

VIRGINIA TECH

THE EFFECT OF STRINGER REPAIR METHODS AND REPAIR FREQUENCY ON THE PERFORMANCE OF GMA-STYLE 48X40-INCH WOOD PALLETS

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Bulletin No. 25



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ABSTRACT

Over 135 million wood pallets were repaired for reuse in 1995. One of the most commonly damaged components in a wood pallet is the notched stringer. 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-inch GMA-style pallets spanning the pallet stringers. Pallets with up to 2 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 2 metal plate or half-companion stringer repairs were as strong or stronger, but less stiff, than the original pallets without stringer repair. However, on average, pallets with 2 stringers repaired with metal plates or half-companions were less strong and stiff than pallets with only 1 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-inch partial 4-way, 3-stringer pallet. Moreover, 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. These grades, based on functionality with material handling equipment, do not reflect the racking performance of these repair methods.

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There were an estimated 400 million new pallets manufactured in the United States each year, and approximately 1.9 billion in use (8). According to ASME MH1 Part 2 (2), the most common pallet style in North America, representing 30% of annual production, is the 48x40-inch, 3-stringer, partial 4-way, non-reversible, GMA (Grocery Manufacturers of America) style pallet. **Figure 1** is a photograph of this pallet.

In 1995, an estimated 171 million pallets were retrieved by pallet suppliers for repair, reuse, or recycling (3). Approximately 75% were reused, and 63% of these pallets required repair before reuse. One of the most common damages to GMA-style pallets is a fracture in the notch fillet of stringers, as shown in **Figure 2**. ASME MH1, Part 3 (2) describes pallet repair methods and minimum acceptable quality levels for several grades of repaired pallets. However, no performance levels are implied for these pallet grades because the effect of these repair procedures on pallet performance is unknown.

According to ASME MH1a, Part 3 (2), 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 the damaged stringer and nailing a similar new or used stringer in its place. Stringer replacement is rarely used to repair GMA-style pallets and was not evaluated in this 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 4 teeth per square inch. A pair of plates is used for each repair, one per stringer side over the fracture (**Figure 3**). 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 stringers (half-companions) are cut 1 inch shorter than half of the stringer length, and are slightly less in height than the damaged stringer being repaired. They are also placed adjacent to the damaged portion of the 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. These two companion repair methods are illustrated in **Figure 4**.

ASME MH1a, Part 3 (2) describes 4 grades of repaired pallets, based on the method and number of stringer repairs:

- R-1 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.



Figure 1: Photograph of a typical 48x40-inch, 3 stringer, partial 4-way, non-reversible, GMA-style pallet.

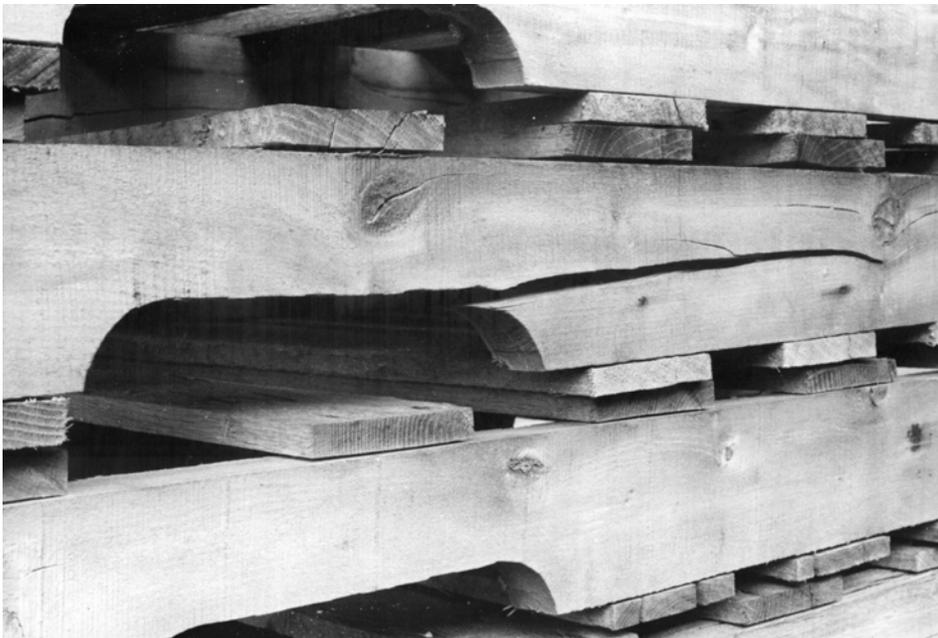


Figure 2: A typical fracture in a stringer notch fillet that must be repaired before reuse.

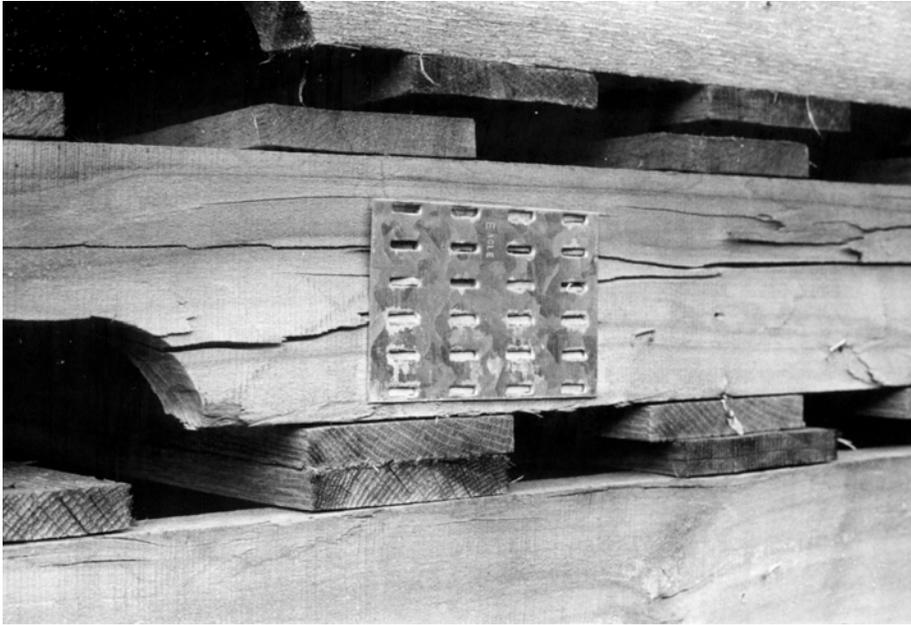


Figure 3: Metal plates manufactured by Eagle Metal Products were used to repair stringer fractures.

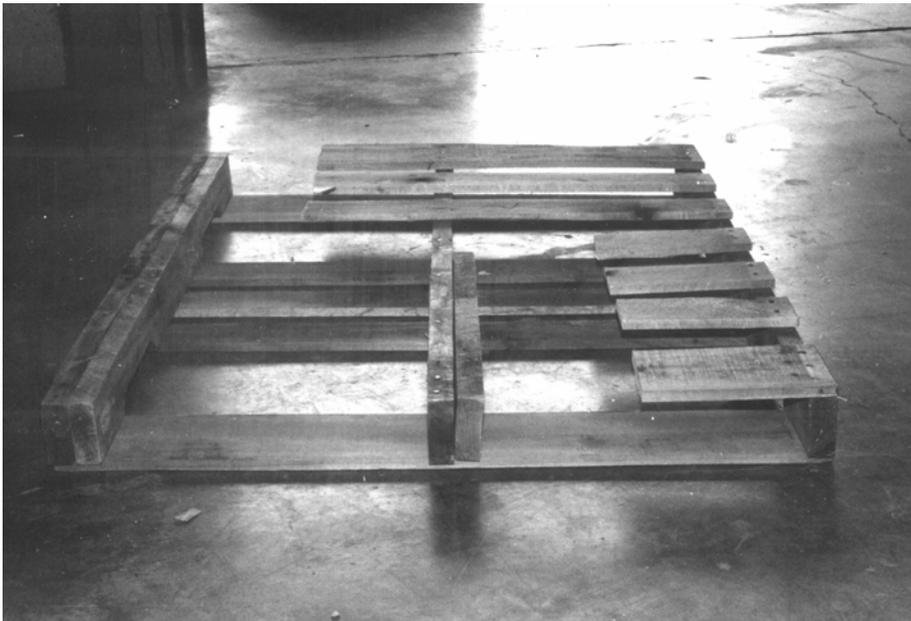


Figure 4. Full-length (left side stringer) and half-length (center stringer) companion stringer repairs. The top deckboards of this pallet have been cut to illustrate the repairs.

Although stringer repair practices for each grade are detailed in this standard, no performance levels are implied. Little is 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 was studied by Clarke et al (5). 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, and not “L-shaped.”

Clarke et al. (4) compared the performance of three grades of repaired GMA pallets from throughout the United States. The results of this study included a documentation of which methods of repair are being used. The performance levels measured for these current repair practices constituted a benchmark of performance that can be used in comparing any changes in practice in the future. According to Clarke et al, the quality of current repair practices did not meet the minimum quality specified in ASME MH1. Given the level variation of repair methods observed within and between each grade of repaired pallets studied, it was not possible 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 ASME 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 repairs reduce the size of openings in pallets, decreasing functionality with material handling equipment such as forklifts and pallet jacks. 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), which maintains a pool of 7.4 million 48x40-inch pallets in Canada, decided in 1999 to eliminate or retrofit pallets containing full companion stringers due to 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.

MATERIALS AND TEST METHODS

Ninety (90), new, 48x40-inch, partial 4-way, non-reversible, GMA-style pallets were sampled from inventory at Williamsburg Millwork Corporation of Bowling Green, Virginia. A detailed description of the physical characteristics of these pallets is given in **Table 1**. A photograph of the typical test pallet is given in **Figure 1**. 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 replicate samples.

Pallets were shipped to the Virginia Tech, William H. Sardo Jr. Pallet and Container Research Laboratory for inspection and evaluation. Pallet component dimensions were measured and pallets were randomly segregated into 6 different groups of 15 samples each. These 6 groups were used to compare the 3 repair methods and 2 damage levels: either 1 damaged stringer per pallet or 2 damaged stringers per pallet. Pallets were air-dried to 10-12% moisture content to represent the moisture level of used pallets in service.

Metal plates were provided by Eagle Metal Products of Timbol, Texas. The 20 gauge plates measured 3x4-inches and exhibited 4 teeth per square inch. The plates are illustrated in Figure 3 and conform to the specifications in ASME MH1, Part 3 (2).

Table 1: Detailed Description of the GMA-Style Test Pallets

| | |
|---|---|
| Size | 48 x 40 inches |
| Average Weight | 40.0 lbs. |
| Average Moisture Content | 15% |
| Top Deck | 2 @ 0.610 in. x 5.350 x 40 in. 5 @ 0.520 in. x 3.360 x 40 in. |
| Bottom Deck | 2 @ 0.610 in. x 5.350 x 40 in. 3 @ 0.520 in. x 3.360 x 40 in. |
| Average Stringer | 3 @ 1.276 in. x 3.433 x 48 in. |
| Notch dimension | 6.20" Location, 8.87" Length, 1.21" Depth, 1.50" Radius |
| Companion Stringers | |
| Half companions | 1.267 x 3.405 x 23 in. |
| Full companions | 1.270 x 3.397 x 48 in. |
| Fasteners | 2.25-inch, 11.5 gauge |
| Pallet Part Grade | Multiple Use and Better* |
| Species Mix of Stringers | 45% Yellow-poplar 34% Oak 21% Medium Density Hardwoods |
| Species Mix of Companion Repair Stringers | 19-62% Yellow poplar 38-69% Oak 0-33% Medium Density Hardwoods |

* As described in ASME MH1, Part 3 "Wood Pallets."

Prior to repair, all pallets were tested in bending to failure spanning the 48-inch pallet length using the procedures outlined in ASTM D1185-98 (1). The test setup is shown in **Figure 5**. The test span was 44 inches, and a uniform flexible load was applied using an inflatable air bag at a rate of 1000 pounds per minute. The strength and stiffness of each new pallet, prior to repair, was determined using this method. Initially, one stringer would fracture at an interior notch fillet during this test. For pallets that were

intended for 1 stringer repair, testing was then halted. For groups intended for 2 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 1 and 2 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 applied at Virginia Tech according to the practices outlined in ASME MH1 (2). A schematic drawing of these repairs is shown in **Figure 4**. Repaired pallets were then tested using the same procedure as 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 the species of companion repair stringers used in the tests could limit the interpretation of the results—specifically comparisons of pallet repair methods.

The JMPIN (7) statistical analysis program was used in the evaluation of the test results.

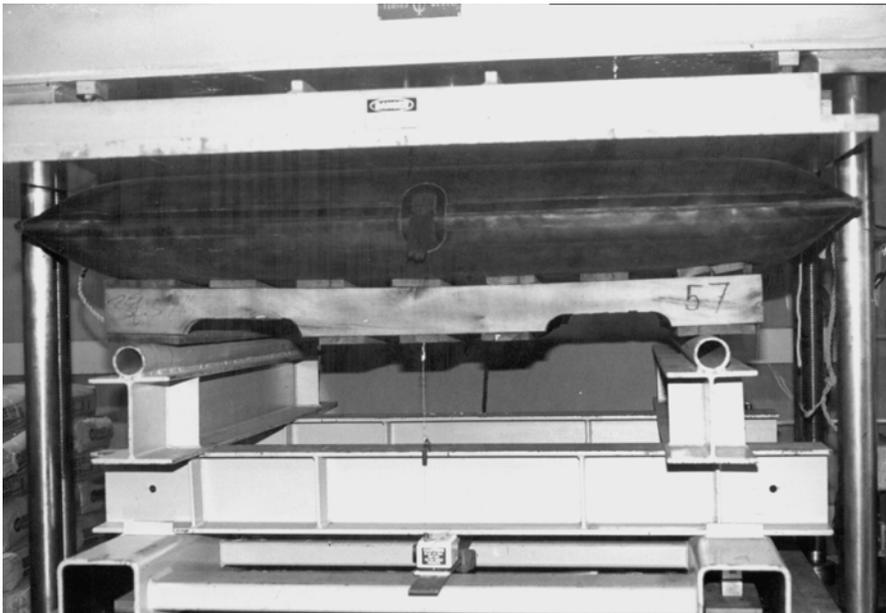


Figure 5: The test used to measure pallet flexural strength and stiffness of GMA-style pallets spanning the pallet stringers.

RESULTS AND DISCUSSION

THE EFFECT OF REPAIR METHOD AND FREQUENCY ON BENDING STRENGTH

Table 2 contains the flexural bending strength of the GMA-style pallets before and after repair . A Tukey-Kramer HSD means comparison test indicated that there was no significant difference in the original strength ($F=0.5155$) before repair between the six treatment groups. It is therefore assumed that the pallets before repair were one statistical population of similar performance.

Table 2: 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.

The repaired treatment group sample sizes are different. This was due to stringer fracture modes during the initial testing that could not be effectively repaired using metal plates or 2 half-stringer companions. For example, vertical stringer fractures cannot be effectively repaired with metal plates. In addition, stringers that fractured at both notches of a stringer during the initial tests were not repaired.

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 2 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 2 full companion stringers, however, exhibited a relatively high COV due to 2 pallets with relatively low strength. These 2 pallets were repaired 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.

THE EFFECT OF REPAIR METHOD AND FREQUENCY ON BENDING STIFFNESS

Table 3 contains the flexural bending stiffness results of the GMA-style pallets before and after repair. A Tukey-Kramer HSD means comparison test indicated that there were no significant differences in the original stiffness ($F=0.4466$) before repair between the six treatment groups, and the pallets were considered one statistical population of similar performance.

While the average original pallet strength was restored by stringer repair, the average stiffness of metal plate and half-companion repaired pallets was less than that of the original pallets. Pallets with two metal plate repairs and 2 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 2 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. A Tukey-Kramer HSD suggests that pallets containing 2 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.

Table 3: 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.

EFFECT OF NUMBER OF REPAIRED STRINGERS ON PALLET STRENGTH AND STIFFNESS

Table 4 contains a comparison of the strength and stiffness of 1 and 2 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.

Table 4: 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% |

CONCLUSIONS

1. The bending strength of GMA-style 48x40-inch 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.
2. Metal plates and half-length companion repairs will restore an average of 65% to 85% of the stiffness of GMA-style 48x40-inch pallets, depending on the number of stringers repaired.
3. GMA-style pallets with two stringers repaired using metal plates or half-length companion stringers are 15-27% weaker and 25 to 29% less stiff than the same pallets with only one stringer repaired.
4. 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.

Literature Cited

- ¹ American Society for Testing and Materials. 1997. Standard D1185-98. *Standard methods of static tests of timbers in structural sizes*. Vol. 4.10, Annual Book of ASTM Standards, ASTM, 1916 Race Street, Philadelphia, PA 19103.
- ² The American Society of Mechanical Engineers. 1999. *Pallets, slipsheets, and other bases for unit loads*. ASME MH1, Parts 2, 3, and 10. ASME, New York, NY.
- ³ Bush, R. J., V. S. Reddy, M. S. Bumgardner, J. L. Chamberlain, and P. A. Araman. 1997. *Recycling in the U. S. Pallet Industry: 1995*. Center for Forest Products Marketing and Management, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061.
- ⁴ Clarke, J. W., M. S. White, and P.A. Araman. *The Physical Properties and Performance of New, Repaired, and Remanufactured GMA-Style Pallets*. Forest Products Journal, 2801 Marshall Court, Madison, WI 53705-2295. (In press).
- ⁵ Clarke, J. W., T.E. McLain, M. S. White, and P.A. Araman. 1993. *Evaluation of Metal Connector Plates for the Repair of Wood Pallet Stringers*. Forest Products Journal, 2801 Marshall Court, Madison, WI 53705-2295. Vol. 43, No. 10, pp. 15-22.
- ⁶ McLeod, J.A., III. 1999. Pallet Design System (PDS) software, copyright by the National Wooden Pallet and Container Association, 1800 North Kent Street, Suite 911, Arlington, VA 22209-2109.
- ⁷ JMPIN Statistical Software, 1995. Release 10Xtra. Minitab, Inc., State College, PA.
- ⁸ Reddy, V., R. J. Bush, M. Bumgardner, J. Chamberlain, P. A. Araman. 1997. *Wood Use in the U. S. Pallet & Container Industry: 1995*. Center for Forest Products Marketing and Management, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061.