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Rice Straw as a Raw Material For Paper Making

Introduction

Ever-increasing demand for paper, dwindling supply of such conventional raw material like bamboo and non-availability of long-fibered coniferous woods have necessitated the Paper Technologists of our Country to innovate methods of high-yield pulping and to find out the suitability and technical feasibility of short fibered cellulosic materials like hard-woods, hemp, jute sticks and agricultural residues for paper-making. Hardwoods utilization is now a viable proposition and in fact many mills have started using hardwoods in a big way and have overcome many technical problems.

Rice cultivation is a main vocation in Coastal Districts of Andhra Pradesh and rice straw is available in abundance. An extensive study on rice straw was undertaken to find out its utility as a raw-material for paper making so that it can be made use of in future.

Experimental

Various pulping methods namely lime cooking, soda cooking,

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Laboratory experiments were carried out with locally procured rice straw for making writing, wrapping & printing grades of paper. Lime, Soda, Sulphate and NSSC pulping methods were tried and the pulp thus obtained was bleached with Calcium Hypochlorite solution. Soda pulping was found to be most suitable. Straw pulp was also blended with Sulphate bamboo pulp in various proportions and the strength properties of the resultant sheets were recorded. Sheets of writing, printing and wrapping grades of paper could be made with the admixture of soda pulp in appropriate proportion with bamboo sulfate pulp.

sulphate cooking, and NSSC cooking were tried with the rice straw, procured locally. The conditions of these experiments along with the results are given in tables I, II, VI & VIII.

Rice straw was shredded into pieces of average length of 5 to 6 cms. Cookings were done in Tumbling Type Digester of 35 litres capacity. Lime cooking was done with 15% lime (based on available CaO) added on B. D. straw basis. Temperature of the

cook was 140°C and the duration was 2½ Hrs. which included ½ hour for raising the temperature to 140°C.

Four soda cooks were done with 5%, 6%, 8% and 10% NaOH added on B. D. Straw basis. Cooking temperature was 140°C and the total cooking period was 2½ hrs. which included ½ hr. for raising the temperature to 140°C. Kraft cooking was done with white liquor of 16% sulphidity. The percentage of chemical added

TABLE No. I
Lime Cooking of Rice Straw

S. No.	Particulars		
1.	Chemical used (Lime as available CaO)	%	15.0
2.	Bath ratio		1:5
3.	Cooking temperature	°C	140
4.	Cooking time	Hrs.	2
5.	Yield	%	79.6
6.	Permanganate No.		37.5
7.	Strength Properties Evaluated at 40°SR		
	I Burst factor		5.4
	II Breaking length	Mtrs.	1060
	III Tear factor		28
	IV Double folds		Nil

was 8% as Na_2O . Temperature of the cook was 160°C and cooking duration was 1 hr.

Two NSSC cookings were done with 10% and 12% Na_2SO_3 with an initial pH of the liquor as 10.6 and 10.8 respectively (3% of Na_2CO_3 on B. D. straw basis was added to the sulphite solution). Cooking temperature was 160°C and cooking time was 1 hr.

After the completion of the cook in each case, pulp was washed well and defibrated to remove the fiber bundles and lumps in the valley beater without applying load. After this treatment, the freeness of the stock was determined. In most of the cases, the freeness was found to be around 40°SR . For the other cooks, the pulp was beaten to bring the freeness to 40°SR prior to sheet making in the British Standard Sheet Maker. All the paper testings were done as per the TAPPI Standard procedures.

Bleaching experiments were carried out with soda, kraft, and NSSC Pulps, the bleaching chemical being calcium hypo chlorite solution. Amount of hypo solution added was 8% and 12% on B. D. pulp basis.

Sulphate bamboo pulp was admixed with straw pulp in all the cases except with lime pulp in different proportions and the strength properties of the result-sheets are furnished in Tables III, IV, V, VII, IX and X.

Proximate analysis results and fiber length values are also presented in Tables XI & XII.

TABLE NO. II
SODA COOKING OF RICE STRAW

S.No.	Particulars	1	2	3	4
1.	Chemical used as NaOH%	5.0	6.0	8.0	10.0
2.	Bath Ratio	1:5.0	1:5.0	1:5.0	1:5.0
3.	Cooking temperature $^\circ\text{C}$	140	140	140	140
4.	Cooking time Hrs. (it includes 30 Mts. for raising the temp. to 140°C)	2.5	2.5	2.5	2.5
5.	Yield %	65.2	62.0	59.0	54.5
6.	K. No.	34.3	30.8	24.0	17.0
7.	Strength Properties evaluated at 40°SR				
	I Burst factor	10.1	10.0	11.4	10.8
	II Breaking Length Mtrs	2550	2110	2760	2750
	III Tear factor	37	32	37	31
	IV Double Folds Nos.	2	3	2	2
8.	Bleaching				
	I Hypo added %	—	8.0	12.0	8.0
	II Retention time Hrs.	—	1.5	1.5	1.5
	III Brightness %	—	35.0	56.0	60.0
	IV Burst factor	—	—	—	13.6
	V Breaking length Mtrs.	—	—	—	2750
	VI Tear factor	—	—	—	31
	VII Double folds	—	—	—	2

Table-3
Strength properties of Soda Pulp of Rice Straw and its admixtures with bamboo chemical pulp. Soda cooking chemical 6% as NaOH.

S.No.	Particulars	100% Rice Straw	80% RS 20% bamboo	60% RS 40% bamboo	40% RS 60% bamboo	100% bamboo
1.	Burst factor	10	15.5	18.9	24	32
2.	Breaking length METRES	2110	3310	4360	5110	6220
3.	Tear factor	32	56	60	64	90
4.	Double folds Nos.	3	6	11	18	125

Table-4.
Strength properties of Soda Pulp of Rice Straw and its admixtures with bamboo chemical pulp. Soda cooking chemical 8% as NaOH

S No.	Particulars	100% Rice Straw	80% RS 20% bamboo	70% RS 30% bamboo	60% RS 40% bamboo	100% bamboo
1.	Burst factor	11.4	16.4	20.9	22.6	32
2.	Breaking length Metres	2760	3560	4480	4630	6110
3.	Tear factor	37	49	53	64	107
4.	Double folds Nos.	2	5	11	15	78

Results and Discussion

The straw used for experiments was greenish yellow in colour and contained lot of husk. Removal of husk was not carried out in the laboratory owing to lack of adequate equipment. However, it is desirable that husk be removed from the straw before its use in the plant. Otherwise, the quality of pulp will not be good.

Proximate analysis (Table XI) reveals that straw contains high percentage of ash and low percentage of lignin.

Lime Pulping

In agreement with the earlier report⁵ lime pulping has resulted in pulp possessing weak strength. So lime pulp is suitable for making straw board only.

Soda Cooking

The yield was 65.2% for 5% soda cook and steadily dropped with increase in chemical as expected. For 10% NaOH cook, yield was 54.5%. K. No. of the pulp also dropped appreciably from 34.3 to 17 when chemical percentage was increased from 5% to 10%. Figure-1 gives the influence of chemical percentage on yield and K. No. However, there is no enhancement in strength with increase in chemical percentage. This may be attributed to the inherent weak strength of the raw material itself. Drainage characteristic of the stock on the wire while making sheet was poor and this could be explained by the fact that the rice straw

Table-5.
Strength properties of Soda Pulp of Rice Straw and its admixtures with bamboo chemical pulp. Soda cooking chemical 10% as NaOH

S.No.	Particulars	100% Rice Straw	80% RS 20% bamboo	70% RS 30% bamboo	60% RS 40% bamboo	100% bamboo
1.	Burst Factor	10.8	21.6	22.2	26.9	31
2.	Breaking length Metres	2750	3950	4450	5450	5830
3.	Tear Factor	31	40	47	55	97
4.	Double folds Nos.	2	4	11	18	43

Table-6.
Kraft cooking of Rice Straw

S.No.	Particulars		
1.	Chemical used as Na ₂ O	%	8.0
2.	Bath ratio		1.5
3.	Temperature raising time	Hrs.	1.5
4.	Cooking time	Hrs.	1.0
5.	Cooking temperature	°C	160
6.	Yield	%	53.1
7.	Permanganate number		16.0
8.	Strength Properties evaluated at 40°SR		
	I. Burst factor		10.5
	II. Breaking length	Mtrs.	2360
	III. Tear factor		32
	IV. Double folds	Nos.	2
9.	Bleaching		
	I. Hypo added as Cl ₂	%	8.0
	II. Retention time	Hrs.	1.5
	III. Brightness	%	63.0
10.	Strength Properties evaluated at 40°SR		
	I. Burst Factor		11.3
	II. Breaking length	Mtrs.	2860
	III. Tear Factor		30
	IV. Double folds	Nos.	2

Table-7
Strength properties of Kraft pulp of Rice Straw and its admixtures with bamboo chemical pulp.

S.No.	Particulars	100% Rice Straw	80% RS 20% bamboo	70% RS 30% bamboo	60% RS 40% bamboo	100% bamboo
1.	Burst factor	10.5	17.0	21.6	25	30
2.	Breaking length Metres	2360	3250	3840	4600	6050
3.	Tear factor	32	51	54	58	97
4.	Double folds Nos.	2	3	7	12	50

pulp is short fibered. Its average fiber length is 1.18 mm.

The bleachability of the pulp increased with increase in percentage of cooking chemical. Bleached pulp strength was more or less comparable with unbleached pulp strength. Since it is possible to bleach the pulp to 60% brightness without affecting its strength, writing and printing grade of paper can be made by blending with suitable proportion of bamboo kraft pulp.

Utilisation of straw pulp alone for paper making is not possible because of its low strength and slow drainage characteristic^a. To incorporate better strength in the pulp and for good runnability on the machine, it is necessary that rice straw pulp should be blended with long fibered pulp. Figures 2, 3 & 4 give the influence of blending bamboo pulp with rice straw pulp on strength property. From the results it is evident that 60% of bamboo pulp is to be mixed with 40% straw pulp for 6% soda cook, to obtain minimum acceptable strength properties, for paper making. However, with 8% and 10% soda cook, it is sufficient to blend 40% of bamboo pulp with 60% of straw pulp.

Kraft Cooking

Kraft pulping was attempted with a view of getting pulp having better strength and bleachability than soda pulp. The yield was 53.1% for the cook using 8% chemical as Na_2O . K. No. was 16. Though the

Table-8
NSSC PULPING OF RICE STRAW

S.No.	Particulars		1	2
1.	Chemical used as Na_2SO_3	%	10.0	12.0
2.	Bath ratio		1:5	1:5
3.	Buffer added as Na_2CO_3	%	3	3
4.	Cooking liquor pH		10.6	10.8
5.	Temperature raising time	Hrs.	1.5	1.5
6.	Cooking temperature	$^{\circ}\text{C}$	160	160
7.	Cooking period	Hrs.	1.0	1.0
8.	Spent liquor pH		7.7	7.6
9.	Yield	%	61.0	60.0
10.	Permanganate Number		25.0	24.0
11.	Strength Properties evaluated at 40°SR			
	I. Burst factor		9.8	10.3
	II. Breaking length	Mtrs.	2550	2660
	III. Tear Factor		31	30
	IV. Double folds		2	2
12.	Bleaching			
	I. Hypo added as Cl_2	%	8.0	8.0
	II. Retention time	Hrs.	1.5	1.5
	III. Brightness	%	48	52
	IV. Strength Properties at 40°SR			
	a. Burst factor		13.8	14.3
	b. Breaking length	Mtrs.	3440	3360
	c. Tear factor		28	30
	d. Double folds		2	2

Table-9.
Strength Properties of NSSC Pulp of Rice Straw and its admixtures with bamboo chemical pulp.
10% chemical as Na_2SO_3

S.No.	Particulars	100% Rice Straw	80% RS 20% bamboo	70% RS 30% bamboo	60% RS 40% bamboo	100% bamboo
1.	Burst factor	9.8	15.9	19.7	21.2	32
2.	Breaking length Mtrs.	2550	3230	3830	4400	5640
3.	Tear factor	31	41	53	58	89
4.	Double Folds Nos.	2	3	5	9	58

Table-10.
Strength properties of NSSC Pulp of Rice Straw and its admixtures with bamboo chemical pulp.
12% chemical as Na_2SO_3

S.No.	Particulars	100% Rice Straw	80% RS 20% bamboo	70% RS 30% bamboo	60% RS 40% bamboo	100% bamboo
1.	Burst factor	10.3	17.0	20.5	24	33
2.	Breaking length Mtrs.	2660	3470	4330	4640	6000
3.	Tear factor	30	39	52	61	133
4.	Double folds Nos.	2	4	7	13	138

bleachability of kraft pulp was better than soda pulp, there is no significant improvement in its strength. Figure 5 gives the influence of bamboo pulp blending with rice straw pulp on strength properties. From the graph it is evident that 60% of straw can be admixed with 40% of bamboo to get the required paper making characteristics.

NSSC Pulping

Yield was good in both the cooks and it was even better than soda cook. Strength properties were comparable with soda pulp though the NSSC pulp was lighter in shade because of the presence of lignin in uncondensed state.

Bleachability was also good² Figures 6 & 7 give the influence of bamboo pulp blending with rice straw pulp at various proportions on strength properties. It may be expedient to conclude that mixture of 40% of bamboo pulp and 60% of straw pulp will possess the desired strength properties for paper making.

Conclusions

1. The bulk density of rice straw is 46 kgs/m³. Hence, handling and storing will be difficult
2. Wrapping, printing & writing grades of paper cannot be made by cooking the straw (available in this region) with lime because of very low strength property of the pulp. It is suitable for making straw-board only.
3. Though soda, kraft and NSSC processes are suitable for making wrapping and writing

Table-11
PROXIMATE ANALYSIS OF RICE STRAW

S.No.	Particulars	%
1.	Ash	13.6
2.	Silica	12.2
3.	Hot water solubility	15.6
4.	1% Alkali solubility	51.3
5.	Alcohol—Benzene extractives	10.3
6.	Pentosans	20.9
7.	Holo-cellulose	72.0
8.	Lignin (Corrected for Ash)	8.3

All the values are expressed as percentages on OD basis.

Table-12.
Fibre length of Rice Straw

S.No.	Particulars	
1.	Minimum	0.24 mm
2.	Maximum	2.72 mm
3.	Average	1.18 mm

grades of paper, soda is the most prospective because of the low cost involved.

4. Cooking of rice straw with 5 to 6% NaOH will yield a reasonably good pulp. Because of its slow drainage characteristic and low strength, straw pulp is to be blended with long fibered pulp, the ideal mixture being 40% of bamboo and 60% of straw pulp.
5. Kraft pulp and NSSC pulp possess strength properties which are almost on par with soda pulp. The bleachability of these two pulps is better than soda pulp. Hence to obtain bright pulp, kraft pulping and NSSC pulping may be preferred.

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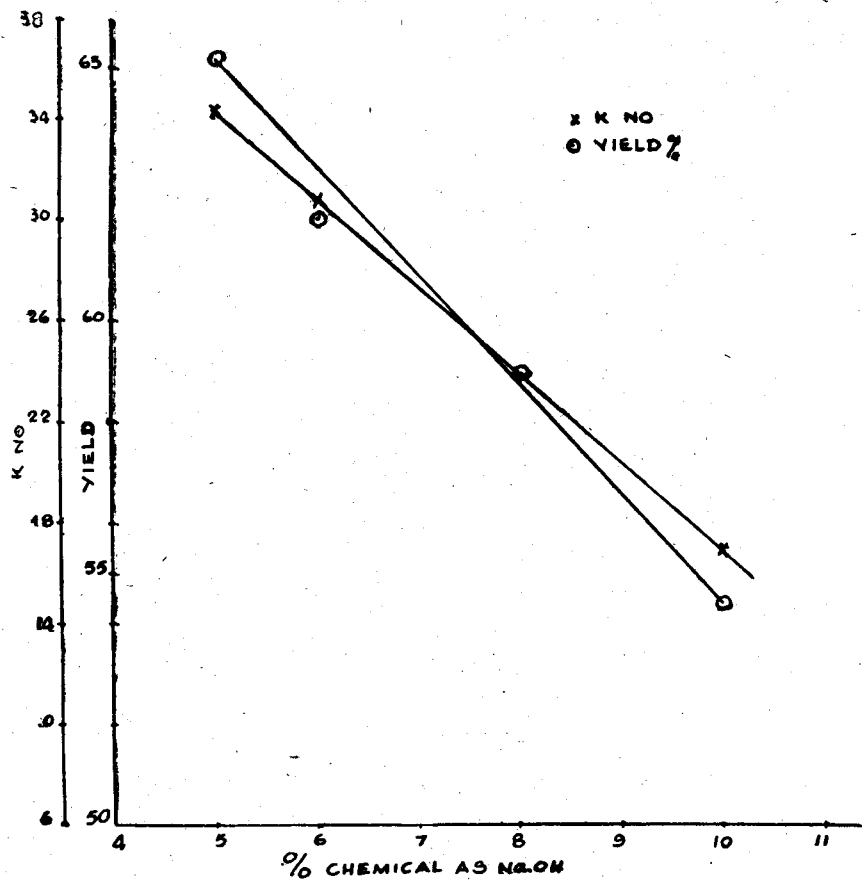


Fig. 1—Influence of chemical percentage on yield and K. No: in soda cookings of rice straw.

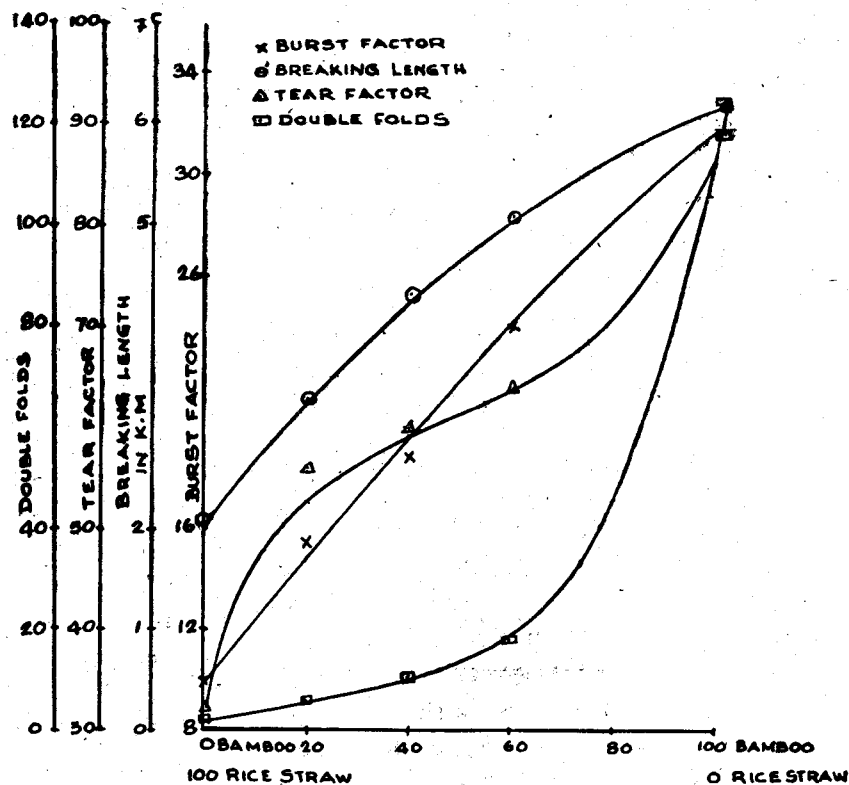


Fig. 2—Influence of blending bamboo pulp with rice straw pulp (6% soda cook) on strength properties.

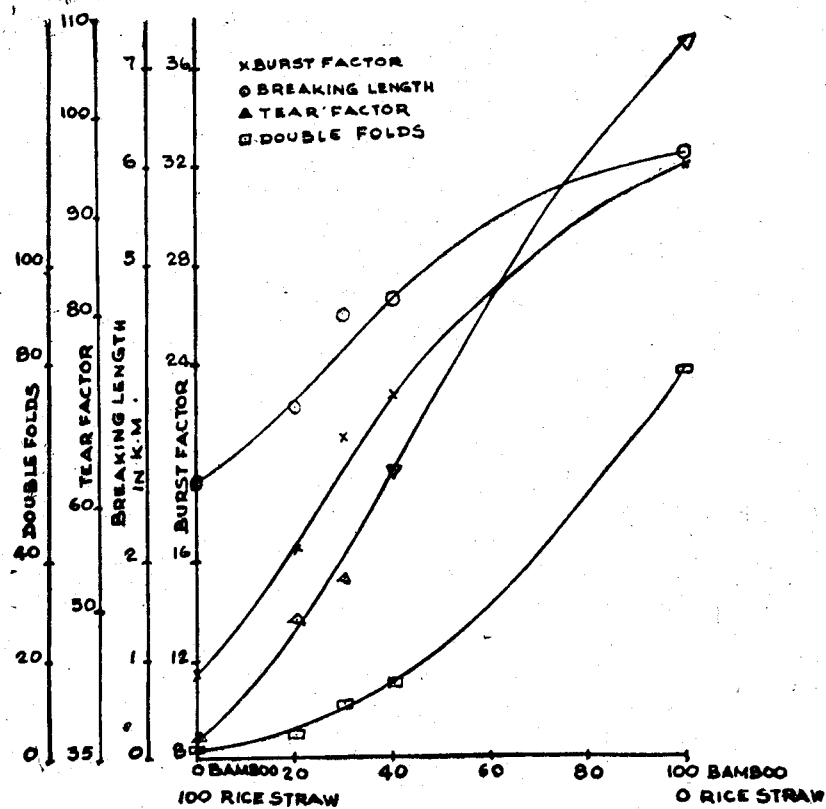


Fig. 3—Influence of blending bamboo pulp with rice straw pulp (8% soda cook) on strength properties.

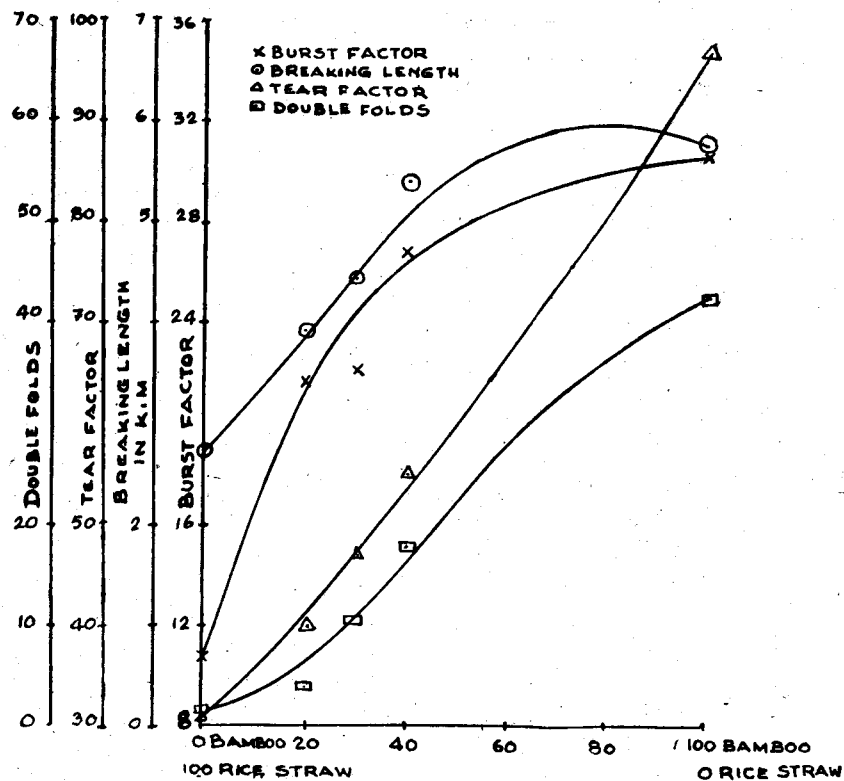


Fig. 4—Influence of blending bamboo pulp with rice straw pulp (10% soda cook) on strength properties.

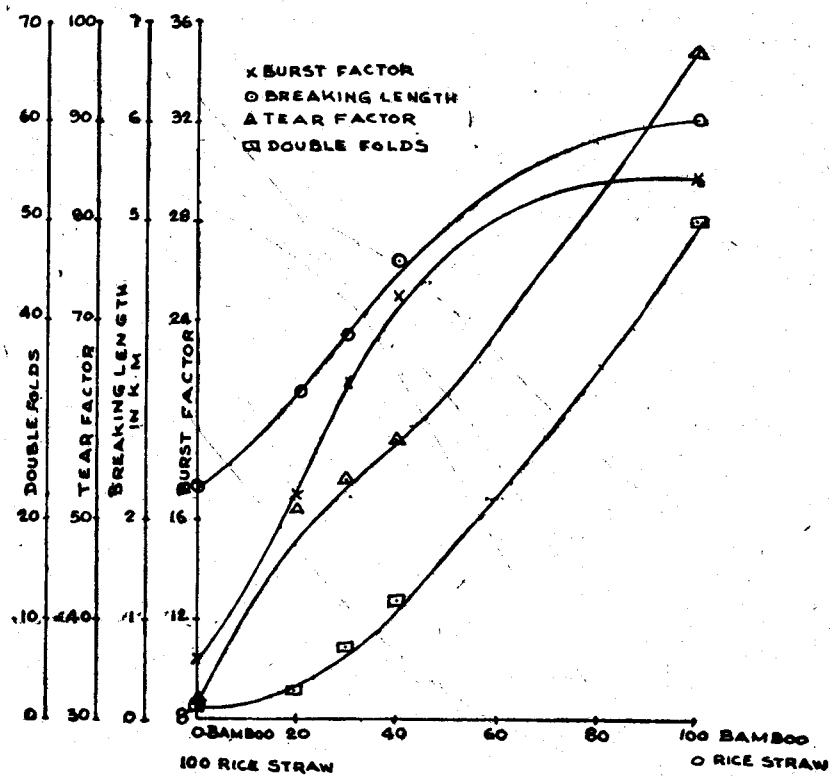


Fig. 5—Influence of blending bamboo pulp with rice straw pulp (kraft cook, 8% chemical as Na_2O) on strength properties.

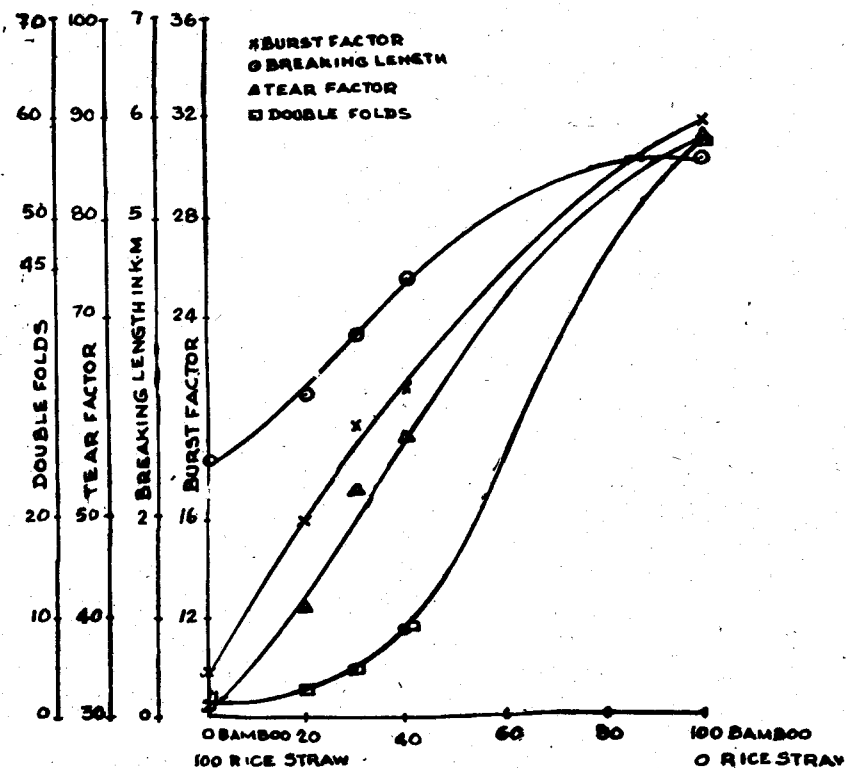


Fig. 6—Influence of blending bamboo pulp with rice straw pulp (NSSC pulping, 10% chemical as Na_2SO_3) on strength properties.

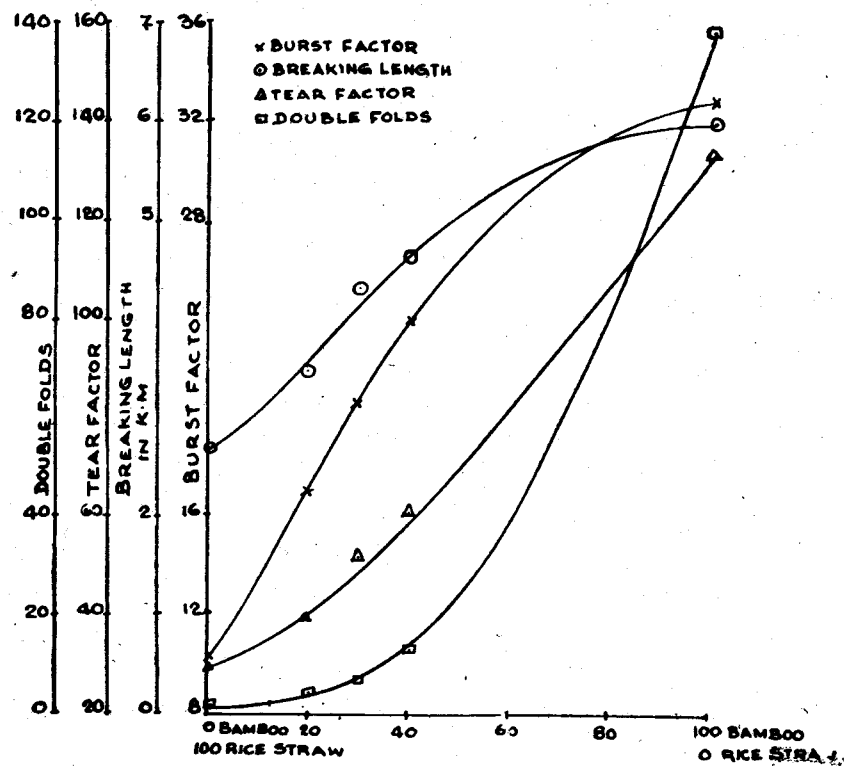


Fig. 7—Influence of blending bamboo pulp with rice straw pulp (NSSC pulping, 12% chemical as Na_2SO_3) on strength properties.