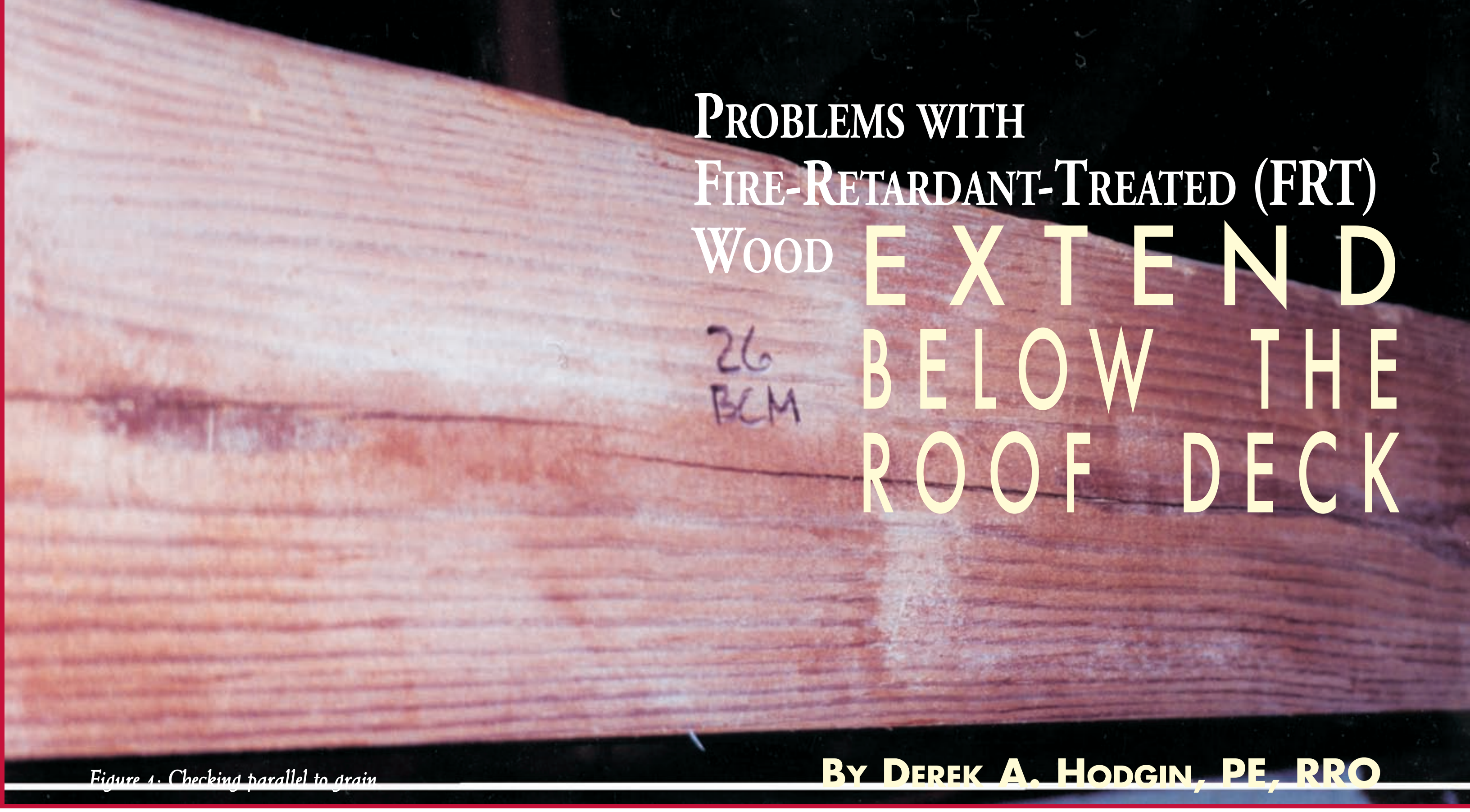


Problems with Fire-Retardant-Treated (FRT) Wood Extend Below the Roof Deck

Figure 1: Checking parallel to grain.

By Derek A. Hodgin, PE, RRO

The degradation of wood strength properties related to the presence of fire retardant treatment (FRT) has been previously documented. This degradation process, referred to as "acid catalyzed dehydration," is directly associated with environmental conditions such as temperature and humidity. The FRT chemicals migrate through the wood during cyclical changes in temperature and humidity, causing changes in pH such that the wood becomes embrittled. This process is most commonly associated with plywood roof decks, where exposure to radiant heat is most significant. However, the effects on dimensional lumber used in roof framing can be equally dramatic. Significant reduction in both the Modulus of Elasticity (MOE) and Modulus of Rupture (MOR) can occur. The MOE is a measure of stiffness, while MOR is related to bending strength.

Analysis of MOE and MOR on wood samples removed from FRT trusses from recent projects in South Carolina revealed reductions of approximately 20 and 40 percent, respectively.[2,4] The in-service life of these trusses was approximately 30 years. Additionally, the failure of the FRT wood samples occurred suddenly with a marked absence of toughness, a reflection of their brittle condition. The significant loss of strength properties can result in truss damages, truss failures, and, possibly, roof collapse.

This paper is intended to provide the reader with a basic understanding of the problems associated with FRT lumber, the variables which are important to the degradation process and how to identify the presence of FRT.

THE PROBLEM

Fire Retardant Treatment (FRT) is applied to building materials such as plywood and structural lumber to reduce the capacity of the wood to contribute to a fire. The FRT chemicals reduce the temperature at which thermal degradation occurs, thereby increasing the amount of char and reducing the amount of flammable volatiles.[6] In this regard, FRT has performed effectively. However, the chemi-

Right: Figure 3: Full break.

Below: Figure 2: Splitting parallel and perpendicular to grain.

cals in the FRT react with the natural fibers of the wood, resulting in an overall brittle condition that occurs over time. This condition is seen as the primary cause of the splits and breaks in the wood roof framing.

While FRT can be applied to stick-built framing, it is most commonly used on engineered trusses to span large buildings. In recent years, it has been observed that certain chemicals used in the FRT have resulted in significant compromise to structural members. The loss of strength can cause premature failure of the trusses. The modes of failure include heavy checking parallel and perpendicular to the grain, splitting, and full cross-grain breaks (*Figures 1, 2,* and *3*).

VARIABLES IMPORTANT TO THE DEGRADATION PROCESS

The FRT chemicals by themselves do not significantly degrade the mechanical properties of the wood. For significant degradation to occur, a number of variables must be present. The extent of the degradation is dependent upon the variables described below.

Temperature

The application of the FRT chemical to wood is typically associated with an initial loss of strength which was previously addressed by the National Design Specification (NDS) in the form of a 10% strength reduction on all wood properties.[8] However, a more severe degradation process takes place over time when the FRT treated wood is exposed to elevated temperatures for long durations. For this reason, the NDS now refers the design professional to the manufacturer of the FRT to determine the specific strength reduction to be used.

The elevated temperatures in a typical attic can reach as high as 130° to 180° F and are more than adequate to compromise the structural integrity of the wood in the presence of FRT chemicals. Published studies have revealed that elevated temperatures (above 150° Fahrenheit) can result in permanent strength loss in untreated wood[3]. However, these studies are based on a continuous exposure (72 months) to elevated temperatures. Roof framing, even in a southern climate, is exposed to elevated temperatures only on an intermittent basis. In a recent project located in South Carolina, wood samples from untreated roof framing were tested after more than 30 years of service life. The tests revealed no loss in MOR and only a minor loss in MOE.[5] The absence of strength loss is considered to be related to the infrequent and limited exposure of the wood to temperatures above 150°.

FRT Chemicals

The most common FRT chemicals used for wood are the inorganic salts, such as diammonium phosphate, monoammonium phosphate, zinc chloride, ammonium sulphate, borax, and boric acid. Some FRT systems for wood are based on the formation of a phosphate salt of an organic compound and are referred to as organic salts. However, all FRT systems for wood rely on the elements of phosphorous, nitrogen, or boron. Phosphorous is usually the central element.[7]

The extent of degradation of the wood is related to a process referred to as acid-catalyzed dehydration, which is

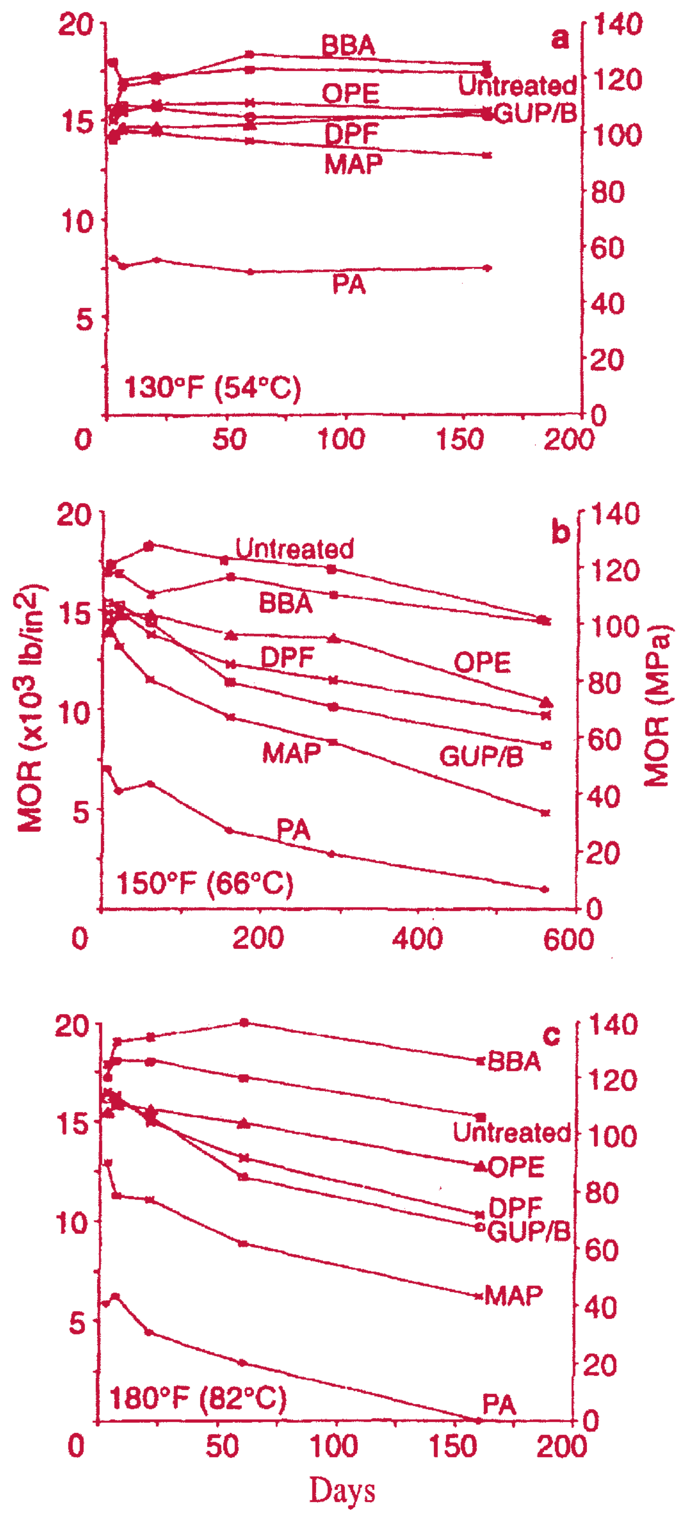


Figure 4: Effect of extended exposure to elevated steady-state temperatures on bending strength for untreated and fire-retardant-treated wood. (a) 130°F (54°C). (b) 150°F (66°C). (c) 180°F (82°C). BBA is borax-boric acid; DPF, dicyandiamide-formaldehyde-phosphoric acid; GUP/B, guanylurea phosphate/boric acid; MAP, monoammonium phosphate; OPE, dietyl-N, N-bis (2-hydroxyethyl) aminomethyl phosphonate; and PA, phosphoric acid. MOR is modulus of rupture; 1 lbs/in.² = 6.894 kPa. (Note differences in scale of x-axis.) Reprinted with permission. © Wood and Fiber Science, United States Department of Agriculture, Forest Products Laboratory.

influenced by acidity and temperature. The different chemicals used in fire retardant formulas alter the pH of the wood to varying degrees. Chemicals which lower the pH of the wood have a stronger attraction for water and thus have a greater drying effect. There is a direct relationship between the pH of the fire retardant chemicals and the effect of the chemicals on the mechanical properties of the treated wood. Additionally, some fire retardant chemicals dissociate more readily at elevated temperatures, thereby increasing the acid concentration in the wood and accelerating the loss of strength properties and embrittlement. The specific parameters of this process vary depending on the fire retardant chemicals used and the duration and level of temperature to which they are exposed.

Based on a review of available literature, the fire retardant chemicals phosphoric acid (PA) and monoammonium phosphate (MAP) appear to result in the most significant affects in terms of wood degredation (*Figure 4*).[10] Specifically, the FRT chemicals lower the pH of the wood, which results in the acid-catalyzed dehydration process. The PA treatment has the lowest pH, and it has the greatest effect on mechanical properties.[6] As inorganic salts, PA and MAP diffuse through the wood with moisture during cycles of temperature change as described above. This diffusion process allows the wood to continually degrade as the acidic salt makes it way through the wood. In a roof environment, changes in temperature and humidity cause shifts in the equilibrium moisture content of the wood. As the moisture moves, so do the inorganic salts. At each new site, the acidic salts can cause further degradation.[7]

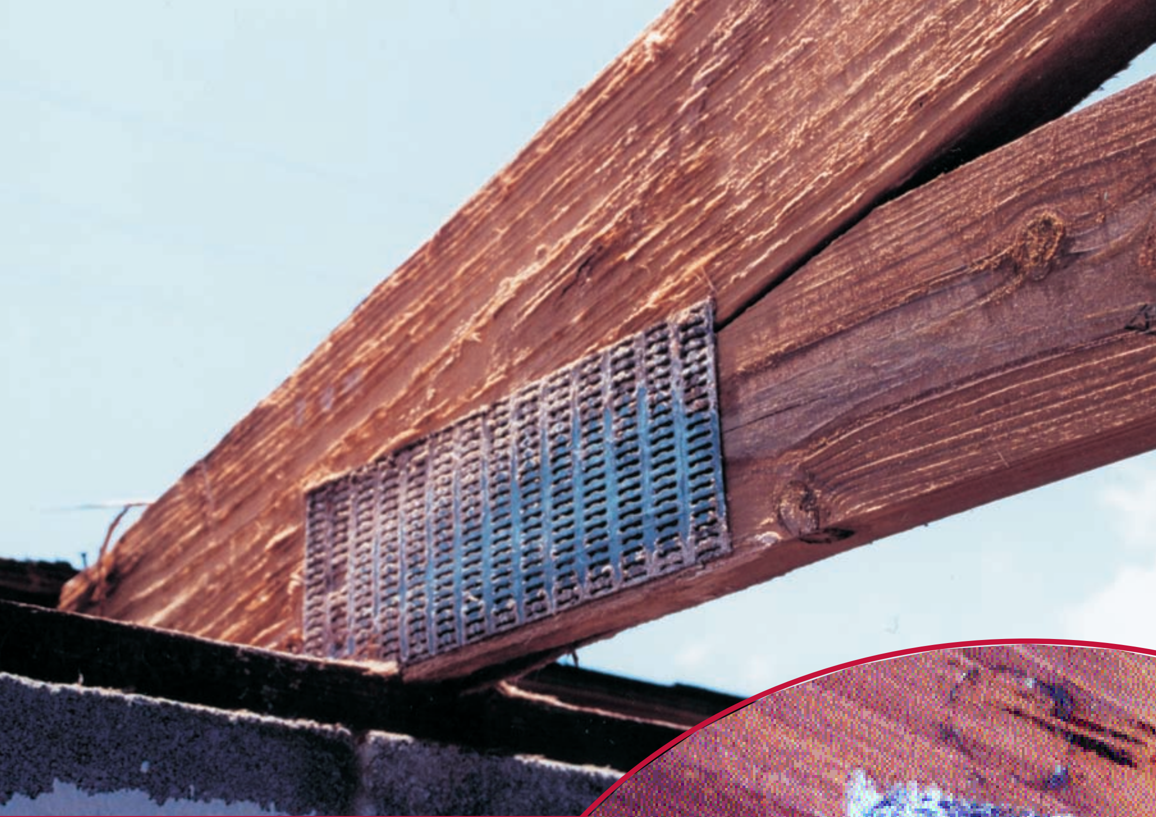
Kiln Drying

Based on the work of many investigators, we now know that most FRTs initially reduce strength from between 10 to 25% and that the magnitude of these reductions varies with the FRT and the property being considered.[9] This work has consistently shown that the temperature used in kiln drying FRT lumber and plywood after treatment is one of the factors most responsible for the magnitude of these strength reductions in FRT material. Accordingly, American Wood Preservers Association (AWPA) Standards, C-20 for FRT lumber and C-27 for FRT plywood both require that the kiln temperature after treatment be limited to <160° F until the average moisture content (MC) of the FRT material is <25%.[1]

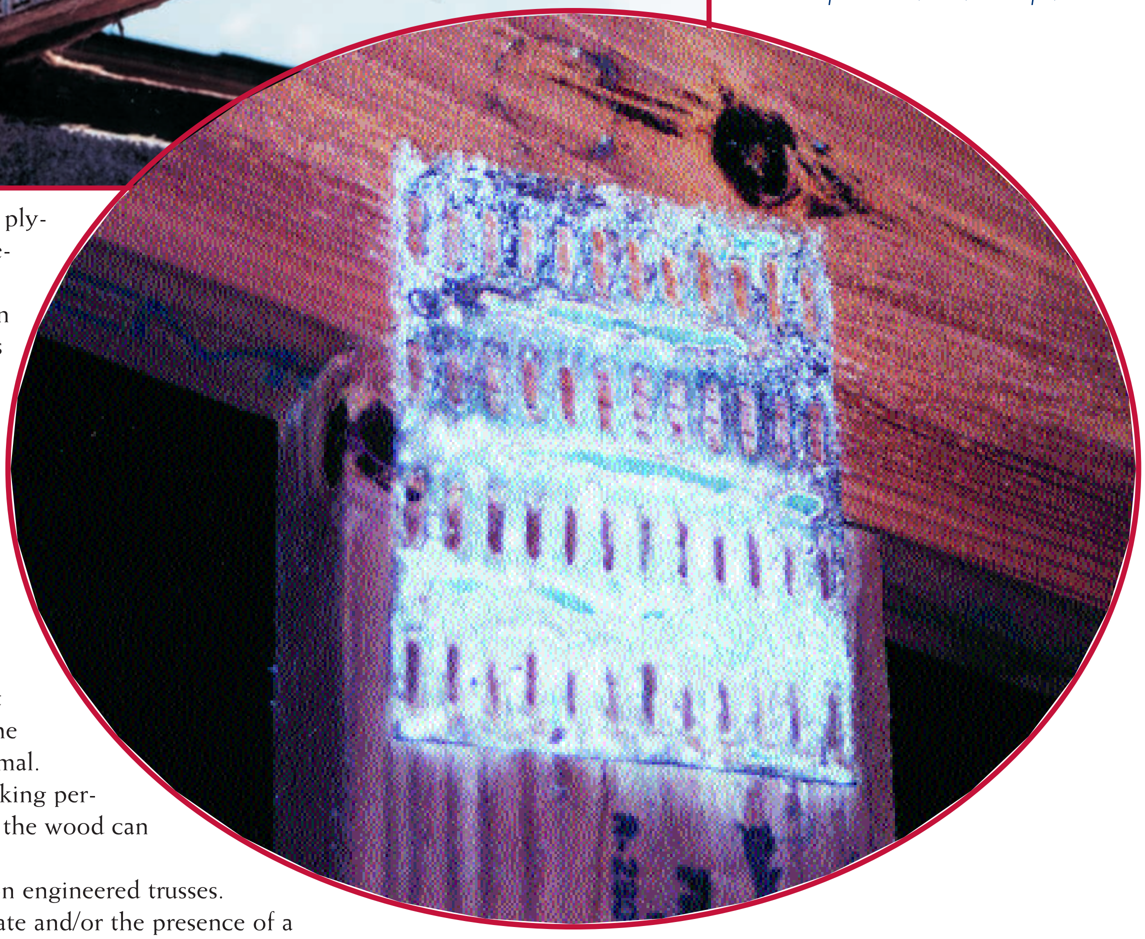
IDENTIFICATION OF FRT

Chemical analysis can be used to positively identify the presence of FRT. However, the list below can be used for general assistance with identifying FRT lumber. The list applies to both plywood sheathing and dimensional lumber (pre-fabricated trusses or stick-built framing), unless noted otherwise.

- Determine the date of construction. FRT problems are commonly associated with buildings built between the mid-1960s to the late 1970s. However, FRT problems may exist on any building, regardless of construction date.
- Look for identification stamps which are typically located on visible portions of the plywood roof deck and the dimensional lumber. The stamps may consist of paper stickers and/or ink stamps. The stamps may identify the proprietary name of the FRT, the manufacturer of the FRT, testing agencies, and the FRT applicator.
- Look at the color of the wood components. FRT wood is typically darker in color. A reddish-brown tint is common (*Figure 5*).



Left: Figure 5: "Fuzzy" surface on FRT truss due to elevated moisture conditoins.



Below: Figure 6: Corrosion and salt deposits on a metal truss plate.

- Look at the surface of the plywood. FRT plywood sometimes degrades and causes the surface to be "fuzzy" in appearance (*Figure 5*). This particular mode of degradation is related to elevated moisture conditions. Therefore, this condition is most often located near the eave or at roof penetrations where water intrusion may occur.
- Look at the surface of the dimensional lumber. Light checking (cracks) along the length of the wood is normal. Heavy checking and checking perpendicular to the grain of the wood can be associated with FRT.
- Look at the metal plates on engineered trusses. Corrosion of the metal plate and/or the presence of a white residue may be associated with the salt from FRT chemicals (*Figure 6*).
- Look for cracks, splits, or breaks in the dimensional lumber. These types of damages can be most extensive in the bottom chord of a truss (the horizontal member at the bottom of the truss which often supports the finished ceiling) and web members closest to the middle of the roof (vertical or diagonal framing members located below the roof ridge).
- Look for the presence of fire-rated walls. The absence of these walls, that are typically covered by drywall, may signal the use of FRT roof framing.

If the conditions described above suggest that FRT wood may be present, a more comprehensive survey of the building is recommended. ■

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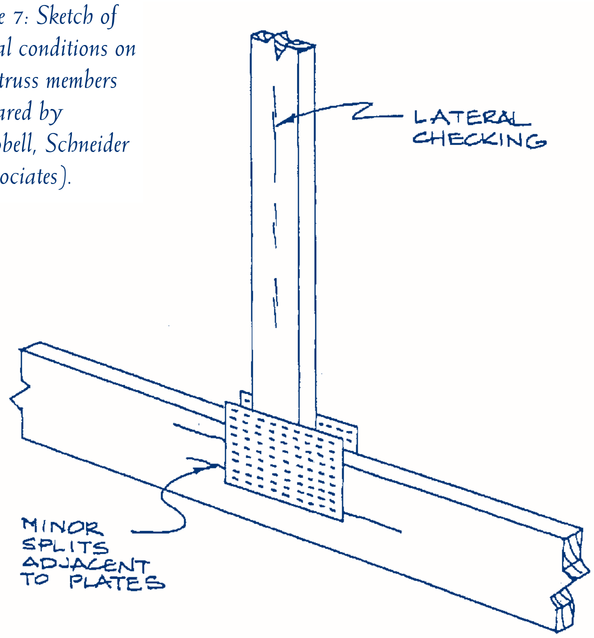

Figure 7: Sketch of typical conditions on good truss members (prepared by Campbell, Schneider & Associates).

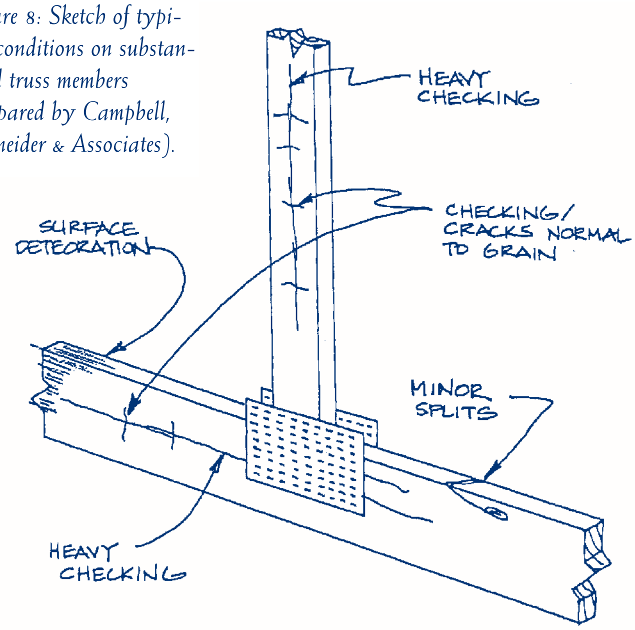

Figure 8: Sketch of typical conditions on substandard truss members (prepared by Campbell, Schneider & Associates).

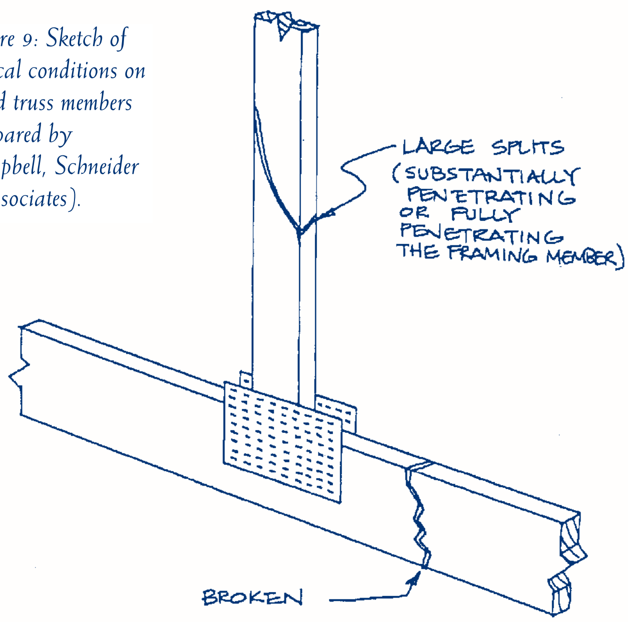

Figure 9: Sketch of typical conditions on failed truss members (prepared by Campbell, Schneider & Associates).

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About the Author

Derek A. Hodgin, P.E., RRO, is a forensic engineer employed by Campbell, Schneider, and Associates, LLC (CSA), an architectural/engineering consulting firm based in Charleston, SC. Hodgin is licensed as a professional engineer in 13 states, and is a Registered Roof Observer with RCI. He currently manages a branch office for CSA in Ramseur, NC, and will soon be opening a branch office for the firm in the Clemson, SC, area. Hodgin specializes in failure investigations of all types of building envelopes and roof systems. He has investigated numerous types of residential and commercial roof failures related to hurricanes, tornadoes, hail, fire, ice, and deficient construction. He has also designed high wind resistant roof assemblies for projects in the southeastern U.S. and the Caribbean.

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