

# ***Structural Failures Cost Lives and Time***



Recent failures of storage bins, silos and other structures highlight the need to increase awareness of hazards associated with these structures. Since 2010, one miner was killed when a storage bin collapsed; another miner was killed when the concrete silo he was standing on collapsed. These deaths and several near misses are alarming. Careful examination and prompt correction of hazards are essential to maintaining these structures. These occurrences can be greatly reduced by utilizing the following best practices.

- Examine structures for indications of damaged, weakened or displaced structural elements, bulging or deformed bin sides or tops, gapped joints, cracked or broken concrete, corroded or fatigue-cracked metal, bent or buckling columns, beams or braces, loose or missing connectors, cracked, broken or inadequate welds, etc.
- Inspect structural elements for reduced load-carrying capacity, thinned or missing sections of beam and column webs or flanges, corroded rusted or flaked metal surfaces, delaminated plywood or water-weakened wooden structures.
- Clean accumulations of material from around the base of structures and flanges of horizontal beams. Carefully inspect for damaged support columns, braces, anchor bolts and eroded foundations.
- Report all areas where indications of structural weakness are found.
- Protect lower level structural elements from collision damage by mobile equipment.
- Minimize spillage and eliminate the source promptly.
- New structures should be designed and certified as appropriate by a registered professional engineer in accordance with local building codes and in conformance with accepted engineering practices. Significant modifications to existing structures should be undertaken only after consultation with an engineer. Structures should be constructed according to plans and specifications by trained workers using good materials and employing generally accepted construction methods.

***Report Structural Damage or Deterioration  
To Your Supervisor***



# Structural Inspection of Processing Plants

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# Structural Condition Assessments



# Structural Materials

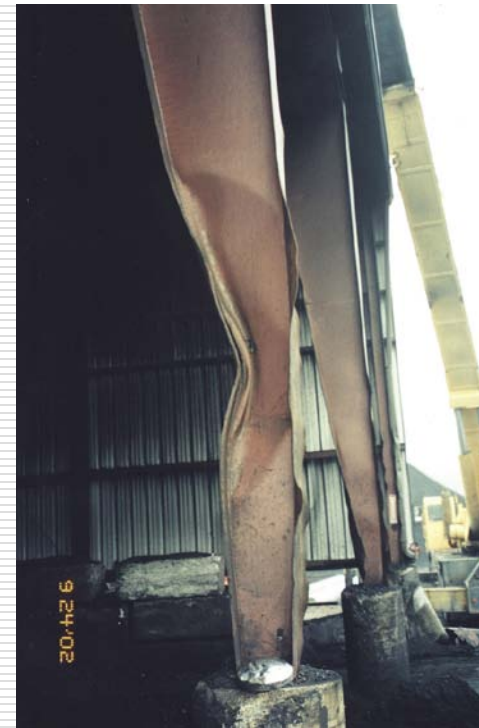
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- Steel
- Concrete (plain, reinforced, pre-stressed)
- Timber
- Other - Masonry, Aluminum, Fiber-Reinforced Polymer (FRP), etc.

# Inspecting Structural Steel

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- ❑ Corrosion  
(holes, delamination & loss of cross section)
- ❑ Cracking (overload & fatigue)
- ❑ Overloads (buckling & deflection)
- ❑ Member Impact Damage





# Corrosion holes & delamination



# Reinforced Concrete

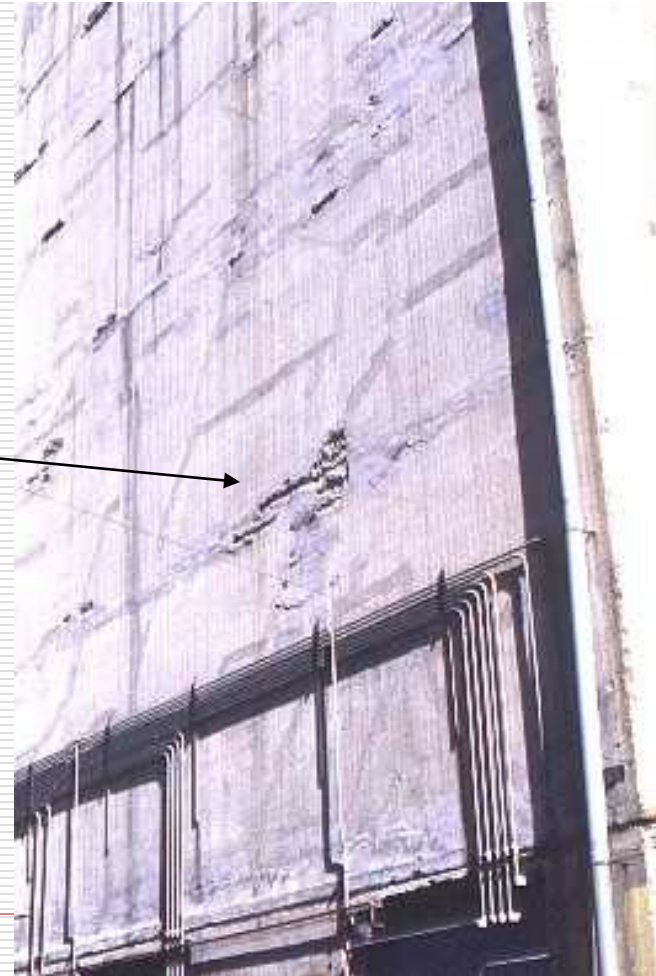
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- Concrete is strong in compression but weak in tension. Rebar is introduced so that steel, which is strong in tension, can carry the tensile load while concrete carries the compressive load.

# Inspecting Concrete Structures

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- ❑ Cracking
- ❑ Delamination  
(Internal Splitting -  
Silos)
- ❑ Spalling
- ❑ Rebar Corrosion
- ❑ Crushing
- ❑ Impact Damage





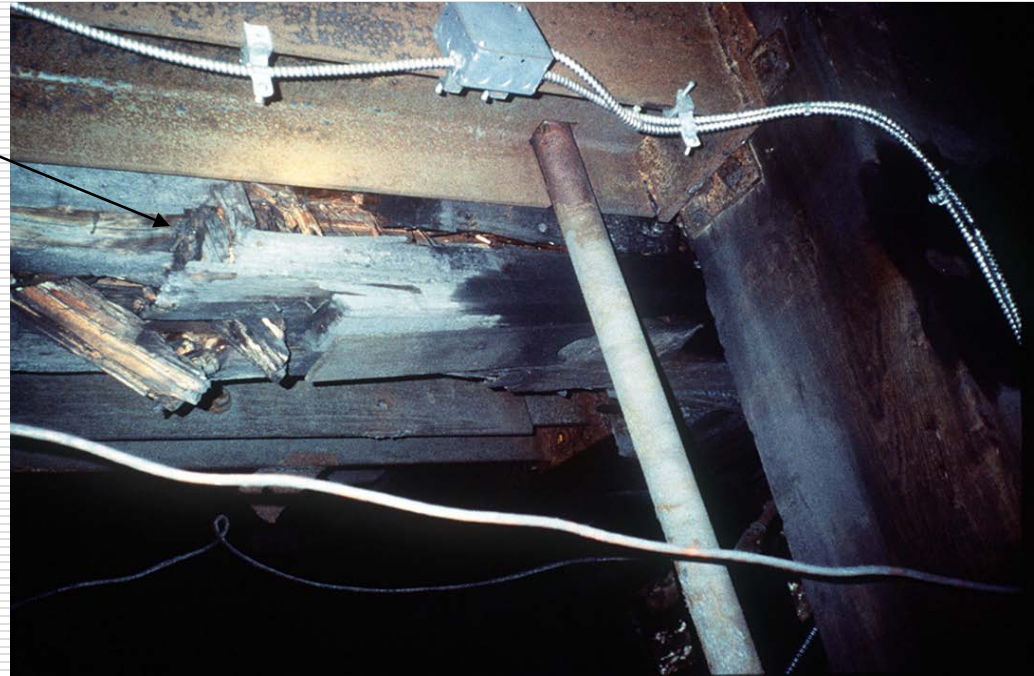
# Spalling & Corrosion from Exposure to Chemicals



# Inspecting Timber Structures

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- ❑ Cracking
- ❑ Deflection / Sag
- ❑ Crushing
- ❑ Fungi - molds, rot, dry rot
- ❑ Wood Boring  
Insect Damage



# Inspection Tools

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- Cleaning
  - chipping hammer, wire brush
- Inspection
  - chipping hammer, screw driver or ice-pick, plumb bob, flashlight, binoculars
- Measuring – tape, calipers, ultrasound, level
- Safety & Misc. - safety harness, dust mask, compass

**MNM Surface - 56.11001**

**MNM Underground – 57.11001**

**Safe Access**

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- Safe means of access shall be provided and maintained to all working places.



MNM Surface - 56.14100

MNM Underground – 57.14100

Machinery & Equipment – Safety Defects

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- b) Defects on any equipment, machinery, and tools that affect safety shall be corrected in a timely manner to prevent the creation of a hazard to persons.

MNM Surface -56.14205

MNM Underground -57.14205

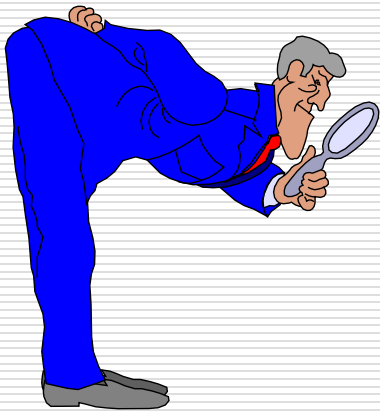
Machinery, Equipment, & Tools

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- Machinery, equipment, and tools shall not be used beyond the design capacity intended by the manufacturer where such use may create a hazard to persons.

# Inspection of Processing Plants

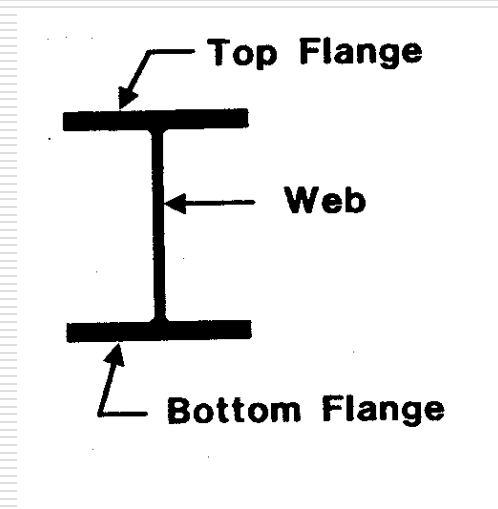
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# Beams - Bending & Shear Resistance

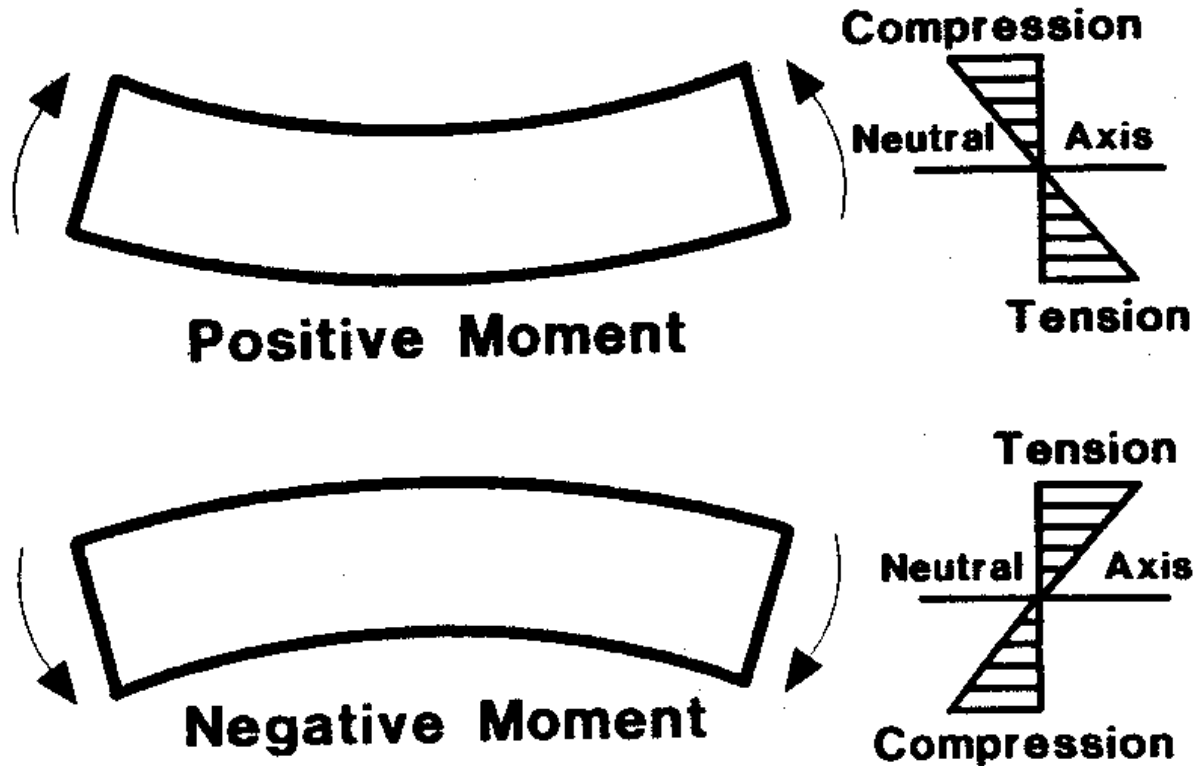
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- Beams and girders are common members used to resist bending moments and shearing forces. Bending is resisted by flanges; shear is resisted by web.



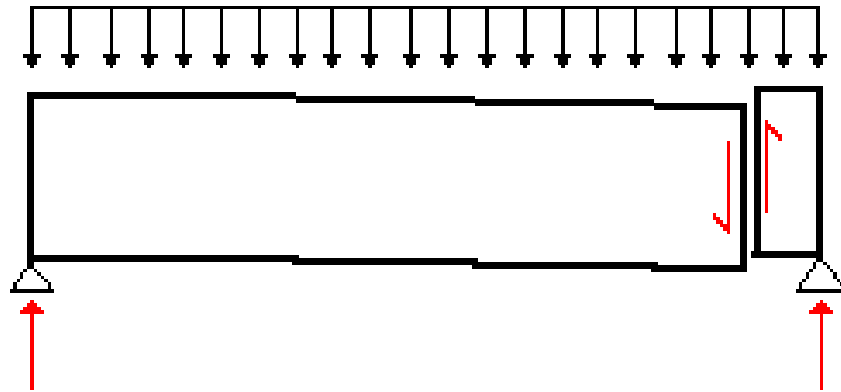


# Bending Moment



# Shear Force

- Equal (magnitude) but opposite (direction) forces which tend to slide one section of a member past an adjacent section.



# Corroded web of wide flange beam



# Long corrosion hole at web to flange interface





This beam was still standing (?)



# Corrosion hole in web of beam (hidden by piping)

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# Corrosion holes in web of beam



# Corroded web @ end of beam



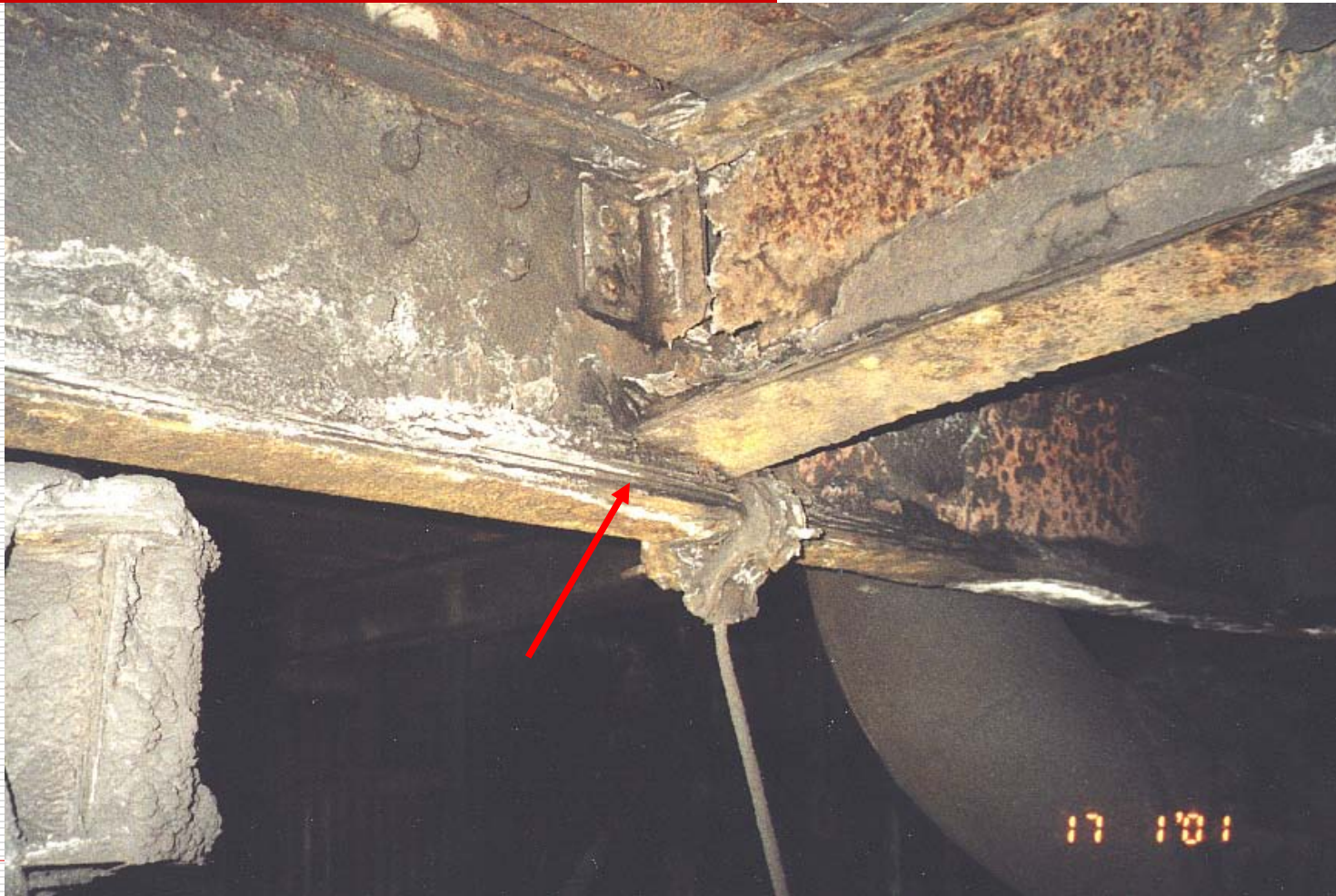


# Corrosion hole in web & buckled top flange





# Heavy delamination of bottom flange



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# Buckled web





# Buckled webs of corroded channels

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# Beam modifications need engineered!





# Columns



Buckled column flanges @ web corrosion hole 29



# Corrosion hole in web of column



Buckled flanges at bottom of column @ corrosion hole





# Repaired column base (appears good)



# Bad Repair At Column Base

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# Another Bad Column Repair (base)

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... a few feet up from base

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# Rotted timber column



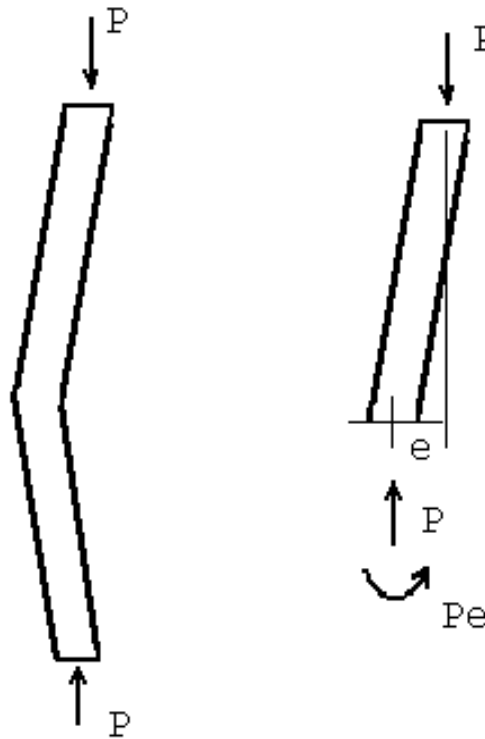


An equipment mishap – these types of repairs can be evaluated by an engineer



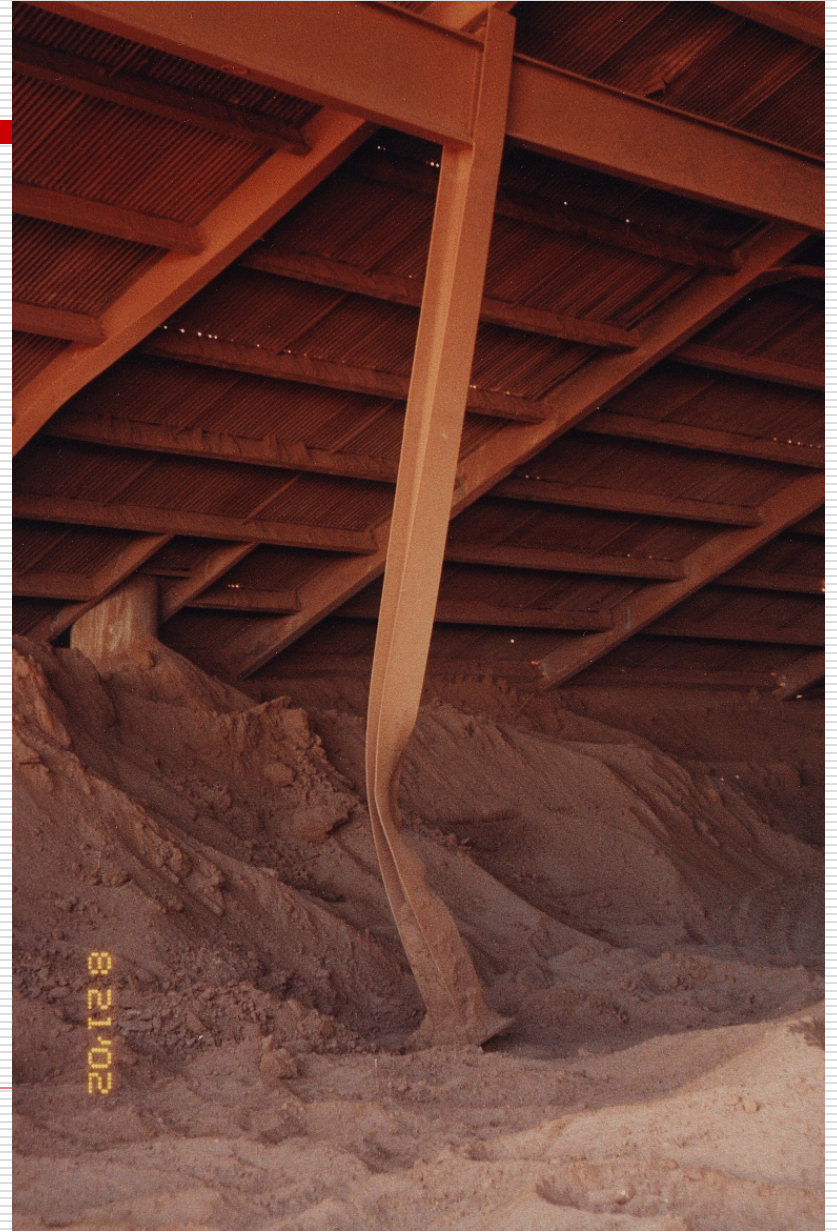
# Crooked Column (creation of moment)

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# Severe equipment damage

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Replacement time!

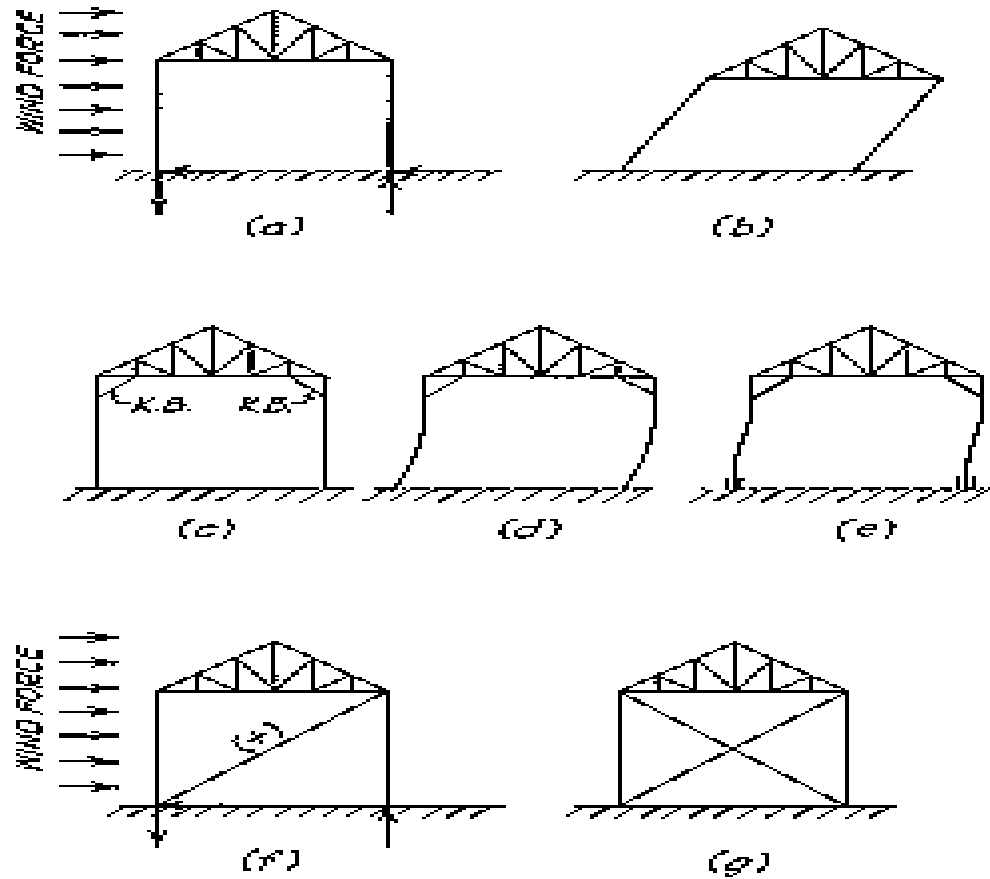




# Inspect the column foundations



# Don't take the bracings out!

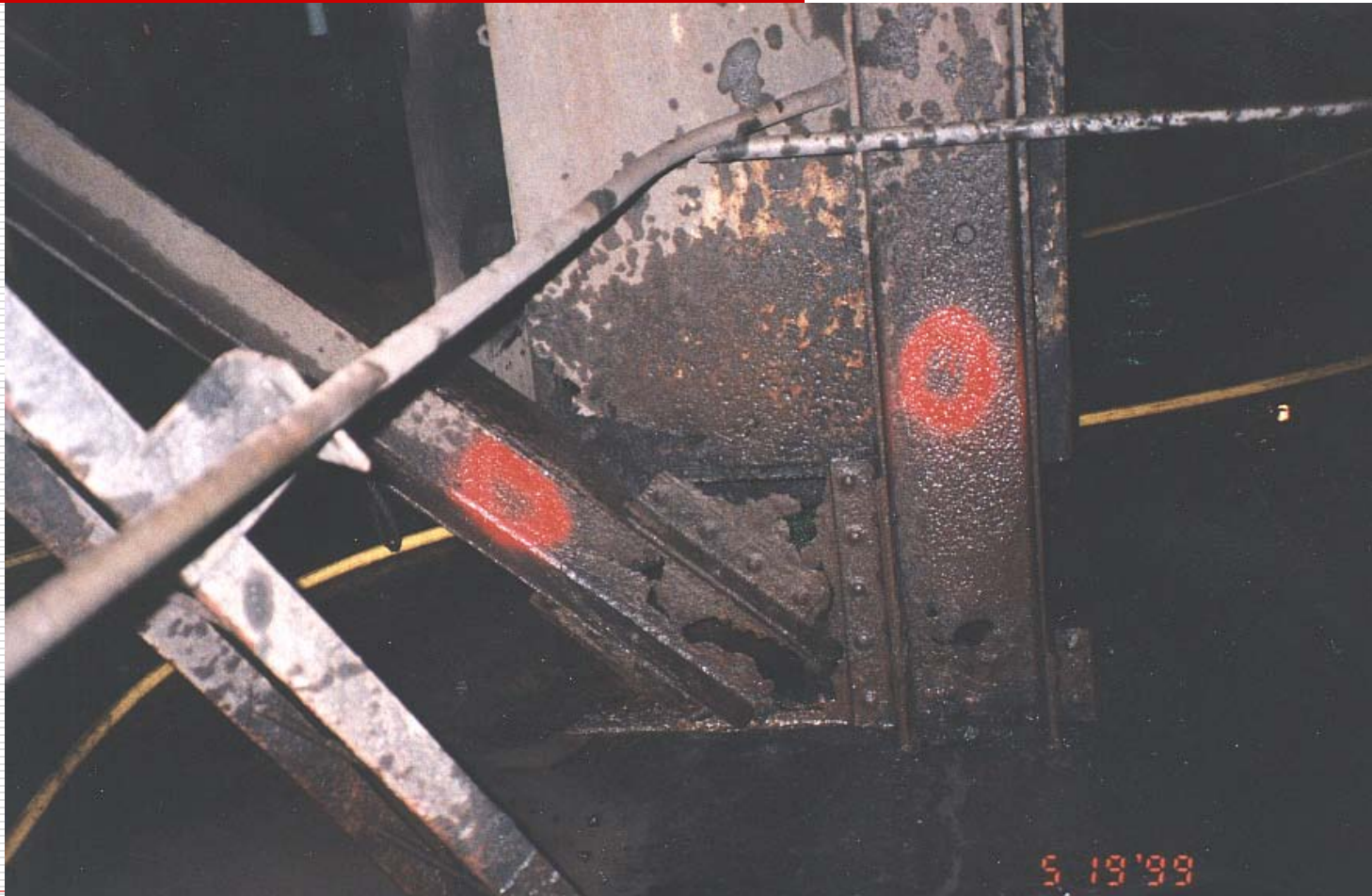




# Corroded diagonal brace



# Corroded diagonal and gusset plate





# Corroded diagonal





# Corroded channels/girts supporting the siding

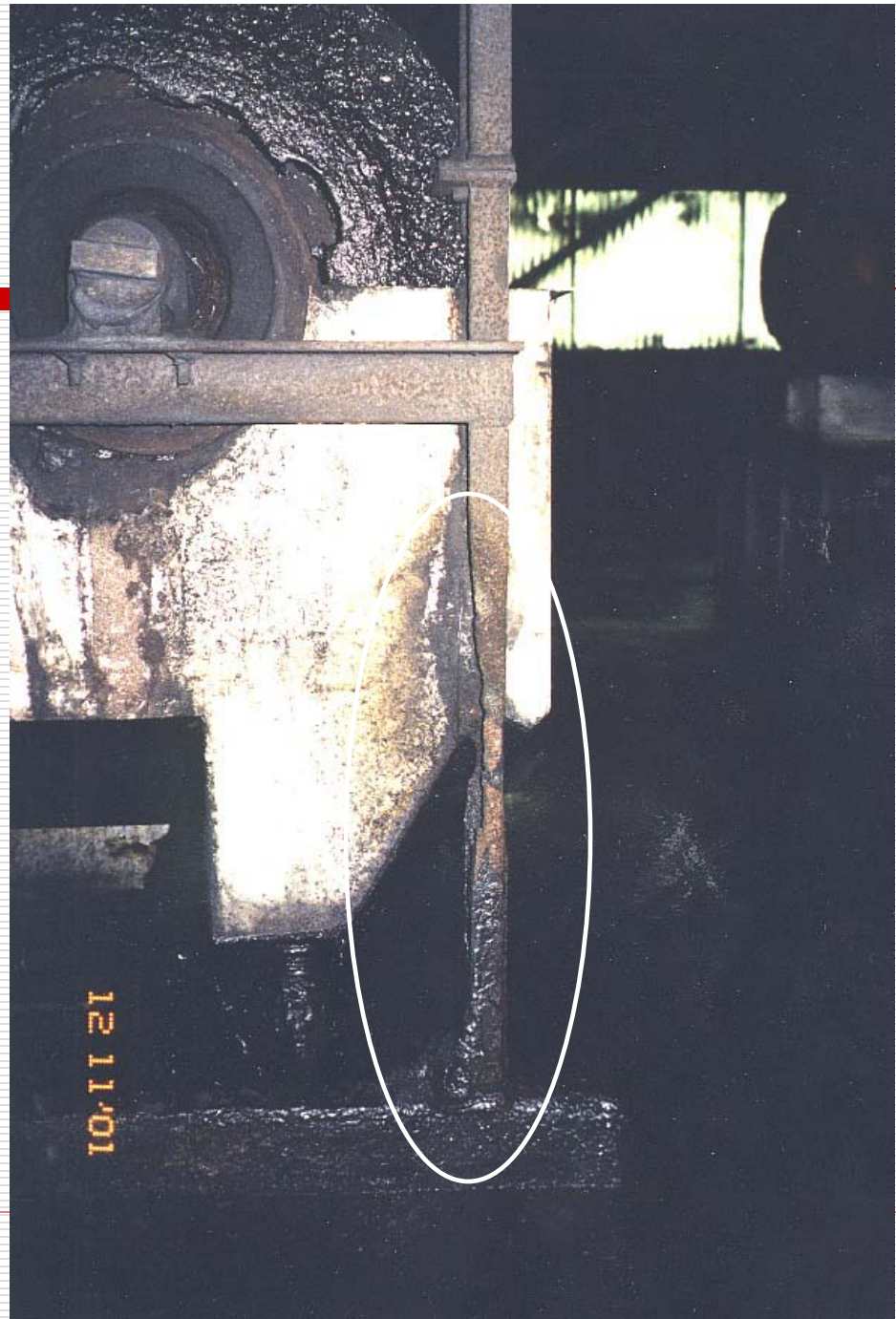


Check equipment supports! Corrosion hole in channel post for a magnetic separator



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Corroded channel  
post support for a  
magnetic  
separator



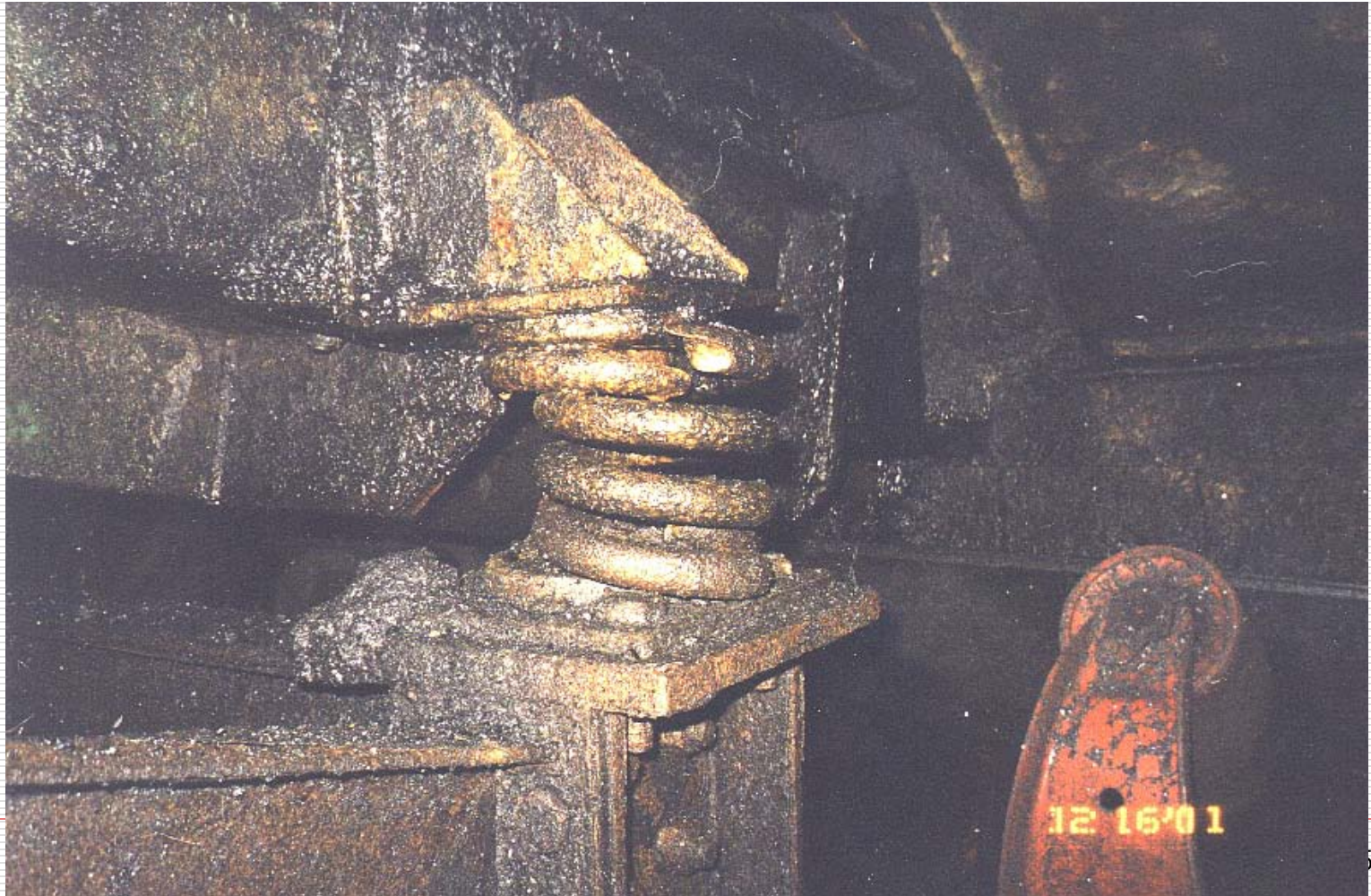


# Crack in a support beam for a shaker screen



# Fractured spring support for vibrating equipment

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# Deteriorated concrete flooring





# Floor slab cracks - a potential source of rebar corrosion





Look at floor grating - corrosion @ supports





# Corrosion at support edge of grating









# Corroded stair channels



# Corroded angle supporting stair tread





Don't forget to check the handrails!



# Corrosion holes in handrail support post





# Heavy Roof Loading

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# Roof Collapse Due to Clinker Buildup and Snow Load

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# Inside of Failed Structure

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Collapsing Roof Support Purlins



# Corrosion of bottom flange of roof support channel





Buckled Vertical Roof Truss Member



# Bolted Connections

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- Check tightness
- Look for
  - missing bolts
  - sheared bolts
  - elongated bolts
  - excessive corrosion

Inspect connections! Corroded bolt heads





# Welded Connections

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- cracked welds
- poor quality - irregular surface
- corrosion in connected parts
- Always use qualified welders

# Fractured weld @ connection



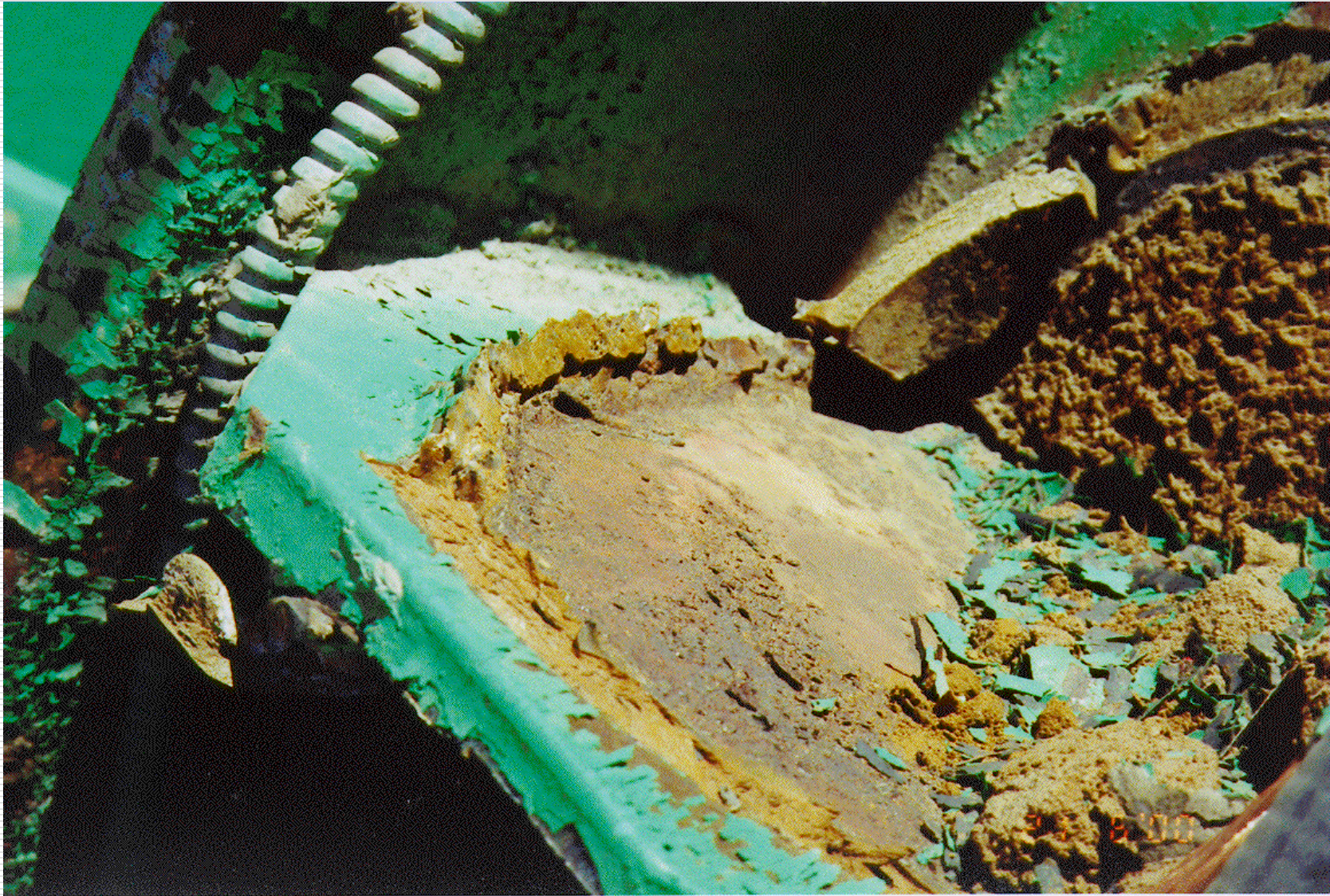


# Vibrating equipment - fracture & poor quality weld





# Irregular weld surface w/porosity





Exposed rebar on the side of a concrete settling tank



# Collapsed floor – Avoid this!





Plant collapses can be costly.



# Recap - Inspection of Processing Plants

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- ❑ Check the beams, columns, diagonal braces
- ❑ Examine members for buckling, corrosion, damage, excessive sag, holes, local buckling, and cracking.
- ❑ Examine connections for corrosion, missing or cracked elements
- ❑ Examine floors, roofs, walls, & foundation
- ❑ Examine equipment supports, stairways, & handrails