Steel Corrugated Grain Bins

Tuesday, July 23, 2013, 1:50 p.m.

Rob Danielson
Associate Engineer
Haag Engineering
Burnsville, Minn.

Robert Danielson is an associate engineer at Haag Engineering Co. in Burnsville, Minnesota, and is licensed as a professional civil engineer in Arkansas, Colorado, Florida, Illinois, Iowa, Louisiana, Minnesota, Missouri, Nebraska, North Dakota, Oklahoma, South Dakota, Texas, and Wisconsin. Rob is currently a member of the American Society of Agricultural and Biological Engineers and the American Society of Civil Engineers.

Rob has been with Haag Engineering since 2009. His primary areas of consulting are structural evaluations, construction-related failure and damage assessments, and wind engineering issues and related storm effects for agricultural and single- and multi-family buildings as well as light-framed commercial buildings. He helps develop and present continuing education seminars as an instructor for Haag.

He graduated from Texas A&M University with a Bachelor of Science in agricultural engineering.

Session Description:
This session will provide an introduction to steel corrugated grain bin terminology, along with the basic operation of these types of bins. Attendees will learn how to identify common problems associated with steel corrugated grain bins, as well as some of the typical failures associated with grain bin operations and storm effects.

Top Three Session Ideas

Tools or tips you learned from this session and can apply back at the office.

1. _____

2. _____

3. _____

Steel Corrugated Grain Bins

Session Outline

Overview

Introduction to Steel Corrugated Grain Bins (Silos)

- Where Found
- Typical Grains
- Protects Commodities
- Moisture Content
- Galvanized-Steel Panels
- Corrugated Profiles
- On-Center Spacing
- Bin Types
    - Stiffener Profiles
    - Stiffener Thickness
    - Unstiffened Grain Bin
    - Internally Stiffened Grain Bin
    - Externally Stiffened Grain Bin
    - Wind Rings
- Regulation
    - Temperature Monitoring Devices
    - Aeration Fans
    - Roof Ventilation – Static and Powered
    - Aeration Vents Flush with Concrete Slab
    - Aerated Floor System Elevated Above the Concrete Slab
- Hooper Bottoms
- Size and Capacity
- Manufacturers

Basic of Grain Bin Operation

- Loaded and Unloaded from Center
- Emptied Through Center Discharge Chute
- Proper Storage
- Regulating the Stored Grain
    - Condensation
    - Grain Spoilage
    - High-Moisture Grain
    - Corroded Grain Bin Walls and Components

Failures of Grain Bins Associated with Operation and Maintenance

- Off-center Unloading or Loading Examples
- Rusted Walls or Components Examples
- Lack of Proper Maintenance Examples
- Improper Aeration Operation Examples

Failure of Grain Bins Associated with Storm Effects

- Wind Damage Examples

Q & A

1

Steel Corrugated Grain Bins

July 2013

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Steel Grain Bin Topics

1. Introduction to Steel Corrugated Grain Bins (silos).
2. Basics of Grain Bins Operation.
3. Failures of Grain Bins Associated with Operation and Maintenance.
4. Failures of Grain Bins Associated with Storm Effects.

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Steel Grain Bin Introduction

- Corrugated steel grain bins can be found on farms, commercial storage/transfer sites, and processing sites.
- Typical grains include corn, soybeans, wheat, rice, etc. that are considered dry and free-flowing.

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Steel Grain Bin Introduction

- Storing grain in bins protects commodities from the effects of weather and pests in between harvest and processing time.
- Grains with lower moisture content and grain temperatures within approximately 10° F of the average outside temperature can be stored longer without spoilage.

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Steel Grain Bin Introduction

- Grain Bin Shells typically comprise corrugated galvanized-steel panels.
- Corrugated profiles may vary from the typical S-style to a trapezoidal-shape.
- On-center spacing between corrugated ribs are typically 2.66 inches or 4 inches.

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Steel Grain Bin Introduction

2.66 inches

4 inches

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Steel Grain Bin Introduction

- Corrugated steel bins can include stiffened and unstiffened type bins.
- Stiffener profiles can vary such as hat-shaped, C-shaped, or Z-shaped.
- Stiffeners can vary in thickness up to approximately 5/16-inch.

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Steel Grain Bin Introduction

- On-farm type bins and smaller commercial type bins are generally unstiffened.
- Large commercial bins typically include stiffeners either on the exterior or interior sides.
- Stiffened bins may also include wind rings for added stiffening of the bins near the top.

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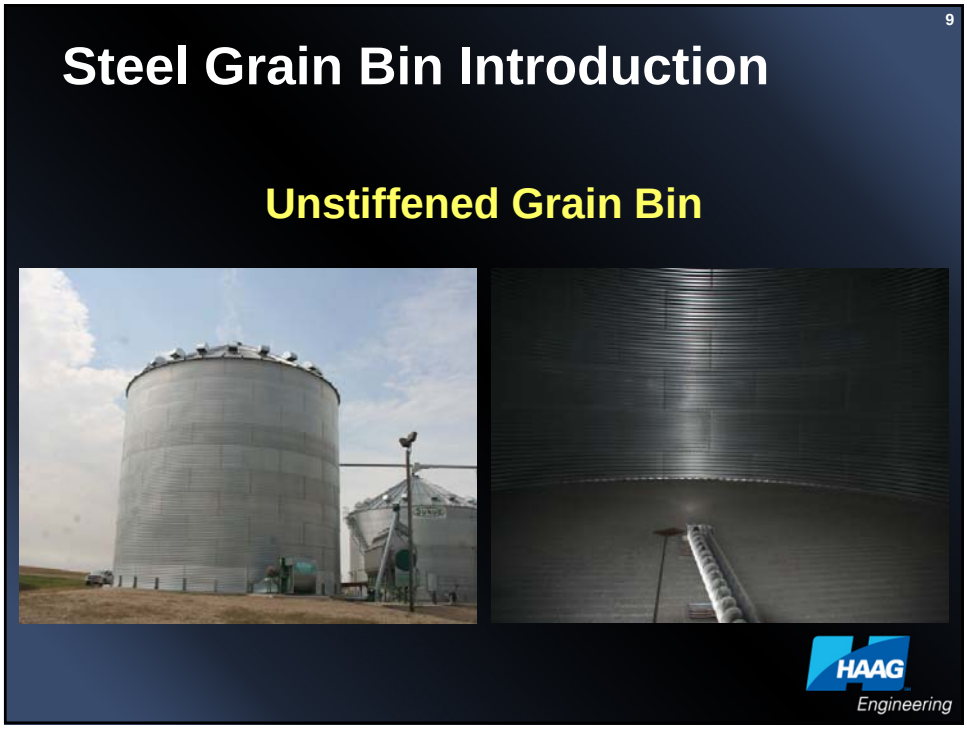
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Steel Grain Bin Introduction
Unstiffened Grain Bin
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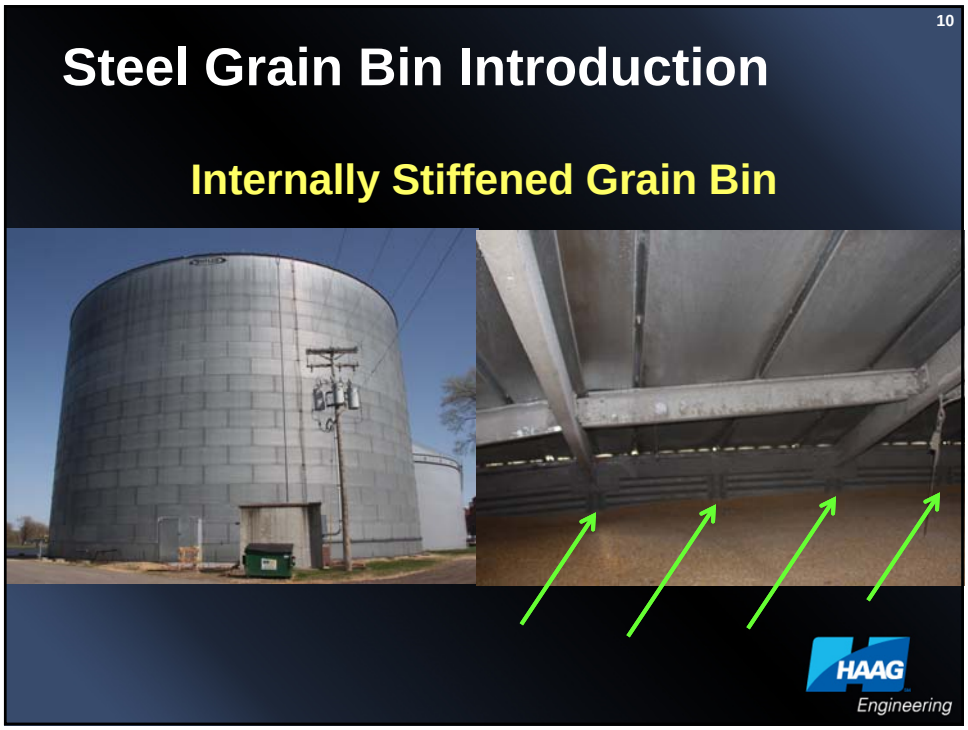
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Steel Grain Bin Introduction
Internally Stiffened Grain Bin
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Steel Grain Bin Introduction

Externally Stiffened Grain Bin

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Steel Grain Bin Introduction

Wind Rings

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Steel Grain Bin Introduction

- Grains stored in the bins can be regulated by means of:
  - Temperature monitoring devices (e.g., temperature cables hanging from the roof framing)
  - Aeration fans that blow air in the bin (pos. pressure) or that pulls air out of the bin (neg. pressure)
  - Venting systems (located in the floor and roof)

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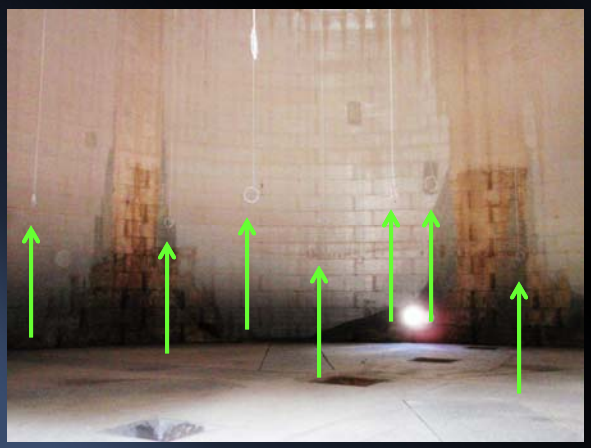
Steel Grain Bin Introduction

Temperature Cables Hanging from the Roof Framing



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Steel Grain Bin Introduction

Aeration Fans

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Steel Grain Bin Introduction

Roof Ventilation – Static and Powered

Powered

Static

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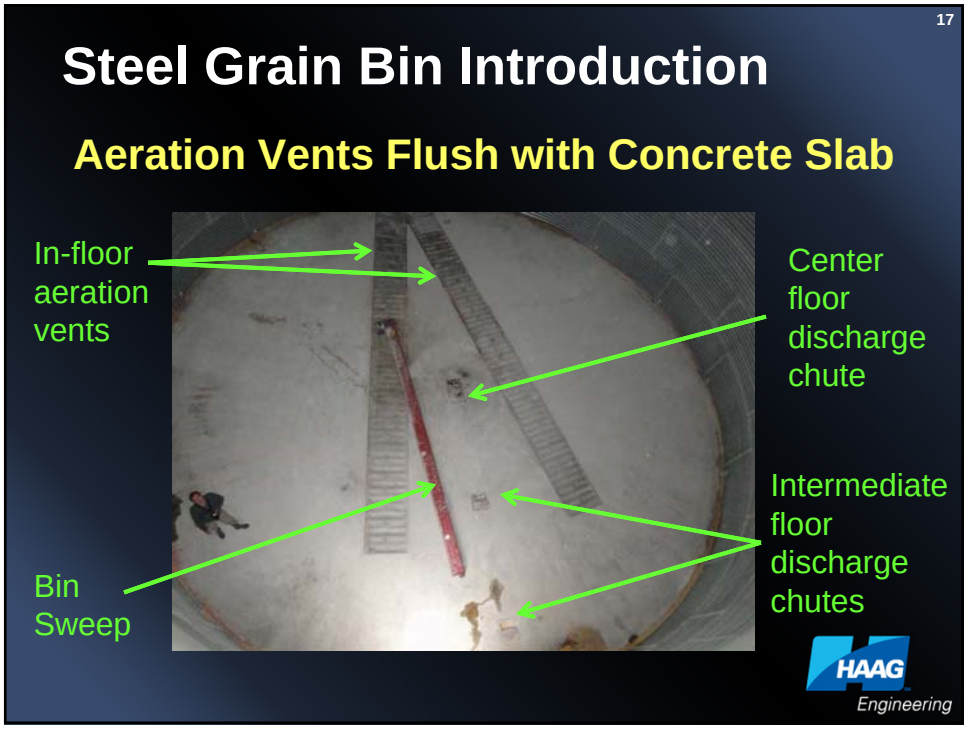
17
Steel Grain Bin Introduction
Aeration Vents Flush with Concrete Slab
In-floor aeration vents
Center floor discharge chute
Intermediate floor discharge chutes
Bin Sweep
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Steel Grain Bin Introduction
Aerated Floor System Elevated
Above the Concrete Slab
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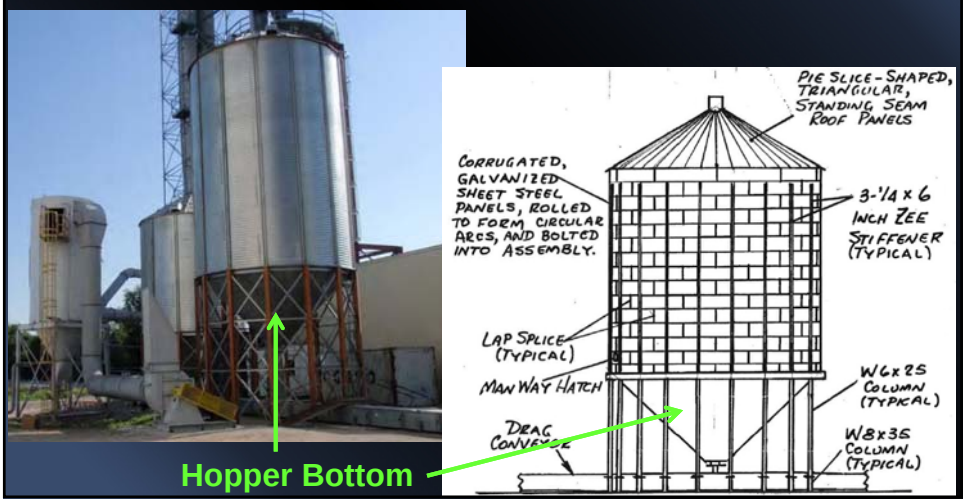
Steel Grain Bin Introduction

- Bins are also available with hopper bottoms for self-cleaning when frequently filled and emptied.



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Grain Bin Sizes and Capacities

- Diameters can vary from about 12 feet to over 150 feet across (about half a football field's length).
- Heights can vary from about 11 feet to approximately 100 feet tall.
- Grain volumes can range from approximately 750 bushels to over 1.5M bushels .

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Manufacturers of Corrugated Steel Grain Bins

- Grain Systems, Inc. (GSI)
- Brock Grain Systems
  - Purchased the grain bin division of Butler Manufacturing in 1997
- Chief Industries, Inc.
- Sukup Manufacturing
- Behlen Grain Systems.
- SCAFCO
- Sioux Steel
- Crippen International

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Basics of Grain Bin Operation

- Corrugated grain bins are designed to be loaded and unloaded from the center to maintain equal weight distribution around the bin perimeter.
- Grain must be emptied completely through the center discharge chute prior to using the intermediate discharge chutes and bin sweeps.

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Basics of Grain Bin Operation

- Proper storage requires monitoring of the grain temperature and moisture.
- Regulating the stored grain can be achieved through temperature readings, aeration (pos. or neg. pressure) fans, drying fans, coring the grain, or by way of stirring and recirculating the grain with augers.

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Basics of Grain Bin Operation

- Improper regulation of the grain temperature can lead to condensation.
- Condensation and improper regulating of the grain moisture content can lead to grain spoilage.
- High-moisture grain can also bridge leaving large voids during loading and unloading.
- Long-term exposure to condensation and high-moisture grain can cause corroded grain bin walls and components.

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Grain Bins Failures

(Note: Failures can vary from bin deformation to complete collapse)

- Operation and Maintenance (Not an exhaustive list)
  - Most Common
    - Off-center unloading, loading, or spoiled/crusted grain due to higher moisture content
    - Corrosion – rusted walls or components
    - Lack of or improper maintenance
  - Less Common
    - Improper aeration operation
- Storm Effects
  - Wind

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Grain Bin Failures – Off-center unloading or loading

- Off-center unloading or loading can cause compression buckling (plastic deformation) of the grain bin walls.
- Non free-flowing grain (e.g., crusted or spoiled) may also cause plastic deformation of the grain bin walls
- Eccentric unloading or loading may also cause anchorage failure at the foundation.

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Grain Bin Failures –
Off-center unloading or loading
Compression buckling due
to eccentric discharging.
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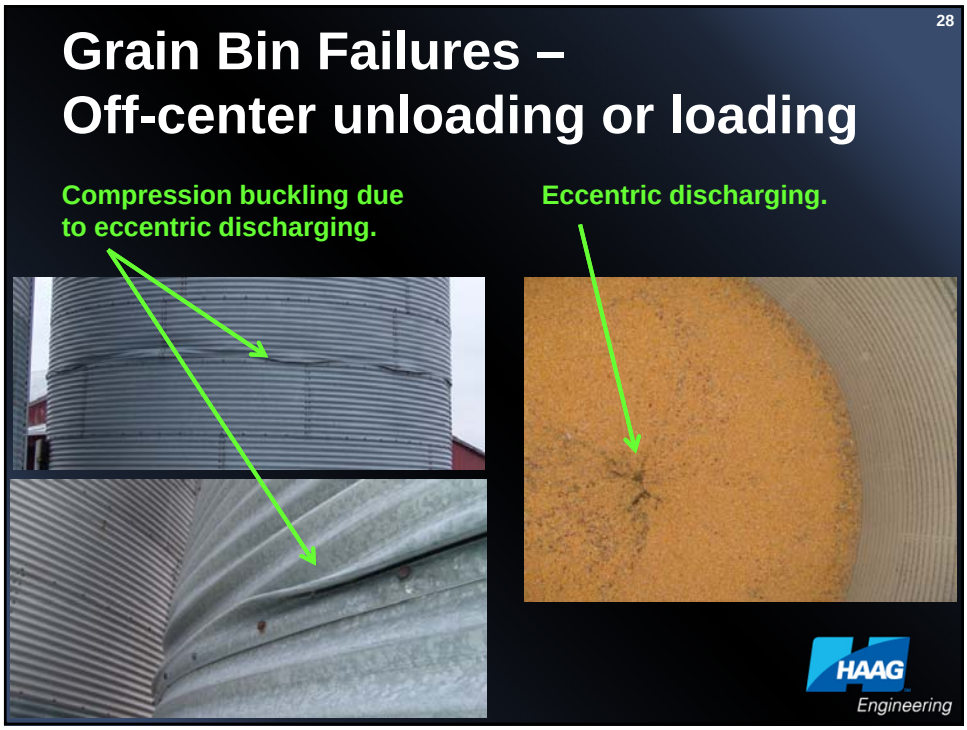
28
Grain Bin Failures –
Off-center unloading or loading
Compression buckling due
to eccentric discharging.
Eccentric discharging.
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Grain Bin Failures – Off-center unloading or loading

Compression buckling due to eccentric discharging.

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Grain Bin Failures – Off-center unloading or loading

Compression buckling due to eccentric discharging.

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Grain Bin Failures – Off-center unloading or loading

Compression buckling due to eccentric loading.

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Grain Bin Failures – Off-center unloading or loading

Bottom edge of bin shell shifted on foundation due to eccentric unloading.

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Grain Bin Failures – Off-center unloading or loading

Eccentric grain flow pattern discernible on the side walls

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Grain Bin Failures – Off-center unloading or loading

Bottom edge of bin shell shifted on foundation due to eccentric unloading.

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Grain Bin Failures – Off-center unloading or loading

Bottom edge of bin shell shifted on foundation due to eccentric unloading.

Attempted prior repair to anchors on the north side

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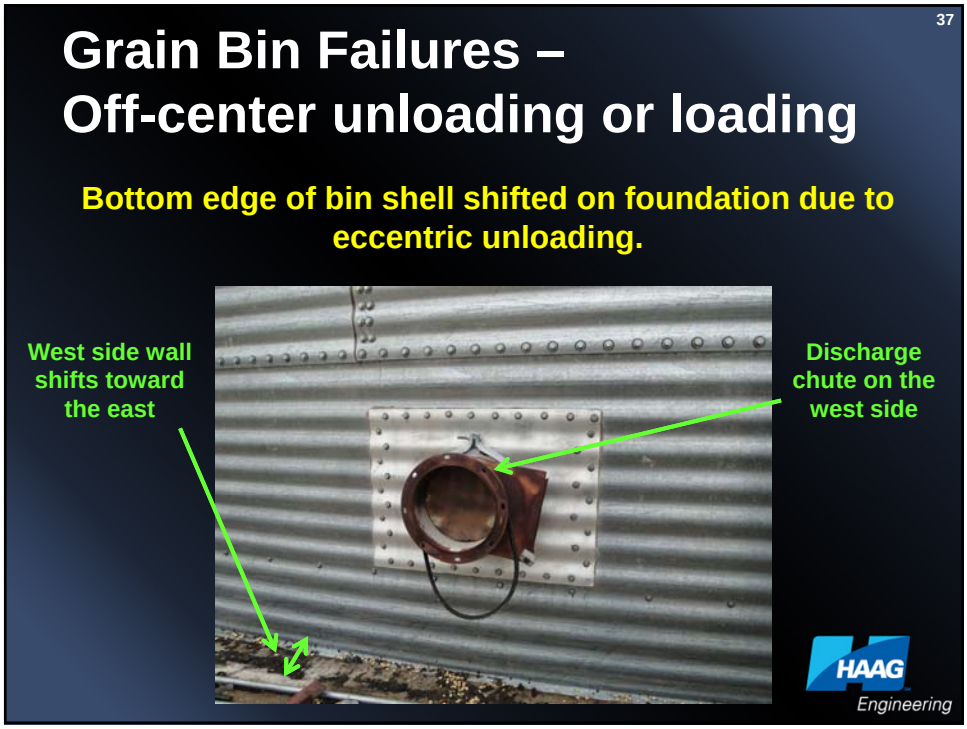
Grain Bin Failures – Off-center unloading or loading

Bottom edge of bin shell shifted on foundation due to eccentric unloading.

Torn anchors on the south side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Grain Bin Failures –
Off-center unloading or loading
Bottom edge of bin shell shifted on foundation due to eccentric unloading.
West side wall shifts toward the east
Discharge chute on the west side
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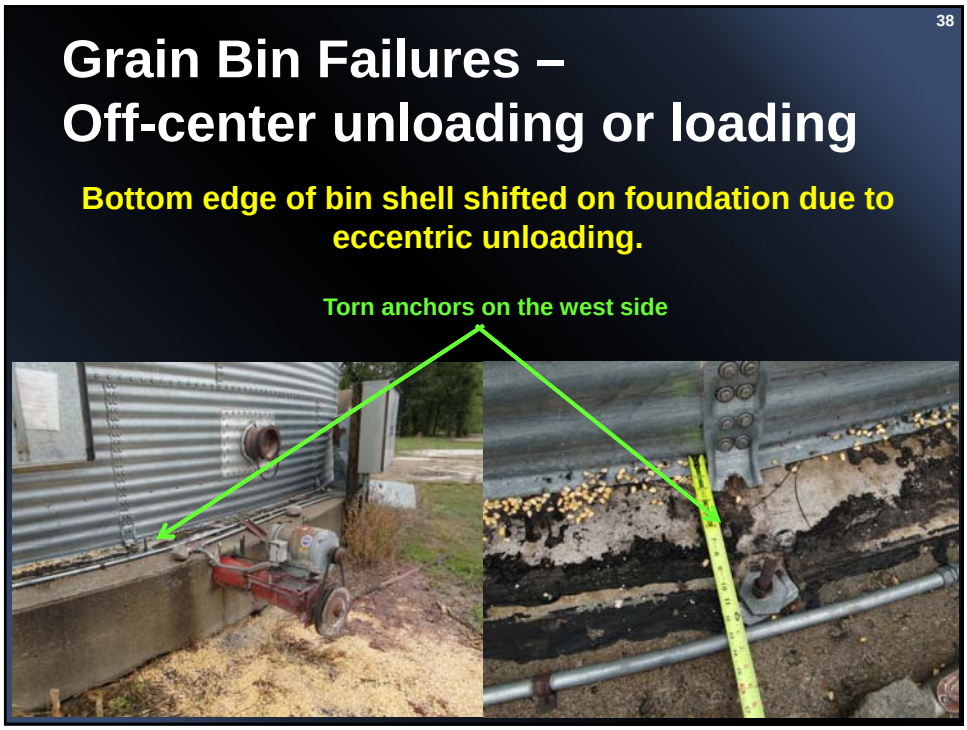
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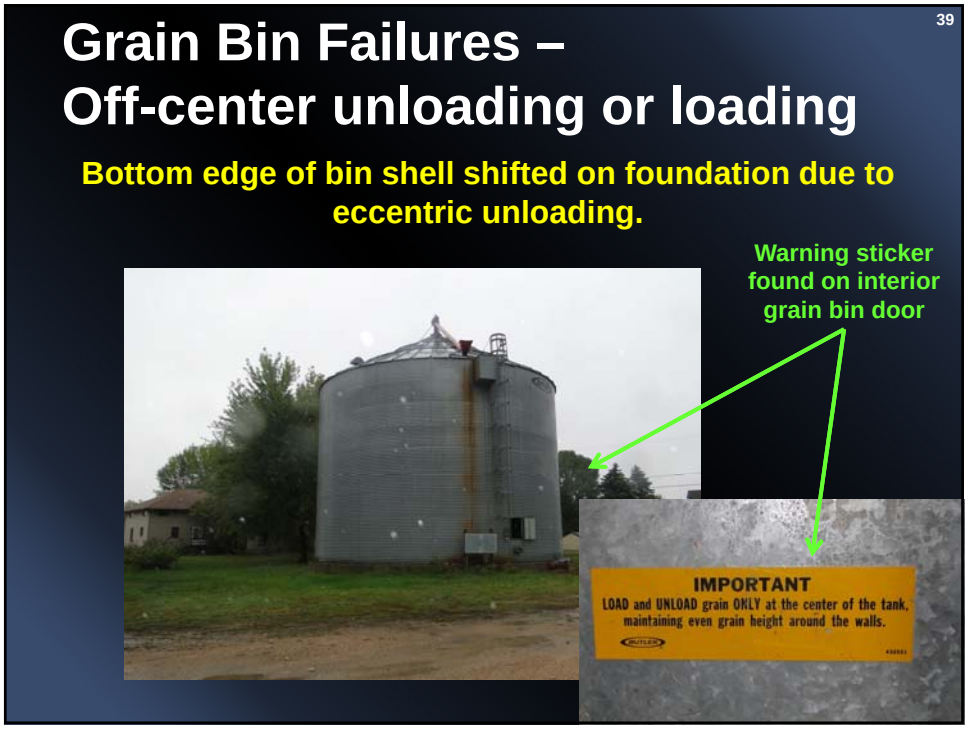
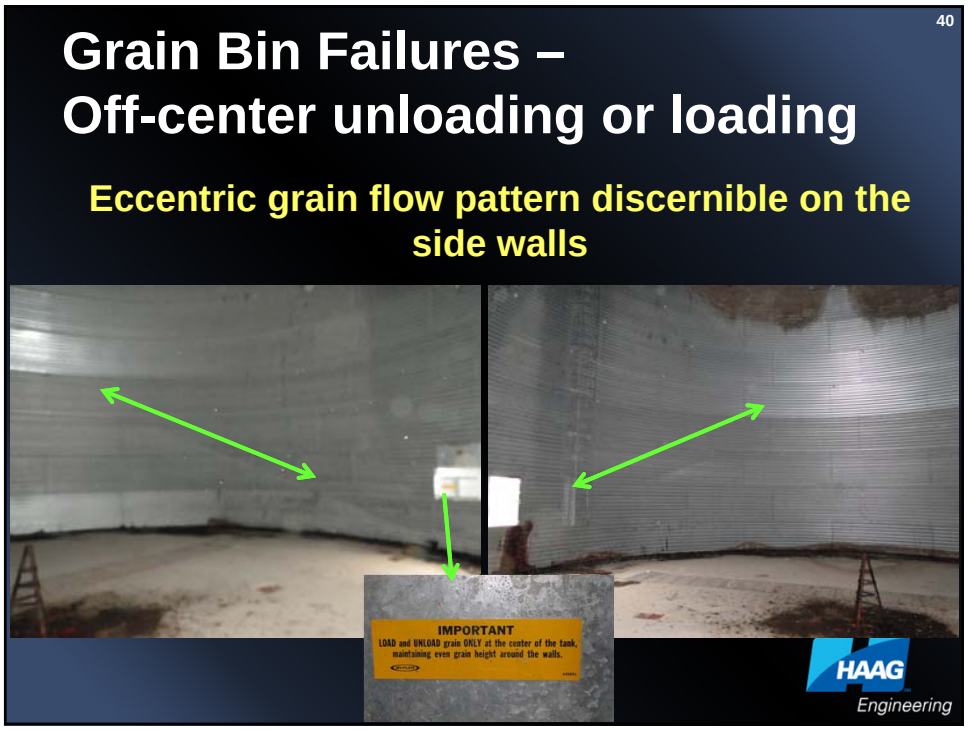
Grain Bin Failures –
Off-center unloading or loading
Bottom edge of bin shell shifted on foundation due to eccentric unloading.
Torn anchors on the west side


39
Grain Bin Failures –
Off-center unloading or loading
Bottom edge of bin shell shifted on foundation due to eccentric unloading.
Warning sticker found on interior grain bin door
IMPORTANT
LOAD and UNLOAD grain ONLY at the center of the tank, maintaining even grain height around the walls.


40
Grain Bin Failures –
Off-center unloading or loading
Eccentric grain flow pattern discernible on the side walls
IMPORTANT
LOAD and UNLOAD grain ONLY at the center of the tank, maintaining even grain height around the walls.
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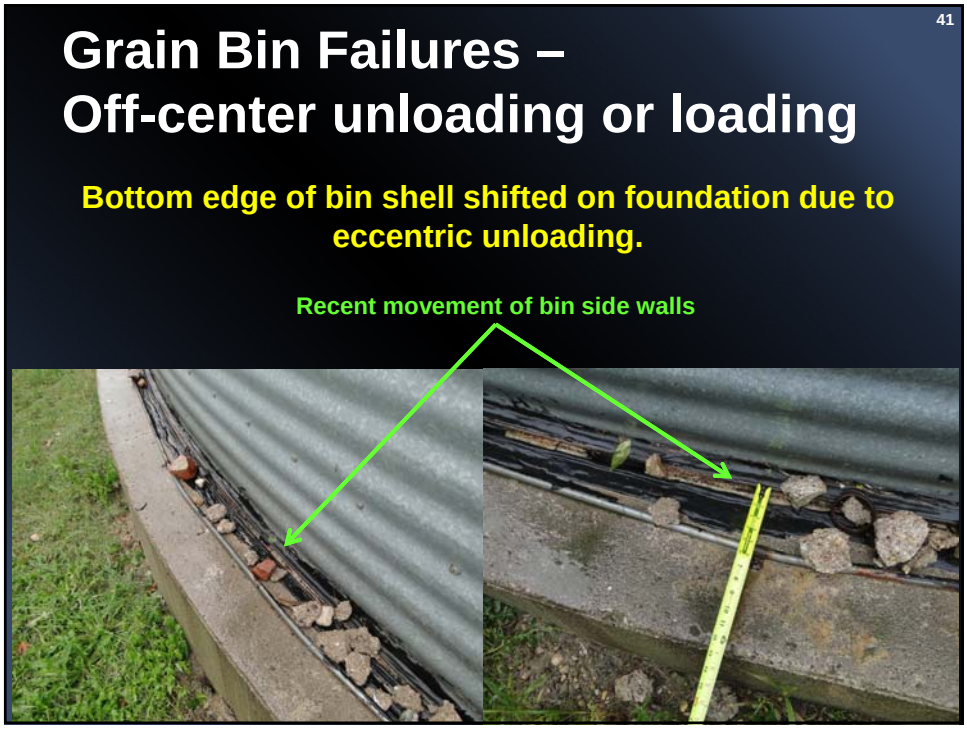
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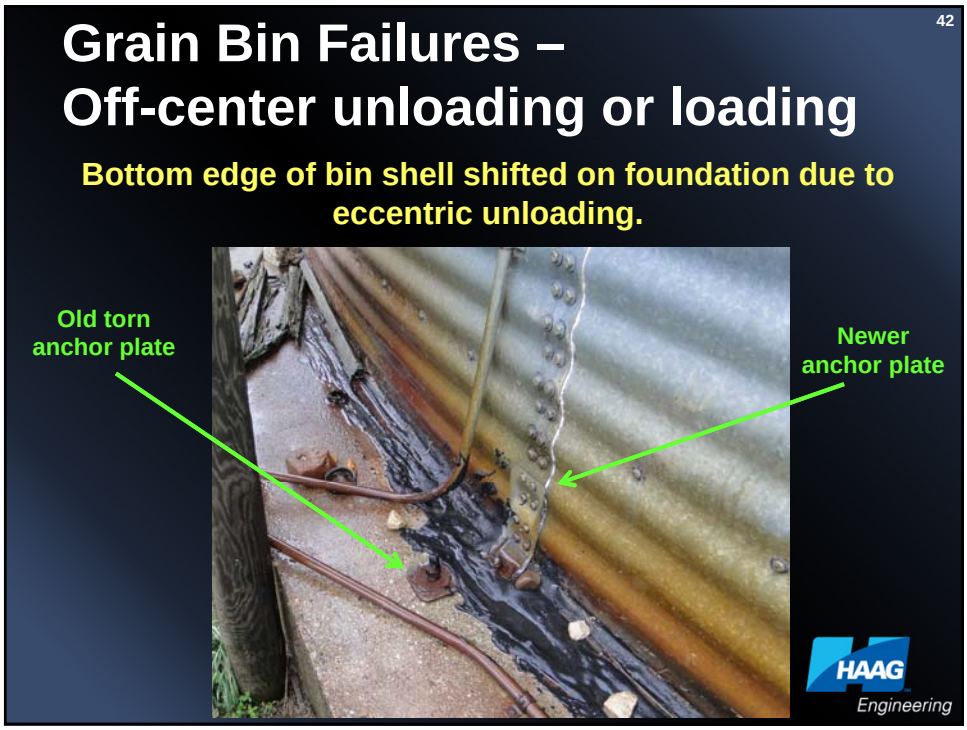
Grain Bin Failures –
Off-center unloading or loading
Bottom edge of bin shell shifted on foundation due to eccentric unloading.
Recent movement of bin side walls


42
Grain Bin Failures –
Off-center unloading or loading
Bottom edge of bin shell shifted on foundation due to eccentric unloading.
Old torn anchor plate
Newer anchor plate
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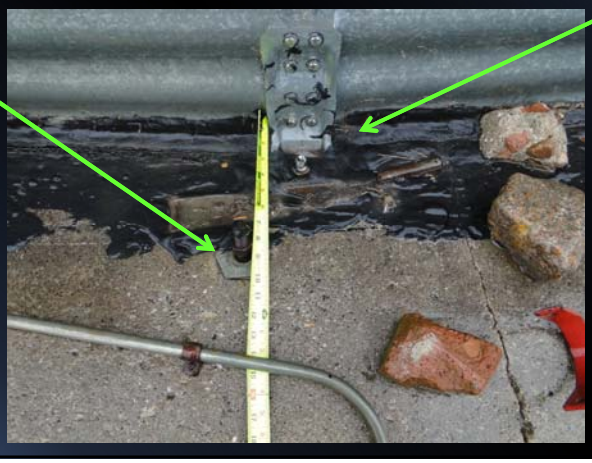
Grain Bin Failures – Off-center unloading or loading

Bottom edge of bin shell shifted on foundation due to eccentric unloading.



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Grain Bin Failures – Rusted Walls or Components

This bin was constructed in the 1970s and was sufficiently full enough to reach the top of the roof cone prior to failure (approximately 90,000 bushels).

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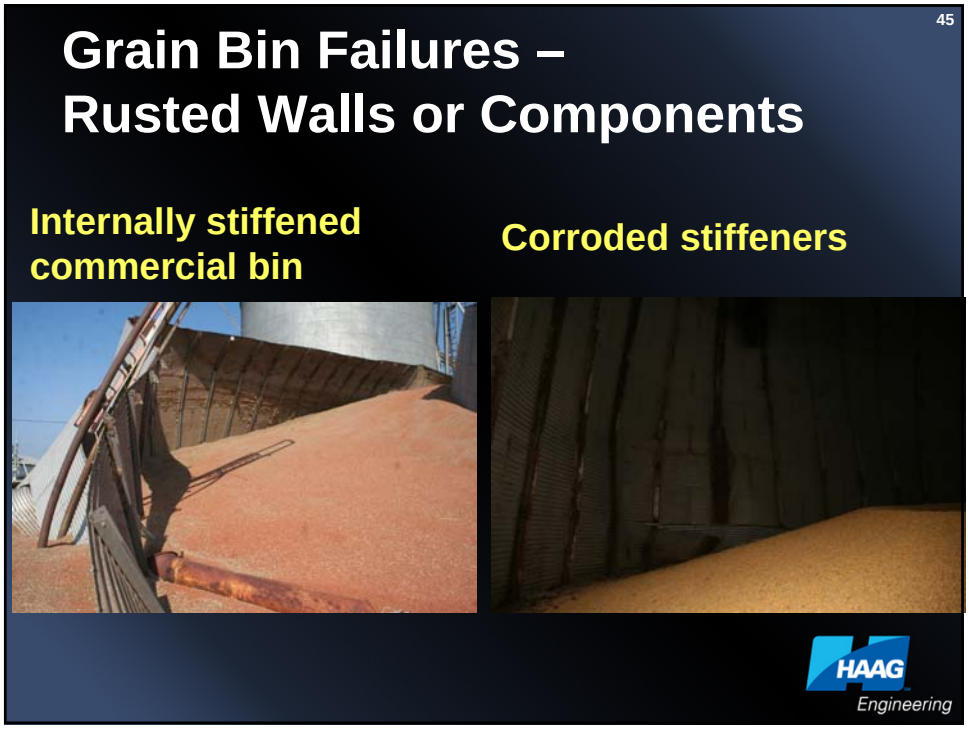
45
Grain Bin Failures –
Rusted Walls or Components
Internally stiffened commercial bin
Corroded stiffeners
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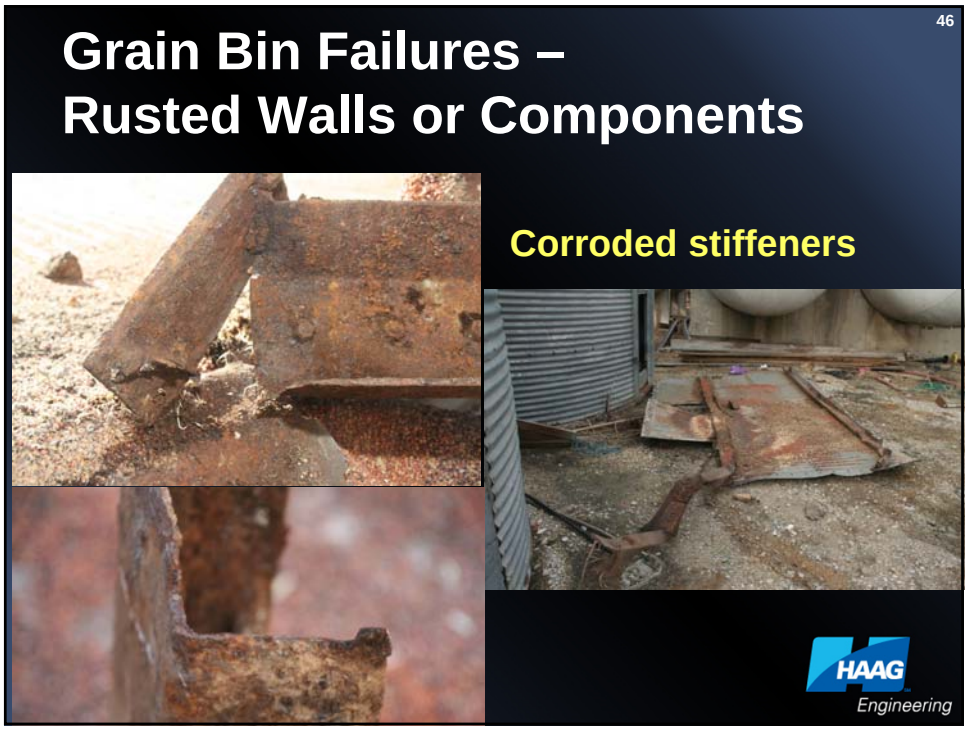
46
Grain Bin Failures –
Rusted Walls or Components
Corroded stiffeners
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Grain Bin Failures – Rusted Walls or Components

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Corroded wall panels

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Grain Bin Failures – Rusted Walls or Components

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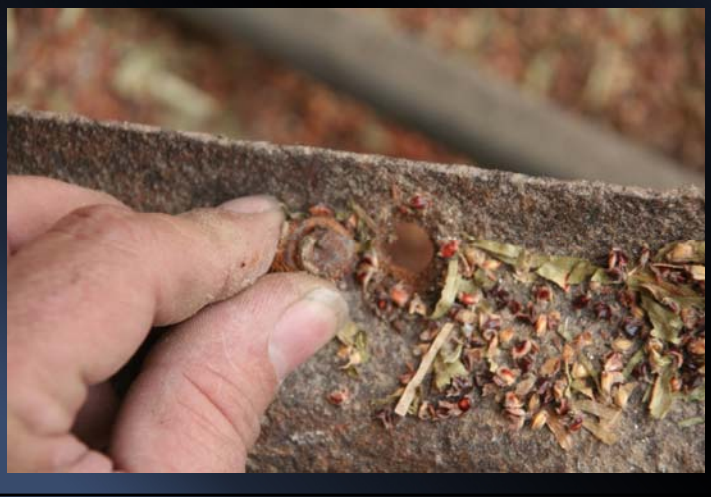
Corroded fasteners



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Grain Bin Failures – Lack of Proper Maintenance

- Owner was aware that certain panels had rusted.
- Rather than replacing damaged panels, temporary repairs were installed.

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Grain Bin Failures – Lack of Proper Maintenance

Latest temporary repairs

Latest temporary repairs

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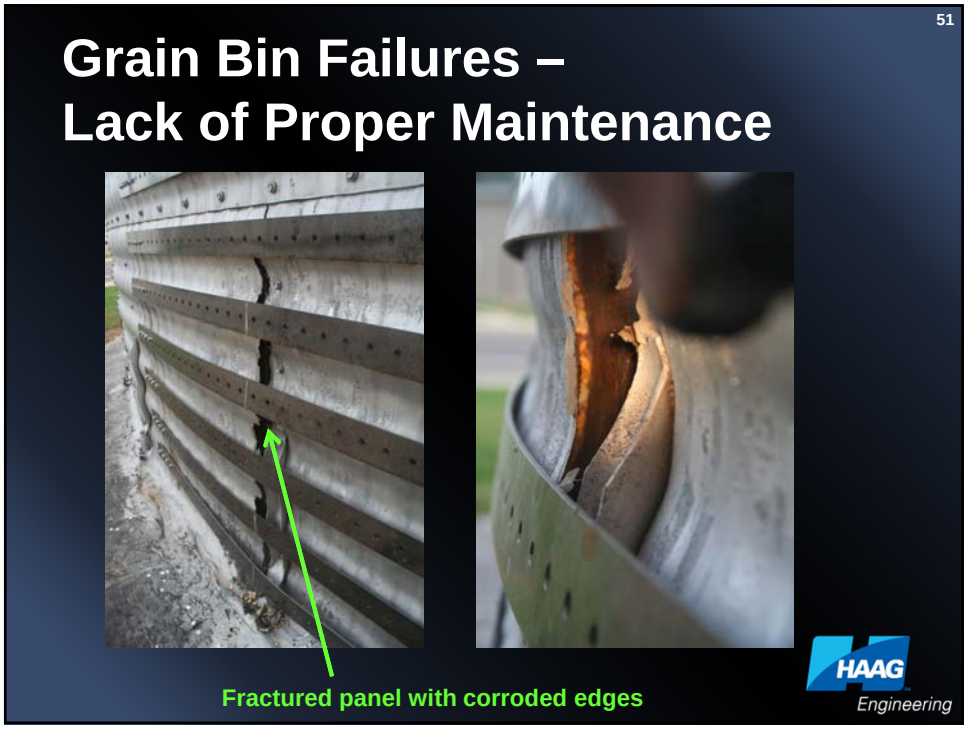
51
Grain Bin Failures –
Lack of Proper Maintenance
Fractured panel with corroded edges
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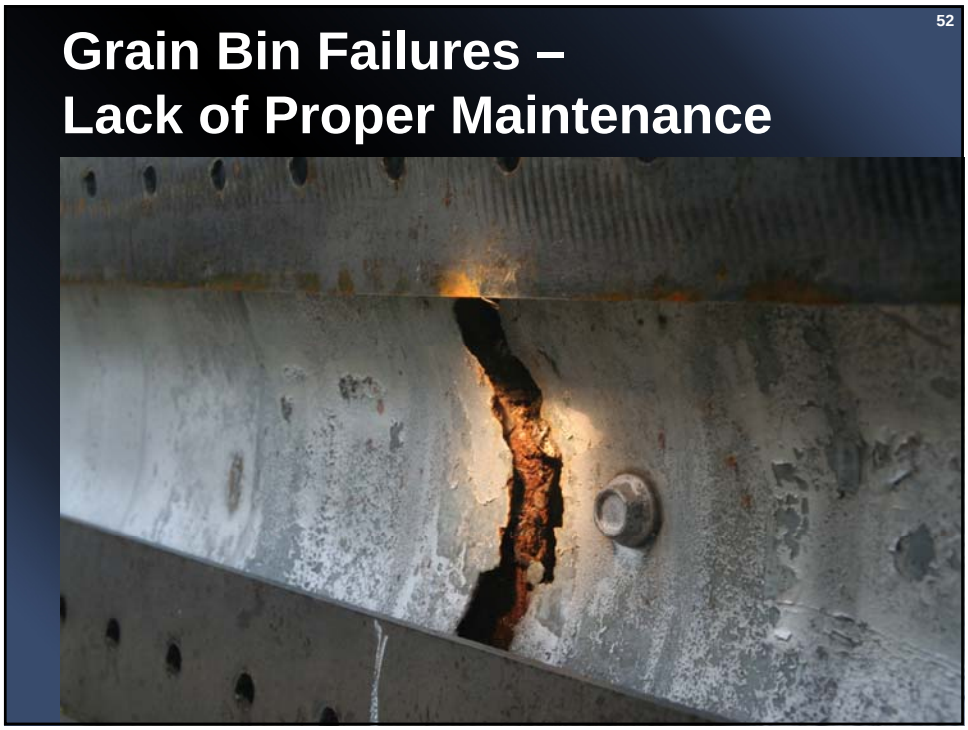
52
Grain Bin Failures –
Lack of Proper Maintenance

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Grain Bin Failures – Lack of Proper Maintenance

Repairs prior to the exterior straps included an interior steel plate over the split wall and caulking

Caulking separated due to continual expansion of the damaged wall

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Grain Bin Failures – Lack of Proper Maintenance

Other fractured panels with corrosion

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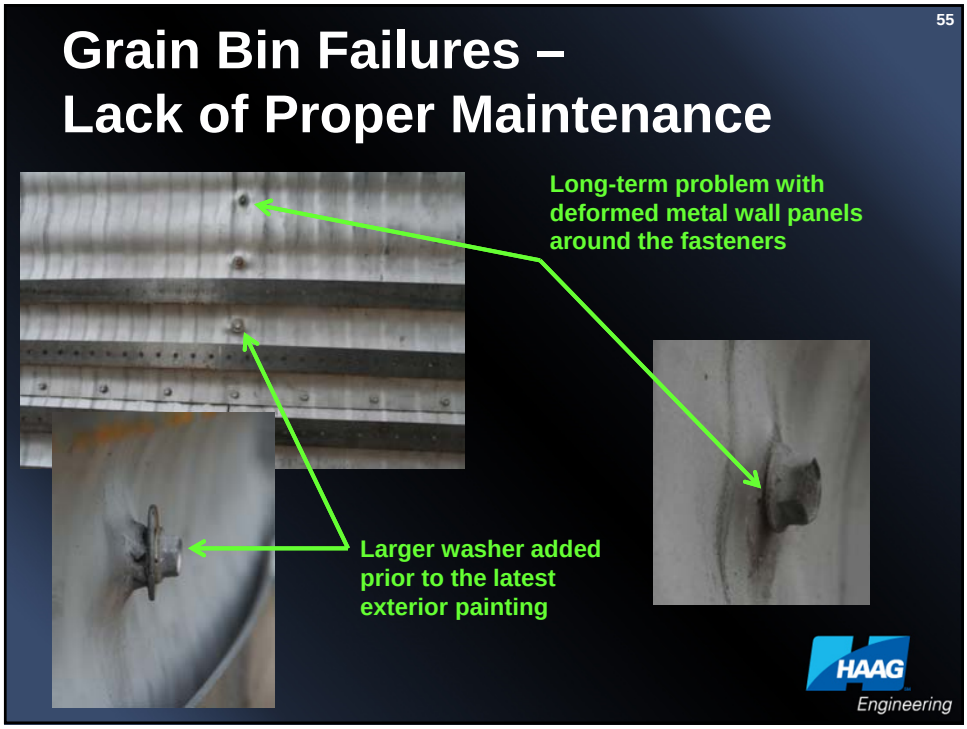
55
Grain Bin Failures –
Lack of Proper Maintenance
Long-term problem with deformed metal wall panels around the fasteners
Larger washer added prior to the latest exterior painting
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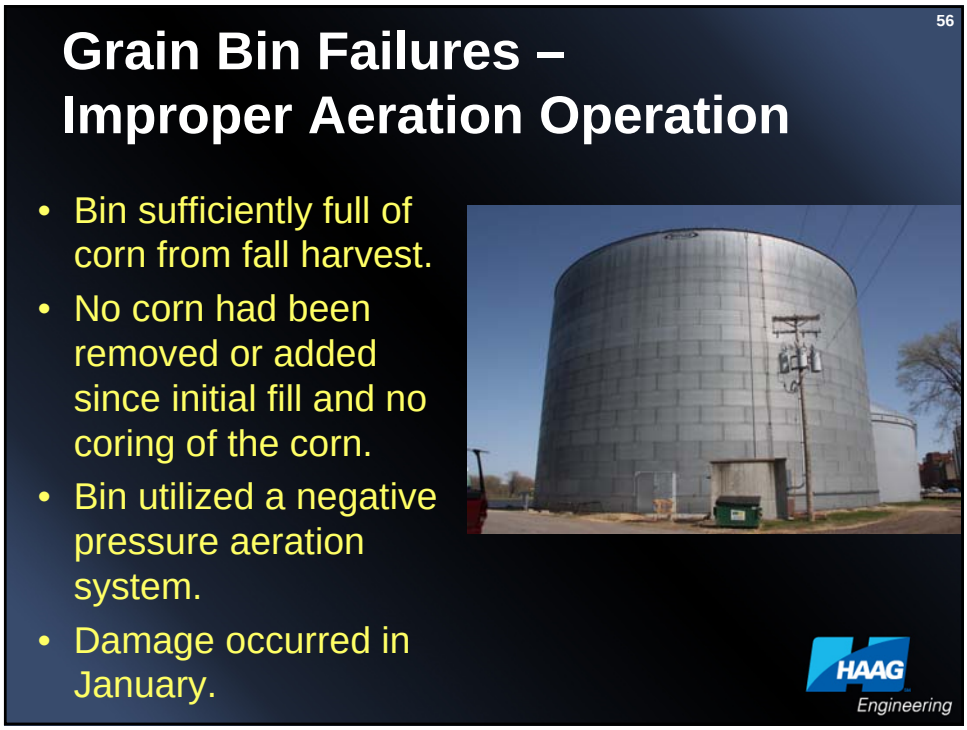
56
Grain Bin Failures –
Improper Aeration Operation
• Bin sufficiently full of corn from fall harvest.
• No corn had been removed or added since initial fill and no coring of the corn.
• Bin utilized a negative pressure aeration system.
• Damage occurred in January.
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Grain Bin Failures –
Improper Aeration Operation
Several aeration fans
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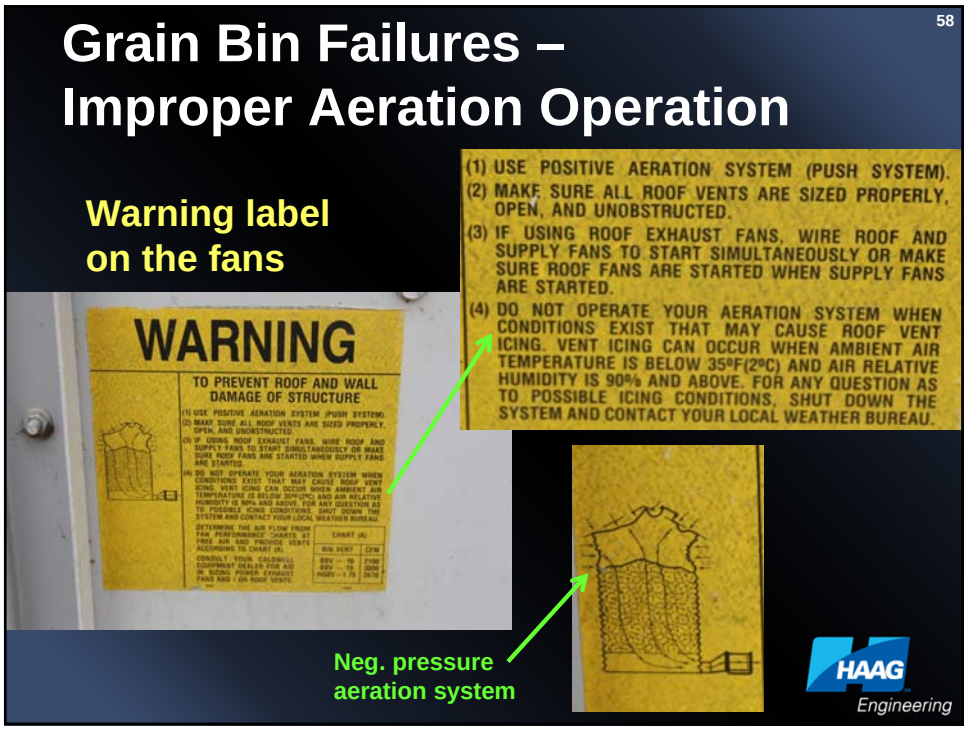
58
Grain Bin Failures –
Improper Aeration Operation
Warning label
on the fans
(1) USE POSITIVE AERATION SYSTEM (PUSH SYSTEM).
(2) MAKE SURE ALL ROOF VENTS ARE SIZED PROPERLY, OPEN, AND UNOBSTRUCTED.
(3) IF USING ROOF EXHAUST FANS, WIRE ROOF AND SUPPLY FANS TO START SIMULTANEOUSLY OR MAKE SURE ROOF FANS ARE STARTED WHEN SUPPLY FANS ARE STARTED.
(4) DO NOT OPERATE YOUR AERATION SYSTEM WHEN CONDITIONS EXIST THAT MAY CAUSE ROOF VENT ICING. VENT ICING CAN OCCUR WHEN AMBIENT AIR TEMPERATURE IS BELOW 35°F(2°C) AND AIR RELATIVE HUMIDITY IS 90% AND ABOVE. FOR ANY QUESTION AS TO POSSIBLE ICING CONDITIONS, SHUT DOWN THE SYSTEM AND CONTACT YOUR LOCAL WEATHER BUREAU.
WARNING
TO PREVENT ROOF AND WALL DAMAGE OF STRUCTURE
Neg. pressure
aeration system
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Grain Bin Failures – Improper Aeration Operation

North side of bin

Upper ring panels buckled inward on north side

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Grain Bin Failures – Improper Aeration Operation

Caved in roof on the north side

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Grain Bin Failures –
Improper Aeration Operation
Partially collapsed roof vents
Caved in roof on the north side
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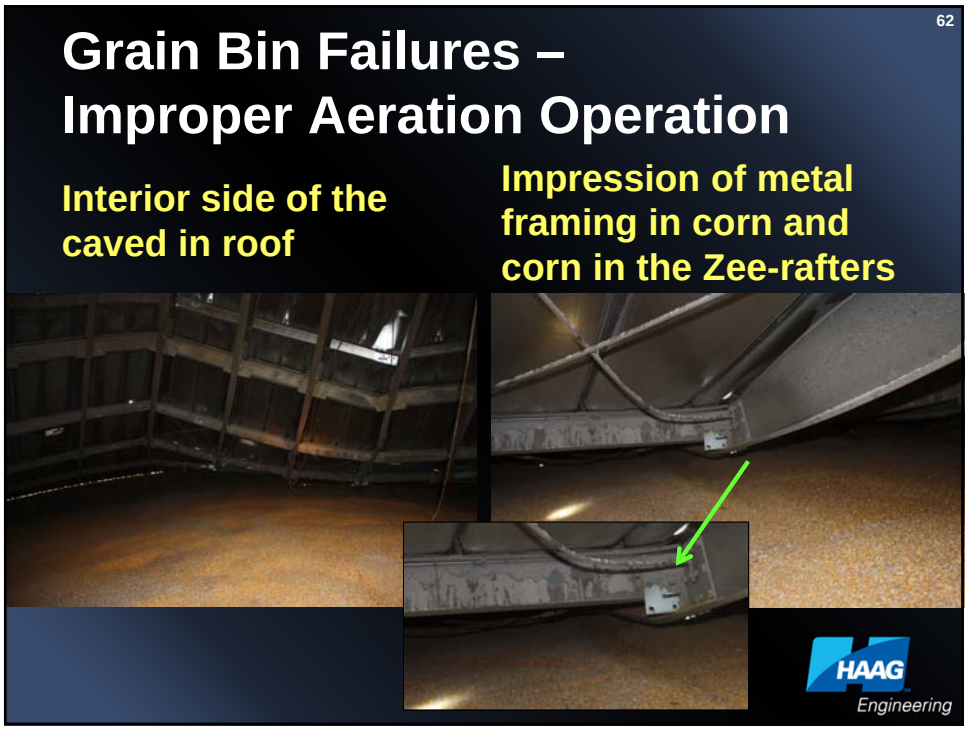
62
Grain Bin Failures –
Improper Aeration Operation
Interior side of the caved in roof
Impression of metal framing in corn and corn in the Zee-rafters
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Grain Bin Failures – Wind Damage

- Bins are stronger against wind forces when full versus empty bins (e.g., a fully sealed coke can versus an empty coke can).

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Grain Bin Failures – Wind Damage

- Empty bin with approximately a 128,000 bushel capacity at the time of the incident.
- Approximately 56 feet in diameter and about 58 feet in height to the eave.

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Grain Bin Failures – Wind Damage

- Empty bin with approximately a 65,500 bushel capacity at the time of the incident.
- Approximately 40 feet in diameter and about 58 feet in height to the eave.

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Grain Bin Failures – Wind Damage

- Empty bin with approximately a 47,000 bushel capacity at the time of the incident.
- Approximately 42 feet in diameter and about 36 feet in height to the eave.

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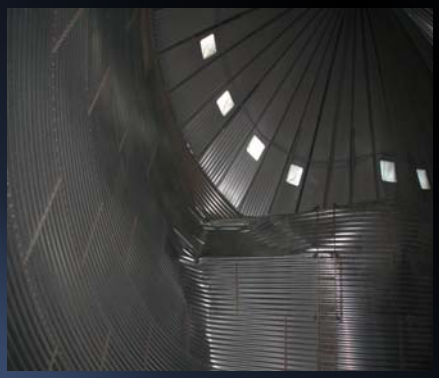
Grain Bin Failures – Wind Damage

View of the empty unstiffened bin from the interior.



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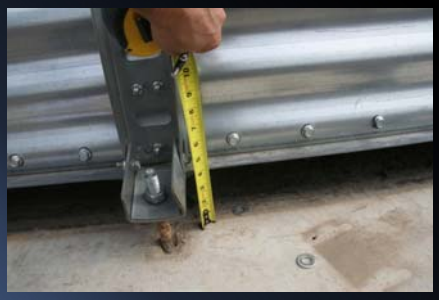
Grain Bin Failures – Wind Damage

Anchor bolts partially withdrawn on the windward side.



Steel failure in the bolted anchor bracket

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Questions?
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