Planning and Building Hay Barns that Work

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Hay is an important investment for all livestock operations and should be made and stored in a way that maximizes the amount of available feedstuff, nutritional quality, and palatability. Storing hay inside a permanent shelter is considered to be an excellent option for many livestock and commercial hay operations. Inside hay storage prevents many of the negative effects of weathering on round hay bales such as loss of dry matter and reduced digestibility. It may seem that weathering on the surface of a bale is minor, but it actually affects a surprising fraction of the hay. Figure 1 shows the percentage of hay in 4-ft and 6-ft diameter round bales that are affected by weathering at two, four, and six inches.

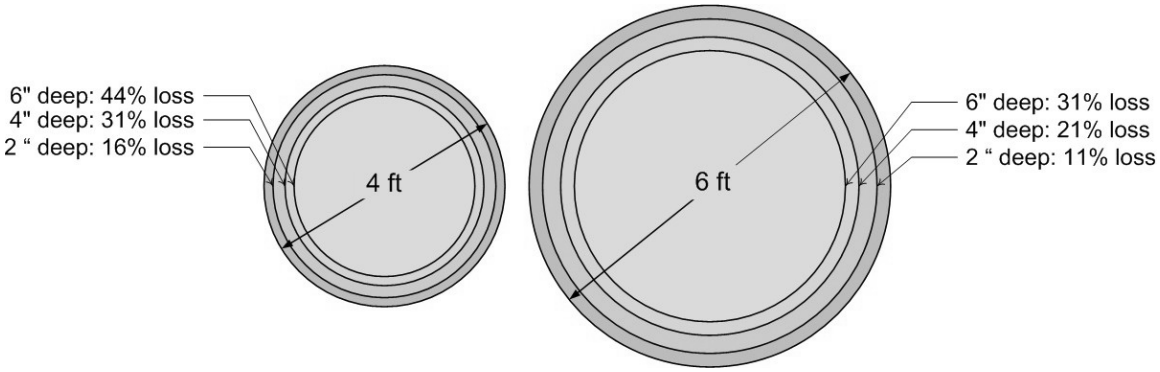


Figure 1. Percentage of bale volume affected by weathering at different depths.

Round hay bales stored uncovered outside have been shown to lose 25-35% of total dry matter compared to only a 4-7% loss of hay stored inside (Collins et al., 1997). For grass hay at $40 per ton and assuming typical construction costs, the difference in dry matter loss for inside versus outside storage can translate into savings in the range of $10 per ton.

It is possible to renovate existing structures to store large round bales. However, the space requirements for handling and storing round bales make storage capacity limited in most farm structures. Wide, clear spans and higher clearances are needed for safe and efficient handling of round bales. Tobacco barns, for example, have load-bearing columns that make maneuvering a tractor inside to place or remove hay bales awkward. Instead, a structure built specifically for round bales may be a better option.

The decision to add a hay storage structure may seem simple when the savings in dry matter and quality are considered. Nevertheless, building a hay storage barn is a major project for any livestock operation and should be considered carefully. Proper

planning is critical. The purpose of this paper is to consider factors in planning and designing a hay barn that is effective, efficient, and safe.

Site Selection and Preparation

One of the first things to consider when planning a new hay storage facility is site selection. The hay barn should be placed in a location with good drainage; easy, all-weather access; and adequate space from other buildings.

Drainage

To prevent water from collecting on or seeping through the floor of a hay barn it should be built in a location where rain and snow melt drain away. The ground around the building should have a downward slope of at least 5% (5 ft vertical drop per 100 ft horizontally). Divert water from adjacent areas away from the building.

Access

Convenient access to the building is an important factor to consider. Tractors and trucks with trailers will need year-round access to place and remove bales. Hay is particularly needed for feeding during the winter months, so the building must be accessible even during inclement weather.

Adequate space must be allowed around the hay barn for maneuvering equipment and trucks. Plan to have sufficient area to allow for vehicle maneuvering. Figure 2 shows recommended dimensions for a vehicle turning area large enough for trucks with trailers. Build roads, bridges, and turnarounds that can accommodate heavy equipment. Access by emergency equipment in cases of fire should also be considered. Be prepared to give clear directions to your hay barn in case a fire or other emergency occurs. Having a 911 address for the farm is recommended.

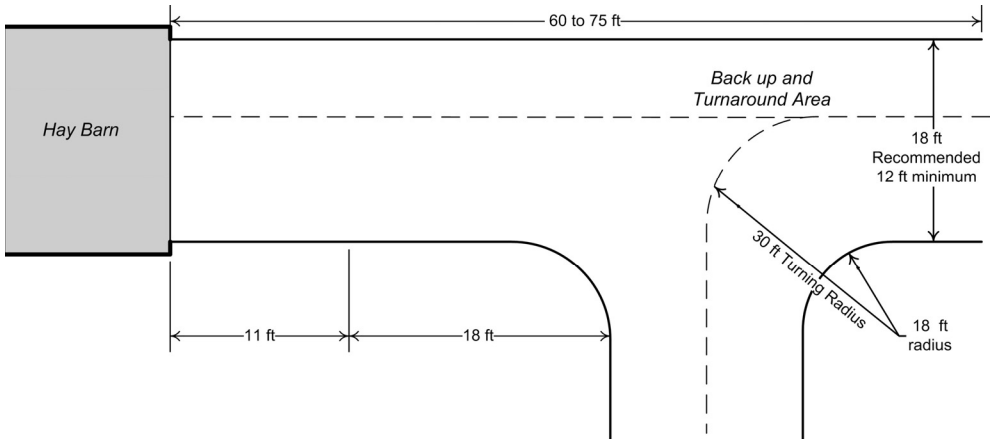


Figure 2. Recommended dimensions for vehicle turning area. Note that drawing is not too scale. *Adapted from MWPS-2 Figure 18.*

Orientation

To reduce wind loads on the structure and better protect hay, the building should be positioned with the open end facing away from the prevailing wind. In Tennessee, as a general rule, the north, south, and west sides of the building should be enclosed. So, an end loading building (see Figure 3 for difference between end and side loaded buildings) should be oriented with the ridge running east to west, whereas a side loaded building should be oriented in the north-south direction.

Proximity to other farm structures

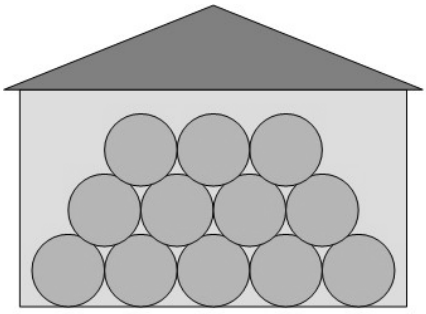
It may seem convenient to position hay storage structures near other farm buildings such as a free-stall barn or cattle handling area. However, hay poses a fire hazard as it can spontaneously combust and is a very flammable material. To protect other buildings, livestock, and equipment on the farm, hay storage buildings should be located at least 75 ft away from the surrounding structures. Access to water, if at all available, is also desirable as a fire fighting aid.

Hay Barn Design

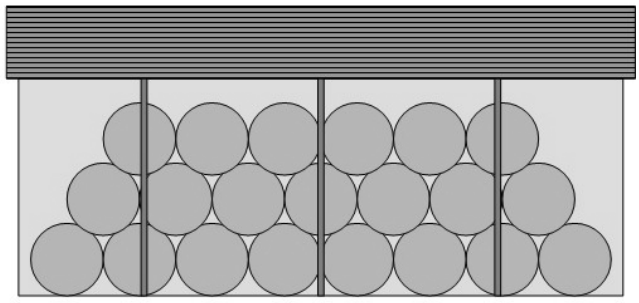
Hay barns are relatively simple structures when compared with other commercial or residential facilities. However, there are several factors that should be considered in design and construction of hay barns including building size, floor and base construction, strength to withstand loads (e.g. wind), and ventilation.

Sizing

As a general rule of thumb, hay barns can accommodate 10 to 15 ft^2/ton for square bales and 16 to 24 ft^2/ton for round bales. For round bales, the area required depends on the staking height. Round bales can generally be stacked two or three bales high using a tractor front end loader. Before the building dimensions are determined, it is helpful to decide if the barn will be front or side loaded (see Figure 3). Side loading offers a few advantages including equal access to more hay. This allows sorting hay according to type or quality. Side loading barns are also a more efficient use of space in that the void areas at the sides of the second and third rows is shorter than for an end loaded building. On the other hand, a side loaded building will have posts that obstruct equipment access and will have greater uplift forces on the roof caused by wind. The worksheet on the following page can be a useful guide for determining the size of a hay barn.



End Loading



Side Loading

Sizing a Hay Barn

Building Length and Width

N_{total} = number of round bales to be stored = _____

D = bale diameter = _____ ft

$\mathbf{L_{bale}}$ = bale length = _____ ft

W = desired width (*or length for side loading*) of building = _____ ft
Width is likely based on truss width.

$\mathbf{N_1}$ = number of bales in bottom row of first stack = (**W** – 4)/**D** = _____
Two feet is allowed on both sides of the stack to account for error in bale diameter and to keep hay from leaning against side walls.

$\mathbf{N_2}$ = number of bales in second row = $\mathbf{N_1}$ - 1 = _____

$\mathbf{N_3}$ = number of bales in third row = $\mathbf{N_2}$ - 2 = _____

$\mathbf{N_{stack}}$ = total number of bales per stack = $\mathbf{N_1}$ + $\mathbf{N_2}$ + $\mathbf{N_3}$ = _____

S = number of stacks = $\mathbf{N_{total}/N_{stack}}$ = _____

$\mathbf{L_{bldg}}$ = length (*or width for side loading*) of building = $\mathbf{S^*L_{bale}}$ + 4 = _____
Two feet is allowed on both sides of the stack to account for error in bale length.

Building Height

For 5-ft diameter bales stacked 3 high, **H** = 16 to 17 ft

For 6-ft diameter bales stacked 3 high, **H** = 19 to 20 ft

Figure 3. End loading hay barn versus side loading hay barn.

Floor and base construction

It is recommended that the floor of hay barns consist of an 8-inch layer of large compacted gravel over a sheet of geotextile material commonly known as filter fabric. The filter fabric allows water to flow through while preventing soil particles from migrating up into the gravel causing it to lose its strength. Concrete may be used for the floor, but is more expensive and does not allow water to drain through.

Structural Considerations

Most hay barns are of post-frame construction. Post-frame buildings, traditionally called “pole-barns” use wooden posts to carry loads and prefabricated trusses to give a wide clear span making it ideal for storing large round bales. Soil forces acting on the bottom of the posts embedded in the ground give walls the strength to resist horizontal wind forces. Soil forces acting on the bottom of posts also resist uplift of the structure caused by wind. Combined with proper bracing, posts also give the structure rigidity.

This paper focuses primarily on post-frame buildings with other types of construction suitable for hay barns are briefly discussed later.

As previously mentioned, post-frame buildings are designed such that posts are the main load bearing elements. The sidewalls in a post-frame building are not designed to carry a significant load in either the vertical or horizontal direction. Therefore, hay should not be allowed to lean on the sidewalls of the structure. This can cause that wall to bend. If for some reason, it is necessary for hay to be supported directly by the walls; additional braces should be installed to support the lateral loads of the hay. But, this is a temporary solution and is not recommended.

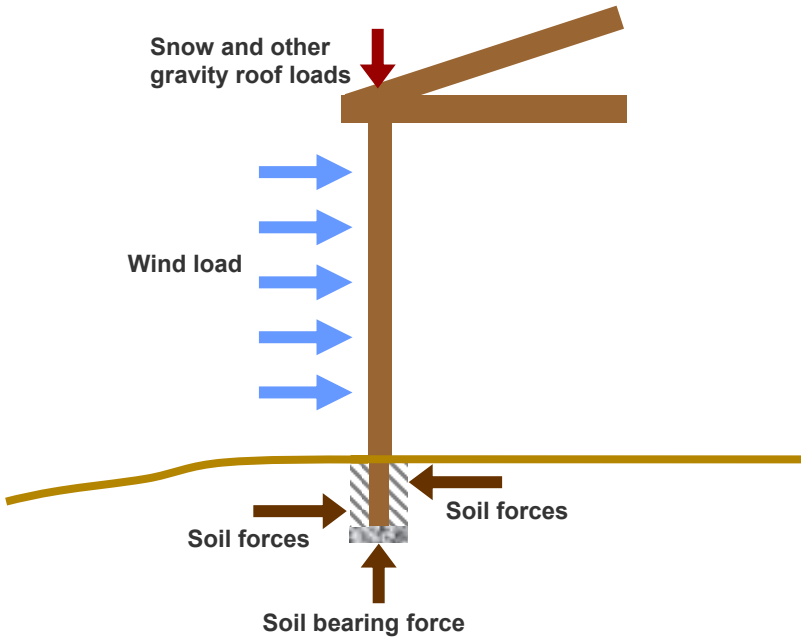


Figure 4. Forces acting on a post.

Figure 4 shows the main forces acting on a post. Soil forces give the building strength to resist wind loads that can cause bending reactions of the post. Soil forces also act against uplift forces on the posts caused by wind. Uplift forces in a partially enclosed building can be substantial and are often the cause of failure in post-frame buildings. For example, in an enclosed building 40 ft wide with posts on 8-ft centers wind uplift forces can be as high as 1824 lbs per post. The same building with an open front would experience uplift forces nearly twice as high. If the posts were spaced 16 ft apart the uplift force would be 6240 lbs per post. Clearly, the soil forces acting on the embedded portion of the post are a critical element to the structural integrity of the building. It is recommended that posts be embedded at least 4 ft in the ground with a concrete collar. Buildings that are especially tall, have open fronts, or have widely spaced posts should have posts embedded at least 5 ft deep with a concrete collar.

Bracing

Much of the strength of a post-frame building comes from the posts, but bracing is required to give the structure rigidity and improve structural integrity. Required

bracing includes wall bracing at corners, X-bracing at end walls and mid length, knee braces to the top chord of trusses, and bracing at the top of the post on open sides.

Other building options

In addition to post-frame wood construction, there are some other types of structures sometimes used for storing hay. Hoop barns are becoming popular for round bale storage because they are easy to install, have high clearance, and are relatively low cost. Wooden sidewalls (similar to post-frame construction) are built the height of the bale diameter. Metal arches are installed and covered with a heavy, water-proof fabric that is ratcheted down tight. Hoop barn kits are available from several manufacturers. Once the sidewalls are erected, hoop barns can be completed in one to two days, depending on available labor. Table 1 gives a comparison of construction costs among post-frame buildings and hoop barns. Costs for do-it-yourself projects are provided along with contracted projects. Hoop barns cost approximately the same as post-frame structures with a roof only (as in Figure 5) and somewhat less than structures with an open front or that are totally enclosed.

The most expensive structure option for hay storage is a steel framed building. Steel frame buildings offer several advantages including larger clear spans and taller sidewalls providing more clearance for equipment. They are most cost competitive for large structures. It should be noted that steel framed buildings require very good foundation work.

Table 1. Costs of construction for a hoop barn versus a post-frame structure. Note that these costs are only estimates. Current prices may vary, but the relative trends are valid

Type of Structure	DIY	Contract
	Cost of construction per ft^2	
Hoop	\$3.00 – \$3.60	\$4.20 – \$5.40
Post-frame		
Roof only	\$2.70 – \$3.90	\$3.90 – \$5.40
Open front	\$3.60 – \$5.40	\$5.40 – \$7.80
Enclosed with doors	\$4.80 – \$7.20	\$7.20 – \$10.20

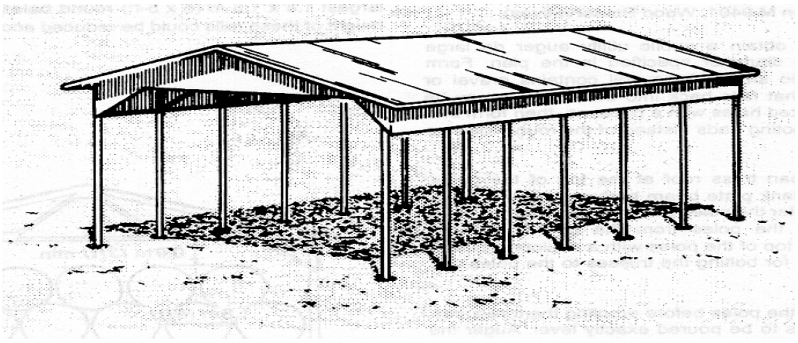


Figure 5. A post-frame structure with a roof only is a good, low cost hay storage option for many farms.

Ventilation

Ventilation of a hay storage structures to remove moisture is necessary for two reasons. Hay is not completely dry when it is placed in storage and will continue to lose moisture. Furthermore, respiration within the hay generates moisture that must be removed. High humidity within a hay storage building can reduce the quality of hay and cause condensation on the structure which can drip onto hay. Condensation can also cause problems to the structure itself.

There are a few easy, practical suggestions to improve ventilation in a hay storage barn. Air inlets should be added at eaves and along the bottom of walls. Natural ventilation occurs when air enters the bottom or side of the building and exits though the top. Air flow through end openings is typically adequate for structures less than 70 ft long. For buildings longer than 70 ft, or totally enclosed, ridge vents should be installed.

Safety

There are three safety hazards associated with building and using a hay barn that should be considered. During construction of the hay barn, workers should be extremely cautious when working on the roof of the barn. OSHA regulations state that workers on a structure edge at heights of 6 ft or higher should be protected from falling by guardrail systems, safety nets, or personal fall arrest systems. Though often ignored on construction sites, such precautions could prevent many major injuries.

Handling large round bales can also be hazardous. The heavy weight of the bale on the front end of the tractor can cause it to tip. Tractors should be equipped with roll-over protection (ROPS) and seatbelts. Bales should only be transported up or down slopes, not side to side. Raising bales for stacking should only be done on a solid, level surface.

Fire is another significant hazard associated with hay storage. Fires in hay are caused by combustion of the bale when temperatures reach as high as 160 to 170 ^{o}F due to microbial activity. The key to preventing hay fires is store hay at proper moisture contents. For large round bales, hay should be 15–18% for baling. It is recommended that large round bales be left outdoors for two weeks after baling to allow time to go through their normal heating cycle while there is no risk of catching the barn or adjacent bales on fire.

Codes and Regulations

Traditionally, agricultural structures have not been subjected to building codes and have largely been ignored by inspectors and building officials. However, as cities continue to spread into emerging farmland producers will likely be forced to adhere to building codes and official inspections more and more. For agricultural structures used for storage and livestock only, the primary applicable portion of building codes is

structural design. The structure must be designed and built to resist loads from wind, snow, and occupants or storage commodities. In some jurisdictions building officials will require the submission of plans stamped by a licensed professional engineer. If that is the case, it is suggested that producers look for an engineer with experience in designing post-frame buildings.

References

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