

Strength and stiffness of post-frame shear walls with wood plastic composite skirtboards

By Loren A. Ross, Donald A. Bender and David M. Carradine

Shear walls in post-frame buildings are commonly constructed with timber posts or laminated columns and horizontally-framed wall girts. The bottom wall girt, called the skirtboard or splashboard, is typically pressure preservative-treated (PPT) lumber due to its location near the ground. Wood plastic composite (WPC) lumber is an alternative to PPT lumber, and WPCs avoid the copper-rich chemical formulations found in PPT lumber that may potentially accelerate the corrosion of steel panels and fasteners. WPC products have mechanical properties different from those of lumber, so testing is required when substituting WPC products for PPT lumber in post-frame shear wall assemblies.

In this study, a commercially-available WPC product and PPT lumber were used as skirtboards in two common framing configurations of post-frame endwalls to evaluate possible effects on shear strength and stiffness. The study found that two nominal 2x6 in WPC boards can be substituted for a single nominal 2x10 in PPT board without significantly affecting the strength or stiffness of the shear walls. A high-density polyethylene WPC formulation was chosen for this study due to its relatively low modulus of elasticity as compared to other commercially-available WPC formulations (e.g., using polypropylene or polyvinyl chloride).

The dominant failure mode of the shear walls was buckling of the ribbed steel sheathing. It should be noted that this study only examined two wall constructions. Additional testing is recommended for wall constructions and materials not studied herein.

Introduction

Post-frame construction differs from

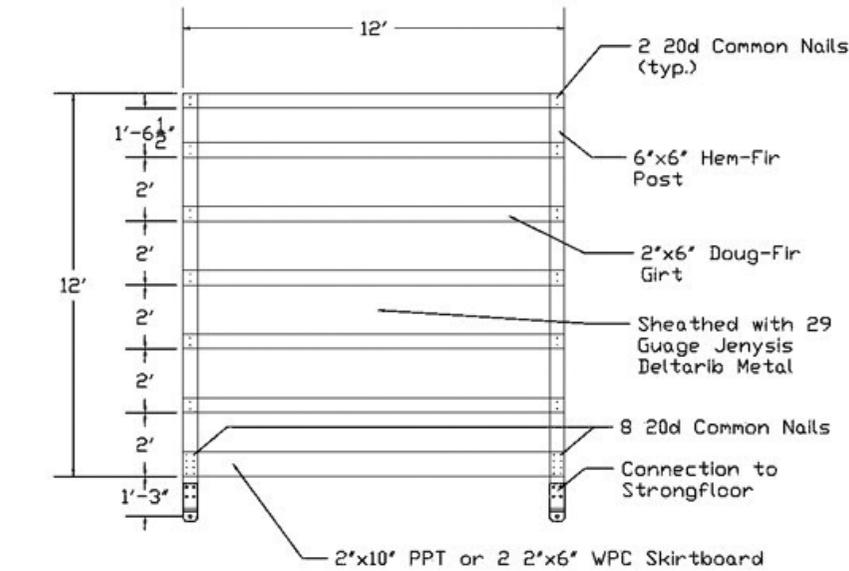


Figure 1: Flatwise wall girt orientation.

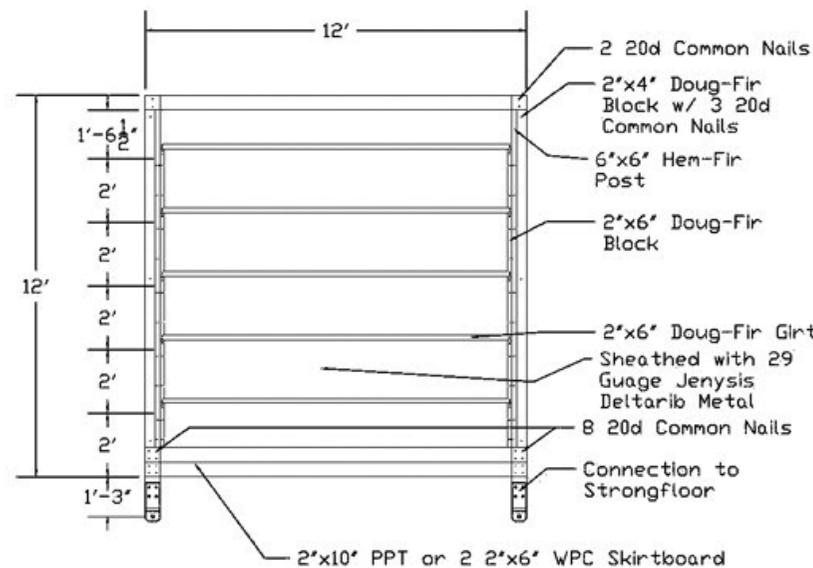


Figure 2: Edgewise wall girt orientation.

traditional light-frame wood construction in that instead of stud walls, post-frame buildings have timber posts or laminated columns and horizontally framed wall girts to allow attachment of sheathing. The bottom girt, called the skirtboard

or splashboard, is typically exposed to wet conditions because it is located near ground level. Not only must skirtboards resist decay and insect attack, but they also act as important components of the load path for post-frame buildings.

The skirtboard collects forces from the sheathing and transfers them into the post foundation; thus, durability of the skirtboard is structurally important.

Lumber treated with chromated copper arsenate (CCA) dominated residential and industrial markets for decades. However, in December 2003 CCA was phased out for many non-industrial applications (Lebow et al., 2003). While the phase-out does not apply to posts or laminated columns for post-frame construction, CCA-treated skirtboard material is now prohibited for sale and use. This has created a movement towards alternate treatment chemicals (Bohnhoff, 2002).

Instead of CCA, chemical formulations with higher copper contents gained market share, such as alkaline copper quaternary (ACQ) and copper azole (CA). These copper-rich formulations may lead to increased galvanic corrosion of fasteners in the treated wood (Zelinka and Rammer, 2006).

Replacing copper-rich PPT lumber with wood-plastic composite (WPC) material is one alternative, and its technical feasibility is assessed in this study. Four 12 ft x 12 ft wall configurations were constructed, half with a commercially-available WPC skirtboard and the other half with a PPT lumber skirtboard. All configurations were subjected to monotonic wall racking tests to evaluate their shear performance.

The objectives of this study were to determine possible influences of skirtboard material (PPT lumber vs. WPC) and wall girt orientation (flatwise vs. edgewise) on the strength and stiffness of post-frame shear walls.

Materials

Two types of skirtboard materials were used. The control case was ACQ pressure preservative-treated (PPT), incised 2x10 Hem-fir No. 2 lumber. Hem-fir is the most common PPT lumber species combination found in the western U.S. A commercial wood plastic composite (WPC) made from a high-density polyethylene formulation was chosen because it represents the most common polymer currently used and one that has a relatively low modulus of elasticity compared to other polymer types such as polypro-

| PROPERTY | ALLOWABLE STRESS DESIGN VALUE (PSI) |
|--|-------------------------------------|
| Flexural stress | 250 |
| Tension | 250 |
| Modulus of elasticity | 100,000 |
| Compression parallel to grain | 550 |
| Compression perpendicular to grain | 625 |
| Shear | 200 |

Table 1: Allowable design properties of WPC

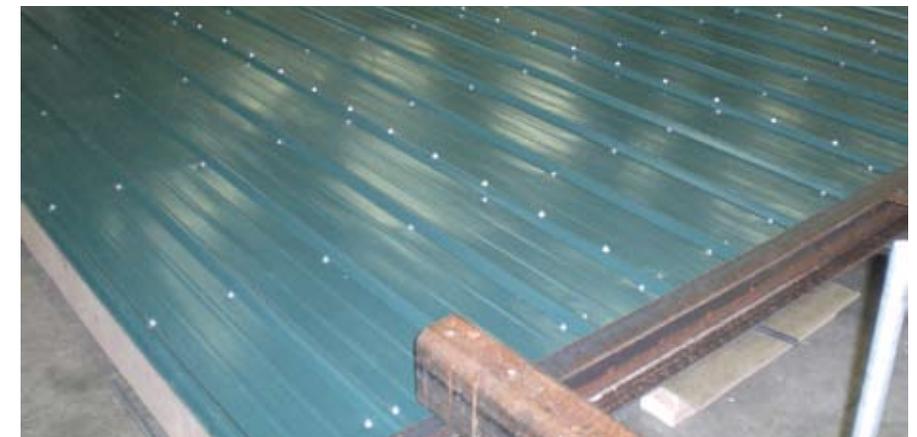


Figure 3: Fastener pattern for attaching steel panels to framing.

pylene and polyvinyl chloride (Bender et al., 2006).

Specifically, the WPC skirtboard was Trex Accents nominal 2x6 (actual dimensions 1.5x5.5 in). WPC is not commercially available in nominal 2x10 size (since primary market is residential decking); hence, we chose to use two 2x6 pieces to compare to the 2x10 PPT lumber. Design properties for the Trex product can be found in ESR-1190 (ICC, 2005) and are summarized in Table 1. All non-treated lumber, used for wall girts and blocking, was Douglas-fir No. 2 and was either a 2x4 or 2x6, depending on location within the wall. Posts were Hem-Fir No. 2 with nominal dimensions of 6x6 in and were incised and pressure-treated with CCA.

Fasteners used to attach framing were 20d bright, common nails with a length of 4 in and a diameter of 0.192 in for wood-to-wood connections. Smooth nails were chosen over threaded nails to facilitate direct comparisons to a previous study commissioned by the NFBA (Braun Intertec, 1996). Smooth nails also provide a more conservative (lower) strength compared to threaded nails. For a metal-to-wood connection, Fabral WoodFast 1.5 in long, galvanized screws were used. Similarly, Fabral WoodFast

1-inch long screws were used for stitch screws, which secured overlapping metal sheets together. Both screws had a diameter of 0.157 in. The metal panel was 29 gauge Delta Rib by Jenysis.

Wall constructions

Two factors were examined in this study: (1) PPT lumber vs. WPC, and (2) edgewise vs. flatwise wall girt construction. The different wall framing configurations are shown in Figures 1 and 2 (on page 28). Posts for all configurations were 13.25 ft long with a wall height of 12 ft. The extra post length was used to attach the walls to the testing floor. Wall construction and fixtures generally followed methods given in the Braun Intertec (1996) report to the National Frame Building Association.

For edgewise girt orientations, interior girts were offset to be in the same plane as the flatwise mounted skirtboard and top girt. Blocking between girts was attached with two 20d nails to the posts, and then two more nails were driven through the top of the girt into the blocking. To allow metal sheathing to be attached around the edges of the walls, a Douglas-fir No. 2 2x4 was attached to the face of the post. For the flatwise girts, two nails were

Table 2: Results of each wall test.

| WALL TYPE | SHEAR STIFFNESS (lb/in) | ULTIMATE SHEAR STRENGTH (lb/ft) | DESIGN STRENGTH WITH 2.5 SAFETY FACTOR (lb/ft) |
|----------------|-------------------------|---------------------------------|--|
| EPT1 | 22,053 | 543 | 217 |
| EPT2 | 20,825 | 530 | 212 |
| EPT3 | 19,472 | 517 | 207 |
| Average | 20,785 | 530 | 212 |
| EWP1 | 23,115 | 550 | 220 |
| EWP2 | 16,285 | 517 | 207 |
| EWP3 | 13,921 | 489 | 196 |
| Average | 17,770 | 519 | 208 |
| FPT1 | 16,645 | 529 | 212 |
| FPT2 | 18,495 | 523 | 209 |
| FPT3 | 17,644 | 533 | 213 |
| Average | 17,599 | 528 | 211 |
| FWP1 | 18,547 | 538 | 215 |
| FWP2 | 27,894 | 513 | 206 |
| FWP3 | 16,999 | 526 | 210 |
| Average | 21,145 | 526 | 210 |

driven through the face of the girt into the post on each side.

The 20d nails were driven by hand with 0.14-in diameter holes predrilled into the WPC. Eight nails were used for each side of the skirtboard. For the PPT skirtboards, 8 nails were driven into each side without predrilling.

Figure 3 (on page 29) shows the screw pattern for attaching the steel panels to the framing. Spacing on stitch screws was 8 in and field screws coincided with each major rib of the panels. The far end of the wall has two rows of fasteners in the 2x10 PPT lumber skirtboard. For the panels constructed with two 2x6 WPC skirtboards, the fastener pattern is the same with one row of fasteners for each piece of WPC.

The Fabral screws were driven with a variable-speed screwdriver. The screws were driven according to Fabral's instructions, which stated that the neoprene washer should not "mushroom" beyond the metal top of the washer (Fabral, 2000).

Test methods

Monotonic wall tests were performed according to ASTM E 564 (ASTM Standards, 2006) and ASABE EP558 (ASABE Standards, 2004). The walls were loaded at a constant rate of 0.25 in/min. Load was applied uniformly across the top of the wall through a steel channel to the top girt using a computer-controlled hydraulic actuator. Additional details on test methods can be found in Ross (2008).

Posts were attached to the reaction floor through pin connections. While embedded posts would have some moment-resisting capacity, pin connections were conservatively used in testing to require the skirtboards to resist more load. Pin connections were created by sandwiching the posts between 0.25 in. metal plates. Four 5/8 in. diameter bolts attached the metal plates to the posts. On the other end of the plates, a single 1 in. diameter threaded bar was passed through the metal plates with a 4x4 in. metal square tube between the plates. This metal tube was then attached to the strong-floor with four 1 in. diameter bolts.

Since walls were constructed and tested parallel to the laboratory floor, rollers were placed under each girt to minimize

deflection due to self-weight of the wall. Similarly, rollers were placed under the steel channel, used to apply the load, so that its weight was not carried by the wall. Steel tubing was also placed just above the steel channel to resist lateral deflection at the top of the wall. The steel tubing did not rest on the channel, and since significant buckling of the top chord never occurred during testing, top chords never made contact with the channel. A roller was also placed under each post to carry its self weight.

Deflection data were collected in four locations on the wall according to ASTM E 564 (ASTM Standards, 2006). Average moisture content was 30.5% for the posts and 9.6% for all other framing lumber.

Results

A total of 12 walls were tested, with six using edgewise girt construction and six using flatwise. Similarly, six of the walls had PPT lumber skirtboards and six had WPC skirtboards. The method for naming the wall groups was that the first letter represents the wall girt orientation: edgewise (E) or flatwise (F). The second set of letters designates the skirtboard material: pressure preservative-treated (PT) lumber or WPC (WP). The last number represents the replication of that type of wall. For example, EWP3 would be the third wall with edgewise girt and WPC skirtboard.

Design shear strengths of walls were found by taking the maximum load and dividing by the width of the wall (12 ft) and by a safety factor of 2.5. The ASABE procedure of averaging all three walls per configuration was used instead of the ASTM method of averaging the weakest two of the three walls. Shear stiffness was calculated by dividing design load by shear displacement at that load (corrected for translation and rotation) and then multiplying by the height-to-width ratio of the wall, which was 1.0 for these walls. Table 2 shows the stiffness, ultimate shear strength and design strength of each wall.

No statistically significant differences were found between flatwise and edgewise girt orientations or between PPT and WPC skirtboards. Figures 4 through 7 show load versus dis-

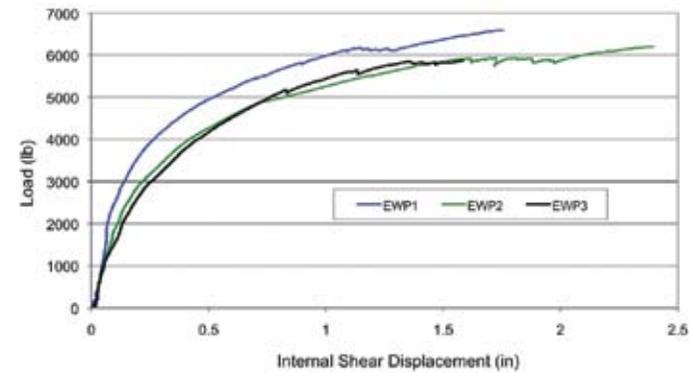


Figure 4: Shear displacements of walls with edgewise girts and WPC skirtboards.

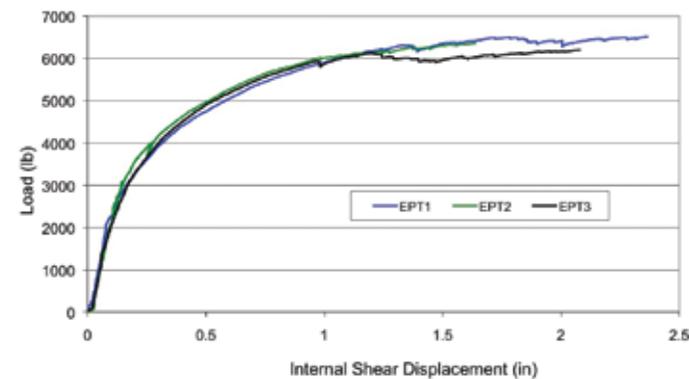


Figure 5: Shear displacements of walls with edgewise girts and PPT skirtboards.

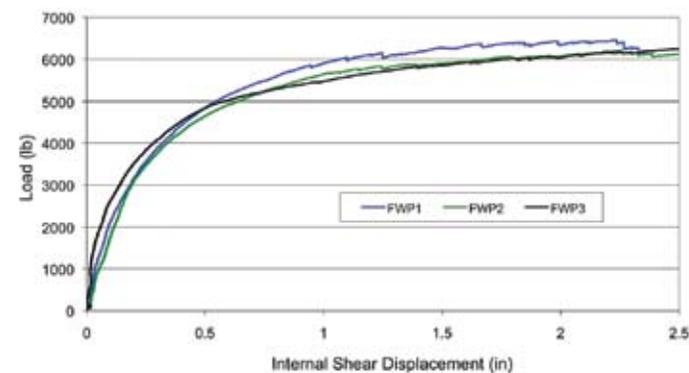


Figure 6: Shear displacements for walls with flatwise girts and WPC skirtboards.

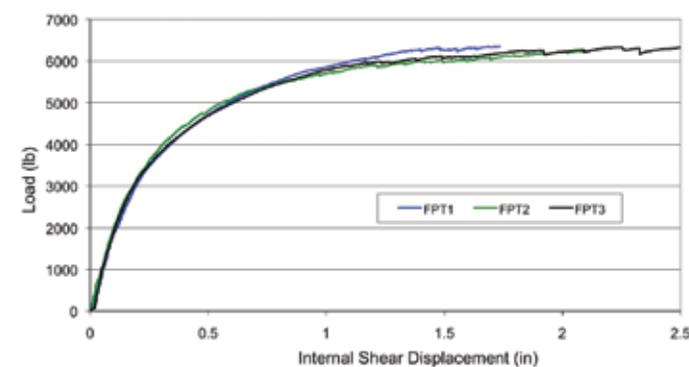


Figure 7: Shear displacements of walls with flatwise girts and PPT skirtboards.



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placement plots for each wall organized by configuration.

Shear strengths of the 12 walls tested were considerably higher than the walls tested in the Alumax Building Products (1992) study. Alumax "Q-2" category of walls is closest to the walls tested in this study; however, the Alumax design strength for flatwise girt walls with pressure-treated skirtboards was 170 lb/ft compared to 211 lb/ft obtained in this study. Alumax walls differed in two significant respects: post spacing and girt spacing.

Alumax posts were spaced 8 ft on center (o.c.), which is a common practice in the eastern U.S. Posts in this study were spaced 12 ft o.c., which is a more common spacing for the western U.S. This difference, however, should have made Alumax's walls stronger.

The second difference (i.e. girt spacing) apparently had more impact on wall shear strength. Alumax's walls had girts spaced at 3 ft o.c., whereas the walls in this study had girt spacing of 2 ft o.c. Since a primary failure mechanism of the walls was buckling of the metal sheathing, reducing the girt spacing significantly increased buckling capacity.

Failure modes

The primary failure mode for the walls was buckling of the metal sheathing. Buckling usually started between the second and third girts (including the skirtboard as a girt) from the bottom. As the load was increased, buckling created diagonal waves throughout the panel sheathing as shown in **Figure 8**.

Stitch screws and screws attaching the metal to the girts were another failure mode for the tested specimens. Screws would either pull out of the wood or metal, or the metal would tear around the screws. This failure mode did not occur in all walls, but happened most frequently on the side of the wall opposite the actuator, which was undergoing compression.

Once a screw failed, buckling of the sheathing was affected as forces were redistributed around that failed section. It was observed that underdriving or overdriving screws negatively affected their performance, highlighting the need for correct and consistent attachment of screws for best wall performance.

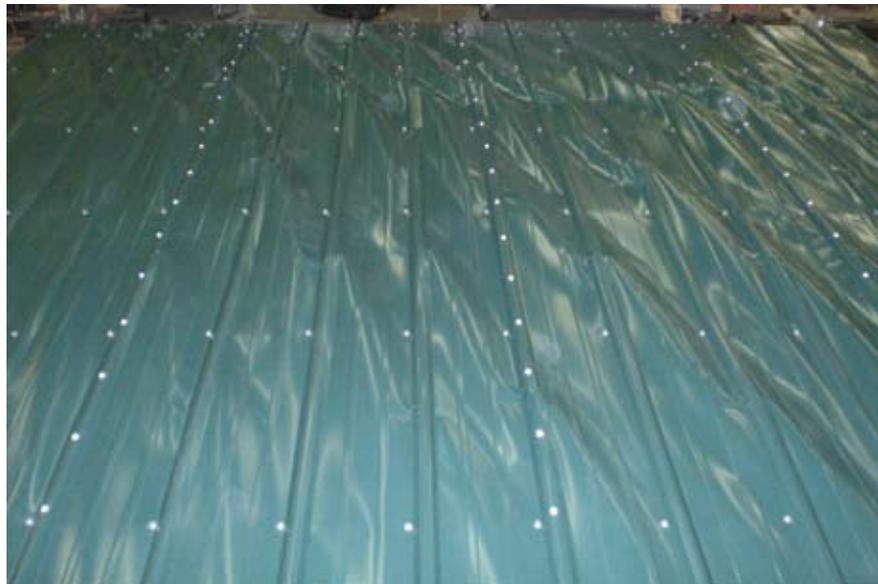


Figure 8: Illustration of panel buckling failure, with the skirtboard located at far end of shear wall.

Skirtboards exhibited minimal out-of-plane displacements (less than 0.2 in) during testing. The WPC skirtboard deflected most, as would be expected with its lower modulus of elasticity; however, deflection of either type of skirtboard was slight and did not appear to affect wall behavior.

Summary and conclusions

Monotonic shear wall tests were performed on four configurations of post-frame walls. Potential differences between a PPT lumber and a WPC skirtboard were investigated for both flatwise and edgewise wall girt constructions.

No significant differences were found between the shear strengths and stiffness of all four wall groups. This suggests that a nominal 2x10 pressure-treated lumber skirtboard can be replaced by two nominal 2x6 WPC boards for the wall configurations and materials presented in this study without sacrificing ultimate strength or stiffness of the walls. We used two 2x6 WPC boards because the product is not available in nominal 2x10 size. A commercially available WPC was selected for this study that is made from high-density polyethylene (HDPE) polymer resin. The modulus of elasticity values of WPCs made from this polymer resin are less than those of other common polymer types such as polypropylene (PP) and polyvinyl chloride (PVC).

Our rationale was that WPCs with

higher MOE values than reported here could be conservatively substituted. Hence, utilizing WPCs for skirtboards appears to be technically feasible and would provide an alternative to copper-rich preservative chemical formulations that may accelerate corrosion in steel and aluminum sheathing, flashing, and fastening materials, and offering an alternative to customers who may prefer to avoid using PPT lumber.

Builders considering using WPC skirtboards should consult the WPC manufacturer concerning any possible limitations for ground contact applications. Further research is needed to examine possible effects of substituting WPCs for PPT lumber for other end wall constructions and fastening systems not tested.

When comparing the strength of these walls with those tested in the Alumax Building Products study (1992), the impact of girt spacing was shown to be a significant factor. By decreasing spacing between girts, an improvement in steel panel buckling capacity was observed.

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3. Listen to their answers. Don't bother asking questions if you are not willing to listen objectively to their answers, as it would be a waste of time and energy.

4. Think about the consequences. You, and only you, are responsible for your life choices and the consequences. By thinking before making decisions, you are more likely to respond (good!) than react (bad!). When you act before thinking (ready, fire, aim!) you usually make poor decisions.

5. Respond appropriately. As you adhere to this discipline, you will most often make good decisions that lead to a more fulfilling life.

A final thought

Never make important decisions when you are tired or angry.

Byrd Baggett, who spoke at the 2009

Frame Building Expo, is an expert at developing authentic leaders and passionately engaged teams. His solutions have been featured in Readers Digest, Bits & Pieces, Guide Posts, and Selling Power magazines. He has authored 13 books on sales, leadership, customer service and motivation.

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