New opportunities and challenges in adopting Eurocodes in Hong Kong

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Department of Civil and Environmental Engineering
The Hong Kong Polytechnic University, Hong Kong SAR.

Hong Kong Constructional Metal Structures Association
Outline

1 Eurocodes

2 British Standards vs Eurocodes

3 Member buckling check for columns and beams
   - EN 1993: Steel beams susceptible to lateral buckling
   - EN 1993: Steel columns susceptible to axial buckling, as well as
   - EN 1994: Steel-concrete composite columns susceptible to axial buckling

4 Iron and Steel Industry in China

5 Hong Kong Constructional Metal Structures Association

6 International Engineering Design Centre for Infrastructures

Concluding Remarks
1 Eurocodes

There are 10 separate Structural Eurocodes, each Eurocode comprises a number of Parts, which are published as separate documents.

Each Part consists of:
- the main body of text
- Normative annexes
- Informative annexes

EN 1990  Eurocode 0: *Basis of structural design*
EN 1991  Eurocode 1: *Actions on structures*
EN 1992  Eurocode 2: *Design of concrete structures*
EN 1993  Eurocode 3: *Design of steel structures*
EN 1994  Eurocode 4: *Design of composite steel and concrete structures*
EN 1995  Eurocode 5: *Design of timber structures*
EN 1996  Eurocode 6: *Design of masonry structures*
EN 1997  Eurocode 7: *Geotechnical design*
EN 1998  Eurocode 8: *Design of structures for earthquake resistance*
EN 1999  Eurocode 9: *Design of aluminium structures*
2. British Standards vs Eurocodes

2.1 Axes

<table>
<thead>
<tr>
<th></th>
<th>BS5950</th>
<th>EC3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Along the member</td>
<td>X (?)</td>
<td>X</td>
</tr>
<tr>
<td>Major axis</td>
<td>X</td>
<td>Y</td>
</tr>
<tr>
<td>Minor axis</td>
<td>Y</td>
<td>Z</td>
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</table>
2. British Standards vs Eurocodes

2.2 Terminology

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>Dead load</td>
<td>W</td>
<td>Permanent action</td>
</tr>
<tr>
<td></td>
<td></td>
<td>G</td>
</tr>
<tr>
<td>Imposed load</td>
<td>W</td>
<td>Variable action</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Q</td>
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<td>Wind load</td>
<td>W</td>
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<table>
<thead>
<tr>
<th></th>
<th>BS5950</th>
<th>EC3</th>
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<tbody>
<tr>
<td>Load factor</td>
<td>1.2 to 1.6</td>
<td>0.75 to 1.5</td>
</tr>
<tr>
<td>Material factor</td>
<td>1.0 to 1.2</td>
<td>1.0 to 1.1</td>
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## 2. British Standards vs Eurocodes

### 2.3 Symbols

<table>
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<th>BS5950</th>
<th>EC3</th>
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<td>N</td>
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<tr>
<td>Z</td>
<td>Weₐ</td>
<td>Mₓ</td>
<td>Mᵧ</td>
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<td>Wₚl</td>
<td>V</td>
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<td>λ</td>
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## 2. British Standards vs Eurocodes
### 2.4 Formulation

<table>
<thead>
<tr>
<th>BS5950</th>
<th>EC3</th>
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<tbody>
<tr>
<td>( P = p_y A )</td>
<td>( N_{c,Rd} = A f_y / \gamma_{M0} )</td>
</tr>
<tr>
<td>( P = p_c A )</td>
<td>( N_{b,Rd} = \chi A f_y / \gamma_{M1} )</td>
</tr>
<tr>
<td>( M = p_y S )</td>
<td>( M_{c,Rd} = W_p I f_y / \gamma_{M0} )</td>
</tr>
<tr>
<td>( M = p_b S )</td>
<td>( M_{b,Rd} = \chi_{LT} W_p I f_y / \gamma_{M1} )</td>
</tr>
</tbody>
</table>
### 2. British Standards vs Eurocodes

#### 2.5 Load combinations

<table>
<thead>
<tr>
<th>Condition</th>
<th>Dead</th>
<th>Imposed</th>
<th>Wind</th>
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<td>1.5</td>
<td>0.75</td>
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<tr>
<td>BS5950</td>
<td>1.4</td>
<td>1.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
</tr>
<tr>
<td></td>
<td>1.4</td>
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## 2. British Standards vs Eurocodes

### 2.6 Slenderness

<table>
<thead>
<tr>
<th>Slenderness</th>
<th>BS5950</th>
<th>EC3</th>
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<tbody>
<tr>
<td><strong>Column</strong></td>
<td>$\lambda = \frac{L_E}{r}$</td>
<td>$\overline{\lambda} = \sqrt{\frac{A f_y}{N_{cr}}}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>where $N_{cr} = \frac{\pi^2 E I}{L^2}$</td>
</tr>
<tr>
<td><strong>Beam</strong></td>
<td>$\lambda_{LT} = u v \lambda$</td>
<td>$\overline{\lambda}<em>{LT} = \sqrt{\frac{W_y f_y}{M</em>{cr}}}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>where $M_{cr} = C_1 \frac{\pi^2 E I_z}{L^2} \sqrt{\frac{l_w}{I_z} + \frac{L^2 G I_t}{\pi^2 E I_z}}$</td>
</tr>
</tbody>
</table>

2. British Standards vs Eurocodes

2.6 Slenderness
2. British Standards vs Eurocodes
2.7 Slenderness – Elastic critical force $N_{cr}$ and elastic critical moment $M_{cr}$

$N_{cr}$ and $M_{cr}$ are generic terms.

$N_{cr}$ and $M_{cr}$ may be readily determined using eigenvalue analysis through finite element method.
2. British Standards vs Eurocodes

2.8 Harmonization of column buckling curves in Eurocodes

An interactive curve for each steel grade / design yield strength:

\[ p_c = \frac{p_E p_y}{\phi + \sqrt{\phi^2 - p_E p_y}} \]

\[ \phi = \frac{p_y + (\eta + 1)p_E}{2} \]

Interaction Perry-Robertson formula

Reduction factor, \( \chi \)

Compressive strength, \( p_c \) (N/mm\(^2\))

Slenderness, \( \lambda = \frac{L_E}{r} \)

Non-dimensional slenderness, \( \bar{\lambda} \)

One interactive curve for all steel grades. The material parameter \( \lambda_1 \) is used:

\[ \bar{\lambda} = \frac{\lambda}{\lambda_1} \]

\[ \lambda_1 = \pi \sqrt{\frac{E}{f_y}} \]

where \( E \) is the Young’s modulus and \( f_y \) is the yield strength.
Same format of design formulae is adopted for all structural members which may buckle:

- Steel
- Steel-concrete composite
- Timber
- Aluminium

More importantly, the design methods for structural members at room temperature and elevated temperatures have been developed into similar formats:

i.e. cold design and hot design are harmonized.
With recent advances in design development of structural design codes, modern design codes allow rational design and analysis on the structural behaviour of a structure against well defined requirements at specific levels of acceptance.

It is very interesting to review the development of a number of national steel codes, and to examine some of the design methods and clauses which have evolved over the years. Illustrations on member buckling check are given below:

- Steel columns susceptible to axial buckling
- Steel beams susceptible to lateral buckling
- Composite columns susceptible to axial buckling
3.1 Member Buckling Check for Steel Sections

*Steel columns: British Steel Code BS 5950*

For a steel column susceptible to axial buckling, the slenderness of the column:

\[
\lambda = \frac{L_e}{r_y}
\]

where

- \(L_e\) is the effective length of the column
- \(r_y\) is the radius of gyration of the cross-section of the column

Through a non-linear interaction curve, which is commonly referred as the Perry-Robertson formula, the effect of axial buckling in a real column is expressed as a *reduction in its design strength from its yield value*, i.e. a *compressive strength*. 

![Column buckling curves to BS 5950](image)
3.1 Member Buckling Check for Steel Sections

**Steel columns: Eurocode 3**

For a steel column susceptible to axial buckling, the slenderness of the column:

\[
\bar{\lambda} = \frac{\lambda}{\lambda_Y} = \sqrt{\frac{N_c}{N_{cr}}}
\]

The effect of axial buckling in a real column is expressed as *a reduction in resistance of the cross-sections*, i.e. a strength reduction factor, \(\chi_c\), multiplied to the axial compression resistance of the cross-section of the member.
3.2 Member Buckling Check for Steel Sections

Steel beams: British Steel Code BS 5950

For a steel beam susceptible to lateral buckling, an equivalent slenderness of the beam:

\[
\lambda_{LT} = u v \lambda
\]

where \( u \) and \( v \) are secondary section properties of the beam related to lateral bending and torsion.

The effect of lateral buckling in a real beam is expressed as *a reduction in its design strength from its yield value*, i.e. *a bending strength.*
3.2 Member Buckling Check for Steel Sections

*Steel beams: Eurocode 3*

For a steel beam susceptible to lateral buckling, an equivalent slenderness of the beam:

\[
\lambda_{LT} = \frac{\lambda}{\lambda_y} = \sqrt{\frac{M_c}{M_{cr}}}
\]

The effect of lateral buckling in a real beam is expressed as a *reduction in resistance of the cross-sections*, i.e. a strength reduction factor, \(\chi_b\) multiplied to the moment resistances of the cross-section of the member.
3.3 Member Buckling Check using Modified Slenderness

**Composite columns: Eurocode 4**

The axial buckling resistances of the composite columns are based on the modified slenderness:

\[ \lambda = \sqrt{\frac{N_{pl}}{N_{cr}}} \]

where

- \( N_{pl} \) is the section capacity of the composite column
- \( N_{cr} \) is the elastic axial buckling resistance of the composite column

The effect of axial buckling in real composite columns is expressed as a *strength reduction to the resistances of the cross-sections of the members*, i.e. a strength reduction factor, \( \chi_c \), multiplied to the compression resistances of the cross-sections of the composite columns.
3.4 Member Buckling Check at Elevated Temperatures

Steel and composite columns: Eurocodes 3 & 4

All of the materials retain only 50% of their original strengths when their temperatures reach 500 to 600 °C.
3.4 Design procedure of a steel beam – cold & hot design

*EN 1993: 1-1 & -2: 2005*

**Cold Design**
- Evaluate the equivalent slenderness, $\lambda_{LT}$
- Evaluate the non-dimensional slenderness, $\overline{\lambda}_{LT}$
- Evaluate $\phi_{LT}$
- Evaluate $\chi_{LT}$
- Evaluate the buckling moment resistance, $M_{b,Rd}$

**Hot Design**
- Evaluate the equivalent slenderness, $\lambda_{LT}$
- Evaluate the non-dimensional slenderness, $\overline{\lambda}_{LT, \theta, \text{com}}$
- Find out the reduction factors: $k_{y,\theta,\text{com}}$ & $k_{E,\theta,\text{com}}$
- Evaluate $\phi_{LT, \theta, \text{com}}$
- Evaluate $\chi_{LT,fi}$
- Evaluate the buckling moment resistance, $M_{b,fi,Rd}$
3.4 Design procedure of a steel column - cold & hot design

*EN 1993: 1-1 & -2: 2005*

**Cold Design**

1. Evaluate the equivalent slenderness, $\lambda$
2. Evaluate the non-dimensional slenderness, $\bar{\lambda}$
3. Evaluate $\phi$
4. Evaluate $\chi$
5. Evaluate the buckling moment resistance, $N_{b,Rd}$

**Hot Design**

1. Evaluate the equivalent slenderness, $\lambda$
2. Evaluate the non-dimensional slenderness, $\bar{\lambda}_\theta$
3. Find out the reduction factors: $k_{y,\theta}$ & $k_{E,\theta}$
4. Evaluate $\phi_{\theta}$
5. Evaluate $\chi_{fi}$
6. Evaluate the buckling moment resistance, $N_{b,fi,Rd}$
3.4 Design procedure of a composite column – cold & hot design


**Cold Design**

1. Evaluate both the design and characteristic plastic resistance to compression, $N_{pl,Rd} \& N_{pl,R}$
2. Evaluate the effective flexural stiffness, $(EI)_{eff}$
3. Evaluate the non-dimensional slenderness, $\bar{\lambda}$
4. Evaluate $\phi$
5. Evaluate $\chi$
6. Evaluate the buckling resistance, $N_{b,Rd}$

**Hot Design**

1. Evaluate both the design and characteristic plastic resistance to compression, $N_{fi,pl,Rd} \& N_{fi,pl,R}$
2. Evaluate the effective flexural stiffness, $(EI)_{eff}$
3. Evaluate the non-dimensional slenderness, $\bar{\lambda}_\theta$
4. Evaluate $\phi_\theta$
5. Evaluate $\chi_\theta$
6. Evaluate the buckling resistance, $N_{b,fi,Rd}$
3.5 Harmonized Design

Owing to the successful design development on member buckling in the Structural Eurocodes, the normalized slenderness ratios:

\[
\bar{\lambda} \quad \text{for steel columns susceptible to axial buckling, and}
\]

\[
\bar{\lambda}_{LT} \quad \text{for steel beams susceptible to lateral buckling}
\]

are shown to be effective to determine corresponding strength reduction factors due to member buckling.

Hence, the harmonized member buckling design of steel beams and columns as well as steel-concrete composite columns at both room and elevated temperatures is presented, and this design method may be regarded as a generalized method readily applicable to various structural members.

Many other key design methods such as cross-section resistances have also been harmonized.
3.6 Construction projects to Eurocodes

It will take some time for the local construction industry to learn the new skills while adopting Eurocodes.

Similar to many successful stories in the past about working with British Standards since the 1980’s, Hong Kong will be able to contribute to many overseas construction projects.

One of the fast growing sectors of overseas construction in the Region is steel construction, working with construction companies and structural steel fabricators to various codes of practice.
## 4 Iron and Steel Industry in China

**Annual steel production (million metric tons)**

<table>
<thead>
<tr>
<th>Year</th>
<th>Australia</th>
<th>China</th>
<th>Japan</th>
<th>U.K.</th>
<th>U.S.A.</th>
<th>World</th>
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<tbody>
<tr>
<td>1980</td>
<td>7.6</td>
<td>37.1</td>
<td>111.4</td>
<td>11.3</td>
<td>101.5</td>
<td>568.5</td>
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<tr>
<td>1990</td>
<td>6.7</td>
<td>66.4</td>
<td>110.3</td>
<td>17.8</td>
<td>89.7</td>
<td>616.0</td>
</tr>
<tr>
<td>2000</td>
<td>7.1</td>
<td>128.5</td>
<td>106.4</td>
<td>15.2</td>
<td>101.8</td>
<td>848.9</td>
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<tr>
<td>2010</td>
<td>7.3</td>
<td>637.4</td>
<td>109.6</td>
<td>9.7</td>
<td>80.5</td>
<td>1428.7</td>
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<td>2012</td>
<td>4.9</td>
<td>716.6</td>
<td>107.2</td>
<td>9.8</td>
<td>88.6</td>
<td>1510.2</td>
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</table>

*Data from World Steel Association ([www.worldsteel.org](http://www.worldsteel.org))*
## Iron and Steel Industry in China

### Major steel-producing countries in 2012

<table>
<thead>
<tr>
<th>Ranking</th>
<th>Country</th>
<th>Annual Production (mmt)</th>
<th>Proportion (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>China</td>
<td>716.5</td>
<td>47.4</td>
</tr>
<tr>
<td>2</td>
<td>Japan</td>
<td>107.2</td>
<td>7.1</td>
</tr>
<tr>
<td>3</td>
<td>U.S.A.</td>
<td>88.7</td>
<td>5.9</td>
</tr>
<tr>
<td>4</td>
<td>India</td>
<td>77.6</td>
<td>5.1</td>
</tr>
<tr>
<td>5</td>
<td>Russia</td>
<td>70.4</td>
<td>4.7</td>
</tr>
<tr>
<td>6</td>
<td>South Korea</td>
<td>69.1</td>
<td>4.6</td>
</tr>
<tr>
<td>7</td>
<td>Germany</td>
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<td>8</td>
<td>Turkey</td>
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<td>9</td>
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<td>2.3</td>
</tr>
<tr>
<td>10</td>
<td>Ukraine</td>
<td>33.0</td>
<td>2.2</td>
</tr>
</tbody>
</table>

**Total world production**: 1510.2

Data from World Steel Association (www.worldsteel.org)
4 Iron and Steel Industry in China

- China Constructional Metal Structures Association
  中国建筑金属结构协会

- China Iron and Steel Association
  中国钢铁工业协会

- China Steel Construction Society
  中国钢结构协会

- National Engineering Research Centre on Steel Construction
  国家钢结构工程技术研究中心
The **Hong Kong Constructional Metal Structures Association** is established in July 2010 among engineers, managers, academics and other construction professionals.

It aims to promote the effective use of metal structures in construction in Hong Kong:

- To provide latest information on education, research, design and construction from overseas for continual professional training of engineers in Hong Kong, Macau, and the Mainland China.

- To promote exchange and collaboration on education, research and professional skills among engineers in Hong Kong, Macau, the Mainland China and overseas.

- To promote wide adoption of the Chinese steel materials and associated design standards, construction practice as well as technical and professional qualifications.
## 5 Hong Kong Constructional Metal Structures Association

### Technological advancements

*Professional Services Development Assistance Scheme: Schedule of Seminars*

<table>
<thead>
<tr>
<th>Date</th>
<th>Topic</th>
<th>Speakers</th>
</tr>
</thead>
<tbody>
<tr>
<td>23 March 2012</td>
<td>Effective Design of Steel Structures to BS EN 1993-1-1</td>
<td>Dr T M Chan</td>
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<tr>
<td></td>
<td></td>
<td>Prof K F Chung</td>
</tr>
<tr>
<td>16 &amp; 17 August 2012</td>
<td>Effective Design of Steel-Concrete Composite Structures to BS EN 1994-1- EC4</td>
<td>Prof K F Chung</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Prof Dennis Lam</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ir H Y Lee</td>
</tr>
<tr>
<td>2 &amp; 9 November 2012</td>
<td>Effective Design of Steel Structures to BS EN 1993-1-1</td>
<td>Ir Dr Gary S K Chou</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ir Prof K F Chung</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dr Paul H F Lam</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ir Dr Michael C H Yam</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ir Alan H N Yau</td>
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<tr>
<td>7 &amp; 14 December 2012</td>
<td>Effective Design of Steel-Concrete Composite Structures to BS EN 1994-1-1 EC 4</td>
<td>Ir Prof K F Chung</td>
</tr>
<tr>
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<td>Prof Dennis Lam</td>
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*Professional Services Development Assistance Scheme: Schedule of Seminars*

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<tr>
<th>Date</th>
<th>Topic</th>
<th>Speakers</th>
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<tbody>
<tr>
<td>12 &amp; 19 April 2013</td>
<td>Effective Design of Steel Structures to BS EN 1993-1-1</td>
<td>Dr T M Chan, Ir Dr Gary S K Chou, Ir Prof K F Chung, Dr Paul H F Lam, Ir Alan H N Yau</td>
</tr>
<tr>
<td>27 Sept &amp; 4 Oct 2013</td>
<td>Effective Design of Steel Structures to BS EN 1993-1-1</td>
<td>Dr T M Chan, Ir Dr Gary S K Chou, Ir Prof K F Chung, Dr Paul H F Lam, Ir Alan H N Yau</td>
</tr>
</tbody>
</table>
5 Hong Kong Constructional Metal Structures Association

Technological advancements

Steel Designers’ Manual, 7th Edition

- **SDM7** in accordance with Eurocodes
  The Steel Construction Institute, February 2012.

- **SDM7 - Traditional Chinese Version**
  jointly published by Macau Society of Metal Structures and HKCMSA, August 2013.

- **SDM7 - Simplified Chinese Version**
  jointly published by China Steel Construction Society, National Engineering, Research Centre for Steel Construction, HKCMSA and MSMS, tentatively 2014.
Effective use of high performance steel in construction

• **High strength steel:** S460, S690, S890 …
  Design rules – cross-section resistances, member resistances, welding
  Composite beams and columns, degree of shear connection, interfacial shear transfer

• **High resistances against corrosion and fire attack and high weldability**
  Steel plates: 6.0 to 150 mm thick plates for fabricated sections
  Steel strips: 1.0 to 5.0 mm thick strips for cold rolled sections and deckings
  0.43 to 1 mm thick strips for sheetings and claddings
5 Hong Kong Constructional Metal Structures Association

Technological advancements

Equivalent steel materials to Modern Steel Design

- Code of Practice for Structural Use of Steel
  Buildings Department, Hong Kong, 2007 & 2011

- Design Guide on Use of Alternative Steel Materials
  Building and Construction Authority, Singapore, 2008 & 2012

First official documents in Hong Kong and Singapore formalize the use of non-British steel materials, in particular, Chinese steel materials (in comparison with approvals on individual projects.)

Different QA procedures to establish Class 1 steel materials with a material factor 1.0, when compared with Class 2 steel materials with a material factor 1.1.
5 Hong Kong Constructional Metal Structures Association

Technological advancements

Equivalent steel materials to Modern Steel Design

• Professional Guide on Selection of Equivalent Steel Materials to European Steel Materials Specifications

Professional organizations and authorities of Hong Kong, Singapore, Malaysia and Macau
5 Hong Kong Constructional Metal Structures Association
Technological advancements

Equivalent steel materials to Modern Steel Design

• Professional Guide on Effective Use of Equivalent Steel Materials
  Professional organizations and authorities of Hong Kong, Singapore, Malaysia and Macau

  a) Modern Structural Steel Design Codes: EN1993-1 & EN1994-1
  b) European Steel Materials Specifications against Australia / New Zealand, China, Japan, U.K., U.S.A.
  c) Detailed materials requirements:
    • Chemical compositions: Carbon, Phosphorus, Sulphur, Carbon Equivalent Value (CEV)
    • Mechanical requirements: strengths, elongation limits, toughness and weldability according to CEV
    • Technical guidelines for approving or disapproving specific batches of steel materials
Equivalent steel materials to Modern Steel Design

Further developments:

- Effective use of Chinese steel materials to modern structural steel design and construction in overseas projects

- Product conformity certification scheme / factory production control system for quality supply of steel materials

- Qualification and inspection schemes of fabricators for steel fabrication
6 International Engineering Design Centre for Infrastructures

Hong Kong Construction Industry

Develops / Architects / Engineers / Surveyors / Project Managers / Legal and Financial Professionals

Professional skills

International exposure and network

Flexibility towards different conditions and constraints

Working experiences in many countries in the Region
6 International Engineering Design Centre for Infrastructures

Some evidence…

A Senior Engineer worked on the following projects in the past 8 years:

- Wave Mega City Centre at Noida, **India**
- IREO City, Gurgaon, **India**
- Resorts World at Sentosa, **Singapore**
- Etihad Towers, Abu Dhabi, **United Arab Emirates**
- Grand Lisboa Hotel, **Macau**
- Shanghai Wheelock Square, China, and
- Many commercial and residential buildings in Hong Kong.
New opportunities and challenges in adopting Eurocodes in Hong Kong

1. Adopting Eurocodes provides the Hong Kong Construction Industry a challenge as well as an opportunity to learn, to grow and to go overseas.

2. Steel construction is fast-growing, and it travels to many parts of the world.

3. Hong Kong is well placed to collaborate with the China Steel and Iron Industry, to lead, to advise and to control quality.

It is happening now! Are you ready to ride on?
New opportunities and challenges in adopting Eurocodes in Hong Kong

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