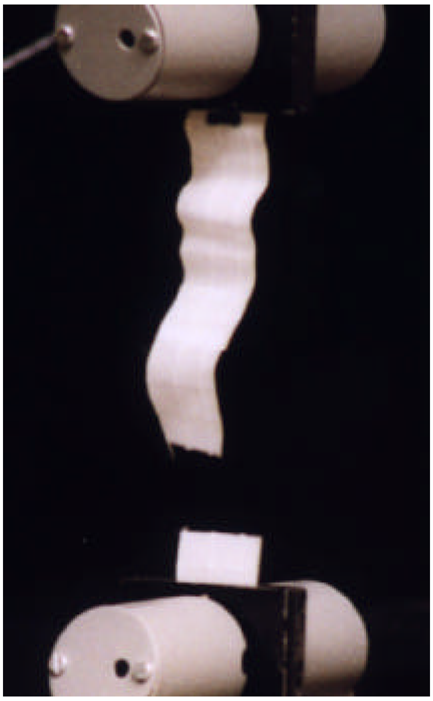
# Strength analysis
# of
# Q- tape
# in sail bonding



## 1.1 Introduction

In a period of three months, during the summer of 1999, a new moisture curing tape from Q-Bond has undergone scientific tests. The tape is designed to be activated in a specially developed activating machine. The project was designed together with Claes von Bülow of Dimension-Polyant and Professor Ulf W Gedde of the Royal Institute of Technology.

The purpose of the project was to test Q-tape in combination with Dimension-Polyant´s range of cloths. The main emphasis of the work was to test the strength of the adhesive joints after different climatic trials and to find out suitable machine settings for the activation of the adhesive.

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## 2.1 Project description

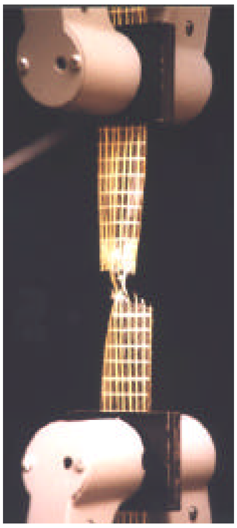
The testing method was designed within framed used by Dimension-Polyant when testing sailcloth. The testing methods have been designed together with the Royal Institute of Technology, in order to take as many test parametres as possible into consideration.

Standard measurements established for all specimens:

| | |
|---|---|
| Width: | 25 mm |
| Length: | 200 mm |
| Overlapping: | 17 mm |
| Width of adhesive (before activation): | 6 mm |

## 2.2 Method

Received cloths were sorted according to material and cut up for adhesive bonding. As the overlapping is irrelevant to the strength results, as the tape area in relation to the structure of the cloth decides the final width of the adhesive joint, a standard of 17 mm for all materials was decided on. This was to cover the spreading of the adhesive during activation.
The aim was to get an adhesive bond that would not be limiting after activation and cure but that the cloth instead would burst. Great consideration was taken to user friendliness in the choice of machine adjustment. Three parameters have been taken into account; pressure (P), amplitude (A) and velocity (V). In those cases where a higher production rate could be chosen without hindering production and strength characteristics that was done.

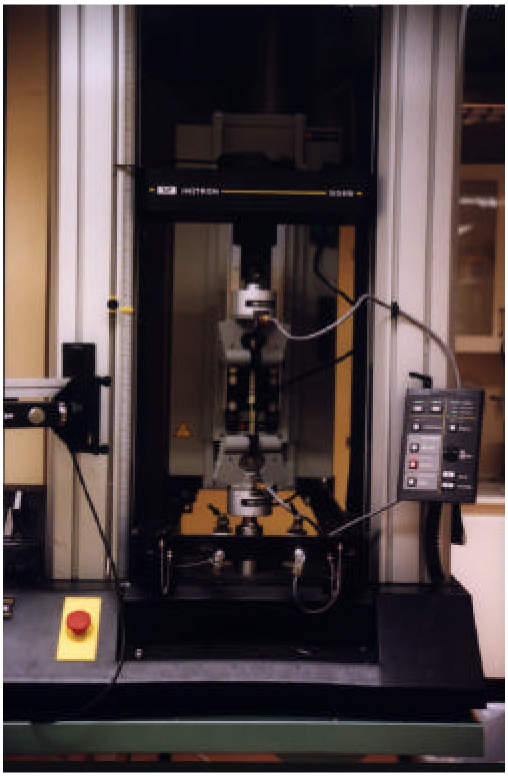


**E180 1.5 mil during test loading.**

The curing of the adhesive was allowed to go on for 10 days in room atmosphere:

| | |
|---|---|
| Temperature: | $23^{o}C$ +/-$1^{o}$ |
| Relative humidity: | 50% +/- 5% |

After curing of the tape the specimens were cut in a laser machine to get the right width.



**Certified Instron 5566 machine used in the loading tests.**

## 2.3 Loading test

All tests were carried out in the laboratory for strength testing at the institution for polymer technology of the Royal Institute of Technology.

A so called Instron machine was used for loading the specimens. The same settings were used with all the loading specimens:

| | |
|---|---|
| Free length of specimen: | 100 mm |
| Pull speed: | 15 mm/min |
| Load cell: | 10 kN |

## 2.4 UV test

Within each category of cloths the thinnest and thickest cloths have been exposed to UV radiation for 300 hours under 40 W UV fluorescent tubes. After radiation the cloths have been loaded and possible change has been noted.

## 2.5 Moisture / heat test

All cloths that have been exposed to UV light have also been stored in moist heat. Loading tests have taken place after 10 days of storing in a humidity cabinet:

| | |
|---|---|
| Temperature: | +40° C +/- 1° |
| Relative humidity: | 100% |

## 2.6 Seam

From each category of cloths a typical cloth was chosen out of Dimension-Polyant´s selection for testing of seams. Also in this case 17 mm overlapping was chosen. The seam was produced with conventional technique, with double-sided tape and a seam suitable for the cloth. The thread was fixed properly at the ends of the joint to simulate equal load on a normal sail.

# 3 Test result

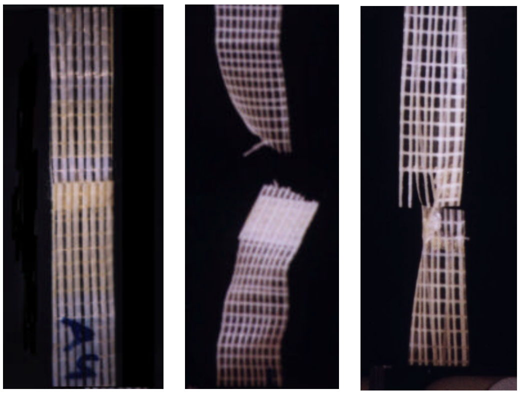
## 3.1 Initial strength

The greatest strength was achieved when Q-tape was applied against dacron or the taft of the kevlar cloths.

**190 B FT tested after UV radiation.**

Also with non-tafted laminated cloths the results were very good. The difference was in how the burst area looked. With dacron and taft cloths the material was pulled off. With non-tafted laminated cloth the picture of the burst was more varied. Depending on the weight of the laminated cloth, i.e. the amount of fibres in the cloth, the burst varied. For heavier cloths, where the films surrounding the fibres never directly touch each other, the bonded film was just pulled off (ex. 1). It follows that the strength of the joint is limited by the strength of the laminated film.

For lighter cloths, where the films directly touch the fibres, two different types of bursts were noted; the cloth was pulled off (ex. 2) or the laminated film was pulled off and the fibres were then pulled out of the laminate (ex. 3).



**Examples: 1 2 3**
**Varied bursts for non-tafted laminated cloth.**
**((PE25, PM05 and PM02)**

## 3.2 Result after UV radiation

Under UV radiation both the cloth material and the strength of the joint were changed. For less dense cloths, where the UV rays more easily come through, the strength of the joint decreased. For dense cloths, where the UV rays have not come through the material, the strength of the cloth decreased but the joint remained unaffected.

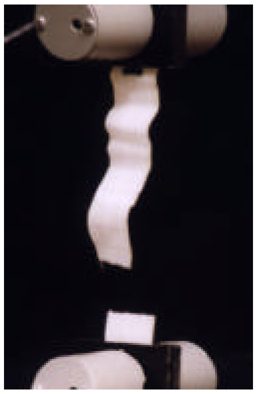
Softening of the joint may also be due to components in the adhesive not being resistant to all softeners. It follows that the change can have taken place through the influence of components in the cloth and not necessarily of the UV radiation in itself.

## 3.3 Result of UV radiation plus moisture / heat storing

After the cloths had been exposed to the testing environment it could be noted that the cloth material had been weakened more than the adhesive. Most of the specimens now showed total delamination or burst material, while the joint remained unaffected. After only UV radiation these specimens showed a picture of the burst with both delamination and deformation of the material.

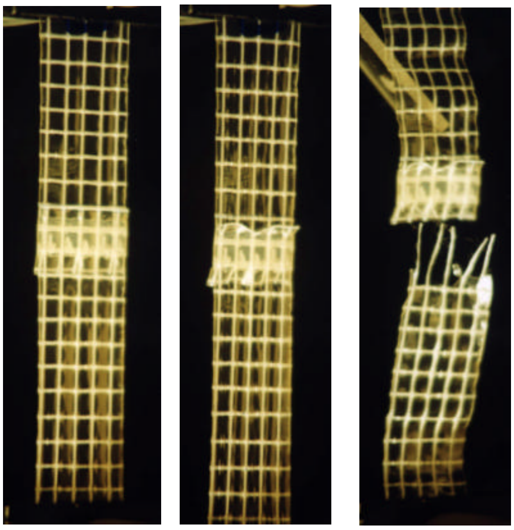
## 3.4 Result comparing seam / adhesive

A comparison of the picture of fracture for adhesive bonds and seams showed that adhesive bonds gives equal load in the whole lap, while the seam cuts in spots through the material because of the needle holes. In the adhesive lap no deform-ation occurs when loaded, instead the elasticity of the material ab-sorbs the forces. During the test cycle

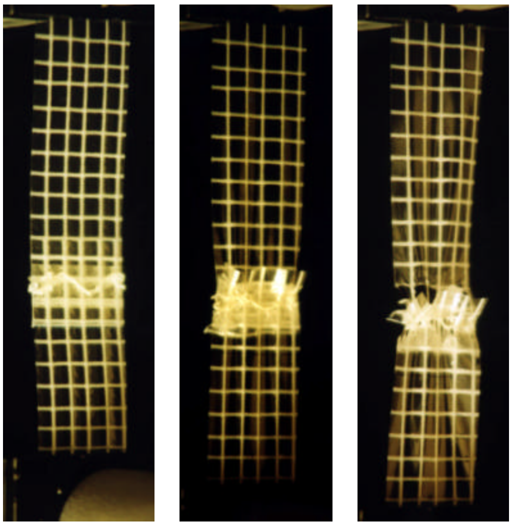


**The shape of 265 SQ HTP PLUS after stretching.**

| Stretching of cloth: | Adhesive: [mm] | Seam: [mm] |
|---|---|---|
| PM 02 1.0 mil | 19.25 | 6.25 |
| 140 BMT OPTI | 28.25 | 11.35 |
| 300 SF HTP PLUS | 28.75 | 5.25 |
| E14T 1.5 mil | 3.49 | 4.50 |
| 90 Constant | 21.50 | 9.00 |



Test procedure for PM02 1 mil bonded with Q-tape.



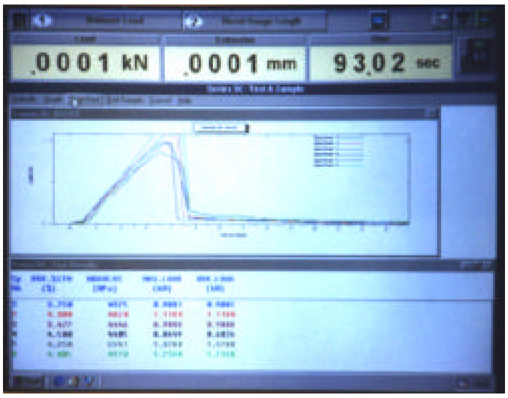
Test course for PM02 1 mil sewn with conventional sewing technique.

| Cloth | Adhesive [kN] | Seam [kN] | Difference [%] |
|---|---|---|---|
| PM 02 1.0 mil | 0.2158 | 0.0973 | 221.8% |
| 140 BMT OPTI | 0.4739 | 0.1497 | 316.6% |
| 300 SF HTP PLUS | 1.295 | 0.2352 | 550.6% |
| E14T 1.5 mil | 1.148 | 0.3134 | 366.3% |
| 90 Constant | 0.5139 | 0.1063 | 483.4% |

the material is stretched. For dacron cloths this occurs when fibres inside the material burst, for laminated cloths when the laminate is stretched. In the sewn joint the deformation takes place in the seam itself, which means that the material is never stretched to the point of bursting. In other words the strength of the material is not used to the same extent.

## 4.1 Establishing number of specimens

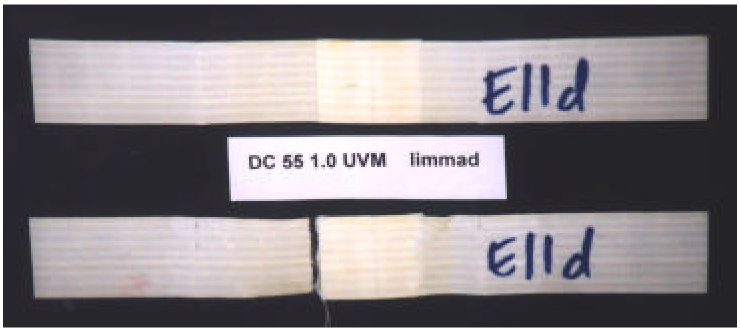
The following series of tests were carried out to establish the amount of repeated measurements demanded to get a reliable result.



**With all tests the software MERLIN was used, Series IX Automated Materials Tester.**

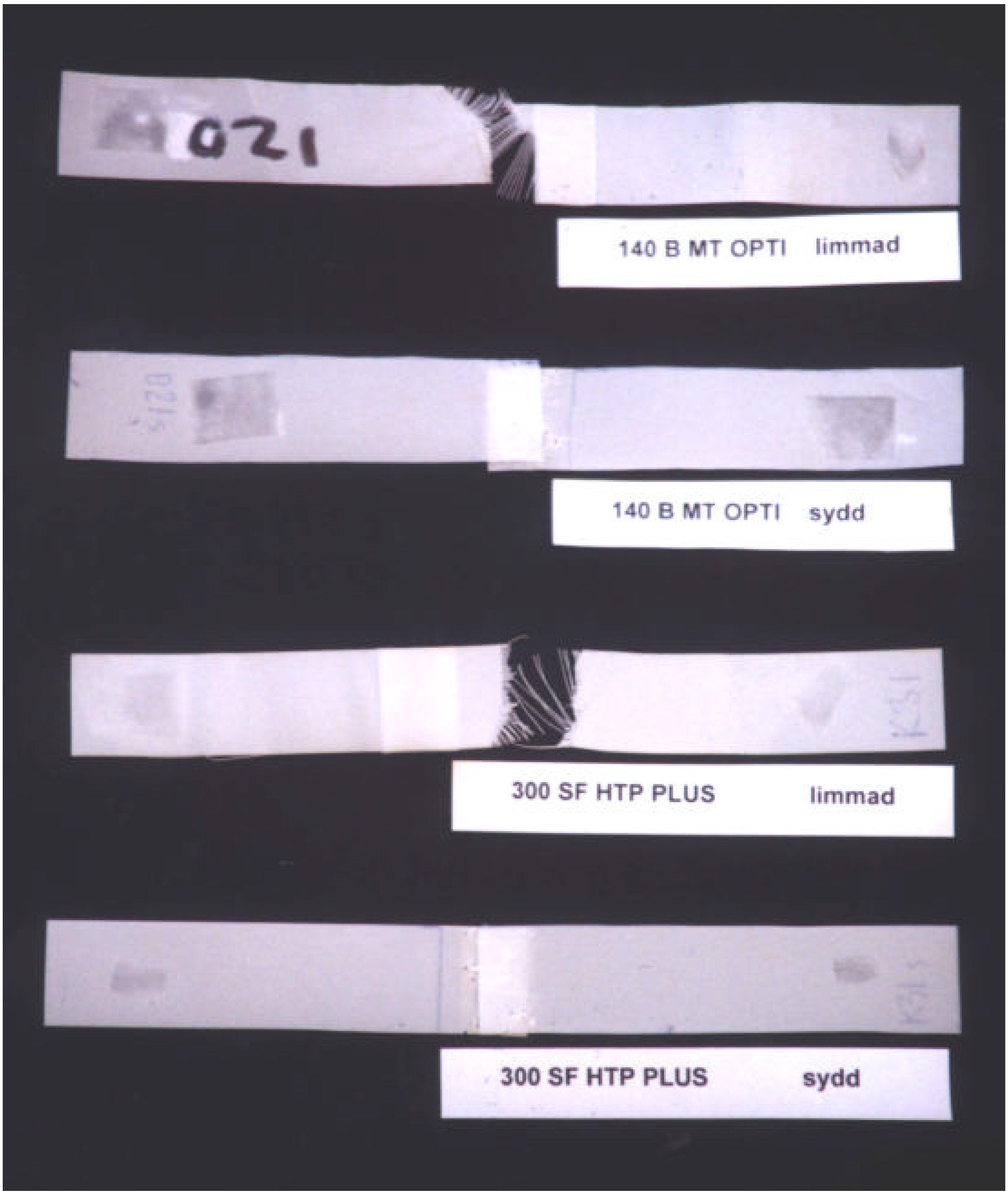
We see that the standard deviation is under 5 per cent, both for bonded and sewn joint. This low standard deviation means that only a few measurements are demanded per specimen. We therefore decided that two measurements per specimen were enough in those cases where these values did not differ more than 10 per cent. In the other cases one extra measurement was carried out

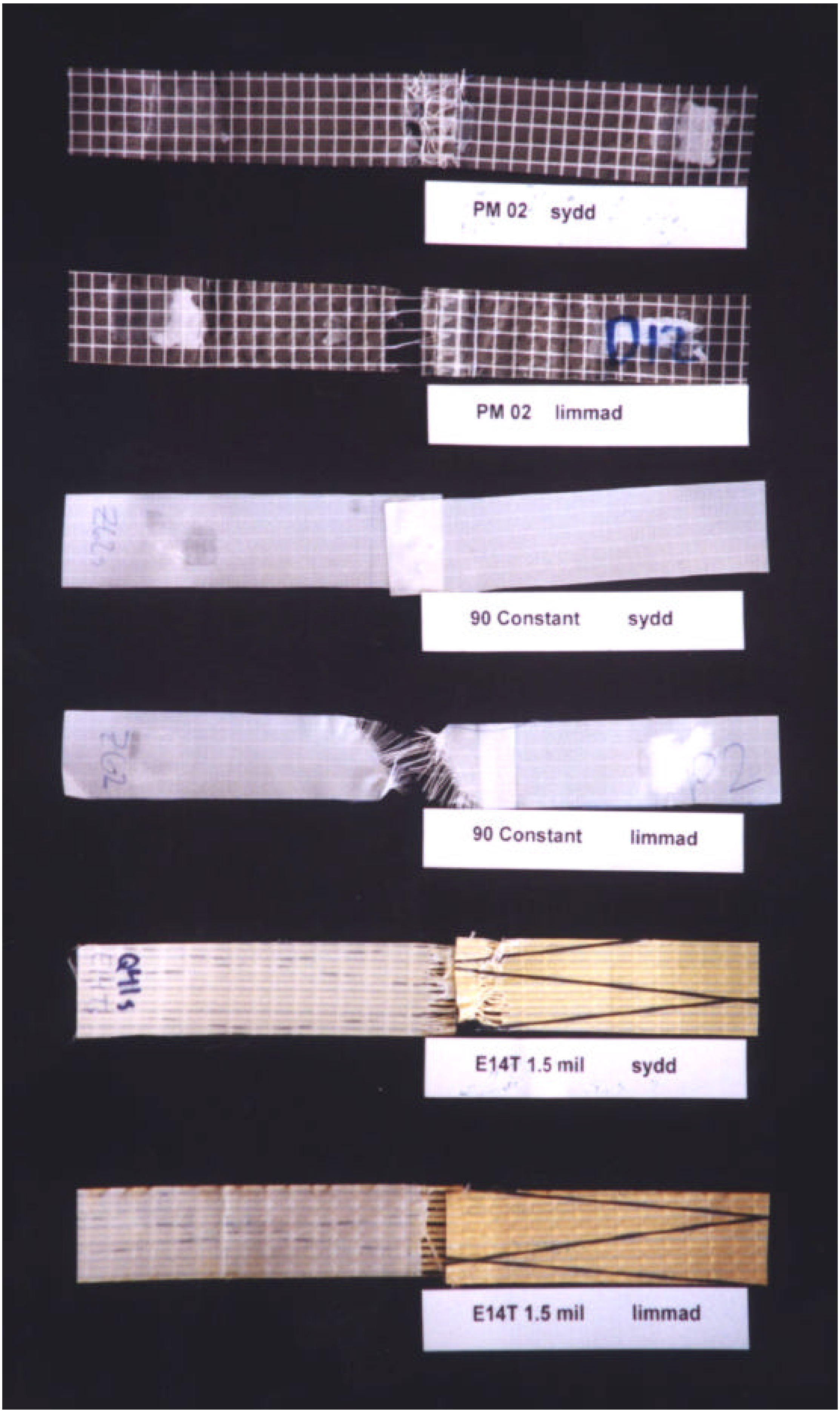
| | | | |
|---|---|---|---|
| **Test series:** | | **Test series:** | |
| **PE10 1.5 mil** | | **140 B MT OPTI** | |
| | | | |
| Type of joint: adhesive | | Type of joint: seam | |
| Test result [kN]: | 0.5285 | Test result [kN]: | 0.1438 |
| | 0.5971 | | 0.1354 |
| | 0.5503 | | 0.1497 |
| | 0.5807 | | 0.1391 |
| | 0.5981 | | 0.1469 |
| | 0.5312 | | 0.1372 |
| | 0.5695 | | 0.1435 |
| | 0.5703 | | 0.1283 |
| | | | |
| Average: | 0.5657 | Average: | 0.1405 |
| Standard deviation: | 0.027 | Standard deviation: | 0.0069 |
| Std deviation [%]: | 4.7749 | Std deviation [%]: | 4.9109 |




**Above and to the left:**
**DC cloths were also bonded with double tapes. With a single tape only the taft was torn off (0.4327 kN DC55, 0.44865 kN DC 77). With double tapes the whole cloth was torn off (0.7650 kN DC 55, 0.8591 kN DC 77). The strength of the bond was increased by 76.70 % (76.80 % and 76.60 % respectively).**

**Down:**
**Pictures of the bursting from comparing tests seam ("sydd") contra Q-tape bond ("limmad").**




PM 02 sydd
PM 02 limmad
90 Constant sydd
90 Constant limmad
E14T 1.5 mil sydd
E14T 1.5 mil limmad

## 5.1 References

**Ulf W. Gedde,** Professor (Polymer Materials), *Royal Institute of Technology.*

**Andreas Krupička,** M.Sc, Ph.D. Student, *Royal Institute of Technology.*

**Mats Johansson**, Ph.D, *Royal Institute of Technology.*

**Jürgen Schnee**, responsible for production, *Royal Sails AB*


**Literature:** **Blom, Gunnar:** *Theory of probability and statistics with implementation Part C*, 1989 fourth edition, student literature, Lund, page 184-188.

**International Standard ISO 1184:** *Plastics – Determination of tensile properties of films*, 1983-08-15
Ref. No. ISO 1184-1983 (E), page 1-7.



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## 6.1 Appendix

**Test 1:** Initial strength of specimens bonded with Q-tape.

**Test 2:** Specimens bonded with Q-tape and tested after exposure to UV-light.

**Test 3:** Specimens bonded with Q-tape and tested after exposure to UV-light and moisture/heat .

**Test 4:** Specimens sewn with conventional sewing technique.

Letters accompanying the values:

**A:** 100% burst of material.
**B:** 50% burst of material, 50% burst of adhesive.
**C:** 100% burst of joint.

| Style | Finish | | Test 1 | Test 2 | Test 3 | Test 4 | Machine settings |
|---|---|---|---|---|---|---|---|
| | | | [ kN ] | [ kN ] | [ kN ] | [ kN ] | |
| 140 B | HTP OPTI | | 0.4700 A | 0.2500 A | 0.2721 A | | P3 A8 V4 |
| 140 B | MT OPTI | | 0.4739 A | | | 0.1497 C | 2.5 6 8 |
| 160 B | HTP PLUS | | 0.4278 A | 0.3088 A | 0.3555 A | | 2.5 6 3 |
| 180 B | HTP PLUS | | 0.6057 A | | | | 2.5 6 4 |
| 190 B | HTP PLUS | | 0.5707 A | | | | 2.5 6 5 |
| 240 B | HTP PLUS | | 0.7793 A | 0.3972 B | | | 2.5 6 2 |
| 160 B | MT | | 0.5182 A | 0.2804 A | 0.2677 A | | 2.5 6 4 |
| 190 B | HMT/MT/FT | | 0.6697 A | 0.4125 A | | | 2.5 6 3 |
| 240 B | HMT/MT | | 0.7770 B | | | | 2.5 6 2 |
| | | | | | | | |
| 200 AP | MT | | 0.7247 B | 0.3674 C | | | 2.5 6 3 |
| 240 AP | HMT | | 0.5662 B | | | | 2.5 8 3 |
| 280 AP | HMT/MT | | 0.6987 B | | | | 2.5 6 3 |
| 320 AP | HMT/MT | | 1.008 B | 0.7712 A | 0.7999 A | | 3 8 2 |
| 200 AP | HTP PLUS | | 0.7519 A | 0.3490 C | | | 2.5 6 4 |
| 240 AP | HTP PLUS | | 0.9971 A | | | | 2.5 8 3 |
| 280 AP | HTP PLUS | | 1.102 A | | | | 3 9 4 |
| 320 AP | HTP PLUS | | 1.145 A | 0.8551 A | | | 3 8 3 |
| | | | | | | | |
| 165 SQ | HMT/MT | | 0.4176 A | | | | 3 6 3 |
| 180 SQ | HMT/MT | | 0.4090 A | 0.1907 A | 0.2571 A | | 2.5 6 3 |
| 203 SQ | HMT/MT | | 0.6647 A | | | | 3 8 3 |
| 205 SQ | HMT/MT | | 0.5099 A | | | | 3 4 1 |
| 245 SQ | MT | | 0.6109 A | | | | 3 8 3 |
| 253 SQ | MT | | 0.7016 A | | | | 3 8 3 |
| 265 SQ | HMT/MT | | 0.7584 A | 0.4323 A | 0.4748 A | | 3 8 3 |
| 130 SQ | HTP PLUS | | 0.6783 A | 0.3208 B | 0.4250 A | | 2 6 5 |
| 165 SQ | HTP PLUS | | 0.4297 A | | | | 3 6 5 |
| 180 SQ | HTP PLUS | | 0.4892 A | | | | 3 8 3 |
| 203 SQ | HTP PLUS | | 0.6830 A | | | | 2 6 3 |
| 205 SQ | HTP PLUS | | 0.3631 A | | | | 3 6 3 |
| 245 SQ | HTP PLUS | | 0.7523 A | | | | 3 6 3 |
| 253 SQ | HTP PLUS | | 0.7633 A | | | | 3 6 3 |
| 265 SQ | HTP PLUS | | 0.5007 C | 0.4456 A | 0.5521 A | | 3 8 3 |

| Style | Finish | | Test 1 | Test 2 | Test 3 | Test 4 | Machine settings |
|---|---|---|---|---|---|---|---|
| | | | [ kN ] | [ kN ] | [ kN ] | [ kN ] | |
| 230 SF | HMT/MT | | 0.6881 B | 0.4017 C | | | P3 A8 V3 |
| 260 SF | HMT/MT | | 0.8137 B | | | | 3 8 3 |
| 300 SF | HMT/MT | | 0.6659 B | 0.4944 C | | | 3 8 3 |
| 230 SF | HTP PLUS | | 0.9872 A | 0.3438 C | 0.3233 C | | 3 6 3 |
| 260 SF | HTP PLUS | | 1.253 B | | | | 3 8 3 |
| 300 SF | HTP PLUS | | 1.295 A | 0.5720 C | 0.5571 C | 0.2352 C | 3 6 3 |
| | | | | | | | |
| DC 55 | 1.0 UVM | | 0.4327 B | 0.5484 B | | | 2 6 3 |
| DC 66 | 1.5 UVM | | 0.4942 B | | | | 2.5 8 3 |
| DC 77 | 1.5 UVM | | 0.4865 B | 0.5172 A | | | 2.5 8 3 |
| | | | | | | | |
| SP02 | 2.0 mil | | 0.3909 B | 0.2987 A | 0.2998 A | | 2 6 3 |
| SP06 | 1.5 mil | | 0.5376 A | | | | 2.5 6 3 |
| SP06 | 2.0 mil | | 0.4720 A | 0.4251 B | 0.4434 A | | 2.5 6 3 |
| | | | | | | | |
| PM02 | 1.0 mil | | 0.2158 A | 0.1182 A | 0.1000 A | 0.0973 C | 2 6 5 |
| PM05 | 1.5 mil | | 0.3876 A | 0.2765 A | 0.2913 A | | 2.5 8 3 |
| PM05 + T | 1.5 mil | | | | | | 2.5 8 4 |
| TT | | | 0.5697 A | | | | |
| FF | | | 0.3652 A | | | | |
| FT | | | 0.3832 A | | | | |
| | | | | | | | |
| PE10 | 1.5 mil | | 0.5807 B | 0.5123 B | 0.5054 A | | 2 6 3 |
| PE15 | 1.5 mil | | 0.6615 B | | | | 2.5 8 3 |
| PE20 | 1.5 mil | | 0.4941 A | | | | 2.5 8 3 |
| PE25 | 1.5 mil | | 0.6709 A | 0.6779 A | 0.6831 A | | 2 8 3 |
| PE25 + T | 2.0 mil | | | | | | 2 8 3 |
| TT | | | 0.5809 A | 0.5526 A | 0.5534 A | | |
| FF | | | 0.4208 A | 0.4491 A | 0.3688 B | | |
| TF | | | 0.5005 A | 0.5911 A | 0.5184 A | | |
| | | | | | | | |
| XP01 | 1.5 mil | | 0.5012 B | 0.5609 B | | | 2.5 8 5 |
| XP11 | 1.5 mil | | 0.5481 C | | | | 2 6 3 |
| XP15 | 1.5 mil | | 0.6332 B | 0.6462 A | | | 2.5 8 3 |
| | | | | | | | |
| P180 | 0.5 UVM | | 0.5009 C | | | | 3 8 3 |
| P220 | 0.5 UVM | | 0.6866 A | | | | 2.5 8 3 |
| P260 | 1.0 UVM | | 0.6908 A | | | | 2.5 8 3 |
| P320 | 1.0 UVM | | 0.4498 B | | | | 3 8 3 |
| | | | | | | | |
| E040 | 1.5 mil | | 0.6305 A | 0.5071 A | 0.4073 B | | 2 8 3 |
| E060 | 1.5 mil | | 0.4779 A | | | | 2 8 3 |
| E090 | 1.5 mil | | 0.8272 A | | | | 2.5 8 3 |
| E140 | 1.5 mil | | 0.8335 A | | | | 2.5 8 3 |
| E180 | 1.5 mil | | 0.8282 B | | | | 2.5 8 3 |
| E220 | 1.5 mil | | 0.9217 A | 1.073 B | 0.8780 A | | 2.5 8 3 |
| E260 | 2.0 mil | | 0.6305 A | | | | 2.5 8 3 |

| Style | Finish | | Test 1 | Test 2 | Test 3 | Test 4 | Machine settings |
|---|---|---|---|---|---|---|---|
| | | | [ kN ] | [ kN ] | [ kN ] | [ kN ] | |
| E14 + T | 1.5 mil | | | | | | P2.5 A8 V3 |
| TT | | | 1.148 A | 0.9881 A | 1.046 A | 0.3134 C | |
| FF | | | 0.9500 A | 0.9888 B | 0.8457 A | 0.3134 C | |
| TF | | | 1.082 A | 1.378 A | 0.8458 A | 0.3134 C | |
| E18 + T | 1.5 mil | | | | | | 2.5 8 3 |
| TT | | | 1.021 A | 1.041 B | 1.044 A | | |
| FF | | | 0.9040 A | 1.020 B | 0.8250 B | | |
| TF | | | 0.9750 A | 1.173 A | 1.065 A | | |
| E22 + T | 1.5 mil | | | | | | 2.5 8 3 |
| TT | | | 1.172 B | 1.077 A | 1.037 B | | |
| FF | | | 0.7680 B | 0.8220 B | 0.6299 C | | |
| TF | | | 0.9390 B | 1.117 A | 0.9115 C | | |
| E26 + T | 2.0 mil | | | | | | 2.5 8 3 |
| TT | | | 1.029 B | 1.222 B | 1.081 A | | |
| FF | | | 0.8550 B | 1.043 B | 0.8260 B | | |
| TF | | | 1.034 A | 1.284 B | 1.009 A | | |
| | | | | | | | |
| 0.75 Dilon | | | 0.1961 A | | | | 1 5 2 |
| 1.5 Dilon | | | 0.2336 A | | | | 1 7 2 |
| 65 Constant | | | 0.2877 A | | | | 1,5 7 2 |
| 90 Constant | | | 0.5139 A | | | 0.1063 C | 2 7 2 |
| 32 CHS | | | 0.2119 A | | | | 1.5 4 3 |

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SCIENCE AND ART

7.1

Department of Polymer Technology/UWG

Stockholm 99-09-23

Q-Bond AB
Djurgårdsvägen 46
115 21 Stockholm

Dear Sir,

I hereby state that the data presented in the report 'Stength analysis of Q-Bond® tapes in sail bonding', are based on experiments carried out in a recommendable way. Different possible sources of error have been carefully considered in the experimental study. The results of the analysis shows significant differences between the different specimens and the conclusions drawn in the report are based on the experimental results obtained.

Sincerely yours

Ulf W Gedde
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