

STEEL MATERIAL SELECTION AND COMPLIANCE WITH STRUCTURAL EUROCODES

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23 February 2017

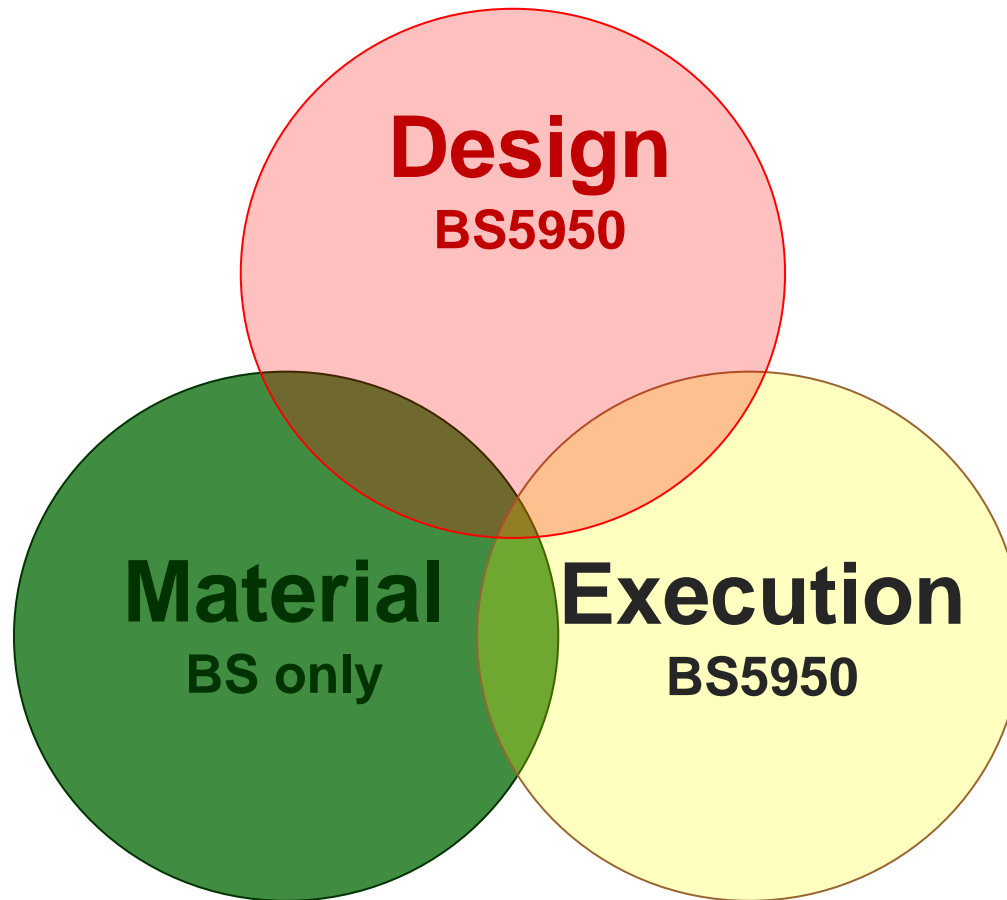
Use of Chinese *Guobiao* Steel in Singapore



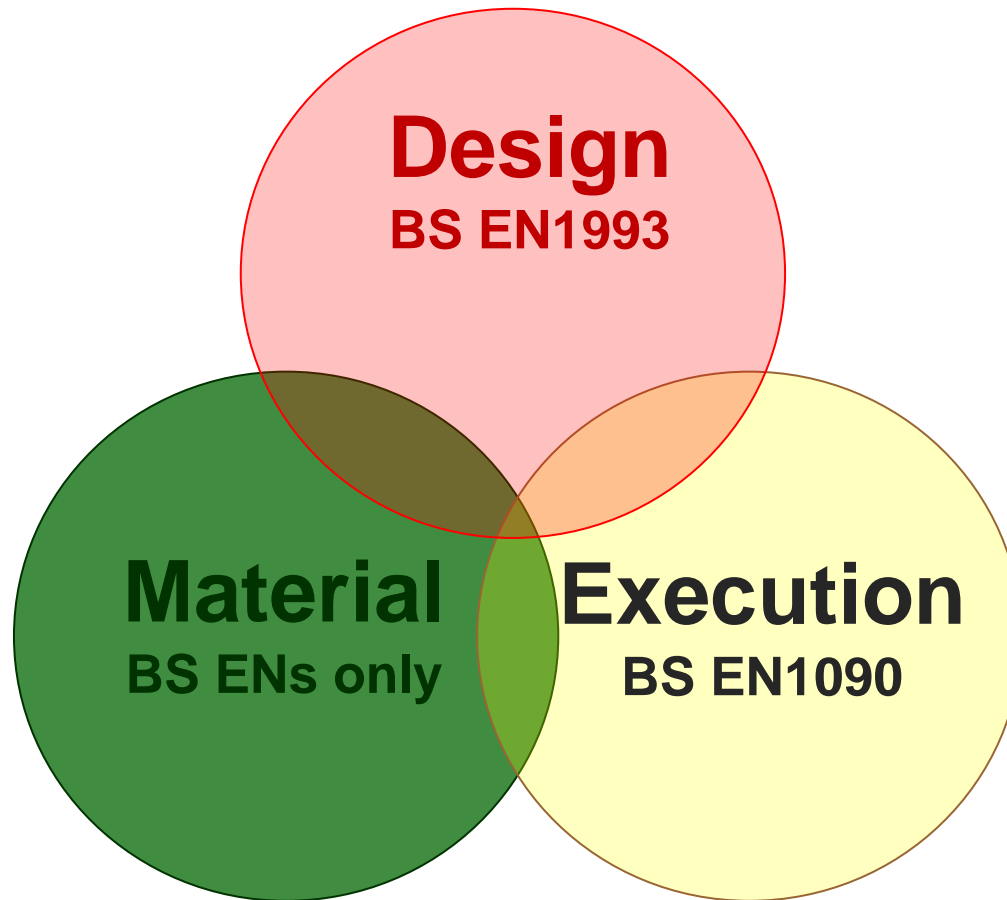
Scope of Presentation

1. Why Material Selection is important ?
2. Steel Construction in Singapore
3. Why BC1: 2008 & 2012 ?
 - Overall framework
 - Consistent quality assurance
 - Interface to bridge material and design

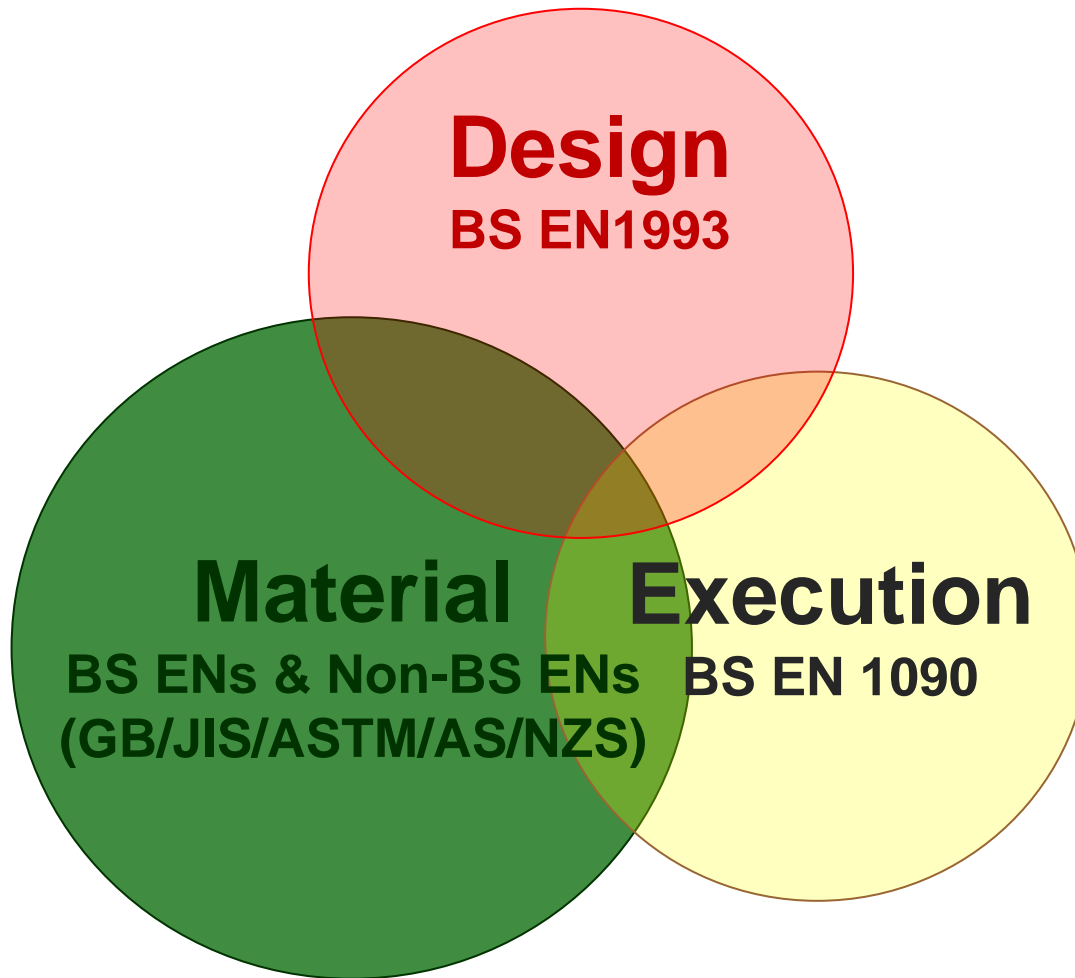
Steel Construction in Singapore



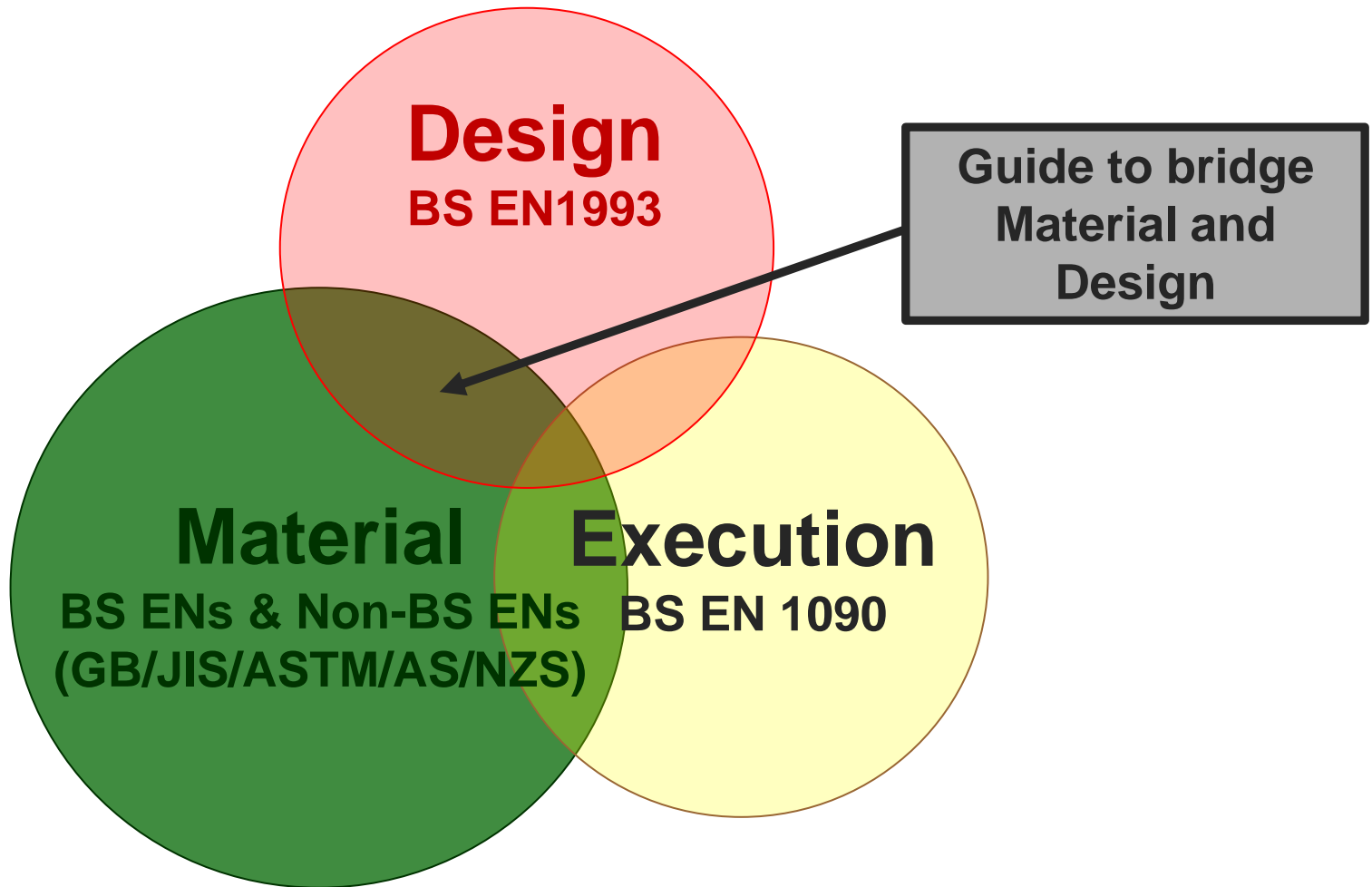
Steel Construction in Singapore (from 1 April 2015)



Uniquely Singapore !



Uniquely Singapore!



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 \Rightarrow 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 \approx 1.3M Tonnes

TOTAL REINFORCING STEEL \approx 1.5M Tonnes

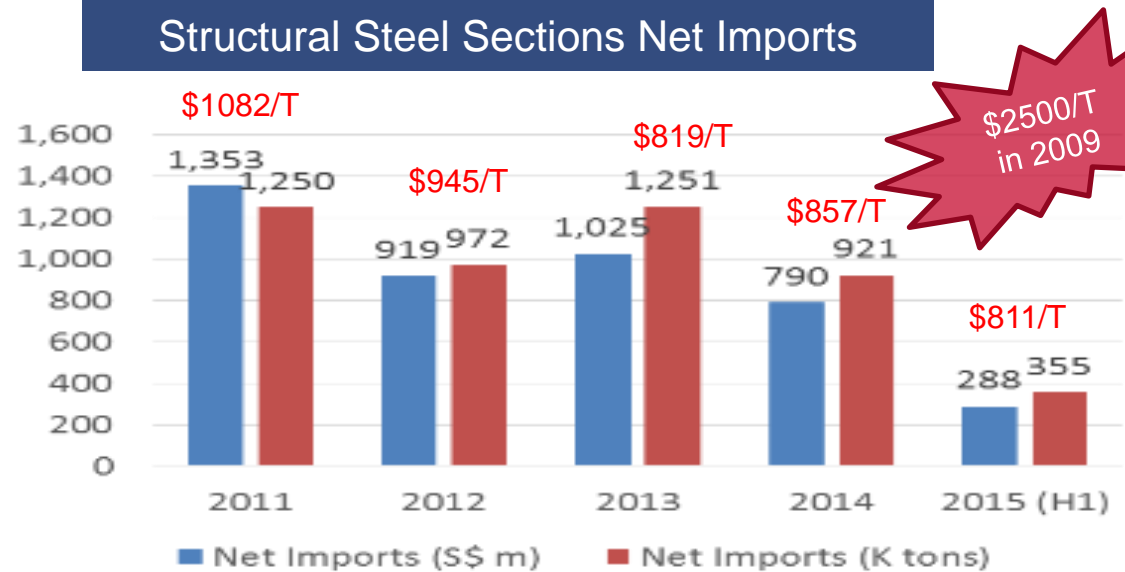
Import of Fabricated Steelwork (2013)

- 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**

To promote Steel Construction...

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

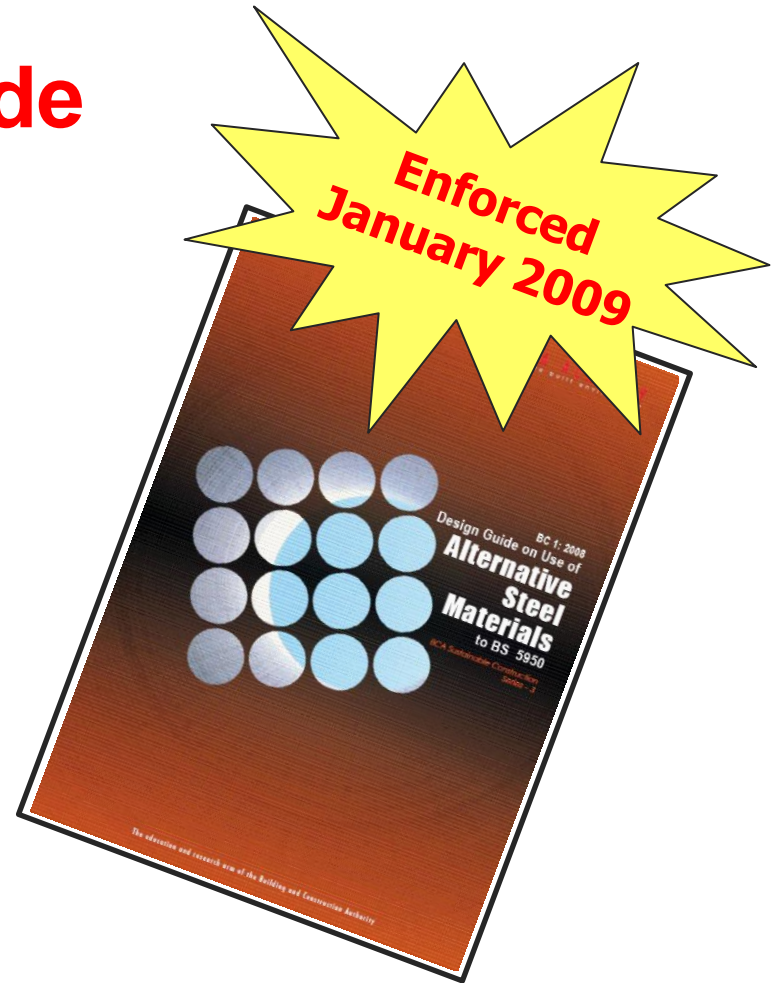
Grand Challenge – Balance Performance !



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)



http://www.bca.gov.sg/Publications/others/Design_Guide_on_use_of_Structural_Steel.pdf
http://www.bca.gov.sg/Publications/others/Explanatory_Notes_for_BC1-2008.pdf

Material Selection & Compliance

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)



Material Selection & Compliance

Selection of Equivalent Steel Materials – Hong Kong & Macau

(Industrial Guide for Best Construction Practice in Hong Kong and Macau)



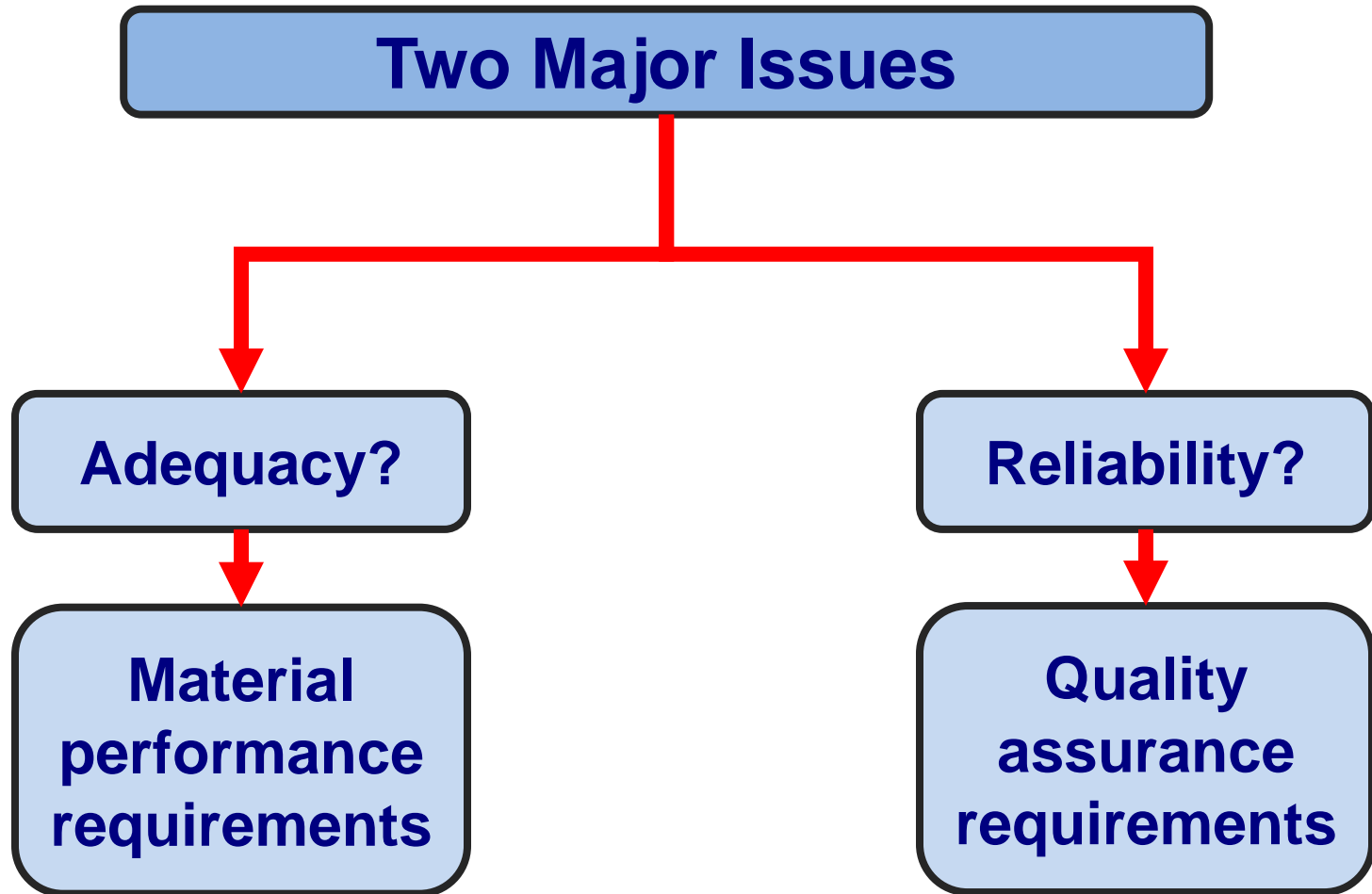
BC 1 - Objectives

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

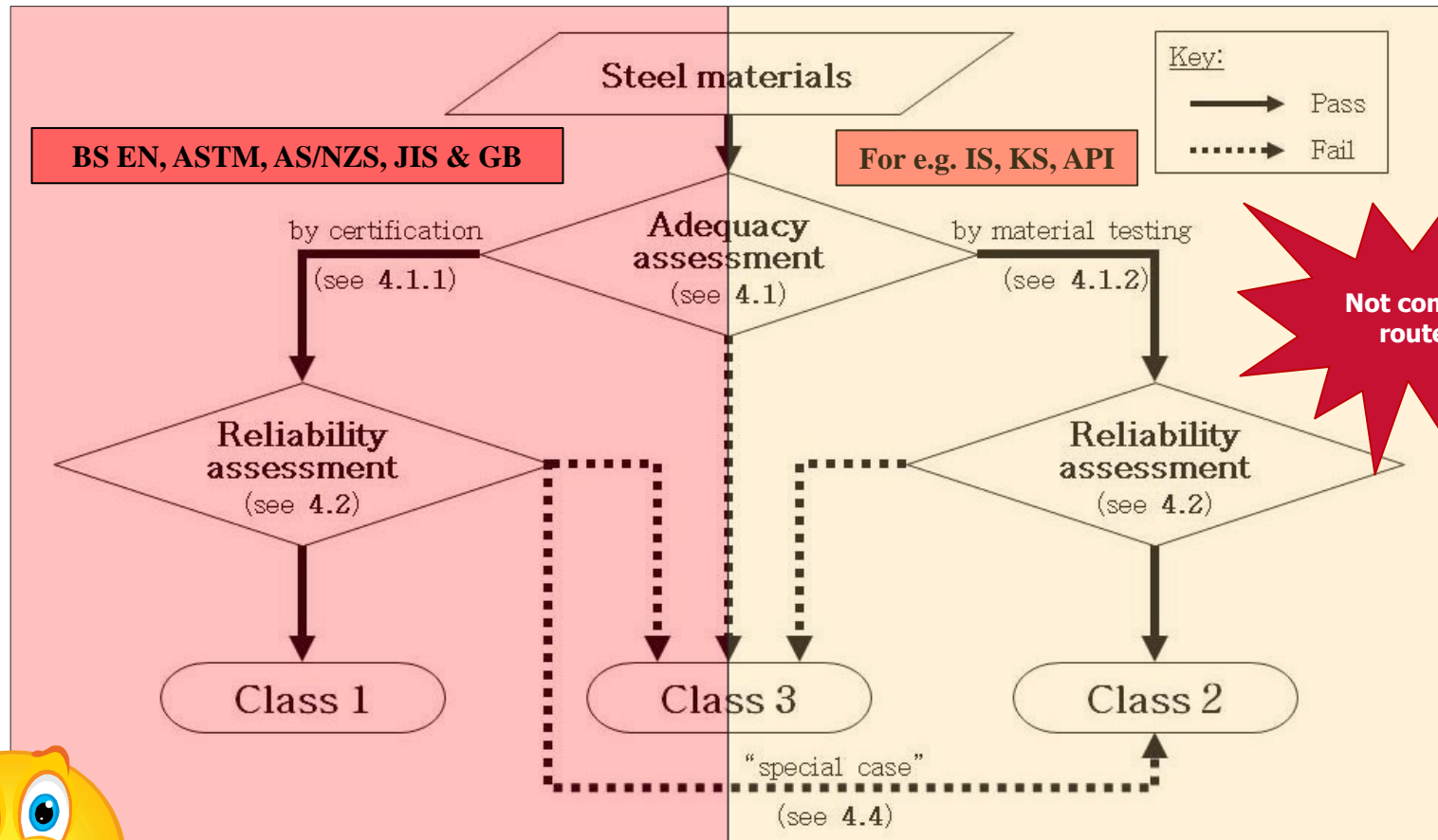
Deliverables:

- 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



BC 1 – Overall Framework



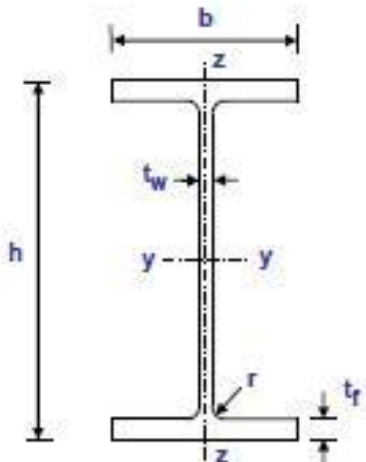
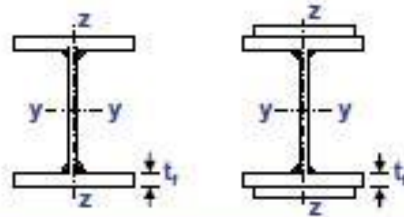
Eurocodes Material Requirements

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

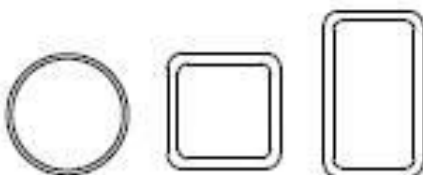
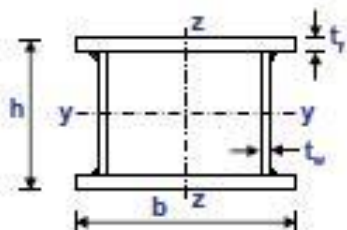
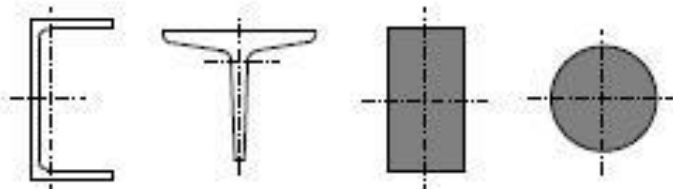
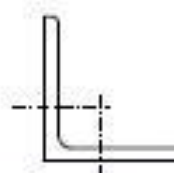
	Reinforcing Steel			Structural Steel	
	A	B	C	Normal strength	High strength
Yield strength (MPa)	400 to 600			≤ 460	> 460 ≤ 700
Modulus of elasticity (GPa)	200			210	
f_t/f_y or f_u/f_y	≥ 1.05	≥ 1.08	≥ 1.15 < 1.35	≥ 1.10	≥ 1.05 ≥ 1.10 (NA)
Elongation (%)	≥ 2.5	≥ 5.0	≥ 7.5	≥ 15	≥ 10
Ultimate strain				$\epsilon_u \geq 15\epsilon_y$	

Current Design Issues and Bridging the gaps with BC1

Column Buckling Curves in EC3

Cross-section		Limits		Buckling about axis	Buckling curve	
					S235 S275 S355 S420	S460
Rolled I-sections		$h/b > 1.2$	$t_f \leq 40 \text{ mm}$	y - y z - z	a b	a_0 a_0
			$40 \text{ mm} < t_f \leq 100 \text{ mm}$	y - y z - z	b c	a a
		$h/b \leq 1.2$	$t_f \leq 100 \text{ mm}$	y - y z - z	b c	a a
			$t_f > 100 \text{ mm}$	y - y z - z	d d	c c
Welded I-sections		$t_f \leq 40 \text{ mm}$		y - y z - z	b c	b c
		$t_f > 40 \text{ mm}$		y - y z - z	c d	c d

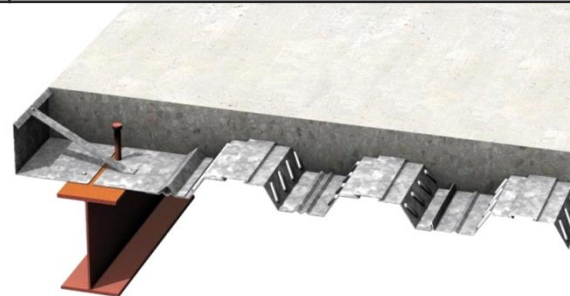
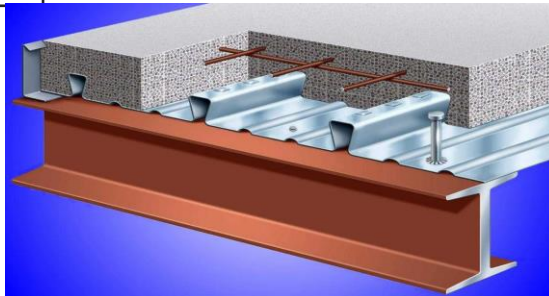
Column Buckling Curves in EC3

Hollow sections		hot finished	any	a	a_0
		cold formed	any	c	c
Welded box sections		generally (except as below)	any	b	b
		thick welds: $a > 0.5t_f$ $b/t_f < 30$ $h/t_w < 30$	any	c	c
U-, T- and solid sections			any	c	c
L-sections			any	b	b

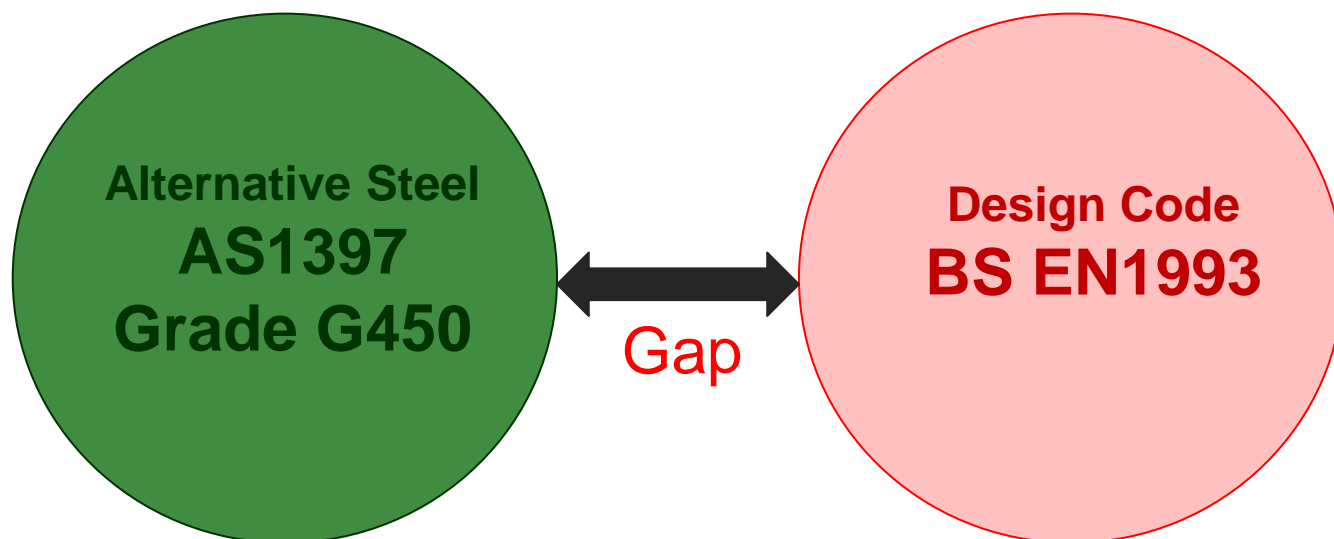
Issue 1 - Profile Steel Sheeting

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.

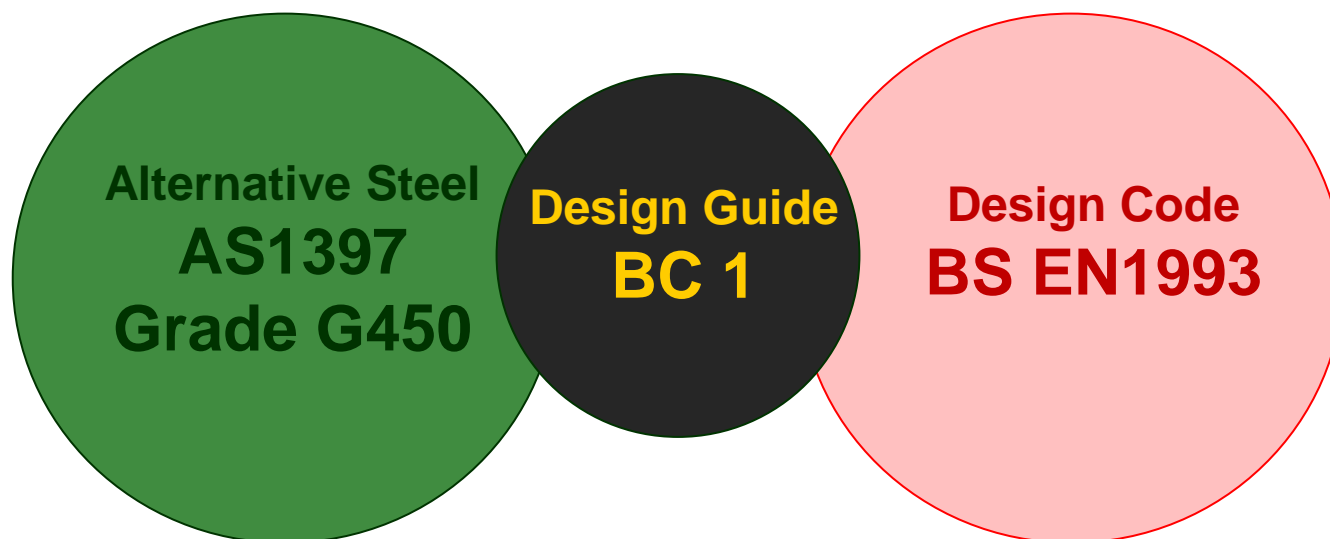
Standard	Grade	Nominal yield strength (MPa)	Nominal tensile strength (MPa)	Strength ratio
AS 1397	G450	450	480	1.07
	G500	500	520	1.04
	G550	550	550	1.00
AS 1595	CA 500	500	510	1.02
EN 10149	S 550MC	550	600	1.09
	S 600MC	600	650	1.08
	S 650MC	650	700	1.08
	S 700MC	700	750	1.07
EN 10326	S550GD	550	560	1.02
ISO 4997	CH550	550	550	1.00



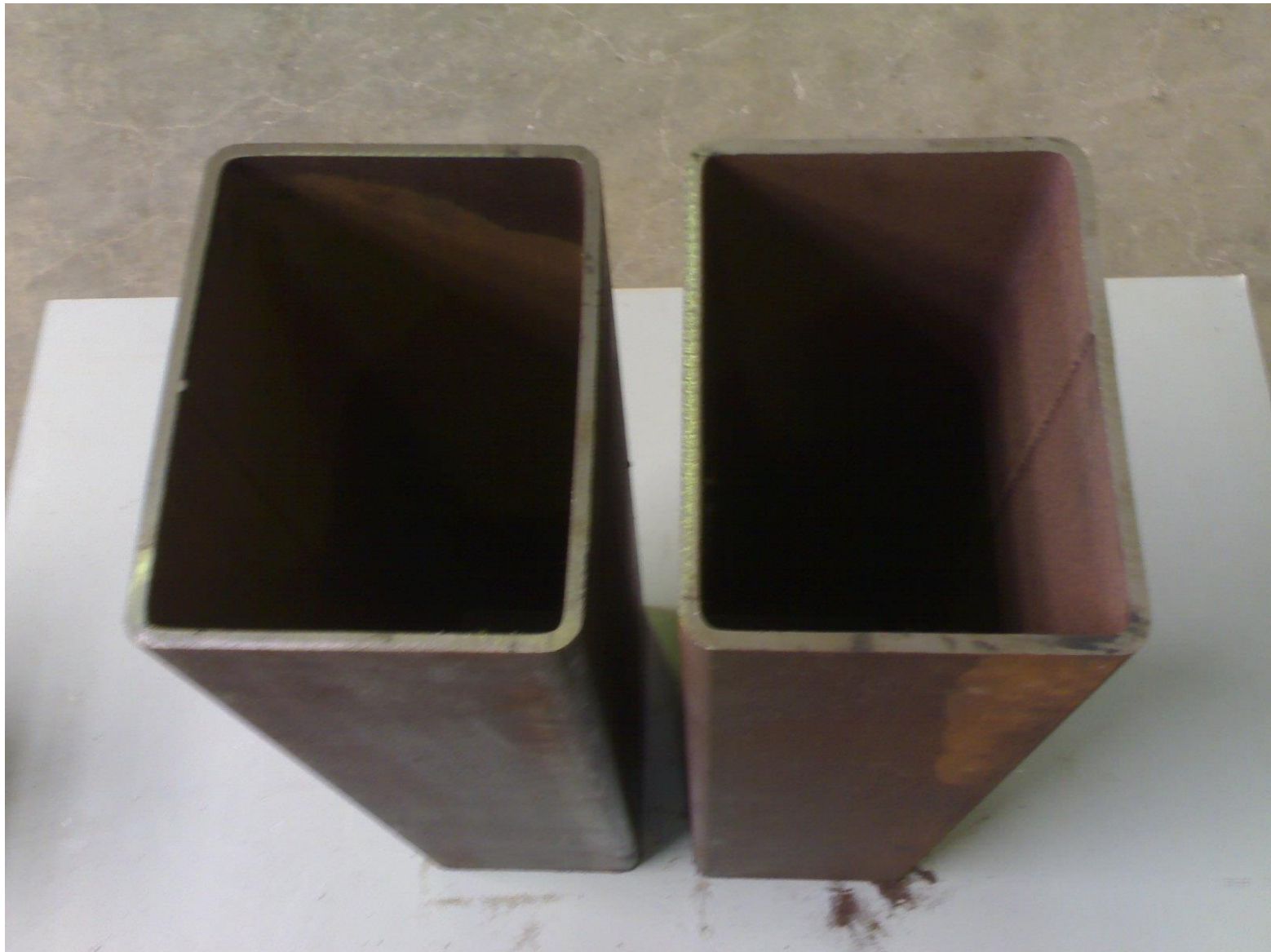
Bridging the Gap...



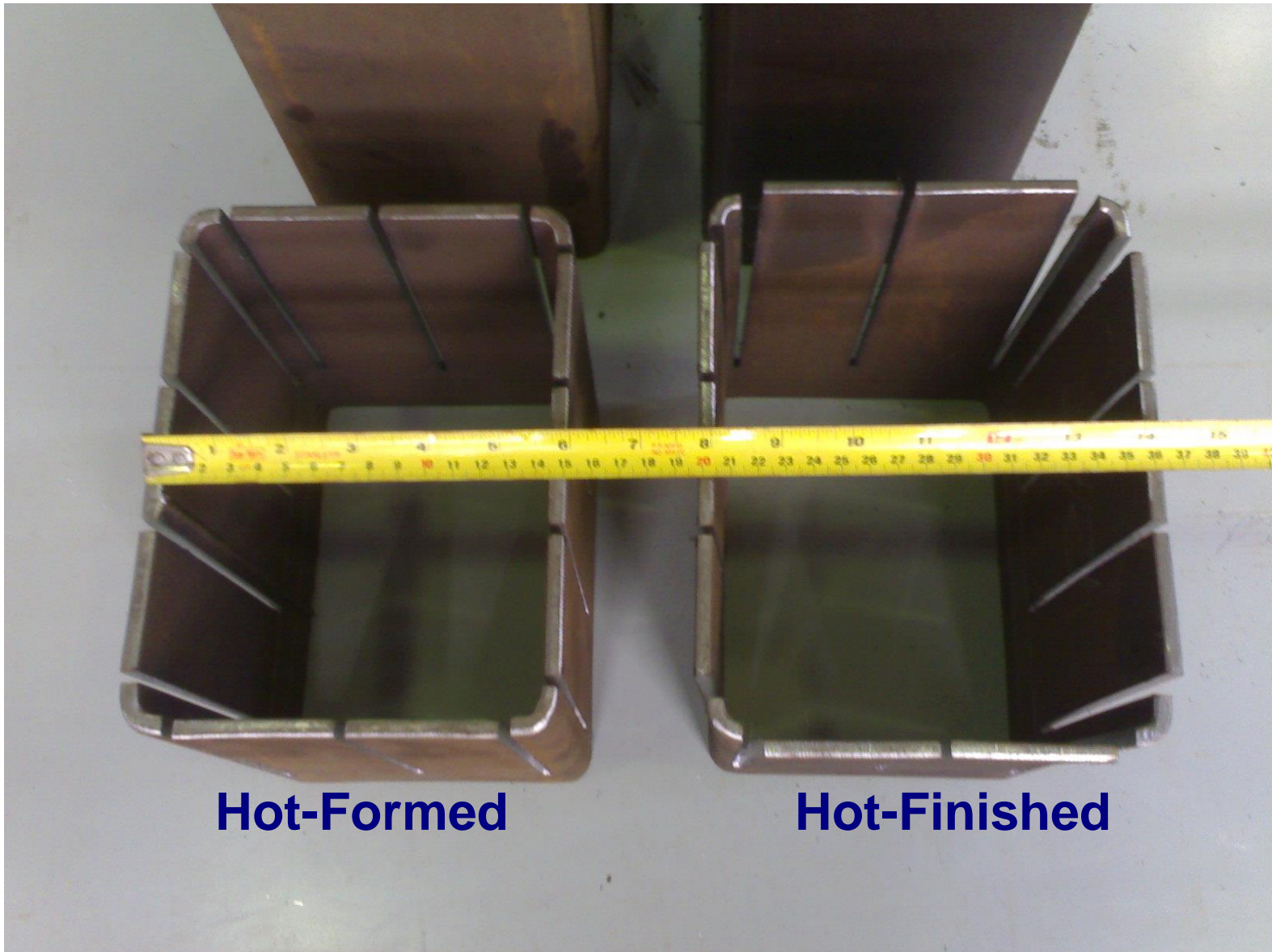
Bridging the Gap...



Issue 2 – Hot Finished Hollow Section



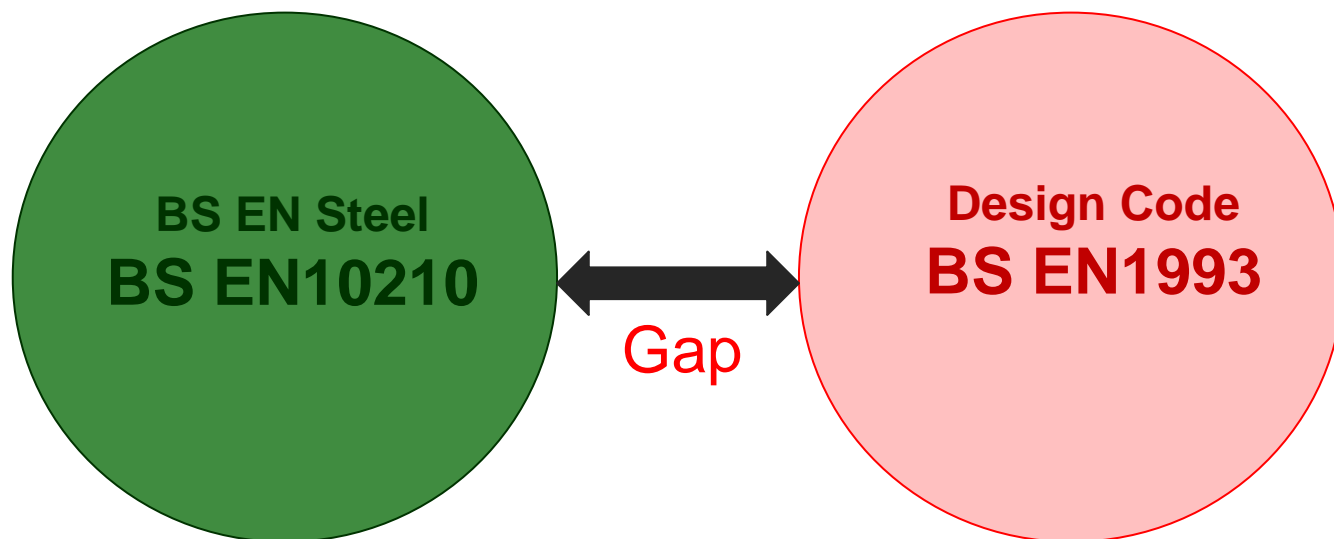
Hot-Finished \neq Hot-Formed !!



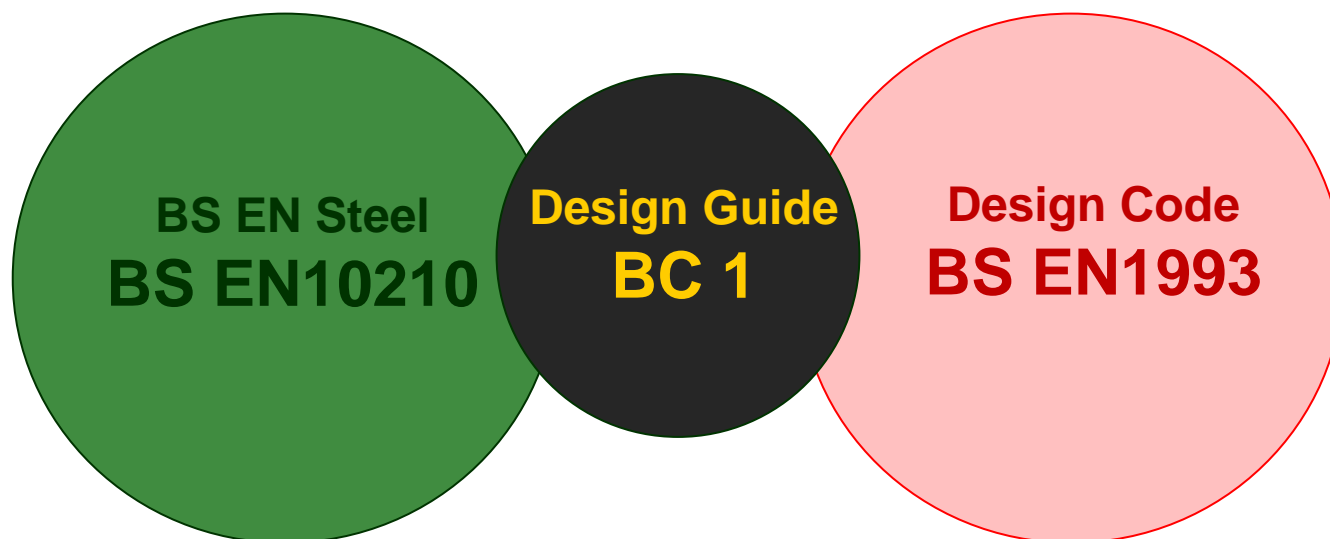
Hot-Formed

Hot-Finished

Bridging the Gap...



Bridging the Gap...



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 !

