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STRUCTURAL REQUIREMENTS OF GRAIN BINS*

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STRUCTURAL REQUIREMENTS OF GRAIN BINS*

Foundations

Except for the heavy loads imposed by grain the same conditions that determine foundation requirements for other farm structures apply to grain bins. Typical design loads are given in Figures 1 and 2.

Anchoring

All parts of the anchoring system (fastenings to bin and ground or foundation and the connecting members between these fastenings) must have sufficient strength and be installed so as to prevent any shifting or lifting of the empty bin by impact of wind, grain-handling equipment, or livestock.

Anchoring systems should not interfere with or be exposed to damage by farm equipment or livestock. For portable bins the anchoring should be easily installed and disconnected. Such anchoring may also be required for temporary emergency bins if they cannot be filled immediately after erection.

In calculating the overturning moment due to wind, which must be resisted by the anchoring system of portable or similar lightweight bins, the following unit pressures per square foot of projected area are recommended: 24 pounds for bins 10 feet high, 27 pounds for bins 15 feet high, and 29 pounds for bins 10 feet high. When these values are used in calculating the overturning moment, an equivalent resisting moment should be safe for all but the most extreme winds. Greater design pressures have been recommended for barns and may be advisable for granaries of comparable size and shape.

Floors

Structural features should prevent water from penetrating to any part of the floor that contacts grain. Particular attention to the design of joints between the floor and outside walls is required. If the bin must be located where surface and soil-water drainage do not protect the subfloor from occasional wetting or continued dampness, the finish or subfloor, or both, should include materials that prevent the penetration of water vapor or capillary moisture.

The construction should be tight enough to prevent excessive leakage of fumigant vapors. If a floor of perforated metal or similar material is used, the design should permit convenient and effective sealing of the space beneath the floor. Easy and complete removal of old grain and foreign material that may harbor stored-grain insects should be possible. Structural details or fabricated materials that introduce obstructions, cracks, or pockets at the floor surface should be avoided if practicable.

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*Adapted from USDA Circular No. 835, "Grain Bin Requirements".

This is particularly important when the bin has a self-cleaning hopper bottom. Floors of this type will not give satisfactory service if the slope is less than the emptying angle of repose of the grain that is stored (Table 1). Ordinarily a slope 10° greater than these angles of repose is needed to assure removal of small particles such as broken kernels and grain dust. If damp grain must be handled, the walls of the self-cleaning hopper will require a slope 25° greater than the angle of repose for clean and dry grain.

In estimating the strength required to prevent loss of grain the average unit pressures given in chart (Fig. 2, A), are recommended. These average pressures represent a load increasing uniformly to the center of the floor producing a bending moment represented by the formula $M = 1/6\ Wl$, where M is the bending moment, W the total load, and l the span. Flooring near doors and corners may be subjected to impact, abrasion, and tearing by shovels and grain-conveying equipment. Protection from or resistance to such damage should be provided. Similarly the floor should be resistant to or protected from gnawing by rodents or damage by termites and cadelle beetles. Structural features or material treatments that will prevent the loss of necessary strength and tightness due to wood rot, metal rust, or disintegration of masonry should be used, especially in permanent storages. However, flooring that contacts grain should not be treated with materials such as creosote, which give grain commercially objectionable foreign odors.

Walls

Exterior wall materials and joints should exclude draining water and rain or snow blown from any direction. If these walls include members such as exterior stay timbers or door frames, where snow or water may accumulate, they should be flashed. Materials used for calking or gaskets frequently fail to give permanent protection.

Exterior walls should be protected from solar heat. Such protection will retard or prevent the development of damage in bulk grain and possible damage to the wall from overloading. White or other reflective surfaces or shading, or both, are generally most practicable for this purpose. If insulation is used to eliminate daily fluctuations in grain temperature, it should have a thermal conductance equivalent to that of a layer of wheat at least 12 inches thick, that is, approximately 0.08 British thermal units per square foot per hour per degree difference in temperature.

All walls should be tight enough to prevent excessive leakage of fumigant vapors. Any of the common types of walls, except perforated metal, will meet this requirement if kept in good repair. All parts of the wall should be self-cleaning to assure removal of old grain that might harbor insects. Many farm storages, especially multiple-bin granaries of wood construction, do not have this desirable aid to sanitation. Designs should include beveled surfaced wherever needed on bracing, cross ties, interior stay timbers, sills and plates; and the shielding or preferably the elimination of inaccessible pockets formed by the wall assembly.

For general use in estimating strength requirements the maximum wall loads given in charts (Figs. 1, A and B; 2, B), are recommended. These allow for ordinary changes in pressure such as those that may occur during filling and emptying, and those due to characteristic reactions of different kinds of grain. For example, shelled corn has a much higher thermal conductivity and lower resistance to air flow than wheat. The coefficient of thermal expansion of wheat is not known, but for dry (9.3 percent moisture wet basis) shelled corn it is 0.187×10^{-4} per $^{\circ}$ F., which is about 3 times that for steel (0.0608×10^{-4} per $^{\circ}$ F). In corrugated steel bins of identical size and construction those used for wheat have shown no evidence of overloading but many of those used for corn have crippled walls where lighter gage sheets have very gradually folded down on heavier gage supporting sheets. This deformation always begins on the wall receiving the most solar radiation and is often limited to it. Protection from possible damage by trucks or other grain-handling equipment may be necessary if walls are made of easily punctured materials. Possible deformation or collapse of stave-type walls because of eccentric filling and emptying requires consideration in the design of deep bins but is relatively unimportant in shallow bins that are slowly filled and emptied.

For bins that require the use of cross ties and cannot be completely emptied without shoveling, the maximum amount of headroom consistent with structural efficiency should be provided. A clearance of at least 5 feet between floor and tie is desirable. But a clearance of 4 feet is suggested as a permissible minimum, especially in bins of small capacity (less than 1,000 bushels).

Roofs

All roof joints should exclude draining or standing water (on either flat or steep roofs) and blowing rain or snow. In localities where fine dry snow is a common hazard, the joints at eaves should be of dust-tight construction or be easily sealed to give equivalent protection. Condensation on the underside of roofs is insufficient to cause damage when bins are filled with grain that is in suitable condition for safe storage.

The roofs or outdoor bins should be protected from solar heat by white or other reflective surfaces or shading, or both. Such protection provides a more confortable space for workmen without the use of ventilators. It also retards insect infestations by keeping the surface layers of grain cooler.

Many flying or crawling stored-grain insects can pass through very small openings. Roof joints, especially at the eaves, should be tight enough to prevent this. Such construction will also help prevent the dissipation of fumigant vapors during windy weather. Any framing that extends under filling hatches or discharge spouts should have self-cleaning surfaces.

When bins are located under a floor where objectionable materials, such as poisonous dusts or fertilizers, may be stored, the floor should be of dust-tight construction.

Any part of the roof that must be used as a deck should have strength to support the following loads without permanent deformation of framing and opening of joints or fracture of the deck surface. Either 300 pounds concentrated at center or 30 pounds uniform, whichever is greater for the spans involved. When the roof is more than 10 feet above the ground, safeguards against injury by slipping and falling, such as cleats or handrails, should be installed.

Headroom should not be less than 2 1/2 feet at a distance of 3 feet from any wall. This headroom will permit reasonably convenient inspection of all surface grain and probing of any portion of the bulk to a depth of 4 to 5 feet. Ordinarily this will be sufficient for determining the need for fumigation or for examining grain that may become too damp as a result of moisture migration. Bin-capacity ratings should be based on this minimum headroom requirement. However, design loads should allow for possible filling of the bin to the eaves.

Openings, Ducts, and Closures

The openings, ducts, and closures of the structure often fail to exclude draining or standing water and blowing rain or snow. Inadequate flashing, defective joints, and deformation at the edges of openings and closures are common faults. Doors or hatch covers that do not fit properly may have to be pried open or hammered shut. Materials are often used without necessary protection or reinforcing to prevent warping and swelling or bending and buckling. Louvres in gable or ridge ventilators and ventilating cowls fail to function during severe storms or blizaards. Wall openings for air ducts may not be closed before such weather occurs.

Air ducts may be used to keep bulk temperatures more uniform. But the risk of damage from condensation on the inner surface of the ducts may be too great to justify their use unless the design of duct joints, perforations, or inner surfaces provides positive protection against wetting of the grain by penetration or drainage of the condensate. Duct-wall and air temperatures differ as much as 10° to 20° F. during daily changes in outdoor temperature.

All ducts or spouts and the framework for openings should be easy to clean or self-cleaning. (See section on Floors, for reference to required slopes). To prevent the entrance of stored-grain insects all openings should be screened or have closures that give equivalent protection. A 24-mesh screen (Tyler Scale) will exclude all of the more important species except the lesser grain borer and the saw-toothed grain beetle. A 32-mesh screen should be used for storages located in regions where insect control is most difficult. This small-mesh screening will have some adverse effect on air flow and the use of ventilated bins in these regions should be restricted. All openings and closures in walls

on floors that must be made vaportight before fumigation should permit easy and effective application of sealing tape, calking, or other temporary aids.

Slow leakage of grain from defective joints in either the framing or the closure of wall and floor openings may not be noticed until a large quantity of grain has been consumed by rodents, birds, or livestock. The location and size of openings for filling a bin by shoveling from wagons or trucks may result in excessive spilling and waste of grain. Whenever practicable such openings should have no dimension less than 2 feet and the bottom edge should not be more than 8 feet above the ground. A minimum dimension of 1 1/2 feet and 10 feet above ground may be considered as permissible limits. Scoop doors in exterior walls should prevent the flow of grain over the edge of the floor. Because of the dragging action of a shovel the grain tends to assume the filling angle of repose (Table 1). This angle should be used in determining the position of the bottom grain board in these doors. The same requirement applies in preventing excessive spilling of grain from wall ports during probing. Closures for openings and spouts discharging grain to elevating equipment or to containers uch as sacks should operate easily and effectively. Failure of these devices to regulate or stop the flow of grain quickly is a common fault in farm storages. To estimate the rate of flow through horizontal (floor) discharge openings the following equations can be used $Q = 0.1753D^3$ or $Q = 0.2232W\ (WL)$ where Q = bushels per minute, and D, W, L = diameter, width, and length of opening in inches, respectively. For vertical (wall) openings the rate of flow will be 1/3 Q.

If air ducts are located in a position that interferes with the removal of grain by ordinary equipment they should be easily removable when free from surrounding grain. Any opening that must be used as a manhole should be at least 2 feet in diameter, or 1 1/2 feet wide if more than 2 feet long. The manhole must be accessible to men working in the bin, especially when the bin is only partially filled. Failure to meet this requirement makes the bin a serious hazard. Workmen may become ill or injured while inspecting, fumigating, or shoveling grain. If access is proveded by a wall ladder it should extend from the manhole to the grain-discharge opening. If this is not practicable (for example; if the manhole is located in the top of a dome roof), a rope ladder should be considered an essential part of the structure.

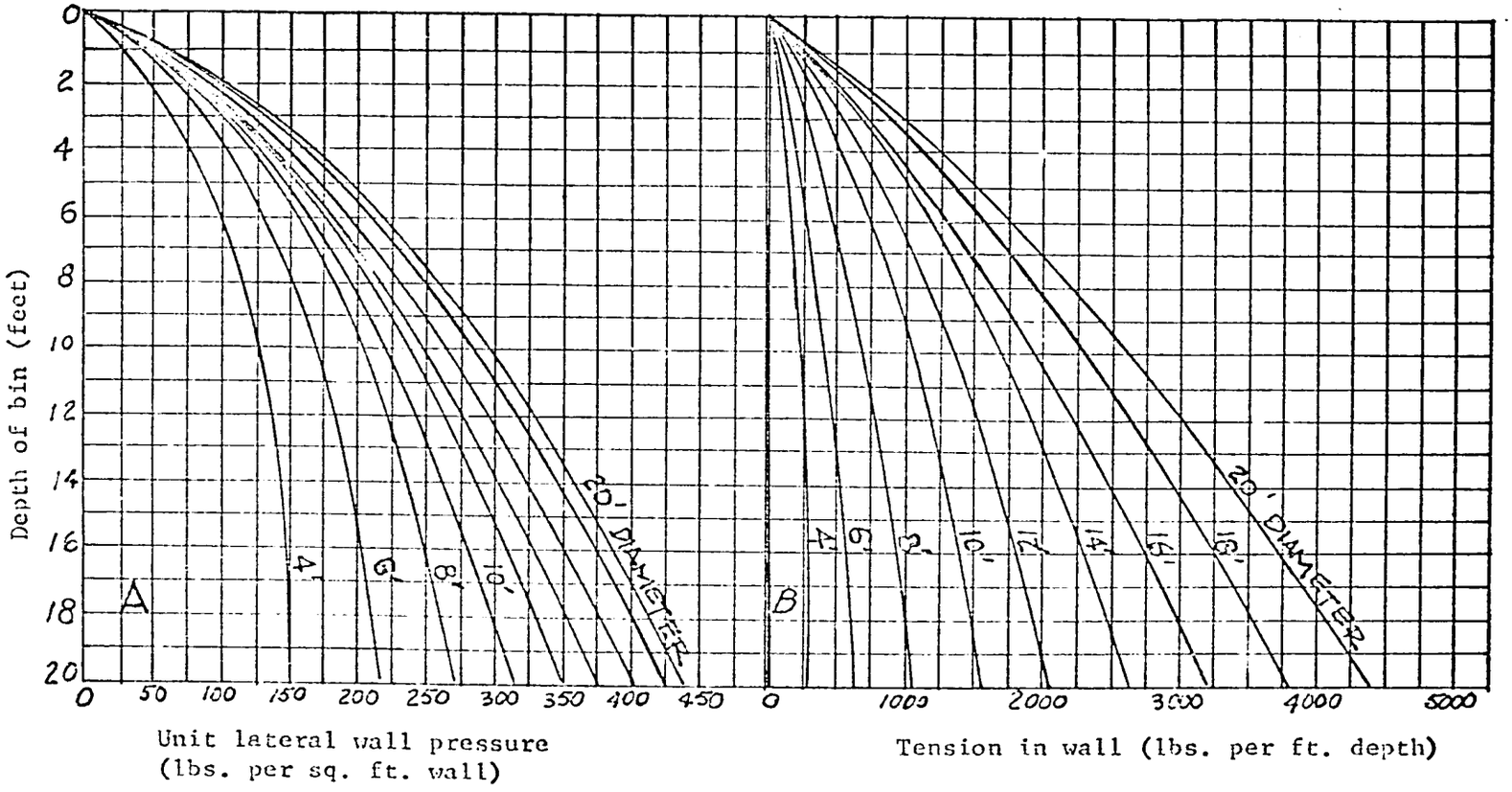
TABLE 1 - Angles of repose and some coefficients of friction for clean and dry grains[1]

Grain	Angles of repose		Average coefficients of friction of grain on —					
						Wall boards		
	Emptying or funneling	Filling or piling	Smooth Shiny Tin	Smooth Side Prest Wood	Across Grain of Plywood	Rough Side Asbestos Cement	Gypsum	Insulite
	Deg.	Deg.						
Rough Rice (paddy)	36	20	0.479	0.554	0.530	0.368	0.637	0.662
Grain Sorghum	33	20	.372	.306	.294	.331	.396	.321
Oats	32	18	.445	.398	.380	.362	.442	.429
Soybeans	29	16	.368	.295	.312	.301	.379	.306
Barley:								
Two row	28	16	.404	.264	.311	.308	.389	.360
Six row	28	16	.378	.266	.287	.298	.344	.354
Wheat:								
Hard Red Spring	28	17	.366	.335	.298	.333	.394	.325
Hard Red Winter	27	16	.340	.306	.294	.323	.392	.287
Soft Red Winter	27	16	.356	.306	.277	.292	.372	.300
Corn	27	16	.447	.306	.302	.264	.416	.257
Wheat, Durum	26	17	.414	.321	.321	.323	.418	.311
Rye	26	17	.406	.324	.330	.354	.398	.350
Flaxseed	25	14	.372	.300	.275	.323	.319	.350
Vetch	25	14	.327	.255	.249	.242	.340	.270

[1] Results of tests made in Grain Storage Laboratory, Ames, Iowa.

Figure 1. Lateral loads in cylindrical grain bins and rectangular bins of equivalent diameter: A, Unit lateral wall pressure (pounds per square foot); B, Wall tension in cylindrical bins (pounds per square foot of depth).

W = 55 lb/cu. ft.
k = 0.6
u = 0.361 (smooth wood walls)

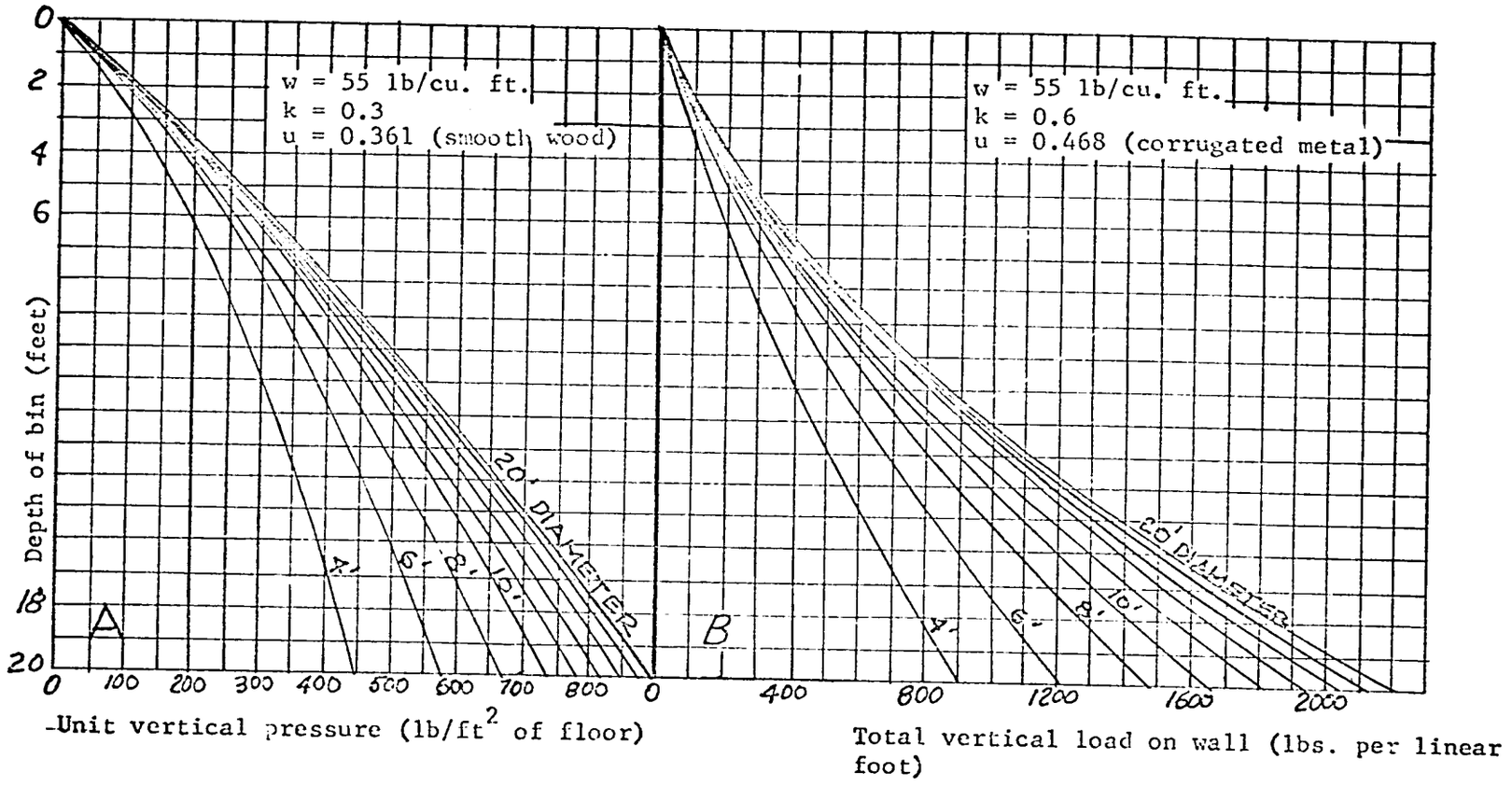


Note: The equivalent diameter of a bin equals 4 times the hydraulic radius, or, $4 \frac{\text{Floor areas}}{\text{Floor perimeter}}$

Thus a bin 6 feet wide and 12 feet long has an equivalent diameter of $4 \frac{72}{36} = 8$ ft.

Figure 2. Vertical loads in cylindrical grain bins and rectangular bins of equivalent diameter.

A, Floor loads (pounds per square foot); B, Vertical wall loads (pounds per linear foot).



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