One Step, Two Step or Meet Half Way

Dual Tie Treatments Compared

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Abstract

Dual tie treatments combine the benefits of traditional oil-borne pressure treatments with the advantages of a diffusible, broad-spectrum borate preservative that penetrates and protects deep within the treated tie. Dual treatments are becoming a common commercial practice and there are a number of different methods for combining the two preservative treatments. The various methods, their potential advantages and treatment requirements are described.

Introduction to Dual Treatments

‘Dual treatments’ of crossties, first tried by the Malaysian railway in the 1960s (Arthur, 1967) are now common practice in the North American railroad industry. Dual treatments typically combine traditional creosote or copper naphthenate in oil treatments with borate, in either a ‘one’-, ‘one-and-a-half’-, or ‘two-step’ process. In the one-step process, a borate ester or boronic acid is dissolved in an oil-borne preservative; or a water-soluble borate such as disodium octaborate tetrahydrate is dissolved in a water-borne preservative such as water borne copper naphthenate or ACZA, with the resulting solution being used to pressure treat ties after normal air drying.

In the one-and-a-half-step process, the air-dried ties are empty cell-treated with water soluble DOT (often with amine oxide) and then over-treated with creosote; or pressure treated green and subsequently boultonized, or steam conditioned and then over treated.

In the two-step treatment, green ties are dip diffusion treated in high concentrations of DOT at elevated temperatures, dipped in a high-concentration colloid (a micro-micelle emulsion) of borate in water at ambient temperatures; or pressure treated with DOT. These borate pre-treated ties are then stacked and allowed to air dry as normal, and then pressure-treated with creosote or copper naphthenate. An advantage of dipping vs. pressure treatment is that all the ties are treated similarly irrespective of wood species, whereas with oaks and hickories that are pressure treated, it is very difficult to achieve the required DOT loading due to their refractory nature.

The use of borate in a dual treatment of railroad ties has recently been standardized by the AWPA who specifies 4.0 k/m3 of DOT retention in a 3” assay zone (or by gauge). Borate pre-treatment of green ties using the two-step method has been commercialized in the United States.
Mills are using either creosote or copper naphthenate in the second step of the treatment process and carrying out borate treatment to meet the new AWPA standard. Currently there are five mills producing ambient dip-treated green ties as described by Kim et al. (2011), for four class one railway customers; two more production facilities under construction. A number of other treatment plants are also doing borate treatment, but with the application taking place to the already seasoned tie.

**Benefits of Borates**

Adding water-soluble borate such as DOT to traditional tie treatments provides a number of potential benefits:

- Diffusion to, and protection of, the inner refractory portion of the tie; internal decay can result in failure of ties in track in as little as 10 years in zone 4 and 5;
- Protection against creosote-tolerant or degrading fungi;
- Prevention of the spread of subterranean termites and other pests in ties after they come out of service and are shipped and re-used for fuel or landscaping timbers;
- Reduction in the risk of corrosion of spikes and other metal components in contact with the wood. “Spike kill”, or loose fasteners resulting from iron induced degrade, is an important component of tie maintenance and replacement requirements.

The two-step process described above has three additional potential benefits not shared by the other treatments, because it is applied to the freshly sawn green tie:

- Reducing the establishment and development of decay fungi during the air drying process;
- Improving treatability of the timber after seasoning by preventing local areas of high moisture content associated with decay activity (Dickinson and Murphy, 1991);
- Reducing the risk of transporting pests such as emerald ash borer (Nzokou et al., 2006), when green ties are shipped to new locations for seasoning or final treatment.

There are other methods to avoid the potential for degradation during tie processing, e.g. boultonizing green ties or kiln drying the green tie and then treating. However, boultonizing requires relatively expensive equipment and extended treatment times and is energy intensive; and the latter option is impractical for many hardwood species.

**The Problem of ‘Stack Burn’**

Wood railroad crossties in the USA and many other parts of the world are open stacked (stickered or ‘German’) and allowed to air dry or “season” for a period of months in order to allow an effective pressure treatment (typically dried to a 40 or 50 % moisture content, requiring six to ten months). During this time, in the USA the wood is 1) unprotected, 2) above the fibre saturation point, and 3) stored outside in USA Hazard zones 3, 4 and 5. Thus it is not surprising that basidiomycete colonization by white and brown rots and wood decay fruiting bodies (‘ears’; Figure 1) are commonly observed on such ties; such colonization and degrade is often called ‘stack burn’ in the railroad tie industry.
Similar infestation by decay fungi of untreated utility poles has been well documented during air seasoning (Corden and Graham, 1983; Dickinson and Murphy, 1991; Lundstron and Edlund, 1987; Mills et al., 1965; Morrell et al., 1987; Panek, 1963; Roff and Laboratory, 1974; Sexton et al., 1992; Taylor, 1980, 1984; Wikander, 1982; Zabel et al., 1980) and has been associated with both incipient decay and premature failures, and has led to universal kiln drying of pine pole stock in the USA. Because incipient decay is known to be associated with considerable losses in wood mechanical properties; poor treatment resulting from localized pockets of higher moisture content in areas of decay activity and carry-over of infection into service, prevention of incipient decay would likely provide much benefit to the performance and durability of the treated tie in service.

Dual treatments of green ties with borate and creosote or copper naphthenate have been shown to be effective in long-term field tests, with initial benefits also being carried long into service (Amburgey et al., 2003). However, it should be noted that these tests were conducted using a two-step process and thus some of the benefit of the dual treatment may have resulted from the borate reducing or eliminating any stack burn.

While ‘ears’ and ‘stack burn’ are a common occurrence in the industry, and it appears obvious to wood scientists that this will impact mechanical properties, there are no direct data available on the impact of incipient decay on tie properties. Incipient decay is known to have major negative
effects on wood mechanical properties; as little as 2% weight loss due to decay can result in up to 50% strength loss (Wilcox, 1978; Winandy and Morrell, 1993). Thus it is logical that the appearance of decay activity and especially fungal fruiting bodies on the surface of drying ties would indicate damage to the ties’ integrity.

In a preliminary study to document the impact of incipient decay on tie properties, a set of air-dried ties was sampled and tested for impact bending toughness.

**Materials and Methods**

A set of 100 mixed hardwood ties that had been air-drying for eight months in Arkansas and subsequently shipped to Alabama USA (both USA hazard zone 4) for treatment, was examined. From an initially clean-looking German stack, a total of six ties with visible signs of decay were selected for further testing: four gum (*Liquidambar styraciflua* or *Nyssa* spp.), one red oak (*Quercus* spp.) and one hickory (*Carya* spp.). Each tie was cut into sections with visible decay and matched sections that appeared sound.

These subsections were then cut into impact bending blanks, which were air-dried to equilibrium at 12% equilibrium moisture content conditions and then machined to their final dimensions (16mm x 16mm x 25 cm longitudinal). The samples were then broken in bending using an impact pendulum to evaluate their toughness (FPL, 1961).

**Results**

Superficially, the ties appeared to be sound and clean; however, upon closer inspection – and especially when the stacks were disassembled - revealing contact points – areas of decay or stack burn were evident (Figure 2).
Figure 2 Ties sampled for incipient decay; clean outward appearance (upper left) and mycelial mats (stack burn) revealed at the contact points (upper right). Areas of bleached and weakened wood were observed on the surface of the ties (lower left) and fungal zone lines were revealed when the ties were cross-cut (lower right).

Many of the toughness samples were obviously decayed, with heavy fungal zone lines, and noticeably reduced density. Brash failures were observed in samples with zone lines and low toughness values (Figure 3). In some cases, the samples broke during their installation into the testing apparatus (so the data reported below are not complete and are more conservative than is actually the case). The toughness of the samples was variable and low on average in comparison with published values (Anonymous, 1999; Figure 4). The sections from the ties that were subjectively evaluated as ‘sound’ had average toughness values that were higher than the samples from the ‘ decayed’ sections, although the differences were not always statistically significant. Because of the generally low toughness values, we suggest that decay was also present in the samples cut from the so-called ‘sound’ sections.
Figure 3  Gum toughness samples after testing; decayed sample showing brash failure and fungal zone lines (top) and sound sample showing normal wood failure (bottom).

Figure 4  Impact bending toughness of air dried railroad tie samples. Error bars are one standard error. Published values from *Wood Handbook (1987)*.
Discussion and Conclusions

The data from this preliminary toughness study revealed reductions in toughness of 50% or more for wood from ‘stack burned’, air dried ties. This is consistent with the supposition that ties with any visible evidence of fungal decay have reduced mechanical properties: “If decay is detectable, the wood should be suspected of lacking almost all strength …” (Wilcox, 1978). This suggests that additional treatments are required in order to allow railroads and treaters to select the best possible treatment approach and to meet the requirements of the AWPA crossties commodity specification: “…Material shall be processed in such a manner as to prevent damage and degrade.” (ISO, 2006). Additional treatment options include boultonizing green ties, kiln drying or borate pre-treatments.

As noted above, it is possible, with hot- or ambient-temperature dip, or pressure processes to borate-treat ties to AWPA specifications. There is also evidence in the literature that borate pre-treatment (of green poles) can provide protection against incipient decay (Dickinson and Murphy, 1991; Schoeman et al.). Thus, if dual treatment of ties including a borate is to be carried out, it makes sense to do this prior to seasoning and as soon as possible after cutting the green tie. Future studies will evaluate the effect of borate dip treatments of green railroad ties and their subsequent strength compared to untreated ties after seasoning. Strength testing will include toughness, compression strength perpendicular to grain, and spike holding capacity.

In addition to this, moisture contents and drying times will be evaluated to check anecdotal evidence that the borate treatment of green ties reduces drying times, possibly by preventing metabolic water production by decay basidiomycetes.

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Borate & Creosote/CuNap dual treatment of ties

- Heartwood protection
- Control creosote resistant fungi
- Protect from corrosion induced decay around spikes and screws
- Prevent incipient decay during pre-treatment drying

Cellutreat

AWPA Standardization – SBX for crossties
- 0.25 pcf DOT/0.17 pcf B$_2$O$_3$
- Green or dry ties
- Gauge or 3” assay zone

Ties dual-treated with DOT and Cu Nap

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