Repair & Reinforcing Pallet Stringers With Metal Plates

By J.W. Clarke, T.E. McLain, M.S. White, and P.A. Araman

Notches significantly reduce the bending strength and life expectancy of stringer-class pallets with partial 4-way entry. Common failures include cracking between the notches (BN), bending failures in the region above the notch (AN) and splitting of end feet (Figure 1). In recent years, several suppliers and manufacturers of metal connector plates (MCPs) have developed equipment and methods to repair pallets with their products. There is considerable concern about the effectiveness of MCP repair and about minimum guidelines for installation and performance requirements for repaired pallets. As an initial response, the National Wooden Pallet and Container Association (NWPCA) issued interim guidelines on the use of MCPs in 1991.

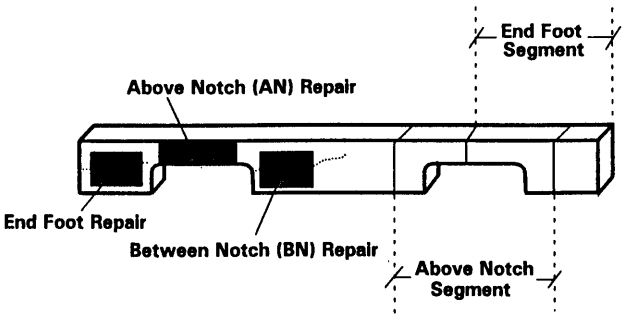

Figure 1: Pallet Stringer illustrating Repair Areas and Test Segments

Table 1: Description of the 20 Gauge Metal Connector Plates in the Study

Plate[1]	Size (in.)	Tooth Length (in.)	Teeth per sq. inch	Tooth style
BN1	3x3	0.374	4.4	6-tooth, round plug type
BN2	3x4	0.336	4.3	4-tooth, round plug type
BN3	3&2x6[2]	0.333	4.2	2-tooth, in-line slot type
BN4	3x4	0.344	4.0	4-tooth, X-shaped plug type
BN5	3x4	0.327	7.9	2-tooth, semi-staggered slot type
BN6	3x4	0.330	5.2	5-tooth, round plug type
AN 1	2x6	0.349	7.0	2-tooth, staggered slot type
AN2	2x6	0.356	4.2	4-tooth, round plug type
AN3	3&2x13[2]	0.333	4.2	2-tooth, in-line slot type
AN4	2x6	0.341	3.9	4-tooth, X-shaped plug type
AN5	2x6	0.329	5.1	5-tooth, round plug type

[1]Plate names indicate use: BN=between the notches; AN=above the notches.
[2]custom geometry, plate shape conforms to stringer notch.

Editor's Note:

I caution readers in advance that this article represents plating research in its infancy. Because of the special attention practiced in a lab, there is the possibility that field practices may be much less precise. This could conceivably change the strength characteristics of individual plates due to natural variations in the "real world." I include this note of caution to reinforce the authors' comments along this same vein. There is some controversy within the pallet plating world, which just reinforces the need for additional field research. The Pallet Recycling initiative recently signed by President Bush will provide more money to study the pallet recycling industry, including this important plating practice.

Virginia Tech, in cooperation with NWPCA and the Southeastern Forest Experiment Station of the USDA Forest Service, recently completed the first phase of a research program on the use of MCPs for repair and reinforcement of stringer-class pallets. This study looked at repair of BN, AN, and end foot failures in damaged stringers of different species, as well as the potential for using MCPs to reinforce new stringers and enhance their bending and impact resistance.

Some of the specific research objectives were:

- to evaluate the effectiveness of different styles of 20 gauge MCPs to restore the bending strength and stiffness and impact resistance of broken stringers,
- to explore the potential of MCPs for reinforcing new stringers, and
- to evaluate several of the specific provisions in the NWPCA interim guidelines for MCP repair.

Repair with MCPs

Various substudies were conducted to determine the effects of repair. Although some whole pallets were tested, most of the research focused on individual stringers or parts of stringers. In general, unbroken samples were tested to failure to determine the original properties, the broken components were then repaired with MCPs, and then retested to determine the repaired properties. The ratio of the property after repair to that for the new component is the *repaired performance* (RP).

One substudy examined the relative performance of different styles of MCPs for repair of the very common between notch (BN-type) failures. The six BN study plates are described in Table 1. Examples of plug and slot-type pallet plates are shown in test specimens in Figures 2 and 4. First six identical groups of 1-1/2" wide, notched oak stringers (30

Figure 2: Test setup used to determine the bending strength and stiffness of stringers. This stringer is reinforced with plug-type MCPs.

pieces in each group) were tested in bending similar to stringers in pallets racked across the stringers (RAS). Each group had the same average initial bending strength. The broken stringers were then repaired, each group with a different plate type, according to NWPCA guidelines. The repaired stringers were then retested and repaired performance (RP) determined. This bending test is shown in Figure 2.

Figure 3 shows the results from bending strength and stiffness tests. Plate repairs that restore the original properties show a RP of 1 or better on the graphs. Each group of stringers had an average greater strength after repair than originally. However, except for the group repaired with plate BN3, the bending stiffness could not be restored. As Figure 3 indicates, there was much overlap in performance, and there was no practical difference between the six different plate styles in oak stringers. Other studies, using southern yellow pine stringers, found that, unlike in oak, both strength and stiffness could be restored with the 3" x 3" plate BN1. Within a species, there was no difference between the RP for 1-1/2" wide and 2-1/2" wide stringers, indicating that the same repair is equally effective for different stringer widths.

Although this study did not find practical differences in the repair of oak stringers with competing plate designs, that does not necessarily mean that all plates are equivalent for all applications. For example, in this study, reasonable care was taken to locate the repair plates on fractures and insure a consistent level of pressing quality. In a production setting, with used pallets, it may be that some external factors such as pressing equipment, pallet style, labor skill, or production rate may tangibly favor the use of one plate over another.

Five different plates for repairing above notch (AN-type) failures were also tested (see Table 1). AN fractures in whole stringers are comparatively rare; so a test setup that forced failure in notched segments was used. No practical difference was found in the ability of any of the five plates to restore bending strength and stiffness of oak segments. However, neither strength (RP=0.70) nor stiffness (RP=0.90) could be completely restored by MCP repair. This may not be a problem however, since only 35 to 50% of the original strength must be restored by AN repaired before strength between the notches will govern the behavior of the stringer. Of greater importance is whether the broken stringer, after repair, can be straightened to make the pallet flat again. This may be more difficult with AN repairs than with BN repairs, but both could be problematic.

To test the ability of MCPs to repair broken end feet, such as seen in Figure 4, segments of notched stringer ends were attached to a dolly which rolled down an incline until stopped by impacting against a forklift tine tip. Impacts were against stringer ends. The impact speed was adjusted to be 2.5-3 mph. Repaired oak and pine end feet withstood more tine impacts before they failed (51-363%) than did new, unplated end feet. MCP repair helped oak end feet more than pine feet because the pine stringer ends tended to split more between the plates, that is, vertically through the stringer cross-section. Future study should include testing this repair technique by impacting against the side of stringer end feet. Studies have shown this impact causes significant damage in pallets.

Several of the NWPCA interim guideline requirements were evaluated, but the

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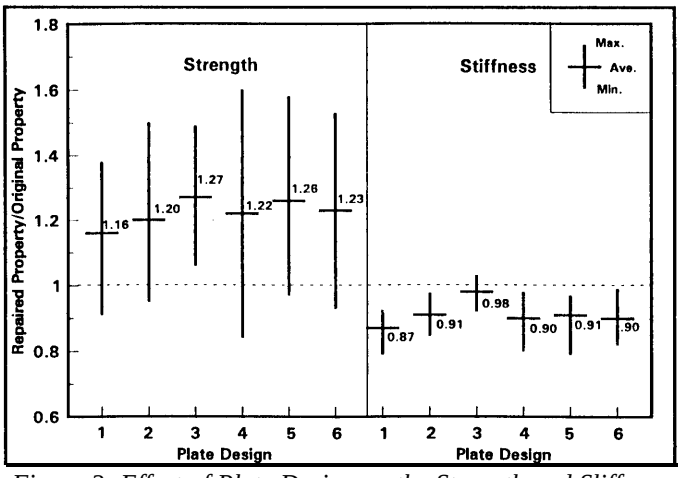

Figure 3: Effect of Plate Design on the Strength and Sliffness of Repaired Oak Stringers.

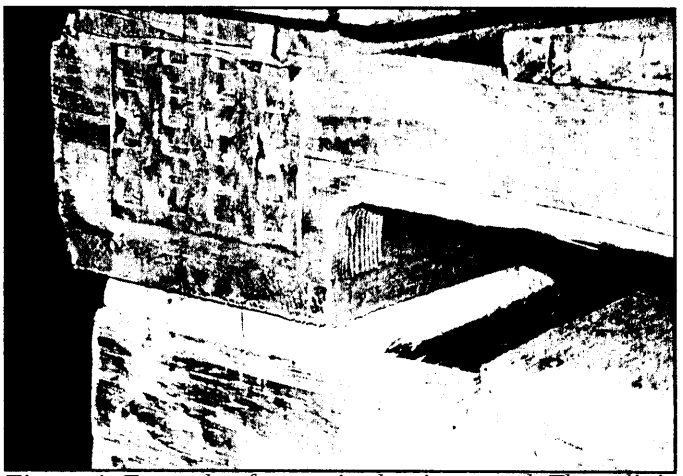

Figure 4: Example of a repaired stringer end. The split is repaired with slot-type MCPs.

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results do not clearly support any changes at this time. For 1-1/2" wide oak stringers, mechanically-closing a BN fracture before plate repair did not improve the performance over that of stringers where the fracture was hand closed. However, the laboratory stringers were cleanly broken with no attached nails or deckboards. In an industrial setting, it is more likely that mechanical closing would result in a higher quality, more consistent repair than hand closing. Again there may be a problem with returning the stringer (and pallet) to a flat condition. Mechanical closing could help that process,

The NWPCA Guidelines currently specify that stringers with BN fractures longer than 8" be repaired with two pairs of plates. Tests of oak stringers found that this length could be extended somewhat and still restore strength, but not original stiffness. Given that measuring the actual crack length in used pallets is difficult, that field placement of repair plates may vary, and that stiffness cannot be restored, no change in the guidelines for fracture length is recommended.

Reinforcement with MCP's

Experience has shown that most stringer failures occur between the notches and at the end feet. Therefore, it may be cost effective to reinforce these areas with MCP's to prevent or delay potential failures. This would help control disposal costs and potentially allow for upgrading the value of low density under utilized woods.

Groups of oak, pine and yellow-poplar stringers, 1-1/2 x 3-1/2 x 48", were reinforced with a pair of plates at each interior notch (4 MCPs per stringer). Bending tests indicate that the reinforced stringers were stronger by 24-108% than the equivalent unreinforced stringers. In some cases, stiffness was also improved (by 0 to 128%). Reinforced end feet (2 MCPs per foot) withstood 34- 117~0 more forklift tine impacts than did the equivalent unreinforced end feet. Pine stringers gained the most from reinforcement between the notches, while oak and poplar gained the most from end foot reinforcement.

Tests of whole pallets, after an accelerated long term handling program, supported the results from the tests of stringers and end feet. Anew setup to test above notch plates may be needed if further work is contemplated in this area. Tests with used pallets are also needed to verify the lack of any effect of plate design, especially with respect to in-service performance and residual strength after the rigors of a handling environment.

The next phase of the cooperative MCP repair research will focus on efforts to develop a performance standard for repaired wood pallets. This will include additional testing of used pallets and components. Specifically, we will look at the relative performance of new, MR, R 1, R2, R3, R4 repairs, as well as MCP repair of GMA style wood pallets.

This article has summarized some of the results of this cooperative study. Additional information is available upon request from: William H. Sardo, Jr. PaIlet and Container Laboratory, Virginia Tech, Blacksburg, VA 24061-0503. ■

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