HYSTERETIC MODELS FOR COLUMN BASE CONNECTIONS

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Column Bases in Steel moment frames in seismically active regions:

1. Are designed as strong-base weak-column systems.
2. The intention is to protect the base connection itself.
3. Column base connections are highly ductile with excellent dissipative characteristics.

Ref: Gomez et al., 2010
HYPOTHESIS

The performance of Steel Moment Resisting Frames could be improved (e.g., reduction of the probability of collapse, and interstory drifts ratios) once flexibility and ductility capacity of column base connections are considered.
EXPOSED COLUMN BASE CONNECTIONS

COMPONENTS

• Steel Column
• Base Plate
• Grout
• Concrete Foundation
• Anchor Rods

LOAD CARRYING MECHANISM

Applied force and moment
Tensile forces in anchor rods
Bearing stresses in footing

Ref: Gomez et al., 2010

Strength
Stiffness
PHYSICS OF CONNECTION RESPONSE

PHASE I: ELASTIC
- Elastic loading

PHASE II: STRAIN HARDENING
- First yield – Flexural yielding of base plate

PHASE III: PEAK STRENGTH
- Mechanism with two yield locations

PHASE IV: UNLOADING
- Elastic unloading

PHASE V: PLATEAU
- Loss of contact with nut/washer and free motion of plate
- Moment carried by eccentric bearing

PHASE VI: UNLOADING
- Contact with grout leading to rapid unloading

Ref: Torres et al. (2016)
MODEL FORMULATION

Parameters defining Backbone Curve:
- Moment at first yield $M_y$
- Initial Elastic Stiffness $K_{initial}$
- Peak Moment $M_{peak}$
- Rotation at Peak Moment $\theta_{II}$

Ref: Torres et al. (2016)
PARAMETERS OF THE MODEL

PHYSICS -BASED

- Moment at first yield $M_Y$
- Elastic stiffness $K_{\text{initial}}$
- Peak moment $M_{\text{peak}}$
- Moment associated with the plateau $M_{\text{initial plateau}}$

EMPIRICAL

- Rotation at peak strength $\theta_{II}$
- Two parameters associate to each mode of deterioration $c, \Lambda$
- Model parameter to define the intermediate plateau $\rho$
- Two parameters defining pinching rules $F_{pr}, a_{\text{pinch}}$
EVALUATION OF THE MODEL

Test #1

Test #2

Test #4

UNCONSTRAINED CALIBRATION

Pu = 411KN
tp = 50.8mm

Pu = 411KN
tp = 38.1mm

Pu = 411KN
tp = 38.1mm

Pu = 0
tp = 25.4mm
EMBEDDED BASE CONNECTIONS

Horizontal Bearing Stresses

Vertical Bearing Stresses

Modes of Failure:

- Horizontal bearing failure
- Joint Shear Failure

Modes of Failure:

- Bearing failure of concrete above/below base plate
- Concrete breakout on the compression side
- Concrete breakout on the tension flap of base plate
- Yielding of the base plate

\[ M_{base} = M_{VB} + M_{HB} \]
\[ M_{VB} = \alpha \times M_{base} \]
\[ M_{HB} = (1 - \alpha) \times M_{base} \]

\[ \alpha = 1 - \frac{d_{embedment}}{d_{reference}} \]

\[ d_{reference} = \frac{C_o}{\rho_o} \]

- Effective resisting stiffness of concrete
- Stiffness of the steel column
- Experimental investigation

Ref: Grilli and Kanvinde (2015)
PHYSICAL RESPONSE

PHASE I: ELASTIC

PHASE II: PEAK STRENGTH

PHASE III: UNLOADING

PHASE IV: RE-LOADING

PHASE V: RE-LOADING

PHASE VI: RE-LOADING
MODEL FORMULATION

HORIZONTAL BEARING STRESSES

Vertical Bearing Stresses

VERTICAL BEARING STRESSES

Base Moment

HYSTERETIC RULES AND MODE OF DETERIORATION

1. Unloading stiffness deterioration
2. Strength deterioration
CONSTRAINED CALIBRATION

PARAMETERS OF THE MODEL

PHYSICS -BASED

- Yield Moment $M_Y$
- Elastic stiffness $K_{	ext{initial}}$
- Peak moment $M_{\text{peak}}$

EMPIRICAL

- Rotation at peak strength $\theta_{II}$
- Two parameters associate to each mode of deterioration $c, \Lambda$
- Two parameters defining pinching rules. $F_{pr}, a_{\text{pinch}}$
EVALUATION OF THE MODEL

Test #1

Base rotation \( \theta \) (Radians)

Base moment (kN-m)

Pu=445KN
demb=508mm

Test #3

Base rotation \( \theta \) (Radians)

Base moment (kN-m)

Pu=0KN
demb=762mm

Test #4

Base rotation \( \theta \) (Radians)

Base moment (kN-m)

Pu=445KN
demb=762mm

UNCONSTRAINED CALIBRATION
CONCLUSIONS AND LIMITATIONS

1. The models are able to reproduce key characteristics of experimental response.
2. The models are recommended for simulating base connections in SMFs.
3. The models are validated against a relatively small data set.
4. Extrapolating the models to highly dissimilar connections may introduce significant error.
5. Cannot simulate axial force and moment interaction.