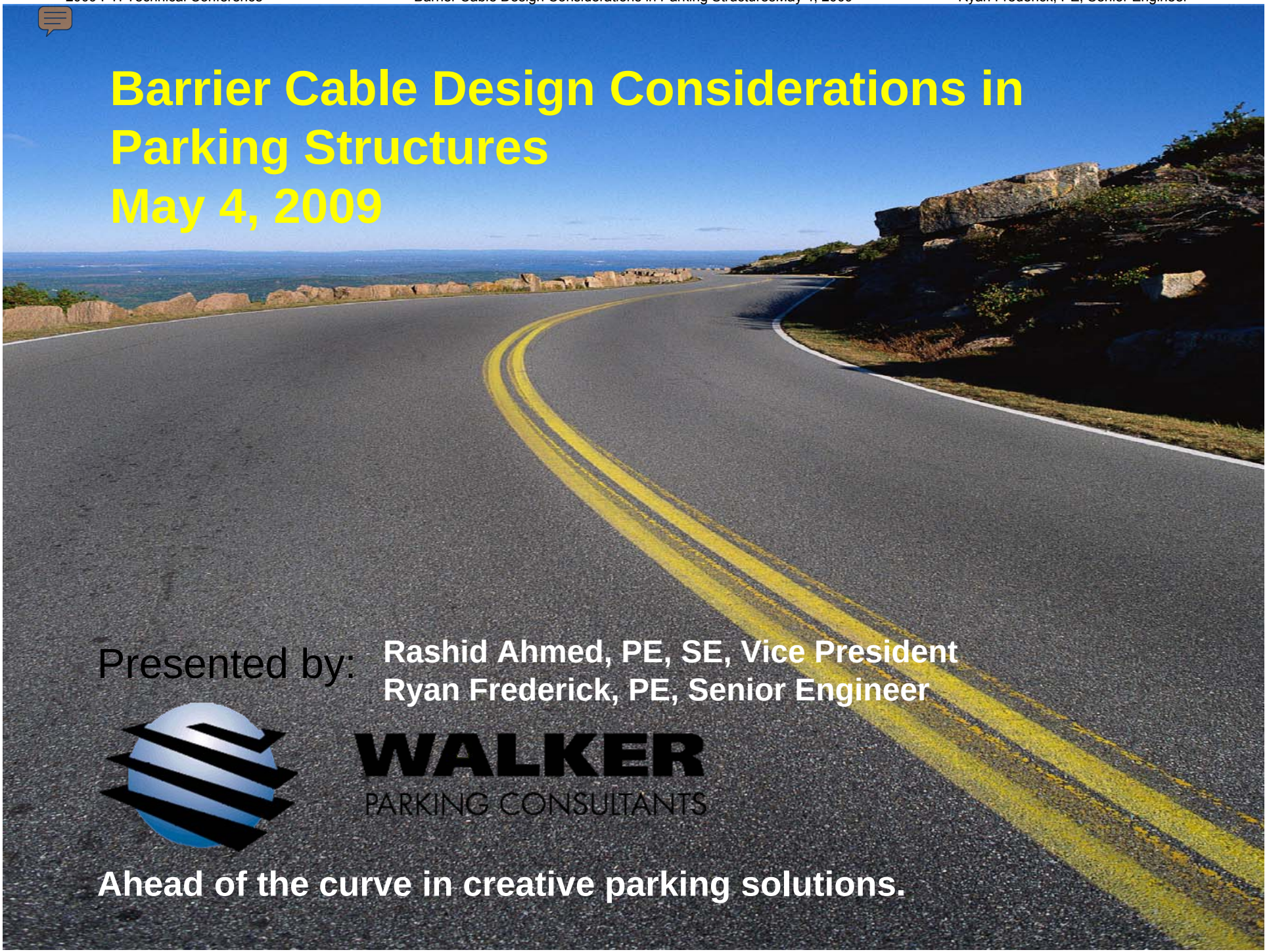
Barrier Cable Design Considerations in Parking Structures
May 4, 2009



Presented by: Rashid Ahmed, PE, SE, Vice President
Ryan Frederick, PE, Senior Engineer

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Ahead of the curve in creative parking solutions.

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Presentation Overview

- Building Code requirements
- Failure mechanisms for barrier cables
- Potential problem areas
- Conclusions and recommendations

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Introduction

- Why are cables popular?
  - Provide openness, good visibility
  - Ductile (if properly anchored)
  - Economy

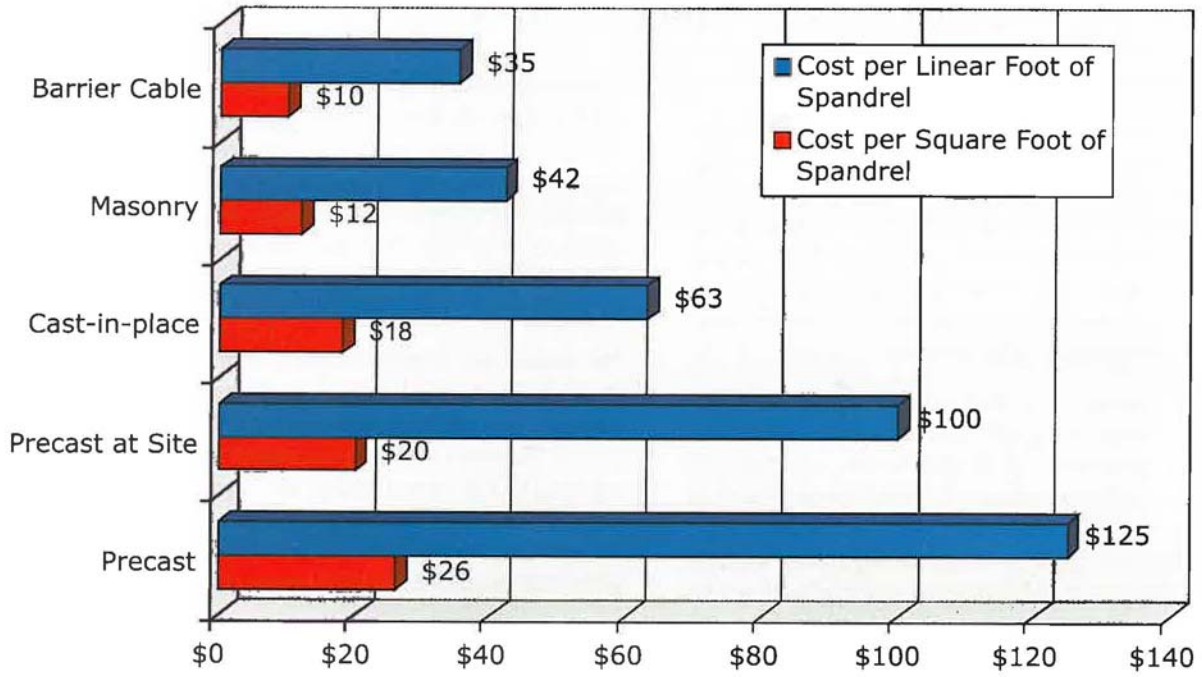

Fig. 16.2 Cost of Exterior Barrier Systems

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Building Code Requirements

Vehicle impact requirements

–IBC 2006
- 6 kips at 18” above finish floor
- Silent as to how many cables take bumper loads
- Silent as to allowable deflection

–IBC 2009
- 6 kips at 18” or 27”
- Still silent as to how many cables take bumper load
- Still silent as to allowable deflection

–Suggestion
- Consider 3 cables share bumper load (as recommended by chapter 16 of PTI design handbook).
- Obviously at ultimate more than 3 cables are engaged.
- PTI recommends 18” maximum deflection.

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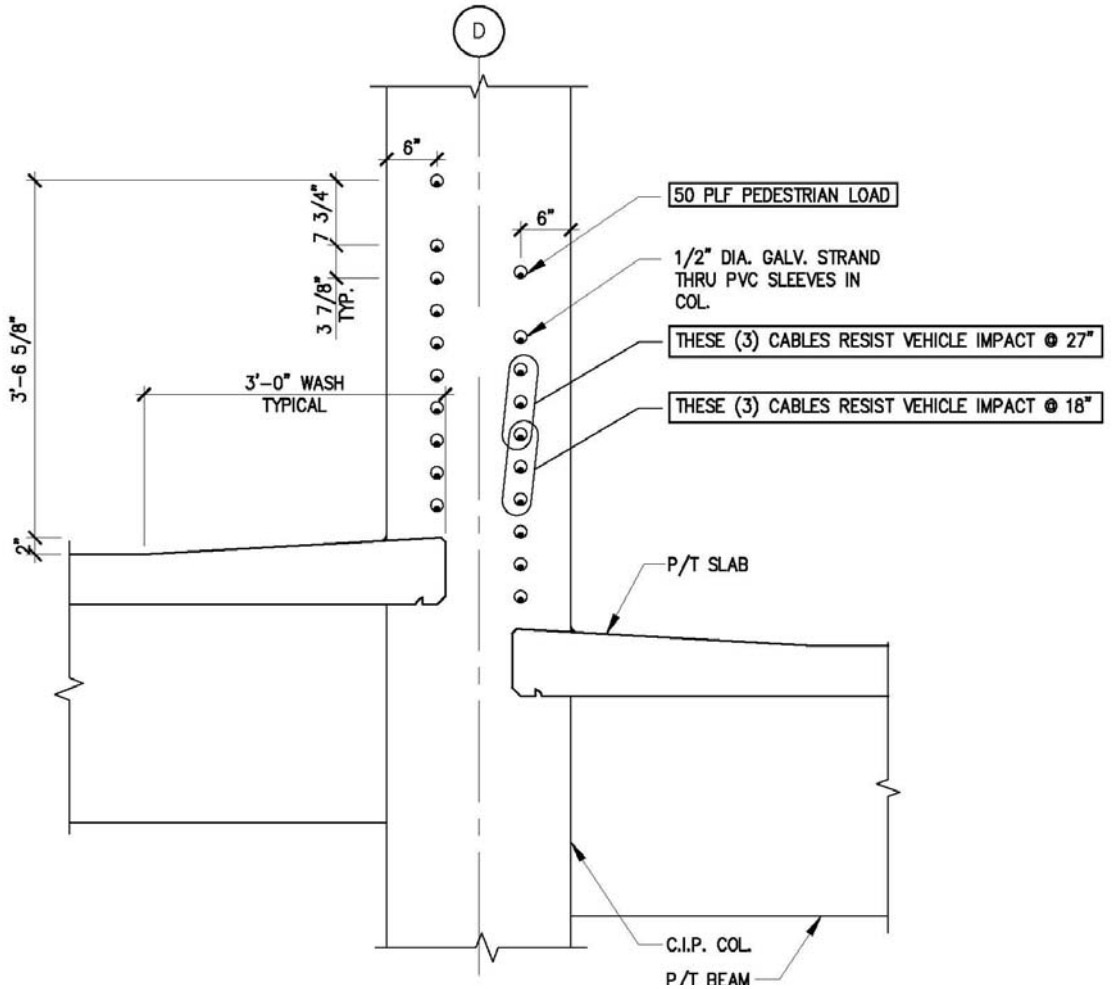
Building Code Requirements

- Pedestrian loads and fall protection (IBC)
  - Fall protection
    - Barriers must be 42” high minimum.
    - 4” sphere shall not pass thru any opening up to a height of 34”
    - 8” sphere shall not pass thru any opening above 34”
  - Design Loads
    - Handrails and guardrails
      - 50 plf applied in any direction
      - 200 point load in any direction on top rail
    - Codes do not explicitly state if pedestrian loads must be applied simultaneously to every bay.
    - Suggest considering a 50 plf live load applied to any single bay

This detail satisfies Code requirements



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Failure Mechanisms

- Failure of anchorage system
- Failure by excessive deflection
- Failure of cable
- Failure of connecting columns, walls, bollards, etc.

Potential problem: Short cable runs

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Potential problem: Short cable runs

There are 2 problems with short cable lengths:

- Short cables develop tremendous tension due to horizontal loads.
- They can be difficult to stress.

Potential problem: Short cable runs

Tension force equation (energy method)

$$T = \sqrt{\left(\frac{EA}{L}\right)\left(\frac{MV}{N}\right) + F_e^2}$$

Note *L is in denominator*

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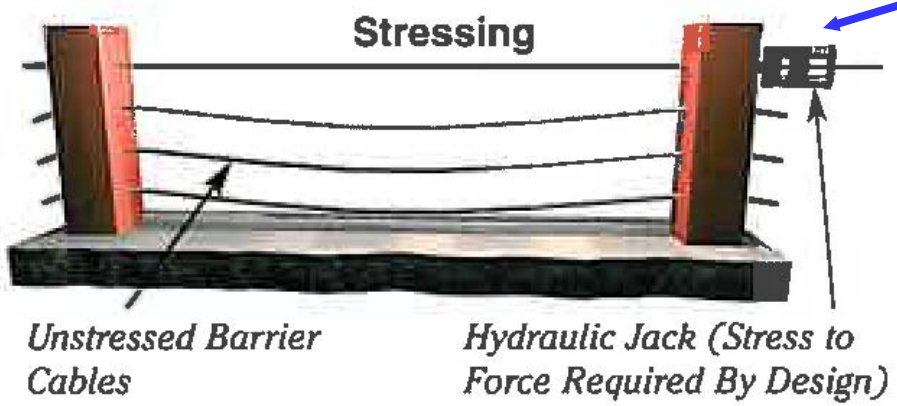
Problem: Stressing short cables

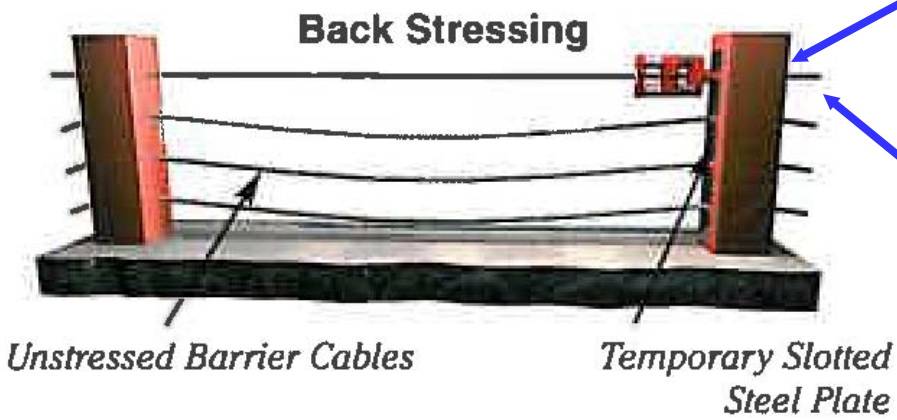
The problem is the hydraulic jack……

Initially pull cables



Jacking force = final cable pretension + add'l force needed to overcome seating losses

Then, back Stress to lock wedges



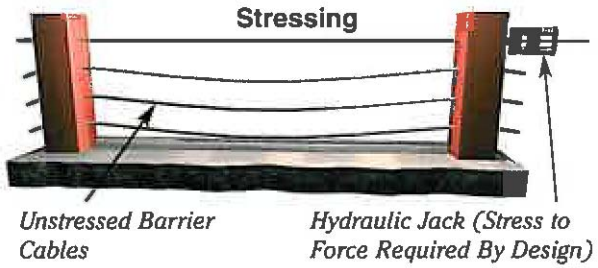
Seating loss varies with hardware, typically = 3/8"

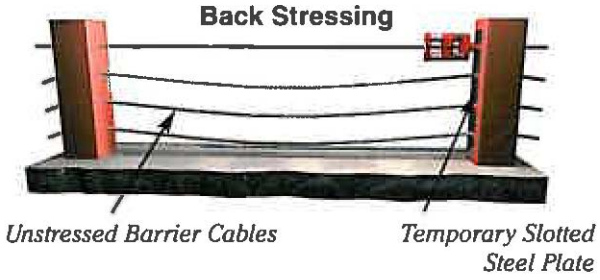
Cable is sucked back in 3/8"

Problem: Stressing short cables

Example: 18' long cable w/ 2 kip specified prestress……

- The cable elongation corresponding to 2 kip prestress = 3/32"
- But, seating loss = 3/8" (more than the elongation)
- The cable needs to be pulled 3/8"+ 3/32" = 15/32"
- This requires an initial pull of 9.6 kips!
- The anchorage must be designed for 9.6 kips.





Problem: Stressing short cables

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Solution: Threaded type end anchors which are stressed by turn of nut.

Swaged end Anchor

Adjustable Anchor GRAB-IT™

Problem: Long spans between supports

Problem: Long spans between supports

- Do not underestimate the amount of pretension required to eliminate sag.
  - 30’ long span requires 3.2 kips pretension to eliminate visible cable sage.
  - PTI recommends 2 kips min. for an 18’ bay to eliminate cable sag.
  - Intermediate supports help limit sag cable (but not lateral deflection)
- Do not underestimate how much long cables will deflect under horizontal loads.
  - Example: (6) 30’ bays = 180 long cable, 3.2 kip pretension, 6 kip bumper load taken by 3 cables (2k/cable)
    - Cable deflection = 22” (does not meet PTI recommendation of 18” max deflection)
  - Spreader bars help distribute load to more than (3) cables, but this is not recognized by any Code or standard.

Problem: Long spans between supports

Potential problem: Anchoring to cantilevered steel posts

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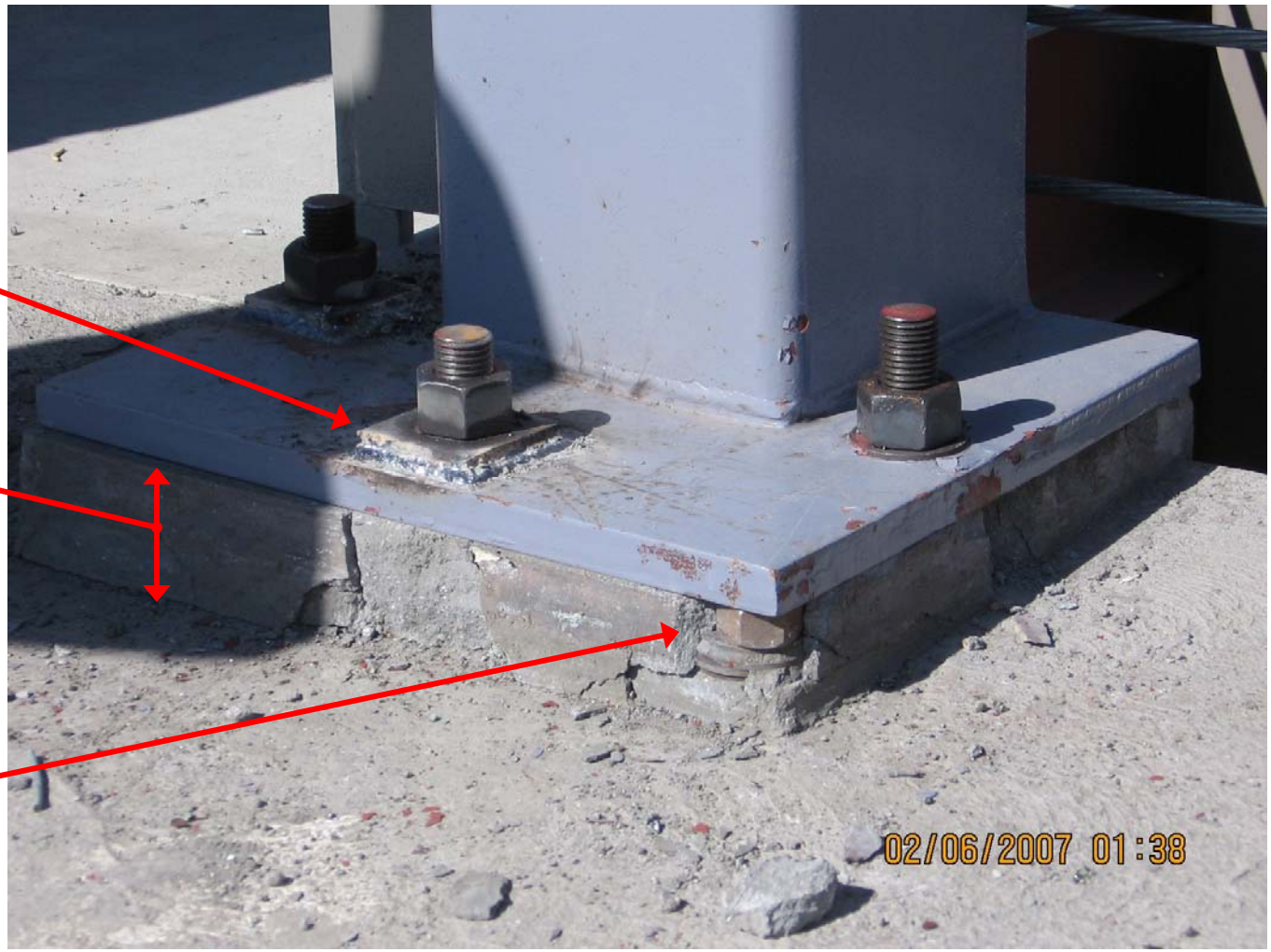
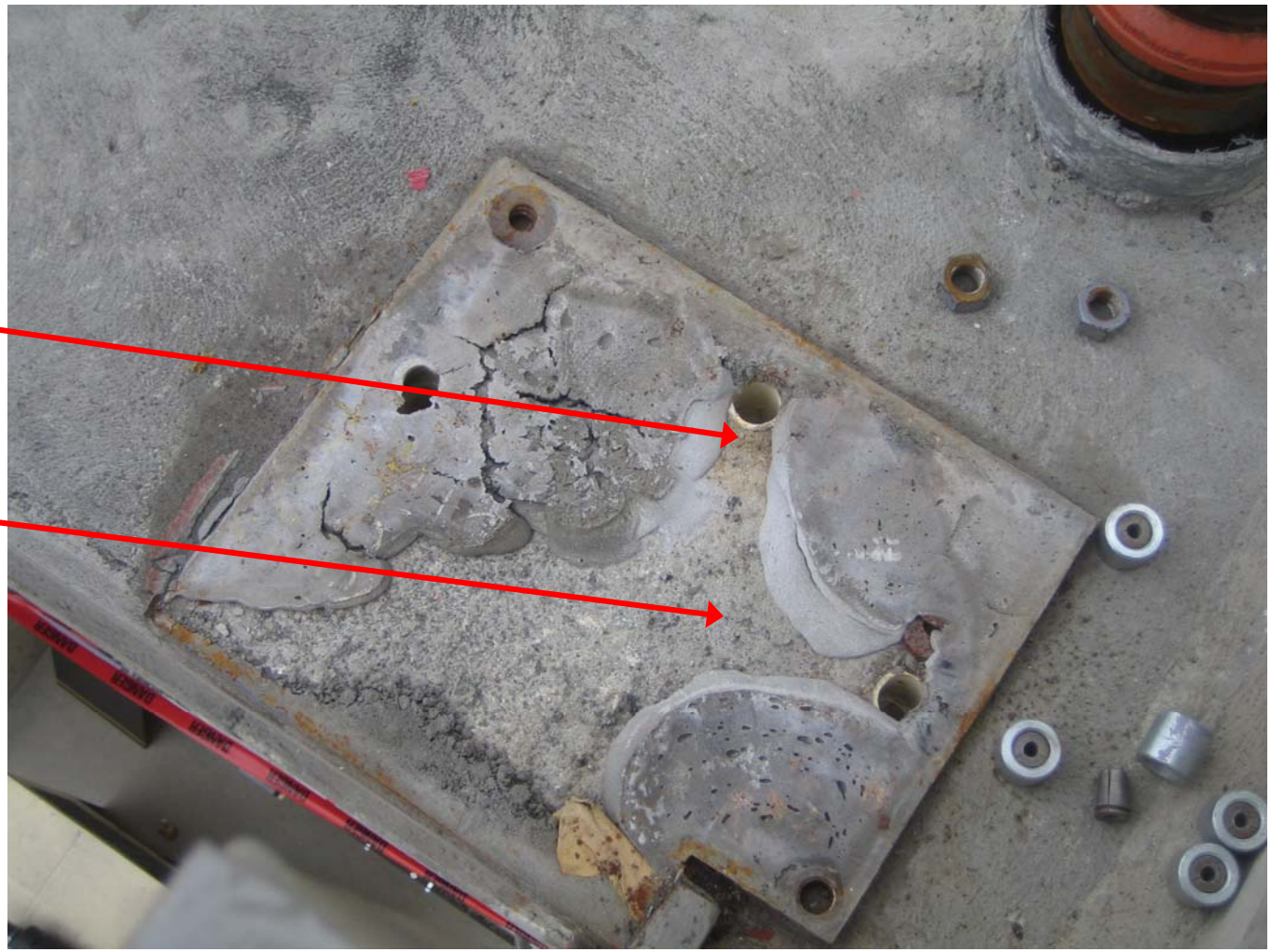
Weld washers

Grout too thick- bolts can deform w/in grout

Bad shims



Potential problem: Anchoring to cantilevered steel posts



Problem: Anchoring to cantilevered steel posts and bollards

- Very sensitive to construction tolerances.
- Sensitive to cable overstressing.
- Beware of using anchor bolts to resist large shear loads. Bolts can bend within grout depth.
- Try to avoid cantilever elements.

Conclusions and Recommendations

- Specifications
  - Require the barrier cable supplier to calculate the required jacking force and submit calculations as part of the submittal package. (Same as for P/T floor submittals).
  - Require Stressing records be kept and submitted to Engineer. Do not allow cables tails to be cut w/o approval of Engineer.

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Conclusions and Recommendations

- Do not allow wedge anchors for cables lengths < 60 ft or so.
- Specify cables be back stressed immediately after stressing to prevent a buildup of forces on the anchorage assemblies.
- The barrier cable installation should be a continuous inspection item.
- After construction, components of barrier cable system need to be regularly inspected and maintained.

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References & Further Information

- Chapter 16, Post-Tensioning Manual, 6th Ed. Post-Tensioning Institute, Phoenix, AZ, 2006.
- Presswalla, H., “Designing Prestressed Barrier Cables”, Concrete International, 1989, pp. 67-73.
- Specification for Seven-Wire Prestressing Steel Strand for Barrier Cable Applications, Post-Tensioning Institute, Phoenix, AZ, 2007.