COMPOLE™/COMARM™- A COMPOSITE WOOD ALTERNATIVE

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INTRODUCTION

In recent years, the Institute of Wood Research (IWR) has studied and developed the use of a composite wood material in the manufacture of wood-based structural products. Initial work centered on the development of a composite wood crossarm (COMARM), which is typically eight feet (2.4 m) in length by 4.75 x 3.75 inches (120 x 95 mm) in cross-section. The COMARM consists of a box section of composite wood material (CWM) with a polyurethane closed cell foam-filled core. The cross-arm development was mainly funded by a group of electric utilities in the Great Lakes region.

The Upper Peninsula Power Company (UPPCO) installed the first prototype COMARM in Houghton, Michigan during February 1979, and ten other prototypes were installed by Detroit Edison in Detroit, Michigan in 1979. All the prototype COMARMS are still in line and are standing up well to the loads and exposures to which they have been subjected.

A further study, funded by the Electric Power Research Institute, was concerned with the production of 40 foot (12 m) composite wood utility poles (COMPOLES). The technical feasibility of this concept was proven with the installation of seven prototype COMPOLES by the following utilities:

- UPPCO in September 1980 in Houghton, Michigan
- Detroit Edison Company in January 1981 in Detroit, Michigan
- Consumers Power Company in February 1981 in Marshall Michigan
- Toledo Edison Company in January 1981 in Toledo, Ohio

These poles have been installed and handled, including climbing and the attachment of different types of hardware, in essentially the same manner as solid wood poles, and no major problems have been experienced. Since the successful conclusion of the feasibility study, more COMPOLES have been shipped to Detroit, Michigan; Fort Worth, Texas; Kansas City, Missouri; Milwaukee, Wisconsin; and Indiana, Pennsylvania. A COMPOLE /COMARM installation in Houghton, Michigan is shown in Figure 1.

An additional development has been the production of 25 foot (7.6 m) COMLITE composite wood light standards for the City of Houghton. COMLITES have a rectangular cross-section with a hollow core to allow electric cable access. The lighting standards can be produced in a variety of cross-sections and lengths to suit the end-use requirement. COMPOLE utility poles more than 40 feet (12 m) in length are also feasible and increasingly cost-effective.

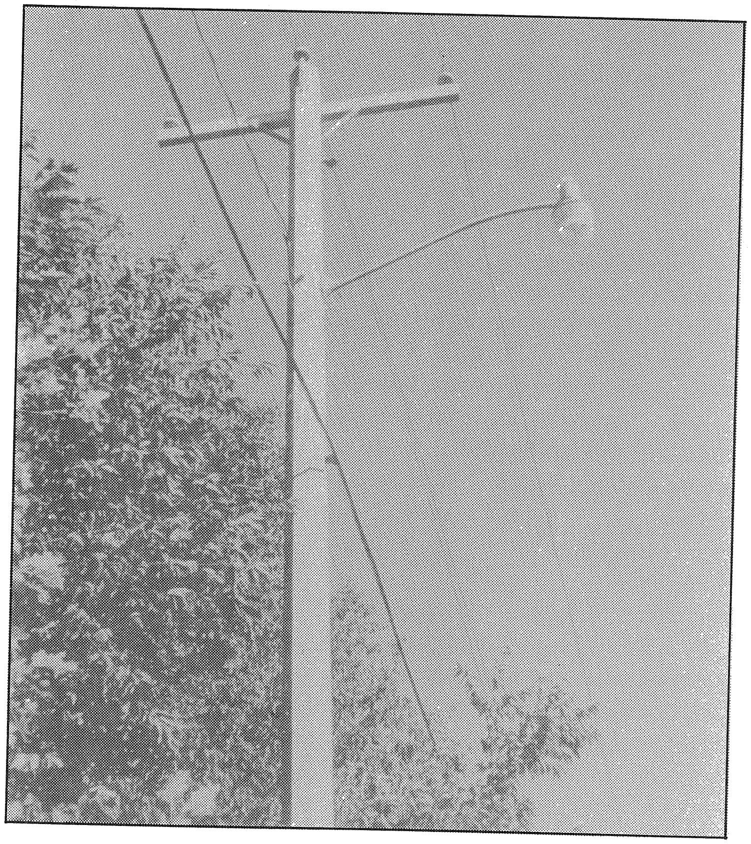

Figure 1. COMPOLE™/COMARM™ Installation in Houghton, Michigan

COMPOSITE WOOD MATERIAL

Definition

The basis for IWR's composite products is composite wood material (CWM), an engineered material consisting of thin, elongated wood flakes that are treated with preservative and bonded together under pressure using a moisture-resistant adhesive. The flakes are highly aligned to provide exceptional longitudinal strength, and the chemical additives provide good durability. CWM meets the following criteria:

- engineered and man-made
- two or more chemically distinct components with distinct interfaces
- components combined three-dimensionally
- properties superior to those of the individual components

The final criterion sets CWM apart from many other composite wood products, such as plywood and particleboard. CWM acquired unique characteristics by retaining the desirable properties of solid wood, such as high strength-to-weight ratio, machinability, low heat conductivity and high electrical resistance, while losing some of the undesirable ones, such as non-uniformity of properties, knots and grain deviations.

Strength Properties

Several factors have been studied in the development of CWM. These include flake geometry, flake alignment, wood species choice, adhesive type and amount, and preservative type and amount. Some of these are discussed in this paper. Small specimen strength properties for CWM of 640 kg/m^3 density are compared to those for Douglas-fir and southern pine clear wood in Table 1.

Table 1

Average Values for Strength Properties of Composite Wood Material Compared to Douglas-fir and Southern Pine

Material[1]	MOR MPa	MOE MPa	EMC %
Douglas-fir	86.2	12130	12
Southern pine	97.9	12960	12
CWM-I	108.6	16000	5[2]
CWM-P	87.6	13720	6[2]

[1]CWM-I - isocyanate bonded CWM
CWM-P - phenol-formaldehyde-bonded CWM

[2]Conditions would give 9 percent equilibrium moisture content for wood.

The original research effort was directed at using wood species with limited commercial value. It was found that species choice had little effect of material strength properties and one of the most significant characteristics of CWM is that woods, not normally considered for structural applications, produce material which has bending strength properties similar or superior to those of the major structural species. The principal reasons for CWM's high strength are an efficient flake alignment method and the use of an isocyanate adhesive which produces material about 20 percent stronger than phenol-formaldehyde-bonded material.

Effect of Adhesive Type

Data showing differences between isocyanate-bonded material and phenolic-bonded material are given in Table 2. These data also indicate the effects of three preservative systems and an accelerated weathering test. The CWM in these tests was made with aspen flakes, an adhesive level of eight percent solids and preservative levels of 1.5 percent active ingredient, which represents 9.6 kg/m^3 (0.6 pcf) preservative in the material. The flakes were treated by spraying

Table 2

Average Bending Strength of Isocyanate-Bonded and Phenolic-Bonded Composite Wood Material Containing Several Preservatives

Material Type[1]	Bending Strength (MPa)[2]			
	Unweathered		Weathered[3]	
	CWM - I	CWM - P	CWM - I	CWM - P
Untreated	104.8	79.6	83.1	54.7
NAPCP	95.1	84.5	81.5	56.3
CCA	97.1	77.2	45.6	29.6
ACA	94.9	80.5	48.1	28.5

[1]NAPCP - sodium penta
CCA - chromated copper arsenate (type C)
ACA - ammoniacal copper arsenate

[2]Values are averages for 10 specimens.

[3]Accelerated weathering, 50 cycles using cycle of soak in boiling water for 10 minutes followed by hot air drying at 105°C for 7.8 hours.

with the appropriate preservative solution. The accelerated weathering test consisted of 50 cycles of 10 minute soak in boiling water followed by 7.8 hours drying in hot air at 105°C.

The strength values were obtained from 300 x 50 x 12.5 mm specimens using 10 replicates to obtain averages. These data show that the strength of phenolic-bonded material averages approximately 20 percent less than that of the isocyanate-bonded material for unweathered CWM. This difference was seen with the three preservative systems listed. After weathering, the bending strength of the isocyanate-bonded material is not degraded as much as the phenolic-bonded. Both adhesives were typical flakeboard adhesives; however, it should be noted that no attempt was made to optimize the type of phenolic adhesive used. This difference may not be seen with all phenolic adhesives. The effect of preservative systems is discussed in more detail below.

PRODUCT DURABILITY

The composite wood products were developed for outdoor exposure. Two aspects of durability are of importance: biodeterioration and weatherability. The wood flakes were treated with chemicals during the manufacturing process in order to provide protection against biological agents. A critical prerequisite of the preservative is that it not substantially interfere with the weatherability, i.e. reduce strength properties. Improved weathering characteristics were obtained by using a water-resistant, isocyanate adhesive to bond the flakes. Segments and laminations were bonded with a resorcinol-formaldehyde adhesive to provide weather resistant joints.

Preservative Screening

Many chemical compounds, including all major preservative systems used in the United States, have been screened as potential CWM preservatives. In this screening test, panels of CWM 12.5 mm thick with a nomal density of 640 kg/m^3 were made using aspen flakes, eight percent isocyanate, one percent wax, and a variety of preservatives which were sprayed onto the flakes. A partial list of preservatives incorporated into the CWM is given in Table 3.

Table 3

Listing of Some Preservatives Incorporated Into Composite Wood Material

AAC + copper chloride
Ammoniacal copper naphthenate
alkyl ammonium compound (AAC)
ammoniacal copper arsenate
ammoniacal copper pentachlorophenol
ammoniacal pentachlorophenol
chromated copper arsenate
copper complex
copper oxine
pentachlorophenol/P9 oil
pentachlorophenol/creosote
sodium pentachlorophenoxide

Test speciments (400 x 50 mm) were cut from the panels. These were tested in bending over a 250 mm span to obtain unweathered bending strength values. The broken end was cut off and used for specific gravity and moisture content determinations, while the remaining 270 mm was subjected to 50 weathering cycles of 1.5 hour soaking in boiling water followed by 4.5 hour drying at 105°C. After conditioning them in the same conditions as the 400 mm lengths, these specimens were tested in bending to provide weathered data. In this way the same specimens were used for weathered and unweathered results. Average bending strengths for six samples are presented in Table. 4.

The data in Table 4 and other unpublished results indicate that several preservative systems can be incorporated in CWM without

Table 4

Average Bending Strength Data for Unweathered and Weathered Material Treated With Various Preservatives

Preservative	Bending Strength (MPa)	
	Unweathered	Weathered
Untreated	83.8	66.7
sodium pentachlorophenoxide	99.0	78.5
pentachlorophenol/creosote	89.2	69.0
pentachlorophenol/P9 oil	81.7	67.7
ammoniacal pentachlorophenol	87.3	69.9
ammoniacal copper naphthenate	78.6	51.0
ammoniacal copper pentachlorphenol	75.5	52.8
ammoniacal copper arsenate	69.9	53.0
chromated copper arsenate	79.3	54.6
alkyl ammonium compounds (AAC)	90.3	66.8
AAC + copper chloride	71.2	54.0
copper complex	78.9	61.9
copper oxine	39.4	35.8

significantly affecting bending strength, either before or after accelerated weathering. Although the preservatives generally have little effect on strength before weathering tests, some differences do appear after samples are subjected to exposure of accelerated weathering. CWM containing sodium penta, penta/creosote, penta in oil, ammoniacal penta and alkyl ammonium compounds lost about the same amount of strength on weathering as treated solid wood. In contrast, CWM containing inorganic salt-type preservatives such as CCA and ACA experienced high strength losses, particularly after weathering.

As shown by the information in Table 4, the addition of copper can have a deleterious effect on bending strength. This effect is demonstrated in comparisons of ammoniacal copper penta and ammoniacal penta, as well as AAC plus copper chloride and AAC. The poor results found with the copper oxine were due to the presence of strong acid, which was required to solubilize the salt before preservative treatment.

Work on the acceptable systems is continuing, as well as new systems being investigated. Both the efficacy of the preservatives and their effect on strength properties are being studied. Test methods include wafers on agar, soil block tests, toast rack tests and use of the fungus cellar. These tests are used to screen the various preservatives, or to indicate the required threshold level of preservative. In addition to the laboratory tests, a large number of decay stakes have been installed in test plots in Florida and Panama to evaluate the decay and termite resistance of treated CWM in the field.

CONCLUSIONS

A variety of wood species, adhesives and preservative systems can be used to produce a composite wood material with strength and durability that compare with those of solid wood from the major structural species.

The inclusion of some preservatives to provide decay and termite resistance can be accomplished without adversely affecting strength properties, while other systems, particularly those containing copper, appear to degrade strength.

A number of products manufactured from the composite wood material have been designed for particular end-use requirements and appear both technically and economically feasible.