Maintaining *Structural Safety* and Avoiding Construction Defects a Part of the the Pre-Planning Process

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What is Structural Safety?

- Avoiding a structural collapse
  - Overloading
  - Shoring errors
  - Major defects- design, workmanship, materials
  - Demolition, coring, etc.
- Damaging the structure
  - From the same items above
- Ensuring that the structure is built with the designed capacity
- Structural Safety issues that create personnel safety for people onsite during construction

GOAL

1. Recognize structural problems before they occur by knowing the typical errors that cause them

we usually get the call to fix them

2. If problems occur, recognize typical signs of structural distress (understanding structural cracks vs non-structural)

3. Incorporating Structural Safety in your Pre-planning Process

WHO IS RESPONSIBLE AND IS THERE A PROCEEDURE?
Someone with the GC, Sub, EOR, Inspector?

Safety Rule

I AM GOING TO ASK YOU FOR A TAKE-AWAY AT THE END

structural TECHNOLOGIES

AGENDA

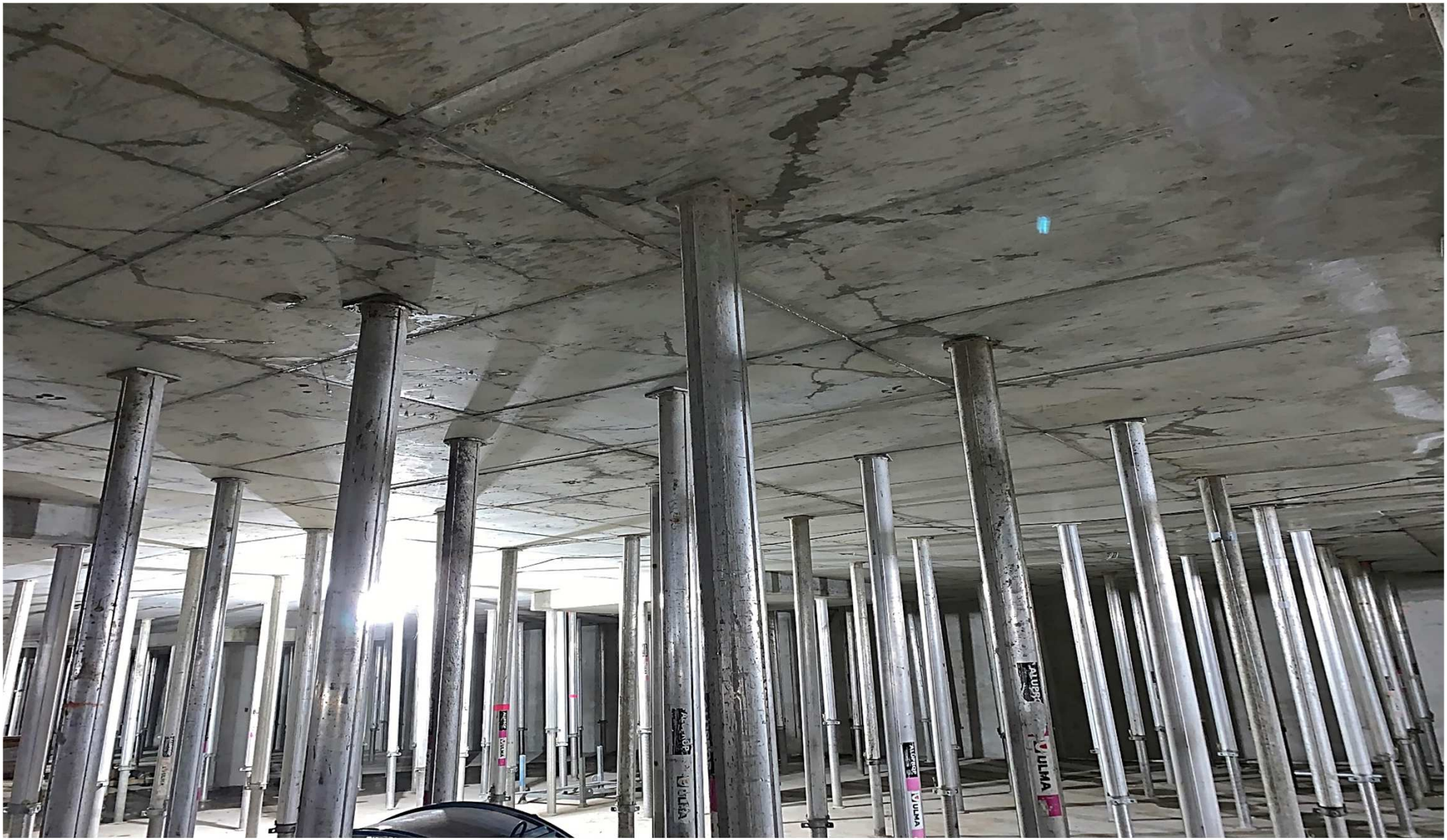
- Most common contributors to Structural Safety situations
- How is reinforced/PT concrete designed- *Eng. 101 for Contractors*
- Safe loading of structures during construction- OVERLOAD
- Understanding the purpose of typical steel placement
- What if that steel is set in the wrong place?
  - *Too high, low or close*
- Avoiding concrete placement errors- Honeycombs & Voids
- Structural Safety issues to avoid when:
  - *Cutting, coring, chipping, drilling concrete*
- Avoiding Shoring/Re-shoring & early loading of slab errors
- Repair strategies if Structural Safety or defects occur
- How do we incorporate Structural Safety in your Pre-planning Process

Subs Overloading Structures With Construction Materials, Equipment and Debris - *With No Preplanning*

DAMAGED

FAILED

Proper Shoring and *Avoiding Early Loading of* ***GREEN*** *Slabs Soon after removal of Re-shoring*

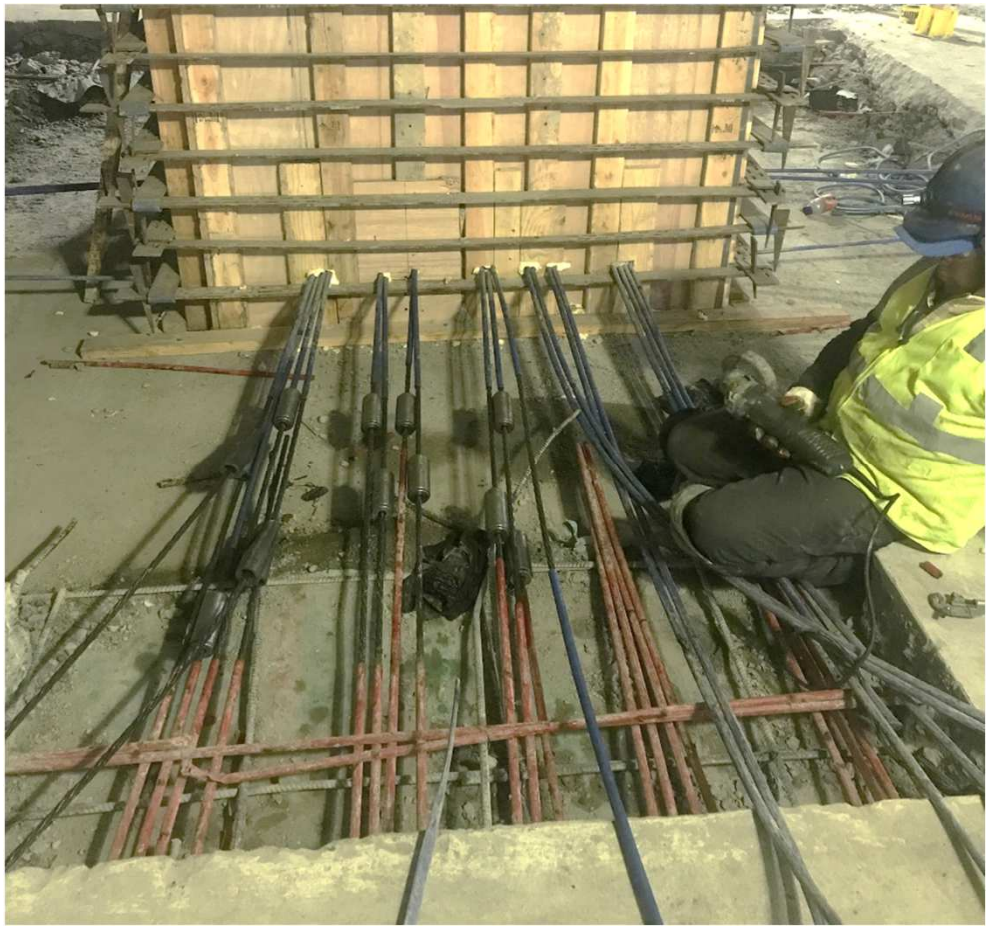


Subs Cut, Core, Chip, and Drill Concrete on Your Structures

With NO Preplanning to Avoid Structural Safety Problems

No Pre-Pour Checklist and Sign Offs

Right steel, Right Place



Installation of *Complex Reinforcement Within Tolerance* ***And*** *Getting Concrete In it*

Some Defects Are Obvious- Missing 30% of Reinforcement

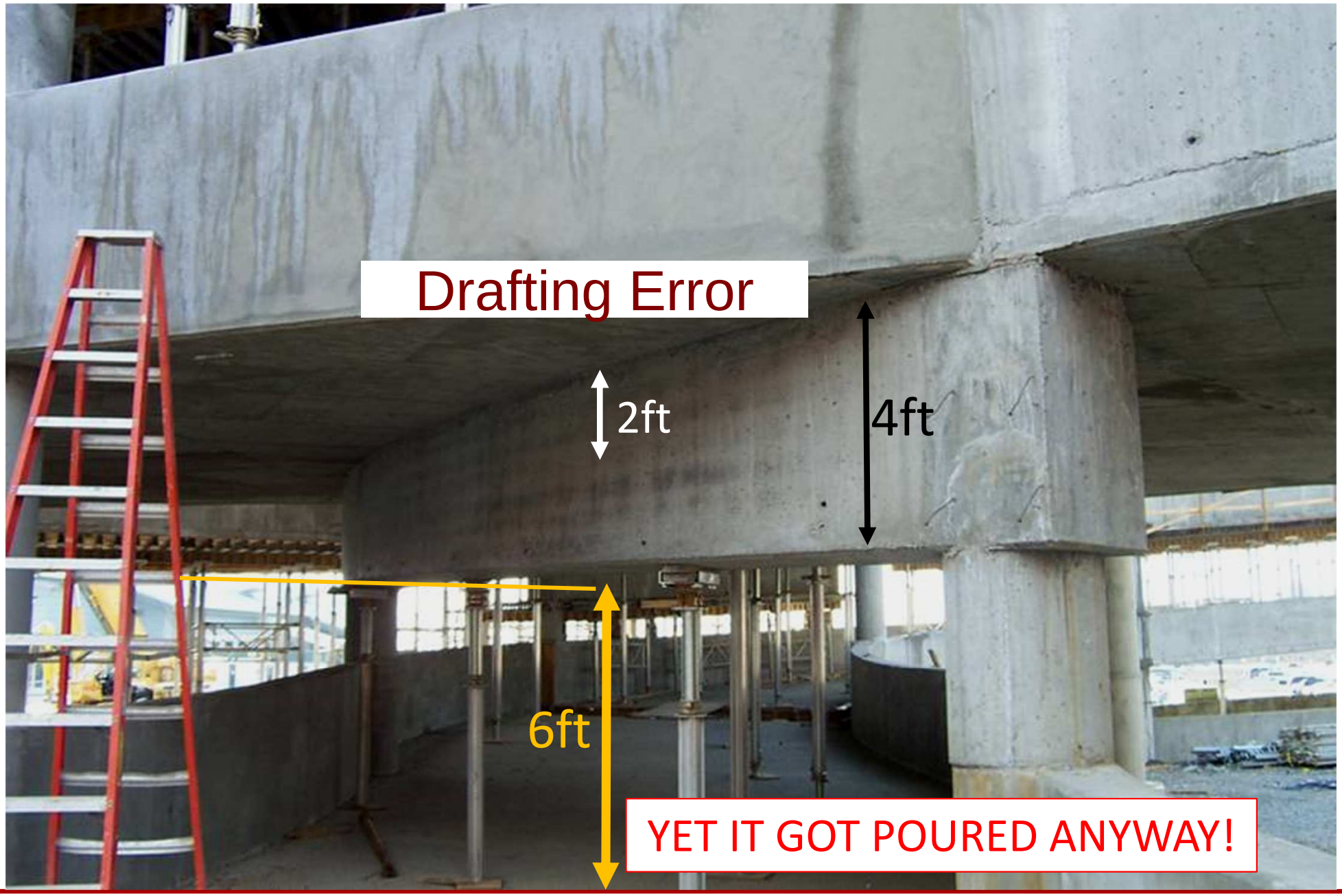
Some Defects are Not Obvious

"See what'?"

Low strength concrete on columns

7000 vs 8000 psi

Sometimes the Defect is Obvious but *Ignored*



For Structural Problem there is No such thing as a *"Little Mistake"*

On almost project with a major structural defect someone said:

"I have built this before & something looks different this time…"

"I knew something was wrong BUT I am not a structural engineer…"

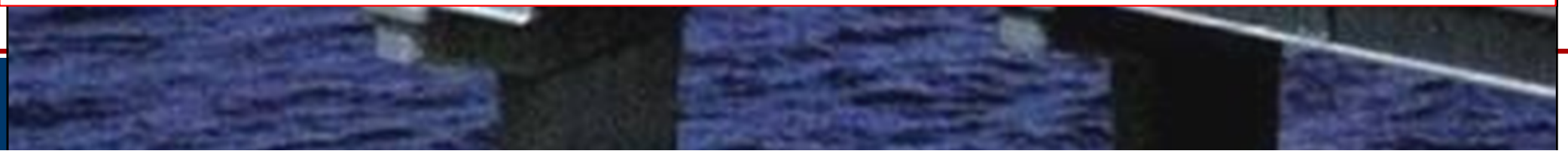
"I was told it was OK"

NOT ASKING OUR PEOPLE TO MAKE ENGINEERING DECISIONS

WE ALL HAVE PERSONNEL TRAINING SAFETY PROGRAMS

BASED ON ABILITY TO *"SEE SOMETHING-SAY SOMETHING"* CONCEPT

TODAY IS A SEE & SAY SOMETHING FROM A STRUCTURAL PERSPECTIVE



AGENDA

- What are the most common defects?
- Guidelines for safe loading of structures during construction to avoid OVERLOADING
- Avoiding shoring errors
- How is reinforced concrete designed- *Eng. 101 for Contractors*
- Understanding the purpose of typical steel placement
- What if that steel is set in the wrong place?
  - *Too high, low or close*
- Avoiding concrete placement errors- Honeycombs & Voids
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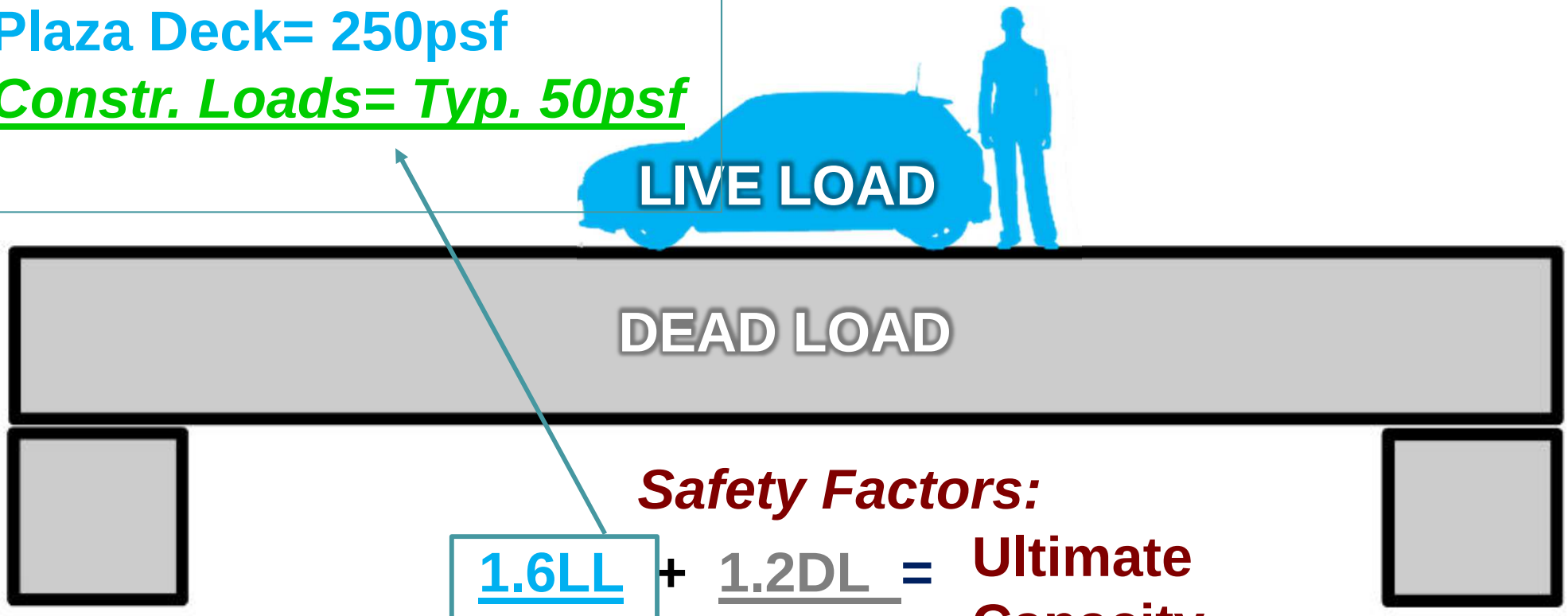
Typical loads and safety factors in concrete design

Standard Live Loads:
Parking= 50psf
Condo = 60psf
Office = 60-100psf
Lobby = 100psf
Mech/Elect= 150-200psf
Plaza Deck= 250psf
Constr. Loads= Typ. 50psf



Safety Factors:

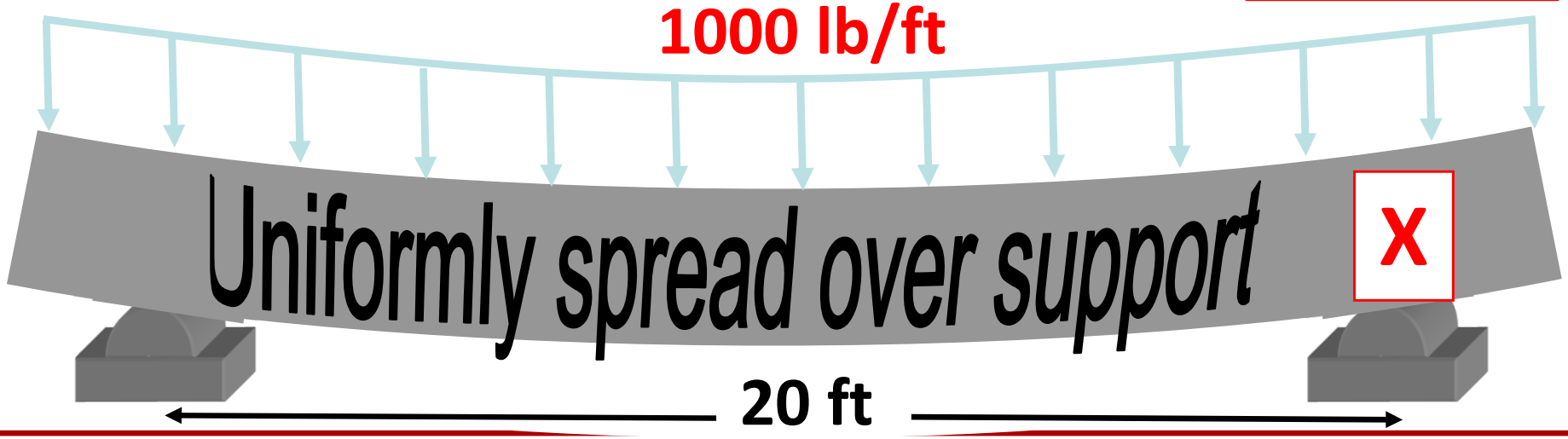
1.6LL + 1.2DL = Ultimate Capacity

Uniform Loads Are Different Than Concentrated Loads

Which is worse?

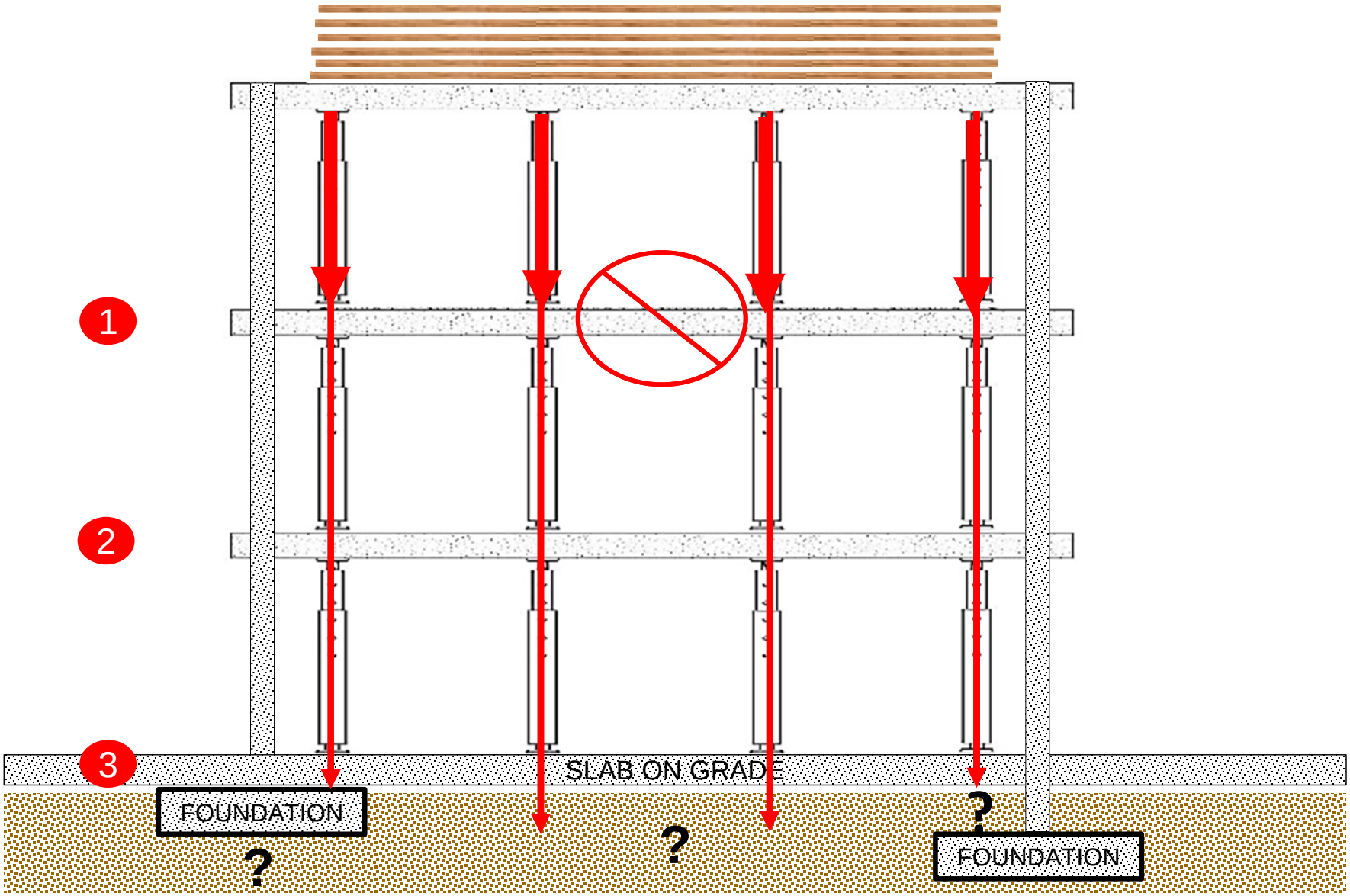
How much worse?

Safety Rule
5000 lbs



HOW DO I DETERMINE ALLOWABLE LOADING?...ASK an ENGINEER!

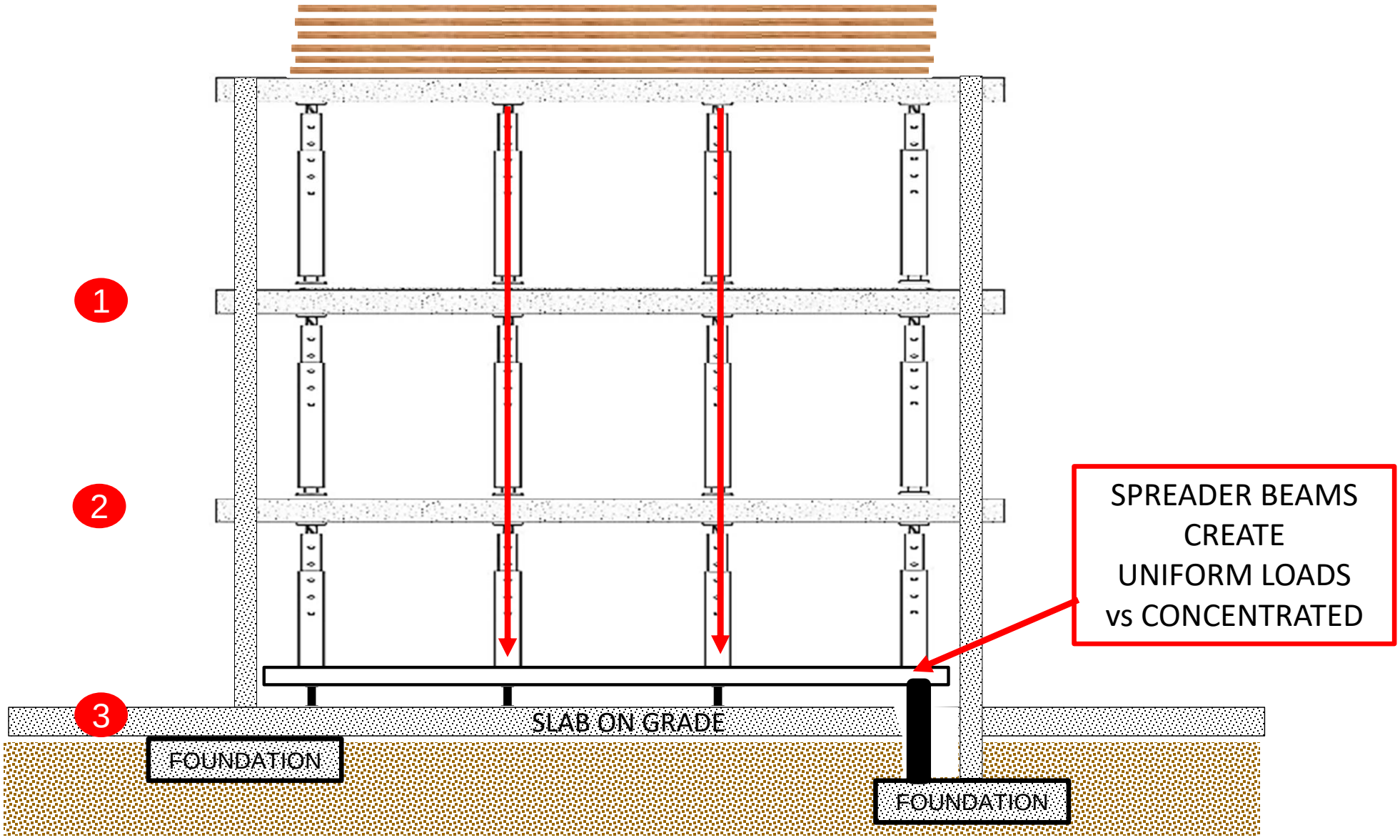
3. HOW MANY LEVELS OF SHORING YOU NEED – WILL BE MORE THAN 1 & POSSIBLY TO GRADE



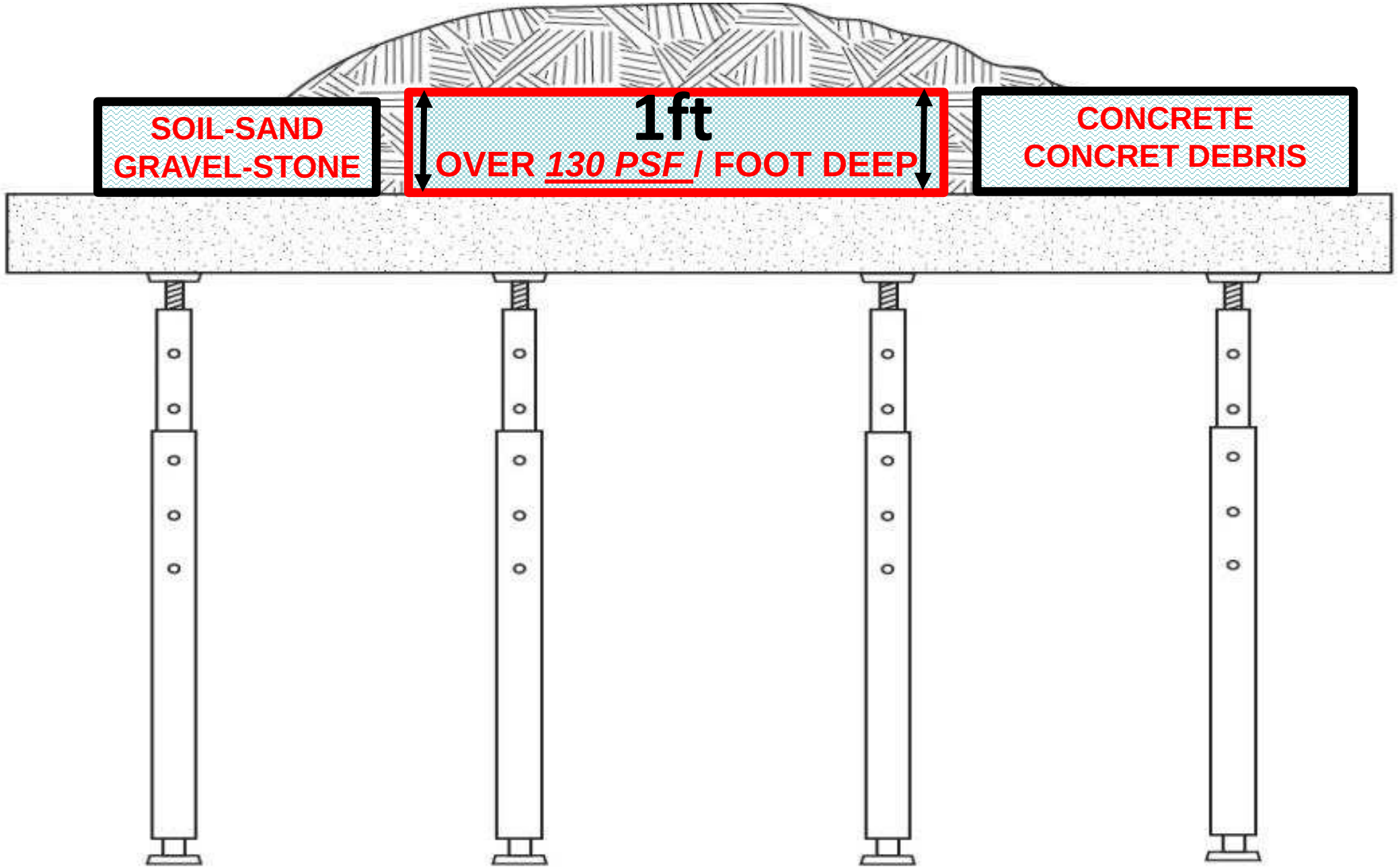
structural TECHNOLOGIES

HOW DO I DETERMINE ALLOWABLE LOADING?...ASK an ENGINEER!

4. IF YOU NEED TO SPREAD THE LOAD OUT AT THE BOTTOM LEVEL OF SHORING



Safety Rule for Construction Debris & Soil



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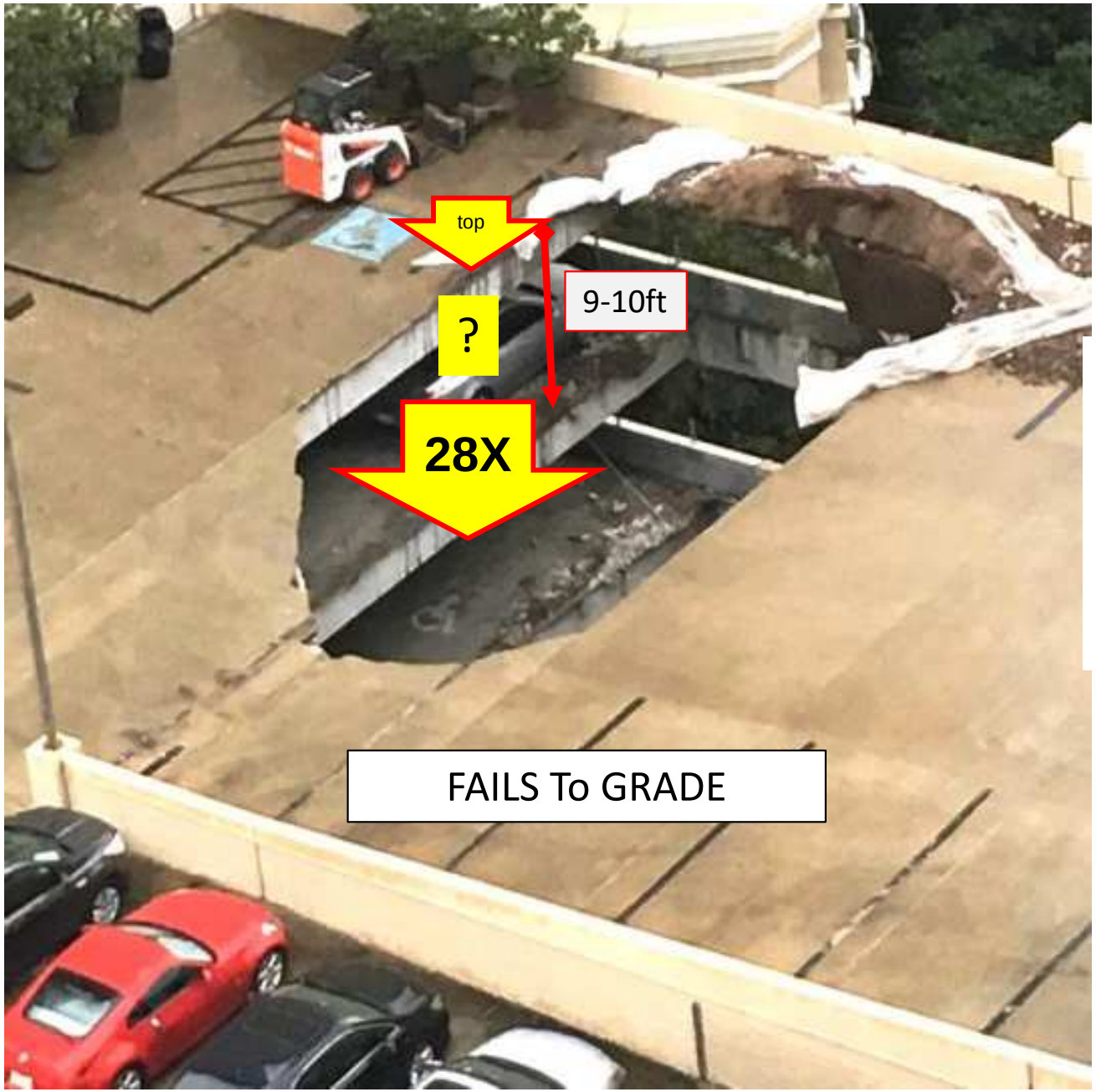
TECHNOLOGIES

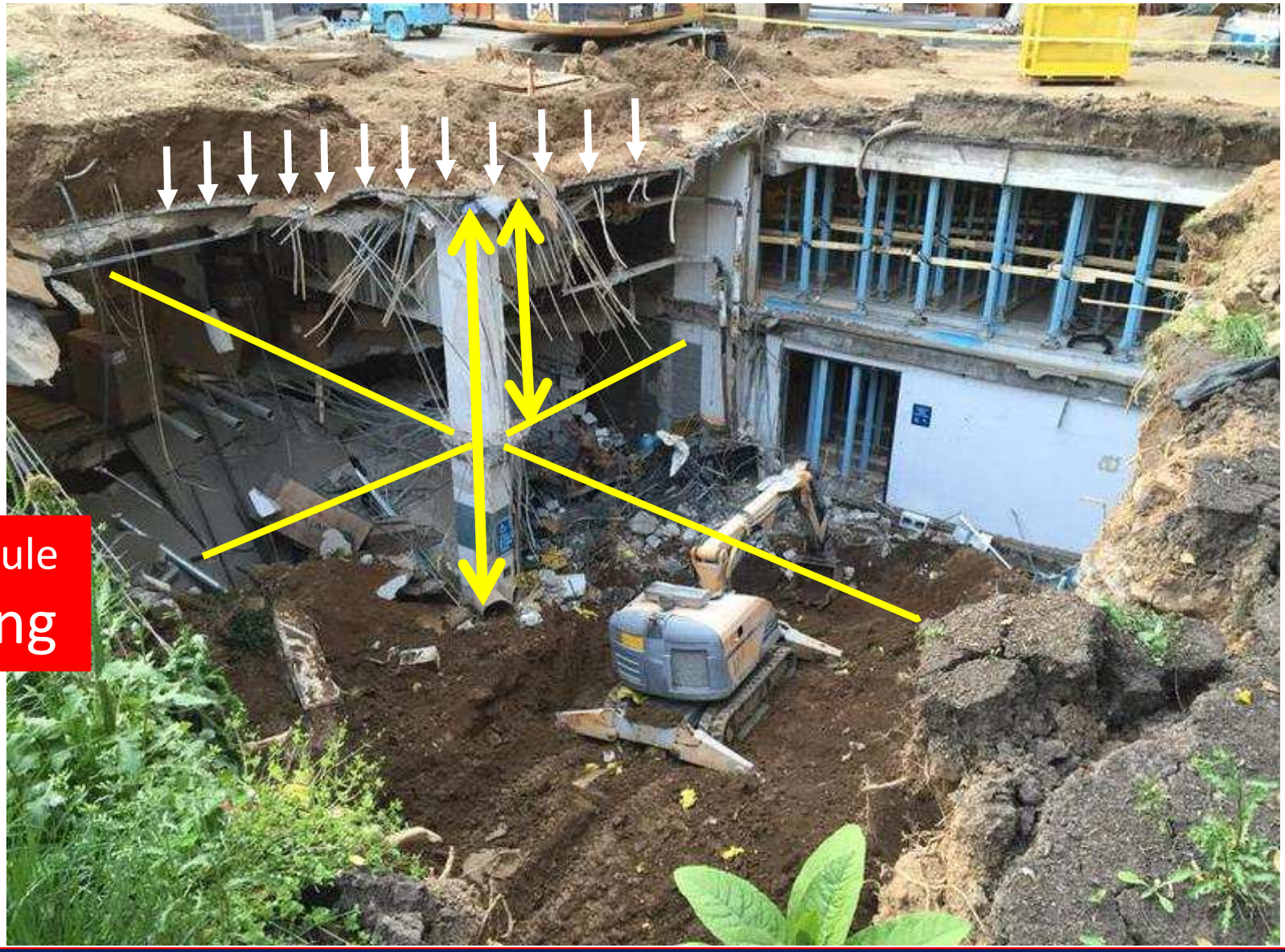


Exceeding Allowable Slab Loading Can Lead to

"Progressive Collapse"

How many multiples of the top Floors mass when it falls 9 to 10 ft?

Slab Overload Failures Can Also Cause Column Buckling!



Safety Rule
Buckling

2 Times the Column Height = Buckles @ 4 Times Less the Force

What is the Structural Effect of INCREASING Span Length

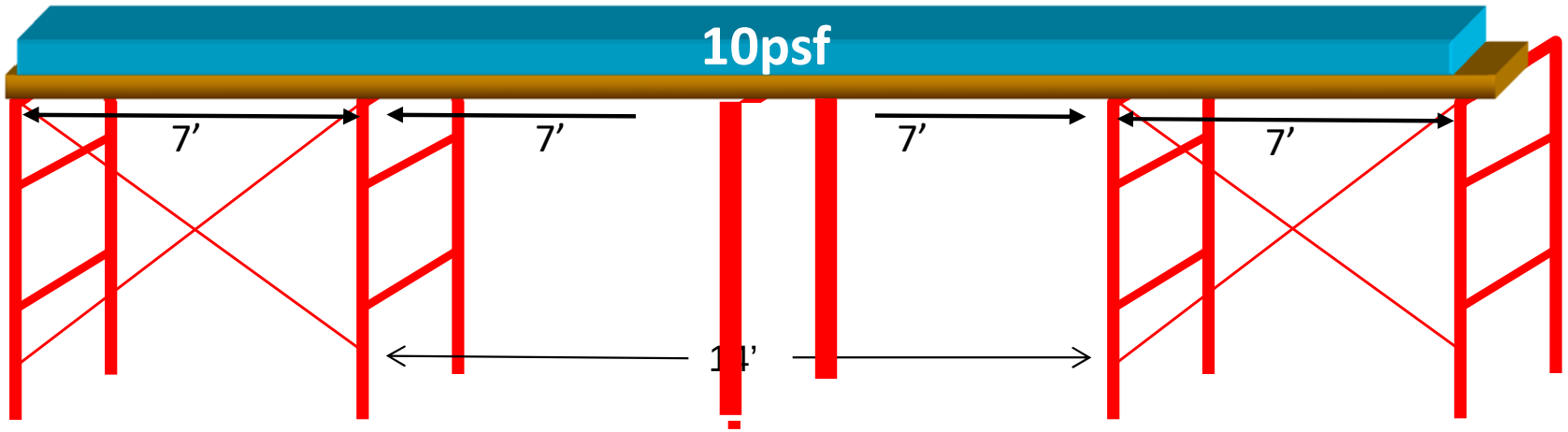
EXAMPLE: Continuous Scaffold or Shoring Tower PLATFORM w/7-foot spans & 10 PSF Load

Force on each 7 foot span= $WL^2/24$ (W= Load, L= Span)

= Load X *Span X Span* ÷ 24

10psf X 7’ X 7’ ÷ 24= **20**

10psf X 14’ X 14’ ÷ 24= **80**



Safety Rule + Spans

Double the Span = 4 Times the Force! 2X = 4X

Half the Span = ¼ the Force! 4 times stronger

AGENDA

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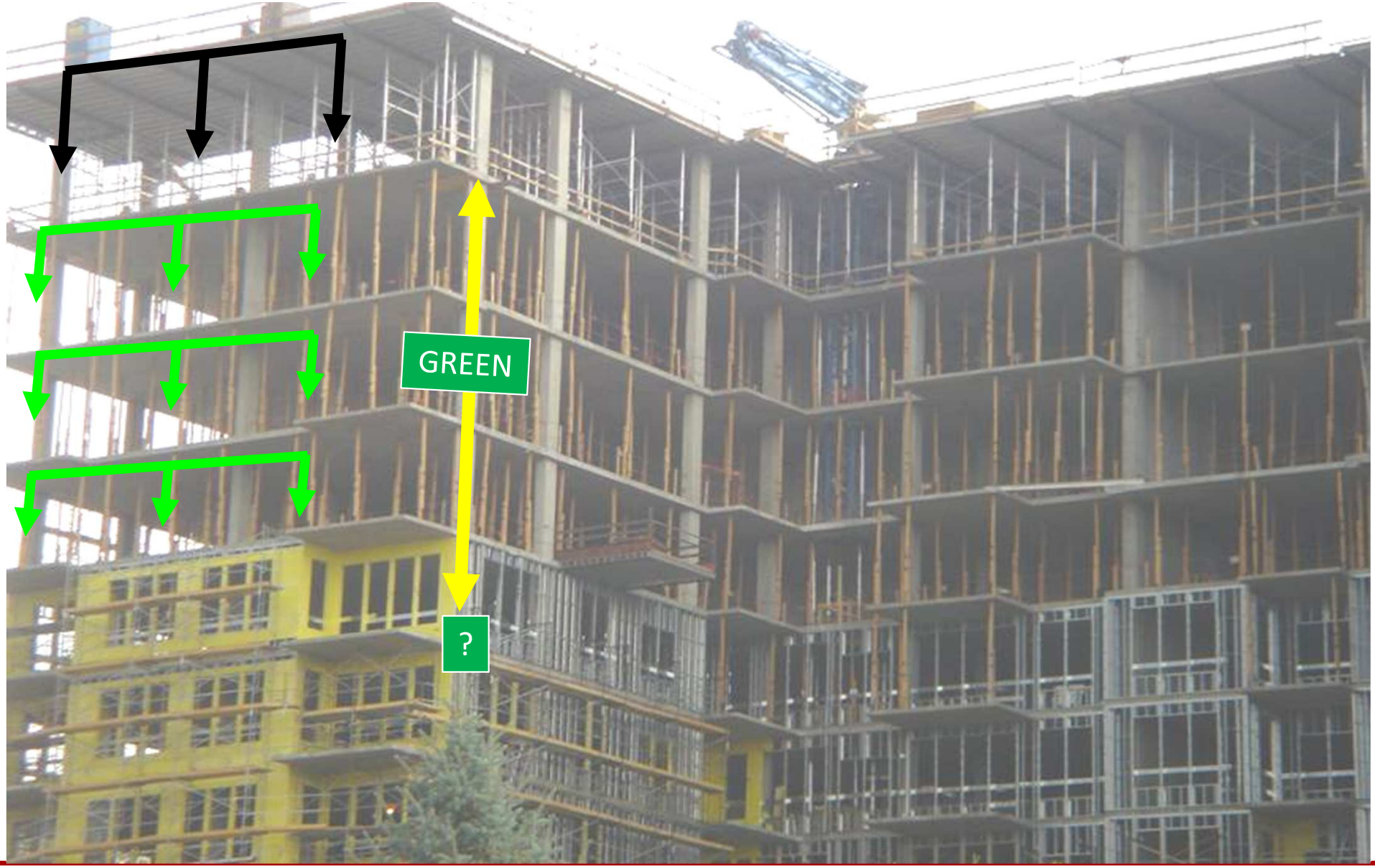
3 Common Concrete Placement Shoring Errors

1. Failures during placement from *faulty installation* or design

Safety Rule
*Pre-Pour **Shoring***
Check

3 Common Concrete Placement Shoring Errors

2. Early removal 3. *Early* loading of GREEN slabs

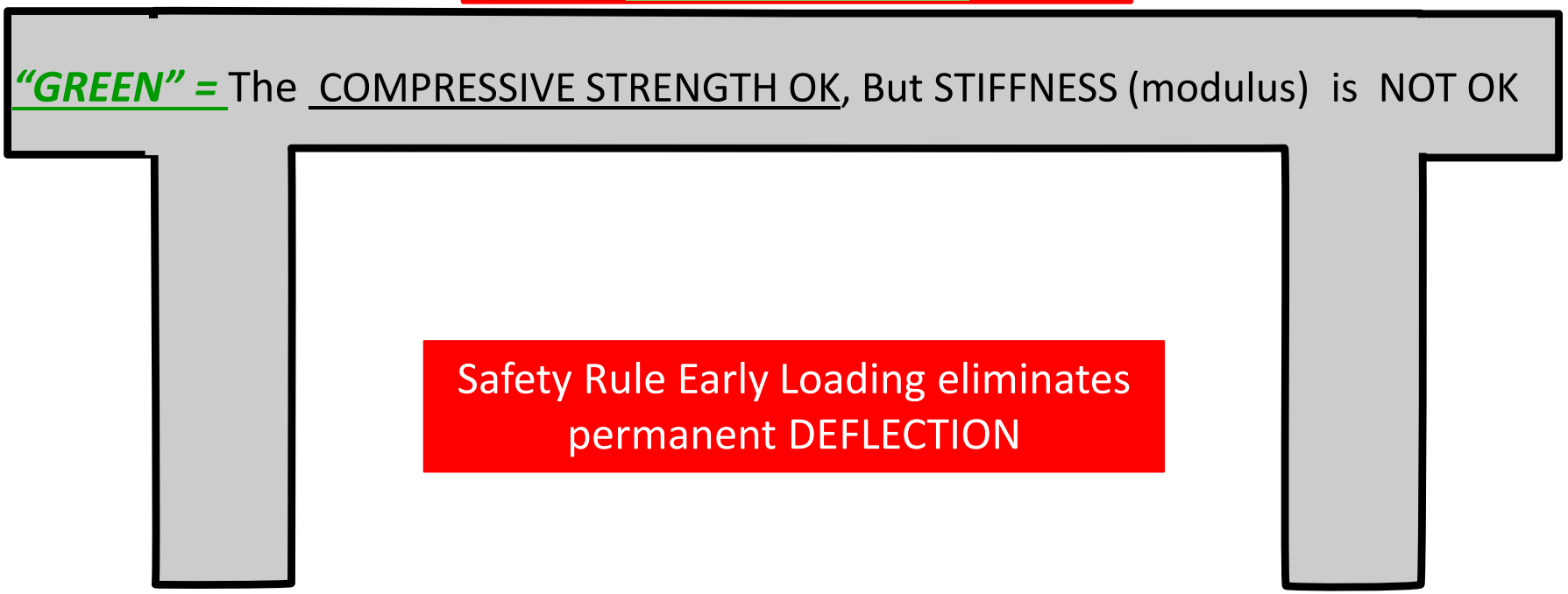


3 Common Concrete Placement Shoring Errors

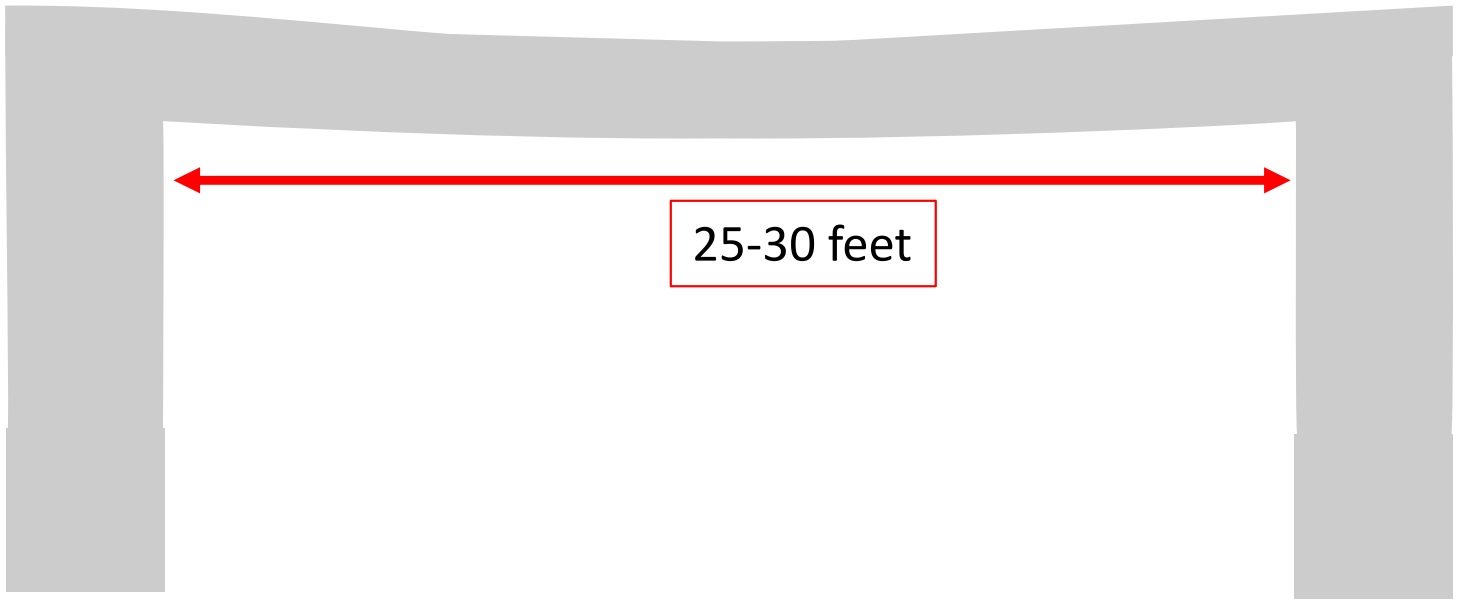
2. Early removal 3. *Early* loading of GREEN slabs

REMOVE SHORING @
Compressive Strength Goal -75%
OR Min # of Days Spec'd.

Construction Materials
Greater than 50PSF Construction Load Specification



Result of Early Loading Of GREEN Slabs= Permanent Deflection of 3 to 5”

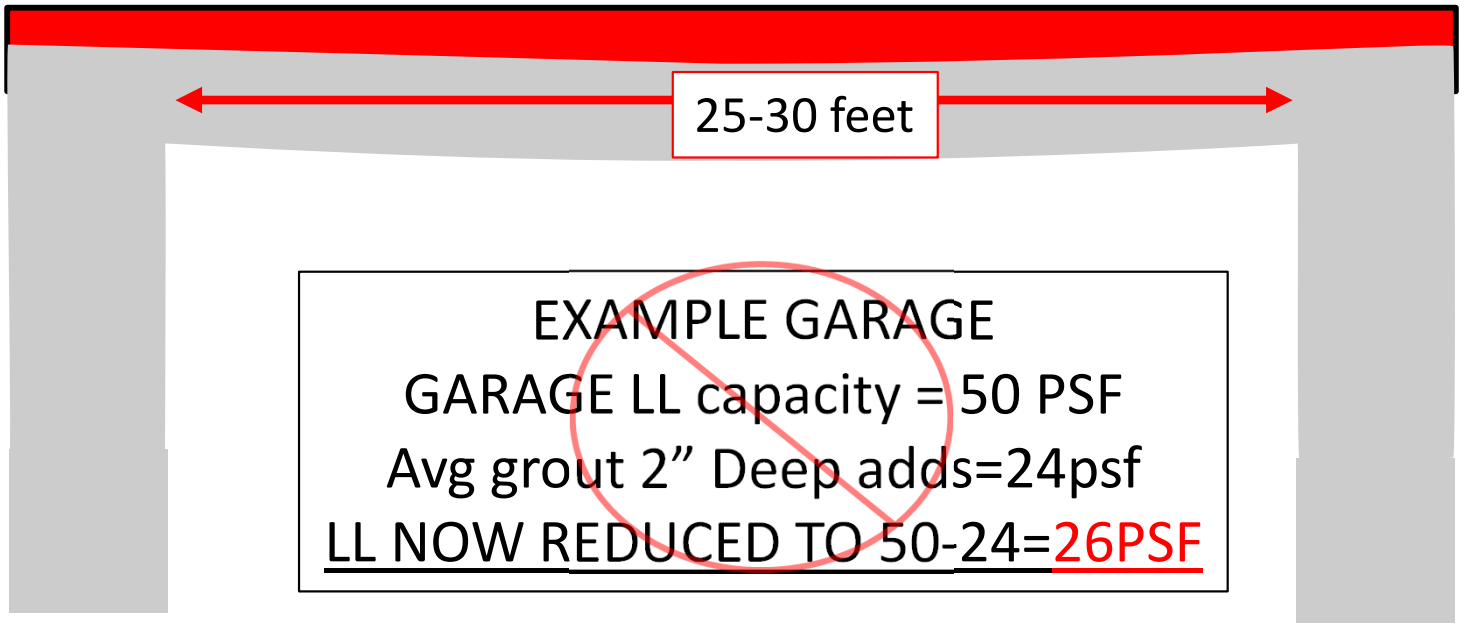


Result of Early Loading Of GREEN Slabs= Permanent Deflection of 3 to 5”

HOW DO I FIX THIS? CALL GROUT SALESMAN!

Safety Rule
1” DEEP concrete = 12PSF

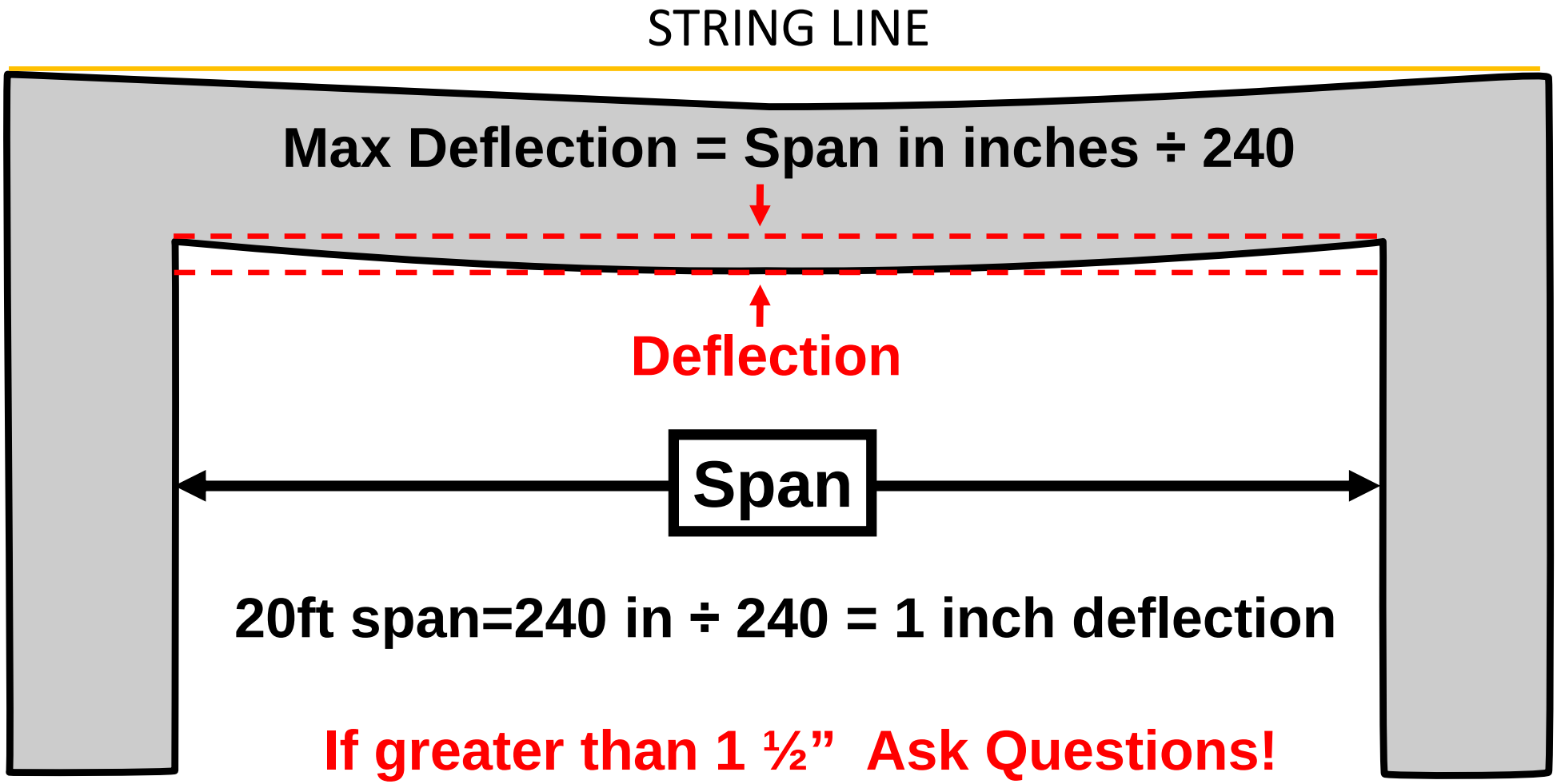
Adds DEAD LOAD- REDUCES LIVE LOAD!



How Do I Avoid This? Do a Deflection Inspection

Need to Know How Much Deflection is OK?

There is a FORMULA for everything engineering"



structural TECHNOLOGIES

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Reinforced Concrete Design

"How do you design a slab that SPAN 30 feet and can carry 60psf LOAD"

Equilibrium

Section Properties

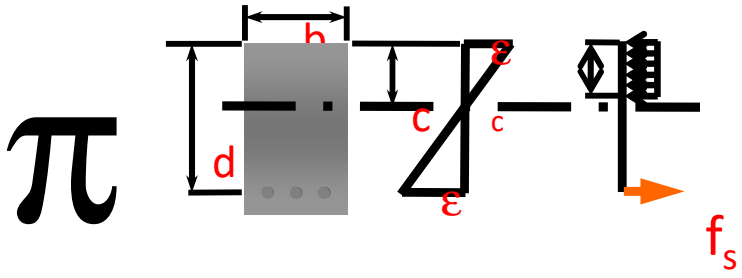
Moment

"Yield"

$\sum f + 3\sigma$

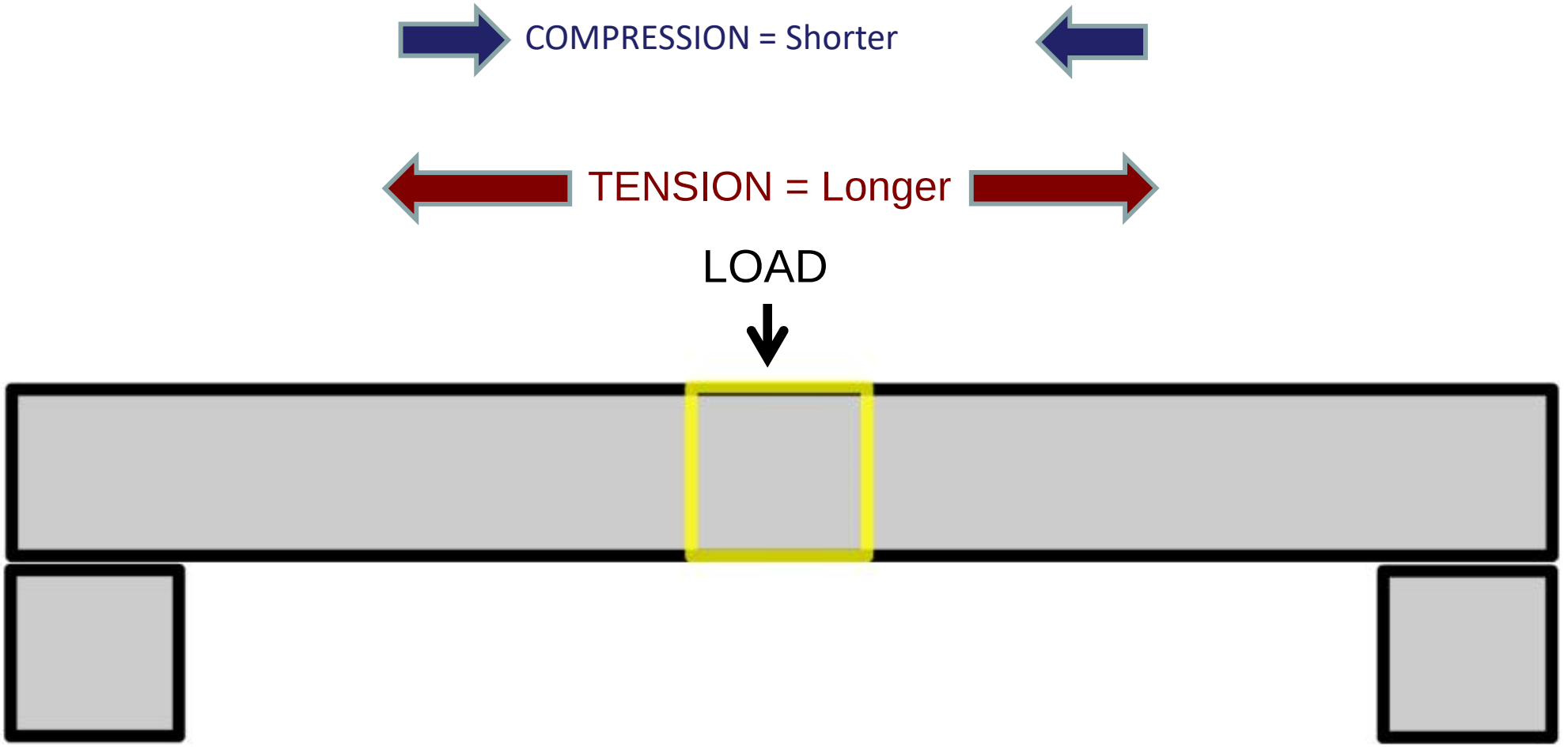
$WL^2/24$

Strain Compatibility

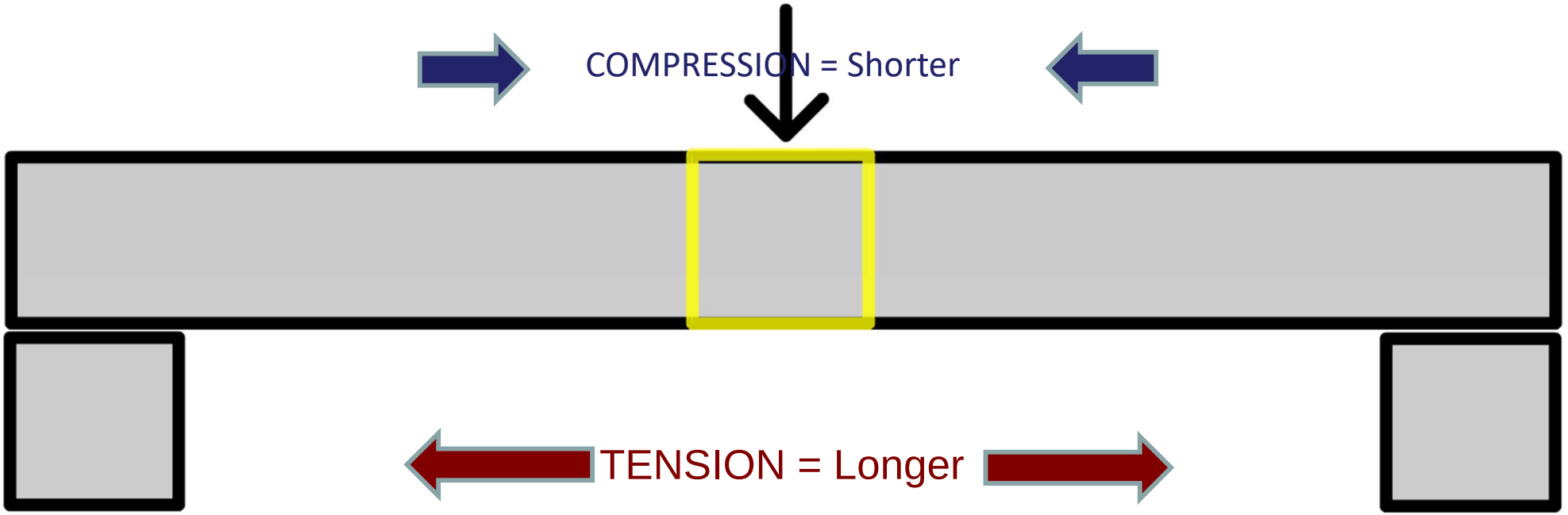


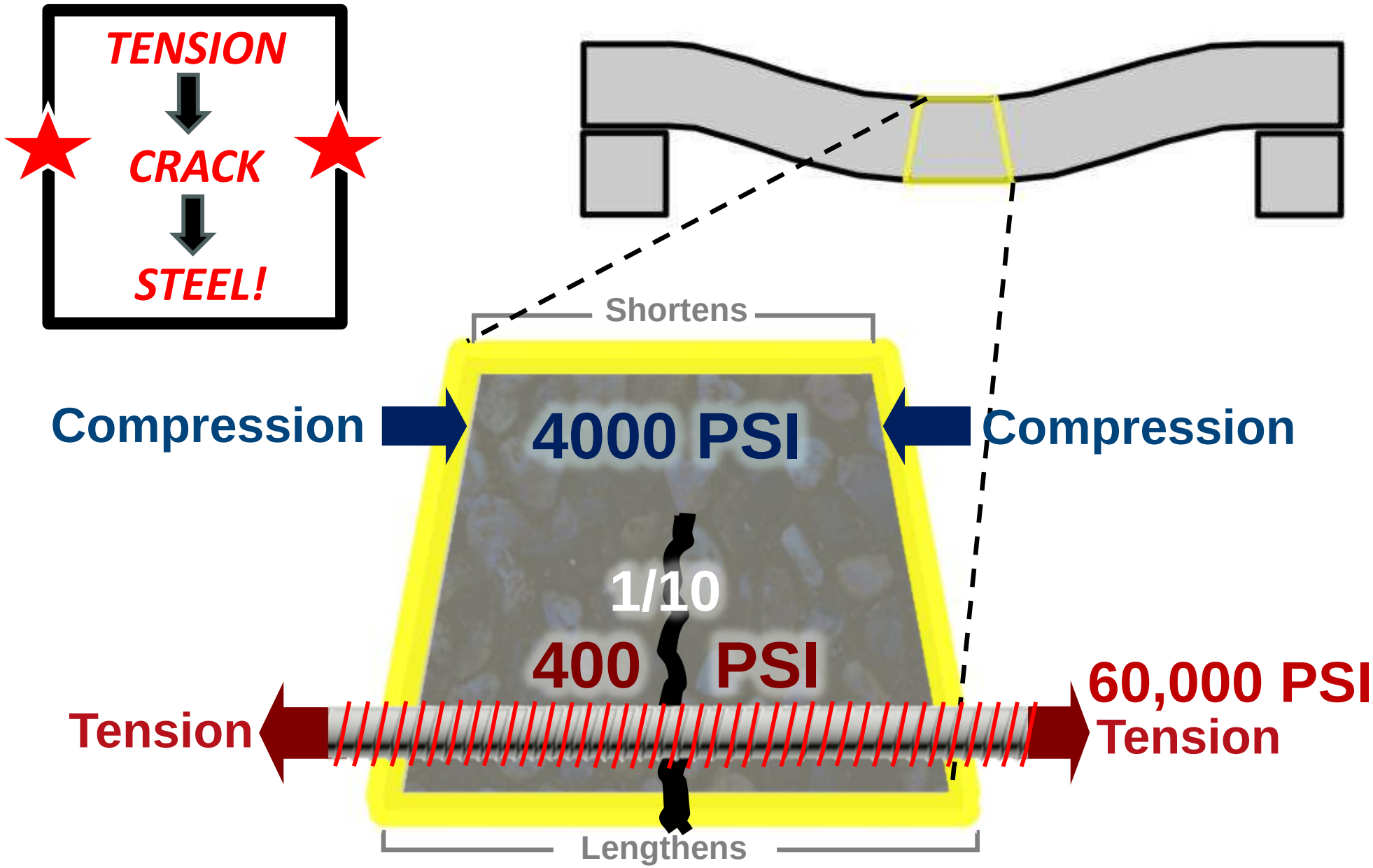
- Basic engineering concepts are *not complex*
- *Basic mechanics* can explain most engineering concepts
- *Explain them today using a Foam Beam* instead of Formulas

Understanding compression & tension

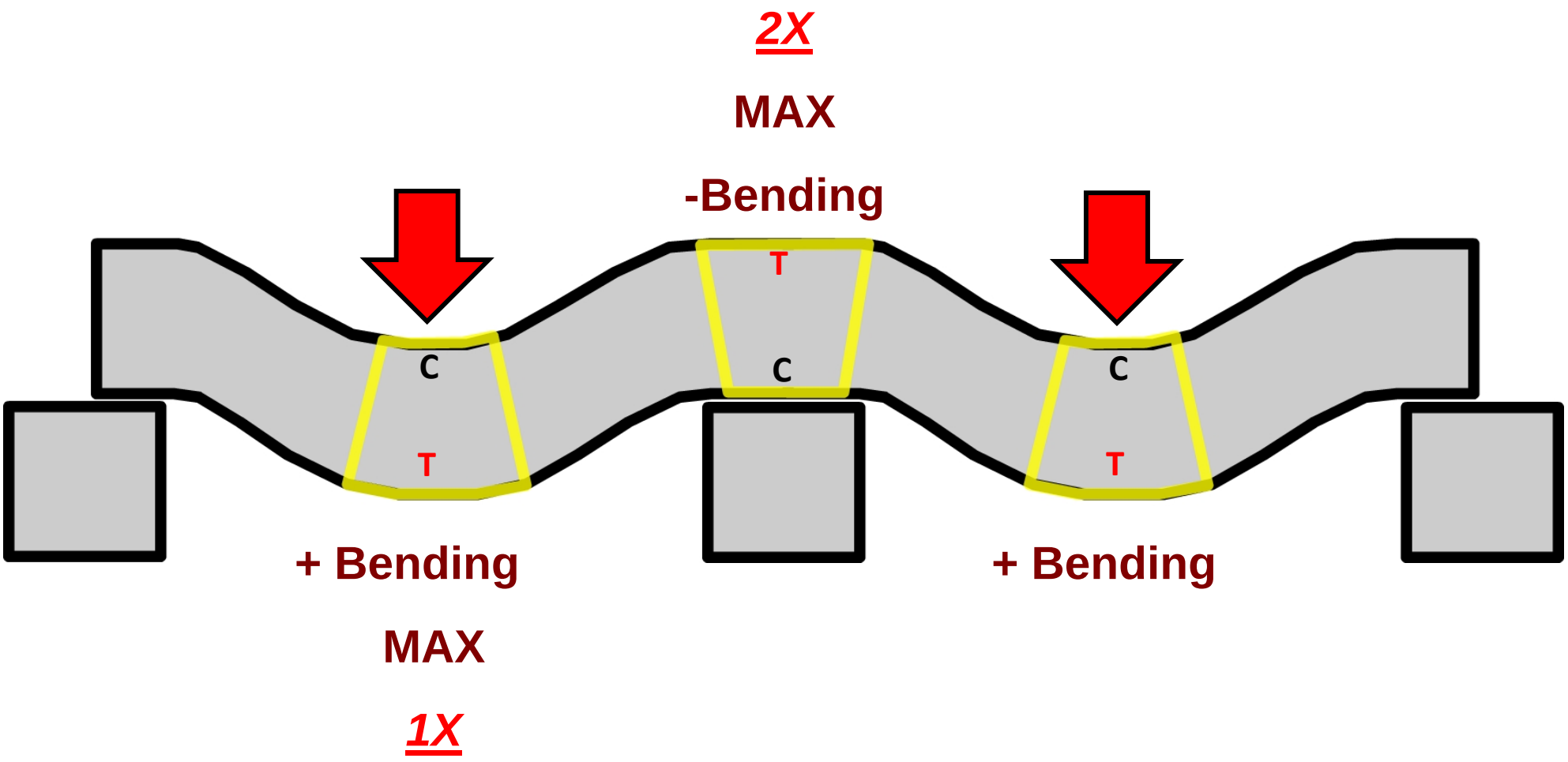


Understanding compression & tension

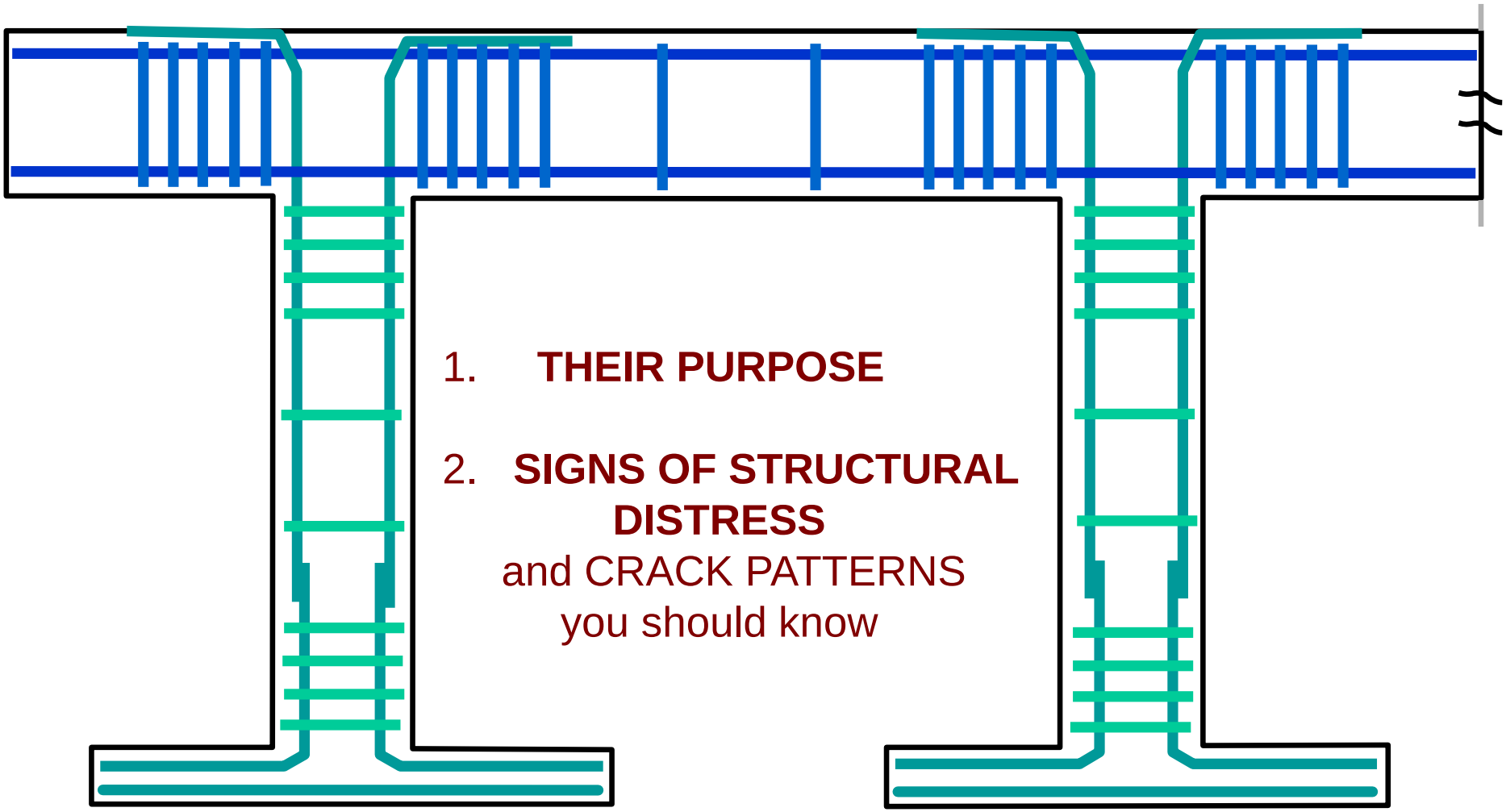



TENSION
CRACK
STEEL!
Shortens
Compression
4000 PSI
Compression
1/10
400 PSI
Tension
60,000 PSI
Tension
Lengthens

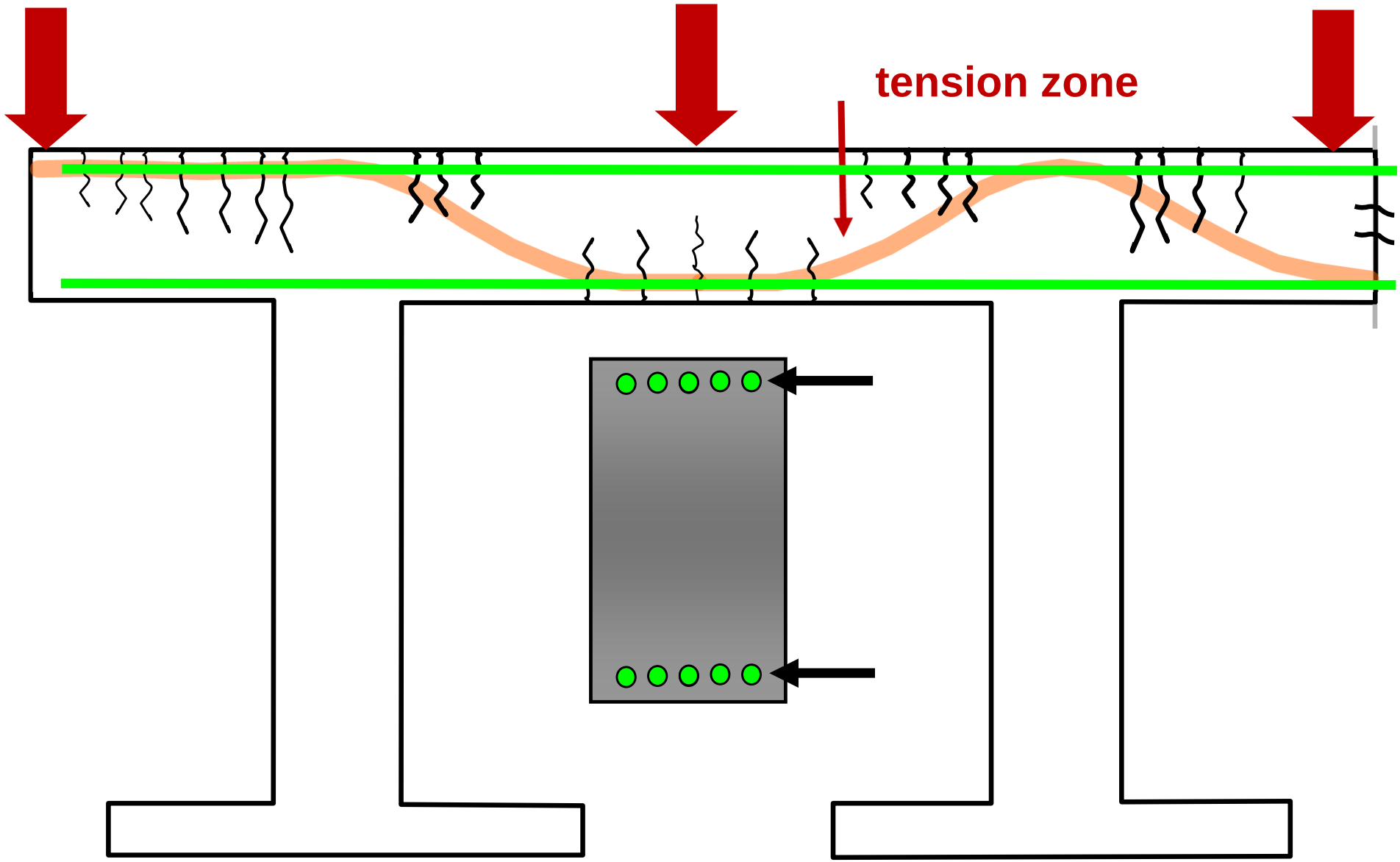
Understanding compression & tension forces on multiple spans



Typical Reinforcement in Beams, Slabs, Columns & Shear Walls

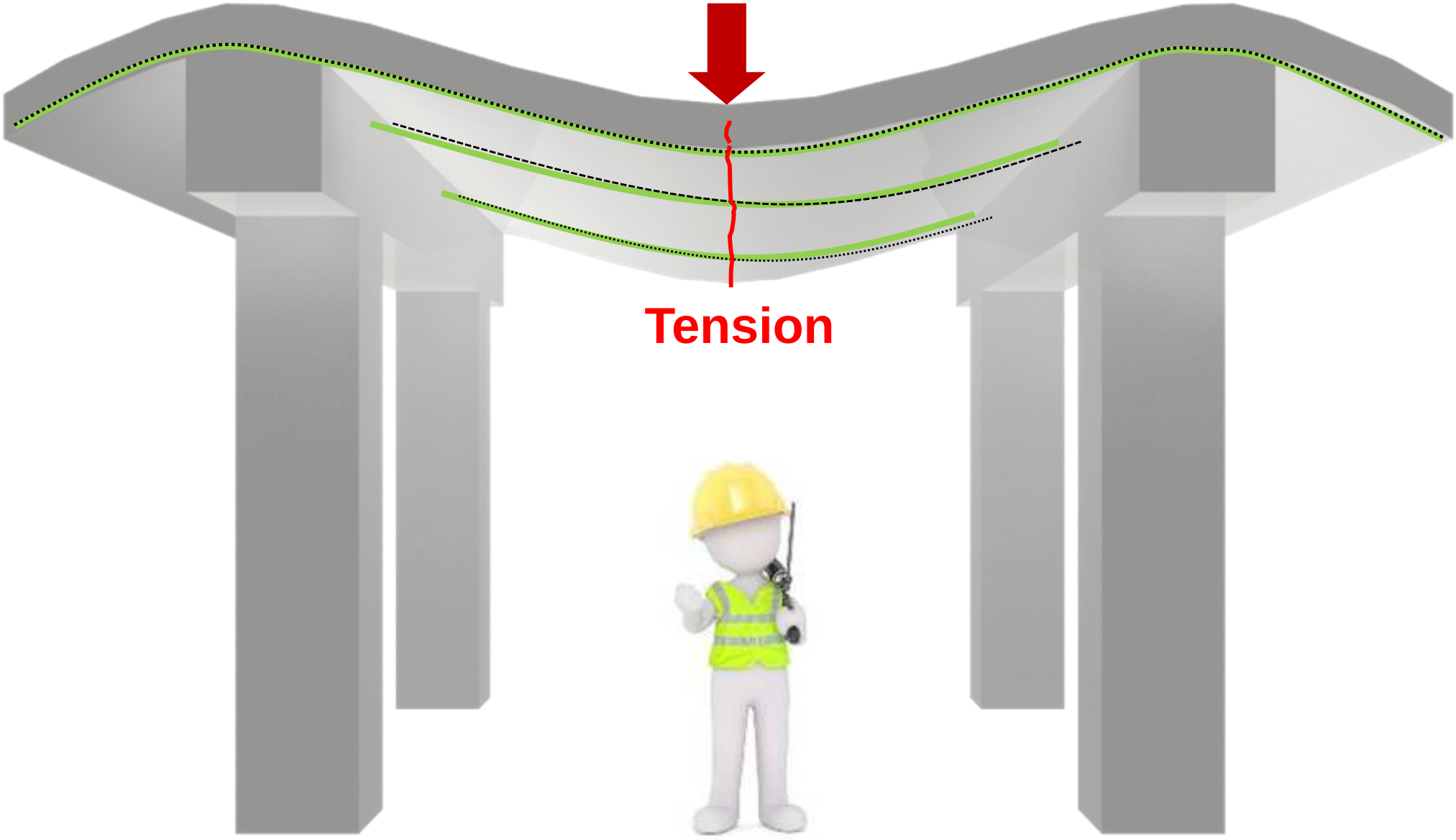


Steel placement in Beam to resist bending forces

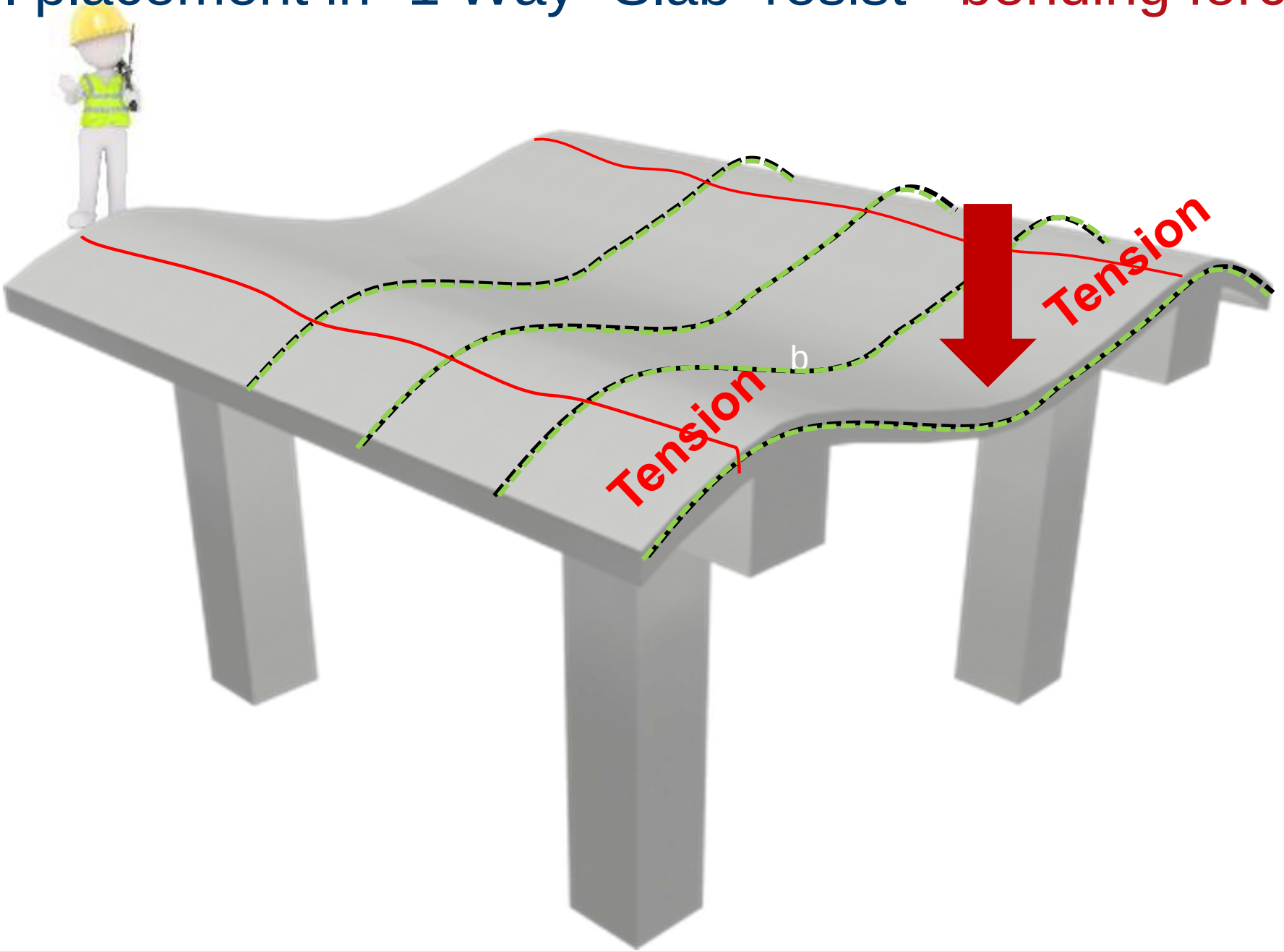


Signs of distress: beam bending cracks

Steel placement in “1 Way” Slab to resist + bending force



Steel placement in “1 Way” Slab resist - bending forces



What do *STUCTURAL CRACKS* look like?

T

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C

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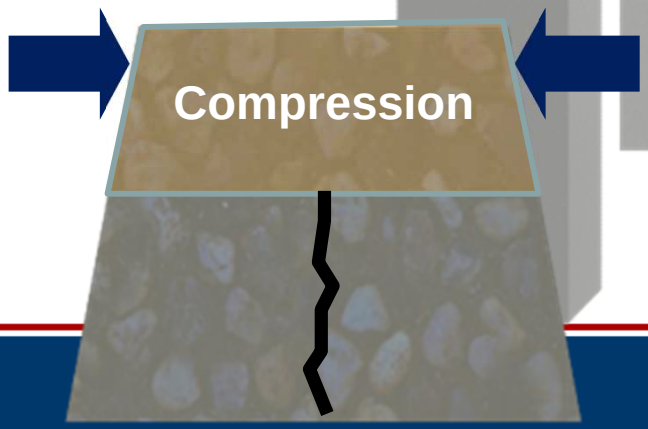
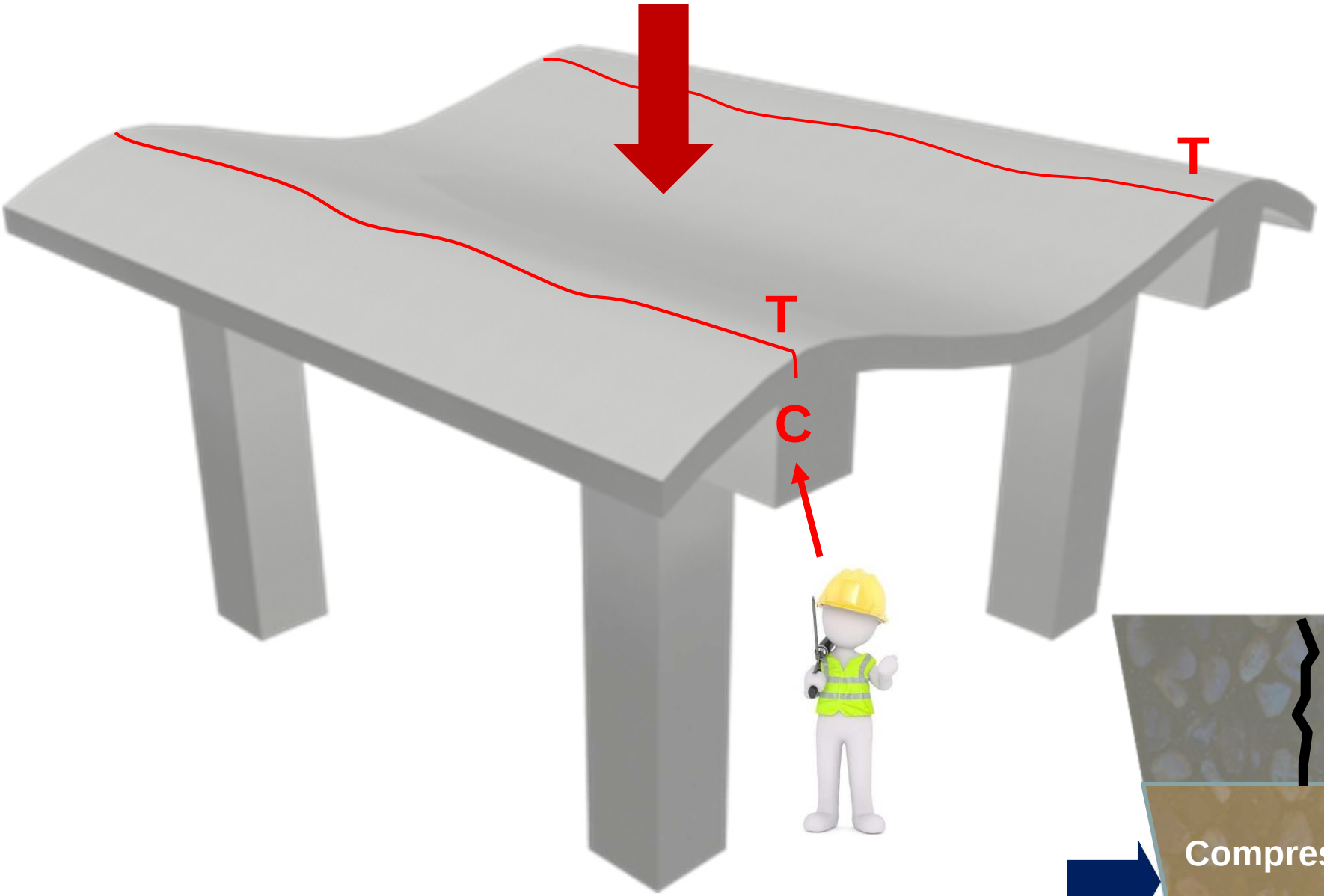
3 Things to look for:

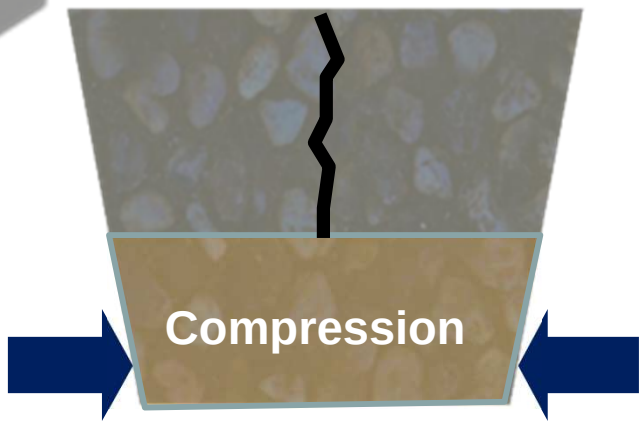
1. In Tension Zone?
2. Is the crack straight?
3. Is it a through crack?

WHERE ARE THE TENSION ZONES?

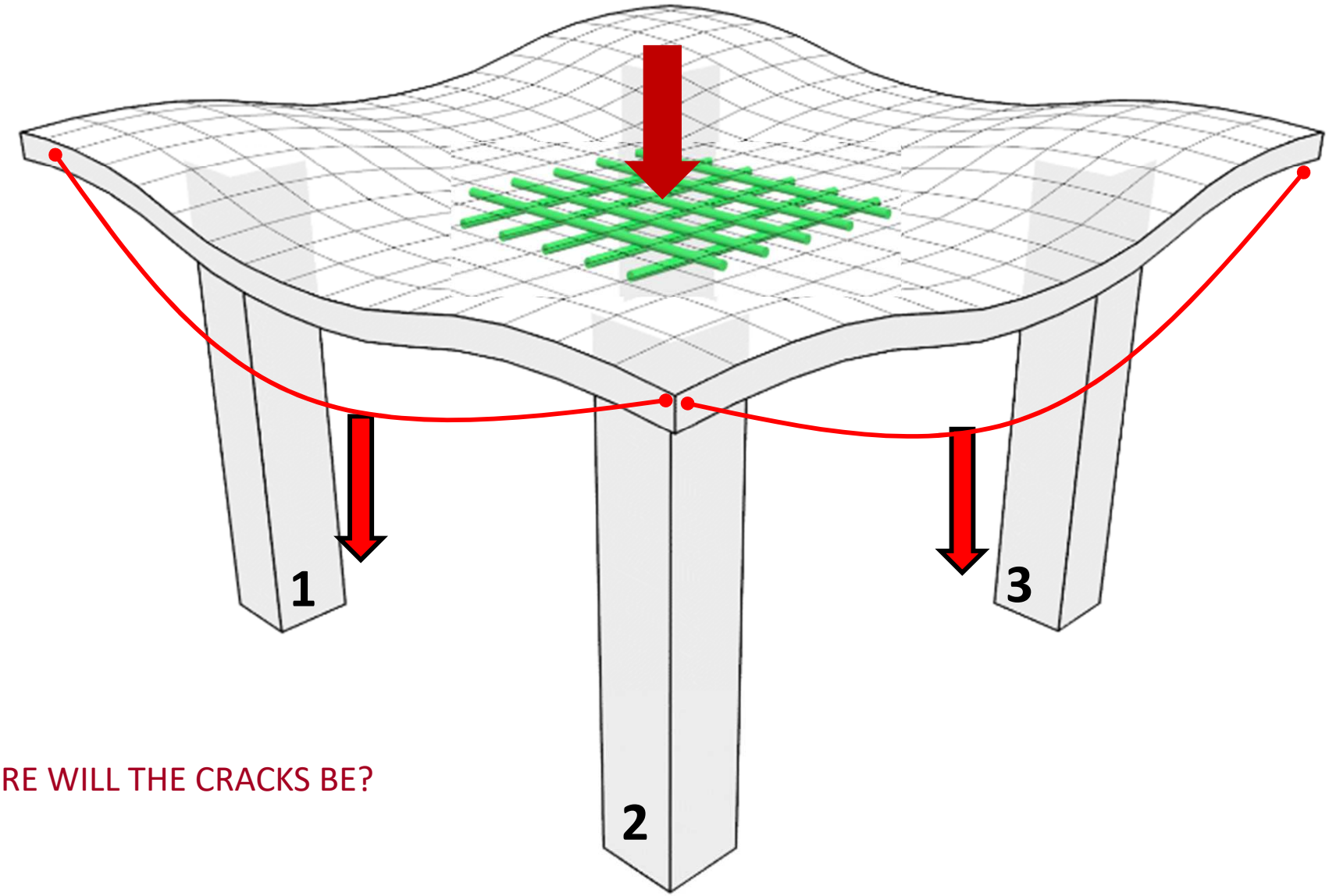


Signs of distress: understanding cracks in concrete



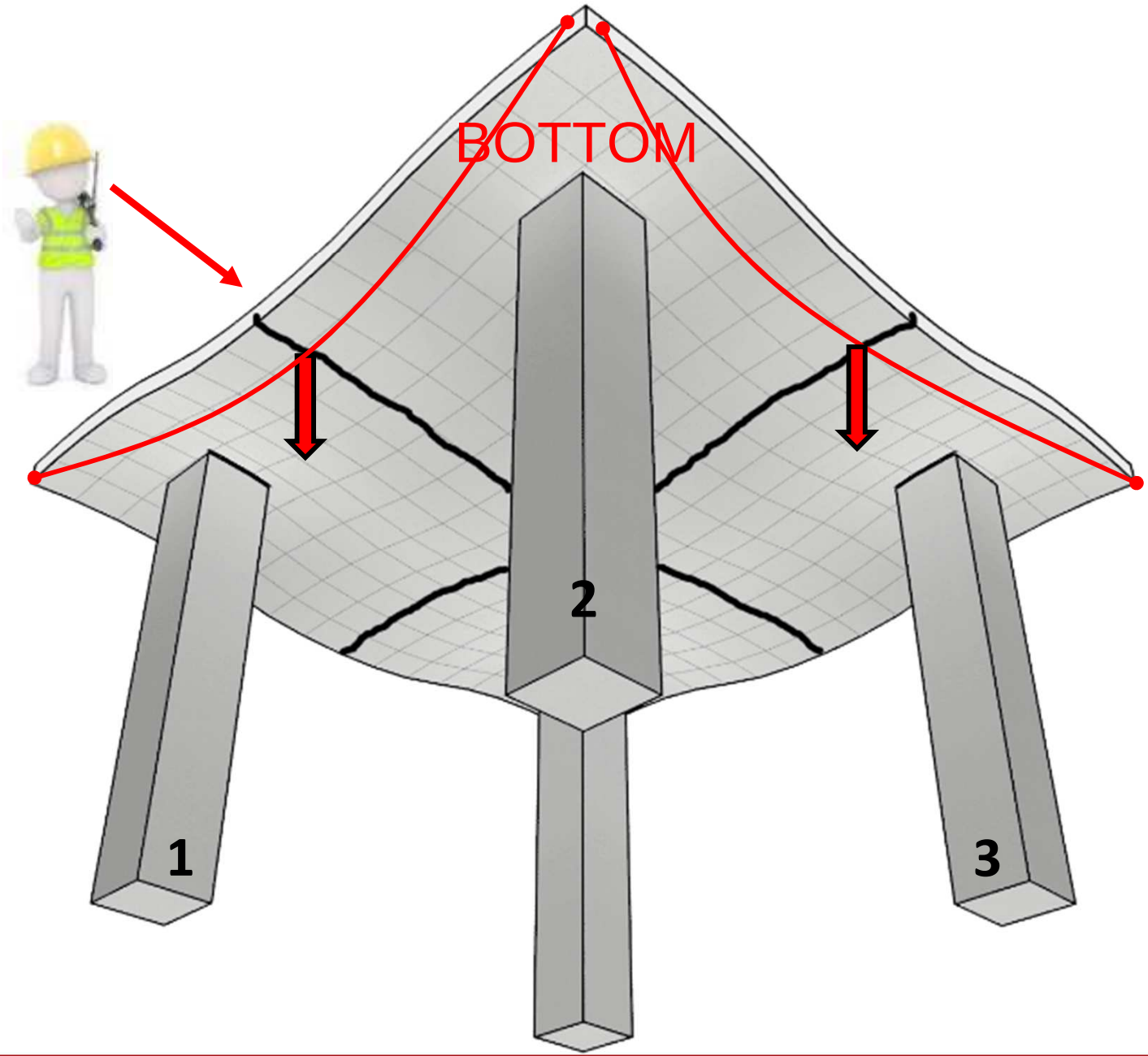


Steel placement in “2 Way” Slab to resist bending forces

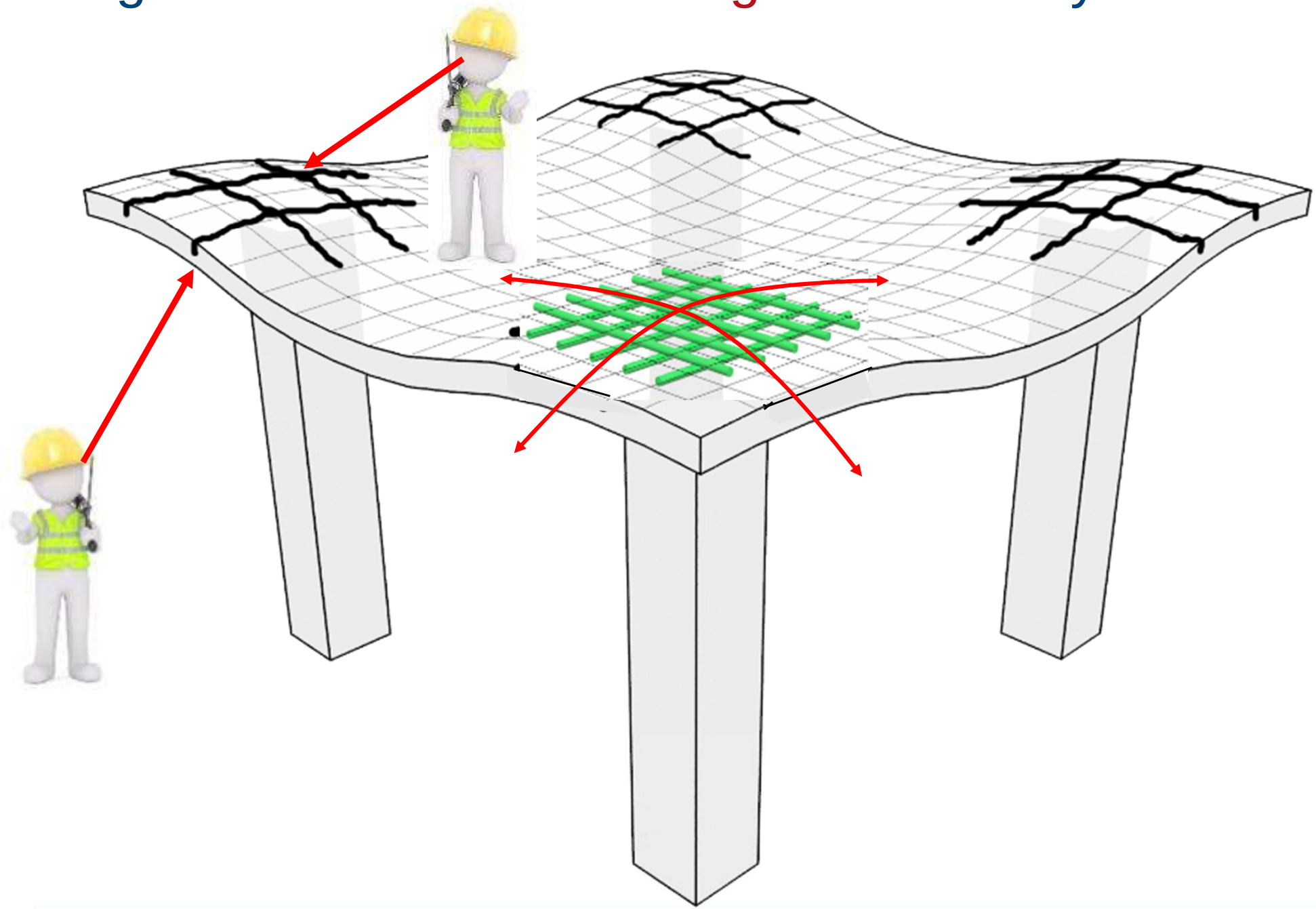


WHERE WILL THE CRACKS BE?

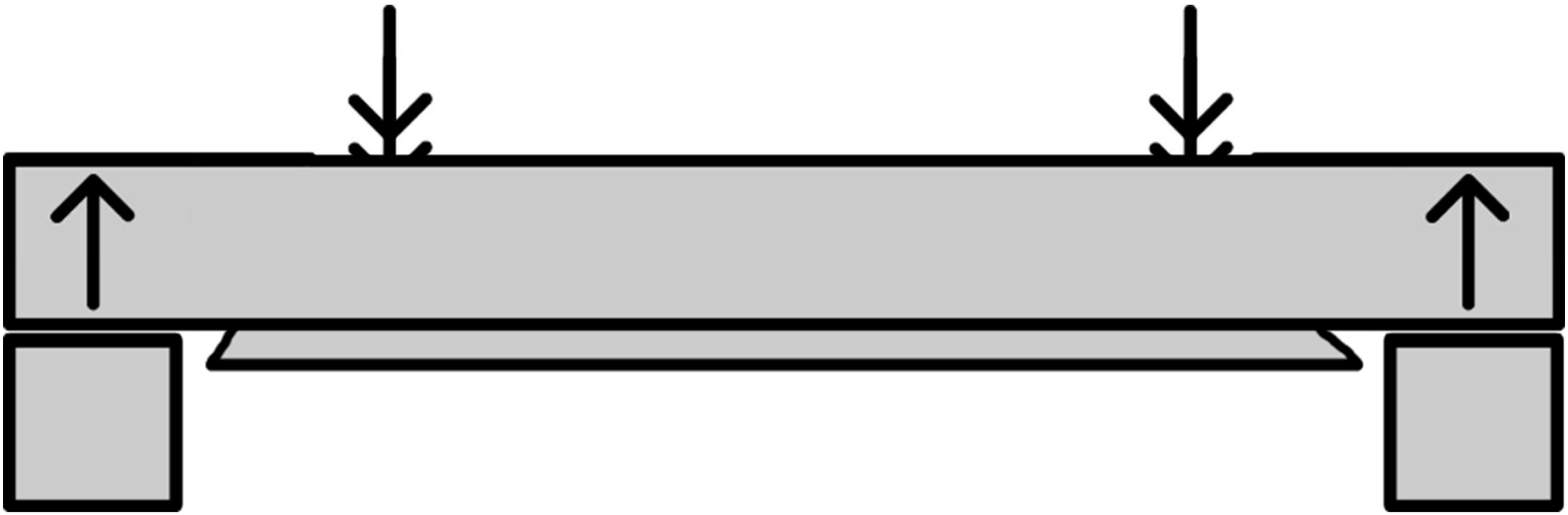
Signs of distress for + bending cracks on a 2 way slab



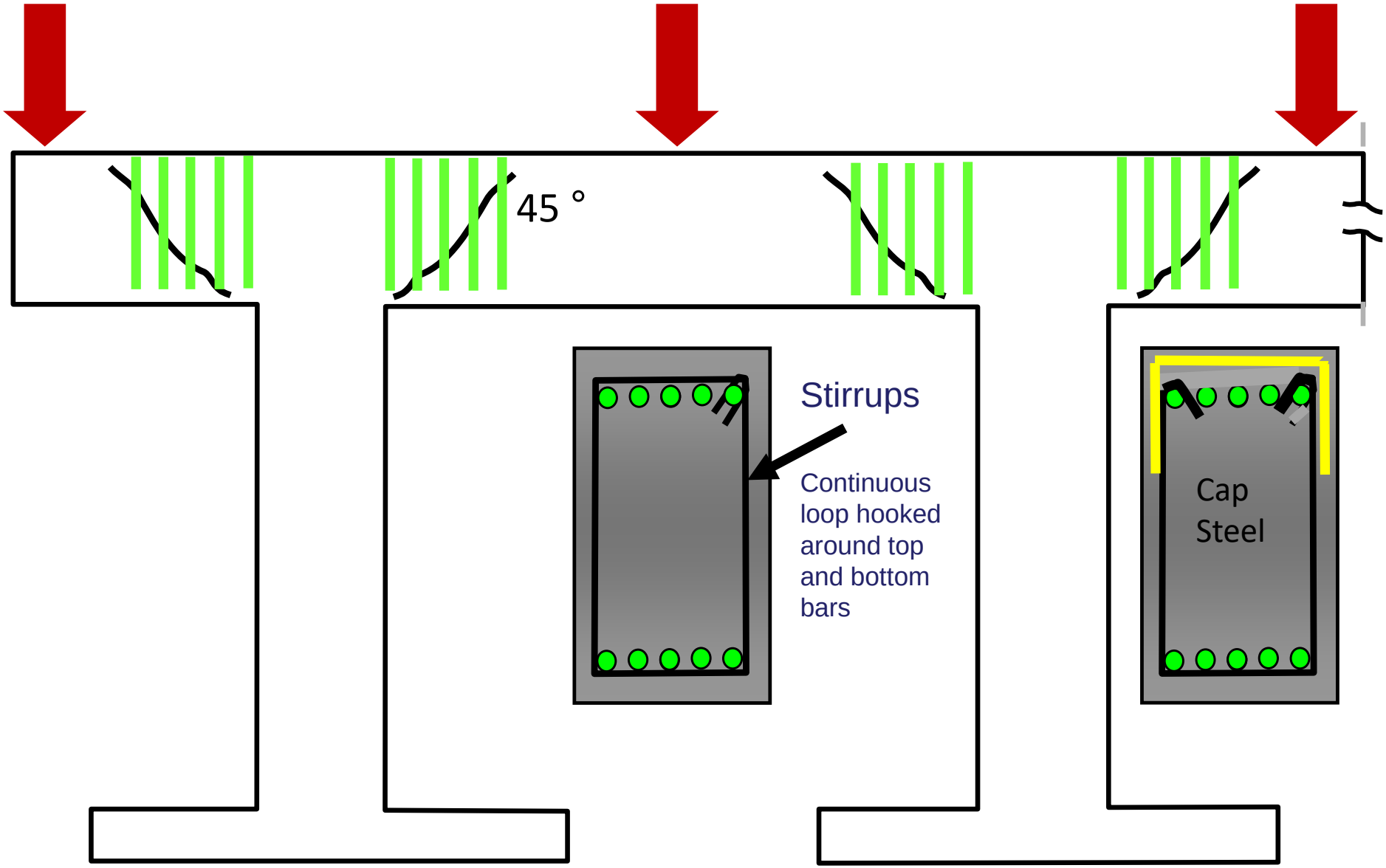
Signs of distress for -bending cracks 2 way slab-TOP



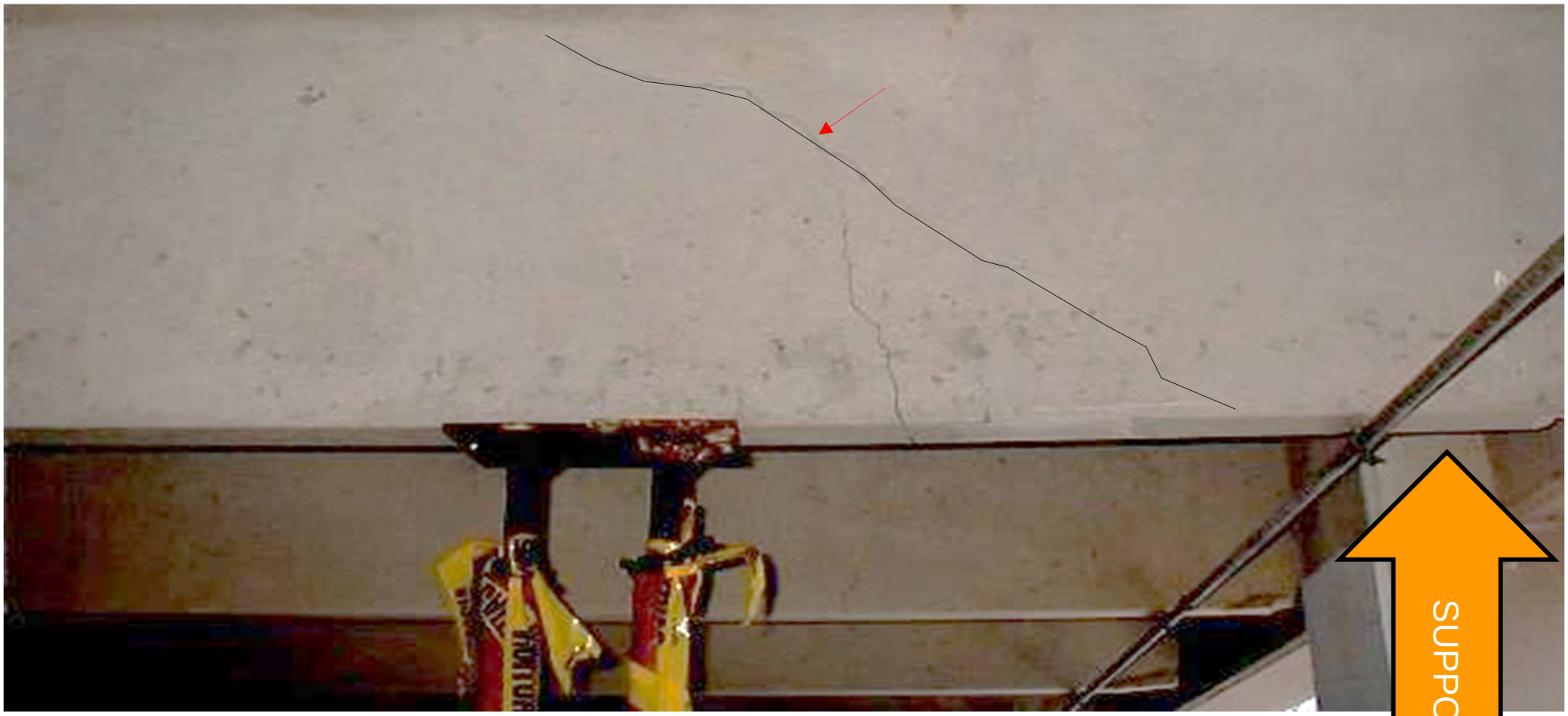
Understanding shear forces
1. Beam shear



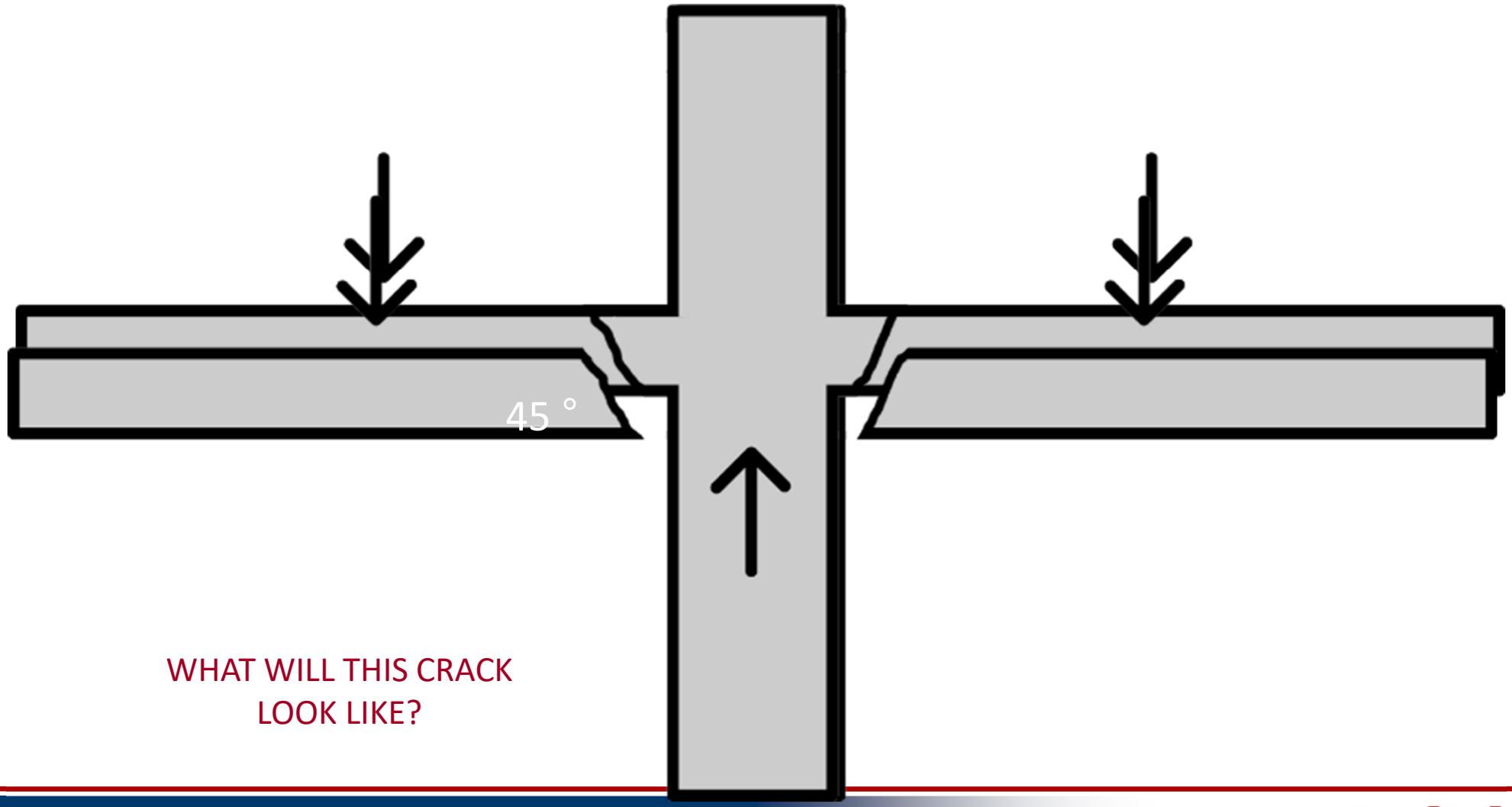
Steel placement in Beam to resist shear forces



Signs of distress: beam shear cracking

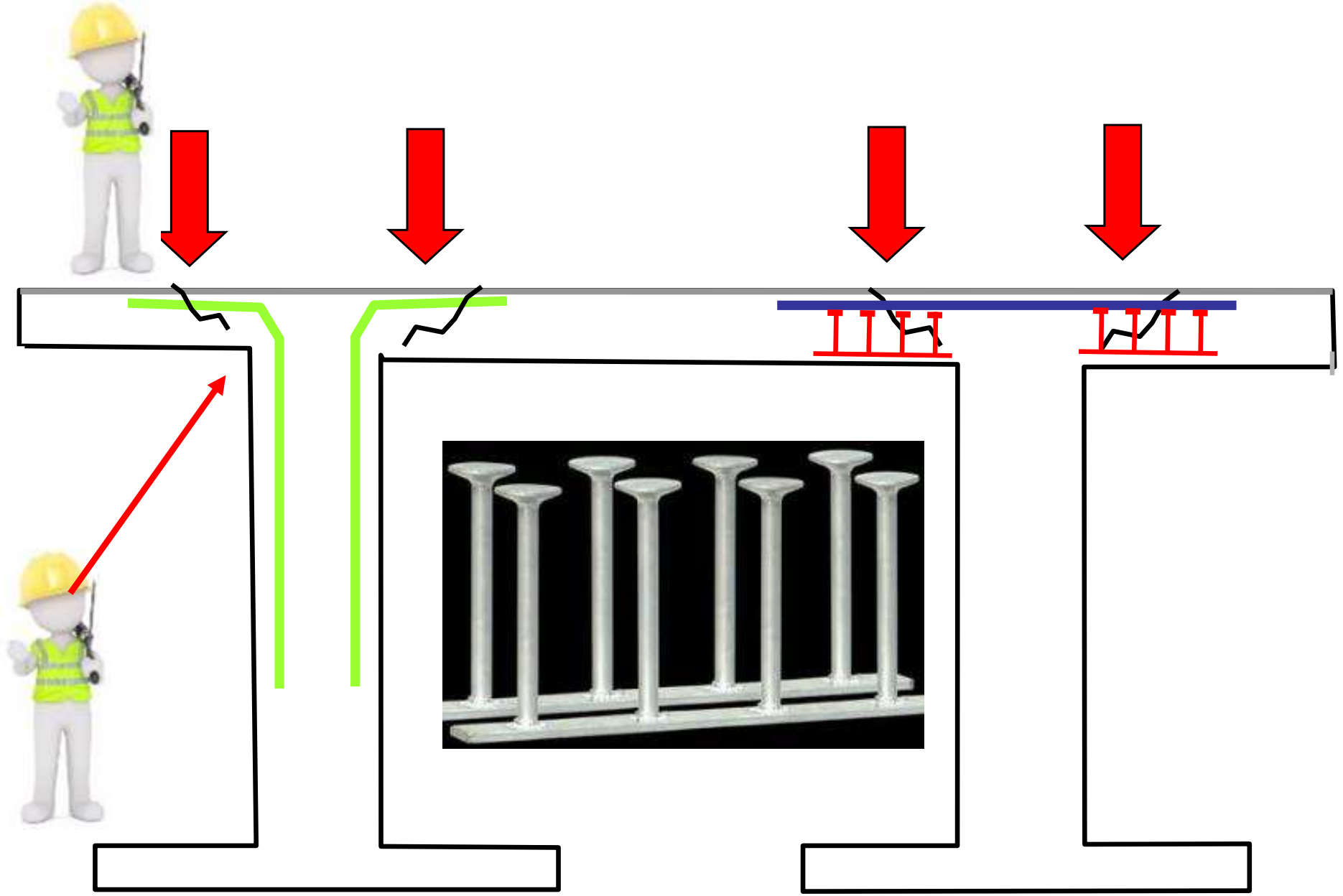


Understanding shear forces
2. Slab Punching shear

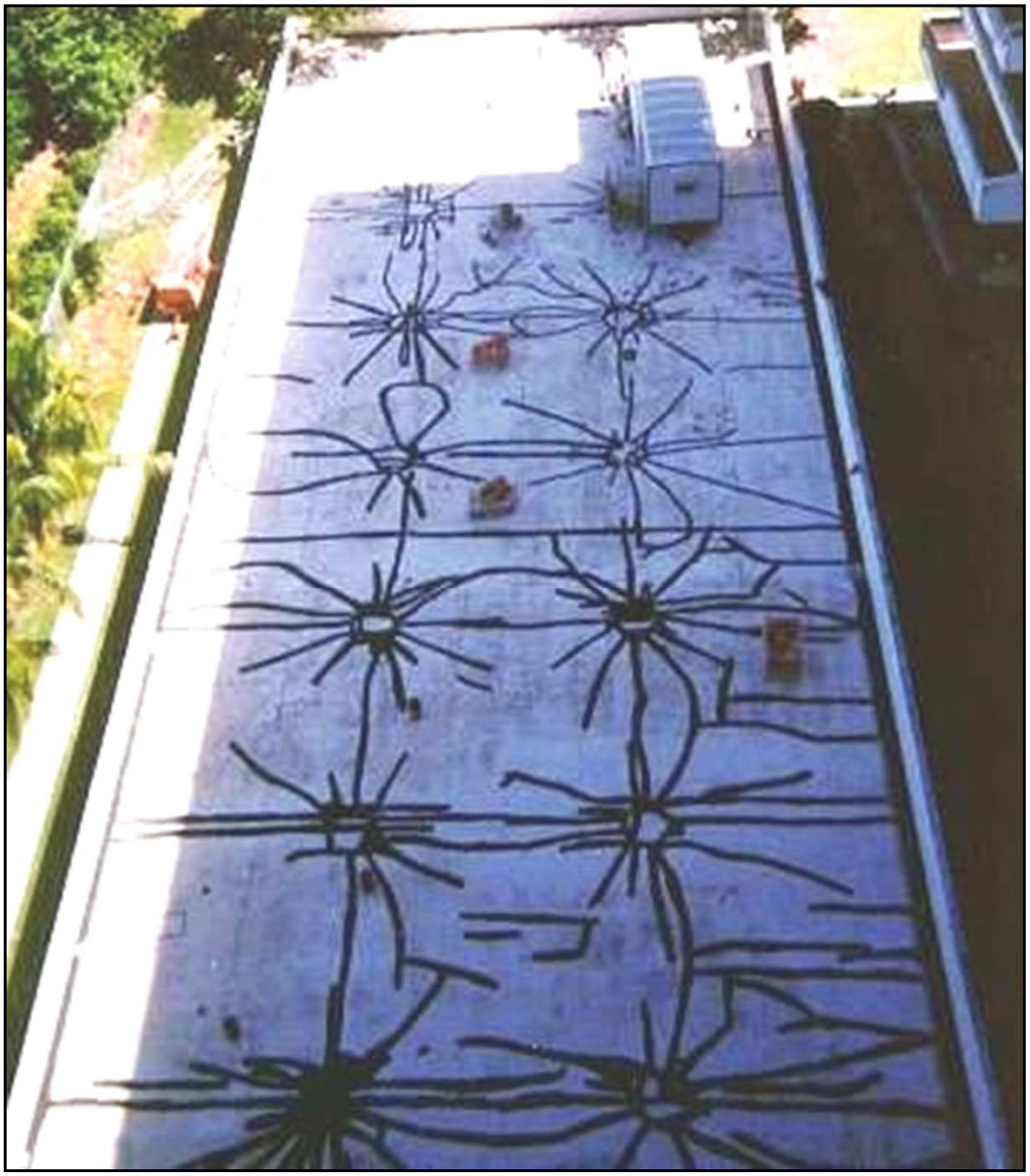


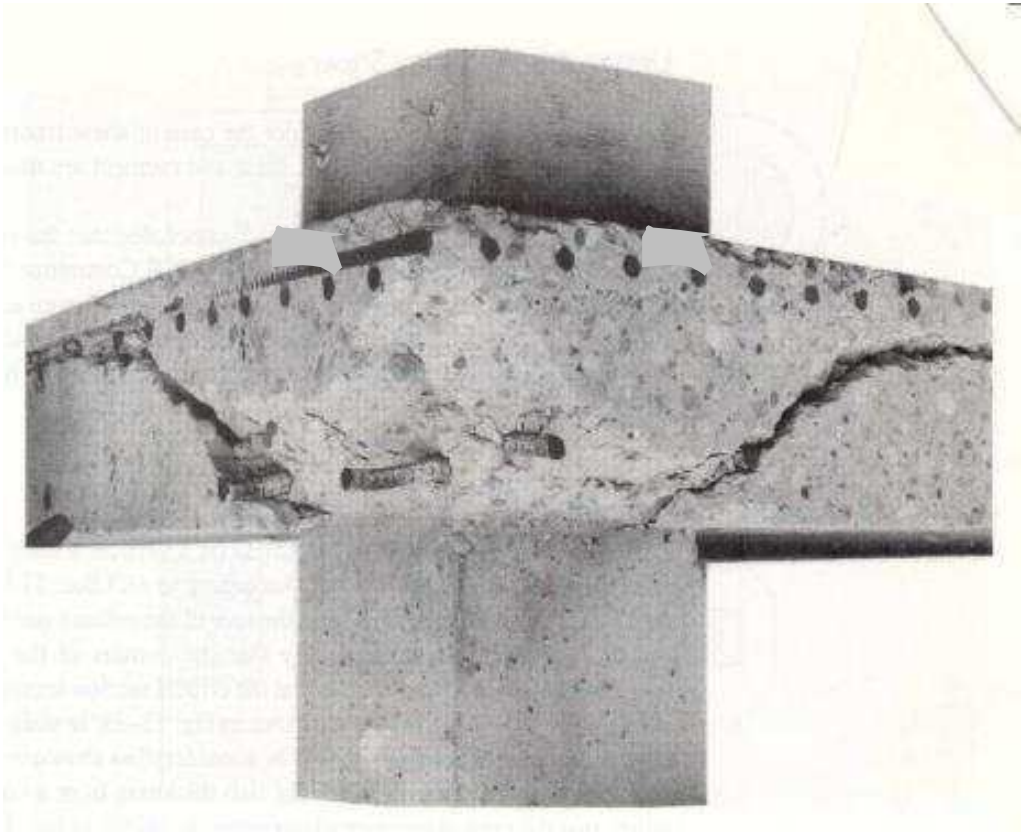
WHAT WILL THIS CRACK LOOK LIKE?

Slab steel placement to resist punching shear



Signs of distress: slab punching shear cracking

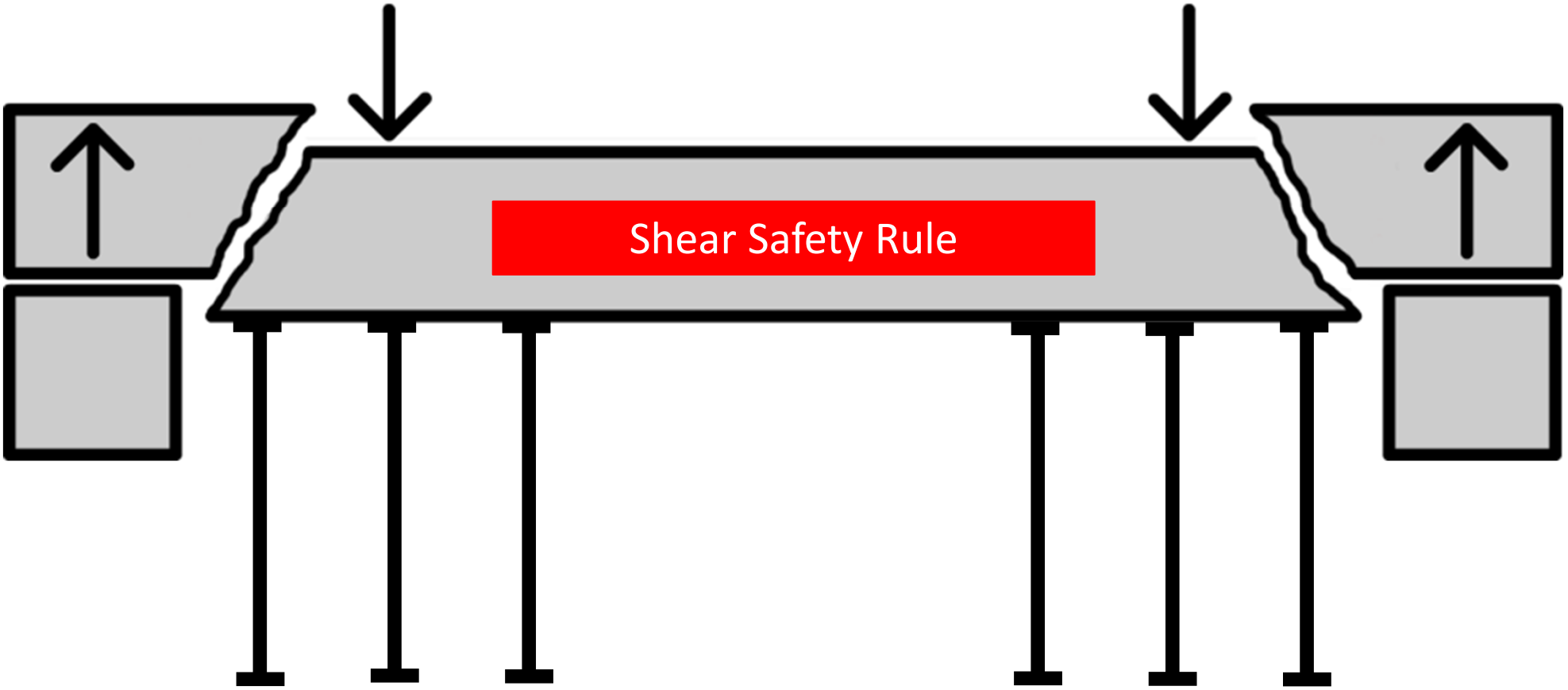


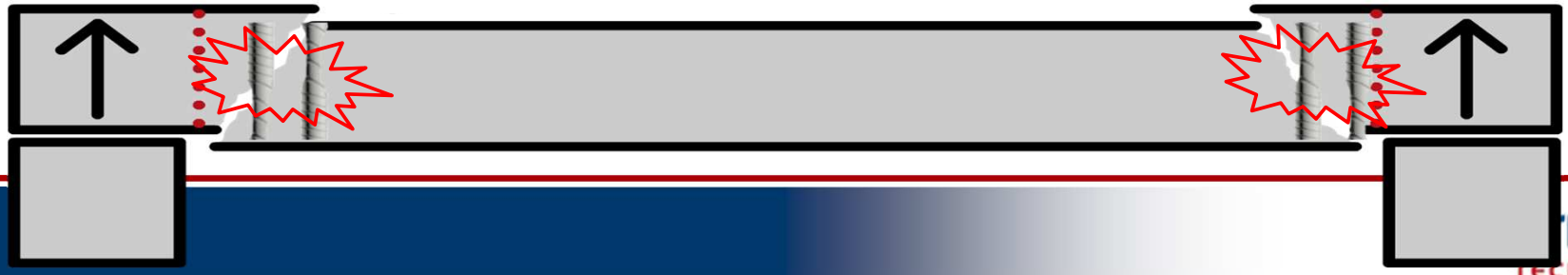


HIGH LEVEL OF CAUTION FOR SHEAR CRACKS!

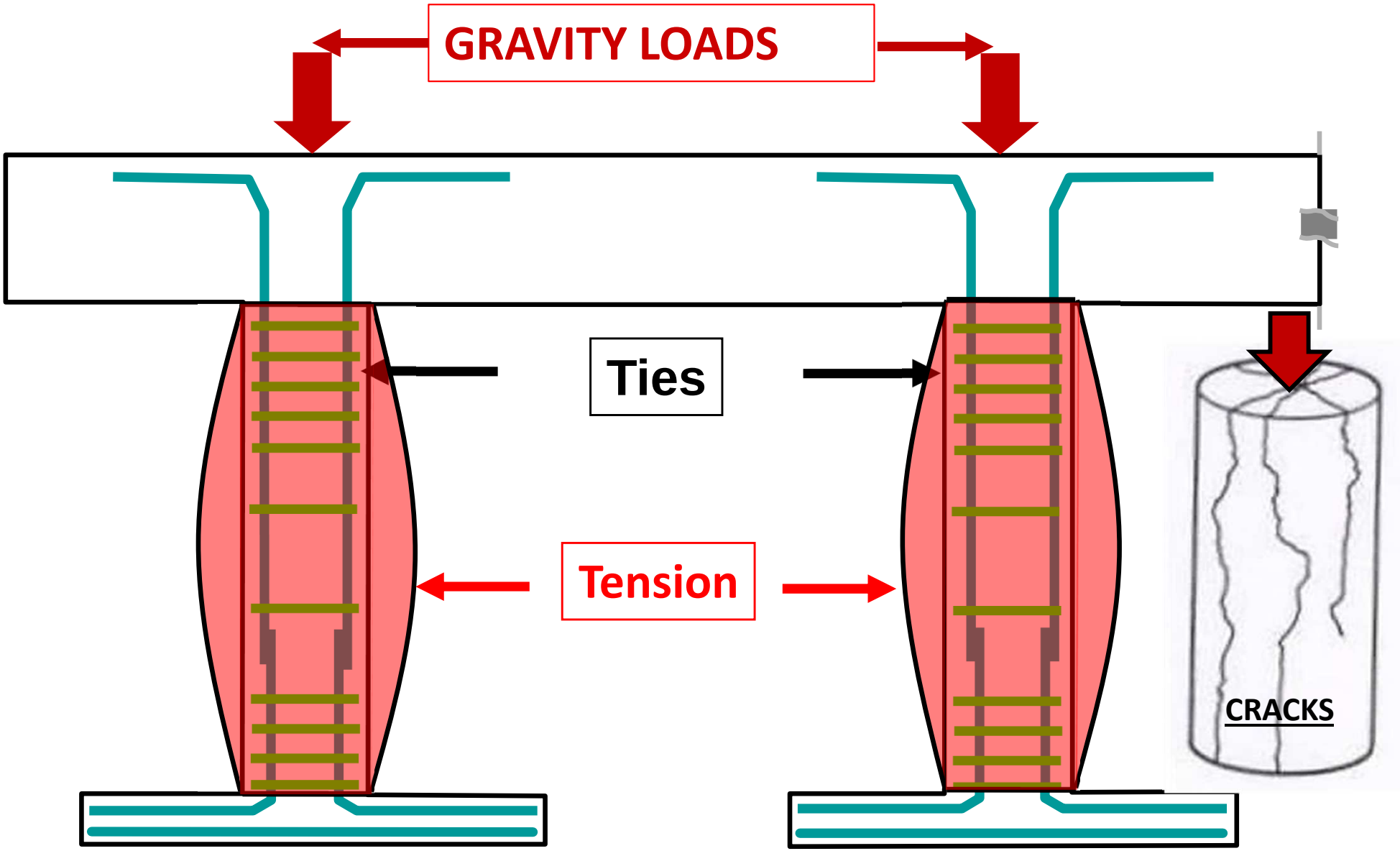
BEAM AND SLAB SHEAR FAILURE IS ABRUBT- NO WARNING

ALERT ENGINEER **SHORE?**

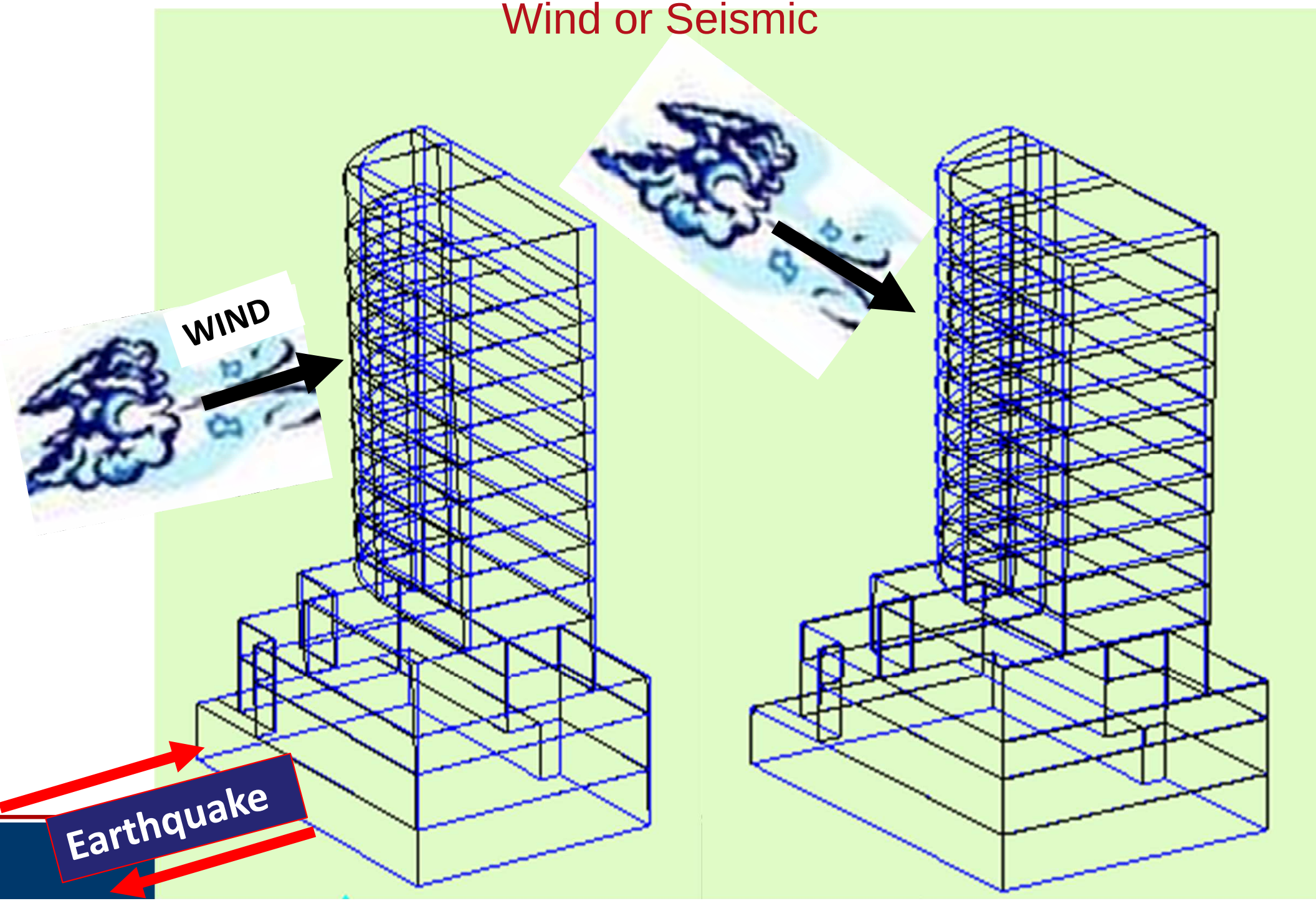




Column steel placement to resist vertical forces

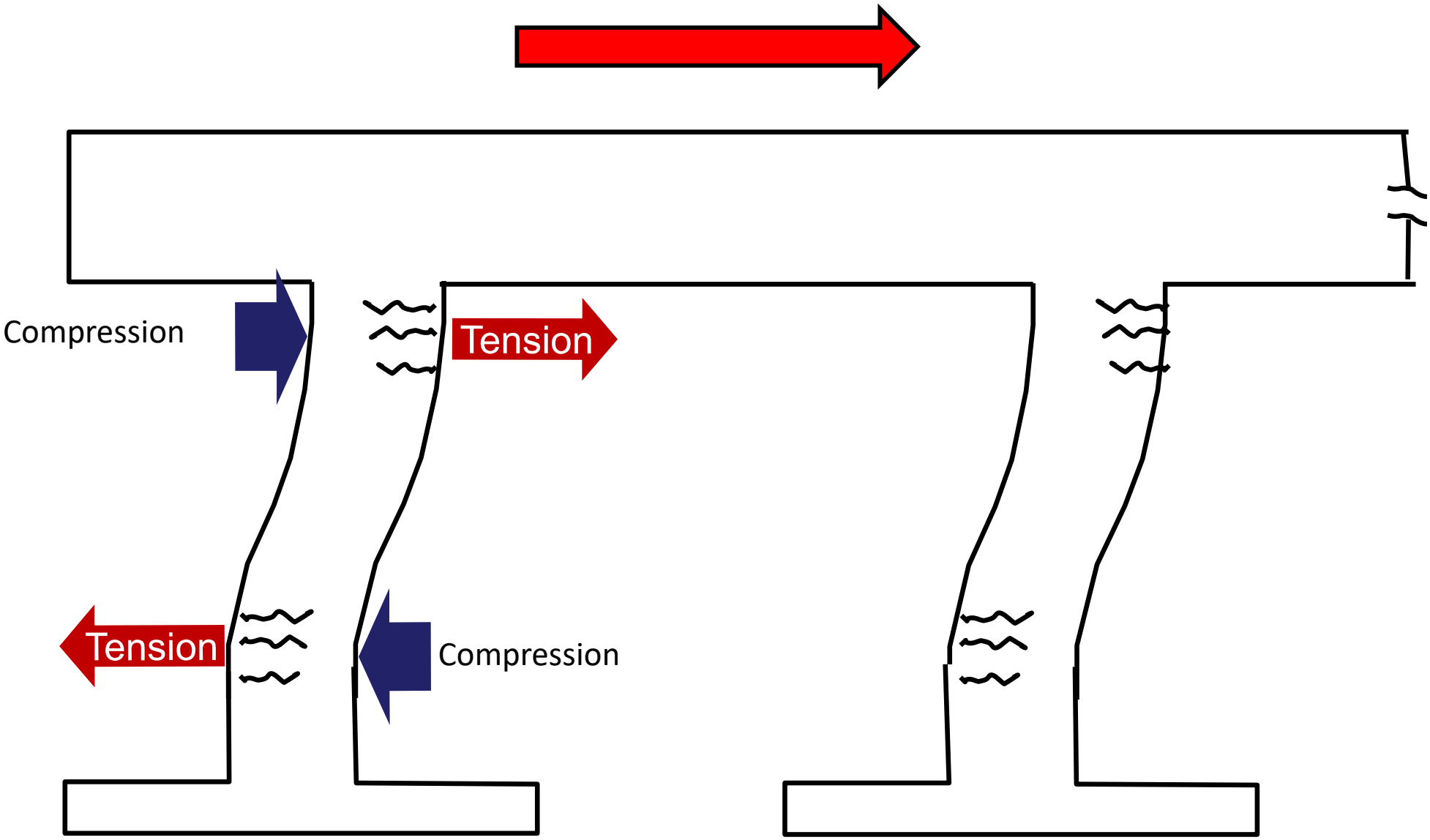


Column steel placement to resist lateral forces



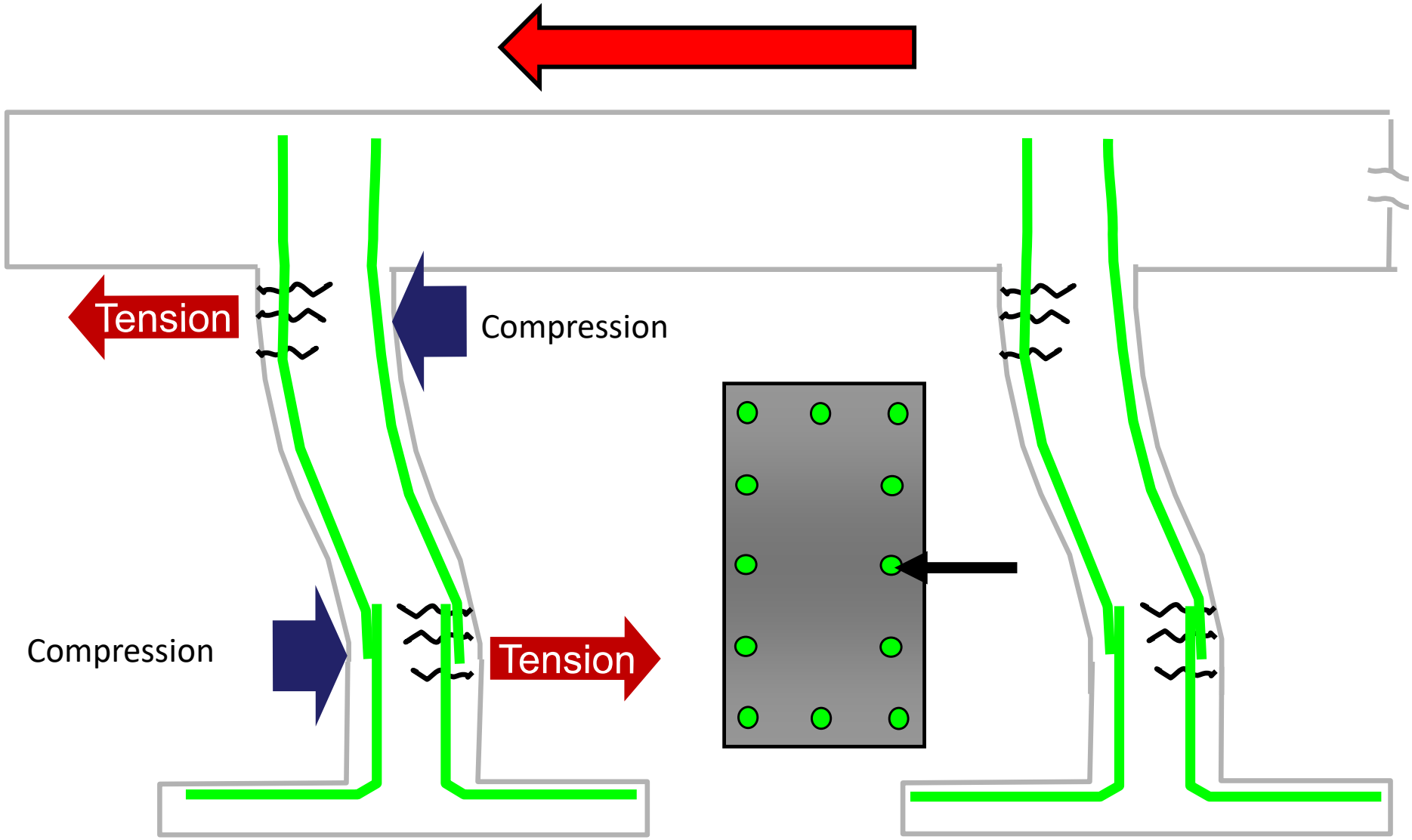
Column steel placement to resist lateral forces

Wind or Earthquake



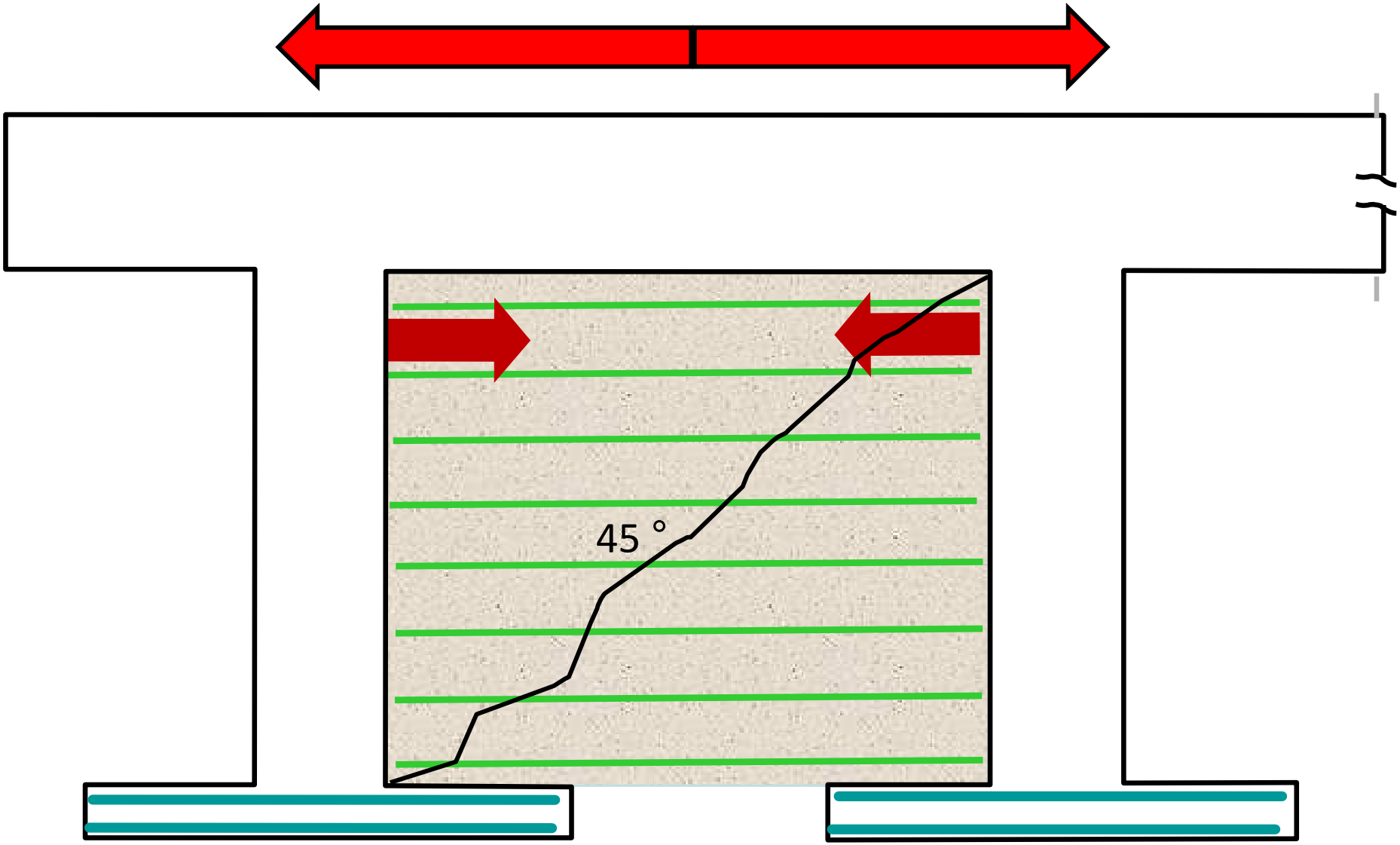
Column steel placement to resist lateral forces

Wind or Earthquake



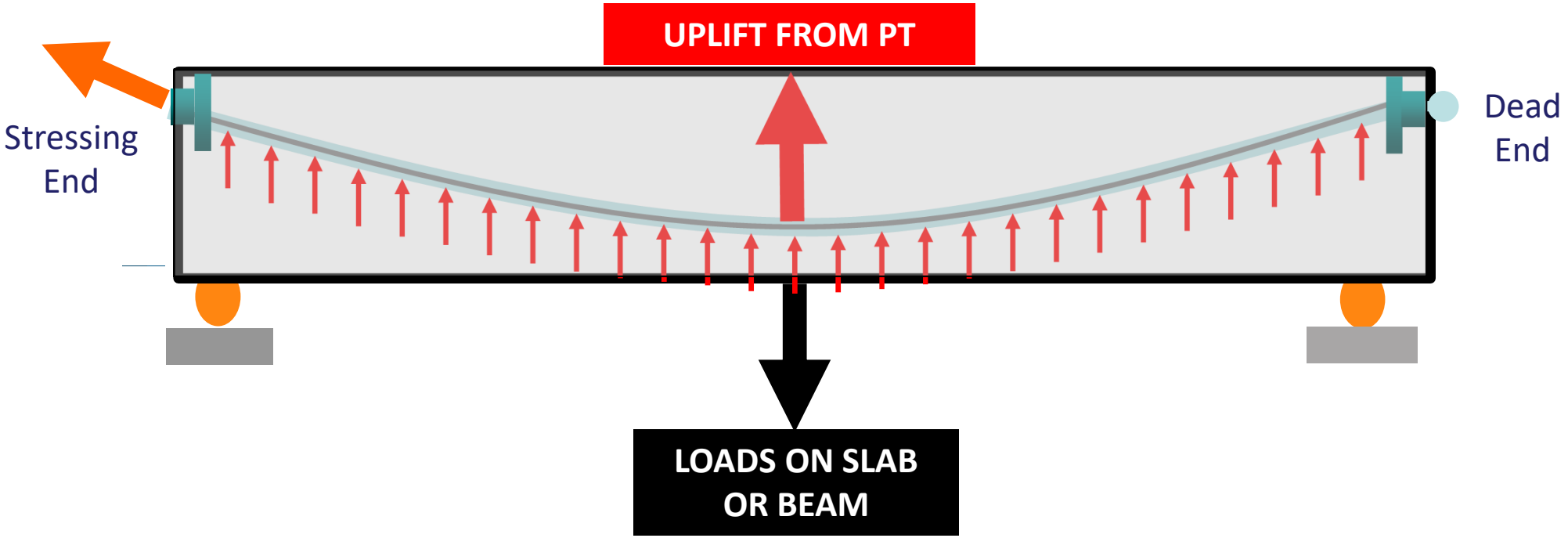
Shear walls to resist lateral forces

Shear Walls



Post Tensioned Concrete- How does it work in a slab or beam?

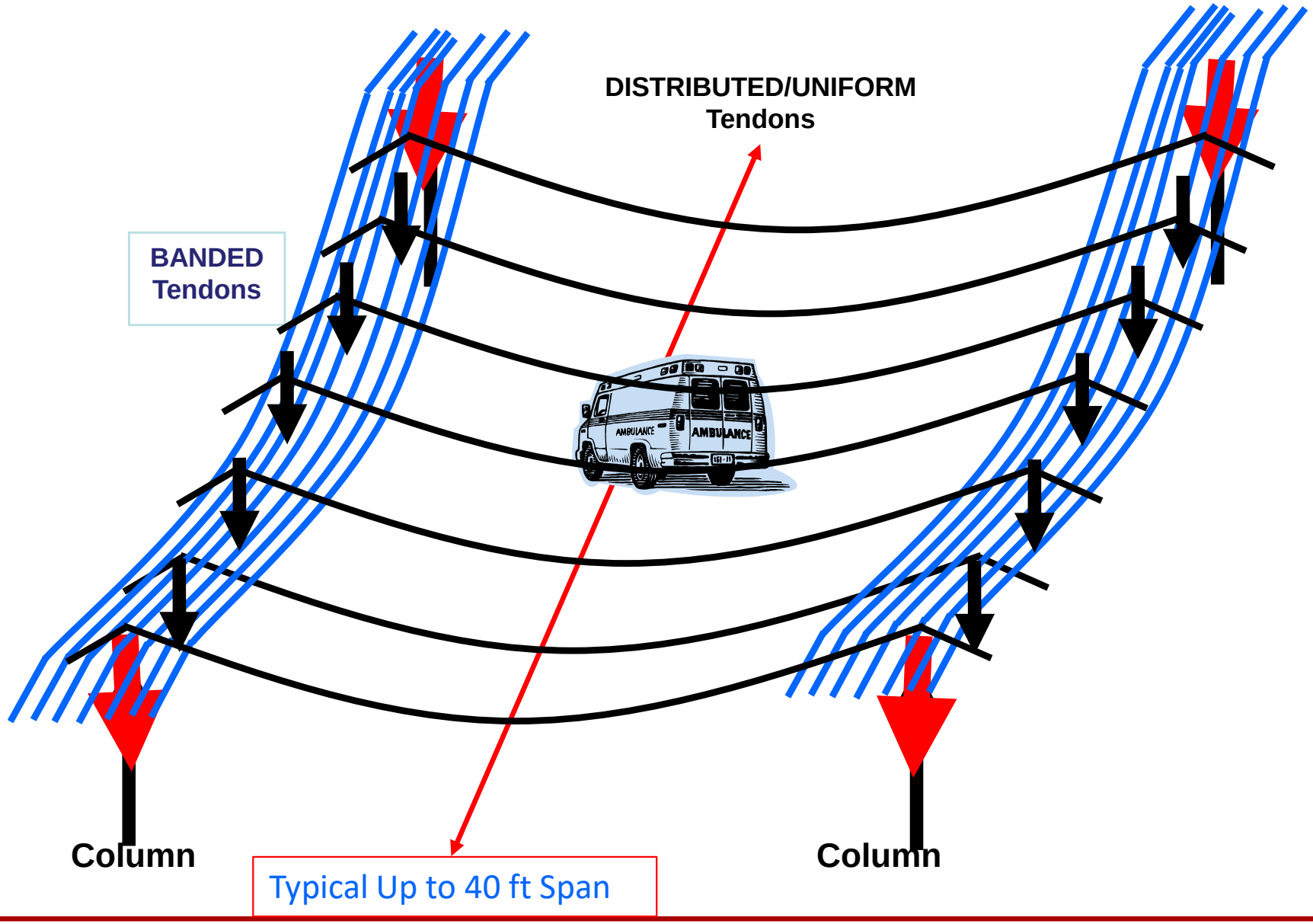
LOAD BALANCING



WHY POST TENSION?

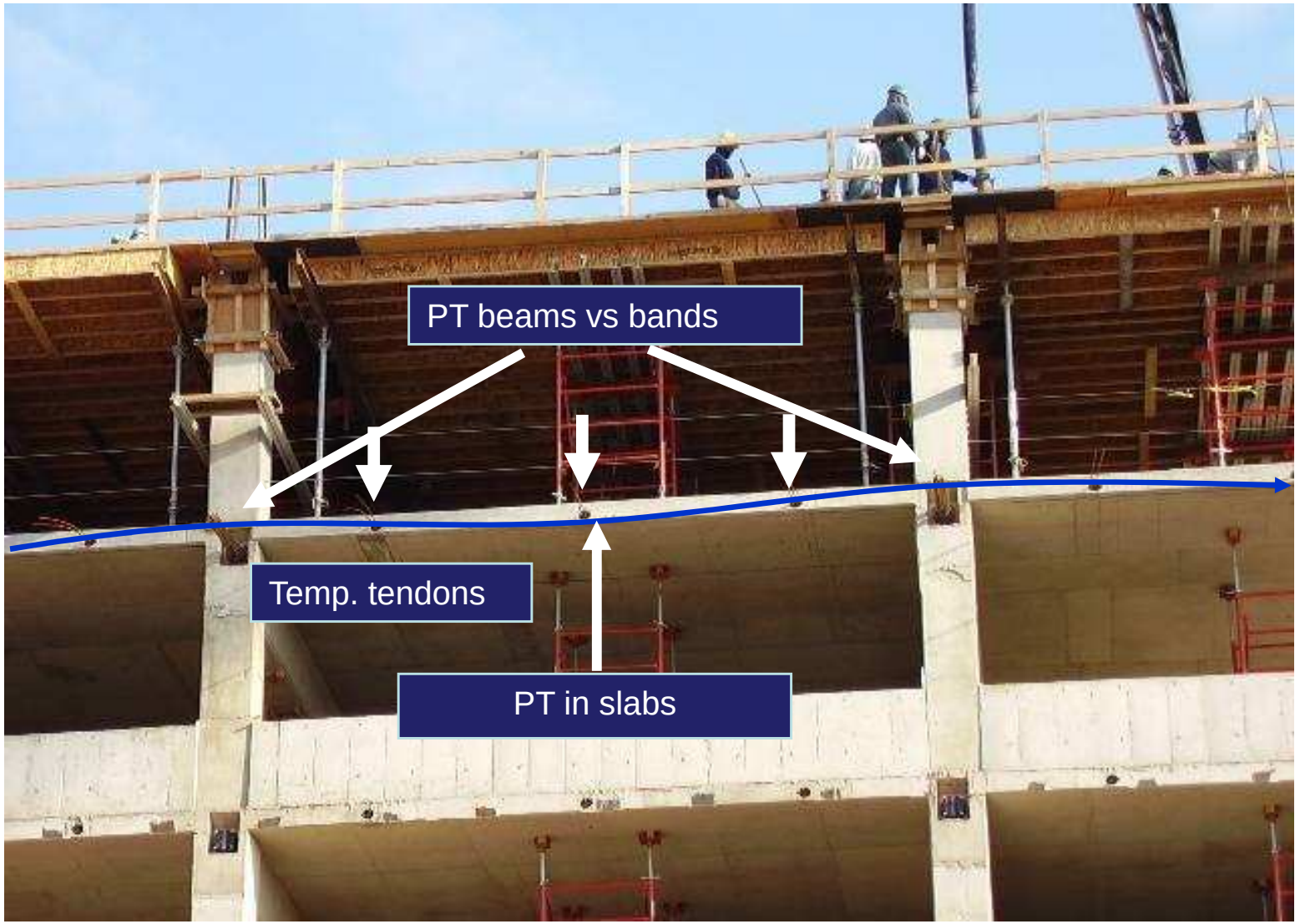
- Less columns & longer spans
- Less cracking (in compression)
- Faster construction (after stressing forms pulled)

2 Common Post Tension Reinforcement Layouts **2-way Slab**



Common Post Tensioned Reinforcement Layout –

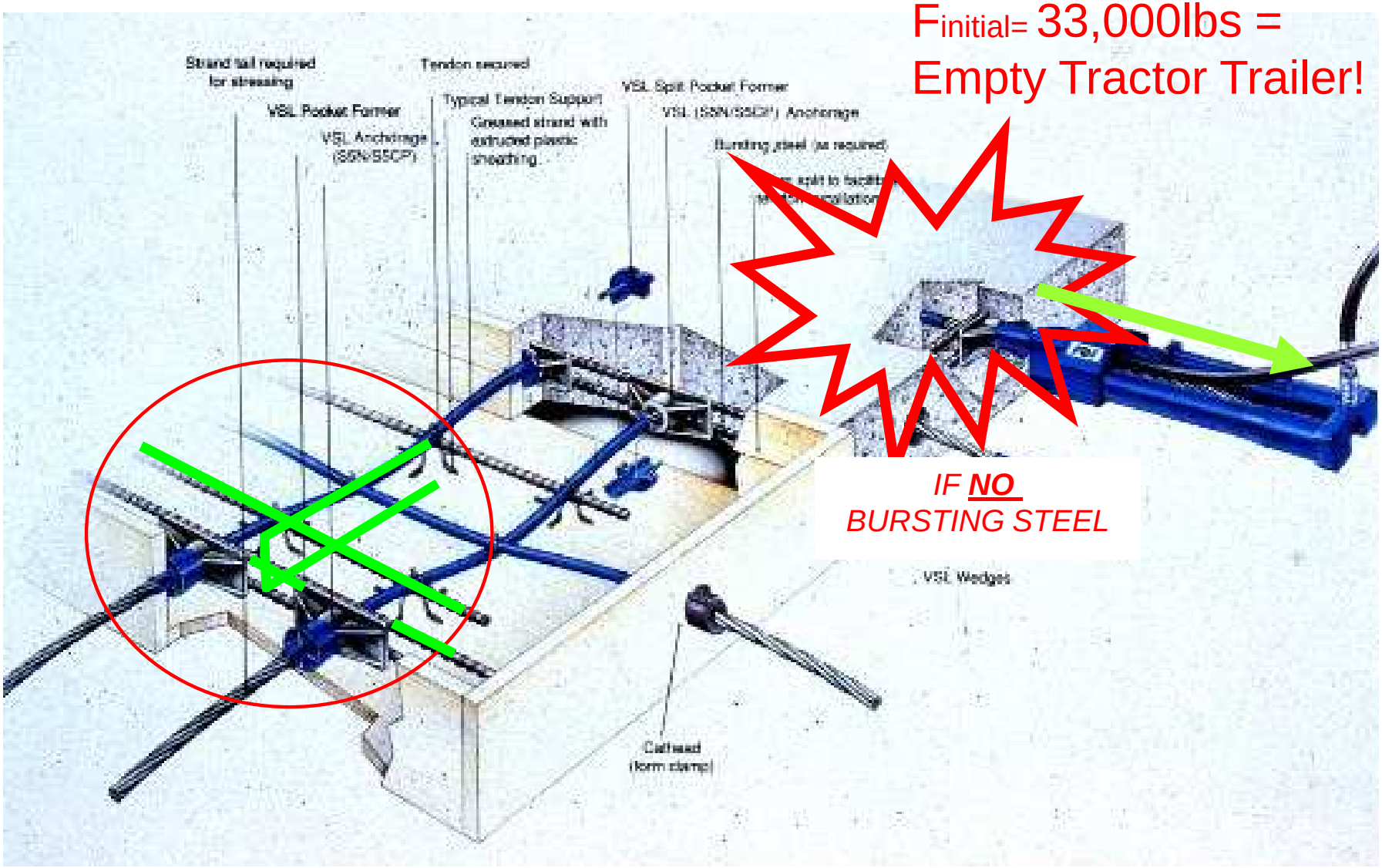
PT beams & 1-way slab



Typical >40 ft Span

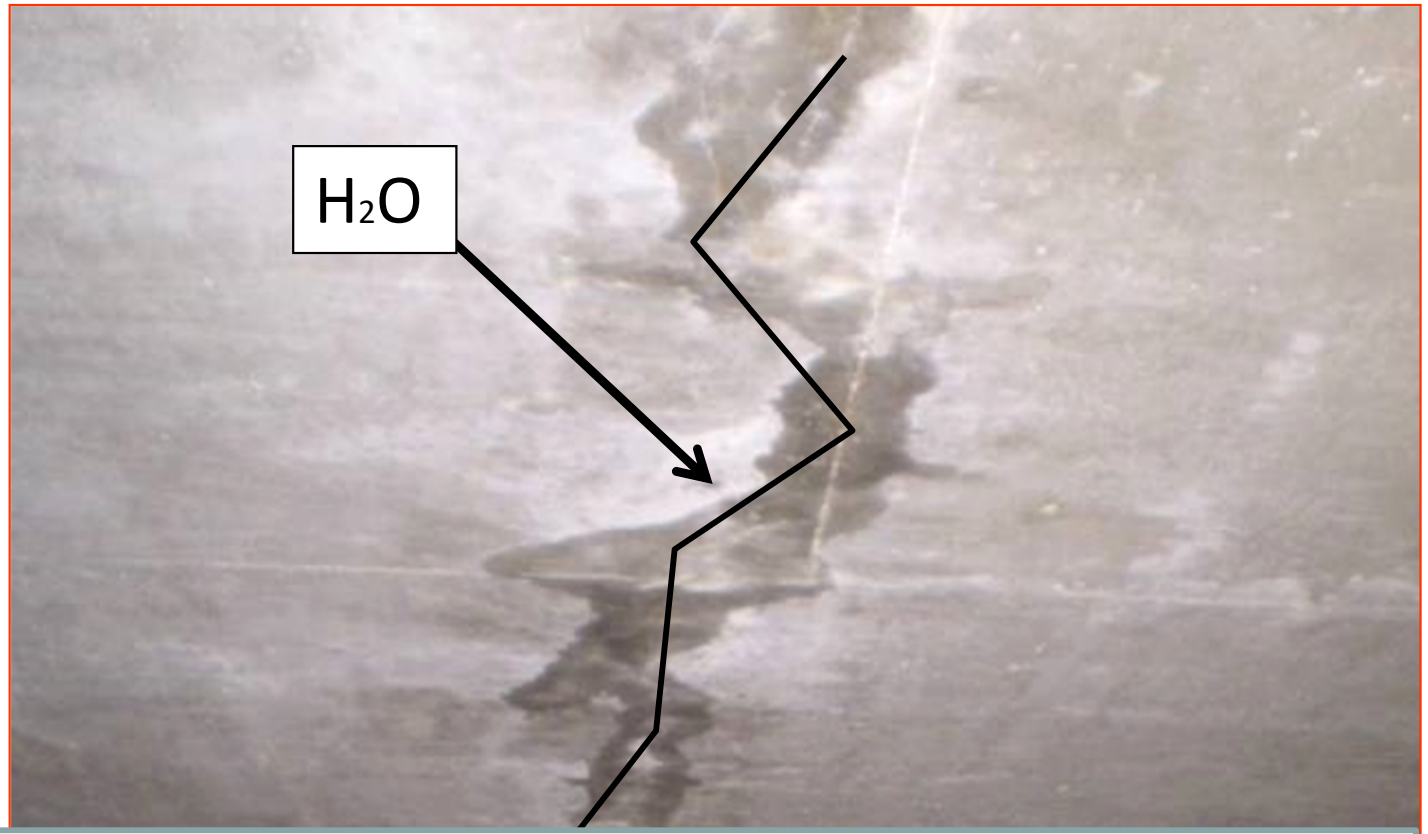
What are the Post Tension anchorage zone reinforcement details

"Bursting Steel" in Slabs



Is this a Structural crack?

(TOP LEVEL OF PARKING GARAGE)

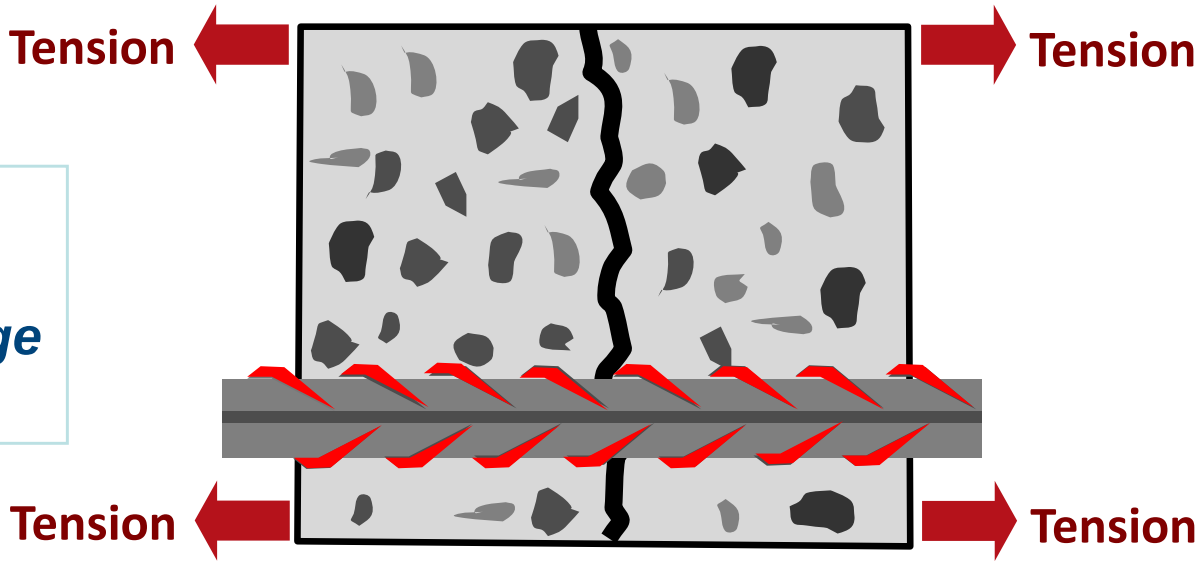


3 Things to think about

1. In Tension Zone?
2. Is the crack straight?
3. Is it a through crack?

Temperature +/-

Drying Shrinkage



What Causes drying shrinkage cracking

EXAMPLE: 0.4 w/c ratio concrete mix design

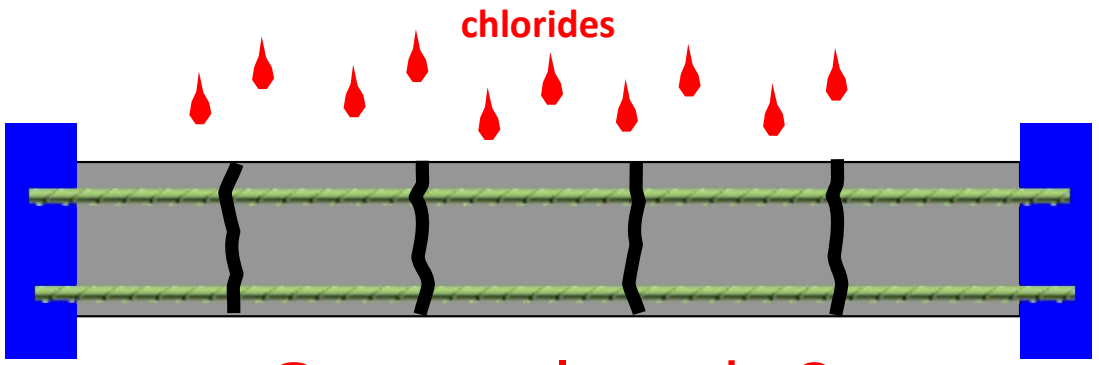
Slab 30’ X 30’ X 8” = 22yds X 32 gal per yard = 700gal

Only ½ so 350 gallons evaporate!

ONLY 50 % OF WATER IS NEEDED TO HYDRATE THE CEMENT

Correct Mix Design
Micro or No Cracking

Excess Water =
Shrinkage Cracking



Structural cracks?

AGENDA

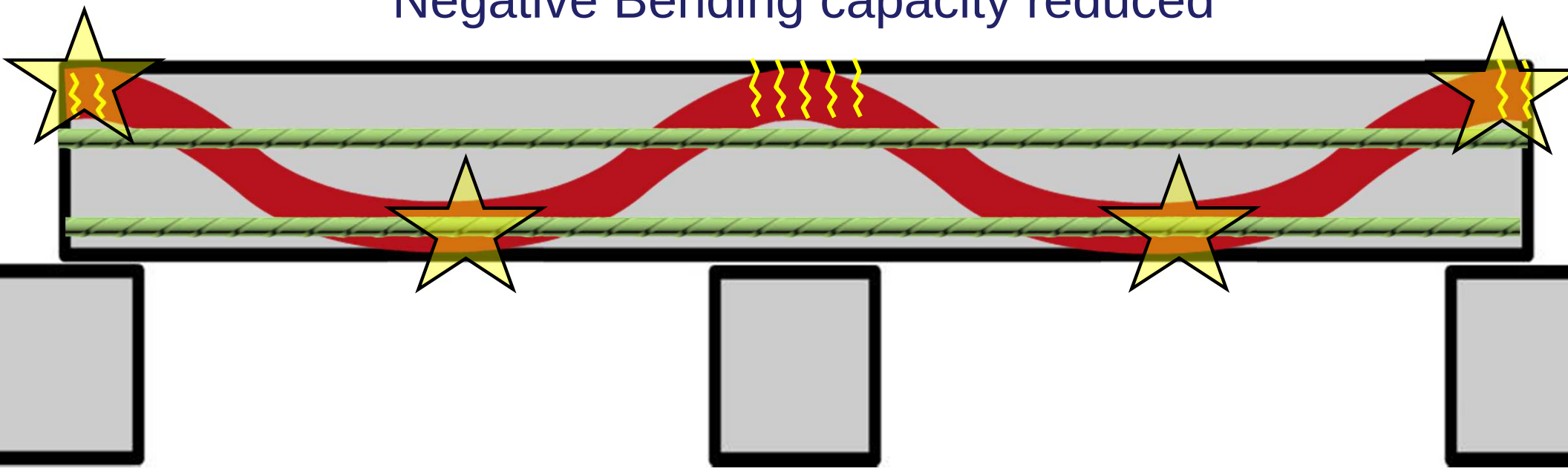
- What are the most common defects?
- How is reinforced/PT concrete designed- *Eng. 101 for Contractors*
- Safe loading of structures during construction- OVERLOAD
- Understanding typical steel placement
- What if that steel is set in the wrong place?
  - *Too low, too high, too close or too short*
- Avoiding concrete placement errors- Honeycombs & Voids
- Structural Safety issues to avoid when:
  - *Cutting, coring, chipping, drilling concrete*
- Avoiding Shoring/Re-shoring & early loading of slab errors
- Repair strategies if Structural Safety or defects occur
- Incorporating Structural Safety in your Pre-planning Process

What if the steel is set in the too LOW?

Safety Rule

Effect #1

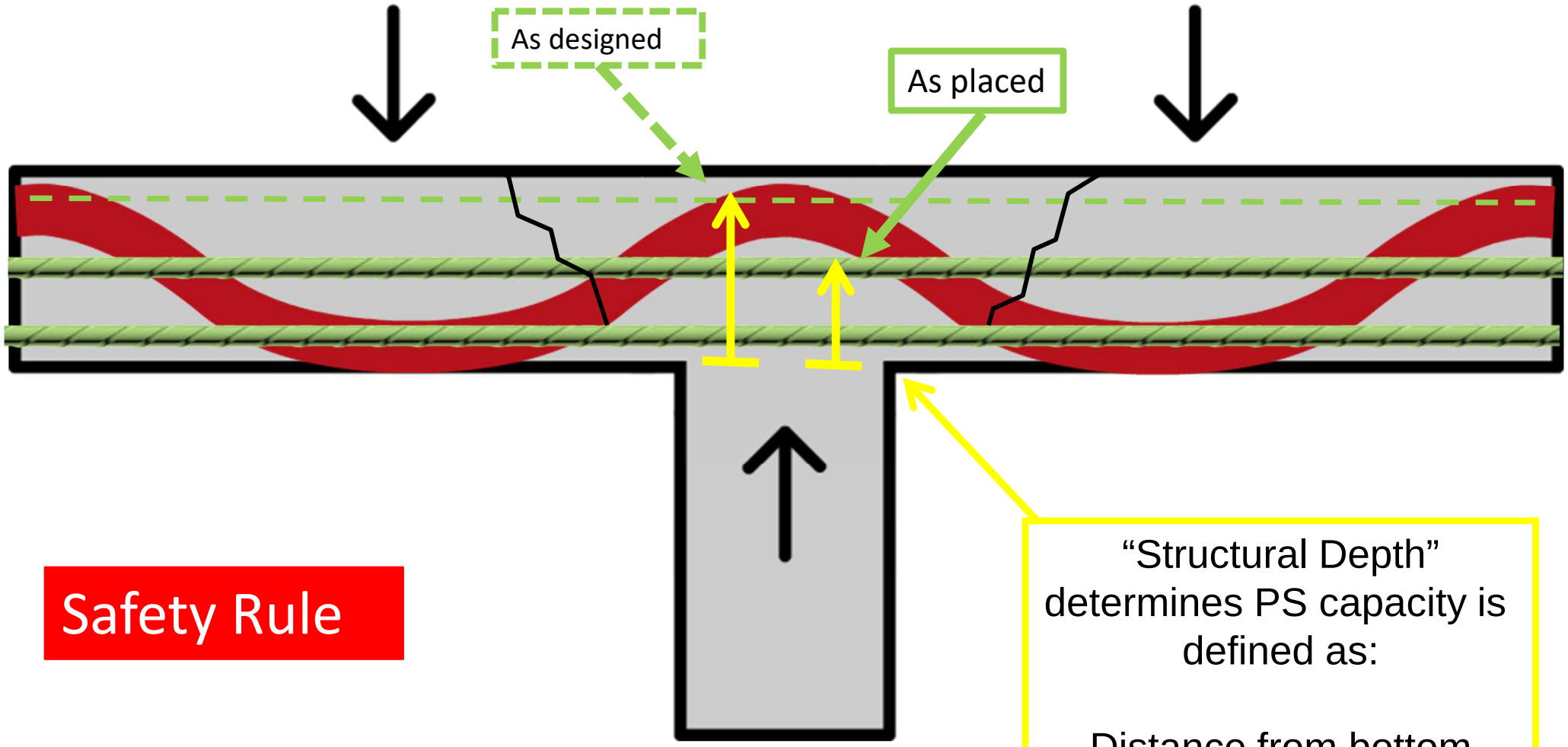
Negative Bending capacity reduced



What if the steel is set in the too LOW?

Effect #2

Slab Punching Shear Reduced



Safety Rule

"Structural Depth" determines PS capacity is defined as:

Distance from bottom
Of slab to highest rebar

What if the steel is set
Too Close to Surface- Less Cover

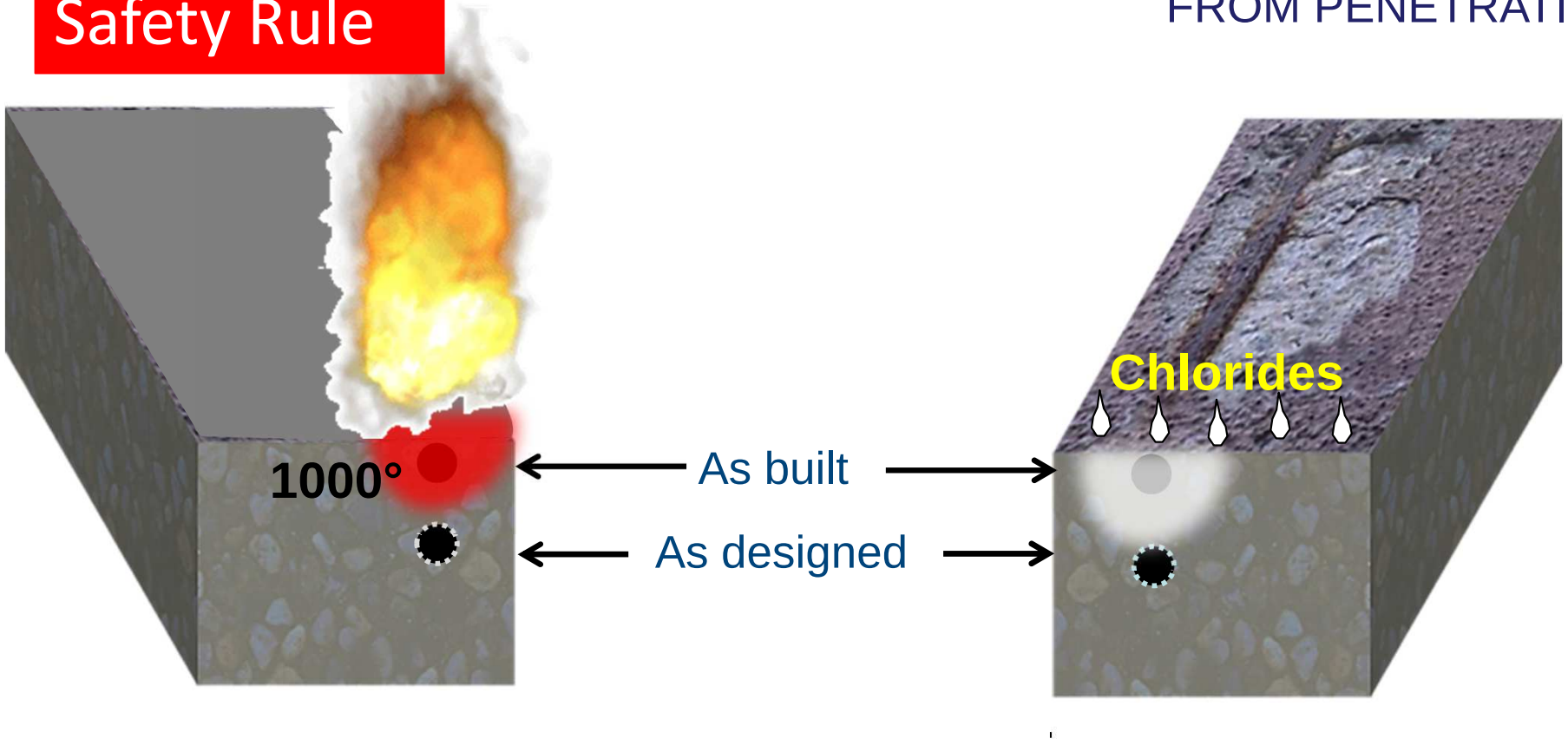
Effect #1

REDUCED FIRE RATING AS COVER INSULATES REBAR FROM HEAT

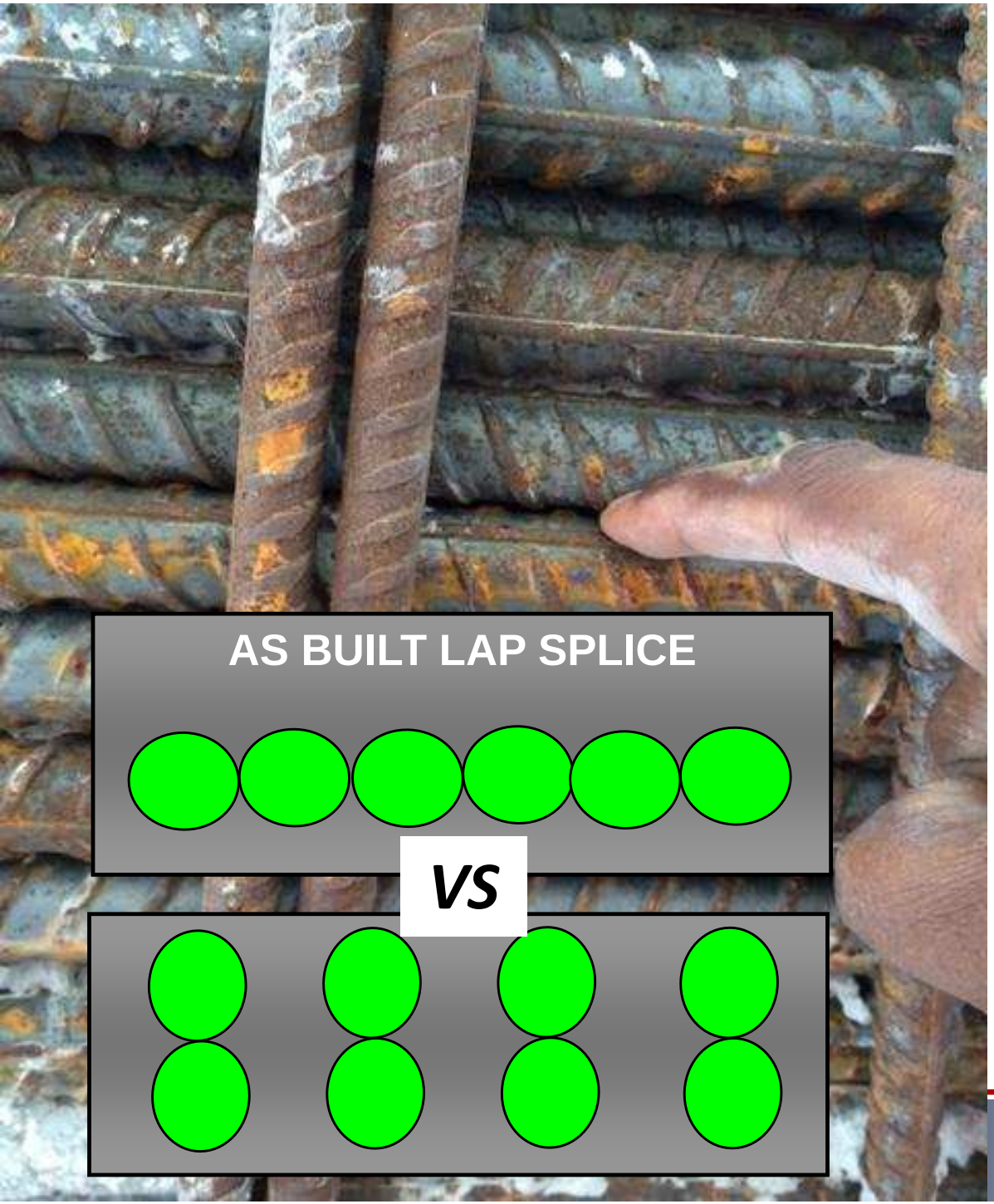
Safety Rule

Effect #2

REDUCED CORROSION RESISTANCE AS COVER IS PROTECTION CHLORIDE FROM PENETRATION



What if the rebar is set too close?...bad lap splices



Min. spacing between bars?

What can't get through?

AGGREGATE!
Min. Rebar Spacing Rule:
1.5 X aggregate size!

¾" Aggregate = 1 1/8" gap

Do you have a pre-pour check off process?

STOP the POUR!

structural TECHNOLOGIES

AGENDA

- What are the most common defects?
- How is reinforced/PT concrete designed- *Eng. 101 for Contractors*
- Safe loading of structures during construction- OVERLOAD
- Understanding the purpose of typical steel placement in:
- What if that steel is set in the wrong place?
  - *Too high, low or close*
- Avoiding concrete placement errors- Voids & **Honeycombs**
- Structural Safety issues to avoid when:
  - *Cutting, coring, chipping, drilling concrete*
- Avoiding Shoring/Re-shoring & early loading of slab errors
- Repair strategies if Structural Safety or defects occur
- Incorporating Structural Safety in your Pre-planning Process

What is a Honeycomb?

(rock-pocket)

Concrete with NO CEMENT!

Safety Rule Drop concrete 3-4ft max.

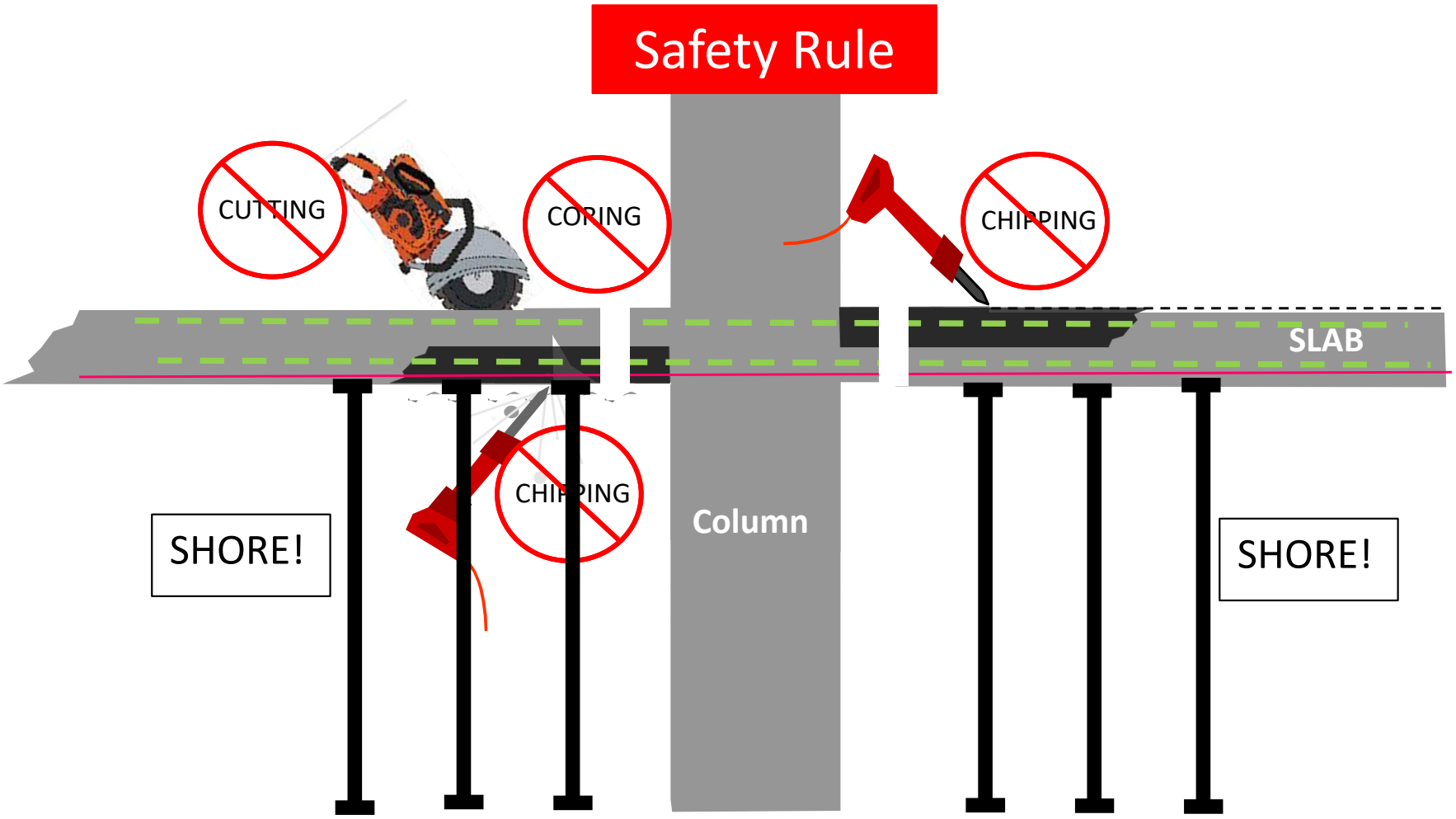
AGENDA

- What are the most common defects?
- How is reinforced/PT concrete designed- *Eng. 101 for Contractors*
- Safe loading of structures during construction- OVERLOAD
- Understanding the purpose of typical steel placement in:
  - *Beams, slabs, columns, shear walls*
- What if that steel is set in the wrong place?
  - *Too high, low or close*
- Avoiding concrete placement errors- Honeycombs & Voids
- Structural Safety issues to avoid when:
  - *Cutting, coring, chipping, drilling concrete*
- Avoiding Shoring/Re-shoring & early loading of slab errors
- Repair strategies if Structural Safety or defects occur
- Incorporating Structural Safety in your Pre-planning Process

*CONSIDERATIONS **BEFORE** CHIPPING **SLAB AREAS AROUND COLUMNS***

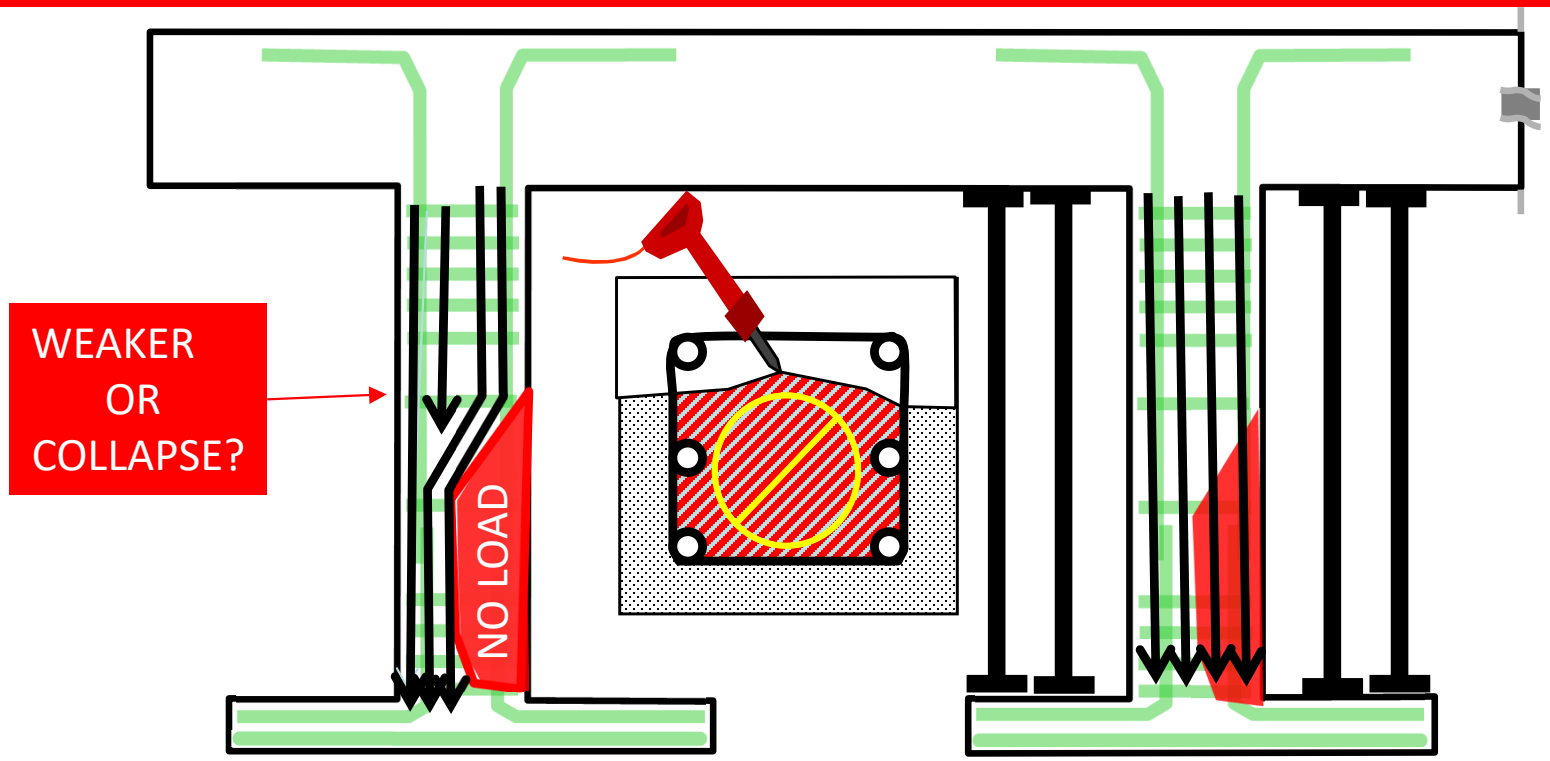
HEAVILY REINFORCED & HAVE HIGH PUNCHING SHEAR & TENSION FORCES! *(2X)*

1. WHERE IS THE STEEL 2. DO I NEED TO SHORE?



CONSIDERATIONS **BEFORE** CHIPPING **COLUMNS**
YOU NEED TO **SHORE!**

Safety Rule- NEVER CHIP A COLUMN'S STRUCTURAL CORE!
(concrete inside the ties)

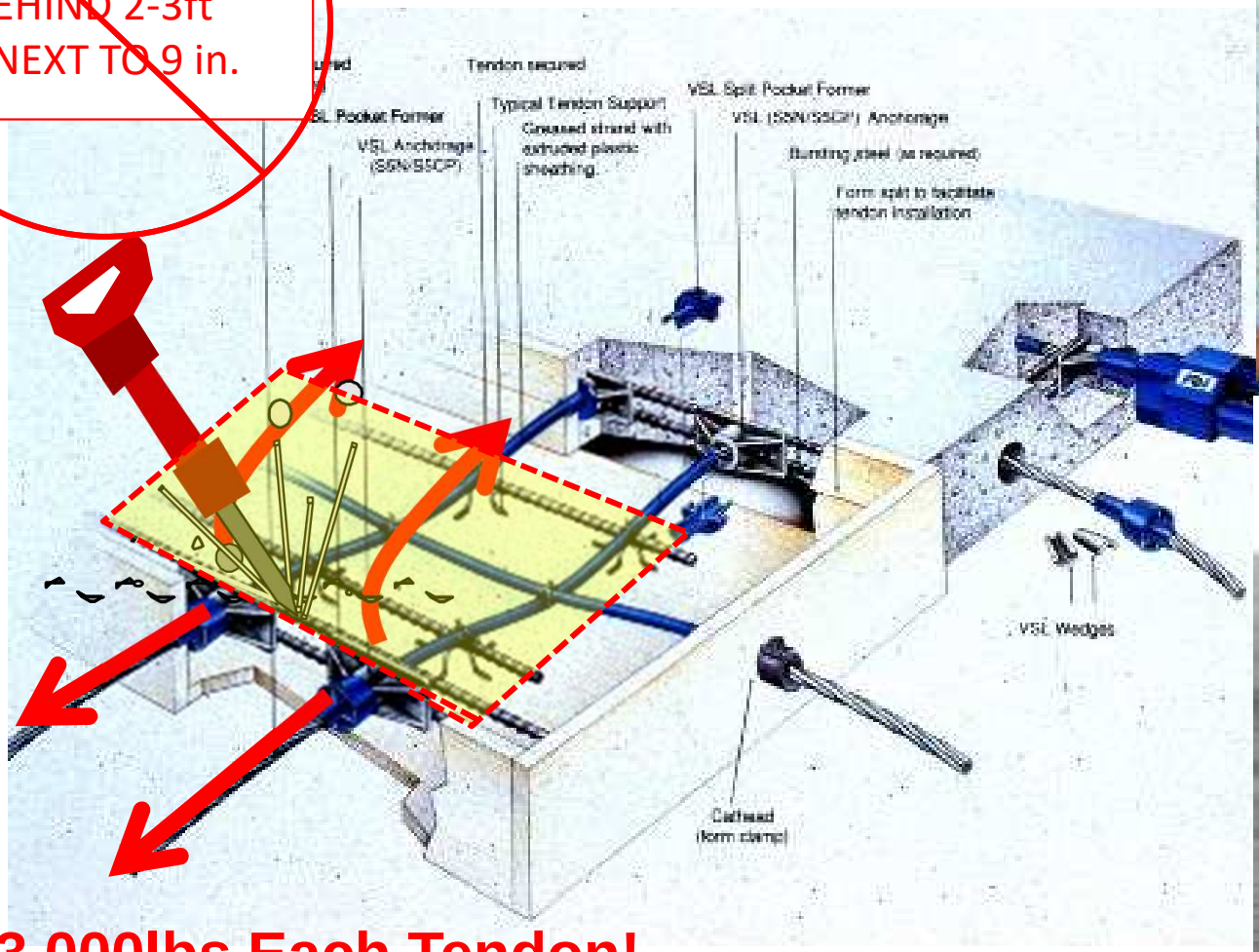


WHO IS RESPONSIBLE? DO YOU HAVE A PRE-PLANNING PROCESS?

Post Tension ***SAFETY RULE***

Hazards during field investigations, repairs, saw cutting & drilling

CHIP or CORE
BEHIND 2-3ft
or NEXT TO 9 in.



SAW CUTTING

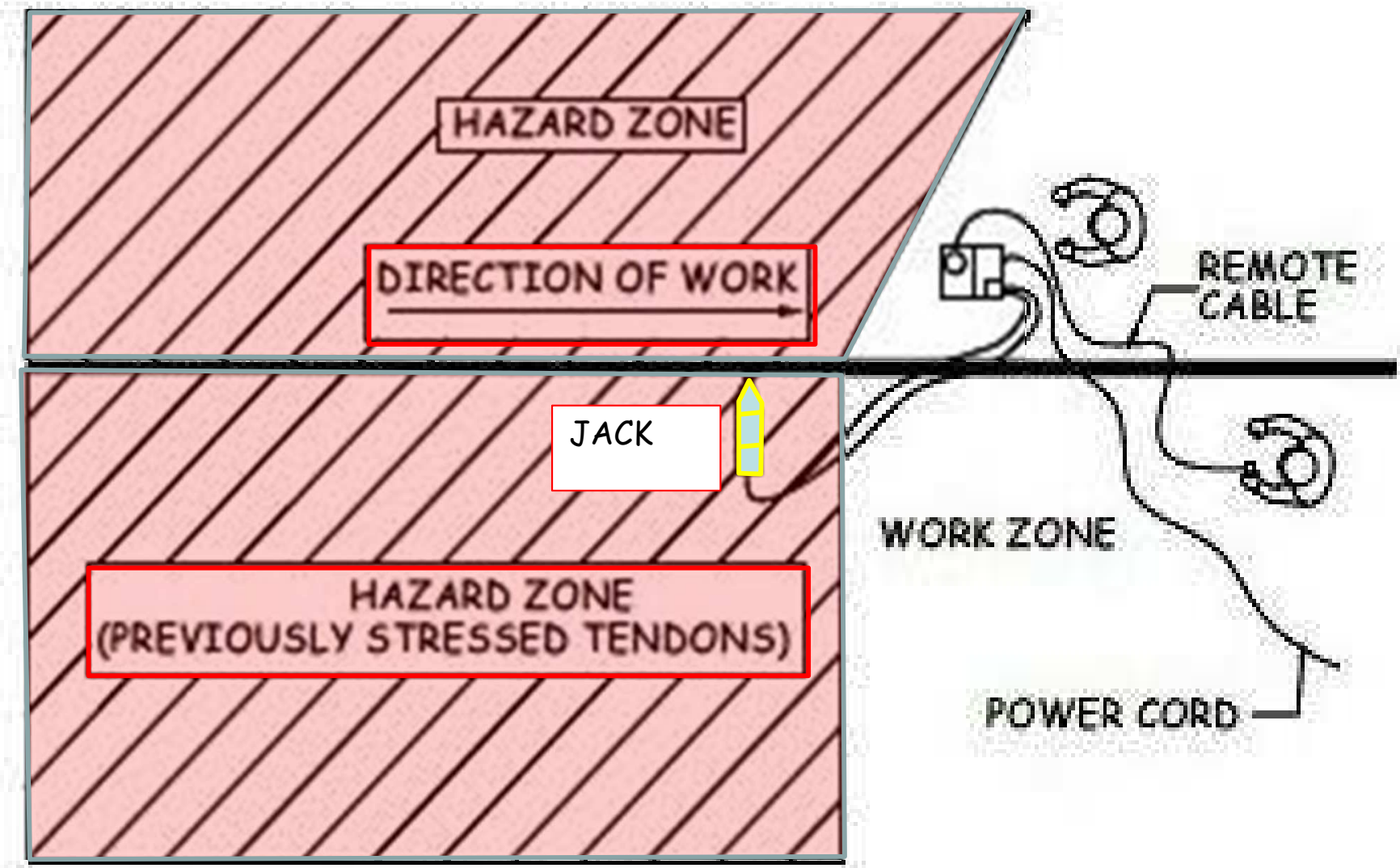
CONCRETE SCREWS

Force= 33,000lbs Each Tendon!

structural TECHNOLOGIES

Post Tension Safety Considerations

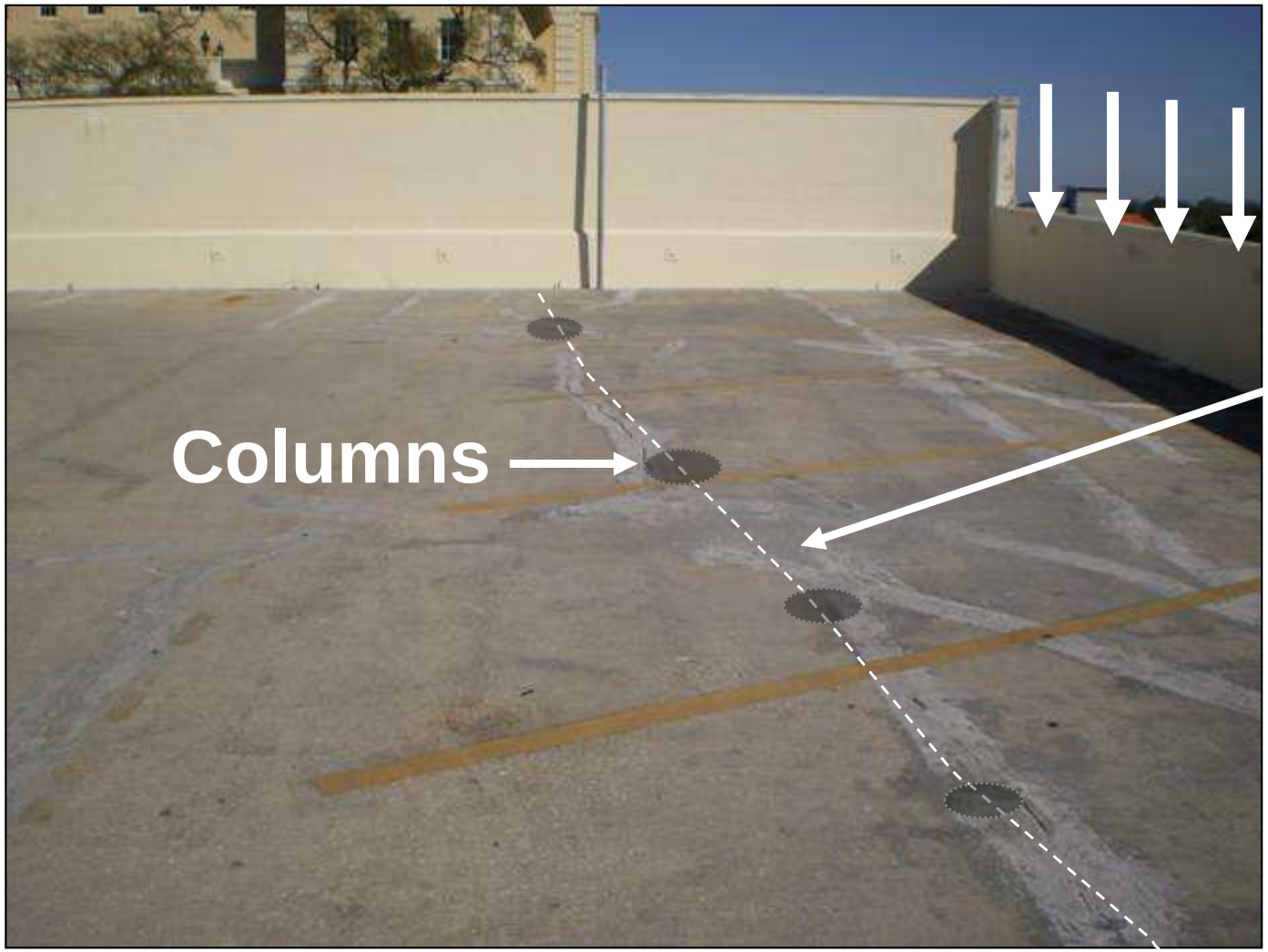
STRESSING SAFETY GUIDELINES (PTI)- *Line of Fire Rule*

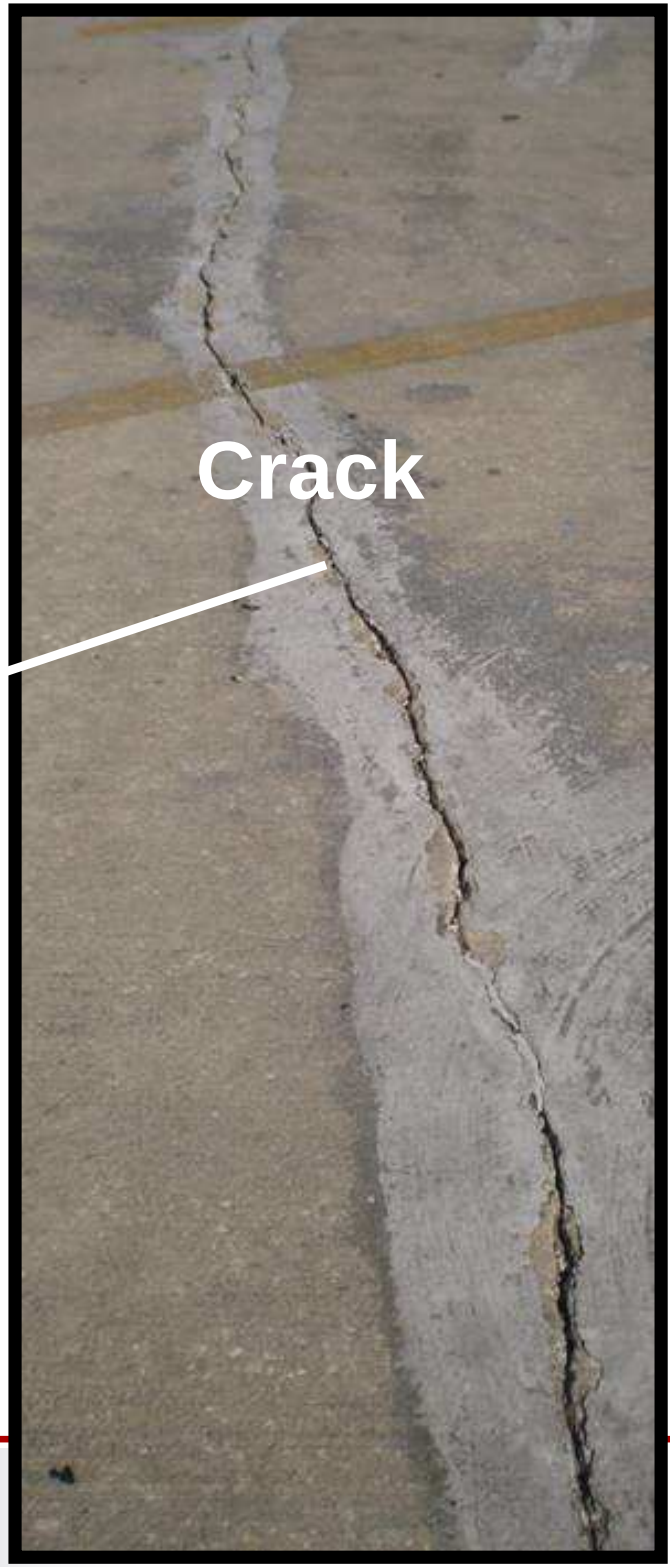


1/S1 STRESSING SAFETY DETAIL
(NTS)

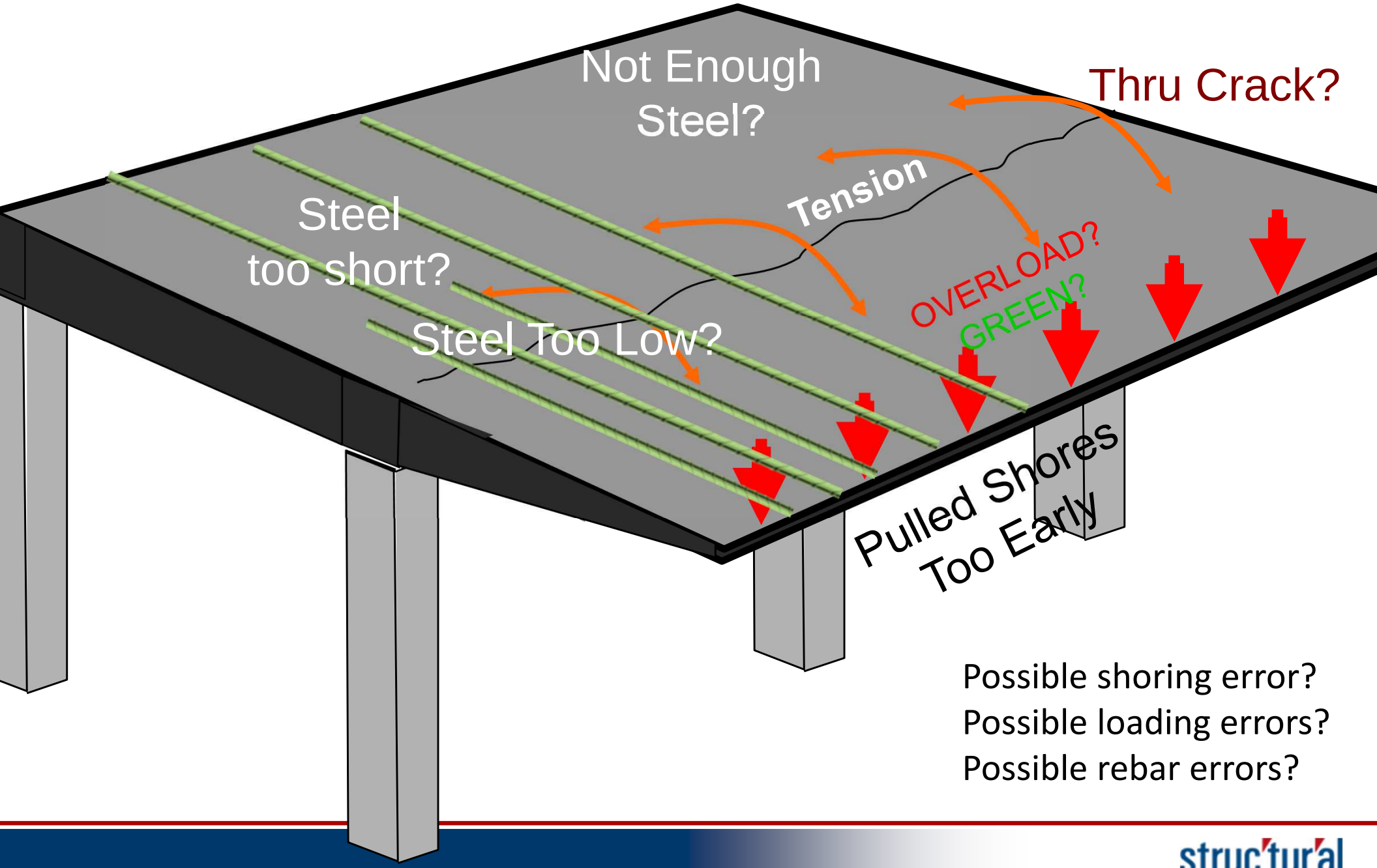
FINAL QUIZ- WHAT HAPPENED?

FINAL QUIZ
WHAT HAPPENED?





What Are The Possible Causes of The Crack?



Possible shoring error?
Possible loading errors?
Possible rebar errors?

AGENDA

- What are the most common defects?
- How is reinforced/PT concrete designed- *Eng. 101 for Contractors*
- Safe loading of structures during construction- OVERLOAD
- Understanding the purpose of typical steel placement in:
- What if that steel is set in the wrong place?
  - *Too high, low or close*
- Avoiding concrete placement errors- Honeycombs & Voids
- Structural Safety issues to avoid when:
  - *Cutting, coring, chipping, drilling concrete*
- Avoiding Shoring/Re-shoring & early loading of slab errors
- Strengthening options if Structural Safety issues or defects occur
- Incorporating Structural Safety in your Pre-planning Process

Strengthening Options- Externally bonded FRP sheets

Slab upgrade for structural defect

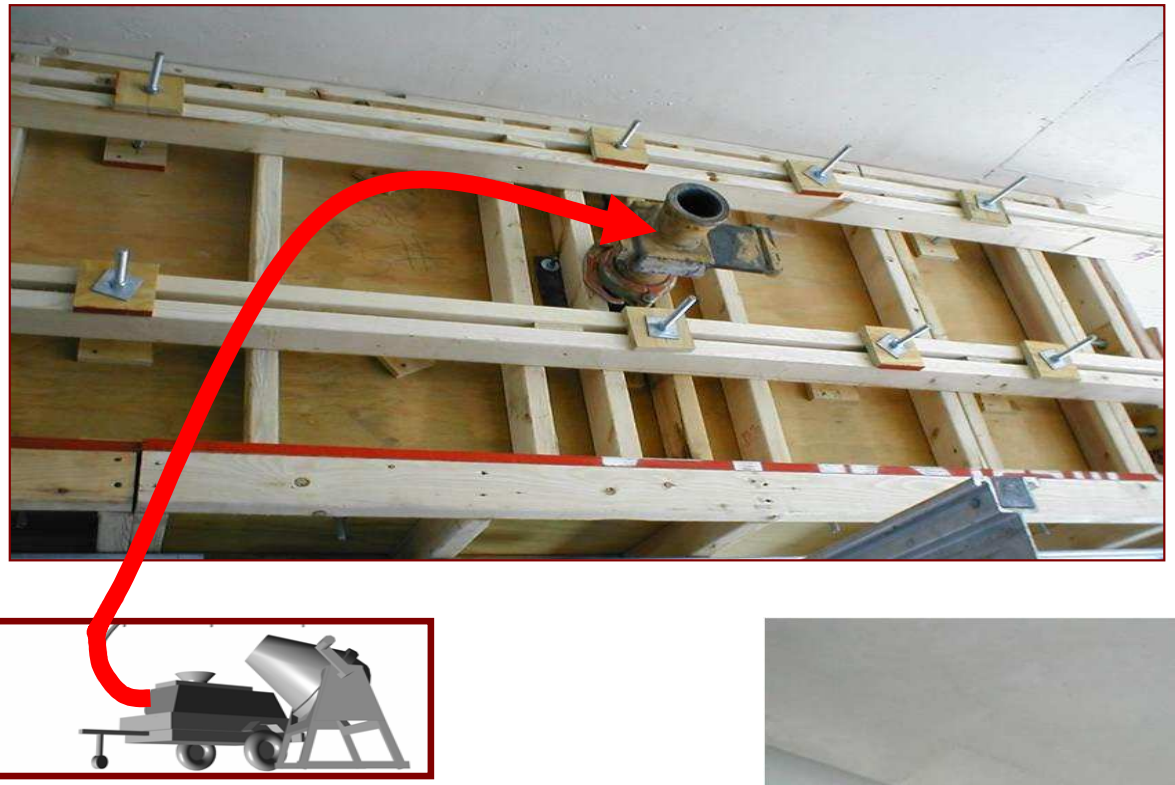
Design, Materials and Installation

Strengthening Options

FRP for low strength concrete breaks

Enlargement using
Form & Pump pressurized placement

Section Enlargement



Pressurized Placement

Finished Product

AGENDA

- What are the most common defects?
- How is reinforced/PT concrete designed- *Eng. 101 for Contractors*
- Safe loading of structures during construction- OVERLOAD
- Understanding the purpose of typical steel placement
- What if that steel is set in the wrong place?
  - *Too high, low or close*
- Avoiding concrete placement errors- Honeycombs & Voids
- Structural Safety issues to avoid when:
  - *Cutting, coring, chipping, drilling concrete*
- Avoiding Shoring/Re-shoring & early loading of slab errors
- Repair strategies if Structural Safety or defects occur
- How to Incorporate Structural Safety in your Pre-planning Process?

  Much Like Your Safety Program it requires, Training, Knowledge, Procedures, Preplanning & *Commitment*

“I will not walk by an UNSAFE ACT
“I will not be unsafe for Production or Profit”
If I SEE something, I will SAY something &
I have the ability to stand down a job”

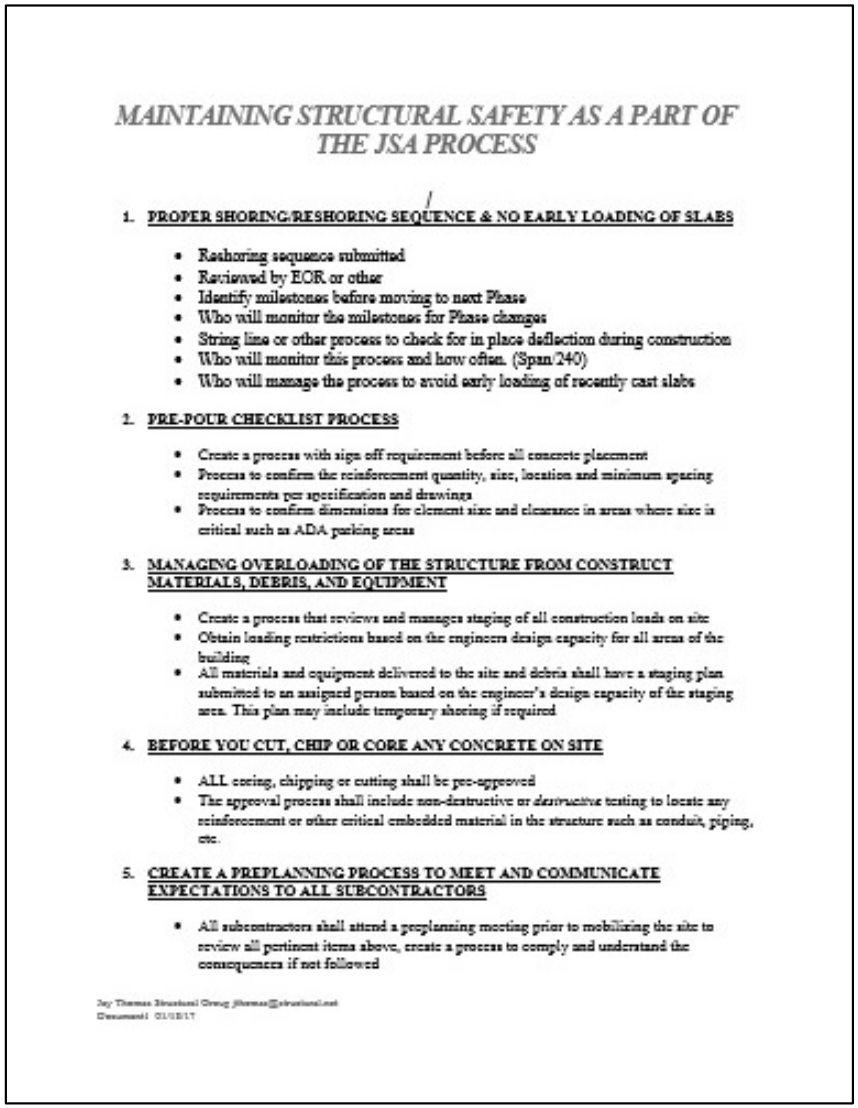
STP!

1. Proper shoring/re-shoring
   and no early loading of green slabs

2. Pre pour review checklist

3. Managing loads for construction
   materials or debris

4. Before you cut, core, chip
   my structure...



MAINTAINING STRUCTURAL SAFETY AS A PART OF THE JSA PROCESS

1. **PROPER SHORING/RESHORING SEQUENCE & NO EARLY LOADING OF SLABS**
   - Reshoring sequence submitted
   - Reviewed by EOR or other
   - Identify milestones before moving to next Phase
   - Who will monitor the milestones for Phase changes
   - String line or other process to check for in place deflection during construction
   - Who will monitor this process and how often. (Span/240)
   - Who will manage the process to avoid early loading of recently cast slabs
2. **PRE-POUR CHECKLIST PROCESS**
   - Create a process with sign off requirement before all concrete placement
   - Process to confirm the reinforcement quantity, size, location and minimum spacing requirements per specification and drawings
   - Process to confirm dimensions for element size and clearance in areas where size is critical such as ADA parking areas
3. **MANAGING OVERLOADING OF THE STRUCTURE FROM CONSTRUCT MATERIALS, DEBRIS, AND EQUIPMENT**
   - Create a process that reviews and manages staging of all construction loads on site
   - Obtain loading restrictions based on the engineers design capacity for all areas of the building
   - All materials and equipment delivered to the site and debris shall have a staging plan submitted to an assigned person based on the engineer's design capacity of the staging area. This plan may include temporary shoring if required
4. **BEFORE YOU CUT, CHIP OR CORE ANY CONCRETE ON SITE**
   - ALL coring, chipping or cutting shall be pre-approved
   - The approval process shall include non-destructive or *destructive* testing to locate any reinforcement or other critical embedded material in the structure such as conduit, piping, etc.
5. **CREATE A PREPLANNING PROCESS TO MEET AND COMMUNICATE EXPECTATIONS TO ALL SUBCONTRACTORS**
   - All subcontractors shall attend a preplanning meeting prior to mobilizing the site to review all pertinent items above, create a process to comply and understand the consequences if not followed

Jay Thomas Structural Group jthomas@structural.net

1. PROPER SHORING/RESHORING & NO EARLY LOADING OF GREEN SLABS

- Reshoring sequence submitted
- Reviewed by EOR or other
- Identify milestones before moving to next Phase
- Who will monitor the milestones for Phase changes

I asked DO YOU HAVE A PROCESS? WHO IS RESPOSIBLE?

YES, NO, YES BUT NOT FUNTIONAL

3. MANAGING LOADING OF CONSTRUCT MATERIALS, DEBRIS, AND EQUIPMENT

- ***Assign a person*** to manage all loading issue
- ***Obtain loading restrictions*** based on the engineer's design capacity for all areas
- Create a process that reviews staging of all construction loads on site
- All materials, equipment and debris on site shall ***submit a staging plan to the assigned person*** based on the engineer's design capacity. This plan may include temporary shoring
- ***Create a procedure*** to comply with consequences if not followed

Preconstruction safety review w/subs?

- pproved
- ctive or *destructive* testing to locate any reinforcement or other
  n as conduit, piping,

5. CREATE A PREPLANNING PROCESS TO COMMUNICATE EXPECTATIONS TO ALL SUBS

- All subcontractors shall attend a preplanning meeting prior to mobilizing the site to review all pertinent items above, create a process to comply and understand the consequences if not followed

Thank You! Concluding Remarks

PULLMAN

- *Questions? Take-Aways?*
- *What "Structural Safety" topics I should add, delete or mod*
- *What groups in your company may benefit from this information regarding your preplanning process ?*