# EUROCODES IN A WORLDWIDE PERSPECTIVE

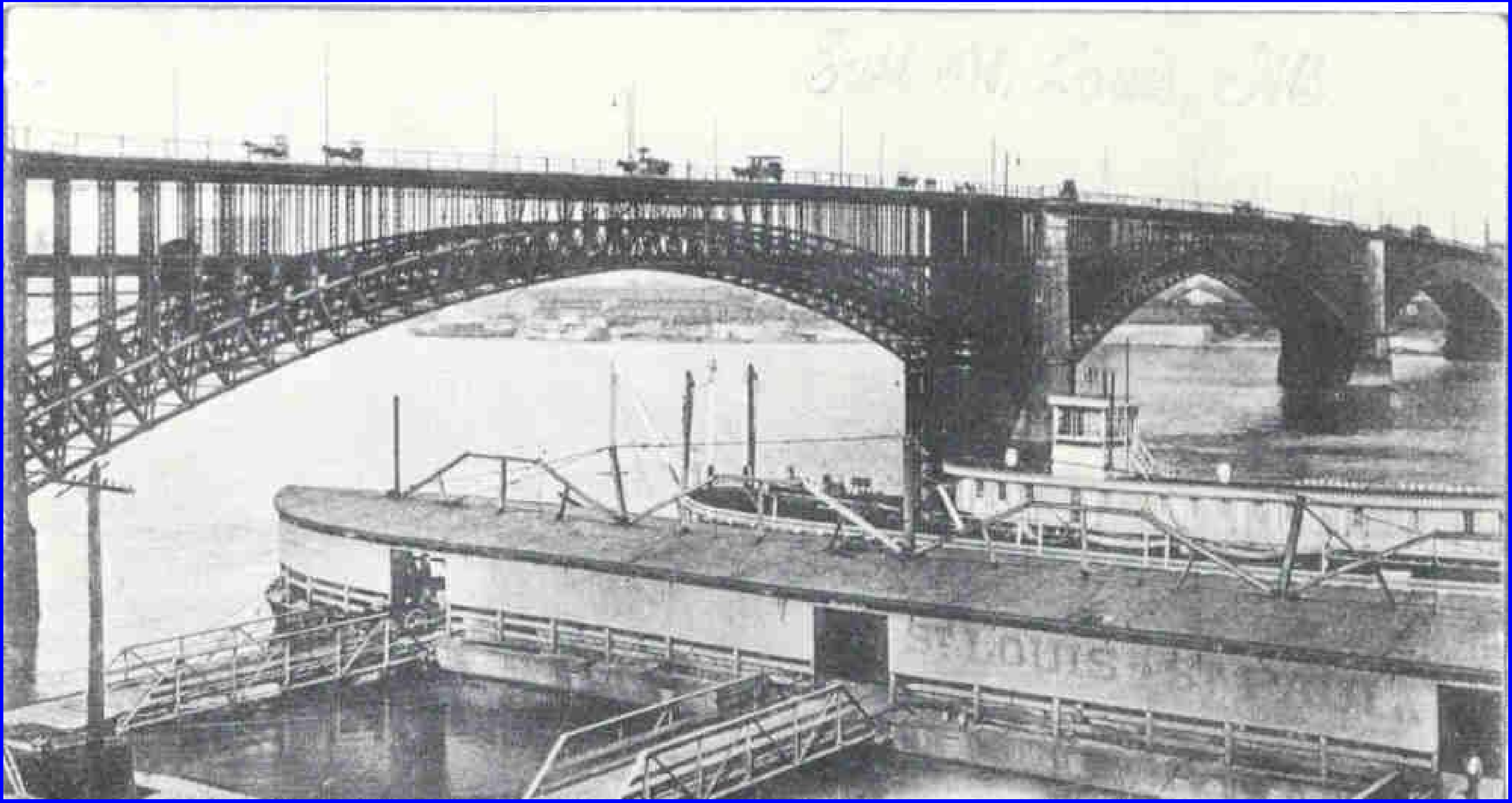
# DESIGN CODES

## A necessity for the highly complex construction market

# DESIGN CODES

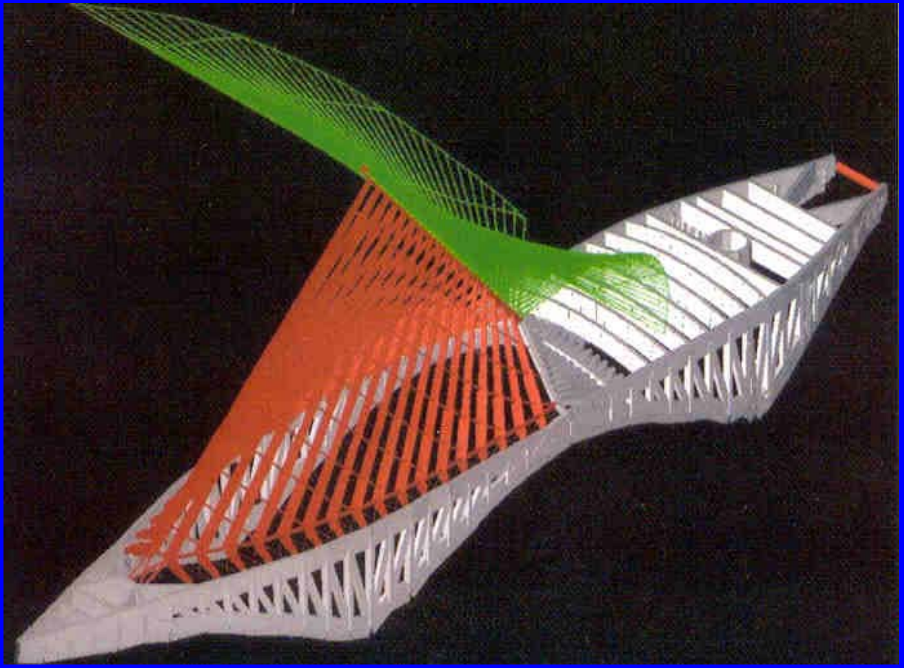
**A necessity especially for the highly complex international construction market**

# 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"



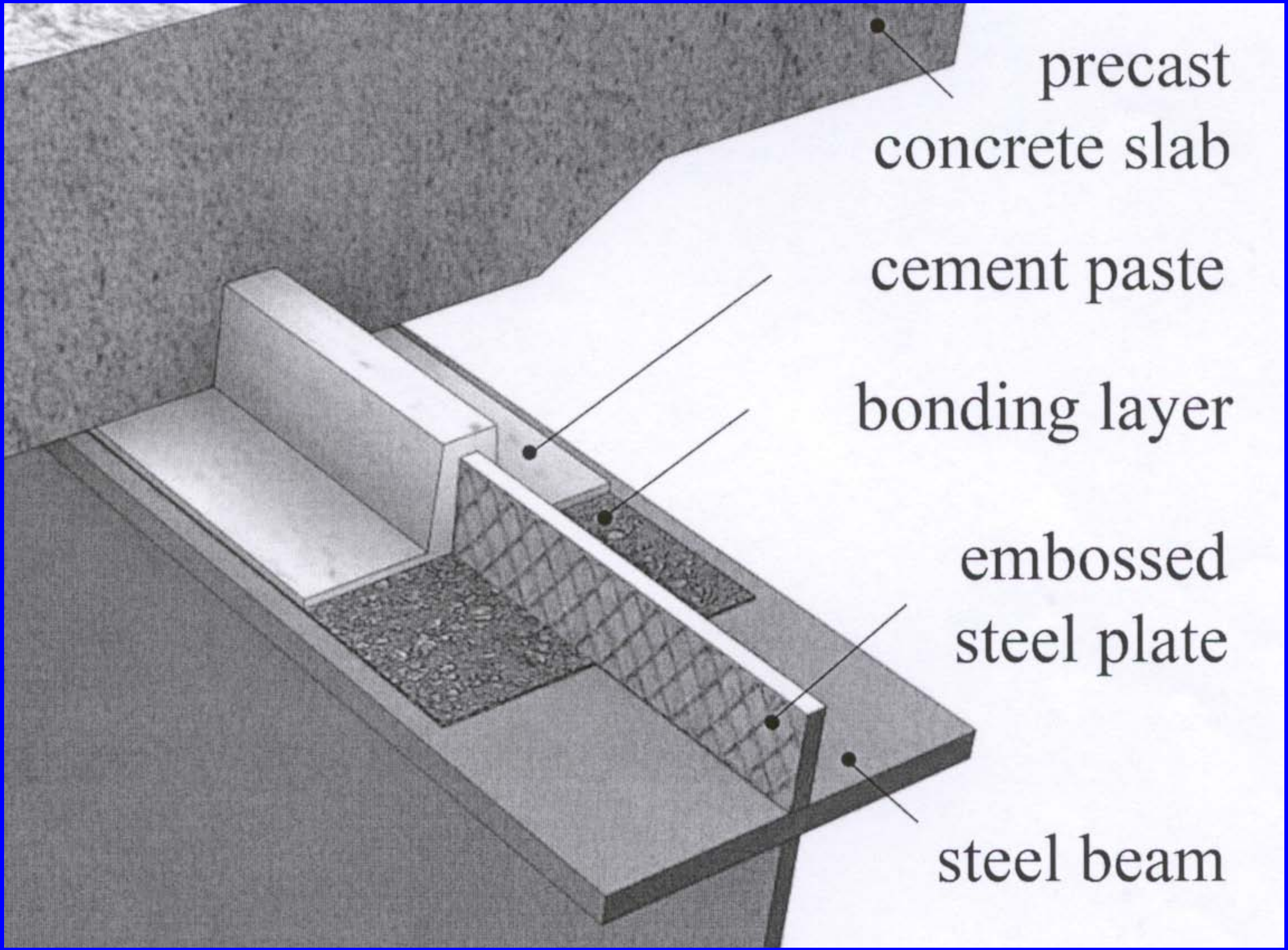
Model of "brise soleil"

# Bridge Structures and Systems

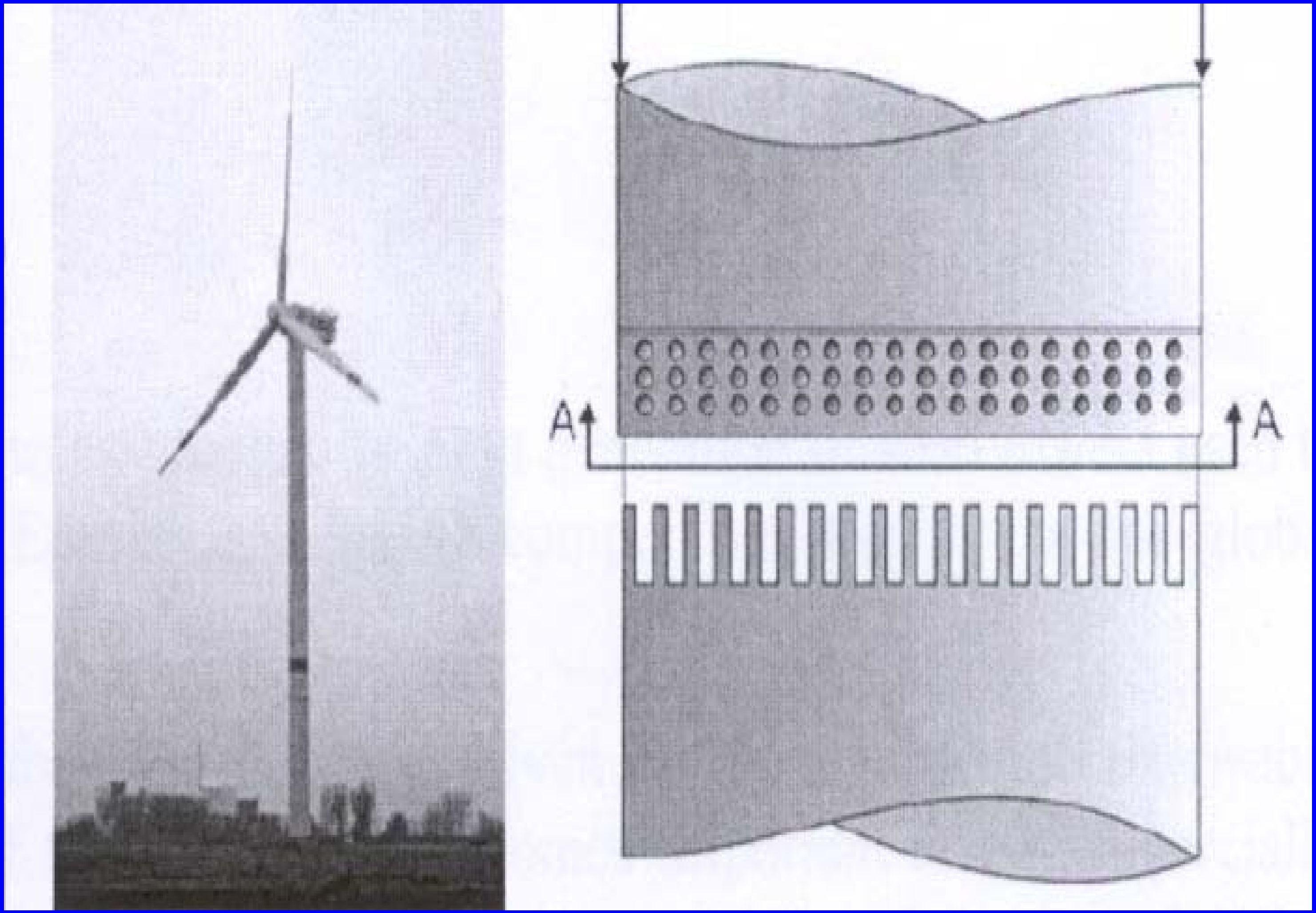
Viaduc de Millau

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**

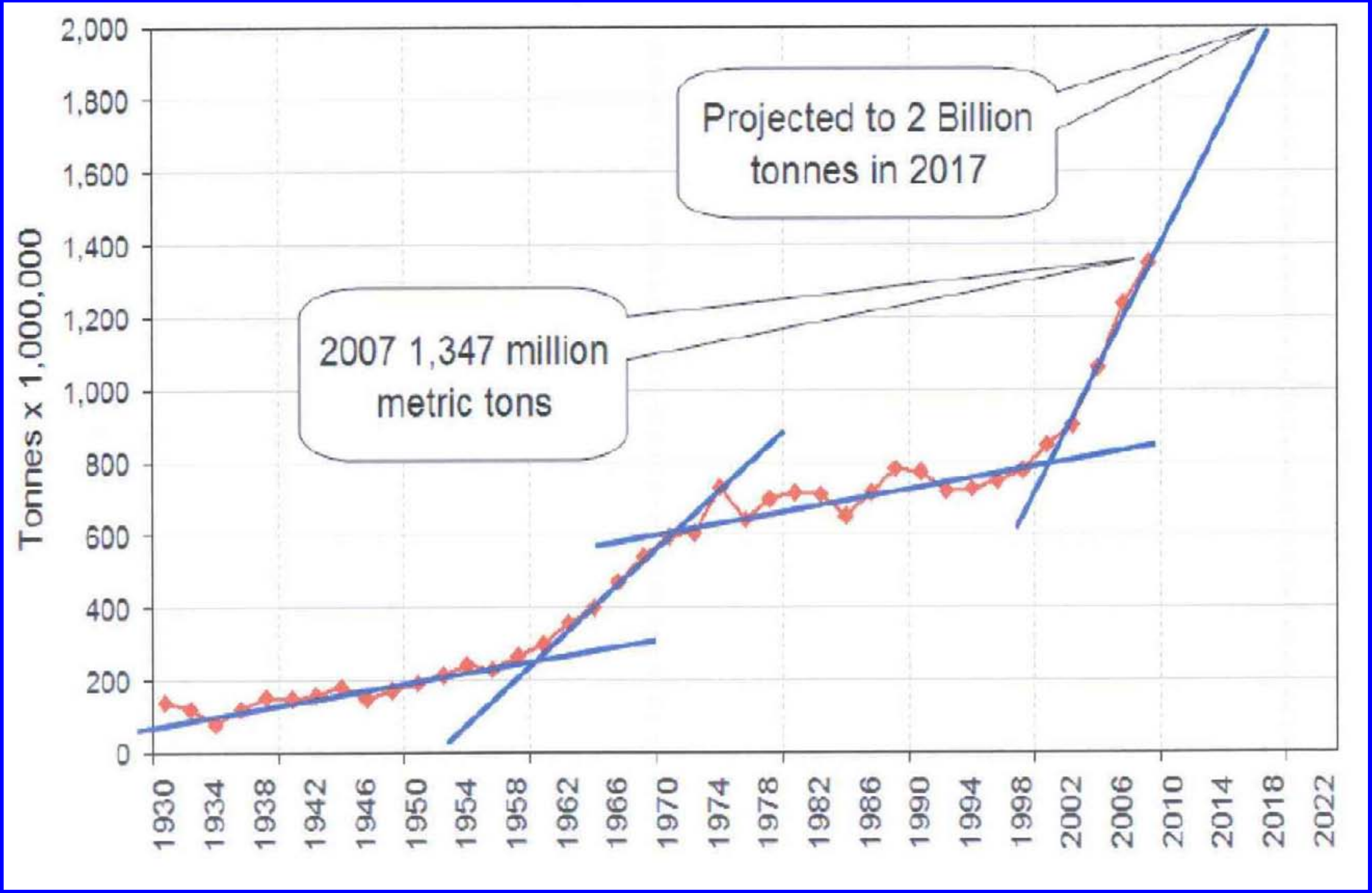
**… and Calatrava and Schlaich and Baker and others have stretched concepts and design and materials and codes to the limit**

# 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



# 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**

# STEEL TYPES - CONTINUED

- 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 ≥ 15 percent is satisfied by all steels
- Yield plateau at least 15 times yield strain
- Some interesting points:

  - EC3 yield-to-tensile ratio ≤ 0.91 (= 1/1.10) is quite lenient

  - Older Norwegian code required ratio ≤ 0.83 (= 1/1.20) <u>for all steels</u>. Is this possible?
- <u>Note</u>: 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)**

  $$\Sigma \gamma_i Q_i \leq \varphi R_n$$

- **Eurocode (Partial Safety Factor Design)**

  $$E_d < R_d = R_k/\gamma_M$$

# 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

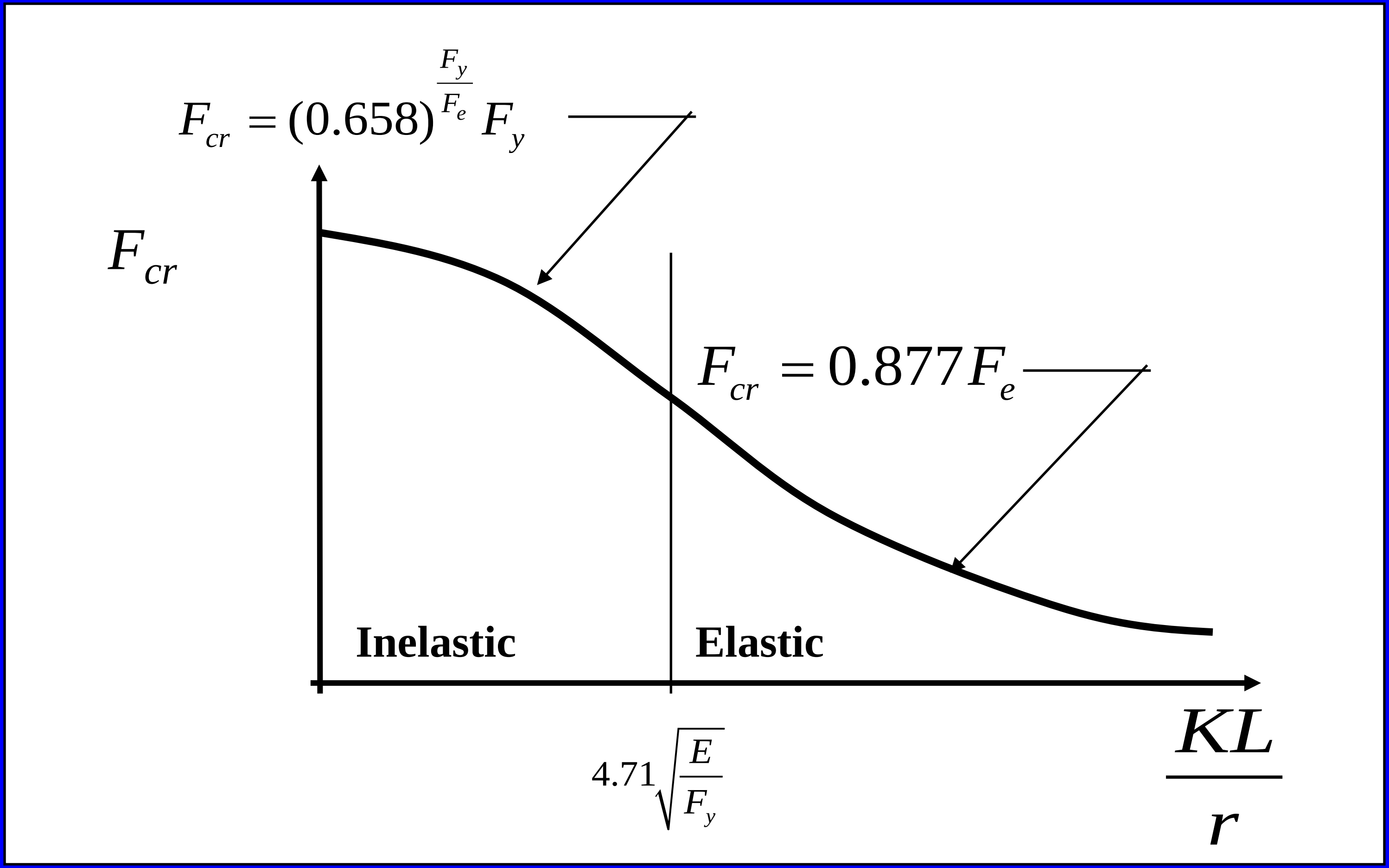
- EC3 is very detailed and very broad, covering a large range and types of structures
- AISC is focused on buildings and building-like structures <u>only</u>
- Some subjects of EC3 are covered by separate codes in the US (e.g. cold-formed steel) and vice versa for EC3 (composite structures)
- Primary technical subject matters are treated very similarly

# SAMPLE COMPARISON:

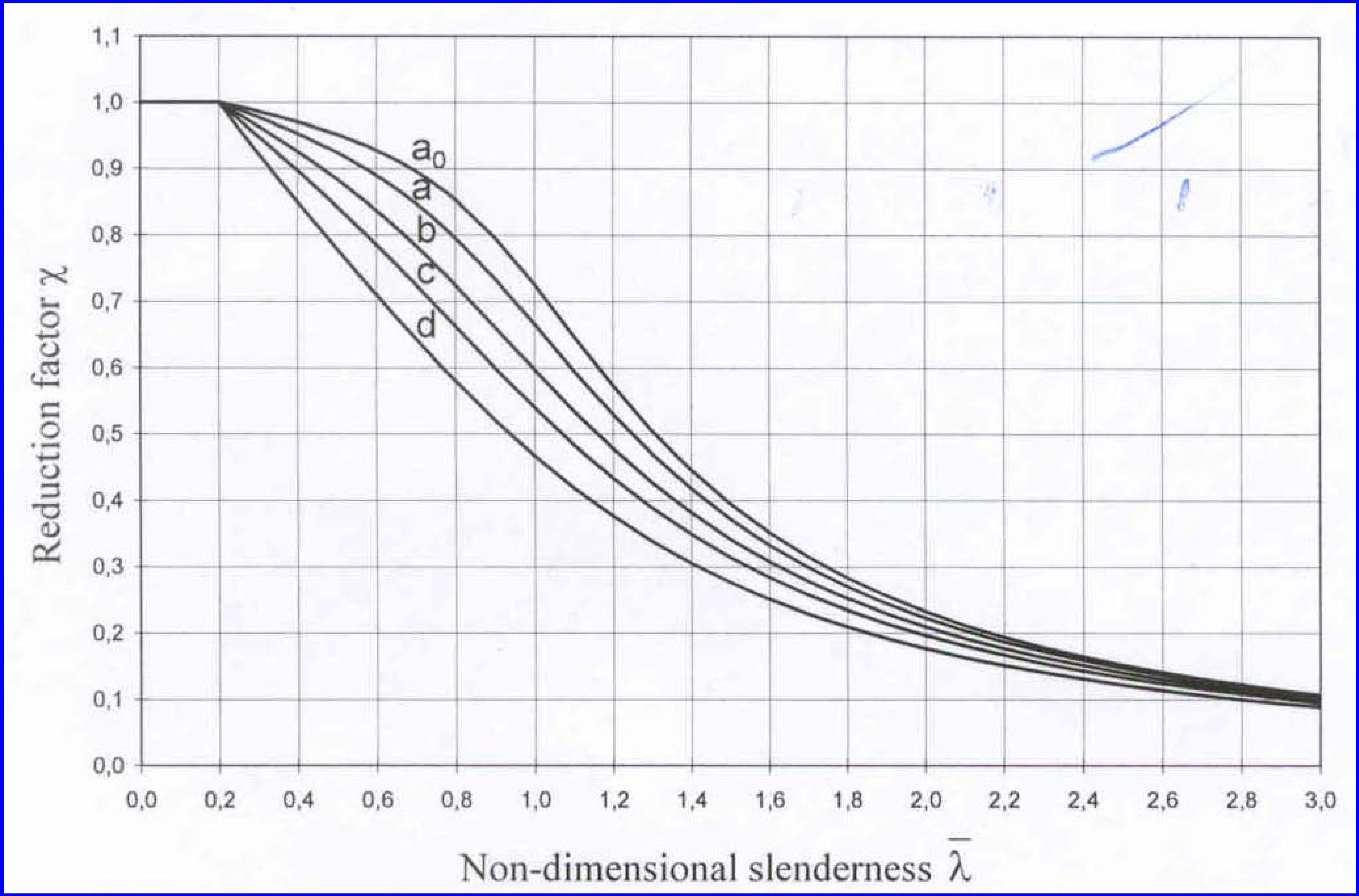
# Column Criteria of EC3 and AISC

# AISC SINGLE COLUMN CURVE

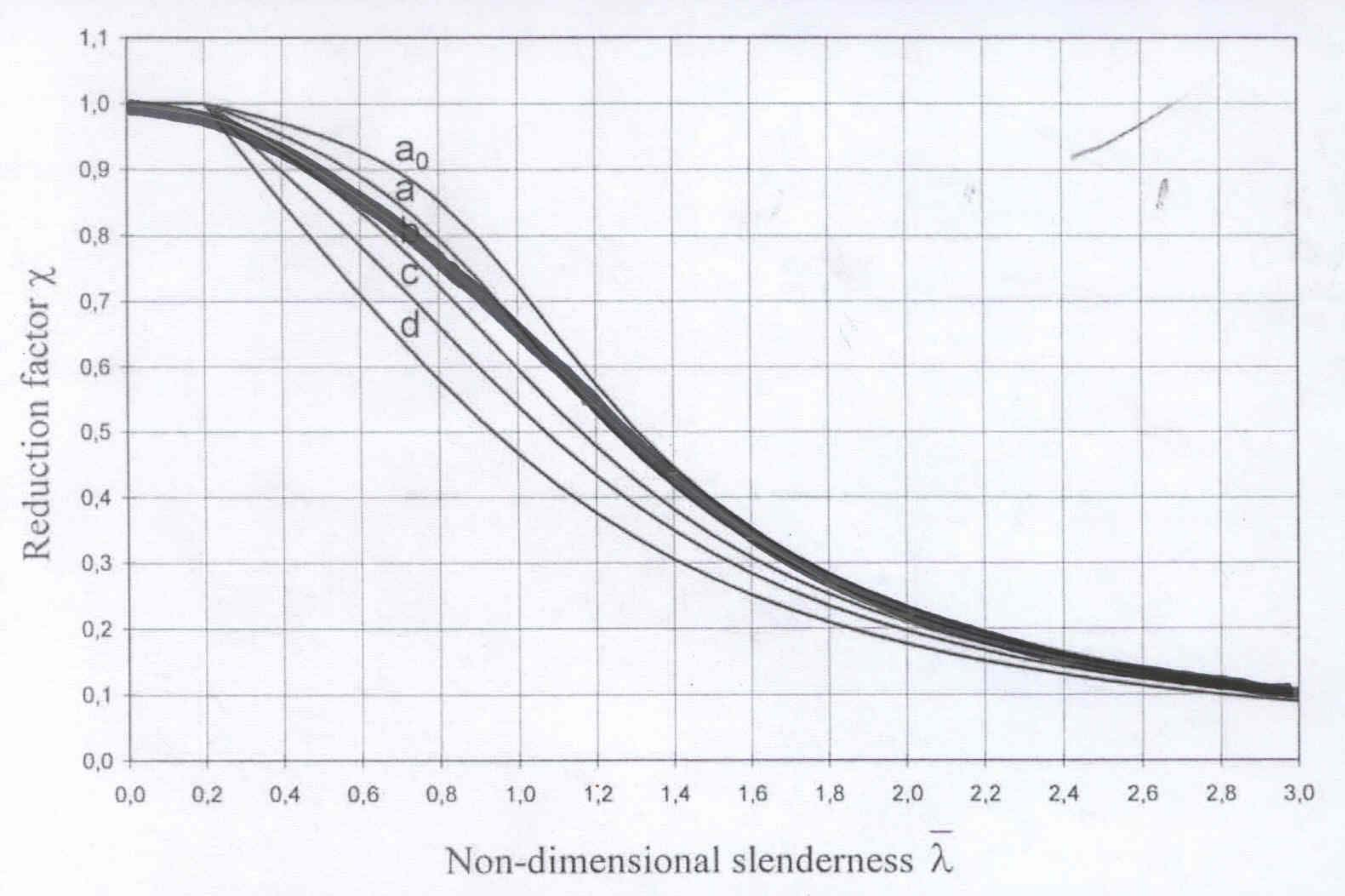
## Resistance Factor φ = 0.9



# EUROCODE COLUMN CURVES



# 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

- <u>West Coast</u>: Chile, Peru, Ecuador, Colombia: history of usage and very similar high-seismic conditions have produced US-based codes
- Will these countries adopt Eurocode: No
- <u>Brazil</u>: 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?*
- <u>Argentina</u>: 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**

# MANY THANKS!

- Gracias
- Danke
- Takk
- Þakka þér fyrir
- Qujanaq
- Dank U
- Dankie
- Obrigado
- Efkaristo
- Děkuji
- Dziękuję
- Köszönöm
- Mulțumesc
- Eskerrik asko

- Merci
- Grazie
- Tack
- Kiitos
- Giitu
- Tänan väga
- Aciu
- Spasibo
- Hvala lepo
- Faleminderit
- Tešekürler
- Tashakor

- Mahalo
- Arigato
- Xie xie
- Dortse
- Tou che chi
- Kamsahamnide
- Khopkun
- Terima kasih
- Salamat po
- Shukran
- Asante
- Ndiyabulela
- Ameseginalehu
- Yekenyeley

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