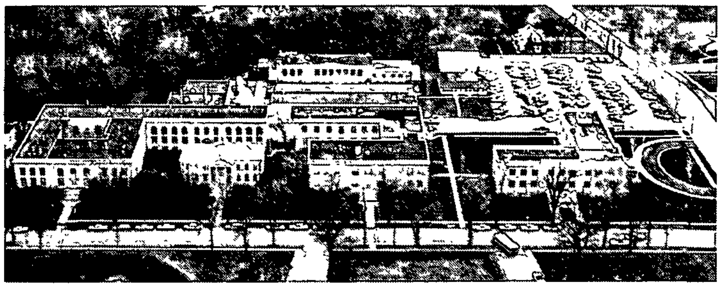

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THE EFFECT OF POLYMERIC STRENGTH AIDS ON FIBER/FIBER BONDING

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The Effect of Polymeric Strength Aids on Fiber/Fiber Bonding

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THE EFFECT OF POLYMERIC STRENGTH AIDS ON FIBER/FIBER BONDING

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INTRODUCTION

The strength of paper has been shown theoretically[1] to depend on both individual fiber strength and fiber-fiber bond strength. Somewhat earlier Leech[2] had intuitively suggested that the number of bonds (bonded area) and the distribution of fibers and bonds (formation) were also involved. His experimental study showed that locust bean gum increased the four factors contributing to sheet strength as follows: bonded area, 15%; formation, 25%; bond strength, 60%; and individual fiber strength, 0%. He suggested that the improved bond strength was a result of the high flexibility of the gum macromolecules. Currently, polymeric dry strength aids are widely used in the paper industry with as yet little additional understanding of their function.

The purpose of the present study was to determine

(1) whether Leech's findings for sheets would be reflected at the level of the individual fiber-fiber bond, and

(2) the location of failure of this bond.

MATERIALS AND METHODS

Earlywood fibers were gently separated from loblolly pine chips that had been kraft pulped to a conventional yield. Fiber-fiber bonds were produced by crossing two fibers, removed from a dilute pulp slurry, at right angles to each other. The pair was pressed/dried between teflon-faced rubber discs under a nominal pressure of 17 psi at 105°C for one hour. Some of the fiber slurry was treated with polymeric strength aids prior to withdrawing fibers for bond formation. A "dual polymer" system previously shown [3,4] to be effective for improving sheet strength was employed. It comprised treatment of the fiber slurry with a 1% add-on of polyamide polyamine epichlorohydrin followed by 0.4% of carboxymethyl cellulose.

The optical contact area, assumed to be the bonded area of the pair, was measured by the vertical polarized light technique[5]. The force required to cause bond failure in a quasi-plane shear geometry was determined using a recently-developed[6], sensitive fiber load/elongation recorder (FLER II).

After failure, the two fibers were coated with gold/palladium to minimize charging effects, and the formerly bonded surfaces were examined in the scanning electron microscope (SEM).

RESULTS AND DISCUSSION

About forty samples of both the untreated and the chemically-treated bonds were measured. As might be expected, a broad range of values was found in each case. The results for the specific bond strength (the ratio of breaking load to bond area) are plotted in Fig. 1 as the cumulative frequency against the bond strength. On this probability grid a straight line would indicate the data could be represented by a normal (Gaussian) error function. The reciprocal of the slope is a measure of the width of the distribution. Nonlinearity indicates a skewed Gaussian. The polymer treatment (T) shifts the distribution of strength values in the direction of stronger bonds.

The effect of the treatment is presented quantitatively in Table I as the arithmetic means of the breaking load, bond area, and specific bond strength.

TABLE I.

AVERAGE VALUES FOR SINGLE FIBER/FIBER BOND PROPERTIES

PROPERTY	ARITHMETIC MEAN UNTREATED	ARITHMETIC MEAN TREATED	TREATED/ UNTREATED
BREAKING LOAD, g	0.44	1.14	2.59
BOND AREA, μm^2	2530	2970	1.17
SPECIFIC BOND STRENGTH, $\mu g/\mu m^2$	220	390	1.77

Bond area increases slightly when the strength aid is present, while the average breaking load increases by over 150%.

The SEM photomicrographs of the formerly bonded surfaces provide salient information regarding the increase in strength. For the untreated, unrefined, earlywood fibers used here, failure occurred at the interface between the two fibers with little or no damage to the fiber walls. A typical example is shown in Fig. 2 where the site of the bond is evident from the somewhat smoother surface.

In contrast, most of the photomicrographs of the samples with the strength aid present showed considerable disruption of the fiber wall. Tearing and "picking" of the surface were present as can be noted in Fig. 3. In some cases it appeared that the failure occurred between the S1 and S2 layers, but more data are needed before this can be generalized. In any event the results to date indicate that the polymeric additives have increased the strength of the bond between the fibers and have shifted the weak spot to within the fiber wall.

We are currently examining the effects of refining and yield on the strength and location of failure in fiber-fiber bonds. A complete report of these results will be submitted later.

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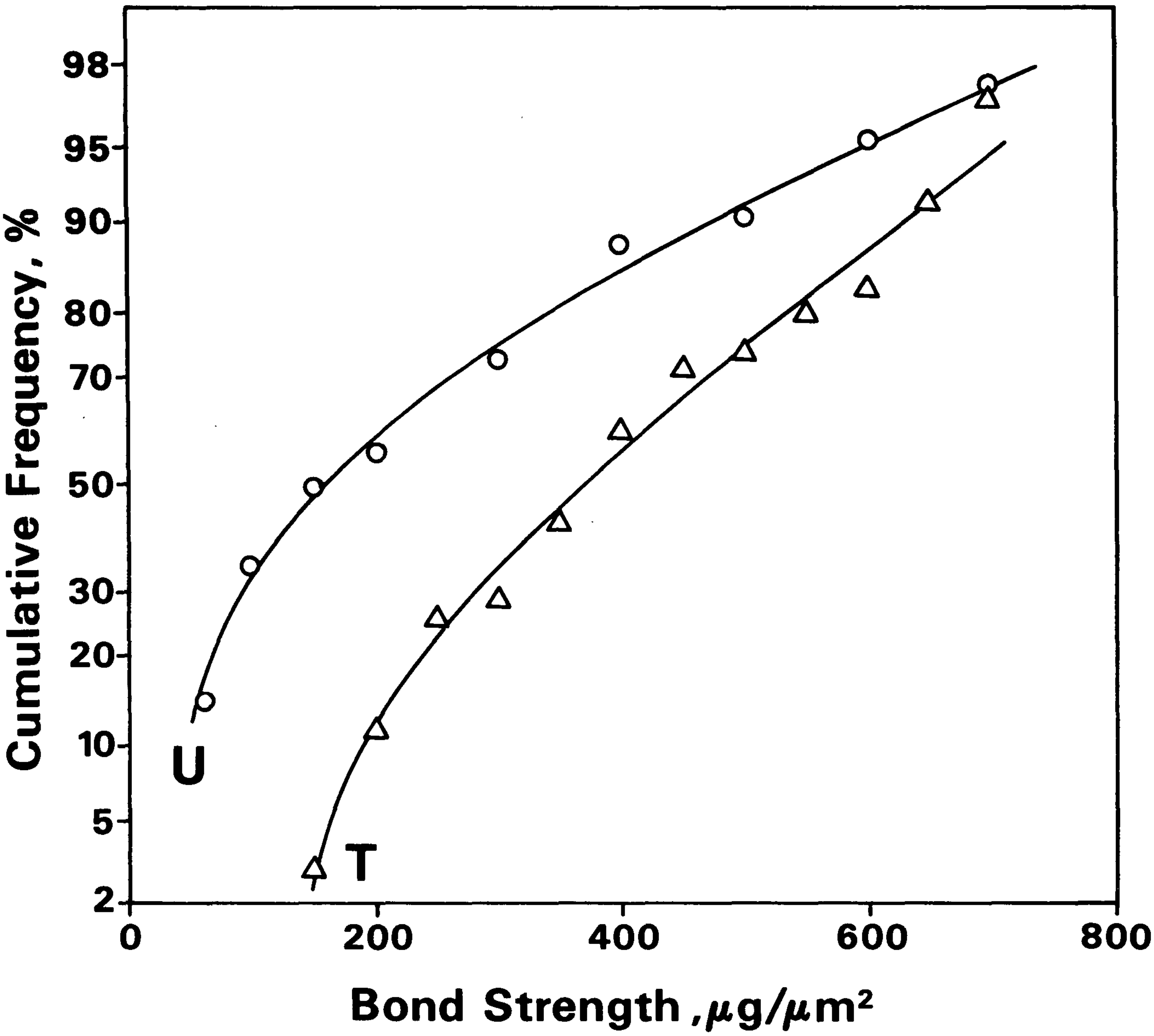
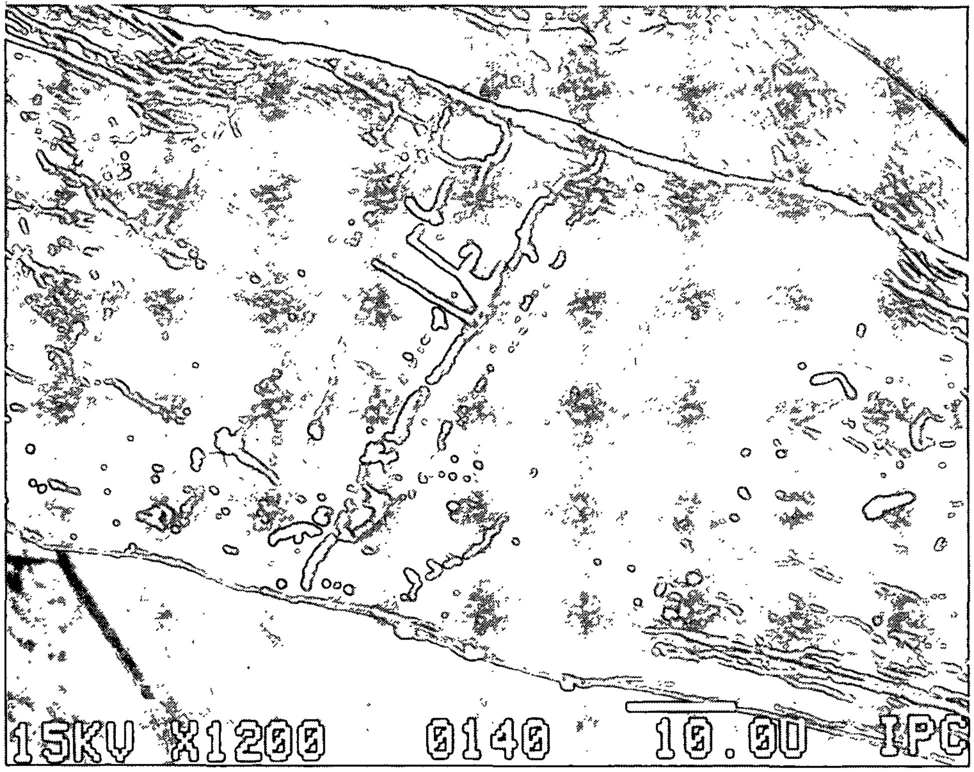


Figure 1. Cumulative distribution of bond strength values for treated (T) and untreated (U) fiber-fiber bonds.

Figure 2. SEM photomicrographs of formerly bonded surfaces of untreated fibers.



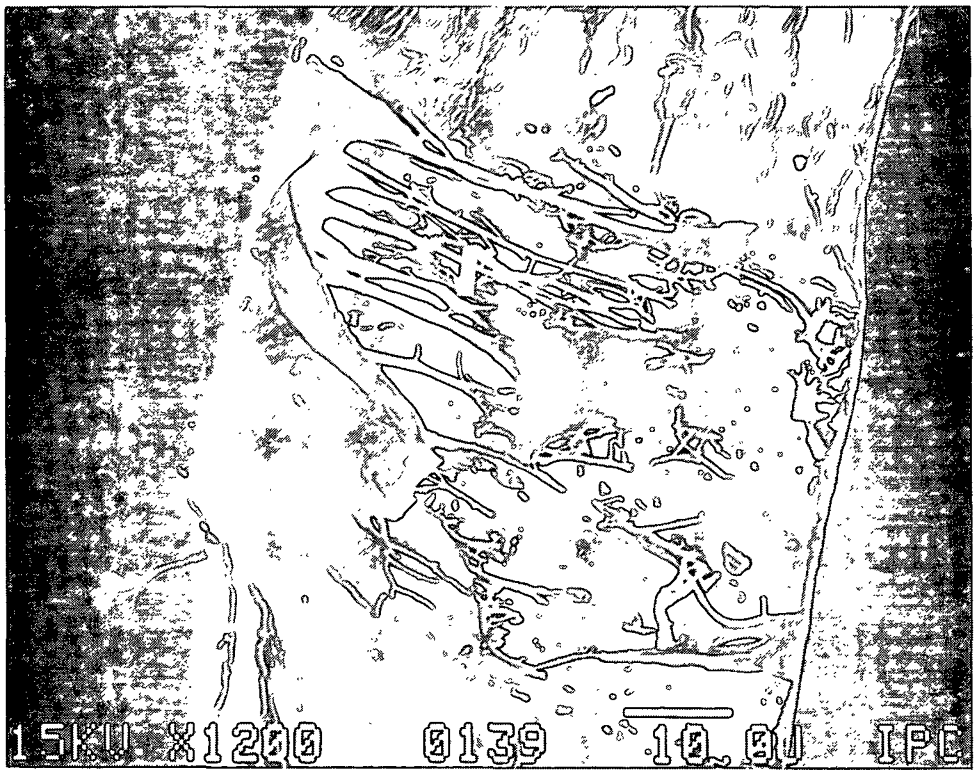


Figure 3. SEM photomicrographs of formerly bonded surfaces of treated fibers.