Evaluating New Pack Factors for Stored Grains
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Grain Storage Systems
Pack Factor

- Pack factor – adjustment factor to calculate the mass of grain from volume measurements
- Adjusts for the true density after compaction (based on test weight w/o compaction)
- Important for accurate grain inventory, government auditing, & insurance purposes
Some issues with current system

- Huge increase in bin sizes and amount held in storage
- Changes in varieties/hybrids
- Measuring the height of grain:
  - Can be difficult to estimate level height
- Sources of current pack factors not well-known or documented
Expansion of on-farm storage
Potential problems estimating level depth

400,000 bu bin
On-farm
2 sidedraws
Project Objective

- Develop new stored grain pack factors for seven grains: wheat, corn, soybeans, sorghum, oats, barley, and rice.

- Incorporate new pack factors into a user-friendly software package.

To be used by USDA-RMA (FCIC), who funded the project, for insurance purposes.
Presentation Outline

- Approach – combining lab and field data with computer modeling.
- Laboratory Measurement Results – brief
- Field Measurement Results – Wheat, Corn, & Soybeans
Approach

- Measure fundamental compressibility relationships in the laboratory for use in science-based modeling.
- Collect field measurements of pack factor for a wide range of bin sizes from around the U.S.
- Refine and calibrate the science-based model to predict pack factor based on physical principles.
Approach – Lab Compressibility Tester
Approach – Connecting the Dots

Model – Pressure vs. Grain Depth

Laboratory – Packing vs. Pressure.

= Predicted pack factor (% packing)
Field Measurements

- Wide range of bin sizes (diameter and eave height), types (materials and shapes)
- Seven grains
  - wheat, corn, soybean, sorghum, oats, barley, and rice
- All major grain-producing locations within the U.S. emphasizing the:
  - Midwest
  - Central Plains
  - Northern Plains
Field Measurement Locations
# Bins Measured

<table>
<thead>
<tr>
<th>Crop</th>
<th>Total No. of Bins</th>
<th>State</th>
<th>Bin Diameter (ft)</th>
<th>Eave Height (ft)</th>
<th>Moisture Content (% wb)</th>
<th>Test weight (lb/bu)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat*</td>
<td>55</td>
<td>KS, OK, TX</td>
<td>15 – 105</td>
<td>10 – 137</td>
<td>10 – 12.5</td>
<td>52.7 – 62.6</td>
</tr>
<tr>
<td>Corn</td>
<td>87</td>
<td>KS, MN, CO, IA, KY, TX</td>
<td>11.8 – 105</td>
<td>14.5 – 91</td>
<td>13.4 – 17.2</td>
<td>54.5 – 60.0</td>
</tr>
<tr>
<td>Soybeans</td>
<td>34</td>
<td>SD, MN, KS, ND</td>
<td>24 – 75</td>
<td>17.5 – 75</td>
<td>8.1 – 11.0</td>
<td>56.4 – 61.0</td>
</tr>
<tr>
<td>Sorghum</td>
<td>6</td>
<td>TX, OK</td>
<td>15 – 89</td>
<td>51 – 137</td>
<td>12.8 – 14.6</td>
<td>57.5 – 58.1</td>
</tr>
<tr>
<td>Oats</td>
<td>18</td>
<td>IA, NE</td>
<td>13.4 – 89.5</td>
<td>84 – 124</td>
<td>11.8 – 13.2</td>
<td>39.3 – 44.7</td>
</tr>
<tr>
<td>Barley</td>
<td>7</td>
<td>MT, ID</td>
<td>88 – 105</td>
<td>60 – 66</td>
<td>9.5 – 9.85</td>
<td>49.0 – 51.5</td>
</tr>
</tbody>
</table>

**Additional Bins** – Time effect studies with Wheat, Corn, and Barley bins.

* Average dockage was 0.5%

Over 200 bins and counting…
Measurement Procedures

- **Input Data for Calibration**
  - Type of grain
  - Moisture content/test weight (Average)
  - Bin diameter, Eave height, & Hopper dimensions
  - Bin wall material
  - Grain height (where grain intersects wall)
  - Angle of Repose
  - Weight of grain at given depths

- **On-Farm Grain Bins**
  - Measured grain volume
  - Collected weights and grain property data after the crop was sold

- **Grain Elevators**
  - Measured grain volume
  - Collected weights and grain property data for incoming or outbound trucks as appropriate
Measuring a bin
Laser meter for distance and angle
Method to Estimate Volume
Calculating volume
Field Results

- Compared field measurements to three methods of predicting pack factor:
  - Published model (WPACKING)
    - Grain: Type, TW, MC, Height
    - Bin: Diameter, Wall material, Filling method
  - Current RMA method
    - Grain: Type, TW
    - Bin: Cross-sectional area
  - Current FSA warehouse group method
    - Grain: Type, TW
WPACKING predicted vs. reported mass

y = 0.9965x - 3.7402
R² = 0.9999

HRW Wheat; Steel Bins

y = 0.9965x - 3.7402
R² = 0.9999
Difference between predicted & reported mass
Steel bins – HRW wheat

% Difference

Reported Mass (t)

WPACKING
RMA
FSA
Difference between predicted & reported mass
Steel bins – HRW wheat

% Difference vs. Reported Mass (t)

- WPACKING
- RMA
- FSA
WPACKING predicted vs. reported mass

Corn; Steel Bins

\[ y = 0.9914x \]
\[ R^2 = 0.9998 \]
Difference between predicted & reported mass
Steel bins - corn
Difference between predicted & reported mass
Steel bins - corn

% Difference vs Reported mass (t)

-8% -6% -4% -2% 0% 2% 4% 6% 8%

0 500 1,000 1,500 2,000

WPACKING
RMA
FSA
WPACKING predicted vs. reported mass

Soybeans; Steel Bins

\[ y = 1.0141x \]
\[ R^2 = 1 \]
Difference between predicted & reported mass
Steel bins - soybeans

Reported Mass (t) vs. % Difference

- RMA
- WPACKING
Difference between predicted & reported mass
Steel bins – barley (steel bins unless noted).

Concrete
Difference between predicted & reported mass
Steel bins – grain sorghum (concrete unless noted).
Difference between predicted & reported mass
Steel bins - oats (concrete silos unless noted).
Summary of current results

- Of the three pack factor methods, the WPACKING model gave predictions closest to the measured mass for corn, soybeans, and wheat.

- The FSA warehouse method gave closer predictions than the RMA method for larger bins, but there was little difference in the accuracy of these two methods for smaller bins.

- Calibrating the WPACKING model based on these laboratory and field data should further improve its predictions of packing.
Acknowledgement

- Thanks to many, many generous Grain Elevator Cooperators and Farmer Cooperators.
- Thanks to many others who gave us contacts and helped arrange visits to elevators and farms.
Thank You !