PRESERVATIVE SYSTEMS FOR WOOD COMPOSITES

Peter Laks, Dana Richter, and Glenn Larkin
School of Forestry and Wood Products, Michigan Tech, Houghton, MI USA

Summary

The number and volume of preservative treated wood-based composites is growing rapidly in North America. This follows the overall trend of engineered wood products replacing solid wood commodities in both interior and exterior building applications. Exterior uses like siding, decking, and trimboards typically need to incorporate a preservative, especially in wet environments or if there is a significant hazard from wood-destroying insects. Most untreated wood composites are prone to fungal and insect attack. Wood preservatives can be applied by post-manufacture pressure treating or by in-process incorporation during the composite manufacture. Some wood composite preservative pressure treatments listed in the American Wood-Preservers' Association standards are CCA, ACQ, sodium borates, creosote, copper naphthenate, pentachlorophenol, and IPBC/chlorpyrifos in mineral spirits. The dominant in-process treatment is zinc borate. Other in-process treatments are registered for composites use, but are used in very limited quantities.

1. Introduction

Wood composites are ubiquitous in modern residential construction. Products based on oriented strandboard (OSB), medium density fiberboard (MDF), laminated veneer lumber (LVL), thermoplastic/wood fiber blends, and other composites are used in both interior and exterior applications. Common interior applications such as sheathing, subflooring, cabinetry, and floor joists have been in place for many years, and the advantages and drawbacks of the materials are relatively well known. In more recent years, wood-based composites have been developed and are being commonly used on a large scale for exterior applications such as siding, trim, fascia, and deckboards. In these applications, product performance is not as well established and some decay-related performance problems have developed. This has been especially true for siding products (Anonymous 2000, Richards 1995, Shell and Donnell 1995). Caution is needed when adopting a new type of material for any exterior use. Biodegradation resistance cannot be assumed (Morris and Cooper 1998).

The purpose of this paper is to present and discuss some information about the intrinsic susceptibility of wood composites to fungal and insect attack, and review the use of preservatives in these materials. Most of the information presented is from relatively recent research work done at Michigan Technological University.

2. Intrinsic Susceptibility of Wood Composites to Fungal Attack

Wood products used for exterior applications are traditionally made from naturally durable species such as redwood, western red cedar, and bald cypress, or at least the heartwood of old growth southern pine, Douglas-fir, etc. These wood materials have two features that make them well suited for out-door applications - some inherent resistance to fungal and insect attack, and relatively small dimensional change upon wetting. Conventional wood composites generally do not have these same positive features. Non durable wood species such as aspen and yellow poplar, or the sapwood from softwood species like southern pine are commonly used. These wood materials do not contain the extractives that make the traditional woods so desirable. In addition, many types of wood composites have problems with dimensional stability, particularly thickness swell. Fortunately, both these drawbacks can be addressed. Wood preservatives can be added to the composite to make it resistant to biodegradation, while it is possible to improve the dimensional stability through product design - higher adhesive content, more efficient water repellents, laminates, etc. Before modifying or designing a composite product for exterior use, however, it is useful to have information on how conventional composites behave in an outdoor environment.

The Michigan Tech wood preservation research group maintains field test sites near Hilo, Hawaii. The environment there is very well suited for accelerated field exposure of wood-based materials (mean annual precipitation - 332 cm, mean annual temperature - 23°C). Figure 1 shows the average rating for lap joint test specimens (AWPA 2000a) made from a variety of wood composite types after 2 years exposure in Hawaii. This is an ongoing test. At the 2 year point, the untreated controls (particularly the Douglas-fir) are starting to show some fungal degradation. The low ratings of the structural composite lumber (SCL) materials are the most striking features in the data. Hilo has a very wet climate. Typically it rains during the night, clears up during the morning with some sun during the afternoon. The solid wood and SCL lap joints are 37mm thick, while the other specimen types are 10-12mm thick. The thicker specimens probably have higher average moisture content because of their lower surface/volume ratio and subsequent lower drying rate. The higher moisture content leads to more decay. Differences between the different thin-section composite materials may be clearer after additional exposure time.

In another study, we evaluated the laboratory decay resistance of southern pine (SYP) OSB and plywood, Douglas-fir plywood, and aspen-based OSB. Small blocks (25x25mm by the panel thickness) were exposed to a brown rot fungus (*Gloeophyllum trabeum*) for 8, 12, or 16 weeks using AWPA E10 soil block test methodology (AWPA 2000b). The average weight losses are summarized in Figure 2. The results illustrate several important points. It is clear that the OSB is more susceptible to decay than the plywood or solid southern pine. This is probably due to the blocks swelling, opening gaps between the flakes on the block sides, allowing better access by the fungus to the block interior, and thus a relatively high decay rate. Within the OSB types, the aspen composite is decaying faster than the pine-based material likely because of the lower intrinsic decay resistance of the hardwood due to its lower lignin content. The higher decay resistance of the plywoods as compared to the solid pine is also interesting. The highly alkaline phenol-formaldehyde (PF) adhesive used for plywood manufacture is probably inhibiting fungal growth by raising the pH of the wood veneers. In general, basidiomycete decay fungi do not grow well even under mildly alkaline conditions (Burpee 1990).

3. Intrinsic Susceptibility of Wood Composites to Termite Attack

A set of termite blocks made from the same composites described above in the lap joint exposure were also exposed to termites using a procedure described elsewhere (Laks and Verhey 2000). Figure 3 shows the average termite ratings for a number of different wood composite types and two solid wood controls (southern pine sapwood and Douglas-fir heartwood) after exposure to Formosan termites for 18 months. This is also an ongoing project. All of the composites are showing substantial attack, although there are some differences between the various materials. The solid wood controls have average ratings of 2 - 3 (close to total failure), showing the higher termite activity at the site. The only composites with average ratings substantially above the control ratings are southern pine OSB and a yellow-poplar SCL. These materials cannot be considered to be termite resistant, however, as they are still showing significant attack. All the other composites are showing ratings that are equivalent to or lower than the solid wood controls.

It is not clear why SYP OSB and yellow-poplar SCL are performing better than the other composites, although an explanation can be hypothesized. The SYP OSB tested is a commercially-manufactured board bonded with a PF adhesive. Work comparing the termite resistance of aspen waferboard bonded with three different adhesives - methylene-diphenyldiisocyanate (MDI), liquid PF, and powdered PF – showed that the PF-bonded boards had marginally higher termite resistance than the MDI board (Laks 2000). PF may exert some protective affect in a composite, but the benefit is small. Certainly, the termites do not like to consume the PF glueline. When the PRF (phenol-resorcinol-formaldehyde) bonded LVL samples fail, it is typical that the specimen is composed of sheets of cured PRF - the termites consume the wood veneers and leave the gluelines behind. The PF "spot-welds" dispersed within the PF-bonded OSB may have a minor feeding deterrent effect on the termites.

Both the aspen and yellow-poplar SCLs are bonded with MDI. The performance difference between the two composites is most likely due to the wood species. A significant proportion of the wood flakes in the yellow-poplar composite is heartwood. In this species, the heartwood may contain extractives that make it somewhat more termite resistant than the sapwood, although there is no data available to prove this. Aspen heartwood and sapwood are similar in chemical composition. Along with the low and even density, this appears makes aspen very prone to termite attack.

Binders other than MDI and PF may have a much stronger affect on termite resistance. Cement/wood fiber composites are being used for siding and nonstructural panel applications. Although, we have not tested this type of composite for its termite resistance, it seems likely these materials will be quite resistant. For more conventional wood composites, the termite resistance of can be greatly increased using a wood preservative.

4. Preservative Systems for Wood Composites

Wood preservatives may be incorporated into a composite in one of two ways - pressure treating the manufactured composite with the liquid preservative system, or adding the preservative to the composite during its manufacture.

Pressure-Treated Composites

Traditional treated solid wood products are produced by pressure treating the lumber or other wood commodity with a wood preservative solution (e.g. CCA in water or pentachlorophenol in an oil) or the liquid preservative itself (creosote). This is also being done with composites. Waterborne preservatives are generally preferable for wood treatments because of the low cost of the systems and negligible offgassing of solvent vapors during post-treatment conditioning and use. However, the nature of the composite may dictate whether a preservative system is suitable or not. The primary issue is thickness swell. Composites such as OSB, particleboard, and MDF are made with relatively small wood elements and will exhibit an unacceptable level of swelling if pressure treated with a water solution. These composites cannot be effectively treated with waterbornes such as CCA or ACQ. Organic solvent based systems can work, however, and are commonly used with these composites.

The American Wood-Preservers' Association (AWPA) maintains standards for pressure treating of composites. By far the most common pressure treated composite is plywood. In 1996, 21 million cubic feet of plywood were pressure treated, primarily with CCA (AWPI 1997). The relevant AWPA standard is C9-99 entitled "Plywood - Preservative Treatment by Pressure Processes" (AWPA 2000c). Treated plywood is used for wood foundations and a variety of other applications. The C9 standard generally limits treatable plywood to softwood veneer products with no surface laminate or overlay that meets U.S. NBS Voluntary Product Standard PS-1. A wide range of waterborne preservatives is listed in the standard including CCA, ACQ, ACZA, and sodium borates. Non-waterborne preservatives listed are creosote, oxine copper, and pentachlorphenol.

The AWPA also has a commodity standard for treated structural composite lumber, C33-97 "Standard for Preservative Treatment of Structural Composite Lumber by Pressure Processes"(AWPA 2000d). Parallel strand lumber (e.g. Parallam™) and LVL are the two SCLs listed in the standard. Listed preservative systems are creosote, pentachlorophenol, copper naphthenate, ACA, ACZA, and CCA. Parallam treated with CCA to a retention of 0.6 pcf CCA is used for timber bridge construction, as well as some residential use in decks and other outdoor structures. Creosote treated Parallam is also used for timber bridge construction, and there is a large potential market being developed for use of the material as railway ties (Merrick 2000). Creosote treated LVL made from Douglas-fir, southern pine, red maple, and yellow-poplar is listed as being suitable for use in both above-ground and soil/fresh water applications.

A number of water-sensitive composites including I-joists, OSB, MDF, and millwork components are pressure treated with a mineral spirits solution of IPBC (a fungicide) and chlorpyrifos (an insecticide) for sale in Hawaii and the Southeast.

In-Process Treatment

The nature of many wood composites allows them to be treated in a more efficient manner than post-manufacture pressure treating. For small particle composites, the preservative can be incorporated into the composite while it is being manufactured. For veneer-based composites, the veneers can be dip or spray treated before layup. This avoids the expensive post-manufacture pressure treating step and minimizes the affect of the treatment on physical properties on the composite. Typically, the preservative is added along with the adhesive and water repellent during the blending step. The performance demands for such in-process preservatives are high (Laks 1999). In particular, the system has to be stable to the high temperature and steam pressure conditions present within the mat during pressing. To my knowledge, the only preservatives that have been registered with the U.S. EPA for in-process treatment of composites are zinc borate (U.S. Borax), chlorpyrifos (Dow Chemical), and tebuconazole (Bayer). In addition, Kop-Coat has a number of registered formulations containing propiconazole, MBT, and an isothiazolone. Other systems are in the process of being registered or at least developed.

Zinc borate (ZB) is, by far, the most commonly used in-process preservative. At the present time, zinc borate is incorporated into commercial OSB sheathing, waferboard siding, MDF trim boards, and other exterior products (Laks 1999). ZB has a nominal chemical formula of $2Zn0\circ 3B_2O_3\circ 3.5H_2O$. It is a white, odorless powder with a median particle size of 7 microns. U.S. Borax manufactures ZB and has the only registration in the U.S. and Canada. Zinc borate has captured the market leader position because of its stability during composite manufacturing conditions, compatibility with common adhesive systems, relatively low water solubility, very low environmental and worker toxicity hazard, efficacy against both fungi and insects, and extensive literature base supporting this use (e.g. Laks and Manning 1997). Typically, the ZB is mixed with the wood furnish, adhesive, and wax (if used) in the blender. The antifungal and anti-insect properties of zinc borate are primarily due to the BO_3^{-3} (borate) anion that is formed upon hydrolysis of the ZB when it is exposed to water. This is why the amount of ZB in a composite is usually expressed as the Boric Acid Equivalent (BAE). The conversion factor for converting of %BAE to %ZB by weight is 1.0% BAE ZB = 1.17% ZB by weight.

Chlorpyrifos and tebuconazole are organic biocides that are currently registered in the United States for wood composite use. These chemicals illustrate a problem that can develop with using organic chemicals as in-process preservatives. In unpublished work, we manufactured MDI-bonded aspen waferboard containing a tebuconazole/chlorpyrifos emulsion formulation, which was applied during the blending step. The resulting boards had good fungal and termite resistance, but chemical assay showed a pronounced difference in the ability of the two biocides to survive the manufacturing process. The average target loadings (reflecting the biocide amounts added to the furnish during blending) and the assayed loadings (measured in the manufactured boards) of the two biocides are shown in Figure 4. Tebuconazole showed good stability with the assayed panel loading comparable to the target. In contrast, only about 60% of the chlorpyrifos remained in the boards after manufacture. Persistence during manufacture will depend on the volatility, reactivity, and thermal stability of the additive. Some biocides which have broad industrial and/or agricultural use (e.g. chlorpyrifos) may not be as well suited for in-process preservation of wood composites due to these contraints.

Another important desirable characteristic of in-process preservatives is compatibility with the adhesive. Figure 5 shows the average internal bond (a measure of adhesive bond strength) for MUF (melamine urea formaldehyde) particleboard containing formulations of Kathon 287 or Kathon 893. These preservative systems are being developed by Rohm and Haas Corporation for use in composites. Boards containing three different loadings of the biocides, plus an untreated control, were evaluated. The 287 formulation did not affect the bonding of the MUF, while it is apparent that the Kathon 893 decreased the bond quality. This does not mean, however, that the latter formulation could not be used in a particleboard application. The bond strength could probably be recovered by increasing the adhesive content of the composite, or possible changing to a different binder.

5. Conclusions

1. Most untreated wood composites are prone to attack by fungi and insects. The degree of susceptibility depends on composite composition, particularly wood species and the binder type and content.

2. The fungal and termite resistance of composites can be greatly increased by the incorporation of wood preservatives. These can be applied by post-manufacture pressure treating, or by incorporating the preservative into the composite while it is being manufactured.

3. The American Wood-Preservers' Association (AWPA) maintains standards for the pressure treating of plywood, LVL, and parallel strand lumber. Some preservative

systems listed in these standards with good demonstrated efficacy at the appropriate retention against the FST are CCA, ACQ, sodium borates, creosote, copper naphthenate, pentachlorophenol, and IPBC/chlorpyrifos in mineral spirits.

4. The dominant in-process wood preservative for wood composites is zinc borate which has both antifungal and antitermitic activity. Some other preservatives registered in the United States for this application are chlorpyrifos, tebuconazole, propiconazole, and MBT. Other preservative systems are being developed for this application because of the rapidly expanding market for treated composites.

6. Literature

Anonymous. 2000. Weyerhaeuser settles hardboard siding suit. Wood Based Panels International, August/September, p. 2.

AWPA. 2000a. E16-98; Field Test for Evaluation of Wood Preservatives to be Used Exposed Out of Ground Contact: Horizontal Lap-Joint Method. American Wood-Preservers' Association Book of Standards. AWPA, Granbury, Texas, pp. 420-425.

AWPA. 2000b. E10-91; Standard Method of Testing Wood Preservatives by Laboratory Soil-Block Cultures. American Wood-Preservers' Association Book of Standards. AWPA, Granbury, Texas, pp. 397-407.

AWPA. 2000c. C9-99; Plywood-Preservative Treatment by Pressure Processes. American Wood-Preservers' Association Book of Standards. AWPA, Granbury, Texas. Pp. 81-82.

AWPA. 2000d. C33-97; Standard for Preservative Treatment of Structural Composite Lumber by Pressure Processes. American Wood-Preservers' Association Book of Standards. AWPA, Granbury, Texas. Pp. 125-128.

AWPI. 1997. The 1996 Wood Preserving Industry Production Statistical Report. American Wood Preservers Institute, Fairfax, VA.

Burpee, L.L. 1990. The influence of abiotic factors on biological control of soilborne plant pathogenic fungi. Can. J. Plant Pathol. 12:308-317.

Laks, P.E. 2000. Susceptibility of Wood Composites to Formosan Subterranean Termite Attack. Residential Construction Materials and Practices to Protect Homes from Formosan Subterranean Termites. Proceedings. Forest Products Society, Madison, Wisconsin. In press.

Laks, P.E. and S. Verhey. 2000. Decay and Termite Resistance of Thermoplastic/Wood Fiber Composites. Proceedings of the 5th Pacific Rim Bio-Based Composites Symposium. In print.

Laks, P.E. 1999. The Past, Present, and Future of Preservative-Containing Composites. 33rd International Particleboard/Composite Materials Symposium Proceedings (Wolcott, Tichy, Bender, eds.), Washington State University, pp 151-158.

Laks, P.E. and M.J. Manning. 1997. Mobility of Zinc Borate Wood Composite Preservative. International Research Group on Wood Preservation. IRG/WP/97-30153.

Merrick, P. 2000. Trus Joist, personal communication.

Morris, P.I. and P. Cooper. 1998. Recycled plastic/wood composite lumber attacked by fungi. Forest Products Journal, 48(1):86-88.

Richards, B. 1995. Louisiana-Pacific agrees to settlement of class-action suits linked to product. Wall Street Journal, October 18, 1995.

Shell, D. and R. Donnell. 1995. Federal grand jury targets L-P. Panel World, July, p. 5.

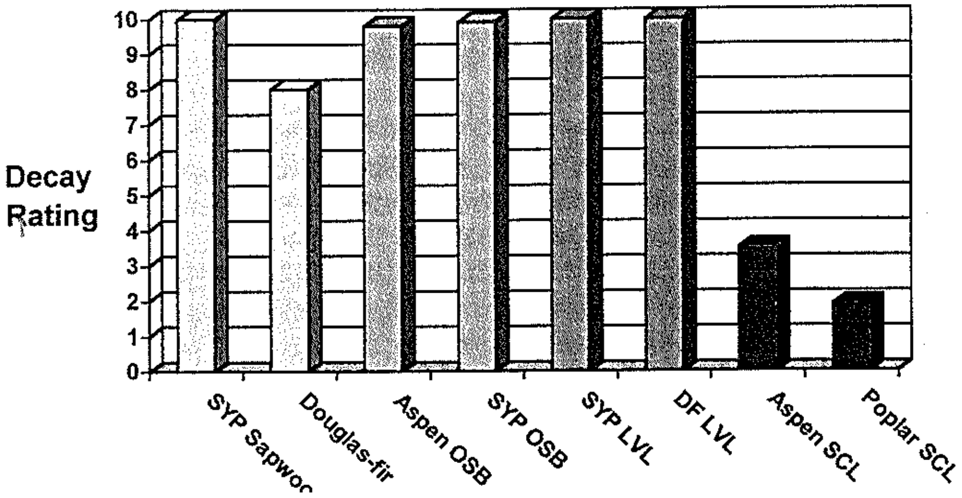

Figure 1. Average decay ratings for various untreated wood composites and solid wood controls after 2 years field exposure as lap joints (5) in a test site near Hilo, Hawaii. Ratings are an average of ten specimens where 10 indicates minimal or no termite attack and 0 denotes failure. OSB = Oriented Strandboard, LVL = Laminated Veneer Lumber, SCL = Structural Composite Lumber, SYP = Southern Yellow Pine, DF = Douglas-fir.

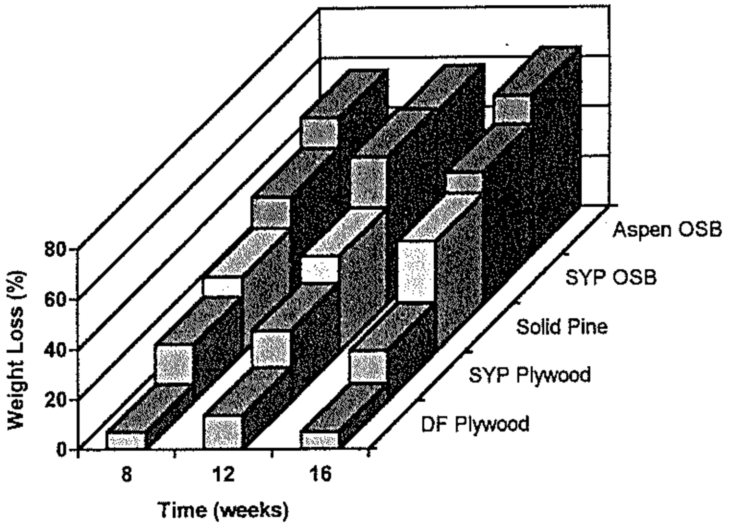

Figure 2. Average weight loss of wood-based panels after 8, 12, or 16 weeks exposure to *Gloeophyllum trabeum* in an AWPA E10 soil block test (6). See Figure 1 for abbreviations.

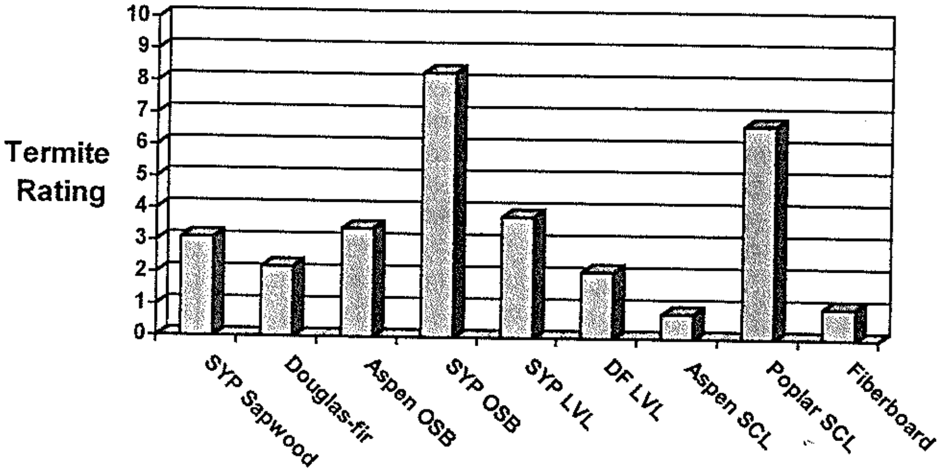

Figure 3. Average termite ratings for various untreated wood composites and solid wood controls after 18 months exposure to the Formosan Subterranean Termite in a test site near Hilo, Hawaii. Ratings are an average of ten specimens where 10 indicates minimal or no termite attack and 0 denotes failure. See Figure 1 for abbreviations.

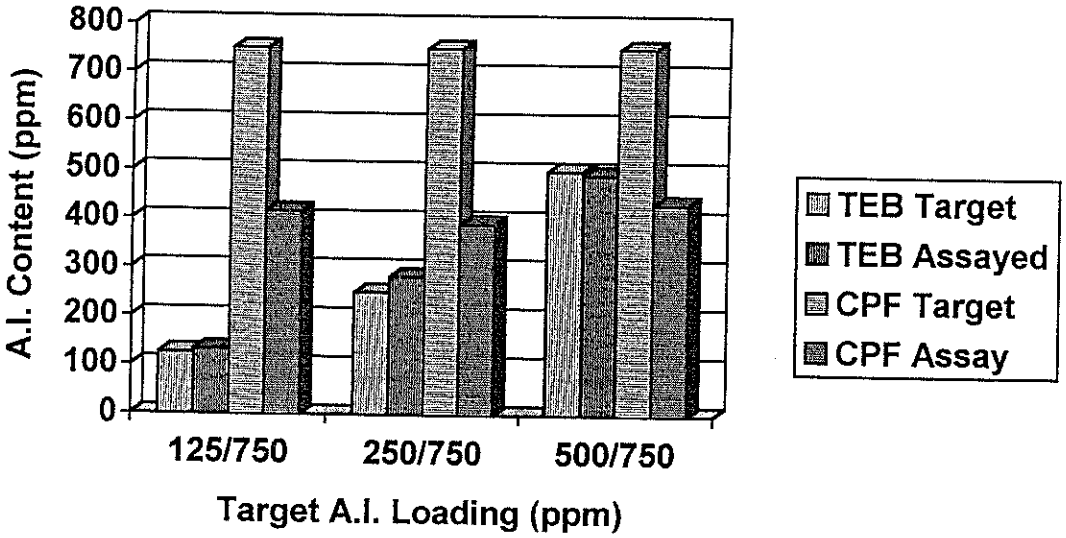

Figure 4. Processing stability of tebuconazole and chlorpyrifos incorporated into MDI-bonded aspen waferboard.

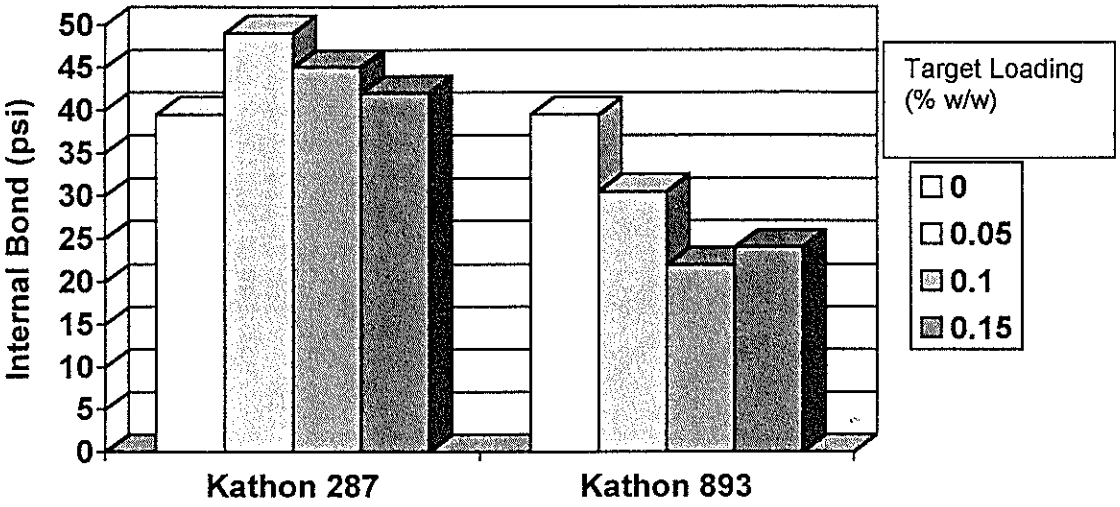

Figure 5. Average internal bond of MDI-bonded aspen waferboard containing formulations of either Kathon 287 or Kathon