GEAPS EXCHANGE 2016
AUSTIN
Concrete Bin Failures and Why
Prepared for: GEAPS Exchange 2016

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Topics

• AG INFRASTRUCTURE FACTS
• AG INDUSTRY LOSSES
• CONCRETE SILO ENGINEERING
  • REASONS FOR FAILURE
  • THE INSPECTION
  • RESTORATION PLAN DEVELOPMENT AND EXECUTION
• SILO INSPECTIONS/MAINTENANCE
SILO CONSTRUCTION THROUGHOUT THE 1950’S
JUST THE FACTS...

• THROUGH THE 1950’S
  • 3 BILLION BU STORAGE ADDED (5.5 BILLION TOTAL)
  • TODAY’S STORAGE, 10.7 BILLION BU, OFF-FARM COMMERCIAL

• AGING INFRASTRUCTURE
  • MORE THAN HALF GREATER THAN 50 YRS
  • ESTIMATED 75,000 CONCRETE SILOS, JUST DURING THAT DECADE AND EARLIER
  • 20% OF TODAY’S TOTAL STORAGE
RUSSELL, KS, JUNE 25, 2010
STRUCTURAL FAILURE, COLLAPSE
constructed mid 1950’s
OWNER DECIDED TO DEMOLISH

WHY THE DECISION TO DEMO?
NOVEMBER 20, 2012 - SILO COLLAPSE
OAKLEY, KS

CONSTRUCTED MID 1950’S
OWNER DECIDED TO REBUILD
APRIL 13, 2010 GRAIN DUST EXPLOSION

BUILT 2004
1. STRUCTURAL EVALUATION
2. CONSTRUCTION COST EVALUATION
3. OWNER DECIDED TO REPAIR
OHIO SILO EXPLOSION, OCT. 2014

CONSTRUCTED 2007
2014 CONCRETE SILO FAILURE
ASSESS YOUR CONCRETE STRUCTURES - ARE YOU ON THAT GREATER THAN 50 LIST?
Concrete Silo Construction

- Concrete (Not cement!)-Portland cement, fine aggregate, coarse aggregate and water
- Steel Reinforcing Bar – “Rebar”
- Qualified Contractor
  - Inspection
Gradient Pressure Theory
CONCRETE CONSTRUCTION TODAY
While Inspecting, look for cracking

Cracking is an indication of structural deficiencies of the concrete wall
Look for these signs of problems:

• Cracking
  - Spider
  - H-cracking
• Surface distress
  - Spalling
  - Scaling
What is causing the cracks?

1. Lack of rebar
2. Wearing of aging equipment
3. Drying and shrinkage
4. Thermal Stresses
5. Weathering
6. Corrosion of Reinforcement
7. Poor Construction Practices
8. Errors in design and detailing
-How much use (CYCLING)?
SPALLING CONCRETE EXPOSED REBAR, CONCERNED?

SPALLING AND DETERIORATION
WELL DEFINED CRACKS...
Define these Cracks.

“H” Cracks
Crack concerns?

Look carefully.
Crack concerns?
INSPECT THESE KEY SILO COMPONENTS:

• Foundation
• Roof: look for shifting with respect to the silo walls (walking) and curb cracks
• Interior silo walls
• Silo sidewall openings – interior
• Exterior silo walls
• Silo sidewall openings – exterior
• Tunnels – Top and sides
What can be done?
Liner?
THE ENGINEERING BEHIND IT

Grain Bin Load Calculator

Bin and Commodity Specifications

<table>
<thead>
<tr>
<th>Diameter of Bin (ft)</th>
<th>Height of Bin (ft)</th>
<th>Thickness of Liner (in)</th>
<th>Strength of Liner (ksi)</th>
<th>Size of Bar Diameter (in)</th>
<th>Vertical Spacing of Bars (in)</th>
<th>Yield Strength of Pipe (ksi)</th>
<th>Coefficient of friction</th>
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<tr>
<td>8.00</td>
<td>10.00</td>
<td>0.15</td>
<td>3000</td>
<td>0.5</td>
<td>6.0</td>
<td>6000</td>
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<tr>
<td>1.00</td>
<td>1.00</td>
<td>1</td>
<td>1200</td>
<td>0.1</td>
<td>2</td>
<td>1500</td>
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If eccentric loading and/or unloading is occurring

<table>
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<th>Distance from center of bin to eccentric loading/unloading point (ft)</th>
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Calculated Values

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<tr>
<th>Area of Steel per inch of height (in²)</th>
<th>Ratio of Internal Lateral Pressure to Vertical Pressure</th>
<th>Vertical Pressure (psi)</th>
<th>Lateral Static Pressure (psi)</th>
<th>Lateral Design Pressure (psi)</th>
<th>Head Stress (ksi)</th>
<th>Allowable Stress in Rebar Provided (ksi)</th>
<th>Head Stress Check</th>
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<tbody>
<tr>
<td>0.003</td>
<td>1.00</td>
<td>10,000</td>
<td>3,000</td>
<td>5,000</td>
<td>25,000</td>
<td>50,000</td>
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Min. Area of Steel Check: OK

Temp. and Shrinkage Check: OK
LINER DESIGN PLAN AND SECTION
RECOMMENDATIONS

PREVENTATIVE MAINTENANCE PROGRAM

• REGULARLY SCHEDULED ENGINEERING INSPECTIONS
• SURFACE TREATMENTS
• REGULAR VISUAL EVALUATIONS BY PERSONNEL
• CONDITION SURVEY LOG
  • CRACK MONITORING

SUGGESTED REPAIRS (PROTECT THE REBAR!)

• INTERIOR LINERS
• SPALL REPAIR
• CRACK PATCH
Be aware of your surroundings