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Building Loads and Failures

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Summary and Implications

During the investigation of a collapsed building, inadequate design loads and inappropriate construction practices are often discovered. A building failure adversely affects a producer's ability to generate income. A well-designed and constructed building costs only slightly more than a mediocre one. Insisting on good design, use of high-quality materials and a qualified contractor reduces the risk of structural failure.

Introduction

Choosing an appropriate agricultural building design load is a task often assigned to the rural builder or building manufacturer. Unfortunately, in an attempt to lower design costs, the selected design loads are often lower than recommended. Despite published design load guidelines, the lack of enforcement and lack of specific design codes frequently results in "as built" agricultural buildings having a low load-carrying capability.

The lack of design codes for agricultural buildings or of load guidelines enforcement contrasts the controls placed on buildings constructed for commercial or industrial use in most metropolitan areas. Most states also have established additional "fire and panic" or life safety regulations which set forth minimum state wide regulations for public buildings.

Obviously, there is little room for argument regarding the importance of designing a building to reduce the risk of losing human life. This argument, however, can be applied to all buildings, because people are present at sometime in **all** buildings. When considering agricultural production facilities, the possible loss of productive capability also warrants consideration. A structural failure directly affects a producer's income-generating ability. Many people argue the problem is not with design loads but with construction techniques. Evidence indicates both areas need improvement.

Causes of Structural Failure

Sometimes, builders fail to recognize or understand the different load-carrying capacities of different species and grades of lumber. Lumber price and availability contributes to this problem. Most lumber suppliers offer minimal choice of lumber species or grade.

Lighter design loads usually require less or lower-quality materials, reducing construction costs. However, because labor is typically about half the cost of erecting a building, the cost of using a good quality 2 inch x 10 inch rafter instead of a 2 inch x 8 inch or mediocre quality 2 inch x 10 inch rafter is relatively insignificant when viewed against the overall cost of the building. Except for a grade stamp, there is no practical way for the end-point user to determine the wood's species, grade or strength characteristics.

Another concern is failure to recognize the limitations of various structural materials. One example is using water-based adhesives to fabricate trusses or other structural components for agricultural buildings. All livestock buildings have high enough internal humidity levels to cause water-based glues and adhesives to deteriorate. Practically speaking, only deterioration rate varies between buildings. Inspection of several failed buildings revealed an outline of glue on gusset and/or truss member contact areas but bonding at the glue line was non-existent. In one situation, glue deterioration occurred in less than 10 years; in another case 10 to 12 years passed before failure occurred. Coupled with a gradual deterioration and loosening of other mechanical fasteners such as staples or nails, both buildings failed at relatively light imposed roof loads. Failure to utilize polyethylene vapor barriers and provide good ventilation contributed to the failure of these two buildings.

Another construction deficiency is an apparent lack of understanding concerning the load carrying or load transfer capabilities of nails and bolts. The influence of grain orientation and fastener position within the wood on load carrying capacity appears to be poorly understood. Whether a fastener is loaded in single shear (2-member joint) or double shear (3-member joint) also significantly affects load carrying capacity. Many builders rely heavily on toe-nailing to develop load transfer joints. The load carrying capacity of a **properly installed** toe-nail is about half the allowable load for shear or withdrawal for a nail installed in the conventional manner. Because of this, many building failures start as joint failure.

Recommended roof design loads are listed in Table 1. The values in Table 1 include a 5 pounds per square foot (psf) allowance for the weight of the structure, plus accumulated snow loads.

With rare exceptions (for example, tall buildings) wind loads are not a major roof design factor for agricultural facilities in Nebraska. However, wind loads must be considered when

Table 1. Recommended minimum total roof design loads for agricultural buildings in Nebraska (weight of structure and snow)

Building Use	Roof Design Loads, psf*
Temporary range and pasture shelters	10
Hay storages	15
Grain and machinery storages	20
Livestock confinement	25

*Increase loads by at least 5 psf for buildings with shingle roofs; roofs with slopes of 3:12 or less; and for buildings in heavy snowfall areas.

designing sidewalls, end walls, doors and such. Upward forces imposed by wind loads determine the need for bracing of truss members, lateral/longitudinal bracing of the overall structure, pole or post embedment and uplift forces at truss-to-post joints. The minimum recommended wind design load is 15 psf. Higher loads are needed for buildings with eave heights greater than 16 feet. A load of 20 psf, roughly the equivalent to an 88 mph wind, is recommended for tall buildings, buildings important to a farming operation and for lower-profile buildings in exposed locations. Loads other than wind, snow and weight of a structure, (i.e., the weight of stored products, suspended feeders, poultry cages, cranes, etc.) should be added to the loads in Table 1 to determine the total roof design loads.

Many designers believe "zero" failure designs are impractical and non-economical. That philosophy is not appropriate for the designer, builder or producer building the structure. The loss of a livestock building during winter conditions can be devastating. In addition to the direct loss of livestock, productivity is adversely affected — often for many months. Buildings are commonly insured for the direct cost of the structure, but there is no practical way to insure against the loss of production. For example, a purebred pork producer with many valuable animals may never be able to re-establish the genetic base. Such losses are generally not insurable.

Causes of structure failures investigated during the past five years include:

1. Lack of longitudinal bracing of truss members loaded in compression. Members buckled and failed. (three buildings)
2. Corrosion of truss plates. Truss failed at mid-span joint.
3. Non-preservative-treated post rotted. Wall pushed out.
4. Inadequate embedment and/or anchorage. Building posts pulled from ground during moderate wind storm.
5. Inadequate fastening at truss-to-post joint (eave of building). Joint pulled apart during moderate wind storm.
6. Inadequate anchorage of grain bins. Bins pulled loose from footing and were destroyed during moderate winds.

Designing for excessively heavy loads can make buildings uneconomical or unaffordable. At the same time, producers should assure the building they purchase will meet their needs with minimum risk of adverse influence on their income-producing ability. Avoid constructing both buildings with an expected life of hundreds of years and those which will fail with the first gust of wind or first few flakes of snow are both unwise.

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