Designing Bulk Potato Storage Structures

Before you consider the design of a building for environmentally controlled potato storage, it is essential that you understand the interaction of the building, its fixed equipment design, and the stored product.

The type of structure you select is primarily a matter of personal preference and economics at the time of construction. The same constraints apply to layout—to allow efficient loading and unloading—regardless of structural type. The structure must readily accommodate the cooling and air-handling systems. It must also provide convenient access to the control system and to the potato pile for inspection and maintenance.

To design and construct for safe, efficient, and economical potato storage, your structure must:

- withstand the pressures potatoes exert on the walls and partitions;
- have adequate insulation in the walls and ceiling to control the gain or loss of heat and to control condensation; and
- have adequate vapor barriers in the walls and ceiling to protect the insulation from condensed vapors.

Product pressure on walls

Design your walls to support lateral and vertical forces imposed by potatoes, structural elements, wind, and snow. This means you must properly select structural members and fasteners used to tie walls together and to the foundation. The critical fasteners are those that secure the sill to the foundation, the studs to the sill and plate, and ceiling joists or lower chords of the trusses to the plate.

Since you will not fill and empty all your bins at the same time, design all bin partitions to be as strong as the exterior walls. Fasteners used on bin walls should be capable of accepting thrust in either lateral direction.

There is a wide variation of lateral pressures on walls of potato bins, even when comparing their pressures for a given wall height and depth of potatoes. Engineers are still investigating these pressure variations to determine what factors cause them.

These factors probably include potato shape and variety, potato surface conditions created by surface moisture, bin-loading sequences, time in storage, and motion of potatoes caused by vibrations (as, for example, from nearby railroad, truck, or tractor traffic).

Recent research indicates that previous design recommendations, based on lateral pressures produced by bulk-stored potatoes, are inadequate for the design of large storages used in the western United States.

Measurements taken over three different storage seasons indicate that peak lateral pressures produced by a 20-foot pile depth may reach values nearly twice those reported in earlier literature.

Recent research findings indicate that sill design forces should be increased 20 to 30 percent to account for this increased wall pressure.

The maximum pressure occurs somewhere between 3 and 7 feet above the floor, depending on pile height. The magnitude of the maximum pressure and its location on the wall tends to change during the storage period.

As additional design information becomes available, present design procedures may require additional modifications. However, the information in this publication incorporates the best data available and the recommended design procedures.

Wall foundations

Figure 1 shows some suggested designs. Most growers do not use concrete floors unless they also plan to store onions or other crops in the structure in the future. Tables 1a and 1b show the stud size and spacings required to support wall and roof loads. These sizes are based on the lateral pressure data presented by Shaper and Yeager (footnote a, tables 1a and 1b).

Outside braced walls

If you plan to locate the air ducts along outside walls (see figure 2), you may find it more convenient to:

- use wider spacing of outside wall studs (2 × 12 or 4 × 12);
- use outside wall bracing that will provide space for ventilation air in main air duct (plenum); and
- strengthen the wall with an outside
- support at the centroid (center) of lateral pressure (to locate this center, divide your approximate pile height by three).

For braced walls higher than 20 feet, use 4 × 12 wall studs, to provide space for ventilation ducts between wall studs. The 2 × 8 bracing studs are spaced on 16-inch centers. Use a 4 × 6 as a horizontal wall brace, and attach the 2 × 8 bracing studs to it.

The values in table 1b include an additional safety factor to compensate for a possible decrease in strength of structural members because of the high humidity present in ventilation ducts.

Inside braced walls

You can also use the pile ht/3 formula on the inside braced-wall design, where the main air plenum chamber is located between two inner walls of the storage (figure 3). The bracing would be between the walls at approximately the 7-foot height (potato pile ht/3). Additional wall support is provided at the points where the inspection walkway is supported. This upper walkway also serves as a duct for return air.

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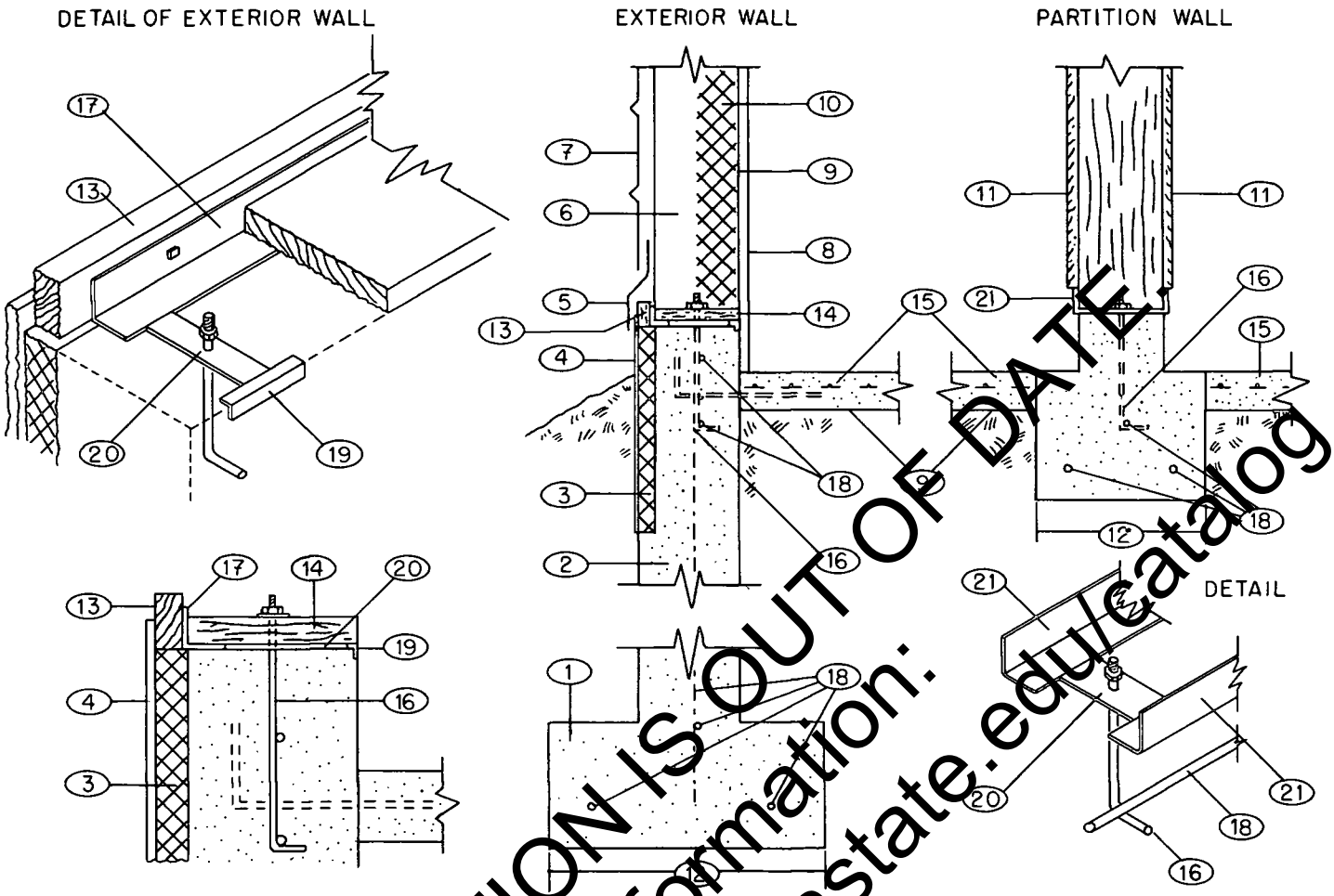

1. Footing below frost line.
2. Concrete foundation.
3. 2″ × 22″ rigid insulation (perm rating less than 0.8).
4. 3/16″ × 24″ high-density, recompressed, exterior-type cement asbestos board or an acceptable metal protective cover.
5. Galvanized metal flashing.
6. 2″ × 12″ or 4″ × 12″ stud.
7. Metal siding applied horizontally.
8. ¼″ exterior-plywood sheathing.
9. 6-mil polyethylene vapor barrier.
10. Insulation.
11. ¾″ exterior-plywood sheathing.
12. Dimension varies according to soil bearing capacity.
13. 2 × 4 nailer.
14. 2 × 12 pressure-treated sill.
15. 4″ concrete floor reinforced with 6″ × 6″ × 6/6 wire mesh.
16. ½″ diameter × 18″ anchor bolt every 2 feet wired to upper two reinforced horizontal bars.
17. 1″ × 1″ × ¼″ steel angle iron in 4′ lengths; ⅜″ × 1½″ lag screws into 2″ × 4″ nailer (13).
18. #4 reinforcing bars—horizontal bars continuous; vertical bars wired every 4 feet to horizontal bars.
19. 1″ × 1″ × ¼″ × 6″ long steel angle iron.
20. ¼″ × 2″ plate drilled for ½″ anchor bolts welded to (17) and (19) for exterior wall or to (21) for partition wall (coat welds with primer).
21. 3″ × 3″ × ¼″ angle iron in 4′ lengths connected by ¼″ × 2″ plate welded to each side piece & drilled for ½″ anchor bolts (16). A 2 × 12 sill plate can be used for ease of attachment of interior wall studs to foundation as shown in detail of exterior wall.

Figure 1—*Typical exterior and partition wood stud wall construction*

The structural dimensions shown in figures 2 and 3 are *only suggestions.* The exact size of a potato storage is a judgment for you as producer or storage owner to determine for your specific conditions.

The supply air duct dimensions shown in figures 2 and 3 are for a building under 150 feet long, with fan housing at one end. Longer buildings would require larger main supply air ducts. Note in the plan that soil is used for the storage floor.

Additional information on fans is available in OSU Extension Circular 1107, *Selecting Fans for Commercial Potato Storage* (50¢ a copy plus 25¢ postage; order from Bulletin Mailing Service, OSU, Corvallis 97331).

Roofs

The information in tables 1a and 1b includes roof vertical forces of 10-psf dead load and 40-psf live load and a wind-gust pressure of 10 psf (or 80 mph) on the leeward side. Stud sizes are based on combination loads.

Normally, clear-span trussed rafters or laminated beams are used for potato storge roof construction. The use of roof trusses or laminated beams lets you move or remove bin partitions if you change handling methods or building uses.

Caution: Decay problems sometimes occur with beams or rafters that are subject to high humidities. Check with your contractor; be sure the beams or rafters you plan to use will withstand high humidities.

Table 1a.—*Wall stud spacing in potato storages (unbraced stud wall design)*[a]

Wall ht. ft.	Potato ht. ft.	Max. moment ft.-lb.	Sill reaction lb./ft. of wall	Maximum spacing 2 × 12 stud	Maximum spacing 4 × 12 stud
16	14	2616	902	12″ OC[b]	24″ OC[b,c]
18	16	3849	1171	11″ OC[b]	22″ OC[b,c]
20	18	5416	1474	8″ OC[b]	16″ OC[b]
22	20	7359	1812	6″ OC[b]	12″ OC[b]
24	22	9716	2185	4″ OC[b]	8″ OC[b]

Table 1b.—*Wall stud spacing in potato storages (braced stud wall design)*[d,e]

Wall ht. ft.	Potato ht. ft.	Max. moment ft.-lb.	Sill reaction lb./ft. of wall	Maximum spacing 2 × 12 stud	Maximum spacing 4 × 12 stud
16	14	1400	221	24″ OC[b]	[h]
18	16	2053	252	21″ OC[b]	[h]
20	18	2879	289	18″ OC[f]	[h]
22	20	3900	330	16″ OC[g]	24″ OC[c,f]
24	22	5140	377	16″ OC[g]	24″ OC[c,f]

[a] Based on Schaper and Yeager, American Society of Agricultural Engineers Technical Paper 78-4524 ($3.50 a copy from ASAE, 2950 Niles Rd., St. Joseph, MI 49085).
[b] No. 2 grade Douglas-fir: F_b = 1450 psi (extreme fiber in bending); F_v = 95 psi (horizontal shear).
[c] Use ⅜″ exterior-grade plywood on wall.
[d] Brace at centroid of lateral load—potato pile height / 3.0.
[e] Based on moment-area method of analysis.
[f] No. 1 grade Douglas-fir: F_b = 1725 psi (extreme fiber in bending); F_v = 95 psi (horizontal shear).
[g] Select structural-grade Douglas-fir: F_b = 2070 psi (extreme fiber in bending); F_v = 95 psi (horizontal shear).
[h] Maximum spacing between studs is 24″ without additional support for plywood.

No detailed information on specific roof designs or truss attachments is provided in this publication. You must design your roof to withstand your area's expected snow and wind—and (in many cases) potato lateral loads. *Be sure to tie your roof trusses securely to your wall.*

If the snowfall in your area is over 30 inches of fresh, loose, dry snow on the ground at any one time, consult your local building officials for additional design information.

Insulation

Potatoes must not freeze in storage. Your walls and ceiling require adequate insulation to eliminate condensation and to reduce heat losses or heat gains to a level you can afford to pay for.

There is considerable controversy about insulation. The areas of concern include fire hazards and fire codes, thermal resistance at various moisture-content levels, moisture permeability, changes of insulation properties as the material ages, and the influence of insulation on condensation.

The *R-value* describes the ability of a material to resist heat flow. The greater the R-value, the better the insulation value. The R-value is normally indicated on the insulation material itself or in charts, either per unit of thickness or for the listed thickness of material.

In areas west of the Cascades, the storage walls should have a minimum insulating R-value of 11. This means that the walls require about 3 inches of a fibrous insulation or 2 inches of a plastic-foam insulation having an R-value of 5 or 6 per inch.

In areas east of the Cascades, use R-19 insulation in the walls. This requires about 6 inches of fibrous insulation or about 4 inches of plastic-foam insulation.

Cover either type of insulation with exterior plywood of ¾-inch thickness and use a vapor barrier directly under the plywood. On walls where stud spacing is 20 to 24 inches, use ⅞-inch exterior plywood. We do not recommend stud spacing of more than 24 inches, unless you use additional support. Follow the manufactur-

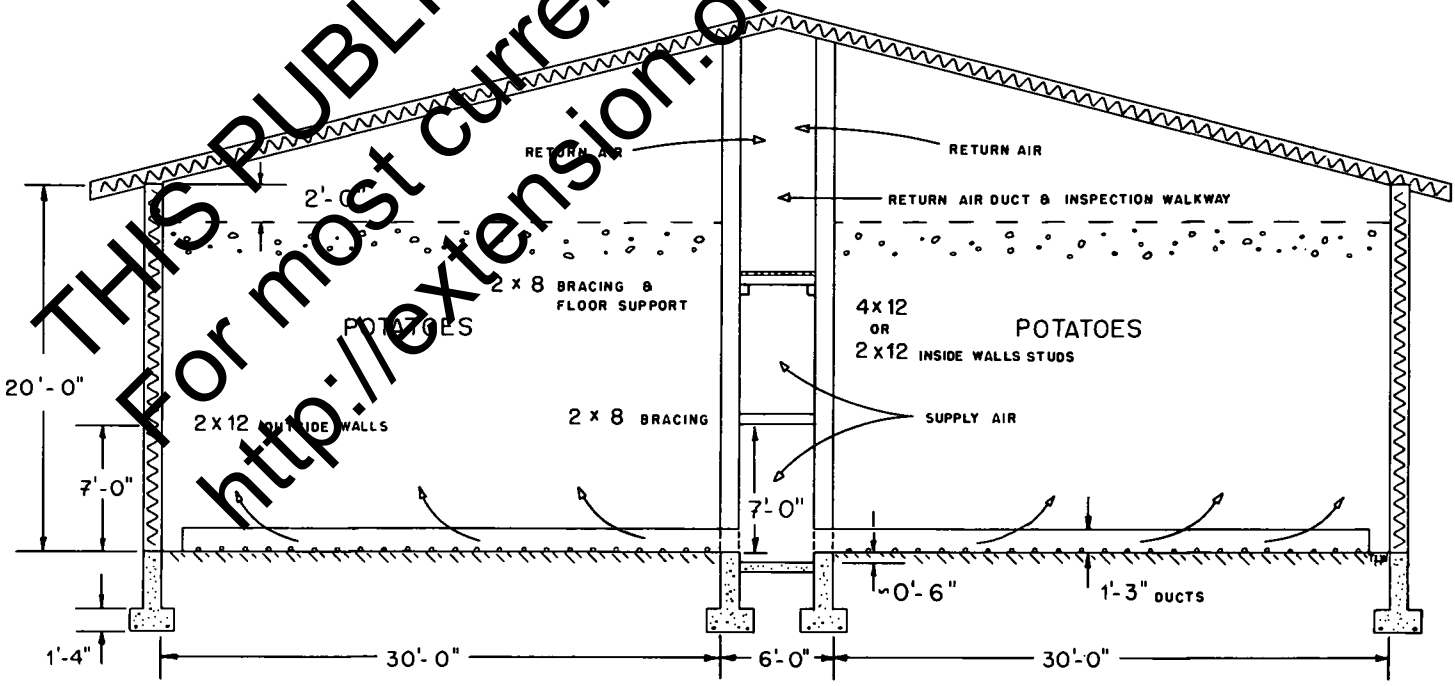

Figure 2.—*Elevation view of a bulk potato storage with braced outside walls*

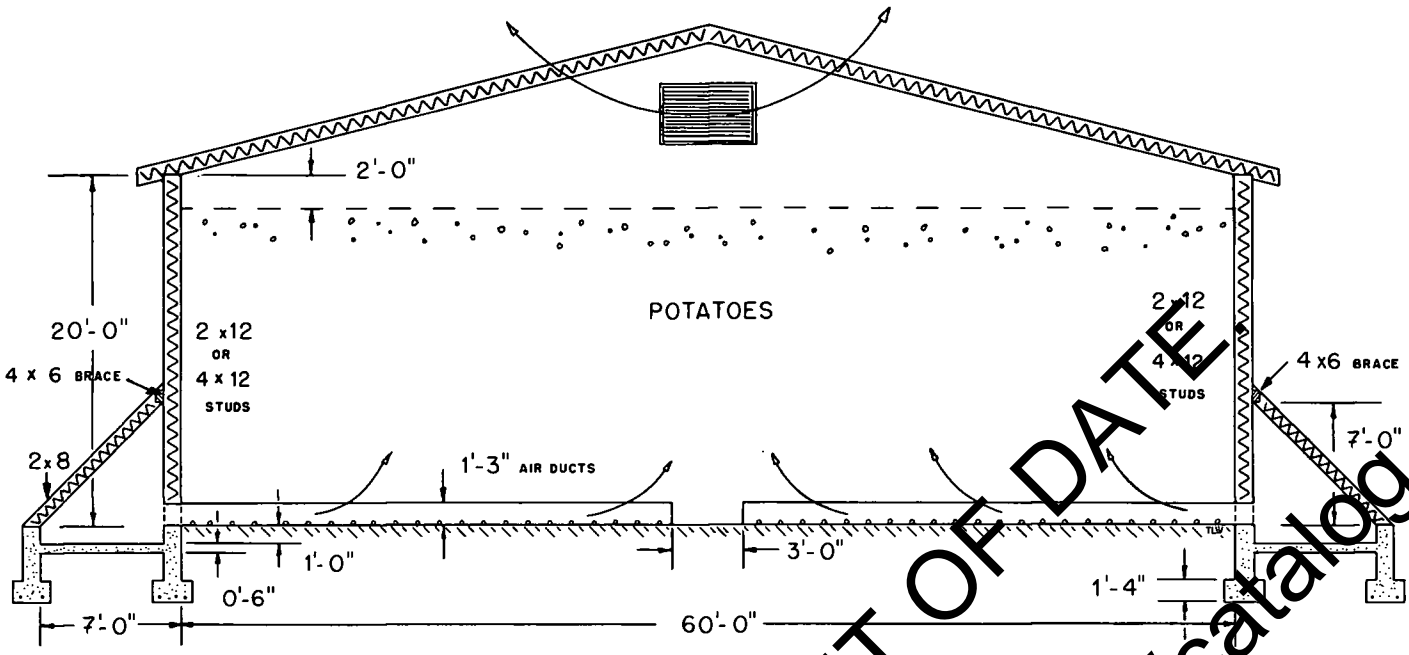

Figure 3.—*Elevation view of a bulk potato storage with braced inside walls*

er's instructions on how to install each type of insulation.

In locations both east and west of the Cascades, the ceiling of the storage should have an insulating R-value of 30. This requires about 9 inches of fibrous insulation or about 5 inches of plastic foam with an R-value of 5 to 6 per inch.

The vapor barrier must face the interior of the building. Place it *directly under* the plywood or other interior wall and ceiling finish. Insulation is important to maintain a uniform holding temperature.

When you install a vapor barrier such as polyethylene, be especially careful not to make holes or tears in the material. Lap and seal the joints carefully.

Use a special vapor barrier sealant on polyethylene seams and joints. These sealants are available commercially.

Any water vapor that gets into the insulation will be trapped and will reduce the thermal resistance value. *It is essential that you provide ventilation above the ceiling insulation to reduce the risk of moisture accumulation.*

Pressure-treated lumber

High relative humidity maintained in potato storages may provide conditions that promote decay in your structural members—and decrease the wood's strength and stiffness. The most critical area affected by moisture is the base of exterior stud walls. Use pressure-treated lumber for sills. Cover pressure-treated lumber with exterior plywood, to prevent tuber contact with the treated lumber.

Summary

1. Design both inside partition walls and outside walls to support the necessary lateral and vertical forces imposed.
2. Since all bins are not filled and emptied at the same time, design all bin partitions to be as strong as the exterior walls. Fasteners in bins should be capable of accepting thrust in either direction.
3. Use at least R-30 insulation on the ceiling of your storage. Provide necessary vapor barriers. Ventilate the air space between the insulation and storage roof covering, to reduce condensation problems.
4. On your walls, use at least R-11 insulation in areas west of the Cascades and at least R-19 east of the Cascades. Use proper vapor barriers and protect the insulation and vapor barrier from injury by machine and by the weight of tubers by using at least ¾-inch exterior-grade plywood as an interior wall covering.
5. Allow ample space in the main air supply ducts to maintain air ventilation under 1,000 feet a minute.

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