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Spotlight on flat roofs
Polymeric roofing membranes

Thermoplastics

Both in construction and excavation work, thermoplastics have rapidly been able to establish a place for themselves. The main reason for this is that the membranes are easy to handle by any type of worker, since the seams and joints can be homogeneously welded using a solvent or hot air.

All the thermoplastics have this decisive advantage. However, in other aspects, and depending on the basic material used, their features differ significantly from each other. They also possess correspondingly different material properties which, once on the flat roof, could undergo a change for the worse; this is particularly the case with plasticized PVC (PVC-P) roof coverings.

In the case of excavation work, this does not pose a problem since the material is not exposed to radiation or to temperature variations. The danger is encountered, in particular, on flat roofs where the physical and mechanical properties undergo considerable change and the effects of chemical attack and radiation are markedly increased.

With increasing temperature, the rate of chemical reaction increases. As a rule of thumb, it doubles with a temperature rise of every 10°C.

At higher the temperature:

- Greater effect that radiation has. Molecular chains are destroyed by the radiation and the freed valences join up with radicals. Radicals are molecules or molecule fragments which have free electrons that immediately react with any substances.

- Higher the water absorption. Reagents are entrained into the membrane.

- Stabilizers and plasticizers are destroyed or washed out. The danger of saponification increases.

- Plasticizers migrate very easily and rapidly vaporize:

These are some reasons that flat roof coverings with high plasticizer content cannot be looked upon as valid long-term solution. The successful use of plastics depends on the correct application of the materials. Knowledge about the plastic's characteristics includes an understanding of the influences and effects that are acting on the roofing system and the various types of roof constructions. Anybody who is knowledgeable about both of these factors will recommend a plasticizer-free roof covering or at least reduce the plasticizer content to a minimum i.e at most 10%.

PVC

PVC is, in itself, a hard material and, if it is to be used as a roofing membrane on a flat roof, then it has to be made flexible by the addition plasticizers.

- What quantities of monomeric or polymeric plasticizers have to be added to PVC to ensure that the membranes can be handled on the building site?
- How do these plasticizers behave under the temperatures that are encountered on the roof?
- How do these plasticizers behave in contact with the substances to which they are exposed?

How do these plasticizers behave when exposed to ultraviolet radiation?

In order to manufacture a plasticized PVC roof sheet, some 40 parts of the normal plasticizer are required for 60 parts of PVC.

First and foremost, this high concentration of plasticizer reduces PVC quality. These liquid plasticizers necessarily involve disadvantages since, on the one hand, they are present in high concentrations and on the other, very high temperatures occur on roofs consequently, there is no way of preventing a rapid and massive loss of plasticizers.

The plasticizers may also migrate into substances with which they are in contact such as, for example, polystyrene, bitumen, dust, deposits on the roof surface, etc. If, in addition, water remains on the roof, this will, in combination with heat, saponify the plasticizers.

At high temperatures, these plasticizers will also evaporate off.

As the plasticizer is lost, the PVC becomes hard once again. As a result of the loss of volume, the plastic is subjected to three dimensional shrinkage which finally leads to the generation of stresses in the membrane and the subsequent destruction of the waterproofing layer.

Why cannot one prevent plasticizer migration?

A PVC-P roofing membrane is made up of a mixture of high molecular polymers (PVC) and low molecular substances (plasticizers). The low molecular substances have a low boiling point and consequently vapourize easily.

As a result, there is no way of retaining these substances in the PVC-P membrane in high concentrations and at high temperatures on the roof surface.

However, there is one thing which is certain: all plasticizers - whether they be monomeric or polymeric - migrate, vaporize, evaporate, may be subject to saponification, and serve as a breeding ground for micro-organisms. Plasticizer loss results in a loss of volume and this leads to shrinkage of the roofing membrane in all directions. Even the thickness of the material is reduced.

In order to resist the shrinkage, a woven fabric is incorporated in the membrane. Yet, in spite of this, the plasticizers are still driven off. The loss of plasticizer results in stresses which lead to a situation in which plasticizer migration is further accelerated.

A further item should also be mentioned here. The higher the plasticizer content, the more favourable the vapour diffusion resistance. However, as the plasticizer loss increases, this advantage too is lost.

The waterproofing becomes more vapour-tight. A study has shown that, with a plasticizer loss of 25%, the diffusion resistance is doubled. In the case of damaged roof coverings, it has been shown that the pure PVC is well adapted to environmental conditions. The surface had retained its shine and appearance, it had not been attacked. Therefore, how can one use this highly suitable material for a flat roof waterproofing?

It is possible to alloy various plastics with each other and to endow this alloy with the good properties of both of its component plastics? EVA terpolymer PVC is just such a blend.

These combined materials bring together both the high strength of PVC and the good elasticity of EVA (ethylene vinyl acetate). In addition, both materials have, independently and in combination, outstanding resistance to weathering and chemicals.

In EVA terpolymer PVC, the PVC is not plasticized by the addition of normal plasticizers but by blending with a high polymer. Both these high polymers are molecularly compatible. Only high polymers can be used for blends of plastics, i.e. macromolecules with a molecular weight of at least 10^4.

These high molecular weight polymers do not vaporize without chemical decomposition of the macromolecules. They cannot vaporize or migrate.

This has been known for decades. Light sections for windows, gutters pipes, etc have been made from PVC. In order to increase its impact resistance, hard PVC has a second high polymer, namely EVA copolymer or EVA terpolymer added to it in small quantities. Since nothing is lost out of this alloy, the material maintains its good properties.

Is it possible to impart elasticity to roofing membranes in the same way as to structural light sections?

For nearly 20 years now, we have been using this type of elasticized roofing membrane in which EVA copolymers are used as elasticizers instead of conventional plasticizers.

As can be seen from Table 1, this EVA terpolymer is a solid material with a high molecular weight. Since the polarity is similar to that of PVC, the two polymers are compatible and result in a good polymer blend. This alloying of solid components has a number of decisive advantages over the traditional PVC-P:

It's what remains that counts:

- The membrane is an elastic polymer yet made almost entirely of solids.
- The substances remain in the membrane and so do the good properties.
- It retains its outstanding low temperature resistance over the long-term - even in the event of extremely low temperatures.
- The high polymer blend has a far higher solid content than the conventional plasticized PVC seal.

The EVA terpolymer PVC roofing membrane has a high polymer content of nearly 80%. The total solid content is at least 90%.

In contrast, conventional PVC-P has a solid content which is usually lower than 60%. These figures are percentages by volume. In the case of EVALON roofing membrane the original mass volumes remain unchanged.

This means no shrinkage of the roofing membrane due to loss of substance and no reduction in membrane thickness.

It is well known that there are no plasticizers which do not evaporate, vaporize, saponify, migrate or which cannot be destroyed by micro-organisms.

The more plasticizer used the higher the loss in a shorter period of time; and, at the same time, the greater the drawbacks as a result of stress, and the greater the shrinkage.

As the mechanical stresses increase, the service life of the material is significantly reduced

The list given below shows the main causes that may lead to plasticizer migration:

Gravel

Gravel causes pressure on the roof seal. When subjected to pressure, the plasticizers migrate more rapidly.

Deposits

Deposits of dust and mud, when dry, avidly absorb the plasticizers which are then washed away with rainwater.

Condensate

There is always moisture in the roof structure. In the form of condensate, this precipitates on the underside of the roof seal and acts as a conductor for the plasticizers. The glassfibre intermediate layer which is intended to impede plasticizer migration then becomes ineffective.

Table 1

Properties	Liquid Plasticizers	EVA terpolymers
Physical appearances	Liquid	Solid granules
Molecular weight	300 – 2,000	250,000
Tensile strength (Mpa)	-	4.2
Module of elasticity (MPa)	-	2.8
Elongation at break	-	1,200%
Vitrification temperature (°C)	-	-36
Density (g/m)	0.96 – 1.09	-
(The molecular weight of PVC is 100,000 to 150,000)		

Table 2

Roofing Membranes	Polymer/ Plasticizer mixture	Plasticizers %		Solids%
		Mass	Volume	
PVC-P (monomeric)	60 / 40	37.6	48.0	52
PVC-P (polymeric)	60 / 40	38.0	44.5	55.5
EVALON	92 / 8	6.4	8.0	92.0