Concrete Tilt-Up Panels: Retrofitting Panels Beyond Their Design Limits

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Limits

- Only discussing the panels themselves
  - Ignoring impacts to foundations, roof framing
- Assumes we have good knowledge on existing panels
- No other deficiencies
- New openings can create lateral issues
- ACI 318-19

New Openings

Problem Statement:

Existing concrete wall requires a new 10 ft wide opening, because of course it does. Design strongback and check wall.

New Openings

<u>Existing Panel Information</u>

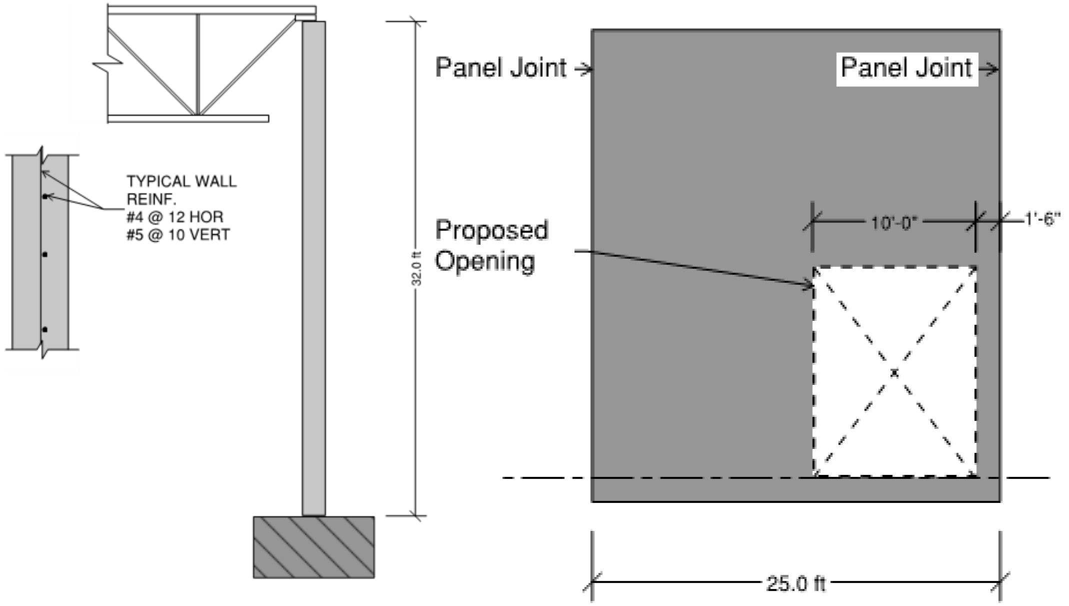
High Bay Warehouse

8" concrete panel
f'c = 4,500 psi
Top bearing joists at 6'-3"oc
Solid panel, No reveals
60 ft end bay

ROOF_DL = 16 psf, 480 lbs/ft
ROOF_SL = 24 psf, 720 lbs/ft
WIND LOAD = 28 psf

Per 1 ft Width of Wall

P_{DL} = 2.03 kip M_{DL} = 1.92 kip-in
P_{SL} = 0.72 kip M_{SL} = 2.88 kip-in
P_{WL} = 0 kip M_{WL} = 43.0 kip-in

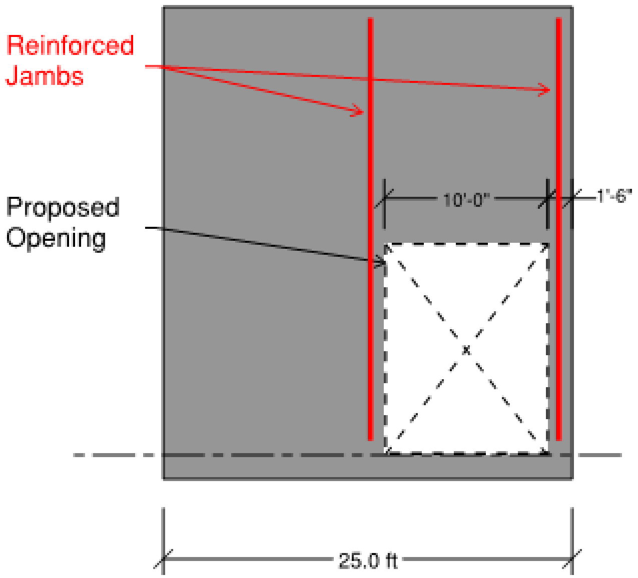


Solid Panel Demand / Capacity Ratio = 0.92
Deflection of Solid Panel = 0.214 in (h/1790)

New Openings

Strengthening

- Most common strategy is strongbacks
  - –Let's gravity stay in the wall
  - –May not require modifying anything but wall
  - –Doesn't require shoring or temp support



New Openings

Analysis - Direct Load

10 ft opening, 18” jamb

- Design strongback to resist Mu

  = 292 kip-in (24.3 kip-ft)

- Design panel to resist Pu

  = 23.3 kip

Ultimate Load Combinations (per ft)

Ultimate Load Cases

	Load Combinations	Pu (k)	Mua (k-in)
a.	1.4*DL	2.84	1.34
b.	1.2*DL + 1.6*LL + 0.5*SL	2.79	1.87
c.	1.2*DL + 1.6*SL +0.5*LL	3.58	3.46
d.	1.2*DL + 1.6*SL + 0.5*WL	3.58	24.96
e.	1.2*DL + 1.0*WL + 0.5*LL + 0.5*SL	2.79	44.88
f.	0.9*DL + 1.0*WL	1.82	43.87

Service Load Combinations (per ft)

	Service Load Combinations	Ps (k)	Msa (k-in)
h.	1.0*DL	2.03	1.92
j.	1.0*DL + 1.0*SL	2.75	2.40
k.	1.0*DL + 0.75*SL +0.75*LL	2.57	2.04
l.	1.0*DL + 0.6*WL	2.03	26.76
m.	1.0*DL + 0.75(0.6)*WL + 0.75*LL + 0.75*SL	2.57	21.39
n.	0.6*DL + 0.6 WL	1.22	26.38

New Openings

- Size steel for all the moment: **W8x18**

  L_p= 4.34 ft for ϕM_p = 63.8 kip-ft

  Δ_{STEEL} = 1.44 in (service) = h/267

  No additional demand to ‘stabilize’ the wall

New Openings

Let the concrete do the work, keep it from falling

- From ACI 318, 6.2.5.1: Column is braced at 'level' if 12x gross stiffness of column
- **W12x136 (or $\frac{W18x76}{W16x89}$)**

  I_g = 768 in^4, n = 7.59

  I_{STL_REQD} = 768 / 7.59 * 12 = 1,214 in^4

  $I_{W12x136}$ = 1240 in^4

New Openings

Check the concrete section

Evaluate Demand ≤ Capacity

- Demand (Required Strength) per 11.4
  - 6.6.4 (moment magnification), 6.7 (elastic), 6.8 (inelastic) or 11.8 (slenderwall)
- Capacity (Design Strength) per 11.5
  - 22.4 (P/M curve), 11.5.3 (simplified) or 11.8 (slenderwall)

New Openings

Capacity

- 6.6.4 & 6.7 use critical buckling load, Pc to magnify moment (δ)

$$\delta = \frac{Cm}{1 - \frac{Pu}{0.75 \times Pc}}$$

$$Pc = \frac{\pi^2 \times (EI)_{EFF}}{(kh)^2}$$ =18.1 k (Pu = 23.3 k)

~~6.6.4~~, ~~6.7~~, ~~6.8~~, 11.8

New Openings

Capacity using Slenderwall?

- Axial load < 0.06 f'c - works
- Δ_{cr} = 0.505 in, $\Delta_{U\text{-}STL}$ = 2.4 in – wall will crack
- ϕMn > Mcr?

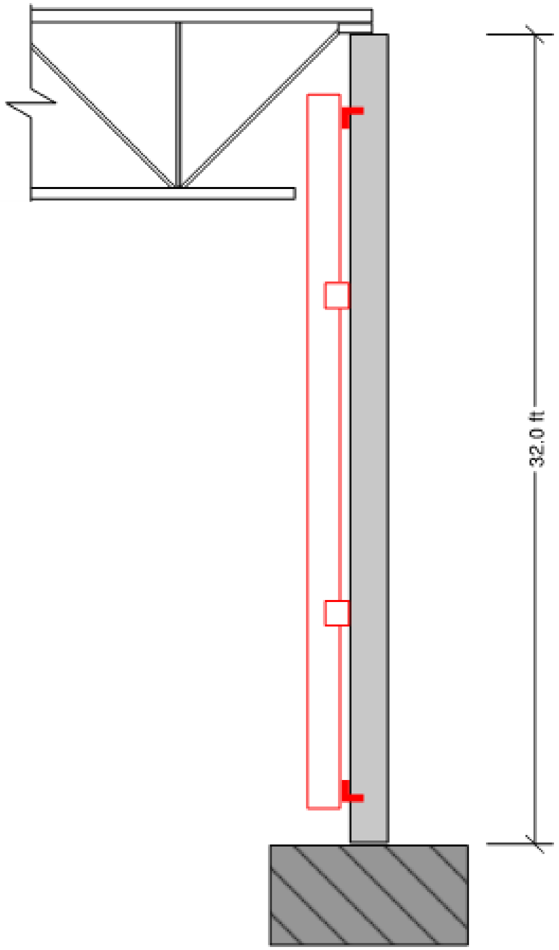
New Openings

Alternative Approach: Steel for everything

- If axial load is reasonable, transfer to steel then back into wall
- (8) 5/8” Epoxy bolts at top & bottom

  or

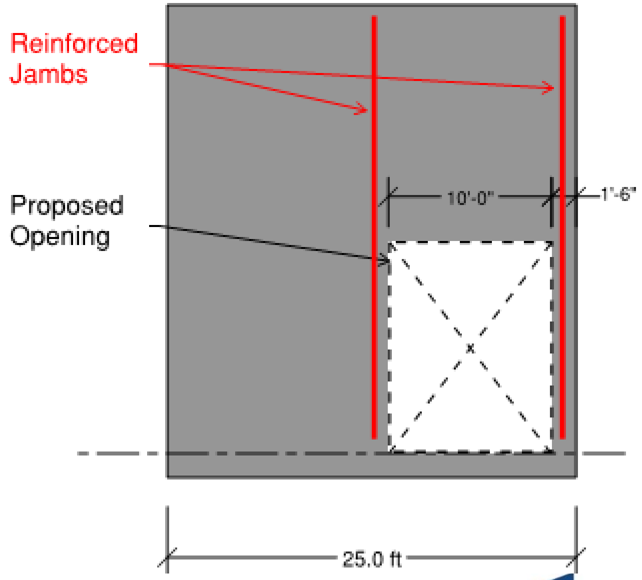
- Or connect with bearing
- W8x18 beam-column, D/C = 0.88



New Openings

Alternative Approach: Steel & concrete together

- Composite section – AISC now specifies this, but not for our section
- Steel section still the workhorse



New Openings

Alternative Approach: Composite Section

- Try W16x31
- Concrete as a tension limit state
- ϕf_{cr} = 302 psi, f_b = 435 psi
- Shear flow, at end q_u = 7.4 k
- Rebar + W16?

New Openings

Alternative Approach: Concrete strongback

- –Account for new eccentricity & new weight
- –Slenderwall acceptable
- –Could be designed compositely, utilizing existing depth *or just the new section*
- –Transfer between concrete strongback & wall

New Openings

Proposed Requirements

- For walls, consider wall braced with strongback stiffer than all of 12 x Icr, 4 x Ig, unmodified panel deflection
- Strongback needs to resist 2% of vertical load at each connection in addition to any applied out of plane load
- Connections spaced no more than 4 x wall thickness

New Openings

Proposed Requirements

- Strain in concrete needs to be less $\varepsilon_c < 0.003$
- Braced wall needs to resist axial load and moment imposed by deflection in strongback
- No second order in wall
- Strongback must extend beyond opening no less than the largest dimension of the opening, up to the extents of the panel as required to develop the solid panel

New Openings

Design Jamb (again)

- External Loads: Pu = 23.3 k, Mu = 24.3 kip-ft
- Brace strongback ≤ 32-in on center
- Bracing demand = 0.02 x 23.3 k / 4 ft = 0.117 k/ft, Mu = 15.0 k-ft
- Total Moment = 39.3 k-ft
- $I_{STL} \geq 73.5$ and 405 in^4 **W16x36**, ϕMp = 240 k-ft, Lp = 5.37 ft, Δu = 0.32 in
- Concrete Demand: Pu = 23.3 k, Mu = 4.9 k-in
- Concrete Capacity: ϕPn = 304 k, ϕMn = 139 k-in

Axial Loading Controlled

Problem Statement

Design panel with new 10 ft opening under joist-girder

Axial Loading Controlled

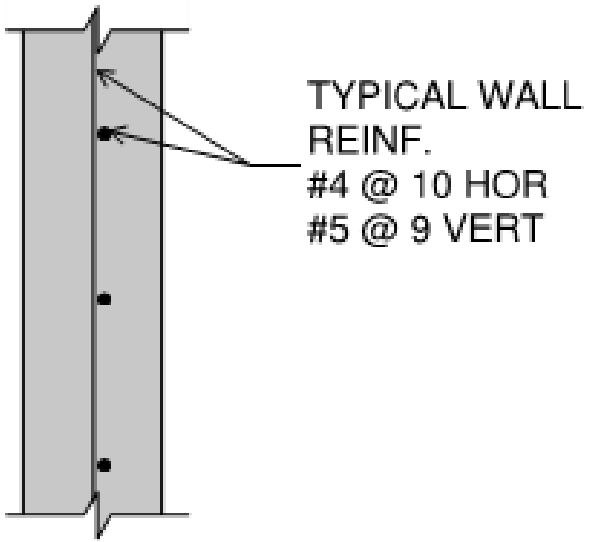
Existing Panel Information

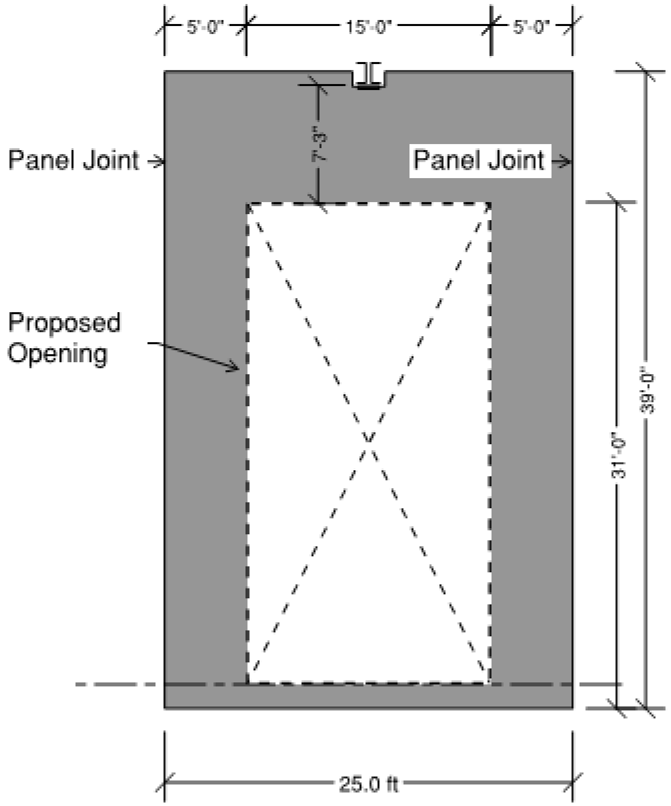
High Bay Warehouse
Girder Reaction

9 1/4" concrete panel
f'c = 4,500 psi
Joist Girder in pocket
Solid panel, No reveals
50 ft x 50 ft tributary bays

ROOF_DL = 18 psf, 22.5 kips
ROOF_SL = 22 psf, 27.5 kips
WIND LOAD = 31 psf

Joist-Girder Support
(2) Layers of (6) #6 @ 8" oc
& #3 tie cage

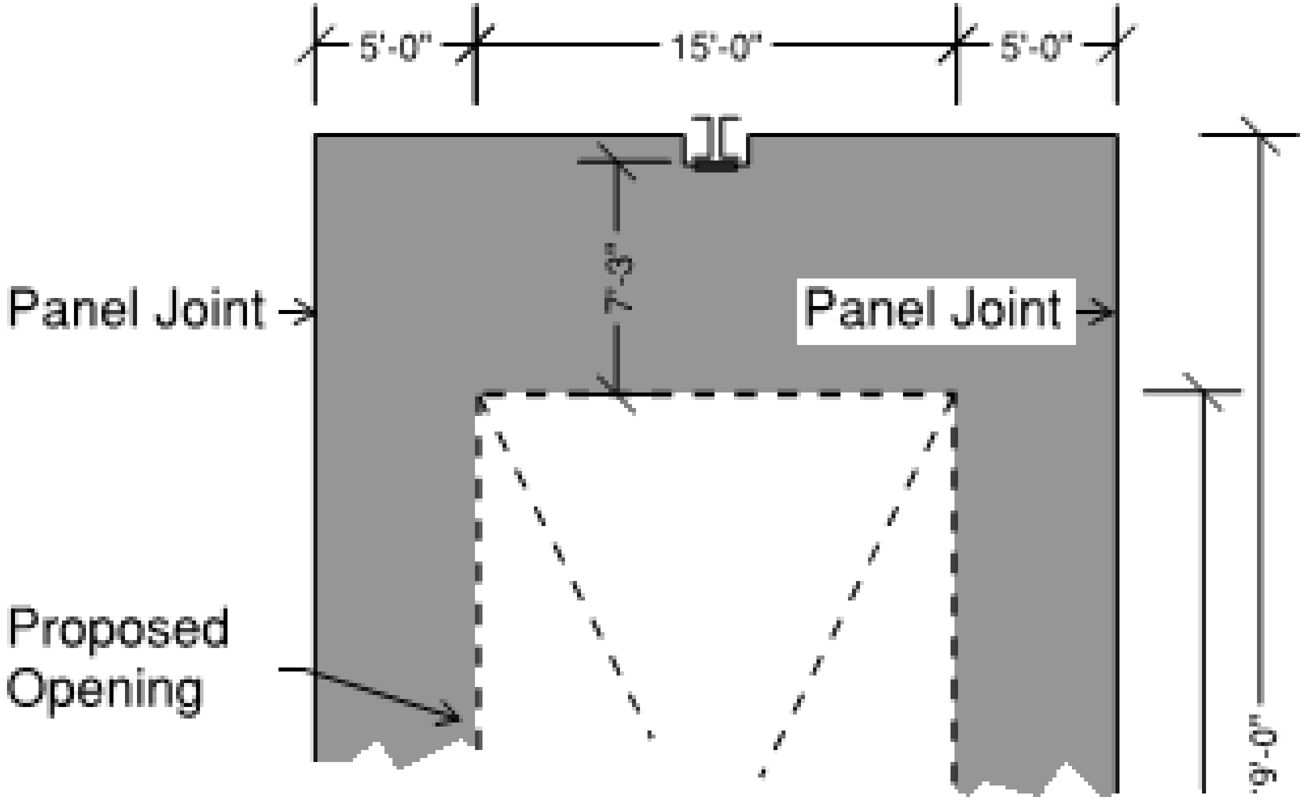




Axial Loading Controlled

Design Header

- Check existing rebar details
- Plain or deep?
- Depth to rebar



Axial Loading Controlled

Design Header

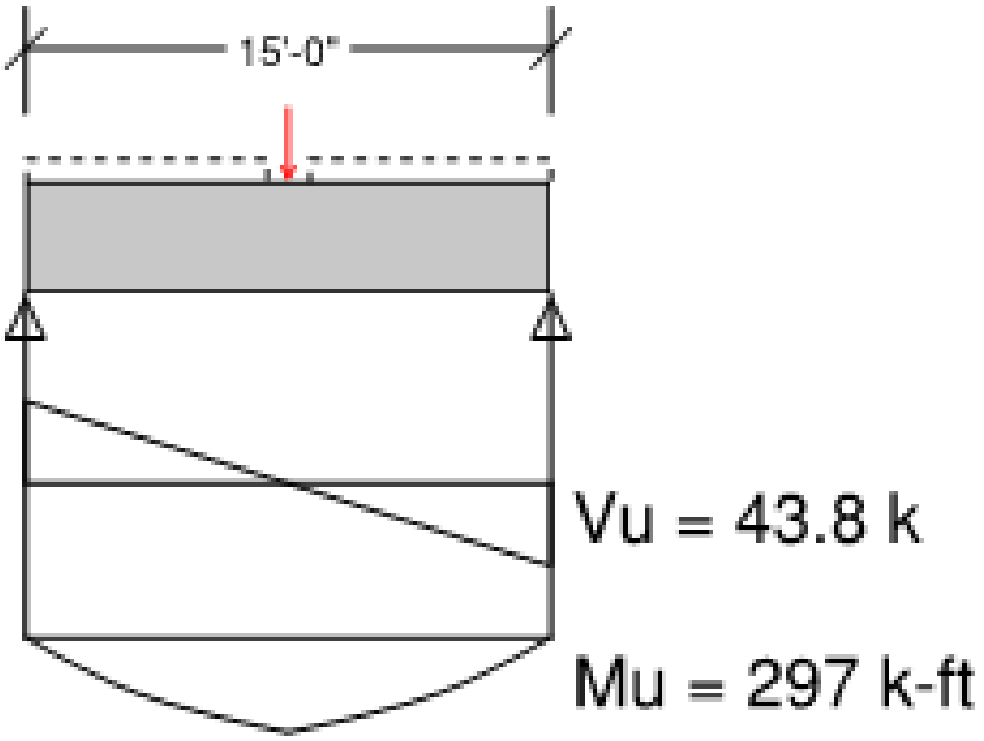
- Reinforced Beam Capacity

  ϕMn = 138 k-ft

  ϕVc/2 = 35.8 k

  Mcr = 244 k-ft

Reinforce that panel

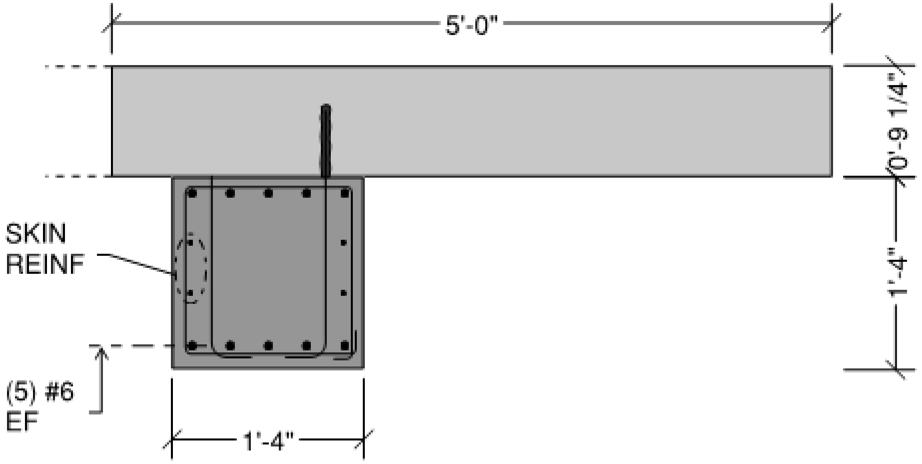


Axial Loading Controlled

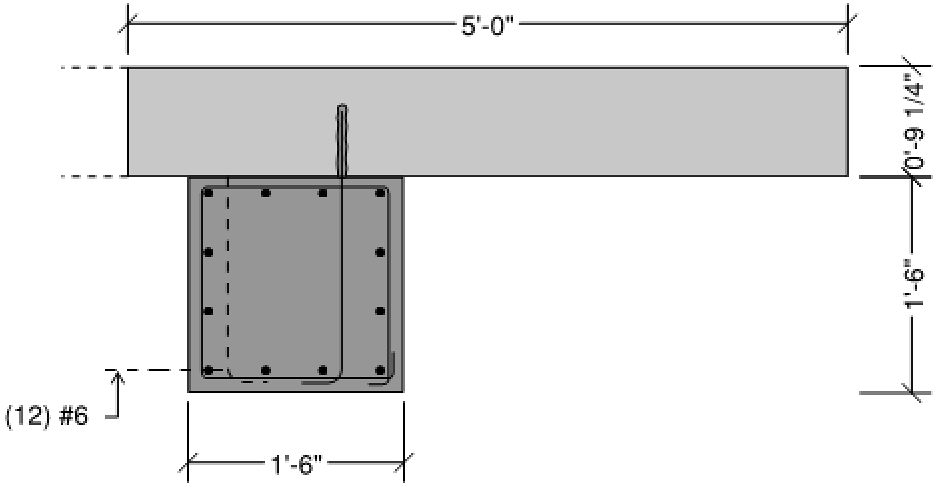
Reinforcing Jambs

- Space allowing, make it a wall
- Pu_max = 57.5 k
- 6% f'c = 270 psi (213 in^2) ~ 16x16
- 10% f'c = 450 psi (128 in^2) ~ 12x12

Axial Loading Controlled



Wall

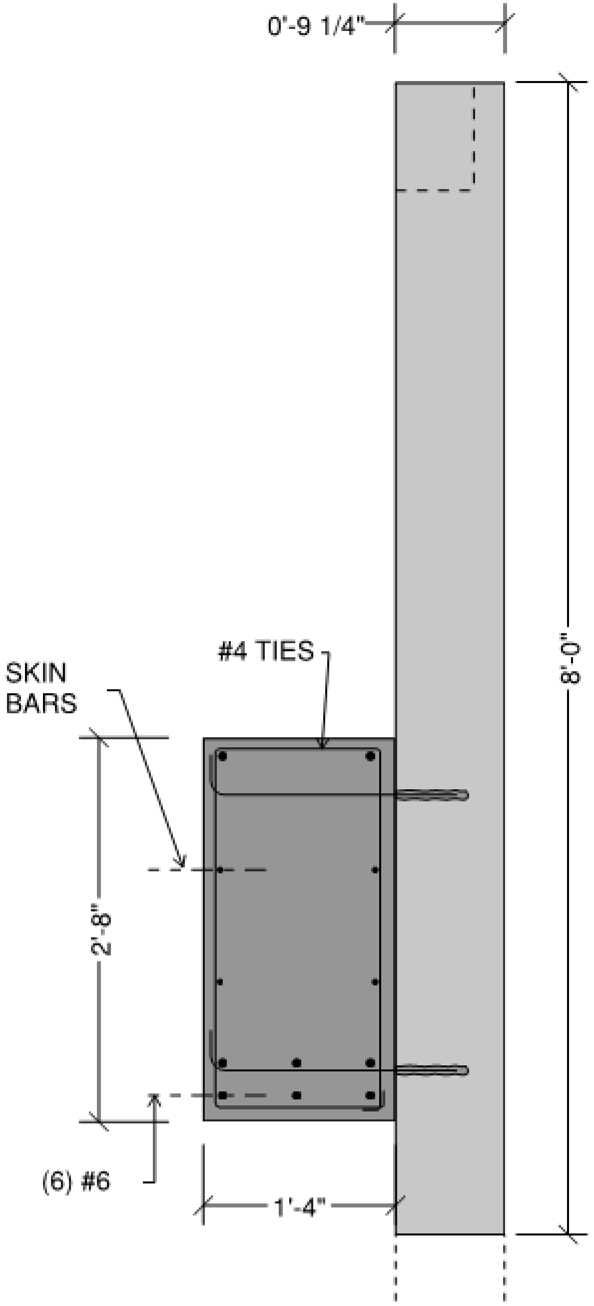


Column

Axial Loading Controlled

Reinforcing Header

- Torsion in beam
  - Can be resisted by kickers
- Dowels into existing panel
  - Concentrated at girder
- Stiffness of wall / new beam



Axial Loading Controlled

Reinforcing Header

- Steel Option: W21x44
  - –Needs torsional restraint of wall
  - –HSS18x6x1/2 alternative with torsion resistance
  - –Deflection limit?
  - –Horizontal slots in bolted connections?

Axial Loading Controlled

Code requirements

- Limitations for deflection undefined
- Header concrete properties:
  - $I_g = 352{,}000\ in^4$
  - $I_{cr} = 17{,}600\ in^4$
  - $I_{stl} = n \times I_{W21} = 6{,}390\ in^4$

Questions

Special Thanks to the 551 Committee

Mark Johnson, PE

Johnson Structural Group

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