Data for Amendment in stiffness specifications for different Paper Grades under BIS Standards

(CESS PROJECT)

Based on the work of

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Executive Summary

Stiffness has become an important parameter for most of paper grades. Bending stiffness is necessary for good runnability on the printing presses and converting machines.

Bureau of Indian Standards has prescribed different values for cover paper, photocopier paper, coated board and straw board. Different terminology has been used in different standards and there is no uniformity in prescribed methods of testing and ways of expressing the results. This is posing lot of problem to Paper manufacturers and traders dealing in national and international market. Detailed studies were carried out on different papers and uniformity has been brought out by specifying the term Bending stiffness index. The recommended values for above grades of paper has mentioned in the report.

TABLE OF CONTENTS

1.0 Background

Bureau of Indian Standards Paper & Paper Product Sectional committee CHD 15, which comprises of members from paper mills, Government organizations, Paper Traders and Academic Institution formulate BIS specifications for different paper grades. These standards are revised every 4 to 5 years duration keeping in view the developments in manufacturing processes and trades. In the recent past, in number of meetings, the members of Committee have raised the enquiries about stiffness parameter defined for Cover paper, Photo-copier paper, coated board & straw board. The general observations are that :-

- Stiffness measurement has become a confused concept according to the procedure prescribed in different BIS standards.
- The nomenclature used in these standards is not as per International Standards.
- The test method prescribed is no longer relevant.
- There is no uniformity in specified values.

The members desired that a systematic study should be undertaken in this area so that relevant alternations could be done in existing BIS standards. This will be beneficial for Paper manufacturers and traders dealing in national and international market.

2.0 Objectives

The project was envisaged with objectives as under

- To evaluate the stiffness parameter for Cover Paper, Photocopier Paper, Coated boards and Straw boards from different mills.
- To specify measuring method, measurement units, the interpretation and recommend values for different paper grades.

3.0 Scope of work

The scope of work of the project was under:

1) Collection of samples from different mills.
2) Evaluation of samples using commonly used stiffness testers in Indian Paper Industry viz Taber type, Bending stiffness type.
3) Evaluation of different test methods.
4) Recommend the values for different BIS standards.

4.0 Importance of Stiffness

For paper or board, a proper bending stiffness is necessary for good runnablility on the printing presses and converting machines. Paper used for printing – so called cultural paper – could not be handled so simply and rationally in printing presses if paper did not have a high stiffness. A uniform tensile stiffness over the width of the paper web is for instance a condition for good register. During post-treatment in the bindery, the folding machines usually require a certain bending stiffness for good convertibility.

In photo copying machine proper stiffness is necessary for proper functioning. Paper products like corrugated fibre board boxes are manufactured from materials which have a marked stiffness towards tensile and compression forces. Modern liquid packages, cartons etc. are further examples of a paper usage which would be impossible without the considerable bending stiffness of the material. Even daily newspaper requires sufficient stiffness for comfortable reading. Overall stiffness has become an important parameter for most of paper grades.

5.0 Comments on stiffness test methods prescribed under different BIS standards

5.1 Stiffness test method mentioned in IS:1060 (Part III) – 1969.

The following are the drawbacks:

- Description of the test instrument to be used is not clear.
- Prescribed sample size 15mm wide and about 50 mm long which do not tally with International standards.
- Bending angle is 5^0 which also is not agreement with international standards.
- Stiffness factor has been recommended for reporting which has been defined as

$$\text{Stiffness factor} = \frac{\text{Stiffness (g.cm)}}{10\ t^3}$$

where, t = thickness in mm

5.2 Stiffness test method mentioned in Photocopier paper standard (BIS14490:1997).

Same as BIS:1060 (Part III) The expression of results is in Taber units.

5.3 Stiffness test method mentioned in Cover paper standard IS: 6856:2001.

Strip width	38.0 ± 0.2 mm
Strip length	38.0 ± 2.5 mm -0.1 mm
Bending angle	15^0
Free length	10 ± 3 mm
Expression of results	Bending stiffness index

5.4 Stiffness test method mentioned in Coated board standard IS: 4658/1986 (Reaffirmed 1994).

Same as Cover paper. The expression of results is stiffness factor.

5.5 Stiffness test methods mentioned in Millboard, Greyboard and Strawboard standard IS:2617-2005.

Same as mentioned under IS:1060 (Part III) 1969 standard. The expression of results is in stiffness factor.

Quite clearly, there is no uniformity in the testing conditions and expression of results mentioned in different BIS standards.

6.0 Recommendation on the way of expressing stiffness results.

Keeping in view the non-uniformity in expressing stiffness results mentioned in different BIS standards it becomes necessary that a term accepted internationally is recommended for Bending resistance. The term Bending resistance index has been suggested under ISO 5270 standard.

The bending resistance index is defined as

$$x = \frac{a.10^6}{w^3}$$

where, x = Bending resistance index, Nm^6/kg^3

a = Mean bending resistance of test piece, in millinewton

w = Mean conditioned grammage of the paper in g/m^2

The formula for evaluation stiffness index using Taber instrument for bending length of 50 mm will be as under.

$$x = \frac{b \times 9.81 \times 10^6}{5 \times w^3}$$

Where b = Mean bending resistance of test piece, in Taber unit.

7.0 Effect of atmosphere climate on the stiffness properties of paper

As paper and board are hygroscopic materials, the stiffness properties are affected particularly by the relative humidity and temperature of the ambient air. It is important to remember that it is current moisture content of the sample which affects the stiffness. The moisture content of the material depends on the earlier climatic conditions because of moisture hysterisis effect. Due to this different moisture content are reached so leading to different stiffness values even in standardized climatic conditions 65 ± 2% RH and 27 ± 1^0C temperature, depending on whether the paper has come to this climate from a dry or a humid climate (Fig. 1).

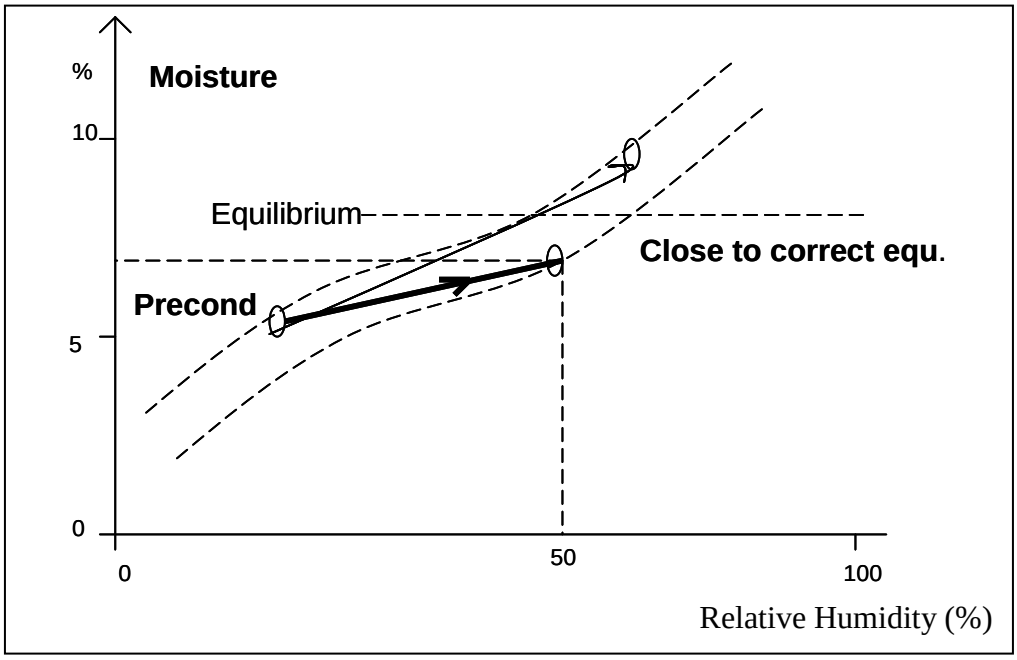

Fig. 1. The moisture content as a function of the relative humidity

To avoid this problem, it is necessary that all testing should be done in a standardized climate and sample should first be preconditioned in a climate 35 ± 5% RH and 27 ± 1^0C temperature. Doing this will help to test the sample under some moisture content view point.

As a rule of thumb, the stiffness is changed by about 5-10% for each unit percentage change in moisture content.

Since the stiffness is a property which is relatively sensitive to moisture content, the paper to be tested must be treated very carefully.

8.0 Experimental

8.1 Methods of Determination of stiffness

Presently in India two instruments are in common use. These are

- Bending stiffness type
- Taber stiffness tester

The samples were evaluated using both these type of instruments. The methods of testing are given below.

8.1.1 Stiffness by Bending stiffness type instrument.

Bending stiffness of Paper and board (ISO 2493)

The principle is measurement of the force required to bend a test piece clamped at one end through a given angle, the force is applied at a constant distance from the line of clamping.

Definitions

Stiffness:- The degree of resistance offered by paper or board when it is bent under condition specified under ISO 2493 standard. This is measured as the bending force.

Bending force:- The force in newtons necessary to deflect a rectangular test piece, clamped at one end, through a bending angle of 15^0 when the force is applied near to the free end of the test piece, normal to the plane which includes the near edge of test piece clamp and the point or line of application of the force.

Bending length:- The constant radial distance between the clamp and the position on the test piece at which the force is applied.

Bending angle:- The angle between the initial plane of the test piece and the plane passing through the line of clamping and the line of application of force at the end of the test.

Free length:- The initial length of the test piece that projects from the clamp.

Apparatus and test method

Typical configuration system of such instrument is shown in fig.2.

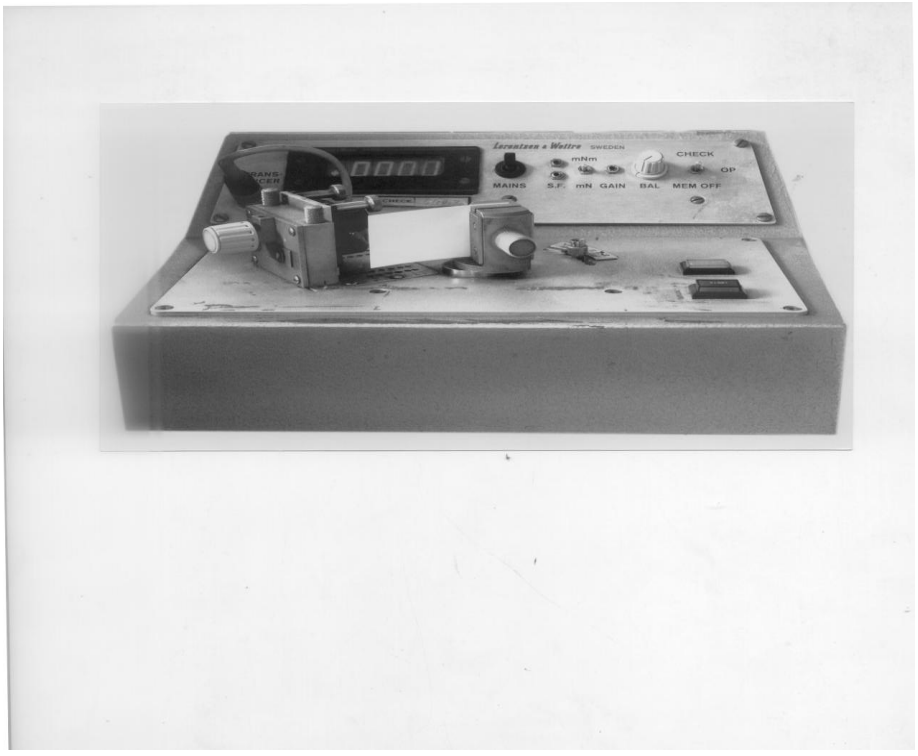

Fig.2. L & W Bending resistance tester.

The test piece shall comply with the following requirements.

Bending angle	15 ± 1^0
Bending length	50 ± 2.5mm
	-0.1
Test piece width	38 ± 0.2mm

The test piece are cut 38 ± 0.2mm wide by 75 ± 5mm long.

The test piece is clamped in a clamp having full width clamp grip not less than 12.7 mm access length. Insert the test piece in clamp. Deflect the test piece through angle of 15^0 at bending length 50mm.

Note the reading in mN.

8.1.2 Bending stiffness by Taber type instrument

This instrument measure the stiffness is Taber unit. One taber unit (gram-force centimeter) is equal to 0.098066 millinewton meters.

The basic instrument is shown in fig.3.

Fig.3. Taber Stiffness tester

The dimension of test piece as same as prescribed for test bending instrument. (8

Width	38 ± 0.2mm
Bending length	50 ± 2.5mm
Bending angle	$15^0 \pm 1^0$a

Bending moment is obtained in Taber unit. The results in SI unit mN.m are obtained by multiplying Taber unit by 0.098066.

Resistance to bending is obtained by dividing bending moment (mN.m) by length (m). Results in force (mN) for 50mm length can be obtained by dividing bending moment (mN.m) by 0.50m.

8.2 Test material and sample preparation

Different commercial paper (Photocopier, Cover paper, Coated board, straw board) were chosen.

The samples were conditioned at temperature 27±1^{o}C and 65±2% relative humidity prior to testing. The tests were carried out as per test methods mentioned above.

9.0 Results and Discussion

The stiffness values of different cover paper, coated board, straw board and photocopier papers using L & W stiffness tester (Bending stiffness type) and Taber tester are recorded in Table 1, 2, 3, 4 respectively. There is some variation in the stiffness results obtained by two instruments which is mainly due to different configuration of the two instruments. However the variation is not much. Based on these results, the following values are recommended for adoption in different BIS standard.

Paper	BIS standard	Recommended Bending stiffness index value Avg MD & CD
Cover paper	6956/2001	5.00
Coated board	4658/1998	4.00
Straw board	2617/2006	1.20

For photocopier paper which is normally in grammage range of 70 to 80 g/m^2, instead of specifying Bending stiffness index, the stiffness in Taber unit or millinewton should be prescribed.

Paper	BIS standard	Recommended stiffness Avg MD & CD
Photocopier paper	14490/1997	Taber unit – 2.5
		mN – 5.0

10.0 Recommendation

The following values are recommended for adoption in different BIS standard.

Paper	BIS standard	Recommended Bending stiffness index value Avg MD & CD
Cover paper	6956/2001	5.00
Coated board	4658/1998	4.00
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For photocopier paper which is normally in grammage range of 70 to 80 g/m^2, instead of specifying Bending stiffness index, the stiffness in Taber unit or millinewton should be prescribed.

Paper	BIS standard	Recommended stiffness Avg MD & CD
Photocopier paper	14490/1997	Taber unit – 2.5
		mN – 5.0

Table1(a) Stiffness Index of different cover samples measured using L&W stiffness tester.

Sample	gsm	Stiffness (mN)			Stiffness Index		
		CD	MD	Avg.	CD	MD	Avg.
1	150	15	18	16.5	4.44	5.33	4.88
2	170	15	26	20.5	3.05	5.30	4.19
3	140	12	20	16.0	4.37	7.28	5.82
4	180	30	52	41.0	5.15	8.92	7.03
5	130	10	12	11.0	4.55	5.45	5.00
6	175	32	74	53.0	5.97	13.80	9.88
7	230	60	113	86.5	4.95	9.30	7.12
8	140	8	14	11.0	2.90	5.00	3.95
9	150	11	17	14.0	3.30	5.05	4.18
10	130	7	11	9.0	3.20	5.00	4.10
11	170	29	42	35.5	5.90	8.55	7.22
12	250	77	115	96.0	4.90	7.36	6.13
13	230	43	86	64.5	3.53	7.07	5.3
14	220	55	116	85.5	5.6	10.90	8.25
15	190	34	70	52.0	4.96	10.20	7.58
16	130	10	12	11.0	4.55	5.45	5.00
17	140	10	15	12.5	3.65	5.50	4.55
18	170	28	32	30.0	5.70	6.50	6.10
19	220	50	110	80	4.69	10.35	7.51
20	230	42	80	61	3.45	6.60	5.01

Table1. (b) Stiffness Index of different cover samples measured using Taber stiffness tester.

Sample	gsm	Stiffness (Taber unit)			Stiffness Index		
		CD	MD	Avg.	CD	MD	Avg.
1	150	8	9	8.5	4.65	5.23	4.94
2	170	8	14	11.0	4.05	5.60	4.82
3	140	5	10	7.5	3.58	7.15	5.36
4	180	15	27	21.0	5.05	9.08	7.06
5	130	5	7	6.0	4.65	6.25	5.45
6	175	16	37	26.5	5.86	13.50	9.68
7	230	32	57	44.5	5.16	9.20	7.18
8	140	4	7	5.5	2.9	5.00	3.95
9	150	6	9	7.5	3.49	5.23	4.36
10	130	4	6	5.0	3.57	5.35	4.46
11	170	15	22	18.5	6.0	8.80	7.4
12	250	38	57	47.5	4.77	7.16	5.96
13	230	22	43	32.5	3.55	6.93	5.24
14	220	28	58	43.0	5.16	10.7	7.93
15	190	17	36	26.5	4.86	10.3	7.58
16	130	5	6	5.5	4.50	5.35	4.92
17	140	5	7	6.0	3.60	5.00	4.30
18	170	14	16	15	5.60	6.40	6.00
19	220	25	55	40	4.60	10.13	7.40
20	230	21	40	30.5	3.40	6.50	4.95

Table2 (a) Stiffness values of different coated board samples measured using L& W stiffness tester.

Sample	gsm	Stiffness (mN)			Stiffness Index		
		CD	MD	Avg.	CD	MD	Avg.
1	224	28	49	38.5	2.49	4.35	3.42
2	210	22	30	26.0	2.38	3.24	2.81
3	200	28	46	37.0	3.50	5.75	4.62
4	225	25	48	36.5	2.19	4.21	3.2
5	223	33	53	43.0	2.98	4.78	3.88
6	300	82	131	106.5	3.04	4.85	3.94
7	350	131	210	170.5	3.06	4.90	3.98
8	400	218	371	294.5	3.40	5.80	4.6
9	280	35	54	44.5	3.12	4.83	3.97
10	225	16	24	20.0	2.76	4.13	3.44
11	230	51	102	76.5	4.19	8.38	6.28
12	228	36	93	64.5	3.03	7.85	5.44
13	230	42	88	65.0	3.45	7.23	5.34
14	235	48	120	84.0	3.70	9.25	6.47
15	240	48	97	72.5	3.47	7.02	5.24
16	220	33	62	47.5	3.10	5.82	4.46
17	250	48	106	77.0	3.07	6.78	4.92
18	220	28	51	39.5	2.63	4.78	3.70
19	220	32	62	47.0	3.00	5.82	4.41
20	250	46	105	75.5	2.00	6.72	4.86
21	215	32	54	43	3.21	5.43	4.32
22	215	33	59	46	3.32	5.93	4.62
23	227	39	64	51.5	3.33	5.47	4.4

Table2 (b) Stiffness values of different coated board samples measured using Taber stiffness tester.

Sample	gsm	Stiffness (Taber unit)			Stiffness Index		
		CD	MD	Avg.	CD	MD	Avg.
1	224	15	25	20.0	2.61	4.36	3.48
2	210	12	16	14.0	2.54	3.38	2.96
3	200	15	24	19.5	3.68	5.90	4.79
4	225	13	24	18.5	2.24	4.13	3.18
5	223	16	26	21.0	2.83	4.60	3.71
6	300	44	65	54.5	3.20	4.72	3.96
7	350	66	105	85.5	3.02	4.80	3.91
8	400	110	186	148.0	3.37	5.70	4.53
9	280	70	108	89.0	3.20	4.90	4.05
10	225	31	47	39.0	2.72	4.13	3.42
11	230	26	51	38.5	4.19	8.22	6.20
12	228	19	47	33.0	3.14	7.78	5.46
13	230	21	44	32.5	3.39	7.09	5.20
14	235	25	61	43.0	3.78	9.22	6.5
15	240	24	49	36.5	3.40	6.98	5.19
16	220	17	32	24.5	3.13	5.89	4.51
17	250	25	55	40.0	3.13	6.90	5.01
18	220	14	26	20.0	2.58	4.79	3.68
19	220	16	31	23.5	2.95	5.71	4.33
20	250	23	51	37.0	2.90	6.40	4.65
21	215	16	27	21.5	3.15	5.33	4.24
22	215	17	29	23	3.35	5.72	4.53
23	227	19	32	25.5	3.18	5.36	4.27

Table3 (a) Stiffness index of different straw board samples measured using L&W stiffness tester.

Sample	gsm	Stiffness (mN)			Stiffness Index		
		CD	MD	Avg.	CD	MD	Avg.
1	1440	3141	4280	3710.5	1.05	1.42	1.24
2	1530	2947	5246	4096.5	0.82	1.47	1.15
3	1033	713	2478	1595.5	0.65	2.24	1.45
4	1400	3040	4350	3695	1.10	1.58	1.34
5	1100	1250	2490	1870	0.93	1.87	1.4
6	1020	600	2020	1310	0.56	1.90	1.23
7	980	2229	4320	3274.5	2.36	4.58	3.47
8	800	1276	1923	1599.5	2.49	3.75	3.12
9	2100	3490	5150	4320	0.37	0.55	0.46
10	1400	3140	4290	3715	1.14	1.56	1.35
11	1550	2870	4450	3660	0.77	1.19	0.98
12	1240	1050	3140	2095	0.55	1.64	1.09
13	1030	650	2080	1365	0.59	1.90	1.24
14	1800	3240	4870	4055	0.55	0.83	0.69
15	1700	2720	350	1535	0.55	0.07	0.31
16	1150	720	1180	950	0.47	0.77	0.62
17	1700	2720	3540	3130	0.55	0.72	0.63
18	1780	960	2440	1700	0.17	0.43	0.3
19	1910	3140	3620	3380	0.45	0.51	0.48
20	1100	920	2340	1630	0.69	1.75	1.22

Table3 (b) Stiffness index of different straw board samples measured using Taber stiffness tester.

Sample	gsm	Stiffness (Taber unit)			Stiffness Index		
		CD	MD	Avg.	CD	MD	Avg.
1	1440	1571	2160	1865.5	1.03	1.42	1.23
2	1530	1475	2624	2049.5	0.80	1.44	1.12
3	1033	357	1239	798	0.64	2.21	1.43
4	1400	1520	2175	1847.5	1.08	1.55	1.31
5	1100	625	1245	935	0.92	1.83	1.37
6	1020	300	1010	655	0.55	1.86	1.20
7	980	1114.5	2160	1637.25	2.32	4.50	3.41
8	800	638	961.5	799.75	2.44	3.68	3.06
9	2100	1745	2575	2160	0.36	0.54	0.45
10	1400	1570	2145	1857.5	1.12	1.53	1.32
11	1550	1435	2225	1830	0.75	1.17	0.96
12	1240	525	1570	1047.5	0.54	1.61	1.07
13	1030	325	1040	682.5	0.58	1.86	1.22
14	1800	1620	2435	2027.5	0.54	0.81	0.67
15	1700	1360	175	767.5	0.54	0.06	0.3
16	1150	360	590	475	0.46	0.76	0.61
17	1700	1360	1770	1565	0.54	0.70	0.62
18	1780	480	1220	850	0.16	0.42	0.58
19	1910	1570	1810	1690	0.44	0.50	0.94
20	1100	460	1170	815	0.67	1.72	1.19

Table4 (a) Stiffness values of different photocopier paper samples measured using L& W stiffness tester.

Sample	gsm	Stiffness (mN)			Stiffness Index		
		CD	MD	Avg.	CD	MD	Avg.
1	79.1	3	6	4.5	6.1	12.1	9.1
2	73.2	3	5	4.0	7.7	12.7	10.2
3	76.8	4	7	5.5	8.8	15.5	12.2
4	75.1	4	6	5.0	9.4	14.4	11.9
5	75.0	4	7	5.5	9.5	16.6	13.1
6	75.0	4	8	6.0	9.5	19.0	14.3
7	75.0	3	6	4.5	7.1	14.2	10.7
8	80.0	3	4	3.5	5.8	7.8	6.8
9	72.8	4	6	5.0	10.4	15.5	12.9
10	79.8	3	5	4.0	5.9	9.8	7.9
11	80.1	3	6	4.5	5.8	11.7	8.8
12	76.2	4	8	6.0	9.0	18.0	13.5
13	75.2	3	4	3.5	7.1	9.4	8.23
14	75.1	5	7	6.0	11.8	16.5	14.12
15	76.2	4	7	5.5	9.04	15.8	12.42
16	75.5	3	5	4.0	6.97	11.61	9.30
17	76.1	4	6	5.0	9.07	13.61	11.34
18	75.2	3	6	4.5	7.05	14.10	10.57
19	75.4	3	4	3.5	6.99	9.33	8.16
20	75.2	4	5	4.5	9.40	11.75	10.60

Table4 (b) Stiffness values of different photocopier paper samples measured using Taber stiffness tester.

Sample	gsm	Stiffness (Taber unit)			Stiffness Index		
		CD	MD	Avg.	CD	MD	Avg.
1	79.1	1.5	3.0	2.25	5.9	11.9	8.9
2	73.2	1.5	2.5	2.0	7.5	12.5	10.0
3	76.8	2	3.5	2.8	8.7	15.5	12.1
4	75.1	2	3.2	2.6	9.3	14.8	12.1
5	75.0	2	3.5	2.8	9.3	16.3	12.8
6	75.0	2	4	3.0	9.3	18.6	13.9
7	75.0	1.5	3	2.25	6.97	13.9	11.6
8	80.0	1.5	2	1.8	5.75	7.7	6.7
9	72.8	2	3	2.5	10.2	15.3	12.8
10	79.8	1.5	3	2.25	5.79	11.6	9.7
11	80.1	1.5	3	2.25	5.72	11.5	9.6
12	76.2	2	4	3.0	8.9	17.7	13.3
13	75.2	1.5	5	1.8	6.9	9.2	8.1
14	75.1	2.5	3.5	3.0	11.5	16.2	13.9
15	76.2	2	3.5	2.75	8.9	15.52	12.21
16	75.5	1.5	2.5	2.0	6.83	11.39	9.11
17	76.1	2	3.0	2.5	8.90	13.35	11.12
18	75.2	1.5	3.0	2.25	6.92	13.84	10.38
19	75.4	1.5	2.0	1.75	6.86	9.15	8.00
20	75.2	2	2.5	2.25	9.22	11.53	10.37

ANNEXURE – I

PROPOSED TEST METHODS FOR EVALUATION OF STIFFNESS

Stiffness of Paper and paper board by Taber – type instrument

Sampling

Obtain sample in accordance with IS:1060 (Part I) : 1966 taking care not to bend, roll, score or otherwise damage the area to be tested.

Conditioning

Condition the sample and make the test in an a atmospheric condition of 27±1^{o}C temperature and 65±2% relative humidity.

Test specimen

Cut five test specimens, 38.0 ± 0.1 mm wide by 70 ± 1 mm long for each MD & CD directions.

Procedure

- Place test specimen in clamp of instrument with one end approximately level with its top edge and the other between the roller.
- With the two clamping screws of clamp align the specimen with the centre line of the pendulum.
- Turn each of the screws to adjust the roller so that they just contact the specimen.
- Switch on the motor to rotate the loading disc to the left and deflect the specimen until engraved mark on the pendulum is aligned with 15^{0} mark on the loading disc Stop the motor, record the scale reading on the fixed annular disc and immediately return the loading disc to zero. Take a similar reading by deflecting the specimen to the right. The stiffness of the specimen is taken as the average of two readings multiplied by the factor required for the instrument range weight. Test five specimen cut in each direction.

- If the specimen is very stiff, or it creases or checks when flexed as much as 15^0, use 7.5^0 deflection mark. Multiply the results by 2.0 for an approximate comparison with 15^0 deflection. If a 7.5^0 deflection is used, state this clearly in the report.

Calculation

(1) Calculate the stiffness value of a specimen as the average of the two readings (left and right direction) multiplied by the factor required for the chosen weight which was used during the test (see manufacturer's instruction).

Report

Take average values of CD & MD direction and calculate Bending resistance index using the following formula.

$$X = \frac{b \times 9.81 \times 10^6}{5 \times w^3}$$

Where, b = Bending resistance in Taber Units

w = Mean condition grammage of paper, g/m^2

X = Bending resistance index, Nm^6/kg^3

Stiffness of Paper and Paper board by Lorentzen and Wetter type instrument.

Sampling and conditioning – same as mentioned for Taber type instrument.

Test specimen

Cut 10 test specimens 38.0 ± 0.1 mm wide by 76 ± 1 mm long for each MD & CD direction.

Procedure

- Set the knife edge of the bending resistance tester 50.0 ± 0.1 from the pivot axis of the clamp.
- Position the specimen in the clamp so that the longer side is horizontal and clamped end of the specimen fills the clamp but does not extend beyond it.
- Adjust the knife carefully until it just makes contact with the specimen along a vertical line and so that the force indicator just reacts but registers not more than 1 mN. Avoid bending the specimen before the test begins.
- Start pivoting the clamp, watch the instrument and note the maximum scale reading when the clamp has turned through 15^0, the full bending angle.
- Use each specimen only once. Test 10 specimen in cross direction and 10 in machine direction. For each direction test 5 specimens towards wire side and 5 towards the felt side.

Calculation

Calculate mean bending resistance and report.

Less than 100 mN	to the nearest 1 mN
100-1000 mN	to the nearest 10 mN
Over 1000 mN	to the nearest 100 mN

Report

Take average value of CD and MD direction and calculate Bending resistance index using the following formula.

$$X = \frac{a\ 10^6}{w^3}$$

Where, X = Bending resistance index Nm^6/kg^3

a = Mean bending resistance of test piece in mN

w = Mean conditioned grammage of the paper in g/m^2

ANNEXURE – II

Conversion factors for different stiffness value

S.No.	Static bending force	Customary unit	Multiply by	SI Unit
1.	Static bending force	Pounds-force (1bf)	4.44822	+newtons (N)
		Pounds-force (1bf)	4.44822	+millinewtons (mN)
		Milligrams-force (1mgf) (or Gurley units)	9.80665	micronewtons (µN)
2.	Bending stiffness	Gram-force centimeter (gmf.cm) or Taber unit	98.0665	+micronewtons meters (µN+m)
		Gram-force centimeter (gmf.cm) or Taber unit	0.0980665	+millinewtons meters (mN+m)
		pound-force inches (1bf●in.)	0.112985	newton meters (N●m)
3.	Bending strength (modulus or rupture)	pound-force per square inch ($1bf/in.^2$)	6.89478	Kilopascal; (kPa)

11.0 Facilities upgraded

The following instrument was procured.

- Humidity chamber – To precondition the Paper samples for speed up the testing and avoid hysterias moisture effects.