Updated Steel Column Hinge Modeling

Reference:

[1]: Beam column hinge modeling summarized by GUAN

[2]: Proposed updates to the ASCE 41 nonlinear modeling parameters for wide-flange steel columns in support performance-based seismic engineering

Background:

The file "Beam column hinge modeling summarized by GUAN" has summarized the findings for beam hinge modeling reported by Lignos. It says "until more experiments are conducted, the equations provided in the study could be used for columns".

More recently, the modeling for **column hinge** has been updated and is summarized in this file.

Modified IMK considers three types of deteriorations: **basic strength**, **post-peak strength**, and **unloading stiffness**.

The **reloading stiffness** deterioration is not reflected.

Equations for parameters

- Limitations are listed below:

  Column section size is between **W12** to **W36**.

  $3.71 <= h/t_w <= 57.5$

  $38.4 <= L_b/r_y <= 120$

  $0.0 <= P_g/P_{ye} <= 0.75$

  Steel section is made up of **ASTM A992 Gr. 50 Steel**.

- Pre-capping plastic rotation:

  Monotonic backbone:

$$\theta_p = 294 \cdot (\frac{h}{t_w})^{-1.7} \cdot (\frac{L_b}{r_y})^{-0.7} \cdot (1 - \frac{P_g}{P_{ye}})^{1.6} \leq 0.20\, rad$$

  First-cycle envelope:

$$\theta_p^* = 15 \cdot (\frac{h}{t_w})^{-1.6} \cdot (\frac{L_b}{r_y})^{-0.3} \cdot (1 - \frac{P_g}{P_{ye}})^{2.3} \leq 0.10 rad$$

- Post-capping plastic rotation:

  Monotonic backbone:

$$\theta_{pc} = 90 \cdot (\frac{h}{t_W})^{-0.8} \cdot (\frac{L_b}{r_y})^{-0.5} \cdot (1 - \frac{P_g}{P_{ye}}) \leq 0.30\, rad$$

First-cycle envelope:

$$\theta_{pc}^{*} = 14 \cdot (\frac{h}{t_w})^{-0.8} \cdot (\frac{L_b}{r_y})^{-0.5} \cdot (1 - \frac{P_g}{P_{ye}}) \leq 0.10\, rad$$

- Reference cumulative plastic rotation:

$$\Lambda_s = 255000 \cdot (\frac{h}{t_w})^{-2.14} \cdot (\frac{L_b}{r_y})^{-0.53} \cdot (1 - \frac{P_g}{P_{ye}})^{4.92} \leq\ 3.0, \quad \text{if } P_g/P_{ye} \leq\ 0.35$$
$$\Lambda_s = 268000 \cdot (\frac{h}{t_w})^{-2.30} \cdot (\frac{L_b}{r_y})^{-1.30} \cdot (1 - P_g/P_{ye})^{1.19} \leq\ 3.0, \quad \text{if } P_g/P_{ye} > 0.35$$
$$\Lambda_k = \Lambda_c = 0.9 \cdot \Lambda_s$$

- Effective yield strength:

$$M_y = M_y^{*} = 1.15 \cdot Z \cdot R_y \cdot F_{yn} \cdot (1 - \frac{P_g}{2P_{ye}}) \quad \text{if } P_g/P_{ye} < 0.20$$
$$My = M_y^{*} = 1.15 \cdot Z \cdot Ry \cdot F_{yn} \cdot \frac{9}{8}(1 - \frac{P_g}{P_{ye}}) \quad \text{if } P_g/P_{ye} \geq 0.20$$

- Residual strength ratio:

  Monotonic backbone:

$$k = M_r/M_y = (0.5 - 0.4 \cdot P_g P_{ye})$$

  First-cycle envelope:

$$k = M_r^{*}/M_y^{*} = (0.4 - 0.4 \cdot \frac{P_g}{P_y e}) \cdot M_y^{*}$$

- Ultimate rotation capacity:

  Monotonic backbone:

$$\theta_{ult} = 0.15$$

  First-cycle envelope:

$$\theta^{*}_{ult} = 0.08 \cdot (1 - 0.6 \cdot \frac{P_g}{P_{ye}})$$

- Peak flexural strength:

  Monotonic backbone:

$$M_{max} = a \cdot M_y$$
$$a = 12.5 \cdot (\frac{h}{t_w})^{-0.2} \cdot (\frac{L_b}{r_y})^{-0.4} \cdot (1 - \frac{P_g}{P_{ye}})^{0.4}, \quad 1.0 \leq a \leq 1.3$$

  First-cycle envelope:

$$a^{*} = 9.5 \cdot (\frac{h}{t_w})^{-0.4} \cdot (\frac{L_b}{r_y})^{-0.16} \cdot (1 - \frac{P_g}{P_{ye}})^{0.2} \quad 1.0 \leq a \leq 1.3$$

- Effective yield rotation:

$$\theta_y = M_y/K_e$$

- Elastic stiffness:

$$K_e = L^2 K_s K_b/[2(K_s + K_b)]$$
$$K_s = GA_w/L$$
$$K_b = 12EI/L^3$$

In all equations above, P_g is the gravity-induced compressive load. P_{ye} is the axial yield strength and is calculated based on expected steel material properties. F_{yn} is the nominal yield stress of steel material.