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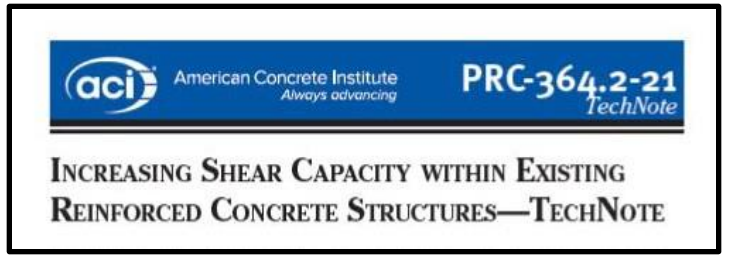
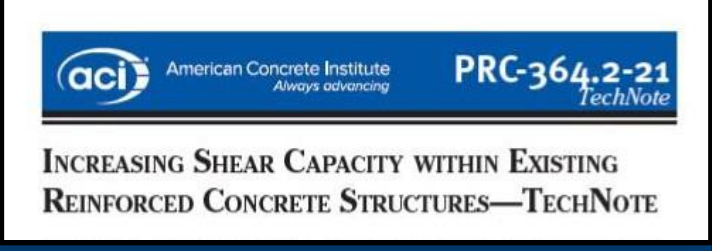
Increasing Shear Capacity within Existing Reinforced Concrete Structures – ACI PRC 364.2

Sean Radley, P.E.
Senior Consulting Engineer
Simpson Gumpertz & Heger
Boston, MA

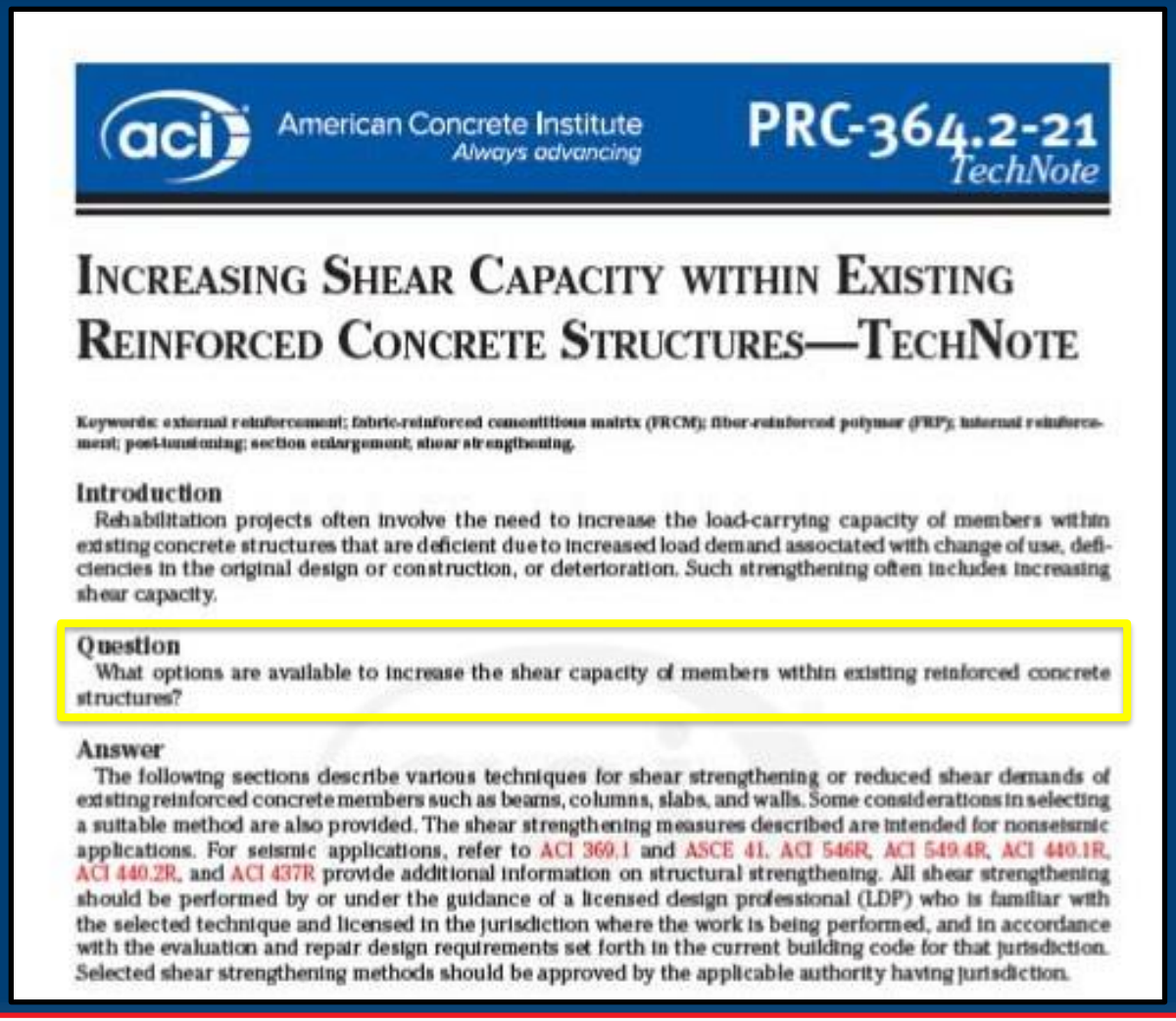


Session Outline



- Scope of TN 364.2
- Structural strengthening in general
- Various methods of shear strengthening
  - Section Enlargement
  - Internal Reinforcement
  - External Reinforcement
  - Near-surface-mounted Reinforcement
  - External Post-Tensioning
  - FRP Composite Systems
  - FRCM Systems
- Considerations for selecting a suitable method

Scope of TechNote 364.2



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PRC-364.2-21
TechNote

INCREASING SHEAR CAPACITY WITHIN EXISTING REINFORCED CONCRETE STRUCTURES—TECHNOTE

Keywords: external reinforcement; fabric-reinforced cementitious matrix (FRCM); fiber-reinforced polymer (FRP); internal reinforcement; post-tensioning; section enlargement; shear strengthening.

Introduction

Rehabilitation projects often involve the need to increase the load-carrying capacity of members within existing concrete structures that are deficient due to increased load demand associated with change of use, deficiencies in the original design or construction, or deterioration. Such strengthening often includes increasing shear capacity.

Question

What options are available to increase the shear capacity of members within existing reinforced concrete structures?

Answer

The following sections describe various techniques for shear strengthening or reduced shear demands of existing reinforced concrete members such as beams, columns, slabs, and walls. Some considerations in selecting a suitable method are also provided. The shear strengthening measures described are intended for nonseismic applications. For seismic applications, refer to ACI 369.1 and ASCE 41. ACI 546R, ACI 549.4R, ACI 440.1R, ACI 440.2R, and ACI 437R provide additional information on structural strengthening. All shear strengthening should be performed by or under the guidance of a licensed design professional (LDP) who is familiar with the selected technique and licensed in the jurisdiction where the work is being performed, and in accordance with the evaluation and repair design requirements set forth in the current building code for that jurisdiction. Selected shear strengthening methods should be approved by the applicable authority having jurisdiction.

Structural Strengthening

- May be needed due to:
  - Higher loads (change of use, additional equipment, planters)
  - Deterioration (corrosion, concrete deterioration)
  - Damage (impact, overloading, fire)
  - Deficient design (older detailing requirements)
  - Construction errors (missing or misplaced reinforcement)
- Always requires engineering analysis and design by LDP

Source: ICRI No. 330.1



METHODS OF SHEAR STRENGTHENING

Section Enlargement

Section enlargement of a joist

Section enlargement of a column to increase slab punching shear capacity

Source: ICRI No. 330.1

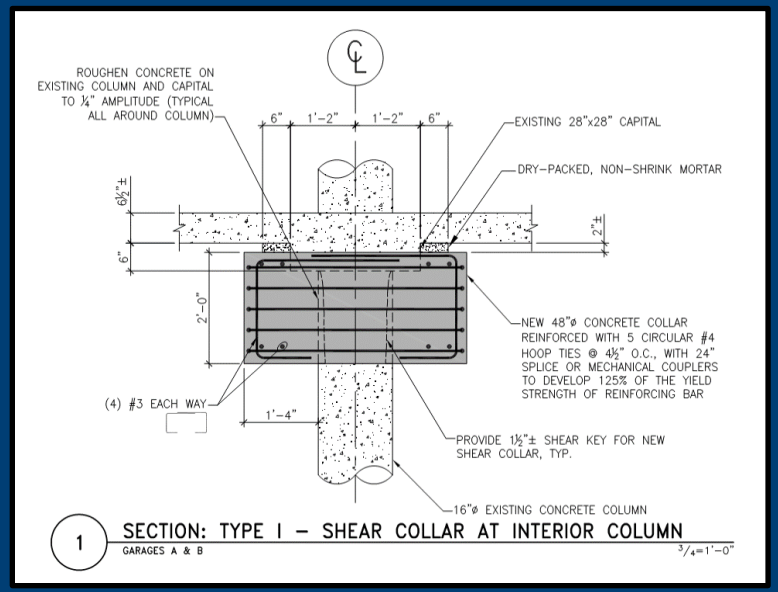
Section Enlargement

Considerations

- Passive method
- Repair deteriorated concrete
- Surface preparation
- Supplemental reinforcement
- Increased DL
- Added stiffness may alter load distribution

Advantages

- Uses conventional construction techniques
- Economical



Disadvantages

- Added weight
- Loss of headroom / space

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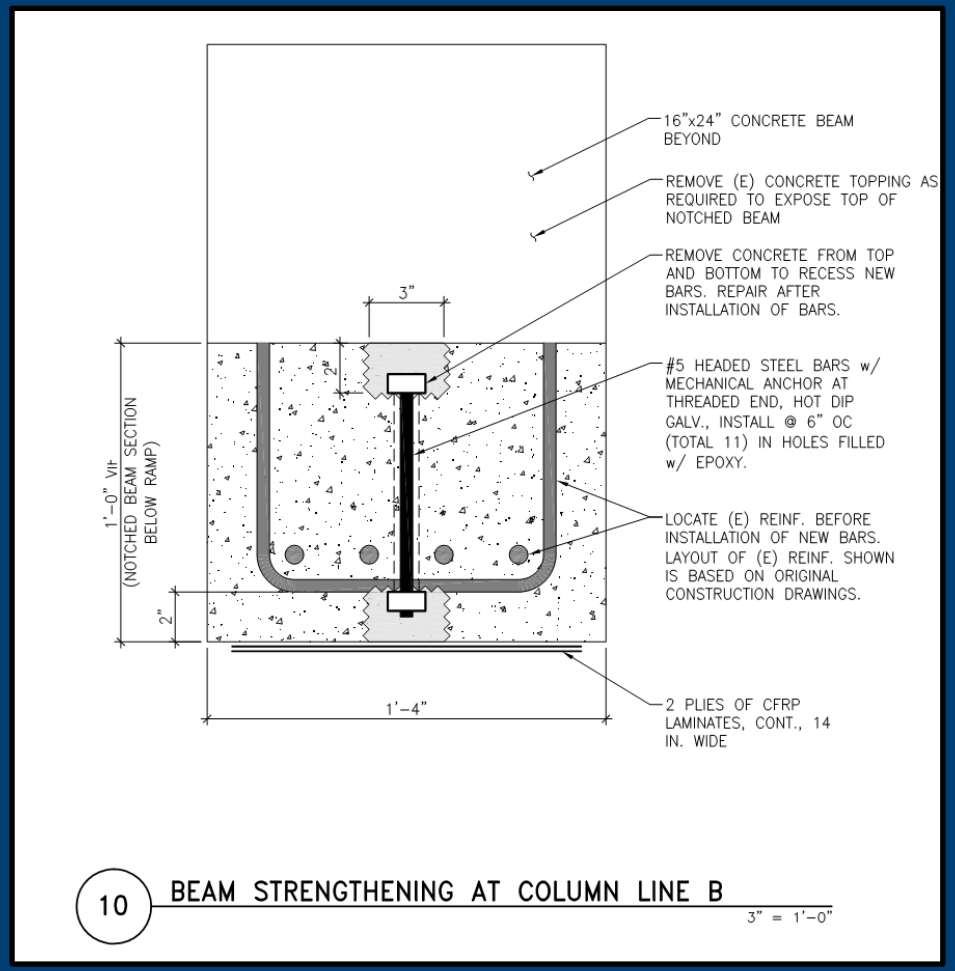
Guidelines provided in ACI PRC-546 and ICRI 330.1.

Internal Reinforcement



Internal Reinforcement

Considerations

- Passive method.
- Use non-destructive testing to avoid cutting or damaging existing reinforcement and conduits.

Advantages

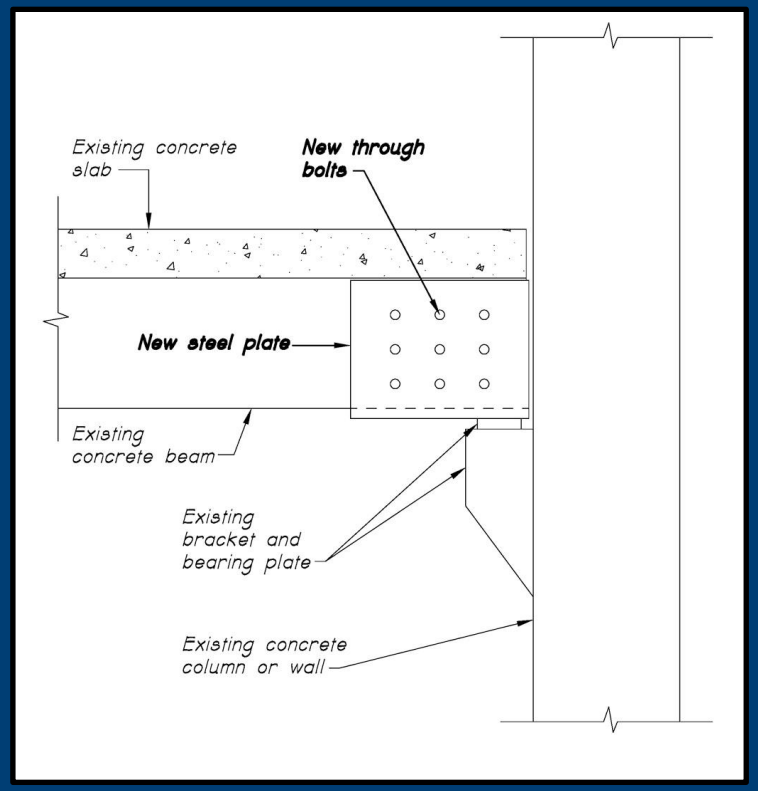
- Relatively easy
- Uses commonly available equipment

Disadvantages

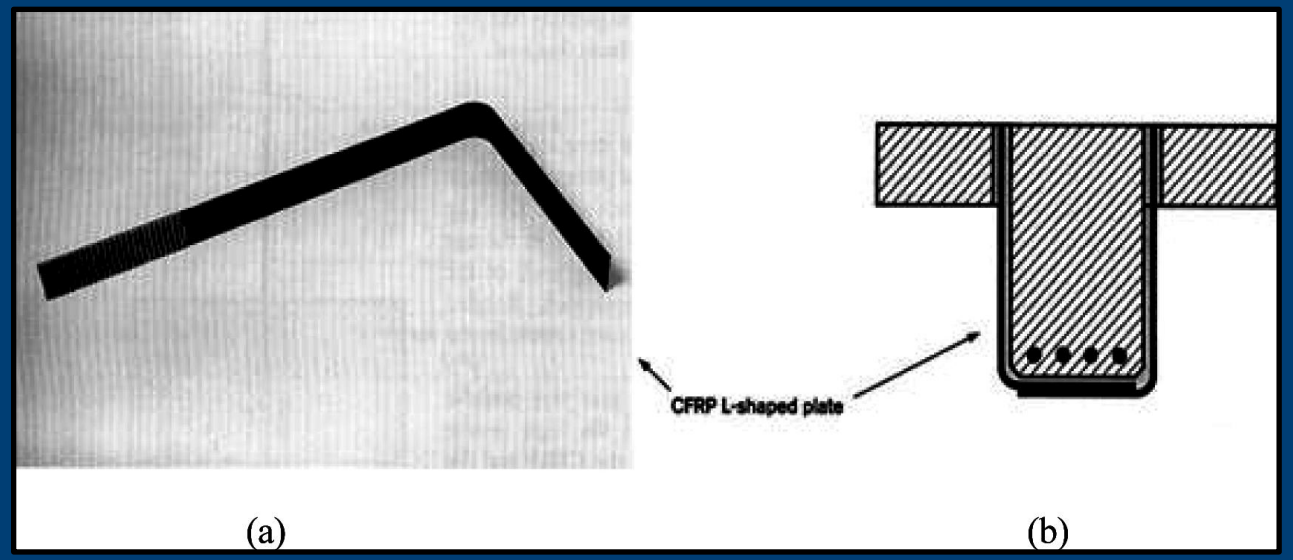
- Difficult to develop the reinf.
- Difficult to install reinf. in heavily-reinforced members.
- Need space around member in order to install reinf.

Guidelines provided in ACI PRC-546.

External Reinforcement



External reinforcement of a beam using steel plates



External reinforcement of a beam using FRP strips

External Reinforcement

Considerations

- Passive method
- Edge distance and group action of bolts
- Surface preparation
- Composite behavior
- Corrosion protection
- Fire protection
- Moisture diffusion

Advantages

- Useful where space constraints limit use of internal reinforcement
- FRP members have high strength-to-weight ratio

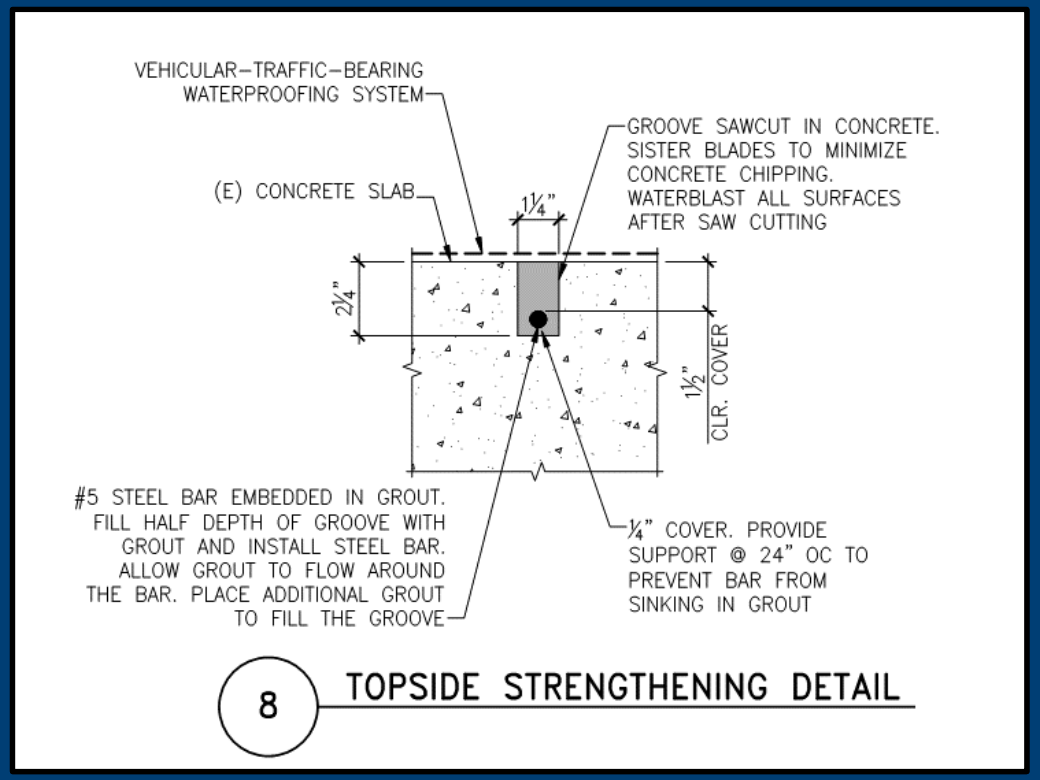
Disadvantages

- Structure needs to have a minimum unrepaired strength
- Steel members difficult to install due to weight
- Steel members may be expensive
- Potential degradation of epoxy adhesive over time
- Aesthetics

Guidelines provided in ACI PRC-440.2 and -546, and ICRI 330.1.

Near-surface-mounted Reinforcement

Sawcut grooves for NSM reinforcement



Source: Dr. Laura De Lorenzis

Near-surface-mounted Reinforcement

Considerations

- Passive method
- Not typically used for shear strengthening
- Depth of concrete cover
- Corrosion protection
- Development length

Advantages

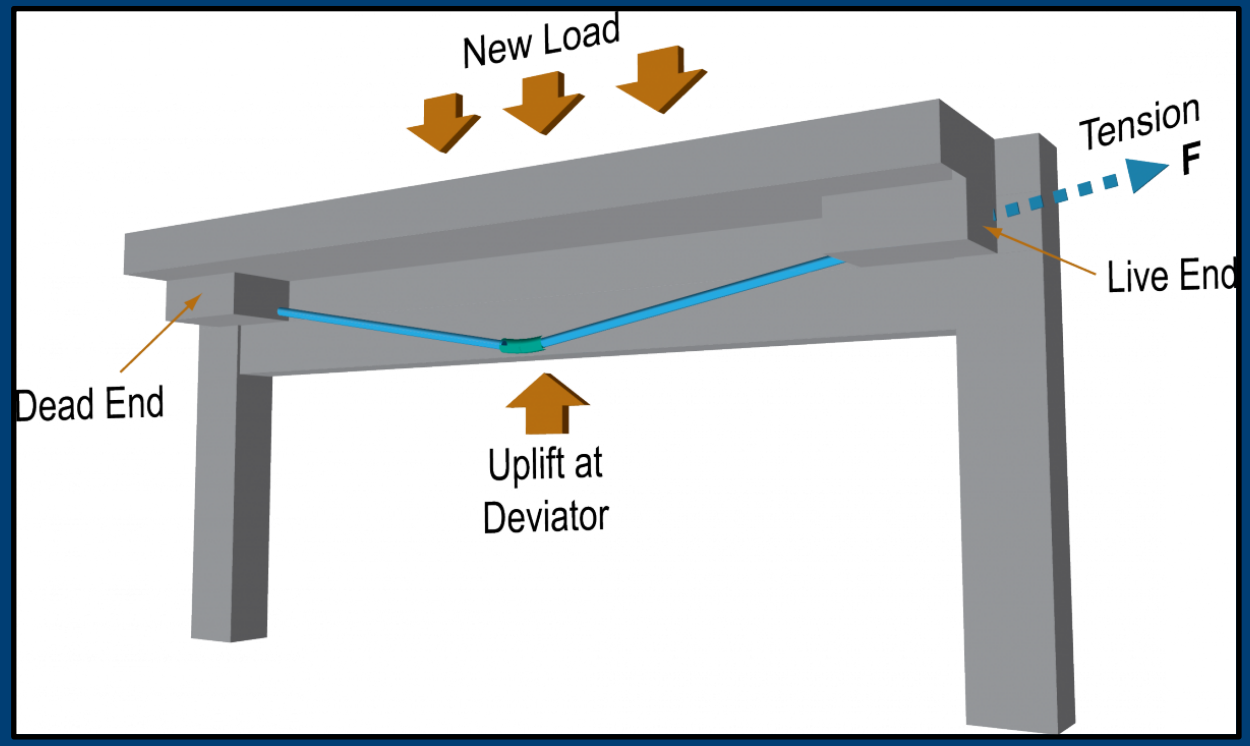
- Reduced chance of damaging existing reinforcement

Disadvantages

- Difficult to develop the bar
- Limited applications

Guidelines provided in ACI PRC-440.2 and ICRI 330.1.

External Post-tensioning



Source: structuraltechnologies.com

External PT of DT beams

Source: pullman-services.com

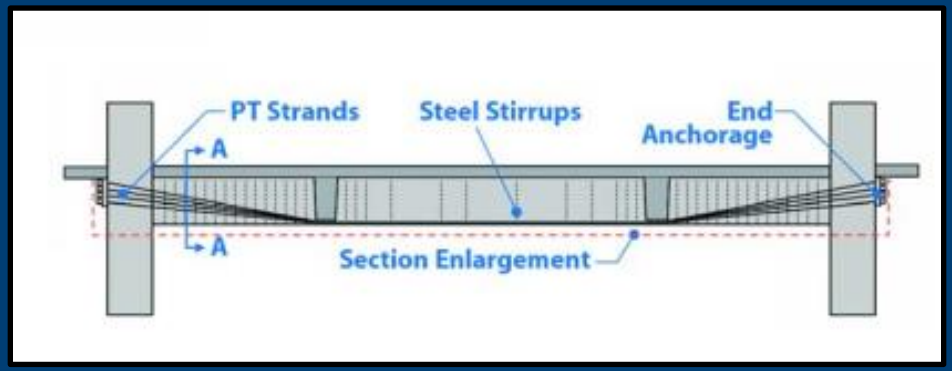
External Post-tensioning

Considerations

- Active method
- Primarily used for flexure
- Corrosion and fire protection
- Balance of strength and serviceability
- Significant internal forces
- Bursting stresses at anchorages
- Effects on adjacent construction
- Post-tensioning losses

Advantages

- Provides greater strength increases than passive methods
- Closes existing cracks



Disadvantages

- Structure needs to have a minimum unrepaired strength
- Difficult to install in congested interior locations
- Requires specialty contractors
- Aesthetics

Source: Alkhrdaji and Thomas 2002

Guidelines provided in ACI PRC-546.

Fiber-Reinforced Polymer Composite Systems (FRP)

FRP composite system installed on a spandrel beam

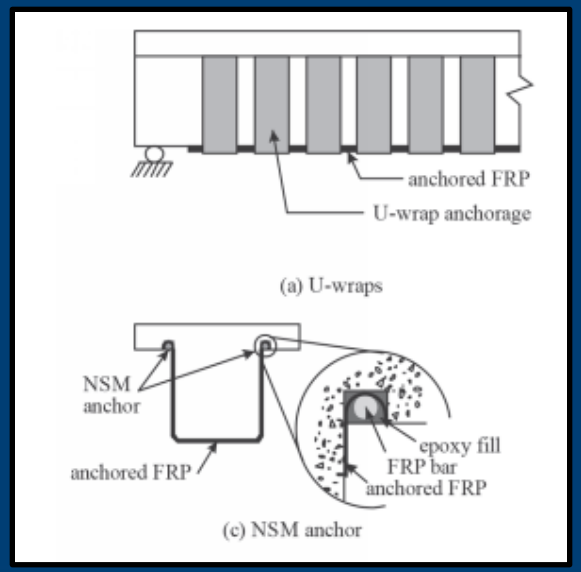
FRP composite system installed on a shear wall

Source: Alkhrdaji 2015

Fiber-Reinforced Polymer Composite Systems (FRP)

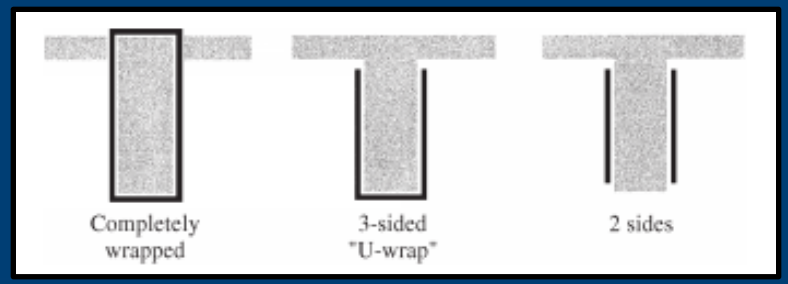
Considerations

- Passive method
- Bond-critical application
- Surface preparation
- Repair deteriorated concrete



Advantages

- High strength
- Light weight
- Conform to various geometries
- Easy installation
- Non-corrosive
- Cost-effective



Disadvantages

- Structure needs to have a minimum unrepaired strength
- Applications are limited on moist surfaces, at high humidity, and low temps.
- Acts as a vapor barrier.
- Aesthetics
- Requires trained contractors

Sources: ACI PRC-440.2
Alkhrdaji and Thomas 2002
De Luca and Tumialan 2014
Arnold 2014

Guidelines provided in ACI PRC-440.2 and ICRI 330.1.

Fabric-Reinforced Cementitious Matrix Systems (FRCM)

Installation of FRCM on a wall

Source: strongtie.com

Installation of FRCM on an arch

Source: De Luca and Tumialan 2014

Fabric-Reinforced Cementitious Matrix Systems (FRCM)

Considerations

- Passive method
- Bond-critical application
- Surface preparation
- Repair deteriorated concrete

Advantages

- Better performance under elevated temperature, humidity, and UV than FRP systems.
- FRCM is non-combustible.
- Easy installation.

Disadvantages

- Relatively new material.
- Not frequently installed by contractors.
- Results of durability testing are limited.

Source: De Luca and Tumialan 2014



CONSIDERATIONS IN METHOD SELECTION

Considerations in Method Selection

- Cause for strengthening
- Magnitude of strength increase required
- Passive vs. active methods
- Size of project
- Cost and schedule
- Environmental conditions
- Indoor air quality
- Strength of existing concrete substrate
- Dimensional / clearance constraints
- Accessibility
- Operational constraints
- Aesthetics
- Availability of materials, equipment, and qualified contractors

Source: ICRI No. 330.1

References

American Concrete Institute

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American Society of Civil Engineers

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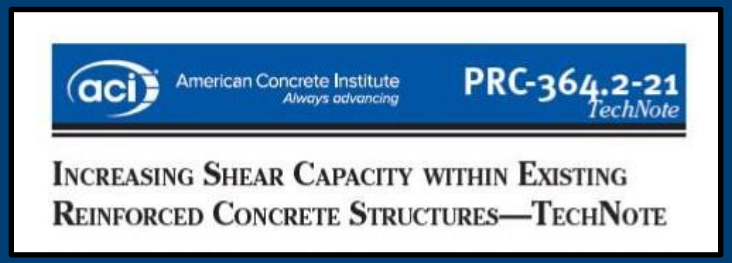

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Sean Radley, P.E.
sdradley@sgh.com
Senior Consulting Engineer
Simpson Gumpertz & Heger
Boston, MA