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Wastepaper fibres in plaster products

R. S. P. COUTTS
CSIRO Division of Forestry and Forest Products, Private Bag 10, Clayton 3168, Victoria, Australia

In Australia the surge in community concern about the environment has led to a glut of waste paper. The usual avenues for re-using this fibre (e.g. as cardboard packaging) are saturated because the collection rate increased eight-fold during 1989.

Unlike the USA and Europe [1, 2], none of the 400 000 tonnes of newsprint made in Australia contains any recycled paper fibre. This is likely to change as the industry is now commissioning a study into de-inking and recycling.

In Australia considerable research has been conducted into the utilization of wood pulp fibre as a suitable reinforcement for inorganic composites [3]. Asbestos has been replaced totally by wood pulp fibre in fibre cement products such as flat sheeting, pipes and moulded products [4, 5]. This technology is now being exported to other countries. Wood pulp fibres also form fibre plaster products with excellent properties [6].

Waste paper offers an inferior source of wood fibre for reinforcement; however, its cost is less than 15% of that of *Pinus radiata* kraft pulp. Thus, on the basis of "performance for cost", such material may still prove an acceptable source for fibre reinforcement of plaster products. An earlier study of wastepaper fibres incorporated in cement products demonstrated that materials having acceptable performance could be fabricated [7].

The fibre source for this investigation was a commercial wastepaper grade used in Australia for the production of corrugating medium. The fibre was received as a ready-mixed lap from a paper company and was slushed, but not beaten, in a Valley beater. It contained recycled magazines, newsprint and other waste material derived from wood pulp fibres. The main constituents were *P. radiata* and mixed eucalypt kraft pulps, *P. radiata* thermomechanical pulp, mixed eucalypt neutral sulphite semi-mechanical pulps and other fibre types present in small amounts due to imported waste products. The distribution of the fibre lengths of this fibrous material was measured on a Kajaani FS-200 and has already been reported [7]. The matrix was prepared from commercially available plaster of Paris (i.e. β-hemihydrate).

The wastepaper fibre-reinforced plaster (WFRP) products were prepared by the slurry/vacuum-dewatering technique described in [8]. After preparation, the samples were stored in a conditioned room at 50 ± 5% relative humidity and 22 ± 2 °C until tested. The flexural strength, fracture toughness and density were determined on nine specimens per test by published methods [8] and are reported in Table I.

TABLE 1 Properties of wastepaper reinforced plaster products

Fibre (wt %)	Flexural strength (MPa)	Fracture toughness (kJ m^{-2})	Density (g cm^{-3})
2	12.9 ± 1.9	0.18 ± 0.01	1.66 ± 0.04
4	11.8 ± 0.5	0.31 ± 0.04	1.60 ± 0.02
6	12.2 ± 0.8	0.41 ± 0.02	1.56 ± 0.02
8	15.2 ± 1.0	0.67 ± 0.07	1.50 ± 0.02
10	17.3 ± 0.9	0.92 ± 0.08	1.46 ± 0.02
12	16.7 ± 1.8	1.03 ± 0.11	1.42 ± 0.02
14	18.4 ± 1.8	1.27 ± 0.15	1.37 ± 0.02
16	16.9 ± 1.8	1.24 ± 0.19	1.34 ± 0.02

Fig. 1 shows the variation of the flexural strength with the change in fibre content for a long softwood fibre (*P. radiata* kraft), a short hardwood fibre (*Eucalyptus regnans* kraft) and waste paper. The flexural strength of the fibre composites decreases from *P. radiata* kraft to *E. regnans* kraft to waste paper.

Although the length of the fibre plays a major role in the reinforcing of the weak matrix, it is the aspect ratio (i.e. the ratio of fibre length to fibre width), that is the fibre property of greatest significance [9]. *P. radiata* has fibre lengths between 2 and 6 mm (average 3.5 mm) and fibre widths between 13 and 45 μm (average 30 μm). This suggests an average aspect ratio of approximately 120 [5]. Similarly, *E. regnans* has fibre lengths between 0.5 and 2.5 mm (average 1.0 mm) and fibre widths between 10 and 23 μm (average 16 μm) and an average aspect ratio of approximately 60 [5]. Although an earlier study established the fibre lengths in the wastepaper sample (average 1.9 mm) by the use of a Kajaani FS-200 [7], no data were available regarding the fibre widths. Thus, no conclusion can be reached as to the value of the aspect ratio for this sample.

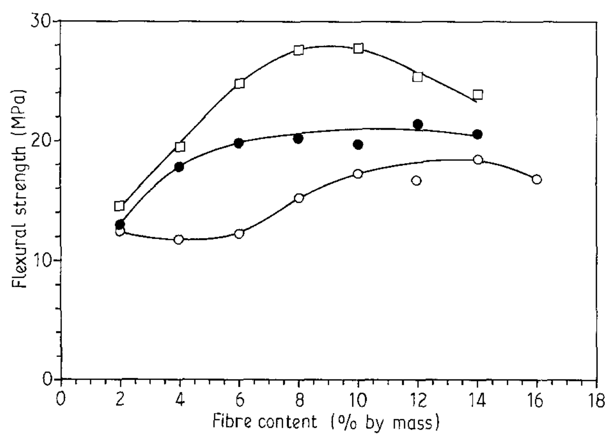

Figure 1 Flexural strength plotted against fibre content: (□) *P. radiata* [6], (●) *E. regnans* [8] and (○) wastepaper (this study).

Although the average fibre length of the waste paper is 1.9 mm compared with 1.0 mm for *E. regnans* the average aspect ratio must be lower as lower values of flexural strength are shown in Fig. 1. This suggests that the wastepaper fibres are considerably thicker than *E. regnans* fibres.

Fig. 1 shows also that the maximum strength occurs at higher fibre loadings as the fibres change from *P. radiata* to *E. regnans* to waste paper. This could be due to the fibres with smaller aspect ratio packing more efficiently into the matrix. In earlier studies [6] poor packing of the fibres was suggested as the cause of this turning point; theoretically the strength of a composite should continue to increase with increasing fibre content due to the "rule of mixtures" [9].

Fig. 2 depicts the change in fracture toughness as the fibre content is increased in fibre plaster samples containing *P. radiata, E. regnans* and wastepaper reinforcement. The mechanisms that take place during the fracture of a fibre composite include fibre breakage and fibre pullout. The latter can have a considerable influence on the value of the fracture toughness. If the fibre is short, then the energy used up in pulling the fibre through the matrix, after the fibre–matrix bond has been broken, can contribute little to the dissipation of energy contained in the advancing crack. Therefore, the crack continues through the sample and the material appears brittle. In Fig. 2, where it can be seen that the long *P. radiata* fibres produce samples with fracture toughness values greater than twice that of *E. regnans*, the importance of the fibre length is confirmed. Although the wastepaper fibres have average fibre length (1.9 mm) greater than that of *E. regnans* (1.0 mm), there is a much greater percentage of very short fibres. In an earlier study of the fibre length distribution, using the Kajaani FS-200 [7], it was recorded that in the case of *P. radiata*, *E. regnans* and waste paper the amount of fibre <0.6 mm was 6.6, 14.8 and 27.8%, respectively. It is the high percentage of short material, which offers virtually no resistance to fibre pullout, that results in such low values of fracture toughness in the case of WFRP.

The density of the wood fibre-reinforced plaster products is also dependent on the packing of the fibres within the matrix, and again it is observed that for those samples containing higher loadings of short material the density is higher. Thus, over a fibre range 2–14 wt% the values of density for products containing *P. radiata*, *E. regnans* and wastepaper fibres are 1.49–1.24, 1.65–1.30 and 1.66–1.37 $g\,cm^{-3}$, respectively.

In conclusion, the use of certain grades of waste paper as a cheap source of reinforcement for plaster products is acceptable if relatively low values of fracture toughness can be tolerated. The flexural strength is more than adequate for their use as a building material. It must be emphasized that "performance for cost" is often the deciding factor for the use of a material, and not the material properties *per se*.

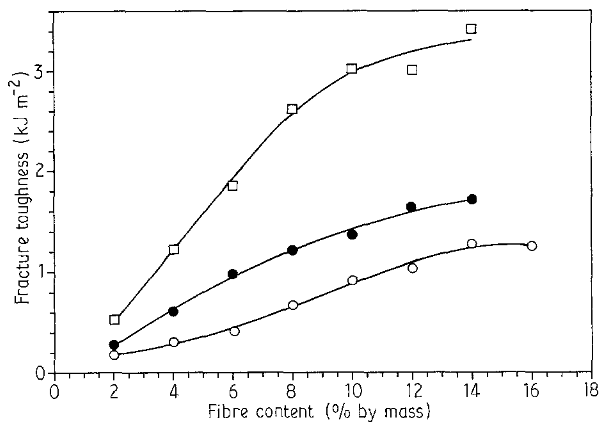

Figure 2 Fracture toughness plotted against fibre content: (□) *P. radiata* [6], (●) *E. regnans* [8] and (○) wastepaper (this study).

References

1. F. D. IANNAZZI, *Pulp, Paper* (March 1989) 114.
2. D. ADAMS GARCIA, *ibid.* (February 1987) 114.
3. R. S. P. COUTTS, *Chem. Aust.* **50** (1983) 143.
4. ANON. *CSIRO Indust. News* No. 146 (May 1982) 1.
5. R. N. SWAMY, in "Concrete technology and design", Vol. 5: "Natural fibre reinforced cement and concrete" (Blackie, Glasgow, 1988) Ch. 1.
6. R. S. P. COUTTS, *J. Mater. Sci.* **21** (1986) 2959.
7. *Idem, Int. J. Cement Compos. Lightweight Concrete* **11** (1989) 143.
8. *Idem, Appita* **41** (1988) 43.
9. D. J. HANNANT, in "Fibre cements and fibre concretes" (Wiley, Chichester, 1978) Ch. 4.

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