

## **Pallets 102: Pallets & Packaging**

### ***Interactive Design for Performance and Cost Optimization***

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This paper is the second in a series. The first paper, Pallets 101 (Clarke 2004), was an overview of the pallet industry, the basic performance measures used to optimize pallet design, and pallet design and material options. This paper, Pallets 102, discusses some of the interactions between packaging and pallets, and how understanding these interactions can lower overall packaging costs and reduce product damage.

Packaging designers are often tasked with lowering packaging costs. We have all witnessed the ongoing material reductions in some common packages. One example is the aluminum beverage can.

- Cans – the average aluminum beverage can weighed over 20 grams in the early 1970's, today the average can is 1/3 lighter at 13.3 grams. (CMI 2007)

Packaging material reductions are a result of our ongoing focus on cost reductions. In general, less material means a lower per unit cost. One of the main factors that limits further material reductions is the potential for increased product damage.

A cost often considered separate from the “real” packaging is the pallet on which the packaged product rests. Pallets are our most common platform for unitizing, storing, and shipping packaged products. Pallets have also seen similar material reductions, such as with the “GMA” 48x40 grocery pallet:

- 48x40-inch GMA pallet – the “typical” hardwood GMA pallets weighed 80 pounds in the early 1970's, today they weigh about 50 pounds.

Dr. Marshall White of the Center for Unit Load Design at Virginia Tech has spoken of the interactive relationship between pallets and packaging (White 2005). Together, packaging and pallets make up the traditional “Unit Load.” Pallets are the direct link between the packaged products and the material handling environment. In many cases, pallet design, quality, and performance will have a direct and significant effect on packaging performance.

Today, most packaging cost savings and pallet cost savings are done separately, rather than interactively. There is still often little consideration of how they truly interact. Purchasing departments rarely understand that the price they pay for pallets could impact the price they pay for packaging. Packaging engineers are in a better position to understand these Unit Load Interactions, and can significantly enhance the opportunities for further material reductions and overall cost savings.

Please note that the dollar figures in this paper are not specific quotes from specific accounts, but merely fictitious figures to give the reader a ballpark understanding of cost/performance tradeoffs as we discuss the interactions.

### **Opportunities for Interactive Pallet & Packaging Design**

Below are 5 common packaging / pallet interactions and potential opportunities for performance improvement and/ or cost savings.

- Pallet Nails and Protective Packaging
- Stress Concentrations at the Pallet Deck
- Moisture in Pallets
- Load Bridging
- Pallets versus Crates

#### **1. Pallet Nails and Protective Packaging**

Wood pallets, plywood pallets, and even some plastic pallets are assembled with fasteners, usually nails. As with most components, there are quality ranges of fasteners. Figure 1 shows two quality levels of helically threaded nails (also called screw nails).



**Figure 1: Two quality levels of helically threaded nails**

The nail on the right has a higher quality thread, or screw, and will be harder to pull out of the pallet stringer than the nail on the left. The CAD based Pallet Design System, PDS; (NWPCA 2007) has 9 input variables for a helically threaded nail. Slight differences in how deep the thread is rolled, the angle of the thread, etc. have a direct correlation to pallet performance.

The impact of fastener quality on pallet performance has been well documented in hundreds of studies (Virginia Tech Pallet Laboratory). Many pallet specifications put out for bid, however, have vague nail specs or no nail specifications. Most pallet designers would prefer to use a high quality nail, but during the typical low bid procurement process, nail quality can be reduced to reduce pallet price. The lower quality nail is “out of sight” initially, and all is well at delivery. During use, however, the lower quality nail can partially pull from the pallet stringer, leaving the nail head slightly above the pallet deck, commonly referred to as “Nail pop.” A nail head raised only 1/8” above the pallet deck can cause damage with some products.

The common solution for nail pop is the addition of some type of pallet pad, such as a corrugated sheet, to protect the product. A typical example is given in Figure 2. This increases protection of the product from nail heads but at the cost of that pad. The more the nails pull up, the thicker (and more expensive) that protective pad must be.



**Figure 2: Protective pad over pallet deck**

Packaging designers often specify pallets, and can include a performance spec for nails that will reduce nail pop. The best way to specify a given level of nail quality is through the MHIA MH1 Industry Standard - Pallets, Slip Sheets, and Other Bases for Unit Loads (MHIA 2005), which

specifies minimum Fastener Withdrawal Index (FWI) and Fastener Shear Index (FSI) values for Limited Use and Multiple Use pallets.

**Pallet Nail Case Study** – higher quality nails will give you (and your customers) longer pallet life, fewer issues with handling equipment, and may eliminate or reduce the need for a protective pallet pad. The higher quality nails will add about \$0.25 to the cost of a typical 48x40” pallet, but many purchasing agents managing high volume pallet accounts will not select a pallet vendor with a higher purchase price. However, protective pallet pads can range in price from \$0.50 to \$1.50 for a 48x40” sheet. A \$0.25 upgrade in the pallet may be offset with a \$0.50 or more reduction in pad costs. If the pallet designer and packaging designer were to work together with purchasing, the pallet designer uses better nails to make a better pallet, the packaging engineer gets better product protection at a lower pad cost, and the purchasing agent (and the company) will get a better pallet and lower cost for the overall unit load.

## **2. Moisture in Pallets**

Most of the wood pallets built in North America are manufactured from green (moisture content > 25%) lumber. There are regional exceptions, but this also applies to most wood pallets manufactured in other parts of the world. Moisture in wood pallets has always been a problem for some products. During my 10 years at the Virginia Tech Pallet Research Lab (4), we fielded many technical assistance calls about pallet moisture related issues (mold, mildew, fastener corrosion, product staining, etc.). Moisture problems have always existed for our domestic shipments, but these problems have more potential for product damage today due to increased international trade and longer term ocean container shipping.

How much moisture is in a typical pallet? A lightweight GMA type 48x40-inch “green” hardwood pallet weighs about 50 pounds when new. This 50 pound pallet will lose about 15 pounds of moisture as it dries to ambient conditions (from 60% to 12% moisture content). This is 2 gallons of water per pallet. Imagine the potential moisture contained in 36 loaded double stacked wood pallets enclosed in a 40-foot ocean container! An example of this problem is shown in Figure 3.



**Figure 3: Green mold, white mold, standing water, and banding corrosion from excess moisture after overseas shipment inside an ocean container.**

There are other factors besides wet pallets that can cause excess moisture in ocean containers, but much of the moisture problem is caused by moisture in pallets.

Products inside ocean containers can be protected from moisture with one or more of the following:

- Desiccants
- Vapor barriers
- Pallet pads
- Oil coatings of metal parts
- Stronger corrugated boxes

Each of these methods of product moisture protection has a cost, and the more moisture inside the container, the more costly these may need to be.

One option for reducing the amount of moisture inside the container is to use a dry pallet. Some “dry” pallet options are:

- Kiln dried new wood pallets
- Used wood pallets
- Plywood and OSB pallets
- Plastic pallets
- Paper pallets
- Metal pallets

**Case Study for Dry Pallets** – Price is heavily dependent on local markets, but often a “dry” pallet will have a higher purchase price than a “green” pallet. A purchasing agent has little incentive to purchase a higher priced dry pallet unless required by the pallet specification. The opportunity is for the packaging designer and the pallet designer to show that the increased cost of a dry pallet can be offset by the reduced need for product moisture protection. Moisture protection materials and product damage costs are usually much more expensive than the cost to use a dry pallet.

### **3. Stress Concentrations on Packaging at the Pallet Deck**

The compression strength of packaged products is typically tested on flat surfaces. Packaging designers understand that real world service conditions are not flat steel surfaces, and various adjustments are used to convert test results to expected real world performance.

Pallets, unlike steel test platens, are not “flat” uniform surfaces when loaded with packaged products. As we have reduced the amount of lumber in wood pallets over the years, we have also decreased the “flatness” of pallets when loaded. Every pallet has an “Effective Bearing Area,” or the area that effectively supports the product. Pallets with thinner pallet deckboards have a lower effective bearing area when loaded than pallets with thicker deckboards. As these boards bend, the product above can be stressed in a manner not predicted in product testing.

A PDS analysis (5) will tell the pallet designer if the pallet is strong enough to support the product weight. However, PDS does not tell the designer if the packaging and product will be strong enough to withstand storage on the pallet deck. Following is an example of how to ballpark calculate an effective bearing area:

- A 48x40” pallet has 1920 in<sup>2</sup> of total surface area for the product (48 inches x 40 inches = 1920 square inches), but...
- The 7 top deckboards only cover 60% of that 1920 in<sup>2</sup>, so we really only have 1152 in<sup>2</sup> of bearing area, but...
- Thin deckboards bend between stringers – if the deckboards flex under load, the product may be resting only on that part of the deck directly over the stringers. Effective bearing area of the pallet deck can be as little as 10% of the full pallet size, or about 200 in<sup>2</sup> of a 1920 in<sup>2</sup> deck!
- Imagine the difference in stress on a packaged product supported by 200 in<sup>2</sup> of point loads versus a 1152 in<sup>2</sup> or 1920 in<sup>2</sup> “flatter” deck.

An example of a unit load that is under stress at the top deck is shown in Figure 4.



**Figure 4: Top Deck bending between the stringers of this lightweight pallet design creates stress concentrations on the packaged product**

If we are using a pallet with a small Effective Bearing Area, and we have a pressure sensitive product, packaging designers must protect their product using some type of additional packaging or padding. This extra packaging will typically cost more than increasing stiffness (or flatness) of the pallet deck.

**Case Study to Reduce Stress Concentrations** – Pallet designers can significantly increase the stiffness, or flatness, of pallet decks by the following methods:

- Thicker deckboards
- Additional deckboards
- More stringers or blocks under the deck
- Winged pallets
- Dry lumber, etc.

Most of these changes add \$1 – 2 to the pallet price. With some designs, adding 1/16" (0.063") thickness to pallet deckboards can increase pallet deck stiffness by 33% and pallet price by only 5%. With the lighter weight pallets, packaging designers may need to use thicker pallet pads, cushioning inside the cartons, or even redesign the product strength, to withstand the stresses from the lightweight pallet. In many cases, a \$1 increase in pallet price would allow a much greater reduction in protective packaging materials and/or reduce product damage from low stiffness pallets. A higher stiffness pallet may also allow even greater cost savings through additional reductions of packaging materials. Potential cost savings from reductions in can wall

thickness, corrugated carton weight, or pail wall thickness will be much greater than the additional cost of a stiffer pallet deck.

#### **4. Load Bridging**

All packaged products have some degree of load bridging when stacked on a pallet. This refers to the degree at which a load will bridge across spans in racks or when stacked on pallet decks.

Figure 5 shows examples of products with very low load bridging and very high load bridging.

More flexible products transfer more of their load weight to the lower stiffness areas of a pallet deck. The degree of product load bridging is a function of the pallet design, the packaging design, and the storage conditions.

- Pallet design – stiffer stronger pallets better support loads
- Packaging design – packaging size, stack pattern, friction, weight
- Storage conditions – rack vs. stack support, storage time, humidity, temperature

A pallet designer is usually asked to support a given load weight in a given handling environment, with only limited influence on the actual configuration of the load. If the pallet designer needs to add strength or stiffness to support more weight, they add materials and cost to the pallet.

However, since loads with more load bridging transfer less of the load weight to the lower strength areas of a pallet, lighter designs are possible. Loads that bridge allow the use of lightweight, lower stiffness, and less expensive pallets

Packaging designers can increase the degree of load bridging with some of these common methods:

- interlock stacking
- tie sheets
- stretchwrap, shrink wrap
- banding
- break away adhesives

The cost of these load bridging methods should be considered against the potential savings of a lightweight pallet.



**Figure 5: Examples of products with low load bridging and high load bridging characteristics**

### **Case study for load bridging**

Overview – The incumbent pallet was a relatively stiff, solid wood, block style, 48x40” pallet. The company wanted to convert to a lightweight lower stiffness plastic pallet to avoid international pest regulations and to save on airfreight charges. The project was being considered at several warehouses, and most were able to use the plastic design. One warehouse, however, had traditionally column stacked boxes on the wood pallets, and then moved pallets 100 yards by forklift from the loading station to a stretchwrap station. Boxes were shifting (or falling) off the pallet during this movement. To make the plastic pallet work in this warehouse required the addition of a bottom deck, which added pallet cost (\$ extra materials per pallet), required additional storage space, and increased pallet weight (\$\$\$ airfreight).

Potential Solutions – Our options were to:

- add bottom decks to each pallet (\$100,000 additional direct materials cost per year, plus 3 extra pounds weight that reduced airfreight savings)
- move the stretchwrap operation closer to the loading station (required significant change for warehouse operations)
- interlock stack current boxes (required significant redesign for packaging engineers, box cost likely to increase)
- increase load bridging - reduce load stress on the lightweight pallet

Solution – any of these solutions would have worked, but it was felt that adjusting load bridging would cause the least disruption to the warehouse operations and packaging staff. To increase load bridging in the column stacked boxes, a corrugated tie sheet was placed between the 3<sup>rd</sup> and 4<sup>th</sup> layers of boxes to “tie” the column stacked boxes. The same plastic pallets that bowed at the sides when lifted under column stacked boxes were now able to support the column stacked boxes with only minimal deflection (see Figure 6). Column stacked boxes were now stable during transit to the stretchwrapper. In addition, the previous wood pallets used a corrugated pad between the deck and bottom boxes to protect against nails and uneven deckboards. The plastic pallet did not need this deck pad. Therefore, at no net increase in unit load cost and no significant changes to warehouse or packaging, the nestable plastic pallet was now a viable alternative to the much stiffer and heavier wood pallet.



**Figure 6: Column stacked boxes remain stable on the low stiffness plastic pallet during handling due to a tie sheet between the 3<sup>rd</sup> and 4<sup>th</sup> box layers.**

## **5. Pallets versus Crates**

### **Case Study - Flat Pallets versus Steel Stacking Racks for storage of Lightweight products in corrugated boxes**

Overview – the incumbent pallet was a heavy duty plywood design. The product was lightweight foam, contained in 6 foot long corrugated boxes. There were 20 boxes per pallet, and these were stacked 3 loaded pallets high during warehouse storage. The pallets were captive to the warehouse; the boxes were top loaded on other freight for outbound shipments. Box crushing

was the problem during warehouse storage. Many of the corrugated boxes on the bottom pallets were damaged, especially during the summer months.

Potential Solutions to reduce box crushing –

- Stronger boxes (\$\$\$)
- Portable Steel stack racks (\$\$)
- Reduce Storage time

We proposed portable steel stack racks, since their vertical steel posts support the weight of top loaded units and reduce stresses on the stacked boxes. The bottom boxes support only the 3-4 box layers above, rather than the 3 loaded full pallets above. Unfortunately, the steel racks were \$250 each, and the plywood pallets were only \$50 each. Even though the plywood pallets were replaced each year, that still left a 5 year payback, well beyond acceptable budgets. However, when we looked at the packaging as well as the crates, we found an opportunity. The box was designed to withstand the rigors of stacking 3 fully loaded pallet units high (although barely since there was damage). If we converted to steel racks, we had the opportunity to reduce box materials and cost. Following are our costs for the 2 options:

Boxes required for plywood pallets      \$1.95 each or \$39.00 per unit

Boxes required for steel racks          \$1.64 each or \$32.80 per unit

1200 pallets in system

12 turns per year

14,400 unit loads per year (1200 x 12)

Cost of unitization with plywood pallets

$$\text{Boxes (12 turns * 1200 units * \$39.00 per unit turn) + Pallets (1200 * \$50) =} \\ \$621,600$$

Cost of unitization with steel stack racks

$$\text{Boxes (12 turns * 1200 units * \$32.80 per unit turn) + Racks (1200 * \$250) =} \\ \$772,320$$

Year 1 – Overall cost to run the steel rack program is only 24% greater than the plywood pallet program (rather than previous 5 to 1 difference for racks vs. pallets)

In year 2, costs for the plywood system would remain at \$621,600. The cost of the steel rack system would be only \$472,320 since the steel racks do not need to be repurchased. When we look at the box and pallet costs as a system, the payback is now 2 years rather than 5 years, and packaging damage is significantly reduced.

## Summary

Packaging designers are tasked with lowering packaging costs while minimizing product damage. Pallet designers are tasked with minimizing pallet costs while supporting the packaged product. This paper explores 5 opportunities to design packaging and pallets as an interactive unit load system to optimize performance while minimizing overall costs.

## Resources to learn more about pallets and packaging performance:

Unit Load Design Short Course  
Virginia Tech  
Center for Unit Load Design  
(540) 231-5370  
[unitload@vt.edu](mailto:unitload@vt.edu)  
Next courses: April 2007 and September 2007

## Packaging / Pallet Test Standards

- ISTA
- PDS, computer program for wood and wood composite pallets
- ASTM D1185
- ISO 8611
- RPCPA Plastic Pallet Test Standards
- MHIA MH1

## References

1. Clarke, John W. Pallets 101: Industry Overview and Wood, Plastic, Paper, and Metal Options. ISTA /IoPP Dimensions.04. 2004.
2. Can Manufacturers Institute. Aluminum Can Reclamation. 2007 (202) 463-7356.
3. White, Marshall S. The Effect of Mechanical Interactions between Pallets and Packaging on Packaging Costs. ISTA / IoPP Dimensions.05. 2005
4. Virginia Tech Center for Unit Load Design. (540) 231-7106.
5. Pallet Design System computer software. 1985-2007. National Wooden Pallet & Container Association. [www.palletcentral.com](http://www.palletcentral.com)
6. MHIA MH1: Pallets, Slip Sheets, and Other Bases for Unit Loads. 2005. Material Handling Industry of America. [mhiastore.org](http://mhiastore.org).