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A Study on Feasibility of Secondary Recycled Fibers for Binderless Board Manufacturing

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Abstract – The fiber length distributions and relative ratios (%) on furnish of recovered newspaper pulps are determined. However, the weight percentage of long fiber- and short fiber fractions (fines) was calculated approximately 46.9% and 43.3% in secondary pulp mixture, respectively. These could be well sign of heterogenous fiber types and distribution of fiber length in various mesh fractions in pulp furnish. The highest internal bond (IB) value of 0.29 N/mm^2 was found for those in medium density (582 kg/m^3) board sample followed by 0.16 N/mm^2 (I) and 0.15 N/mm^2 (D) samples. Moreover, regardless of experimental conditions only J type panel, which is the highest density (768 kg/m^3) among study, give a bending strength value of 3.05 N/mm^2. It has already well established that strength feature is usually correlate relative bonding area, the surface activation and fiber flexibility, which originates from the fiber properties. However, recycling stages could be made shortened fibers and creating fines. These impact on lowering strength with creating poor surface accessibility for bonding. It has realized a poor compatibility between secondary waste newspaper fibers in boards matrix structure. This is due to non-fibrous heterogeneous elements in furnish and these interfere fiber-fiber bonding to develop appropriate strength in board structure. A cleaning procedure of these nonfibrous additives could be improved strength developments of panels. It is also realized that without any synthetic and/or natural adhesive usage, it is very difficult to get a well strength on these panel products which made from recovered newspaper fibers.

Keywords – Newspaper, Secondary Fiber, Recycling, Strength, Board Properties.

I. INTRODUCTION

Because natural forest lands have emerging for supplying timber for forest products industry, many studies have already been conducted to find an alternative raw material sources for industry. In this regards, many lignocellulosic material including agricultural wastes [1,2] annual plants [3,4] secondary fiber sources [5-7] have considered to be useful in various level of manufacturing process (pulp and paper, composite, structural elements). However, recycling of post consumer wood and cellulosic materials have also become important topic in this context.

However, waste paper recycling processes are generally designed to run under atmospheric conditions in lower working and processing cost with low-level energy usage. In the post-consumer waste paper, many of the non-fibrous substances (dirt, adhesives, fillers, functional additives, etc.) could be removed easily by repulping/fiberization unit which is the first stage of recycling, and then the screening and washing phase [5]. These make an important consideration to utilize recovered secondary cellulosic fibers as raw material source for pulp and paper industry.

It has already well established that composite or paper products which made from longer and thinner cellulosic fibers show higher strength properties than it made from shorter and thicker fibers [8]. Since multi stage recycling operations impact on physico-chemical changes, on the recovered fibers that has usually shortened length and reduced surface area for bonding [7]. However, these are key limits to impact on strength properties of products. Typically, the strength properties of recovered fibers from waste papers are lower than those produced from wood pulp. These changes occurring as a result of complex physicochemical changes during recycling process [5-8]. It has already well established that paper recycling causes the loss of both fibre flexibility and specific surface bonding potential of fibres [5,8].

However, there are some mechanical and chemical methods of those secondary fibers to improve properties some level. It has already proposed that the chemical and mechanical treatments are effective way for these purposes. A number of researchers have already reported many valuable information on changes of cellulosic fibers during recycling and further information s could be found elsewhere [5,7, 8-10].

One way to understand and explain the chemical processes in the interaction between fibers-fibers, which could be the basis for controlling manufacturing conditions. In this sense, the main purpose of this complimentary laboratory-scale investigations is to study the effects of recovered secondary newspaper fibers on the strength development of boards in carefully controlled conditions.

II. Material And Methods

Daily newspapers were supplied from a kiosk and disintegrated in a laboratory-type blender per standard procedure in water. After 30-40 minutes to disintegration in water, all the sheets convert to the secondary pulp slurry. Then the pulps washed with fresh water and screened on a 200 mesh screen. However, there is no any further chemicalls and treatments condcuted on repulped/defiberized pulps. The recovered secondary fibers were used to made into boards following standard laboratory procedures. The sheet properties of post-consumer newspaper subject in recycling procedure are supplied by newspaper company and some technical information are shown in Table 1.

The Bauer McNett classifier was used for fiber fractionation of recovered secondary pulps according to TAPPI T 233 cm-06. This instrument is designed to measure the weighted average fiber length of a pulp. If a fiber is in a length (I) and weighs (w), then for a given pulp, the weighted average length or the sum of the products of the weight times the length of each fiber divided by the total weight of the fibers in the sample.

$$L = \Sigma(wl)/\Sigma w$$

The recycled pulps were fractionating in hydrocyclones. Six streams were formed from the hydrocyclone fractionation. The classifier has six tanks set up in a cascade arrangement from the largest openings to the smallest. The weight percent on the six screens and the percent that passed through the smallest screen (the fines part) is reported. Approximate sieve size of the Bauer McNett screen used in this study as follows;

- R16: 1.20 mm, retained fibers of a 16-mesh screen,
- P16/R30: 0.599 mm retained fibers of a 30-mesh screen, passed 16 mesh screen,
- P30/R50: 0.297 mm retained fibers of a 50-mesh screen, passed 30 mesh screen,
- P50/R100: 0.152 mm retained fibers of a 100-mesh screen, passed 50 mesh screen,
- P100/R200: 0.074 mm retained fibers of a 200-mesh screen, passed 100 mesh screen,
- P200: <0.074 mm passed fibers of a 200-mesh screen.

The recovered fibers were dried at labaratory conditions to reach moisture content of 25-40%. The board paste was screened onto a metal plate which had been covered with wax paper. The mat was evenly distributed to give as uniform a density as possible. There is no any binder agent employed. Cold pressing took place under a pressure of 5.0 MPa to reach 9.0 mm thickness, after which the boards was hot pressed compression for specified time. A total of 10 experimental boards were made. The experimental procedure for manufacturing experimental boards summarizes in below;

- Cold press pressure and durations: 5.0 N/mm^2 and 5 min,
- Hot press pressure and durations: 2.5-3.0 N/mm^2 and 5.0 min,

- Hot press temperature: 130-150 ^{0}C,
- Board dimensions (mm): 330x330x9.0 cm.
- Adhesive type and ratio: None

In order to limit the study to a certain level, it is not considered to remove any other substance from secondary pulp, since the effect of all fibrous and nonfibrous constituents are considered.

After manufacturing, the experimental panels were conditioned at 20 ºC and 65% relative humidity and samples were cut to find the IB (Internal Bond), MOE and MOR (Modulus of Elasticity and Rupture), by TS EN 310 (1999), TS EN 319 (1999) standards, respectively.

Table 1. Technical properties of newspaper

Property	**Specifications**
Grammage (g/m^2)	45-48 for cover pages, 40-44 for inside pages
Caliper (micron m.)	65-75
Bulk (cm^3/g)	1.50-1.60
Iso Brightness (%)	65-68 for cover pages, 60-64 for inside pages
Opacity (%)	92-96
Sheet network fiber properties	Up to 50% recycled and rest of wood pulp
Pulp proportions	Up to 50% recycled, 10-30 chemical and rest of mechanical pulp

III. Results And Discussions

It has already well predicted that fiber dimension analysis is vital for fiber quality optimization for cellulosic fiber-based products (i.e. paper and fiberboards). Due to the heterogeneous nature recycled pulp furnish, fiber dimensions (lengths and fines) evaluation is a challenge [11]. The comparative fiber length distributions and relative ratios (%) on furnish of secondary pulp are shown in Table 2. The longest fiber fractions (R16) were found to be only 0.15 gr (1.5%). However, weight percentage of long fiber fractions was calculated of 46.9% (I+II). It is also found that increased screen mesh (III-V) resulted in low fiber aspect ratios of 2.4% for III, 2.6% for IV and 4.8% for V, respectively. But it is important to note that almost half of pulp has very short fiber fractions (fines) (VI: 43.3%) in pulp mixture.

It has proposed that paper made from retained fibers in 16 mesh screens (R16) show the high fiber bonding ability, evaluated as tensile strength and apparent density of long fiber laboratory sheets. On contrast, pulp sheets made from retained fibers in 200 mesh screens (P100/R200) showed the lowest fiber bonding ability, with a consecutively falling scale between 16 mesh and 200 mesh sieve size [12,13]. However, the fibrous elements could also be collapsed during multi stage recycling, and their surface area modified. But the length is one of the fundamental properties for cellulosic fibers. Because these fiber classifications studying an indication showed that, whether they are a mixture of various lengths or all of one length, but the numerical values of the exponents might be changed. The results presented in Table 2 can be attributed to heterogenous fiber types and distribution of fiber length in various mesh fractions.

Table 2. The comparative fiber length distributions of recycled newspaper pulp

Codes	**Fractions**	**Quantity (gr)**	**Relative ratio (%)**
I	R16	0.15	1.5
II	P16/R30	4.54	45.4

III	P30/R50	0.24	2.4
IV	P50/R100	0.26	2.6
V	P100/R200	0.48	4.8
VI	P200	4.33	43.3
Total	**-**	10.0	100

Internal Bond (IB) strength properties of the experimental panels are given in Table 3. The highest IB value of 0.29 N/mm^2 was found for those in density of 582 kg/m^3 (E) sample. However, sample I have shown second highest IB value of 0.16 N/mm^2 and followed by sample D (0.15 N/mm^2) and sample F (0.14 N/mm^2), respectively.

The IB strength feature are usually correlate relative bonding area (RBA) as well as the surface activation and fibre flexibility, which originates from the fibres properties. But deformed fibres is shown weaker in strength with creating high amount of fines resulting poor surface accessibility for bonding. However, there is also a poor potential for segment activation which is an important factor in development of strength. Although it is assumed that during board manufacturing from recycled newspaper pulps, which consists of re-slushing, soaking, disintegration, drying, pre-formation and pressing may influence fiber binding to each other (H-bonding potentials), thus may help to develop strength feature. But data presented in Table 3 clearly show poor compatibility between secondary waste newspaper fibers in boards matrix structure. This could be expecting considering many of surface coating residues such as; plastics, films, dye molecules, rubber-like particles and inks, which have a lower specific gravity and are called "*stickies*", could not removed by only washing. Therefore the recycled furnish has more heterogeneous elements than furnish made of wood pulp, and these interfere fiber-fiber bonding to develop proper strength in matrix.

It is important to note that regardless of manufacturing parameters and density of boards, only J type panel, which is the highest density among study, give a bending strength value of 3.05 N/mm^2. It has predicted that sheet density is usually sensitive to fibre flexibility that the flexible fibers conform well on the plane of structure which give in enhancing the relative bonded area and by doing so they form a denser product. However, neither of these suggestions quantifies surface bonding and flexibility loss due to complex recycling procedures, but they all confirm that the non-fibrous recycled furnish elements deteriorates surface bonding potential of fibers as well as their flexibility. Hence, it is plausible to assume that the major change in fiber properties is due to surface bonding loss than the loss in fiber flexibility. But it is also clear that without any synthetic and/or natural adhesive usage, it is very difficult to get a bending strength on these panel products which made from recovered newspaper fibers.

Table 3. The strength (IB) properties of panels made from recycled newspaper fibers

Board Codes	**Density (kg/m^3)**	**IB (N/mm^2)**
Density level 0.5 g/cm^3 (± 0.05)		
A	495	0.07
B	509	0.12
C	529	0.10
Density level 0.6 g/cm^3 (± 0.05)		
D	577	0.15
E	582	0.29
F	591	0.14
G	596	0.12
Density level 0.7 g/cm^3 (± 0.05)		

H	673	0.13
I	757	0.16
J	768	0.08

Figure 1 show the correlation between experimental boards density and IB properties. It could be realized that the lowest IB values of boards produced by recycled fibers was found 0.07 N/mm^2 for the lowest density (A: 495 kg/m^3) and 0.08 N/mm^2 for highest density (J: 768 kg/m^3) of samples, respectively. It has already reported for sheet products that higher density indicates better inter-fiber bonding in the sheet and a positive correlation between screen mesh number and strength [13]. But in this study, there is not any correlation found between density, screen mesh number and IB strengths of panels made directly from recycled newspaper fibers. In addition, Sutjipto and his friends (2008) proposed that the small increase in density may be attributed to the straightened fibers some level for sheet network [14]. But the density of the board product could be appreciably affected by fiber length if the fibers are the similar coarseness. In addition, hemicelluloses, which is hydrophilic substance may help swelling and improving arrangements of fibrous elements in matrix system could be removed during recycling while lignin which is hydrophobic substance may interface fiber-fiber bonding, can be retained on fibers [5,8,15]. Those plausible impact on swelling and strength developments of fibers negatively. In order to regulate this negative situation to a certain extent, it is recommended to adduct of certain chemicals or to carry out sensitive refining processes on fibers [6,7,10]. But in this study, in order to limit the experiments to a certain level and to investigate the effects of secondary recycled newspaper fibers to matrix structure, it is not considered to further experimental approaches or any other additives rather than post-consumer newspaper fibers, since only the recovered newspaper fiber's compatibility are considered.

As mentioned above, strength development of cellulosic fibers is closely related to fiber arrangement that is softer and well-organized fibers could be better bonded and lowering void volume, increasing density in matrix system. It has already reported that wood-based composite materials produced from fibers (fiberboards) at the same density level are usually higher strength properties than those produced from chip or particles (chipboards) [16,17]. But in this study, the results found for all experimental panels (Table 3, Figure 1) not support this hypothesis that secondary fibers could not well adaptive to matrix structure. These is probably due to nonfibrous elements that typically present in recycled pulp furnish. The result found in above clearly support this hypothesis. Hence further cleaning procedure of these nonfibrous additives during recycling may improve strength developments of panels made without using any binder from recycled newspaper fibers.

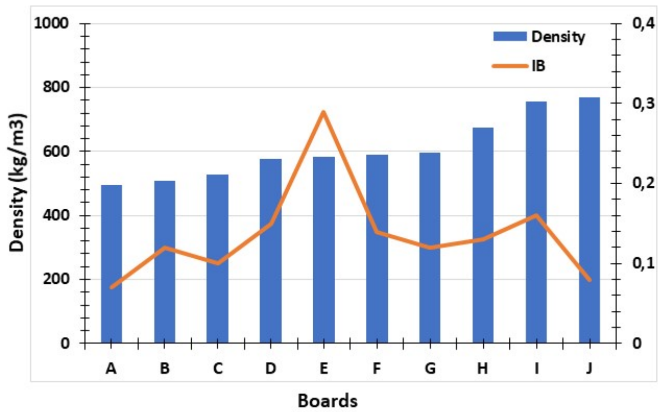

Figure 1. The board density and strength (IB) properties of boards.

IV. Conclusions

Post-consumer waste paper products have gain importance throughout the world due to ready to use cellulosic fibers in sheet structure. However, use of these materials to composite panel manufacturing is an alternative way to help from cellulosic fibers. In this study, post-consumer newspaper was recycled to fibers, using experimental panel manufacturing without using any adhesive or other process aid chemicals. It has found that regardless of experimental conditions and density properties, all experimental panel products show very low strength properties and only one experimental board (J) has bending strength values. This is due to the fact that a newspaper has considerable percentage of nonfibrous elements in sheet network. However, further processing (recycling) could also be generated deformed (i.e., kinked, curled, dislocated or micro compressed) fibers. In order to make panels from recovered newspaper fibers with acceptable strength level, it should be suggested to applying cleaning and surface treatment procedures to made experimental panels with high strength and quality properties.

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