In Situ Performance of APP Modified Roofing Sheets.
Impact of the Application Technique. No Flame Concept.

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Field investigation, modified bituminous membrane, APP, durability , ageing, cold adhesive, no flame, application technique.

Abstract

Modified bituminous waterproofing membranes have now reached their mature stage. They have had the opportunity to be developed, have a strong presence on the marketplace and have had the time to build their reputation. These products are applied on various roof constructions and under severe and extremely hot or cold climate. This paper will evaluate their performances after so many years of roof life. The focus of this presentation is the study on APP modified membranes.

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Introduction

The parameters of laboratory techniques to characterize the ageing of roof membranes enable to analyze, in a comparative manner, the evolution of a product during the time. These analyses never can be considered as absolute and representative for the real evolution of the roof. Evidence of this is that the assessments on the waterproofing membrane's durability made by the different organizations and laboratories worldwide rely on different criteria. Accelerated ageing in the oven may vary from 4 to 24 weeks at temperatures ranging between 70°C and 80°C. Some prefer the QUV test or Xenon exposure ageing method.

Criteria and tests carried out after ageing are even more diverse. Some give more importance to the cold flexibility after ageing while others privilege the relative modification of mechanical properties. The UEAtc has just published a guide[1] with a list of tests and procedures for the member countries, but we are forced to notice that many countries stick to their own specificities parallel to this guide.

No matter which test or ageing method is opted for, all the evaluations only bear onto the waterproofing membrane alone. There is no test describing the assessment on the evolution of a roof system in the course of time. Obviously, the composition of the roof system is of major importance, and the influence of insulation, quality of the deck, application of a protecting coating or application itself play an important part on the ageing the waterproofing membrane's characteristics.

An important part of this article is dedicated to the influence of the application method.

At the same time, in one and the same country, following the only and unique product evaluation methods defined, the place where the product is applied is not taken into account for distinction.

A country like the United States with its warm, cold, wet and dry areas, mountains and deserts as well as coast gusts is a very striking example. It is, of course, impossible to adapt a series of tests in function of the numerous environmental types, which is one of the reasons for the different organizations to opt for some kind of evaluation methods.

The only manner to be closer with reality and attempt to understand more clearly the evolution of a roof's characteristics in the course of time is to cut roof samples and analyze them after years of exposure. This is the only way to prove to the users and guarantee the real durability of a roof membrane in real use circumstances.

In such an approach studies only can be carried out with material we can access their technical characteristics at new stage. The results of the studies listed below only refer to APP membranes double-reinforced with polyester and fiberglass fleece. Both reinforcements are placed close to the upper side of the roofing membrane. The amount of bituminous blend exposed is reduced and the reinforcements' positions confer an increased resistance to abrasion to the product.

The different studies presented in this article have been ordered from official organization and the samples have been tested by their laboratories. The general conclusions were written by their own officials.

The tendencies we will point out in the result interpretation relate to a certain type of APP membrane but can be transposed onto other membranes provided they have identical characteristics at new stage. We will avoid taking the responsibility to make general conclusions for the APP bituminous membranes of various quality or low polymer content. We can speculate that the properties of product with lesser quality modified bitumen blends may be more adversely affected. Our conclusions will focus on what might be expected from an APP-modified waterproofing membrane that is manufactured to last

The results are issued from studies carried out in the United States[2], Sweden[3], Norway[4,5], Belgium[6], the Netherlands[7,8,9] and Italy[10]. All together, 150 roof cuts were evaluated. Generally, the membranes are laid in single layer onto insulation. The application method is specific for each country. Mechanical fastening with torched overlaps are commonly found in the Nordic countries whereas in Belgium and in the Netherlands it is more usual to work with cold adhesion and torched overlaps. In Italy, torching is preferred.

Results interpretation

Several tests were carried out on the samples taken from roofs after natural exposure: low temperature flexibility around a 30 mm mandrel, mechanical resistance tests and T-peel tests onto the overlaps. From all these measurements only cold flexibility temperature seemed relevant to us.

The evolution of mechanical properties is not significant and lacks reproducibility. From a general point of view the variation of mechanical properties does not exceed 20 percent. The peel tests onto overlaps show the same tendency. Obviously, for low-quality products, the mechanical properties or overlap resistance may reveal critical.

Cold flexibility temperature is a basic criterion of a new product. Separation between bitumen and polymer, oil separation and, consequently, the stiffness of the blend are the main negative effects revealed during the evolution of a bituminous blend. This stiffness will create weak points occurring in presence of thermal shocks or movements of the roof structure. The difference of cold flexibility at new stage and after natural ageing will, therefore, be kept as a main parameter to interpret the results.

Influence of the formula

When the production of APP-modified waterproofing membranes started, the quality of the different polymer sources varied a lot.

The first APP came from IPP (Isotactic Polypropylene) production residue. The polymer producers hardly cared about these by-products considering them as nearly waste products. There was great variation in the molecular weight and crystallinity level of the different sources, even within one and the same product. Oil or other compounds were sometimes added to the available polymers. Consequently, compared to now, it was difficult to control the steadiness of bitumen/APP blends. The generic APP's we used to know 30 years ago have evolved a lot. Although they still are available and used in commodity products, several plastic material manufacturers offer alternative Polypropylene-Based products, often copolymers, which are specially manufactured to be mixed with bitumen. The advantage of these new generation blends mainly consisting of these new polymers is the better control achieved on their steadiness throughout time, as well as a better chance to reach optimal performances. This also was possible to do with well characterized old APP but more difficult to achieve. These new generations of high molecular weight polymers with controlled crystallinity have a deep impact on the durability of the membranes. TPO (Thermoplastic polyolefins), FPO (Flexible Polyolefins) and APAO (Amorphous Poly-alpha Olefins) are the names given to these new ranges of products. The most important basis criteria remains the mastery of raw material choice. Even with polymers specifically designed to be mixed with bitumen, the guarantee to be able to produce a blend of quality requires in-depth knowledge of the bitumen and formulation. We have already demonstrated that the generic composition of the bitumen is a very important factor to ensure compatibility with a polymer[11]. It takes years of experiments and development to reach proper identification of the parameters that will help us in selecting steady sources of quality. This mastery is the proof that enables us to present probative results relating to the longevity of propylene-base polymers modified bituminous membranes.

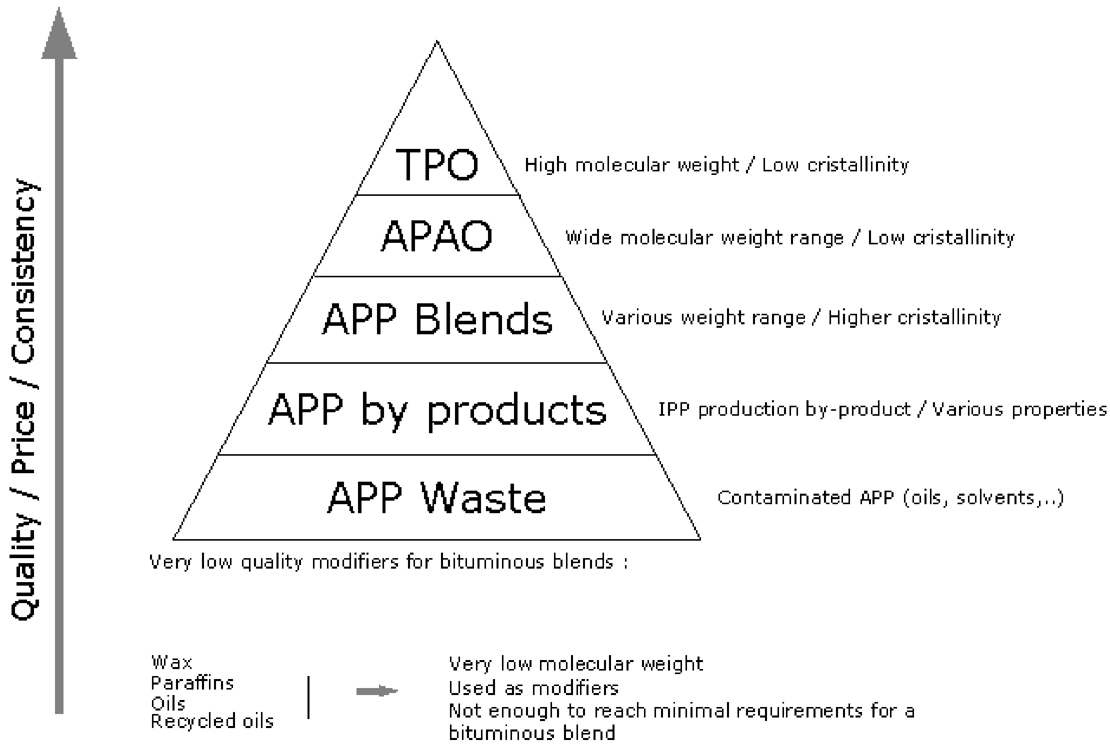

Figure 1 : Polyolefins for bitumen modification

It has been possible to have such measurements in study reports from Scandinavia where products coming from the old and new generation of APP blends could be applied onto the roofs under identical conditions both as far as the roof system opted for is concerned, as well as their climatic exposure.

In both cases, the cold flexibility of new membranes reached -20°C.
We notice that under identical conditions, products that mainly are made of generic APP's tend to loose their flexibility more quickly.

The "important" loss of flexibility is not critical to the extent that one could declare the roof as not being waterproof or risky. Even when the flexibility after ageing is slightly beneath 0°C, the official control organizations conclude that the life of the roof still can be extended and one can expect a life time even exceeding 25 years[4,8,9,10].

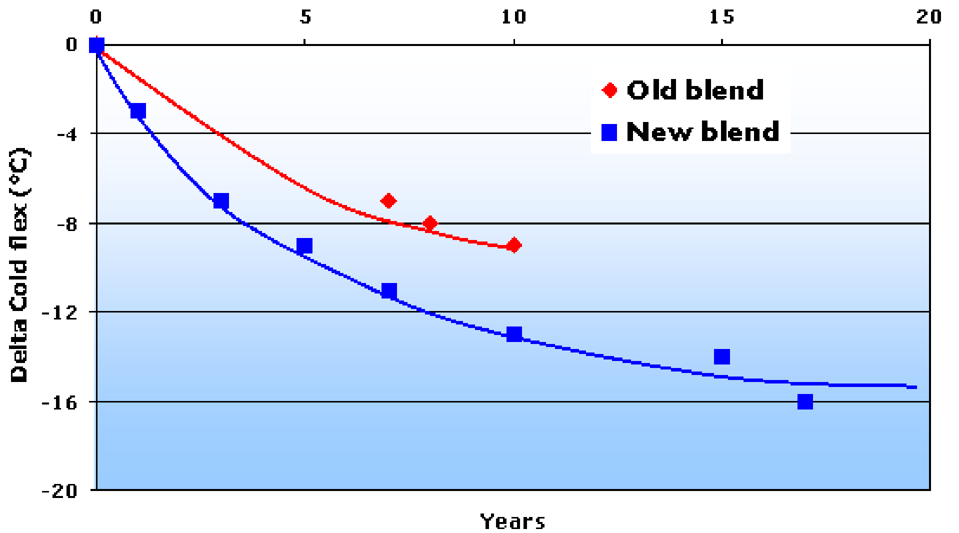

Figure 2 : Influence of the polymers incorporated in the formulation

Influence of the roof structure, climate and application technique

Roof membrane samples were taken in different countries. Local habits account for the fact we could not compare roofs with an identical structure. In the Scandinavian countries, they typically install an important insulation layer up to 30 cm thickness of mineral wool or expanded polystyrene. More south, the insulation layers are thinner (10 cm) and mostly of mineral wool. Application methods also differ from one area to the other. Northward, mechanical fasteners are resorted to on the majority of the roofs. In Belgium and in The Netherlands, cold adhesion now has an important experience. And Italy is traditionally oriented toward torching. Moreover, the climate is much different in terms of amount of sunshine and temperature differences. The evolution of cold flexibility temperature is illustrated in Figure 3.

Scandinavia Mechanical fastening Average temp:6.5°C Min temp : -22°C Max temp : 23°C Sunshine/year : 1423 h	**Italy** Torch application Average temp:14°C Min temp : -7°C Max temp : 39°C Sunshine/year : 2613 h	**Belgium** Cold application Average temp:10°C Min temp : -6°C Max temp : 29°C Sunshine/year : 1485 h

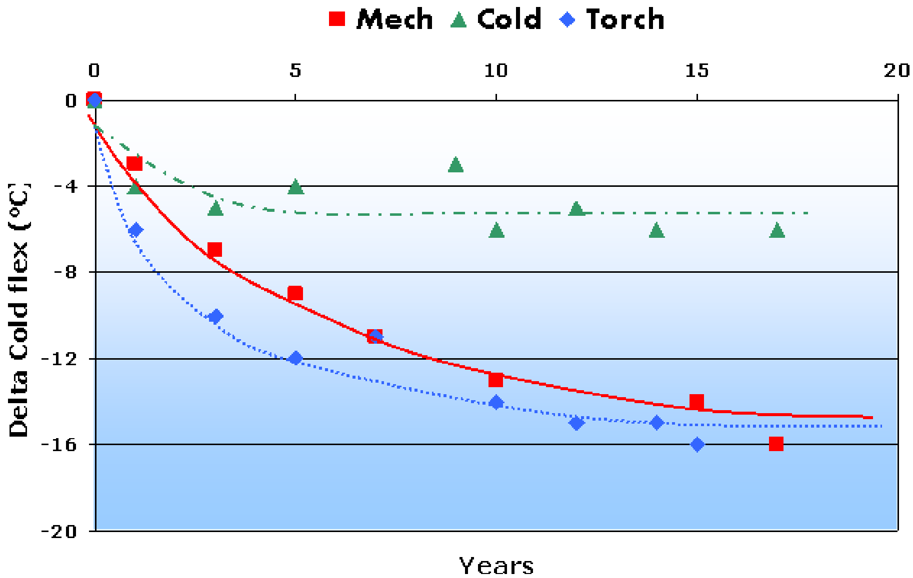

Figure 3 : Evolution of the cold bend flexibility vs. application technique

In the Scandinavian countries, loss of flexibility in the products can occur in a homogeneous way and spread over time. The membrane is not attacked by any flame but undergoes important thermal shocks. Because it is applied onto an thick insulation layer, the ageing phenomenon is increased. The membrane being black, after a long period of sunshine, the waterproofing sheet can sometimes range between 70° and 80°C on its upper side. This energy is stored and the temperature kept within the membrane can be very high due to the thermal resistance of the insulation. A series of experiments were carried out internally studying the cold flexibility variations of waterproofing membrane submitted to Infrared rays in function of the thickness of the insulation beneath. One notices that if the membrane surface is heated up to 80°C, the underside will reach 90°C in presence of 10 cm mineral wool insulation and 100°C in presence of a thickness of 30 cm of mineral wool.

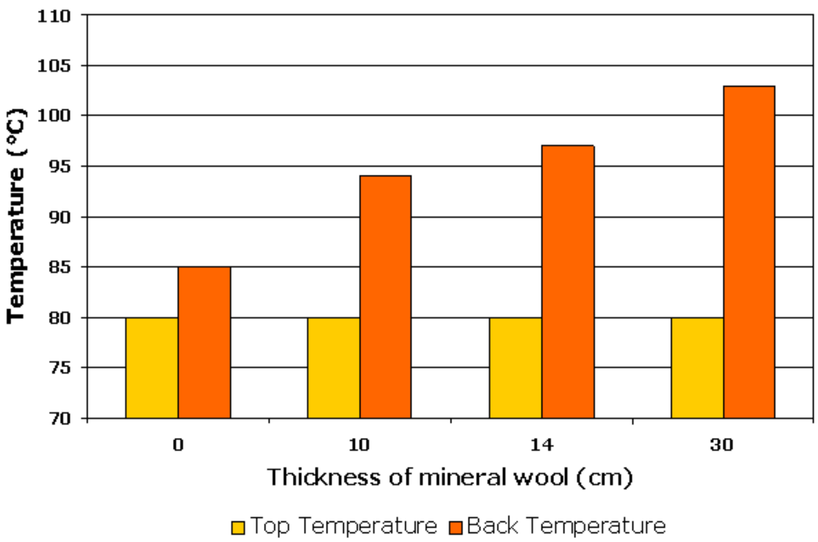

Figure 4 : Temperature on the top/back side of a 4-mm modified bitumen membrane vs. thickness of mineral wool. IR irradiation monitored to have 80°C at the surface.

In Italy, the tested membranes are cut from roofs where torching was used for application. Unlike Scandinavia, the thickness of the insulation is greatly reduced. Looking at the loss of flexibility curve one notices that the slope of the tangent taken at the origin is more important. The product looses flexibility much more rapidly. Applying an important source of heat results in an accelerated premature ageing of the membrane. The application of open flame disrupts the balance between polymer bitumen blend.
But stabilization of the cold flex value is quickly reached, of course not as good as in mechanical fastening, but sufficient enough to warrant the roof complex its waterproofing performance.

With membranes adhered with cold bituminous adhesive, a totally different behavior is observed. The recordings were made in Belgium and the Netherlands where the thickness of the mineral wool insulation is close to 10 cm under a temperate climate. In this case, the loss of cold flex is limited to some degrees, even after more than 15 years. When applying the roof complex, we not only add compatible material in the shape of solvent to the waterproofing membrane but also totally avoid an accelerated ageing through skipping the application of intense heat. Other advantages of cold adhered waterproofing membranes are described in a later stage of this article.

In all the cases, the membranes tested keep a cold flexibility below 0° C even after 20 years of exposure to poor climatic or application conditions. For this reason and combined with additional results obtained on the overlap resistance (T-Peel strength), remaining mechanical properties and on waterproofing tests, the general conclusions of the different organizations contacted are identical. The membranes assessed have a proven durability of 25 years, and their life expectation can be warranted from 30 years to 35 years. Similar studies will be conducted in the future to confirm this life expectation on objective bases.

Influence of the product's structure

A study carried out in the United States compared the behavior of a broad series of APP- or SBS-modified bituminous membranes. This study was based on visual roof inspection instead of the performance of each component after aging. The general conclusion on the products are[2] :

> "For some APP-modified bituminous sheets, the primary area of concern is the propagation of cracks through unsurfaced membranes or membranes without protective reinforcement near the top of the cap sheet. For some SBS-modified bitumen sheets, the primary area of concern is degradation of the membrane because of ultraviolet exposure after loss of granules".

These conclusions clearly demonstrate that even if a type of bituminous blend can perform under laboratory conditions, the structure of the finished product is very important and that in each case, a surface protection against the attack of climatic factors is very important too. A surfaced product or product reinforced near its top will provide a longer lifetime. A surfaced membrane with reinforcement near to the top (e.g. fiberglass) will provide the membrane a better life expectation.

Cold adhesive application

More than 50 years of experience with bituminous cold adhesives allow us to make a global evaluation of cold application technique for various bituminous membranes.

Since the middle of the 20th century, several companies started to apply their roofing membranes with cold adhesives. This application technique took off slowly for several decades and was mainly used close to the production sites. In Europe, the cold adhesive was first developed in Belgium[12] and until the middle of the 1980's nearly all European cold adhesive was produced and applied in Belgium.

The main product in a cold adhesive is bitumen. Its quality choice will, therefore, be of major importance for the final properties of the adhesive. Classic bitumen characteristics, like softening point or penetration, will determine the products' capability to receive fillers and fibers into its formulation. High penetration values will increase adhesive "open time" (time during which the adhesive is sticky) and increase its compatibility with a variety of substrates. On the other hand, lower penetration values will increase the peel resistance or the wind-uplift performance.

The generic composition of the bitumen will have an impact on its compatibility with various types of polymers. Selecting the right bitumen for the right polymer remains a key factor. This will assure a durable compatibility between polymer and bitumen.

The solvent also is an important parameter, especially for the product pot life. Before the application and curing of the adhesive, bitumen, as wellas polymers actually are being dispersed into the solvent. The type of solvent, will, therefore determine the product stability during its storage before use.

As a consequence of the growing environmental issues concerning VOC’s in general, we observe that in the past few years most halogenated solvents have disappeared and now are replaced by low aromatic content or aliphatic solvents. “Green” or “Natural” solvents also are introduced, but they appear in most cases to have only emotional value because chemically, health and security wise they are very close to classical distillation type solvents.

During the application, the solvent plays a major roll for the compatibility with various substrates. Polystyrene or other insulation board facers may or may not be compatible with the solvent. This aspect needs to be well-defined in the technical approvals.

Along with bitumen and solvent, polymers may be added to the cold-adhesive blend. The ratio and type of these three components will enable to control and steer the set up time of the adhesive. We can observe an important difference in curing time between different cold adhesives. This is one of the most important characteristics of a bituminous cold adhesive. Short curing times tend to appeal to us because we observe a fast increase in peel or wind uplift value as a function of time. A correct equilibrium however needs to be found. Moderating the curing rate will indeed have a positive influence on the adhesive’s open time and therefore on its workability. It will generally increase its compatibility with different substrates.

The polymer type and concentration also will determine the final performance of the cold adhesive. After the application, as the solvent evaporates, the polymer will start to cross-link forming a network structure. The result is that with a good cold adhesive formulation, we obtain up to 10.000 Pa wind-uplift resistance on concrete decks. Applied on insulation boards, fixed on steel decks, we can reach wind-uplift values between 5.000 Pa and 7.000 Pa.

Rheological additives, fibers and fillers are added to the formula to enable the control of the products’ rheology. Bitumen/solvent blends have a Newtonian rheology behavior meaning that the viscosity doesn’t change as a function of the shear rate. The goal is to get a “ready to use” product. The viscosity needs to be high at very low shear rate . When the product is applied, the viscosity must drop off very fast to ease the application (by squeegee or adapted spray equipment). This shear tinning behavior (thixotropic effect) can be obtained by choosing the right rheological additives.

The cold adhesive has a positive impact on the roof longevity. In a torch-applied bituminous membrane, an average of 1 mm of bitumen blend is molten for its adhesion to the support. At the same moment, a considerable thermal shock is given to the membranes. The blend stability can be modified and improper reinforcements could shrink as a result of heat increase. None of these negative events occur while working with cold adhesives. Moreover, an extra quantity of bitumen blend is added to the system. Analyses on cold-applied roofs show that cold adhesive and membrane finally tend to form a single monolithic membrane. This creates a compact roof without any loosely laid membranes.

A cold adhesive is not only a common mixture of different raw materials. The knowledge and experience of formulation and blending is very important.

A different supplier means a different adhesive, which means different performance. Therefore, it becomes necessary to characterize the cold adhesives and fix these characteristics in specific technical approvals describing the adhesives:

- Composition / FTIR identification
- Compatibility tests
- Peel tests / performance
- Wind uplift test / performance
- Rheology / product behavior and use

Since the early 1990s, we can observe a tremendous increase of cold adhesive use both in the United States and Europe. Several events are at the base of this sudden evolution:

The integration of the cold adhesive as part of a cold-applied flat roof system is an important breakthrough. We can see that countries that introduced the cold adhesive as an integrated part of the roof system obtained the highest speed of application versus other application techniques.

A second point is the automation for the use of cold adhesives. In Europe, roofing contractors still have a tendency to apply the cold adhesive in a traditional way by using the adhesive from pails and adapted squeegees. Roofing contractors in the United States worked out several ways to automate the application.

Considering the cold adhesive as an integrated part of the roof system offers some major advantages for both contractor and final costumer:
Technical literature will describe the type, quantity and application of the cold adhesive, as well as the membrane.
All technical assistance and support can be organized and executed by the same manufacturers.
Compatibility between adhesive and membrane, as well as compatibility between adhesive and substrate are both well defined. This is insurance for longevity. The use of cold adhesive becomes an interesting investment for the final customer.

Since the early 1990s some contractors in the United States added a new dimension to the use of cold adhesive. At first by pumping the adhesive onto the roof, and then by adapting hydraulic-driven high-pressure pumps allowing to spray the adhesive directly on the roof, they succeeded in automating the application.

Of course, these roofing contractors were thinking in economical terms. Applying the cold adhesive at 8 to 10 kg per minute (about 10 m² per minute) does offer a well-trained roofing team probably the fastest application technique available. Reducing the application time and, therefore, the application costs has to drive our attention. This is not the only advantage that came with the automation…

Improved ergonomics made the contractors' job a lot more comfortable. Reducing physical stress will provide a better continuity on job site and more stability for a roofing contractor's crews.

As the adhesives are provided in containers or specific tote tanks, which can be used over and over again, the automation also has a positive impact on the environment.

With the automation also comes the roof management: analyzing all parameters will optimize productivity and efficiency. Cold-adhesive application technique often is the best economical choice and helps the contractor to win jobs against competition.

The use of cold adhesives eliminates a considerable number of health and security hazards on job site.

Who hasn't seen the results of accidents with hot asphalt kettles ? Every year, buildings burn down as a direct result of torch-applied roof jobs. Regular usage of cold adhesives eliminates 80 percent to 90 percent of the use of torches on the roof. Only flashings and overlaps generally are finished using a flame. Recent developments however enable 100 percent flameless applications. This became possible using specific flashing mastics for laps and flashings or by using membranes with self-adhesive overlaps.

General conclusion

When a plastomer (APP)-bitumen base waterproofing membrane is designed to last, the durability of the exposed product is quite long. Official reports conclude that the same product with the same formulation and the same structure applied in different climatic condition following different application rules has a proven life of 25 years and a life expectancy up to 35 years[9]. These conclusions are valid for one specific unsurfaced membrane with fibreglass reinforcement near the top.

Ageing of the product follows different evolution depending on the structure of the roof and application technique. It is obvious that cold-adhesive application has a tendency to increase the life expectancy of the roof complex. This is because of two factors: no thermal shock on the membrane (no flame or heat) and added waterproofing material (1 mm of bituminous cold adhesive).

Cold-adhesive application exists in Europe and more precisely in Belgium since the middle of the 20th century. Since then, cold-applied waterproofing membrane continuously won market shares. Development of the formulations and better knowledge of the raw materials place bituminous cold adhesives as a trend for the future. Compact roofs with high wind-uplift resistance, developments of state of the art application techniques and increased durability of the roof complex are the key points to insure technical and economical win-win situations.

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