Using Single-Column Bents With Large Eccentricities to Avoid Straddle Bents

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Outline

- Intro
  - C-Piers vs. Straddle Bents
- 2 Case Studies
  - Honolulu Authority for Rapid Transportation (HART) in Honolulu
  - I-405 Sepulveda Widening in Los Angeles
  - Both design-build projects between Kiewit and HNTB
- Flexible vs. Stiff C-Piers
  - Convert HART supports from Stiff to Flexible

Introduction

- Cantilever Bents aka “C-Piers” are typically used for eccentricities (ecc) less than 10ft, above which a Straddle Bent is used
- Pictured from HART West Oahu/Farrington Hwy (WOFH):
  - Straddle Pier 244
    - foreground
    - ecc = 22.6ft
  - C-Pier 245
    - background
    - ecc = 9.3ft

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2 Case Studies

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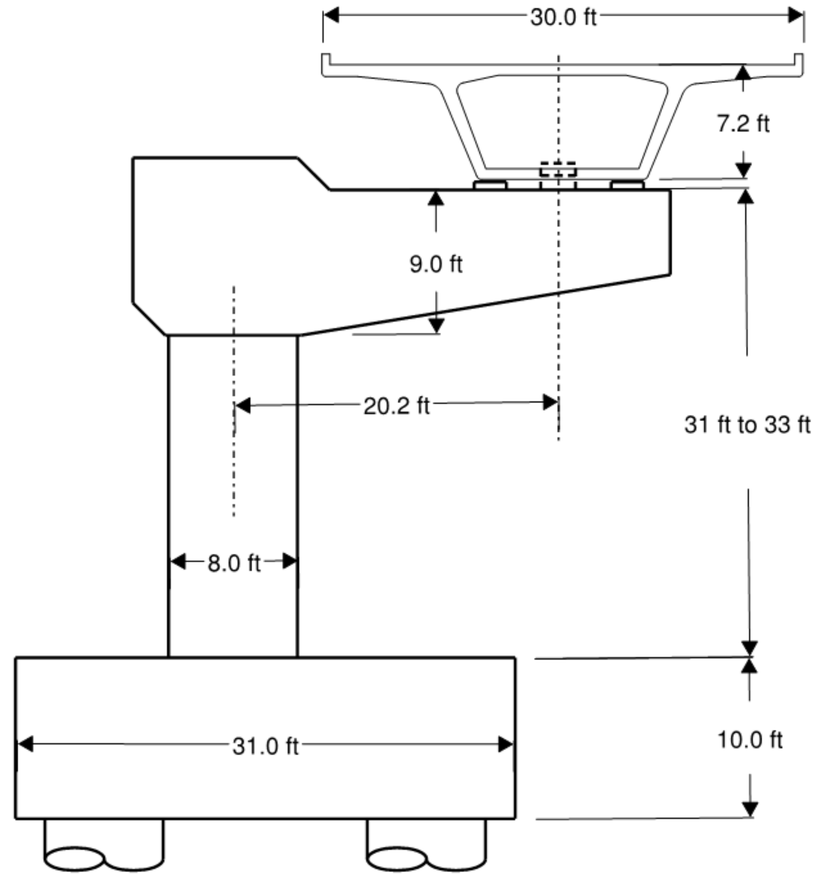
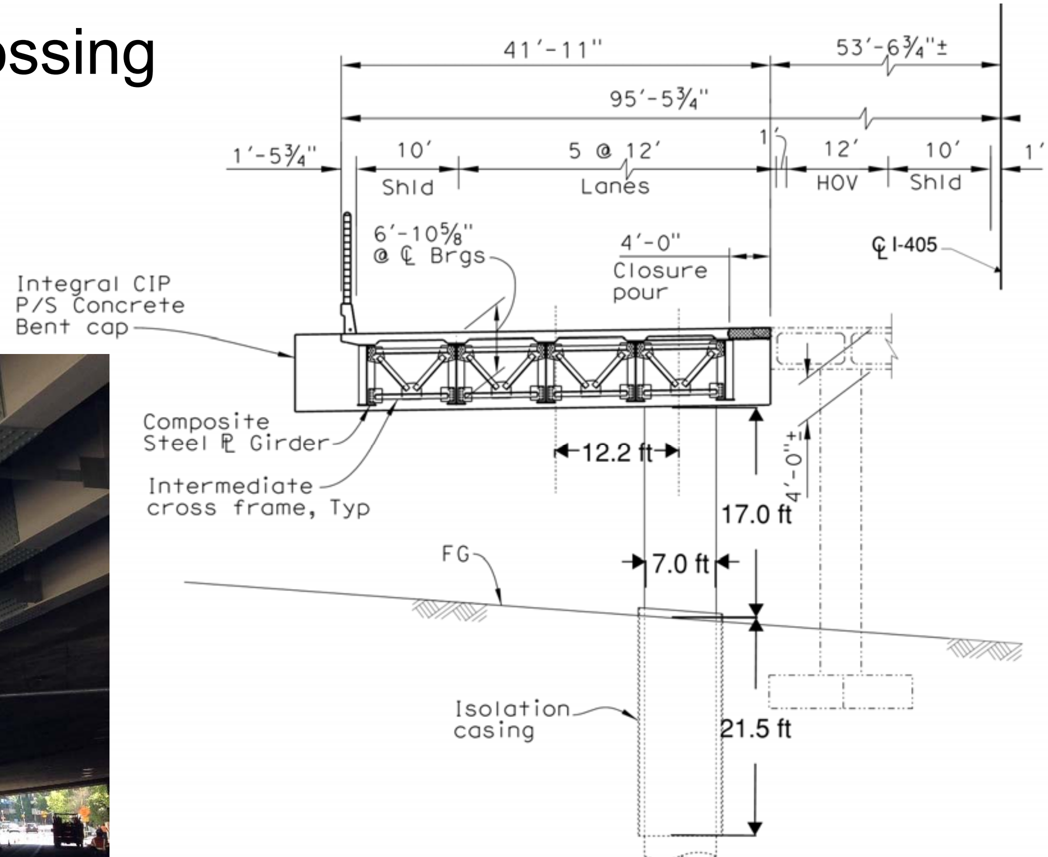
- Kamehameha Highway Guideway (KHG)
  - C-Piers 277 to 279



I-405 Sepulveda Widening

- Sepulveda Blvd Undercrossing
  - aka “Bridge 23”
    - Bent 3



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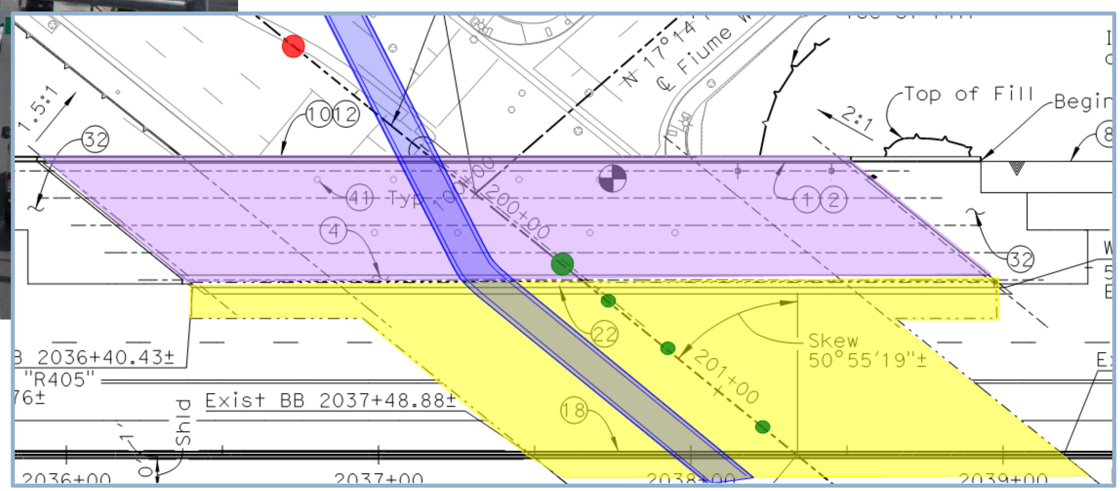
2 Case Studies: Bridge Comparison

- C-Piers 277-279
  - 2 tracks of Light-Rail
  - 4 x 145ft spans
  - built 2016, open in ~2020
  - ecc = 20.2ft
    - no skew
  - segmental superstructure
  - post-tensioned cap
    - non-integral to superstructure
  - post-tensioned column
  - moderate seismic demands
- Bridge 23
  - Highway bridge widening
  - 4 spans total L = 260ft
  - built 2013, open in 2014
  - ecc = 12.2ft
    - Increases to 19.3ft along skew
  - Composite steel plate girder
  - post-tensioned cap
    - integral with superstructure
  - RC column
  - high seismic demands

2 Case Studies: Why a C-Pier?

Bridge	Obstruction	Why not a Straddle?
C-Pier 277-279	2 left-hand turn lanes	Aesthetics
Bridge 23	Sensitive 96” ϕ water line	Cannot place 2nd column



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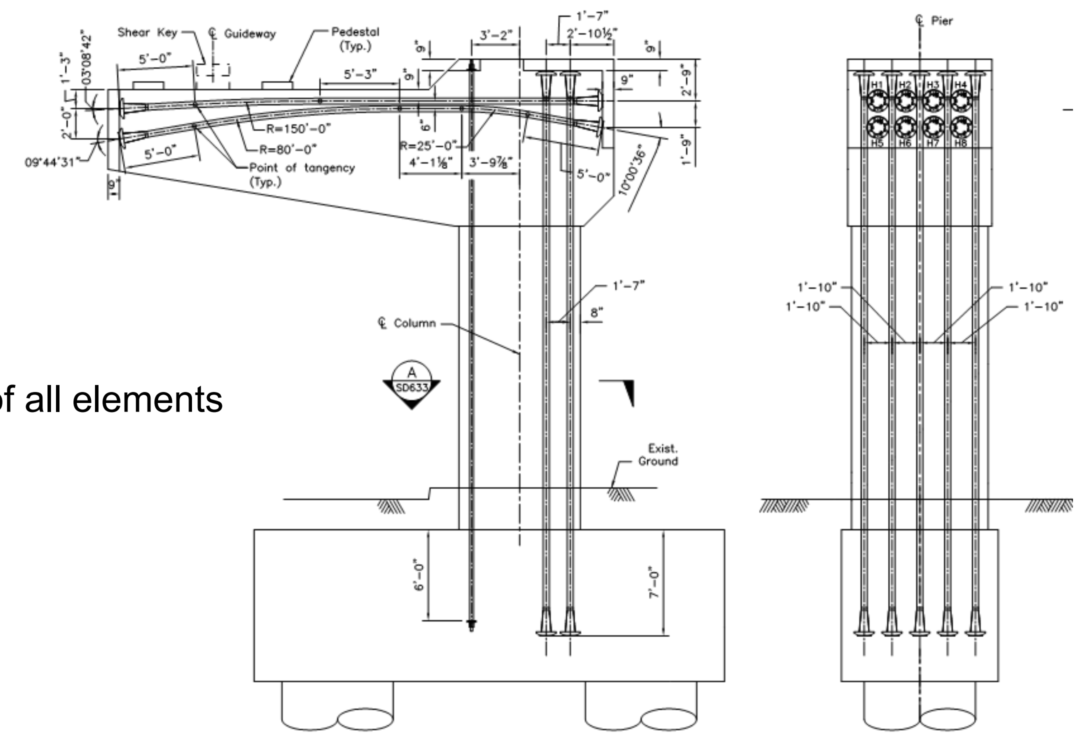
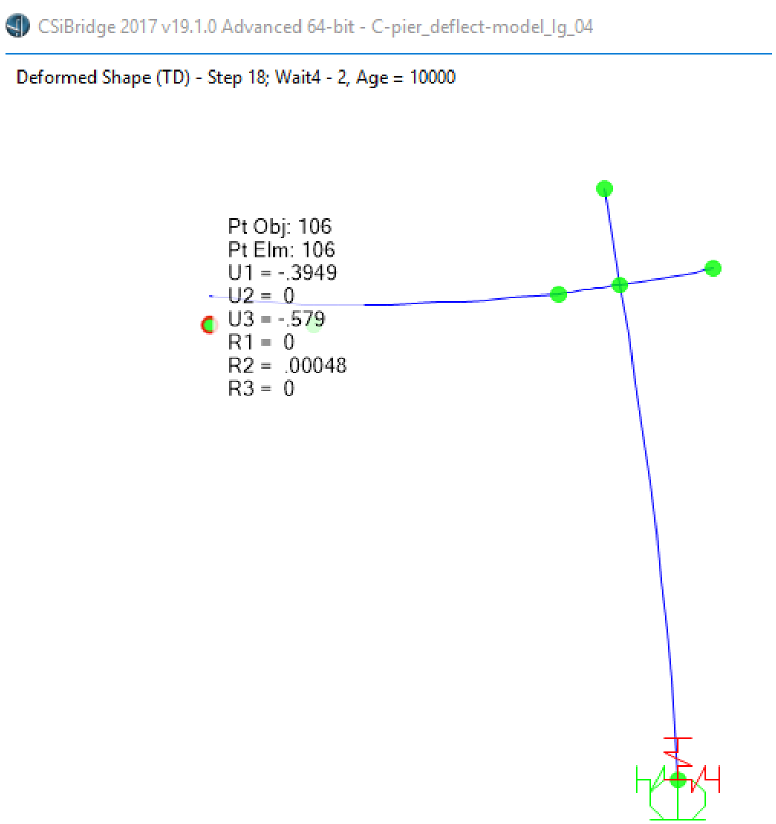
Case Study: Design of C-Pier 277 to 279

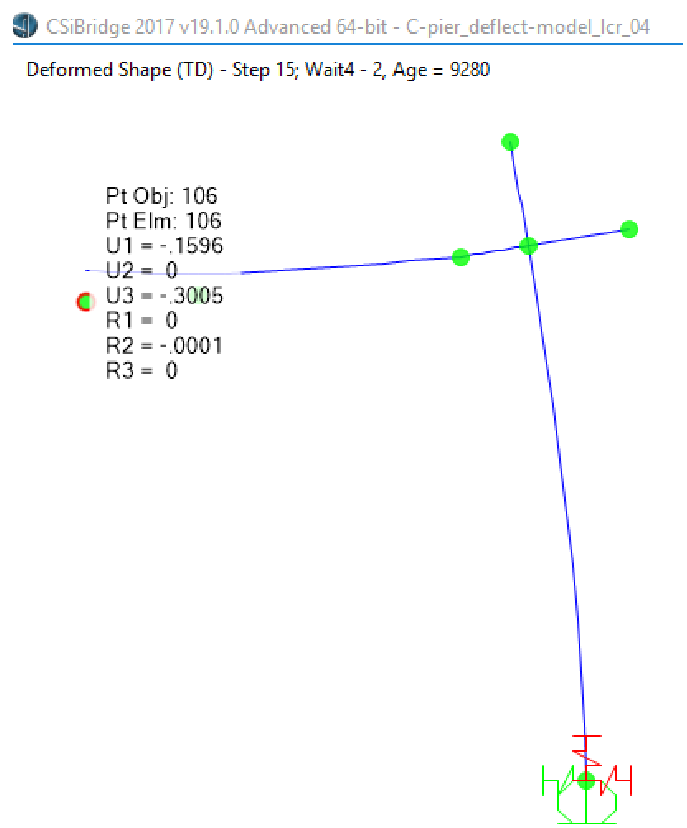
- Post-tensioning (PT) Design:
  - Column = 9x27-strand ducts in 8ft deep x 9ft wide section
  - Cap = 8x27-strand ducts in 9ft deep x 9.5ft wide section
  - Controlling load combinations = Strength 1 & Extreme 3 (Derailment)
  - Service stress design = partial prestressing (design variance)
- Seismic Design:
  - AASHTO Seismic SDC B
  - Peak acceleration = 0.44g
  - Controls the torsion design of all elements



Case Study: Design of C-Pier 277 to 279

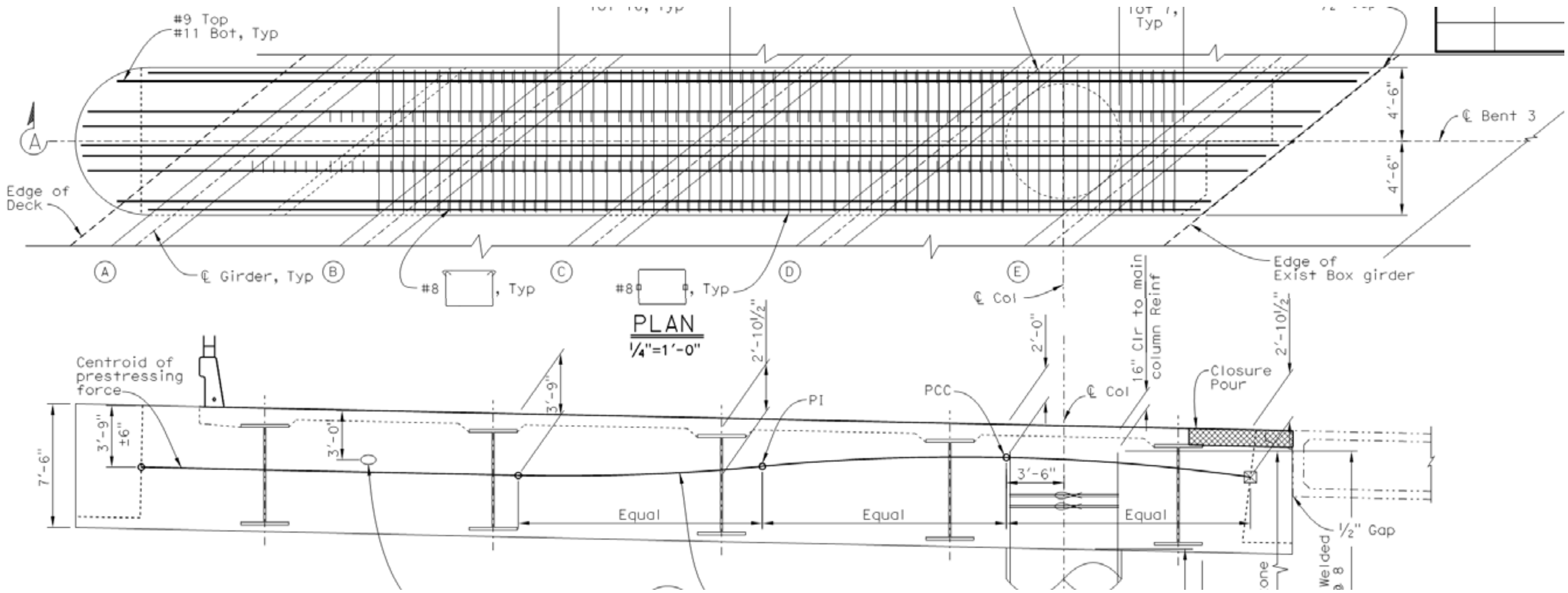
- Deflection Analysis in CSiBridge
  - Camber = 7/8” (= 0.579” + 0.301” from below)
  - Live load = 1” vs 1 3/4” allowed (= L/1000)





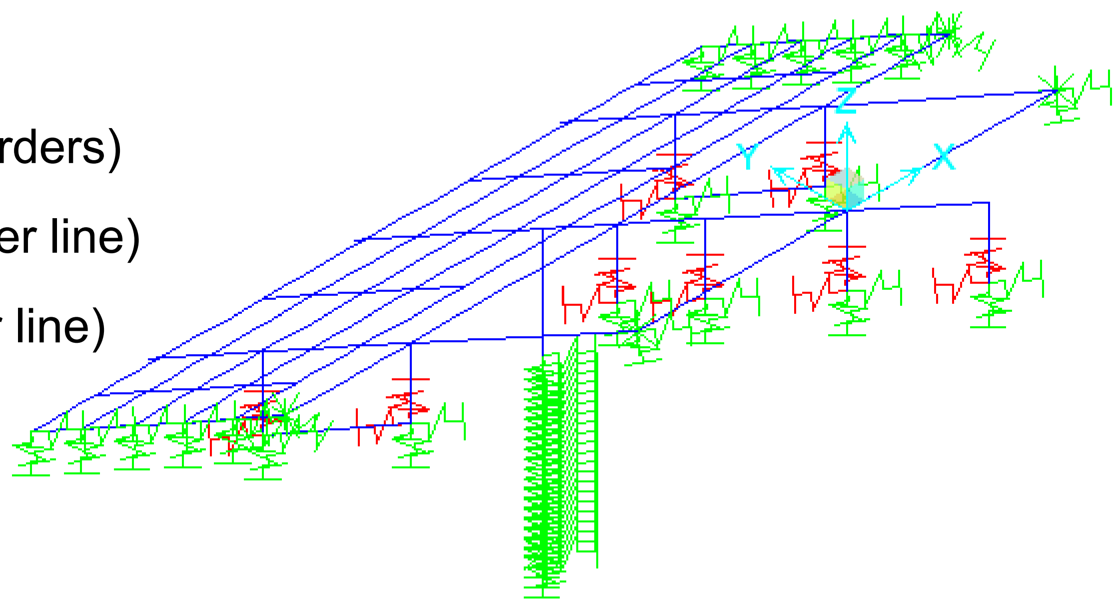
Case Study: Design of Bridge 23

- Controlling service design = Strength 2 (permit truck)
- RC column = 7ft ϕ column w/ 2% steel
- PT cap = 4x16 strand tendons in 7.5ft deep x 9ft wide section
- Cap torsion = compatibility torsion (not equilibrium torsion)
- Closure pour: concentrated demands at the bent, however the 1ft deep slab is not deepened at the cap



Case Study: Design of Bridge 23

- Seismic design:
  - Peak acceleration = 1.25g
  - 2 girders adjacent to column are capacity protected
  - Cap beam is capacity protected by torsion shear friction
  - Stiffness of widening cannot be less than the original
- Seismic model:
  - Widened (5 lines of girders)
  - 1969 widening (1 girder line)
  - 1960 original (1 girder line)



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Constructability of C-Piers 277-279

- Column PT uses embedded dead ends
  - Temporary PT rods were used to reduce temporary tension
- Cap PT was installed in stages

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Constructability of Bridge 23

- Deck pour was sequenced to minimize DL demand on column
- Temporary struts supported the girders during deck pour for stability
- Holes in plate girders for PT and rebar
- Pile isolation casing prevents loads onto the buried water line

Flexible vs Stiff C-Piers & Test Case

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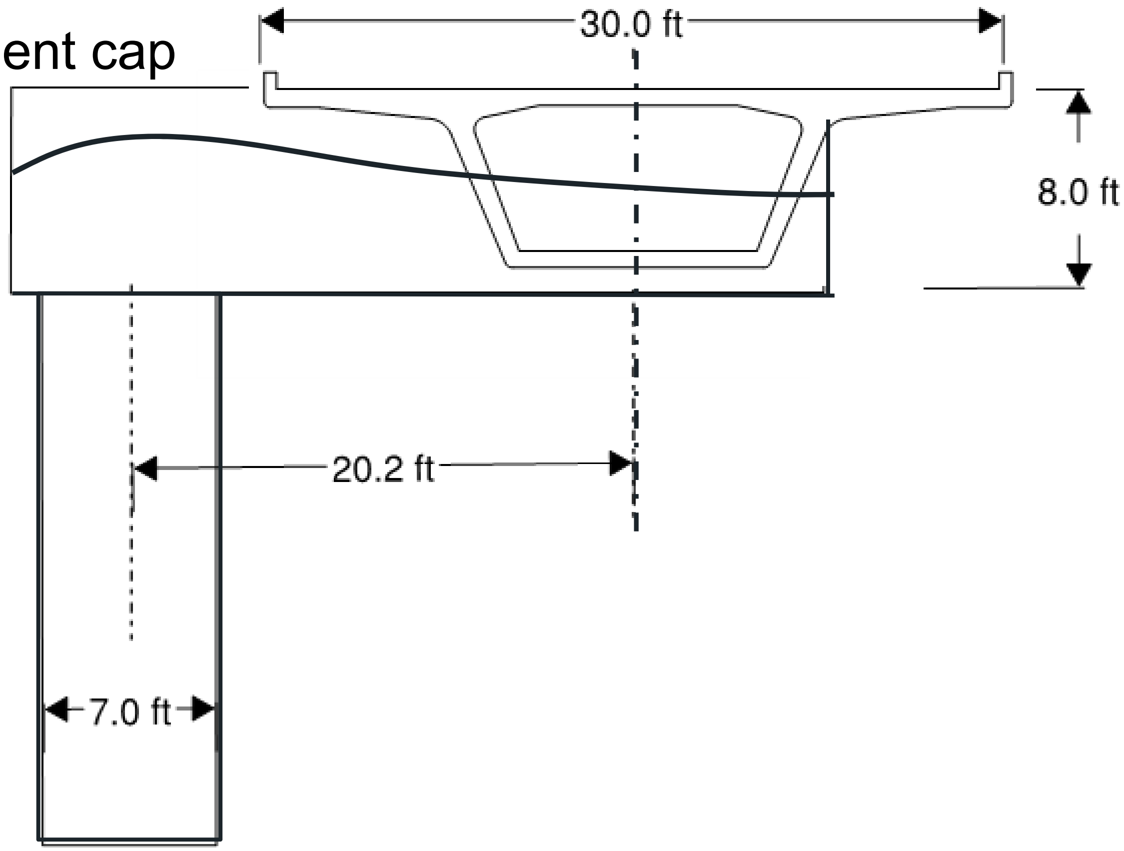
Flexible vs. Stiff C-Piers

- "Stiff" supports will induce negative moments under dead load
- A "stiff" support occurs when the substructure is ~10x stiffer than the superstructure
- Substructure stiffness:
  - C-Piers 277-279: 740 kip/in
  - Bridge 23 Bent 3: 220 kip/in
- C-Piers 277-279 are "stiff"
  - if superstructure was made continuous over the supports, negative moment would be similar to typical "rigid" support condition
- Bridge 23 Bent 3 is "flexible" with the substructure and superstructure stiffnesses roughly the same
- The outside girders of Bridge 23 support the bent cap DL
- **"Stiff" C-Piers require column PT; "Flexible" C-Piers require integral connection**

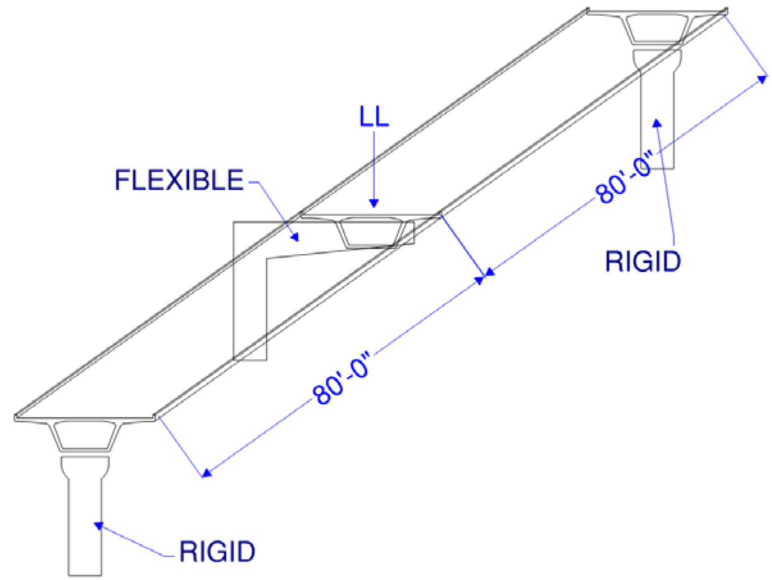
Convert HART (C-Piers 277-279) Supports

- Step 1 = cast RC column
- Step 2 = erect superstructure and release formwork
- Step 3 = cast & PT bent cap



Theoretical Design of C-Pier Column

- 2-span configuration with rigid – flexible – rigid supports over 160ft
- Superstructure stiffness = 160 kip/in
  - EI = 2E8 kip-ft^2
- C-Pier stiffness = 220 kip/in
- Live Load point load = 400 kip



Force	Load Factor	Factored Demand (kip-ft)
Cap DL	1.25	4,100
Live Load	1.70	8,000
Total	-------	12,100

- ϕMn = 18,000 kip-ft
- Live Load deflection limit controls: 1.1” actual vs. 1.0” limit (= L/1000)

Credits

- Kiewit (contractor of both bridges)
- HART (C-Piers 277-279)
- Metro (Bridge 23)
- FIGG
  – Superstructure designer & global modeler of HART
- IDC Consulting Engineers
  – Independent checker for Bridge 23
- Multiple HNTB Offices
  – Oakland, San Jose, Santa Ana, Seattle, Kansas City, Chicago

Questions

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THANKS FOR LISTENING!