ADDING SUPPLEMENTAL SHEAR CAPACITY IN BEAMS USING DOWELS

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40 Concrete Beams With A Problem:

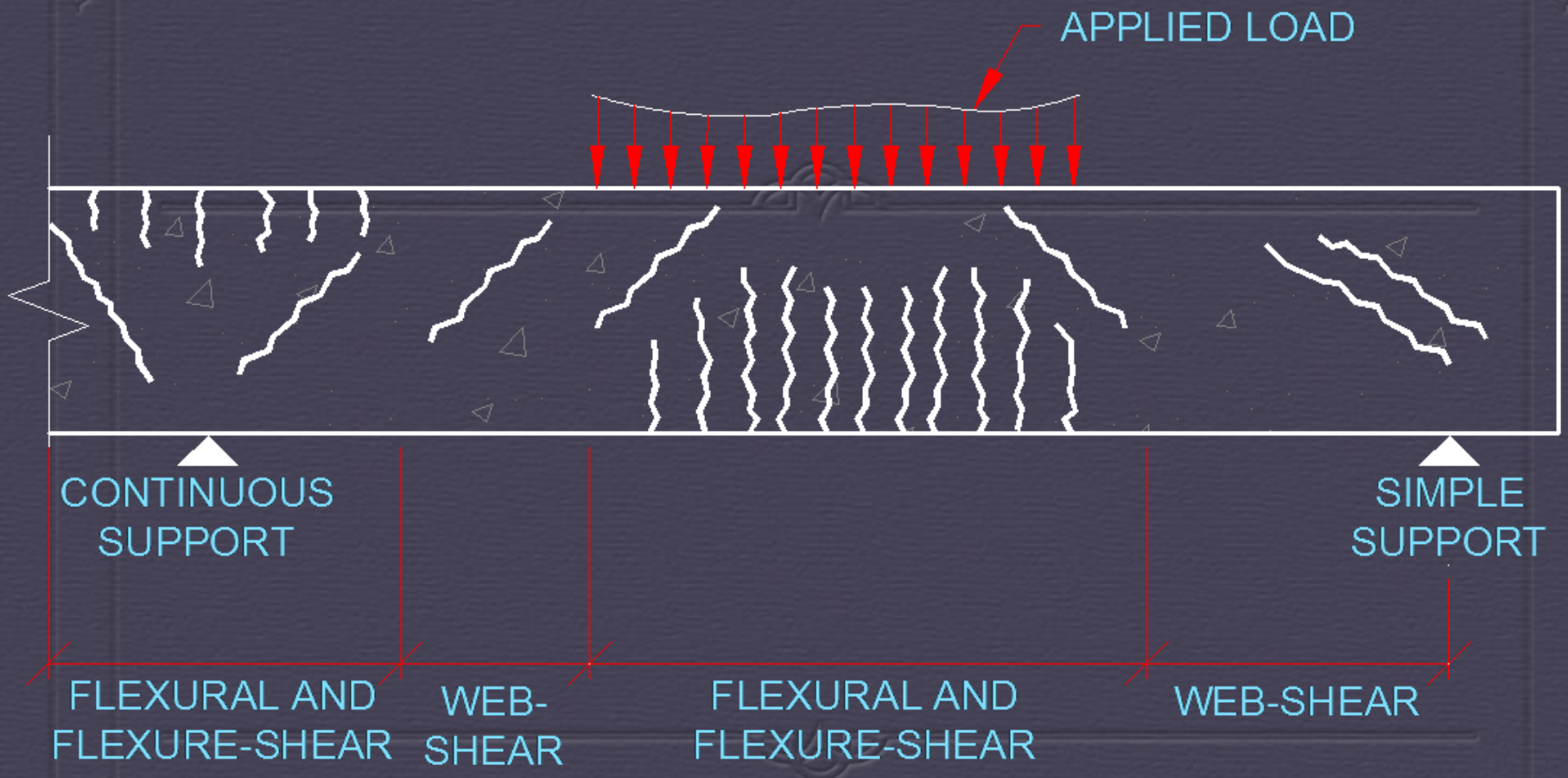
- Beam stirrup spacings exceeded the allowable per the building code
- 100 psf live load
- Moderate amount of flexural reinforcement
- 70 beams: typical concrete beam 20” wide x 20” deep, 26’ span, 7” thick concrete slab

A heavily used public parking structure in the Minneapolis-St. Paul metropolitan area:

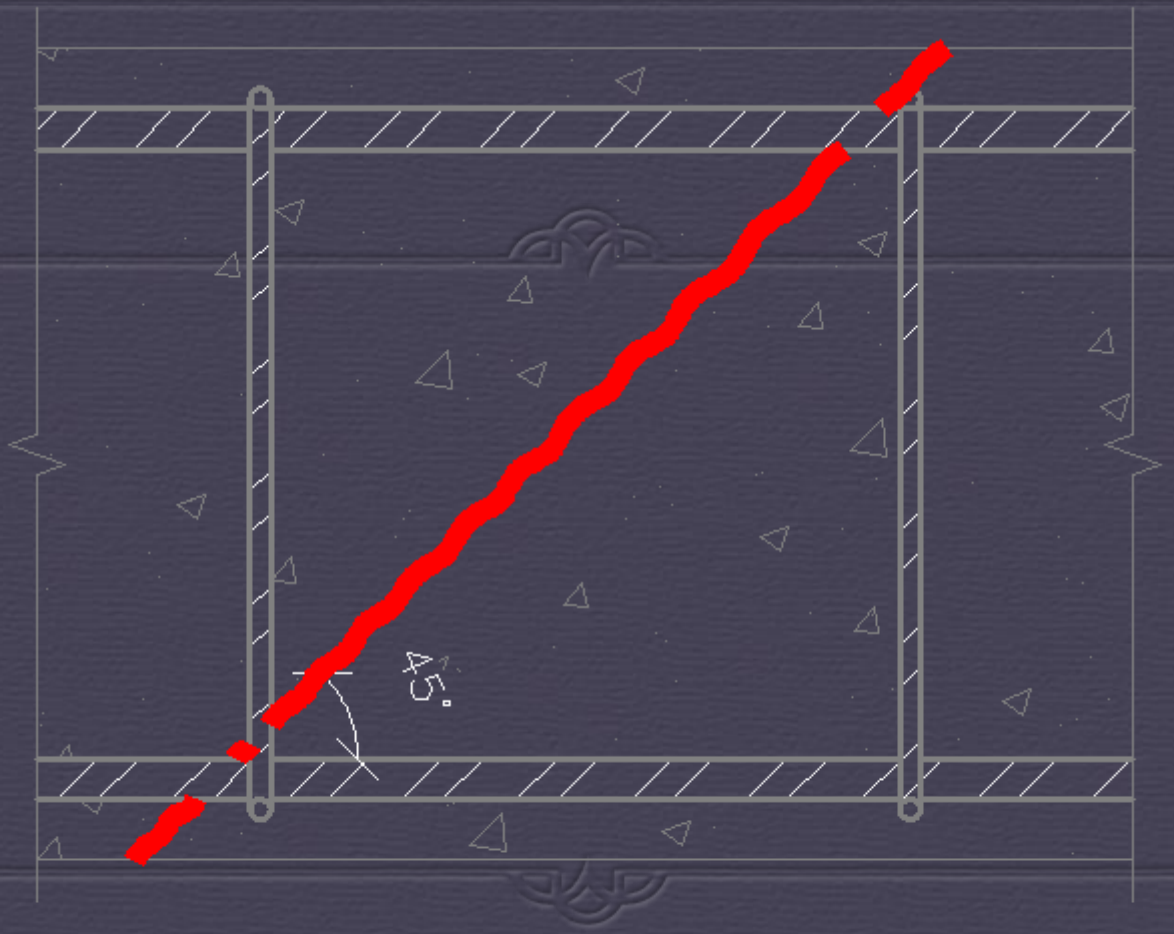
- Structure had been in use for over 10 years
- No indications of structural failure
- Decision to proceed with repairs to bring the structure back into compliance with the building code

Exterior view of building with deficient beams

Typical beam in public lobby area



CRACKING UNDER LOADING



TYP. BEAM WITH THEORETICAL SHEAR CRACK
(STIRRUP SPACING TOO GREAT)

(SLAB NOT SHOWN)

Pedestrian density vs. floor loading
100 psf example

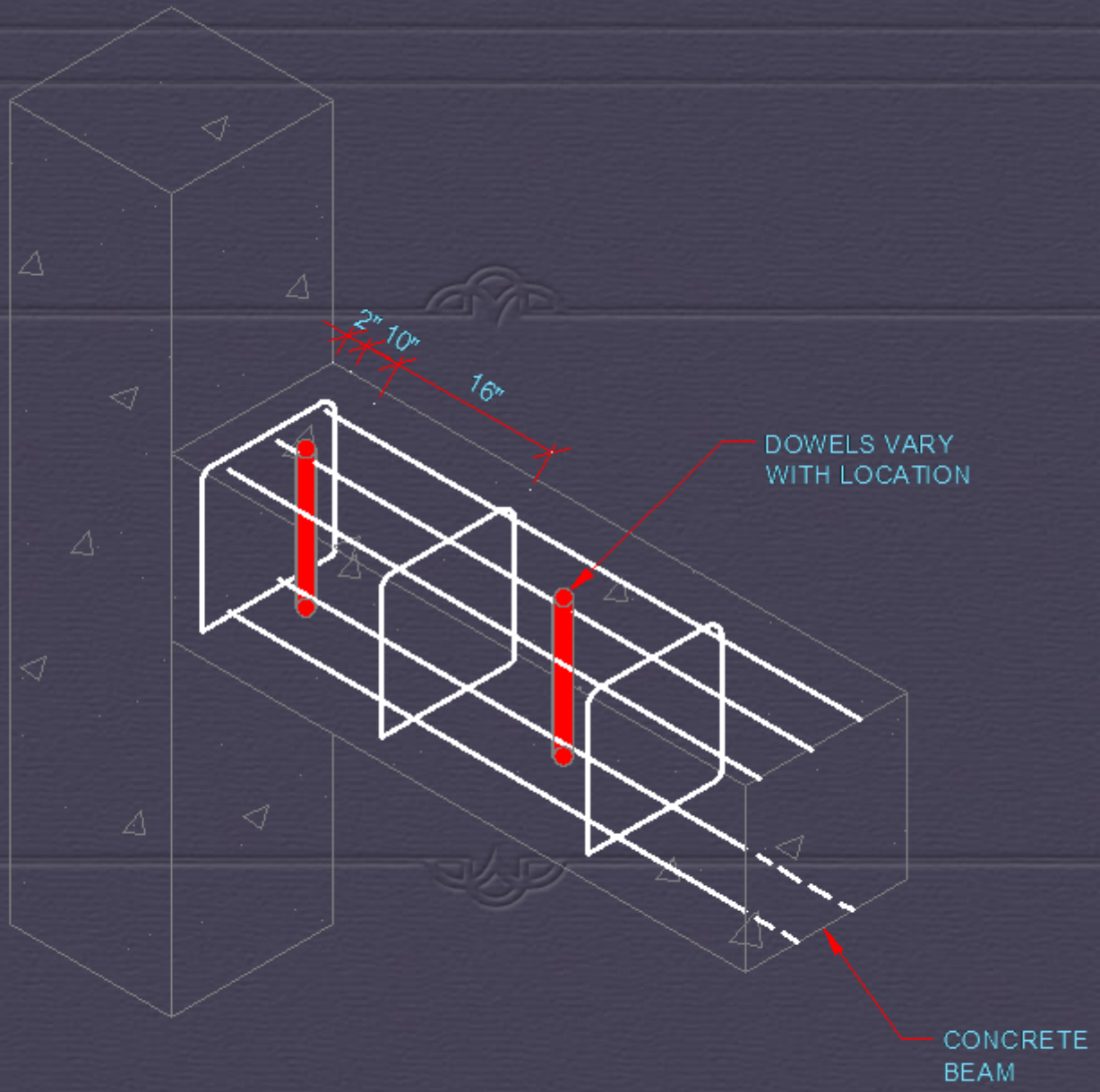
How to Repair?

- Structure was and is heavily used
- Owner wanted to minimize disruption to the users
- Load testing was not an option, due to risk of shear failure

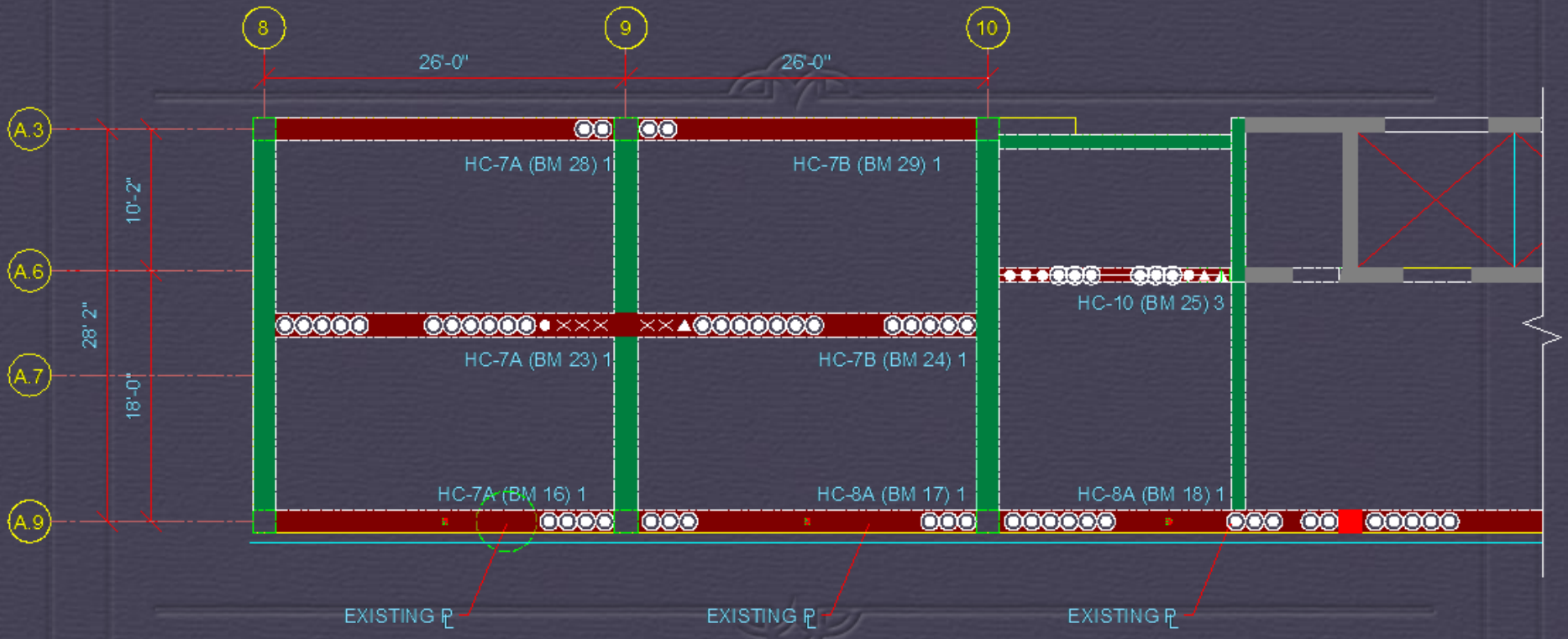
Congested areas below beams

Repair method:

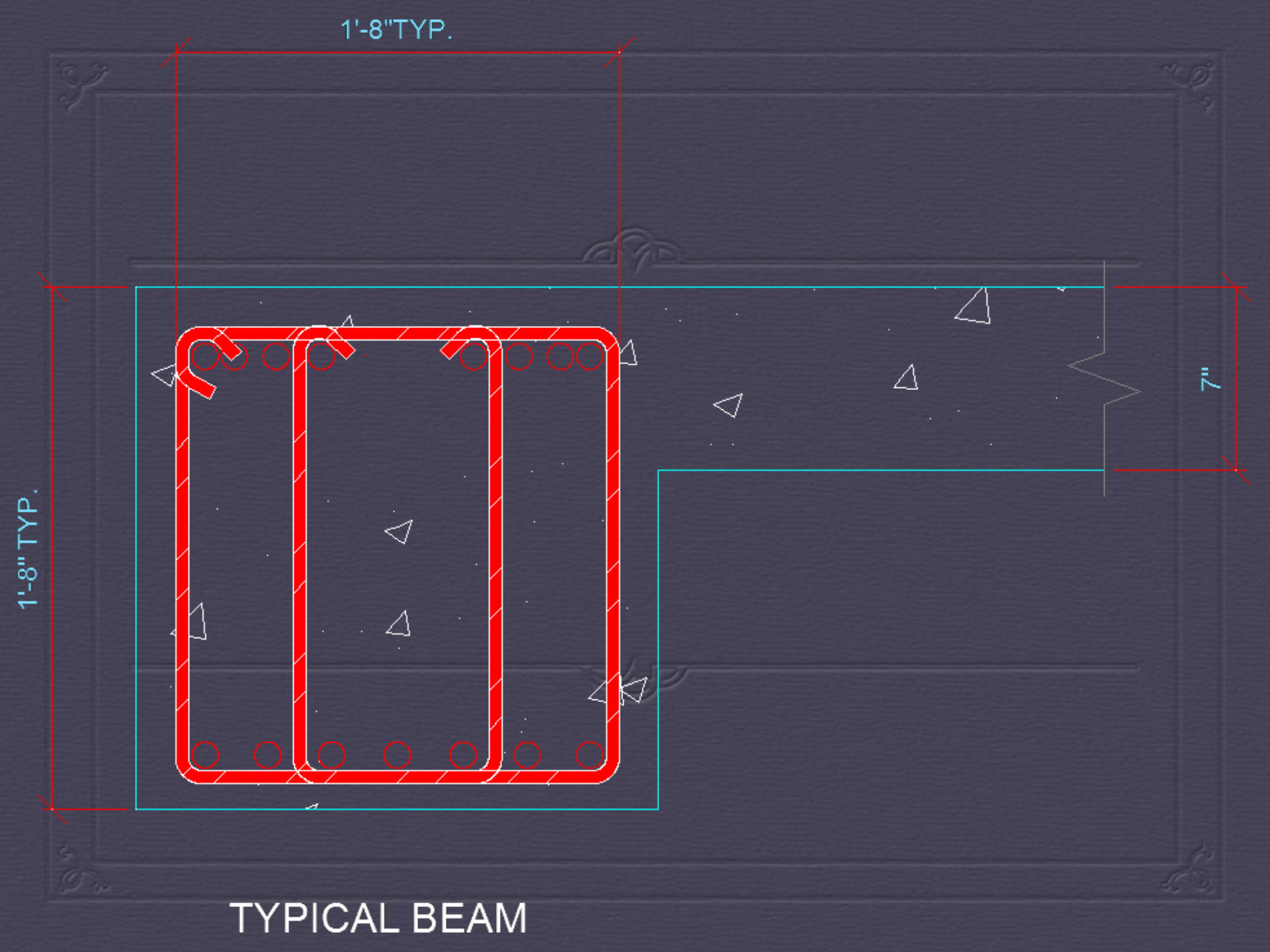
- Dowels added to provide shear reinforcement
- Proprietary adhesive system selected
- Pre-drill dowel hole using a proprietary percussion bit with a vacuum system
- All work done late at night, to minimize impact on the public
- Unique system - the building codes had not fully adapted this at the time of the repair
- This repair approach was independently confirmed by others



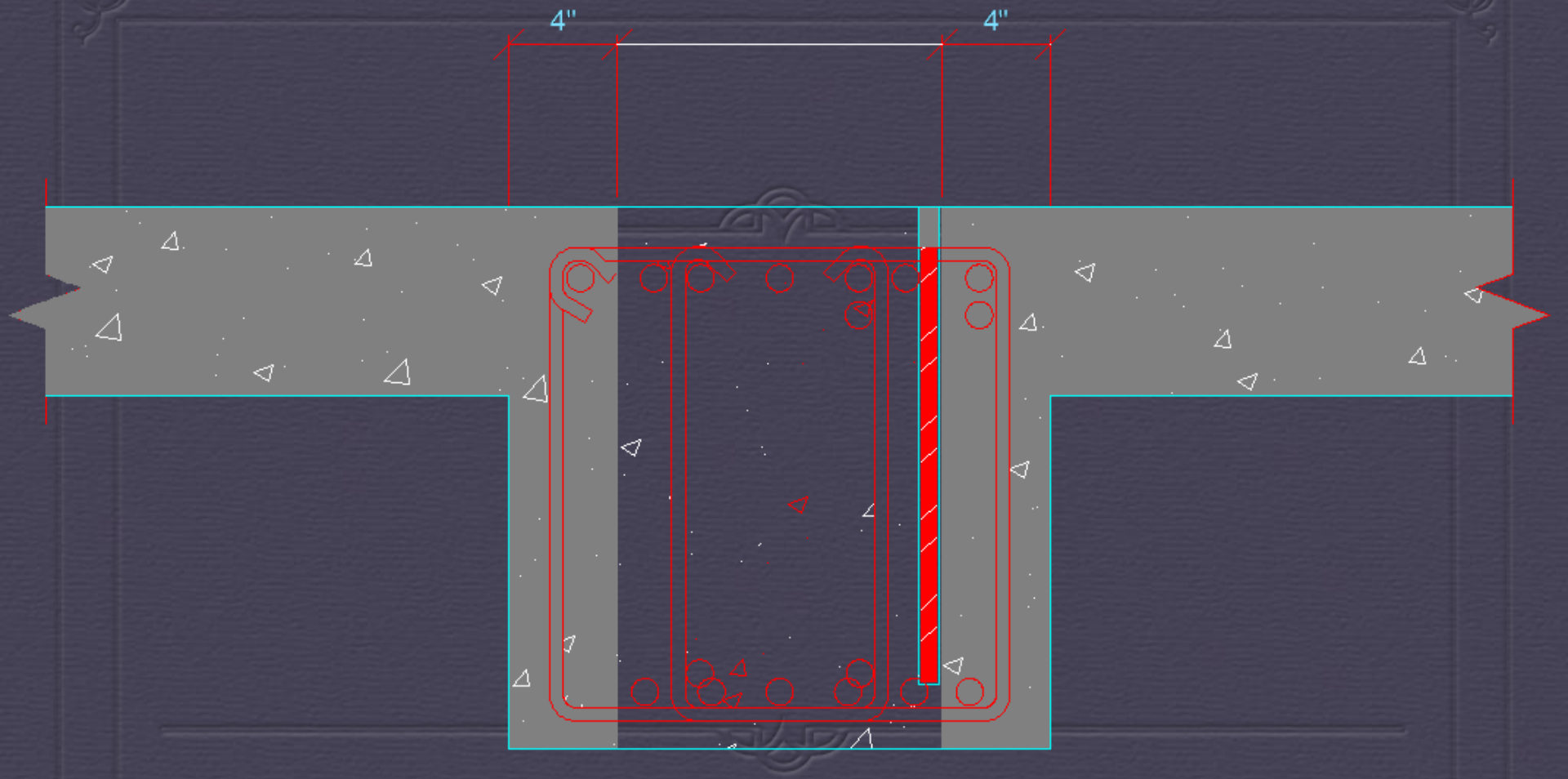
INTERNAL STEEL REPAIR



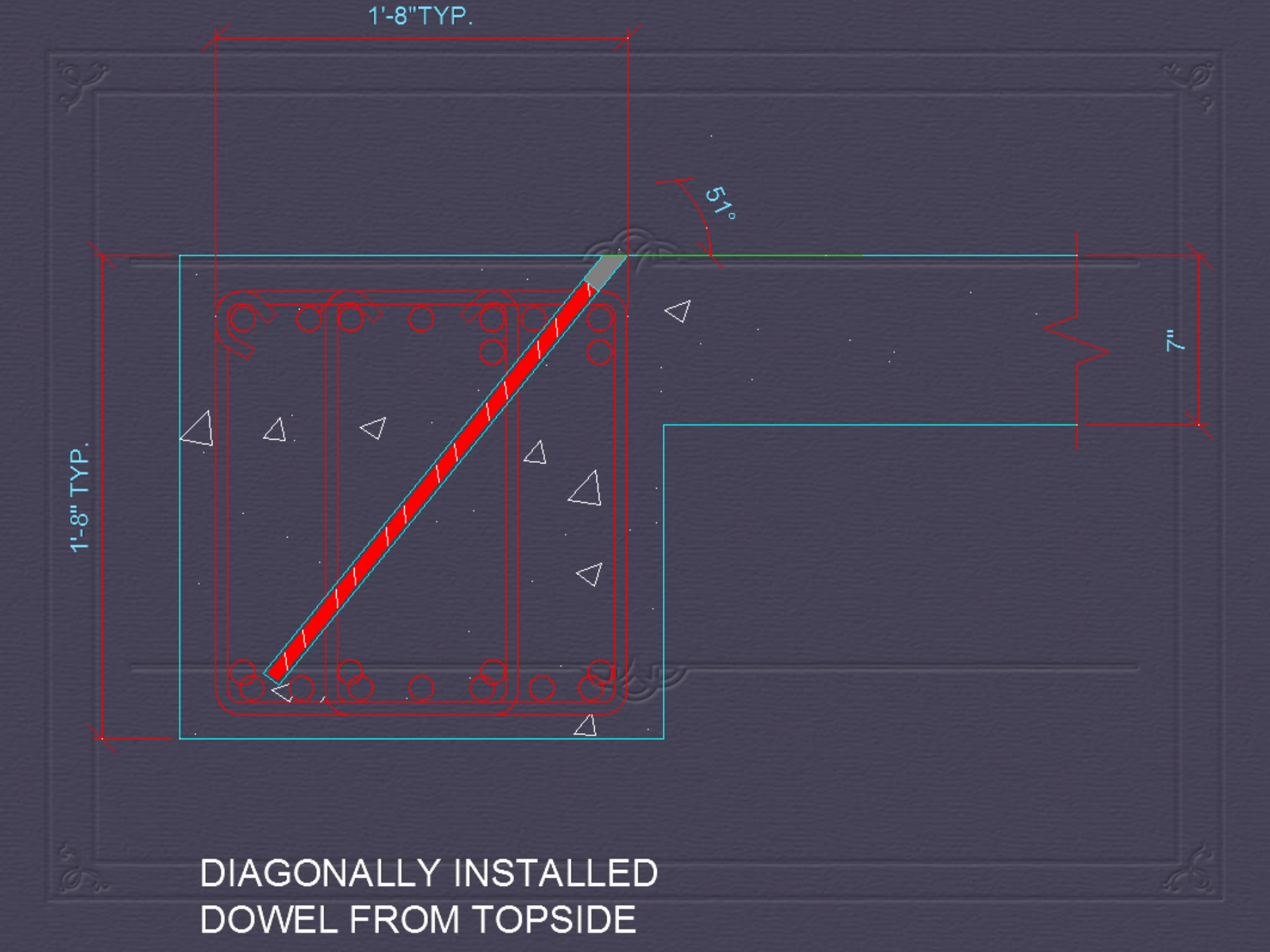
TYPICAL BEAM LAYOUT



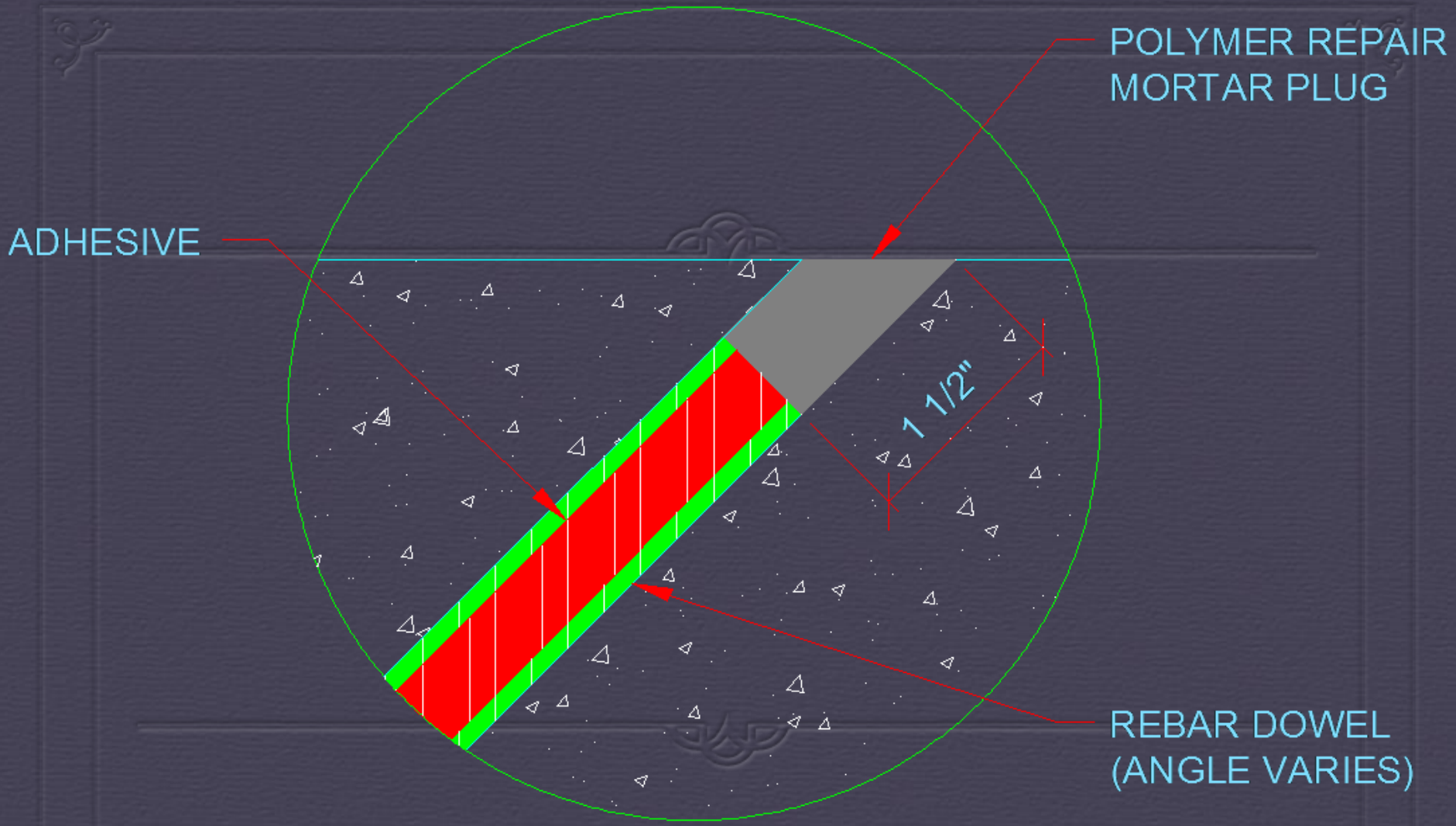
TYPICAL BEAM



VERTICALLY INSTALLED
DOWEL FROM TOPSIDE

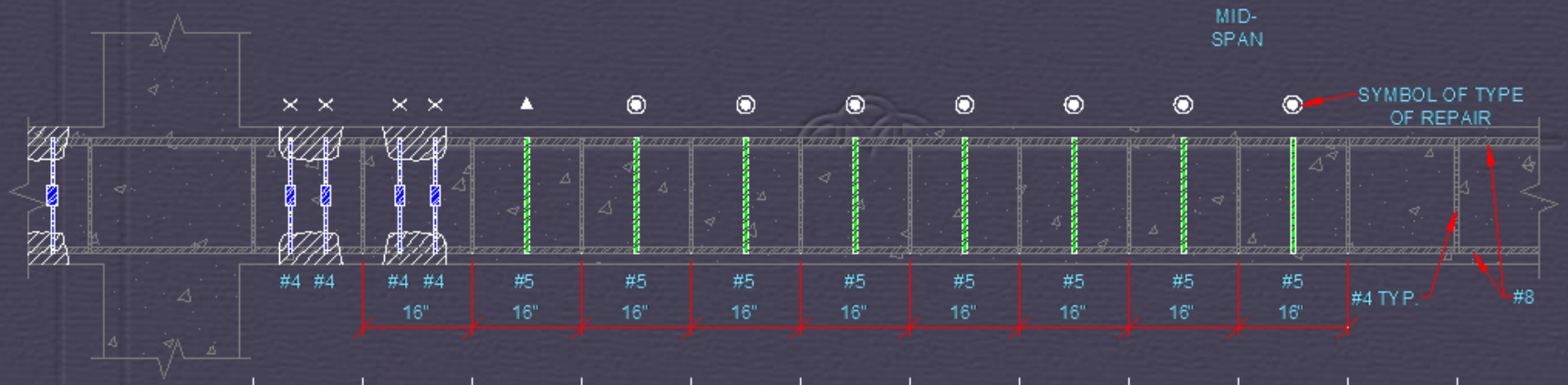


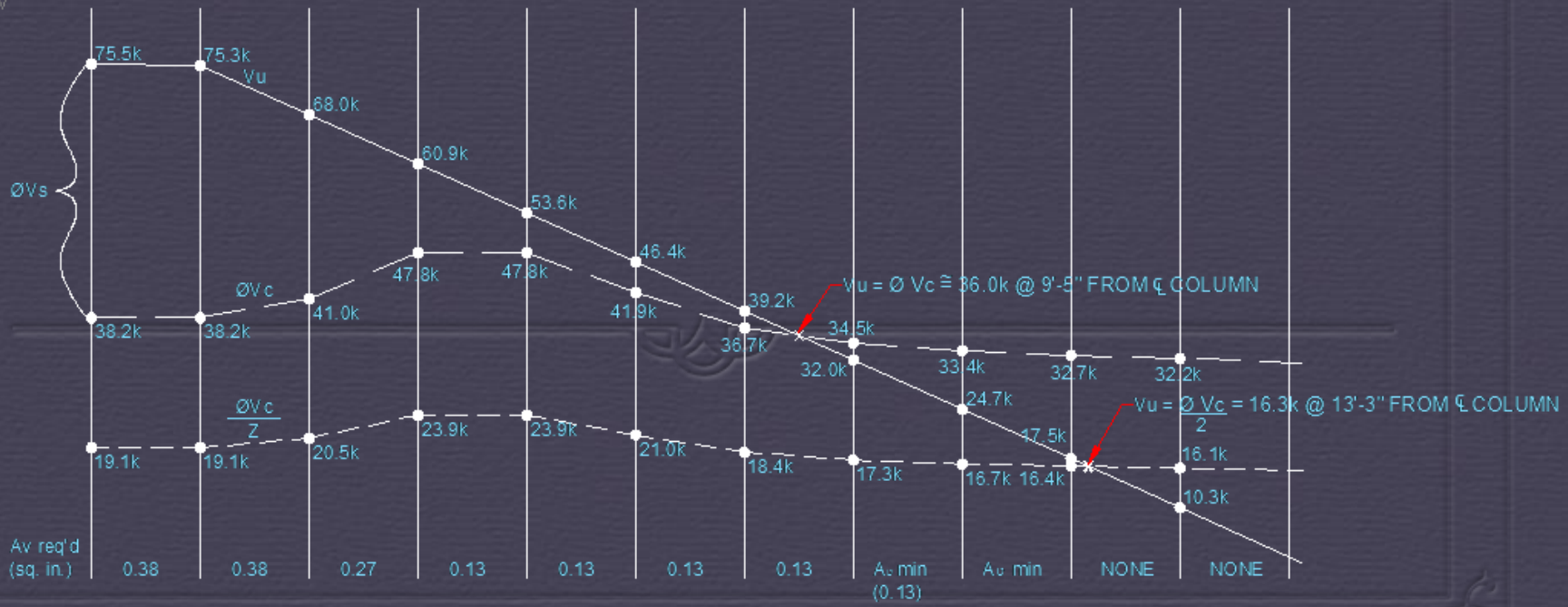
DIAGONALLY INSTALLED
DOWEL FROM TOPSIDE



DOWEL DETAIL

BEAM 24 - DESIGN OF DOWELS





Development of Dowels:

- ACI 318-08, 12.13.1 Commentary: Single leg stirrups of deformed bars discontinued in 1989 ACI 318 because difficult to hold in place during concrete placement and lack of a hook may make the stirrup ineffective as it crosses shear cracks near the end of the stirrup.
- ACI 318-08, 12.13.4: Longitudinal bars bent to act as shear reinforcement…if extended into a region of compression, shall be anchored beyond mid-depth d/2 as specified for development length in 12.2 for that part of fyt required to satisfy Eq. (11-17).

Development of Dowels:

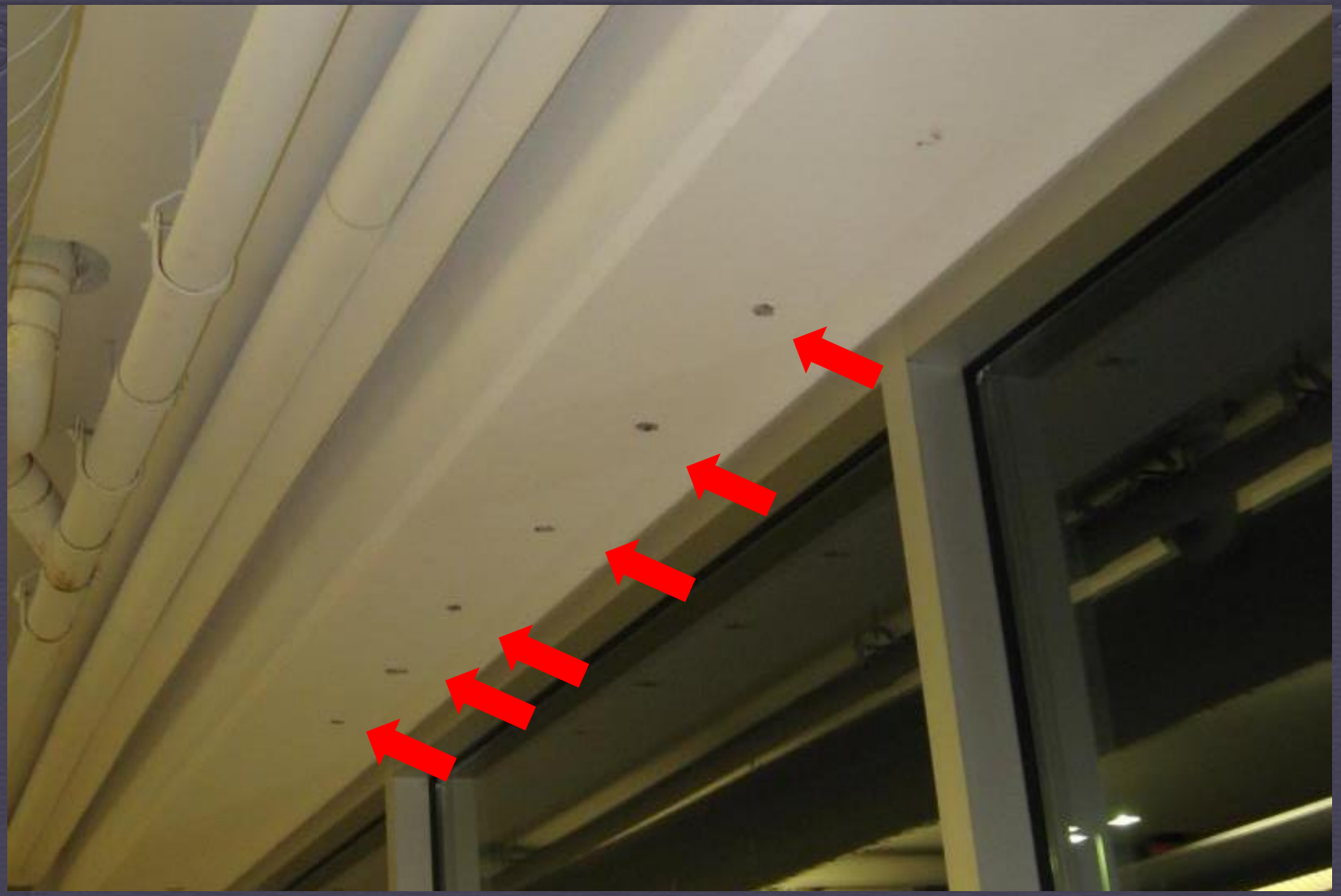
- Therefore, look to code prior to 1989…

  ACI 318-83 (1986), 12.13.2.2: Embedment d/2 above or below mid-depth on the compression side of the ember for full development length ℓ_d but not less than $24d_b$; or for deformed bars or deformed wire, 12 in.

Installing dowel in angled configuration from underside of beam

Epoxy fill of dowel hole

Vacuum dowel drill system minimized protection needed



Dowels installed into underside of beam

Repair method:

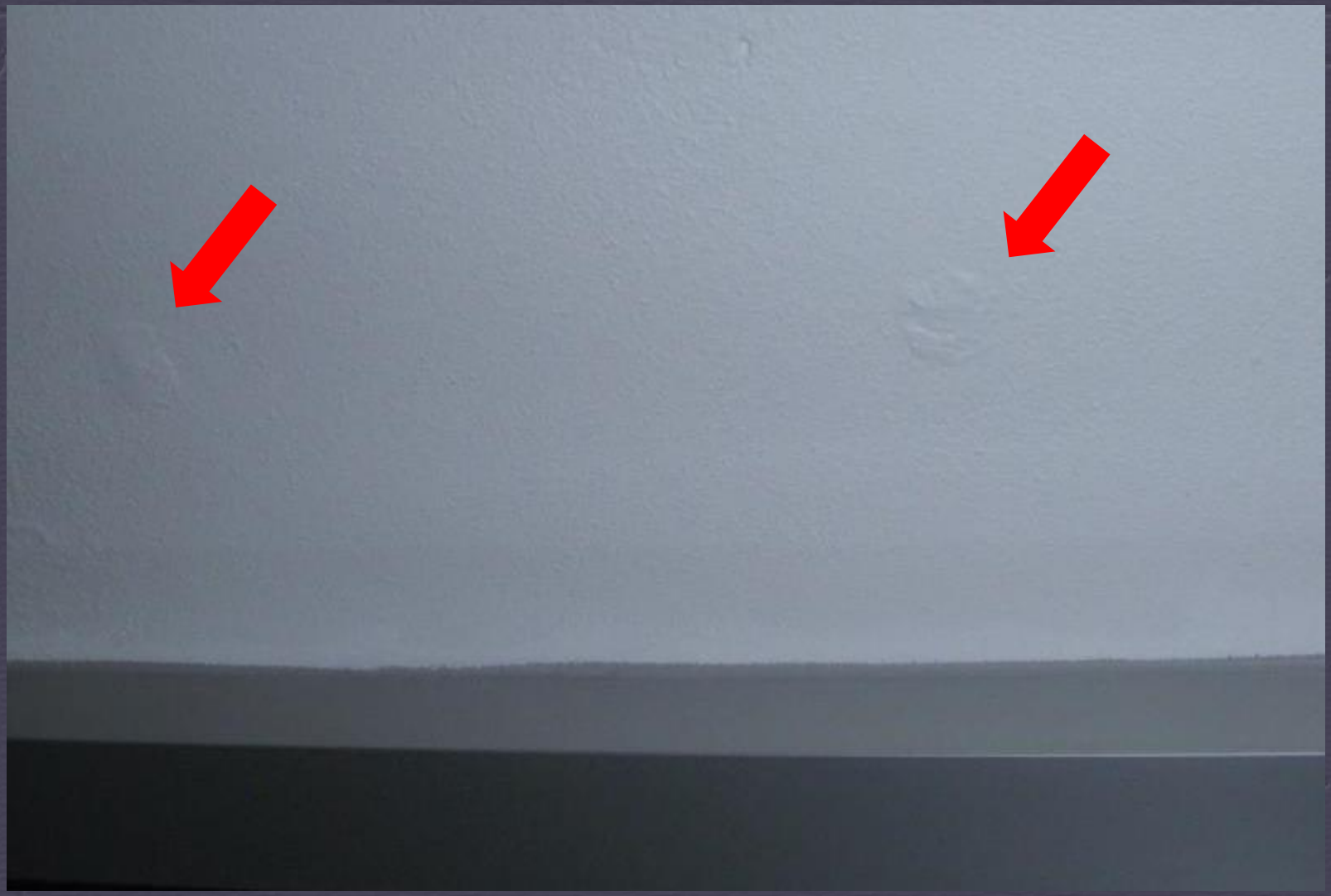
- 3 bars sizes existing reinforcement - #4, #5, & #6 bars
- 19 dowel configurations used for different beam and reinforcing arrangements
- 4 different supplemental dowel shear insertion types
- Used where dowels could not be placed:
  - Shear capacity
  - Spacing limitations
- This method used at 10 of 633 supplemental shear reinforcement locations

Hooked dowels installed in roof

Placing polymer repair mortar prior to roof patching

Construction:

- 18-week schedule, completed in 16 weeks
- $645,000 budget – actual cost $600,000
- 633 supplemental shear reinforcement locations
  - 462 installed on topside
  - 161 installed from bottom side



Repair of finishes – touchup of dowel location

The outcome:

- Adhesive dowels into the beams minimized
- Options so dowels could be installed in congested areas
- With several options, contractor was able avoid existing pipes/ducts/conduits
- With this repair, contractor able to remove minimal amount of finishes
- s-built beams closely matched the design drawings – this does not always happen!