

# waterproofing

## WATERPROOFING MATERIALS, THEIR PROPERTIES AND THEIR DEVELOPMENT

The roof's watertight seal, continuous seals, discontinuous seals • Waterproofing methods from the past • Present day waterproofing materials • Tar and bitumen • How bitumen is made from oil • Traditional bitumen coating • Bitumen sheets • Poured asphalt • Polymers in waterproofing products • Synthetic sheets • Liquid membranes • Polymer bitumen membranes • APP polymer bitumen membrane • SBS bitumen membranes • Phase inversion mix • APP and SBS bitumen mix characteristics • Membrane reinforcement • Influence of the reinforcement of the membrane's thermal and mechanical behaviour • Special case of heat induced shrinkage of non-woven polyester reinforced membranes • APP vs. SBS bitumen membranes • Membranes of the future • Composite polymer bitumen membranes: the DUO range • Mineral design membranes • Regulations • Chemical resistance of membranes • Behaviour of polymer bitumen membranes when exposed to sunlight • Behaviour of membranes in a fire • Resistance to root growth • Resistance to hail • Compatibility of membranes • On-site tests • Application of membranes • Hot air bonding • Mechanical fixing • Waterproofing civil works

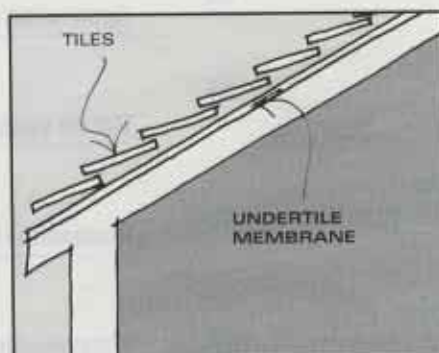
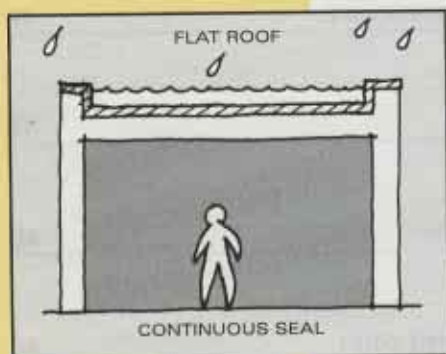
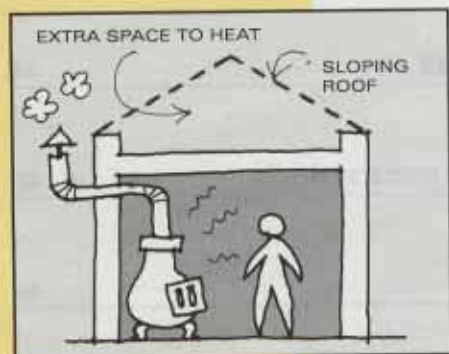
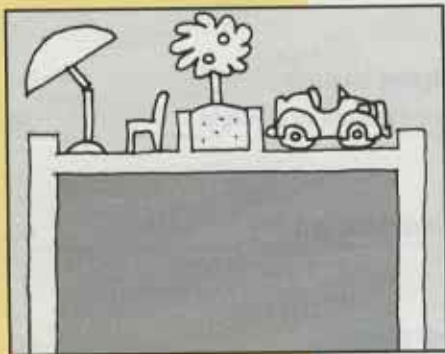
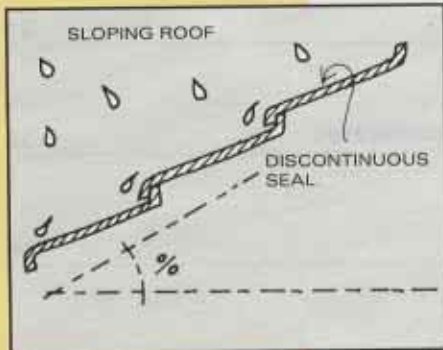


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## THE ROOF'S WATERTIGHT SEAL, CONTINUOUS SEALS, DISCONTINUOUS SEALS

The watertight seal of a sloping roof is created by overlapping a series of small and large elements. The inclination of the roof has to be enough to prevent the water from entering the roof covering under the overlaid elements. Leaf roofing on a primitive hut, tiles and asbestos cement sheets are all examples of discontinuous roof seals. Often a sloping roof is not convenient or possible and a flat roof is chosen. Flat roofs represent the most efficient use of urban space, architectural freedom, control of the downflow of water to the drainage system and energy savings; modern construction also tends more and more towards roof parking, roof gardens and roof terraces.



The watertight seal of a flat roof must be continuous and is made from melted polymer and bituminous materials or by spreading bitumen alternated with multi-layer bituminous sheets or by creating a continuous carpet of polymer bitumen or polymeric sheets.

A continuous waterproof covering is indispensable to a flat roof seal but it can also be used successfully on sloping roofs and geometrically complex roofs. Continuous coverings can also be used as a safety element on shallow roofs with a discontinuous seal on top, such as tiles, or in windy areas. Such applications are called "undertile" coverings.

## WATERPROOFING METHODS FROM THE PAST

**F**lat coverings, called "terraces" because they were covered with earth, have been common since ancient times. Among the materials used for waterproofing are clay, lime, coal tar pitch (originally vegetable matter) and bitumen of fossil origin taken from Middle Eastern deposits. Bitumen was used to seal the joints between stones and, when mixed with mineral powders, was spread in continuous layers and sometimes reinforced with plant fibre strips.

A continuous covering of poured asphalt started to be used in the 16<sup>th</sup> century; its main component was taken from deposits of natural asphalt, a calceous rock shot through with bitumen fossil. Well-known in southern Italy and France, it began to spread through Germany and Holland during the 18<sup>th</sup> century with the discovery of new deposits.

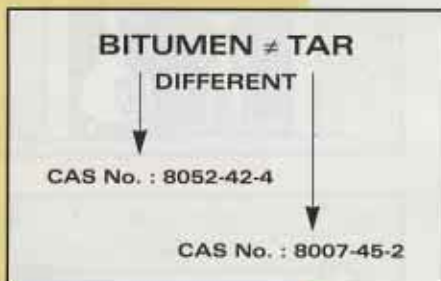
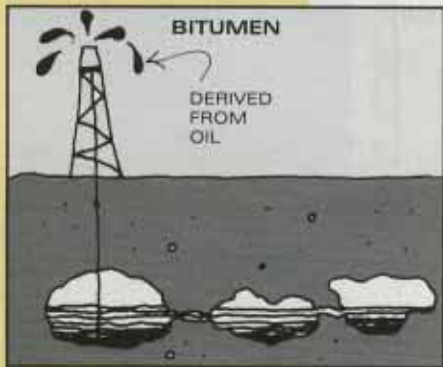
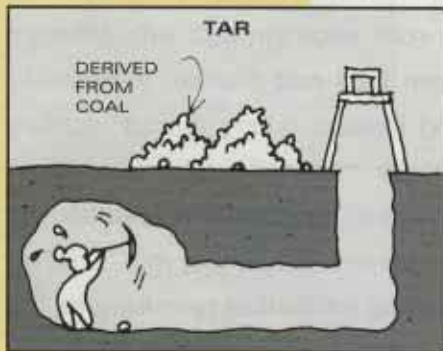
In 1772 near Nuremberg in Germany, Margerger spread several layers of coal tar of mineral origin to line a timber roof. Coal tar was obtained from coal in England for the first time towards the end of the 17<sup>th</sup> century and with the advent of the Industrial Revolution during the 19<sup>th</sup> century, enormous quantities became available.

## PRESENT DAY WATERPROOFING MATERIALS: TAR AND BITUMEN

With the development of the modern chemical industry, tar and coal tar pitch have become widespread. They are derived from the distillation of coal and were spread on roofs alternating with tar paper. More recently, wide availability of oil has meant tar and pitch have been substituted by bitumen. Even today the different products are confused, both being black and used in construction, just as tar paper and bitumen paper and tar and bitumen-based paints are confused.

Tar is mainly composed of aromatic hydrocarbons while bitumen contains a much higher percentage of high molecular paraffin and naftene hydrocarbons and their derivatives. In reality, bitumen and tar are very different both in their origins and chemical structure although they are used in the same sector. Both are insoluble in water and have excellent adhesive properties.

The Chemical Abstract Service clearly distinguishes them, giving tar and coal tar pitch the CAS number 8007-45-2 and bitumen CAS number 8052-42-4. Tar can be harmful to man and this is the main reason for its replacement by bitumen.



## HOW BITUMEN IS MADE FROM OIL

**B**itumen obtained from distilled oil, called distilled bitumen, is a very thick black liquid that has to be closed in containers and is classified on the basis of a penetration test. The test assesses the hardness of the solution by measuring the penetration of a standard needle in standard conditions into the distilled bitumen in decimillimetres. The softer the bitumen, the further the needle enters. The most common types have a penetration value of between 180/200 dmm. and 80/100 dmm.

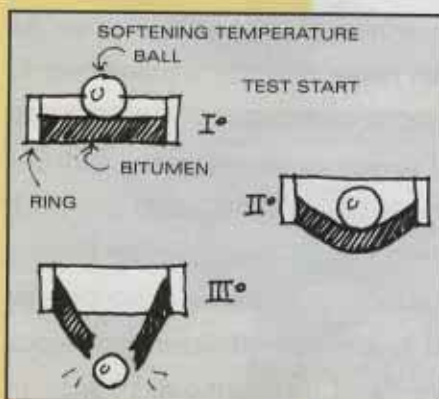
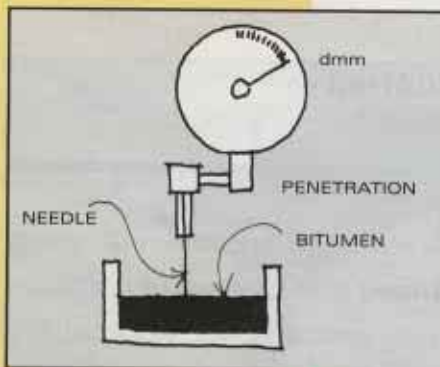
Distilled bitumen is widely used as a binder in road-building but is unsuitable for roof linings because it melts at 50°C and becomes brittle at 0°C.

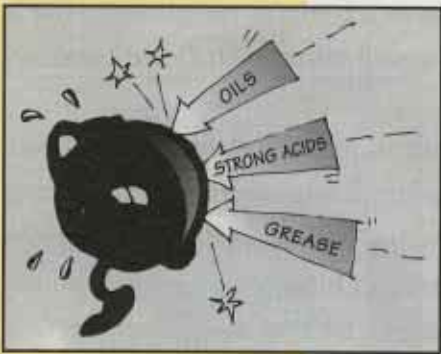
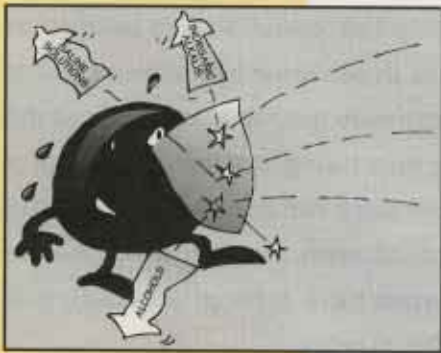
It was then noticed that the thermal stability of the bitumen could be improved by altering its structure with oxygen. The resulting product is known as "oxygenated" or "blown" bitumen and is obtained by bubbling air through high temperature, molten bitumen. The stability field of blown bitumen ranges from -5°C to +70°C and is therefore suitable, and widely used, for roof linings. It is the raw material for waterproofing coverings around the world.

Blown bitumen is a slightly rubbery, thermoplastic solid at room temperature and is supplied in bags or cakes. It is classified by its softening temperature which is given by the "ring and ball".

A disc of solid bitumen is held in a ring and heated in a standard manner until it becomes so soft that it lets a metal ball drop through. The penetration value and softening temperature together are used to describe the type of bitumen - first the softening point and second the penetration value. For example, 85/25 blown bitumen softens at 85° and is penetrated 25 dmm. by a needle. Blown bitumen is used on roofs to adhere layers of traditional bituminous covering and is the raw material in bitumen sheets. Its main use is to bond insulation panels in the roof covering.

Bitumen is an extremely complex mixture of heavy hydrocarbons and contains small amounts of nitrogen, oxygen and sulphur. It cannot be divided into single elements nor can its exact chemical composition be defined but conventionally, on the basis of its different solubility in selected solvents, it is divided into asphaltenes (heavy hydrocarbons) and maltenes (light hydrocarbons). Its specific weight is 1-1.07 kg/l and specific heat 1.674 kJ/kg°C. Its thermal conductivity is 0.14 kCal/mh°C and dielectric rigidity is 20-30,000 V/mm. It has a calorific power of

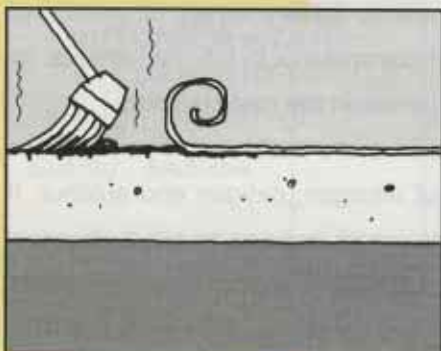




9,000-9,300 kCal/kg, is insoluble in water but soluble in common organic solvents.

Bitumen resists diluted acids and inorganic alkalis, saline solutions and alcohols but it is not resistant to concentrated, strong acids especially if oxidisers. It is attacked by oils and greases. Oxygen attacks its surface slightly in a combined action with sunlight and heat.

## TRADITIONAL BITUMEN COATING



This method is based on a multi-layer application of various types of bitumen sheets alternated with coatings of hot blown bitumen. The bitumen is heated in special boilers, extracted at a temperature of 200-220°C, poured into pails and is then spread onto the surface to be lined by workmen using wide brushes. As the bitumen is spread, bitumen paper rolls are unrolled over it. Approximately 1500 g/m<sup>2</sup> are used in each coating.

The operation can be repeated several times and ranges from 3-4 layers using bitumen paper sheets weighing 500-2000 g/m<sup>2</sup> to 2 layers of heavier paper weighing 4000-5000 g/m<sup>2</sup>. The English method of spreading bitumen is to pour it directly in front of the roll being laid. The final result is a solid multi-layer continuous covering weighing 8-10 kg/m<sup>2</sup> and measuring 8-10 mm. in thickness.

## BITUMEN SHEETS

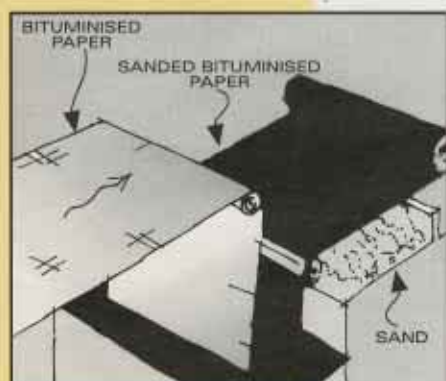
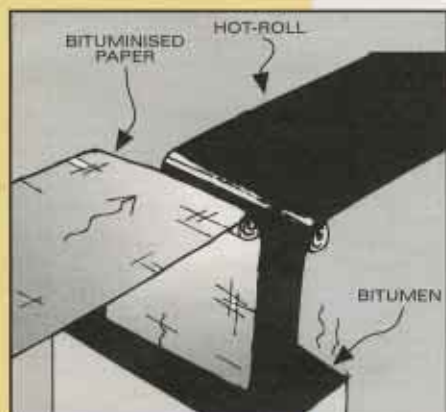
These act as the reinforcement of traditional bitumen covering. Originally sheets of paper, jute or cotton were laid between layers of blown bitumen to give the waterproof covering sufficient mechanical properties. The difficulty of impregnating them completely with bitumen on the building site, plus the fact that they absorbed water, led to the development of the bitumen sheet industry. The first and most common bitumen sheeting was bituminised paper based on felt paper impregnated with hot distilled bitumen. This ends as completely black, absorbent paper. As it is still able to absorb 30% weight in humidity, the process called "re-covering" was developed. This involves simply dipping the paper in hot blown bitumen again so that the felt paper is covered a second time and further absorption prevented. As the surfaces of the paper are now covered with excess bitumen, they are covered with sand or talc to prevent the wrapping of the rolls sticking to them. During the early 1960's, the use of glass-fibre felt instead of felt paper became common as the latter tended to deteriorate with time. This new material is non-decomposable, heat resistant and has greater dimensional stability although it is more brittle than felt paper. Bituminised jute sheets used to line important, small areas of the roof had greater mechanical resistance than felt paper but were subject to attack by micro-organisms and so were quickly replaced by the glass-fibre material.

As glass-fibre cannot decompose and is more porous than paper sheets, it does not require impregnation with distilled bitumen and is normally only covered with blown bitumen.

Surface finishing of bitumen sheets has also developed. It was found that longer lasting protection was given to the covering if the upper face of the bitumen sheet was covered with chips of slate or natural or coloured ceramic. It also improved the appearance. Gradually, the practice of laying 3-4 layers of bitumen paper weighing 300-1200 g/m<sup>2</sup> passed to application of covered sheets weighing 3000-4000 g/m<sup>2</sup> in 2 or 3 layers at most.

The reduction in the number of coatings and on-site manual operations by using heavier sheets that, besides reinforcing the covering, also contained enough bitumen to create the waterproof seal, successfully reduced labour costs.

Today traditional bitumen sheets have disappeared from some





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countries to be replaced by polymer bitumen membranes but in other countries there is a wide production of various materials. Reinforcement has been developed to incorporate non-woven polyester and blown bitumen is often bitumen modified with polymers even if laying is still traditionally carried out with hot blown bitumen.

There also exist special sheets like bituminised aluminium sheeting to create vapour barriers and sheets protected with metal foil for a more attractive appearance.

In the USA and Canada, manufacturers of bitumen sheets also produce SHINGLES, bituminised tiles that are bitumen sheets reinforced with paper or glass-fibre felt and covered with blown bitumen. The upper side is protected by coloured ceramic chips and the sheets are cut into smaller shapes, usually measuring approximately 90 x 30 cm. The tiles are then nailed overlapping on timber roofs to create a discontinuous watertight seal. They are widespread across the whole of North America where about one billion square metres are produced per year.



## POURED ASPHALT

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**E**ven though poured asphalt is a waterproofing material dating from hundreds of years ago, it is still used widely in some countries.

**Asphalt** is a calcareous or arenaceous stone impregnated with bitumen fossil found in nature.

The richest European deposits are found in southern Italy and various regions of France. It contains a quantity of bitumen ranging from 4- 20%.

Cakes of asphalt mastic are prepared, the raw material for poured asphalt.

**Asphalt mastic** contains approximately 15% of bitumen obtained from asphalt rock through melting. It is mixed with fine mineral material and formed into 25 kg cakes. If the asphalt rock is not sufficiently rich, bitumen is added that may be extracted from the same rocks, or natural bitumen such as Trinidad or Selenizza or bitumen derived from oil. The mastic is considered "natural" if prepared with asphalt rock and "synthetic" if obtained from calcareous rocks to which natural bitumen or oil derived bitumen is added.

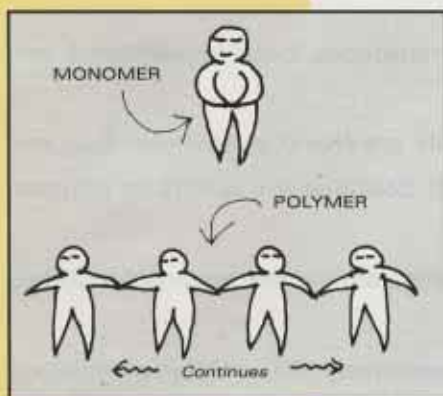
**Poured asphalt** is a continuous waterproof layer, 12-25 mm. thick, obtained by applying one or more layers of a mixture of asphalt mastic and bitumen with wooden spreaders at a temperature of 240°C. It can be prepared on-site mixing the components - asphalt rock, bitumen and crushed stone - but it is more common to use cakes of asphalt mastic melted in boilers with bitumen.

Addition of sand and crushed stone renders the cooled layer capable of withstanding foot traffic so that terraces, roof gardens, pavements and industrial acidproof and sparkproof floors can be paved and waterproofed at the same time.

When waterproofing bridges and roads, it is protected by a bituminous mix.

In many countries there are asphalt producers that deliver the material molten to the building site using special tank trucks. German "Gussasfalt" is similar and is largely used to waterproof bridges and roof carparks.

## POLYMERS IN WATERPROOFING PRODUCTS



**P**olymers are made up of macro molecules which are formed by chains of small, equal molecules called monomers. If the small molecules in the chains are not all the same but of two different types, the polymer is called a co-polymer; if of three different types, it is called a terpolymer.

When monomers are taken alone in their natural state, they form a liquid. Indeed, the molecule is usually so small and light that in nature monomers are found in a gaseous state. Once monomers undergo a chemical reaction of polymerisation and become large molecules, they are transformed into a solid material. For example, ethylene is the monomer base for the polymer called polyethylene used to make plastic shopping bags. In its natural state, ethylene is a gas, as is propylene which turns to polypropylene when turned into a polymer.

Polymers are not simply macromolecular substances produced artificially by man, but exist in nature in different forms. Horn, Ivory and many vegetable resins are natural macromolecular substances. Latex, secreted from the rubber tree, is a natural polymer and so is plant cellulose, the chemical that imitates nature.

There are many small molecules that can be converted into polymers and many polymers can be obtained with different characteristics. Polymers are named and classified according to their origin. "Synthetic resins" are so-called because they are obtained artificially as opposed to "natural resins" found in nature. Here are some polymer names derived from the prefix "poly-" followed by the monomer's chemical name:

poly - ethylene

poly - propylene

poly - ester

Alcohol poly - vinyl

poly - vinyl chloride

The following names are derived from addition of the suffix "-plast":

pheno - plast

proteino - plast

thio - plast

## SYNTHETIC SHEETS

Often they are identified by the commercial name given them by the manufacturer:

Hypalon	- polyethylene chlorosulphonate
Neoprene	- polychloride butadiene
Buna S	- co-polymer butadiene styrene
Plexiglas	- polyacrylate
Nailon	- polyamide
Tihocol	- polysulfides

Under new standards some are now recognised by abbreviations:

PVC	- polyvinyl chloride
PE	- polyethylene
PP	- polypropylene
PET	- polyester

Several types are given in the section dealing with synthetic waterproofing sheets. Polymers can also be identified by the name of the chemical family their monomers belong to.

The name "polyolefins" identifies a large variety of thermoplastic polymers deriving from polymerisation of "olefins", the name given to unsaturated linear hydrocarbons or alkenes, also called olefin hydrocarbons because, when treated with bromine, they are transformed into oily products. Hundreds of years ago they were also called "Dutch chemists' oil". Polyethylene, polypropylene and copolymer ethylene-propylene etc. belong to this family (it also includes APP).

All the above gives an idea of the anarchy involved in the use of chemical names despite the existence of an official terminology. Thanks not only to manufacturers, the most illogical names are used to define polymers in specifications which then put engineers and waterproofers into difficulties.

Polymers are divided into families taking account of their physical and mechanical properties. Polymers that change shape when pressure is imposed on them and return to their former shape when the pressure is removed, have properties of elasticity. They are called elastomers, synthetic rubbers etc. Polymers that change shape when pressure is imposed on them but which retain the new shape when the pressure is removed have plastic properties. They are called plastic materials or plastomers. They are thermoplastics if they melt with heat, solidify when cooled and

can then be remelted, and they are thermosetting materials if the polymer hardens under heat and does not melt.

Sulphur has a hardening effect on some elastomeric polymers and the process with which it takes place is called vulcanisation. It is used by the rubber industry to give to natural elastomeric polymer (natural rubber) or synthetic elastomeric polymer the necessary properties of elasticity and hardness. If rubber is not vulcanised with sulphur it is plastic and so sticky that it would have no use. Sulphur or other vulcanising agents create bonds between the polymeric chains that harden and render the material elastic.

Elastomeric polymers with intrinsic rubbery characteristics have now been developed that do not need vulcanisation. Their physical and mechanical properties mean that they can be defined as both plastic and rubber materials (such as SBS).

Polymers are used in a vast range of industries. In waterproofing, they are used in:

- reinforced and non-reinforced homogenous synthetic sheets;
- liquid membranes in which they are the basic binding and filming element;
- mixed with bitumen in polymer bitumen membranes.

## SYNTHETIC SHEETS

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Synthetic sheets are waterproofing membranes, with or without reinforcement, to be applied in a single layer. They are based on both plastomeric and elastomeric products and are used for calandering, extrusion and buttering.

In comparison with bitumen waterproofing coverings, synthetic sheets are thin, rarely more than 1.5 mm. thick, and are bonded to each other using different techniques. The joins can be attached in many ways depending on the type of sheet: they can be bonded using hot air, given solution heat treatment, stuck with double-sided adhesive tape or a hot wedge etc.

Synthetic sheets were first used in Berlin in 1938 when a sheet of polyisobutylene (PIB) was adhered to hot blown bitumen.

They can only be applied in a single layer and are nearly always used when protected by paving or a layer of gravel because they are not normally adhered to the support surface. They need special care in application and protection from anti-perforation layers. Application should be carried out by trained personnel. Throughout the world, use of synthetic sheets is less popular than bitumen derivatives.

Types that can be used on roof applications are listed below together with their chemical abbreviation.

PIB:	Poly-isobutylene
PVC:	Polyvinyl chloride
EPDM:	Terpolymer ethylene propylene diene
EPM:	Co-polymer ethylene-propylene
ECB:	Co-polymer ethylene and bitumen
EVA:	Co-polymer ethylene vinyl-acetate
EAC:	Co-polymer ester acrylic
CPE:	Polyethylene chlorinate
PE:	Low density polyethylene
HDPE:	High density polyethylene
CSM:	Polyethylene chlorosulphonate (Hypalon)
CP:	Polychloroprene (Neoprene)
IIR:	Co-polymer isoprene-isobutylene
MT:	Elastomer polymers modified with tar
NBR:	Co-polymer nitril butadiene (nitril rubber)

The most widely used type of synthetic sheet in Europe is plastified PVC which was first produced without reinforcement but then strengthened to give sufficient dimensional stability.

It is also used for lining hydraulic works and the inside of tunnels

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where its lightness and large dimensions are appreciated. HDPE is used for lining sewage pipes for its chemical inertia and the fact that sheets up to 11 metres wide can be manufactured. In the USA, the most common synthetic sheet uses EPDM.

## LIQUID MEMBRANES

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The first applications were coatings of bituminous emulsions that had been stabilised with bentonite or special clays. The applications were called "cold asphalt" because they were ready for use and did not need heating but they were still affected by rainwater while drying so that it was necessary to choose the time of application with care.

During winter applications, bituminous adhesives dissolved in solvent were preferred because emulsions thicken with low temperatures. The covering is made up of alternate layers of the thinnest possible sheets of glass-fibre or jute or standard glass-fibre sheets. Between 1 and 1.5 kg of product is used on each application; partial drying must take place before the next coat can be spread. Generally, there were at least 3 coats and 2 layers of reinforcement. This method was mostly used on irregular, sloping roofs which were difficult to cover using traditional, hot spread bitumen. A typical application was the lining of domes.

There also exist mechanical spray application systems based on emulsion mixed with glass-fibre and, more recently, with precipitants that thicken the emulsion rapidly so removing the drying time.

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Following bituminous derivatives, mono and bicomponent polymers in water solutions both with and without solvents were also used. In general, the following have been used for waterproofing:

- polychloroprenic resins
- acetovinylic resins
- mono and bicomponent polyurethanic resins either pure or modified with tar
- epoxy and epoxy-polyurethanic resins either pure or modified with tar
- tricomponent polyester resins.

Most have not had a great success while acrylic resins in solvents, emulsion or a water solution have achieved some popularity in the marketplace due to their good performance/price ratio. They are used where traditional coverings or prefabricated membranes either cannot be used at all or cannot be used conveniently.

They are applied almost exclusively on concrete surfaces and have had good results in mixed applications where a single layer is spread over polymer bitumen slate chip membranes. They are largely used for lining or covering asbestos cement sheets and as a protective layer for site sprayed polyurethane foam.

INDEX's 3rd Division produces the following liquid membranes:

Waterbase Primer

Fiberproof Elastoliquid

Elastoliquid PUR

Elastoliquid PUR, self-extinguishing

Plastoliquid SV

Fixasbest Allumasol

Protifer

Indemastic

Idrolastik

Indesol

Elastobit S



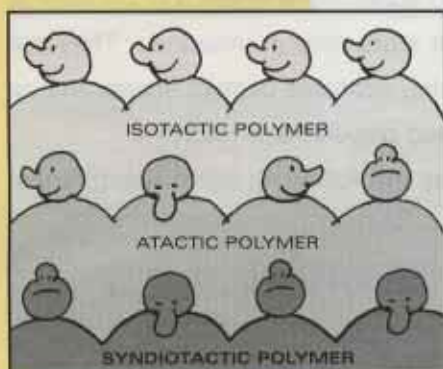
## POLYMER BITUMEN MEMBRANES

### APP POLYMER BITUMEN MEMBRANE

During the early 1960's, traditional bitumen covering was mainly represented by bitumen paper and bitumen. Bituminised glassfibre felt, which was appreciated for its dimensional stability and resistance, had only just been brought onto the market. At the time, polymer chemistry was being developed rapidly. New horizons were opened with the advent of stereospecific catalyzers, discovered by Nobel Prize winner Professor Natta, developed to polymerise propylene.

For the first time it was possible to order polymer chain molecules which previously only joined in a disorderly manner. If we can imagine them as diamonds in a necklace, it became possible not only to order the diamonds correctly in the necklace but for the first time to place them all facing in the same direction.

This gave the resulting polymer chain greater mechanical resistance and higher resistance to heat. The type of polymer created was called "**ISOTACTIC**" and is identified by the abbreviation IPP. The name for disordered polymer chains is "**ATACTIC**" and is identified as APP.



In the case of isotactic polypropylene, mechanical resistances of 400 kg/cm<sup>2</sup> and heat resistance up to 150°C are reached. Atactic polypropylene is more malleable and elastic, similar to rubber, and can be stretched as much as 600%.

Early stereospecific polymerisation technology had approximately a 90% success rate in creating isotactic polymers. The remaining 10%, for example of atactic polypropylene, given its properties, was not used in plastic material transformation but instead in the production of hot-melt adhesives as a substrate for moquettes and, more important, in bitumen modifiers.

Modern polymerisation technology gives such a high success rate that the few atactic polymers that are left over remain in the isotactic material and the atactic polypropylene required by the markets is produced in dedicated plants. No longer is it a byproduct of stereospecific polymerisation but a top quality product specially formulated for different applications.

The move to bitumen modification using APP was made when it was necessary to dispose of great quantities of by-product which made them available at low cost.

Natural rubber and synthetic polymer latex modifications to road bitumen had been in use for some time but for economical and

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technical reasons (poor heat resistance), those modifications had not been applied significantly to roofing bitumen sheets.

However, the APP bitumen mix was very heat resistant with a ring and ball softening point of 150°C as opposed to the 85°C of blown bitumen. The result was the production of 50 g/m<sup>2</sup> bitumen sheets reinforced with glass-fibre felt. The rolls did not soften in the sun as occurred with blown bitumen spread on glass-fibre.

Until then the technique of heat-bonding a 3 mm. single layer had been used only for applying heavy sheets over roof projections; now it was proposed for covering an entire roof.

To encourage fusion, the membrane was not sanded but sprinkled with a very fine talc, then rolled together with a sheet of polyethylene that was removed before flame-heating.

The traditional technique had been radically modified. Flame application no longer required a boiler to melt the blown bitumen and on-site equipment and materials had been drastically reduced. It was now only necessary to lay a single 3 mm. layer rather than 3 layers of bitumen paper with 4 separate coatings. The economic advantages were obvious and producers of traditional bitumen paper that did not modernise their factories to the new technology went by the board.

Membranes in APP bitumen came to be called "sheaths". Given their thickness and the stickiness of the black surface, they could not be produced in the plants used for bituminised felt paper, whose cooling system after addition of reinforcement was based on water-cooled steel rollers (the traditional sheets were covered with sand so did not stick to the rollers); it was therefore necessary to create a more effective and faster cooling system using only direct contact with water. A new mixing system was also necessary to prepare the polymer bitumen mixture.

The new method of waterproofing roofs soon found favour with operators who were able to double their workload with the same workforce, reduce the number of accidents through burns and scalds, and use only half the amount of transport and lifting equipment to do the job.

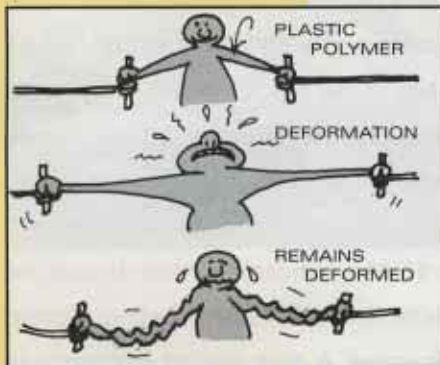
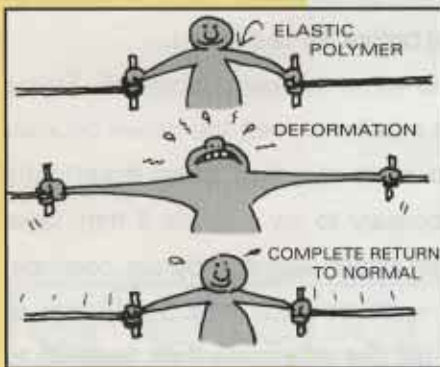
## SBS BITUMEN MEMBRANES

At the end of the 1960's and in the early 1970's, Shell produced a family of elastic polymers which had thermoplastic properties; the styrene-butadiene co-polymer that had been block polymerised (SBS). In this process, chains of polybutadiene with elastic properties branched out from blocks of polystyrene with plastic properties.

The chains could be either radial or linear depending on the polymerisation conditions. This particular type of configuration is different from the classic one seen in styrene-butadiene rubber (SBR) or BUNA-S where the molecules of the two monomers alternate in the linear polymer chain.

The result is that the polymer has a more clear-cut softening point; once the material reaches the melting point of the polystyrene block (80°C), the polymer turns fluid like a plastic material which makes it workable with the plastic industry equipment plus it is simpler, faster and less costly than rubber materials and it does not require vulcanisation.

When used to modify distilled bitumen, it was found that these new polymers created a product that gave good elasticity and flexibility at low temperatures and good resistance to heat. Subsequently, SBS bitumen technology to create bitumen roofing sheets was first developed in France but it only served as an improvement on traditional sheets which continued to be used with hot blown bitumen. Only at the end of the 1970's did INDEX develop the first thick SBS bitumen membrane with a heat film that could be applied by flame-bonding. The membrane was called HELASTA.



## PHASE INVERSION MIX

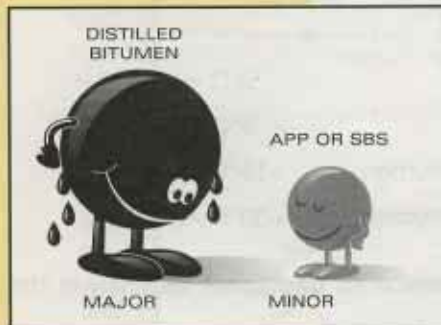
In both APP and SBS bitumen and polymer mixes, the polymer is added in much lower quantities than the bitumen. When the two ingredients are mixed at a temperature higher than the polymer melting point, if the concentration of polymer is sufficient and the bitumen is compatible, a mix called "phase inversion" is created where the polymer (the minor ingredient) becomes the dominant characteristic of the mix and the bitumen (the major ingredient) becomes the less important of the two.

An analogy is that of a sponge (the polymer) which absorbs a quantity of water (the bitumen) that weighs more than itself without breaking up. And like the sponge filled with water, it maintains its own shape; the polymer bitumen maintains the characteristics of the polymer, the dominant characteristic, and does not adopt those of the bitumen although that is the major ingredient.

This phenomenon can be highlighted using an ultra-violet microscope. When the mix is lit by ultra-violet light, the bitumen appears black and the polymer yellowish. The phase inversion polymer bitumen mix appears as a yellow matrix (the polymeric dominant characteristic) which contains the round black particles of bitumen.

If, on the other hand, the result is a black background (the bitumen) encircling yellowish stains, it means that phase inversion has not taken place because the bitumen was incompatible or because there was insufficient polymer concentration. The characteristics of this mixture will be closer to bitumen than to the polymer.

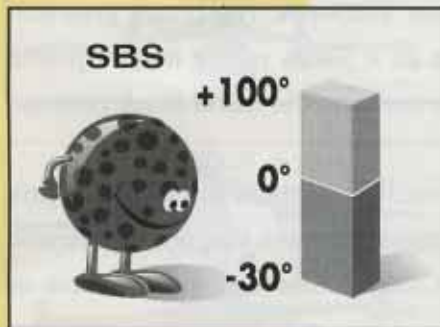
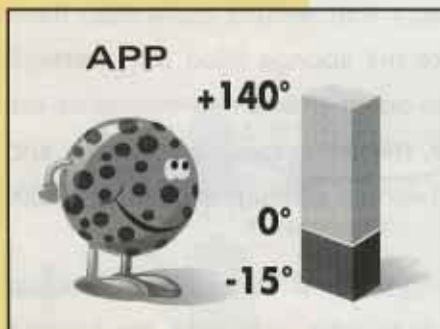
The bitumen used in polymer bitumen mixtures is almost always distilled because it is rich in maltene oils which are compatible with the polymers.



## APP AND SBS BITUMEN MIX CHARACTERISTICS

The addition of both polymers notably increases the field of stability of distilled bitumen with the variation of temperature, both easily exceeding that of blown bitumen. Using the parameters of cold flexibility at low temperatures and the softening point at high temperatures, the fields of stability for the various materials are as follows:

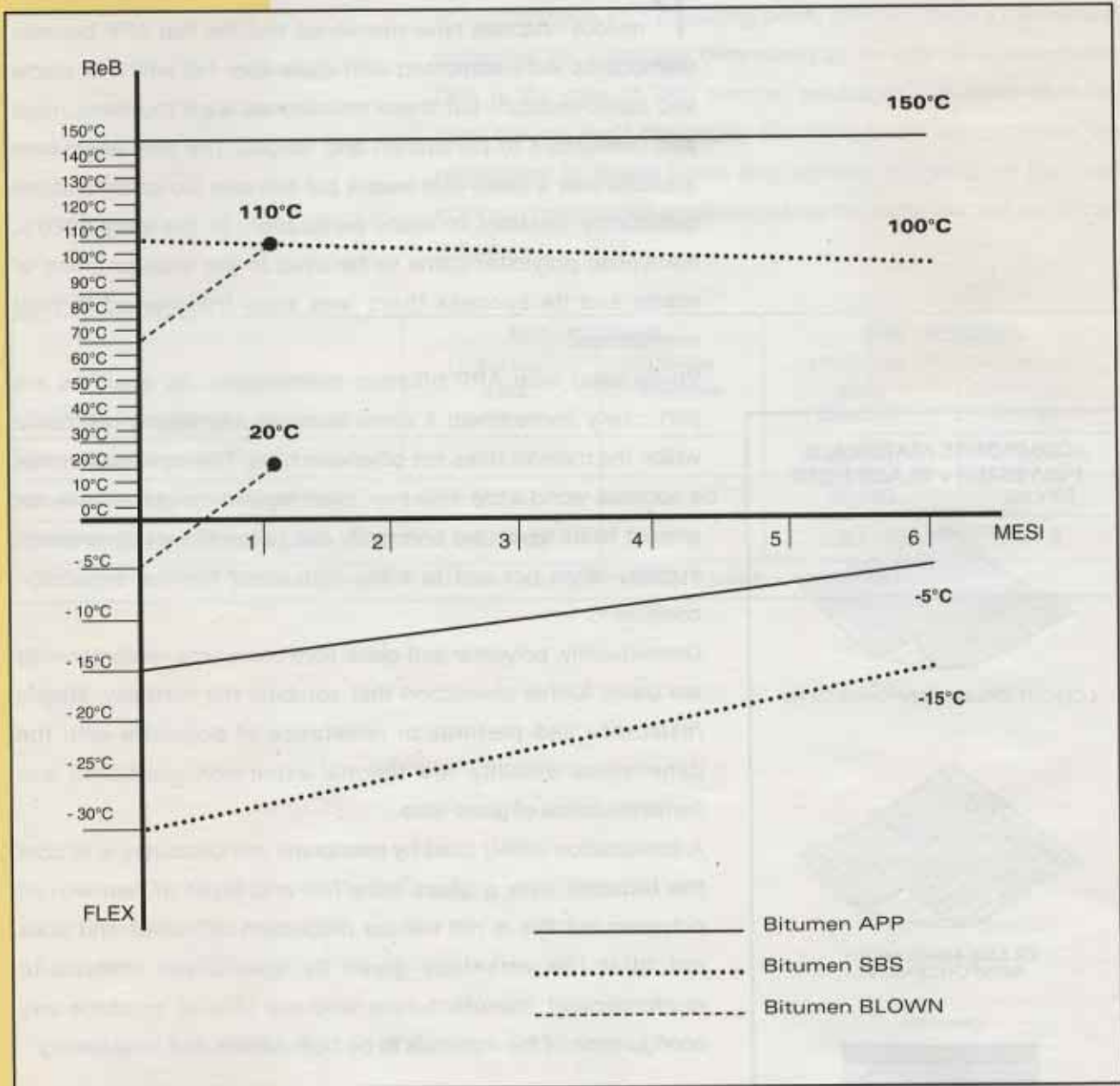
distilled bitumen	0°C → 50°C
blown bitumen	- 5°C → 70°C
UEAtc compliant APP bitumen	-15°C → 150°C
UEAtc compliant SBS bitumen	-30°C → 100°C*



Another advantage in comparison to traditional bitumen is the resistance to ageing that the polymers give.

Blown bitumen becomes brittle after a month of artificial ageing at 70°C while a polymer bitumen mix is still flexible after six months. The graph overleaf shows how the field of stability for the different materials alters with accelerated ageing.

\* (The actual requirements of the UEAtc directives for both mixes are less than those stated but the average values of the products with Agreement on the market reflect those above).



## MEMBRANE REINFORCEMENT

Previous chapters have mentioned that the first APP bitumen membranes were reinforced with glass-fibre felt which is stable and flame-resistant but these membranes were too weak, rigid and unresistant to perforation and fatigue. The only alternative available was a glass-fibre weave but this was too costly and not sufficiently resistant to static perforation. In the early 1970's, nonwoven polyester came to be used in the waterproofing of roads and its success there was soon transferred to roof membranes.

When used with APP bitumen membranes, its qualities are particularly appreciated: it offers elasticity and fatigue resistance which the material does not otherwise have. The combination was a success world-wide. However, even non-woven polyester is not without faults which are principally due to insufficient dimensional stability when hot and to a too high linear thermal expansion coefficient.

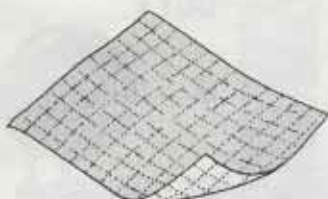
Consequently, polyester and glass-fibre composite reinforcements are being further developed that combine the elasticity, fatigue resistance and perforation resistance of polyester with the dimensional stability, low thermal expansion coefficient and flameresistance of glass-fibre.

A combination widely used by membrane manufacturers is to coat the bitumen over a glass-fibre felt and layer of non-woven polyester but this is not without production difficulties and does not offer the versatility given by specialised composite reinforcement manufacturers who are able to produce any configuration of the materials to be both reliable and long-lasting.

### COMPOSITE MATERIALS: POLYESTER + GLASS FIBRE



LONGITUDINAL REINFORCEMENT



GLASS-FIBRE MESH  
REINFORCEMENT

(section)



THREE LAYER REINFORCEMENT  
(PES - GF - PES)

At temperatures above freezing point, the membrane's mechanical properties are practically determined by its type of reinforcement. Only in the case of SBS bitumen reinforced with glass-fibre felt does the mix itself contribute. The table below demonstrates the resistances to tensile stress and ultimate elongation of the most common membranes produced using the same mix but reinforced differently.

Reinforced membrane	APP - BITUMEN		SBS - BITUMEN	
	UTS or max. stress (daN/5 cm)	Ultimate elongation (%)	UTS or max. stress (daN/5 cm)	Ultimate elongation (%)
Glass-fibre 50 g/m <sup>2</sup> (L/T)	30 / 20	2 / 2	30 / 20	2 *(≥20) %
Non-woven polyester 160 g/m <sup>2</sup> (L/T)	60 / 50	30 ÷ 50	60 / 50	30 ÷ 50
Glass-fibre weave DIN 200 g/m <sup>2</sup>	100 / 100	2 / 2	100 / 100	2 / 2

\* Ultimate elongation of SBS bitumen mix only after breakage of glass-fibre reinforcement



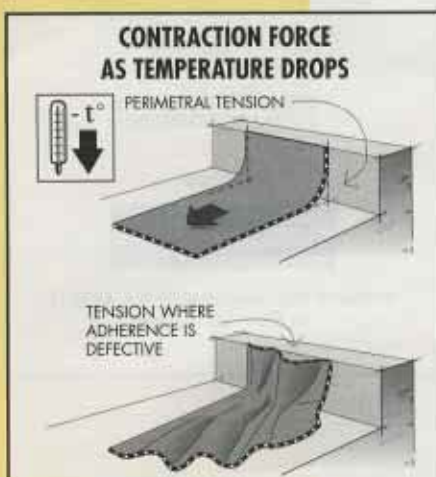
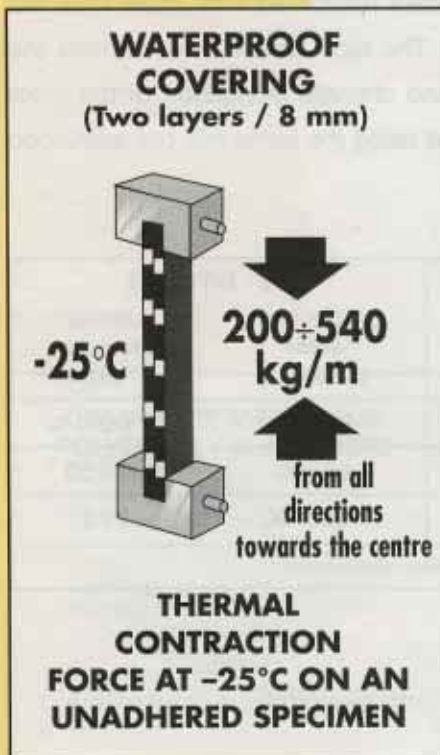
## INFLUENCE OF THE REINFORCEMENT OF THE MEMBRANE'S THERMAL AND MECHANICAL BEHAVIOUR

Like polymer bitumen mixes, bitumen by itself is soft at high temperatures and rigid at low temperatures.

When hot, the polymer bitumen mix is inconsistent and it is the reinforcement that provides the required mechanical resistance. At low temperatures, it goes rigid and acquires force. The mix contributes to the resistance of the covering and, at the same time, contracts as the temperature drops if it is not held in some way: reinforcement reduces that contraction. The action is more effective for reinforcements that have a low thermal expansion coefficient such as for bitumen which goes rigid at low temperatures. Therefore the most stabilising effect is given by reinforcements that contain glass-fibre.

Temperature variations cause the membrane to elongate and shorten but if the membrane is fixed at the ends or is adhered to the surface below and movement is impeded, low temperatures cause the membrane to shrink towards its geometric centre with a tension in the order of a few dozen kilograms per linear metre for temperatures down to  $-10^{\circ}\text{C}$ . However for temperatures lower than  $-25^{\circ}\text{C}$ , the values increase to hundreds of kilograms.

Forces caused by cold tend to increase with the ageing of the material. When the membrane is adhered or fixed to other membranes, the same phenomenon is true for all the waterproof covering which acts a single entity. Induced tension is an important consideration in cold climates and for open coverings on very thick thermal insulation where high thermal shocks will be experienced.

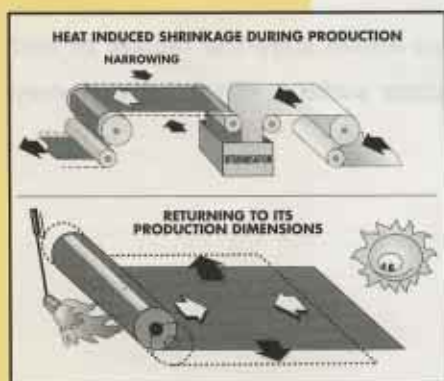


## SPECIAL CASE OF HEAT INDUCED SHRINKAGE OF NON-WOVEN POLYESTER REINFORCED MEMBRANES

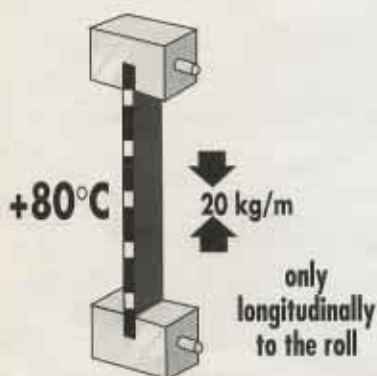
Polymer bitumen mixes expand with heat but the reinforcement may cause the membrane to contract seemingly inexplicably. Although the glass-fibre reinforcement is practically stable, the non-woven polyester reinforcement shortens rather than lengthens with increase in temperature and causes the membrane to contract. What is happening is that it is undergoing a return to its dimensions prior to being bituminised.

During production the polyester is put under tension while coated with the polymer bitumen mix which is then cooled. The cooled and hardened mix holds the reinforcement in this state of tension until the membrane is exposed to the sun or a flame is applied to it. The mix then softens and the polyester reinforcement is able to return to its previous dimensions. It contracts lengthways and expands widthways. The phenomenon is irreversible so that once the tension has been lost and the membrane shortens, the material behaves normally again, lengthening with heat and shortening with cold.

Also in this case the presence of glass-fibre ameliorates the situation. The table below gives the dimensional changes caused by a temperature of 80°C on a specimen membrane free to contract.



### POLYESTER MEMBRANES



**FORCE OF SHRINKAGE TO PRODUCTION DIMENSIONS AT 80°C ON AN UNADHERED SPECIMEN**

	LONGITUDINAL SHRINKAGE	TRANSVERSAL EXPANSION
- Membrane with 160 g/m <sup>2</sup> polyester reinforcement	4 ÷ 7 cm X 10 m	0.1 ÷ 0.2 cm X m
- Membrane with 50 g/m <sup>2</sup> GF+130g/m <sup>2</sup> PES 2 layer reinforcement	1 ÷ 2 cm X 10 m	0 ÷ 0.1 cm X m
- Membrane reinforced with composite PES strengthened with 150 g/m <sup>2</sup> glass-fibre	2 ÷ 3.5 cm X 10 m	0.1 ÷ 0.2 cm X m
- Membrane composite PES-GF-PES 150 g/m <sup>2</sup> reinforcement	2 - 2.5 cm X 10 m	0 ÷ 0.1 cm X m

If the membrane is bonded to the laying surface, the phenomenon is reduced because part of the shrinkage is lost during flame-heating and because of the contrary force created by the adherence.

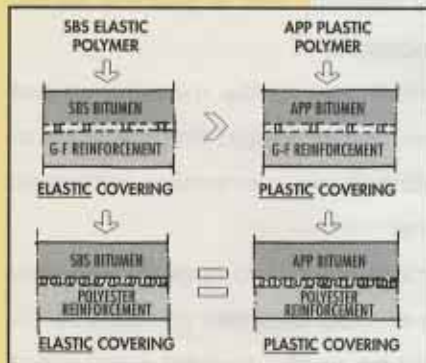
SPECIMENS BONDED TO A CONCRETE SURFACE

	LONGITUDINAL SHRINKAGE AT 80°C
- Membrane with 160 g/m <sup>2</sup> polyester reinforcement	0.8 - 10.2 cm X 10 m
- Membrane with 50 g/m <sup>2</sup> GF+130g/m <sup>2</sup> PES 2 layer reinforcement	0.0 cm X 10m
- Membrane reinforced with composite strengthened with 150 g/m <sup>2</sup> glass-fibre	PES 0.5 cm X 10 m
- Membrane composite PES - GF - PES 150 g/m <sup>2</sup> reinforcement	0.0 : 0.2 cm x 10 m

N.B. The measurements given above were the results of test specimens bonded to a concrete surface, other surfaces may affect the results.



## APP VS. SBS BITUMEN MEMBRANES



The preceding chapters described the APP bitumen mix as comprising two components whereas it actually contains a wide range of adjuvant polymers, both plastomers and elastomers, that are responsible for the mix's elastic and plastic behaviour. Consequently it is now possible to produce APP bitumen membranes with flexibility at temperatures of  $-20^{\circ}/-25^{\circ}\text{C}$  nearly the equal of SBS bitumen mix membranes. On the other hand, SBS bitumen mixes have undergone the same evolution and mixes are produced with softening points between  $120 - 130^{\circ}\text{C}$ .

The ECMB mix of the Flexter Flex membrane is an example: it contains polyolefin co-polymers which belong to a new family of polymers catalysed with metallocene, latest generation stereospecific catalyzers able to select molecular weight more accurately and to keep the tenor of the co-monomer in its different molecular weights stable. There are other polymers widely used in association with APP: the polyolefin co-polymers produced using Catalloy technology, a different technology to that based on metallocenes, which have been used for some time in the INDEX range of elastoplastomeric mixes.

However, the physical and mechanical behaviours of SBS and APP mixes show a difference between the two types. Elasticity and fatigue resistance of SBS elastomer mixes is unequalled; elasticity of 100 - 300% cannot be matched by APP bitumen mixes however they are modified. And SBS bitumen mixes are more sensitive to the action of sunlight compared to APP bitumen which makes it wrinkle, but it is also true that this is a superficial phenomenon that does not penetrate deep and the mix below remains elastic for a long time.

Viscosity of APP bitumen mixes at high temperatures is generally lower than that of corresponding SBS bitumen mixes and that benefits flame-bonding as adhesion to the surface to be lined is achieved more quickly. APP bitumen mixes are more rigid at hot temperatures while SBS bitumen is soft and sticky. At cold temperatures, SBS bitumen mixes are less susceptible to physical shocks.

In conclusion, the high elasticity of SBS bitumen mixes, which in the tightly controlled building, regulatory and legislative context of France for open coverings allows use of a two layer system reinforced with glass-fibre felt, is actually less advantageous once

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the elastic mix is reinforced with non-woven polyester which gives the APP bitumen the necessary elasticity and in practice equals the performance of the two membranes.

As what is important is the performance of the membranes and not the performance of the mixes, it can be said that the fields of application of APP and SBS bitumen mix membranes reinforced with polyester are nearly the same.

Exceptions might be metallic roofs subject to large movements where the elastic reformation of SBS bitumen mixes, even if reinforced with polyester, may be useful to limit permanent deformation of the covering; likewise they might be used where application during winter means very low temperatures indeed.

APP bitumen membranes, on the other hand, are more suited to application in hot or equatorial climates and on large area vertical surfaces exposed to the sun because their resistance to heat does not lessen with time.

## MEMBRANES OF THE FUTURE

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The previous chapters have illustrated that polymer bitumen technology is known and accepted around the world.

INDEX has now laid the basis for membranes of the future: the DUO range of composite membranes and the Design membranes have been the only real innovations in the industry over the last few years.

These are innovations that have not simply mixed bitumen with the latest polymer to appear on the market or bituminised the most recent and most bizarre reinforcements on sale. These are new product lines with new fields of use.

## COMPOSITE POLYMER BITUMEN MEMBRANES: THE DUO RANGE

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**T**raditional production technologies allow the manufacture of membranes with a single waterproofing element, i.e. the mix used to impregnate the reinforcement is the same mix that covers both the upper and lower side of the sheet.

This means that, with the exception of the membrane's mechanical characteristics, its other properties are determined uniquely by the type of polymer used. It has often been tried to combine the qualities of APP bitumen mixes with those of SBS, mixing the two together, but the results so far have been disappointing because SBS loses much of its elasticity once mixed with a plastomer.

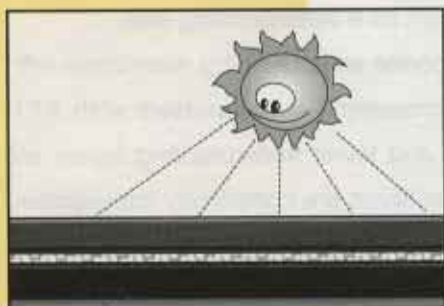
The line of research that INDEX has followed has led to the use of both polymers but not mixed together. Membranes have been developed in which layers of different materials are ordered according to their specific uses. In order to do this, it has been necessary to design and build a new production line which allows differentiated layering and to perfect innovative systems of combination to guarantee excellent and long-lasting adhesion between layers.

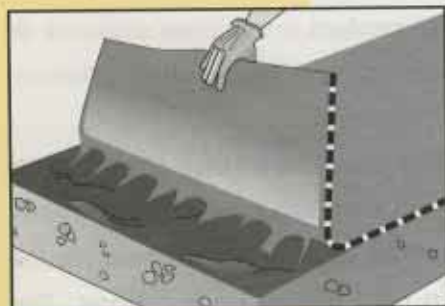
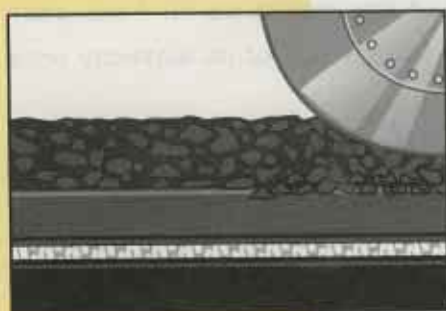
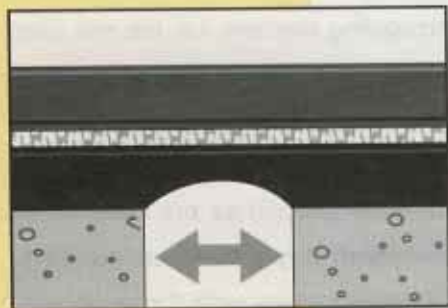
The result is that INDEX can now offer a new range of composite membranes, so-called because they are made up of several different layers which work together, and specialised because the membranes are designed to fulfil particular functions. The following membranes are in production:

**PROTEADUO** is a composite waterproofing membrane with SBS bitumen impregnated reinforcement; the layer underneath that is in contact with the laying surface is also coated with SBS bitumen while the upper layer is coated with APP bitumen.

**PROTEADUO's** reinforcement is also the result of careful research: it is a special three layer composite reinforcement of glass-fibre laid between two non-woven layers of Spunbond continuous polyester thread which cannot damage the bituminous section. Stability is ensured by the glass-fibre and the mix is protected and reinforced by the non-woven polyester.

The composite membrane has a greater resistance to tearing by nails than ordinary reinforcements so that **PROTEADUO** can be applied using mechanical fixing. The fibres are completely impregnated and lined with the elastomer mix using an exclusive process to guarantee absolute watertightness, high tear and





shock resistance and excellent elasticity even at low temperatures.

The elastomeric layer gives excellent adhesion on the most commonly used building materials, polymer bitumen membranes and also on coatings of blown bitumen and old bitumen coverings. To give the surface polymeric layer high resistance to heat, **PROTEADUO** can be covered with either a bitumen mix or hotpoured asphalt. **PROTEADUO** can remain exposed to sunlight without heavy protection although a coat of light coloured paint is advisable especially for applications on heat insulation, both to reduce thermal shock and to increase the covering's overall thermal insulation properties.

The version **MINERAL PROTEADUO** is manufactured for open coverings. Its slate chip surface protection is available in different colours and is certainly longer-lasting than a paint job; the chips are also stuck using APP bitumen which has been shown to be more effective than SBS bitumen as a waterproofing seal.

**HELASTADUO** is also a composite waterproofing membrane with non-woven polyester reinforcement impregnated with APP bitumen in which both upper and lower waterproofing layers are made of SBS bitumen mix. The fibres are completely impregnated and lined by the elastoplastomeric mix which, with a softening point of 150°C, notably higher than SBS bitumen mixes, gives **HELASTADUO** greater rigidity at high temperatures without reducing its elasticity and flexibility at low temperatures.

In contrast, **FLEXADUO** is a composite waterproofing membrane whose non-woven polyester reinforcement is impregnated with SBS bitumen while its upper and lower waterproofing layers are made of APP bitumen mix.

The fibres are completely impregnated and lined by the elastoplastomeric mix using an exclusive process which guarantees absolute watertightness and high tear resistance.

This treatment allows **FLEXADUO** to stretch much more at low temperatures than membranes impregnated and lined only with APP bitumen.

## MINERAL DESIGN MEMBRANES

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Where the waterproof coating is the final element in a roof covering (open coverings), problems that may have an environmental impact or requirements of aesthetic finishing may arise. To avoid such difficulties it is advisable to use a product which guarantees a watertight seal and allows decoration of the roof covering.

**Mineral Design** is the new generation membrane manufactured by INDEX that is protected by slate chips. The slate is in a single shade of colour but several colours are available in exclusive INDEX patterns.

Besides being decorative, Mineral Design is technically valid for the creation of a long-lasting seal and has an advanced, high-performance design with a new composite reinforcement to resolve problems of dimensional stability.

Mineral Design is a leap forward in the evolution of slate chip protective membranes. Today the roof designer has a new tool available to him to decorate a roof in patterns that till now have been unthinkable. Now roofs of schools, churches or residential buildings can be made colourful.



## REGULATIONS

Many countries have adopted standards on the use of polymer bitumen membranes which generally describe:

- test methods;
- acceptance limits.

The first measure the properties and characteristics of membranes, the second establishes the minimum acceptable levels of those characteristics. There also exist classification standards which are often included in the acceptance limits regulations.

For example, UNI 8202 and DIN 52123 standards describe the methods to be followed and the equipment to be used in carrying out tests. On the other hand, UNI 8629 and DIN 52133 standards lay down the minimum acceptable values of the characteristics measured using the methods described in the other standards.

DIN 52133 also includes membrane classification:

- PYP: if modified with plastomers;
- PYE: if modified with elastomers;

to which the reinforcement symbol is added:

- PV 200 = non-woven polyester from 200 T to 250 B;
- G 200 = glass-fibre weave from 200 g/m<sup>2</sup>;
- J 300 = jute weave from 300 g/m<sup>2</sup>;

and, finally, the abbreviation and numbers:

- S = flame bonded membrane
- 4 or 5 = thickness in mm.

The following DIN 52133 identification describes a German membrane with slate chip surface, 5 mm thick, with elastomer bitumen and reinforced with non-woven polyester: **DIN 52133 - PYP - PV 200 S5.**

UNI has issued a specific classification standard, UNI 8818, which defines:

- the nature of the mix;
- the nature of the reinforcement;
- the finishing of the upper face;
- the finishing of the lower face.

A UNI 8188 definition of the membrane specified above would be:

- BPE = polymer bitumen elastomer;
- 11 = non-woven polyester reinforcement;
- 51 = slate chip upper face;
- 33 = flame-bonded polypropylene film on the lower face,

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which gives a final identification code of BPE 11-51-33.

Unfortunately, the DIN standard does not correspond to the UNI standard and the example given above only describes the composition and minimum characteristics, while the UNI identification only describes the materials used. To know the minimum characteristics it is necessary to refer to UNI 8629 p3 where two classes of product are found with different minimum values. Further differences between the standards types are due to test methods and the characteristics measured.

It is also true that a product that corresponds to a UNI standard does not necessarily correspond to a DIN standard and vice versa. Resistance to tensile strength as measured by DIN 52133 is not the same as that measured by UNI 8202. Durability is not considered in DIN standards while the accelerated ageing test is one of the characteristics that must be measured to establish a class of product under UNI standards.

The European Community has authorised CEN to define a common standard to facilitate free exchange of goods, however each country can request special additional tests which it considers in the national interest. Compliance with the standard to be defined will allow the product to carry the EC trademark.

A body called UEAtc (European Union Technical Agreement on Construction) has existed for some time. It is made up of various specialised European building institutes which issue technical opinions on the suitability of new materials for use in construction which are not yet covered by the standards. Prestigious research institutes are part of it like the CSTB in France, ICITE (CNR) in Italy and BBA in England etc.

The Institutes have established common judgement directives to enable different opinions and mutual approval to be compared. In the specific sector of membranes for roof coverings, specific UEAtc directives exist:

- |   |              |
|---|--------------|
| - GENERAL WATERPROOFING MEMBRANE DIRECTIVES                                       | JULY 1982    |
| - DIRECTIVES REGARDING APP BITUMEN MEMBRANES                                      | JANUARY 1984 |
| - DIRECTIVES REGARDING SBS BITUMEN MEMBRANES                                      | JANUARY 1984 |
| - TECHNICAL GUIDE FOR THE AGREEMENT ON SINGLE LAYER MEMBRANES                     | MARCH 1991   |
| - COMPLEMENTARY TECHNICAL GUIDE FOR THE AGREEMENT ON MECHANICALLY FIXED MEMBRANES | APRIL 1991   |

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- TECHNICAL GUIDE FOR THE AGREEMENT ON  
WATERPROOFING SUPPORT INSULATION SYSTEMS  
FOR FLAT AND SLOPING ROOFS

FEBRUARY 1993

The UEAtc directives are not true standards but guidelines for Institutes to use in issuing their judgements on materials.

They also deal with quality control requirements by means of self controls and via an outside body. In practice, an institute will issue a judgement on a product or a system but demands that the manufacturer has a proper quality control system and checks, through external controls, that that is the case. In summary, an Agreement document is not a simple technical control document of one or more characteristics of a sample but a true attestation of suitability for use of a product for which quality is constantly guaranteed.

INDEX membranes HELASTA P4, MINERAL HELASTA P4, FLEXTER TESTUDO POLYESTER SPUNBOND 4, MINERAL FLEXTER TESTUDO POLYESTER SPUNBOND and FLEXTER TESTUDO BIARMATO are all attested with Agreement documents issued by ICITE and distributed throughout the various European Community countries.

INDEX has acquired ISO 9001 certification which means that the company works according to documented internal procedures that have been prescribed by the ISO 9000 standard. The quality of INDEX products and services is assured in design, purchasing, production, quality control, storage, delivery and pre- and postsale assistance to the customer.

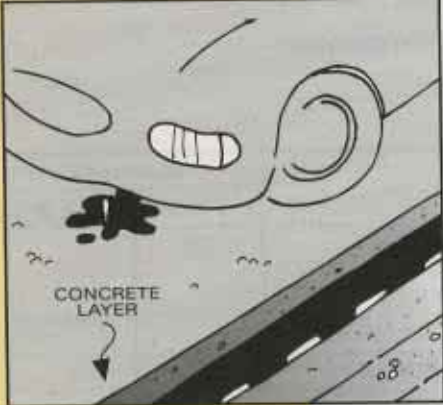
INDEX manufactures membranes that meet many other standards, both European and non-European. INDEX's design department is qualified to design membranes that answer the most varied needs and which are produced in a factory that totally satisfies the quality criteria established in the quality manual.

## CHEMICAL RESISTANCE OF MEMBRANES

**B**itumen-based membranes have good chemical inertia to inorganic substances but are attacked by organic substances, oils, grease, petroleum products, etc. The table below summarises the situation.

ORGANIC ACIDS	Conc. %	Temperature			Temperature	
		up to ca. 30°C	up to ca. 65°C		up to ca. 30°C	up to ca. 65°C
SULPHURIC ACID	< 25	+	+	PYRIDINE & HOMOLOGOUS SUBSTANCES	-	-
	45	+	0		SALINE SOLUTIONS	
	sup. 95	-	-			
<b>OR</b>		-	-	SULPHATES		+
OLEUM		-	-	CHLORIDES	+	+
NITRIC ACID	< 10	+	0	NITRATES	+	+
	> 10	-	0	CALCIUM CHLORIDE	+	+
	65	-	-	VARIOUS PRODUCTS		
HYDROCHLORIC ACID	< 25	+	+	DRINKING WATER	+	
	> 25	+	0	SOAPY SOLUTION	+	+
	36	0	-	FORMALINE	+	+
<b>ORGANIC ACIDS</b>				GLYCERINE	+	+
LACTIC ACID		+	+	GLYCOL	+	+
CITRIC ACID		+	+	MOLASSES	+	+
TANNIC ACID	< 25	+	+	SUGAR	+	+
	> 25	+		BEER	+	0
TARTARIC ACID	< 25	+	+	WINE	+	0
	> 25	+		MILK	+	0
FORMIC ACID	40	+	0	LIQUID MANURE	+	0
ACETIC ACID	25	+	+	WASTE WATER	0	0
BUTYRIC ACID		-	-	ALCOHOL	+	0
OLEIC ACID		-	-	DIESEL FUEL	-	-
OXALIC ACID		+	+	MOTOR OIL	-	-
PHTHALIC ACID		+	-	PETROL	-	-
PHENOLS		-	-	TOLUENE	-	-
<b>INORGANIC BASES</b>				TURPENTINE	-	-
CAUSTIC POTASSIUM		+	0	SEED OIL	-	-
CAUSTIC SODA		+	0			
AMMONIA		+	+			
SODA		+	0			
<b>ORGANIC BASES</b>						
TRIETHANOLAMINE		+				
ANILINE		-	-			

+ = resists    - = does not resists    0 = resistance must be proven



In some cases the chemical resistance of a material is emphasised while neglecting the context and the chemical aggressor. For example, in the case of roof car parks, with a hurried assessment one might conclude that a polymer bitumen membrane is not suitable because it is attacked by car oil and petrol.

In actual fact, it has been shown that below both bitumen mixes and below concrete surfaces, the membrane does not suffer given the modest entity of the percolate; bitumen membranes are the most popular waterproofing system in the world for roof car parks. The problem of chemical aggression should be neither overemphasised nor undervalued, but closely studied in all its aspects by carrying out specific tests.

## BEHAVIOUR OF POLYMER BITUMEN MEMBRANES WHEN EXPOSED TO SUNLIGHT

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When polymer bitumen membranes are used in open coverings, the reaction of bitumen to sunlight must be taken into account. Resulting from exposure to heat and sunlight, bitumen produces an infinitesimal quantity of water-soluble dust ranging in colour from dark brown to rust.

The phenomenon cannot be controlled and depends on the origin of the crude oil and the process used to produce the bitumen. It is also more apparent when the product is first applied and decreases with the passing of time.

It is generally considered that after 2-3 months the quantity of dust that appears is notably reduced but it has been observed after longer periods. As the dust is water-soluble, it is dissolved in rainwater and carried away to the drainage points. On sloping roofs, the phenomenon is difficult to observe and ends more quickly because of the effectiveness of the downflow of the water.

On flat roofs where, very often, the inclination is not enough to carry away all the water, the dust collects in ponded water. This water in turn evaporates and leaves the dust concentrated in one place where a dark, brownish liquid collects. It appears oily but that cannot be the case as it is soluble in water. Once the water has evaporated, a dark brown stain is left similar to that left by a spill can of petrol or diesel fuel.

To prevent the dust from being produced, the bitumen membrane needs to be hidden from sunlight. Heat alone is not enough to produce the phenomenon, it can accelerate and increase it but only in the presence of light.

Slate chip surface membranes substantially reduce the dust produced, though not completely, and are the best solution to the problem. A paint finish will also help but its effectiveness is not guaranteed and complicated by the fact that the dusty surface on which the paint is applied impedes the paint from properly sticking. In fact, it is common to apply a second coat of paint a year later which greatly increases effectiveness.

Washing the covering before painting increases grip and life of the paint. Another important factor is the slope of the roof: on flat roofs the inclination should be as regular as possible to prevent water from ponding.

## BEHAVIOUR OF MEMBRANES IN A FIRE

Polymer bitumen membranes are as combustible as wood with a thermal value of approximately 9000 Kcal/kg but they are not easily inflammable products - to catch fire, they must be considerably heated.

Membrane combustion can be slowed to meet standard requirements in various countries which often use different methods of assessing behaviour in a fire.

Test methods are based on the hypothesis of fire originating externally, for example, a burning coal or spark landing on the covering.

Naturally the tests are only performed on membranes where such a situation might actually occur. Roof protection systems placed under flooring or gravel are considered fire-resistant enough already; the same is true for open coverings finished with metal sheeting. For other open coverings, however, standards evaluate the behaviour of the materials and/or whole system in a fire.

Several types of INDEX membranes have been subjected to fire behaviour tests in different European countries and the results are given in the table overleaf.

PRODUCT	COUNTRY	LABORATORY	METHOD	CLASSIFICATION	
				Reaction	Behaviour of the system
DEFEND 3	Germany	FMPA	DIN 4102 teil 1	Class B2	/
FLEXTER TESTUDO	UK	Warrington Research C.	BS 476 part 3	/	EXT F. AC.
TESTUDO Sp. 20/4	UK	Warrington Research C.	BS 476 part 3	/	EXT F. AC.
MINERAL FLEXTER	UK	Warrington Research C.	BS 476 part 3	/	EXT F. AC.
MINERAL TESTUDO 4,5	UK	Warrington Research C.	BS 476 part 3	/	EXT F. AC.
SAP 4000 CHIODATO + MINERAL PROTEADUO POLIESTERE	Svezia	SP	SS 02 4824 (NT/FIRE 006)	/	Passes the test on rockwool
<b>Products with normal mixes</b>					
TESTUDO TEX	Germany	FMPA	DIN 4102 teil 7	/	Passes test with S=15° & 45°
WEDEMINERAL on ROLLBASE H on PSE 20	Holland	TNO	NEN 6063 - DIN 4102 17	/	Passes test with S=15°
WEDEFLEX CRT 3 on PSE 20	Holland	TNO	NEN 6063 - DIN 4102 17	/	Passes test with S=15°
WEDEFLEX D4 su ROCKWOOL	Holland	TNO	NEN 6063 - DIN 4102 17	/	Passes test with S=15° & 45°
<b>Products with additives</b>					
EUROHELASTO 30 ARDS FI/V	France	SNPE	D.M. 17/10/57	M3 on incombustible MC surface	/
BITUME OSSIDATO 95/35+ HELASTOPOL P3 + MINERAL HELASTOPOL P (with additives)	Finlandia	VTT	SS 02 4824 (NT/FIRE 006)	/	Passes the test on rockwool
MINERAL FLEXTER F	Svezia	SP	SS 02 4824 (NT/FIRE 006)	/	Passes the test on wood and rockwool
MINERAL NOVA POLIESTERE F	Svezia	SP	SS 02 4824 (NT/FIRE 006)	/	Passes the test on wood and rockwool
WEDEFLEX D4 FIRE-STOP on ROCKWOOL and PSE 20 (with additives)	Holland	TNO	NEN 6063 - DIN 4102 17	/	Passes test with S=15° & 45°
<b>Normal production membranes tested as per USA standards</b>					
TESTUDO SPUNBOND	USA	Underwriters Laboratories	UL 790	/	Classe A (non-combustible decks)
MINERAL TESTUDO	USA	Underwriters Laboratories	UL 790	/	Classe A (non-combustible decks)
MINERAL TESTUDO	USA	United States Testing Company (California Div)	ASTM E 108-83	/	Classe A (non-combustible decks) Classe B (over combustible substrates)
<b>Membrane / Systems which correspond to European Norm pr EN 1187.1</b>					
FLEXTER TESTUDO SPUNBOND POLIESTERE 4+ FIRESTOP PV3 (additivato)	Belgio	Universiteit Gent	pr EN 1187.1 (NBN)	/	Passes the test

KEY: S = SLOPE



CHARACTERISTICS OF MEMBRANES IN A CLIM

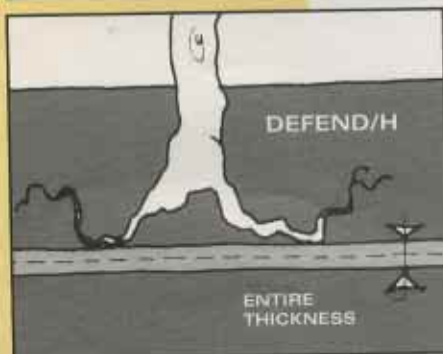
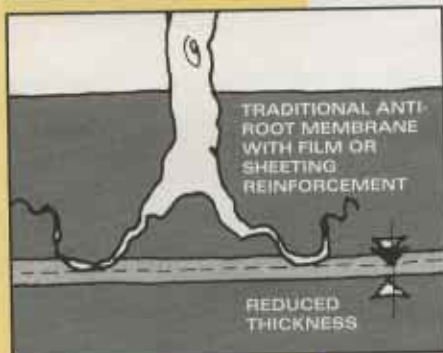
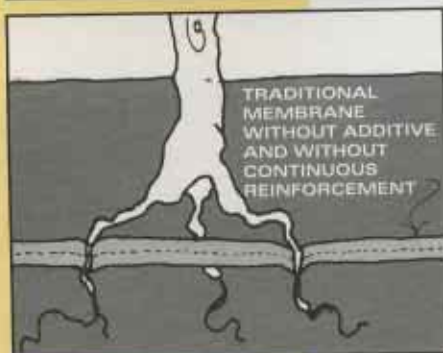
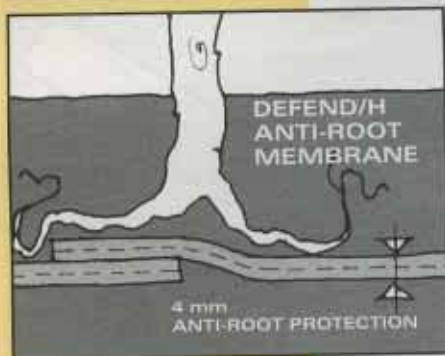
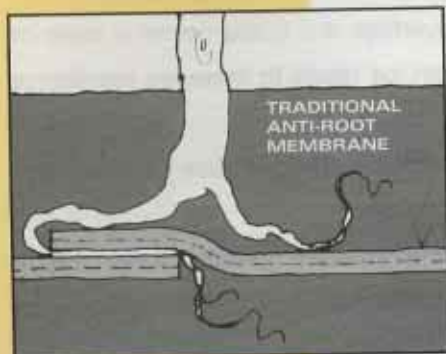
As can be seen from the table, in order to pass the fire behaviour tests in France and Sweden where requirements are stricter, INDEX has had to create special membranes whose waterproofing coatings have had flame-retardant additives included.

There are numerous flame-retardant additives available but many are unable to stand the working temperatures during application or are too reactive and interfere with flame bonding or alter the mix characteristics. Others are too expensive or give off toxic gases during combustion or during application.

INDEX chose a natural additive, resistant to high temperatures, that does not produce toxic gases during combustion and which affects overall price only very slightly.

MEMBRANE	THICKNESS	WEIGHT	STRENGTH	PERMEABILITY	TEMPERATURE	FLAME RETARDANT	TOXIC GASES	PRICE
INDEX 100	1.5	1.5	10	0.1	-30 to +100	Yes	No	Low
INDEX 200	2.0	2.0	15	0.1	-30 to +100	Yes	No	Low
INDEX 300	2.5	2.5	20	0.1	-30 to +100	Yes	No	Low
INDEX 400	3.0	3.0	25	0.1	-30 to +100	Yes	No	Low
INDEX 500	3.5	3.5	30	0.1	-30 to +100	Yes	No	Low
INDEX 600	4.0	4.0	35	0.1	-30 to +100	Yes	No	Low
INDEX 700	4.5	4.5	40	0.1	-30 to +100	Yes	No	Low
INDEX 800	5.0	5.0	45	0.1	-30 to +100	Yes	No	Low
INDEX 900	5.5	5.5	50	0.1	-30 to +100	Yes	No	Low
INDEX 1000	6.0	6.0	55	0.1	-30 to +100	Yes	No	Low

## RESISTANCE TO ROOT GROWTH



**D**efend Anti-root/H is INDEX's 4 mm. thick anti-root membrane produced to waterproof roof gardens. It is made from a resistant, elastic, continuous non-woven polyester thread reinforcement that is impregnated and lined with polymer bitumen and PREVENTOL B2 additive. Preventol B2 is an anti-root additive produced by Bayer.

Traditional anti-root membranes depend on a physical barrier such as metallic sheeting or plastic film reinforcement a few tenths of a millimetre thick. This protection ceases at membrane overlaps as the reinforcements are only overlaid themselves and the continuity of the covering is only given by the waterproofing section of the membrane which covers the reinforcement. Therefore the roots are able to work their way between the overlaps and perforate traditional membranes.

Defend Anti-root/H is resistant throughout its whole waterproofing thickness thanks to its anti-root additives, overlaps included, and constitutes a 4 mm. thick continuous barrier. Anti-root tests as per DIN 4062 show this. Normal membranes may become completely perforated by roots or at least have their side in contact with the soil eaten into. Even the upper surface of membranes with metallic or plastic sheeting reinforcement are attacked by roots.

Defend H not only is not perforated by roots, its upper side in contact with the soil is not even damaged and at the end of the test all of its waterproofing body remains intact.

Defend Anti-root/H's anti-root resistance is long-lasting while the additive is resistant to heat and insoluble in water, therefore it does not get washed away and does not damage other plants. Preventol B2 has been used in Germany and other countries for more than 20 years and there has been no report of damage from root penetration of membranes that satisfy standard DIN 4062.

All INDEX membranes to be used for waterproofing hydraulic works and protecting underground structures such as foundations, the extrados of tunnels and underground car-parks can have Preventol B2 added on request. And membranes used for lining surfaces where plants may grow accidentally, such as road structures and coverings under gravel, can have Preventol B2 added too.

INDEX membranes with Preventol B2 have been approved and used by the French Railways to waterproof 150,000 square metres of tunnel for the new high speed TGV Atlantique line, and in underground coverings of Paris Metro stations.

The best hail resistant coverings are those below a layer of heavy protection but steps can be taken to increase resistance even of open coverings:

- using polyester reinforced membranes with a slate chip surface
- applying SBS bitumen membranes.

Absolute resistance to extreme weather conditions cannot be guaranteed so there is no such thing as a hail-proof membrane as yet.

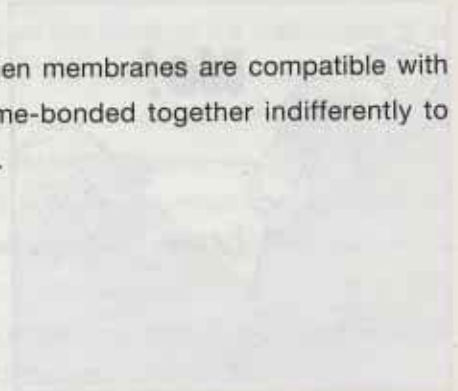
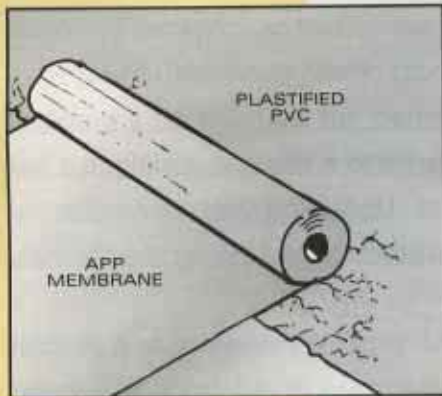


## COMPATIBILITY OF MEMBRANES

Polymer bitumen membranes can be placed in contact with most of the commonly used construction materials, it is only with some that effects may occur: for example, in contact with softened PVC, membranes tend to extract the softeners and dry out the PVC:

In the interface between an APP bitumen membrane and a blown bitumen or bituminised membrane based on softened blown bitumen such as 100/40, 110/30 or 85/40, there may be oily sweating and poor adhesion. Compatibility must be checked with peeling tests before and after thermal ageing. The effect on old blown bitumen is practically nil. However, APP bitumen membranes must only be flame-bonded onto blown bitumen and not hot spread.

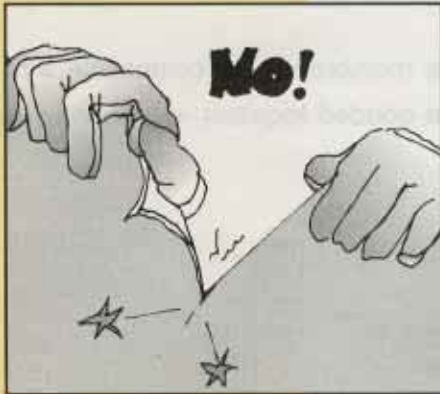
INDEX APP and SBS bitumen membranes are compatible with each other and can be flame-bonded together indifferently to create a waterproof covering.



## ON-SITE TESTS

Previous sections have shown how changing a test method can give different results. If an on-site test is performed instead of carrying out a laboratory test following a well-defined procedure in relation to temperature, speed, time etc., not using calibrated instruments and working in different temperatures at different times will give results that have nothing to do with the values established in standards. The results reflect only the impressions of the moment and cannot be reproduced or compared with other apparently similar empirical results or with standards' values.

For example, a tear test carried out by hand on a piece of membrane has no correspondence to a tear test relating to a nail as established by UNI standards, UEAtc and CEN regulations; the nail tear test exists as an assessment of a nailed membrane's resistance to wind.



Empirical evaluations may result in giving preference to a product that does not offer sufficient guarantee of resistance after being nailed down with respect to a product that may be more easily torn by hand but which in practice will not ever be subjected to stress such as hand-tearing on the roof.

Polymer bitumen membranes are made from thermoplastic material and they vary in consistency with temperature. One roll may therefore be judged soft, rigid or workable depending on when it is applied - in summer, winter or in between. In actual fact, however much the producer tries to create the widest possible field of stability of a membrane for temperature, a workman will receive different sensations depending on the season in which he applies the material but the fact that those sensations differ does not mean the material is of poor quality. Professional operators know that working in winter requires different methods and approaches to working in summer.

## APPLICATION OF MEMBRANE

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**M**embranes with the lower side lined with Flamina film are always flame-bonded. They cannot be bonded with a coating of hot blown bitumen, nor with cold adhesives.

Membranes with the upper side lined with Flamina film can have another membrane flame-bonded to it. Hot blown bitumen cannot be used, nor paint.

Membranes with the upper side sanded or covered with talc can be flame-bonded to another membrane or can be used with hot blown bitumen or can be given a coat of paint.

Membranes with the lower side sanded or covered with talc can be bonded using hot blown bitumen, cold adhesives or be flame-bonded.

These descriptions only refer to attachment of the membrane or surface treatment depending on the finish of the membrane. It is therefore necessary to choose the most suitable attachment or treatment depending on the application context, the nature of the membrane and its position in the roof covering etc.

For example: a coating of hot blown bitumen applied to bond insulation panels on the talced side of an APP bitumen membrane which is to act as a vapour barrier is permissible. It is not permissible if the membrane is the final layer in an open covering as the coating will in a short time begin to crack.

Another example: the bonding of an APP bitumen membrane (even with the upper face sanded) on an insulation panel which is to be lined with a coat of hot blown bitumen, cannot happen at the same time as the application of the bitumen. Instead, to ensure adhesion, it must be followed by flame-bonding onto the bitumen coat once it has cooled.

## HOT AIR BONDING

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**T**his method is generally used to bond synthetic sheet overlaps but in particular situations where flames cannot be used it is possible to bond membrane overlaps with a manual, hot air device fitted with an 80 mm. nozzle.

The Leister Variant-Plus 4R7 automatic hot air welder has given excellent results with 120 mm. overlaps used with mechanical fixing under the joint. For this type of bonding, membranes with both sides lined with Flamina, or Flamina and talc, are preferred.

## MECHANICAL FIXING

This is an application system that is becoming more common on support surfaces in metal sheeting and timber which can be easily nailed, and which is also being tried on concrete surfaces.

It is practical and clean and in certain countries finds approval as it allows separation of the waterproof covering and the insulation panels during removal of a roofing protection system at the end of its life; this in turn means lower costs.

The trend is towards fixing insulation with nails and laying a single layer membrane with mechanical fixing under the joint. It is an "extreme" system which requires the use of very stable materials. INDEX suggests that membranes used with mechanical fixing should have a two-layer or composite glass-fibre/polyester reinforcement, and that insulation panels should be made from mineral fibre.

Contrary to the usual method of application, it is convenient to align the head-to-tail overlaps of the rolls which will be taken in between two strips of membrane.

Less problematic and safer is application of a base covering fixed mechanically across the whole of its surface and on which the waterproofing seal is flame-bonded.

In the INDEX range of membranes, Mineral Flexter F.M. has been approved for application with mechanical fixing under joints. It should be remembered that bonding must be carried out on both parts of the nail so that the head is completely covered inside the joint. In this case, if the wind exerts much force, the joint will undergo tensile strength stress, not peeling, for which its resistance is greater.



## WATERPROOFING CIVIL WORKS

INDEX membranes are widely used in Civil Works and many solutions other than those found in the Technical Specifications are possible.

- **TESTUDO 20/4** and **ELASTOPOL PONTS** (the former in APP bitumen and the latter in SBS) are two polyester reinforced membranes approved by SETRA for waterproofing road foundations and successive lining with bitumen mix at 180°C.

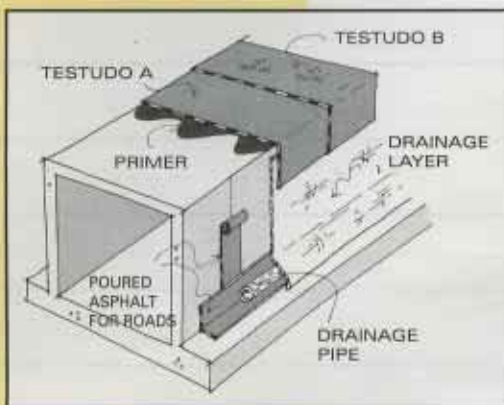
- **NOVA P4**, SNCF Agreement type, is the special APP bitumen membrane designed to line bridges on top of which poured asphalt is laid at 240°C. NOVA P4 is also used to line roof carparks using the same lining method (SOCOTEC Agreement).

- **TESTUDO A** and **TESTUDO B** are membranes approved by the French railways (SNCF) used to line the tunnels of the TGV high speed train on its Atlantic route. A layer of Testudo A was followed by a single layer of Testudo B. The railway bridges, on the other hand, used two layers of Testudo B over a layer of Testudo A on top of which the ballast was placed. More information is available from related publications.

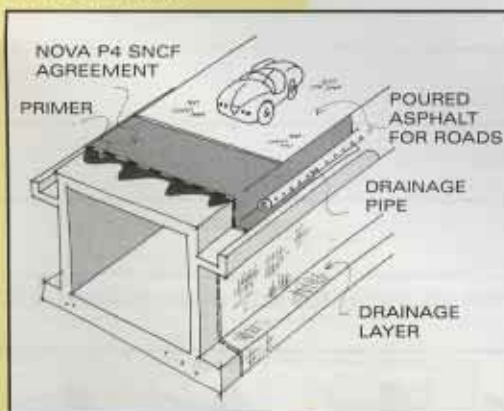
- **TESTUDO 25/5**: besides being used to line bridges covered with a bitumen mix paving, it has been approved by the Bureau Veritas for lining carpark covered with a bitumen mix paving.

- **TESTUDO 20/4** has good dielectric power and is used to line electric tramway foundations with the aim of containing dispersion of electricity into the earth which may create problems of corrosion in surrounding areas. The tramline Saint Denis - Bobigny on the edge of Paris has been lined using Testudo 20/4.

### T.G.V. ATLANTIQUE



### PARIS METRO





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