



STRENGTHENING HIGH-RISE STRUCTURES USING FRP COMPOSITE MATERIALS

DAVID WHITE, P.E.
SIKA CORPORATION

ICRI 2015 SPRING CONVENTION - NYC

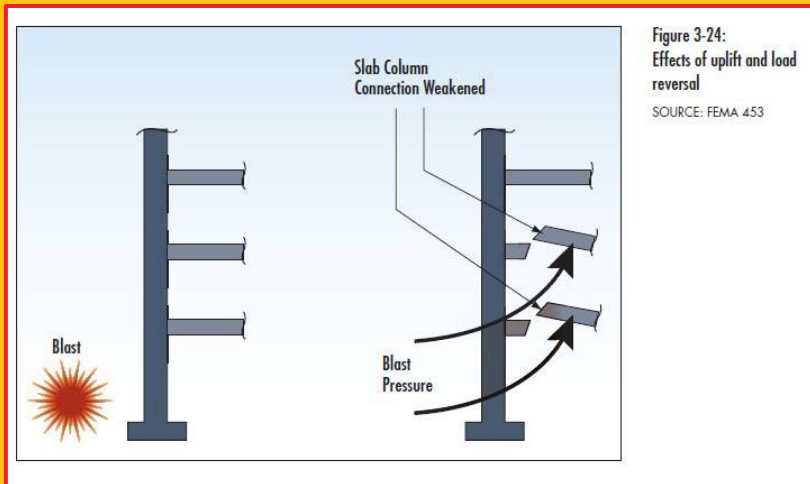


BUILDING TRUST



BUILDING REPAIRS WITH FRP COMPOSITES

- Building modifications
- Balcony repairs
- Corrosion damage
- Façade repairs
- Seismic repair and upgrades
- Blast hardening
- Change in use



“The greenest structures are the structures that are already built”

- Carl Elefante, AIA

Dir. Sustainable Design
Quinn Evans Architects



CODES AND STANDARDS

- **ACI 440.2R-08**

Guide for the Design and Construction of Externally Bonded FRP Systems for Strengthening Concrete Structures

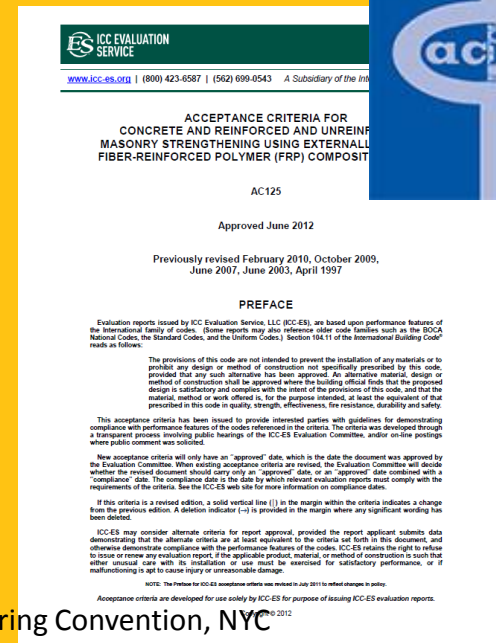
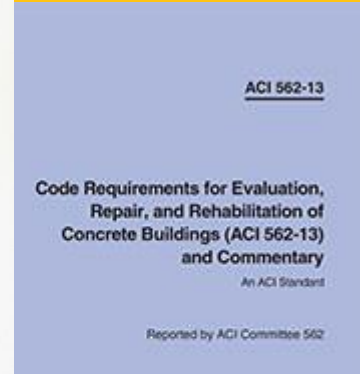
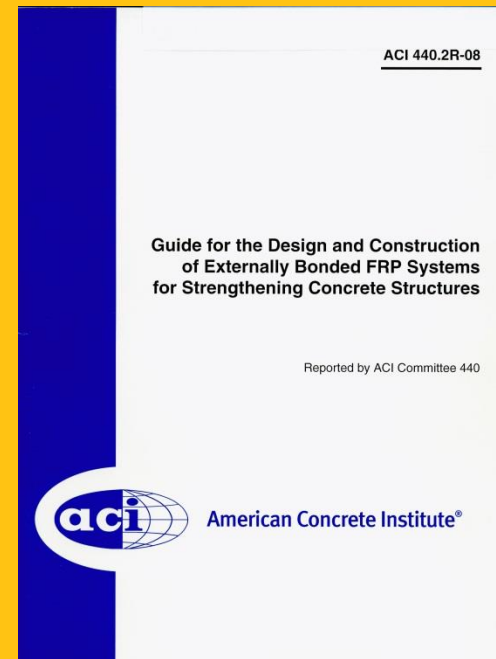
- **ACI 562-13**

Code Requirements for Evaluation, Repair, and Rehabilitation of Concrete Buildings

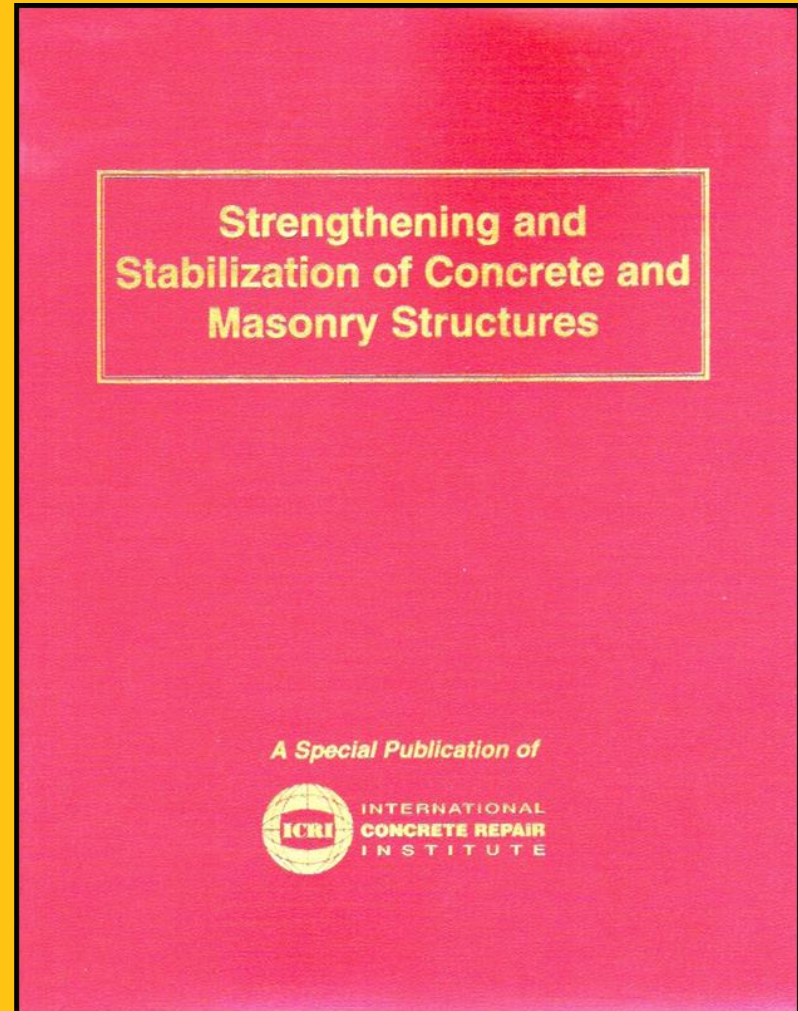
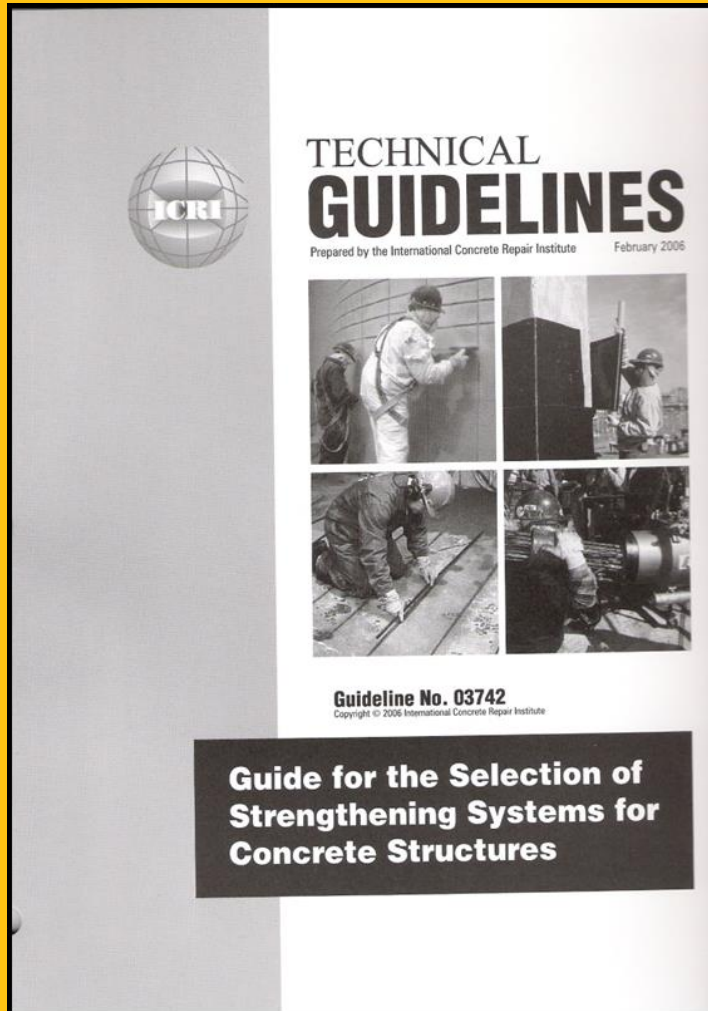
- Developed for adaptation into International Existing Building Code
- Use of FRP allowed as long as consistent with ACI 440

- **ICC Evaluation Service**

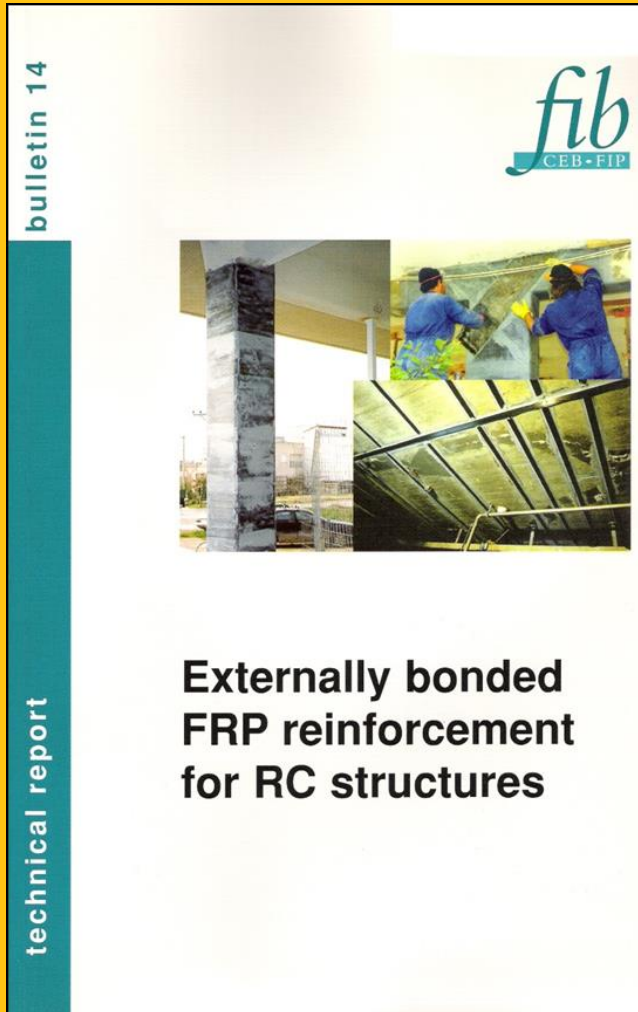
- Technical evaluation of building products for compliance to building codes such as IBC
- Products independently tested per Acceptance Criteria



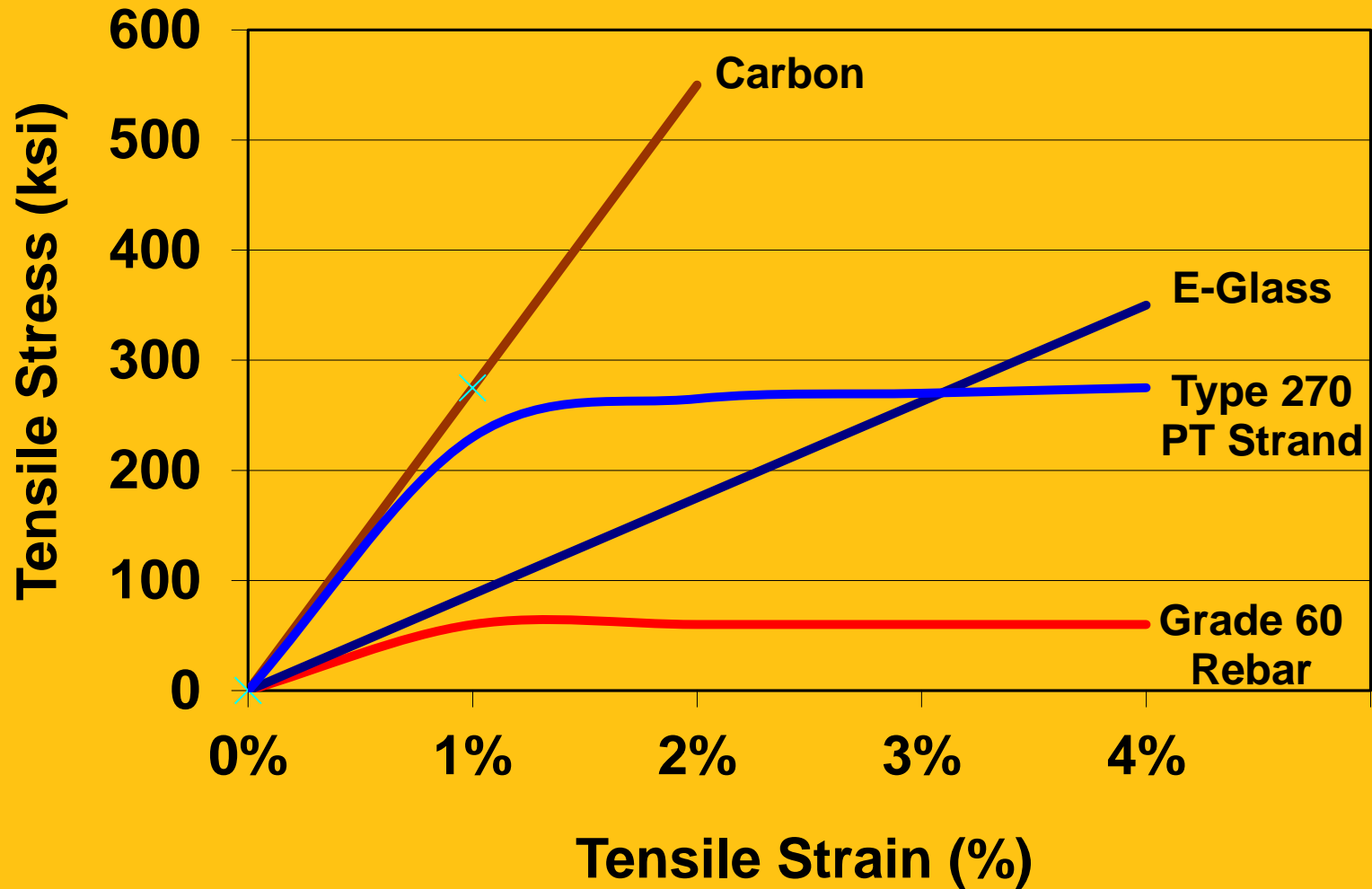
ICRI DOCUMENTS



INTERNATIONAL DOCUMENTS



MATERIAL PROPERTIES



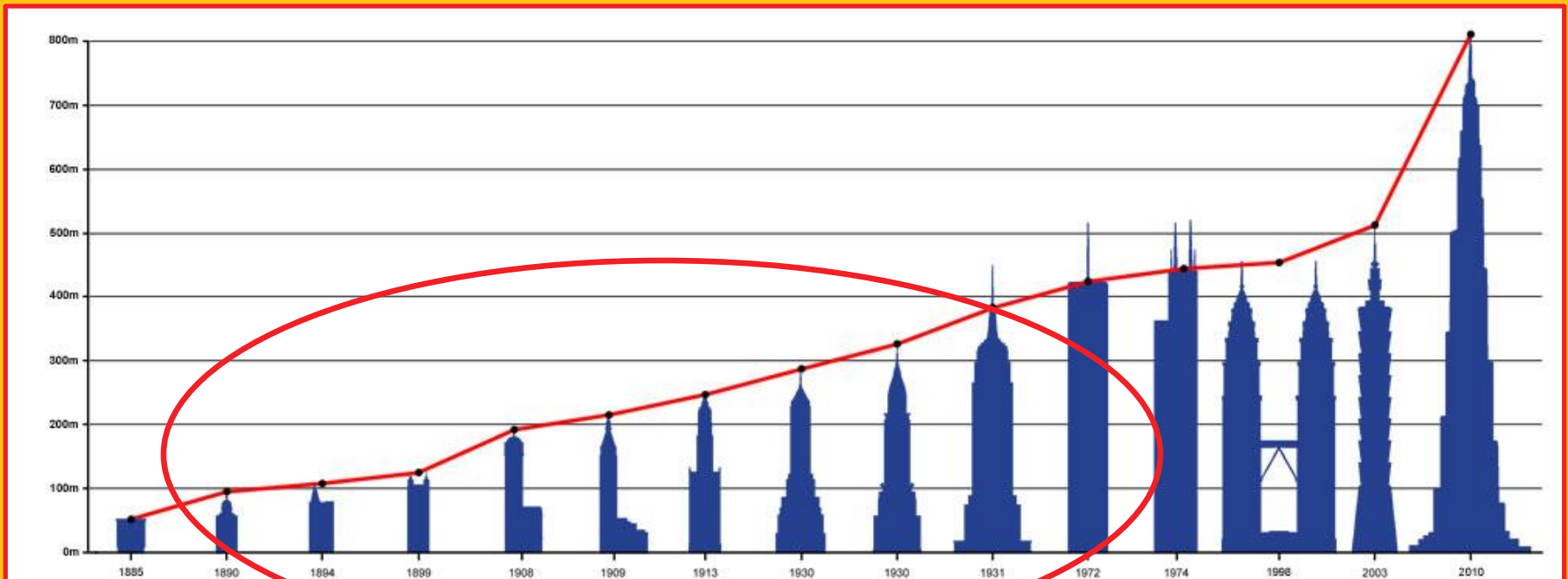
CASE STUDIES



TALLEST BUILDINGS IN THE WORLD

- NYC had the tallest building in the world (continuously) from 1890 – 1974 (10 different buildings)

QUIZ



1 WORLD TRADE CENTER (1972)

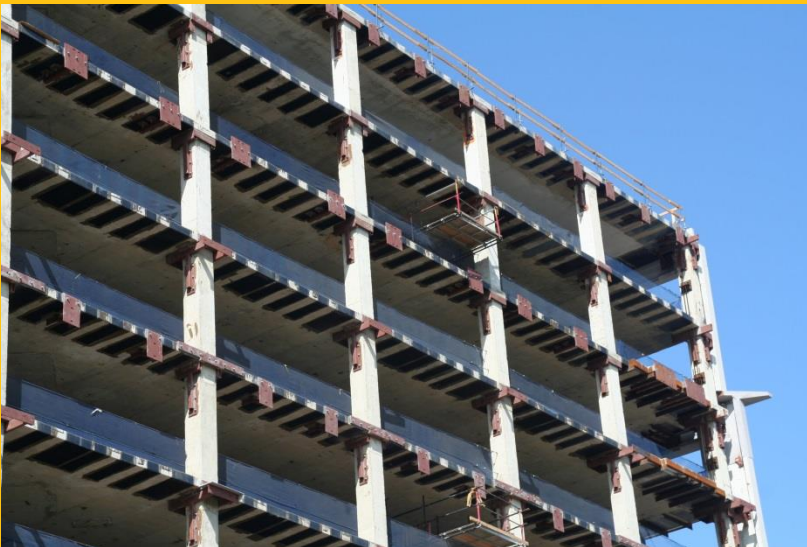


EMPIRE STATE BUILDING (1931)



OFFICE BUILDING – METRO DC

- 600,000 sf building gutted to its core
- **Blast hardening** existing concrete frame bldg.
- Slab edge protection before curtain wall installed
- Roof/slab strengthened with carbon fiber plates for uplift pressure
- Column perimeter strengthened for punch through forces
- Renovated to LEED certification
- Blast proof per D.O.D. requirements



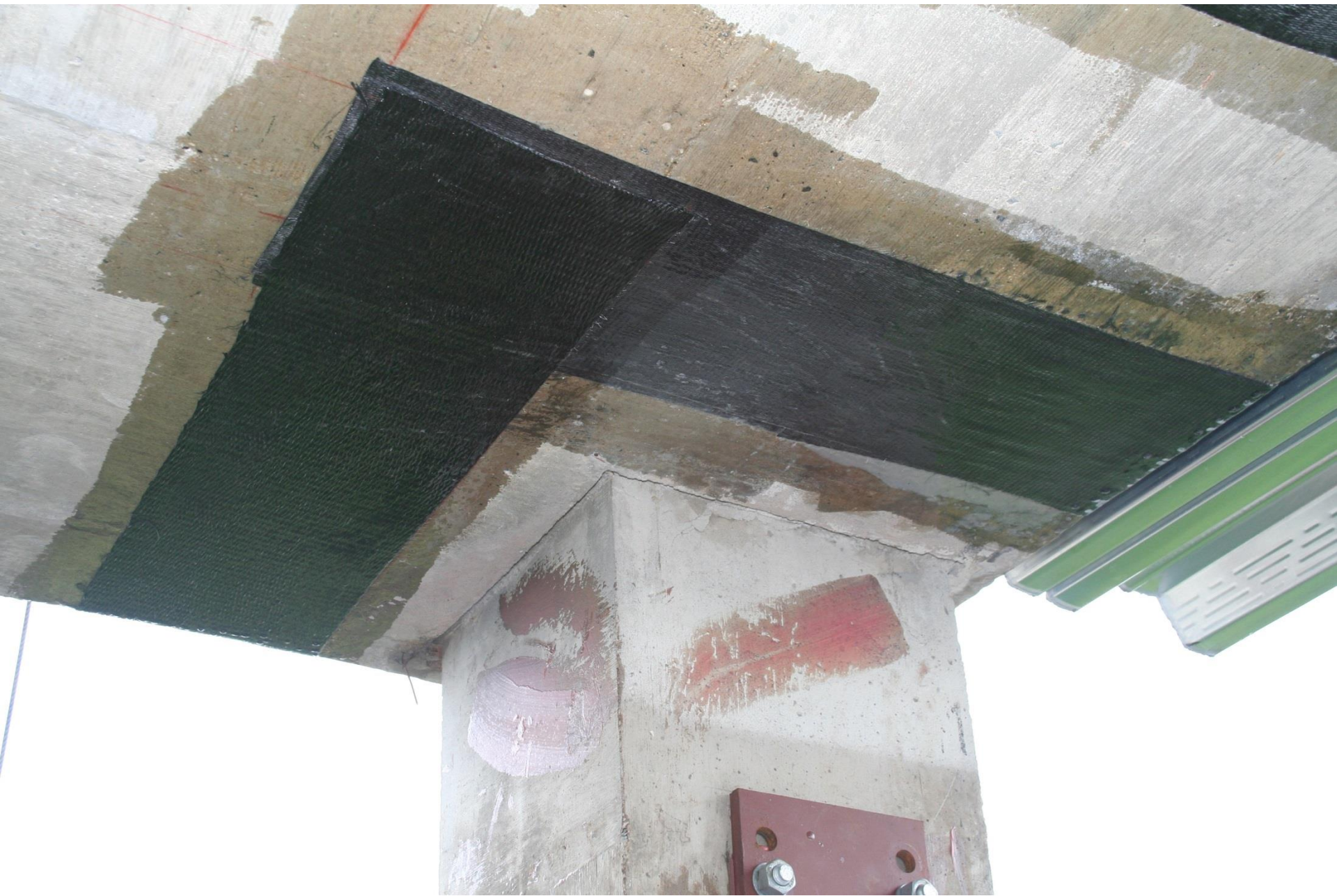


2008 5 29

CAUTION
CAUTION
CAUTION



2008 5 29





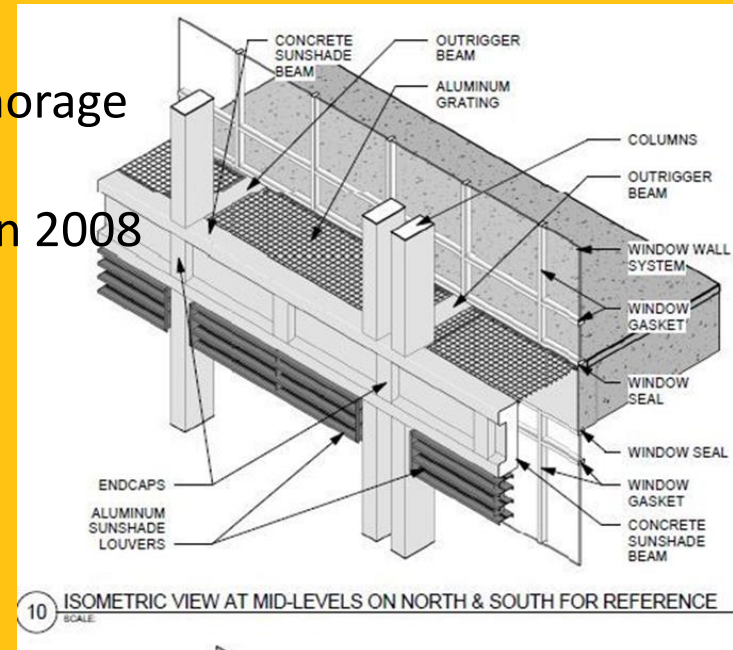
HARRIS COUNTY ADMINISTRATION BUILDING

HOUSTON, TX



HARRIS COUNTY ADMINISTRATION BUILDING

- Government building constructed in 1978
- One floor basement – 9 floors above grade – mechanical penthouse on roof
- Reinforced concrete slab supported on PT concrete beams and spandrel beams
- “Sunshade” beams line perimeter of building
- “Outrigger” beams cantilever beyond window wall perimeter to support sunshade beams
- Precast concrete caps protect button-head anchorage system of PT outrigger beams
- Loose concrete pieces starting falling off HCAB in 2008
- Other problems included:
 - Concrete spalling
 - Cracking
 - Honeycombing
 - Deteriorated concrete

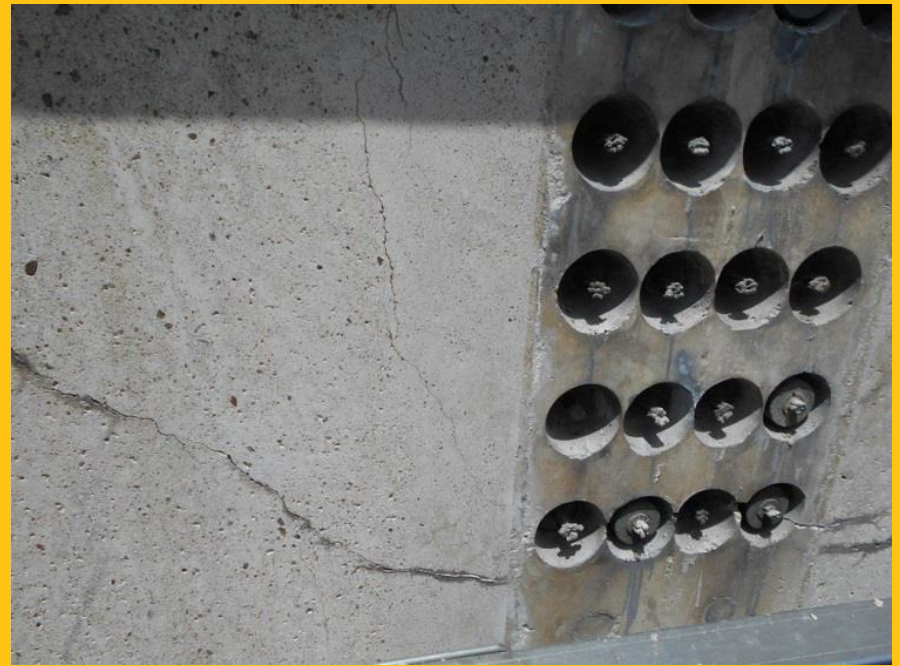


GENERAL SCOPE OF REPAIRS

- Complete diagnosis of existing conditions
- Removal and replacement of deteriorated concrete
- Removal and replacement of precast concrete end caps
- Epoxy crack injection
- Pressure washing concrete surfaces
- Removal and replacement of window's exterior sealant and glazing gaskets
- Corrosion inhibitor treatment
- FRP composites to strengthen building façade, sunshade and outrigger beams
- Skim coat all existing and repaired concrete surfaces
- Application of new elastomeric, anti-carbonation coating on entire façade



CONCRETE DETERIORATION



CONCRETE REPAIRS



FRP REPAIRS



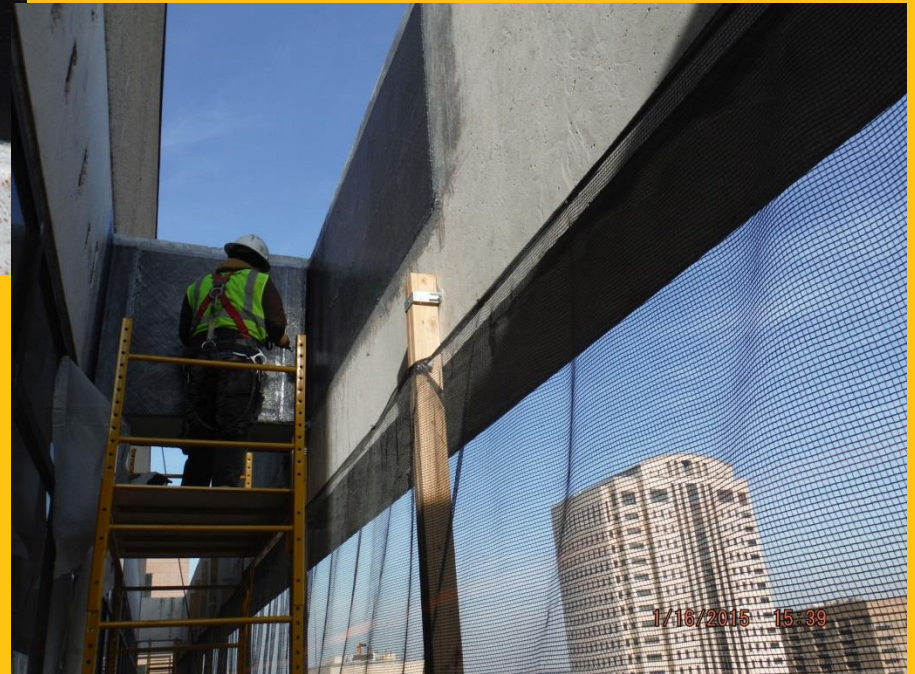
Bond strength testing

SUNSHADE BEAM FRP REPAIRS



Uni-directional CFRP fabric

+/- 45° Bi-directional CFRP fabric





Mock-up Area

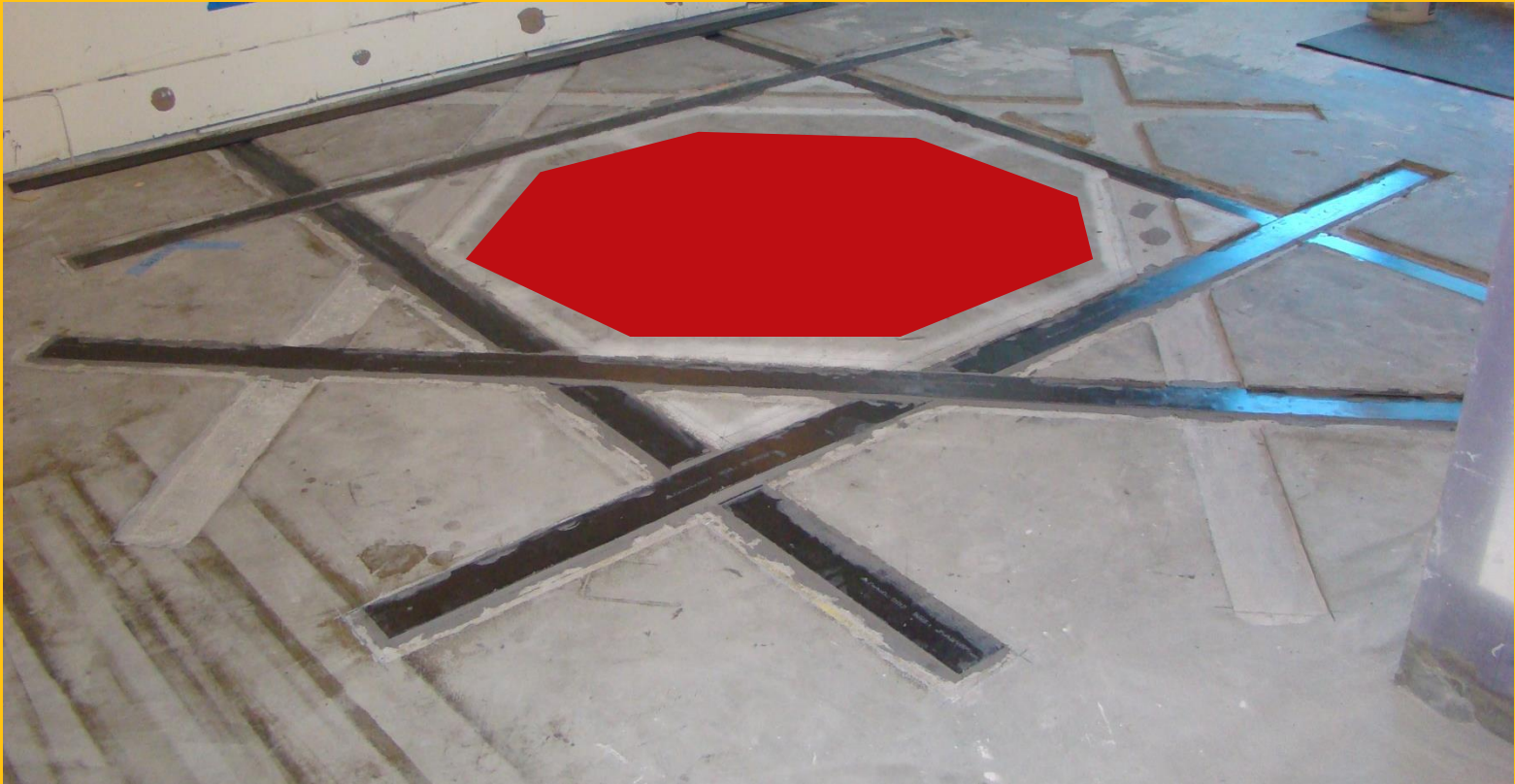
- FRP Repairs
- Skim Coat
- Façade Coating

CHRYSLER BUILDING (1930)



CENTRAL PARK WEST CONDO

- New octagon shaped staircase cut into reinforced concrete slab
- Carbon fiber plates inserted into grooves cut into concrete on top and bottom of slab



WORLD TRADE CENTER COMPLEX

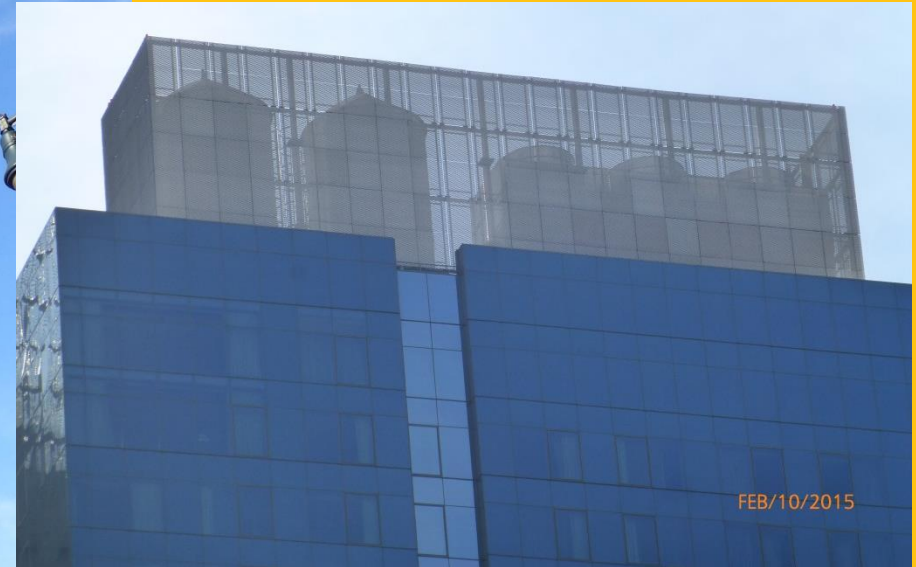


- Foundation wall strengthening during construction
- Modifications for mechanical cores



INTERCONTINENTAL HOTEL, W. 44TH ST. – NYC

HOME OF SHAKE SHACK



- Large screens added to roof to hide water tanks
- Roof not designed to carry heavier loads

INTERCONTINENTAL HOTEL, W. 44TH ST. - NYC



- Carbon fiber fabrics bonded to roof slab to carry additional loads



ROX-SAN MEDICAL TOWER

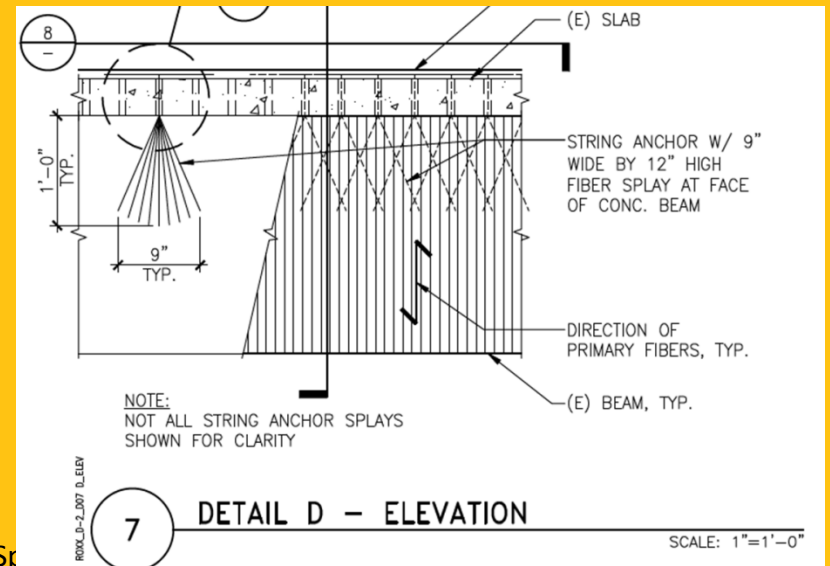
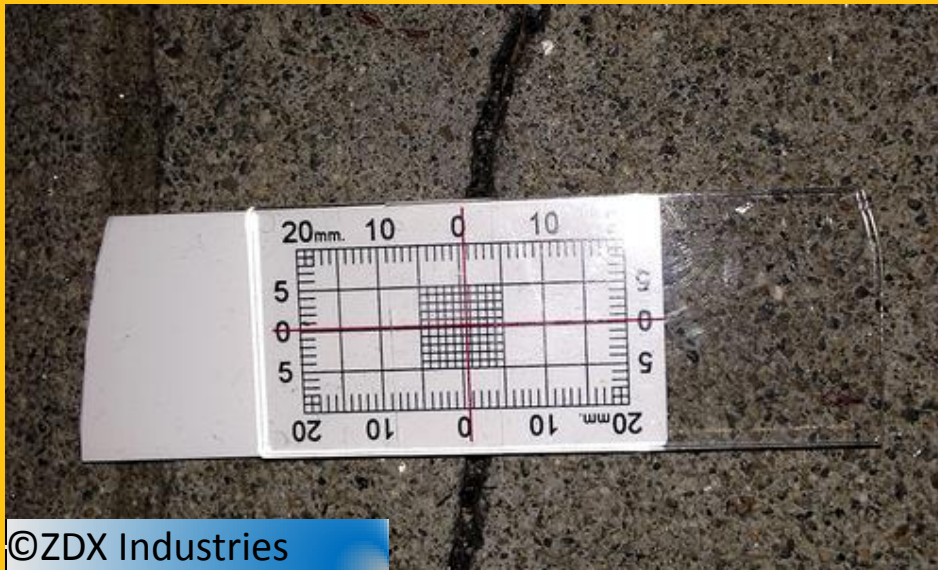
BEVERLY HILLS, CA



- 11 Story RC building
- Built 1963
- Retrofitted 2014-2015

ROX-SAN MEDICAL TOWER

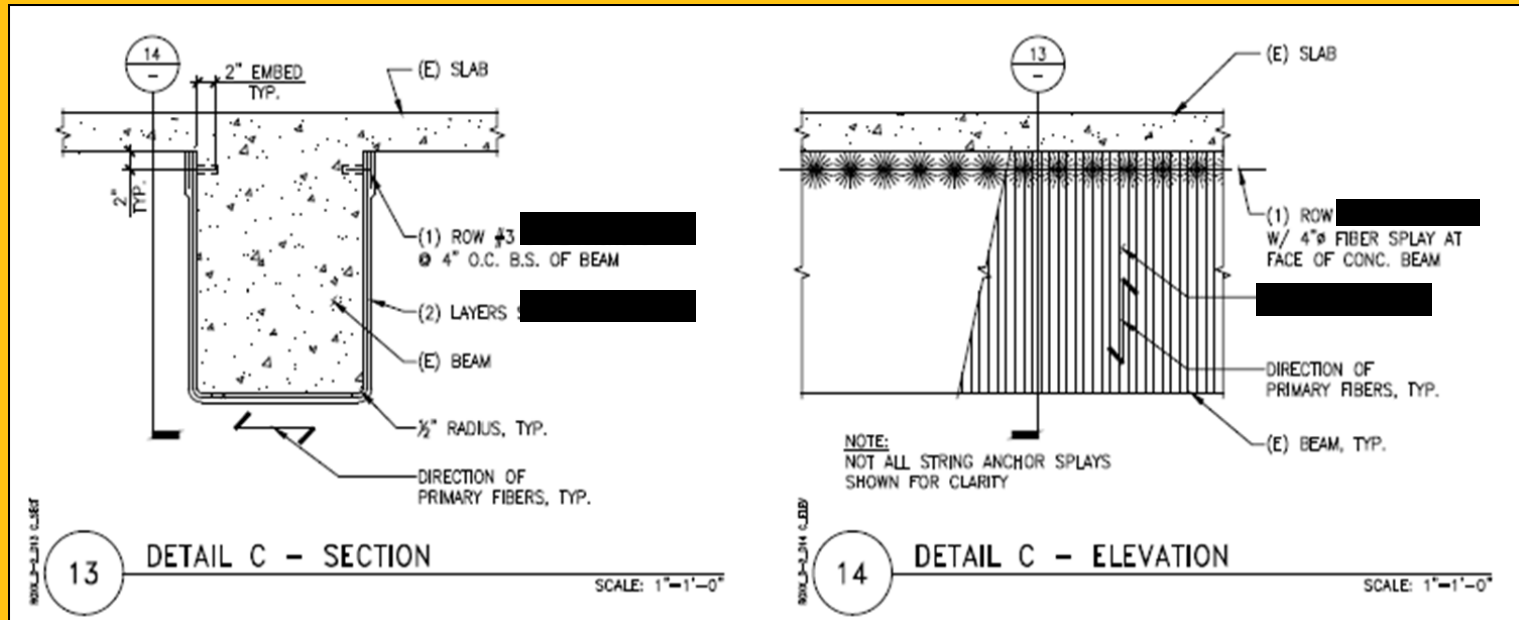
- Seismic retrofit of office building in Southern California
- Shear cracks identified in critical support beams
- Crack monitors installed to measure movement over extended period of time
- Structural analysis performed by structural engineers identified deficiency in concrete members
- Cracks injected with epoxy resin to stabilize movement
- New reinforced concrete shear walls added to stabilize building
- Concrete beams wrapped with CFRP fabrics for seismic strengthening
- CFRP fiber anchors installed to enhance “through-slab” connections



SHEAR CRACKS IN CRITICAL SUPPORT BEAMS



FRP REPAIRS



WOOLWORTH BUILDING (1913)



MET LIFE TOWER (1909)





Thank you for your attention

Dave White, P.E.

Sika Corporation

www.usa.sika.com

white.dave@us.sika.com



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