NANYANG TECHNOLOGICAL UNIVERSITY

School of Materials Science and Engineering

Reg. No. 200604393R

28 February 2018

Total Integrated Solutions Pte Ltd
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Singapore 737853

Dear Sir,

Test Report on Fabric Ducting Material (DuctEasi IFR Fabric, 0.3mm, 264g/m^2)

1.0 Introduction

Fabric Sample DuctEasi IFR with specifications 0.3mm thickness, 264g/m^2 density for ventilation ducting was received for the testing of various properties, and comparison of these properties to manufacturer's data.

2.0 Summary of Results

	Properties	Test Results	Remarks
1	Weight	262.51 g/m^2	Measured using weighing scale
2	Thickness	0.298 mm	Measured with micrometer screw gauge
3	Tensile Strength	Weft: 1842N/50mm Warp: 1322N/50mm	Tested with Instron Mechanical Tester until failure.
4	Elongation	Weft: 24.4% Warp: 35.9%	Tested with Instron Mechanical Tester until failure.
5	Resistance to Tearing	Weft: 236.40N Warp: 255.07N	Tested with Instron Mechanical Tester until failure.
6	Shrinkage in Wash	0.02754% (Shrinkage) Weft: 0.15% (Expansion) Warp: 0.21% (Shrinkage)	Subject to washing cycles and measurements made at specific intervals.
7	Water Absorption	25.78%	Dry / wet mass of fabric weighed before and after soaking in water

3.0 Description of Characterization Tests

This section describes the methodology of the various tests conducted.

3.1 Weight

According to the manufacturer's specifications, the weight of the fabric is specified based on an area of $0.0025m^2$ (5cm x 5cm square). Essentially, this weight is specified in terms of weight (g) / area (m^2). For this measurement, the average of 3 samples was used, with 2 readings per sample. The average weight of the fabric was found to be **$262.51g/m^2$.**

Details are shown in Appendix A.

3.2 Thickness

The thickness of the fabric was measured using a micrometer screw gauge at multiple locations. The average thickness was **0.298mm** with a standard deviation of **0.034.**

Details are shown in Appendix A.

3.3 Tensile Strength & Elongation

Tensile strength and elongation were measured in both the warp and weft fabric orientations using an Instron Mechanical Tester with a 1kN load cell and pneumatic grips to ensure non-slippage. The fabric was cut into strips measuring 20mm by 175mm as shown in *Figure 3.3.1.* For each test, 5 strips of samples were measured along the weft and warp directions.

Each sample was pulled at 100mm/min with reference to EN-ISO 13934-1. The maximum load (N) required to pull each sample to failure, as well as the elongation (%) before the sample breaks are reported (*Appendix B*) and tabulated in *Table 3.3.2* below.

As the specimen strips used for testing were 20mm in width and tensile strength (N/50mm) was relative to 50mm strips, calculations (Appendix B) were done to convert to like units, shown in *Table 5.3.*

The mean elongation along the weft and warp directions was found to be **24.4% (weft)** and **35.9% (warp)** respectively. The average tensile strength along weft and warp directions were calculated to be **1841.99N/50mm (weft)** and **1322.04N/50mm (warp)** respectively.



Fig 3.3.1 Tensile Test Samples in Warp (left) and Weft (right) Orientations

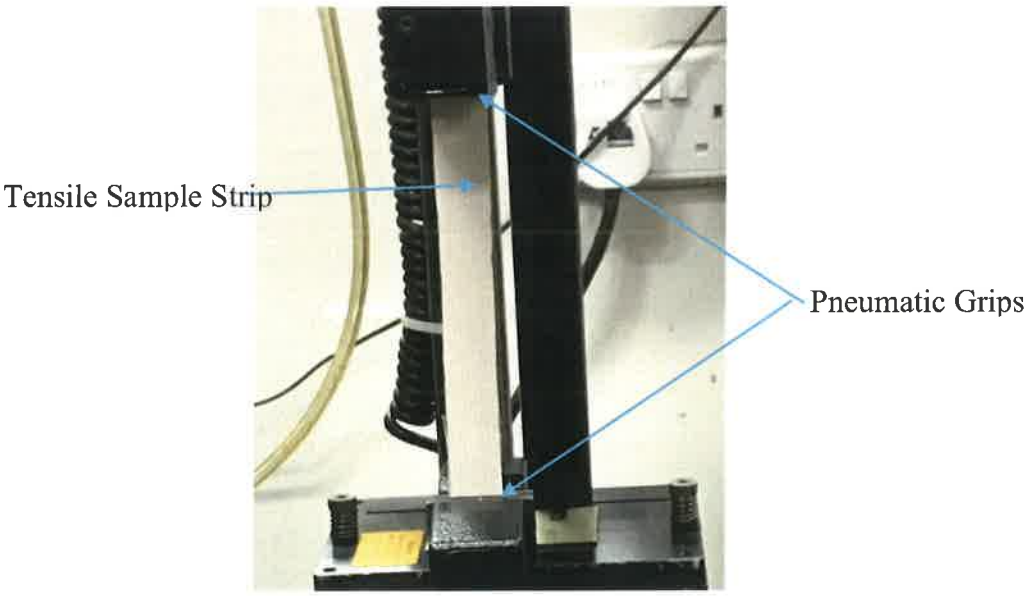

Figure 3.3.2 Mounted Tensile Sample on Mechanical Tester with Pneumatic Grips

Table 3.3.3 Tensile Test & Elongations Results

Direction	Sample #	Thickness (mm)	Max Load (N)	Tensile strength (N/50mm)	Elongation (%)
Weft	1	0.293	705.6966	1764.2416	23.1
	2	0.303	654.8913	1637.2284	22.0
	3	0.286	773.4197	1933.5493	25.6
	4	0.297	764.3264	1910.8160	26.0
	5	0.296	785.6432	1964.1081	25.3
		Mean	**736.7954**	**1841.9887**	**24.4**
Warp	1	0.298	544.4071	1361.0177	36.0
	2	0.302	554.2704	1385.6761	36.7
	3	0.294	457.5628	1143.9071	31.6
	4	0.299	543.2843	1358.2109	37.2
	5	0.304	544.5496	1361.3742	38.0
		Mean	**528.8148**	**1322.0372**	**35.9**

3.4 Resistance to Tearing

Resistance to tearing test was done in accordance to ASTM D4533/D4533M standard, which is the trapezoid tearing test. Following the template shown in *Figure 3.4.1*, 10 rectangular samples (5 in weft orientation and 5 in warp orientation), measuring 150mm by 75mm, were cut out from the fabric and markings were done as indicated in *Figure 3.4.2*. A 15mm notch was cut in the middle of each sample as shown. The sample was then clamped in the Instron Mechanical Tester's grip along the markings and pulled until failure. The test set up is shown in *Figure 3.4.3*.

The average load required for tearing of the samples is **236.40N (weft)** and **255.07N (warp)**.

The details of the test results are shown in *Appendix C*.

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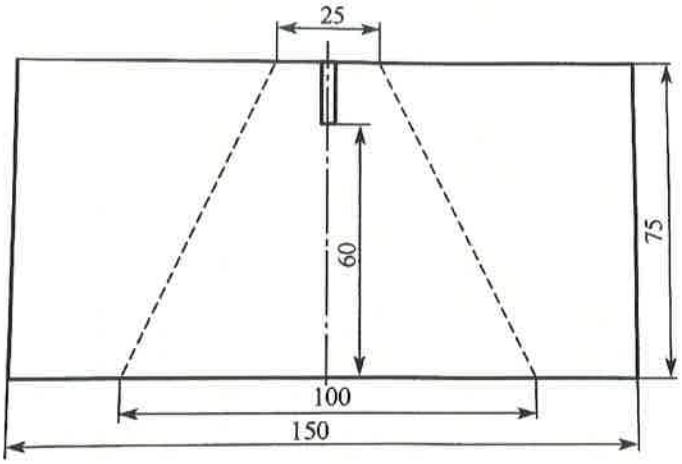

Fig 3.4.1 Cutting Template for Trapezoid Tearing Test

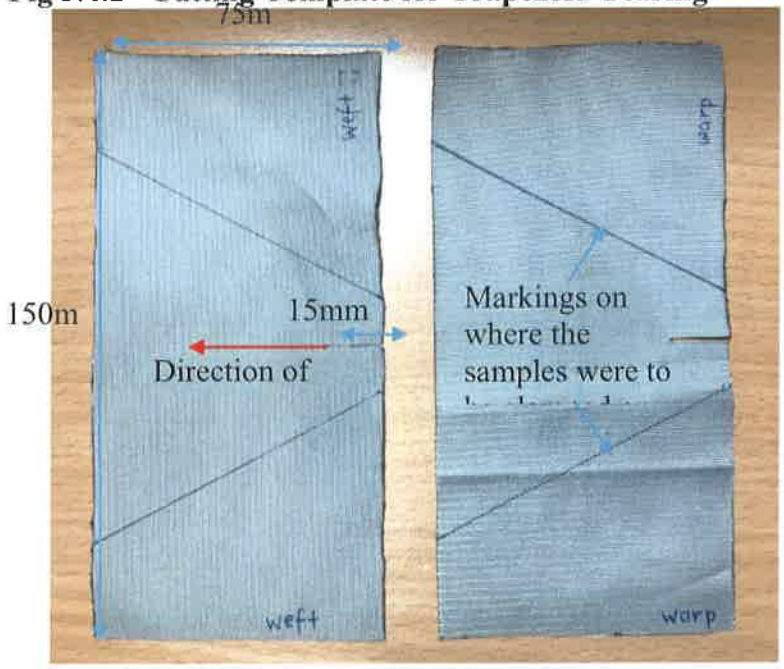

Figure 3.4.2 Tearing Sample Strips in Weft (left) and Warp (right) Orientations

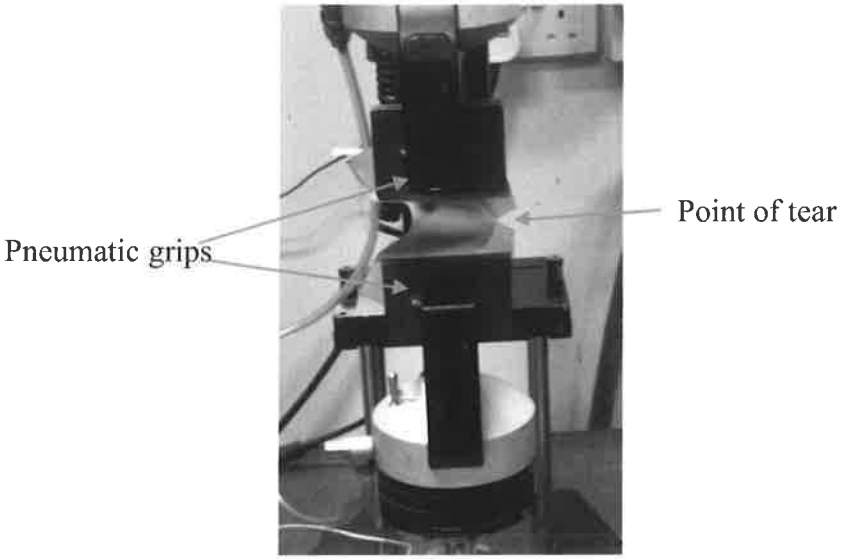

Figure 3.4.3 Tearing Sample mounted onto Instron Mechanical Tester

3.5 Shrinkage in Wash

In accordance to EN-ISO 5077 standard, 5 samples of 50cm by 50cm were cut out with markings at 5cm away from edges. The samples were then washed in a Maytag commercial laundry machine using Dynamo Power Gel detergent at recommended quantity for 50 cycles. Samples were dried and measured at 10-cycle intervals, with the results were tabulated in Appendix D.

Shrinkage (%) was calculated by:

$$\frac{final\ measurement - initial\ measurement}{initial\ measurement} \times 100\%$$

An overall value of **0.029% (shrinkage**) was obtained, with **0.207% shrinkage (warp)** and **0.152% expansion (weft).**

3.6 Water Absorption

For water absorption test, ASTM D570 standard was used. 5 samples of 5cm by 5cm were cut out and dried in a box oven at 40°C overnight and placed in a desiccator cabinet to cool. The dry mass of each sample was then weighed. The samples were subsequently submerged in

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water at 25°C for 24 hours before being removed and patted dry. The samples were then weighed for their wet mass.

$$Water\ absorption(\%) = \frac{wet\ mass - dry\ mass}{dry\ mass} \times 100\%$$

Water absorption was found to be of an average of **25.78%.** The readings are as shown in Appendix A.

Yours sincerely,



Dr. Alfred Tok
(C.Eng MIMMM, Ph.D)
Associate Professor

Appendix A

Weight and Thickness

Table A1 Tabulated Results for Weight of Fabric

#	Readings (g)	Weight (g/m^2)
1	0.6646	265.84
2	0.6639	265.56
3	0.6505	260.2
4	0.6509	260.36
5	0.6545	261.8
6	0.6533	261.32
Average	0.65628	262.51

Table A2 Tabulated Results for Thickness of Fabric

#	Readings (mm)
1	0.299
2	0.287
3	0.293
4	0.287
5	0.304
6	0.287
7	0.309
8	0.287
9	0.308
10	0.303
11	0.287
12	0.31
13	0.308
Average	0.29762

Appendix B

Tensile Strength & Elongation Test

$$tensile\ strength = \frac{Max\ Load}{Area} = \frac{Max\ Load}{width \times thickness}$$

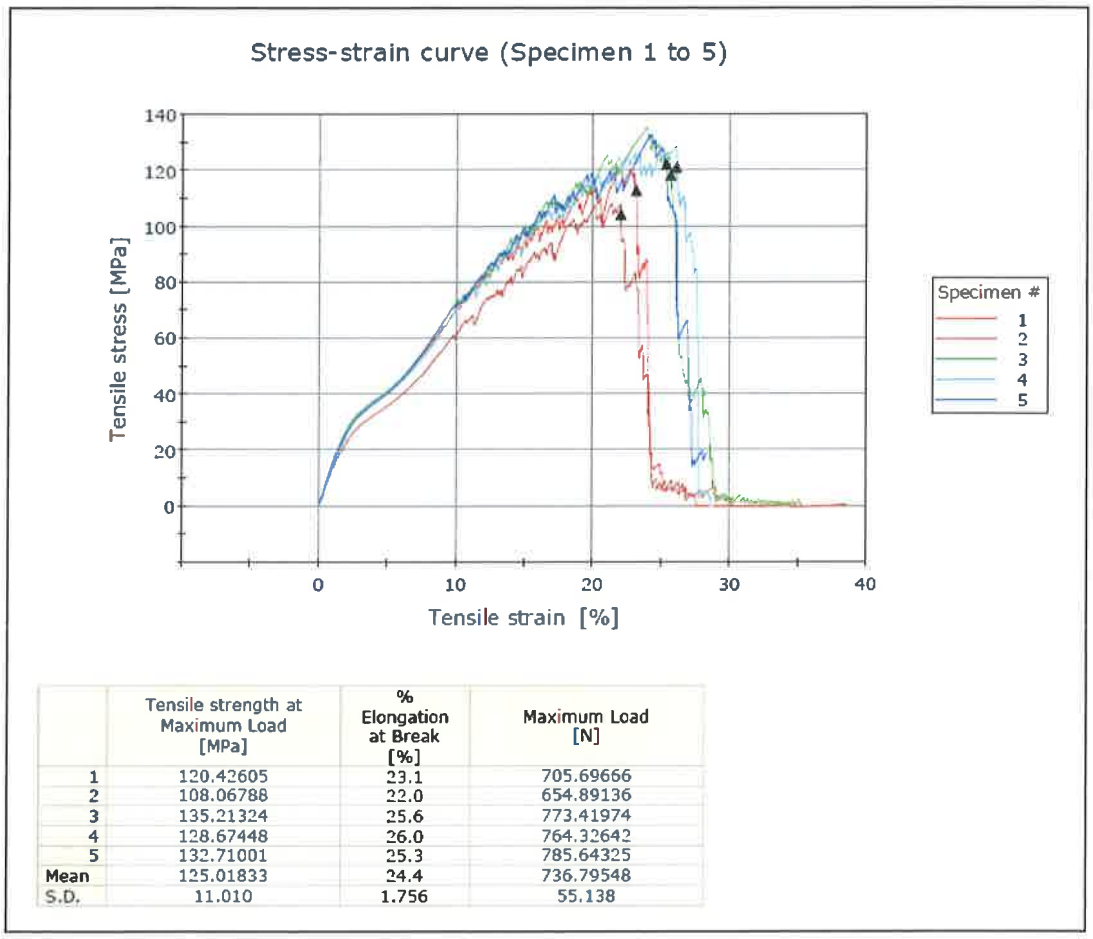
Since thickness should be approximately the same for the same fabric,

$$tensile\ strength \approx \frac{Max\ Load}{width}$$

$$\therefore tensile\ strength = \frac{Max\ Load\ (N)}{20\ (mm)} = Max\ Load\ \left(\frac{N}{20mm}\right)$$

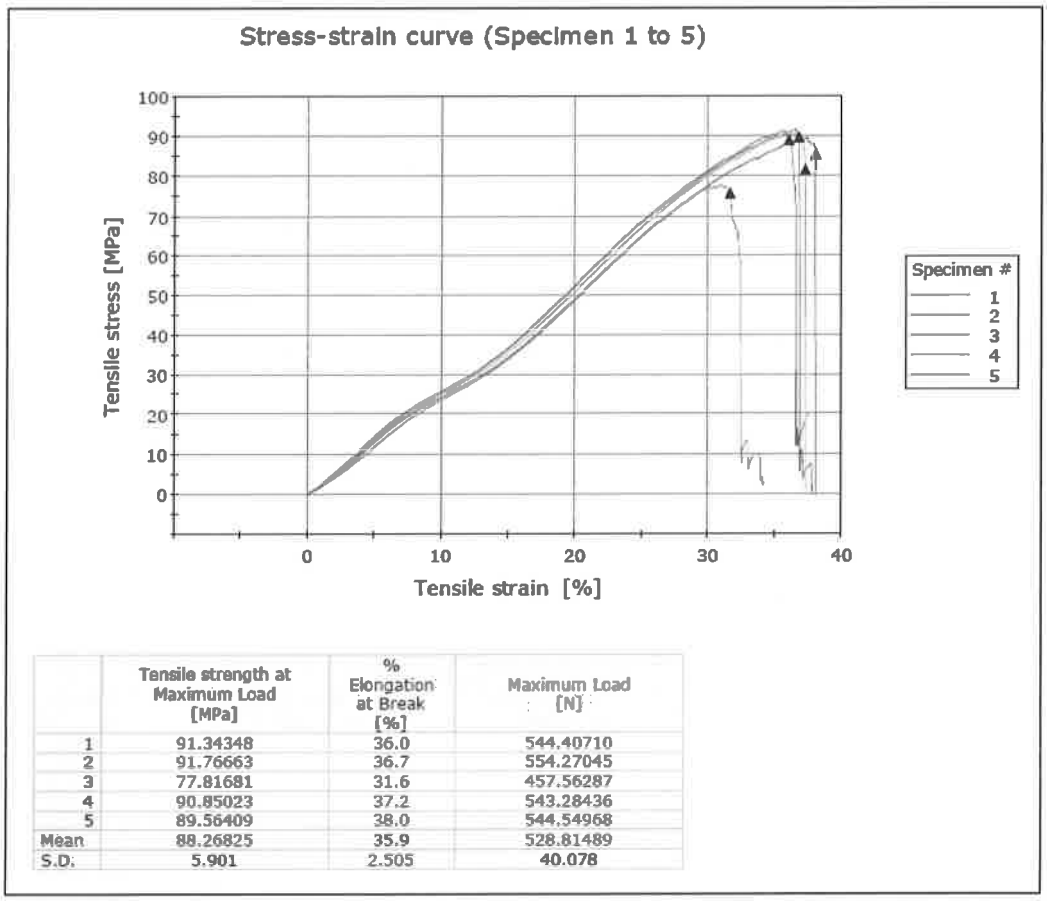
To relate it to N/50mm:

$$\frac{Max\ Load\ (N)\ \div\ 20}{20\ (mm)\ \div 20} \times \frac{50}{50} = \frac{Max\ Load\ (N)\ \div\ 20 \times 50}{50\ (mm)} = Max\ Load\ \div 20 \times 50\left(\frac{N}{50mm}\right)$$



	Tensile strength at Maximum Load [MPa]	% Elongation at Break [%]	Maximum Load [N]
1	120.42605	23.1	705.69666
2	108.06788	22.0	654.89136
3	135.21324	25.6	773.41974
4	128.67448	26.0	764.32642
5	132.71001	25.3	785.64325
Mean	125.01833	24.4	736.79548
S.D.	11.010	1.756	55.138

Figure B1 Stress-Strain Curve of 5 samples in Weft Direction



	Tensile strength at Maximum Load [MPa]	% Elongation at Break [%]	Maximum Load [N]
1	91.34348	36.0	544.40710
2	91.76663	36.7	554.27045
3	77.81681	31.6	457.56287
4	90.85023	37.2	543.28436
5	89.56409	38.0	544.54968
Mean	88.26825	35.9	528.81489
S.D.	5.901	2.505	40.078

Figure B2 Stress-Strain Curve of 5 samples in Warp Direction

Appendix C

Resistance to Tearing Test

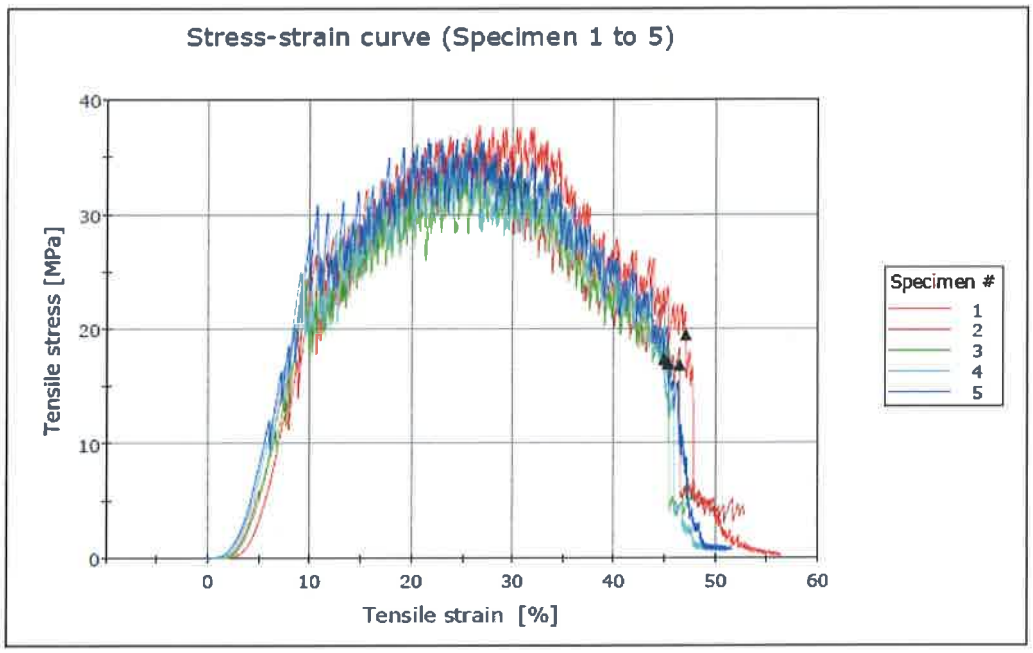


Fig C1 Stress-Strain Curve for Tearing of 5 samples in Weft Direction

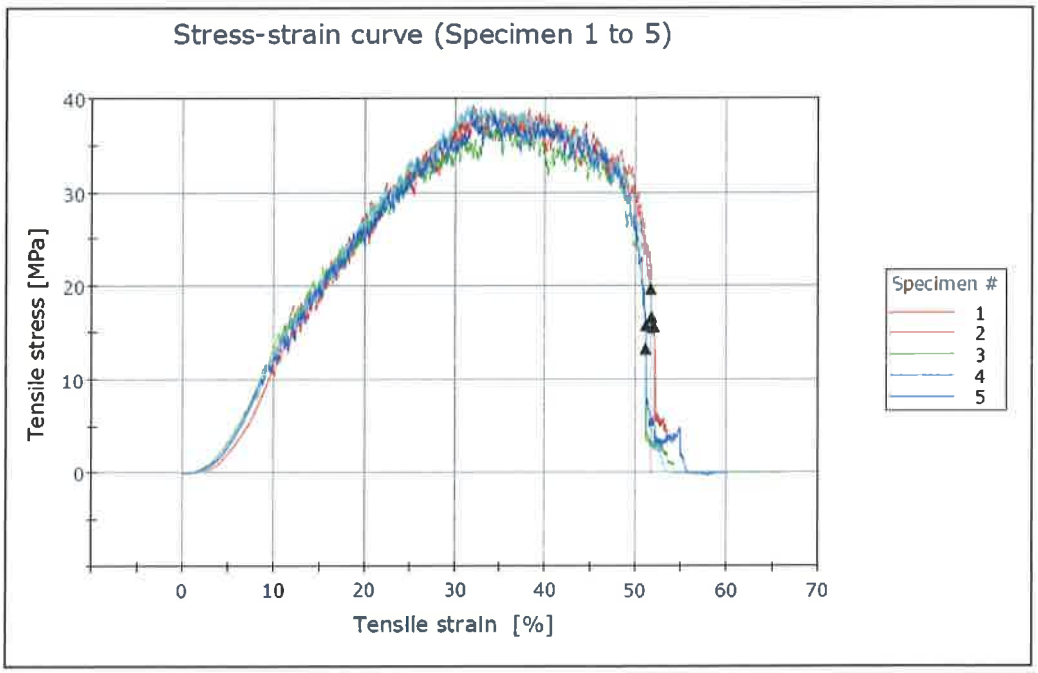


Figure C2 Stress-Strain Curve for Tearing of 5 samples in Warp Direction

Table C3 Maximum Load Required to Tear Samples (ASTM D4533)

Orientation	Sample #	Max Load (N)
Weft	1	229.7295
	2	239.6430
	3	225.9446
	4	244.6277
	5	242.0718
	Mean	236.4033
Warp	1	256.3114
	2	259.0063
	3	246.3561
	4	258.7508
	5	254.9364
	Mean	255.07224

Appendix D

Shrinkage in Wash

Table D1 Washing Shrinkage Results (50 cycles of washes, with 10 cycles interval measurements)

Specimen #	Side #	Initial Reading (cm)	10 cycles (cm)	%	20 cycles (cm)	%	30 cycles (cm)	%	40 cycles (cm)	%	50 cycles (cm)	%	Overall %
1	1 (weft)	39.6	39.55	-0.12626	39.6	0.12642	39.5	-0.25253	39.55	0.12658	39.6	0.12642	0
	2 (warp)	40.4	40.4	0	40.4	0	40.4	0	40.45	0.12376	40.4	-0.1236	0
	3 (weft)	39.15	39.1	-0.12771	39.15	0.12788	39.15	0	39.2	0.12771	39.15	-0.1276	0
	4 (warp)	40.2	40.15	-0.12438	40.15	0	40.1	-0.12453	40.15	0.12469	40.1	-0.1245	-0.248756
2	1 (weft)	39.7	39.65	-0.12594	39.7	0.1261	39.65	-0.12594	39.75	0.25221	39.8	0.12579	0.251889
	2 (warp)	40	40	0	40	0	39.95	-0.125	39.95	0	39.95	0	-0.125
	3 (weft)	39	38.9	-0.25641	39	0.25707	39.1	0.25641	39.15	0.12788	39.1	-0.1277	0.25641
	4 (warp)	40.25	40.25	0	40.25	0	40.25	0	40.25	0	40.25	0	0
3	1 (weft)	40.5	40.45	-0.12346	40.6	0.37083	40.55	-0.12315	40.6	0.1233	40.6	0	0.246914
	2 (warp)	40	39.9	-0.25	39.9	0	39.95	0.12531	39.9	-0.12516	39.9	0	-0.25
	3 (weft)	40.3	40.3	0	40.4	0.24814	40.4	0	40.35	-0.12376	40.4	0.12392	0.248139
	4 (warp)	39.85	39.8	-0.12547	39.8	0	39.75	-0.12563	39.8	0.12579	39.75	-0.1256	-0.250941
4	1	39.2	39.2	0	39.25	0.12755	39.2	-	39.25	0.12755	39.25	0	0.127551

	(weft)							0.12739					
	2 (warp)	40.45	40.4	-0.12361	40.4	0	40.4	0	40.4	0	40.35	-0.1238	-0.247219
	3 (weft)	39.05	39.05	0	39.1	0.12804	39.1	0	39.15	0.12788	39.05	-0.2554	0
	4 (warp)	40.25	40.15	-0.24845	40.2	0.12453	40.2	0	40.15	-0.12438	40.1	-0.1245	-0.372671
5	1 (weft)	38.85	38.75	-0.2574	38.85	0.25806	38.85	0	38.85	0	38.9	0.1287	0.1287
	2 (warp)	40.1	40.05	-0.12469	40.05	0	40.05	0	40.05	0	40	-0.1248	-0.249377
	3 (weft)	38.65	38.65	0	38.7	0.12937	38.7	0	38.65	-0.1292	38.75	0.25873	0.258732
	4 (warp)	39.98	39.9	-0.2001	39.9	0	39.9	0	39.95	0.12531	39.85	-0.2503	-0.325163
												Total	-0.028989

warp	-0.11967		0.01245		-0.02498		0.025		-0.0997	-0.206922
weft	-0.10172		0.18995		-0.03726		0.07602		0.02529	0.152269

Appendix E

Water Absorption

Table E1 Dry Mass, Wet Mass and Percentage of Water absorbed

#	Dry Weight (mg)	Wet Weight (mg)	Water Absorption (%)
1	677.4	861.4	27.16
2	657.8	830.1	26.19
3	645.3	813.5	26.07
4	672.3	835.9	24.33
5	640.6	801.6	25.13
Average	658.68	828.5	25.78