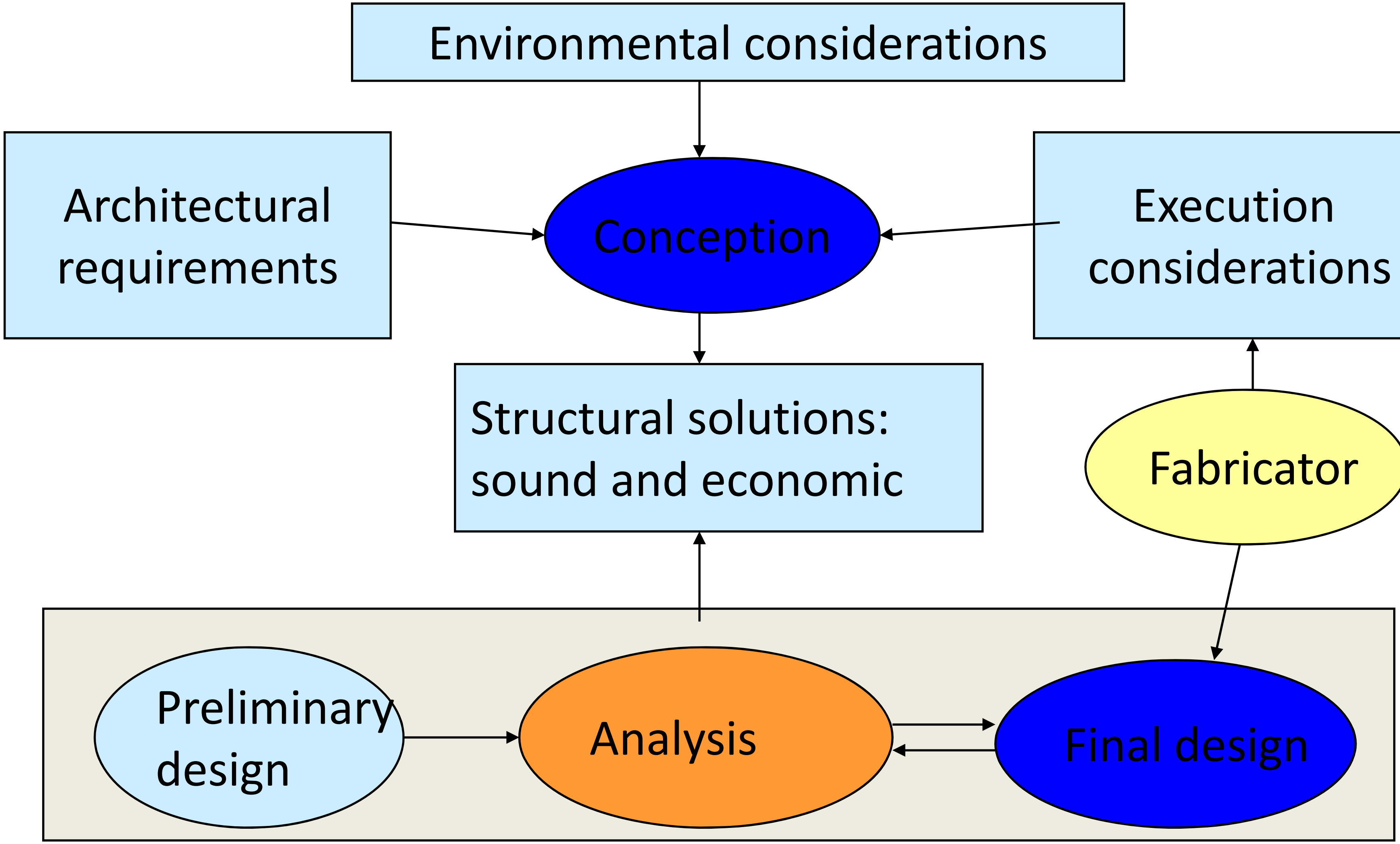
UTM
UNIVERSITI TEKNOLOGI MALAYSIA
Faculty of Civil Engineering

"Inspiring creative and innovative minds"

Frame Design

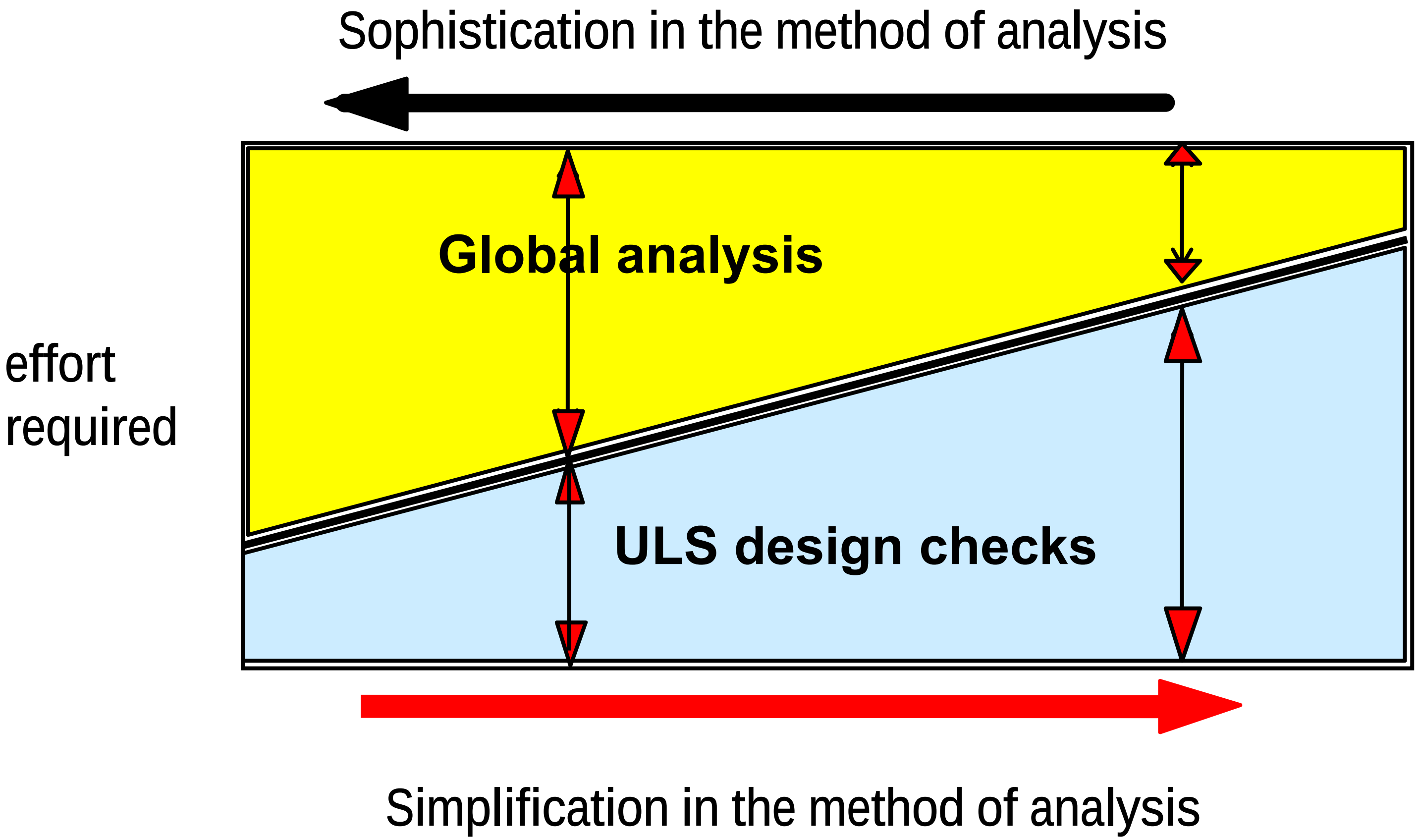
Conception to final design



Decisions related to the analysis approach – EC3

- Choice between
  - an elastic and a plastic global analysis
  - 1st order and 2nd order analysis
  - a traditional approach and a modern approach to connection representation
  - Combination of the above

Implications for design of the choice of the global analysis

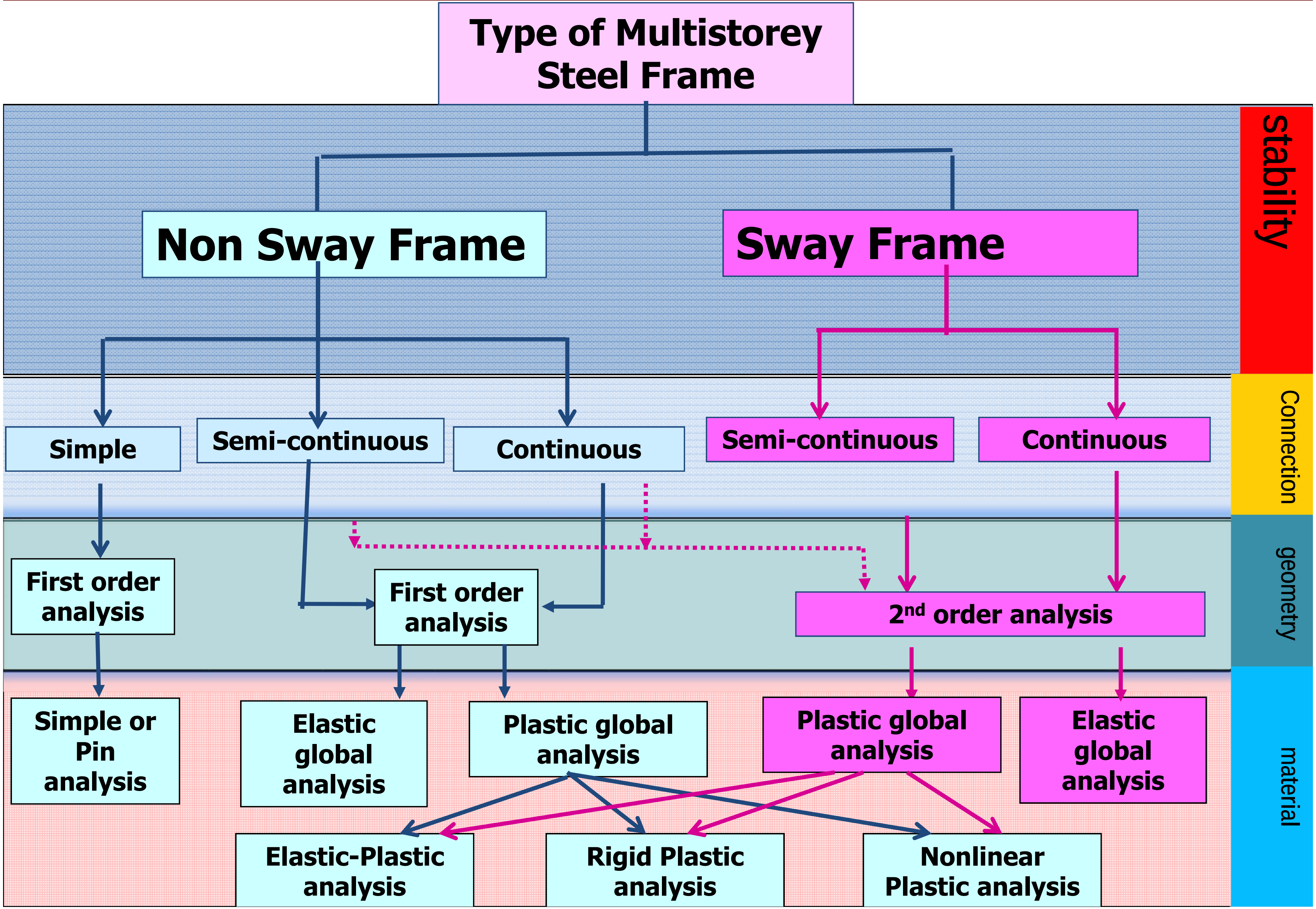


Overall Design Task= Analysis + Design Checks

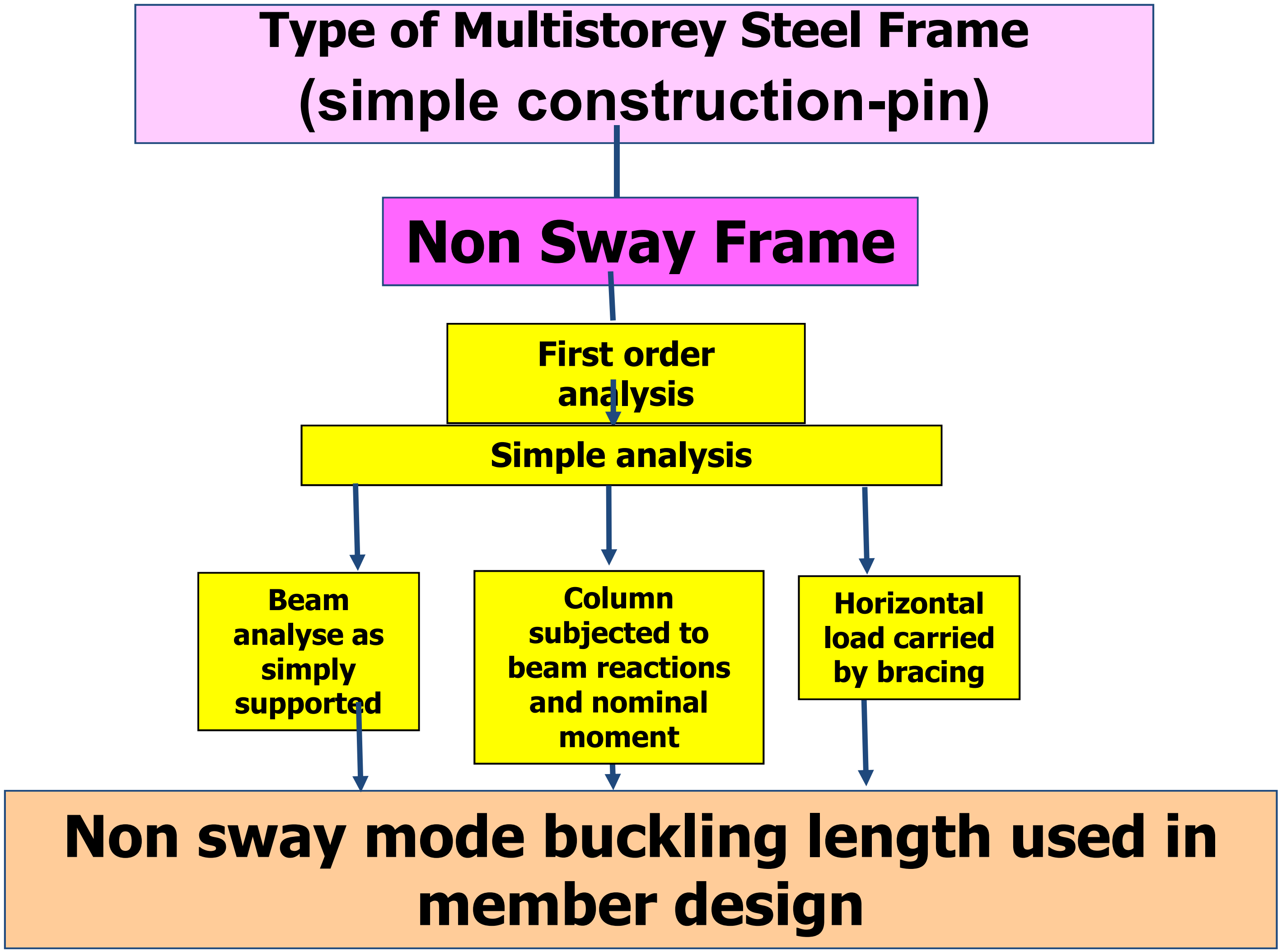
Steel Frame

		Non-sway	Sway
Definiton		Depends on frame geometry and load cases under consideration	
Definiton		Determined by influenced of PΔ effect	
Definiton		Horizontal loads are carried by the bracing or by horizontal support	Horizontal loads are carried by the frame
Definiton		Change of geometry (2nd-order effect) is negligible	Change of geometry (2nd-order effect) significant
Method of analysis	Elastic analysis	First-order elastic analysis (stifness analysis, moment distribution)	First-order elastic analysis with indirect allowance for second order effect (P-Δ and P-δ effect)
Method of analysis	Elastic analysis	Second-order elastic analysis	
Method of analysis	Plastic analysis	First-order rigid-plastic analysis	First-order rigid-plastic analysis with indirect allowance for second order effect (P-Δ and P-δ effect)
Method of analysis	Plastic analysis	Second-order elastic plastic hinged analysis	
Method of analysis	Plastic analysis	Second-order elasto-plastic analysis	

Relationship between type of frame, construction and analysis



Relationship between type of frame, analysis and design



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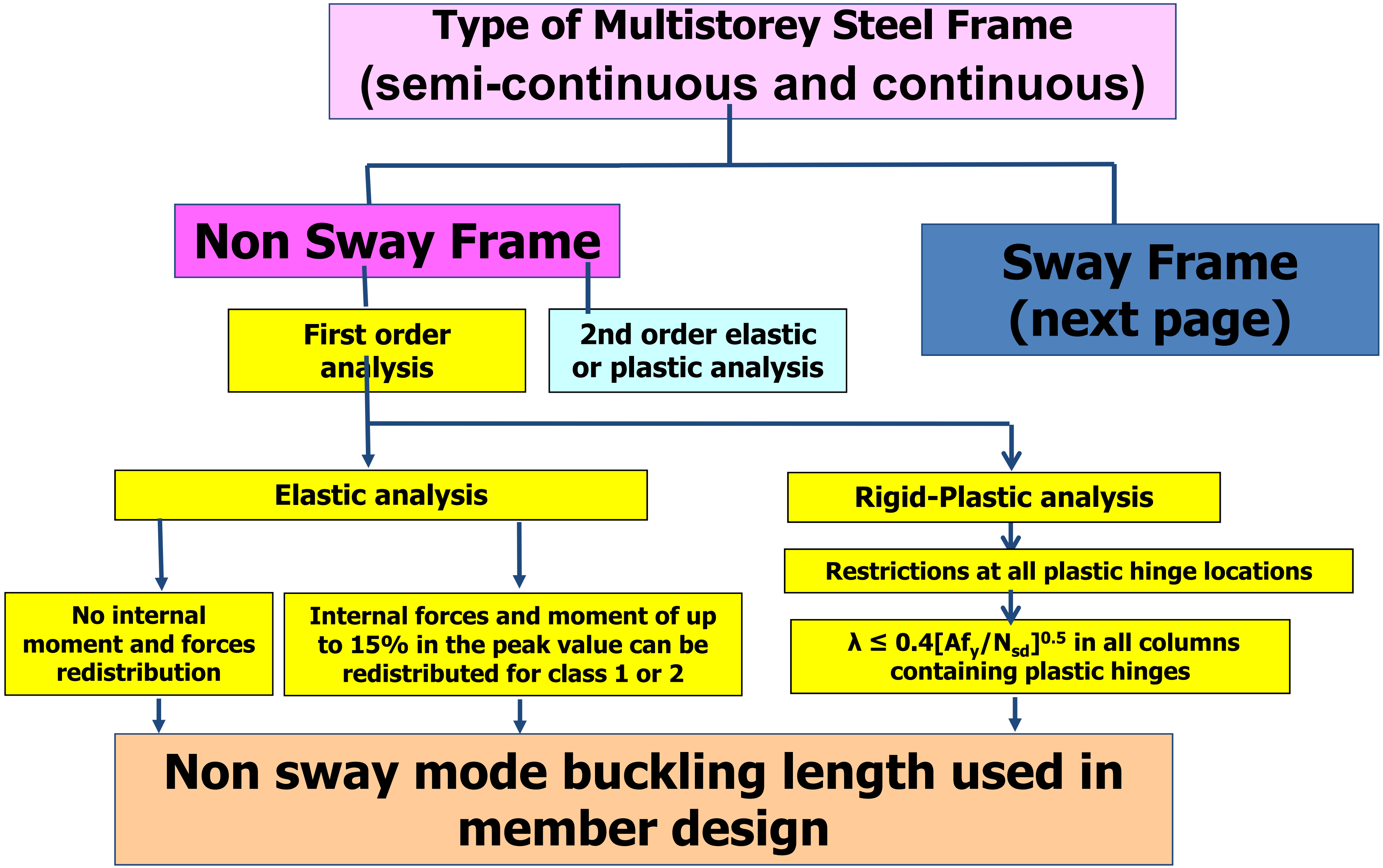

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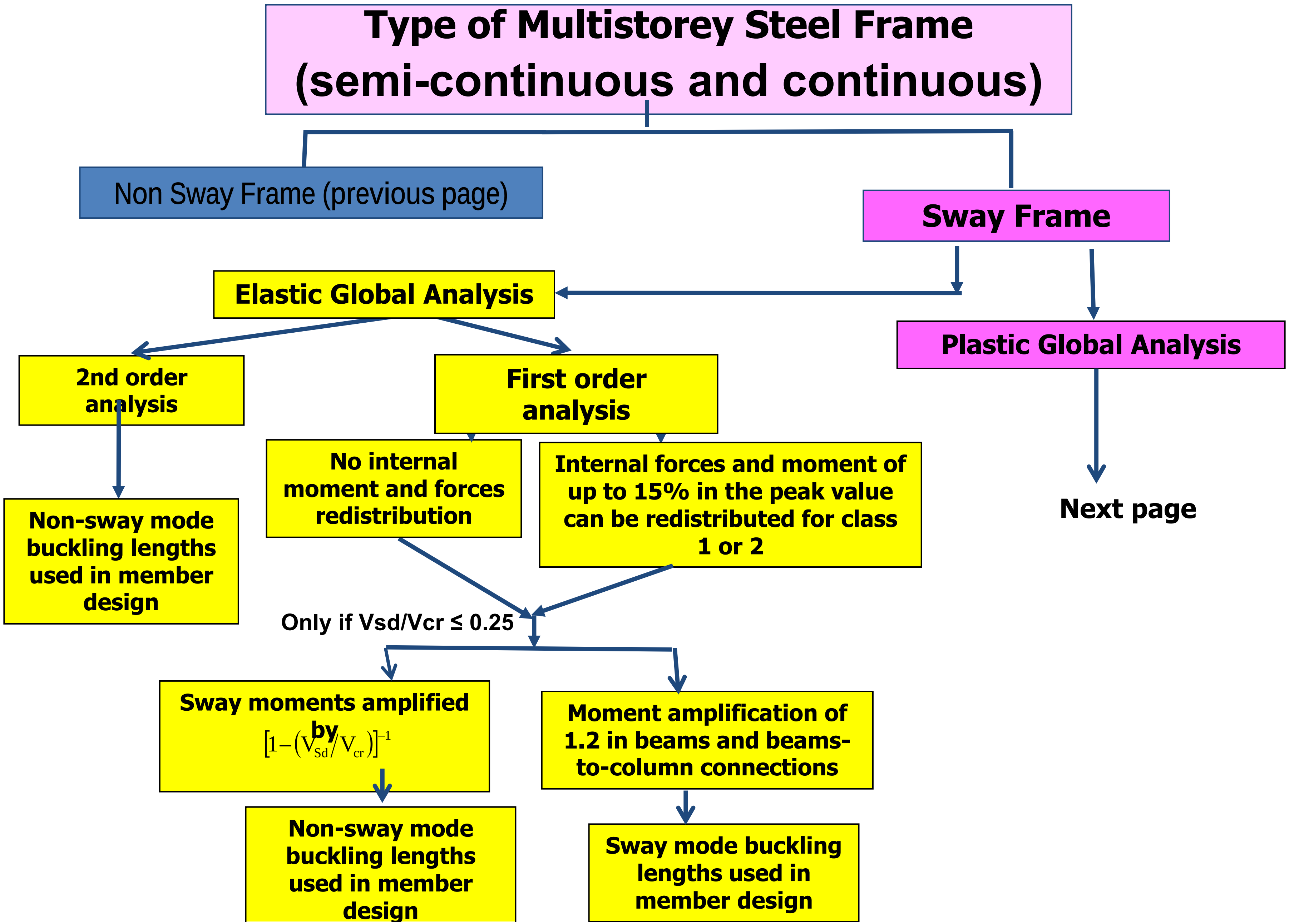
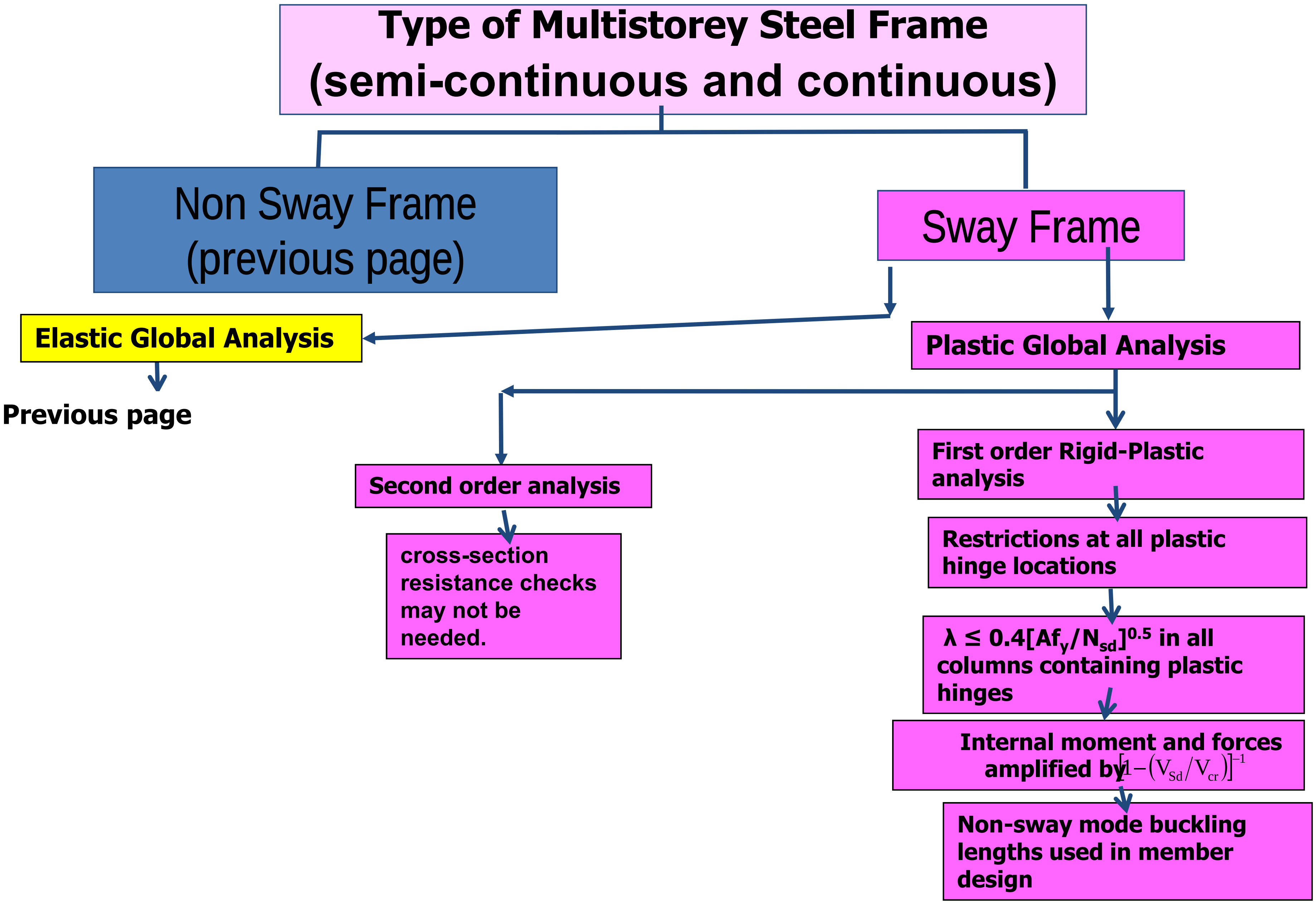
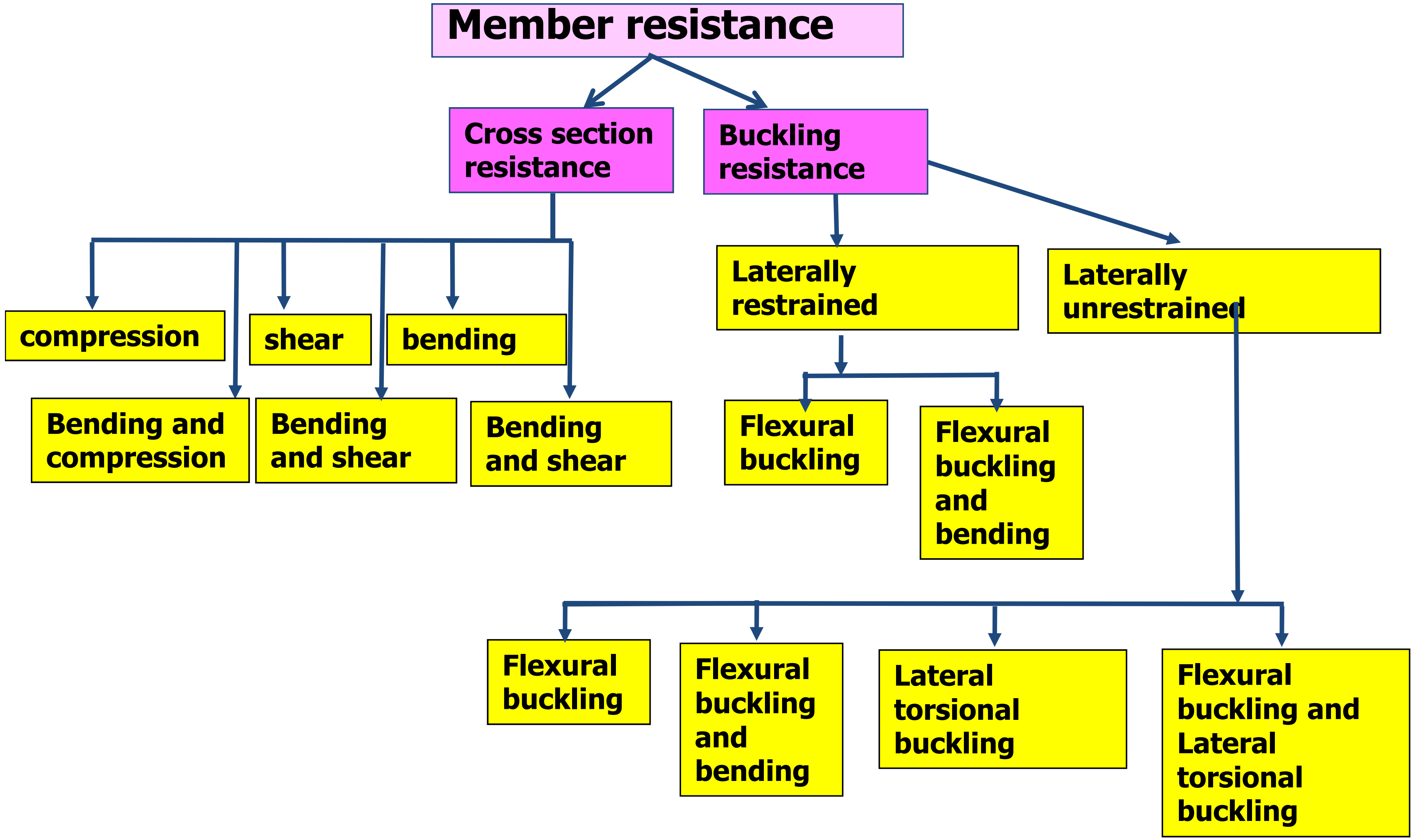


Relationship between type of frame, analysis and design



Resistance of frame members subjected to a combination of compression, shear and bending moment



Implications of the choice of the type of analysis on design

The more sophisticated the analysis tool employed, the less are the design check tasks following analysis.

- With a “true” 2nd order elastic analysis, the in-plane stability check, for the members and for the frame, is no longer needed.
- Following a “true” 2nd order elastic-plastic analysis, in addition, cross-section resistance checks may not be needed.

Choice between elastic analysis and plastic analysis

- Elastic analysis can always be used.

- Plastic analysis allowed only when one meets the restrictions on steel properties, cross-section classification, restraints (at or near plastic hinges) and, if needed, on joint ductility.

Choice of method of analysis/design

Factors which orient the choice:

- type of structure : conception meeting architectural, environmental and execution considerations and needs
- availability of class 1 and 2 sections for plastic analysis/design
- other Eurocode requirements: 1st or 2nd order analysis?, seismic design needed?
- available software/designer's experience

Frame classification

- Decision on the use of bracing or not influences sway classification
- Preliminary member sizing and estimates of column vertical loads: use to provide an *indication of the sway classification* using:

$$V_{Sd}/V_{cr} \leq 0,1 : \text{Non-sway : can use 1st order analysis}$$

$$V_{Sd}/V_{cr} > 0,1 : \text{Sway : must allow for 2nd order effects}$$

- Industrial portal frame: EC3 not suitable

Sway frame : 2nd order effects

Alternatives to a "true" 2nd order analysis:

- 1st order analysis + "Amplified Sway Moment" method when:

$$\text{Elastic design: } V_{Sd}/V_{cr} \leq 0{,}25 \Rightarrow \text{Amplify } M_{sway} \text{ by } 1/(1 - V_{Sd}/V_{cr})$$

$$\text{Plastic design: } V_{Sd}/V_{cr} \leq 0{,}20 \Rightarrow \text{Amplify all forces by } 1/(1 - V_{Sd}/V_{cr})$$

- 1st order analysis + "Sway Mode Buckling Length" method (20% sway moment increase) - *use not advised*

1st order elastic analysis and relevant design checks

- Member sections and joints: ultimate design resistance: redistribution possible
- In-plane and out-of plane beam-column stability check - usually with in-plane buckling lengths
- In-plane frame stability : accounted for by including 2nd order effects (when needed)
- Beams: Lateral torsional buckling
- Others:Local buckling, Fire resistance etc.

1st order plastic analysis and design

- Restrictions: (steel properties, section class etc.)
- Rigid-plastic analysis and design:

  braced non-sway frames, or unbraced of no more than 2 storeys (but see exception)
- Elastic-plastic analysis and design
- Relevant design checks usually as for 1st order elastic design

2nd order plastic analysis and design

- Elastic-plastic analysis and design
- Rigid-plastic analysis and design with amplified forces -based on Merchant-Rankine formula (use restricted)
- Merchant-Rankine approach - not explicitly mentioned in EC3
- Design checks depend on analysis tool, mostly as for 2nd order elastic analysis

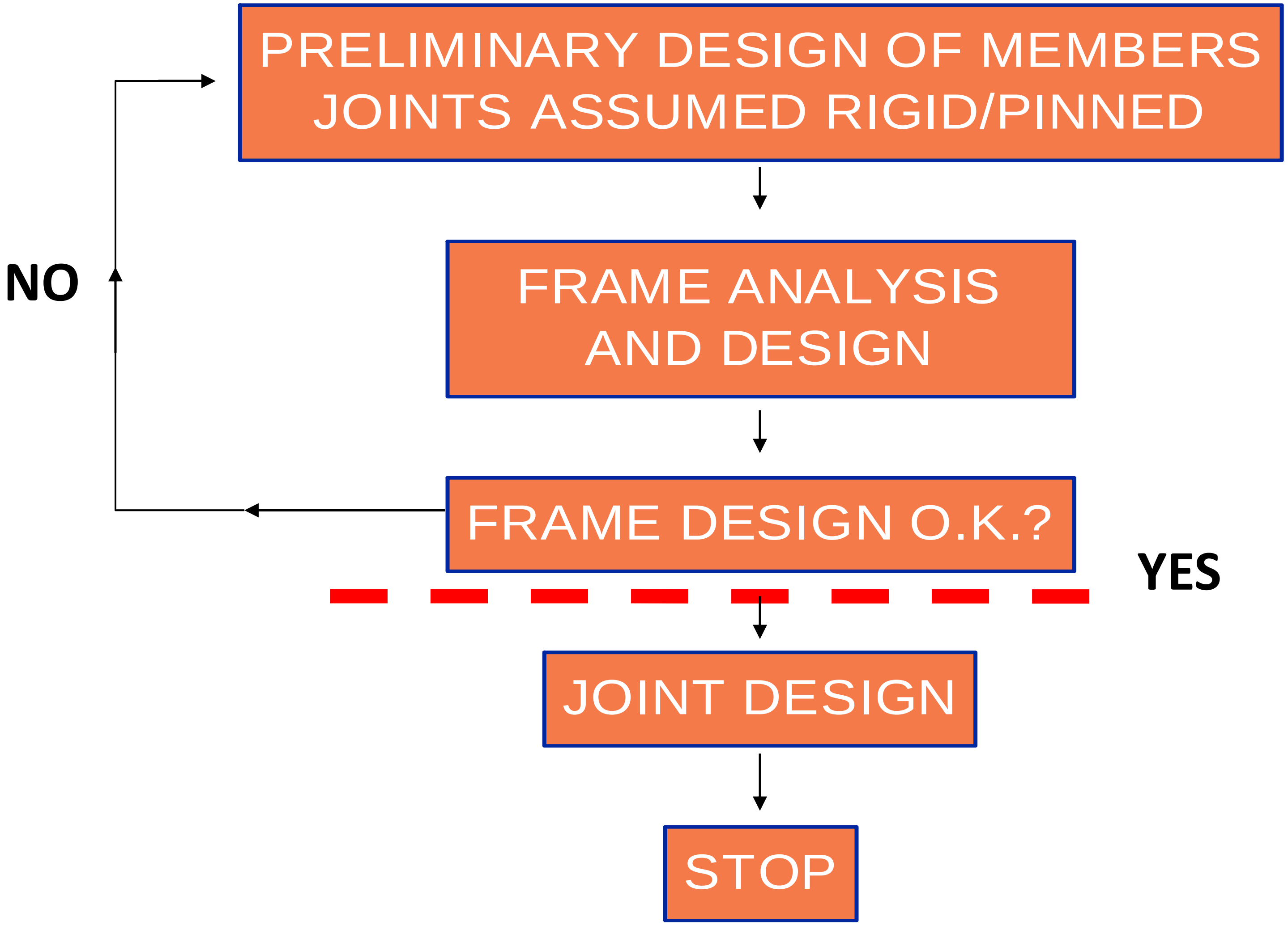
Traditional approaches to design

- Pinned-Rigid Joints + elastic analysis
- Rigid- plastic analysis/design : in some countries only: Industrial portal frames and other frames of no more than 2 storeys
- “Wind-moment” + elastic analysis

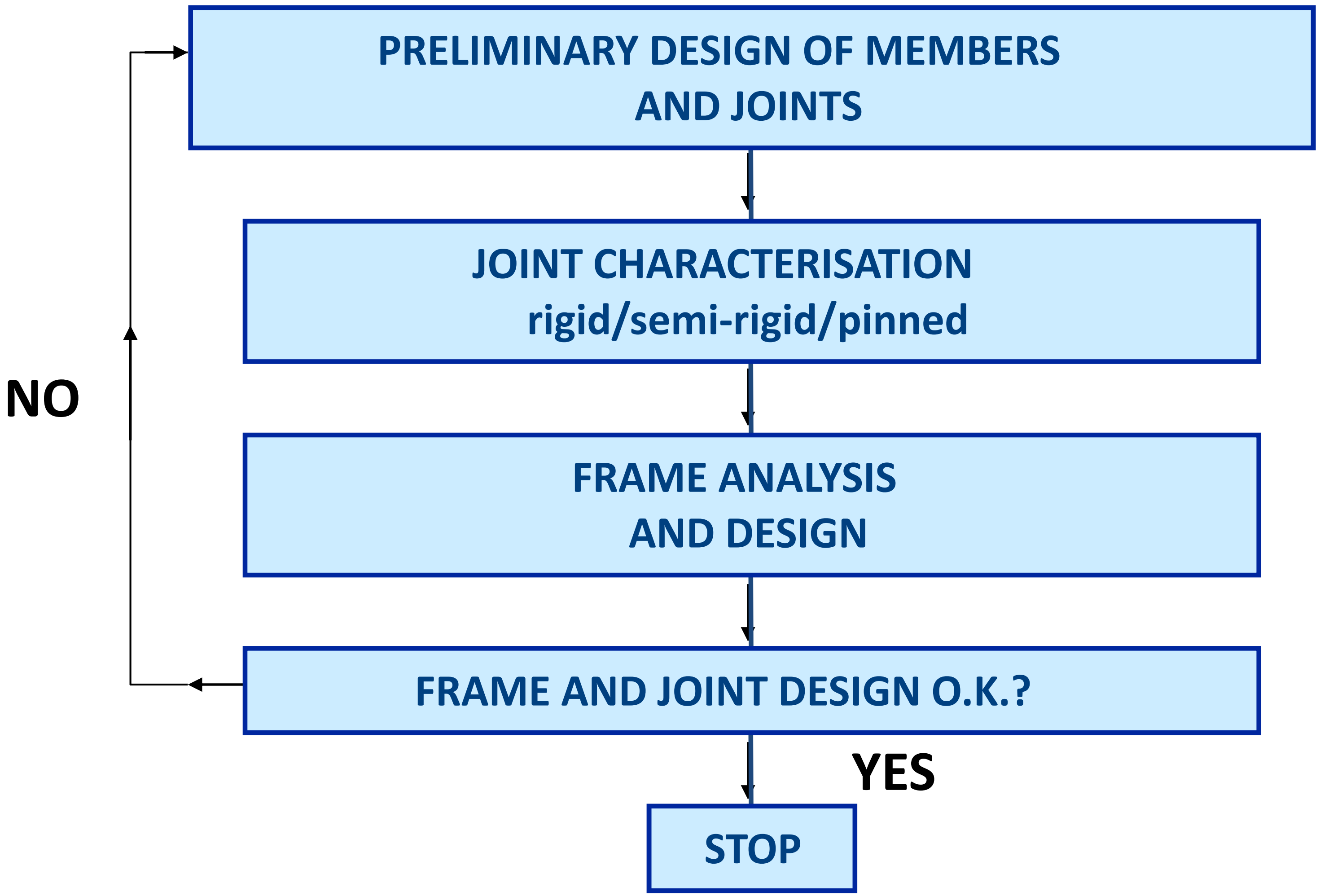
  - no moment in joints for vertical loads only

  - joints transmit moments due to wind
- Partial strength non-sway frames: plastic hinges at joints and in beam span

Traditional design approach

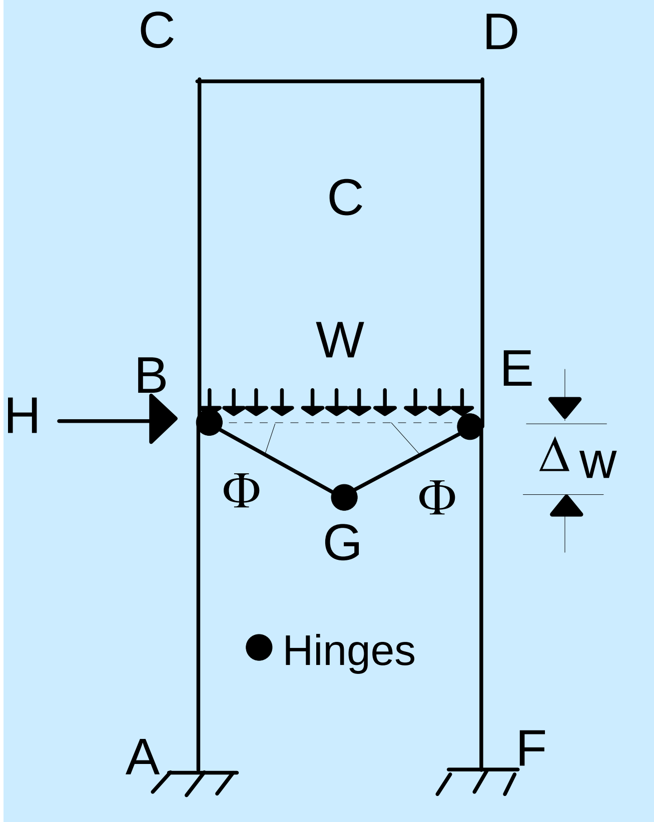


Modern design approach



Partial strength approach

- Braced non-sway frames
- Objective: economical beam sizes (floor depths) and joints
- Beams of class 1
- Joints: ductile partial strength
- Column size: may change from traditional solution



Beam mechanism

Modern approach = consistent design : include joint response

- Joint response allowed for from the outset i.e. from the preliminary design stage
  - Member sizing allows for joint response
- Better appreciation of structural behaviour
- Can optimise overall costs, noting that
  - a significant part of fabrication and erection costs is related to joints
  - the least weight frame solution is not necessarily the cheapest

Note: If sway, advised to use "true" 2nd order analysis