

SUCCESS AND FAILURE WITH (APP) MODIFIED BITUMEN

NICO A. HENDRIKS

BDA Buro Dakadvies BV
Gorinchem, The Netherlands

In the Netherlands alone, there are more than 50 different trade names for APP modified bitumen rolls. SBS products number about 20. This almost ridiculous number of different brands of modified rolls, in a market of not more than 20 million square meters of flat roof constructed per year, is the result of an enormous growth in popularity, particularly during the last five years.

As some of the expressions used in this paper might not be commonly understood, the following explanations are provided:

■ **APP modified bitumen** is penetration bitumen, mixed with 20 to 30 percent atactic polypropylene. Its general features are plastic behavior and excellent resistance against weathering which requires no protection. Most types are reinforced with 150 to 170 g/m² (0.03 to 0.035 lbs/sq. ft) spunbonded polyester mat. Usual thickness of torch-on materials is 4mm (0.16 inches).

■ **SBS modified bitumen** is penetration bitumen, mixed with 8 to 12 percent styrene butadiene styrene copolymer. Its general features are elastic behavior and good resistance against weathering, but mineral protection is required. Most types are reinforced with 150 to 20 g/m² (0.03 to 0.05 lbs/sq. ft) spunbonded polyester mat. Usual thickness of torch-on materials is 4mm (0.16 inches) and of pour-on materials 3mm (0.12 inches).

APP modified bitumen was applied on roofs in Holland for the first time in 1972. In the seven years thereafter, its market share grew to 10 percent. In the meantime SBS modified bitumen was introduced. In 1984 the market share of APP and SBS has grown to about 40 percent, which means that more than 50 percent of all the roofs annually constructed in Holland are covered with a top layer of modified bitumen.

We investigate about 500 roof failures a year, and we have conducted numerous tests in our laboratory on almost all available products. Based on our experience as roofing consultants, I can state that the introduction of modified bitumen represents enormous progress in the quality of bituminous roofings. We have found, however, that manufacture and quality control are complicated and also that application of these high performance membranes requires good workmanship and supervision. The quality of the modified product depends on several factors, including the quality of base bitumen, the quality of the APP or SBS added, the type of mixing, the temperature, the mixing time and the type of machine used. Relatively small aberrations in any of these factors can have a significant influence on quality.

In this paper I present some examples of success and failure. Because of the limited time available I restrict

myself to APP modified bitumen. Some other time, given the opportunity, I will give similar examples of SBS modified bitumen applications. I would like to emphasize that in describing three cases of failure and three of success, I do not want you to conclude that the chance of success or failure is fifty-fifty. In actual fact, the number of roof failures with modified bitumen is a very low percentage of the installed roofs.

FAILURES

Case 1 is an industrial building with a flat roof, consisting of a steel deck with EPS insulation board and two-ply roofing. The top layer consisted of 4mm APP modified bitumen with a reinforcement of 170 g/m² (0.035 lbs/sq. ft) polyester mat. The roof was applied in 1981, and we investigated it in 1983.



Figure 1 Part of the Case 1 roof

On an important part of the roof the slope was nil or negative, resulting in a lot of ponding. The total surface of the roof showed extreme cracking, which looked like alligator skin in many places. This phenomenon was the worst at ponded areas, but it was also very serious in dry areas. The polyester reinforcement was easily visible through the craquele-cracks.

Samples of the roof were investigated in our laboratory. We found a ring and ball temperature of 112C (234F), which is very low for an APP mixture. As far as it was possible the low temperature flexibility test showed that the product did not even pass at 10C (50F), although the manufacturer stated -15C (5F) in its specification. We also found a relatively high, 15.7 percent filler content.

Unfortunately it is almost impossible to determine the amount of APP in a modified mixture. However, because of the relatively low ring and ball temperature, we suspect that

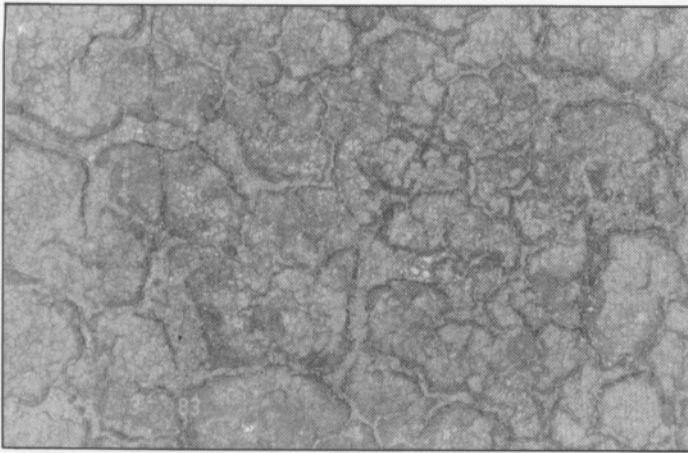


Figure 2 Case 1: Deterioration resulting in alligator skin

the amount of APP was less than 15 percent and/or the APP and base bitumen were not properly mixed during the production. Furthermore APP mixtures contain a certain amount of oxidizing components that can dissolve in water. This caused a brownish discoloration, which is typical for APP roofs. Good quality APP roofings show this only moderately, and after about a year the discoloration washes away.

In this case there must have been far more oxidized, soluble components than normal, combined with, for instance, nonhomogeneous mixture. Of course, I would prefer more definite conclusions, based on sound technical facts. However, information about the mixing and the quality of the base bitumen can only be determined with the cooperation of the manufacturer. Generally, we advise that extensive comparative research be done on this subject, with close collaboration between manufacturers and research institutes. Anyway, we are convinced that failures of this nature, which are very rare, can be avoided by good manufacturing quality control.

Case 2 is an industrial building and warehouse with a flat roof, consisting of a steel deck, EPS insulation board and two-ply roofing. The top layer of the roofing consisted of 4mm APP modified bitumen with a reinforcement of 170 g/m² (0.035 lbs/sq ft) of spunbonded polyester mat. It was applied in 1982 and examined in 1983.



Figure 3 Part of the Case 2 roof.

Contrary to our advice, the top layer was applied with hot bitumen (oxidized bitumen 110/30). Our advice is based upon the fact that there is not much difference between the 150C (302F) softening point of APP and the 180 to 200C (356 to 392F) application temperature of the adhesive bitumen. This may result in poor adhesion. The roofing company preferred pouring with hot bitumen rather than the more normal torching. Their reason was production speed is substantially higher with pouring.

One year later the roofing showed strong longitudinal shrinkage and transverse wrinkling over about one-third of the total 25,000 square meters (approximately 2700 squares) roof area. We cut several samples from the roof and found that free shrinkage at 80C (176F) was 0 to 0.2 percent. The shrinkage on the roof, which was easily measured at the transverse overlaps, showed a total shrinkage of just under 0.7 percent. This meant that the product itself met the specified quality requirement of 0.7 percent maximum. In other words, there was not enough resistance against shrinkage forces in the polyester mat.



Figure 4 Shrinkage and wrinkling of the Case 2 top layer

We found that the APP product was good quality. However, application with hot bitumen is very risky because of the excellent chance for poor adhesion. It allows the polyester mat to revert to its original form before being coated with APP bitumen. This causes longitudinal shrinkage and transverse wrinkles. APP modified roofing, applied by torching, very seldom shows marked shrinkage.

We concluded that this failure could have been avoided by using the right application technique.

Case 3 is a hotel and showroom complex with a flat roof, consisting of a concrete deck, polyurethane board insulation and single-ply roofing. The single-ply consisted of APP modified bitumen, reinforced with 170 g/m² (0.035 lbs/sq ft) spunbonded polyester mat and premineralized with slate chips. This layer was applied with cold mastic with the overlaps torched. It was applied between January and March 1984 and examined during April and May 1984.

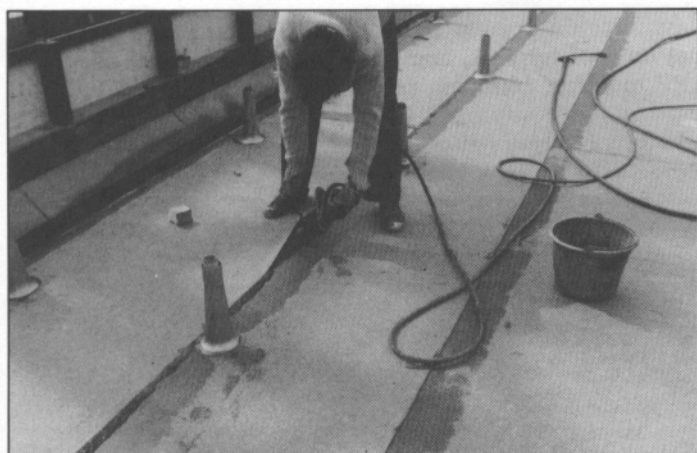


Figure 5 Separate torching of the Case 3 overlaps

Shortly after application, while the majority of the project was unfinished, it was noticed that the roofing surface showed several extremely soft, brownish "bleeding" spots. This was rather alarming, because on a warm day it was almost impossible to walk on the roof without damaging it. As it was only single-ply roofing, and the showrooms underneath contained valuable goods, the owner was very worried, despite the fact that no leaks had yet occurred.

This type of failure was completely new to us. Single-ply roofing of modified bitumen is certainly not promoted by us, because of the risk of application failures. We know that APP bitumen mixtures can be very sensitive to solvents. Some years ago we performed several accelerated weathering tests on different modified bitumens and found that APP modified bitumen can deteriorate significantly if it is finished with a solvent based coating.¹

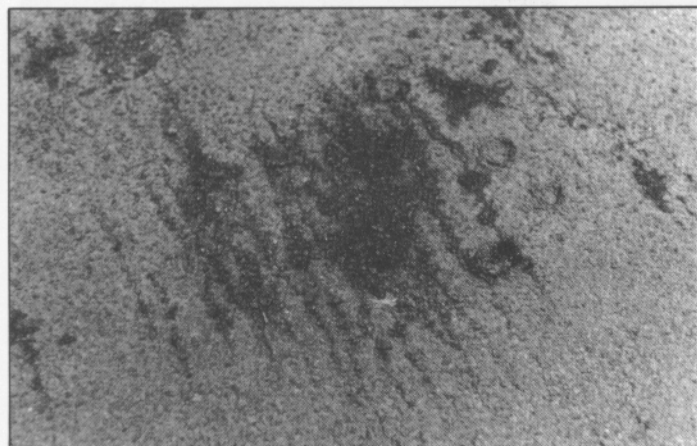


Figure 6 Case 3 "bleeding" spots

Luckily, rolls of the applied material still were available on the site, so we could compare several properties of the modified bitumen, before and after application, in our laboratory. We also did comparative tests in our modified Q.U.V. accelerated weathering tester and found remarkable results. Table 1 shows some of these results.

Property	APP-sample before application	APP-sample after application with cold mastic
Ring & Ball temperature	149C (300F)	146C (295F)
Penetration	43.10 ⁻¹ mm	46.10 ⁻¹ mm
Flow test at 120C	pass	fail (dripping)
Iterative cold bending temperature before aging	- 17C (+ 1.4F)	+ 20C (+ 90.5F)
after aging (1000 hc.Q.U.V.)	- 10C (+ 14F)	+ 20C (+ 90.5F)
4 h. 70 UV 4 h 40C ' viscosity at 161C (322F)	1664 MPa.s	1516 MPa.s

Table 1

From our observations it was quite clear that the APP bitumen mixture was desintegrated by the cold mastic solvent. It caused segregation, which actually resulted in a soft bitumen phase, containing APP particles. However, the method of application with a sprayed-on cold mastic was identical to that employed on many other roofs that perform well. The amount of applied cold mastic was between 500 and 1000 g/m² (1 to 2 lbs/sq ft). At places where the spraying machine had started, we found substantially more, but that is normal.

In fact, the only property of the APP bitumen on the new rolls that was *not* normal was the penetration, 43.10⁻¹mm. Values between 20 and 30.10⁻¹mm are more usual. This gave us the idea to test the viscosity of the mixture at a certain temperature and compare this with the literature. Here we got a really important difference. Using a Haake viscosity meter we found a value of about 1600 MPa.s at 161C.

According to the literature viscosity at this temperature should vary between 6,000 and 10,000 MPa.s. Apparently the manufacturer had used a low molecular weight APP. Mixtures with this type of APP are much more sensitive to separation by solvents than blends with high molecular weight APP which have a much higher viscosity. However, this requires more research.

Other factors that may have influenced the failure to a certain extent are the amount of cold mastic and the mineralized surface. This may have limited the evaporation of the solvent.

We recommend care with the use of cold mastic as an adhesive for APP modified bitumen, particularly if the penetration of that bitumen is higher than 30.10⁻¹mm. One can easily test in the laboratory whether or not the proposed product is extremely sensitive to the solvent in the cold mastic.

SUCSESSES

Actually there are relatively few failures with APP modified bitumen that can be related to poor raw material properties. Technical people are, however, much more interested in failures. Therefore the success stories I relate will be much shorter.

Case 4 is a paper factory with a flat roof, consisting of lightweight concrete elements and a bituminous roofing. Because of the extreme conditions of high temperature and

relative humidity inside the factory, the roof had deteriorated as a result of excessive condensation. It was therefore decided to replace the roof completely. However, this had to be performed within 15 working days, with the construction required to meet high performance criteria.

During the night the contractor demolished and removed part of the existing roof and installed a new steel deck. In the early morning the roofing contractor started to install a double layer of foamglas insulation board, which was covered with a floating coat of hot bitumen.



Figure 7 Installation of Case 4 floating coat

During the rest of the day the roofing was applied. It consisted of a first layer of granulated, perforated bituminized glassfleece to prevent blistering, covered with a floating coat of hot bitumen. The last layer, applied by torching, consisted of 4mm (0.16 inches) APP modified bitumen, reinforced by 170 g/m² (0.035 lbs/sq ft) spunbonded polyester mat. The whole operation was a big success.

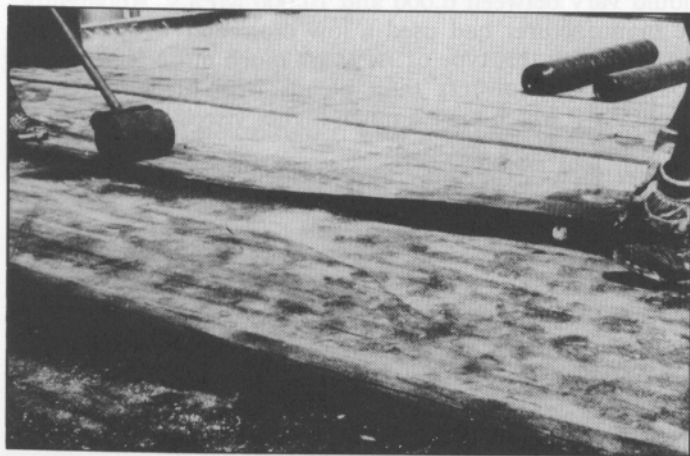


Figure 8 Case 4: Pressing the overlaps after torching

In Case 5 apartment buildings with a shopping center and other services, were newly constructed during 1982 to 1984. Several types of roofs were evident including normal roofs, roof terraces, roof streets and roof gardens. Also several types of construction, such as aireated concrete elements, underlayment and insulated concrete decks, were employed. The majority consisted of concrete with foamglas board insulation and roofing consisting of either bituminized

glassfleece on normal flat roofs and bituminized polyester mat on roof terraces, and a top layer of 4mm (0.16 inches) APP modified bitumen, reinforced with a 170 g/m² (0.035 lbs/sq ft) polyester mat. The materials were selected on the basis of good experiences and the project is now performing very satisfactorily.

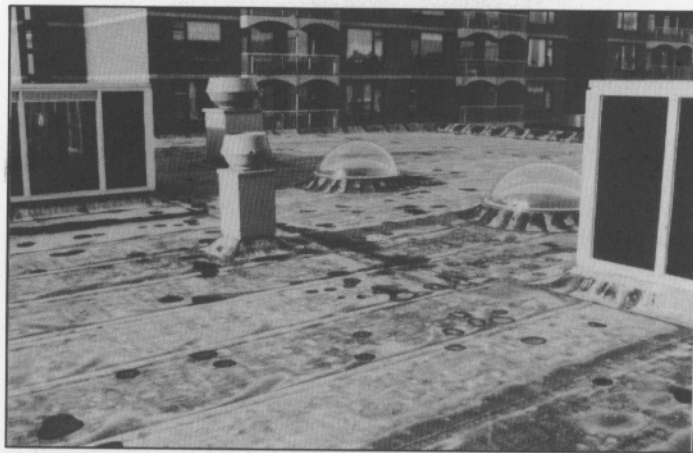


Figure 9 One of the Case 5 roofs

Case 6 is a steel factory in Belgium. The roof of one of the large production buildings had to be renovated in 1974. This was done by applying a new layer with cold mastic. The layer consisted of 4mm (0.16 inches) of APP modified bitumen with a reinforcement of glassfleece at the top and a 120 g/m² (0.025 lbs/sq ft) polyester mat in the middle. Preparation of the existing roofing consisted simply of cutting the blisters and wrinkles and applying a prime coat.



Figure 10 Application of the APP modified bitumen rolls with cold mastic in Case 6

The cold mastic was applied with a brush and the overlaps were torched separately. No special measures were taken with respect to the moving substrate which consisted of a steel structure and lightweight concrete elements. No other materials were used, even at the expansion joints.

We inspected this roof in 1983 because we were specifically interested in examining adhesion between the top layer and the old roofing. We found the roof still in excellent condition. Only at the expansion joints were some cracks evident. The samples, which we tested in our laboratory, showed an

