Effect of Stringer Repair Methods and Repair Frequency On GMA Performance

The information presented here came from a 1995 study conducted by John Clarke, Dr. Marshall White, and Philip Araman of Virginia Tech and the USDA Forest Service, Southern Station. Many readers are aware of the extensive pallet research conducted by the Pallet Lab at Virginia Tech, often combined with Forest Service work. The researchers in this project are leaders in the world of pallet research. The report they released on September 22, 2004 is entitled "The Effect of Stringer Repair Methods and Repair Frequency on the Performance of GMA-Style 48x40-Inch Wood Pallets." You can obtain a copy of this report by calling Sharon Daley at 540/231-7105 or e-mailing her at daley@vt.edu.

Abstract

Over 135 million wooden pallets were repaired for reuse in 1995. Notched stringers are one of the most commonly damaged components. Metal plates, half companion stringers, and full companion stringers are repair methods described in the U.S. industry standard published by the American Society of Mechanical Engineers. This study evaluated the effect of these three stringer repair methods on the bending strength and stiffness of 48x40 GMA-style pallets spanning the pallet stringers. Pallets with up to two stringers repaired with full-companion stringers were stronger and stiffer than new, undamaged pallets. In general, pallets with one or two repaired stringers using up to two metal plates or half-companion stringer repairs were as strong or stronger, but less stiff, than the original pallets without stringer repairs.

On the other hand, on average pallets with two stringers repaired with metal plates or half-companions were less strong and less stiff than pallets with only one such repair. These results indicate that all three repair practices (metal plates, half-companions, and full companions), when properly applied, will restore pallet strength when used to repair one notch on one or two stringers of a 48x40 partial 4-way, three stringer pallet.

There may be an additional species effect on repair performance that warrants further evaluation. Current repaired pallet grades group metal plate repairs in upper grades, while companion member repairs are placed in lower grades. Based on functionality with material handling equipment, these grades do not reflect the racking performance of these repair methods.

Table 1: Effect of Stringer Repair Method and Frequency of Repair on the Bending Strength of 48 x 40-inch GMA-style Pallets.

Repair Method	Number of Stringers Repaired	Test Replicates	Original Strength (lbs)	Repaired Strength (lbs)	Relative Change in Strength after Repair
Metal Plates	1	14	4681 (18)*	5628 (13)	+20%
	2	9	4327 (25)	4116 (30)	-5%
Half-Companion Stringers	1	15	4461 (24)	5493 (22)	+23%
	2	12	4692 (28)	4689 (24)	0%
Full-Companion Stringers	1	15	4046 (19)	5851 (21)	+45%
	2	15	4634 (22)	6282 (42)	+36%

* Numbers in parenthesis are coefficients of variation in percent.

Table 2: Effect of Stringer Repair Method and Frequency of Repair on the Bending Stiffness of 48 x 40-inch GMA-style Pallets.

Repair Method	Number of Stringers Repaired	Test Replicates	Original Stiffness (lbs/in.)	Repaired Stiffness (lbs/in.)	Relative Change in Stiffness after Repair
Metal Plates	1	14	7824 (14)*	6650 (24)	-15%
	2	9	7207 (16)	4699 (20)	-35%
Half-Companion Stringers	1	15	7388 (15)	5816 (17)	-21%
	2	13	6961 (16)	4818 (26)	-31%
Full-Companion Stringers	1	15	7293 (12)	7544 (21)	+3%
	2	15	7274 (13)	9652 (21)	+32%

* Numbers in parenthesis are coefficients of variation in percent.

Introduction

In 1995, an estimated 171 million pallets were retrieved by pallet suppliers for repair, reuse, or recycling. Approximately 75% were reused, and 63% required repair before reuse. One of the most common damages to a GMA-style pallet is a fracture in the stringer notch fillet. According to ASME MH1a, Part 3 (1996) there are four standard repair methods for damaged pallet stringers: replacement, metal connector plates, full-length companion stringers, and half-length companion stringers. Replacement is the process of removing a damaged stringer and nailing a similar new or used stringer in its place. Stringer replacement is rarely used to repair GMA

pallets and was not included in the study. Metal connector plates are applied to each side of a stringer fracture using specialized equipment. Only horizontal or diagonal stringer splits may be repaired. Plates must be 20-gauge steel, galvanized, a minimum of 2.75 inches in length and 11 square inches in area, and have at least four teeth per square inch. A pair of plates is used for each repair, one per stringer side over the fracture.

A full-length companion stringer (full-companions) can be placed adjacent to the damaged stringer and nailed to all top and bottom deckboards. Full companion stringers should be equal in length and slightly less in height to the damaged stringer to be supported. Half-length companion stingers (half-companions) are cut one inch shorter than half of the stringer length, and are slightly less in height than the damaged stringer being repaired. A half-companion is placed adjacent to the damaged portion of a stringer and nailed to applicable top and bottom deckboards. Full and half-companion stringers should be notched for forklift tine entry similar to the damaged stringer.

ASME MH1a, part 3(1996) describes four grades of pallet repairs based on the method and number of stringer repairs:

R-l Component replacement with similar elements

R-1P Component replacement and appropriate proper stringer metal plating

R-2 Single full or half-companion stringer and metal plating

R-3 Multiple half-stringer companions and metal plating

Although stringer repair practices for each grade are detailed in this standard, no performance levels are implied. Little has been known of the relative effect of each stringer repair practice on pallet performance.

The effect of metal connector plate repair on the performance of individual stringers has been studied. These plates, when properly applied, were found to restore the strength of stringers fractured between stringer notches at the notch fillet. Stiffness, however, was only restored by using an L-shaped plate that extended over the stringer notch. Most plates in use are rectangular, not L-shaped.

The three researchers previously compared the performance of three grades of repaired GMA pallets from throughout the United States. The repair practice performance levels they measured constitute a bench mark of performance for comparing changes in future practices. They found that the quality of current repair practices did not meet the minimum quality specified in ASME MH1. Because of the level variation of repair methods observed between each grade of repaired pallets, the researchers were not able to determine the relative impacts of various stringer repair procedures on pallet performance.

Most pallet recyclers have established proprietary grades that resemble, but are not identical, to the standard ASTM grades. In general, used pallets with no repairs or metal plate repairs are higher in grade than pallets with half or full-companion stringer repairs. Companion stringers reduce the opening sizes for materials handling equipment, decreasing the functionality with material handling equipment. Therefore, the lower grade ranking given to pallets with companion stringer repairs is due more to this loss of functionality than to any

documented loss of strength and stiffness. For example, the Canadian Pallet Council (CPC) decided in 1999 to eliminate or retrofit pallets containing full companion stringers because of equipment functionality and weight issues. The CPC's preferred stringer repair method is now metal connector plates.

Due to the lack of performance-based analysis regarding various stringer repair methods, this study targeted the warehouse racking strength and stiffness of GMA-style pallets before and after various stringer repairs. The objective of this research was to determine the effect of three notched stringer pallet repair practices – metal connector plates, full companion stringers, and half companion stringers – on pallet bending strength and stiffness during simulated warehouse racked storage spanning the stringers.

Table 3: Effect of Stringer Repair Frequency on the Bending Performance of 48 x 40-inch GMA-style pallets.

Strength (lbs)			
Repair Method	1 Repaired Stringer	2 Repaired Stringers	Relative Performance (2 Repair/1 Repair)
Metal Plates	5628 (13)	4116 (30)	-27%
Half-Companion Stringer	5493 (22)	4689 (24)	-15%
Full-Companion Stringer	5851 (21)	6282 (42)	+7%
Stiffness (lbs/in)			
Metal Plates	6650 (24)	4699 (20)	-29%
Half-Companion Stringer	6441 (17)	4818 (26)	-25%
Full Companion Stringer	7544 (21)	9652 (21)	+22%

Materials and Test Methods

Ninety new 48x40 GMA-style pallets were sampled from inventory at Williamsburg Millwork Corporation of Bowling Green, Virginia. Also sampled were 75 stringers for use as companion repair members. New pallets from one manufacturer were selected to control the non-treatment variability inherent to used pallets from multiple sources, manufactured to different specifications. New pallets provided a realistic method of comparing repair treatments while maintaining a practical number of samples.

Pallet component dimensions were measured, and pallets were randomly segregated into six different groups of 15 pallets each. These six groups were used to compare the three repair methods and two damage levels: either one damaged stringer per pallet or two damaged stringers per pallet. Pallets were air-dried to 10-12% moisture content to represent the moisture level of using pallets in service.

Eagle Metal Products of Texas provided the 20 gauge metal repair plates, which measured 3x4 inches and exhibited four teeth per square inch.

Prior to repair, all pallets were tested by bending to failure spanning the 48-inch pallet length using the procedures outlines in ASTM D1185-98. The strength and stiffness of each new pallet, prior to repair, was determined. Initially, one stringer would fracture at an interior notch fillet during this test. For pallets that were intended for one stringer repair, testing was then halted. For groups intended for two stringer repairs, testing continued until a second stringer was fractured. Only pallets with one crack or damage per stringer were included in the study. Following these initial tests, pallets with one and two broken stringers were repaired with metal plates, half-companion stringers, or full-companion stringers. IFCO Systems of Richmond, Virginia applied the metal plates using a hydraulic plater. All full and half-companion repairs were made at Virginia Tech according to the practices outlines in ASME MH1.

Repaired pallets were then tested using the same procedure outlined above. The test was stopped as soon as a visible fracture occurred in any stringer at any location. It is important to note that variability with regard to species of companion repair stringers using in the tests could limit the interpretation of results, specifically comparison of pallet repair methods.

In general, pallets with one stringer repaired using one pair of metal plates, one half-companion stringer, or one or two stringers repaired with full-companion stringers, were statistically stronger than the original pallets.

RESULTS AND DISCUSSION

Effect of Repair Method and Frequency on Bending Strength

Table 1 (page 68) contains the flexural bending strength of the GMA pallets before and after repair. There were no significant differences in original stiffness before repair between the six treatment groups. Thus, it is assumed that the pallets before repair were one statistical population of similar performance.

The repaired treatment group sample sizes are different because of stringer fracture modes during the initial testing that could not be effectively repaired using metal plates or two half-stringer companions.

In general, pallets with one stringer repaired using one pair of metal plates, one half-companion stringer, or one or two stringers repaired with full-companion stringers, were statistically stronger than the original pallets.

Repairs to one pallet stringer increased strength by 20 to 45%. Pallets with two stringers repaired with metal plates or half-companions were statistically similar in strength to the original pallets. These results suggest that all three stringer repair methods, applied to one or two damaged stringers with one fracture per stringer, will at least restore pallet bending strength spanning the pallet length.

In general, the coefficient of variation (COV) between original and repaired pallets was similar. The repaired pallets containing two full companion stringers, however, exhibited a relatively high COV due to two pallets with relatively low strength. These two pallets were re-

paired with companion stringers that contained knots in similar locations as the fracture in the original stringer. This indicates that care should be used when selecting the companion components for repair. The quality of repair components will affect the performance of repaired pallets.

Effect of Repair Method and Frequency on Bending Stiffness

Table 2 (page 68) contains the flexural bending stiffness results for the GMA pallets before and after repair. Statistical analysis indicates that there was no significant difference between the original stiffness before repair between the six treatment groups; the pallets were considered to be one statistical population of similar performance.

While the original pallet strength was restored by stringer repair, the average stiffness of metal plate and two half-companion repairs were statistically less stiff (35% and 31% respectively) than the original pallets. Pallets repaired with one metal plate repair, one half-companion, or one full-companion were statistically similar in stiffness, while the average pallets with two full-companion stringers were 32% stiffer than the original pallets. The average repair to one pallet stringer did not completely restore original stiffness, but the differences were not significant. Statistical analysis suggests that pallets containing two full companions were stiffer than all other repair methods.

Increased stiffness and strength following repairs indicates that the original broken components that were repaired have residual strength and stiffness that contribute to performance after repair.

Effect of Number of Repaired Stringers On Pallet Strength and Stiffness

Table 3 (page 70) contains a comparison of the strength and stiffness of one and two stringer repairs for each repair method. In general, the effectiveness of metal plate and half companion stringer repair declines by 15-29% as the number of stringers requiring repair increases from one to two. However, two full companion stringer repairs are an average of 7% and 22% stronger and stiffer than one stringer repair, respectively. Full companion stringers use more wood volume and nails than the other repair methods, however, and therefore are a relatively expensive repair method.

Conclusions

These research conclusions are summarized below:

The bending strength of GMA-style 48x40 notched stringer pallets with one or two damaged stringers can be restored using metal plates, half-length companion stringers, or full-length companion stringers as described in ASME MH1 Part 3.

Metal plate and half-length companion repairs will restore an average of 65% to 85% of the stiffness of GMA-style 48x40 pallets, depending on the number of stringers repaired.

GMA-style pallets with two stringers repaired using metal plates or half-length companion stringers are 15-27% weaker and 25-29% less stiff than the same pallets with only one stringer repaired.

GMA-style pallets with full-length companion stringers used to repair one or two stringers are stronger and stiffer in bending than the original pallets before damage.