Effect of Cationic Starch and Long Fiber Pulp in the Development of Burst and Tear Index of Recycled Bagasse Paper

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ABSTRACT

The bursting and tear strength of paper are the important properties; since these are very much essential various grades of paper like computer stationary, carry bag and kraft papers. The commercial bleached bagasse pulp was used in the present study and the use of cationic starch along-with the retention aids was incorporated to recover the loss in the burst index and the tear index of bagasse paper. As bagasse pulp has low recycling potential, therefore, its blending with bleached bamboo pulp in different proportions was studied to improve the burst and tear index of paper as well as the recycling potential of the paper. To attain the optimized strength properties of the paper produced for the specific use, the blending of long fibered pulp and the addition of strength improving chemicals were carried out on the stoichiometric basis in the furnish for paper making. The agro-residues and secondary recycled fibers seem to be the promising raw materials of the future.

INTRODUCTION

In the modern era, the paper has taken the most important role in the human life. The development of the civilized society has been measured in terms of per capita consumption of paper. The average and maximum per capita consumption of paper in U.S.A. is 328.67 kg per person per year, which is maximum all over the world and this country is considered in the top ranking of developed countries where as this figure in India is only 4.28, which is too low and it can be improved by recycling of paper.

For the increased utilization of recycled fiber, there are various technical bottlenecks limiting to its use. Most important of them are being the reduction in strength and other desirable properties of fiber during recycling [**3**]. Recycling of chemical pulps made from agri-residues is very limited due to short fiber and low strengths. Very little information is available on the characteristics of recycled agri-residue pulps. More efforts have not been made to improve the characteristics of the recycled pulp [**1**]. But more pulp will be produced from agri-residue, which needs to be recycled for economic and environment reasons [**7**]. Therefore an attempt has been made to study the recycling of agri-residue pulps for their characteristics and explores the possibility of improving its strength properties [**6**]. The objectives of the present work are to study the effect of recycling on the characteristics of agri-residue pulp (bagasse) and improvement of the burst and tear index of recycled pulp [**9**].

The paper industry has turned to fast growing wood species, alternative non-wood fibers and the use of secondary fiber for paper production due to the fast depletion of forest resources and its impact on ecological balance. The selection of best fibrous raw material which will be available on sustained basis appears to be of prime importance and further, the quality of end product will largely dependent on the type of fiber and their blends in making the stock. The agri-residues and secondary recycled fibers seem to be the promising raw materials of the future. The addition of filler such as soapstone is regarded as an integral part of the paper making process. The fillers are highly desirable in printing papers where they increase the opacity, raise the brightness, and generally improve the printing properties. The application of fillers is especially important when opacity is needed at the low basis weight [**8**]. The addition of fillers is harmful as they reduce the strength properties of the paper. Therefore the strength improving chemicals are required to compensate the reduction in the strength properties of the paper produced from the agri-residue pulps [**10**]. In this study, the cationic starch is used as a strength-improving chemical, which is a complex and valuable material [**4**]. Cationic starch is having good tendency for making the strong bond formation with the cellulose fibers as it possesses the similar chemical structure like cellulose and gets adsorbed on the surface of fiber [**5&11**].

Experimental

The bleached bagasse commercial pulp collected from a large integrated paper mill was used in the present study. The bagasse pulp was prepared in continuous digester and bleaching sequences CD- EOD were used. The long fiber bamboo pulp was used for blending with the bagasse pulp.

For the strength improvement, the cationic starch in different doses was used in making the standard paper sheet at different CSF in the pulp samples. The standard paper sheets of 60 gm/cm^2 basis weight were prepared by adding 1.2% fortified rosin size and ecorite PAC 2014 to control the pH of the pulp admixture at 5.0 0.5. The quantity of soap stone filler added was 15% of the quantity of oven- dried pulp.

The cationic starch in the standard paper sheet was added in different doses to observe the effect in strength

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development in the standard paper sheet. The cationic starch added was in 0.5%, 0.7%, and 1.0% of the total quantity of the oven-dried pulp. For maintaining the good retention of chemicals in the paper sheet, the retention aids chemicals N* [N-7607 (0.1%) coagulant and N7530 (0.25%) flocculent] were added in the admixture [**2**].

RESULTS AND DISCUSSIONS

Study of recycling of paper sheet made by bleached bagasse pulp

The paper sheet prepared from the bleached bagasse pulp was recycled five times. The burst and tear index of paper sheet were measured after each stage and the results are plotted in **Fig.1**. The burst index of paper sheet increases with a decrease in CSF. This is due to the fact that the specific surface area of the fiber increases due to the beating action of the fiber. The increase in surface area of the fiber leads to the strong bond formation among fibers resulting in an increase in burst index of the paper sheet. It can be noticed that the maximum loss of burst index was there in case of first recycled stage. The reduction in burst index is 16.4 % at 310 CSF, 29.3% at 510 CSF, and 27.2% at 560 CSF in first recycled paper sheet. Similarly, in the second recycled paper sheet 25.3% at 310 CSF, 32.6 % at 510 CSF and 36.2% at 560 CSF reductions in burst index were observed. In case of fifth recycle 48.7% at 310 CSF, 39.7% at 510 CSF, and 39.4% at 560 CSF losses in burst index was observed. The losses in burst index from first to 5th recycled paper sheet are gradual. The gradual decrease in burst index indicates gradual decrease in strength properties and it can be maintained by addition of strength improving chemicals and retention aids or by blending with long fibered bamboo pulp.

The **Fig.1** shows that at high CSF the reduction in burst index of first recycled sheet is more as compared to low CSF. This higher reduction occurs due to the hornification of the fiber in drying process at the initial stage, that leads to low bonding capacity at high CSF. At low CSF, the fibers are well beaten having greater specific surface area and the pulp contains more fibrillated fibers. When the paper sheet is made for first recycled stage, loss of burst index is less due to the good bonding of well-beaten and fibrillated stock at the low CSF. The only loss occurred in this case is due to the reduction in intrinsic strength of the fiber. This loss can be recovered by blending with beaten long fibered bleached bamboo pulp. The experiments were conducted by blending of bamboo pulp with bleached bagasse pulp. The effect of blending of bamboo pulp with bleached bagasse pulp and addition of fortified rosin size, poly aluminum chloride-2014 and retention aids on burst index of paper sheet are shown in **Fig.2**.

The reduction in burst index of the original paper sheet occurred due to the mixing of fortified rosin size and poly-aluminum chloride 2014, but the reduction occurred in the burst index was negligible due to the addition of retention aids in the stock prior to the standard sheet formation. The further reduction in burst index occurred by the addition of 15% soapstone filler. The reduced burst index was 2.24 at 310 CSF, 1.54 at 510 CSF, 1.74 at 560 CSF and 1.47 at 590 CSF**,** but blending with long fiber bamboo pulp and retention aids prevented the further loss in burst index. The **Fig. 2** shows that with the addition of cationic starch in the standard sheet. The improvement in strength properties was observed up to the appreciable extent i.e. up to 39.3% at 310 CSF with 1.0% dosing of cationic starch and 10% blending of bleached bamboo pulp. Similarly 61.7% increase in burst index was observed at 510 CSF and 43.7% increase in burst index was observed at 560 CSF.

Improvement in the burst index was observed with the (20%) blending of the bamboo pulp (**Fig. 3).** An increase (7.4 %) in burst index at 310 CSF was observed due to 1.0% dosing of cationic starch in the standard paper sheet. The increase in burst index due to the addition of 1.0% cationic starch dosing in the stock is 20.5% at 510 CSF and 32.1% at 560 CSF. It can be noticed that the addition of 1.0 % cationic starch content is more effective at higher CSF values of the bleached bagasse pulp. The blending of long fibered bamboo pulp with the bagasse pulp is more effective at 510 CSF with 1.0% cationic starch for the strength development in the standard paper formation. An increase in burst index (62.5%) was observed at 310 CSF due to 30% blending of the bleached bamboo pulp. Similarly an increase in burst index was noticed due to blending with 30% bleached bamboo pulp 62.5% at 310 CSF, 66.9% at 440 CSF, 79.2% at 510 CSF, 53.3% 540 CSF, 44.3% at 560 CSF, and 40.8% at 590 CSF (**Fig. 4**). It was also observed that the cationic starch plays a significant role in the burst index development of the standard paper sheet (15.6% increase in the burst index at 310 CSF, 9.1% increase at 510 CSF, and 13.5% at 560 CSF).

Effect on burst index of first recycled standard paper sheet

The maximum burst index of the paper sheet (2.04) was obtained at the 310 ml CSF along with the blending with bleached bamboo pulp due to an increase in the dose of cationic starch (1.0%) and retention aids N* (**Fig. 5**). An increase in burst index (about 33.8 %) was observed due to the increase beating action on the stock (i.e. from 590 CSF to 310 CSF). The loss in burst index of original paper sheet and first recycled stage is about 34.6 %. It shows that there is much loss in burst index at this recycling stage due to low bonding of fibers, which mainly occurs due to the hornification of fibers. The hornification turns the fibers hard and fiber looses the tendency to hold water become less flexible. This reduces the strong hydrogen bond formation among the fibers and the paper ultimately becomes weak and comparatively bulkier.

Effect of long fibered bamboo pulp blending ratio on burst index

The effect on burst index due to the increased blending (20%) of bamboo pulp is shown in **Fig.6**. An increase in burst index (31.0% at 310 CSF) was noticed and this could be possible due to the adhesion among the fibers by the cationic starch bond formation. The cellulose fiber and cationic starch possess the similar chemical structure. An improvement in the burst index of the paper sheet was noticed from (**Fig. 7)** when the blending of bamboo pulp was increased 30%.

Effects on burst index of second recycled paper sheet

The burst index of the paper sheet was found to be very low after the first recycle. In the re-slushing process, there was wear and tear of the fiber in the disintegration process of paper when paper sheet converts into the pulp. This was due to the fact that starch creates the hydrophobic characteristics in paper sheet, which contain considerable wet strength and require more mechanical treatment in the disintegration of paper pulp process. In view of the low strength of the second recycled paper sheet, the requirement of fresh pulp addition was needed to improve the burst index of the paper produced. Therefore, 50 % fresh pulp (A mixture of 70 % bagasse pulp and 30 % bamboo pulp) on oven dried basis was mixed with 50 % first stage recycled pulp (for all the four different sheets) for making the second recycled paper sheet. There were four paper samples after second recycle stage with the following compositions:

1. Pure bagasse pulp + 50 % fresh pulp
2. Bagasse pulp with 10 % bamboo pulp + 50 % fresh pulp
3. Bagasse pulp with 20 % bamboo pulp + 50 % fresh pulp
4. Bagasse pulp with 30 % bamboo pulp + 50 % fresh pulp

The results for the burst index are shown in **Fig. 8** and **Fig. 9** and the following conclusions can be drawn:

It was observed that the increase in burst index at 560 CSF with 1.0% starch dose and without long fiber pulp blending was about 9.0% compared to paper sheet prepared with 50% fresh pulp having no starch dose and no long fiber pulp blending. This shows that 1.0% starch addition is quite effective on 560 CSF (**Fig.8)**. At 310 ml 50% fresh pulp blending and 1.0% cationic starch dosing was carried out along with retention aids N* and an increase in burst index (28.3%) was observed as per the analysis of results of (**Fig.8)**. It indicates that 50% blending as a fresh pulp with the pulp of first recycled paper sheet provides the good result. This shows that the recycling of bagasse paper have good potential in recycled papermaking. In case of second recycled pulp at 310 CSF, the improved burst index 2.08 was observed by the addition of 1.0% cationic starch dosing and 30% long fibered bleached bamboo pulp blending. This shows 6.8% increase in burst index at 310 CSF against 8.2 % increase at 560 CSF. This shows that at low (310-CSF) the improvement in burst index is less compared to high CSF (CSF-560). From these results it can be concluded that the pulp fiber possesses low intrinsic strength due to the more beating treatment on the fibers. The pulp becomes weak due to the more mechanical treatment carried out in the beater as well as in the disintegrator at the time of re-slushing of the paper sheet for converting recycled paper into pulp. Moreover, by increasing the dose of starch content, there is less improvement in the burst index due the low intrinsic strength of the fibers. So for the strength development of the recycled paper sheet the long fiber blending is preferred instead of the strength improving chemicals.

Tear Index Improvement

The standard paper sheets were prepared for the study of tear index from the bleached bagasse pulp was recycled five times. The tear index of paper sheet was measured after each stage and the results are plotted in **Fig.10**. Normally the tear index increases up 540 CSF in this case, but if the degree of polymerization of the bagasse pulp is less then it may decrease earlier from the value mentioned above, because when the sugar mills starts in the beginning of the season the sugar cane supplied to the mills may have immature grown sugar cane along with low sugar content. The bagasse prepared from such sugar cane may contain the low degree of polymerization. It is observed that the tear index of paper sheet increase with a decrease in CSF up to a certain limit, afterward it starts decreasing as shown in **Fig.10**. This is due to the fact that the specific surface area of the bagasse fiber increases due to the beating action on the fiber. The increase in surface area of the fiber leads to the strong bond formation among fibers resulting in an increase in tear index. It can be noticed that the maximum loss of tear index was noticed in case of first recycled stage. The loss in tear index from first to 5th recycled paper sheet is gradual. The gradual decrease in tear index indicates gradual decrease in tear strength and it can be maintained by addition of strength improving chemicals and retention aids or by blending with long fibered pulp. In this case the bleached bamboo pulp was used for blending as a long fibered pulp in the bagasse pulp.

The **Fig.10** shows that at high CSF the reduction in tear index of first recycled sheet is less as compared to low CSF. This higher reduction occurs due to the hornification of the fiber in drying process at the initial stage which leads to low bonding capacity at low CSF and moderate bonding at high CSF. At low CSF, the fibers are well beaten having greater specific surface area and the pulp contain more fibrillated fibers having low intrinsic strength. When the paper sheet is made for first recycled stage, loss of tear index is less due to the good bonding of well-beaten and fibrillated stock. The only loss occurred in this case is due to the reduction in intrinsic strength of the fiber. This loss can be recovered by blending with beaten long fiber pulp. For the study of tear strength of beaten pulp samples contained in different containers having different CSF of pulps like 590, 560, 540, 510, 440 & 310 were tested after making the standard paper sheets. The seven varieties of standard paper sheets were made of each sample of beaten pulp separately (e.g. at 590 CSF). The first variety of paper sheet was made by pure bleached bagasse pulp without adding any chemical in the paper sheet. The second variety was made by pure bagasse pulp by adding fortified rosin size, poly-aluminum chloride (PAC) and retention aids N*, like (100% BG + No (SS+CS) + N*). The third variety of the standard paper sheet was prepared by pure bagasse pulp adding fortified rosin size, poly aluminum chloride, soap stone filler and retention aids N*, like (100% BG, X+Y +N*). The fourth verity of standard paper sheet was prepared by 90 % bagasse pulp and blending of 10% bleached bamboo pulp, adding fortified rosin size, PAC2014, soap stone filler and retention aid N*in it, like (90% BG + 10 % BB, X+Y + N*). The fifth variety of standard paper sheets were prepared by 90 % bleached bagasse pulp and 10% bleached bamboo pulp by adding fortified rosin size, PAC2014, soap stone filler and 0.5% cationic starch and retention aids N*, the brief composition of the paper sheet may be written as (90% BG + 10% BB, X + Y + 0.5% CS+ N*). The sixth variety of standard paper sheets were prepared from 90% bleached bagasse pulp and 10% bleached bamboo pulp by adding fortified rosin size, PAC- 2014, soap stone filler and 0.7% cationic starch and retention aids N*. The composition of sheets may be written as (90% BG + 10% BB, X + Y + 0.7% CS + N*). The seventh verity of paper sheets were prepared by 90% bleached bagasse and 10% bleached bamboo by adding fortified rosin size, PAC 2014, soap stone filler and 1.0% cationic starch and retention aids N*. Its paper sheets composition may be written as (90% BG + 10% BB, X + Y + 1.0% CS + N*). The composition of the standard paper sheets are the same at different CSF like 590, 560, 540,510, 440 and 310 as given in the figure. The graph represents that the average tear index of standard paper sheets as per the paper sheet composition given in the legend at the bottom side of the graph in **Fig. 11**. It was observed that the maximum tear index i.e. 2.82 was achieved at 540 CSF value of the pure bleached bagasse pulp. The tear index was observed on decreasing trend at 510 CSF. The tear strength also decreases by the addition of fortified rosin size and poly-aluminum chloride and retention aids to tear index 2.76 which indicate that the tear index gets affected by the addition of rosin size and alum contents. It is also observed that the maximum tear index is about 3.07 which is achieved with the addition of 1.0% cationic starch content with the blending of 10% bleached bamboo pulp 510 CSF.

Experiments were conducted by blending of bamboo pulp with bleached bagasse pulp. The effect of blending of bamboo pulp with bleached bagasse pulp and addition of fortified rosin size, poly aluminum chloride 2014 and retention aids on tear index of paper sheet are shown in **Fig.11**.

The reduction in tear index of the original paper sheet occurred due to the mixing of fortified rosin size and poly-aluminum chloride 2014. The further reduction in tear index occurred by addition of 15% soapstone filler but blending with long fiber bamboo pulp and retention aids prevent further loss in tear index **Fig.11** shows that with the addition of 1.0% cationic starch in the standard sheet, the improvement in tear index was observed up to the appreciable extent i.e. up to 12.7%. The improvement in the tear index was observed with an increase in blending of the bamboo pulp 10% the improvement in tear index varies from 3.07 to 3.46 at 540 CSF. The results of the tear index of standard paper sheets were given in **Fig. 12,** which depicts the effect of rosin size, PAC, and the effect of bleached bamboo pulp blending along with the effect of varying the doses of cationic starch. It was also observe that the maximum tear index i.e. (3.46) was achieved at 540 CSF with 20% bamboo pulp blending along with 1.0% cationic starch dosing **Fig. 12**. The increase in tear index was observed due to the increase in bamboo pulp blending on a increasing the rate i.e. from 10 to 20 %. This increases the tear index about 12.7 %, which shows that the blending of bleached pulp is helpful in achieving the good strength development in the paper sheets. These results also indicate that the further beating is not beneficial as per the results mentioned in case of tear index as per the **Fig. 12**. This decrease has been recovered by the addition of 1.0% cationic starch and 30% long fibered bamboo pulp in the stock. It was observed from **Fig.13,** that when the blending of bleached bamboo pulp was carried out up to the level of 30 % along with 1.0 % cationic starch dosing the maximum tear index was achieved to a value of 4.39, which is the 43 % more strength development then that the value given in **Fig. 11** (tear index 3.07). So this increase in tear index is helpful in making the specialty paper of desired strength for the specific purpose.

The blending of this 30% long fibered bamboo pulp and 1.0% cationic starch resulted in the increase in tear index up to 3.46 from 4.39. This improvement was only possible by the use of cationic starch 1.0% and 30% blending of beaten long fibered bleached bamboo pulp as per the **Fig. 13**.

First recycling of paper sheet: The results mentioned above of tear index were of original paper sheets. If these paper sheets were recycled, a decrease in tear index was observed, but to improve the tear strength in terms of tear index the blending of long fibered bleached bamboo pulp was carried out using varying doses of cationic starch content. It was observed that the maximum tear index with 10% bamboo pulp blending along with 1.0% cationic starch dosing was observed about 2.57 at 540 CSF as per the **Fig. 14.** The tear strength of bleached bagasse pulp was reduced appreciably, as in the case of first recycling process but these are the low results of the tear index of the recycled paper sheets, when the bleached bamboo pulp was blended up to 20 % along with 1.0 % cationic starch dosing. This value of tear index was increased up to 2.82 at 540 CSF as in the **Fig. 15**, which is 9.73 % more then the value given in the **Fig. 14**. The tear index achieved as per the **Fig. 15** has still low value, which can be further improved to the maximum value of 3.13 at 540 CSF as given in **Fig.16**. This value of tear index is 21.8 % more then the value of tear index mentioned in the **Fig. 14**. The value of tear index is still sufficient for the various grades of papers used for different specific purposes, and these papers can be further recycled. The tear index of paper decreased from 3.07 to 2.36 as per the **Fig. 11** to **Fig. 14**. at 510 CSF due to the recycling process. It can be further observed that the decrease in the tear index was 23.13%. This significant decrease in tear index was observed and it has been recovered by the addition 1.0 % cationic starch and 30% long fibered chemical pulp in the furnish. The improvement was observed with the use of 15% soap stone filler and 1.0% cationic starch at the first recycle stage. The recovered strength by using 20% long fibered pulp and 1.0% cationic starch improved the strength of tear index up to 2.65 at 510 CSF **Fig.15,** and 2.71 tear index was observed at 510 CSF **Fig.16.** Where as more strength of tear index was observed at 540 CSF with 20% long fibered pulp blending and 1.0% cationic starch dosing i.e. 2.82 tear index Fig. 15, and 3.13 tear index at 540 CSF with 30% long fiber blending and 1.0% cationic starch dosing in Fig.16.

Second Recycled of paper: The tear index of the paper sheet was found to be very low after the first recycle. Therefore, 50 % fresh pulp (A mixture of 70 % bagasse pulp and 30 % bamboo pulp) on oven dried basis was mixed with 50 % first stage recycled pulp (for all the four different sheets) for making the second recycled paper sheet as mentioned earlier in the case of burst index improvement.

The results of the second recycled papers prepared from these papers whose results are mentioned in **Fig. 17** and **Fig. 18**. In this case of second recycled paper sheets were made from the papers of first recycled paper sheets. The strength of paper sheet was decreased appreciably. So to improve the tear strength of the second recycled paper sheet 50% fresh pulp was blended to improve the strength and surface properties of paper in each case. It was observed that the previous papers having pure bleached bagasse fibers attained the maximum tear index 2.44 at 560 CSF **Fig.17**, which good enough for the writing or specialty paper. The second recycled papers having 10% bleached bamboo pulp, blended with 50% fresh pulp at 1.0% cationic dosing possess the maximum tear index 2.59 at 560 CSF as shown in **Fig.18**. The tear index of second recycled paper was observed 2.85 at 560 CSF in the case of 20% bleached bamboo pulp blending with 1.0% cationic starch dosing in **Fig. 18**, which is 9.3 % more than the value 2.59. When the blending of bleached bamboo pulp was increased to 30% with 1.0% cationic starch dosing, the maximum tear index 2.92 was observed which is 12.7% more than the previous result (i.e. 2.59) as shown in **Fig.18**. From the observation of the above results, it can be concluded that the good strength recycled bagasse paper can be produced many times by blending of the long fibered bleached bamboo pulp which is non wood fast growing specie by using strength improving chemical like cationic starch. The results for the tear strength are shown in **Fig. 17** and **Fig. 18** and the following conclusions can be drawn:

From the study of **Figs. 10 to 18** of recycling of agri-residue bagasse pulp, it can be concluded that the bagasse based recycled paper can be recycled many times using strength improving chemicals and blending of long fibered pulps for making the various grades of specialty papers for the specific use in our daily life. The tear index of the bagasse pulp may be achieved in the optimized range by the study of various beating degree i.e. from 560 to 510 CSF range for getting good tear index of the paper sheet.

CONCLUSIONS

The fortified rosin size and poly aluminum-chloride were used for controlling the water repellency characteristics of the paper, but these chemicals also reduced the strength properties of paper produced in the manufacturing of paper from the secondary fibers of bagasse paper. More reduction in strength properties occur due to the addition of inorganic chemicals like soap stone filler which provide the surface smoothness, glaze and ink receptivity in the paper sheet. Efforts were made in the present study to recover the strength properties of paper by adding strength improving chemical like cationic starch. The cationic starch gets adsorbed on the large surface area of the fiber fines and improves the paper sheet consolidation with the action of retention aids (polyelectrolytes) on the wire part into the paper web at the time of sheet consolidation. These retention aids chemicals improve inter-fiber bond among the cellulose fibers due to the interaction between fiber and cationic starch, which result in achieving the improved dry strength of the paper produced. To improve the burst and tear index of paper, some quantity of bleached long fibered bamboo pulp along with appropriate quantity of retention aids like coagulant and flocculent were added in the stock prior to the standard paper sheet formation.

It is observed that addition of strength improving chemicals are effective up to certain limit but for more improvement in the burst and tear index, it is necessary to add some quantity of long fibered pulp into the stock prior to first recycled paper sheet formation. The long fibered chemical pulp like bleached bamboo pulp blending was carried for the improvement in the burst and tear index of paper sheet. The present study indicates that there is very good potential of recycling of the bagasse paper. It has been observed that long fibered pulp and cationic starch are beneficial for increasing the burst and tear index of the recycled paper.

The recycling of bagasse paper sheet will be economical to the agro-residue based paper manufacturing mills. Moreover, the use of bagasse as the raw material for paper manufacture will help in conserving the ecological balance as the bagasse pulp require low bleaching chemicals compared to other raw materials. The recycling of the bagasse pulp will reduce the pollution load of the paper mills and require low consumption of chemicals, water, electricity, manpower and transportation charges. Further, it will also reduce the transportation load of raw material and crowdedness on roads and it will not be wrong to say that the recycling of the bagasse based paper recycling is eco-friendly.

The paper produced using cationic starch has high gloss and good surface properties. The paper containing cationic starch content possesses the hydrophobic characteristics or wet strength, which consume relatively more time and power at the disintegration stage of paper into pulp. The recycling of bagasse paper will be economical to the agro-residue base paper manufacturing mills.

Nomenclature

BB	Bleached Bamboo Pulp (Long Fiber Pulp)
BG	Bleached Bagasse Pulp
BI	Burst Index
CS	Cationic Starch T-25
CSF	Canadian Standard Freeness
FP	Fresh Pulp
N*	Retention Aids (Coagulant N-7607 and Flocculent N-7530)
X	Fortified Rosin Size and Poly Aluminum Chloride
Y	Soap Stone Filler (SS)
TI	Tear Index of paper sheet

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FIGURE CAPTIONS

Fig.1- B.I. of the original and recycled paper prepared from BG pulp at different CSF.

Fig.2- B. I. vs. CSF, paper prepared from BG, BB (10%) pulp and chemicals.

Fig.3- B. I. vs. CSF, paper prepared from BG, BB (20%) pulp and chemicals.

Fig.4- B. I. vs. CSF, paper prepared from BG, BB (30%) pulp and chemicals.

Fig.5- B. I. vs. CSF, 1st recycled paper prepared from BG, (10%) BB pulp and chemicals.

Fig.6- B. I. vs. CSF, 1st recycled paper prepared from BG, (20%) BB pulp and chemicals.

Fig.7- B. I. vs. CSF, 1st recycled paper prepared from BG, (30%) BB pulp and chemicals.

Fig.8- B. I. vs. CSF, 2nd recycled paper prepared from BG, 50% fresh pulp and chemicals.

Fig.9- B. I. vs. CSF, 2nd recycled paper prepared from BG, 50% fresh pulp and chemicals.

Fig.10 - T. I. of the original and recycled bagasse paper sheets samples vs. CSF.

Fig.11- T. I. vs. CSF of paper, prepared from BG pulp blended with 10% BB pulp and chemicals.

Fig.12-T. I. vs. CSF of paper prepared from BG pulp, blended with 20% BB pulp and chemicals.

Fig.13-T. I. vs. CSF of paper prepared from BG pulp, blended with 30% BB pulp and chemicals.

Fig.14-T. I. vs. CSF of 1st recycled paper prepared by blending of 10 %BB pulp with BG pulp and chemicals.

Fig.15-T. I. vs. CSF, of 1st recycled paper prepared by blending of 20% BB pulp, with BG pulp and chemicals.

Fig.16-T. I. vs. CSF, of 1st recycled paper prepared by blending of 30% BB pulp, with BG pulp and chemicals.

Fig. 17- T. I. vs. CSF, of 2nd recycled paper prepared by BG pulp adding fresh pulp and chemicals.

Fig.18- T. I. vs. CSF of 2nd recycled paper prepared by blending of BB pulp, with recycled BG pulp along with fresh pulp and chemicals.

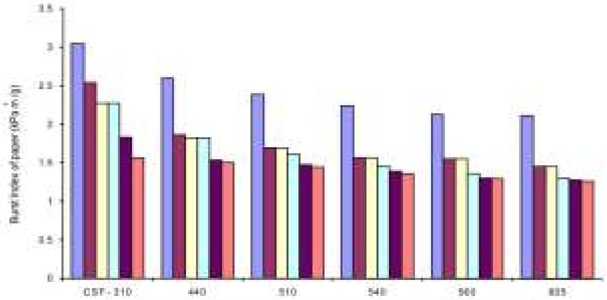

Fig.1

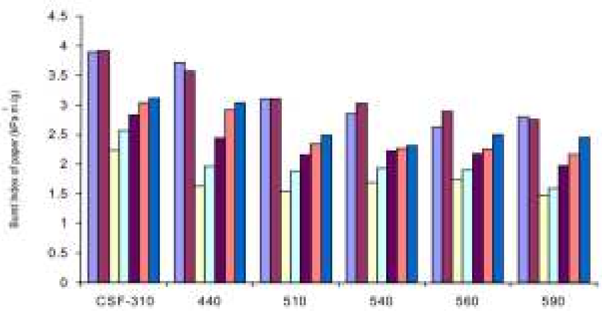

Fig.2

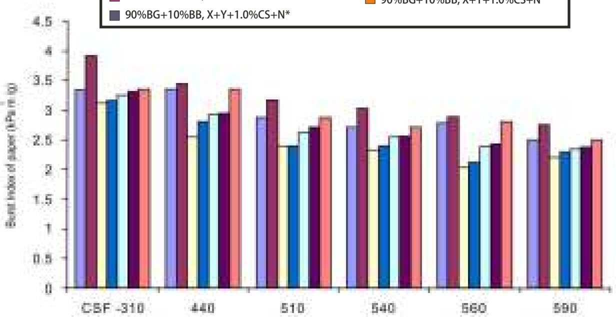

Fig.3

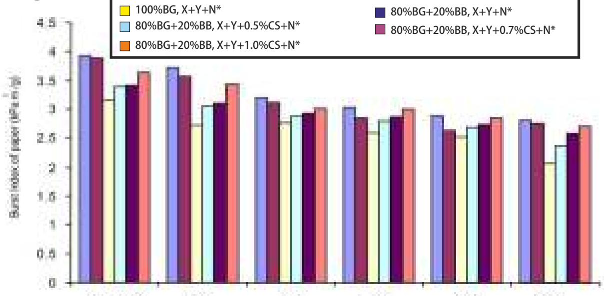

Fig.4

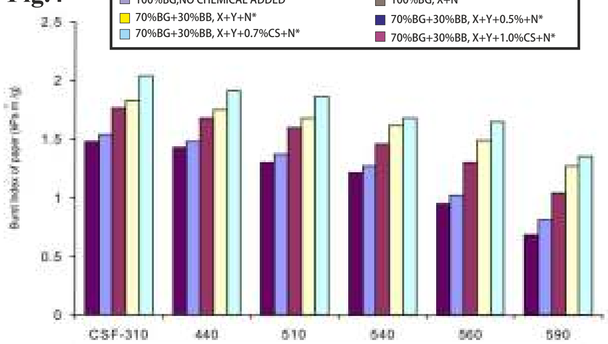

Fig.5

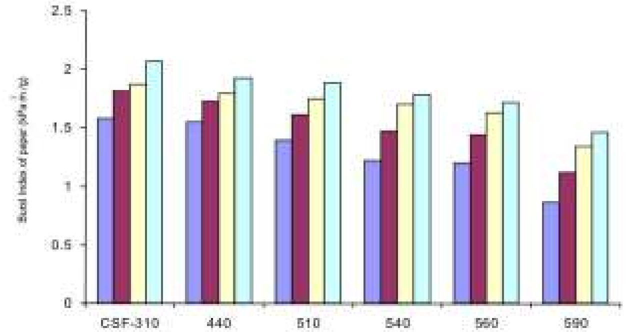

Fig.6

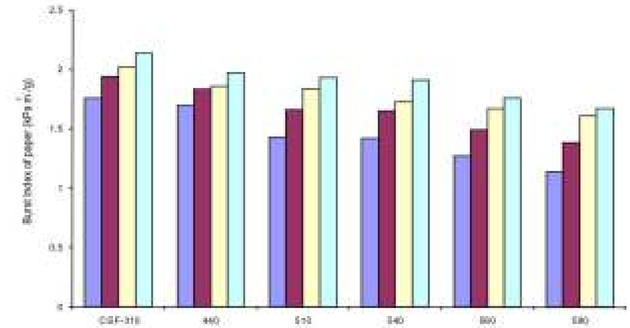

Fig.7

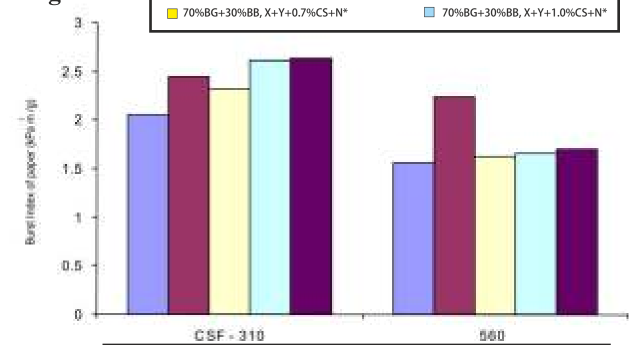

Fig.8

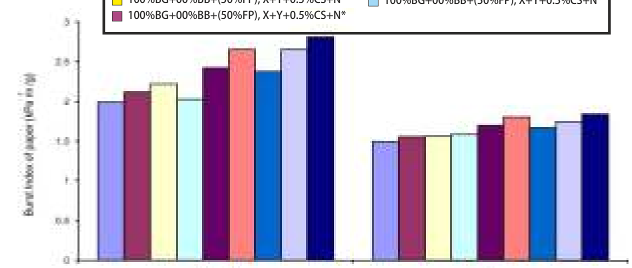

Fig.9

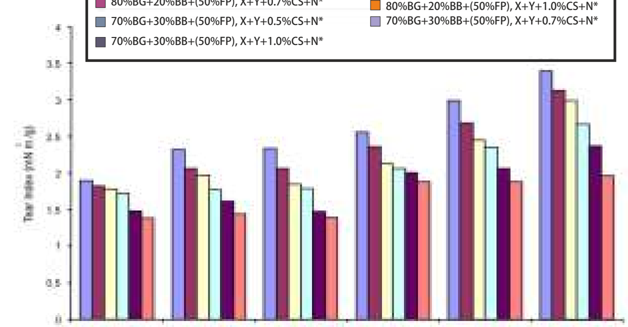

Fig.10

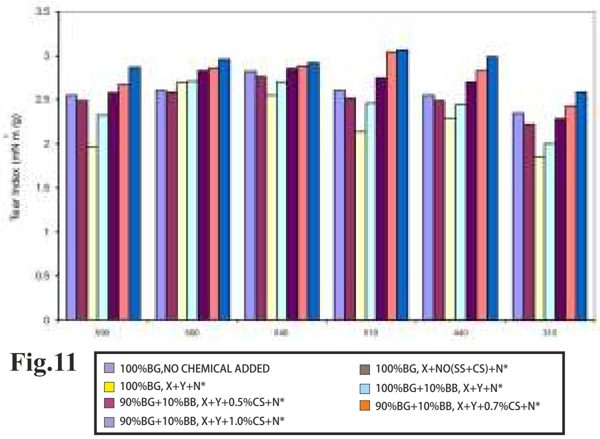

Fig.11

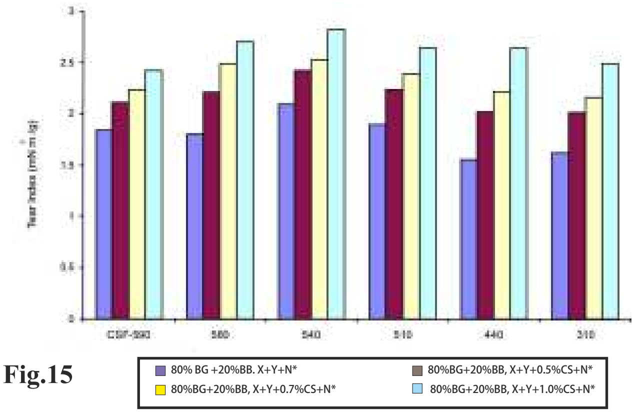

Fig.15

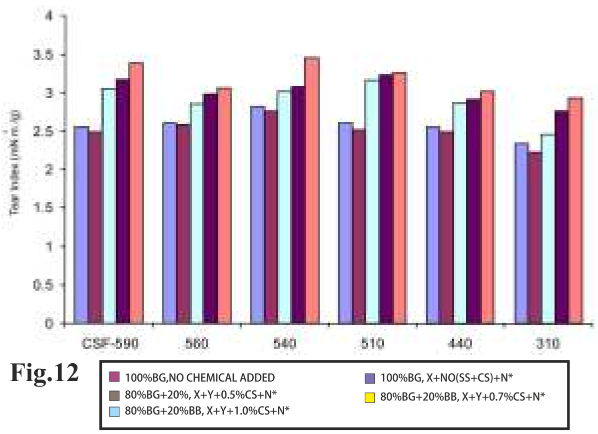

Fig.12

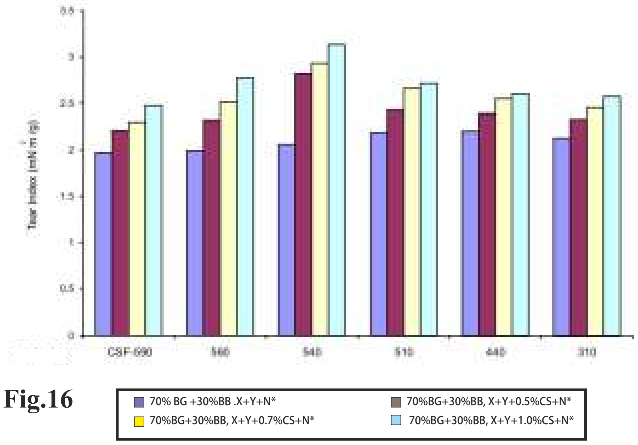

Fig.16

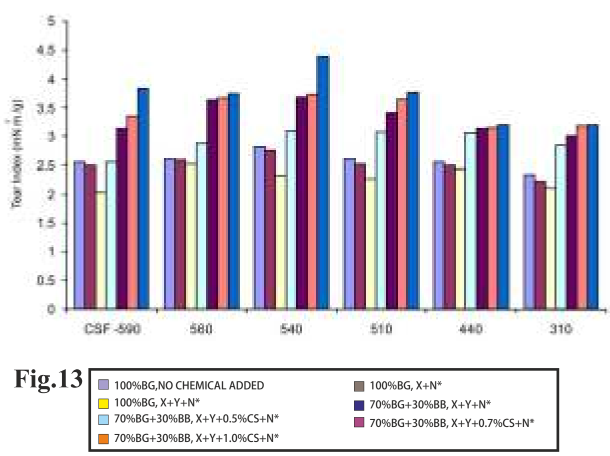

Fig.13

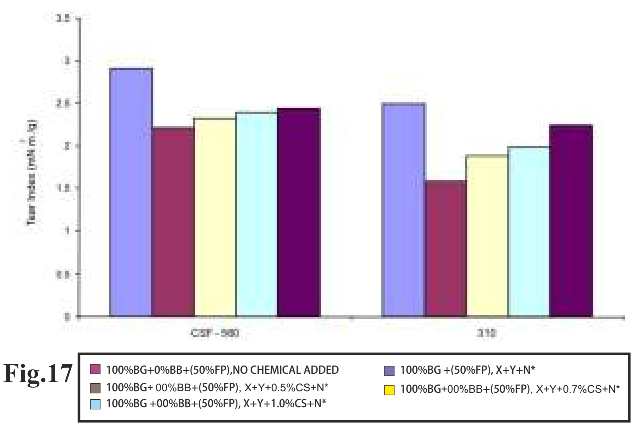

Fig.17

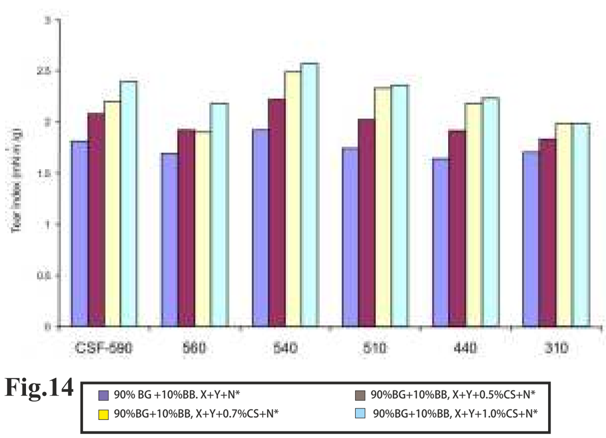

Fig.14

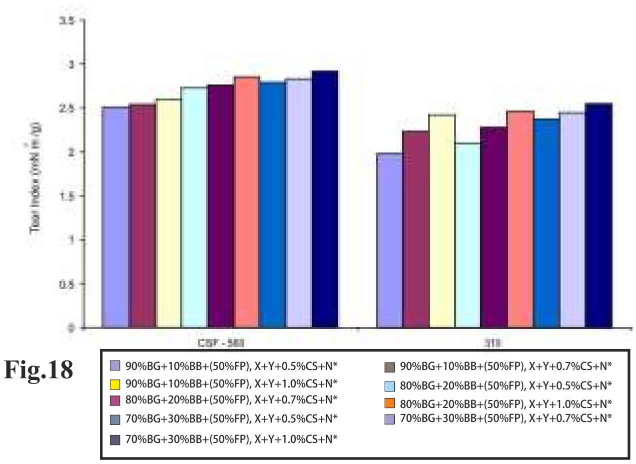

Fig.18