Heat Straightening Repairs of Damaged Steel Bridges

J. D. ECKMAN INC.
CONSTRUCTION
J.D.E.
BRIDGE HIGHWAY
EST. 1945

Heat Straightening

References

- US Department of Transportation, Federal Highway Administration, Heat Straightening Repairs of Damaged Steel Bridges, A Technical Guide and Manual of Practice
- FHWA, Krishna Verma, http://www.fhwa.dot.gov/bridge/heat.htm
- Louisiana State University, R. Richard Avent, Ph.D.,

Outline

- Basics of heat straightening theory
- Brief overview of technical guidelines
- Practical considerations

What is Heat Straightening?

- Repair procedure in which a limited amount of heat is applied to the plastically deformed regions of damaged steel in repetitive heating and cooling cycles to produce a gradual straightening of the material.
- Limited amount of heat
- Specific patterns conforming to damage
- Upsetting during heating
- Contraction during cooling
- Force used as restraint only

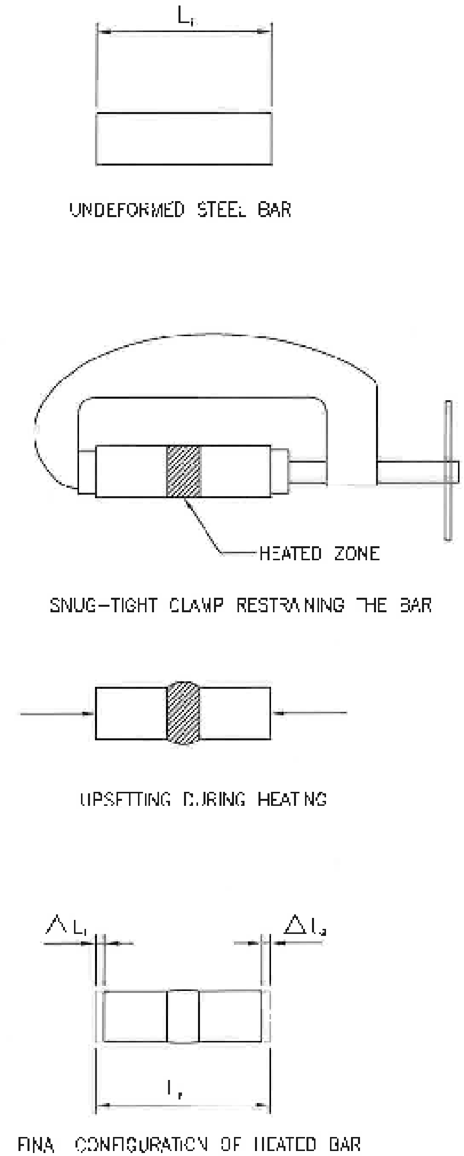
What heat straightening is not

- Hot mechanical straightening
  - Applied external force
  - May fracture steel
  - May adversely affect material properties
  - May produce local deformations
- Hot mechanical straightening
  - Use force to straighten with high heat
  - May fracture steel
  - May change mechanical properties, eg. Brittleness
  - May produce local deformations

Heat Straightening Characteristics

- Maximum heating temperature does not exceed either
  - Lowest temperature at which molecular changes occur
  - Temper limit for quenched and tempered steel
- External forces produce stresses less than the yield stress in the heated condition
- Only regions in the vicinity of the plastically deformed zones are heated

Basics



UNDEFORMED STEEL BAR
HEATED ZONE
SNUG-TIGHT CLAMP RESTRAINING THE BAR
UPSETTING DURING HEATING
FINAL CONFIGURATION OF HEATED BAR

Heating Fundamentals

- Acetylene/oxygen heat
- Multiple orifice (rosebud) heating tips
- Temperature monitoring crayons or equipment
- Limit temperature
  - 1200 degrees F. - carbon and low alloy ≤ 60 ksi
  - 1100 degrees F. - quenched & tempered A514 & A709 grades 100 and 100W
  - 1050 degrees F. - queched & tempered A709 grade 70W
- Limit restraining forces
- Full cooling to below 250 degrees F.

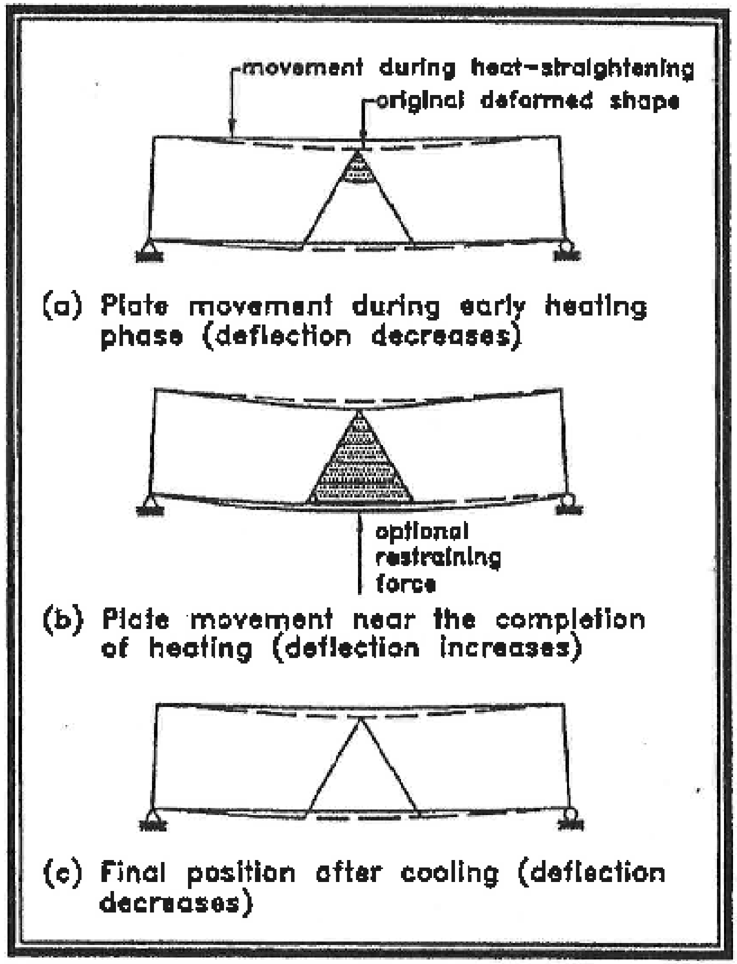


Figure 2.2. Stages of movement during vee heat.

Categories of Damage

- Category S: Strong axis bending
- Category W: Weak axis bending
- Category T: Twisting
- Category L: Localized damage

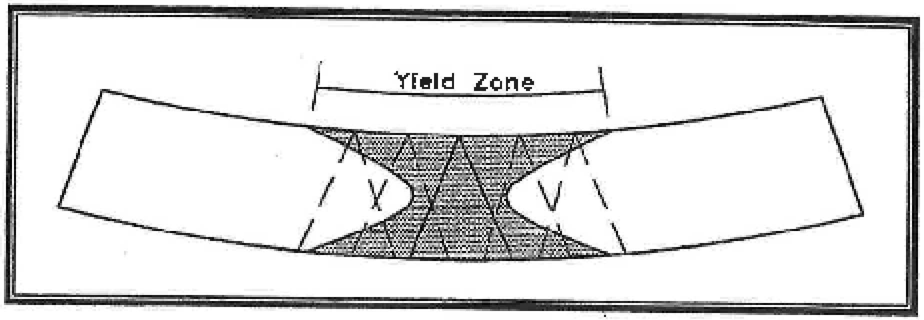


Figure 2.10. Plate vee heat pattern over yield zone.

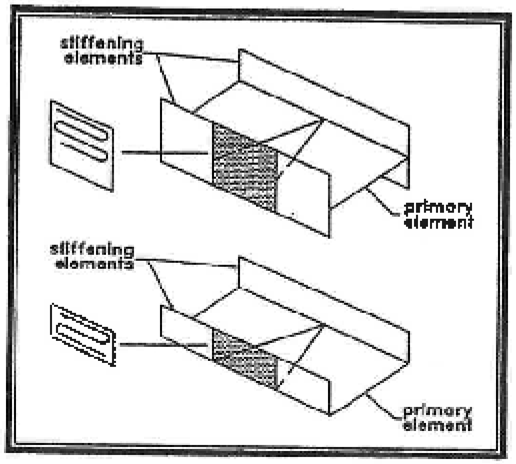


Figure 2.11. Heating patterns for wide flanges and channels bent about their major axes (Category S).

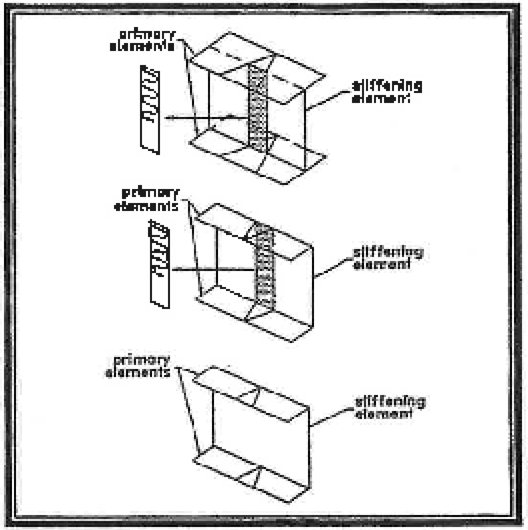


Figure 2.12. Heating patterns for wide flanges and channels bent about their minor axes (Category W).

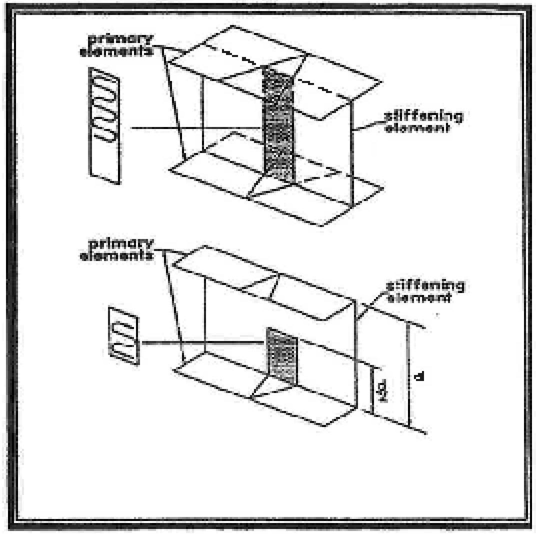


Figure 2.13. Wide flanges and channels with twisting damage (Category T).

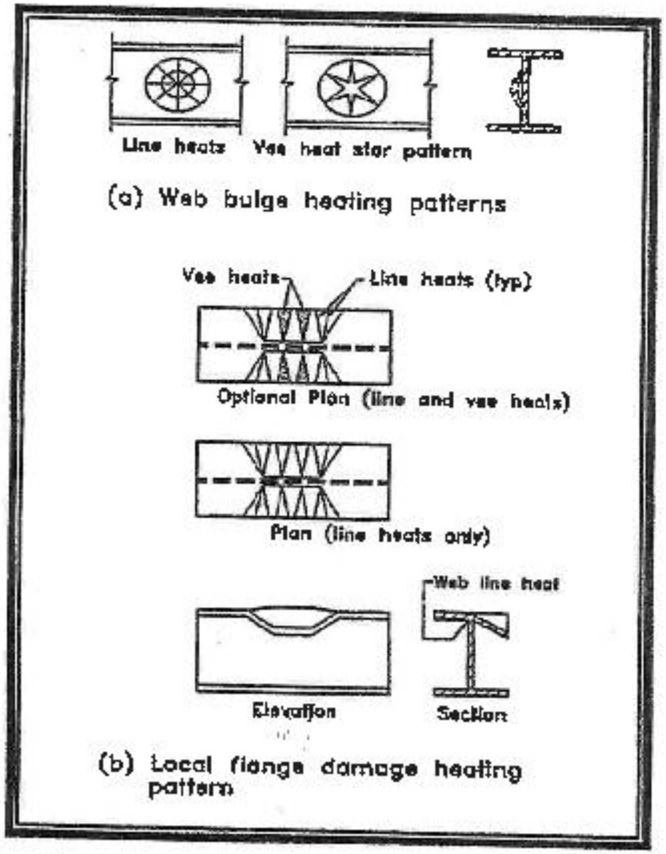


Figure 2.14. Typical heating patterns for local damage.

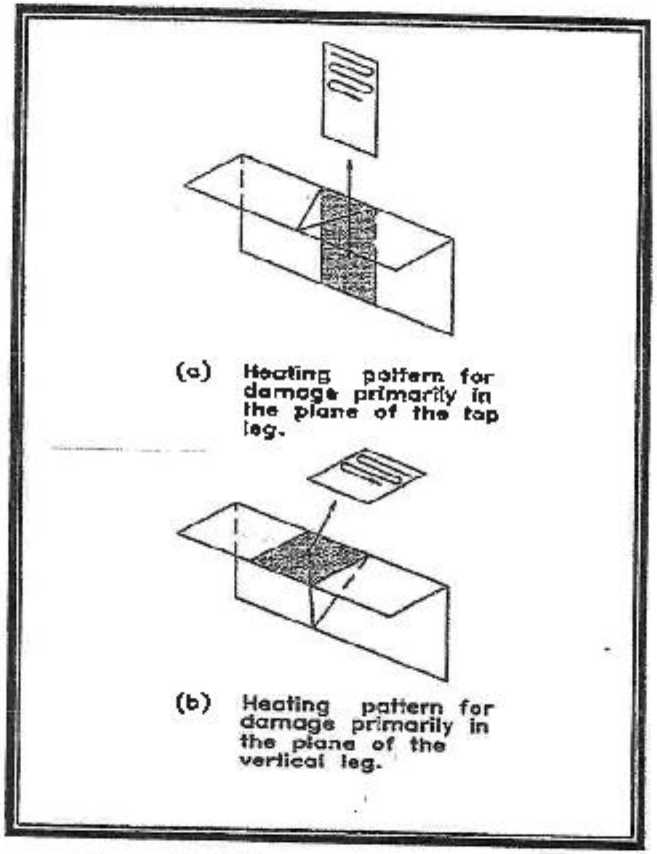


Figure 2.15. Heating patterns for angles.

Design Considerations

- Degree of damage determination
  - Radius of curvature, R
  - Strain ration, *u*
- Determination of jacking load
- Determination of number of heats

Radius of Curvature

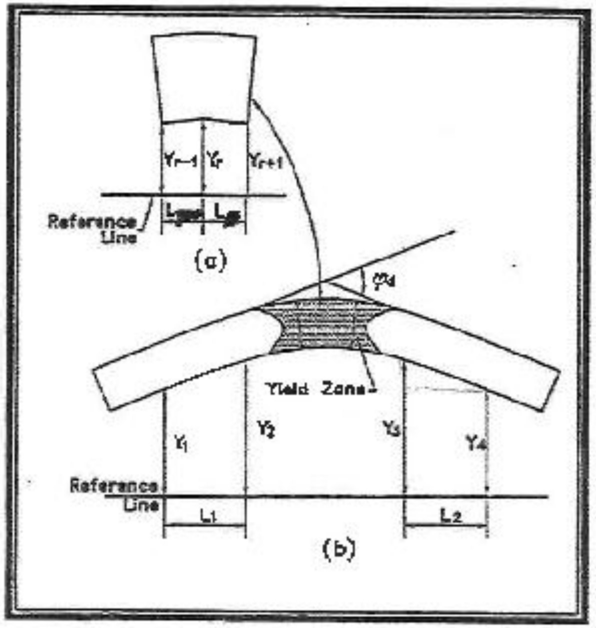


Figure 3.2. Offset measurements to calculate degree of damage and radius of curvature.

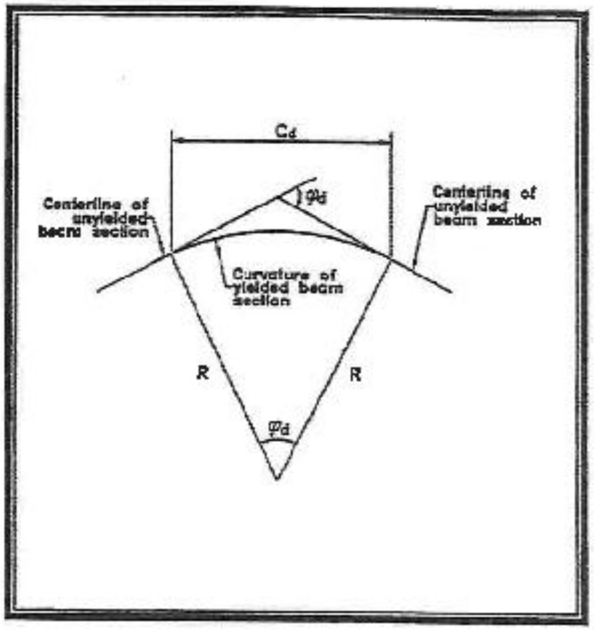


Figure 3.3. Relationship of degree of damage to radius of curvature and cord length.

chord

Candidate for heat straightening?

$$\Phi_d = \tan^{-1}\left(\frac{y_2 - y_1}{L_1}\right) + \tan^{-1}\left(\frac{y_4 - y_3}{L_2}\right)$$

$$R = \frac{c_d}{2\sin(\Phi_d/2)}$$

$$\varepsilon_{MAX} = \frac{1}{R} y_{MAX}$$

$$\varepsilon_y = \frac{F_y}{E}$$

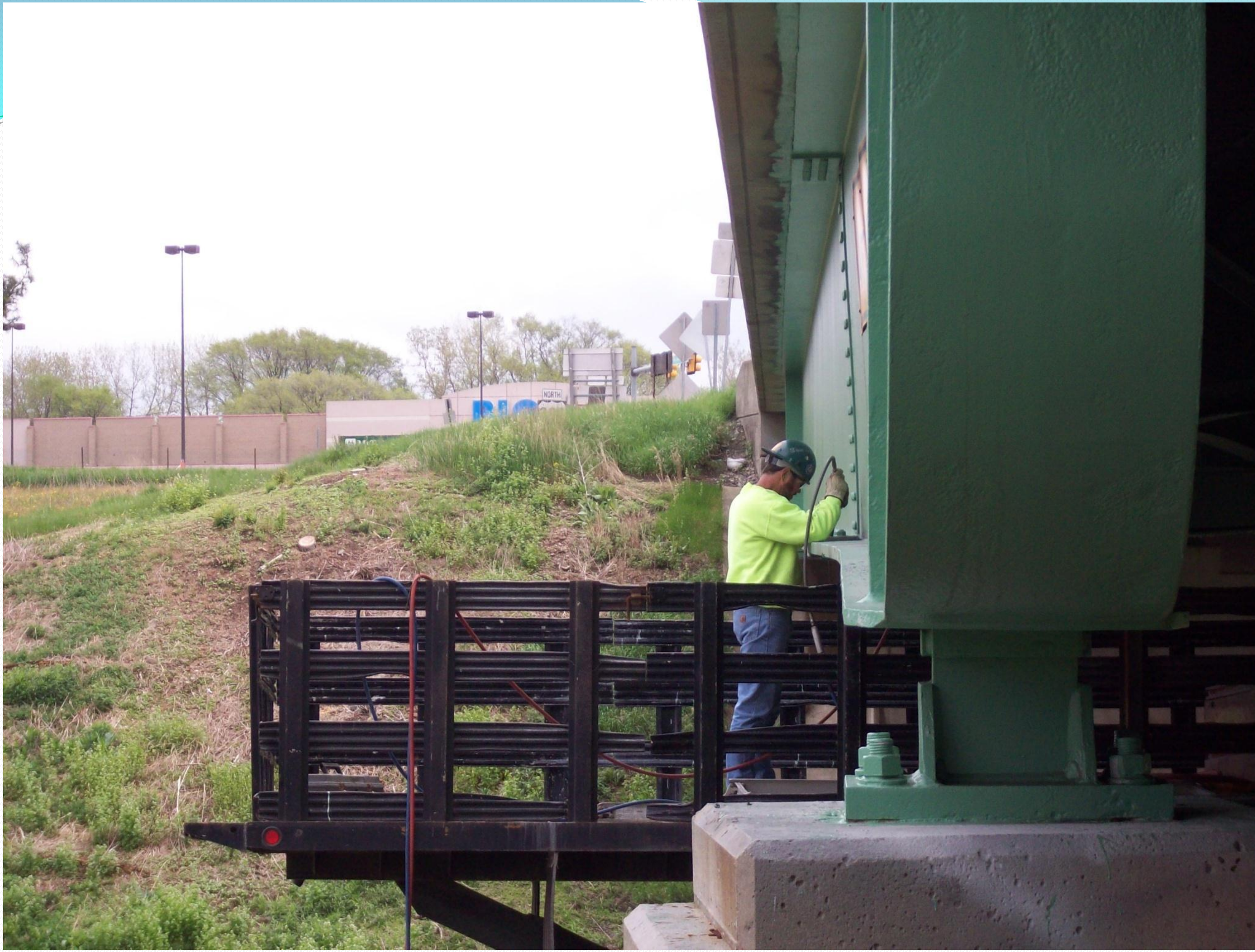
$$\text{STRAIN RATIO} = \frac{\varepsilon_{MAX}}{\varepsilon_y} \leq 100$$

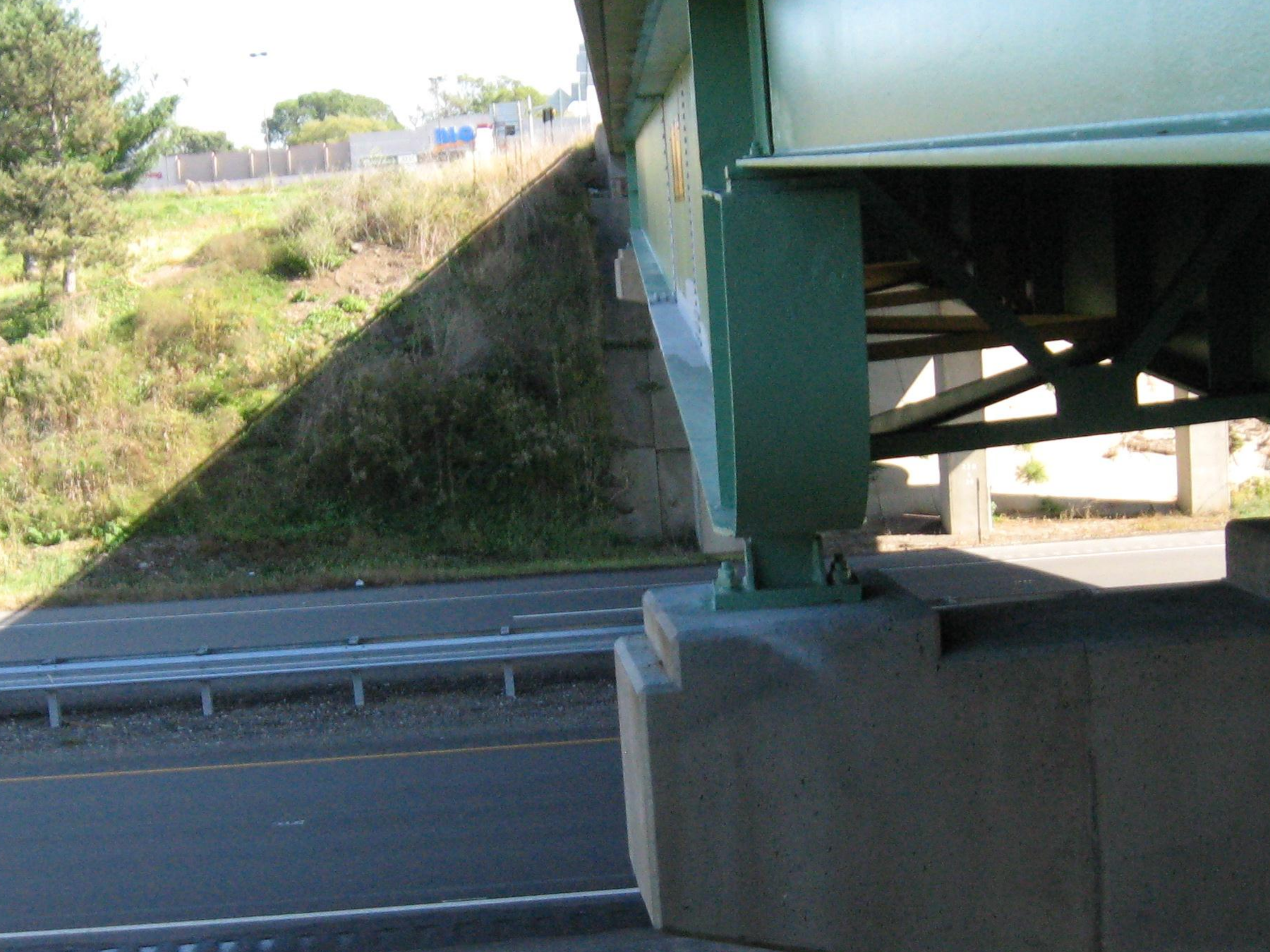
Determination of Jacking Load

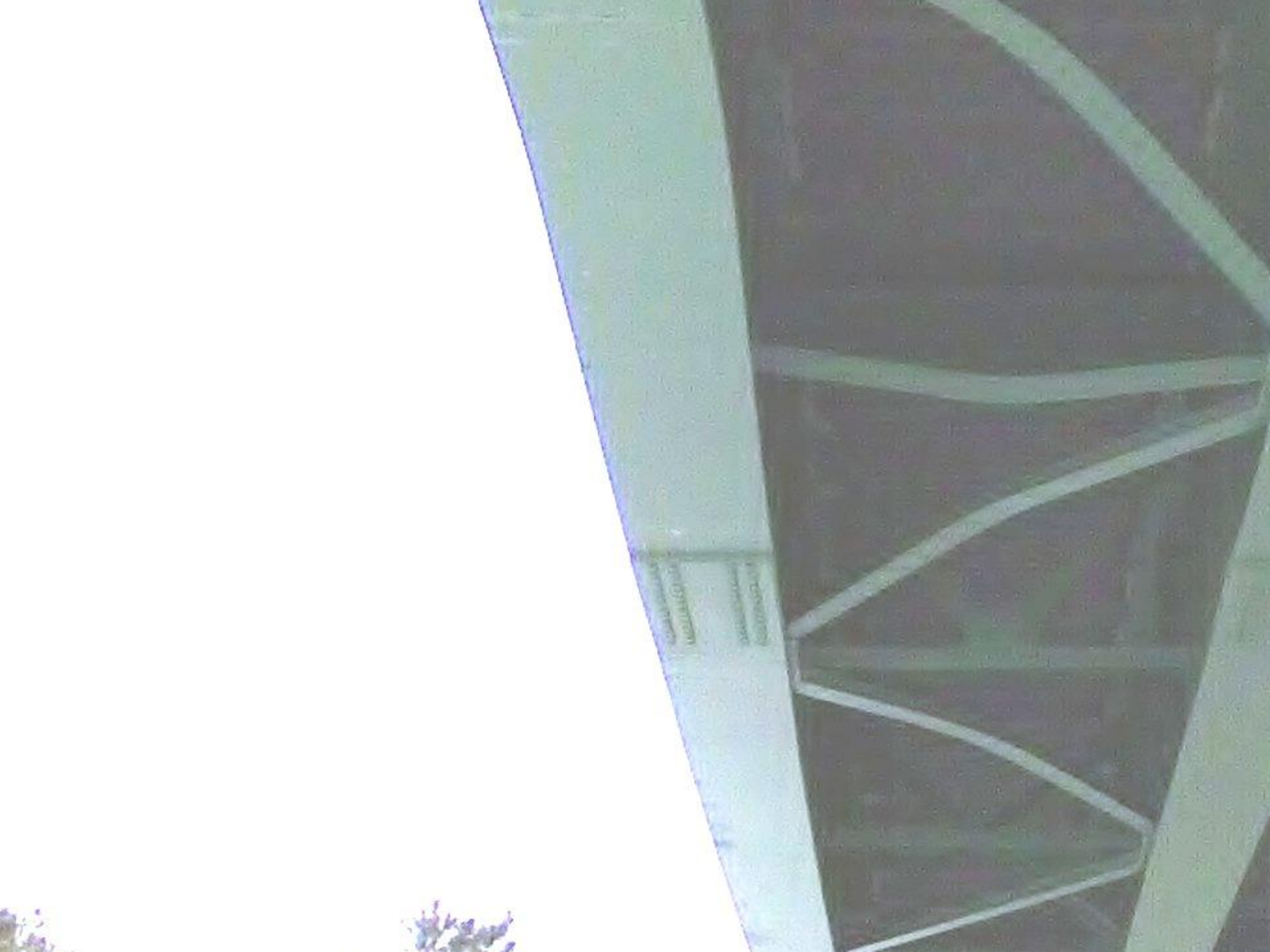
- P_j Jacking Force

$$\frac{P_j}{P_u} = \frac{M_j}{M_u}$$

WHERE $M_j = 0.5 M_p$


NORTH

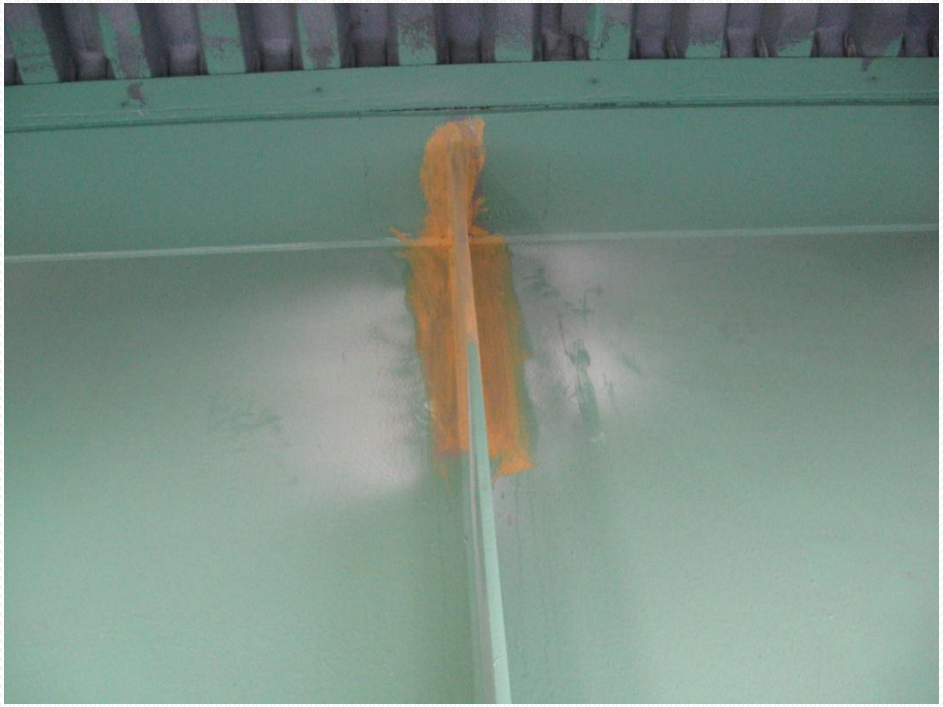




Stiffener 5 Bottom

Stiffener 5 Top

Stiffener 6 Top



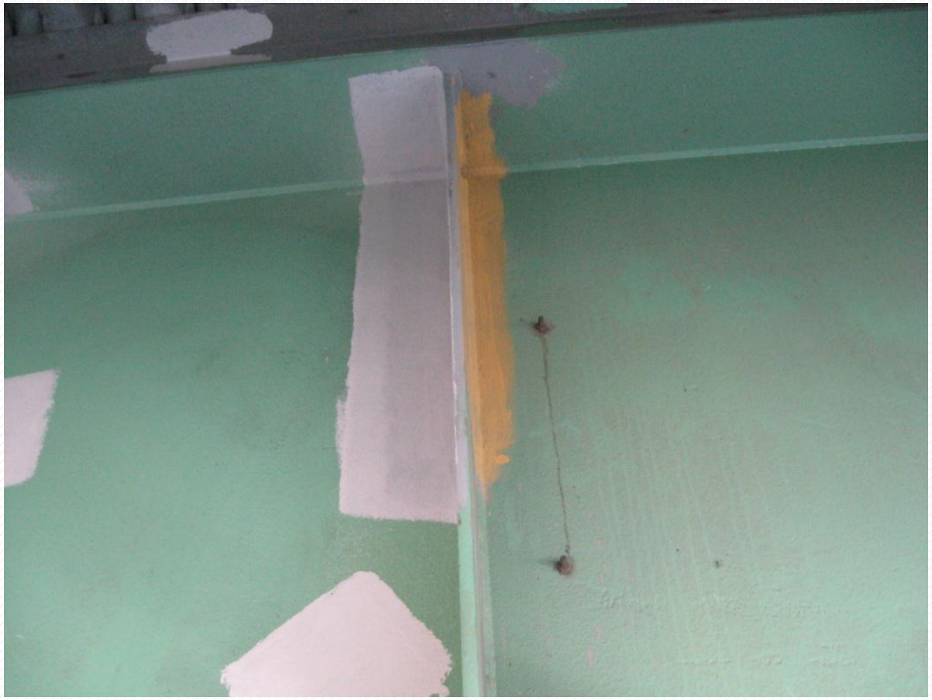
Stiffener 7 Top

Stiffener 8 Bottom

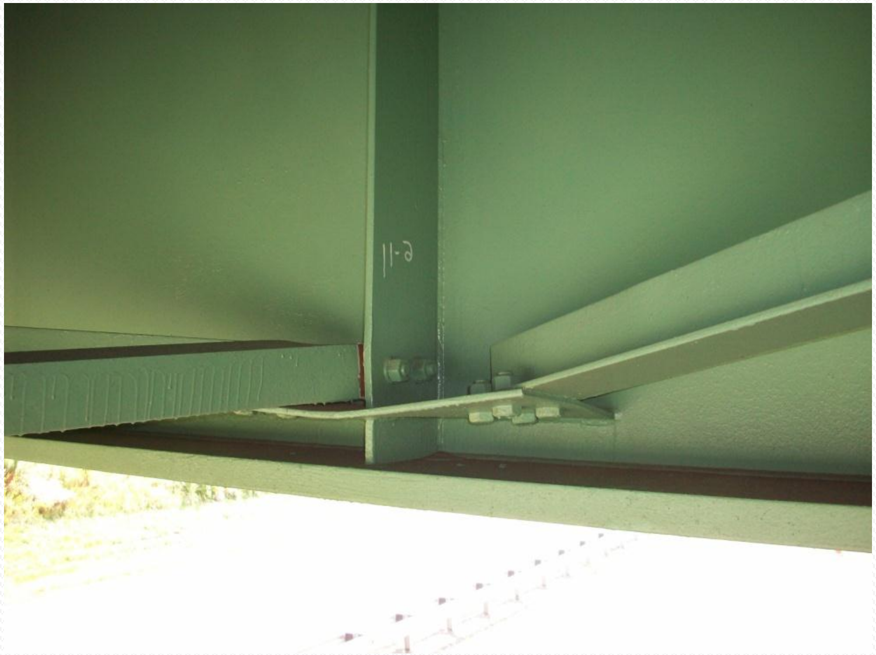
Stiffener 8 Top

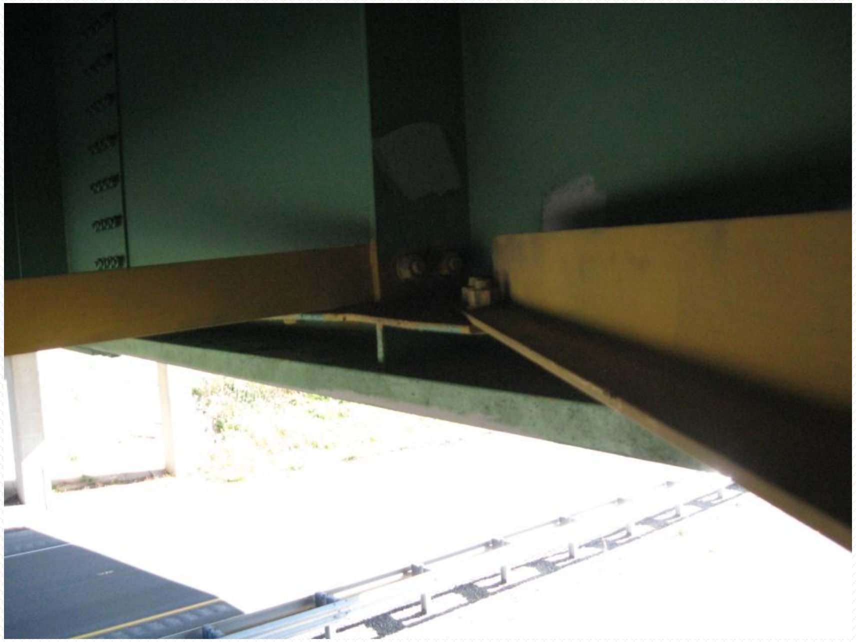
Stiffener 9 Top

Stiffener 10 Top



Stiffener 11 Bottom





Stiffener 11 Top

Stiffener 12 Top

Stiffener 13 Top

Not Always Appropriate


ANCE
IN


14 FT


CLEARANCE
14 FT IN

Questions?