SECOND-ORDER PLASTIC-ZONE ANALYSIS OF STEEL FRAMES

Part II: Effects of Initial Geometric Imperfections and Residual Stress

Arthur R. Alvarenga and Ricardo A.M. Silveira

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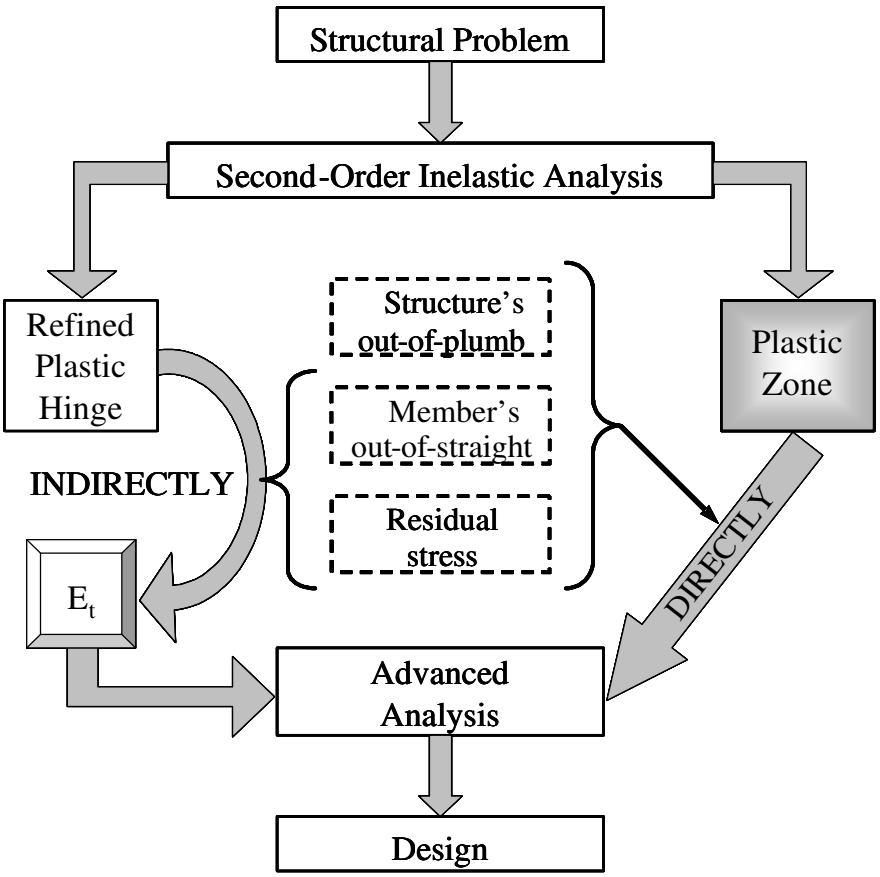
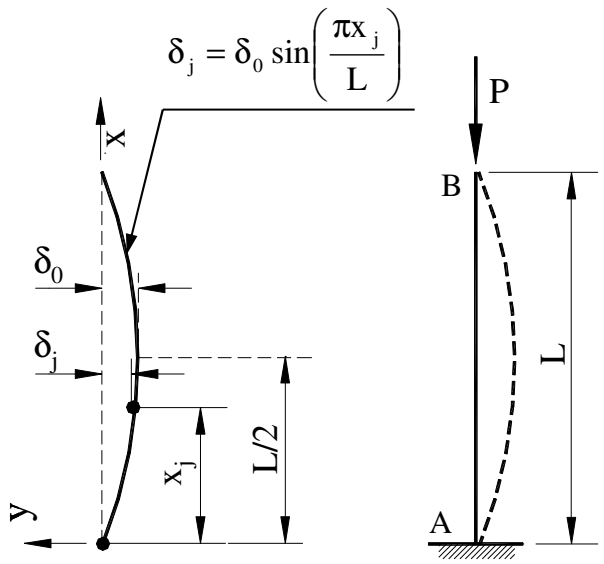
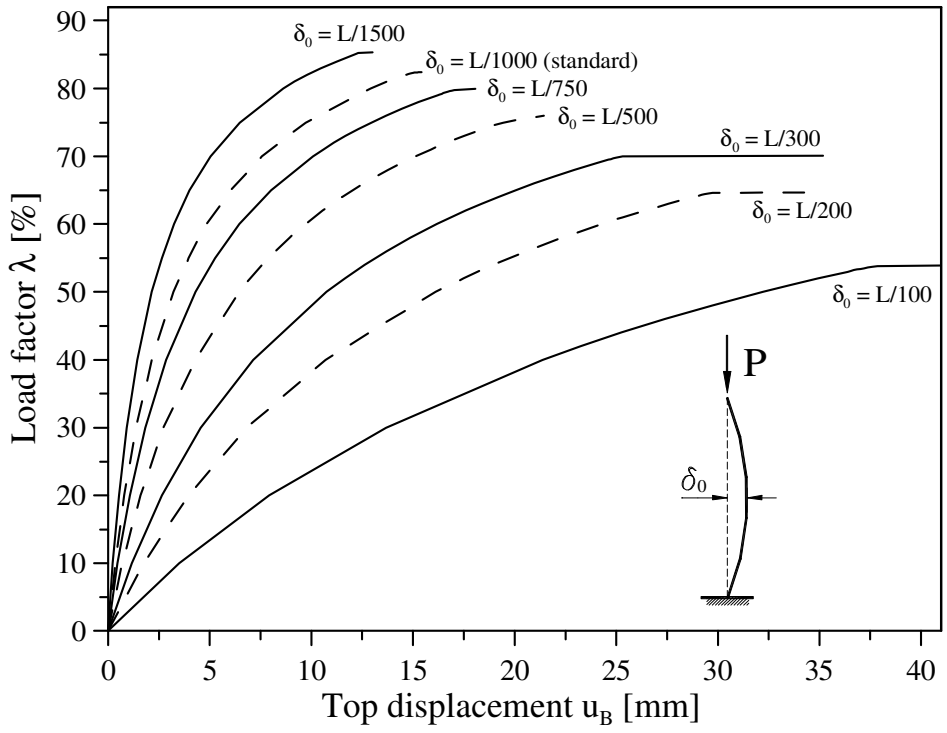


Figure 1: The advanced analysis concept.

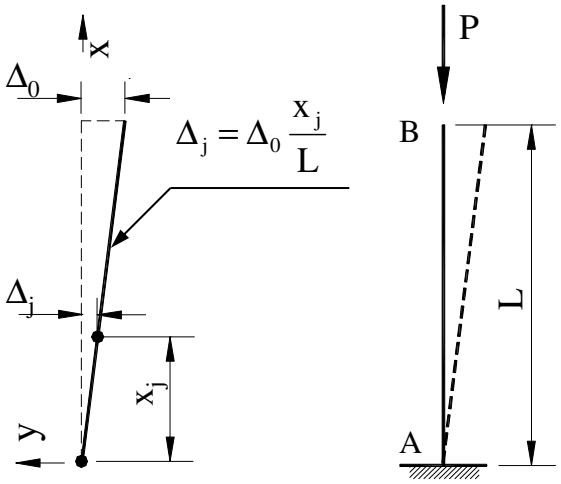


(a) Out-of-straightness. (b) Fixed-free column' out-of-straightness.

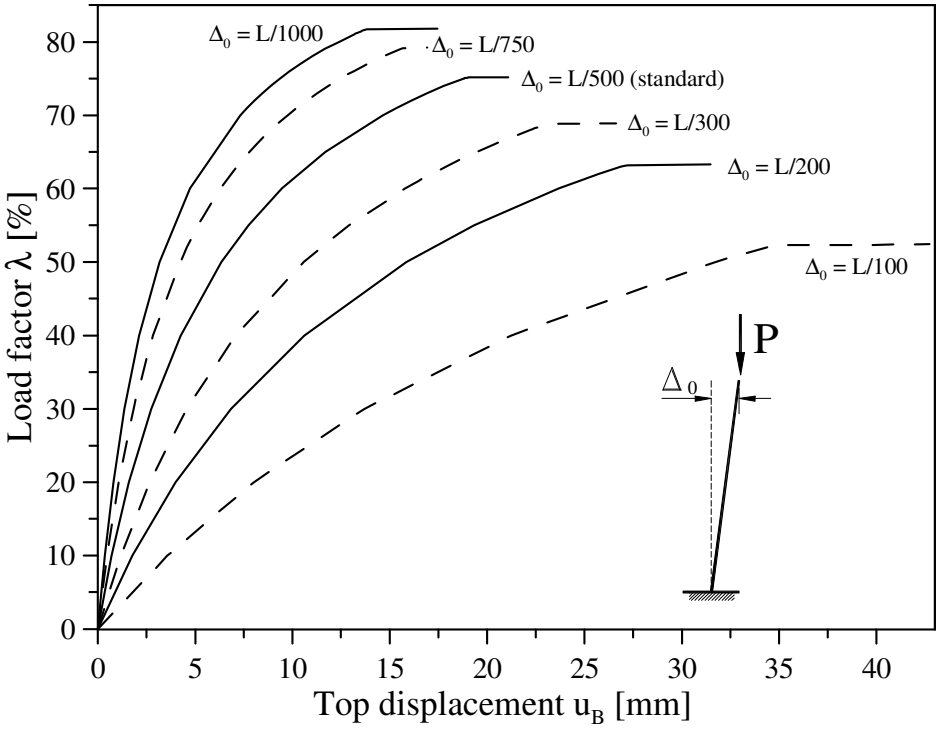


(c) Equilibrium paths.

Figure 2: Member's out-of-straightness modeling and influence.

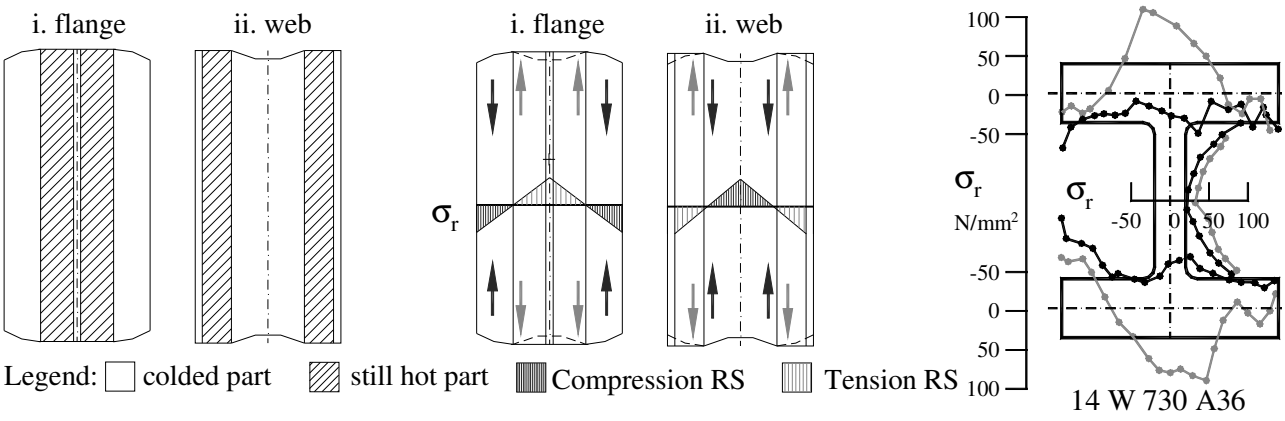


(a) Out-of-plumbness. (b) Fixed-free column's out-of-plumbness.



(c) Equilibrium paths.

Figure 3: Structure's out-of-plumbness modeling and influence.



(a) Cooled external parts. (b) Still-hot parts cannot contract. (c) Actual RS diagram.

Figure 4: Residual stress set-up.

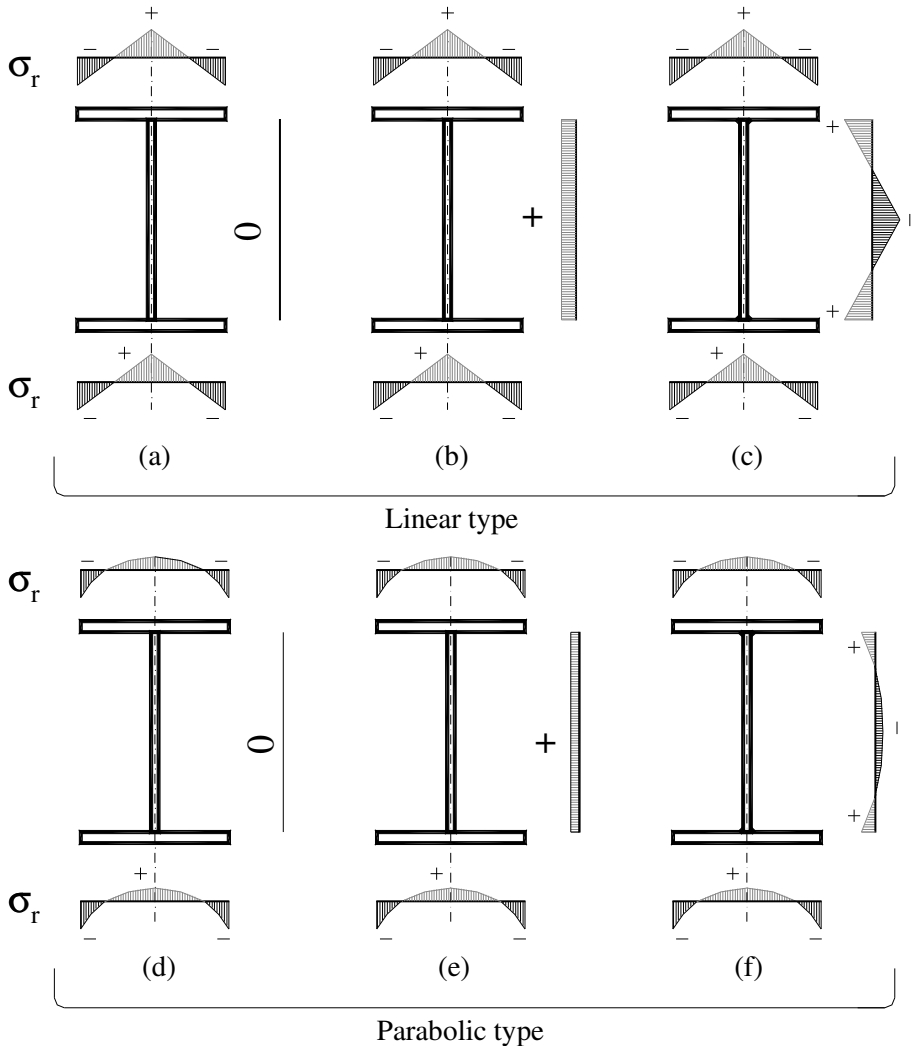
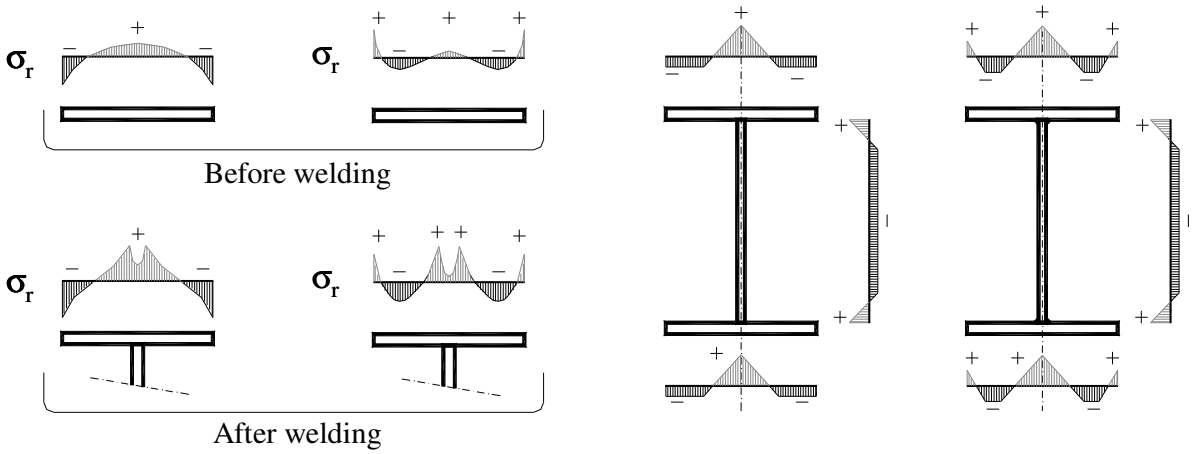


Figure 5: Residual stress diagrams of hot-rolled sections.



(a) Rolled plates. (b) Hot-cut plates. (c) Welded rolled plates. (d) Welded hot-cut plates.

Figure 6: Residual stress diagrams of built-up sections.

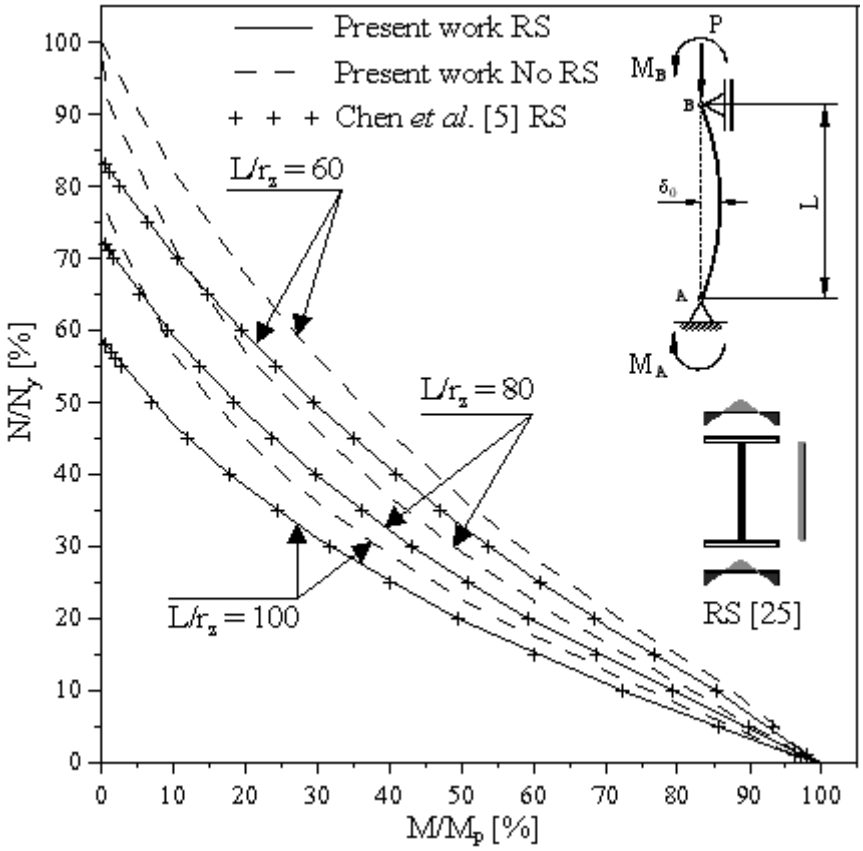
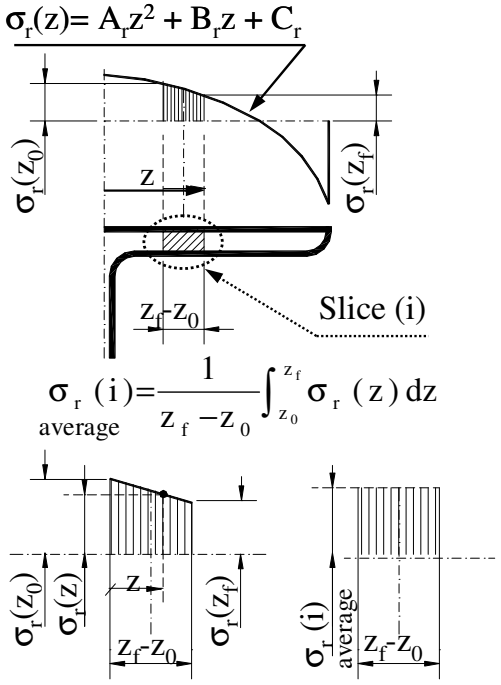
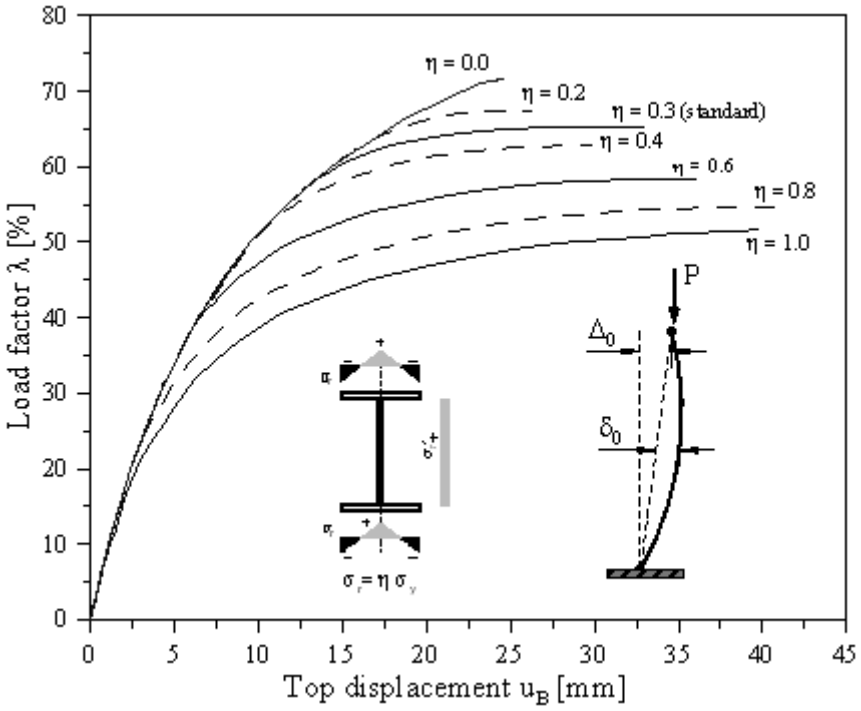


Figure 7: Residual stress effect on Galambos and Ketter's beam-column [25].

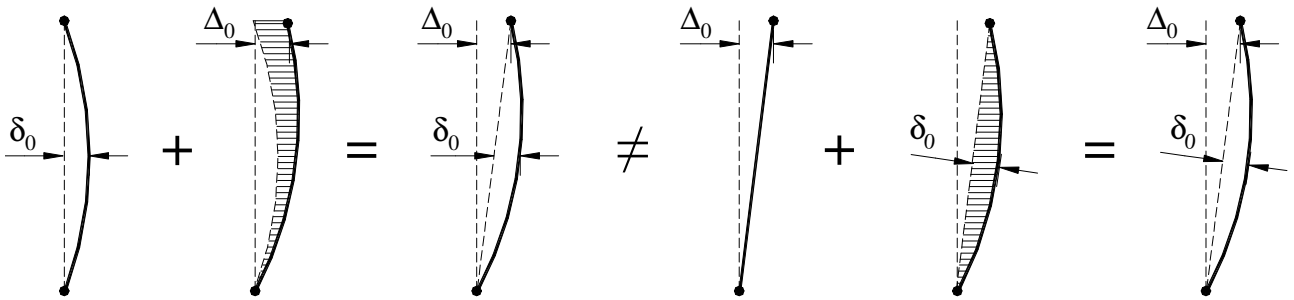


(a) Residual stress on fiber.



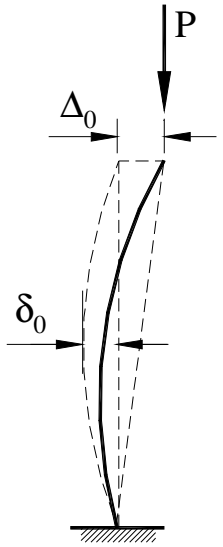
(b) Equilibrium paths.

Figure 8: Residual stress modeling and influence.

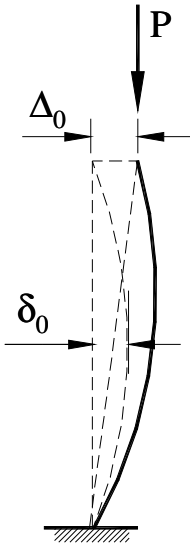


(a) Out-of-straightness and out-of-plumbness. (b) Reverse order (not recommended).

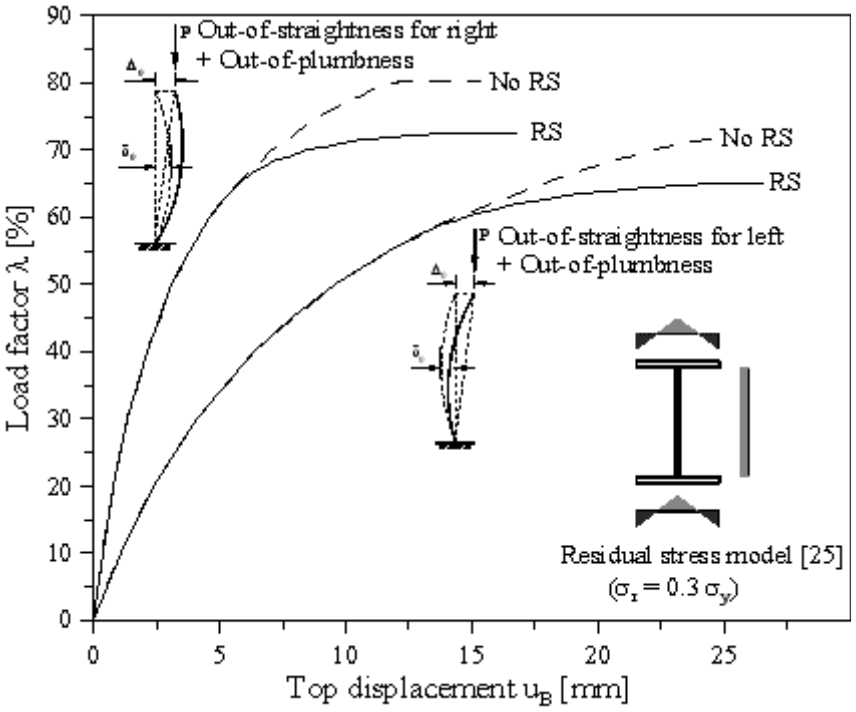
Figure 9: Combination of initial geometric imperfections.



(a) Out-of-straightness for left.

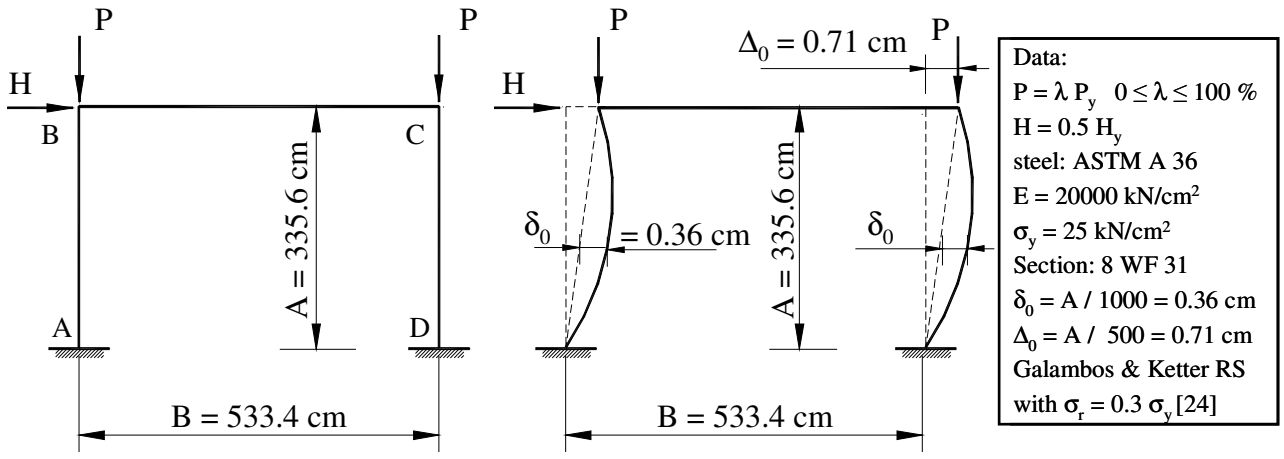


(b) Out-of-straightness for right.



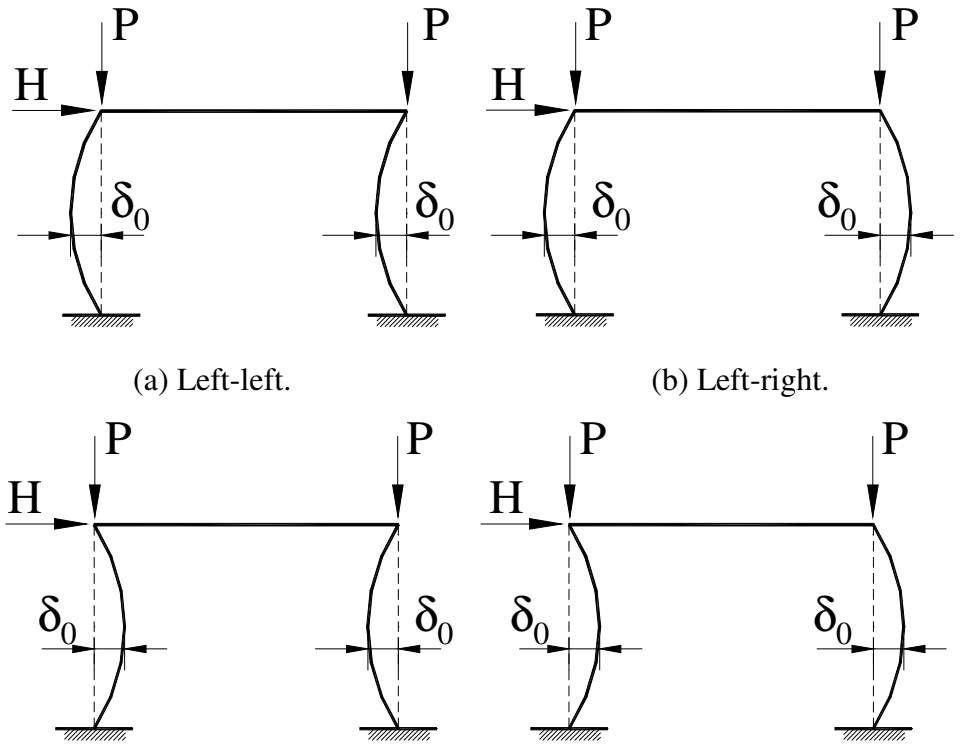
(c) Equilibrium paths.

Figure 10: Advanced analysis of fixed-free column.



(a) Idealized frame. (b) Frame's initial geometrical imperfections and data.

Figure 11: Steel portal frame.



(a) Left-left. (b) Left-right.

(c) Right-left. (d) Right-right.

Figure 12: Portal frame with members' out-of-straightness.

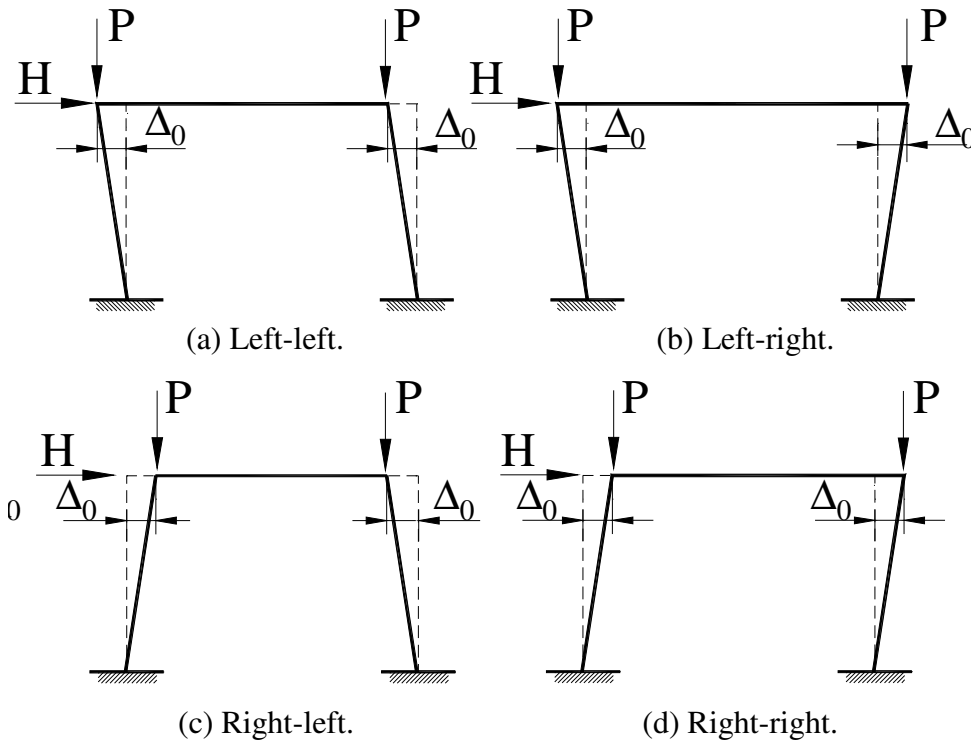


Figure 13: Portal frame's out-of-plumbness.

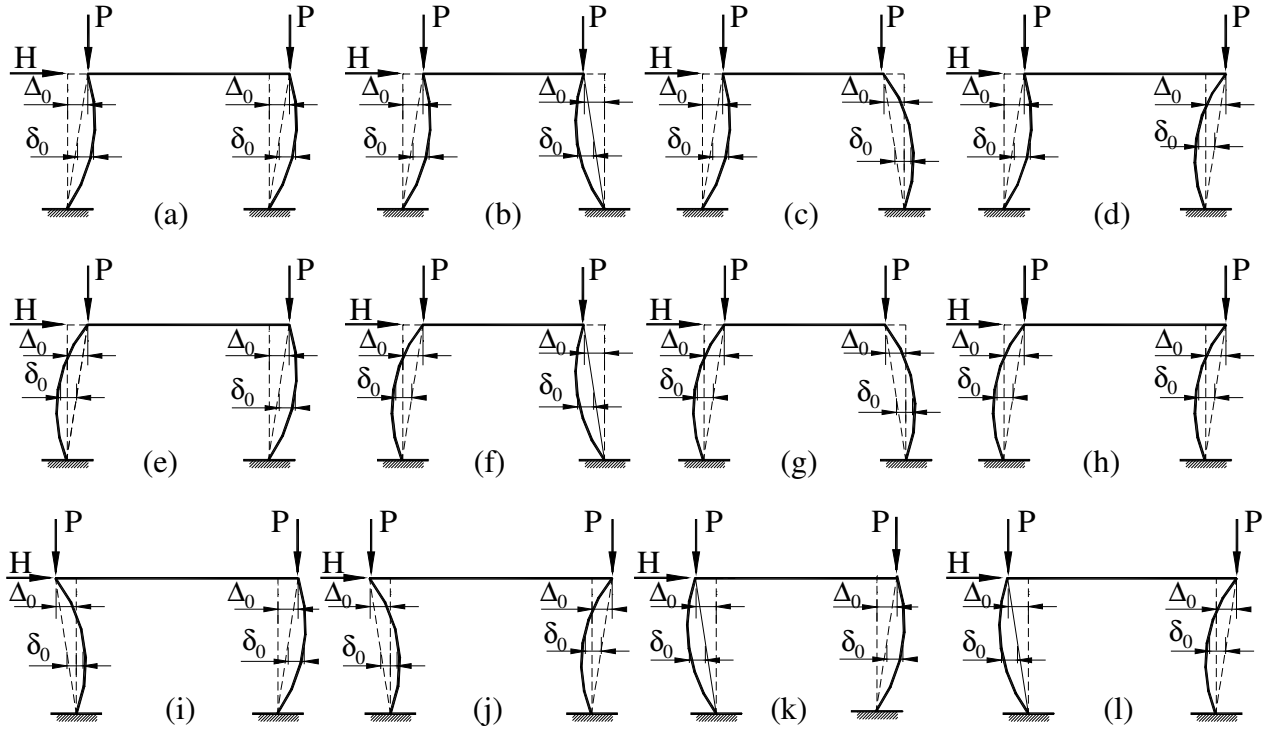
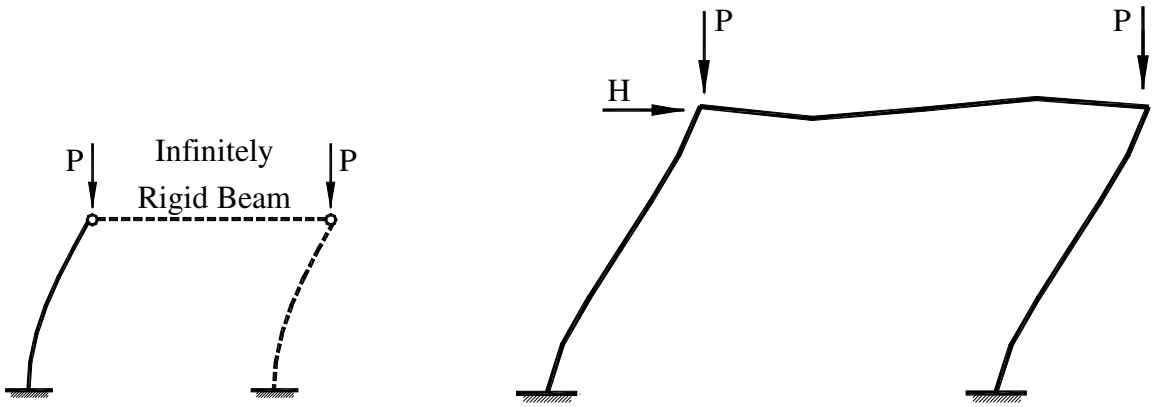
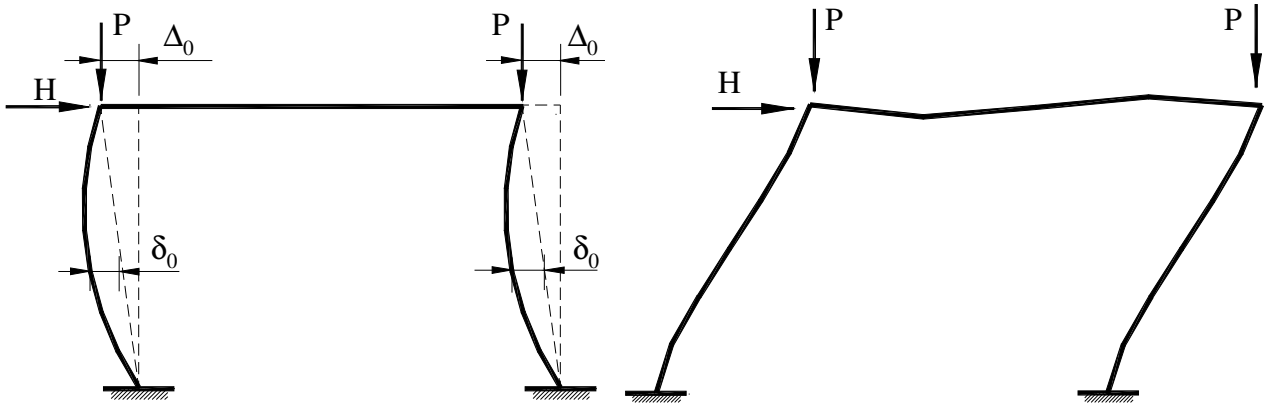


Figure 14: Combined initial geometrical imperfections of steel portal frame.



(a) Fixed-free column mounted as a frame. (b) Portal frame study: worst initial geometrical model.

Figure 15: Collapsed configuration using advanced analysis.



(a) Opposite of the worst geometrical configuration. (b) Correspondent collapsing deformed geometry.

Figure 16: Effect of opposite of the worst initial geometrical configuration model.

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Table 1: Collapse load factor λ of fixed-free column [23].

Case	Geometric Imperfection Models (1)	Figure (2)	λ : Hajjar *et al.* [23]		λ : Present Work (3)	
			No RS	With RS	No RS	With RS
1	No imperfection	–	1.000	–	0.7361 (3)	0.5972 (3)
2	OP	3b	0.750	0.681	0.7512	0.6839
3	OS (L or R)	2b	0.823	0.727	0.8239	0.7279
4	OP + OS L	10a	0.712	0.650	0.7148	0.6516
5	OP + OS R	10b	0.801	0.723	0.8019	0.7258

Notes: 1. Abbreviations: OP (out-of-plumbness), OS (out-of-straightness), RS (residual stress), L (left) and R (right); 2. Figures related to imperfect geometry; 3. Load P = λ F (the authors used F = 2000 kN; P_y = 1472.5 kN).

Table 2: Combination of initial geometric imperfections of the steel portal frame.

Load factor [%]	$H=\beta_H H_y$ (2)	OP + OS (1) a: ⌡⌡	b: ⌡⌊	c: ⌡⌉	d: ⌡⌠	e: ⌠⌡	f: ⌠⌊
λ_y (3)	β_H = 0.0	91.4	89.8	97.1	95.8	89.5	97.1
	β_H = +0.5	55.8	56.1	59.2	59.2	54.9	61.5
λ_{col} (4)	β_H = 0.0	92.7	93.4	97.6	97.4	93.5	97.6
	β_H = +0.5	64.5	64.9	67.5	68.0	65.0	68.5
Load factor [%]	$H=\beta_H H_y$	OP + OS (1) g: ⌠⌉	h: ⌠⌠	i: ⌉⌡	j: ⌉⌠	k: ⌊⌡	l: ⌊⌠
λ_y (3)	β_H = 0.0	95.9	92.4	97.1	95.9	95.8	97.1
	β_H = +0.5	58.1	57.9	59.0	59.1	57.9	61.3
λ_{col} (4)	β_H = 0.0	97.3	93.8	97.5	97.4	97.3	97.5
	β_H = +0.5	68.0	65.4	67.4	67.8	67.9	68.3

Notes: 1. Abbreviations: OP (out-of-plumbness) and OS (out-of-straightness); 2. Two loading cases: with H (β_H = 0.5) and no H (β_H = 0), where $H_y = 2M_p/L$, M_p is the section plastic moment and L is the column length; 3. λ_y: yield start; and 4. λ_{col}: collapse load factor.

Table 3: Advanced analysis of steel portal frame.

(a) With horizontal load H (β_H = 0.5)

Case	Geometry case (1)	Fig. (2)	Load factor [%] no RS (1) λ_y (3)	λ_{col} (4)	Load factor [%] with RS (1) λ_y (3)	λ_{col} (4)
1	No imperfection	11a	60.2	68.0	35.5	66.4
2	OS	12a	59.1	67.4	34.8	66.0
3	OP	13d	56.9	65.0	33.6	63.6
4	OS + OP combined	14a	55.8	64.5	33.0	63.3

(b) No horizontal load H (β_H = 0; only vertical 2P load)

Case	Geometry case (1)	Fig. (2)	Load factor [%] no RS (1) λ_y (3)	λ_{col} (4)	Load factor [%] with RS (1) λ_y (3)	λ_{col} (4)
1	No imperfection	11a	–	100.0	72.5	97.9
2	OS	12b	95.9	97.3	69.5	96.1
3	OP	13d	93.1	94.2	67.8	91.1
4	OS + OP combined	14a	91.4	92.7	66.5	90.3

Notes: 1. Abbreviations: OP (out-of-plumbness), OS (out-of-straightness) and RS (residual stress); 2. Figures related to imperfect geometry; 3. λ_y: yield start; and 4. λ_{col}: collapse load factor.