OPEN FORUM
PROBLEMS AND SOLUTIONS

The comments and opinions expressed herein are those of the contributing author and do not necessarily reflect official PCI policy. Some of the provided answers may have alternate solutions. Reader comments are invited.

Double Tees With Extreme Daps

Q1: A precast, prestressed concrete parking structure, using double tees with 60 ft (18.3 m) spans, was recently erected in the Northeast United States. The double tees were 11 ft (3.35 m) wide and 2 ft 10 in. (0.86 m) deep.

Due to severe headroom limitations, the double tees were required to be fabricated with unusually deep daps at their ends. A height of 1 ft 8½ in. (0.52 m) was dapped out of the 2 ft 10 in. (0.86 m) deep double tees leaving a 1 ft 1½ in. (0.34 m) nib dimension. Because of this constraint, the likelihood of inferior dap performance and cracking during both stripping at the plant and normal service conditions was greatly increased.

Under normal circumstances, a design engineer could turn to the section on daps in the PCI Design Handbook.[1] Unfortunately, in the case of members with extreme daps, such cases are not covered in the Handbook dap provisions. The question, then, is how should one proceed in designing double tees for these extreme daps?

A1: Section 4.6.3 of the PCI Design Handbook[1] contains design provisions for daps which are not more than one-half the depth of the full member and the shear span to nib depth ratio is not more than 1.0. In this severe condition, the dap is much greater than one-half the depth of the full member.

To solve the problem, the method advocated by Mattock and Theryo[2] was used to complete the dap design. Specifically, Reinforced Scheme II was employed. Detailed calculations are shown in an Appendix section that follows. Note that in the design, a minimum of one prestressing strand passed above the dap to reduce the prestress transfer tensile stresses at the re-entrant corner.

By using this design method, cracking was eliminated

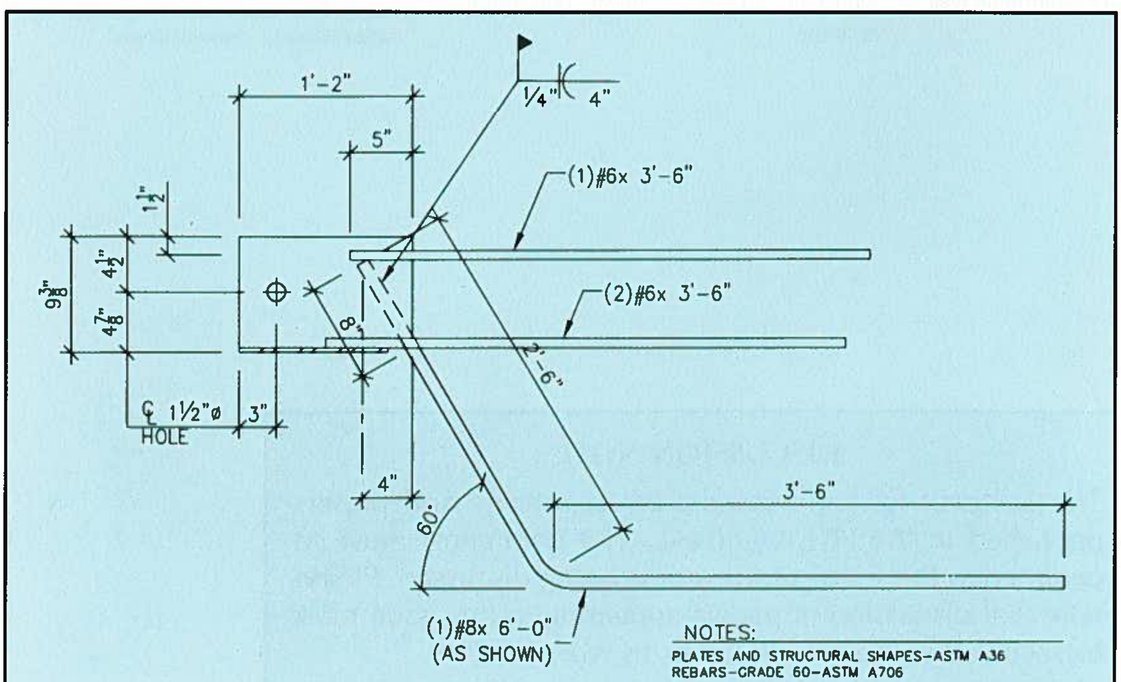


Fig. 1. Elevation of extreme dap bearing plate.

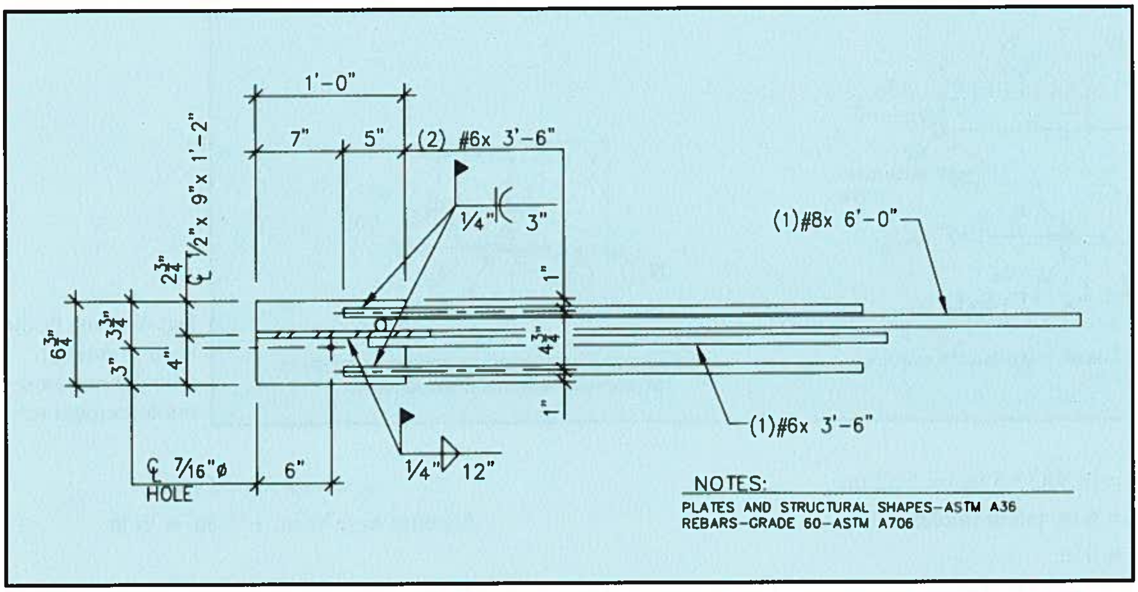


Fig. 2. Plan of extreme dap bearing plate.

during fabrication stripping and these double tees are continuing to perform well in service. The bearing plate and end reinforcing details are shown in Figs. 1, 2 and 3. For background material on the design method, see Ref. 2.

REFERENCES

1. *PCI Design Handbook – Precast and Prestressed Concrete*, Fifth Edition, Precast/Prestressed Concrete, Chicago, IL, 1999, pp. 4-59 to 4-63.
2. Mattock, A. H., and Theryo, T., "Strength of Members with Dapped Ends," Research Project No. 6, University of Washington, Seattle, WA, pp. 87-90.

[*Contributed by David Nasser*
The Consulting Engineers Group
San Antonio, Texas]

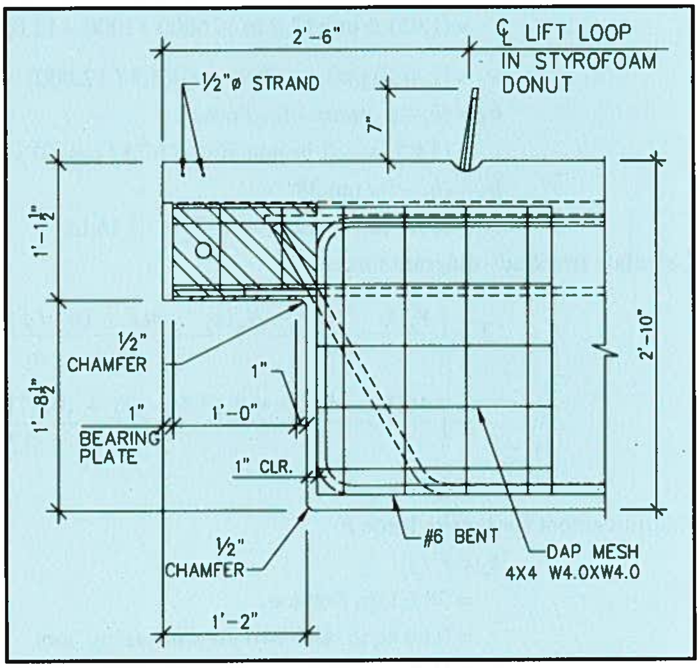


Fig. 3. Extreme dap reinforcing design summary.

APPENDIX – DETAILED CALCULATIONS

For a 60 ft Double Tee Span (11 DT 34):

Double tee weight: Dead load = 86 psf

Parking floor: Live load = 50 psf

Dead load = (86 psf)(11 ft / 2)(60 ft / 2) = 14.2 kips

Live load = (50 psf)(11 ft / 2)(60 ft / 2) = 8.3 kips

$V_u = 1.4(14.2) + 1.7(8.3) = 34$ kips

Take $N_u = (0.2)V_u = 6.8$ kips

$N_n = N_u / \phi = 6.8 / 0.85 = 8$ kips

$V_n = V_u / \phi = 34 / 0.85 = 40$ kips

$f'_c = 6000$ psi

$f_{y\,plate} = 36$ ksi

$f_{y\,rebar} = 60$ ksi

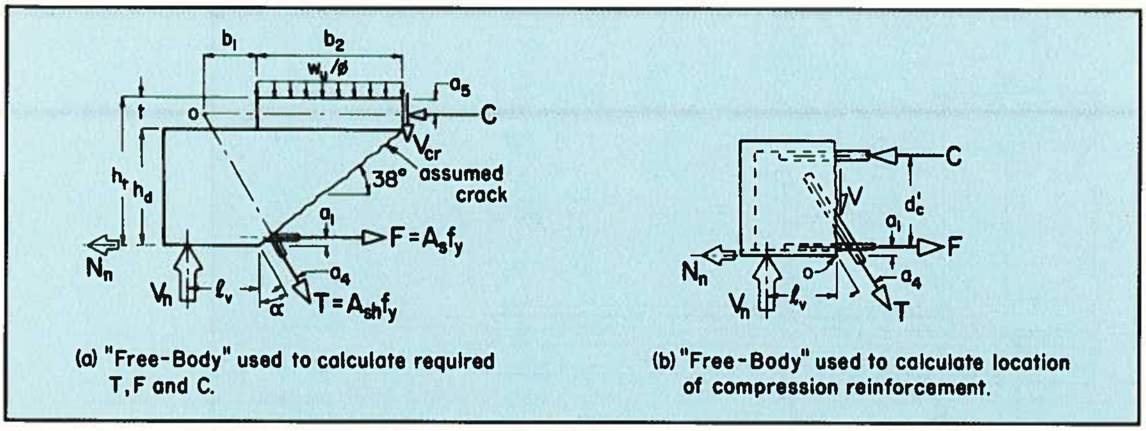
For shear take $\phi = 0.85$

Using Reinforcement Scheme II from PCI Research Project No. 6 (Ref. 2) [see Fig. A].

From dap geometry:

$d_d = 0.9\ h_d$

Assume $a_5 = t / 2$



(a) "Free-Body" used to calculate required T, F and C.

(b) "Free-Body" used to calculate location of compression reinforcement.

Fig. A. "Free Bodies" used in strength calculations for second reinforcement scheme.

$d_d = (0.9)(13.5 \text{ in.}) = 12.2 \text{ in.}$

$b_d = 6 \text{ in.}$ (stem thickness)

$l_v = 8 \text{ in.}$

$V_{CR} = 1.95 b_d d_d \sqrt{f'_c}$

$= (1.95)(6 \text{ in.})(12.2 \text{ in.})\sqrt{6000} / 1000 = 11.0 \text{ kips}$

$w_u = [1.4(50 \text{ psf}) + 1.7(50 \text{ psf})](5.5 / 12{,}000) = 0.071$ kips per in.

$b_1 = (h_t - a_5)\tan\alpha - (a_4 / \cos\alpha)$

$= (13.5 \text{ in.} - 2 \text{ in.})\tan 30^\circ - (1.75 / \cos 30^\circ) = 4.62 \text{ in.}$

$b_2 = (h_t - t) / \tan 38^\circ$

$= (13.5 \text{ in.} - 4 \text{ in.}) / \tan 38^\circ = 12.16 \text{ in.}$

$a_5 = 4 \text{ in.} / 2 = 2 \text{ in.}$

Assume $a_1 = 3/8 \text{ in.} + 1/2 \text{ in.} = 7/8 \text{ in.}$

Assume $a_4 = 1\,1/2 \text{ in.}$

Assume $\alpha = 30^\circ$

Calculate free body diagram forces:

$$F = \left(\frac{V_u(l_v - b_1) + N_n(h_t - a_5) + (w_u / \phi)(b_2)(b_1 + b_2/2) + V_{CR}(b_1 + b_2)}{(h_t - a_5 - a_1)} \right)$$

$$= \left(\frac{40(8 - 4.62) + 8(13.5 - 2) + (0.071/0.85)(12.16)(4.62 + 12.16/2) + 11(4.62 + 12.16)}{[13.5 - 2 - (7/8)]} \right)$$

$= 38.6 \text{ kips}$

Reinforcement for tensile force F:

$A_s = F / f_y$

$= 38.6 \text{ kips} / 60 \text{ ksi}$

$= 0.64$ sq in. Use two #6 reinforcing bars.

$T = V_n / \cos\alpha$

$= 40 \text{ kips} / \cos 30^\circ$

$= 46.1 \text{ kips}$

Reinforcement for tensile force T:

$A_s = T / f_y$

$= 46.1 \text{ kips} / 60 \text{ ksi}$

$= 0.77$ sq in. Use one #8 reinforcing bar.

$C = -N_n + T(\sin\alpha) + F$

$= -8 + 46.1(\sin 30^\circ) + 38.6$

$= 53.6 \text{ kips}$

$d'_c = -a_1 + (V_n l_v + T a_4 + F a_1) / C$

$= -7/8 + [40(8) + (46.1)(1.75 \text{ in.}) + (38.6)(7/8) \text{ in.})] / 53.6 \text{ kips}$

$= 8.10 \text{ in.}$

Height of vertical plate not less than $(d'_c + a_1)$:

$d'_c + a_1 = 8.9 \text{ in.}$

Use a 9 in. vertical plate.

NOTE:
1 ft = 0.3048 m
1 in. = 25.4 mm
1 psi = 0.006895 MPa
1 ksi = 6.895 MPa
1 kip = 4.448 kN
1 psf = 0.0479 kPa