Concrete Grain Elevators: Their Early Design, Construction, Successes and Failures

Chris Hartnett, PE, LEED AP
- Preservation Engineering Group

Meyer Borgman Johnson
Structural Design & Engineering

- Minneapolis, MN
- Wanderer/Gatherer Societies
- Became Agrarian Societies

Needed to store and grind grain
Flat Houses – Early Grain Storage
Early Elevators

- Stored grain between harvest and use
- Provided a transfer point from farm to user
Elevators started on the docks
Conveyors moved grain from ships to docks to trains.
Conveyors moved grain within the elevator
Two Types of Grain Elevators:

Country Elevators
- Smaller (25k-35k bushels)
- Set in rural communities
- Transfer from farm to truck/rail.
- Store grain after harvest
Country Elevators

Wood – Cribbed Construction
- planks laid flatwise, spiked together
- high stiffness resists lateral pressure
Two Types of Grain Elevators: Country Elevators

Wood – Studded Construction
- Standard balloon-frame construction
Wood Elevator Problems:

- Prone to fire
- 5-10 year economic life
- Expensive to insure
Wood Elevator Problems:

A burst country elevator
19th Century Transportation Advances
19th Century Transportation Advances
Two Types of Grain Elevators: Terminal Elevators

- Capacity: millions of bushels
- Located in cities, at ports, rail intersections
- In the Midwest, eastern Plains: Minneapolis; Chicago; Buffalo, NY

Terminal Elevator “T” in Minneapolis
Two Types of Grain Elevators:
Terminal Elevators

Pennsylvania Elevator, Erie, PA
Rialto elevator, Chicago, IL
Terminal Elevators: Steel Elevators

- Used pressure vessel technology
- Similar to locomotive boilers, building boilers.

Pillsbury’s Great Northern Elevator in Buffalo, NY
Great Northern Steel elevator in Superior, WI.
- Designed by Max Toltz
Terminal Elevators: Steel Elevators

Great Northern Steel Elevator, Buffalo, NY
Terminal Elevators: Steel Elevators

Pioneer Steel Elevator, Minneapolis

Chandia Railroad Steel Elevator, Toledo, OH
Terminal Elevators: Tile Elevators

- Provided good thermal insulation
- Expensive to build

Masons building the Peavey tile elevator.
Duluth, MN
The Beginning of the Concrete Elevator: “Peavey’s Folly”

- F.H. Peavey led the largest grain handling company in the world.
- Engaged C.F. Haglin to design a test elevator in St. Louis Park, MN.
“Peavey’s Folly” - Haglin’s Patent.

- Charles Haglin’s patent # 662,266 drawings, dated Nov 20, 1900.
- Concentric forms
- Wood forms supported by wood frames.

Elevation of bin forms with yokes
“Peavey’s Folly” - Haglin’s Patent.

- Steel yokes connected the inside form to the outside form
- Screw jack lifted forms from top of the day’s pour.
The Beginning of the Concrete Elevator: “Peavey’s Folly”

- Grain was stored for 6 months in a Minnesota winter
- The resulting grain was dry and unspoiled
The Concrete Elevator: Improvements on Haglin’s Design
The Concrete Elevator: Improvements on Haglin’s Design

Screw jack supported on vertical rod
The Concrete Elevator: Improvements on Haglin’s Design

Yokes and screw jacks atop a bin

Elevator forms around a bin
The Concrete Elevator: Improvements on Haglin’s Design

Screw jack supported on vertical rod
Forms rising up bins
The Concrete Elevator: Construction Photos

- Bin floors on supporting piers
- Beam reinforcing before beam forms are set
The Concrete Elevator: Design

How to prevent this...
The Concrete Elevator: Design

\[ L = \frac{wR}{f} \left[ 1 - \frac{1}{kfh} \right] \]

where—

- \( L \) = unit horizontal pressure,
- \( w \) = unit weight of grain,
- \( R \) = ratio area of cross-section: perimeter
- \( f \) = coefficient of friction of filling on walls,
- \( k \) = ratio of horizontal to vertical pressure,
- \( h \) = depth of filling,
- \( D \) = diameter of bin,
- \( e \) = constant, usually taken = 2.7183.

(50pcf)

(0.42)

(0.60)
The two variables on the right side of the equation are:

- \( h \), the depth of the grain; and
- \( D \), the bin diameter.

Inserting the constants and simplifying the equation give:

\[
L = 30 \times D \times (1 - 1/h)
\]

- As “\( h \)” approach increases, \( L \) approaches \( 30 \times D \).
- Therefore, the maximum lateral pressure on the bins is 30 times the diameter.
- Pressure, \( L \), is in psf; the diameter is in feet.
- Maximum pressure is reached @ \( h = 2 \frac{1}{2} - 3 \times \) bin diameter
The Concrete Elevator: Design

- It can also be shown that the Bursting Pressure,
  \[ T = 0.5 \times L \times D \]
- And that the required area of horizontal steel,
  \[ A_s = \frac{T}{f_s} = 0.5 \times L \times D / f_s \]
- Designers used a nomograph to select spacing of horizontal bars.
The Concrete Elevator: Design

Steps:
1. Choose a height
2. Move across to a desired diameter.
3. Move up diameter to desired rebar size
4. Move across to required spacing.
The Concrete Elevator: Notable Failures

Haglin’s Duluth elevator:
• Bins – 33’ diameter x 104’ tall
• Bins separated by 6’ long connecting walls, enlarging interstitial bins and increasing loads against outside face of the bins.
The Concrete Elevator: Notable Failures

December 12, 1900 outside bin failure
The Concrete Elevator: Notable Failures

Second failure occurred in 1903 to another outside bin
The Concrete Elevator: Notable Failures

Cause of failure:
C.A.P. Turner:
1. Bins loaded as arches.
2. Connecting walls insufficiently stiff to resist rotation at joint
3. Allowed curved wall to rotate, reducing (-) moment, increasing (+)
The Concrete Elevator: Notable Failures

University of Minnesota Testing:
- Loaded a ring to failure
- Determined that bins have sufficient capacity to resist interstitial loads (as an arch) equal to main bin loads
Conclusion

Thank you.

Washburn Crosby Elevator, Minneapolis