<tr>
<td></td>
<td></td>
<td>t_f ≤ 100 mm</td>
<td>y - y</td>
</tr>
<tr>
<td></td>
<td></td>
<td>t_f &gt; 100 mm</td>
<td>y - y</td>
</tr>
<tr>
<td>Welded I-sections</td>
<td>t_f ≤ 40 mm</td>
<td>y - y</td>
<td>z - z</td>
</tr>
<tr>
<td></td>
<td>t_f &gt; 40 mm</td>
<td>y - y</td>
<td>z - z</td>
</tr>
<tr>
<td>Section Type</td>
<td>Hot Finished</td>
<td>Cold Formed</td>
<td></td>
</tr>
<tr>
<td>-----------------------</td>
<td>--------------</td>
<td>-------------</td>
<td></td>
</tr>
<tr>
<td>Hollow sections</td>
<td>any</td>
<td>a</td>
<td></td>
</tr>
<tr>
<td></td>
<td>a</td>
<td>a₀</td>
<td></td>
</tr>
<tr>
<td>Welded box sections</td>
<td>any</td>
<td>b</td>
<td></td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>b</td>
<td></td>
</tr>
<tr>
<td></td>
<td>any</td>
<td>c</td>
<td></td>
</tr>
<tr>
<td></td>
<td>c</td>
<td>c</td>
<td></td>
</tr>
<tr>
<td>Thick welds: a &gt; 0.5t₁, b/t₁ &lt; 30, h/t₃ &lt; 30</td>
<td>any</td>
<td>c</td>
<td></td>
</tr>
<tr>
<td></td>
<td>c</td>
<td>c</td>
<td></td>
</tr>
<tr>
<td>U-, T-, and solid sections</td>
<td>any</td>
<td>c</td>
<td></td>
</tr>
<tr>
<td></td>
<td>c</td>
<td>c</td>
<td></td>
</tr>
<tr>
<td>L-sections</td>
<td>any</td>
<td>b</td>
<td></td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>b</td>
<td></td>
</tr>
</tbody>
</table>
Higher grades, e.g. AS1397 G450 commonly used in Singapore have nominal values which cannot comply with EC3 in terms of strength ratio and 10% elongation.

<table>
<thead>
<tr>
<th>Standard</th>
<th>Grade</th>
<th>Nominal yield strength (MPa)</th>
<th>Nominal tensile strength (MPa)</th>
<th>Strength ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>AS 1397</td>
<td>G450</td>
<td>450</td>
<td>480</td>
<td>1.07</td>
</tr>
<tr>
<td></td>
<td>G500</td>
<td>500</td>
<td>520</td>
<td>1.04</td>
</tr>
<tr>
<td></td>
<td>G550</td>
<td>550</td>
<td>550</td>
<td>1.00</td>
</tr>
<tr>
<td>AS 1595</td>
<td>CA 500</td>
<td>500</td>
<td>510</td>
<td>1.02</td>
</tr>
<tr>
<td>EN 10149</td>
<td>S 550MC</td>
<td>550</td>
<td>600</td>
<td>1.09</td>
</tr>
<tr>
<td></td>
<td>S 600MC</td>
<td>600</td>
<td>650</td>
<td>1.08</td>
</tr>
<tr>
<td></td>
<td>S 650MC</td>
<td>650</td>
<td>700</td>
<td>1.08</td>
</tr>
<tr>
<td></td>
<td>S 700MC</td>
<td>700</td>
<td>750</td>
<td>1.07</td>
</tr>
<tr>
<td>EN 10326</td>
<td>S550GD</td>
<td>550</td>
<td>560</td>
<td>1.02</td>
</tr>
<tr>
<td>ISO 4997</td>
<td>CH550</td>
<td>550</td>
<td>550</td>
<td>1.00</td>
</tr>
</tbody>
</table>
Bridging the Gap...

Alternative Steel
AS1397
Grade G450

Gap

Design Code
BS EN1993
Bridging the Gap...

- Alternative Steel: AS1397, Grade G450
- Design Guide: BC 1
- Design Code: BS EN1993
Issue 2 – Hot Finished Hollow Section
Hot-Formed ≠ Hot-Finished !!
Bridging the Gap...

BS EN Steel
BS EN10210

Gap

Design Code
BS EN1993
Bridging the Gap...

BS EN Steel
BS EN10210

Design Guide
BC 1

Design Code
BS EN1993
Conclusions

1. The design guide BC1 paves the way and serves as a bridge to allow alternative structural steel such as Guobiao steel to be used in Singapore.

2. Singapore is a small city state with limited resources and needs to focus on identifying the ‘gaps’ and bridge them by developing our own design guides when necessary.

3. Singapore has taken a bold step to liberalize and formalize the use of alternative structural steel and this has served us well since 2009.
Thank you!