THE NEW TAILORED WET-LAID NON-WOVEN BASE MATERIALS FOR BITUMEN ROOFING FELT

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Wet-laid nonwoven material have been developed that combine excellent property characteristics and economy. These new materials utilize the wet-laid nonwoven process in blending different kinds of fibres to produce an optimum balance of performance properties at the right price.

A combination of polyester and cellulose pulp fibres is used, which when bonded with the aid of a polymer latex binder, gives a range of properties that can be tailored to match the product design requirements at prices between those of organic felts (ragfelt) and pure polyester materials. In general, the similarity of wet-laid nonwoven material to pure polyester material grows as the polyester fibre content is increased. However, the modified composition of the nonwoven greatly improves its on-machine dimensional stability. As a result, a typical basis weight of about 125 grams per square meter can be used compared to a basis weight of about 170 grams per square meter for pure polyester materials. Elongation performance of wet-laid nonwoven material avoids the thermal cracking problems that have limited the use of cheaper fiberglass mats in areas with large seasonal temperature variations such as Scandinavia. Organic felt's major drawback of high water uptake also is avoided with wet-laid nonwovens.

Thorough laboratory testing combined with extensive field trials have shown that these new nonwoven materials form an effective reinforcement for bitumen roofing felts. The low drape resistance of the finished products permits easy unrolling and ensures good conformity to irregular surfaces, even when applied at winter temperatures. The new range of materials thus fills a significant price/performance gap in the roofing felt market.

This paper deals with aspects of the development work and describes the properties that can be obtained with these new wet-laid materials in comparision to other base materials for bitumen roofing felts. These new materials have been field tested since 1982 and in commercial production for roofing felts in Sweden since the end of 1983. They have created considerable interest both in other European countries and in the United States, where trials are being carried out by many roofing felt manufacturers. A brief comment on the European market situation is presented.

MARKETS FOR ROOFING FELT BASE MATERIALS IN EUROPE

The total market for roofing felt in Europe is stable at around 800 million square meters per year. The largest market is West Germany, followed by the United Kingdom, Italy and France. In Europe, wet-laid, fiber glass nonwoven webs dominate bitumen roofing felt material manufacture today. Organic felt products based on predominantly textile fibres are next in importance. Polyester spunbonded material is increasing very rapidly in importance and soon should surpass organic felt in total market share. In the future, fiber glass material is expected to fall somewhat in market share while organic felt is expected to drop drastically. The rest of the market is divided among other types of products.

As far as cost/performance is concerned, the organic felt materials are at the lower end of the scale, while polyester spunbonded materials are in the upper regions. Fiber glass web materials give good economy for many uses but have the drawbacks of low elongation properties and brittleness. This is especially important for markets that have climates with large seasonal temperature variations such as Scandinavia. Expansion and contraction of the deck must be accommodated by the reinforcement material, or cracks can develop in the roofing felt.[1,2]

All these factors indicated that there were distinct market possibilities for a roofing base material that could fill the gap in cost/performance, and development work was initiated with this end in mind.

DEVELOPMENT OF WET-LAID NONWOVEN ROOFING BASE MATERIAL

Our experience in the production of coating substrates for flooring and wallcovering provided important background from which to start the development work. Well-established contacts with fiber and binder manufacturers enabled rapid progress to be made in obtaining the large range of raw materials required for the initial laboratory screening tests. It was necessary to obtain polyester fibers with non-standard dimensions. Fiber suppliers cooperated by producing trial quantities of polyester fibers with the range of lengths and deniers (diameters) needed for the search for fiber compositions with optimal properties. The binder is a very important factor in the design of a material with viable properties, and it was necessary to evaluate many types of binders to find the best combination of properties. Compatability and good adhesion to bitumen are very important binder properties, as is high strength in the hot bitumen bath.

A series of production trials was carried out in which sufficient amounts of prototype materials were produced to enable the manufacture of finished bitumen roofing felt. These trials allowed further optimization work to be completed including research on dimensional stability and runability in the bitumen coating process. A study of the dispersion and formation of various fibre blends, the optimization of the choice of fibre dimensions, and an evaluation of the fibre's interaction with bitumen in establishing optimal property profiles also were possible during these trials.

PROPERTIES OF THE WET-LAID NONWOVEN ROOFING BASE MATERIALS

The development work has led to the production of two commercial qualities, designated in this paper as wet-laid nonwoven materials 581 and 585 (*Table 1*). These materials are tailored to fill the gap in cost/performance between spunbonded polyester at the high end and organic felt and fiber glass webs at the low end. The wet-laid nonwoven material 581 contains 40 percent polyester fibres and 60 percent wood pulp, and is bonded by an acrylic binder. This well-balanced composition provides a number of improved properties over organic felt and fiber glass nonwovens. The wet-laid nonwoven material 585 contains 65 percent polyester fibers and 35 percent wood pulp, and is bonded by an acrylic binder. This gives properties comparable to, and in some cases better than, a 100 percent polyester spunbonded nonwoven roofing base.

Typical values for the main properties and a cost index with which we can compare these base materials are shown in Table 1. This illustrates the large gap in property levels between organic felt and fiber glass on the one hand and polyester spunbonded material on the other. The wet-laid nonwoven materials 581 and 585 are seen to lie in between these extremes as far as tensile strength, elongation, tear strength and cost are concerned. Note that the materials compared here have widely differing basis weights.

More important, however, are the properties that are obtained in the finished bitumen-coated roofing felts manufactured from these base materials. The interaction of the bitumen with the substrate can play a very important role in the properties of the final product. A description of the various properties of bitumen roofing felts manufactured from these base materials is presented in this paper. The description shows how the polyester/cellulose wet-laid nonwoven-based felts complement more established base materials. The roofing felts have been manufactured according to the Swedish Standard SS 23 69 03 using oxidized bitumen 95/35 with a softening point of 95C and a limestone filler content of 35 percent. The various quality identification numbers used in this standard indicate the following:

SAL 4000 — Cap sheet of bitumen-impregnated and coated organic felt with a sand underside applied at the rate of 300 grams per square meter (6.2 pounds per 100 square feet) and a slate granule topside applied at the rate of 1200 grams per square meter (2.5 pounds per 100 square feet. Total basis weight is 4,000 grams per square meter (82 pounds per 100 square feet).

SAP/C 4000 — Cap sheet as above with wet-laid nonwoven material carrier.

YAP 2500 — Underlaying felt of bitumen-impregnated and coated spunbonded polyester or wet-laid nonwoven material sand-applied at the rate of 300 grams per square meter (6.2 pounds per 100 square feet) per side and a total basis weight of 2,500 grams per square meter (51.3 pounds per 100 square feet).

YAM 2000 — Underlaying felt of bitumen-coated wet-laid fiber glass non-woven material with 300 grams per square meter (6.2 pounds per 100 square feet) of sand per side and a total basis weight of 2,000 grams per square meter (41 pounds per 100 square feet).

The values are put in perspective by comparing them with the present Swedish standard values (SS 23 68 03) for these types of roofing felts. These are the minimum levels that the standardizing authorities believe give adequate performance in various roofing applications. Testing is made according to standard Swedish industrial methods for bitumen roofing felt (Swedish Standard SS 23 68 05) unless otherwise stated. These testing methods are similar to ASTM methods and European UEATC test methods. In all of the bar charts, the values for machine direction and cross direction test results are shown as the left- and right-hand bar respectively for each property.

TENSILE STRENGTH

Figure 1 shows a comparison at 0C of the tensile strengths of bitumen roofing felts manufactured as 4,000 grams-per-square-meter cap sheets based on organic felt (SAL 4000) and on wet-laid nonwoven material 581 (SAP/C 4000), related to the requirement in the Swedish Standard SS 23 68 03 for cap sheets designated SAL 4000. The organic felt has a somewhat higher tensile strength than the wet-laid nonwoven material 581, but the Swedish standard requirement is adequately fulfilled by both. The ASTM D226 requirements are not strictly comparable due to differences in basis weight. They are, however, exceeded by the tensile strengths of both of these materials.

Figure 2 shows a comparison of the tensile strengths at 0C for underlaying felts made from spunbonded polyester (YAP 2500) and for wet-laid nonwoven 585. Underlaying fiberglass nonwoven felt (YAM 2000) is included as a reference to show the difference in performance. The bar charts show values in the machine direction and cross direction. The requirements for underlaying felt designated YAP 2500 according to the Swedish Standard SS 23 68 03 are shown. Here it can be seen that the polyester spunbond-base material gives the highest values while the wet-laid nonwoven material 585 and fiber glass web give roughly the same values. The ASTM D2178 requirements for fiber glass felts are not strictly comparable because of basis weight differences. They are, however, exceeded by the tensile strengths of these materials.

ELONGATION

Figure 3 shows a comparison of the elongation values at 0C for 4000-grams-per-square-meter cap sheet bituminous roofing felts made from organic felt (SAL 4000) and from wet-laid nonwoven material 581, (SAP/C 4000). The requirement of the Swedish standard for this material is set low to accommodate the low values obtained from organic felt. The values for the wet-laid nonwoven material 581 are much higher. This allows for a quality improvement that gives considerably better performance leading to a reduced risk of membrane failure. The ASTM specification for organic felts D226 does not specify elongation values and cannot be compared.

Figure 4 shows the elongation at break measured at 0C for underlying felts made from spunbonded polyester (YAP 2500) wet-laid nonwoven material 585. Underlaying felt with a fiberglass web base (YAM 2000) again is included as a reference. Here is an enormous spread between the very high values for the polyester spunbonded material and the extremely low values for the fiberglass web.

The new wet-laid nonwoven material 585 fills the gap at a level that fulfills the requirements of the Swedish standard. The level of elongation of the wet-laid nonwoven material is sufficiently high to prevent cracking, which can occur with the fiber glass material when subjected to stresses brought about by large temperature variations. The ASTM standard D2178 for glass felt roofing material does not specify elongation values and cannot be compared.

TEARING STRENGTH

The Swedish standard tearing strength method is based on the German DIN 53.356 method and is similar to ASTM 2262-83 (tongue tear in tensile testing machine). Figure 5 shows a comparison of the cap sheets manufactured from organic felt (SAL 4000) and the wet-laid nonwoven material 581 (SAP/C 4000) showing the very low Swedish standard requirement of 4,000 grams per square meter, which has been set to allow for organic felt. The wet-laid nonwoven 581 is a considerable improvement over the unsatisfactory performance of rag felt.

Figure 2 shows a comparison of the results of tearing strength measurements at 25C for the underlying felts (YAP 2500) made from spunbonded polyester and wet-laid nonwoven material 585. YAM 2000 felts based on fiber glass nonwoven is included as a reference to show the difference in performance. Here it can be seen that the spunbonded polyester and wet-laid nonwoven values are both at a high level while the fiber glass web ranks extremely low.

The ASTM standards for organic and fiber glass felts do not specify tearing strength levels and cannot be compared.

PERFORATION RESISTANCE

Perforation resistance is measured with two instruments, a cylinder and a wedged chisel, according to the Swedish standard method. These instruments are pushed at constant speed through the roofing felt under standard conditions and the force for penetration is registered. Figures 7 and 8 show results from measurements with the cylinder and chisel methods for cap sheets (SAL 4000), manufactured from organic felt and from wet-laid nonwoven material 581. Both materials exceed the Swedish standard requirements by a good margin. Figure 9 shows the results from measurements with the cylinder method for the underlaying felts (YAP 2500) manufactured from spunbonded polyester and from wet-laid nonwoven material 585. Fiber glass nonwoven (YAM 2000) is included as a reference. Figure 10 shows results with the chisel. In both cases the spunbonded polyester quality gives slightly higher values than the wet-laid nonwoven material 585 while the glass nonwoven gives rather low values, especially in the case of the chisel method.

WATER ABSORPTION

The water absorption test is a test that gives an idea of sensitivity to wetting. The Swedish standard method is based on the ASTM D570-63 method. The results are shown in Figures 11 and 12. Note the vast difference in the scale of these figures. Measurements were made after one and seven days. The Swedish standard specifies that water absorption should be less than 1 percent after one day. It is clear from Figure 12 that underlying felt manufactured from spunbonded polyester, wet-laid non-woven 581 (YAP 2500), and fiber glass nonwoven (YAM 2000) all fulfill this requirement by a large margin. After seven days, a considerable increase in water absorption has taken place, but all these materials still show values which are well within the limit. As far as the cap sheet based on organic felt (SAL 4000) is concerned, we see in Figure 11 that it is within the limit after one day but after seven days the organic felt material has absorbed a very large amount of moisture, whereas the cap sheet (SAP/C 4000) based on wet-laid nonwoven material 581 still shows very low water absorption. The high water absorption of the organic felt gives rise to blistering problems which do not arise when using the wet-laid nonwoven material.

AGING

The effect of aging is illustrated in Figure 13. The tensile strengths of cap sheets with basis weights of 4,000 grams per square meter manufactured from various base materials have been measured after soaking in water for various lengths of time, up to six months. Here it can be seen that the spunbonded polyester and the polyester/cellulose wet-laid nonwoven felts show almost no loss in strength compared to fiberglass nonwovens and organic felts. Aging tests also have been carried out with an Atlas weatherometer according to ASTM D529-82 and have shown excellent results for the wet-laid nonwoven materials 581 and 585 whereas the organic felts performed unsatisfactorily. Field tests started in 1982 have found no signs of deterioration or failure of the wet-laid nonwoven felts on roofs.

DIMENSIONAL STABILITY/PROCESSABILITY

Dimensional stability to heat is a very important property which relates to the ability to process a roofing base material. Dimensional stability in the presence of moisture also is important for satisfactory aging properties. The new wet-laid nonwoven materials contain blends of polyester fibres and cellulose wood pulp, which provide a good balance of dimensional stability in the presence of both heat and moisture. The cellulose component provides the heat stability, while the polyester fibre gives good moisture stability. The heat stability properties can be noted during the processing of the wet-laid nonwoven materials into bitumen roofing felts, when low shrinkage is noted. Figures 14 and 15 show heat shrinkage values from laboratory testing. The method used involves heating samples in an oven to 70C for 24 hours, cooling to room temperature for 24 hours, and then heating again to 70C for 10 days before cooling again. The results from cap sheets SAL 4000 and SAP/C 4000 manufactured from organic felt and from wet-laid non-woven material 581, and from underlaying felts (YAP 2500) manufactured from polyester spunbond and from wet-laid non-woven material 585, are shown. Underlying felt (YAM 2000) manufactured from fiber glass nonwoven is included as a reference for comparison. The results show that the polyester spunbonded felt shrinks considerably. The organic felt and fiber glass nonwoven felts have low shrinkage. The wet-laid non-woven felts have intermediate values that give very satisfactory processability compared to the polyester spunbond, which is rather sensitive to heat shrinkage.

Figure 16, 17 and 18 show the results of weathering tests under ordinary outdoor conditions. Cap sheet qualities SAP 4000 and SAP/C 4000 based on spunbond polyester and wet-laid nonwoven material 585 show no visible deterioration, wheras quality SAL 4000 based on organic felt shows a considerable deterioration because the low moisture stability causes swelling and folds in the felt.

FLAMMABILITY

The results from flammability testing according to Nordtest 006 are shown in Figures 19 and 20 (Swedish Standard SIS 02 48 24). This test is similar to ASTM E108-80a, but cannot directly be compared. The method measures the way in which a roofing felt behaves when exposed to a burning object. It provides information on how a cap sheet protects the underlying material from ignition. In the figures, the results are expressed as the length of damaged area for the cap sheet and for the deck on which it is applied for the test.

Here it can be seen that cap sheets (SAP/C 4000) made from wet-laid nonwoven materials 581 and 585, give very good results in comparison to those made from the organic felt (SAL 4000) material. Cap sheets manufactured from spunbonded polyester (SAP 4000) and fiber glass nonwoven (SAM 4000) gave results which were much better than the organic felts but not as good as the wet-laid nonwoven felts.

SUMMARY AND CONCLUSIONS

Table 2 shows a summary in very general terms of the performance of several roofing base materials; organic felt, glass nonwovens, spunbond polyester, and wet-laid nonwoven of polyester/pulp blends. The various property parameters are graded as low, medium or high.

The polyester spunbond material is very highly rated except for dimensional stability and processability. In both these cases, the heat shrinkage properties contribute to the lower rating. Organic felt material rates poorly as far as stretch, dimensional stability, water repellency and processability. In this case the bad dimensional stability is caused by the influence of moisture which can cause swelling. Processability is rated poor because of the difficulty in obtaining complete bitumen impregnation and the need to mix different bitumen qualities during processing. Nonwoven glass web has low ratings for stretch and "body" (thickness).

The new wet-laid nonwoven roofing base materials are rated in between the polyester spunbond and the organic felt and glass nonwovens for both properties and cost.

These ratings indicate the way in which the new wet-laid nonwoven material complement the range of roofing base materials available and provide the possibility of substitution in the middle area of cost/performance.

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REFERENCES

[1] Nico A. Hendriks, The Construction Specifier, April 1980, pp. 57-60.

[2] Richard G. Mansfield, Textile World, February 1984, pp. 45-48.

		Organic[1] felt (ragfelt)	Glass[2] Nonwoven	Wet-laid[3] Nonwoven 581	Wet-laid[4] Nonwoven 585	Polyester[5] Spunbond
Basis weight	g/m^2	570	90	125	125	180
	$lb/100\ ft^2$	11.7	1.8	2.6	2.6	3.7
Thickness	μm	1550	590	700	900	1080
	mils	61.0	23.2	27.6	35.4	42.5
Density	kg/m^3	370	150	180	140	170
	lb/ft^3	23.1	9.4	11.2	8.7	10.6
Tensile	MD kN/m	6.9	6.6	6.4	6.0	12.1
	lbf/in	39.4	37.7	36.5	34.3	69.1
	CD kN/m	4.2	4.5	5.2	4.8	9.2
	lbf/in	24.0	25.7	29.7	27.4	52.5
Elongation	MD %	1.3	1.4	4.5	8.0	37
	CD %	2.8	1.3	6.0	10.0	40
Tear	MD N	2.1	0.9	18.0	28.0	50.0
	lbf	0.5	0.2	4.1	6.3	11.2
	CD N	2.0	0.7	20.0	30.0	65.0
	lbf	0.5	0.2	4.5	6.7	14.6
Cost index	(per m2)	35	20	65	85	100

[1] Organic felt (ragfelt) according to Swedish Standard 23 68 03. Composition: 85 percent textile fibres (of which at least 10 percent wool), 15 percent wood pulp (of which maximum 5 percent ground wood) similar to organic felt described in ASTM D226.

[2] Wet-laid fiber glass web similar to glass felt base material described in ASTM D2178-84.

[3] Wet-laid non-woven 581-fiber composition: 40 percent polyester fibres, 60 percent wood pulp fibers; bonded with acrylic binder.

[4] Wet-laid non-woven 585-fiber composition: 65 percent polyester fibres, 35 percent wood pulp fibers; bonded with acrylic binder.

[5] Spunbond polyester needle punched and bonded with an acrylic binder.

Table 1 Typical properties and cost index of roofing base materials

	Organic felt Ragfelt	Glass fiber Non-woven	Wet-laid Non-woven Polyester/Cellulose	Spunbond Polyester
Tensile	H/M	M	M	H
Stretch	L	L	M	H
"Body" (thickness)	H	L	M	H
Perforation resistance	M	L	H/M	H
Water repellency	L	H	H	H
Dimensional stability	L	H	H	M
Processability	L	H	H	M
Cost	L	L	M	H

L = Low M = Medium H = High

Table 2 Base materials for roofing felt — relative performance

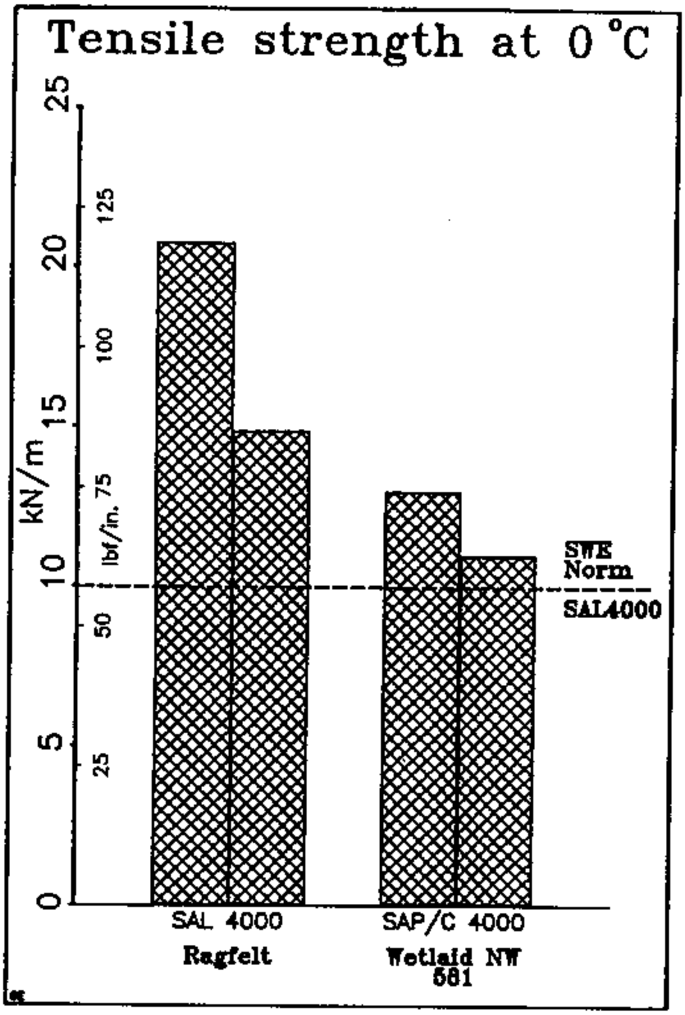

Figure 1 Tensile strength at 0C for cap sheets based on organic felt (SAL 4000) and wet-laid nonwoven 581 (SAP/C 4000), basis weights 4,000 g/m²

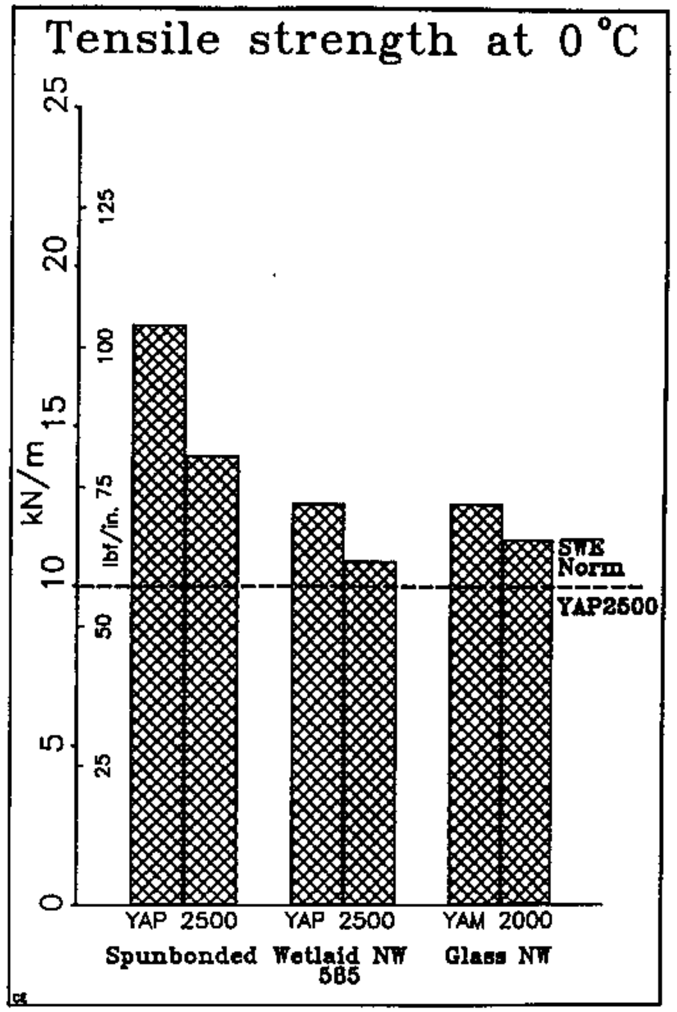

Figure 2 Tensile strength at 0C for underlaying felts (YAP 2500) based on spunbonded polyester and wet-laid nonwoven 585, basis weights 2,500 g/m² and YAM 2000 based on glass fibre non-woven, basis weight 2000 g/m²

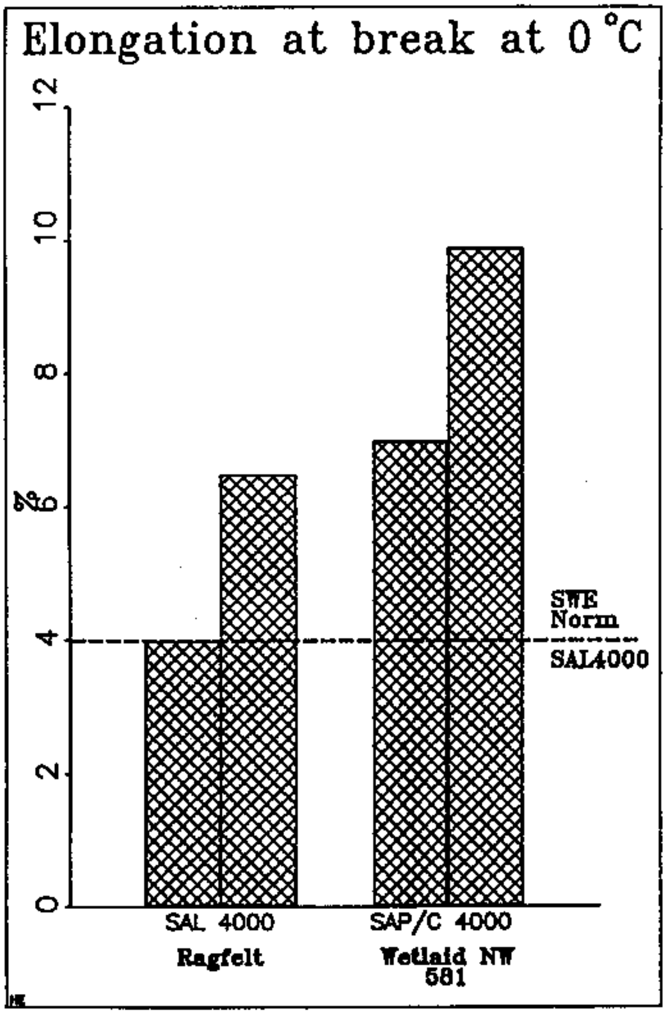

Figure 3 Elongation at break at 0C for cap sheets based on organic felt (SAL 4000) and wet-laid non-woven 581 (SAP/C 4000), basis weights 4,000 g/m²

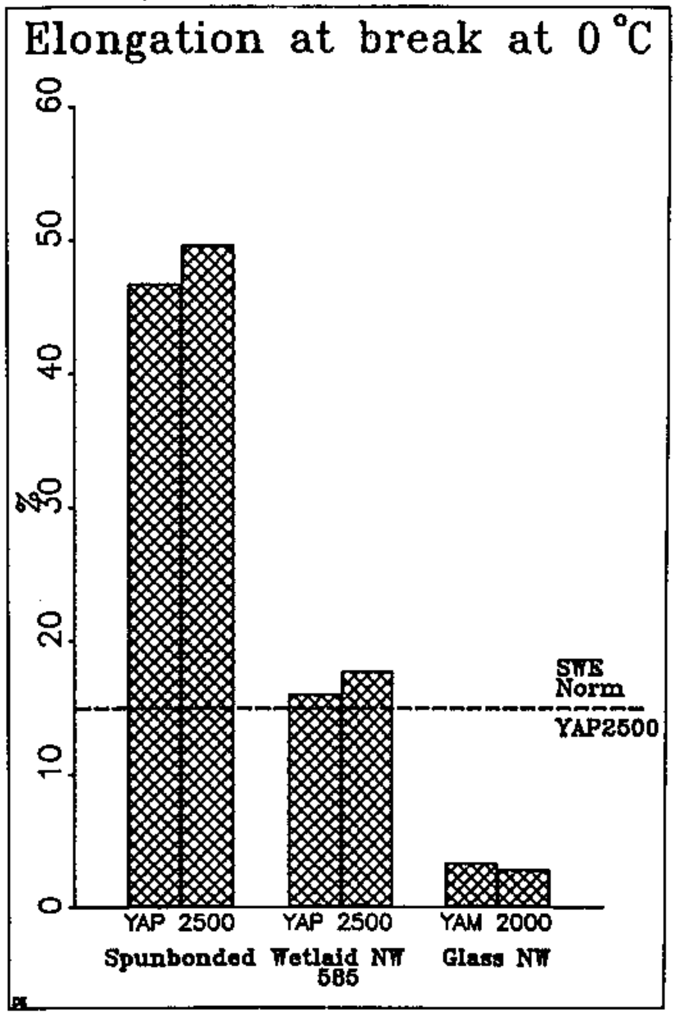

Figure 4 Elongation at break 0C for underlaying felts (YAP 2500) based on spunbonded polyester wet-laid nonwoven 585, basis weights 2500 g/m² and YAM 2000 based on glass fibre non-woven, basis weight 2,000 g/m²

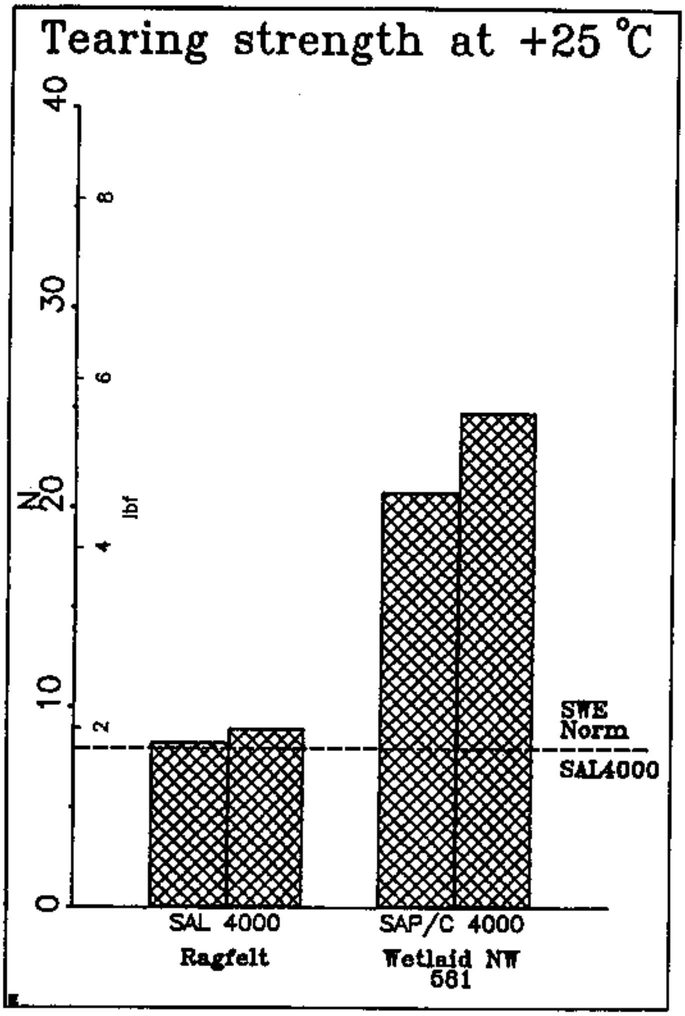

Figure 5 Tearing strength at 25C for cap sheets based on organic felt (SAL 4000) and wet-laid nonwoven 581 (SAP/C 4000), basis weights 4000 g/m²

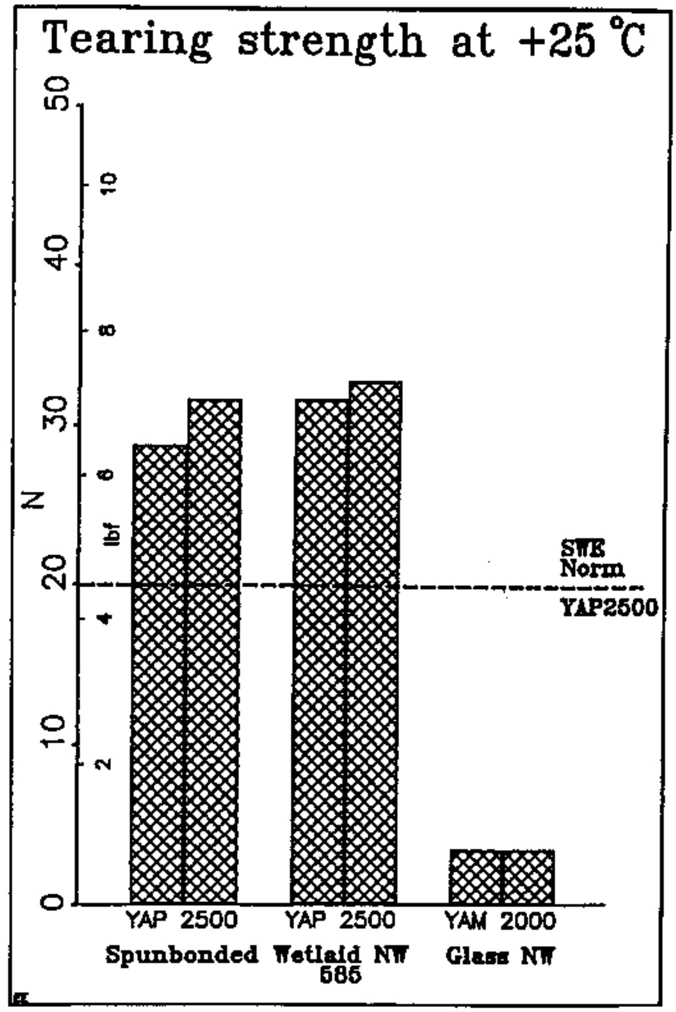

Figure 6 Tearing strength at 25C for underlaying felts (YAP 2500) based on spunbonded polyester and wet-laid nonwoven 585, basis weights 2500 g/m² and YAM 2000 based on glass fibre nonwoven, basis weight 2,000 g/m²

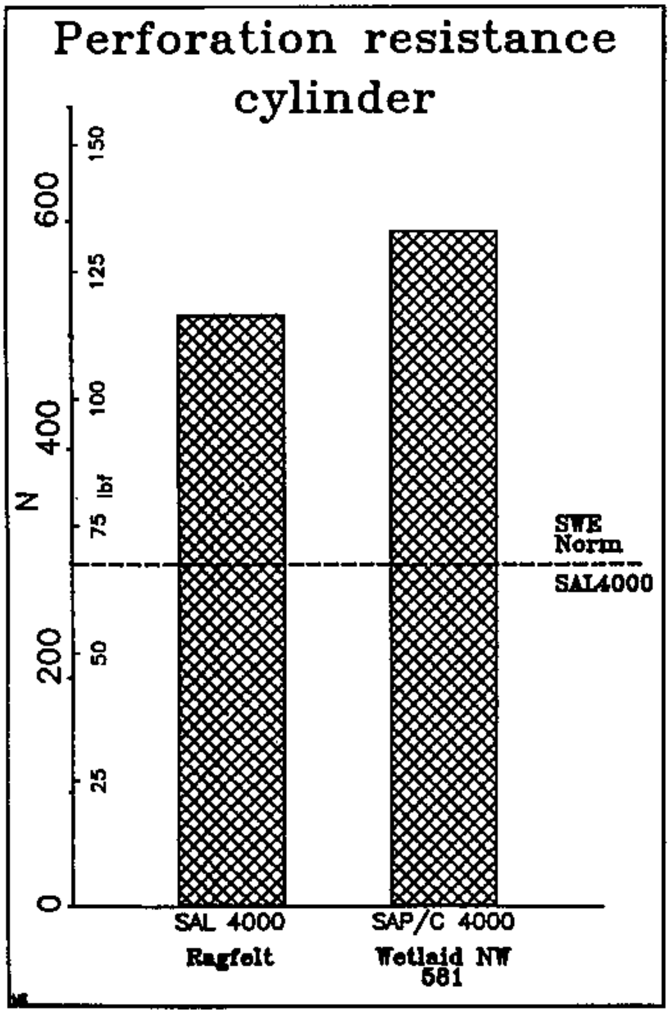

Figure 7 Perforation resistance with cylinder for cap sheets based on organic felt (SAL 4000) and wet-laid nonwoven 581 (SAP/C 4000) basis weights 4,000 g/m²

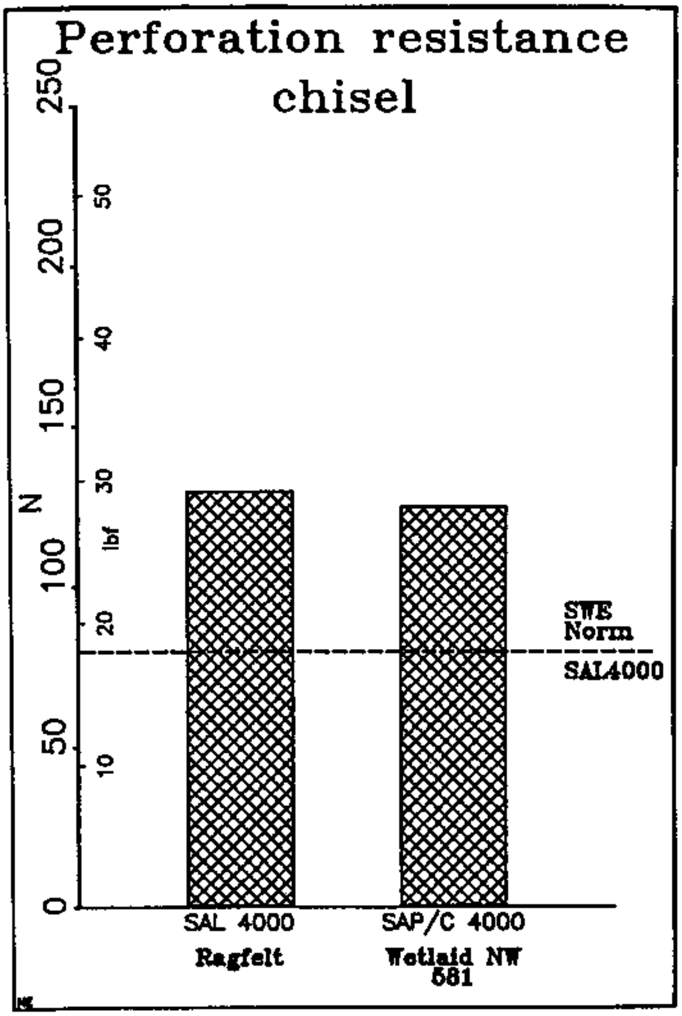

Figure 8 Perforation resistance with chisel for cap sheets based on organic felt (SAL 4000) and wet-laid nonwoven 581 (SAP/C 4000) basis weights 4,000 g/m²

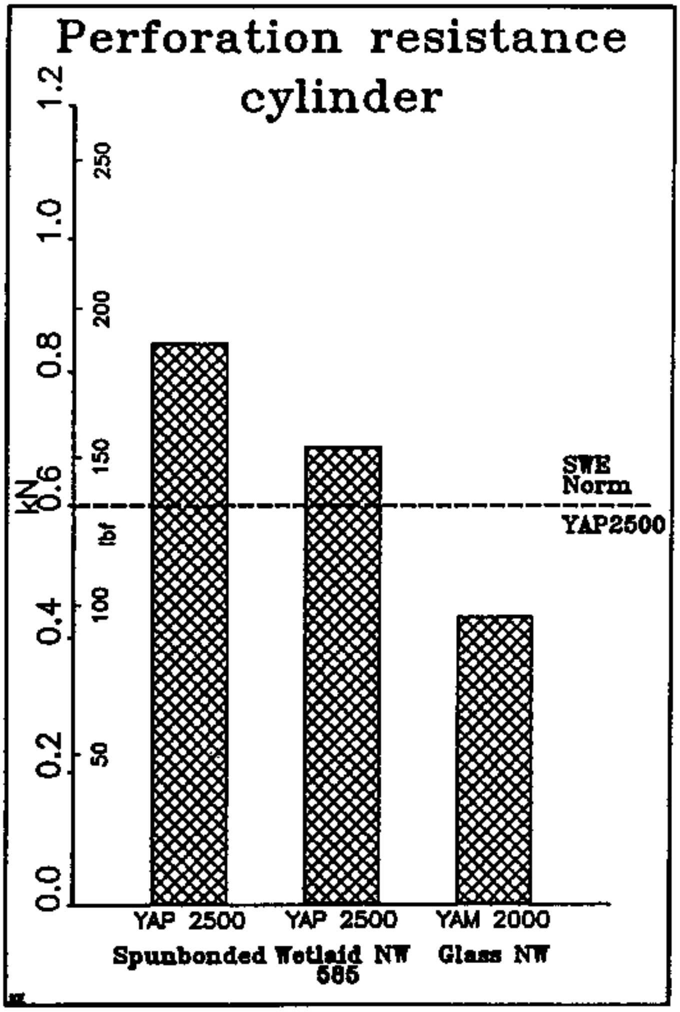

Figure 9 Perforation resistance with cylinder for underlaying felts (YAP 2500) based on spunbonded polyester and wet-laid nonwoven 585, basis weights 2,500 g/m² and YAM 2000 based on glass fibre non-woven, basis weight 2,000 g/m²

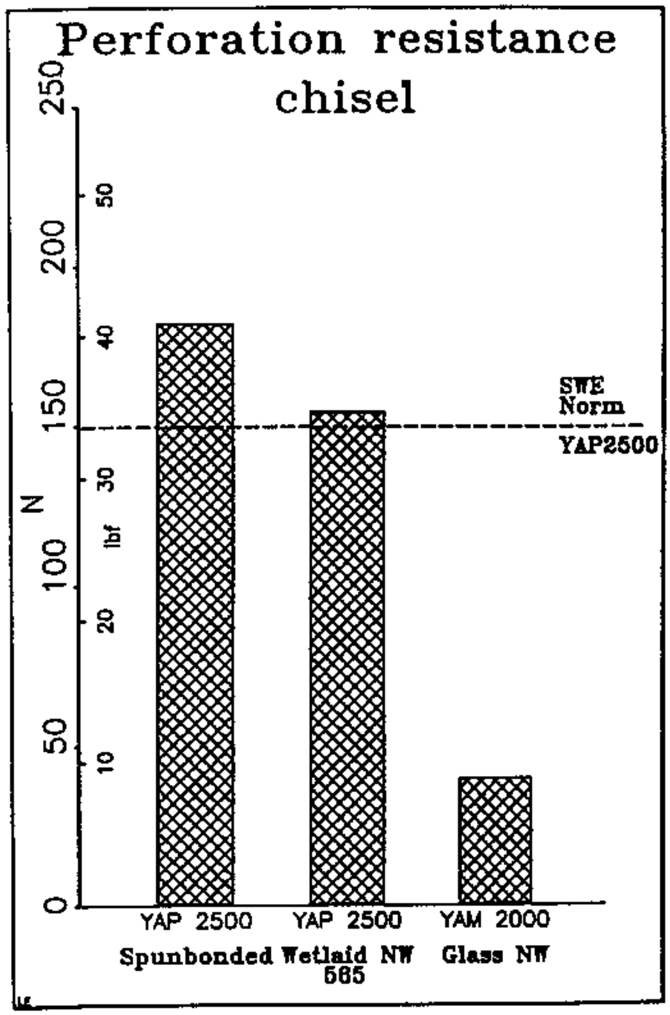

Figure 10 Performation resistance with chisel for underlaying felts (YAP 2500) based on spunbonded polyester wet-laid nonwoven 585, basis weights 2,500 g/m² and YAM 2000 based on glass fibre nonwoven, basis weight 2,000 g/m²

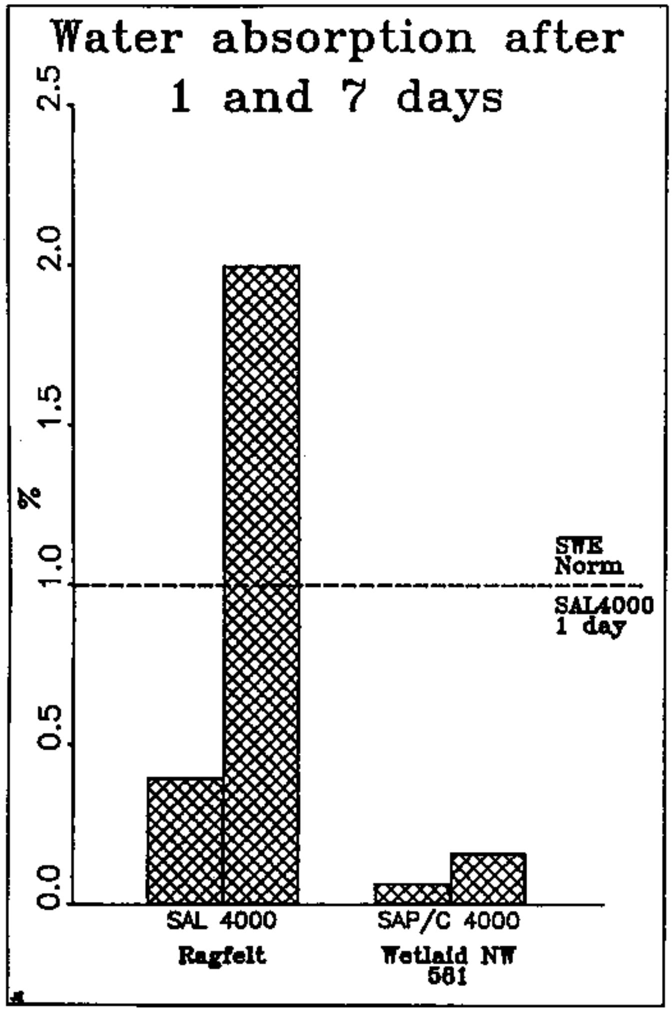

Figure 11 Water absorption after one and seven days for cap sheets based on organic felt (SAL 4000) and wet-laid nonwoven 581 (SAP/C 4000) basis weights 4,000 g/m²

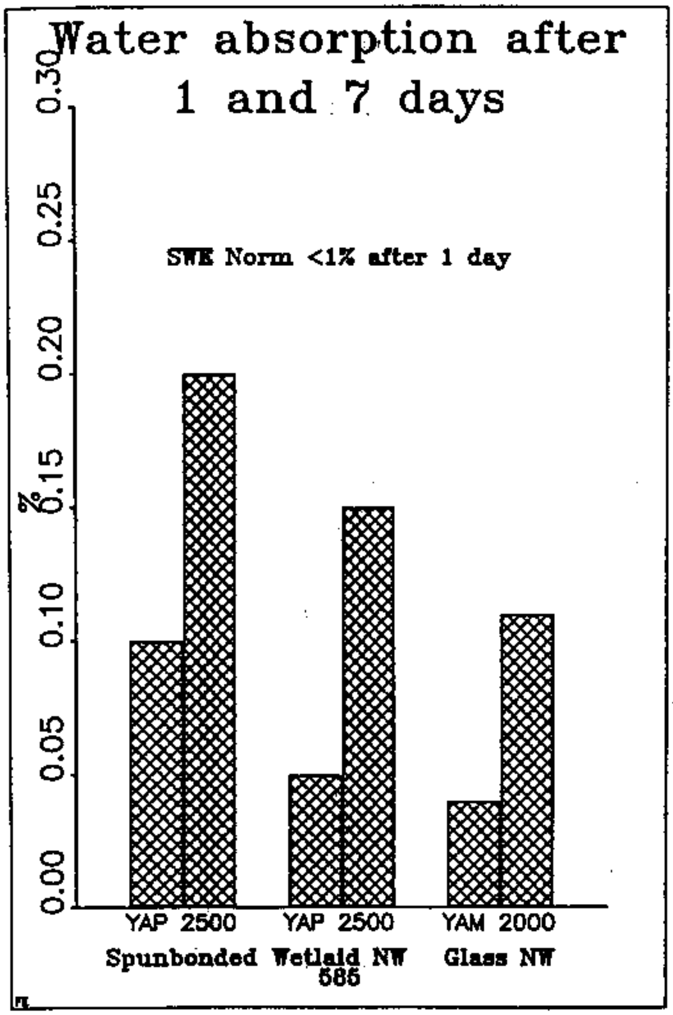

Figure 12 Water absorption after one and seven days for underlaying felts (YAP 2500) based on spunbonded polyester and wet-laid nonwoven 585, basis weights 2,500 g/m² and YAM 2000 based on glass fibre non-woven, basis weight 2,000 g/m²

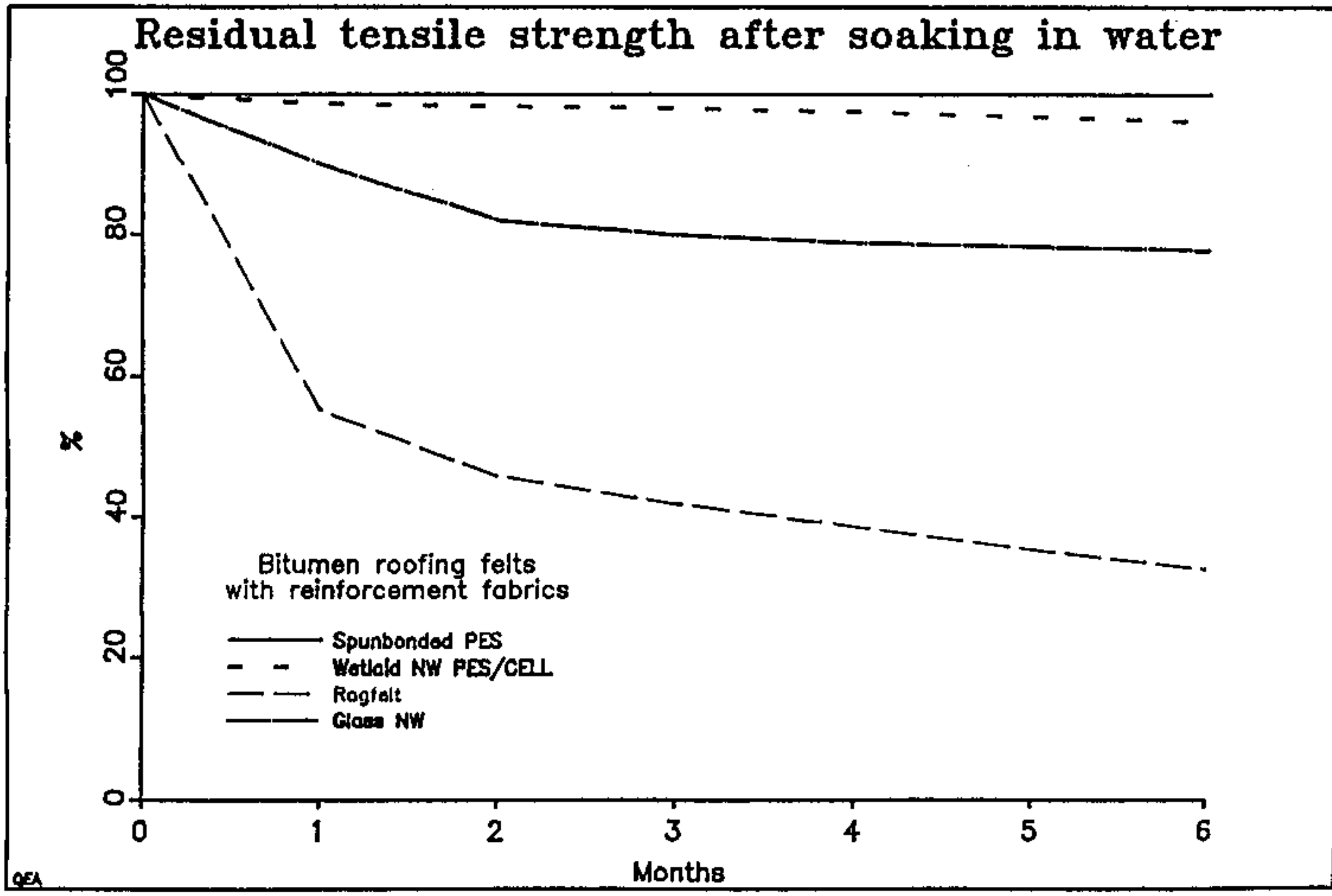

Figure 13 Residual tensile strength after soaking in water for cap sheets based on spunbond polyester, wet-laid nonwoven 581/585, organic felt and glass fibre nonwoven, basis weight 4,000 g/m²

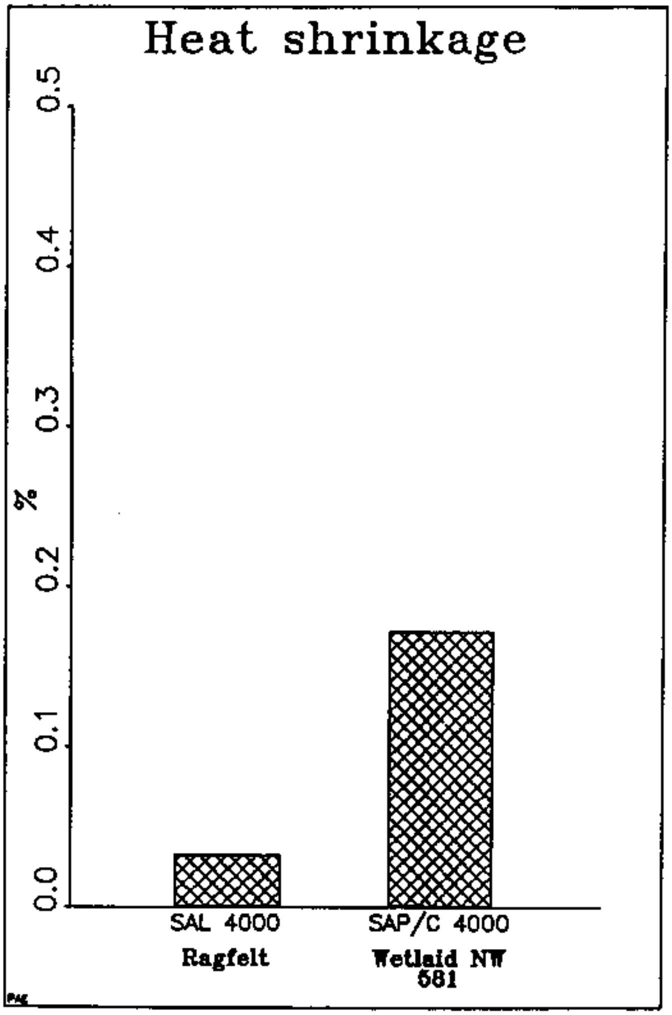

Figure 14 Heat shrinkage for cap sheets based on organic felt (SAL 4000) and wet-laid nonwoven 581, (SAP/C 4000), basis weight 4,000 g/m²

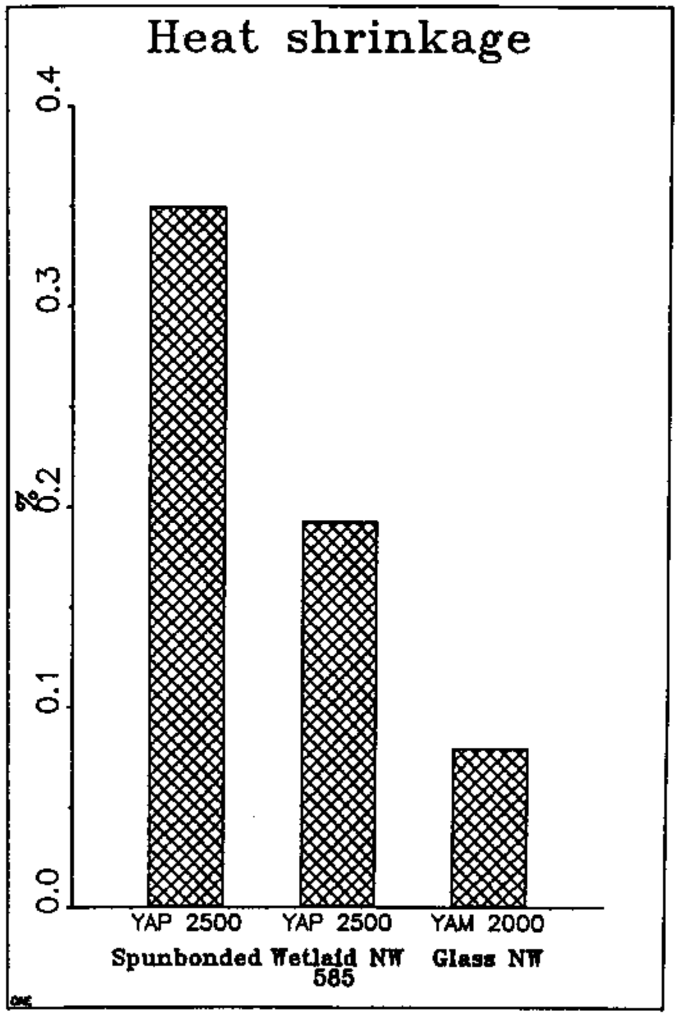

Figure 15 Heat shrinkage for underlaying felts (YAP 2500) based on spunbonded polyester and wet-laid non-woven 585, basis weights 2,500 g/m² and YAM 2000 based on glass fibre nonwoven, basis weight 2,000 g/m²

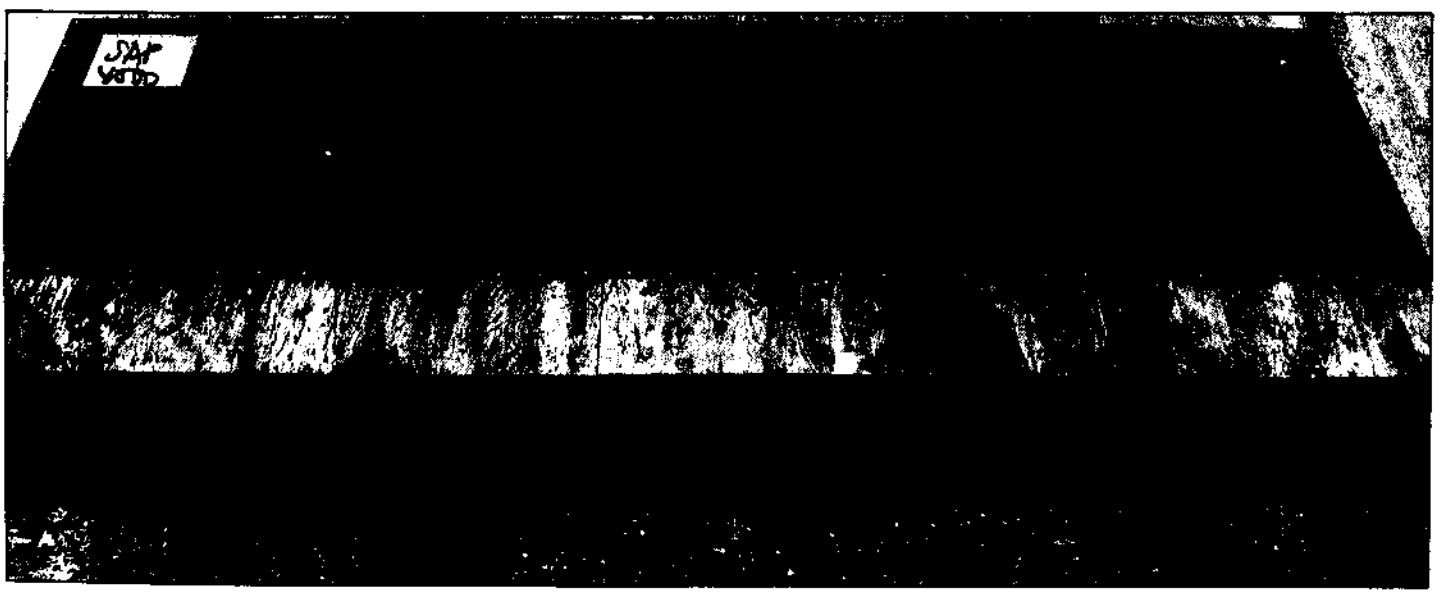

Figure 16 Cap sheet (SAP 4000) based on spunbond polyester basis weight 4,000 g/m² after one month in outdoor climate

Figure 17 *Cap sheet (SAP/C 4000) based on wet-laid nonwoven 581, basis weight 4,000 g/m² after one month in outdoor climate*

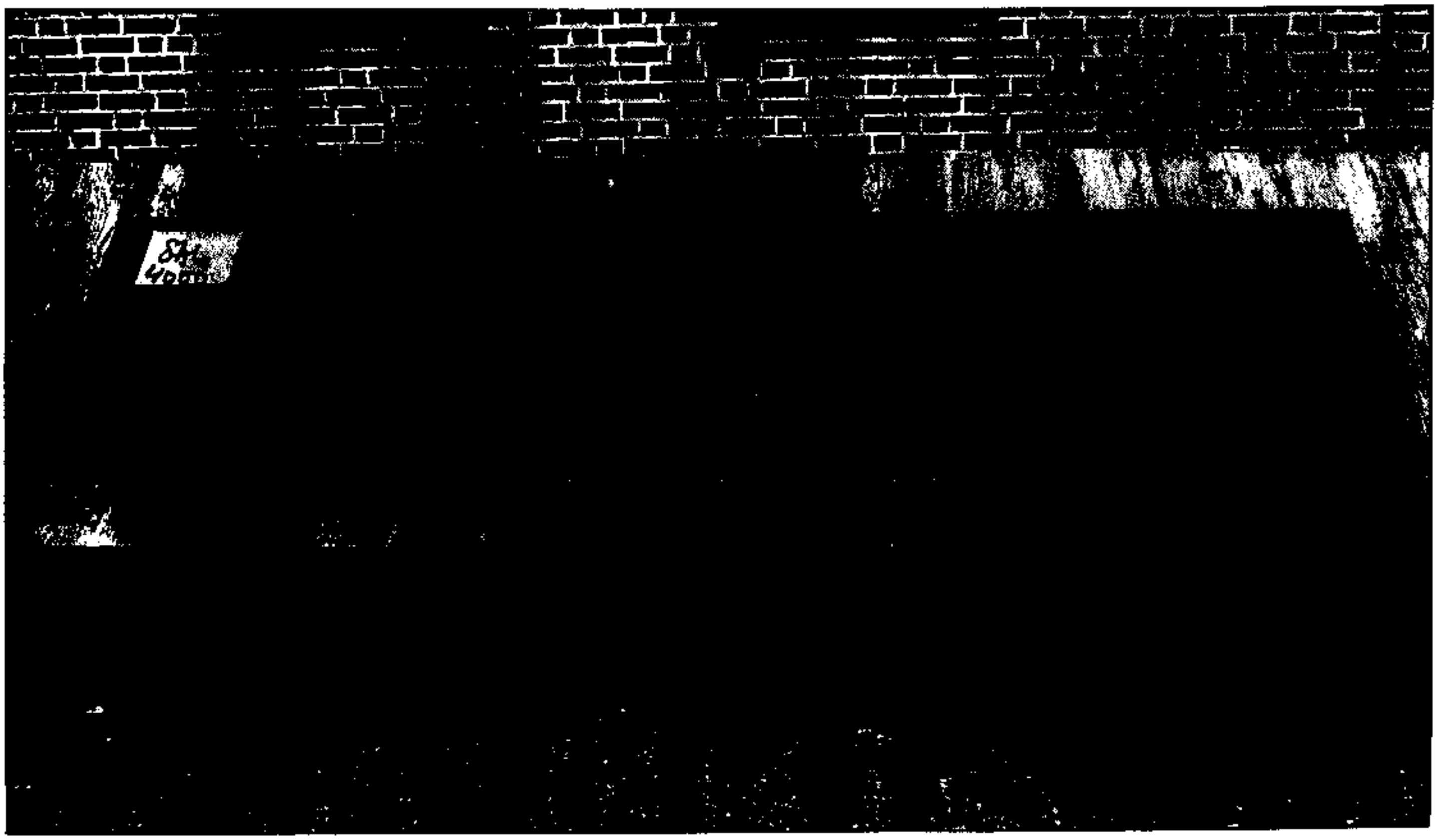

Figure 18 *Cap sheet (SAL 4000) based on organic felt basis weight 4,000 g/m² after one month in outdoor climate*

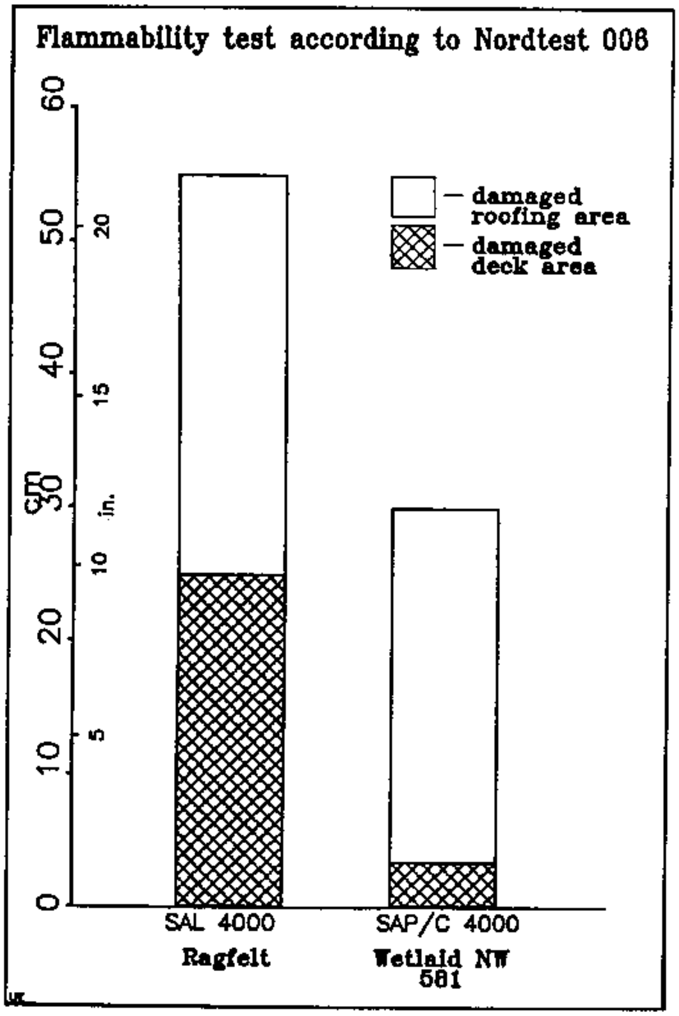

Figure 19 Flammability test according to Nordtest 006 for cap sheets (SAL 4000) based on organic felt and (SAP/C 4000) wet-laid nonwoven 581, basis weight 4,000 g/m²

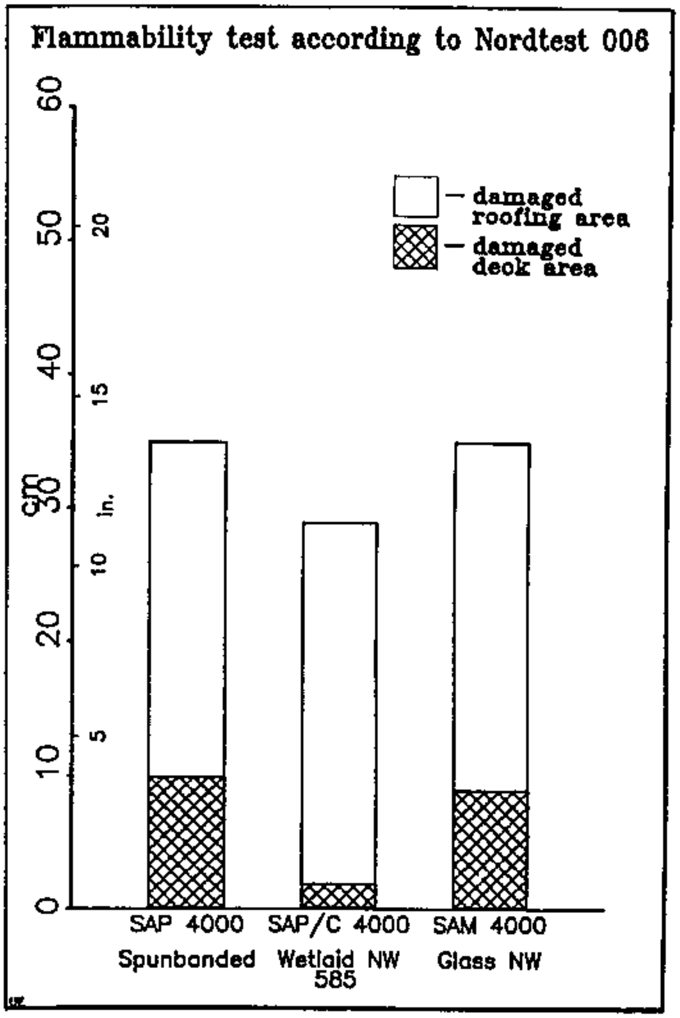

Figure 20 Flammability test according to Nordtest 006 for underlaying felts (SAP 4000) based on spunbond polyester, (SAP/C 4000) based on wet-laid nonwoven 585 and (SAM 4000) based on glass fibre nonwoven, basis weight 4,000 g/m²