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Emergency Grain Storage in Existing Buildings

Bruce A. McKenzie, Extension Agricultural Engineer
Purdue University

Grain storage in drive areas of cribs and sheds is one of the easiest and quickest adaptions of existing space for small volume storage. Open machinery storage, utility buildings, and barn areas are prospects for larger volumes. The conversion of ear corn storage to shelled corn, both in rectangular stud frame and pole frame designs as well as with circular metal ear corn storages, is also a logical adaptation. Silage silos may also be converted to dry shelled grain storage. Discussion of silos is contained in a separate release entitled Adapting Silage Silos for Dry Grain Storage.

Converting Ear Corn Storages

AED-12, "Remodeling Ear Corn Cribs for Shelled Corn" is an excellent reference concerning the adaptation of stud and pole frame cribs. Stud frame cribs are relatively easy to convert, assuming they are in good repair. Many pole cribs require a more complete over-haul, since the support system between the pole spacing of 4' to 5' may not be adequate to withstand shelled grain loads.

In recent years, many stud frame conversions have been done using banding steel as the added cross tie. The banding steel is galvanized, 1 -1/4" wide. Its advantage is low cost and the simplicity of installation -- the bands are simply looped around opposite studs, tensioned with a device similar to a fence stretcher and clamped with clip-type fasteners applied with a device like a giant hog ringer. They are quick to install, require no outside wale or framing member, and have been reasonable in cost. Several lumber yards and/or grain equipment dealers in central Indiana stock the banding steel and rent the tensioning and clamping installation device. Details are presented in AED-12.

Both round sheet metal and wire ear corn cribs have been converted to shelled corn storage. Such structures are usually weak in hoop tension in the lower section up to the height of the door. It is usually necessary to install 3 silo hoops or cables around the lower section -- one at the bottom, middle and top of the door. In addition, some of the units are weak in vertical sidewall strength, and the manufacturer will recommend the installation of stiffners.

Several manufacturers make liner kits for round wire cribs. It is always a good idea to check with the storage manufacturer, before starting a round crib conversion. Some farmers have installed a home-made liner in a wire crib, using standard corrugated roofing sheets installed vertically inside the crib wall. The key is in working out an edge-binding system that is adaptable to the wire crib involved.
On perforated sheet metal wall storages, a common practice is to pound the perforation closed, and then paint the inside surface of the bin with a fibrous asphalt-type paint. Some farmers have had the storage sprayed using car undercoating material. Others do not close the perforations nor do any painting. Some water penetration may result in this latter system in a driving rain. Attempts to use plastic liners may cause almost impossible problems in keeping the plastic in place during filling and unloading. Too, the plastic liner may funnel water down a fold and dump it into the grain in a concentrated point that will cause far greater spoilage than from no liner at all.

Bottom center unloading should be planned for all conversions of circular wire and sheet metal grain storages. Side withdrawal will unbalance the sidewall loading, will probably force the structure out-of-round, and may cause it to tip over in complete structural failure. See MWPS-13, Planning Grain-Feed Handling for details on mechanizing unloading and installing aeration systems in round metal crib conversions. Any storage over 2000 bushels should have an aeration system installed. See AE-71, Aeration of Stored Grain.

Estimating Flat Storage Volume

It is often surprising how little storage volume can actually be accomplished in what first appears to be a large open building space. We tend to forget that round metal bins store grain 16-20' deep in storages with vertical sidewalls, therefore requiring relatively little floor area per unit of storage.

In contrast, grain storage in shelter structures is typically limited to a maximum of 2' to 3' of depth on the sidewalls. Even though piled high in the center, the pile increases in depth slowly toward the center, at the angle of repose for the materials -- essentially 27° above horizontal, which is approximately a 1:2 side slope.

Figure 1. Schematic of grain mass with top surface. Slopes equal to 27° angle of repose. End sections taken together form a pyramid resting on a square box. Midsection forms a wedge sitting on a rectangular box. If sides are not retained, the rectangles illustrated disappear and only the pyramid and wedge section result. (Value of h can be easily estimated on the basis of a 1:2 side slope.)
This is illustrated in Figure 1. The schematic represents a pile of grain retained on the sides and ends and piled to maximum height along the center length. The two end sections, taken together, form a pyramid resting on a square box. The base of the pyramid and the box will be square, and equal to the width of the storage. The center section forms a wedge-shaped section, resting on a square or rectangular box.

The storage volume of the entire structure can easily be estimated by calculating the volume of the square or rectangular box plus the triangular top unit for each section, and adding all of the totals together. Consider a 20' wide by 60' long shed area, with a side and end wall retained at a 2' depth.

Combining the two end sections for simplicity, the volume is:

\[
V_e = 20' \times 20' \times 2' + 1/3 \times 20' \times 20' \times 5' = 1466 \text{ ft}^3
\]

Considering the center section:

\[
V_c = 20' \times 40' \times 2' + 1/2 \times (20') \times (40') \times 5' = 3600 \text{ ft}^3
\]

Then, the total volume is:

\[
V_T = V_e + V_c = 1466 + 3600 = 5066 \text{ ft}^3
\]

To convert cubic feet to bushels of grain, recall that 1 bushel = 1.25 cu.ft. We can either divide the total cubic feet by 1.25 ft³/bu or multiply by 0.8 bu/ft³. Thus, the total storage capacity of the 20' x 60' shed area, piled 2' deep at the sides and ends, is only 4050 bushels. This is about equal to a 21' diameter x 16' deep round metal bin.

Note that if the sides and ends of the grain mass are not retained, the volume calculation simply eliminates the square or rectangular base volumes. Too, if one end of the mass is piled vertically against an endwall, only one half pyramid end shape is involved. See MWPS-3, 6, 7, 8 or 15 for simple formulas to compute the volume of various shapes.

Structural Strength and Stability in Shelter Structures

The primary problems in adapting existing shelter-type farm and elevator buildings to grain storage include: 1) structural strength of the side and endwalls; 2) quality of the floor construction and surface; 3) grain handling, primarily distribution during filling and gathering during load-out; 4) rodent, bird and insect control; and 5) grain aeration and management.

The side and end walls of shelter structures are simply not built to withstand lateral loads other than those normally sustained from wind pressure or an occasional bump by an animal or equipment. Such walls can usually sustain no more than 2 to 3 feet of grain depth piled against them, assuming the walls are in good repair and alignment.

Under the lateral pressure of grain loading, the building wall may fail or be permanently damaged by tipping the foundation wall outward; possibly shearing...
or tearing out the anchor bolts in the sill; bowing the sill and/or wall sections between the anchor bolts; and/or structural failure in the wall sections above the foundation wall.

Shelled corn places roughly 4 times the sidewall loading on a crib wall, as did ear corn. A 20' depth of shelled corn places roughly 400 pounds/square foot lateral pressure on the sidewall at the bottom. When we consider that a typical corn crib wall was a heavily framed construction additionally supported by heavy cross ties from wall to wall to sustain ear corn loads, we can better appreciate the problem of shelled grain pressures on shelter structure walls never designed for any lateral loading.

The floor/foundation wall/stud wall attachments are especially critical in grain storage structures. The foundation wall must be tied to the floor either by casting them in one piece, or by lacing reinforcing rods through the joint to make them act one unit. Since the load from the wall is transferred into the foundation wall and floor via the anchor bolts or stud attachments at the base of the wall, both the floor and the anchor bolts have to be adequate for the heavy loads.

It is usually not economical to add strength to a shelter structure wall to carry grain pressures over 2-3' deep. Although diagonal props or braces along the outside of the wall, or diagonal floor ties to the inside floor may be used, their cost, maintenance and inconvenience usually rule them out. Strengthening the wall essentially involves constructing a building within a building, an equally uneconomical answer.

Tables 1 and 2 present data on safe depths for several shelled grains for different joist and stud spacings and lengths.

**Table 1. Safe depth of wheat, rye, shelled corn, grain sorghum, or soybeans\(^1\) in bins with joists of common sizes and spans, with 2 and 3 supports, for 24-inch spacings.\(^2\)**

<table>
<thead>
<tr>
<th>Size of joist (inches)</th>
<th>6-foot</th>
<th>8-foot</th>
<th>10-foot</th>
<th>12-foot</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>feet</td>
<td>feet</td>
<td>feet</td>
<td>feet</td>
</tr>
<tr>
<td>JOISTS SUPPORTED AT ENDS ONLY (24-inch spacing(^3))</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 x 6</td>
<td>3-1/2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 x 8</td>
<td>5</td>
<td>3-1/2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 x 10</td>
<td>6</td>
<td>4-1/2</td>
<td>3-1/2</td>
<td></td>
</tr>
<tr>
<td>2 x 12</td>
<td>7-1/2</td>
<td>5-1/2</td>
<td>4-1/2</td>
<td>3-1/2</td>
</tr>
<tr>
<td>JOISTS SUPPORTED AT EACH END AND AT CENTER (24-inch spacing(^3))</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 x 4</td>
<td>3-1/2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 x 6</td>
<td>6</td>
<td>4-1/2</td>
<td>3-1/2</td>
<td>3</td>
</tr>
<tr>
<td>2 x 8</td>
<td>8</td>
<td>6</td>
<td>4-1/2</td>
<td>4</td>
</tr>
<tr>
<td>2 x 10</td>
<td>10</td>
<td>7-1/2</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>2 x 12</td>
<td>12</td>
<td>9</td>
<td>7</td>
<td>6</td>
</tr>
</tbody>
</table>

1 Depth of oats may be 1/2 more and barley 1/3 more than above.
2 This table is based on the ordinary commercial sizes of lumber. If joists are full-sized rather than nominal, depth of grain may be increased 1/3. If soft, lightweight lumber is used, reduce depth of grain 1/3. Joists should be bridged.
3 If joists spacing is 12 inches, grain depth may be doubled.
Table 2. Safe depth of wheat, rye, shelled corn, grain, sorghum, or soybeans in bins with studs of common sizes and spacings. 1,2

<table>
<thead>
<tr>
<th>Size of studs (inches)</th>
<th>Spacing center to center</th>
<th>Length of stud</th>
<th>Depth of grain (inches)</th>
<th>Spacing center to center</th>
<th>Length of stud</th>
<th>Depth of grain</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 x 4</td>
<td>24 inches</td>
<td>8 inches</td>
<td>5 feet</td>
<td>2 x 6</td>
<td>24 inches</td>
<td>8 inches</td>
</tr>
<tr>
<td>2 x 4</td>
<td>16 inches</td>
<td>8 inches</td>
<td>6 feet</td>
<td>2 x 6</td>
<td>16 inches</td>
<td>10 inches</td>
</tr>
<tr>
<td>2 x 4</td>
<td>12 inches</td>
<td>8 inches</td>
<td>7-1/2 feet</td>
<td>2 x 6</td>
<td>24 inches</td>
<td>10 inches</td>
</tr>
</tbody>
</table>

1 This table is based on the ordinary commercial sizes of lumber. If the studs are full-size rather than nominal, the depth of grain can be increased 1/3. If large knots occur in any of the studs or if the lumber is soft and lightweight, ties should be used across the bin. Studs should be well fastened to the floor system.

2 Depth of oats may be 1/2 more and of barley 1/3 more than above.

NOTE: Tables 1 and 2 taken from USDA 2009, Storage of Small Grains and Shelled Corn on the Farm -- Out of Print.

Round metal bins without roofs have occasionally been installed in rectangular areas in barns and warehouses, to increase storage capacity and gain sidewalls capable of sustaining grain loads. Again, the practice essentially involves constructing a building within a building. About all that is saved is the roof. Too, the bin sizes to fit the old building are frequently smaller than what would be used if a new bin was installed outside. Unloading and filling may be a problem as may be bird control.

Such an installation is probably most justifiable when the bins are relatively small, possibly hopper bottomed, and used and justified as working bins to make the grain handling and feed processing system work well.

Hay mow storage for shelled corn can be used but offers few advantages. Baled hay weighs about 10 pounds per cubic foot, loose hay about 4 pounds per cubic foot. Corn, in contrast, weighs roughly 45 lbs/ft³. Thus, the corn weight is 10 times the loose hay and 4-1/2 times the baled hay. Therefore, 1' of corn equals 10' of loose hay and 4.5' of baled hay -- a mow that could store 20' of loose hay can only support 2' of shelled corn! In general, the handling, bird contamination, rodent problems and structural strength considerations eliminate hay mows for shelled grain storage.

In the final analysis, the most economical answer for strictly short term storage is to pile grain only 2-3' on the sidewalls and peak the pile as much as possible. Any construction more than this must be viewed in terms of its long run performance and cost in relation to other permanent storage systems.

Preparation of the Floor

Open areas in existing buildings frequently have irregular and cracked concrete floors or earth floors. Such floors normally have no vapor barrier.
There are really only two alternatives, short of installing a new floor with a vapor barrier. One is to place the grain directly on the bare floor or earth. This should be considered only for very short term, 1-3 month, storage, and usually anticipates that there may be some marketing loss because of spoilage and dirt contamination.

The second alternative is to install a vapor barrier on top of the floor surface. The vapor barrier is usually a 4-6 mil plastic sheet, although asphalt impregnated roofing paper or a vapor-proof kraft paper may also be used. The major problem concerns keeping the vapor barrier intact and out of the way while filling and unloading the storage. When the storage is unloaded, it is difficult to remove grain by either hand or power equipment without snagging on the vapor sheet and getting torn pieces into the equipment and grain.

**Grain Handling**

Storage filling into open temporary storages is usually easiest accomplished with a portable auger or other inclined conveyor. The auger can be easily shifted to shape the pile. Although fines distribution will be a problem, this will usually not be a big factor in 1-3 month storage of cool, dry grain, unless the grain quality is very bad.

In filling and shaping wide flat areas, such as the open space under a hay mow in a barn, it may be possible to lay a horizontal auger on the grain pile or suspend it from the mow floor, to distribute grain over a wide area. The horizontal auger discharge point can be rotated to deliver in all directions from the initial fill point. The horizontal transfer auger may be of smaller diameter than the main fill unit, if fill delivery is not continuous. The small relay auger will catch up between loads. Alternatively, two small relay augers can be used to match the flow of one large unit. Fines deposit in and around the initial drop point where the relay auger re-conveys the grain may have to be considered.

The horizontal transfer or relay auger may also be placed on top of the mow floor in barn storages, with the grain dropped through entry holes in the floor. However, the capacity must then match the delivery conveyor, unless an overflow feeding arrangement is used.

Storage unloading may not be as critical in terms of time and delivery rate as is grain receiving and filling at harvest. However, temporary storage tends to preclude the installation of any permanent handling equipment for grain removal. The alternatives are then inclined augers plus scoop shovels; the possible addition of a manually positioned grain sweep to the intake of the inclined conveyor (but a very dangerous device in terms of operator safety); and the use of a power scoop on the front of a tractor. Some elevator operations that have considerable flat storage may have a tractor mounted horizontal grain storage unloader that will continuously gather and convey the grain into the load-out vehicle.

**Rodent, Bird and Insect Control**

The only workable recommendation on rodent control in temporary flat storages is to work hard at keeping the rodent population down on the premises. It is virtually impossible to keep rodents out of a good quality flat storage that has tracked doors and big removable bulkheads. The problems in temporary storages never really designed for grain are worse. You must be continually aware that more and more grain moves into human food channels and that the quality requirements for such grain are critical.
Bird control in temporary storages may be easier than that for rodents. Give consideration to how birds are gaining access, and see if you can economically block their entry. If night roosting in the building is a problem, check with your extension office concerning information and possible procedures for treating the storage.

Insect control and management in temporary storage is really no different than that normally practiced except that the shape of the grain mass may not be ideal for in-storage treatment. If grain and feed materials have not been stored in the area, insect control will probably not be a problem in the 1-3 months of temporary storage.

Grain Aeration and Management

The grain should ideally be placed in the storage in a cool and dry condition. The grain should be at least dried to 15-1/2% moisture, wet basis, and preferably 14% for greater safety. Grain of poor quality should be dried 1% more dry than that required for good quality material.

Cool the grain to 50°F or below before placing in the storage, if at all possible. High speed batch and continuous flow dryers can usually not cool grain lower than 10°F above the outside air which they are moving. This means that drying would have to be done in very cold 40°F weather, or the grain cooled in a Dryeration or storage bin during the night hours, before placement in the temporary storage. Since the last harvest of the season will tend to go to temporary storage, this grain will naturally be more cool. If grain at temperatures above 50°F must be placed in the storage, the necessity for a well designed and managed aeration system will be much greater.

The emergency storage can be equipped with an aeration system. However, this forces additional investment for a short run storage, that may not be usable in the future in this same storage. Keep in mind, however, that the grain may be worth $2.25 to $3.00/bushel -- an investment well worth protecting.

The aeration systems in wide, peaked flat storages are usually of round, or half-round perforated duct(s) laid on top of the floor. The ducts usually run in the direction of the long peak in a rectangular pile and are usually spaced at intervals roughly equal to twice the average grain depth. Positioning the ducts slightly toward the center of the pile, thereby more directly under the more deep portion and away from the shallow edges, will tend to give a more uniform air distribution throughout the grain mass.

The duct and fan size is critical for a correct aeration system design. The farm and elevator operator should obtain technical design help in planning and selecting components for a system. AE-71, Aeration of Stored Grain, gives guidelines on system planning and management. Copies of the latter are available from your Cooperative Extension Office.

Freestanding Portable Bulkhead

There is frequently a need for a freestanding bulkhead that can be placed across the exposed end of a grain storage mass in an open area. A copy of the University of Illinois Farm Building No. 21 entitled Self Supporting Portable Walls for Grain Storage is appended to this paper. The bulkhead is an "L" shaped structure, designed such that when grain is placed on the horizontal leg of the "L", the weight of the grain keeps the vertical wall from tipping over. The legs of the "L" are tied together with a diagonal tie and corner bolt assembly. The
concept is not unlike the old problem of stepping on the rake, and having the handle strike you in the face.

Note that there is essentially as much material in the horizontal leg of the "L", as there is in the vertical wall. Hence, the portable bulkhead is really "two" walls, one horizontal and one vertical.

REFERENCES

AED-12, Remodeling Corn Cribs for Small Grain Storage
AE-71, Aeration of Stored Grain
MWPS-13, Grain Handling Handbook
Farm Buildings 21, Self-Supporting Portable Walls for Grain Storage,
University of Illinois.

SELF-SUPPORTING PORTABLE WALLS FOR GRAIN STORAGE*

Existing buildings or new buildings constructed for purposes other than grain storage can be adapted for safe storage of shelled corn and small grains by the use of self-supporting portable walls (see photo). Self-supporting walls are a separable and independent part of the building in which they are used.

APPROXIMATE STORAGE CAPACITY
OF RECTANGULAR BINS

The self-supporting portable walls carry the entire grain load, while the building provides protection from the weather, rodents, birds, etc. A vertical panel holds the grain in place. The vertical panel is secured to a floor panel which is prevented from sliding by the weight of the grain.

The wall and floor panels can be fabricated in modular-length units of eight feet or more for installation in pole frame, rigid frame, or stud construction machinery or cattle sheds, garages, etc. Most of the material can be salvaged for other uses when the panels are no longer needed for grain storage.

* From Engineering Tips (Farm Buildings No. 21) by Gene C. Shove, Department of Agricultural Engineering, University of Illinois, Urbana, Illinois.
SECTION OF WALL AND FLOOR PANEL
DETAILS OF SELF-SUPPORTING PORTABLE WALL

Recommended Size and Spacing of Portable Wall Members

<table>
<thead>
<tr>
<th>Stud height (feet)</th>
<th>Stud size (inches)</th>
<th>Stud spacing (inches)</th>
<th>Tie rod height (feet)</th>
<th>Tie rod diameter (inches)</th>
<th>Wale support size (inches)</th>
<th>Wale panel size (inches)</th>
<th>Floor panel width (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>2 x 4</td>
<td>24</td>
<td>3 1/2</td>
<td>3/8</td>
<td>4 x 4</td>
<td>2 x 6</td>
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<td>8</td>
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</tr>
<tr>
<td>12</td>
<td>2 x 10</td>
<td>24</td>
<td>6 1/2</td>
<td>1/2</td>
<td>4 x 6</td>
<td>2 x 10</td>
<td>8</td>
</tr>
</tbody>
</table>

A 4 x 6 wale must be placed with the 4-inch edge next to the stud.

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