TIMBER SATURATION *re-examined*

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The concept of using epoxy to saturate and seal the surface of timber is not new. The so-called WEST method (which stands for Wood Epoxy Saturation Technique) was promoted by Gougeon Brothers nearly 30 years ago and has been part of modern boatbuilding lore ever since (see The Gougeon Brothers on Boat Construction). Yet timber saturation does not appear to be universal, we see examples of timbers hardly appearing to be saturated, and many epoxy manufacturers do not even mention it in their literature. It seemed timely to re-examine this piece of technology.

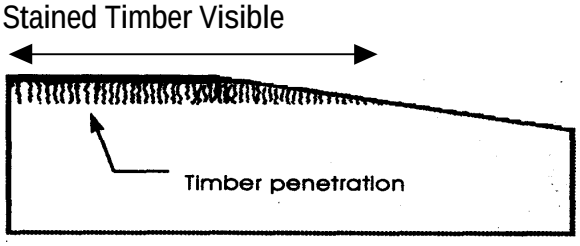
Firstly, we'll refer to it as the TEST method (Timber Epoxy Saturation Technique), to avoid confusion with the brand name of a particular epoxy coating.

The principle of the TEST method is that the epoxy forms a uniform unbroken coating on the timber, and in addition it is absorbed into the surface pores of the timber, filling them, and permanently sealing them against ingress of water and oxygen in particular. This stabilises the timber, preventing the development of dry rot, and strengthens the surface by bonding the fibres of the timber together more strongly. Confusion arises in the minds of some users who expect the timber to become literally saturated with resin; that is wrong, it is purely a near surface effect. Some questions are, how far does that absorption go, how effective is it, and does it really matter?

How deeply is an epoxy resin absorbed into timber? It is known that different timbers absorb differently, the denser timbers being the least penetrated. Intuitively, we would expect a thinner, i.e. lower viscosity epoxy to be absorbed more deeply. To test these we have measured the penetration into both side and end grain of a selection of timbers commonly used for boat construction, using several commercially available epoxy systems.

TECHNIQUE

The resin was pigmented black, to enable it to be seen in the timber. Several coats were applied to both side and end grain, allowing 15 minutes between coats, until the timber became fully saturated and a liquid film remained on the surface. After the epoxy cured, the side grain sample surfaces were routed to a very low angle taper of 0.5 degrees, so that the taper passed down through the surface and into virgin timber. By examining the length on the tapered surface where staining occurred, the depth of penetration was thus magnified some 120 times. *See sketch.* Absorption into end grain was much greater than into side grain, and could be measured directly. The. measurements in different samples of the same timber varied rather widely, over a range of 35 percent, and this variability must be considered in making comparisons between the different materials.



The timbers examined were Gaboon (Okoume) plywood, Western Red Cedar, medium density Meranti, and Eucalypt hardwood (marketed as Tasmanian Oak). These represent the range of readily available timbers of quality suitable for modern boat building.

The epoxies tested were.

- Bote-Cote
- Bote-Cote plus TPA, a low viscosity. epoxy additive designed to enhance timber penetration
- System Three
- West System
- Everdure.

With the exception of Everdure, these are 100 percent solids epoxies, whereas Everdure contains approximately 50 percent solvent so has extremely low viscosity.

	Western Red Cedar	Gaboon	Meranti	Eucalypt
SIDE GRAIN	Penetration	Penetration	Penetration	Penetration
Bote-Cote	85 µm	80 µm	160 µm	80 µm
Bote-Cote/TPA	140 µm	200 µm	175 µm	80 µm
System Three	80 µm	70 µm	150 µm	
West	80 µm	65 µm	195 µm	65 µm
Everdure	100 µm	60 µm	170 µm	60 µm
END GRAIN				
Bote-Cote	3 mm	4 mm	0.2 mm	0 mm
Bote-Cote/TPA	3.5 mm	4 mm	0.3 mm	0 mm
System Three	3 mm	1 mm	0.2 mm	0 mm
West	3 mm	4.5 mm	0.2 mm	0 mm
Everdure	5 mm	1 mm	0.2 mm	0.1 mm
Timber Density				
Kgm/cu m	350	420	645	975

ABSORPTION RESULTS

The table shows the maximum penetration of the pigmented epoxy into the timber surfaces. The penetration was not uniform, but followed grain fissures, which confirms that the theory that the epoxy should be sealing up porosity in the timber. The only exception to this was with the Bote-Cote/TPA system which showed rather uniform absorption into the end grain of the Gaboon plywood. The depths are measured in micrometres for side grain, millimetres for end grain.

Firstly, the depths of penetration do not show a simple correlation with timber density, although the dense Eucalypt hardwood certainly absorbed the least.. Absorption into both Meranti and Eucalypt end grain was negligible, whereas their side grain absorptions were greatest and least respectively. Generally, the lower density timbers will absorb epoxy resin, but the extent is clearly influenced by the surface and cellular properties of individual timbers.

Variations in the absorption of the different epoxies is of greater interest. The straight resin systems were all quite similar, and tended to penetrate less into side grain than the low viscosity liquids, Bote-Cote/TPA and Everdure. The overall high absorption into Meranti reduced the differences between resin types, so clearly this timber becomes very well saturated with all systems. The solvent based Everdure only showed high penetration selectively into Western Red Cedar, but was no better than the straight resins for the other timbers. Bote-Cote/TPA gave the most consistent maximum penetration into the grain structure of all the timbers.

ADHESIVE BOND STRENGTH

	Western Red Cedar		Gaboon		Meranti		Eucalypt	
	Force	% wood failure	Force	% wood failure	Force	% wood failure	Force	% wood failure
Bote-Cote	2.1	100	21.1	100	16.2	60	15.6	10
Bote-Cote/TPA	2.9	100	29.3	100	15.8	90	18	6
System Three	2.3	100	29.3	100	14.8	10	21	0
West	5.0	100	24.7	100	17.2	0	18.8	0
Everdure	4.4	100	34.1	100	18.2	90	21.3	0

Pre-coated timber test strips were sanded, then bonded together using the same epoxy as an adhesive as had been used for the coating. The force to peel them apart was measured (calculated as kN per mm sample width), noting the nature of the fracture surface in terms of percent of timber breakage at the join.

These measurements only reassure us that the different epoxy systems are behaving consistently with the different timbers. Where there is 100 percent timber fracture, the strengths measured must be those of the timber samples, therefore they illustrate the range of the timber variability.

Where there is fracture in the epoxy bond line, the measurement relates to a crack propagation process in the epoxy resin. The similarity of the measurements confirms that the epoxy strengths are similar, and there is no variation of adhesion on any particular timber surface. Bote-Cote is at the lower end of the strengths because it is designed. to be less brittle than the other epoxies, that is it has more 'give' before ultimate fracture.

The extent of timber fracture mirrors the degree of penetration into the surfaces.

RESIN ABSORPTION AND WATERPROOFING

An unbroken epoxy coating film presents a high barrier to moisture absorption. Further absorption of resin into the pores of the timber should enhance the water resistant properties of the coating system. It is important to realise that no coating is 100 percent waterproof. Epoxy happens to have a much slower rate of water diffusion compared to any other coatings, however after long immersion even epoxy coated timber will show some moisture uptake. Intuitively we would expect the low viscosity systems to provide maximum waterproofing, and many people add solvent their resin to achieve this end. According to a US Forest Products laboratory report (W. Feist & G Peterson, 1987) 100 percent solids epoxies are more than 90 percent effective in excluding moisture from timber over the long term, whereas solvent containing epoxies are only about 50% effective. The reason for this is that the solvent cannot evaporate from epoxy trapped inside the pores of the timber, and solvent retained in cured resin yields a rubbery mass with much reduced strength and resistance characteristics. Therefore the addition of solvent to make a thin saturating epoxy in fact, would appear to be counter-productive. Surprisingly, with the exception of Western Red Cedar, the solvent based Everdure had no better penetration than the undiluted resins, therefore it would not be expected to offer any enhanced waterproofing properties.

CONCLUSIONS

This re-examination of timber epoxy saturation shows that enhanced moisture protection properties can be expected from a correctly chosen epoxy system. Reduced viscosity is desirable to obtain maximum penetration into the pores of the timber, so pore penetration will not be achieved simply by applying an epoxy resin/hardener system alone. Solvent thinning is not the correct way to achieve this. A combination of lower viscosity with superior surface tension and wetting properties is required, and an epoxy additive such as Bote-Cote/TPA is preferable. Pore penetration of the epoxy liquid is not simply related to timber density. Different timbers show selective absorption, a high density Eucalypt hardwood having negligible absorption, Meranti having the most absorption of the timbers tested.

A coating combining the usual waterproof properties of epoxy together with maximum pore penetration will enhance the resistance and stability of the epoxy/timber composite. The Bote-Cote/TPA coating provides the best system to achieve this end for the timbers tested.

AUSTRALIAN AMATEUR BOATBUILDER

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