STUDY OF BENDING PROPERTIES OF FABRICS

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Abstract: *The fabric samples have been prepared with 3 types of weaves as plain, twill and satin with 3 types of weft yarns and 3 levels of picks per inch. The tensile characteristics and bending properties have been measured. The tensile strength of fabrics for all cases is higher for warp direction compared with weft. The weft way tensile strength and breaking elongation increases with increase in pick density with few exceptions. The breaking elongation for plain weave fabrics is high for warp way as compared to weft. While the fabric with twill weave and satin weave shows the opposite trend. The bending rigidity is low for plain weave fabric followed by the twill and satin weave. The bending recovery is high for satin weave fabric followed by twill and plain weave. The coercive couple which is related to the energy loss is high for plain weave fabric followed by twill and satin weave. As far as the effect of pick density is concerned no specific trend is observed for these parameters.*

Keywords: - *Bending Recovery, Cyclic Hysteresis, Fabric, Weave*

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1. INTRODUCTION:-

Comfort is an essential element of garments especially when garment comes in contact with skin. The body response decides the sweatability of garment. This aspect which is called as the skin sensorial aspect is expressed in terms of low stress mechanical properties. Bending is one of the important low stress mechanical property which contributes the fabric comfort. Bending and recovery from bending is important for apparels in the parts like knee, elbow, sleeves etc. [1]. Cloth bending recovery is measure of its ability to recover from gentle crushing; a fabric with poor bending recovery has a crumpled appearance. When crumpled gently, it can however be easily smoothed out as no permanent distortion in fiber has taken place. On the contrary in true creasing permanent distortion takes place and behavior is governed by elastic recovery of fibers. The bending behavior of the material is expressed in terms of bending rigidity. Bending rigidity is a measure of ease with which the fabric bends. The fabrics bending rigidity basically depends on the constituent fibers and yarns from which the fabric is manufactured, the fabric construction and most importantly the nature of the chemical treatment given to the fabric. Inter-yarn and intra-yarn friction plays important role in deciding the bending behavior and the type of chemical treatment given to the material, mainly controls this frictional restraints. [1].

In study [2] micro polyester woven fabrics with plain, twill and satin weave structures with five different weft densities were produced. The effects of weft density and weave structures on the physical and mechanical properties of these fabrics were investigated. The existing models for predicting the bending rigidity of woven fabrics, applied to bending hysteresis in various directions [3]. The results show that Cooper's model was the most reliable in predicting polar diagrams of bending hysteresis in cotton plain woven fabrics. The effect of warp and weft density on the bending properties of polyester viscose woven fabrics was studied [4].

Bending at low stress is more important because it has a direct relationship and greater association with fabric handle. The higher the rigidity, the lower the fabric handles value. In this study, we have made an attempt to study the bending characteristics of different weave fabrics made with different weft yarns and different PPI.

2. EXPERIMENTAL :-

2.1 Materials :-

2.1.1 Yarn Specifications –

Warp yarn – 2/60s cotton yarn

Weft yarn – 30s Cotton yarn, 30s Cotton/Polyester (55.51%/44.49%) core spun yarn, 30s Cotton/Lycra (51.88%/48.12%) core spun yarn

2.1.2 Fabric Specifications –

Weaves – Plain 1/1, Twill 2/2, Satin 8 with different weft yarns and different pick densities.

2.2 Methodology:-

The fabrics were manufactured from the yarns specified above. The detailed specifications of fabric are given in Tables 1, 2 and 3.

Table 1: Sample code for Plain Weave

Sr. No.	Weave	PPI	Warp Material	Weft Material	Sample Codes
1	Plain 1/1	60	Cotton	Cotton/Polyester Core Spun	1PP60
2	Plain 1/1	60	Cotton	Cotton/Lycra Core Spun	2PL60
3	Plain 1/1	60	Cotton	Cotton	3PC60
4	Plain 1/1	54	Cotton	Cotton/Polyester Core Spun	4PP54
5	Plain 1/1	54	Cotton	Cotton/Lycra Core Spun	5PL54
6	Plain 1/1	54	Cotton	Cotton	6PC54
7	Plain 1/1	48	Cotton	Cotton/Polyester Core Spun	7PP48
8	Plain 1/1	48	Cotton	Cotton/Lycra Core Spun	8PL48
9	Plain 1/1	48	Cotton	Cotton	9PC48

Table 2: Sample code for Twill Weave

Sr. No.	Weave	PPI	Warp Material	Weft Material	Sample Codes
10	Twill 2/2	60	Cotton	Cotton/Polyester Core Spun	10TP60
11	Twill 2/2	60	Cotton	Cotton/Lycra Core Spun	11TL60
12	Twill 2/2	60	Cotton	Cotton	12TC60
13	Twill 2/2	54	Cotton	Cotton/Polyester Core Spun	13TP54
14	Twill 2/2	54	Cotton	Cotton/Lycra	14TL54

				Core Spun	
15	Twill 2/2	54	Cotton	Cotton	15TC54
16	Twill 2/2	48	Cotton	Cotton/Polyester Core Spun	16TP48
17	Twill 2/2	48	Cotton	Cotton/Lycra Core Spun	17TL48
18	Twill 2/2	48	Cotton	Cotton	18TC48

Table 3: Sample code for Satin Weave

Sr. No.	Weave	PPI	Warp Material	Weft Material	Sample Codes
19	Satin 8	60	Cotton	Cotton/Polyester Core Spun	19SP60
20	Satin 8	60	Cotton	Cotton/Lycra Core Spun	20SL60
21	Satin 8	60	Cotton	Cotton	21SC60
22	Satin 8	54	Cotton	Cotton/Polyester Core Spun	22SP54
23	Satin 8	54	Cotton	Cotton/Lycra Core Spun	23SL54
24	Satin 8	54	Cotton	Cotton	24SC54
25	Satin 8	48	Cotton	Cotton/Polyester Core Spun	25SP48
26	Satin 8	48	Cotton	Cotton/Lycra Core Spun	26SL48
27	Satin 8	48	Cotton	Cotton	27SC48

2.3 Evaluation of yarn and fabric properties:-

2.3.1 Yarn Characteristics:-

i) Tensile Characteristics:-

Yarn tenacity and breaking elongation were measured on Premier Tensomaxx 7000 machine. The test was carried out according to ASTM D76 standards.

ii) Unevenness:-

The yarn evenness test was carried out on *PREMIER* iQ Qulicenter ver.M3.0.5. The yarn was passed through the capacitor plates for one minute at the speed 400mt/min. The test was carried out according to ASTM D1425 standards.

2.3.2. Fabric Characteristics:-

i) Tensile Characteristics:-

The strength and elongation of fabric was measured on Instron 5565 machine. The test was carried out according to ASTM D5035-11 standards. The specimen dimensions used for the test were 2”×8”. The rate of loading used for the test was 300 mm/min.

ii) Bending Properties:-

The bending test was carried out on cyclic bending tester which is shown in figure 1. The clamping of specimen and procedure for carrying out the test is as follows -

The specimen AB is held at one end in a rotatable clamp C, which carries an index reading against a scale of degrees D, to the other end of the specimen is attached a long, light, pointer arm P which, under the action of gravity, provides the couple in the specimen. In order that the couple within the specimen should be as uniform as possible, the centre of gravity of the pointer arm should be as far from the specimen as possible. Provided the specimen is sufficiently short relative to the diameter of the scale and the distance from the specimen to the pointer centre of gravity, the curvature is proportional to the angle x and the couple to sin θ.

Fig. 1 Cloth Bending Tester

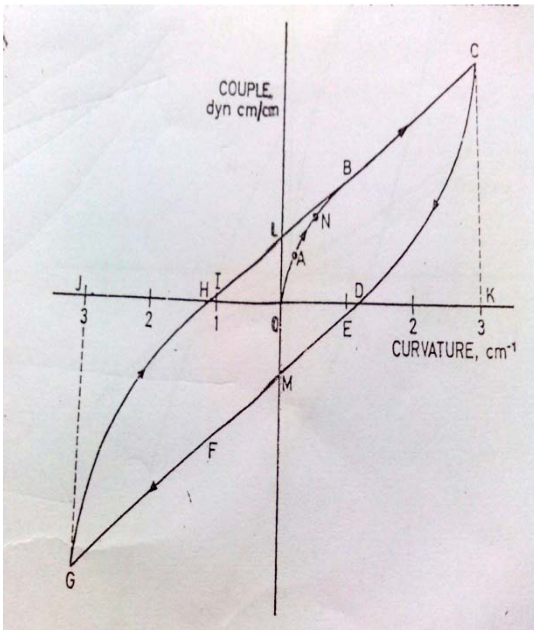


Fig. 2Typical Bending Hysteresis curve

Table 4: Bending parameters

Parameter	Symbol	Definition, with reference to figure	Units
Coercive couples	C_0	EF/2	dyne cm/cm
Initial flexural rigidity	G_1	Ratio of couple to curvature at A	dyne cm^2/cm
Final flexural rigidity	$G_ø$	Mean slope of BC and FG	dyne cm^2/cm
Low curvature elastic flexural rigidity	G_0	Mean slope of EF and LB	dyne cm^2/cm
Residual curvature	K_R	HD/2	cm^{-1}
Bending recovery	R_B	100 (JK-HD)/JK	%

The sample size used for the test was 12mm×25mm. The test was carried out according to the procedure as given above. The curve was plotted from the results. From the curve the bending parameters (Table 4) were evaluated. [5]

2.2.3 Statistical Analysis:-

Statistical analysis was carried out with general factorial expansion by using mini tap.

3 RESULTS AND DISCUSSION:-

3.1 Yarn characteristics:-

The characteristics of yarns used for manufacturing the fabrics are summarized in the Table 5.

Table 5: Yarn characteristics

Yarn Properties ↓	Warp	Weft		
Samples →	Cotton	Cotton	Cotton/Lycra Core Spun	Cotton/Polyester Core Spun
Count	2/60s	30s	30s	30s
Rkm	24.04	16.69	17.51	17.1
Elongation%	5.04	5.13	8.58	6.18
H3	345.7	250.4	635.2	681.6
Um %	10.87	18.02	9.39	8.34
CV%	13.91	23.02	11.86	10.61
Thin places/km	0	537	1	2
Thick places/km	610	1960	16	21
Neps/km	19	1554	25	43

3.2 Fabric Characteristics:-

3.2.1. Tensile Characteristics:-

The results obtained for tensile characteristics of fabrics are summarized in Table 6, 7, and 8.

It is observed that the tensile strength of the fabrics for all cases is higher in warp direction in comparison with weft way strength. The weft way tensile strength is found to increase with increase in the number of picks per inch for all cases except for core spun cotton/polyester weft, satin fabric. For this case tensile strength is increased with decrease in pick density. The satin fabric with cotton/lycra core spun yarn in weft corresponding to 54 picks per inch shows significantly high tensile strength.

As far as the breaking elongation is concerned the trend changes with weave. It is observed that, for plain weave warp way breaking elongation is high compared to the weft. While the fabrics with twill and satin weave show the opposite trend.

The weft way breaking elongation for different weaves is elaborated as follows -

In case of plain weave fabrics with core spun cotton/polyester yarn and cotton yarn in weft, the breaking elongation increased with increase in pick density. While the fabrics with cotton/lycra core spun yarn in weft shows opposite trend.

In case of twill weave the fabrics with cotton yarn in weft breaking elongation increased with increase in pick density. The fabrics with core spun cotton/lycra yarn and core spun cotton/polyester yarn in weft, show lower breaking elongation as the pick density was increased.

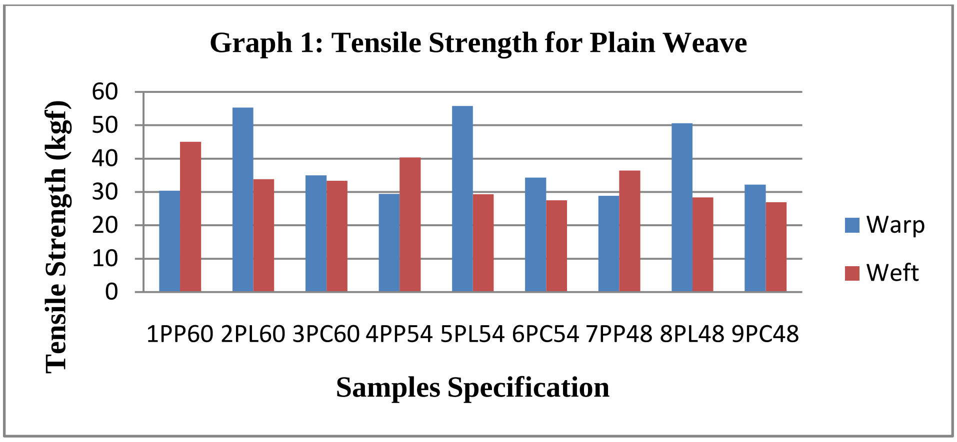
As far as the satin weave is concerned the breaking elongation was found to increase with increase in pick density.

The fabric with satin weave with cotton/lycra core spun yarn in weft corresponding to 54 picks per inch shows significantly high breaking elongation.

Table 6: Tensile characteristics of fabric for plain weave

Sample No.		Tensile Strength (kgf)	Tensile Elongation (%)
1PP60	WP	30.39	23.54
	WT	45.09	24.55
2PL60	WP	55.31	27.2
	WT	33.81	113.04
3PC60	WP	34.98	20.81
	WT	33.36	16.3
4PP54	WP	29.38	25.25

	WT	40.32	19.2
5PL54	WP	55.83	52.89
	WT	29.3	120.6
6PC54	WP	34.31	18.96
	WT	27.48	15.8
7PP48	WP	28.86	23.7
	WT	36.46	17.42
8PL48	WP	50.57	26.19
	WT	28.41	126.32
9PC48	WP	32.2	20.67
	WT	26.95	13.9



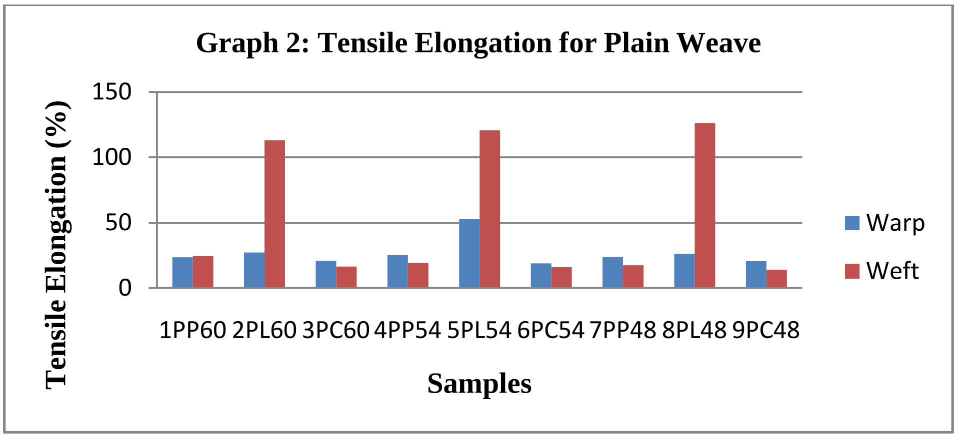
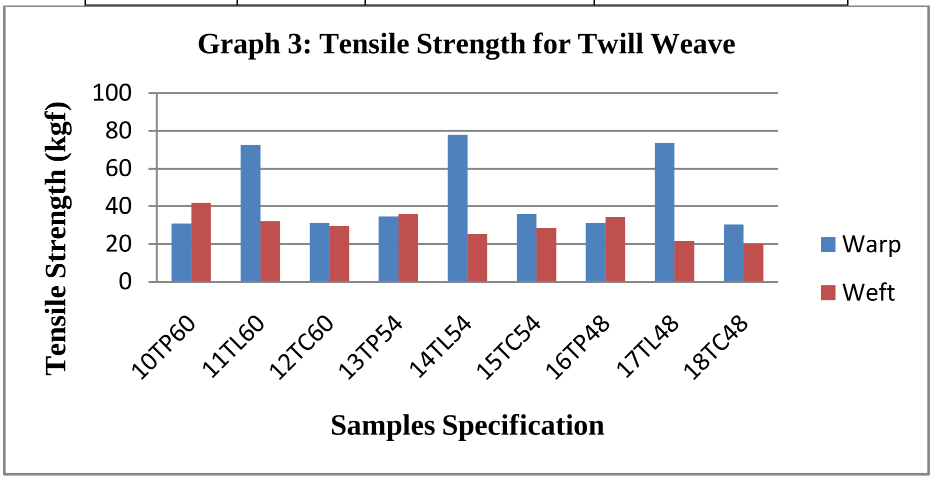


Table 7: Tensile characteristics of fabric for twill weave

Sample No.		Tensile Strength (kgf)	Tensile Elongation (%)
10TP60	WP	30.88	17.64
	WT	41.9	24.27
11TL60	WP	72.42	23.6
	WT	32.05	157.57
12TC60	WP	31.22	15.73

	WT	29.5	19.8
13TP54	WP	34.57	18.78
	WT	35.82	22.15
14TL54	WP	77.9	26.44
	WT	25.53	178.03
15TC54	WP	35.76	16.36
	WT	28.53	17.75
16TP48	WP	31.24	16.51
	WT	34.3	35.95
17TL48	WP	73.56	26.46
	WT	21.69	188.17
18TC48	WP	30.36	13.55
	WT	20.12	15.9



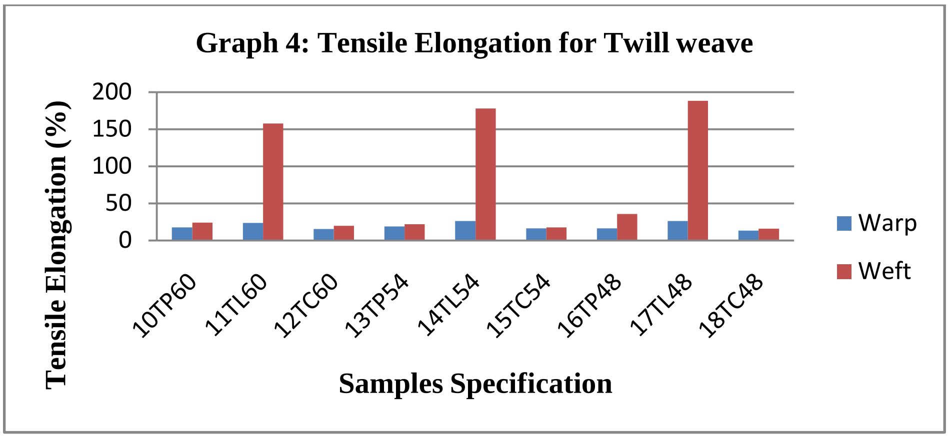
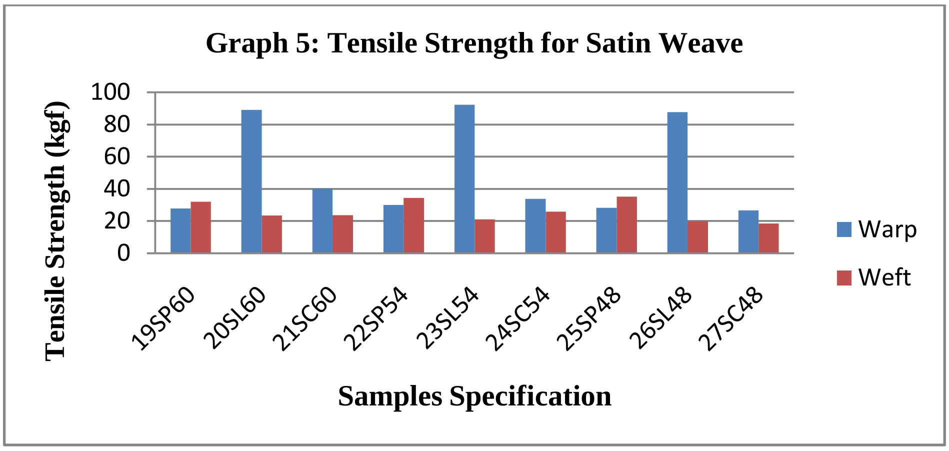
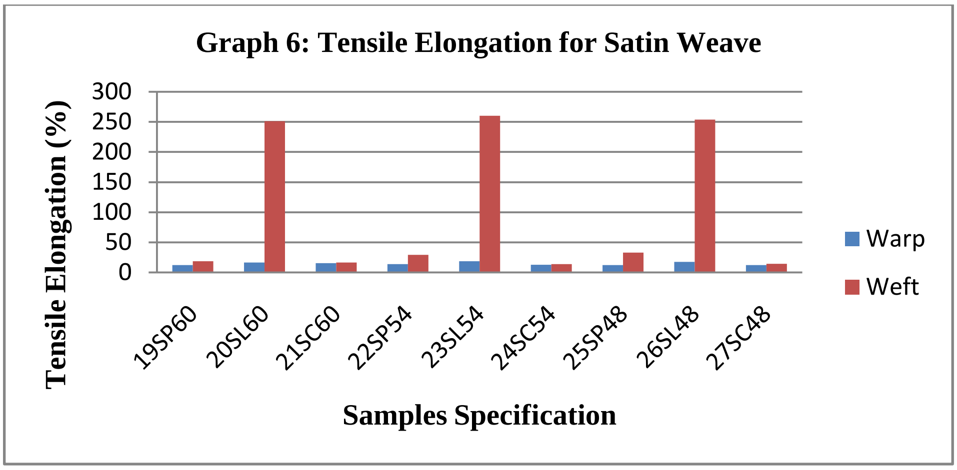


Table 8: Tensile characteristics of fabric for satin weave

Sample No.		Tensile Strength (kgf)	Tensile Elongation (%)
19SP60	WP	27.74	12.23
	WT	32.01	18.37
20SL60	WP	89.01	16.41
	WT	23.5	251
21SC60	WP	40.13	15.14

	WT	23.67	16.4
22SP54	WP	30.11	13.59
	WT	34.32	29
23SL54	WP	92.19	18.39
	WT	21.14	260.33
24SC54	WP	33.71	12.52
	WT	25.82	13.57
25SP48	WP	28.32	12.46
	WT	35.13	32.67
26SL48	WP	87.64	17.44
	WT	19.94	254
27SC48	WP	26.58	12.26
	WT	18.39	14.52





3.2.2. Bending Characteristics:-

The bending rigidity, recovery and hysteresis in bending are the low stress mechanical properties of the fabric which are related to the handle of fabric. The bending characteristics of fabric are summarised in table 9, 10 and 11.

Warp direction

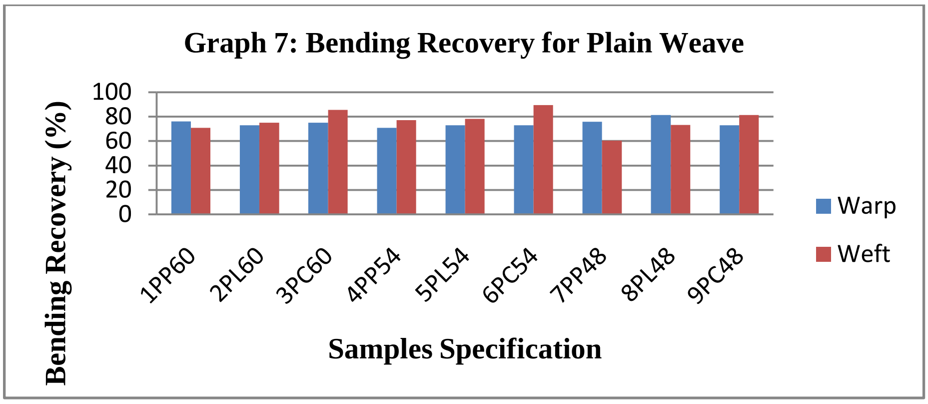
It is observed that, for almost all cases the bending recovery in weft is significantly high in comparison with the warp.

i) Plain Weave:-

The bending recovery for all cases lies between 70%to90%. It indicates that the bending recovery of the fabric is quite high. It is observed that fabrics with cotton weft for all pick densities have high bending recovery in comparison with fabric made with cotton/polyester core spun and cotton/lycra core spun weft. The initial rigidity which is the resistance to bending lies in the range 0.16 to 0.32 dyne cm^2 /cm. Especially for the cases 3PC60, 7PP48 which records lowest values of rigidity, 0.16 dyne cm^2 /cm. undergo easy bending. These cases also record significantly higher coercive couple indicating that while bending the yarns undergo slippage due to comparatively low frictional restraints. The rest of the cases show comparatively low values of coercive couple.

Table 9: Bending Hysteresis Parameters of Plain Weave

Sample No.	Testing Position	C_0 (dyne cm/cm)	G_1 (dyne cm^2/cm)	$G_{\underline{\Phi}}$ (dyne cm^2/cm)	G_0 (dyne cm^2/cm)	K_R (cm^{-1})	R_B (%)
1PP60	WP	0.15	0.32	0.22	0.45	0.71	76.04
	WT	0.16	0.32	0.15	0.24	0.87	70.83
2PL60	WP	0.13	0.35	0.2	0.15	0.81	72.91
	WT	0.13	0.32	0.2	0.24	0.75	75
3PC60	WP	0.12	0.32	0.16	0.24	0.75	75
	WT	0.14	0.16	0.16	0.26	0.87	85.5
4PP54	WP	0.11	0.32	0.24	0.24	0.875	70.83
	WT	0.11	0.24	0.16	0.23	0.68	77.08
5PL54	WP	0.14	0.18	0.16	0.16	0.81	72.91
	WT	0.165	0.24	0.26	0.4	0.65	78.33
6PC54	WP	0.1	0.32	0.08	0.3	0.81	72.91
	WT	0.11	0.32	0.3	0.16	0.625	89.58
7PP48	WP	0.14	0.32	0.16	0.2	0.725	75.83
	WT	0.195	0.16	0.13	0.13	1.18	70.41
8PL48	WP	0.14	0.32	0.2	0.26	0.56	81.25
	WT	0.135	0.32	0.16	0.32	0.8	73.33
9PC48	WP	0.12	0.16	0.16	0.26	0.81	72.91
	WT	0.1	0.32	0.06	0.16	0.56	81.25



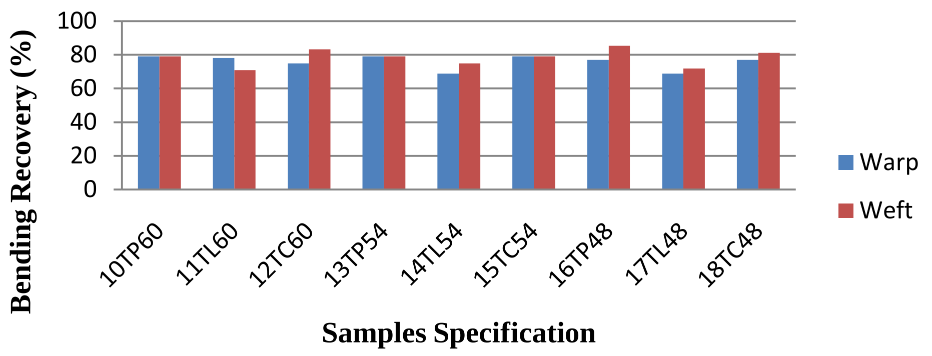
ii) Twill Weave :-

Like plain weave, the bending recovery of twill fabric is also quite high and found to lies between 70% to 86%. As such there is no specific trend observed between different wefts as well as different pick densities. The initial bending rigidity lies between 0.24 to 0.32 dyne cm^2 /cm. In comparison with the plain weave the rigidity values are quite consistent most of the values are closer to 0.32 dyne cm^2 /cm. which means that the resistance to bending is quite high. The coercive couple which lies between 0.08 to 0.15 dyne cm/cm. is quite low compared to plain weave fabrics. This is mainly because of less interlacement in twill weave reduces the frictional restraints.

Table 10: Bending Hysteresis Parameters of Twill Weave

Sample No.	Testing Position	C_0 (dyne cm/cm)	G_1 (dyne cm^2/cm)	G_ϕ (dyne cm^2/cm)	G_0 (dyne cm^2/cm)	K_R (cm^{-1})	R_B (%)
10TP60	WP	0.11	0.32	0.14	0.26	0.625	79.16
	WT	0.11	0.32	0.14	0.2	0.625	79.16
11TL60	WP	0.12	0.32	0.18	0.32	0.65	78.12
	WT	0.15	0.28	0.14	0.22	0.87	70.83
12TC60	WP	0.09	0.24	0.08	0.16	0.75	75
	WT	0.1	0.32	0.16	0.24	0.5	83.33
13TP54	WP	0.11	0.32	0.2	0.13	0.625	79.16
	WT	0.1	0.32	0.14	0.24	0.625	79.16
14TL54	WP	0.12	0.2	0.08	0.24	0.93	68.75
	WT	0.14	0.32	0.16	0.24	0.75	75
15TC54	WP	0.08	0.32	0.16	0.24	0.625	79.16
	WT	0.1	0.32	0.16	0.24	0.625	79.16
16TP48	WP	0.1	0.24	0.16	0.16	0.68	77.08
	WT	0.08	0.24	0.16	0.2	0.43	85.41
17TL48	WP	0.11	0.24	0.16	0.24	0.93	68.75
	WT	0.15	0.32	0.16	0.24	0.84	71.87
18TC48	WP	0.1	0.32	0.16	0.16	0.68	77.08
	WT	0.1	0.32	0.16	0.21	0.56	81.25

Graph 8: Bending Recovery for Twill Weave

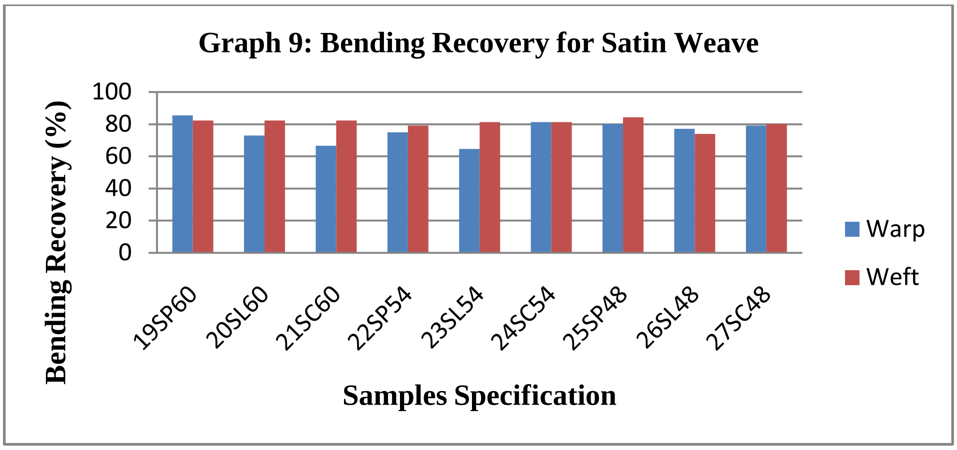


iii) Satin Weave:-

The fabric with satin weave also records high values, of bending recovery. The bending recovery is found to lie between 73% to 86%. As such there is no specific trend observed between different wefts as well as different pick densities. The initial bending rigidity lies between 0.24 to 0.48 dyne cm^2 /cm. The initial rigidity for satin is high means that the resistance to bending is comparatively high. The coercive couple which lies between 0.08 to 0.15 dyne cm/cm. is same as for twill weave. The low values of coercive couple are mainly attributed to longer float length in satin fabrics.

Table 11: Bending Hysteresis Parameters of Satin Weave

Sample No.	Testing Position	C_0 (dyne cm/cm)	G_1 (dyne cm^2/cm)	G_{ϕ} (dyne cm^2/cm)	G_0 (dyne cm^2/cm)	K_R (cm^{-1})	R_B (%)
19SP60	WP	0.11	0.32	0.53	0.53	0.43	85.41
	WT	0.12	0.32	0.25	0.24	0.53	82.29
20SL60	WP	0.09	0.16	0.08	0.16	0.81	72.91
	WT	0.14	0.32	0.22	0.38	0.53	82.29
21SC60	WP	0.08	0.16	0.08	0.08	1	66.66
	WT	0.13	0.32	0.28	0.32	0.53	82.29
22SP54	WP	0.11	0.32	0.16	0.25	0.75	75
	WT	0.13	0.32	0.16	0.24	0.625	79.16
23SL54	WP	0.11	0.08	0.08	0.08	1.06	64.58
	WT	0.14	0.36	0.26	0.4	0.56	81.25
24SC54	WP	0.09	0.32	0.16	0.22	0.56	81.25
	WT	0.09	0.24	0.24	0.16	0.56	81.25
25SP48	WP	0.12	0.32	0.16	0.32	0.59	80.2
	WT	0.09	0.32	0.16	0.24	0.46	84.37
26SL48	WP	0.08	0.16	0.08	0.08	0.68	77.08
	WT	0.15	0.48	0.16	0.22	0.78	73.95
27SC48	WP	0.09	0.24	0.16	0.16	0.625	79.16
	WT	0.1	0.32	0.16	0.24	0.59	80.2



4. CONCLUSIONS:-

The fabric samples have been prepared with 3 types of weaves as plain, twill and satin with 3 types of weft yarns and 3 levels of picks per inch. The tensile characteristics and bending properties have been measured. From the observation and results, the following conclusions can be drawn –

- The tensile strength of fabrics for all cases is higher for warp direction compared with weft. The weft way tensile strength increases with increase in pick density except for satin weave fabric with cotton/polyester core spun weft yarn for which the trend is opposite. The breaking elongation for plain weave fabrics is high for warp way as compared to weft. While the fabric with twill weave and satin weave shows the opposite trend. In plain weave fabric the breaking elongation increased with increase in pick density for core spun cotton/polyester yarn and cotton yarn in weft, while for the fabric with cotton/lycra core spun yarn in weft, breaking elongation increased with decrease in pick density. In twill weave fabric with cotton yarn in weft breaking elongation increased with increase in pick density, while for the other fabrics breaking elongation decreased with increase in pick density. In satin weave fabric breaking elongation increased with increase in pick density.
- For all the fabrics bending recovery in weft is significantly higher compared to warp. In plain weave the bending recovery is high for fabric with cotton in weft compared to others. In twill and satin weave there is no specific trend observed between different weft types as well as different pick densities. In twill weave initial rigidity values are quite consistent compared with plain weave means the resistance to

bending is high and the coercive couple is low as compared to plain weave fabric. In satin weave the initial rigidity is high and coercive couple value are low which mainly attributed to longer float length.

- Here we can conclude that the bending rigidity is low for plain weave fabric followed by the twill and satin weave. The bending recovery is high for satin weave fabric followed by twill and plain weave. The coercive couple which is related to the energy loss is high for plain weave fabric followed by twill and satin weave. As far as the effect of pick density is concerned no specific trend is observed for these parameters.

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