EUROCODES IN A WORLDWIDE PERSPECTIVE
DESIGN CODES

A necessity for the highly complex construction market
DESIGN CODES

A necessity especially for the highly complex international construction market
The Eads Bridge, St. Louis, Missouri
James B. Eads, Structural Engineer
Built 1867-1874
Milwaukee Art Museum
Santiago Calatrava, Architect

The museum and its “brise soleil”

Model of “brise soleil”
Bridge Structures and Systems

Viaduc de Millau

Sutong Bridge
Innovative Joining Techniques: How to Deal with Novel Approaches
What about New Types of Structures and Industries?
Great Structures
Works of Art

... but design codes did not exist for James Eads

... and Calatrava and Schlaich and Baker and others have stretched concepts and design and materials and codes to the limit
Engineers as Artists

• Great engineers are artists as well
• Eads, Roebling, Freyssinet, Arup, Robertson, Khan, Baker, Calatrava, Schlaich …
• … but most engineers need guidance through the complexity and time demands of their work …
SOME COMMENTS ON THE MATERIALS AND THEIR EVOLUTION
STEEL PRODUCTION WORLDWIDE

Projected to 2 Billion tonnes in 2017

2007 1,347 million metric tons
STEEL TYPES AND PROPERTIES

• Basic mild steels:
  AISC: A36 (248 MPa) - EC3: S235

• Basic high-strength steels:
  AISC: A572, A913 (four grades, including 345 MPa), A992 (345 MPa), A588, A852 – EC3: S355, S420, S460

• Quenched and tempered plate steels:
  A514 - S690 (and S960?)

• Quenched and self-tempered steels
• Yield stress is the key parameter for strength design criteria
• Ultimate tensile strength governs many joint design requirements
• Yield-to-ultimate ratio is very important:
  - AISC: required for A992: ratio ≤ 0.85
  - EC3: required for all steels: ≤ 0.91
    (actually $f_u / f_y \geq 1.10$)
STEEL TYPES - CONTINUED

• For EC3 and AISC: elongation at rupture $\geq 15$ percent is satisfied by all steels
• Yield plateau at least 15 times yield strain
• Some interesting points:
  - EC3 yield-to-tensile ratio $\leq 0.91 (= 1/1.10)$ is quite lenient
  - Older Norwegian code required ratio $\leq 0.83 (= 1/1.20)$ for all steels. Is this possible?
• Note: The value of E is 210 GPa in EC3 – it is 200 GPa in the AISC code
STEEL TYPES AND PROPERTIES

- Some characteristics of contemporary steels:
  - Low carbon content (less than 0.1 %)
  - Higher strength achieved through alloys
  - High ductility and fracture toughness
  - High weldability
  - High corrosion resistance
- Through-thickness properties?
- Lamellar tearing and laminations?
- Many steel products produced by EAF-s and continuous casting processes
- High performance steel grades for buildings and bridges
DESIGN CODES

A necessity especially for the highly complex international construction market
SOME PROMINENT CODE GROUPS

- Eurocodes
- British standards important for many Commonwealth countries
- North American codes (AISC, AISI, CSA, Mexico)
- Japan Standards
- China and Hong Kong Standards
- Australia/New Zealand codes
- Many individual country standards
As a brief illustration, some comparisons will focus on the current AISC steel design code (limit states (LRFD) criteria only) and Eurocode 3
Overall View of Code Contents

RESISTANCE

- Limit states design universally accepted
- Basic reliability approaches
- Basic design criteria
- Nominal strength expressions
- Member and connection criteria
- Overall structure criteria, including stability
Overall View of Code Contents

SERVICEABILITY

- Deflections and similar criteria
- Drift (sway) considerations
- Wind-induced motion of structures
- Structural vibrations
- Expansion and contraction
- Connection slip
- Required or suggested?
RELIABILITY MANAGEMENT

- Significant differences between Eurocode and AISC
- EC: Consequences Classes 1-3, Reliability Classes 1-3, Design Supervision Levels 1-3
- Class levels 2 are normal and comparable to AISC requirements
- AISC criteria do not address class levels, and probably never will
BASIC DESIGN CRITERIA

- North America (LRFD)
  \[ \sum \gamma_i Q_i \leq \varphi R_n \]

- Eurocode (Partial Safety Factor Design)
  \[ E_d < R_d = R_k / Y_M \]
SOME DESIGNATIONS

- AISC
  - load factors $\gamma_i$ - loads $Q_i$ - load factors vary as a function of load type, load combinations, etc.

- EC
  - partial factors $\gamma$ - effect of actions $E_d$ - design resistance $R_d$ – characteristic value $R_k$
CODE COVERAGE - EC

- EC3 for buildings: 12 sections, including:
  - general rules for buildings, structural fire design, cold-formed steel, joints, fatigue, fracture, selection of steel, steel properties
- EC3 has 8 additional sections, for bridges, tanks, cranes, etc.
- EC4 for composite structures
- EC8 for seismic design
- EC1 for actions (loads etc.)
CODE COVERAGE - AISC

• AISC: 13 chapters and 7 appendices, including:
  - Hot-rolled shapes and plates and tubes (HSS)
  - Buildings and building-like structures
  - Composite construction
• Separate AISC seismic design code
• Cold-formed steel in separate code (AISI)
• Bridge design code by AASHTO
• Various other codes for pre-engineered buildings (MBMA), rack structures (RMI), mill buildings (AISE)
• Building loads by ASCE 7 – bridge loads by AASHTO
Comments on Code Coverage

• EC3 is very detailed and very broad, covering a large range and types of structures
• AISC is focused on buildings and building-like structures only
• Some subjects of EC3 are covered by separate codes in the US (e.g. cold-formed steel) and vice versa for EC3 (composite structures)
• Primary technical subject matters are treated very similarly
SAMPLE COMPARISON:
Column Criteria of EC3 and AISC
AISC SINGLE COLUMN CURVE
Resistance Factor $\varphi = 0.9$

$$F_{cr} = (0.658) \frac{F_y}{F_e} F_y$$

$$F_{cr} = 0.877 F_e$$

$F_{cr}$

Inelastic

Elastic

4.71 $\sqrt{\frac{E}{F_y}}$

$\frac{KL}{r}$
EUROCODE COLUMN CURVES

- Non-dimensional slenderness $\bar{\lambda}$
- Reduction factor $\chi$

Curves labeled a₀, a, b, c, d
AISC and Eurocode Curves
Column Criteria Assessment

- Both sets of criteria are accurate and technically correct
- EC 3 offers much more detailed provisions, through multiple curves
- Reliability levels are comparable for the types of shapes and steel materials
- Traditional selection of column shapes and slenderness differ (US columns are typically heavier than European choices)
- AISC is significantly less complex
EUROCODES IN A WORLDWIDE PERSPECTIVE
EUROCODES

• The largest, longest-lasting and most complex code development effort in the world
• Including National Annexes, the Eurocodes are now being adopted in the countries of the European Union
• Some non-EU countries are also adopting the Eurocodes
• What about the rest of the world?
The Rest of the World

- North America
- South America
- Asia
- Australia and New Zealand
- Middle East
- Africa
- … and non-EU Europe …
BJORHOVDE
“PREDICTIONS”
North America

• United States: extensive family of codes (e.g. first AISC code in 1923)
• Will USA adopt the Eurocodes: No
• Canada: extensive family of codes (CSA), very similar to the US
• Will Canada adopt the Eurocodes: No
• Mexico: extensive family of codes, heavily based on US format
• Will Mexico adopt the Eurocodes: No
South America

- **West Coast**: Chile, Peru, Ecuador, Colombia: history of usage and very similar high-seismic conditions have produced US-based codes
- Will these countries adopt Eurocode: No
- **Brazil**: has adopted a version of EC2. Previous steel code was heavily US-based – current steel code is a strange mix, but mostly US. Most Brazilian steel designers use AISC
- Will Brazil adopt Eurocode 3: *Qui sabe?*
- **Argentina**: long history of European immigration, etc. Design has been a mix of US and European practice. The current CIRSOC code is US-based
- Will Argentina adopt Eurocode 3: No
Asia

- **China**: extensive family of codes
- Will China adopt the Eurocodes: No
- **Hong Kong**: excellent advanced steel code (2005). Will not adopt Eurocodes.
- **Japan**: extensive family of codes (JIS), heavily seismic-oriented
- Will Japan adopt the Eurocodes: No
- **Korea**: extensive family of codes
- Will Korea adopt the Eurocodes: No
- **Singapore and Malaysia**: strongly influenced by British practice, have committed to adopt Eurocodes, exact timing is not known (2013?)
- **Indonesia**: nothing known
Australia and New Zealand

- **Australia**: extensive family of codes – the steel design code is very similar to US
- Will Australia adopt the Eurocodes: No
- **New Zealand**: extensive family of codes, most now published jointly with Australia
- Will New Zealand adopt the Eurocodes: In view of the close collaboration with Australia - No
Middle East

- Current (2010) usage is mostly US or pre-EC British codes in all Middle East countries
- For instance, Dubai allows any valid international code (*Burj Khalifa* was designed with AISC, ACI and the criteria of the US building code (IBC))
- It is too early to say whether Eurocodes will be used. The selection is often the choice of the client, sometimes based on the recommendation of the designers
- Abu Dhabi has adopted the US building code (IBC)
Africa

- **South Africa**: extensive family of codes, but adopted the Canadian steel design code in late 1980-s
- SA may adopt the Eurocodes, once the British are fully committed
- SA is adopting the Australian cold-formed code (which is heavily based on the US CF (AISI) code)
- Other African countries mostly follow the older British, French or SA codes
What about Russia and India?

- **Russia**: extensive family of codes
- Will Russia adopt the Eurocodes: as far as RBj knows, no official comments have been made, but adoption is highly doubtful
- **India**: traditionally British standards oriented, but current designers use what individual clients demand
- Will India adopt the Eurocodes?
A Few Final Comments

- Eurocode procedures appear to be efficient and all-encompassing.
- Very complex operations due to many countries and languages.
- What is the status of Eurocode "Commentaries"?
- Very important: How will code maintenance be handled and paid for?
SUMMARY

• Current international steel design codes are primarily limit states based
• Reliability approaches and management vary somewhat, but basic principles are the same
• Treatment of strength criteria are the same, for all practical purposes
• Treatment of serviceability varies
SUMMARY - CONTINUED

• Some codes offer very accurate, very detailed criteria
• Code complexity can be a significant issue
• Code acceptance by design engineers can be slow, especially in high activity market conditions
• Economics of construction continues to be a major question
CONCLUSION:

Although codes vary, their focus is always on safe, serviceable and economical structures.
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- Tashakor
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- Dortse
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- Kamsahamnide
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