Constitutive relations for use in steel frame analysis

1 Beams and columns

The beams and columns of the frame will use fiber-discretized wide-flange sections, and the material used should be able to implement residual stresses. The intent of the strongback is to minimize damage to the surrounding frame; this damage must be able to be evaluated.

Proposed for now: Steel02

Proposed for later: Shen steel

1.1 Steel02 (Giuffré-Menegotto-Pinto)

Advantages

- Smooth transition from elastic to plastic behavior
- Relatively simple to set up—incorporated in section generators and installed by default

Disadvantages

- Parameters that control elastic-plastic transition are poorly defined
- Commonly used; no standout features

1.2 Shen Steel

Advantages

- Incorporates the yield plateau, which may be important for modeling these elements that provide less energy dissipation than the braces
- If desired, allows for better modeling of local buckling

Disadvantages

- May be overkill for these elements
- Will take more work to get running; I don't have the material on my installation of OpenSees.

1.3 Elastic-perfectly-plastic

Advantages

- Allows for direct setting of residual stress (through initial strain)
- Extremely simple, allowing effort to go to more critical elements/elements of interest

Disadvantages

- Zero stiffness elements can bork the analysis
- Simplicity can miss interesting behavior

2 Conventional braces

The braces are the primary energy-dissipating element of the frame, and will most commonly be HSS. W sections are also seen in the literature for use in the strongback. The sections will be fiber-discretized, and residual stresses should be available.

Proposed for now: Steel02

Proposed for later: Abdel-Rahman (HSS), Shen steel (W)

2.1 Abdel-Rahman

Advantages

- Specifically developed for use with cold-formed shapes like HSS, incorporating the residual stresses in the corners of such sections
- Multi-linear nature is easily explained and documented

Disadvantages

- Not as applicable to W sections
- Not installed on my machine

2.2 ShenSteel

Advantages

- Versatile and applicable to both W and HSS sections—can be used to incorporate both Lehigh and HSS residual stress patterns.
- Yield plateau useful for high-cycle low-strain analyses

Disadvantages

- Complicated; lots of parameters
- Not installed on my machine

2.3 Steel02 (Giuffré-Menegotto-Pinto)

Advantages

- Allows for direct setting of residual stress
- Smooth transition from elastic to plastic behavior
- Relatively simple to set up—incorporated in section generators and installed by default

Disadvantages

- Parameters that control elastic-plastic transition are poorly defined
- Commonly used; no standout features

3 Buckling-restrained braces

Buckling-restrained braces will eventually be incorporated into the strongback model. The complexity of a BRB means, somewhat paradoxically, that they frequently use very simple models fit to experimental data. Typically a single element is used, taking advantage of the lack of internal deformation to prevent buckling. Residual stresses are less important. Incorporating both kinematic and isotropic hardening is desired. Capturing the effect of fracture may be worth investigating, but may also be at such high loads as to be irrelevant.

3.1 Steel02

Advantages

- Examples of application to BRBs already exist in the literature
- Includes isotropic hardening
- Simple, quick to get up and running

Disadvantages

- Critical elements should probably receive more detailed simulation
- Not clear if it includes kinematic hardening

3.2 Zona and Dall'Asta

Advantages

- Incorporates both kinematic and isotropic hardening
- Specifically developed for BRBs, though still requires calibration
- Captures initial tangent and yield nicely, which other models miss—good for pushover analysis

Disadvantages

- No OpenSees implementation; has been done by Rossi (2014) but code is not publicly available
- Doesn't have a mechanism to capture fracture