BIN PALLETs FOR AGRICULTURAL PRODUCTS

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Introduction

Throughout the United States, the handling of agricultural products in containers with large capacities is rapidly becoming popular. Most operators who have used forklift equipment and bin pallets in moving fruits and vegetables in bulk find that this method makes the handling of produce easier and saves them time, money, and labor.

Essentially, a bin pallet is a combination pallet and bin, holding 15 to 40 or more bushels of produce (fig. 1). A pallet is a platform on which goods are stored and transported by means of forklift equipment. It forms the floor or base of the bin and is an integral part of the unit. Most bins are made with stringers in the base that permit entry of handling equipment from two sides only. Others have 9 posts and permit entry from all 4 sides. Bin pallets have been variously called bulk bins, pallet bins, tote bins, bulk boxes, and pallet boxes.

Bin pallets are being proposed and used for all kinds of harvesting, transporting, storing, processing, and shipping. Many processors and farmers are changing to bin-pallet handling. All major processors and many growers already have the forklift trucks needed to handle bin pallets. Many other growers are providing themselves with lift equipment. Relatively cheap fork attachments are available for conventional farm tractors.

Many farmers and growers have timber on their land suitable for sawing into lumber for building bin pallets. By using the skills and lumber available in off-season periods, they can make their own containers with a minimum of expense. The sawn lumber should be air dried before the containers are built. This can be done simply and with little cost by following the procedures in the Forest Products Laboratory Report No. 1657, "Air Drying of Lumber," by E. C. Peck.1

1 Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

2 This report and others can be obtained free by writing to the Director, U. S. Forest Products Laboratory, Madison, Wis.

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Fabricators of pallets and growers and processors are anxious to have information on design, quality of materials, and recommended construction practices. Without attempting to recommend any one type of container over another, this report illustrates several designs that are adequate, discusses ways and means of controlling the quality of the materials without sacrificing economy, and recommends building practices that insure sound and serviceable bin pallets. This report presents 15 designs of bin pallets for agricultural products (figs. 2 to 16). Each one has one or more outstanding features. None of them, however, has all of the desirable features, and the designer should consider the sections entitled "Design Considerations," "Materials," and "Good Construction Practices" before deciding how to build the container for his own particular set of conditions.

**Design Considerations**

Bin pallets for handling agricultural products are intended to be reusable containers. It is not unusual to expect 10 years of continuous seasonal use with very little repair or upkeep. The design as well as the workmanship, therefore, should be sturdy and durable to withstand the many bumps and impacts expected in the lifetime of the container.

**Size**

In general, the size of bin pallets is determined by one or more of the following criteria:

1. The size should be such that when the bins are loaded they can be handled easily by the available lift and transporting equipment. Some of the attachments for farm tractors have definite limitations that make impossible the handling of loads over a certain maximum.

2. Bin pallets should be of such dimensions that they will fit into railroad cars or highway trucks for shipping. An outside dimension of 47 inches has been suggested and is good because the width of two such bins on a truck does not exceed the maximum allowable width for highway travel.

3. The dimensions of the containers should be chosen so that the bin pallets stack well in storage. The height of the roof and the area available between posts in storage buildings must be considered. This is important because space, especially in cold-storage warehouses, is expensive.

4. The maximum inside height is governed by how easily the commodity is crushed or bruised. As examples, 30 inches is about maximum for apricots and clingstone peaches, 35 inches for Delicious apples, 42 inches for potatoes, and 66 inches for almonds and other nuts.
Racking Resistance

Bin pallets need to be strengthened to resist the racking stresses that can be expected in normal use. These stresses occur when fully loaded bins are placed on uneven ground or when they are handled roughly. Many methods of dumping bins also place severe racking stresses in the side panels. When bin pallets are racked, the nails pull or bend, and the containers are skewed out of square (fig. 17), which causes difficulty in their dumping, handling, and stacking.

These stresses may be resisted by placing more nails in the side panels or by adding diagonal members. Well-placed and well-nailed diagonals can increase greatly the usable life of a bin.

Deck Boards

The size, strength, and fastening of deck boards demand special attention to insure that a bin pallet will give satisfactory service for a long time. Occasionally, if forks of a lift truck are tilted, the weight of a loaded bin may be raised on only one board. Sturdy fastenings and strong, stiff boards are required to prevent breakage and deflection in such cases. Excessive deflection can cause shifting and bruising of the commodity in the container.

Bottom deck boards strengthen the base by tying the stringers together and by helping to distribute the loads when the bins are stacked. Many users find that these bottom deck boards, sometimes called skid boards, are necessary to make transportation easier with straddle trucks (fig. 18). The bins are placed on long, narrow skids with the bottom deck boards of the bins perpendicular to the skids. This elevates the load so that the lifting shoes of the straddle truck can be positioned beneath the ends of the bottom deck boards. Other growers object to the bottom boards because they tend to pick up dirt in the field or orchard, which if carried into the plant, may end up in the processing line.

Protection Against Bruising

When designing bin pallets, one of the major considerations is to prevent bruising of the commodity. The edges of the boards that face toward the fruit are nearly always rounded or eased to prevent damaging the fruit on the sharp corners. The radius of this rounding is approximately 1/16 inch. Some bins, when used for fragile fruits, have the inner edges rounded or "bullnosed" to a 3/8-inch radius.

When posts or framework are on the inside of the bins, they must also be considered a potential cause of bruising. A rather popular design has inside corner posts made by ripping nominal 4- by 4-inch timbers on the diagonal. These present a smooth surface toward the fruit and, according to some researchers, minimize bruising.

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Ventilation

Many agricultural commodities have definite ventilation requirements for periods of storage and conditioning. These must be considered and provided for by spacing the boards in side panels or on the bottoms or both. Leaving spaces between boards reduces the racking resistance of the bin and, therefore, its useful life. Therefore, these provisions for ventilation should be carefully thought about and the spaces between boards kept to a minimum to keep the container as durable as possible.

Repair

Regardless of the care that goes into the design, selection of materials, and construction, many bin pallets will require some repair over the years. If this fact is kept in mind when the bins are designed, features can be incorporated that will aid in repairing and thus reduce the costs of upkeep substantially. Assembly by means of bolting allows the bin to be demountable so that panels for the side, ends, or bases can be replaced immediately and repaired later. Designs are also available that make possible the easy replacement of individual sideboards without any further disassembly (fig. 2).

Materials

Wood and nails are the materials from which most bin pallets for agricultural products are built. Bolts, rivets, steel strap, and spring clips are also sometimes used for assembling sides, ends, and bases. Many bin pallets have also been made with angle iron or steel reinforcements at the corners and edges.

Wood

Good workmanship and selection of lumber has more influence on the strength and life span of a bin pallet than the grade or species of wood used. However, an understanding by the builder of the strength and limitations of individual species and the effect of defects in the wood on durability will enable him to construct products that are better able to withstand the rigors of handling and shipping.

Extremely low-grade lumber has been used economically to build containers that were structurally sound and able to perform all the functions for which they were designed. Just as for any wood product, good practices of selective cutting and careful selection of component parts are necessary to use satisfactorily lumber that contains defects. Properly seasoned lumber that is free of such serious strength-reducing defects as decay, excessive cross grain, and large knots or knotholes, will produce good bin pallets.
Generally, bins can be built from boards or wood parts that contain the following defects:

1. Knots can be included if they are no larger than three-eighths of the width of the member. Large knots are objectionable because of the distortion and discontinuity of the grain that reduce seriously the strength of the wood. Large, loose knots should be avoided because they are likely to drop out.

2. Cross grain resulting from diagonal sawing or twisted grain in the log can be included if the slope is no steeper than 1 in 10. This slope is measured by the angle between the general direction of the grain and the long axis of the member. Slight local grain deviations, such as around knots, can be disregarded, but when a member contains both diagonal and spiral grain, the combined damaging effect should be taken into account (fig. 19).

3. Checks, splits, and shakes can be included if they are no longer than two times the width of the piece.

4. Wane not exceeding \( \frac{3}{4} \) the thickness and \( \frac{1}{6} \) the width of the piece is not large enough to have a serious effect on the strength of a member (fig. 20).

5. Stains and discoloration do not present a problem if they are not associated with decay. Any form of visible decay should be avoided. Decay can usually be detected by use of the pick test. Some of the grains or fibers in suspicious looking areas are lifted up with a knife or chisel. If the material is softer, more punky or brash than healthy wood, and breaks without splintering, it is probably decayed. Suspicious areas usually are brown, bleached looking, or mottled and indicated by the absence of luster that is present in normal wood.

Moisture Content

The moisture content of wood that goes into bin pallets is very important. Bins that are built from green or partially green lumber often fail prematurely by warping, cupping, twisting, or splitting of boards at the nails. This increases costs of repair and upkeep tremendously and offsets many of the savings that can be realized by bulk handling of the product. Softwoods and the soft hardwoods in classes A and B should have a moisture content not greater than 19 percent at the time they are used for building the bins. The hardwoods in class C should be not greater than 22 percent for nominal 1 inch or thinner lumber, and 26 percent when thicknesses are over 1 inch. In some climates, it may be necessary to stack green lumber in the open for a considerable time to achieve these moisture contents, but the improved durability of the finished products will more than justify the effort.
Classification of Species

Almost any species of wood can be used successfully for bin pallets. However, some are stronger, tougher, and less likely to split. The species of wood that are commercially important can be classified as follows:

Class A.--The softer woods of both the coniferous and broad-leaved species. They are relatively free from splitting when being nailed, have moderate nail-holding power, moderate strength as a beam, and moderate shock-resisting capacity. They are soft, lightweight, easy to work, hold their shape well after manufacture, and are easy to dry.

| Aspen       | Hemlock              |
| Basswood    | Pine (except southern yellow) |
| Buckeye     | Redwood              |
| Cedar       | Spruce               |
| Cottonwood  | Willow               |

Class B.--The heavier coniferous woods and the medium density hardwood species. They are more inclined to split when being nailed than the woods of class A, but have greater nail-holding power and greater strength as a beam. They are softer, lighter, easier to work, and easier to dry than the woods of class C.

| Ash (except white) | Southern yellow pine |
| Chestnut           | Sweetgum             |
| Cypress            | Tamarack              |
| Douglas-fir        | Tupelo                |
| Hackberry          | Western larch        |
| Magnolia           | Yellow-poplar        |
| Soft elm           |                      |

Class C.--The heaviest hardwood species. They have the greatest nail-holding power, greatest strength as a beam, and the greatest shock-resisting capacity. They are difficult to drive nails into, have the greatest tendency to split at the nails, and are difficult to dry. They are the heaviest and hardest domestic woods and are therefore difficult to work.

| Beech       | Oak                    |
| Birch       | Pecan                  |
| Hard maple  | Rock elm               |
| Hickory     | White ash              |

Fasteners

The service life of many bin pallets is limited by the methods employed for fastening the lumber parts together. The wrong type of fastener or the improper use or application of fasteners causes the failure of many pallets and causes the most frequent problem in upkeep. Consequently, an understanding of
fasteners is one of the important considerations for both bin-pallet builders and users.

Nails.—Nails are the most common fastenings used for bins. Their obvious advantages are low cost and ease of application. However, many improvements have been made in nails, and the results show that deformed-shank nails (fig. 21) have holding abilities under certain conditions of 2 to 3 times those of common or coated nails. Spiral- and annular-grooved nails have been developed that are particularly effective in building bin pallets.

The spiral-grooved nails should have at least 4 flutes and a helical angle of thread such that the projection of the thread across the axis of the nail makes an angle of about 30 degrees. The annular-grooved nails should have about 20 ring threads per inch, and the top surface of each ring should be approximately perpendicular to the axis of the nail. The sides of each ring should taper toward the point of the nail. Disregarding these recommendations for nail shanks leads to poorly constructed bins that may cost the user too much to maintain and repair.

Bolts.—When bolts are used they should be carriage or step bolts in the coarse thread series. Either square or hexagonal commercial nuts may be used with the nut-bearing surfaces faced with flat washers.

Hollow Rivets.—Patented hollow tube rivets have been used and are claimed to be cheaper and more effective than bolts. They are crimped in production with a special hydraulic-pneumatic crimper and can be tightened with a hand tool when they get loose.

Steel Straps.—Steel straps are quite often nailed to the assembly to strengthen it (fig. 3). A prepunched 3/4-inch-wide strap about 12 inches long is convenient for this use. Steel tension strap can be used to bind together the side panels instead of bolts or nails (fig. 4). It should be high-strength steel that is treated to resist rusting.

Clips.—Patented clips made from spring steel can be used to fasten side to end panels and both side and end panels to the base (fig. 5). These clips are snapped onto the corners and can be removed so that the bins can be knocked down when empty.

There are other fasteners as well as angle iron and steel reinforcements that are too numerous to mention. Disadvantages of the angle-iron-framed bin illustrated in figure 6 are initial high cost and a tendency to rust and bend. Experience has shown that costs of upkeep are high.

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Good Construction Practices

When bin pallets have been designed and the materials selected, it remains to build and assemble the containers according to good commercial practices. All members should be cut with their edges parallel and their ends square. All of the boards should be of the same thickness and the stringers or posts of the same height.

Side and Deck Boards

The boards used on the sides and for the top and bottom deck boards, if both are required, may be any width within certain practical limits. Anything narrower than nominal 4 inches (3-5/8 inches minimum) fails to contribute any significant resistance to racking because of the short nail couples. Wider boards permit greater spacing of nails and, therefore, the nail couples are effective in resisting the stresses in the plane of the panel. However, boards that are too wide -- wider than nominal 9 inches (8-1/2 inches minimum) -- split readily from shrinkage stresses, thus weakening the construction in several respects. Therefore, a good general rule for boards in bin pallets is to limit the widths to between 4 and 9 inches.

The edge boards of pallets and the top boards of bins are especially subject to damage from rough handling. It is wise to consider this in construction and there are several steps that can be taken to prevent failure. First, these edge and top boards should never be narrower than nominal 6 inches (5-5/8 inches). Boards this wide and wider have more space for nails than narrower boards, and they resist impact bending stress against their edges better. It is also well to place both the best boards, with respect to such defects as knots, splits, and others, and the densest ones, in these critical positions. Many builders using a class A or B species will obtain special class C lumber to use for the edge deck boards and top bin boards that are more readily damaged. Still another remedy, when spaces between boards are provided for ventilation, is to butt the two edge or top boards so that there is no space between them. Then when impacts are applied to the edge or top, two boards will be acting as one to resist the stress.

It is not necessary to surface boards unless the fragility of the commodity requires it to prevent bruising. Because unsurfaced boards are thicker than surfaced boards, they are also stronger and tougher. For the handling of many fruits and vegetables, boards surfaced on only one side, the one toward the inside, have worked out very well. Extremely delicate fruits can be protected from the rough boards by using waxed, corrugated fiberboard inserts (fig. 7).

Generally, deck boards and sideboards should not be thinner than 3/4 inch. However, this minimum thickness depends on so many variables that it is difficult to make recommendations. If the span is less than 2 feet, then the thickness can be reduced to 5/8 inch (fig. 8). Also, if a side has a diagonal (fig. 3) or center post (fig. 9) or if the commodity is of low density as, for example, string beans, then thicknesses can be reduced to 5/8 inch for
species in classes A and B and to 1/2 inch for woods of class C. Such types of handling as lifting, transporting, and dumping should also be taken into account when minimum thicknesses are specified.

Stringers and Posts

Stringers are wood runners to which the deck boards and sides are fastened. They serve as spacers between the top and bottom decks to permit entry of tines of forklift trucks. As spacers, they should be nominally 3 or 4 inches. The 3-inch depth has the advantage of occupying less space in warehouses, but since these bins will be handled on rough and sloping fields or orchards, the 4-inch depth is preferable.

Stringers and posts need not be surfaced. They must be square cut and uniform in depth. The practice of cutting stringers from boxed heart material is poor. The difference between shrinkage in the radial and tangential direction is the greatest in a boxed heart timber. This difference causes serious splitting and checking after the containers are built. Since nearly all the rigidity and unity of a bin pallet depends on the fastenings into the structural stringer or post, it is advisable to have members that will remain sound for a long time.

Pallets without bottom deck boards depend on the stringers for bearing area when the bins are stacked on top of each other. It is recommended that these stringers be at least nominal 3 inches wide. When the loads are heavy and the stacking high, it is better that they be nominal 4 inches wide.

Diagonals

Diagonals are frame members placed at an angle of nearly 45 degrees to other members and serve as braces to make bin pallets more rigid. The cost of materials and labor for providing diagonals will be offset by increased service life and reduced upkeep. Any bin pallet more than about 30 inches high should have diagonals. The only logical reason for not providing them is that they increase the cubic displacement and, therefore, reduce the usable space in an expensive cold-storage warehouse. Any other reason, including increased cost, is not logical.

Nailing

A bin pallet must be adequately nailed to use the maximum strength of its members. A good many failures occur in bins that can be traced to the wrong number or size of nails. Nailing can be classified into two types, fabrication and assembly. Fabrication nailing consists of fastening the various members together to form panels and assembly nailing consists of fastening these panels together to make the enclosure or bin.

Patterns of fabrication nailing have been devised so that the number and placement of nails at places where the members cross are such that maximum efficiency is closely approximated. Too many nails at these points result in splitting
of the members when they are stressed. Too few nails will permit separation of
the members when the panel is racked (fig. 22). The recommended number for
members of various widths is shown in figure 23.

When the total thickness of members that cross is 3 inches or less, it is good
practice to drive the nails through the thinner into the thicker member and
clinch the nails on the back. Sinker, cooler, or corker nails are used for this
purpose. Nails with coatings, roughened surfaces or deformed shanks are not
necessary when nails are clinched, as the clinch serves satisfactorily to resist
withdrawal. Clinching across the grain is much more effective than with the
grain, and the minimum clinch should be 1/4 inch.

For fabrication and assembly nailing where the total thickness of members that
cross is greater than 3 inches, clinching is not necessary and spiral- or
annular-grooved nails should be used. Nails should be driven through the thin-
ner member first and then into the thicker member. The nails should be long
enough so that the portion penetrating the thicker part is 2 to 2-1/2 times the
thickness of the thinner member without protruding but not less than 1-1/2 in-
ches. For example, a 3/4-inch-thick deck board nailed to a stringer requires a
nail about 2-1/2 inches long and two 1-5/8-inch-thick members should be nailed
together flat with 3-1/4-inch nails.

Nails should be spaced and driven so that they will provide the greatest with-
drawal resistance. Figure 24 illustrates improper and proper placing of nails.
In sketches A and B, the nails are forced outward because of local grain di-
vergence. Sketch C shows improper sloping of the nail and D, the result of edge
and end spacing that is too close. In E, the nail was placed so far in from
the end that it has missed the frame member. The nail in F has been placed
properly with respect to the thickness of the receiving member, but contact with
a knot has caused a "shiner." Sketch G shows that corner nails require care in
placement to prevent contact with each other during driving. Finally, H shows
a properly placed and driven nail that is not driven near a knot or another
nail.

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Figure 1.--Bin pallets for agricultural products. Top, two-way entry, stringer type. Bottom, four-way entry, post type.
Figure 2: Design of bin pallet featuring 1-1/8-inch-thick framing, short replaceable side boards, and assembly with ladder bolts.
Figure 3. -- Design of bin pallet featuring diagonals that provide racking resistance to the bin and permit the use of thinner boards. The straps nailed at the corners help strengthen the assembly.
Figure 4.--Design of bin pallet featuring steel tension strapping that strengthens the assembly and makes it easier to build. Intermediate horizontal member permits the use of thinner boards and resists bulging of the bin midheight.
Figure 5. -- Design of bin pallet featuring assembly by means of spring clips and four horizontal rails. The side boards are thinner, class C members.
Figure 6. -- Design of bin pallet featuring 1-1/2- by 1-1/2-inch angle-iron frame. The sides are built into panels that are assembled to the frame with bolts. The stringers are 3- by 4-inch members on edge.
Figure 7. -- Design of bin pallet featuring waxed, corrugated inserts to protect the produce from bruising and steel corner brackets to strengthen the assembly. The slots in the bottom are for ventilation.
Figure 8. --Design of bin pallet featuring vertical boards and corner posts with chamfered edges. Placing boards vertically allows the use of shorter and thinner pieces.
Figure 9.--Design of bin pallet featuring outside framing with diagonals on 2 sides and intermediate vertical members on 2 sides. Assembly of side, end, and base panels is with bolts.
Figure 10.—Design of bin pallet featuring outside corner posts and bolted assembly. Half the boards are vertical and half horizontal. The side, end, and base panels are assembled with step bolts.
Figure 11.--Design of bin pallet featuring inside framing. The 2 diagonals permit and reinforce for dumping in 1 direction. Inside edges are eased and the top assembly is fastened to the base with carriage bolts.
Figure 12.--Design of bin pallet featuring plywood sheathing and four-way entry. There are nine 4- by 4- by 6-inch posts. Slots have been left at the bottom of two panels for ventilation.
Figure 13. --Design of bin pallet featuring bolted assembly and notched 4- by 4-inch stringers. The diagonals make the bin more rigid and permit the use of thinner boards.
Figure 14. --Design of bin pallet featuring diagonally ripped corner posts, which tend to reduce bruising. The slots at the bottom of side and end panels are for ventilation in storage.
Figure 15.--Design of bin pallet featuring inside 2- by 4-inch corner posts. The top assembly is fastened with nails to the pallet base.
Figure 16. --Design of bin pallet featuring 3-inch inside corner posts and outside steel corner reinforcement. The top assembly is fastened to the pallet base with large-diameter screws.
Figure 17. --A bin pallet that has been tested in the Laboratory and illustrates the type of twisting and racking that results from repeated rough handling.

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Figure 18. --A straddle truck, commonly used for lumber, is picking up 14 loaded apple bins for transporting to the processor.

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Figure 19. -- Types of cross grain in wood.
Figure 20. --Examples of wane.
Figure 21.--Deformed-shank nails. Left, annual grooved; right, spiral grooved.
Figure 22. -- Potato pallet that failed in Laboratory test because there were not enough fabrication nails in the diagonals.
Figure 23. --Patterns for fabrication and assembly nailing of bin pallets.
Figure 24.--Proper and improper nailing practices.  A and B, nails forced outward by grain, C, nail improperly sloped, D, nail incorrectly edge and end spaced, E, nail missed frame, F, nail deflected by knot, G, nails contacted one another, and H, nail properly placed and driven.