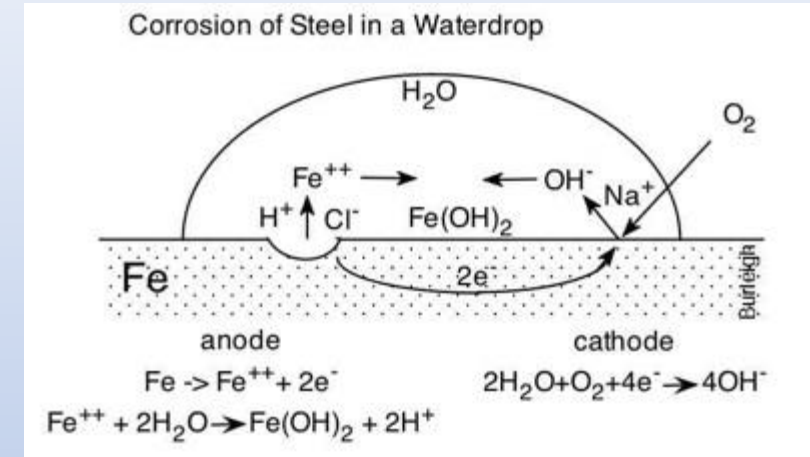


Structural Corrosion Issues in Aggregate Processing Plants

By: Larry Deem, PE

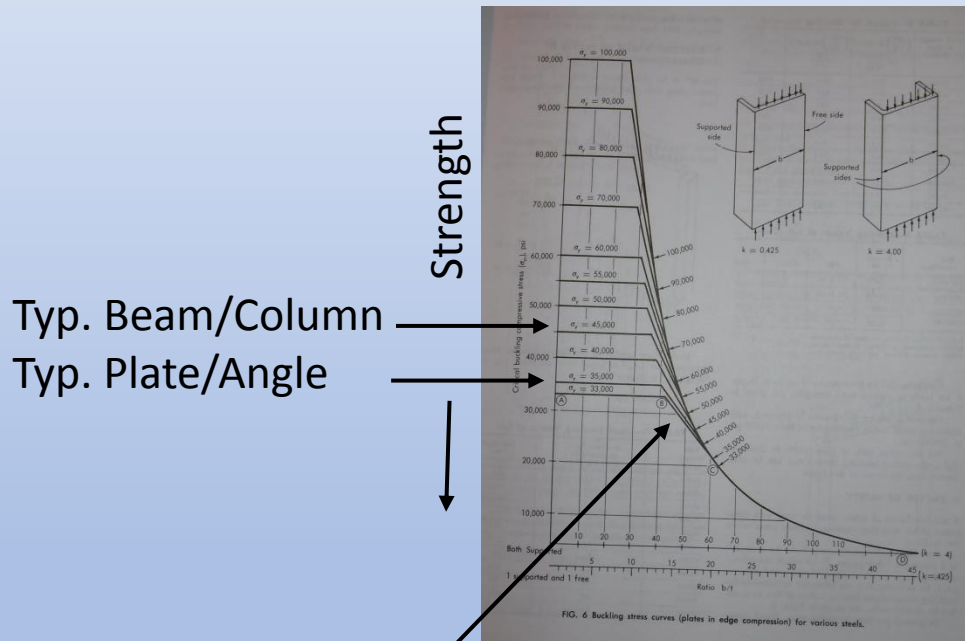
Corrosion – Why Does It Happen

- Steel corrosion or rust is chemical process that requires the presence of a water and oxygen in contact with the steel.
- Key Points
 - Protection of steel from water and oxygen prevents rust. Low pH water will accelerate the corrosion process.
 - Sacrificial coating (HDG) protect surface and will corrode in place of the steel if the surface is damaged. Repair methods ASTM A780.
 - Cathodic protection of damaged area limited to damage less than ¼" wide but length is not limited.
 - Isolation between HDG and nongalvanized steel. Paint, rubber strips, etc.
 - Weathering steel (Cor-Ten) – unique advantages and disadvantages. Understand both before using.
 - Rust is six times the volume of base steel



Structural Basics – Buckling – Compressive Loads

- Buckling failures are critical because they can happen suddenly and with little warning.
- Allowable strength for buckling is a function of the width to thickness ratio for each part of a member. When flanges or webs thin from rust they become more likely to buckle.



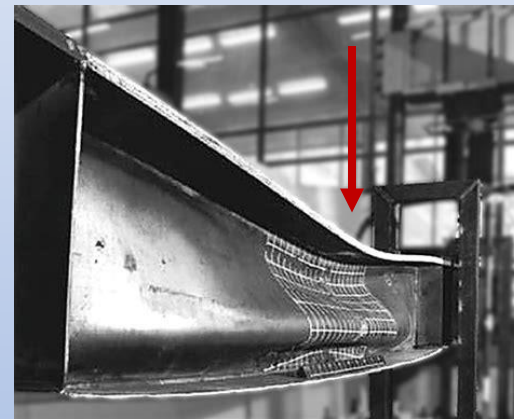
Typ. Beam/Column
Typ. Plate/Angle

Strength

Width/Thickness →

Typical Buckling Strength Chart

Strength no longer depends on original steel strength



Localized Web Buckling Concentrated Loads



Overall Column/Brace Buckling Axial Load

Structural Basics - Trusses

Top and Bottom Chords

Bracing

Connections



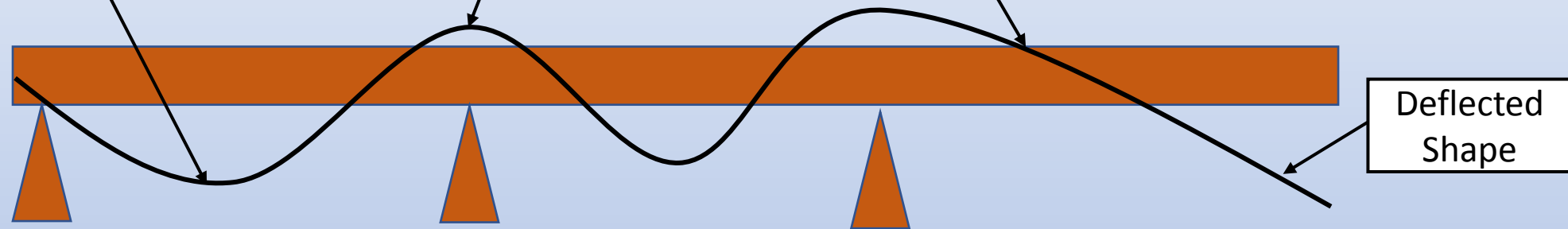
Bent Legs / Anchorage

Trusses

Top in Compression
Bottom in Tension

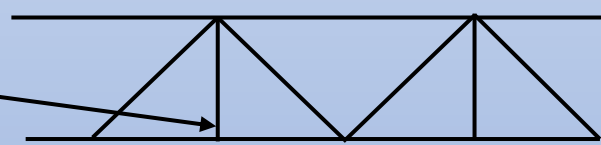
Top in Tension
Bottom in Compression

Tension and compression loads in chords may be higher over supports than between supports.



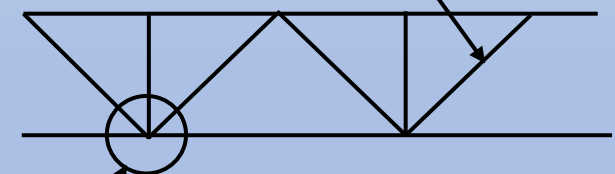
Deflected Shape

Horizontal braces on the compression side of truss are critical to preventing the chord from buckling



Plan View

Diagonals may be in compression or tension



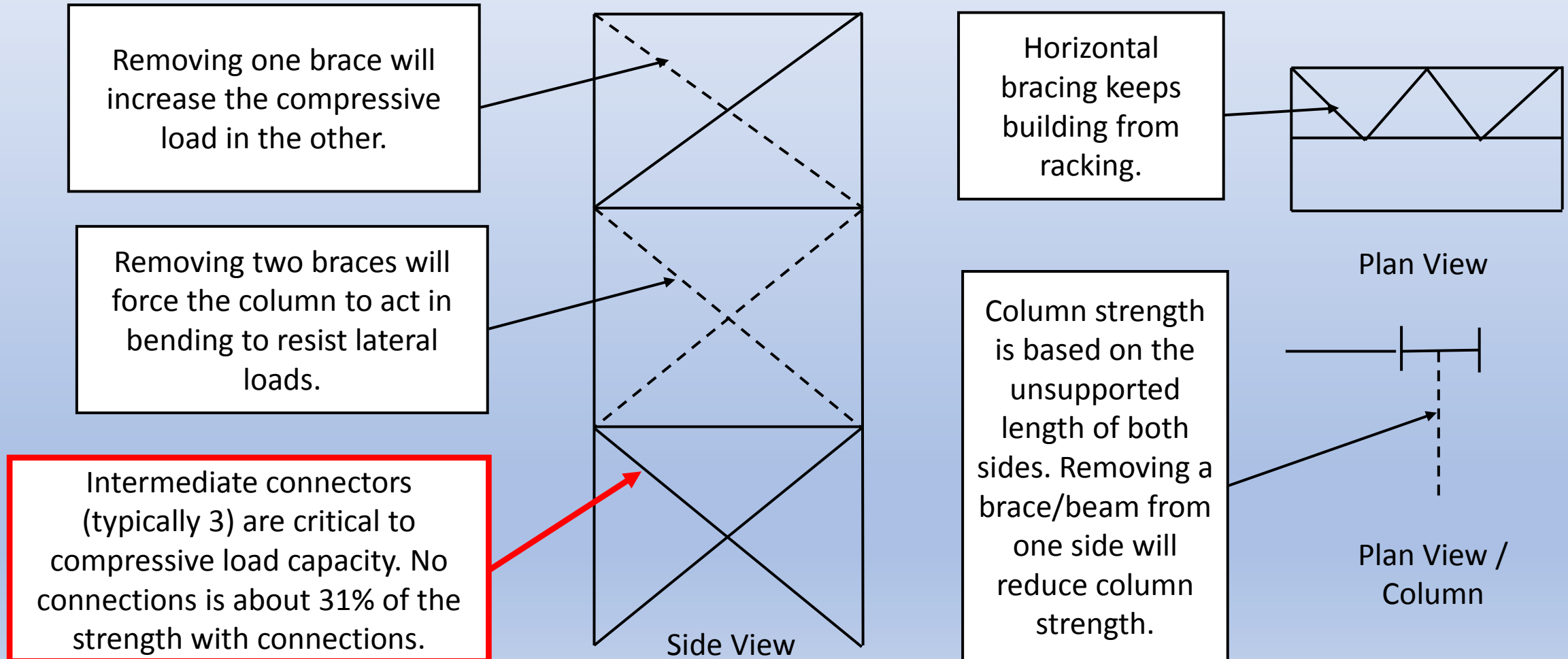
Side View

Connections must tie diagonals and chord

Typical 4x4 Angle	Capacity
4' span	50.5 kip
8' span	27.7 kip
Reduction	45 %

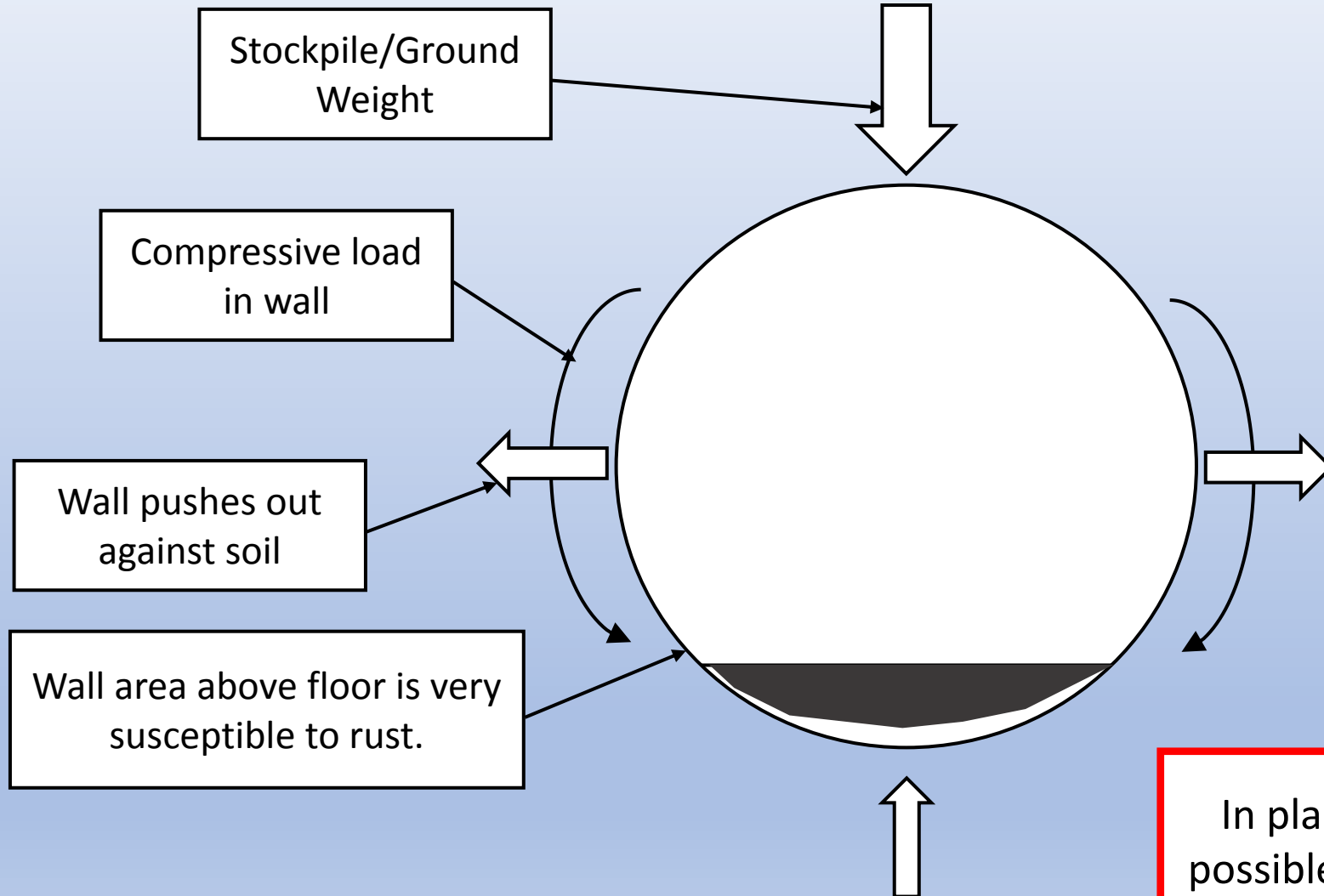
Structural Basics – Braced Frames

- Bracing provides lateral strength for wind, seismic, equipment, conveyor loads, etc.



Steel Reclaim Tunnels

NCSPA Corrugated Steel Pipe Design Manual
NCSPA Design Data Sheet 19 – Evaluation Criteria



Pipe shape is important when evaluating an existing tunnel. Measuring the shape after installation will provide historical reference for future checks.

Factory applied coatings are very inexpensive and can provide protection to the underlying galvanizing. Coat both sides full circumference.

Mastic seal concrete floor to tunnel wall joint.

In place structural repair of failed pipe is possible but requires assessment of existing conditions and engineering evaluation.

Evaluating Structures

- Before starting.
 - Establish evaluation criteria and be consistent
 - A – no to 10% section loss
 - B – 10 to 30% section loss, etc.
 - Grade connections, look for broken welds
 - ACI provides guidance in ACI 201.1R or Army Corps EM1110-2-2002 for concrete
 - Consider how important a member's function is when evaluating
 - Personnel safety – ladders, walkway, handrail etc.
 - Equipment – drive supports, primary structural members, etc.
 - Have the right equipment
 - Chipping hammer, 2 lbs sledge, vernier caliper, measuring tape, flashlight, camera etc.
 - Print any drawings to help with note taking
- During Inspection
 - Start at one place and work in a constant direction.
 - Take lots of pictures and notes. Record the time in notes and location so you can later find relevant pictures.
 - Comprehensive inspection requires being able to physically touch the member being inspected.
 - Clean off packed fines
- Write reports as soon as possible after the inspection.

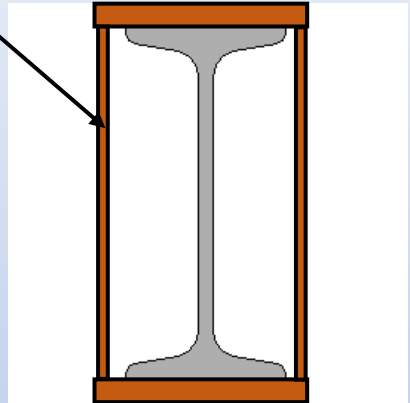
Interpreting Inspection Results

- Making an accurate determination of remaining service life or suitability for intended purpose can be difficult.
 - Rate of section loss should not be based on one inspection.
 - 10% loss of section does not always equal 10% reduced strength.
- Just because it works now doesn't mean the structure meets an adequate safety margin.
- Unusual or infrequent loads need to be considered when evaluating the adequacy of existing structures. Such loads can be high winds, plugged chutes, increased conveyor pulls, impact from equipment, ice accumulation, etc.

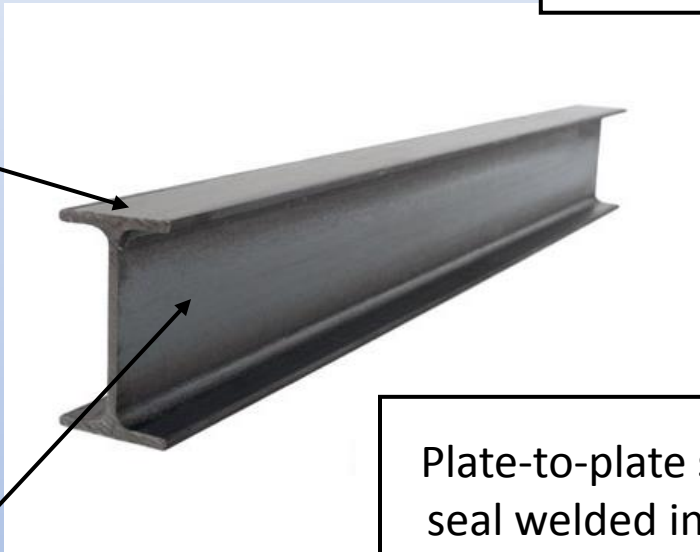
Actual Screening Tower		
Column Drawing Load	Calculated Column Strength	Difference
255 kip	273 kip	7%
116 kip	132 kip	14%

Common Repairs – Steel

Boxing beams and columns can be effective but should be engineered. Enclosed voids can rust from the inside if not properly sealed.

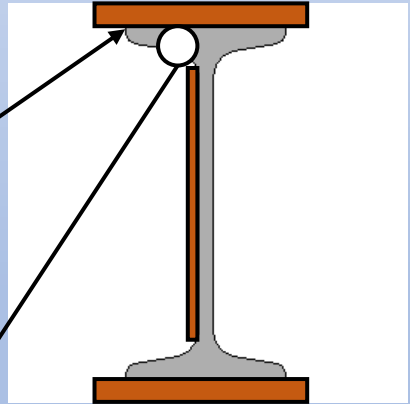


Flange Plates, extend well past damaged area. Splices in plate should be full penetration welds



Web Plates, weld between top and bottom of plate to flange is critical.

Plate-to-plate surfaces should be seal welded in addition to welds required for strength.

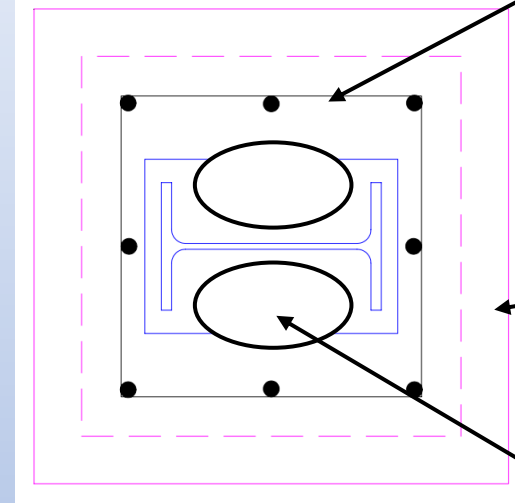


Particular concern when flange is plated and there is a gap between flange and web plate

Anchor Bolts

Typically used for columns with large uplift.

Welding anchor bolts to base plates is not recommend. Most anchor rod material is not easily weldable.



Typical Column

Typical rebar layout in pedestal. Edge of original concrete to tie 1.5" to 2". Tie ~1/2". Main vertical bars inside ties.

Watch for pedestals that have been encased in new concrete for repair.

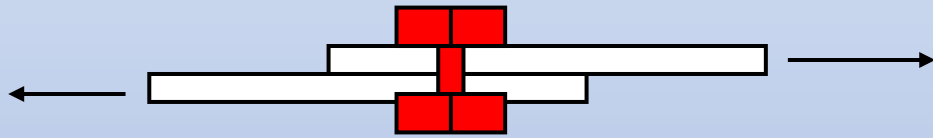
Area usually clear for adding new anchor bolts.

Adhesive Anchor – Importance of Hole Cleaning – Summary of Published Research

Proper Installation	Improper Installation	Difference
10 kip	4.2 kip (no clean)	58 %
10.8 kip	7.6 kip (brush only)	30 %

Bolted Connections

- Common to see heavy corroded bolts.
- Generally safe to remove and replace one bolt at a time but connections with few bolts or heavily loaded in tension need engineering evaluation.
 - Generally body of the bolt inside the connection remains sound.



- Two main types of bolted connections
 - Bearing style – bolt body bears on sides of bolt hole to resist the load. Common in structural connections.
 - Slip-Critical or Pretension style – bolt tension creates clamping force and load is resisted by friction between surfaces. Common for cyclic loading, equipment and oversize/long slotted holes.

ASTM (A325 or A490) bolts are not the same as SAE (Grade 5 or Grade 8) bolts and should not be substituted.

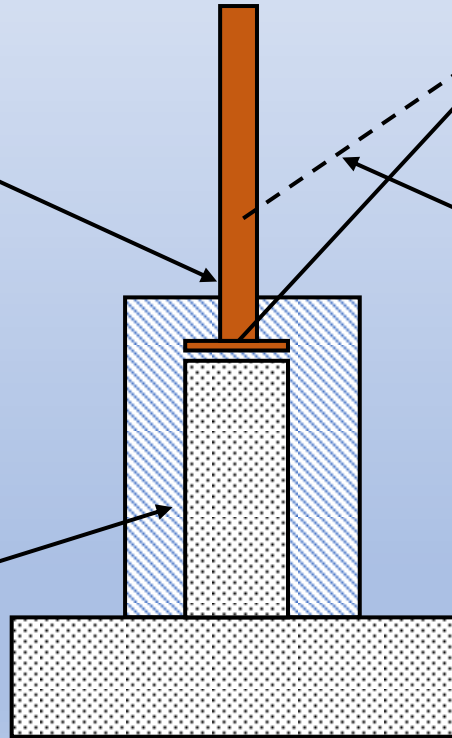


Foundation Repairs

Clean and zinc rich prime steel to concrete interface. Slope concrete away from steel and add mastic to seal gap.

Encasement With Concrete

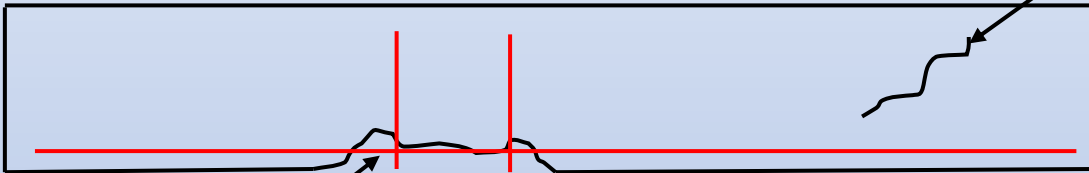
- Does not replace damaged rebar or anchor bolts
- Need to consider effect of added weight, especially on clay soils
- Use air entrained concrete with correct water/cement ratio



Moving up braces can greatly increase overturning moment on the foundation and should be evaluated by an engineer.

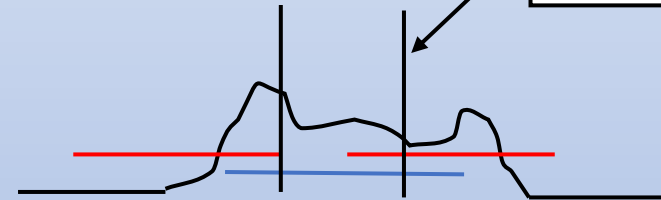
Common Concrete Repair

- ACI 562 and EM 1110-2-2002 (Army Corps)



Consider epoxy injection for cracks

Do not overlook repairing stirrups and ties



- Clean with high pressure water jet
- Remove rust and zinc rich prime rebar.
- Use appropriate repair concrete for conditions and depth of repair.
- Use bonding agents where possible.

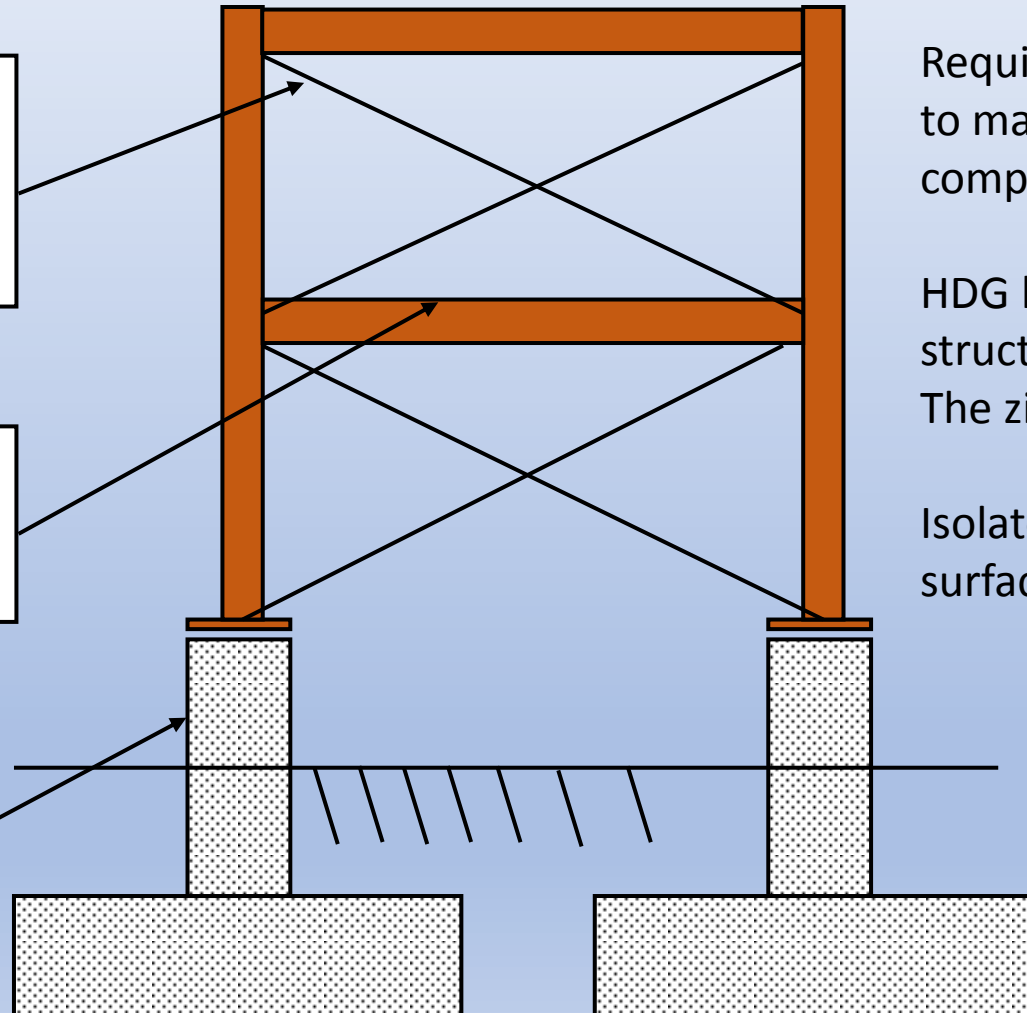
Rebars must have enough embedment length to develop the required strength. Lapping a new rebar next to a damaged one will probably not work. Welding rebar requires special procedure AWS D1.4. Mechanical connectors may work.

Design Stage Suggestions

Use 5/16" or heavier angles with 1/2" gusset plates. Consider single leg wide flange or enclosed pipe in place of double angle.

Crown or slope concrete floors for drainage.

- Increase concrete clear cover to 2.5 to 3" on all concrete.
- Use tall pedestals to keep steel further above grade.



Repair all damaged paint or HDG coating after construction.

Require minimal field fabrication to maximize shop painting or HDG component size.

HDG bolts in steel or paint structures are not recommended. The zinc will be quickly used up.

Isolate bare steel from HDG surfaces.

Questions?