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A vapour phase preservative treatment of manufactured wood based board materials

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Summary. The preservative treatment of four different wood based board materials using an esterified borate applied in the vapour phase was investigated. Under optimum conditions complete impregnation via the board faces was achieved in all boards treated. Board moisture content and treatment time had a major influence on retention and depth of penetration of the borate vapour.

Introduction

In recent years there have been a number of reports of biodeterioration problems associated with the use of board materials (Deppe 1970; Deppe, Gersonde 1977). Considerable attention has been given to determining appropriate methods of test for the decay resistance of various board types and to defining the situations in buildings under which conditions appropriate for decay may arise (Savory 1969; Lea, Bravery 1986). At the same time several authors have investigated the effectiveness of preservative treatment systems for board materials (Hall et al. 1982; Schmidt et al. 1983; Okoro et al. 1984; Viitanen 1984). Improvement in durability by preservative treatment is seen as one way in which the range of uses of many board types can be extended.

The objective of this investigation was to assess the potential of trimethyl borate (TMB) applied in the vapour phase as a preservative treatment for wood based board materials. Deposition of boric acid in wood results from the combination of TMB with moisture present on or within the wood cell walls in the following reaction:

$$B(OCH_3)_3 + 3\,H_2O \longrightarrow H_3BO_3 + 3\,CH_3OH$$

Borate esters have, on a number of occasions, been considered as intermediates in the deposition of boric acid in wood and other materials. Schuerch (1968), in a general review of the treatment of wood with gaseous reagents considered the possibility of fire retardent treatment of solid wood, while Madacsi et al. (1977) reported the successful use of TMB vapours in the fire retardent treatment of cotton batting. Most recently, Vinden et al. (1985) investigated the treatment of solid wood and considered the parameters influencing boric acid uptake. An important general point with respect to borate esters is their hydrolytic instability (Gerrard 1961). All previous workers have indicated that moisture content of the substrate is a critical factor in treatment.

For example, in the report by Vinden et al. treatment of *Pinus radiata* with trimethyl borate vapour at 0% moisture content gave complete penetration of 50 mm × 100 mm cross section material, but at 12% moisture content insignificant penetration resulted. It was concluded that problems such as splitting and warp, associated with drying wood down to treatable moisture levels were a significant limitation in the exploitation of this approach to preservation.

With regard to the present study it is known that the moisture contents of most board materials coming off the press are generally much lower than those of solid wood after conventional kiln or air drying and that board materials normally have equilibrium moisture contents below those of solid wood under comparable conditions. In addition, board moisture contents can be reduced to low levels without experiencing the problems associated with solid wood. Board materials were considered therefore, to offer a range of properties particularly appropriate for combination with a trimethyl borate preservative treatment system.

Materials and methods

Board materials

Four different board types were selected for study. These were: chipboard (CB) (BS: 5669 type ii/iii), medium density fibre board (MDF), aspen waferboard (AWB), and an oriented strandboard (OSB). Board thicknesses were 17 mm, 15 mm, 20 mm and 16 mm respectively. OSB was used as the main substrate for development of the method.

Trimethyl borate preservative

The chemical chosen for this work was a binary azeotrope of trimethyl borate and methanol (F.W. 135.84 g; Bpt. 54.3 °C) supplied by Aldrich Chemical Company.

Sample preparation

In order to determine accurately the moisture content of boards before treatment, samples of the four types measuring 100 mm × 100 mm × board thickness, edge sealed with ABS polymer, were dried for 18 hours at 105 °C. After recording the oven dry weight of each sample they were left in the laboratory at 20 °C and approximately 50% relative humidity until equilibrium moisture content was reached. Mean equilibrium mosture contents for the different board types under these conditions were 6%, 8%, 10% and 6% for OSB, MDF, CB, and AWB respectively. Board samples were then re-dried to target weights to achieve specific moisture contents before treatment.

Treatment

Five replicate samples per treatment were dried down from equilibrium moisture content to the required moisture content at 105 °C and while still at this temperature, were placed in a vacuum oven preheated to 65 °C. A vacuum, equal to the vapour pressure of water was then pulled before admitting trimethyl borate gas (8×10^{-3} moles/litre) to the treatment chamber. At the end of a treatment time of 45 minutes the exposed samples were weighed to determine increase in mass. Additional "blank" treatments in which the preservative was replaced with air (to the equivalent pressure drop of the TMB treatment) were also conducted to determine any moisture loss from the boards during treatment. These results were then used as correction factors to determine retention of boric acid within the board samples.

Assessment of boric acid distribution

The distribution of boric acid within the treated boards was assessed visually after cross cutting each sample in half and spraying one of the exposed faces with a reagent consisting of 0.25 g of curcumin and 10 g of salicylic acid dissolved in 10 mls of concentrated hydrochloric acid diluted with 100 moles of ethanol (BS 5666 pt2, 1980). Using this reagent a red colouration appears at boric acid retentions of above 0.2% w/w (oven dry basis) in wood. The red complex formed, provided the basis for estimating the mean depth of boron penetration for each set of replicates which was determined from an average value for each replicate based on measurement from both outer faces to the centre of the sample.

Influence of board moisture content on treatment

An investigation was carried out using the standard treatment conditions (65 °C, gas conc^{n} 8×10^{-3} moles/litre and 45 minutes treatment time) with OSB to determine the relationship between preservative penetration and retention and board moisture content. A range of moisture contents (0, 1, 2, 3, and 4%) were used. Further work was then conducted with the other board types using moisture contents of 0%, 2% and 4%.

Influence of time on treatment at constant moisture content

Using standard treating conditions of 65 °C and gas concentration of 8×10^{-3} moles/litre with a board moisture content of 2%, a study was carried out to determine the influence of treatment time upon distribution and retention of boric acid within the OSB.

Results

The initial results from work on OSB show that boric acid retention increased with increasing board moisture content, while penetration of boric acid into the board decreased (Fig. 1).

With respect to the other three board types treated at 0,2 and 4% moisture content the general trends indicated in Fig. 1 for OSB were comparable. However, at

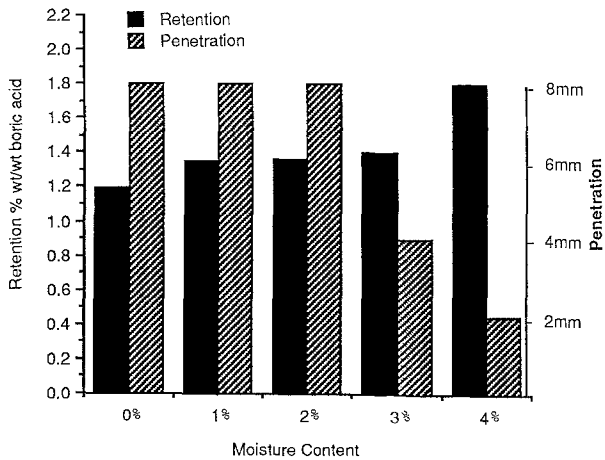

Fig. 1. The influence of moisture content on uptake of boric acid for oriented strand board

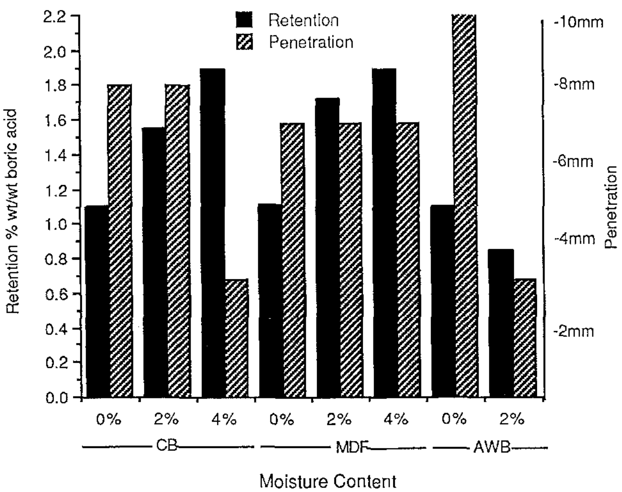

Fig. 2. The influence of moisture content on uptake of boric acid for chipboard, medium density fibreboard and aspen waferboard

2% and 4% moisture contents, retentions and levels of penetration varied between the different board types (Fig. 2). It was notable that full penetration resulted at 4% moisture content in MDF whereas penetration of aspen wafer board was incomplete at 2%. As a consequence, treatment of AWB was not attempted at the higher moisture level. The results achieved with OSB and CB were in close agreement with one another.

The relationship between treatment time and preservative penetration and retention for OSB at 2% moisture content is shown in Fig. 3. Preservative penetration clearly increased with treatment time with full penetration occurring at 45 minutes. Associated with the improved penetration was a proportional increase in retention.

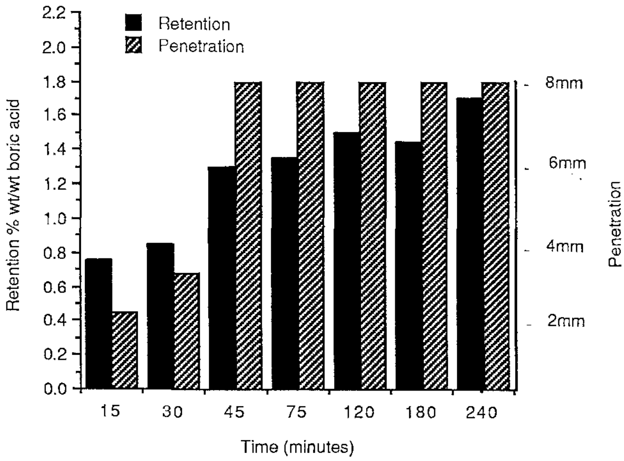

Fig. 3. The influence of treatment time on penetration and retention of boric acid for oriented strand board

Discussion

The present study considered a method by which penetration of a range of board materials with boric acid can be achieved in relatively short treatment times using a vapour phase application system. The fungicidal and insecticidal properties of boron based wood preservatives have been recognised for many years (Bunn 1974; Cockcroft, Levy 1973). Boric acid has many properties which make it ideal for use as a preservative for wood based board materials:

1. Proven effectiveness against decay fungi and insects.
2. Low mammalian toxicity.
3. Minimal vapour pressure.
4. Colourless.
5. No deleterious effects on wood.

The commonly cited disadvantage of the leachability of borate is not considered to be problematical in the present application since most wood based boards are not intended for use in situations of high leaching hazard. The treatment under investigation in the present study was intended for use with manufactured boards and thereby avoids another potential disadvantage in board treatments, namely that of interference of the preservative with the bonding of the board during manufacture. The application of preservatives to board materials after manufacture allows fabrication to proceed under optimal production conditions and has a secondary advantage in that a varying proportion of board output can be treated in response to demand for preserved boards.

Further advantages accruing from the use of this method include a completely dry board which is ready for use immediately after treatment, no apparent swelling of the board (a problem associated with waterbased preservative systems) and no solvent recovery/loss problems inherent in an organic solvent based preservative treatment.

The study has shown that under appropriate conditions complete penetration of a variety of board types could be achieved in relatively short treatment times. It was notable that as board moisture content increased it became a major limitation with respect to fast treatment. Figure 3, which shows retention against time at 2% moisture content indicates that retention and penetration increase with time. It may be inferred from this, that at higher moisture contents (providing gas concentration is not a limitation) retention and penetration should increase with extended treatment times.

In addition to the treatment variables of time and moisture content, penetration was also influenced by the structural properties of the board being treated i.e. density, particle size and possibly species composition. This is illustrated by the data obtained with MDF and aspen wafer board. In the case of MDF it appeared that the uniform fibrous structure assisted full penetration even at the 4% moisture content level whereas with aspen waferboard which has a disordered structure and is manufactured from two different wood species (birch core, aspen outer layers) penetration was inhibited at moisture contents as low as 2%. Clearly further study on board permeability and structural properties in relation to this potential treatment method is required.

Preliminary studies on the fungal decay resistance provided by vapour phase trimethyl borate treatment have indicated control of decay by *Coniophora puteana* and *Coriolus versicolor* at approximately 0.5% w/w boric acid equivalent in the four board types used in the present study (Turner, Murphy 1987). Preservative retentions achieved by trimethyl borate treatments in further developments of the method need to be targeted towards those levels imparting the required fungal resistance.

Further work is currently underway to explore the relative influence of the different treatment variables upon levels of boric acid distribution and retention. The present data suggest that, for some boards, conditioning may be required prior to treatment although for other types which use dry powdered resins such as OSB of this study, boards may be available at appropriate moisture contents at the production site. Clearly, the costs associated with any conditioning would have to be incorporated into an assessment of the commercial viability of the method. However, current work in progress at Imperial College concerned with reducing the influence of moisture content on levels of penetration and retention looks particularly promising. This approach may also have important implications for the treatment of solid wood, including refractory species. The results of this extended work will be reported at a later date.

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