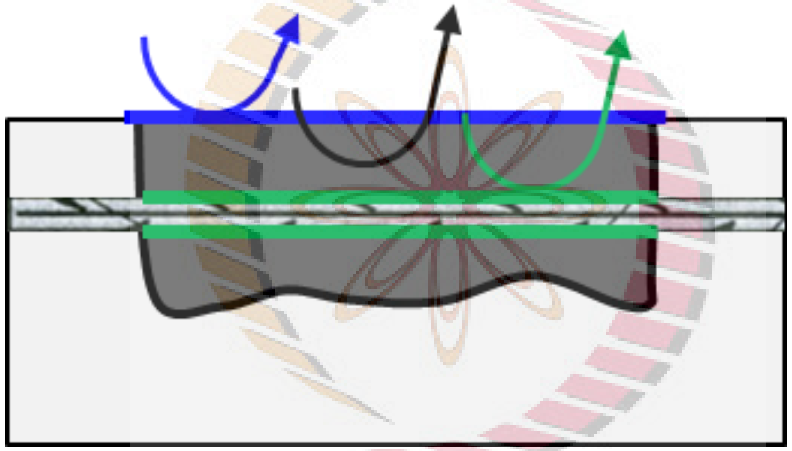
Lecture 13

Strategies and Materials for Surface Repair

(Root-cause analysis and repair strategies)



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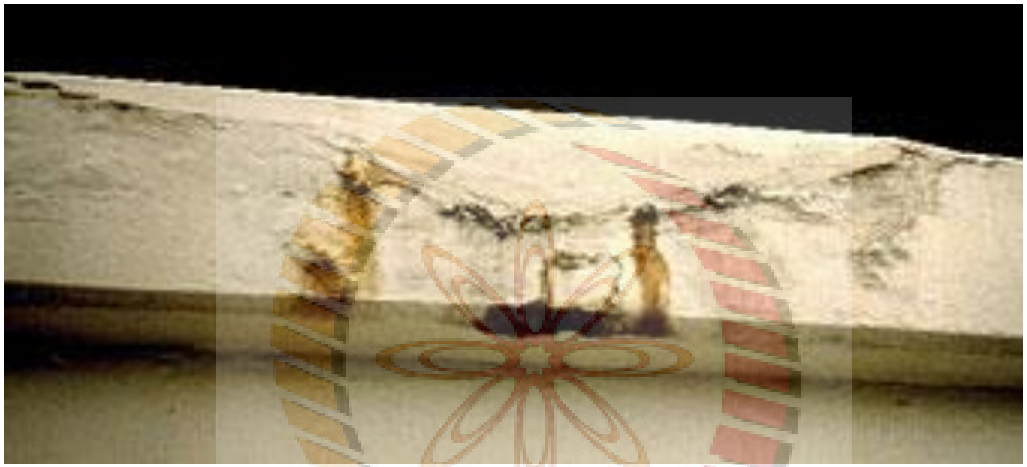
NPTEL – MOOC Course on Maintenance and Repair of Concrete Structures

Courtesy: Some images are sourced from the internet for demonstration purposes.

Outline of Module on
Strategies and Materials for Surface Repair

- Root-cause analysis and repair strategies
- Selection of repair materials
- Compatibility of repair materials with substrate

An unsuccessful repair



- Cause was not addressed adequately
- Surface preparation was not done adequately
- Bond between old & new materials was inadequate

Root-cause analysis of the problem is essential before designing a durable repair system

- https://www.matec-conferences.org/articles/matecconf/pdf/2018/58/matecconf_iccrrr2018_10008.pdf

Surface/Near surface repair is a complex task

- Special concretes → different additives
- Precise material design
- Aggressive environments
- Atmospheric pollution & de-icing salts
- Placement techniques and tools are critical
- Durable repair technology must be the target
- Less redundancy / economics / importance
- Success of a step depends on the success of others

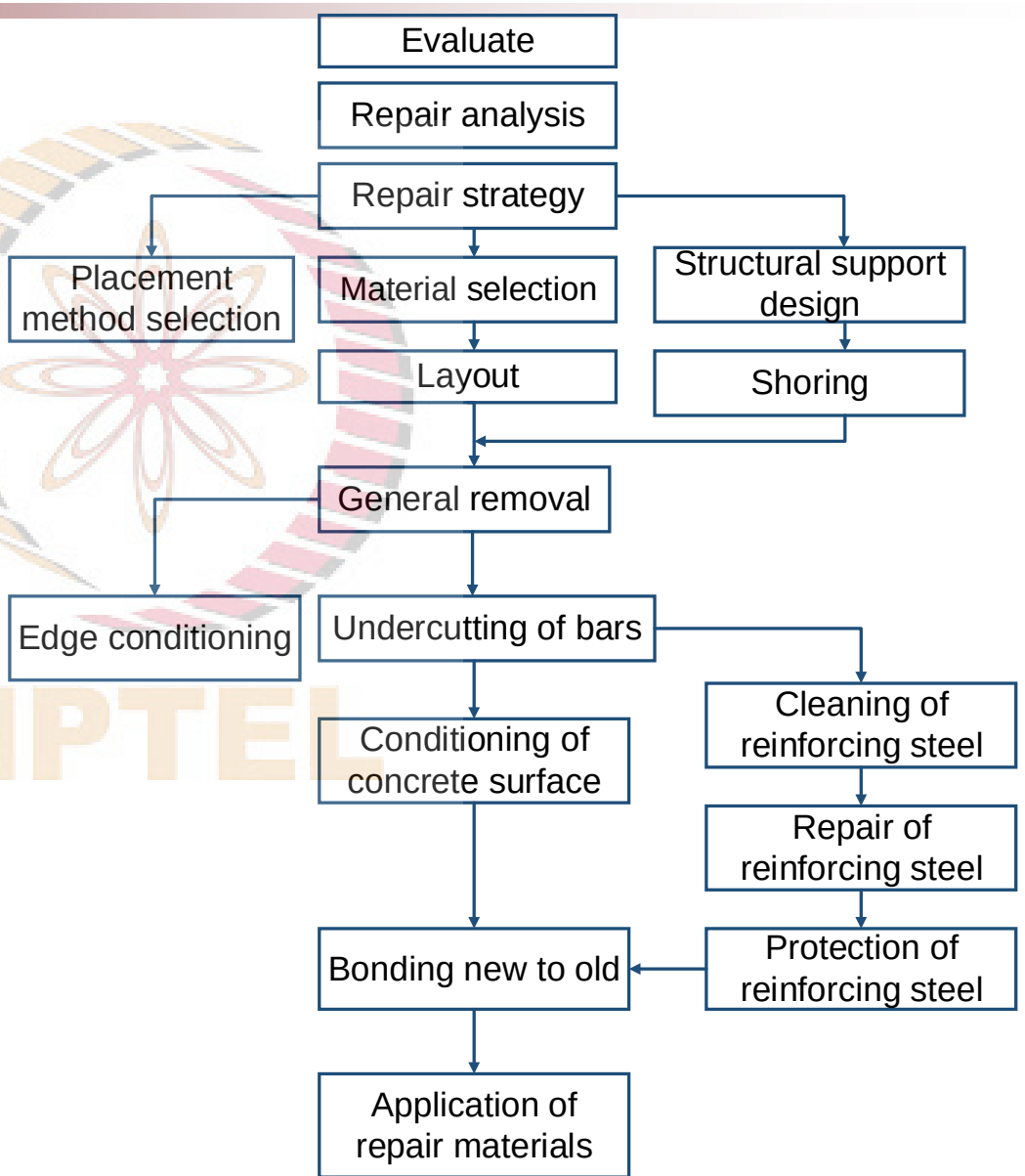
Surface repair types

- Protection/Appearance (Cosmetic)
- Load carrying (Structural)
  - Live loads
  - Barrier to unwanted environment
  - Aesthetic
  - Wear resistant
  - Impact loads
  - Dead loads
- Both cosmetic and structural

http://mmeeqg.info/hydraulic-concrete-patch/hydraulic-concrete-patch-from-repairing-cracks-in-your-concrete-to-repairing-loose-or-missing-mortar-to-stopping-an-active-water-leak-sakrete-of-north-america-lb-wtr-stop-cement-wall/

General procedure for surface repair

- Get to the root of the problem
- Major or minor problem
- Determine the repair method
- Prepare the existing concrete for repair
- Apply the repair material
- Cure the material



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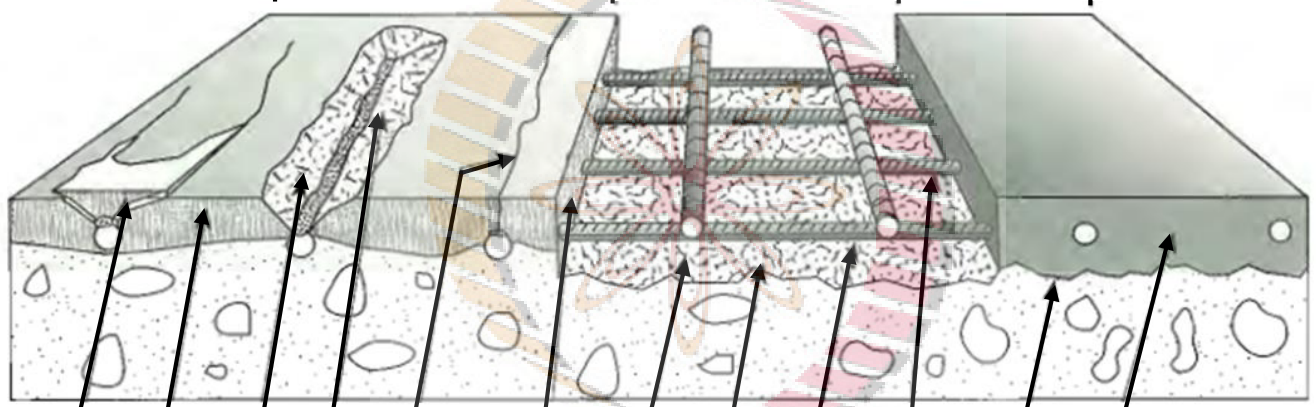
Anatomy of surface repairs



Delamination

Spall

Contaminated concrete with chlorides and carbonation

Heavily corroding reinforcing bar

Crack

Edge conditioning

Removal of contaminated concrete
Undercutting of reinforcing steel

Concrete surface conditioning

Reinforcing steel cleaning

Reinforcing steel protection

Bonding new to old

Durable repair material

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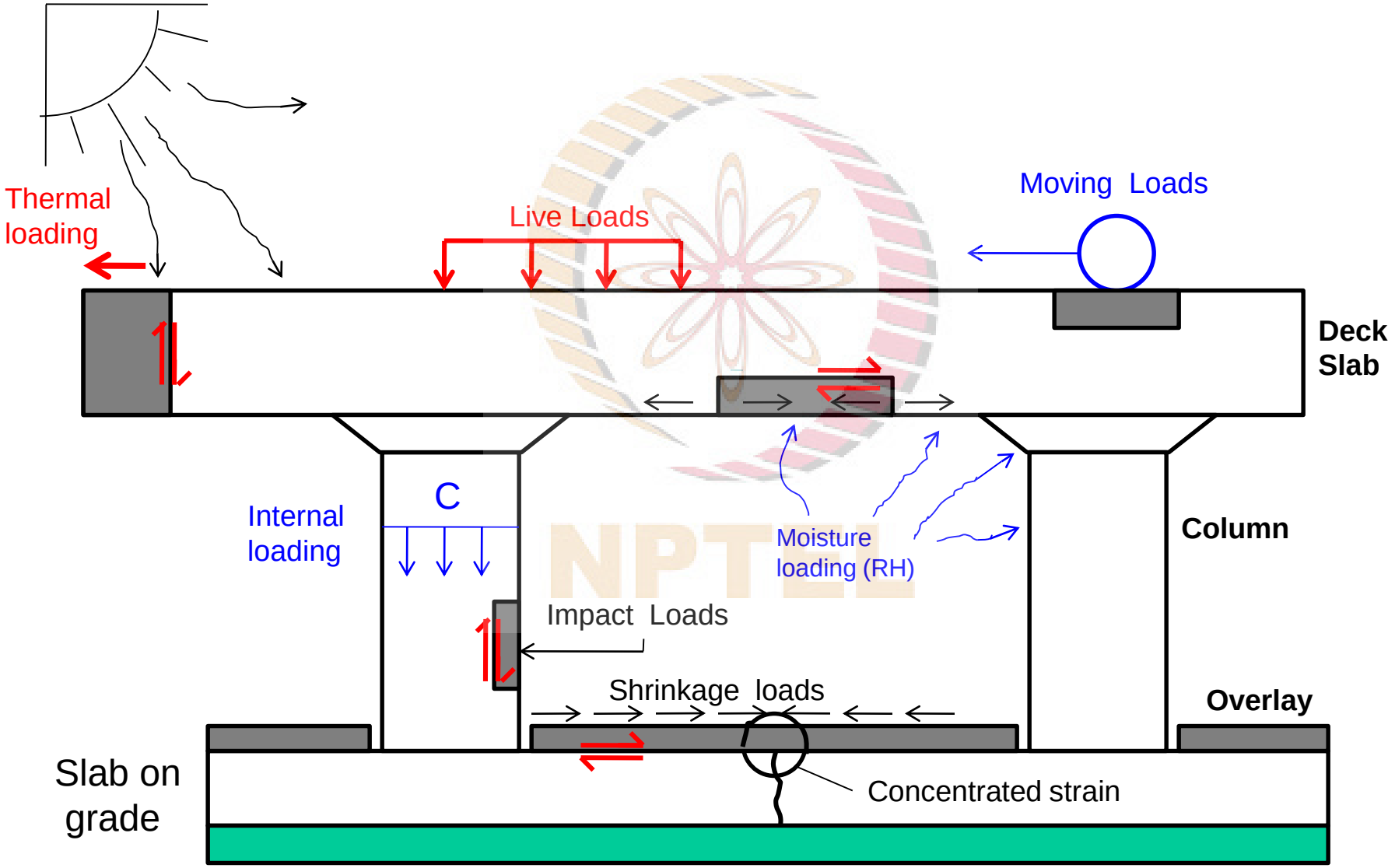
Types of stresses (due to relative volume changes and loads)



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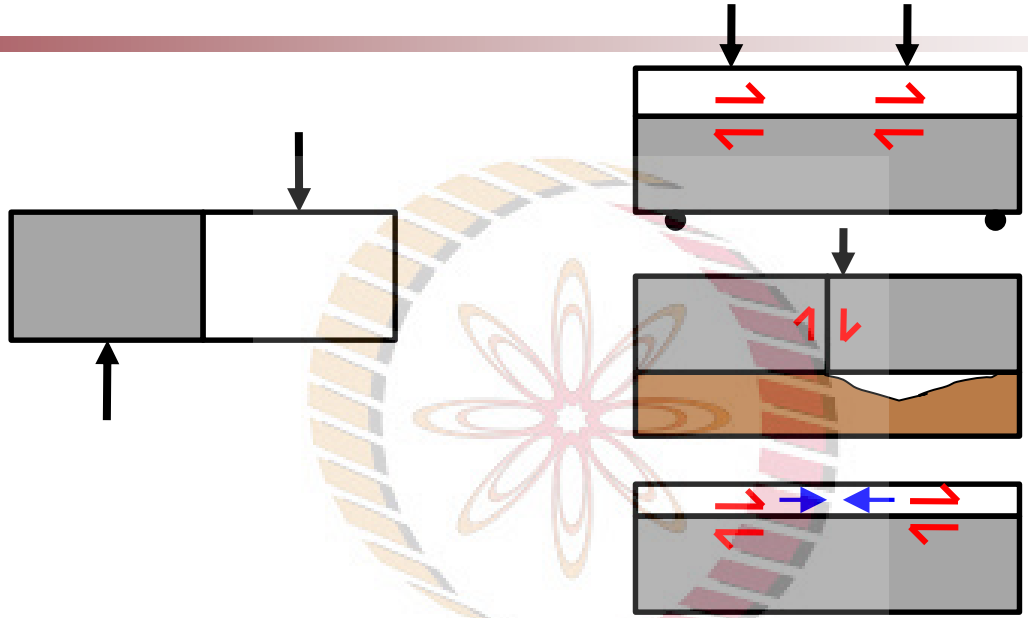
Types of stresses (between the old and new materials/concretes)

- **Shear bond**

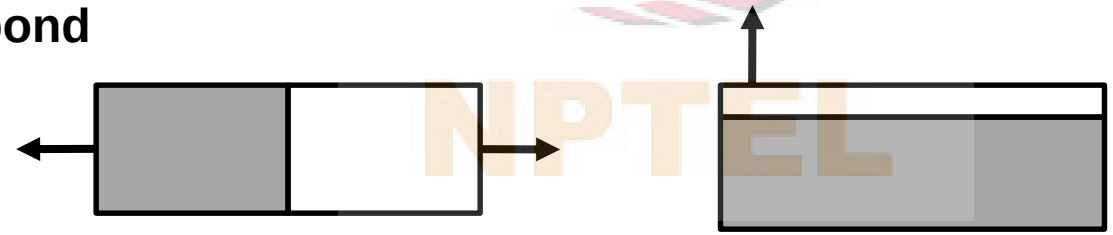


Composite overlay

Settlement

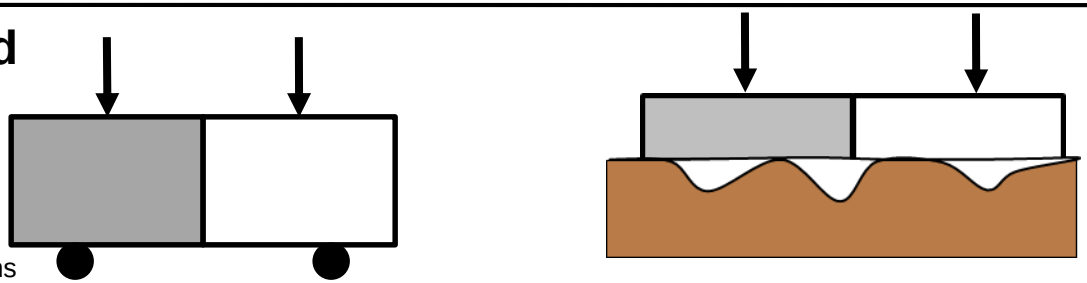
Contraction OR expansion

- **Tensile bond**



Uplift due to temperature or shrinkage effect.

- **Flexural bond**



Uneven support

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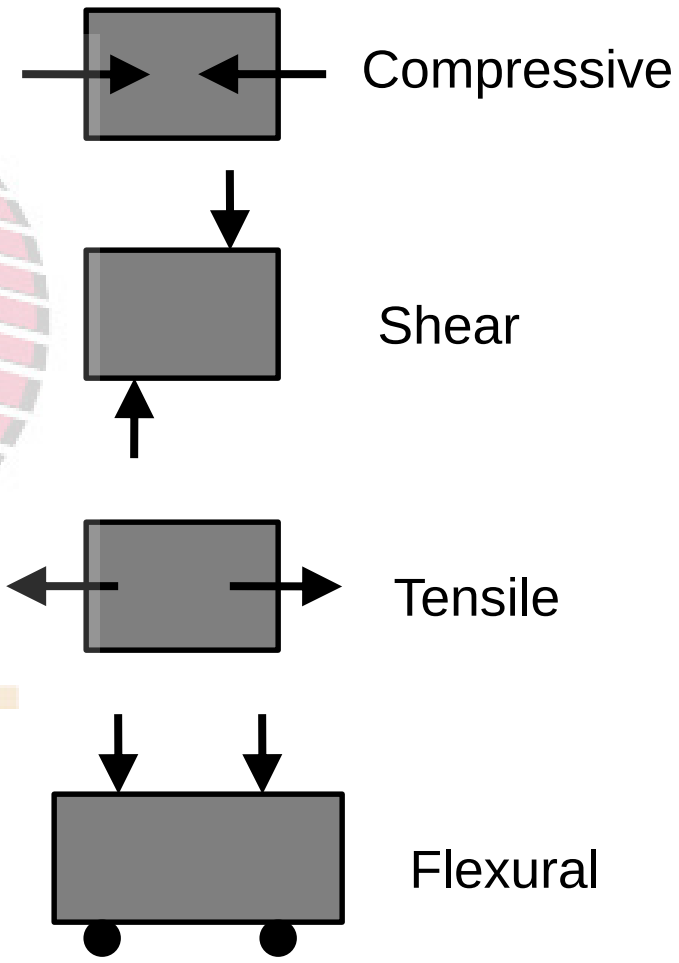
Types of stresses (within the new materials/concretes)

- Structural loads
  - Structural forces (internal)
  - Static concentrated loads (external)
  - Moving loads (horizontal and vertical)
  - Impact loads
- Temperature
  - Expansion and contraction
- Moisture
  - Expansion and contraction
- Concentrated strain
- Combinations of these



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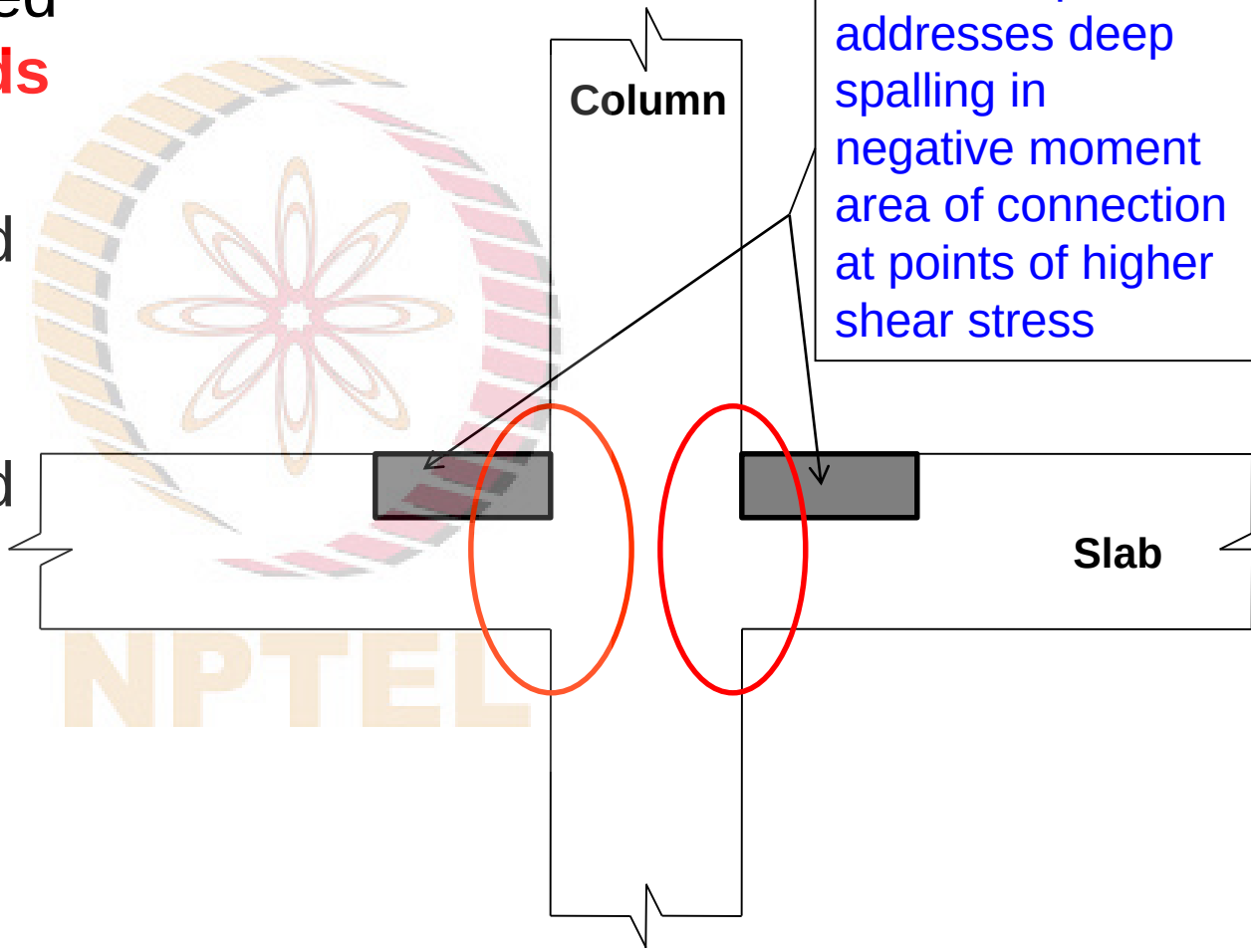
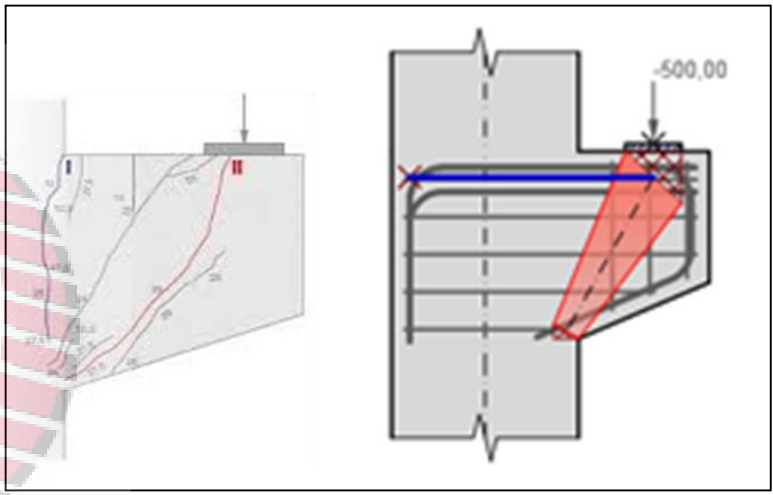
Primary repair performance requirements for a column-slab joint

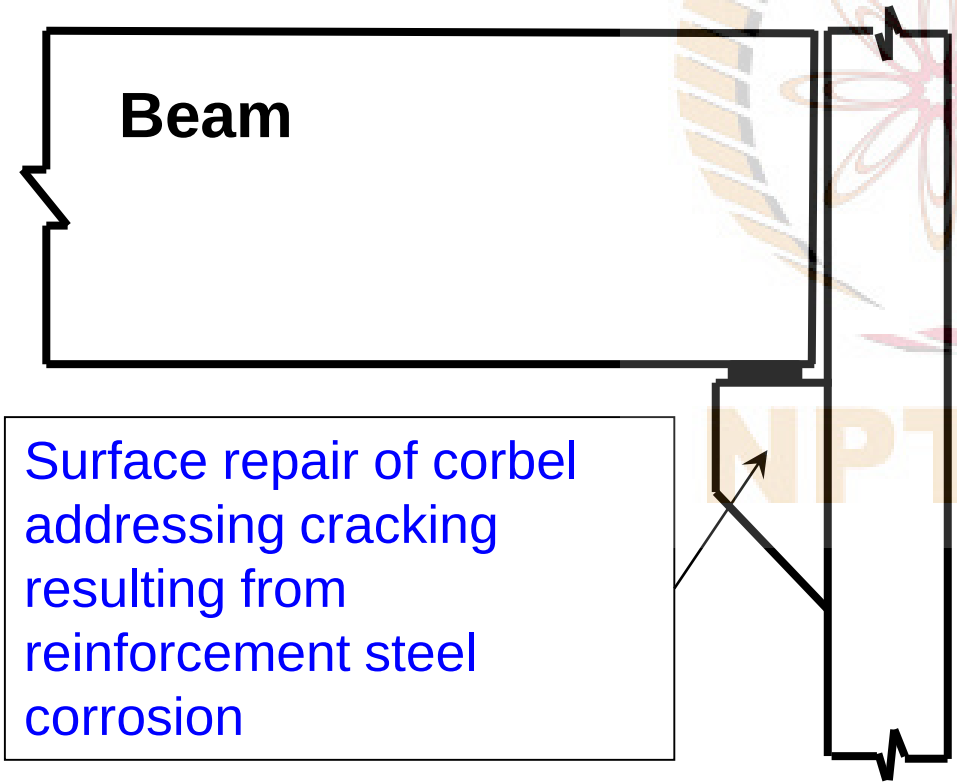
1. Surface repairs need to carry **shear loads**
2. Encased tensile reinforcement need to transfer load
3. Embedment reinforcement need to be protected



Primary repair performance requirement for a beam-column joint

1. Surface repair must transfer **structural loads** from the beam into the column



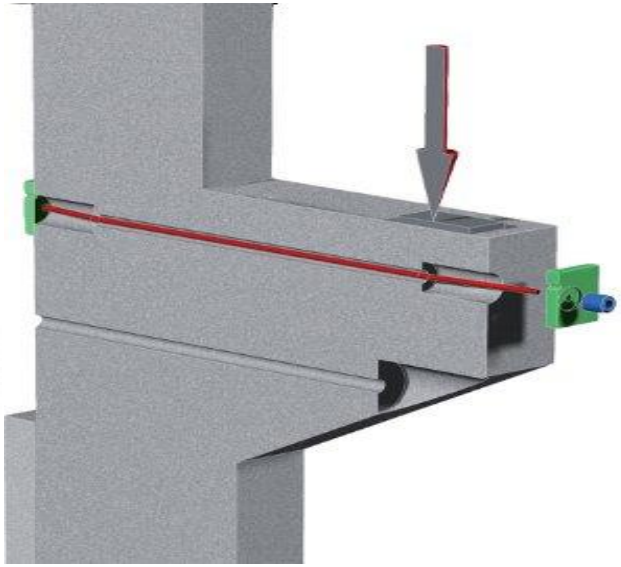


Surface repair of corbel addressing cracking resulting from reinforcement steel corrosion

http://www.idea-rcoms. /idea-statica-concrete-en/

Corbel repair – Case study

- Increase in load-carrying capacity by 500% and prolonged life-span
- Stressing short strand is challenging



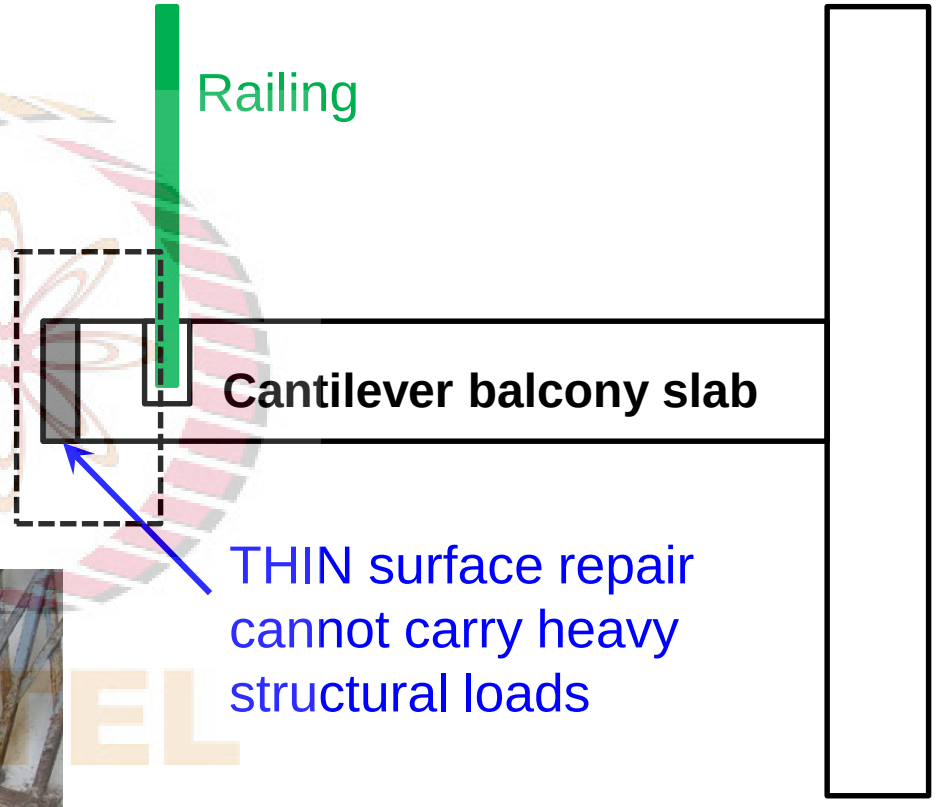
http://www.peem.cz/a-complete-system-of-reinforced-concrete-strengthening-constructions

A typical damage of a joint – probably due to improper edge design and erection practice

Source: web

Repair performance requirements – surface repair must…

1. Protect the embedded reinforcement
2. Be aesthetically pleasing
3. Be perfectly adhered to the substrate



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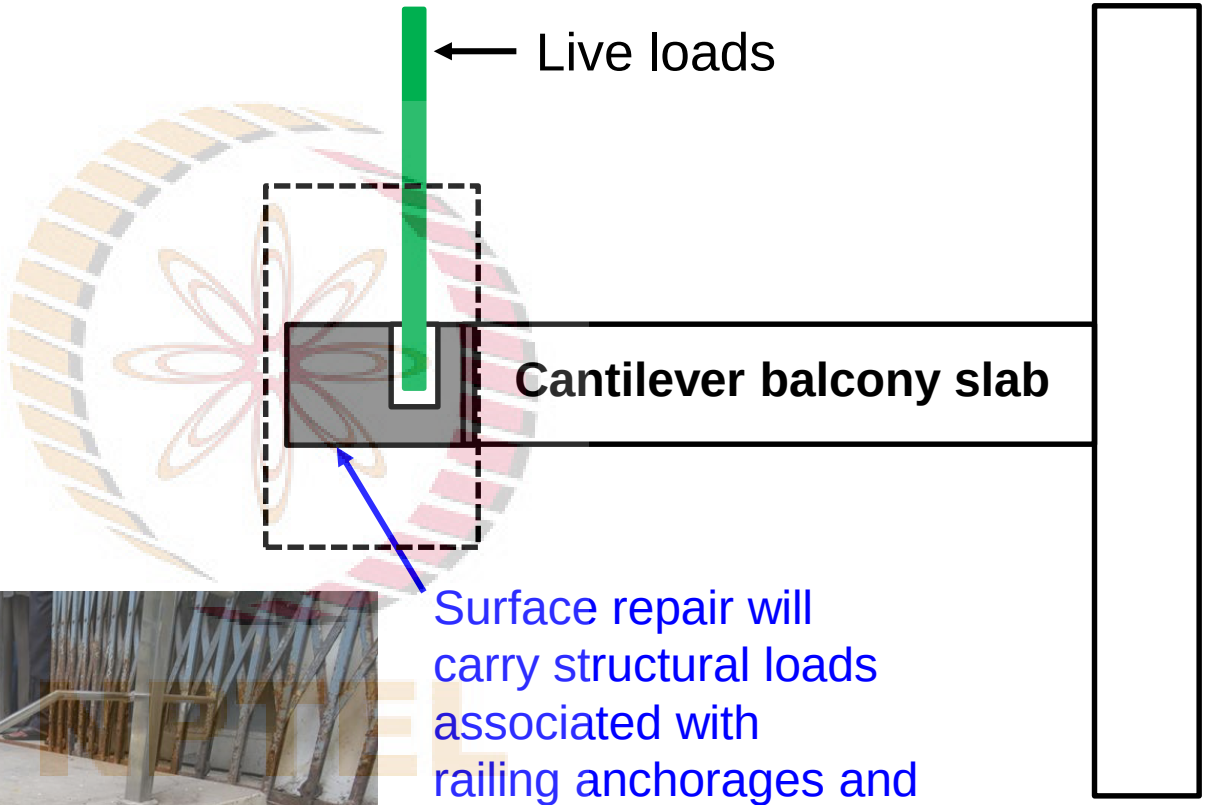
Repair performance requirements – surface repair must…

1. Protect the embedded reinforcement
2. Be aesthetically pleasing
3. Be perfectly adhered to the substrate
4. Carry structural loads from the railing system



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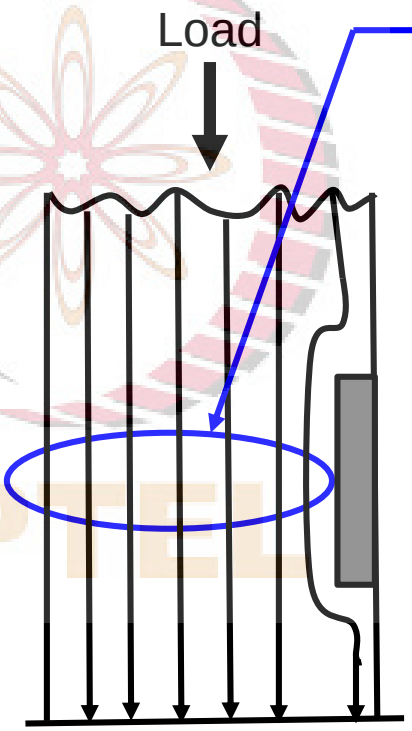
Repair performance requirements – load transfer through surface repair on a column

1. Protect the embedded reinforcement
2. Be aesthetically pleasing
3. Be perfectly adhered to the substrate



If the stress level in the remaining concrete is acceptable, then the surface repair is not required to carry structural loads

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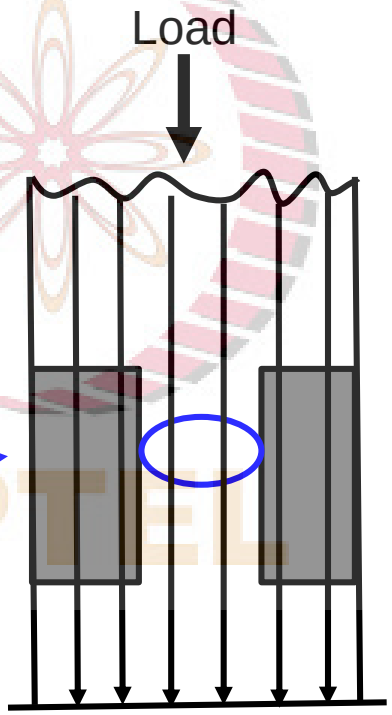
Repair performance requirements – load transfer through surface repair on a column

1. Protect the embedded reinforcement
2. Be aesthetically pleasing
3. Be perfectly adhered to the substrate
4. Carry structural loads

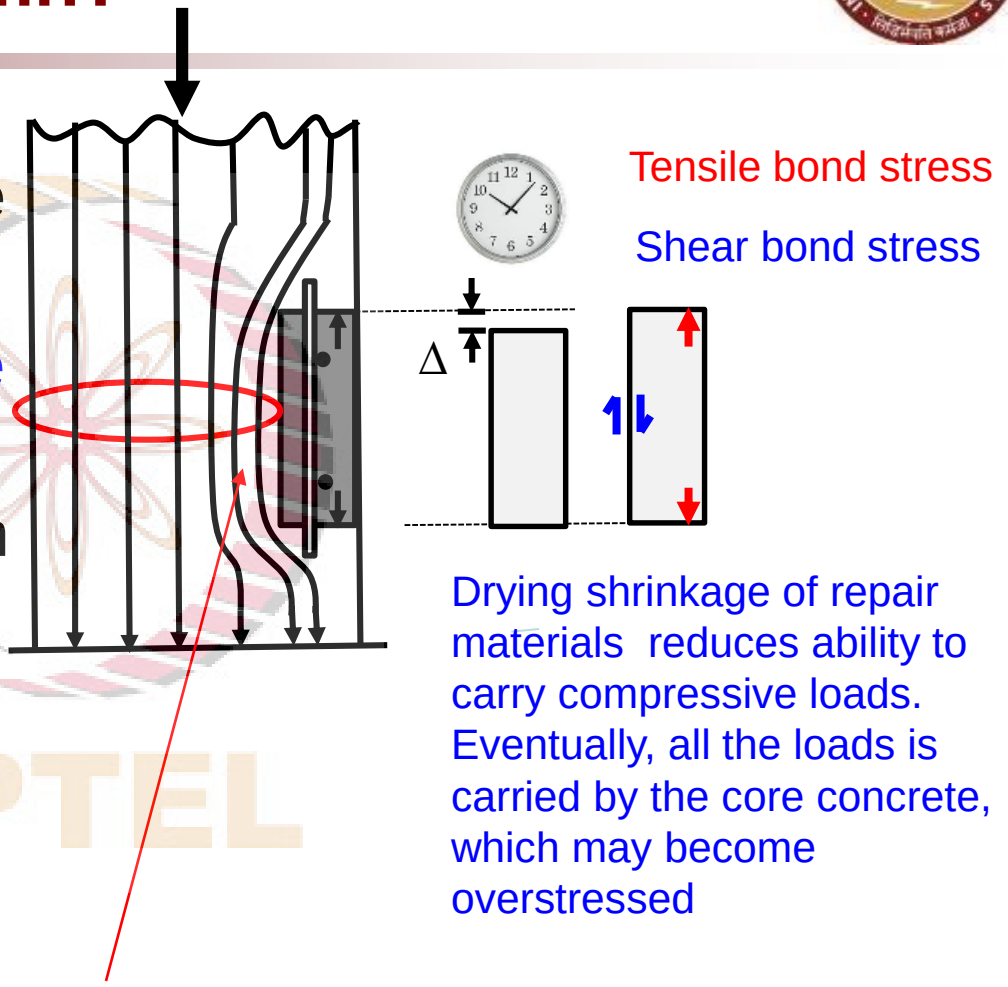


If remaining cross-section is overstressed, then surface repairs are required to carry a portion of structural loads.

Recreated from Peter H Emmons
http://www.swconsult.com.au/product/structural-propping/

How to ensure proper load transfer through surface repair on a column?

- If possible, stresses must be removed before surface repair
  - Shoring/jacking until the repair is matured
- Use material with minimum volume change (due to shrinkage)
- Low creep
- Stress-strain compatibility



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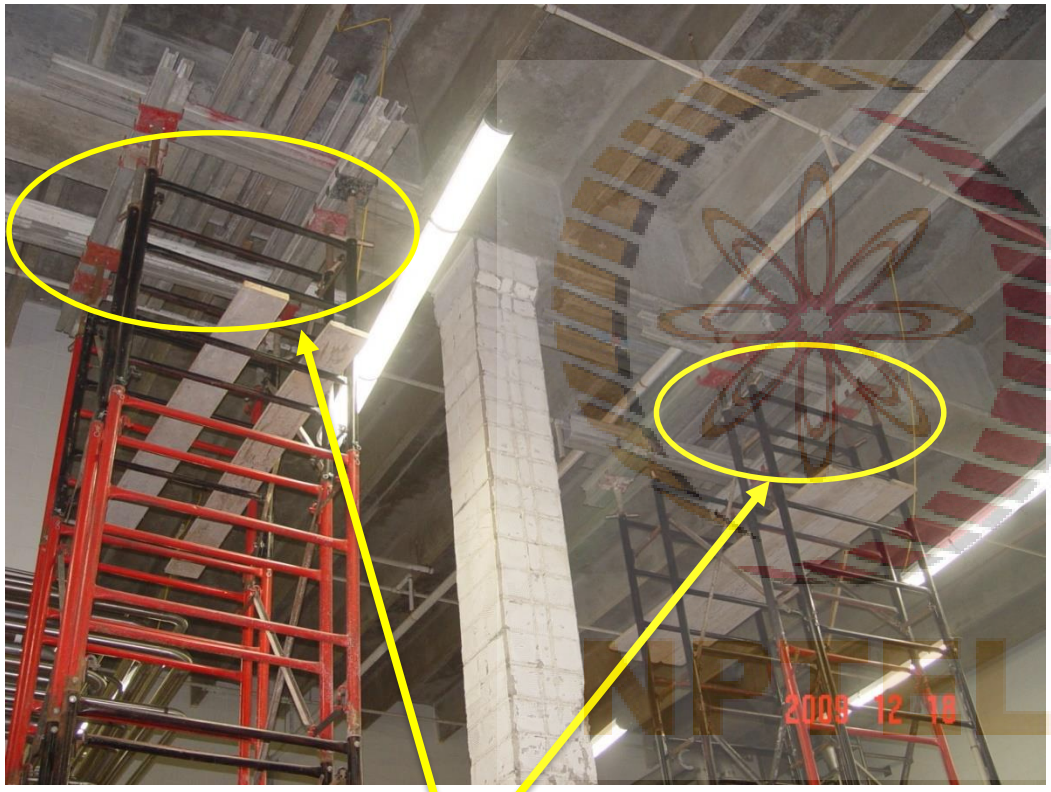
Repair performance requirements – load transfer through surface repair on a column

Column repair – case study

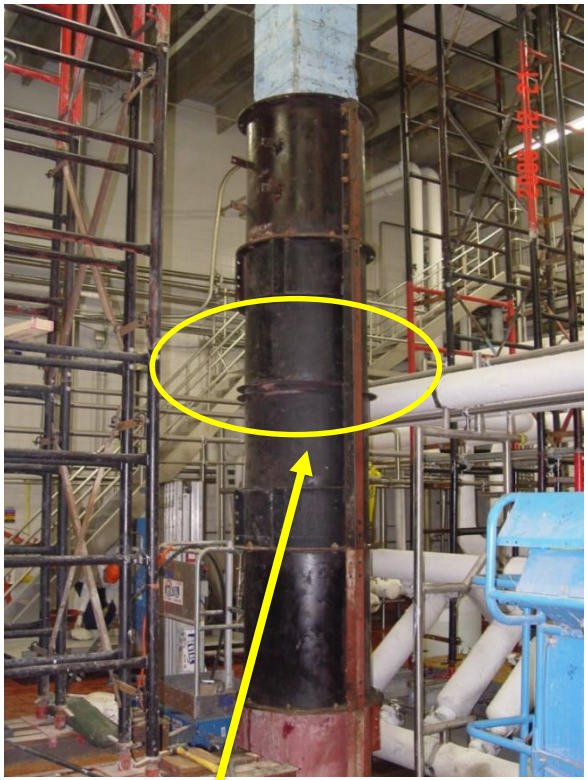
- Temperature cycling (Differential temperature) → cracks in the concrete surface → chloride ingress → steel corrosion

http://www.gestech.net/concrete_column_repair.htm

Release the dead load on the columns prior to repair



Design of shoring towers to support dead and live load during repair



Column prepared for high strength concrete pour

http://www.gestech.net/concrete_column_repair.htm

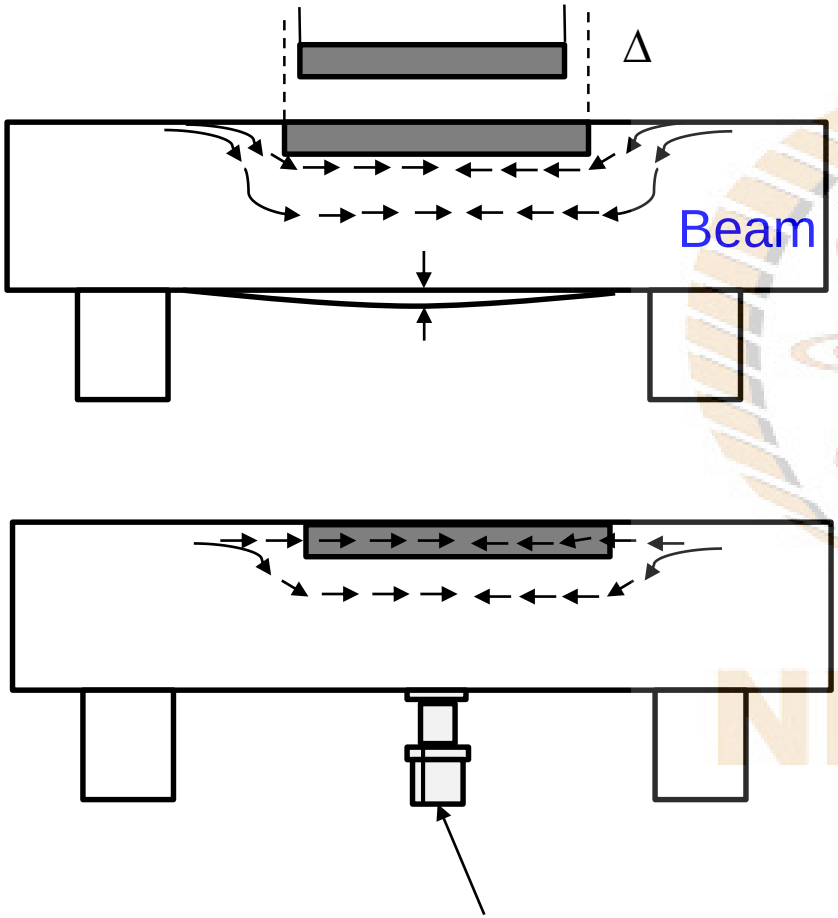
Use good quality concrete for surface repair and longer life ahead

Concrete pouring

Column insulated against thermal cycling stresses

http://www.gestech.net/concrete_column_repair.htm

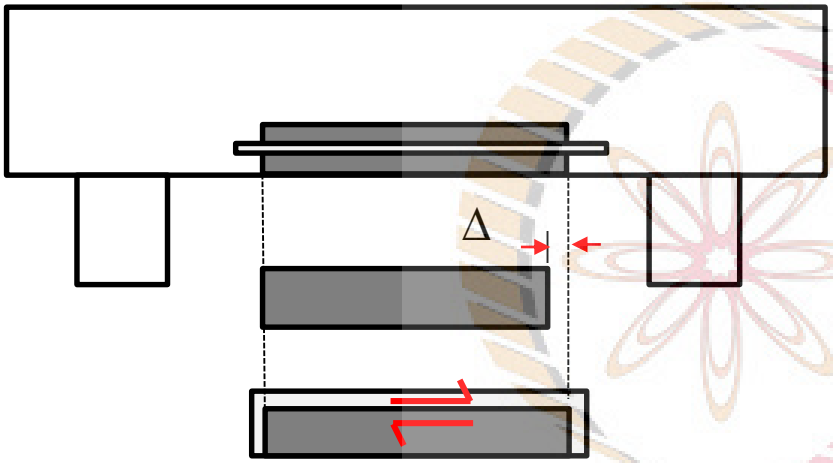
How to ensure load transfer through surface repair on a beam or deck/slab?



- Member might have been deflected
- Repair does not participate in load sharing stresses redistribute around deteriorated areas
- Load relief during repair operation may enable the repair materials to carry its share of stress

Recreated from Peter H Emmons
https://www.drfixitinstitute.com/download/microconcrete-publication.htm

How to ensure load transfer through surface repair underneath a beam or deck/slab?



Shrinkage and expansion can occur

- Reinforcing steel carries most of the load in the tension zones

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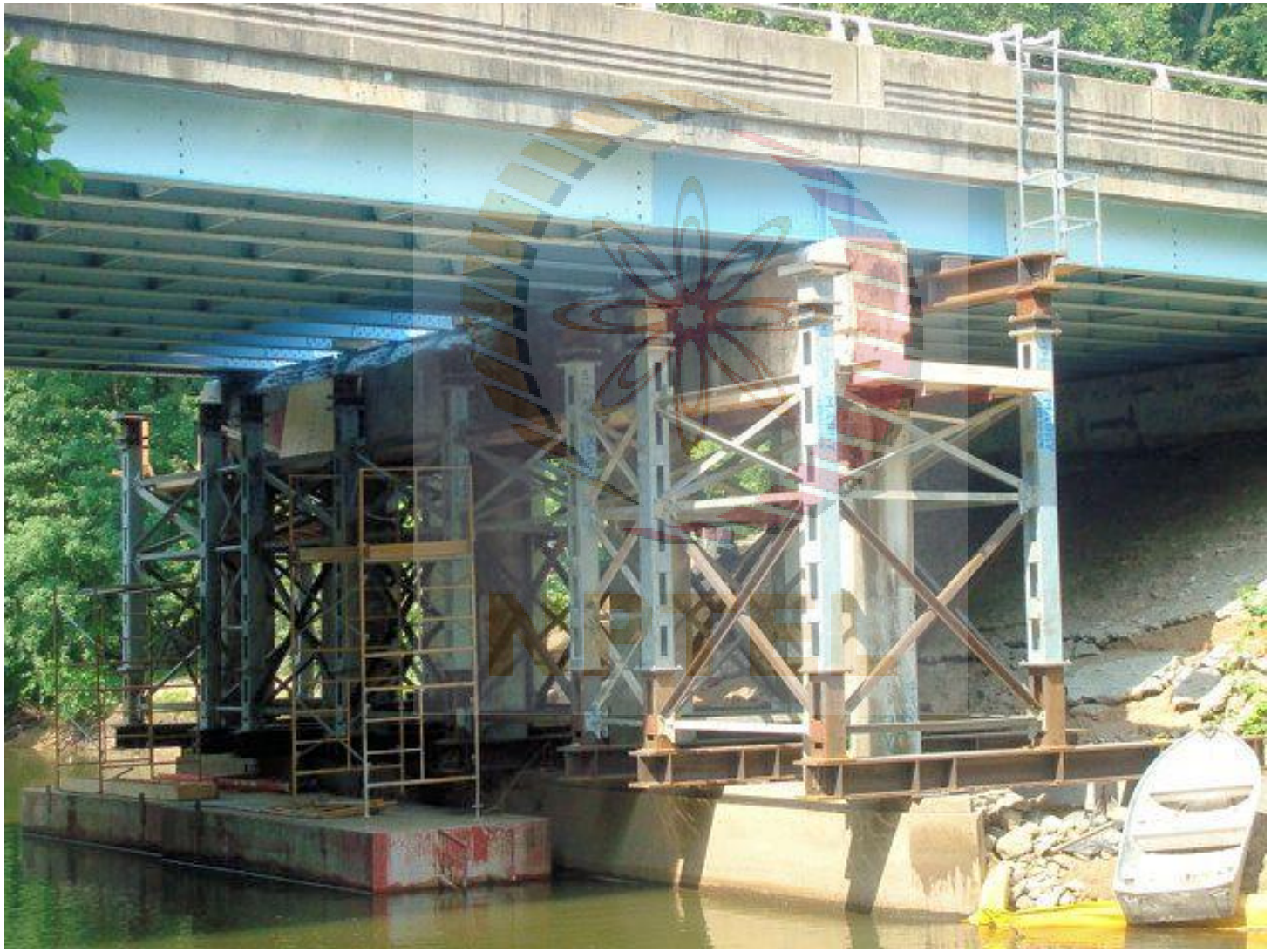
Bridge deck/beam repair – case study

- Significant volume of highway traffic
- Worn out bearings, cracked deck
- Bridge jacking and structural shoring prior to the repair of deck → release dead loads

http://www.mabey.com/products-services/structural-shoring/featured-projects/j-slagter-bridge-repair/

Bridge deck/beam repair – case study



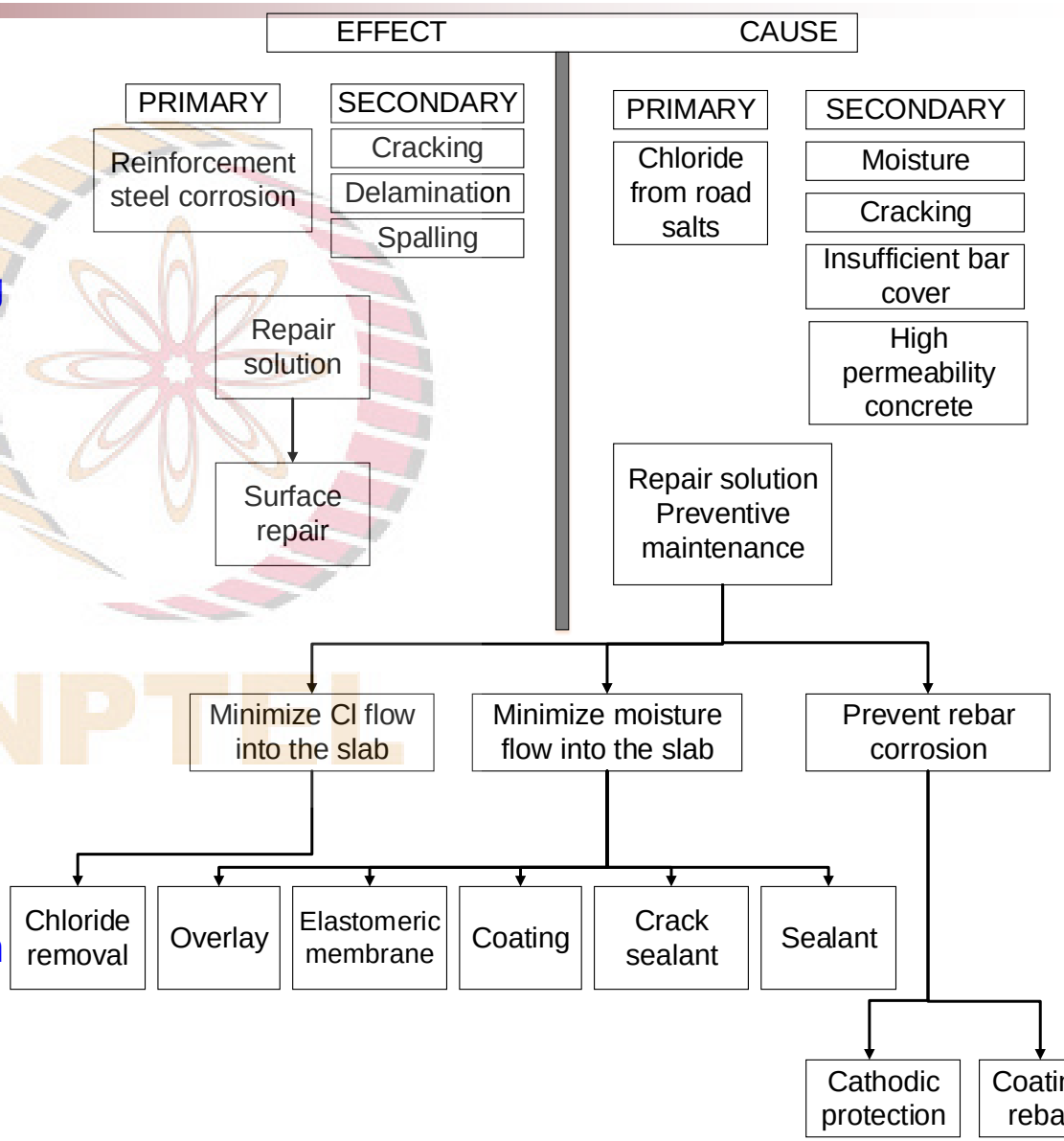
http://www.mabey.com/products-services/structural-shoring/featured-projects/j-slagter-bridge-repair/

Bridge deck/beam repair – case study

http://www.mabey.com/products-services/structural-shoring/featured-projects/j-slagter-bridge-repair/

Analysis of the repair problem

- Visual inspection / screening tests
- In-depth evaluation to assess both problem (effect) and cause
  - Multiple tests or levels of testing may be required
  - Understanding the cause can prevent further damage of the unaffected areas
  - History, other documents might be required
  - Primary causes
  - Secondary causes
- Preventive maintenance strategies
  - Owners need to be convinced on the benefits, especially when additional money is required



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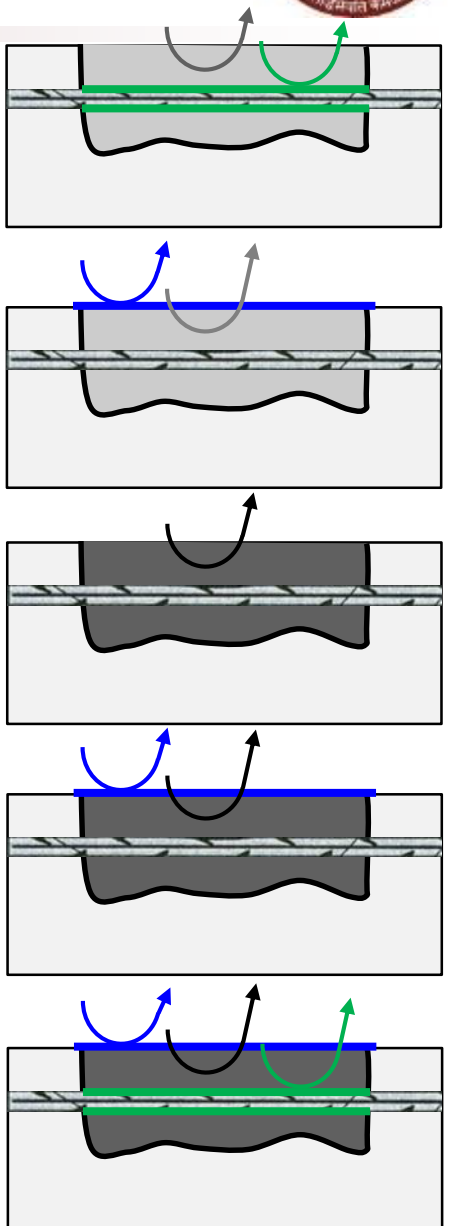
Strategies for surface repair

- Strategy 1 (1 redundancy)
  - Durable repair material (similar or slightly better than existing concrete)
  - Protection system for steel
- Strategy 2 (1 redundancy)
  - Durable repair material
  - Protective sealer/coating/membrane on concrete surface
- Strategy 3 (0 redundancy)
  - Significantly durable repair material (fillers, admixtures, etc.)
- Strategy 4 (1 redundancy)
  - Significantly durable repair material (fillers, admixtures, etc.)
  - Protective sealer/coating/membrane on concrete surface
- Strategy 5 (2 redundancies)
  - Significantly durable repair material (fillers, admixtures, etc.)
  - Protective sealer/coating/membrane on concrete surface
  - Protective system for steel

Strategies can be chosen based on the importance of the structure



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Summary

- Root cause of the problem and prevent the same
- Repair types
  - Structural
  - Cosmetic
  - Both
- Type of stress acting on the repair must be analyzed
- Behavior and performance requirements of a repair material should be considered in design
- Strategies can be chosen based on the importance of the structure

References

- Emmons, P. H. (1993), Concrete Repair and Maintenance Illustrated, R.S. Means Company, Inc.
- Spuy, P. and Niehaus, H. (2018), Strengthening, rehabilitation and widening of the existing arch bridge on national route 7 over the Olifants River, South Africa, MATEC Web of Conferences 199, 10008, ICCRRR.
- Pattanaik, S. H. (2009), Structural strengthening of damaged R.C.C. Structures with polymer modified concrete, (Paper published in proceedings of WSRR09 (Workshop 2009 on Rehabilitation and Retrofitting of Structures) held at Indian Institute of Technology, Mumbai).