BS EN 1994-1-1 for composite structures of steel and concrete

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The ten Eurocodes

EN 1990	Basis of design	1 Part	2000
EN 1991	Actions	10 Parts	2000-03
EN 1992	Concrete structures	4 Parts	2002-04
EN 1993	Steel structures	20 Parts	2002-04
EN 1994	Composite structures	4 Parts	2002-04
EN 1995	Timber structures	3 Parts	2001-03
EN 1996	Masonry structures	5 Parts	2002-03
EN 1997	Geotechnical design	3 Parts	2002-03
EN 1998	Seismic design	6 Parts	2002-03
EN 1999	Aluminium alloy structures	3 Parts	2003

Eurocodes BS EN 1990 to 1999

To remove barriers to trade in construction works in the European Union

To harmonise design philosophy and methods:

- **across structural materials** (steel, concrete, masonry, timber, geotechnical, etc.)
- **across types of structure** (buildings, bridges, masts, chimneys, pipelines, foundations, etc)
- **across Europe**, from Iceland to Greece, and Latvia to Portugal

The scope of BS EN 1994-1-1, ‘Composite structures of steel and concrete’ includes:

- **steels** up to grade S460
- **concretes** up to grades C60/75 and LC60/66
- unbraced and braced **frames**, with simple, semi-rigid or rigid **joints**
- concrete-encased **columns** and concrete-filled tubes
- partially-encased **beams**

Scope of EN 1994 (continued)

- **box girders** and composite plates
- **trusses** with either or both chords composite
- bowstring arches and half-through bridges with the **deck in axial tension**
- **prestress** by external tendons or by jacking at supports
- resistance of buildings to **fire**, by three alternative methods

EN 1994-1-1 compared with BS 5950-3-1

In BS 5950, not in EC4:

- transverse reinforcement above beams (in EC2)
- slenderness limits for Classes 1 to 3 (in EC3)

Not in BS 5950 but in EC4:

- Effective width of concrete flanges
- Control of width of cracks in concrete
- Lateral torsional buckling of beams

Design compressive strength of concrete in flexure and compression

In EN 1992-1-1: $f_{\mathrm{cd}} = \alpha_{\mathrm{cc}} f_{ck} / \gamma_{\mathrm{C}}$

in its NA: $\alpha_{\mathrm{cc}} = 0.85$

In EN 1994-1-1: $f_{\mathrm{cd}} = f_{ck} / \gamma_{\mathrm{C}}$

and factor 0.85 appears in the formulae for resistances of beams and columns

Modular ratios

(with simplifications for buildings)

	Variable actions	Permanent actions (for creep factors from 1 to 3)
BS 5950-3-1	6	18
EC4, C20/25 for shrinkage:	7 -	15 to 30 (14) 12 to 18 (omit)
EC4, C60/75 for shrinkage:	5.5 -	11 to 23 (11) 8 to 14 (omit)

Simplifications permitted for buildings

Conditions:

- No members susceptible to: fatigue
  sidesway instability
  lateral-torsional buckling

Then:

In global analyses for Ultimate Limit States neglect:

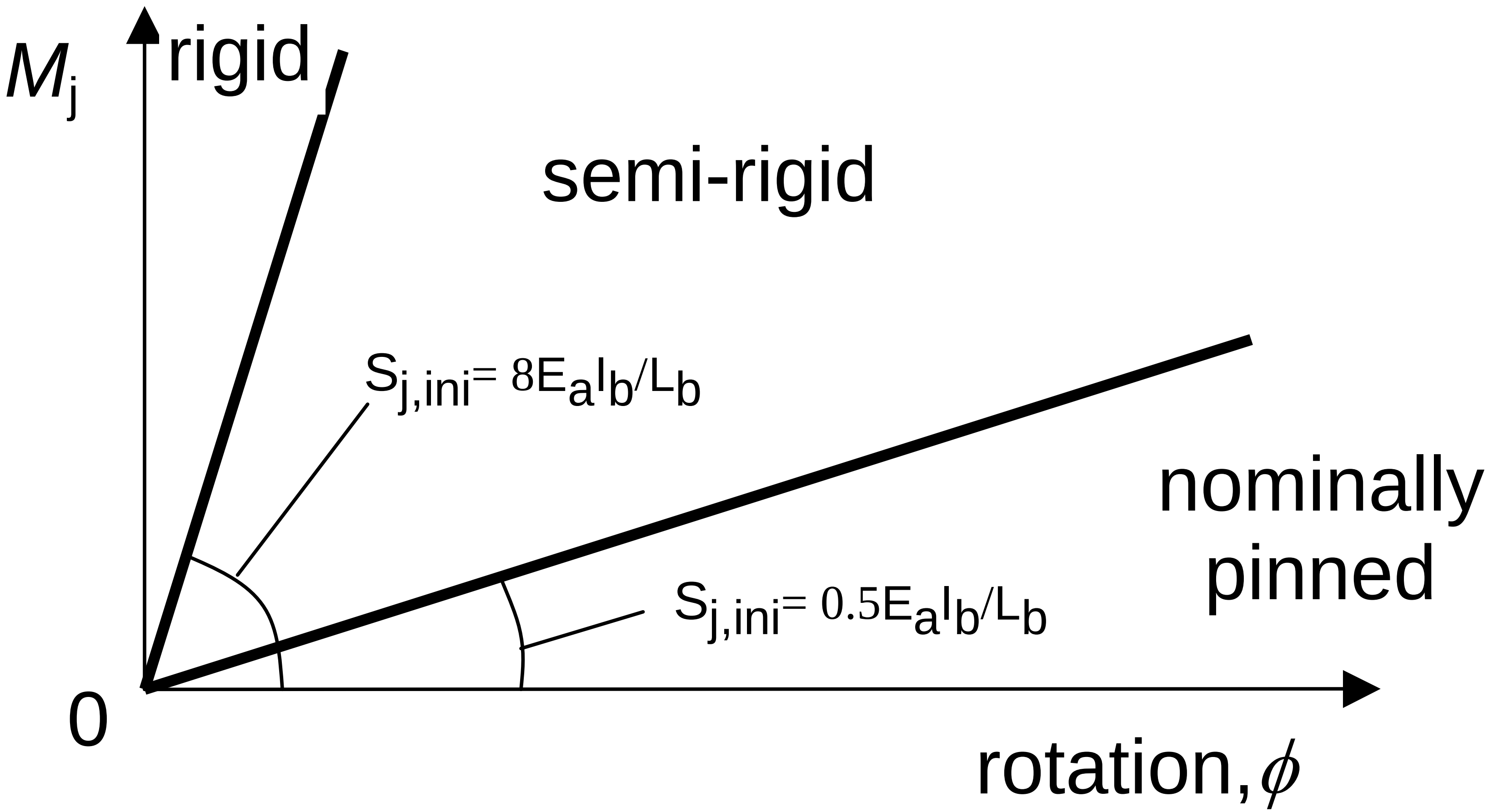
- primary and secondary shrinkage and creep
- all effects of staged (unpropped) construction
- differential temperature and settlement

Bending moments in members of a no-sway frame

'Simple' design, avoiding continuous beams

- Choose 'simple' beam-to-column joints
- Check that Class is 'nominally pinned', to EC3-1-8 or from 'experience' (cl. 8.3.4(2)
- Design beams as simply-supported, with reinforcement at supports to cl. 7.4.1(4), to avoid wide cracks
- Decide location of 'nominal pins'; hence BMs in columns are known

Classification of joints by initial stiffness



Bending moments in members of a no-sway frame

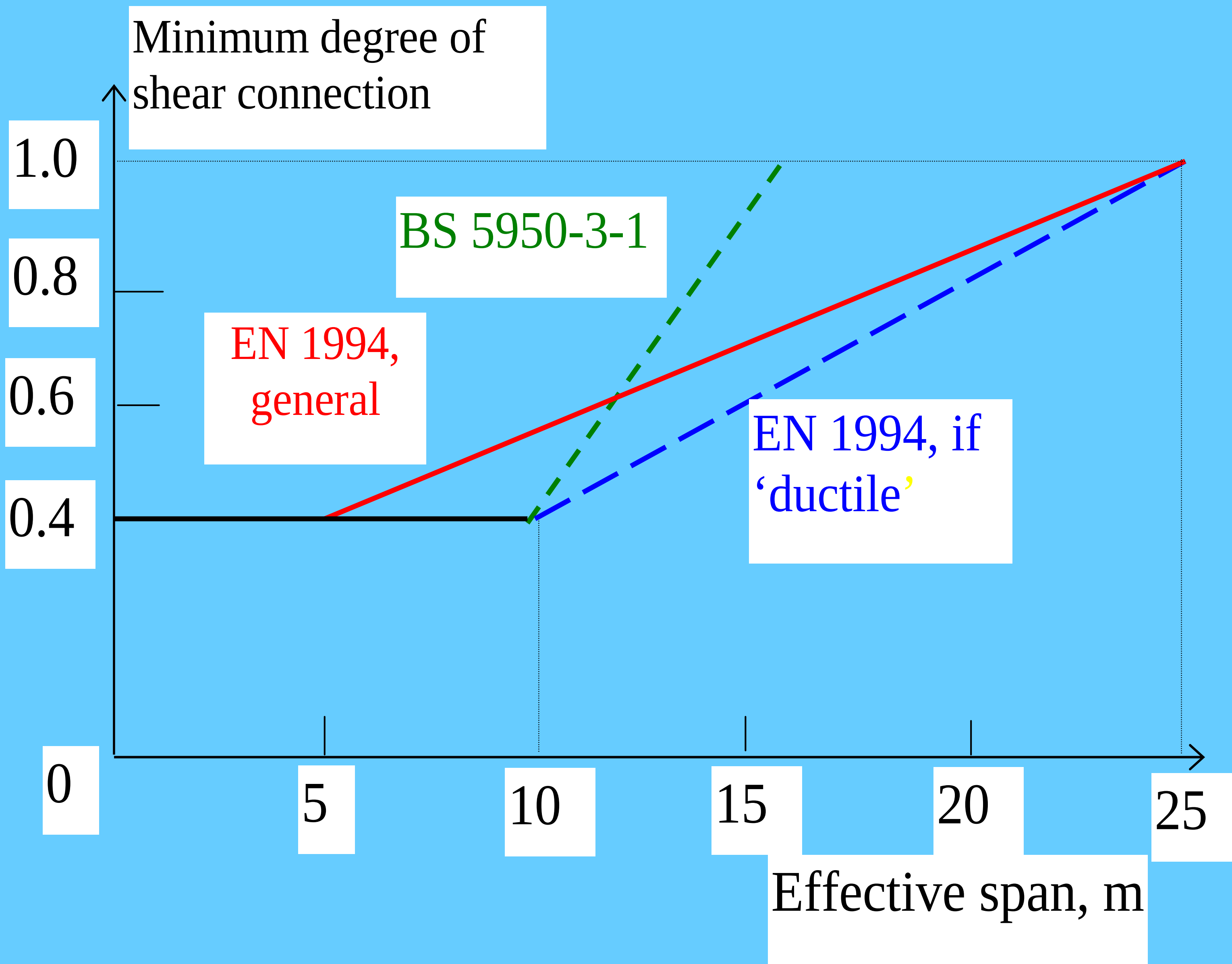
Design with continuous beams

- Choose ‘rigid’ beam-to-column joints to EC3-1-8 and EC4
- Do elastic global analysis, with ‘uncracked’ cross-sections
- Redistribute moments (RoM) in beams by up to 20% (Cl.3) to 40% (Cl.1)
- No RoM permitted in composite columns

[Note: include effects of imperfections in checks on members]

OR: use semi-rigid joints for efficient structure but more work

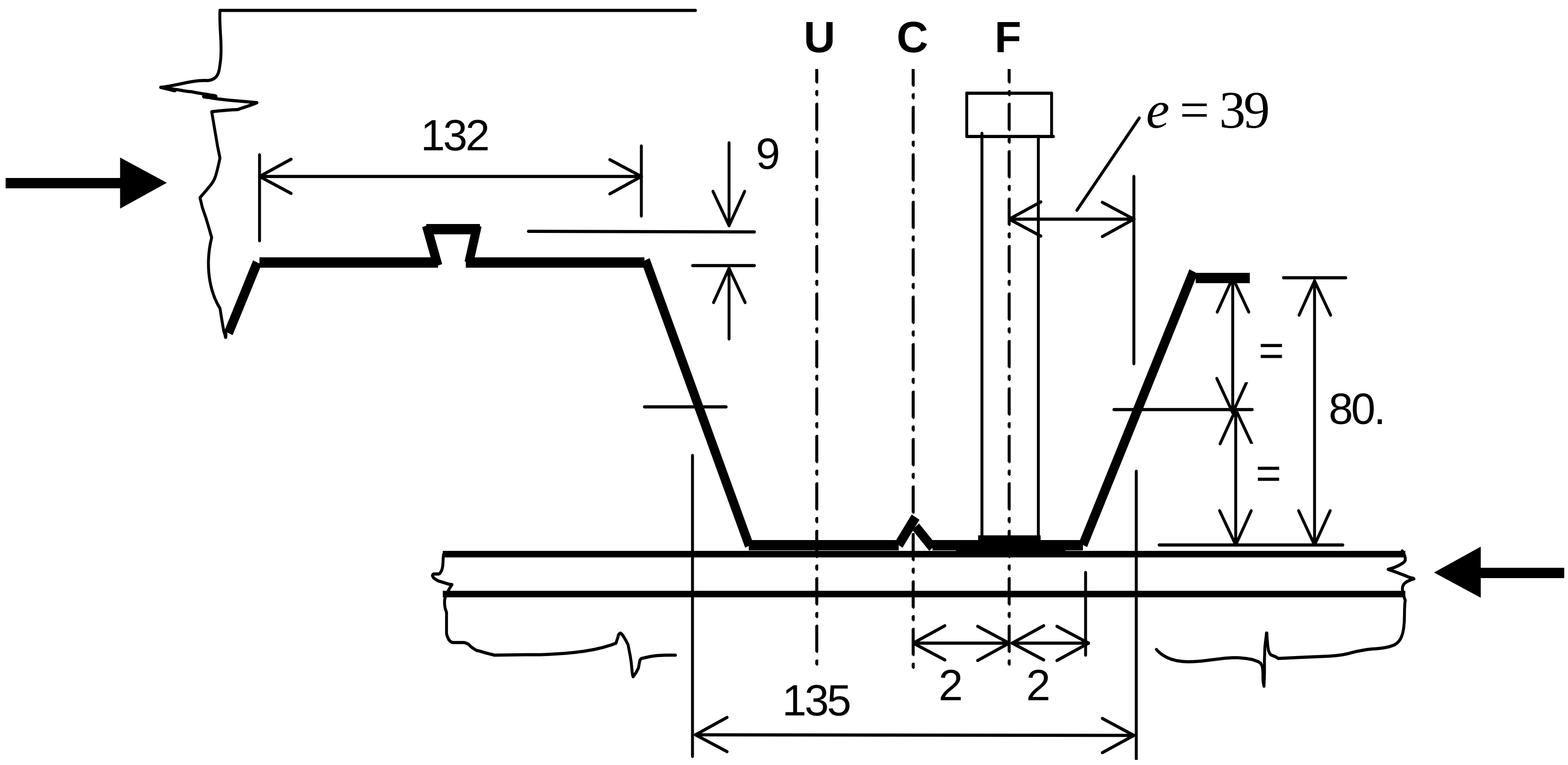
Partial shear connection in composite beams



Studs in troughs of sheeting

- Slip capacity needed for uniform spacing
- 6 mm sufficient in solid slabs
- Studs work well in solid slabs
- Some slip capacities in sheeting < 2 mm
- Caution where two or more of
  - studs off-centre in troughs
  - two or more studs per trough
  - heavy point loads
  - long spans
  - low degree of shear connection
  - edge beam

Trough in sheeting with a stud in the ‘F’ location



Composite columns in EN 1994-1-1

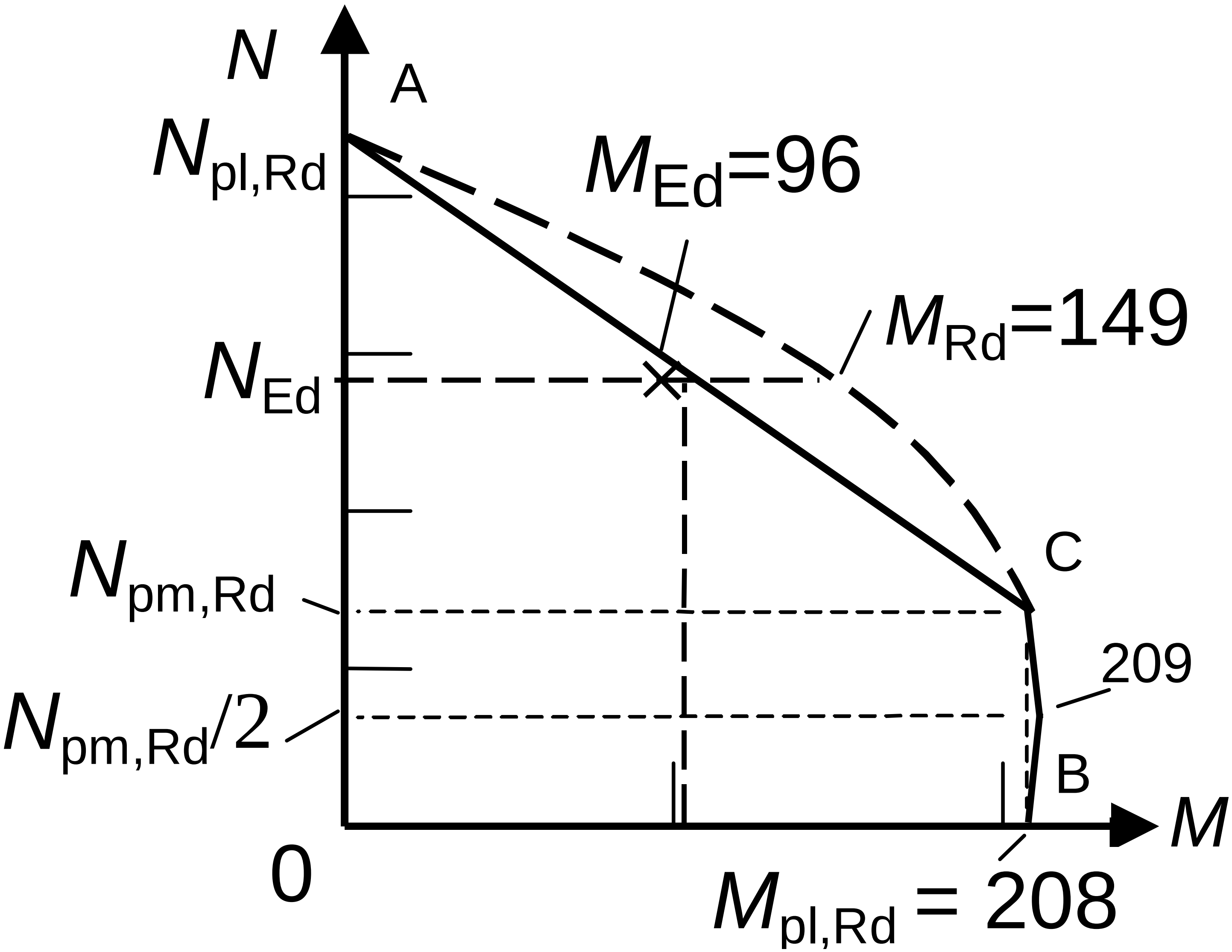
- Scope: web-encased steel sections

  fully-encased steel sections

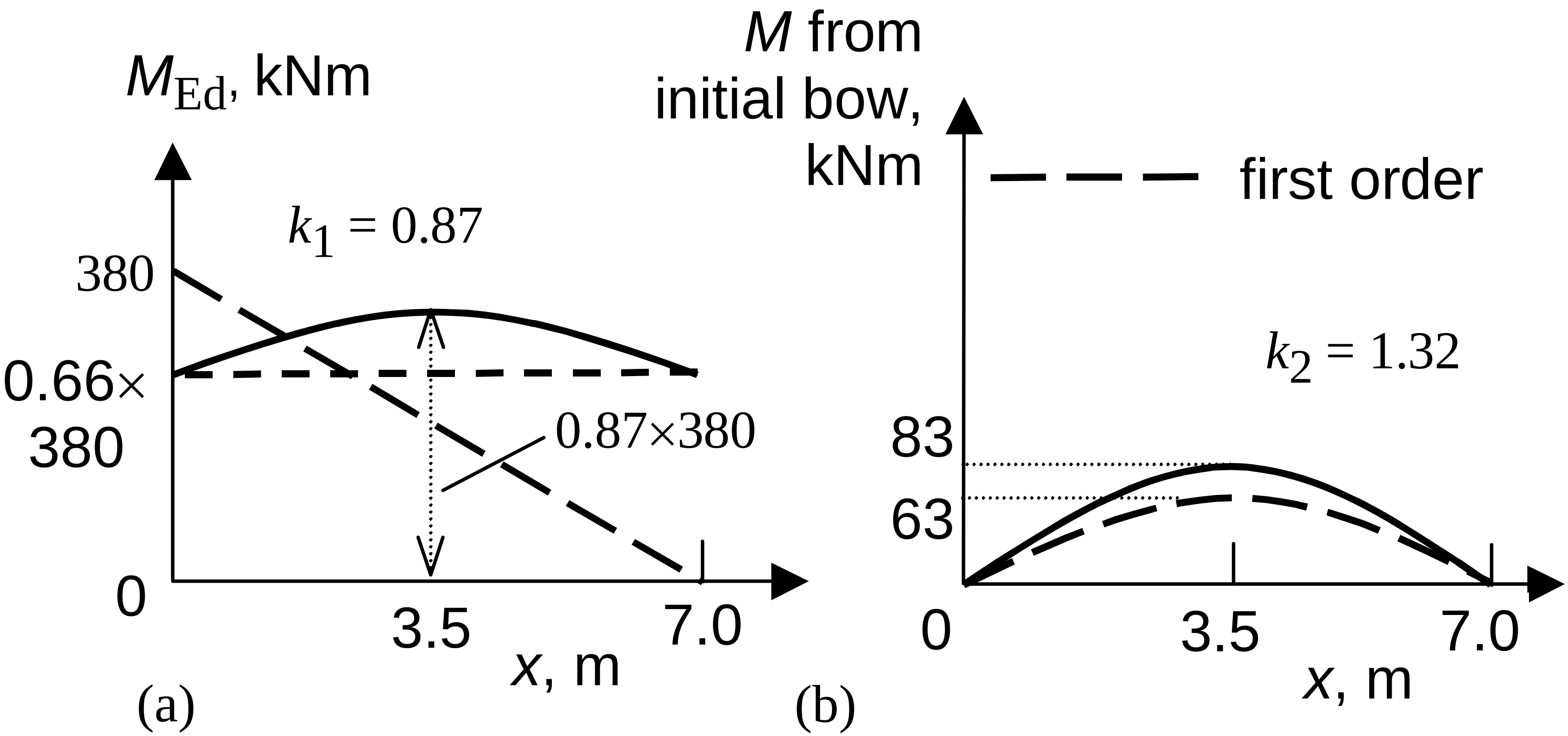
  concrete-filled steel tubes

- Simple method for uniform doubly symmetrical sections
- Back to basics: different from rules for columns in EC2 and EC3
- No use of effective lengths or column curves
- Interaction diagram for plastic resistance of section to N and M
- Direct calculation of second-order effects of M and of initial bow

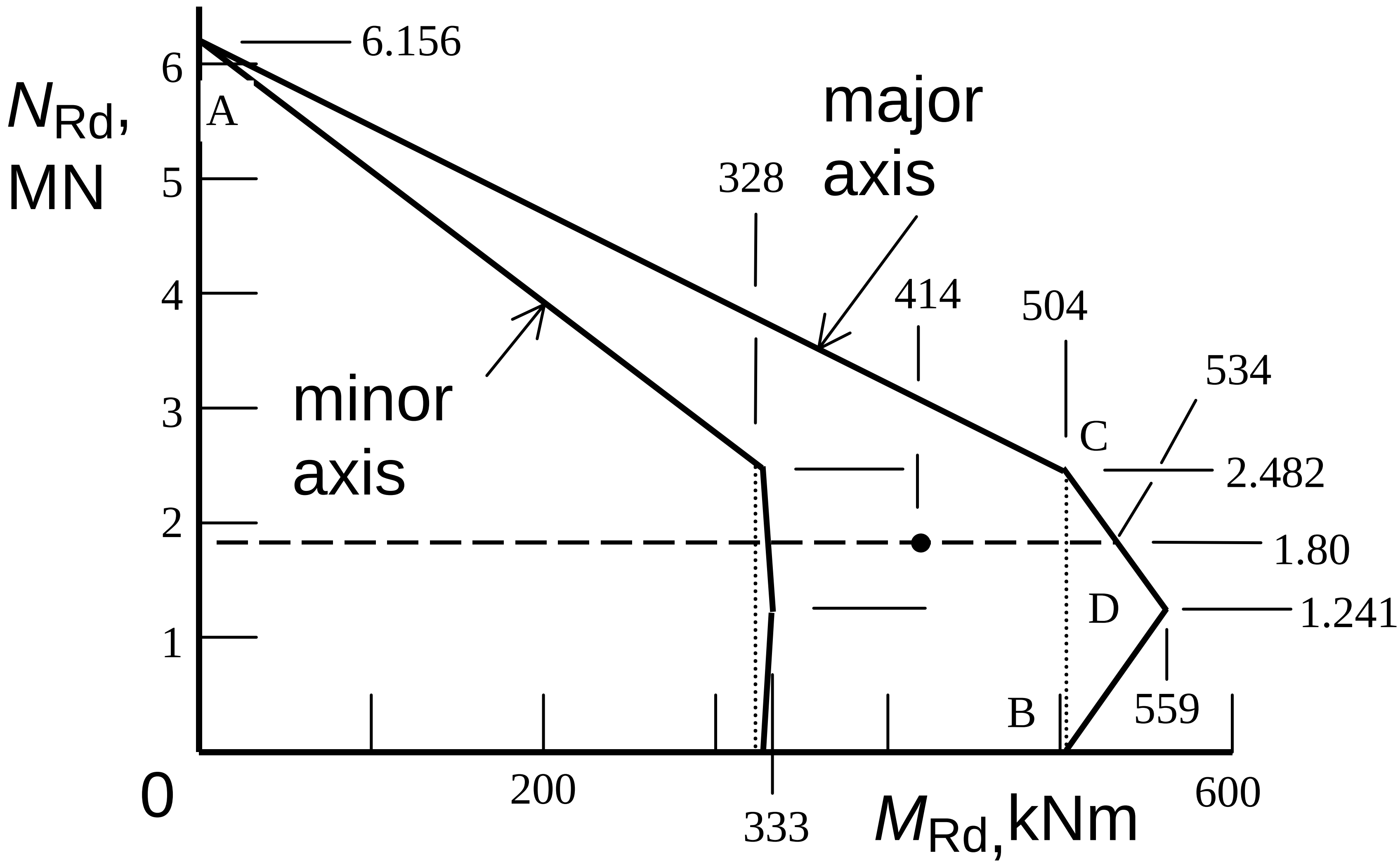
Interaction curve and polygon for composite column



First- and second-order bending moments in a column of length 7.0 m



Interaction polygons for cross-section of a composite column



How to start to use EN 1994-1-1 for a building structure

- Look at EN 1990, especially Annex A1
- Look at EN 1991-1, on actions for buildings
- Use EC2-1-1 and EC3-1-1 (and 3-1-8) for simple structures (and for bridges, EC3-1-5 and 3-1-9)
- Study worked examples on EC4-1-1
- In your copy of each code, enter changes from its NA

NDPs from National Annexes

For EC3-1-1:

- For plastic global analysis, higher properties for steel
- Different curves for lateral-torsional buckling
- Lower γ_{M2} for fracture resistance in tension

For EC4-1-1:

- Minimum sheeting thickness: ‘bare metal’ not ‘nominal’
- Different γ_V for studs in profiled sheeting