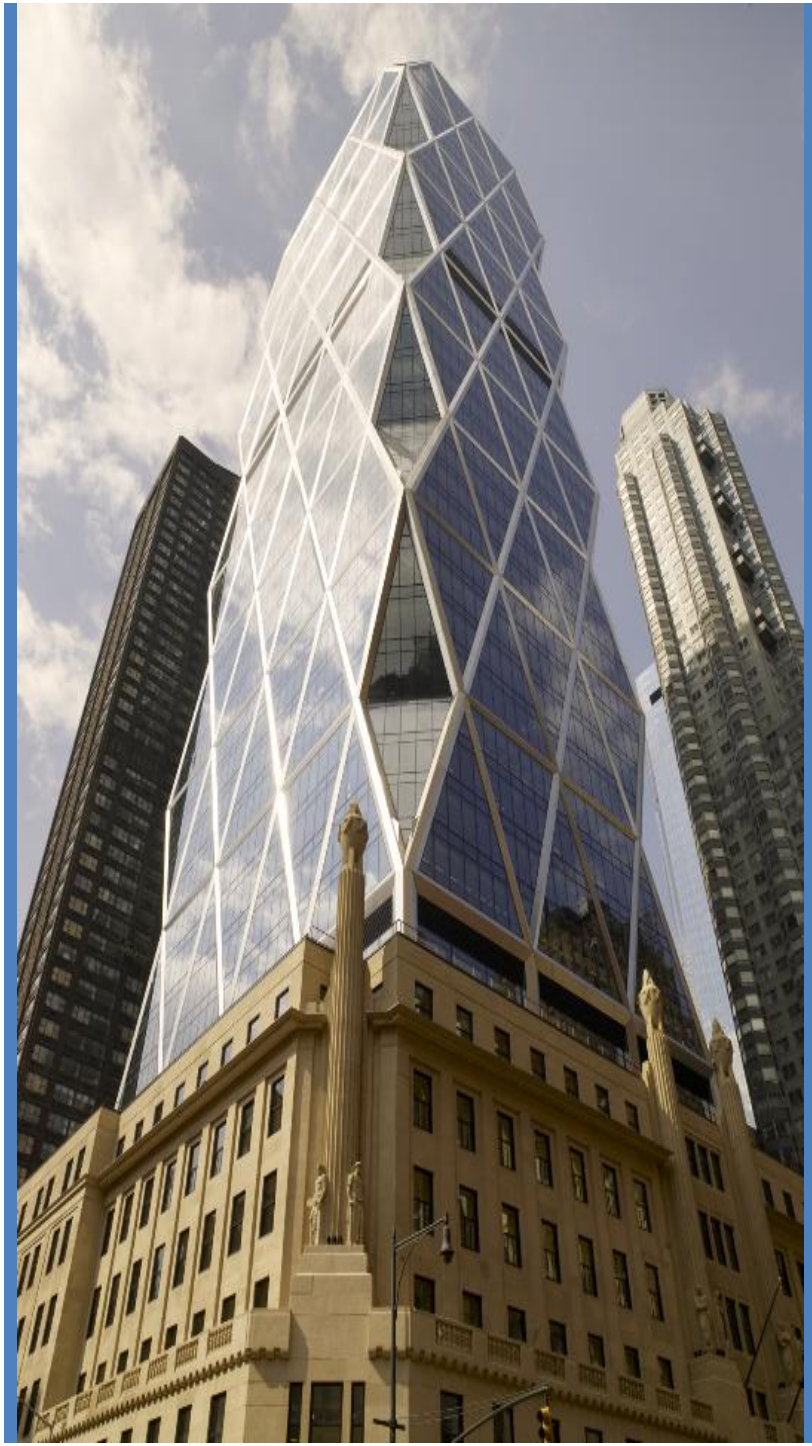
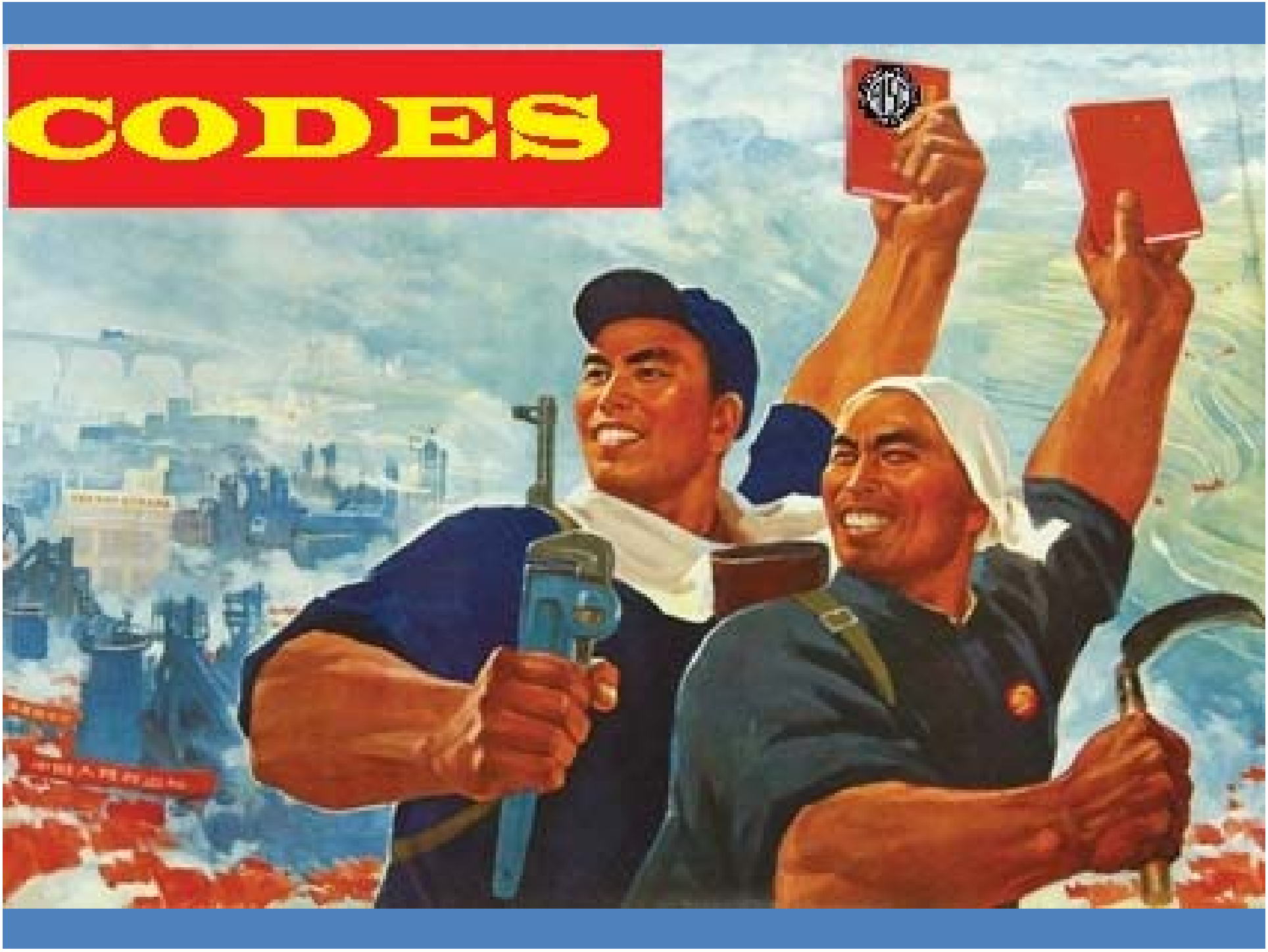
REHABILITATION and RETROFIT of EXISTING STEEL STRUCTURES

Larry S. Muir

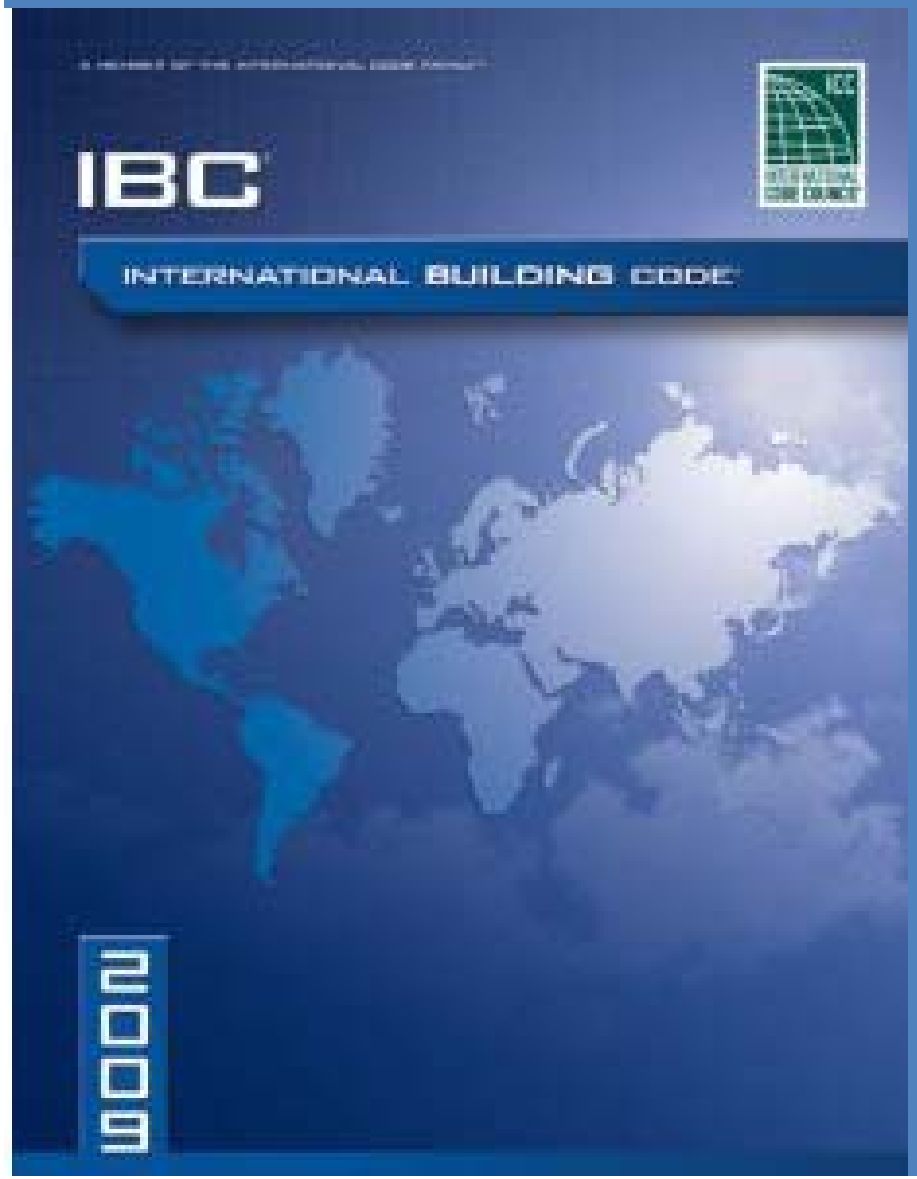


REHABILITATION and RETROFIT of EXISTING STEEL STRUCTURES

RESOURCES


CODES

CODES - IBC



Chapter 34 provides information related to Existing Buildings and Structures.

CODES - AISC

APPENDIX 5

EVALUATION OF EXISTING STRUCTURES

This appendix applies to the evaluation of the strength and *stiffness* under static vertical (gravity) *loads* of existing structures by *structural analysis*, by load tests or by a combination of structural analysis and load tests when specified by the *engineer of record* or in the contract documents. For such evaluation, the steel grades are not limited to those listed in Section A3.1. This appendix does not address load testing for the effects of seismic loads or moving loads (vibrations).

The Appendix is organized as follows:

5.1. General Provisions
5.2. Material Properties
5.3. Evaluation by Structural Analysis
5.4. Evaluation by Load Tests
5.5. Evaluation Report

5.1. GENERAL PROVISIONS

These provisions shall be applicable when the evaluation of an existing steel structure is specified for (a) verification of a specific set of design loadings or (b) determination of the *available strength* of a *force* resisting member or system. The evaluation shall be performed by *structural analysis* (Section 5.3), by *load* tests (Section 5.4), or by a combination of structural analysis and load tests, as specified in the contract documents. Where load tests are used, the *engineer of record* shall first analyze the applicable parts of the structure, prepare a testing plan, and develop a written procedure to prevent excessive permanent deformation or catastrophic collapse during testing.

5.2. MATERIAL PROPERTIES

1. Determination of Required Tests

The *engineer of record* shall determine the specific tests that are required from Sections 5.2.2 through 5.2.6 and specify the locations where they are required. Where available, the use of applicable project records shall be permitted to reduce or eliminate the need for testing.

2. Tensile Properties

Tensile properties of members shall be considered in evaluation by *structural analysis* (Section 5.3) or *load* tests (Section 5.4). Such properties shall include the *yield stress*, *tensile strength* and *percent elongation*. Where available, certified material test reports or certified reports of tests made by the fabricator or a testing laboratory in accordance with ASTM A6/A6M or A568/A568M, as applicable, shall be permit-

Appendix 5 provides information related to Evaluation of Existing Structures.

RESOURCES

WELDING TO EXIST. STRUCTURES

- Field Welding to Existing Steel Structures - Ricker – EJ 1st Qtr. 1988
- Welding to Existing Structures - Garlich, - 2000 NASCC
- Reinforcing Steel Members and the Effects of Welding - Tide – EJ 4th Qtr. 1990
- AISC Design Guide 15 - Rehabilitation and Retrofit Guide
- AISC Design Guide 21 - Welded Connections

RESOURCES

HEAT STRAIGHTENING

- What You Should Know About Heat Straightening Repair of Damaged Steel – Avent and Mukai – EJ 1st Qtr. 2001

RESOURCES
STRENGTHENING

- Reinforcing of Steel Joist - Fisher – 2004 NASCC
- The Reinforcement of Steel Columns - Tall – EJ 1st Qtr. 1989
- Reinforcing Steel Members and the Effects of Welding - Tide – EJ 4th Qtr. 1990

MATERIAL PROPERTIES

MATERIAL PROPERTIES TESTING

Acceptable Sources:

- Certified material test reports
  - –ASTM A6 or A568
- Bolt Markings

MATERIAL PROPERTIES TESTING

Bolt Head Markings:

A307	
A325	
A490	
A449	

MATERIAL PROPERTIES TESTING

Tests:

- *ASTM A370 – tensile tests*
- *ASTM A751 – chemical composition*
  - *–Welding*
- *Charpy V-notch toughness*
  - *–tension splices in heavy shapes*
- ASTM F606 - Bolts

MATERIAL PROPERTIES TESTING

Acceptable Assumptions:

- Bolts – A307
- Rivets - ASTM A502, Grade 1

MATERIAL PROPERTIES TESTING

Strength of Existing Welds

- Chemical analyses
- Mechanical tests
- Magnitude and consequences of imperfections

DIMENSIONAL DATA

Obtained from:

- Design or shop drawings - Analysis
  –verify critical dimensions
- Field Survey – A must for construction

WELDING

WELDING

Easy Fixes:

- Check actual leg size
- Directional strength increase
- Try inelastic design

WELDING

Considerations:

- Combustion
- Reduction in Properties
- Weldability

WELDING

Combustion (You may start a fire)

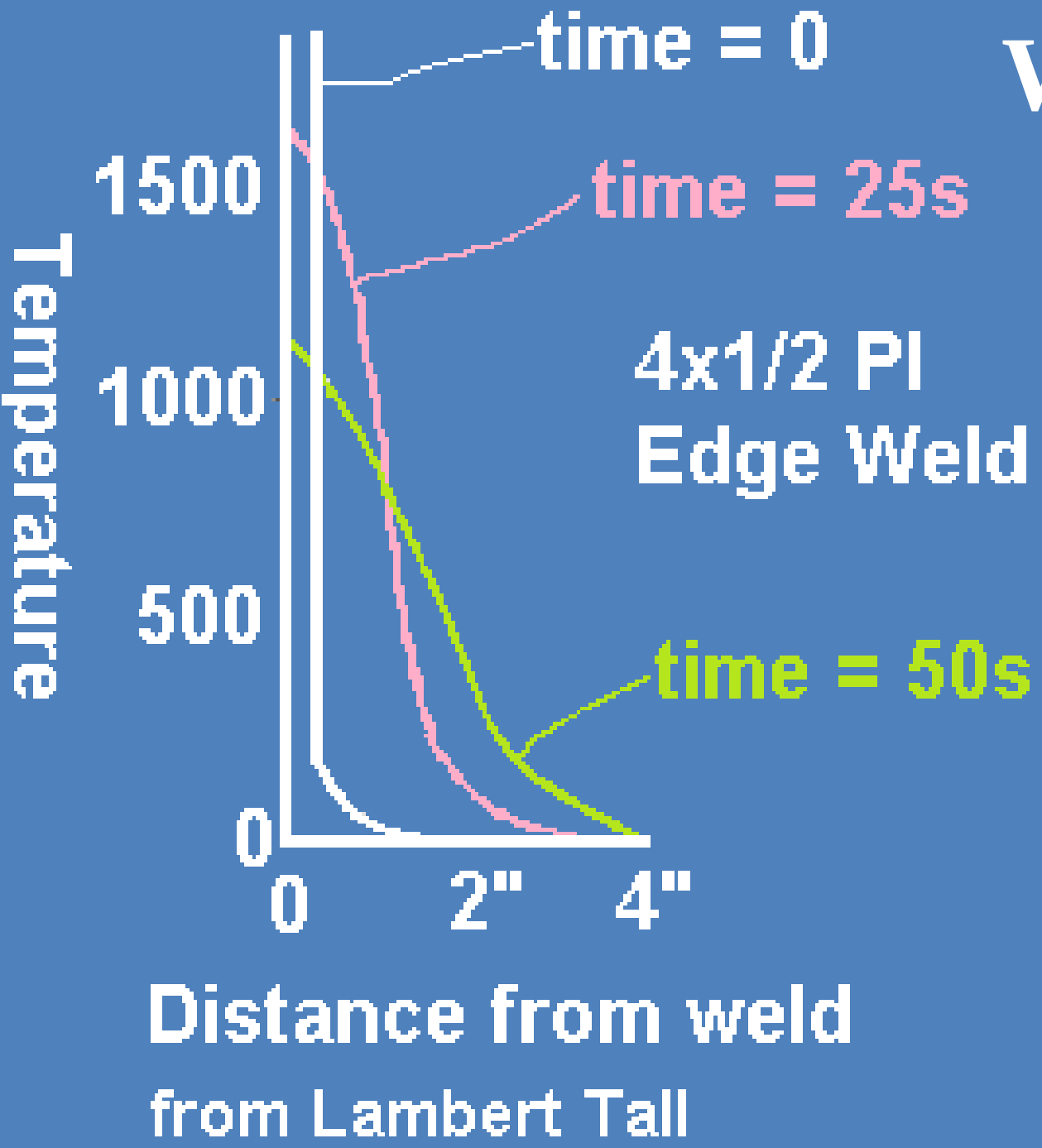
- Welding itself
- Preheating torches
- Circuit – work lead should be attached as close as possible to area being welded.

WELDING

Reduction in Properties

- Loss of strength and stiffness as steel is heated
- Negligible loss to about 650 °F – Welding interpass temperature should not generally exceed 550 °F
- Small portion experiences reduction at a time

WELDING



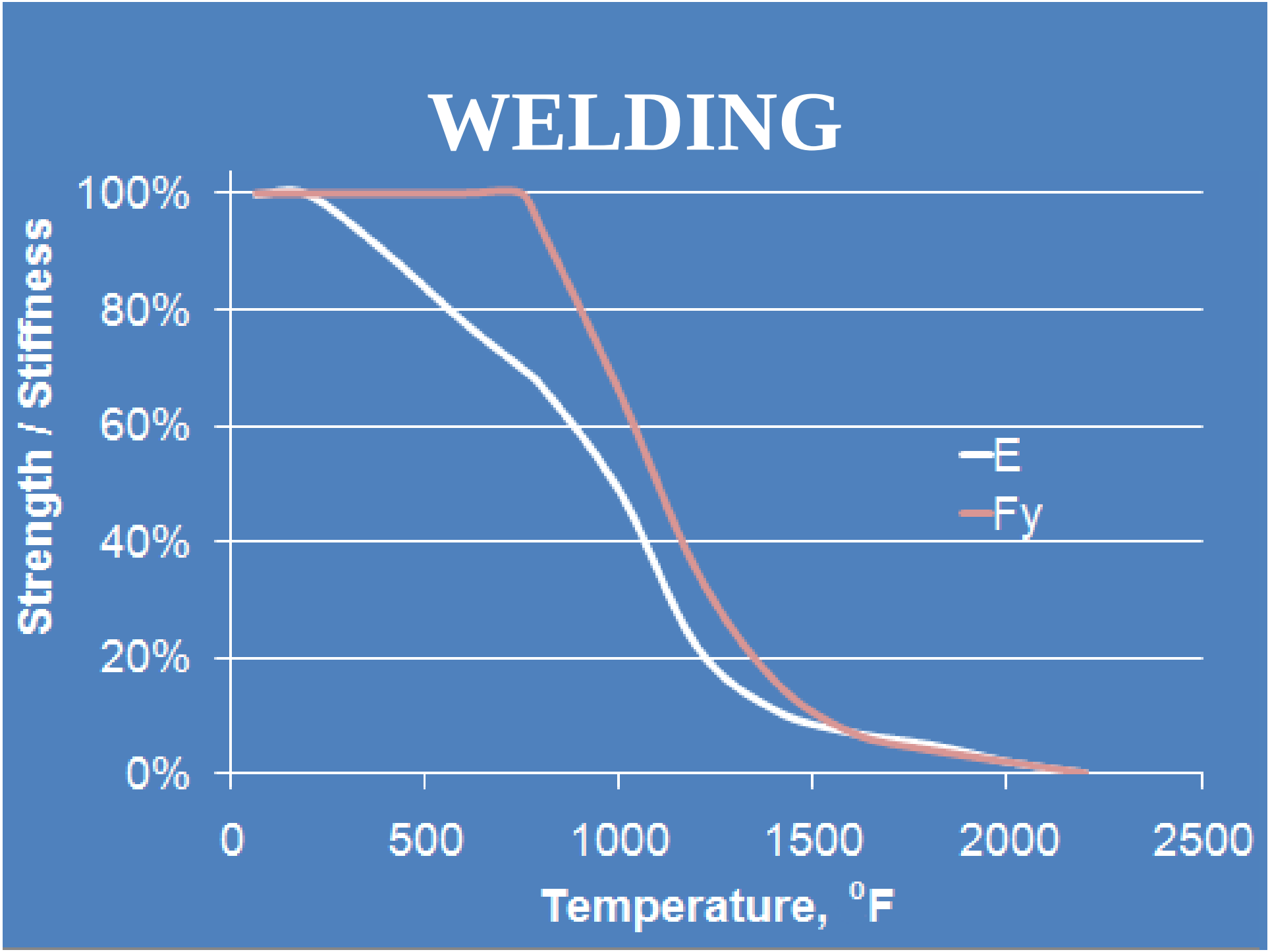
Only a small area experiences reduction at a time

from Lambert Tall

WELDING

Reduction in Properties

- Welding parallel to stress preferred over transverse – effects less of cross-section


WELDING
100%
80%
60%
40%
20%
0%
Strength / Stiffness
E
Fy
0
500
1000
1500
2000
2500
Temperature, °F

WELDING

Weldability

- Representative chemistry
- Simple field tests

WELDING

Weldability - Cast iron

- Should not be structurally welded
- Cosmetic welding okay

WELDING

Weldability - ASTM - A7

- 1900-1967
- must be evaluated on a case-by-case basis
- late 1950s+ historically weldability was good

WELDING

Weldability - ASTM – A9

- 1900-1939
- must be evaluated on a case-by-case basis
- Only existed prior to popular welding

WELDING

Weldability - ASTM – A373

- 1958-1965
- Generally good weldability

WELDING

Weldability - ASTM – A242

- 1963-Current
- Weathering Steel
- No limit of phosphorous
- Not prequalified

THERMAL CUTTING

THERMAL CUTTING

- Shoring recommended
- Care needed especially for tension members

BOLTING

BOLTING

Easy Fixes:

- Are bolts designed as SC but can be bearing?
- Are bolts designed as N but really X?
- Substitute A490s for A325s
- End-loading?

BOLTING

New Holes:

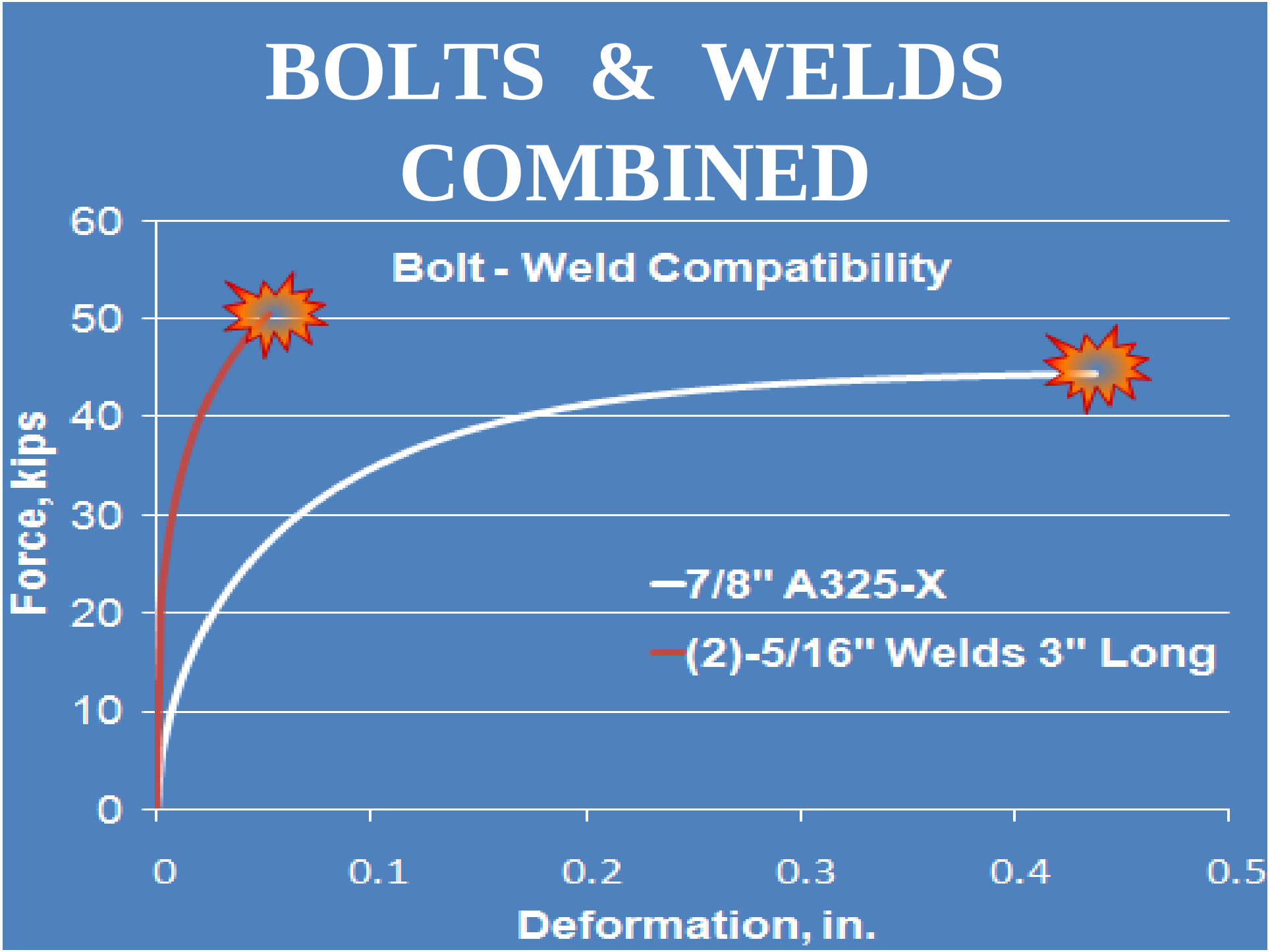
- Black A325 bolts can be reused
- Spec. Part M allows thermal cutting of holes - Intended for shop plasma cuts
- Magnetic drill

BOLTS & WELDS COMBINED

BOLTS & WELDS COMBINED

- Generally it is a bad idea to combine the strengths of bolts and welds
- When making alterations can be combined:
  - SC connections can resist existing load.

BOLTS & WELDS COMBINED

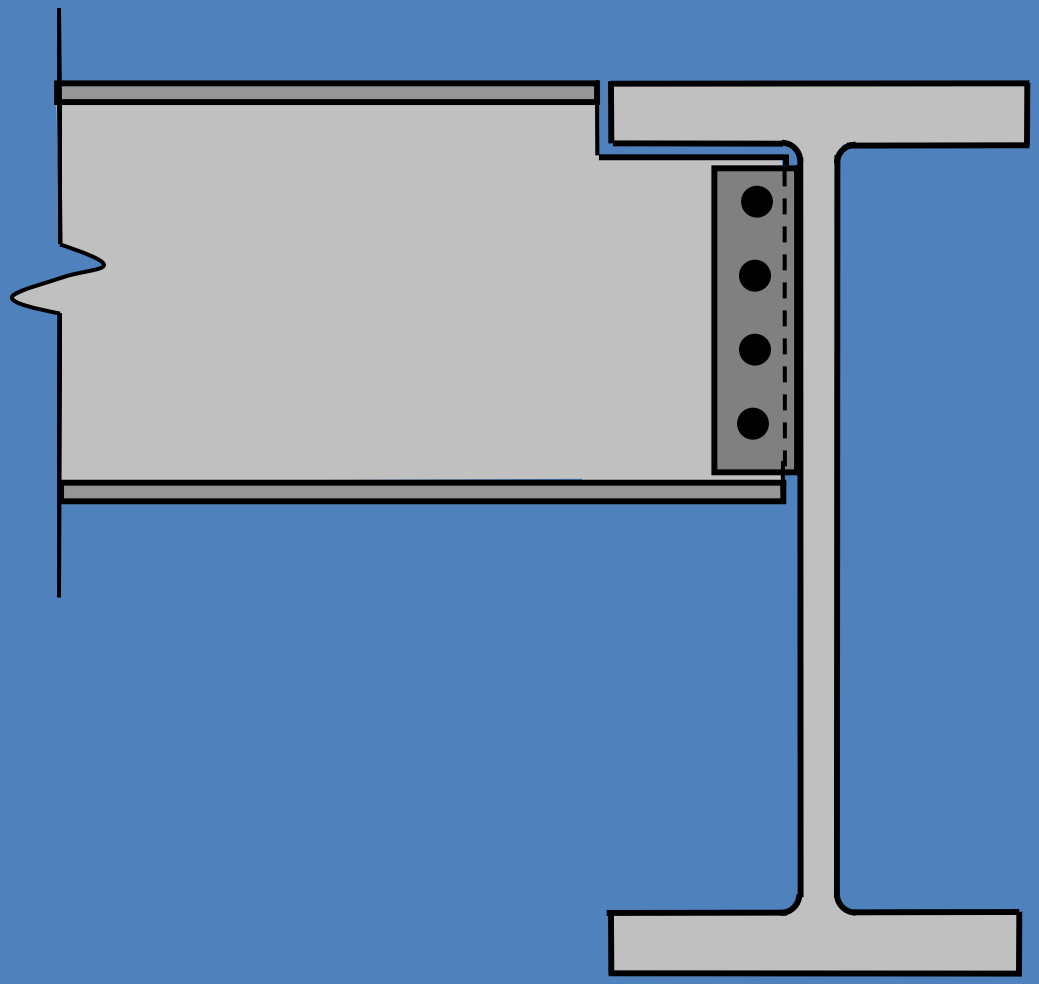


OTHER COMPATIBILITY ISSUES

OTHER COMPATIBILITY ISSUES

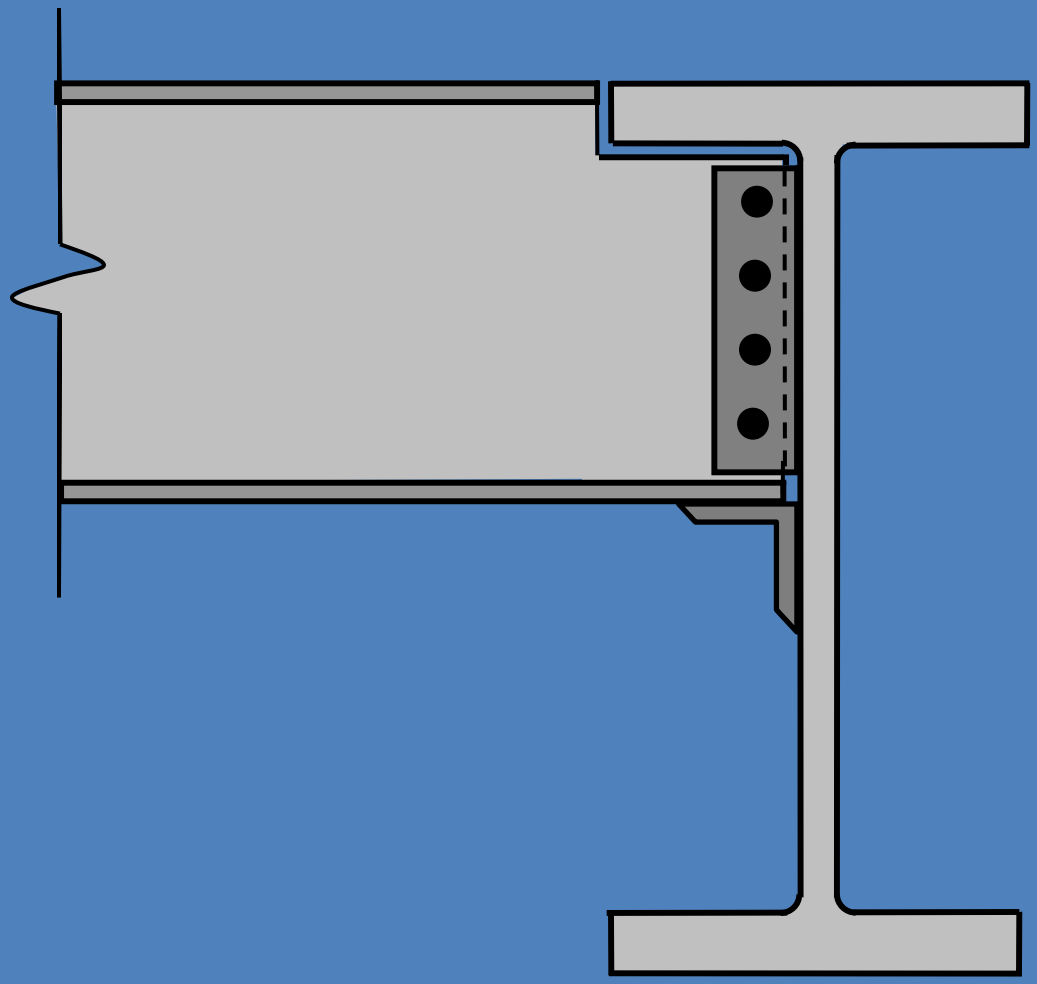
Though the Spec. only addresses compatibility of welds and bolts, compatibility must be considered in many retrofit situations.

OTHER COMPATIBILITY ISSUES



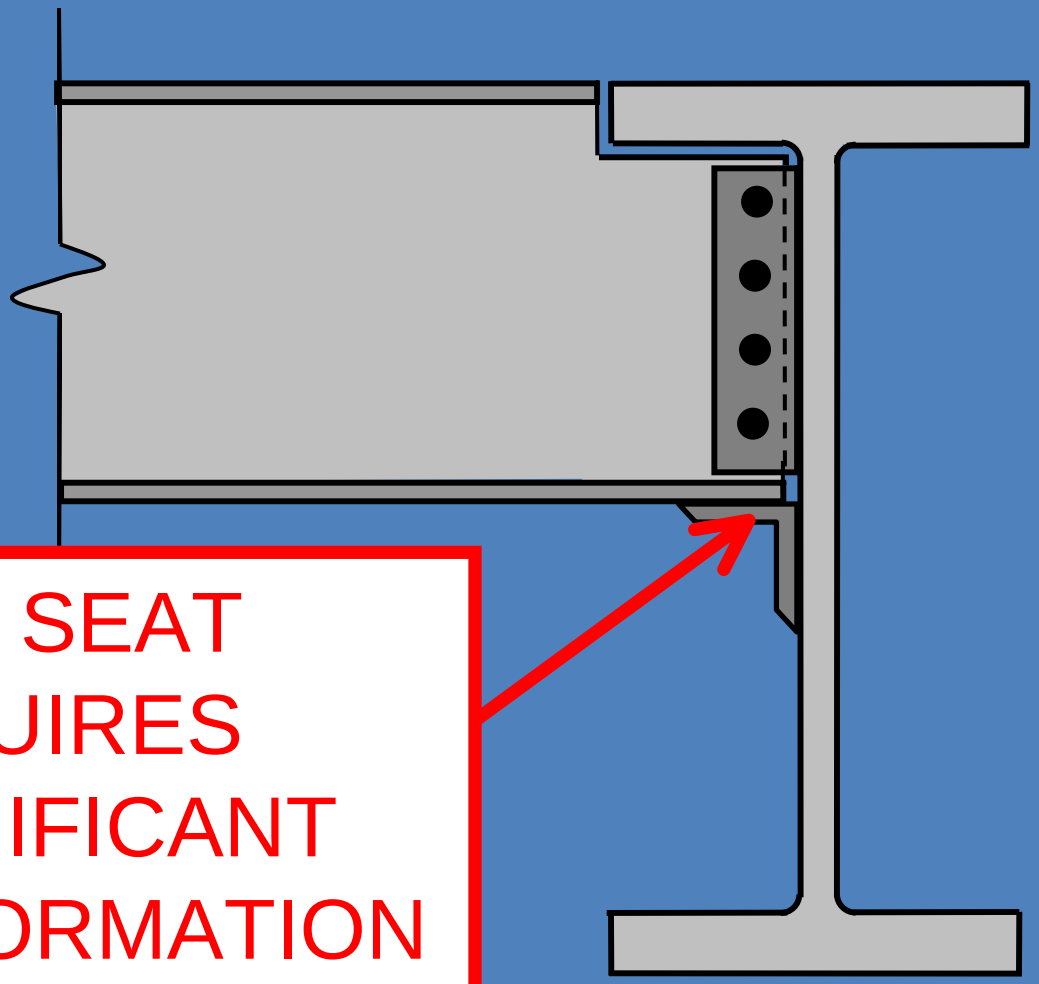
The beam reaction has increased.

OTHER COMPATIBILITY ISSUES



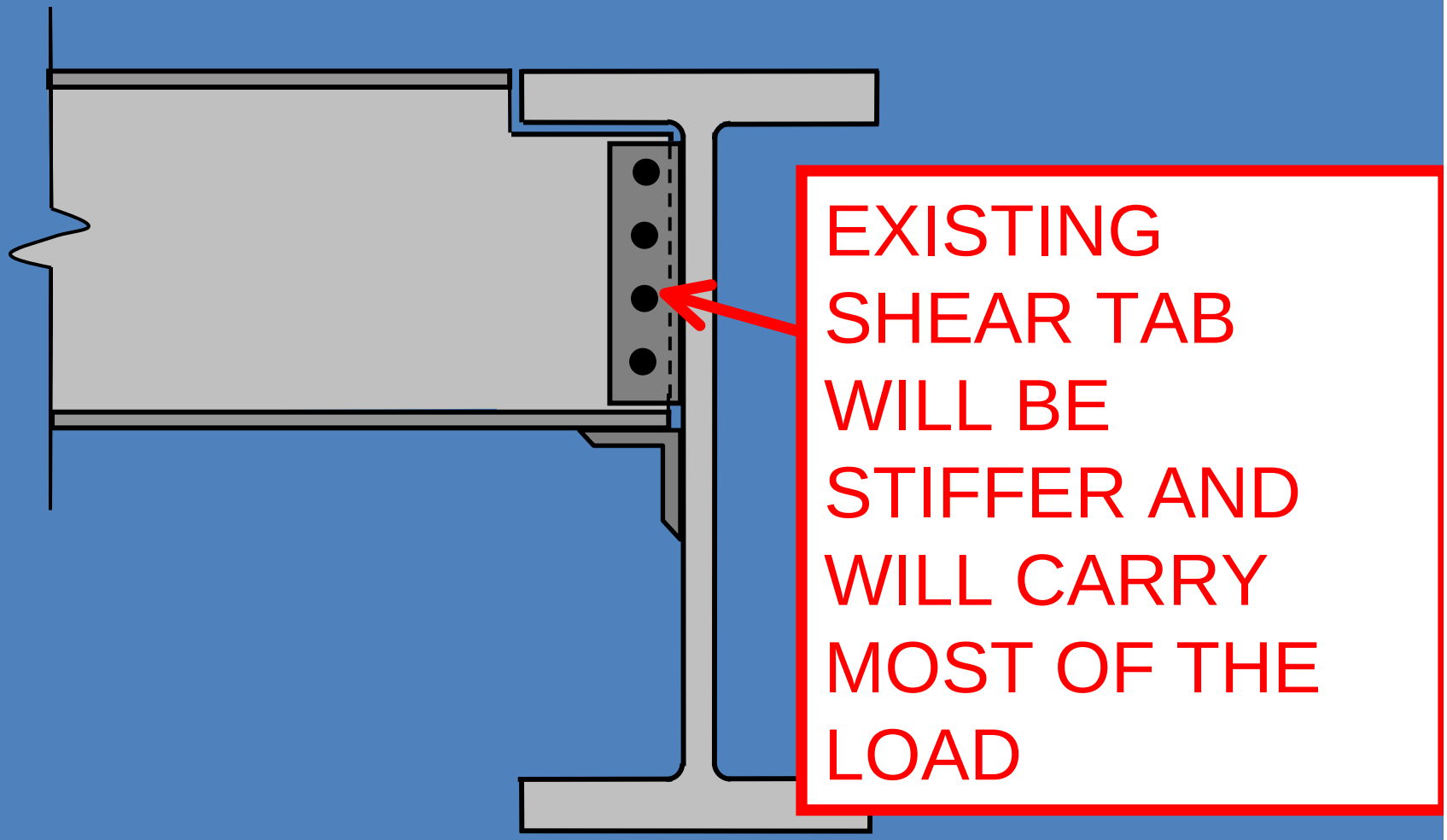
One commonly proposed solution is to add a seat designed to carry the additional load.

OTHER COMPATIBILITY ISSUES



NEW SEAT REQUIRES SIGNIFICANT DEFORMATION TO PICK UP LOAD

OTHER COMPATIBILITY ISSUES



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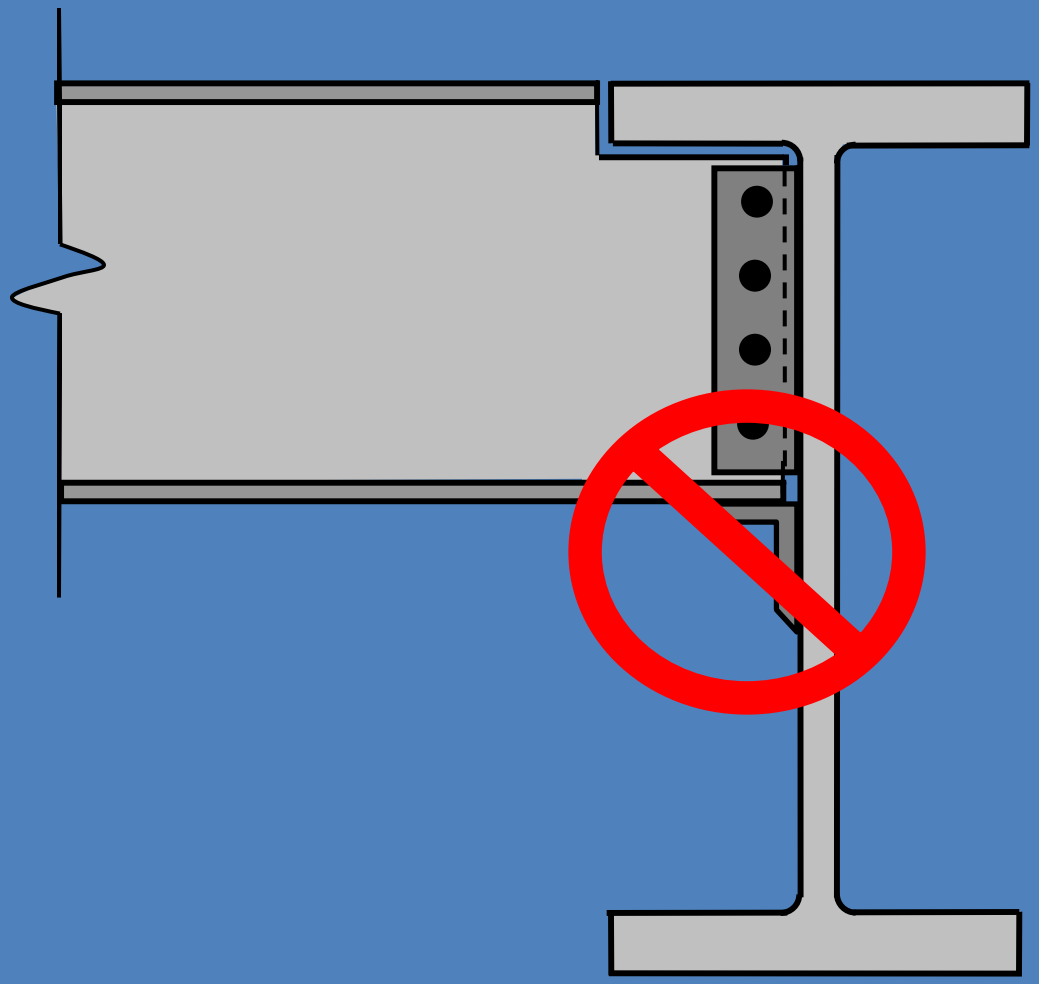

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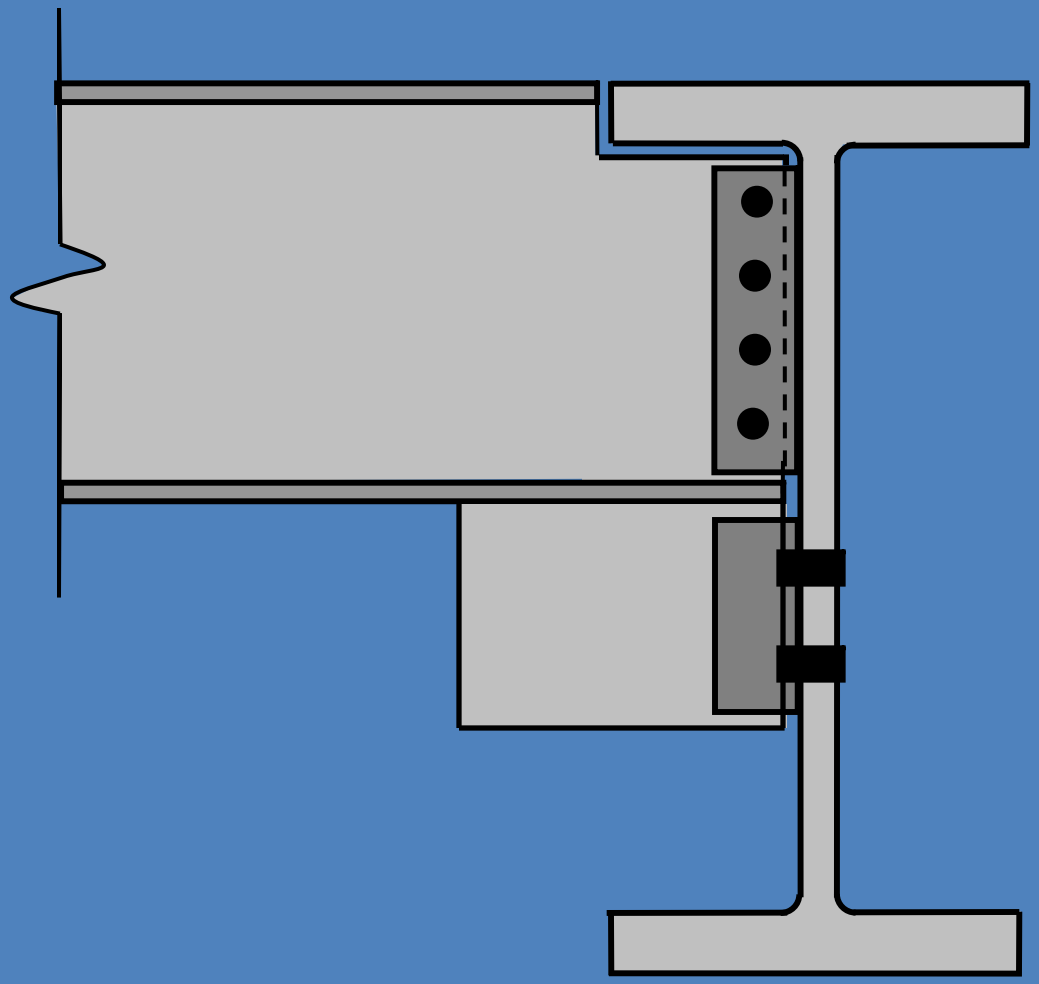


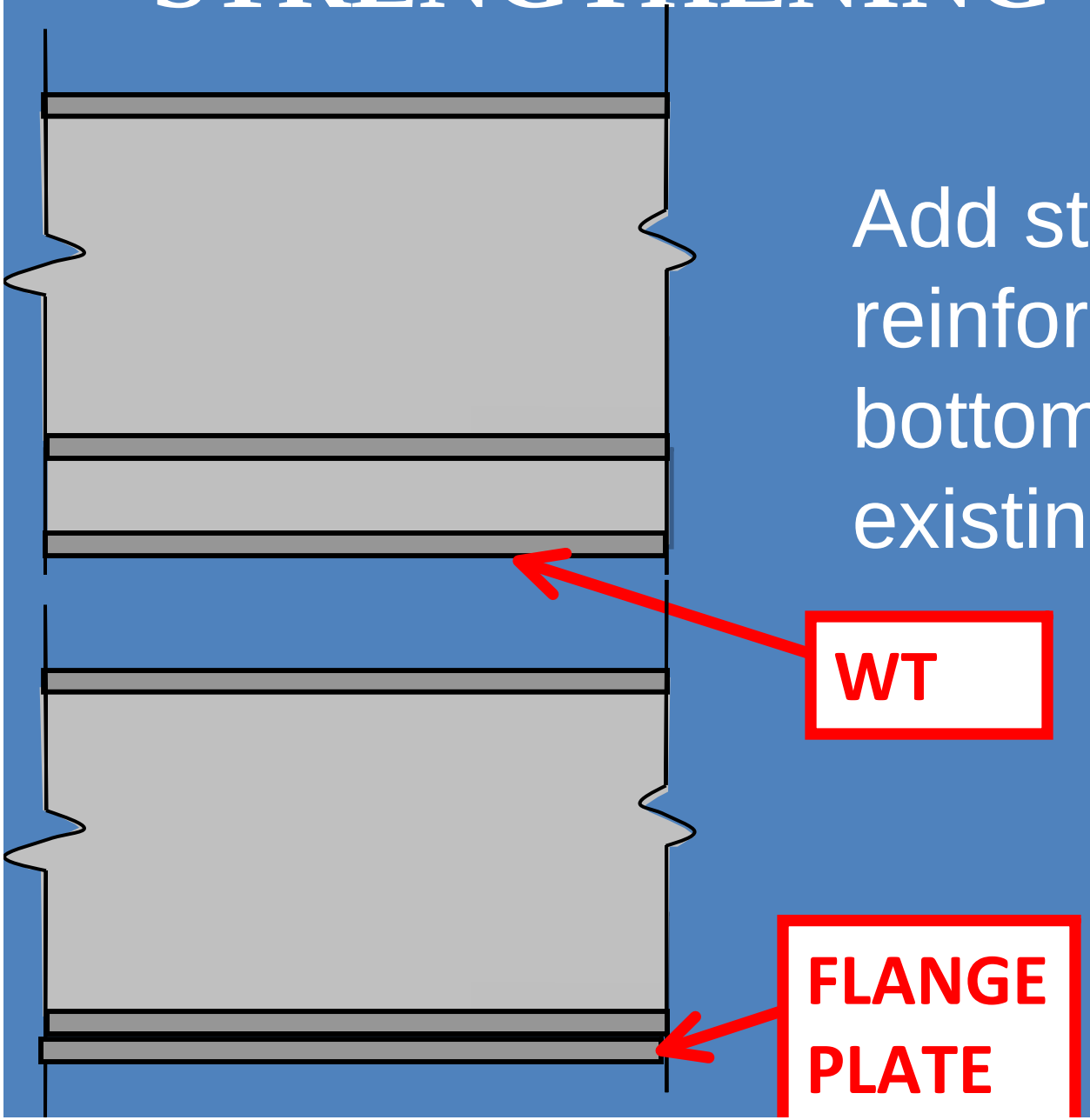
A haunch provides a more compatible solution.

STRENGTHENING FLOORS

STRENGTHENING FLOORS

1. Add intermediate support
2. Inserting new beams, parallel to the existing ones
3. Add steel reinforcement to bottom flanges of existing beams
4. Add pre-tensioned steel cables to beams
5. Add shear connectors.

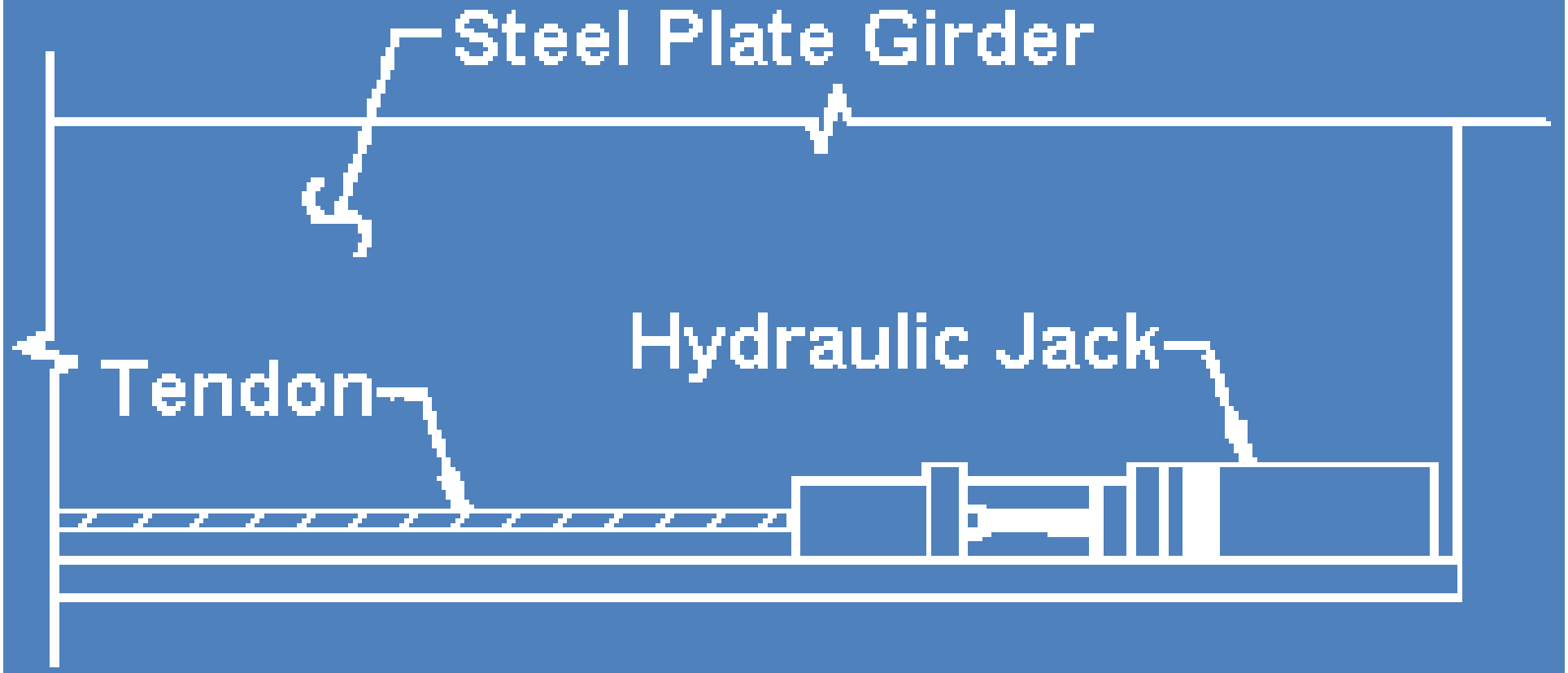
STRENGTHENING FLOORS



Add steel reinforcement to bottom flanges of existing beams.

STRENGTHENING FLOORS

Pre-tensioned steel cables to beam

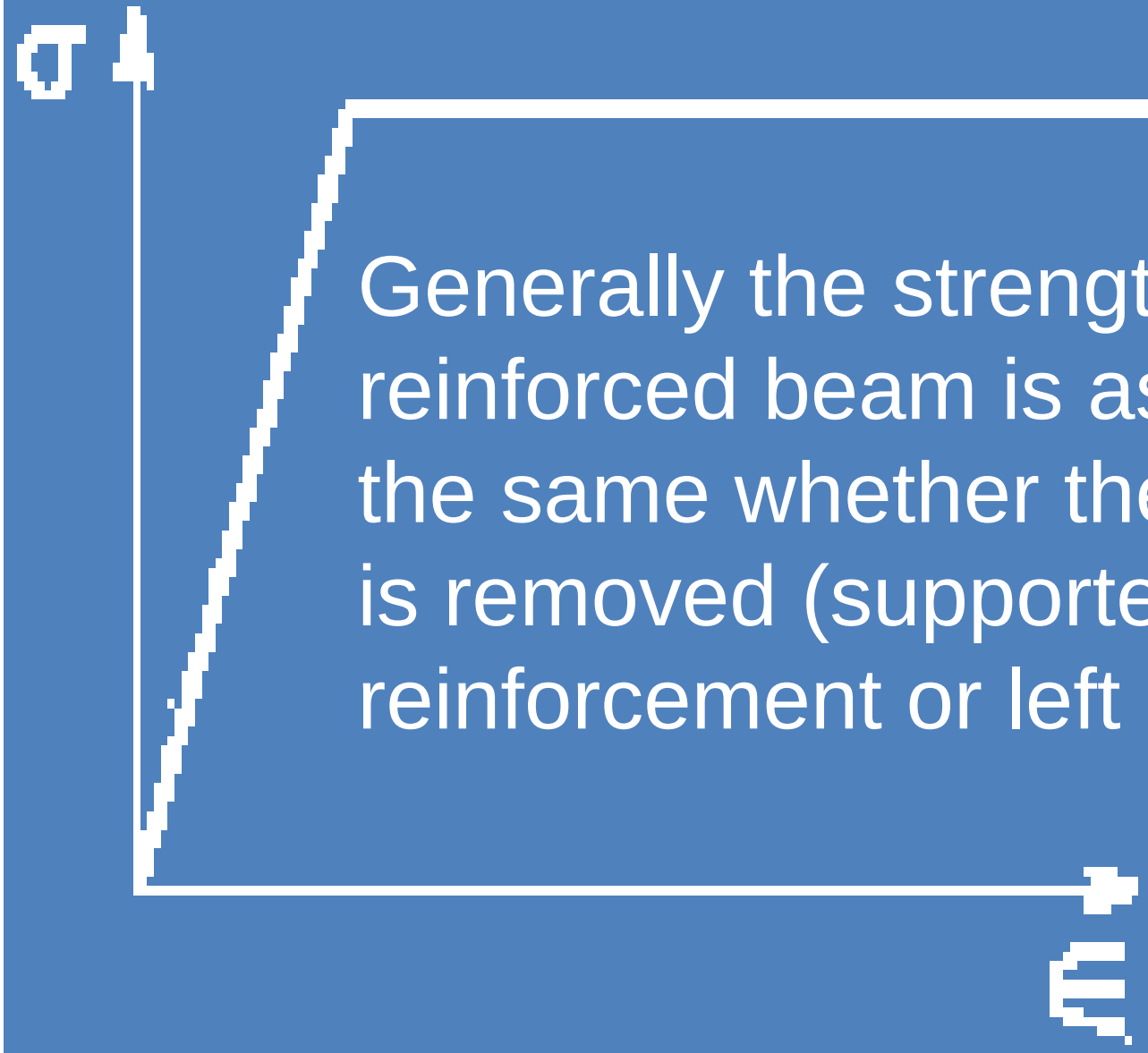


STRENGTHENING FLOORS

Add shear connectors

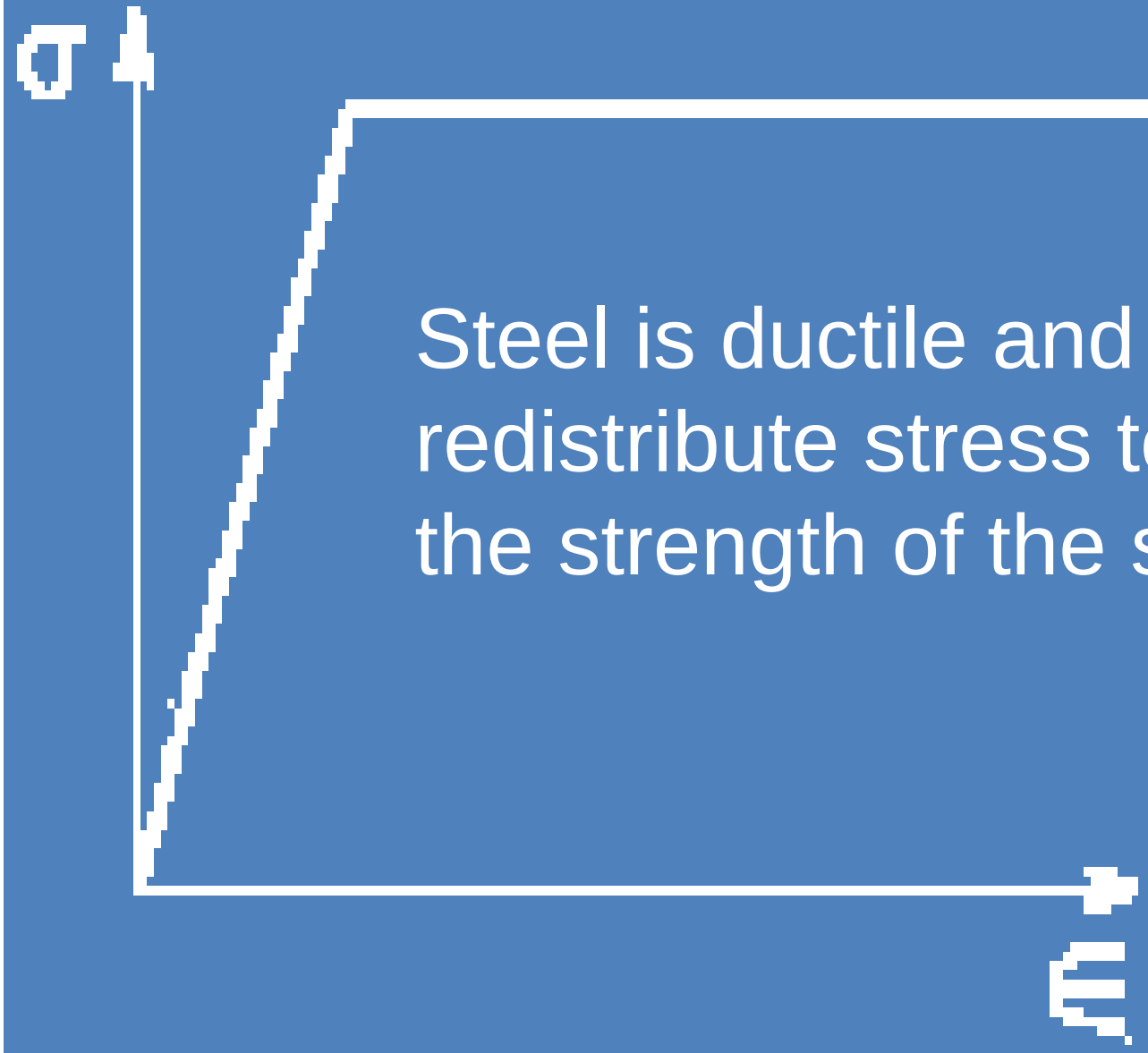
- Cored holes of a diameter sufficient to allow stud placement and grouting.
- Shrink-compensating grout with strength at least equal to the existing slab.
- The strength of the resulting beam is independent of the initial load present.

STRENGTHENING FLOORS



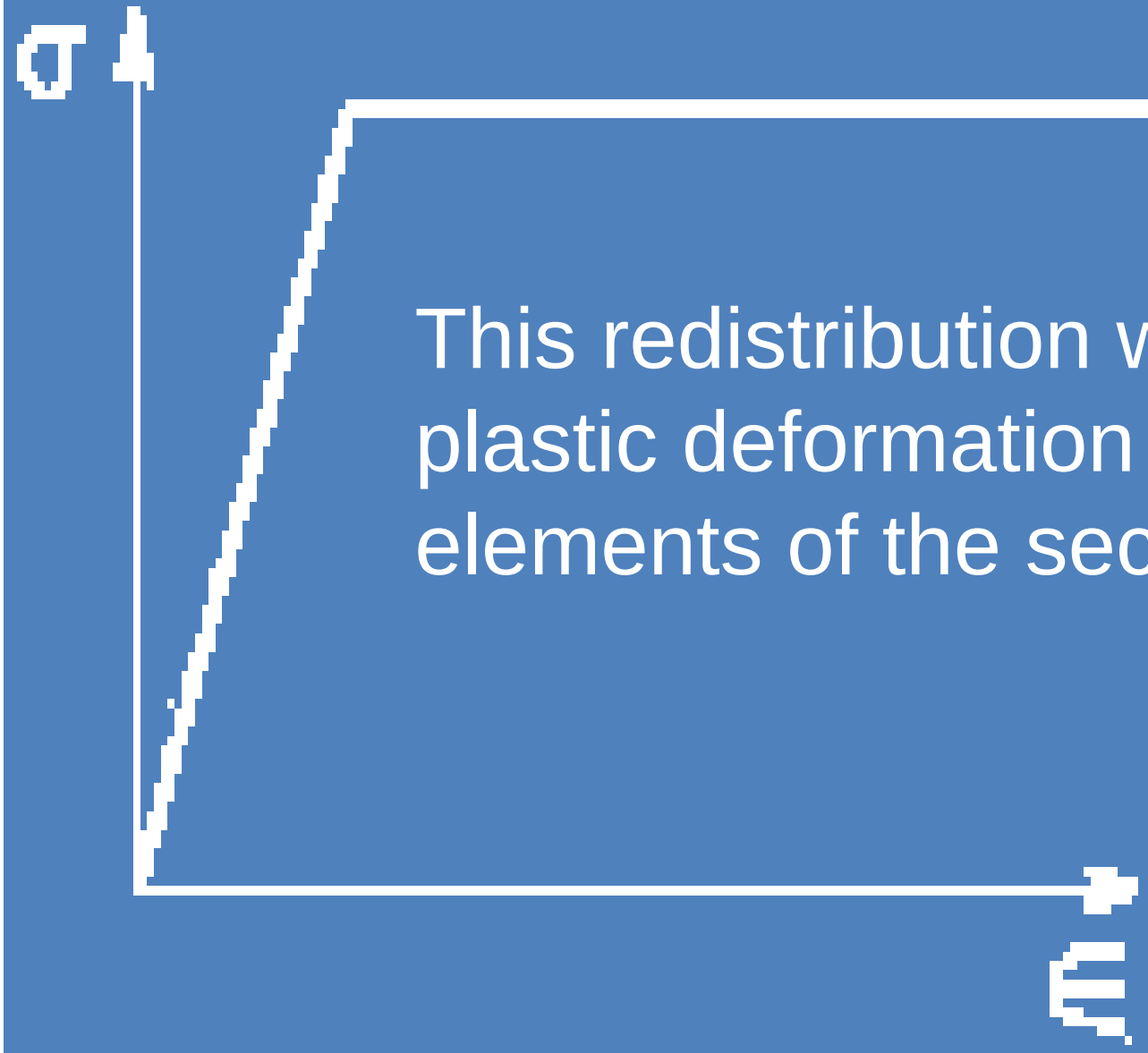
Generally the strength of the reinforced beam is assumed to be the same whether the existing load is removed (supported) during reinforcement or left in place.

STRENGTHENING FLOORS



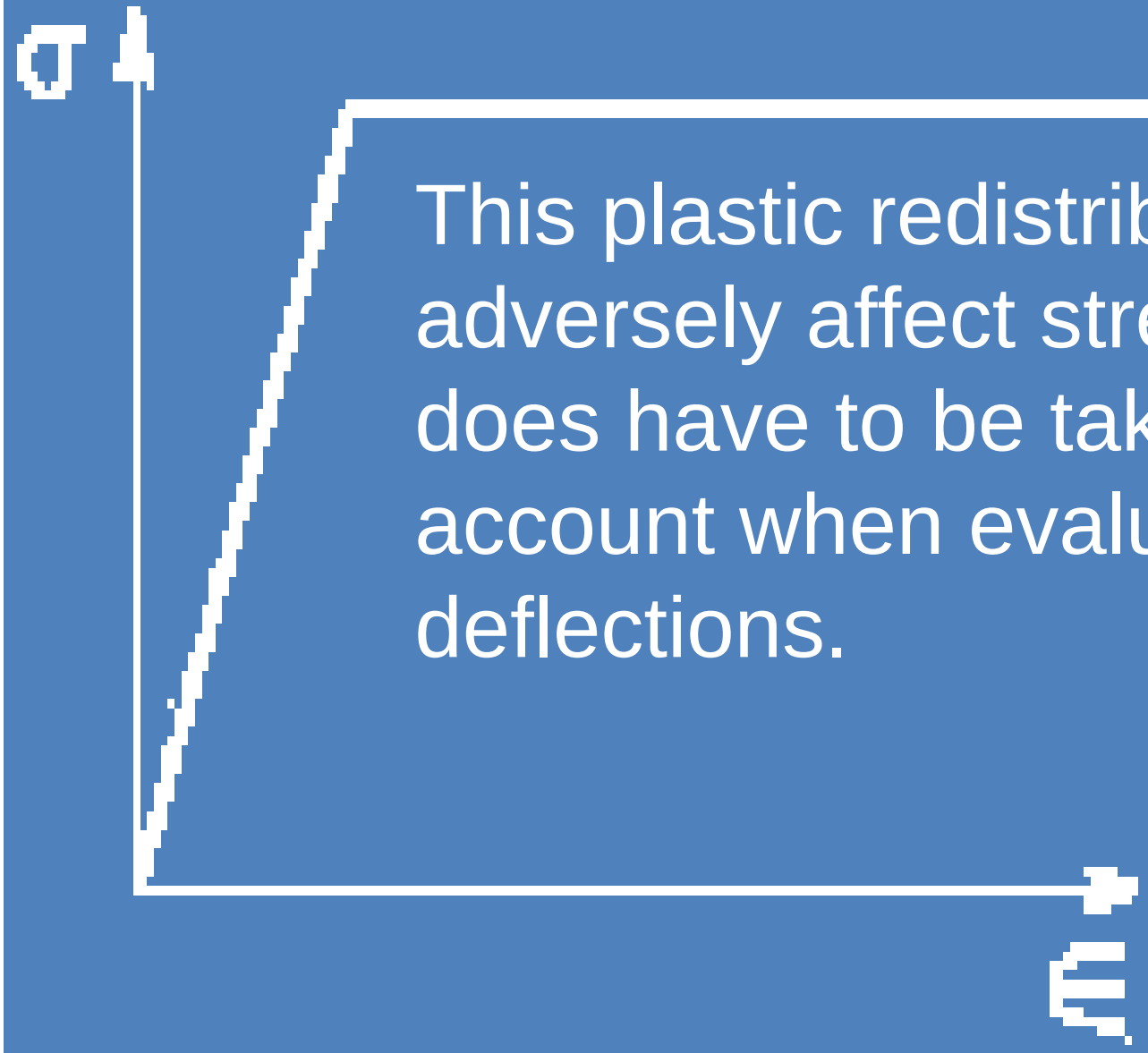
Steel is ductile and will redistribute stress to maximize the strength of the section.

STRENGTHENING FLOORS



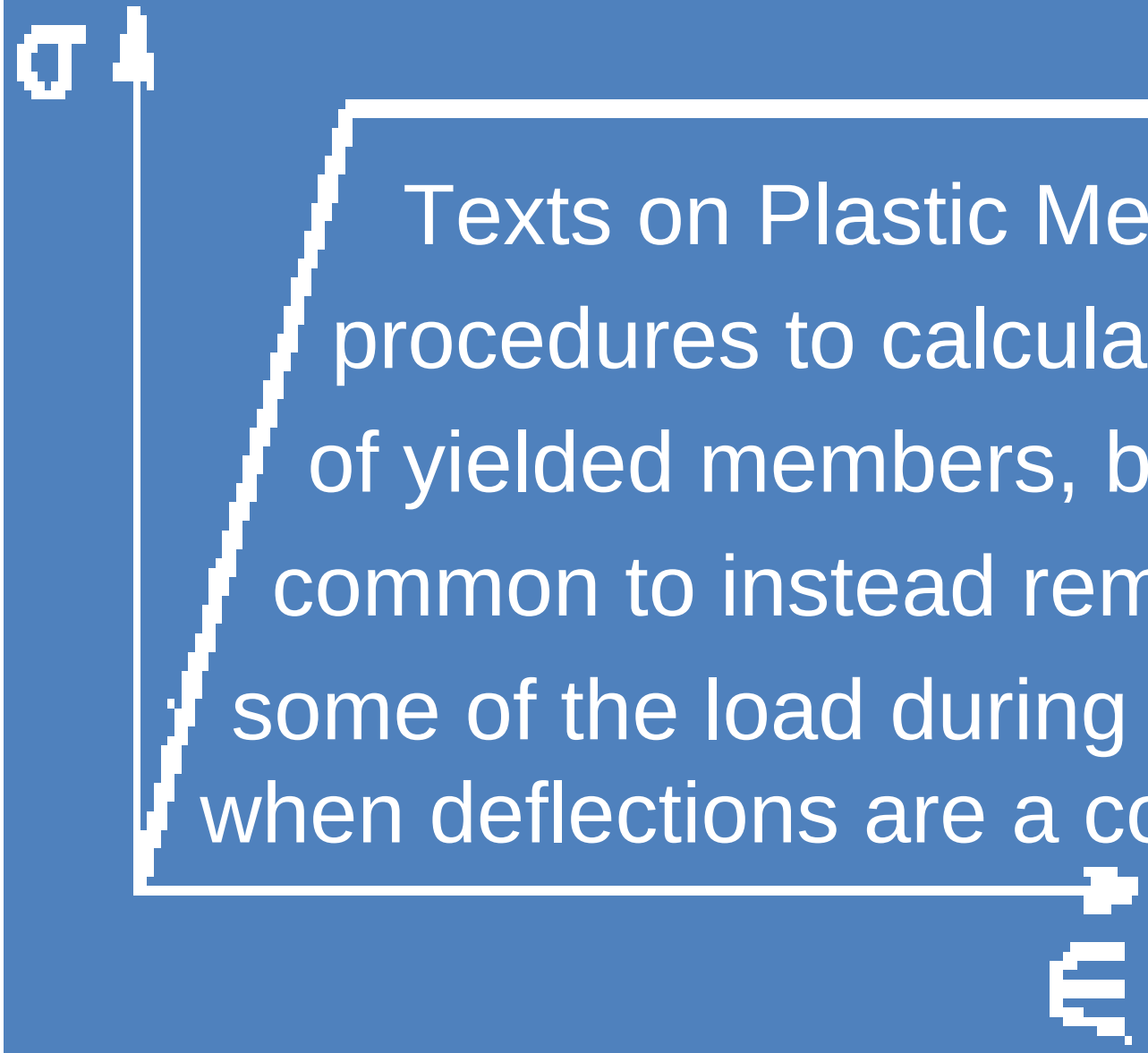
This redistribution will involve plastic deformation of some elements of the section.

STRENGTHENING FLOORS



This plastic redistribution will not adversely affect strength, but does have to be taken into account when evaluating deflections.

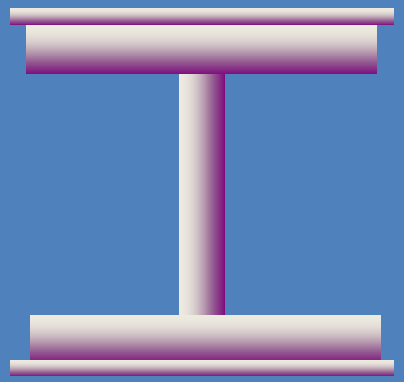
STRENGTHENING FLOORS

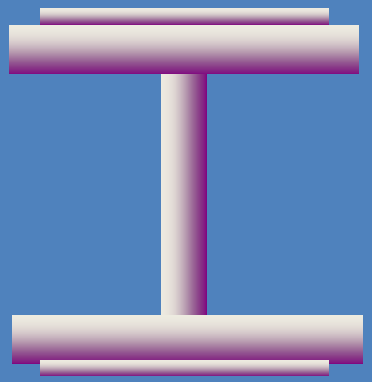


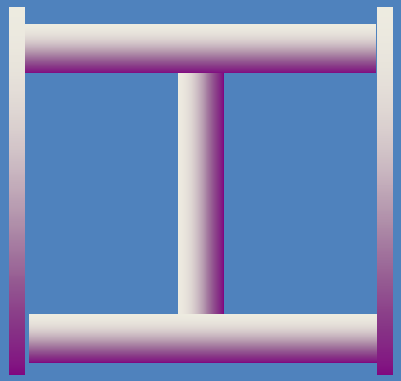
Texts on Plastic Methods provide procedures to calculate deflections of yielded members, but it is common to instead remove all or some of the load during reinforcing when deflections are a concern.

REINFORCING COLUMNS

REINFORCING COLUMNS







REINFORCING COLUMNS

Two schools of thought concerning reinforcing columns under load:

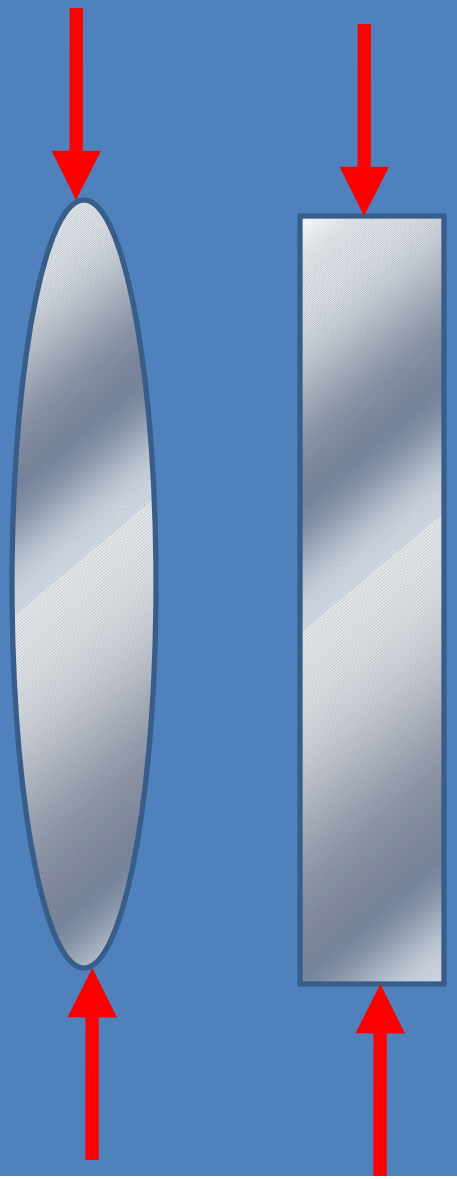
1. The strength is the same as an unloaded reinforced column – Lambert (EJ 1989), Tide (EJ 1990)
2. The strength of the reinforcement is limited due to the stress already present in the existing column – Brown (EJ 1988), Ricker (EJ 1988)

REINFORCING COLUMNS

I believe there is ample evidence to assume that the strength of a column reinforced under load is identical to the strength of a column reinforced without load.

In practice the loaded case may have somewhat greater strength due to the realignment of residual strength.

REINFORCING COLUMNS



A tapered column will have nearly the same strength as a prismatic column.

Reinforcing can often be terminated clear of the connections.

REINFORCING COLUMNS

A practical approach to the non-prismatic column strength can be found in:

N.M. Newmark “Numerical Procedure for Computing Deflections, Moments, and Buckling Loads,” Transactions, ASCE, 108 (1943).

QUESTIONS???

THE STEEL SOLUTIONS CENTER
www.AISC.org

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Black & White Photos by Lewis Hine