P-Delta and
Minimum Base Shear
Min. Base Shear

• \( V = (0.8Z N_v I/R)W \) for drift limitation?
• Is it for ground motion uncertainty or "modeling" uncertainty or both?
• Let’s say explicitly what it is for!
• Should be the same "enforcement" as for code-conforming structures
• If for modeling uncertainties and alternative design, then it belongs to Level 3 – if for collapse safety?
Collapse Safety + Drift $\equiv$ P-Delta

P-Delta is controlled by

- $P$ (large in lower stories)
- Delta - but inelastic $\delta$
- Collapse mechanism
- Length of post-yield “plateau”
- Effective post yield stiffness
- Deterioration
- Frame problem very diff. from wall problem
Pushover Deflection Profiles, without and with P-delta -- N =18, T = 3.6 -- Frame

T₁ = 3.6 s, N = 18, α = 0.03

parabolic load pattern

Normalized Roof Displacement, \( x_r / x_{ry} \)
Global Pushover Curve, without and with P-Delta -- N =18, T = 3.6 -- Frame

\[ T_1 = 3.6 \text{ s}, N = 18, \text{parabolic load pattern} \]

hardening ratio:
- $\alpha = 0$
- $\alpha = 0.03$
- $\alpha = 0.06$

\[ \theta_{s1} = 0.130 \]
\[ \theta_{s1} = 0 \]
Global Pushover Curve, LA-20, without and with P-Δ

ROOF DRIFT ANGLE vs. NORMALIZED BASE SHEAR
Pushover (NEHRP '94 k=2 pattern): LA 20-Story, Pre-Northridge, M1, M1-NPD

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Sensitivity to Strain Hardening, Pushover, LA-20

ROOF DRIFT ANGLE vs. NORMALIZED BASE SHEAR
Pushover: LA 20-Story, Pre-Northridge, Model M2, \( \alpha = 0\%, 3\%, 5\%, 10\% \)

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Elastic and Inelastic Stability Coefficient

$N = 18$, $T = 3.6 -- Frame$

GLOBAL PUSHOVER CURVES

$N = 18$, $T_1 = 3.6$, BH, Peak Oriented Model, LMSR-N, $\xi = 5\%$,

$\alpha_s = 0.03$, $\delta_c / \delta_y = \text{Inf}$, $\alpha_c = \text{N.A}$, $\gamma_{s,c,k,a} = \text{Inf}$, $\lambda = 0$

Normalized Strength, $V/V_y$

Normalized Roof Displacement, $\delta_r / \delta_{yr}$

$K_0$, $\alpha_{x_0} K_0 = 0.04 K_0$, $\theta_i = 0.37$, $\theta_e = 0.09$

Pushover Curve with P- $\Delta$ Effects
Pushover Curve w/o P- $\Delta$ Effects

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Effect of P-Delta on Median Collapse Capacity (Deteriorating Frame Systems)

EFFECT OF $P-\Delta$ ON MEDIAN $[S_{a,c}(T_1)/g]/\gamma$

$N=\text{Var}$, $T_1=\text{Var}$, BH, Peak Oriented Model, LMSR-N,

$\xi=5\%$, $\alpha_s=0.03$, $\delta_c/\delta_y=4$, $\alpha_c=-0.10$, $\gamma_{s,c,k,a}=\text{Inf}$, $\lambda=0$

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Effect of P-Delta on Median Collapse Capacity (as function of base shear yield coefficient)

Frames versus Walls (8-story)

P-Delta Effect on $\eta_c$ (MRF)

$N = 8, T_1 = 1.2, \gamma = \text{var.}, \text{Stiff.&Str. = Shear, SCB = 2.4-1.2, } \bar{\xi} = 0.05$

$\theta_p = 0.03, \theta_{\mu}/\theta_p = 5.0, \lambda = 20, M_c/M_y = 1.1$

P-Delta Effect on $\eta_c$ (SW)

$N = 8, T_1 = 0.8, \gamma = \text{var.}, \text{Str. = var., } \bar{\xi} = 0.05$

$\theta_p = 0.02, \theta_{\mu}/\theta_p = 1.0, \lambda = 20, M_c/M_y = 1.1$
So, what’s the point?

- P-Delta, which is amplified by deterioration, causes collapse (not the only source)
- P-Delta effect is very sensitive and not straightforward to predict
- We should safeguard against prediction errors
- But min. base shear does not look like the right vehicle to do so
- In codes: establish a limit on $P\delta/(V_yh)$?