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Properties of Corrugated Paper from Recycled Paper Blended with Semantan Bamboo Pulp

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ABSTRACT

The effect of virgin pulp blended with recycled paper in terms of corrugated paper properties has been studied. The proposed virgin pulp was Semantan bamboo and for some comparison, the recycled paper was also blended with softwood long fiber and kenaf soda-anthraquinone (AQ) pulp. The Semantan bamboo was pulped with soda-AQ pulping process with the enhancement of 8000 beating revolutions. The percentage of virgin pulp used was only 5 or 10% for each batch of paper while the rest of the paper raw material used was recycled paper. The zero-span index and flat crush test index for Semantan bamboo and recycled paper blending showed positive increment with the addition of higher percentage of Semantan bamboo pulp. The results showed that Semantan bamboo fiber is comparable with softwood long fiber and therefore can be substituted for imported virgin softwood pulp.

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INTRODUCTION

The usage of recycled paper is a great effort in decreasing the dependence on wood resources for pulp and paper making industry. Recycled paper resources can be varied from old corrugated board, old copier paper and old newspaper. But, there are some limitations in using the recycled paper as the raw material for pulp and paper industry such as the hassle of deinking process and the fiber can be recycled up to five to seven times only before it become stiff and difficult to collapse during paper making process. Generally, the use of recycled fibre produces paper with poorer mechanical properties due to a decrease in the interfiber bonding (Rushdan, 1998).

The recycled pulp must be treated to restore its bonding strength, for which there are six methods possible: mechanical treatment, chemical additives, chemical treatment, fractionation, papermaking process modification and blending with virgin fiber (Minor *et al.*, 1993).

Nowadays, most of the paper factory used imported softwood virgin pulp as the treatment in maintaining the paper strength by blending it with the recycled paper due to the softwood has longer fiber that will increase the fiber to fiber bonding during the paper making process. But, imported softwood virgin pulp is getting more expensive year by year and thus will increase the production cost (FOEX, 2014).

This study would introduce the usage of Semantan bamboo as the alternative sources of long fiber virgin pulp as the bamboo fiber is longer than kenaf and other hardwood species. Bamboo has been recognized as the second importance non-timber forest produced by Malaysian Government. It can be a good substitute for timber in producing high value added products (Azmy *et al*., 2009). It is one of the most diverse groups of plants in the grass family (Bambusoidae). It is the fastest growing plant on earth that can grow up to a meter a day and reach its full height in two or three months. Its fast growth rate and better mechanical properties than many other wood species make this resource an alternative raw material for various types of composite panel production (Fuyuan & Jianmin, 1988; Midmore, 1998; Ganapathy *et al*., 1996).

Bamboo is one of the long type fiber species and can produce high strength paper with environmentally friendly (soda-anthraquinone pulping) process i.e. low consumption of chemicals and energy. It is suitable to be used as raw material for corrugated paper that mainly used in box packaging that need strong paper to protect goods. Salmela *et al*. (2008) studied bamboo in terms of oxygen bleaching for kraft pulping and stated that bamboo is an attractive raw material for chemical

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pulp, due to its long fibers, it has strength properties comparable to those of softwood pulp.

Semantan bamboo (scientifically known as *Gigantochloa scortechinii*) exits locally in Malaysian forest and can be harvested in only 3 to 5 years, much less time compared to hardwood and softwood trees which are currently the major sources of fibers for the paper making (Chen *et al*., 2000). Thus the potential of commercializing products from Semantan bamboo is very promising.

MATERIALS AND METHODS

Bamboo, softwood and kenaf pulp blended with recycled paper:

The best bamboo paper was produced from whole Semantan bamboo (paper making from pulping conditions of 15% A, 160^{o}C T and 8000 beating revolutions) (Nurul Husna *et al*., 2013) based on the highest bonding index, were chosen to be blended with commercial recycled paper collected from Pascorp Paper Sdn Bhd, Bentong, Pahang. The paper making process for 120 g/m^2 paper was basically same with the 60 g/m^2 paper based on TAPPI standard T205 cm-88. Only slight modification was done during the mixing process of Semantan bamboo pulp with the recycled pulp. The recycled pulp was reslushed by using the hydrapulper for 20 min, and then the moisture content (m.c.) of the recycled paper was determined using the m.c. analyzer. The mixing was based on 36.4g o.d. pulp, in producing 10 sheets of papers for each batch of paper. After that, 120 g/m^2 paper were produced and turned into corrugated form by passing it through the Concora Medium Flutter machine and tested for the flat crush strength by using L & W Crush Tester machine based on TAPPI standard T 809 om-99 with 10 replications for each paper sample. Zero-span test was based on TAPPI standard T231 cm-96 by using zero-span jaws with 10 replications for each paper sample. Besides blending bamboo with recycled paper, as the purpose of comparison, the recycled paper was also blended with softwood long fiber and kenaf soda-AQ pulp. Table 1 shows the percentage of bamboo, softwood, kenaf and recycled paper used in the blending process.

Table 1: Recycled Paper, Bamboo, Softwood and Kenaf Pulp Blending.

Treatment	Bamboo Pulp (%)	Recycled Paper (%)
1 (RP)	0	100
2 (B-5)	5	95
3 (B-10)	10	90
Treatment	Softwood long fiber (%)	Recycle Paper (%)
4 (SF-5)	5	95
5 (SF-10)	10	90
Treatment	Kenaf soda-AQ (%)	Recycle Paper (%)
6 (K-5)	5	95
7 (K-10)	10	90

The 120 g/m^2 paper produced as described above was passed through the Concora Medium Flutter machine to turn it into corrugated form and tested for the flat crush strength based on TAPPI standard T 809 om-99 with 10 replications for each paper sample.

The statistical analysis was carried out using the Statistical Package for the Social Sciences (SPSS). Analysis of Variance (ANOVA) was used to determine the differences in virgin pulp species and ratio of virgin pulp percentage. After that, Duncan's Multiple Range Test (DMRT) was used to determine the significant level of all the parameters evaluated. This method ranks the means (at $p \leq 0.05$) and calculates the least difference that must occur between the means or be considered significantly different with each other. The differences are reflected in the letters (a, b, c, etc.) given in each mean. Means followed by the same letter are not significantly different at $p \leq 0.05$.

RESULTS AND DISCUSSIONS

Comparison between bamboo, kenaf and softwood pulp blended with recycled paper:

Table 2 shows the zero-span index and flat crush test index according to their treatment conditions and raw material used either bamboo, softwood long-fiber or kenaf soda-AQ pulp blended with recycled paper pulp. Paper for Control 1, Control 2 and Control 3 were made from 100% of Semantan bamboo, softwood long-fiber and kenaf soda-AQ respectively. Semantan bamboo fiber produced the highest zero-span index among the three samples used and proved that bamboo fibers were individually strong compared to recycled paper fibers, softwood long fibers and kenaf soda-AQ fibers. But when it came to FCT index, Semantan bamboo as well as kenaf fibers showed some decreasing in the strength reading. This might be due to different orientation of the fibers during FCT testing compared to normal paper testing, as the same phenomenon can be found in machine direction (MD) and cross direction (CD) in commercial paper testing.

Table 2: Zero-span and FCT Index for Bamboo, Kenaf and Softwood Blended with Recycled Paper.

Treatment	Bamboo (%)	Recycled Paper (%)	Zero-span Index (Nm/g)	Flat Crush Test Index (Nm/g)
1 (RP)	0	100	78.83	1.49
2 (B-5)	5	95	91.38	1.49
3 (B-10)	10	90	96.90	1.61
Control 1	100	0	126.88	1.04
Treatment	Softwood long fiber (%)	Recycled Paper (%)	Zero-span Index (Nm/g)	Flat Crush Test Index (Nm/g)
4 (SF-5)	5	95	93.89	1.63
5 (SF-10)	10	90	94.06	1.55
Control 2	100	0	117.21	1.78
Treatment	Kenaf soda-AQ (%)	Recycled Paper (%)	Zero-span Index (Nm/g)	Flat Crush Test Index (Nm/g)
6 (K-5)	5	95	81.61	1.45
7 (K-10)	10	90	88.35	1.55
Control 3	100	0	119.25	0.98

All the bamboo, softwood long-fiber and kenaf soda-AQ blending with recycled paper pulp were made into 120 g/m^2 paper and turn into corrugated paper using Medium Concora Flutter machine. The 120 g/m^2 were tested for zero-span index and the corrugated paper was tested for flat crush test.

Figure 1 shows the zero-span index for 5 and 10% of bamboo, softwood long-fiber and kenaf soda-AQ paper blended with recycled paper. The highest zero-span index was found in column number 3, that consists of 10% bamboo pulp, followed by column number 5 (10% of softwood long-fiber pulp) and followed by column number 4 (5% softwood long-fiber) with zero-span index 96.90, 94.06 and 93.89 Nm/g respectively.

The lowest zero-span index showed in column number 1 which consists of 100% recycled paper pulp. From column number 2 to number 3, number 4 to number 5 and number 6 to number 7, they can be seen the increasing of zero-span index with the increasing of the percentage of the bamboo, softwood long-fiber and kenaf soda-AQ addition. These findings proved that the recycled paper pulp has low strength of fiber due to the stiffness of the fiber, and with the addition of virgin pulps, the fiber strength can be improved.

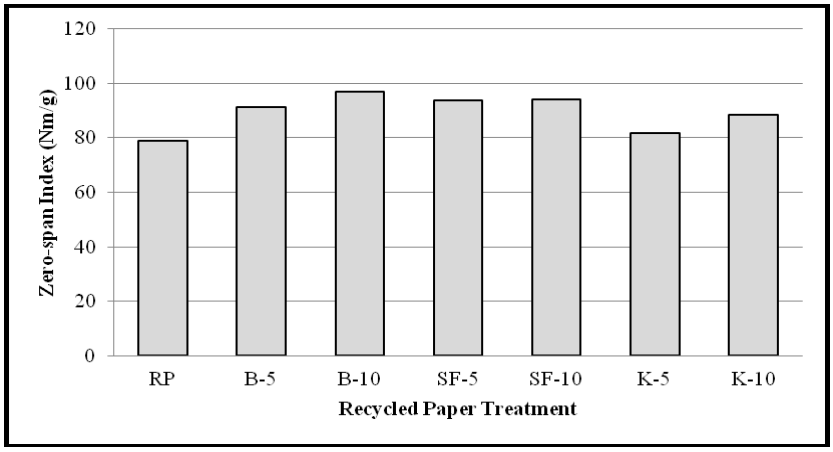

Fig. 1: Zero-span Index for Bamboo, Kenaf and Softwood Pulp Blended with Recycled Paper.

Note: RP = recycled paper; B-5 = bamboo pulp, 5%; B-10 = bamboo pulp, 10%; SF-5 = softwood pulp, 5%; SF-10 = softwood pulp, 10%; K-5 = kenaf pulp, 5%; K-10 = kenaf pulp, 10%

Figure 2 shows the flat crush test index for bamboo, softwood long-fiber and kenaf soda-AQ pulp blended with recycled paper pulp. Contradict with the zero-span index finding, the flat crush test index for 5% softwood long-fiber (column number 4) has the highest flat crush test index, followed by 10% bamboo (column number 5) and 10% softwood long-fiber (column number 3) with flat crush test index 1.63, 1.61 and 1.55 Nm/g respectively.

In bamboo and kenaf soda-AQ pulp, the increasing percentage from 5% to 10% of additional virgin pulp into the recycled pulp, increased the flat crush test index, while in softwood long-fiber, the additional from 5% to 10% of virgin pulp, decreased the flat crush test index results. This may due to flocculation of softwood long fibers during paper making process. Flocculated fibers tend to contribute to the weakness point in a paper sheet, as less bonding area can occur in flocculated fibers compared to straight align fibers, thus decreased the FCT index reading.

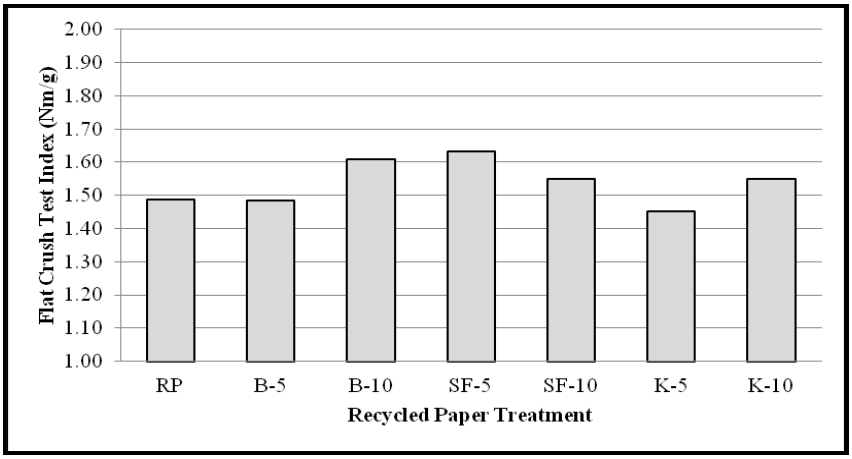

Fig. 2: Flat Crush Test Index for Bamboo, Kenaf and Softwood Pulp Blended with Recycled Paper.

Note: RP = recycled paper; B-5 = bamboo pulp, 5%; B-10 = bamboo pulp, 10%; SF-5 = softwood pulp, 5%; SF-10 = softwood pulp, 10%; K-5 = kenaf pulp, 5%; K-10 = kenaf pulp, 10%

Table 3 shows the summary of ANOVA for bamboo, kenaf and softwood blended with recycled paper pulp were significantly different at significant level of 0.05, between the types of raw material used to be blended with the recycled paper pulp to the value of zero-span and FCT index.

Table 3: Summary of ANOVA for Bamboo, Kenaf and Softwood Blended with Recycled Paper.

Variables	df	F-value (Zero-span Index)	F-value (FCT Index)
Species	3	72.72**	8.992**
Percentage in RP	2	121.41**	7.516**
Species X Percentage in RP	4	2.03**	5.957**

Note:**- highly significant

Table 4 shows the effect of species or types of raw material that being added to the recycled paper pulp in terms of their zero-span and FCT index. Semantan bamboo shows dominant effect on zero-span index and also gave higher value compared with softwood long-fiber. It proved that Semantan bamboo fiber has strong individual fibers that can influenced the recycled paper fiber and improve the recycle fiber strength. But the result was contradict with FCT index where 100% Semantan bamboo gave the lowest value for FCT index, this might be due to flocculation of fibers happened during paper making process as being discussed earlier.

Table 4: Effect of Species for Bamboo, Kenaf and Softwood Blended with Recycled Paper.

Species	Zero-span Index (Nm/g)	FCT Index (Nm/g)
Semantan Bamboo	1.05×10^{2} [c]	1.29 [a]
Recycled Paper	78.89 [a]	1.34 [a]
Kenaf-AQ	295.06 [b]	1.34 [a]
Softwood	1.02×10^{2} [c]	1.66 [b]

Means with the same letters are not significantly different ($p \leq 0.05$)

Lastly in Table 5 shows the effects of percentage of bamboo, kenaf and softwood blended with recycled paper pulp. Zero-span index shows positive effect with the virgin pulp addition where the zero-span index increased with the increasing of percentage of virgin pulp added to the recycled paper pulp. FCT index also shows positive effect with addition of Semantan bamboo and kenaf pulp to the recycled paper pulp. But the addition from 5% to 10% of softwood long-fiber to the recycled pulp, decreased the FCT index. This also might be due to flocculation of long fibers inside the paper sheets during paper making that contribute to the weakness point in a paper sheet.

Table 5: Effect of Percentage of Bamboo, Kenaf and Softwood in Recycled Paper Blending.

Percentage in RP	Zero-span Index (Nm/g)	FCT Index (Nm/g)
5%	88.45 [a]	1.52 [b]
10%	92.79 [b]	1.49 [b]
100%	1.08×10^{2} [c]	1.29 [a]

Means with the same letters are not significantly different ($p \leq 0.05$)

Conclusion:

This study was on corrugated paper properties using recycled paper with bamboo pulp addition as the virgin pulp, to improve the recycled paper strength. At 100% of recycled paper pulp, zero-span index was found to be 78.62 Nm/g, and with the additional of Semantan bamboo pulp as low as 5% up to 10%, the zero-span index for "recycled paper-Semantan bamboo paper" increased and ranged from 91.38 to 96.74 Nm/g. According to the zero-span index and flat crush test index, it showed a positive relationship of the significant increasing paper properties with the addition of bamboo pulp into the recycled paper pulp. It showed that the paper strength can be improved by using bamboo pulp and the results are better and comparable with other pulp such as softwood long-fibre and kenaf soda-AQ pulp.

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