technical specification 11

TUNNELS

In modern urban systems, expecially in cities, there is a well established basis to go underground for the construction of new transit ways and for rail and road transport systems. Together with these works there is an ever-growing development of specialised service areas such as underground stations, carparks, garages and services which are linked by tunnels or subway. Some areas are characterised by persistent snowfalls until late in the season and the resulting accumulation of snow on the mountain slopes might threaten road and rail structures. In these instances there is a need for protection by anti-avalanche galleries. The concrete foundations/structures of these galleries have to be protected with a waterproofing membrane to prevent water penetrating the concrete and corroding the reinforcing rods. This work is carried out on top of the exposed part of the structure and puts the waterproofing barrier in direct contact with the surrounding ground. For proper water drainage it is necessary to lay draining belts made of suitable panels and perforated tubes.
When planning waterproofing protection for tunnels, one must take into account what else has been done in the underground works (see Foundations). The durability of the waterproofing mantle must be the same as the rest of the protected works since it would be quite difficult to carry out repairs at a later date on works which may be underground. It is therefore vitally necessary to choose materials with proven performance and good resistance to perforation to withstand the weight of static loads and building traffic.
Some years **INDEX** introduced to the market such highly reliable membranes as **TESTUDO SPUNBOND POLYESTER** and **HELASTA** and these are particularly well-suited for underground use.

1 PROBLEM and MATE

PROBLEMS

During application, the waterproofing for tunnels and underground works is often subjected to the physical actions of dynamic puncture, initially as a result of yard traffic and subsequently as a result of the material which will be placed over the waterproof layer. During its operational life, the waterproofing is mainly subjected to static puncture and to the effects of movement over cracks. These fissures occur as a result of the shrinkage of the concrete and the effects of fatigue. Fatigue effects arise as a result of vibration caused by the movement of motor vehicles, traffic, etc. During the earth covering operation, the lining is stressed by abrasion and by the traction of the vertical parts covered with drylined membranes (Fig. 1) The waterproof membranes are chemically attacked by underground waters, including the waters polluted by humic acids, fertilisers, and


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soil micro-organism. Often the covering serves two functions such as being a parking facility as well as a cover for areas beneath (see Technical Specification No. 8). It is usual to lay a bituminous mix or asphalt on top of the waterproofing layer (Fig. 8). Both of these resist thermal shock on the waterproof mantle (Fig. 2). In this last case the waterproofing will be exposed in winter to frost-defrost cycles and to the chemical attack of road salts. Finally, in case of a seismic event the waterproofing will be stressed by the differential movements of the layers of concrete in which it is inserted (see Tecnical Specification No. 5.2).
According to the level of stress to which the


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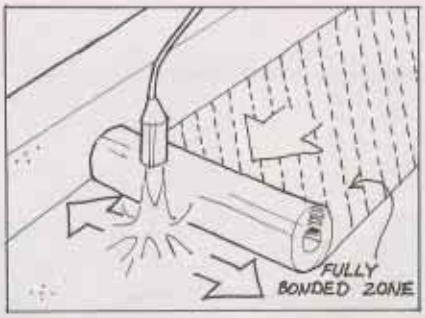
membrane may be subjected, it must be:
- APPLIED FULLY BONDED TO THE WORKS THAT HAVE TO BE PROTECTED. This will reduce the possibility of water seepage to a minimum in the event of accidental perforation and will resist the stress caused by the parallel forces which are due to differential movements in the two layers of concrete into which the membrane has been inserted. In addition there is the stress caused by earth movement on the vertical walls and top of the structure.
- APPLIED THICKLY: for total adherence the membrane must be a minimum of 4mm thick to overcome both the roughness of the substructure and such unavoidable problems as



small stones and other granula materials which are always present in tunnel-like structures.
- APPLIED THICKLY: where there is a possibility of earthquake or other movement to withstand the abrasive action of the granules detached by friction from the cement surfaces upon which the membrane was applied.
- REINFORCED WITH ELASTIC MATERIALS: the membrane must be highly resistant to fatigue from fissures in the substructure onto which it is bonded.
- STRENGTHENED WITH REINFORCING MATERIALS WHICH GIVE THE BEST CONTINUOUS STRENGHT compatible with the adhesion of the waterproofing and **APPLIED** to obtain a waterproofing layer of a uniform mechanical behaviour and puncture resistance in all thicknesses.
- INHERENTLY PUNCTURE RESISTANT: before it is covered and protected by successive layers the membrane is exposed to accidental puncture which could cause problems difficult to find and repair later (Fig. 3). It must therefore be:
- RESISTANT TO CHEMICAL AND BIOLOGICAL AGENTS PRESENT IN THE SOIL AND TO OTHER MATERIALS WITH WHICH IT IS IN CONTACT.
- ROOT RESISTANT IN ALL THICKNESSES. In cases where the waterproofing layer (see Tecnical Specification No.10) is in contact with the soil of a roof garden, or where the works are to be covered with earth in which thick vegetation might subsequently grow.
- APPLICABLE IN SINGLE OR MULTI-LAYERED BONDABLE SHEETS, thus allow-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ing the incorporation into the waterproofing cover of other specific functions (such as anti-piercing function) and at the same time allowing the reinforcement of the waterpoofing element.
- sufficient in its coefficient of friction, **IN SEISMIC AREAS**, to avoid excessive sliding between the works and waterproofing layer (see Technical Specification No. 5.2) in the foundations during high intensity shocks and to ensure stability during low intensity shocks.
- RESISTANT TO TRAFFIC, to thermal shock and to puncture during installation and during the application of asphalt.

MATERIALS

In the field of membranes used for waterproofing tunnels, underground railways, anti-avalanche galleries, etc. INDEX S.P.A. has devoted considerable time to research and testing to develop membranes of high resistance and reliability such as **TESTUDO SPUNBOND 25** polyester, TESTUDO SPUNBOND 20 polyester, MINERAL TESTUDO SPUNBOND polyester and **HELESTA P.** The performance and the quality of the membranes has been checked and approved by **ITALIAN AND FOREIGN INSTITUTES WHICH SPECIALISE IN CIVIL ENGINEERING WORKS.**
TESTUDO SPUNBOND POLYESTER 25-5 mm has been tested and approved by the laboratories of the LCPC (Laboratoire CENTRAL DES PONTS ET CHAUSSEES) of the French Ministry of Public Works in accordance with the S.T.E.R. 81 rules, and by the SNCF (Societe Nationale Des Chemins De Fer Francais) which has used the membrane for the waterproofing of engineering works, including 150,000 M^2 of tunnel on the new high speed TGV Atlantique line.
In Paris this membrane has been used for waterproofing several of the METRO underground railways. The membrane has also been tested and approved by the LGC (Laboratoires of the University of Liege) and by The Belgian Ministry of Public Works.
The **MINERAL TESTUDO SPUNBOND 4.5** has received **SNCF** Agrement, approval for the material to be used as an anti-puncture waterproofing layer and also reinforcement over **TESTUDO SPUNBOND 25-5** which has been used to waterproof the TGV Atlantique tunnel. In addition, **TESTUDO** has been used to waterproof stations on the Paris Metro.
TESTUDO SPUNBOND POLYESTER 20-4 mm has been checked and approved by LCPC in accordance with STER 81 rules. In has been used in Italy to protect the anti-avalanche gallery in the province of Bolzano. The Polytechnic of Milan has tested its performance as a foundation membrane in earthquake areas. The performance of **HELASTA P 4 mm** as a foundation membrane in earthquake zones, has also been tested at the laboratories of the University of Munich in Bavaria where Milan's data has been confirmed. The membranes are applied fully torch bonded in single or multi-layers of 4-5 mm thickness. These membranes are reinforced with a non-women polyester fabric which has been impregnated and coated with either an elasto-plastomeric bituminous compound or with elastomeric material. They are resistant to both low and high temperatures, to polluted water and are rot resistant. The membranes can resist frost-defrost cycles and de-icing salts and they have a coefficient of friction with the cement layer which is 3 times more resistant than that of neoprene. The **TESTUDO SPUNBOND 25** and **TESTUDO SPUNBOND 20** membranes are heat resistant when laid and can withstand the stresses associated with the application of asphalt. Altough the membranes are root resistant and meet the DIN 4062 requirements, they can be further treated with ® PREVENTOL B2 BAYER, an anti-root additive which will give the membrane high resistance in all its thickness and in the selvedge.
The schemes of technical specifications outlined below have been developed by INDEX as a result of experience in Italy and abroad. It has been decided to publish these in the

ERIALS

hope that they might prove useful as guidelines in the planning and building of similar works. However, because each work to be undertaken presents unique problems that require individual solutions, these guidelines cannot in totality be applied to all works. They should however help in arriving at the best solution for each individual case.
During the planning of individual constructions, our membranes can be used to meet any special requirements. Our experienced technicians are always available to assist the customer to determine the most suitable materials and systems.
The leaflet BUILDING WITH WATERPROOFING MEMBRANES: THE SEISMIC ANSWER which contains the combined results of the research carried out by INDEX and THE POLYTECHNIC OF MILAN, can be supplied on request.

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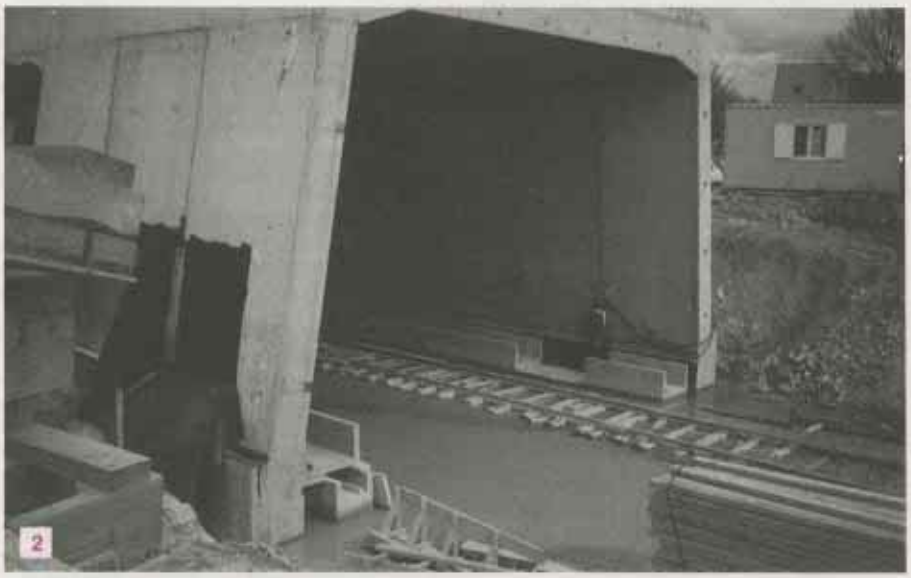
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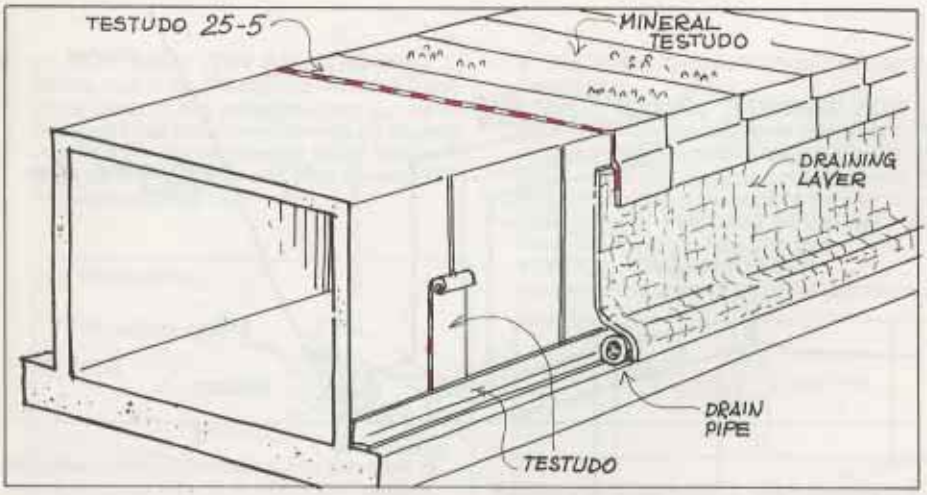
1 - WATERPROOFING THE PARIS UNDERGROUND
2 - TGV ATLANTIQUE TUNNEL
3 - PROTECTIVE EFFECT OF AN ANTI-AVALANCHE GALLERY

2 APPLICATIONS



TECHNICAL SPECIFICATIONS

WATERPROOFING ON THE TGV ATLANTIQUE TUNNEL TYPE

The tunnel of the new Atlantique TGV line (Train Grand Vitesse = High Speed Train) runs completely underground for some kilometers. The lateral walls are constructed from jointed perfabricated elements. These support the top of the structure which is made of prefabricated beams covered by reinforced concrete. The concrete has a joint every 9-10 m. As there is no water bearing table, the waterproofing sheath of Index membranes used on the roof of the tunnel is continued on the vertical sides for at least 1 m. where it is joined to the vertical drainage. This layer made of a 20 mm non woven yarn is coupled with a geotextile filtering layer which weighs about 150g/sq.m. At the foot of the vertical side of the tunnel the drainage layer is joined to a drainpipe where it is sealed with mastic (rubber cement). The vertical joints in the walls of the tunnel are protected by the application of heat bonded strips of **TESTUDO 200-300 mm** wide.

At the point where the vertical sections join the base a layer of **TESTUDO** should be bonded along the joint where the vertical and horizontal sections meet. Prior to applying the membrane the concrete should be coated with a bituminous primer. The waterproofing element of the covering should be a layer of **TESTUDO SPUNBOND** polyester 25-5 which is torch bonded and this is protected by a puncture resistant layer. Initially the protective layer was made up of a simple polyester membrane; subsequently this was replaced by the planners with a **MINERAL TESTUDO**. Both membranes are polyester reinforced. The **MINERAL TESTUDO** is protected with slate granules. The **MINERAL TESTUDO** is heat bonded onto the first layer and acts both as a protective and waterproofing element. In those areas where the normal slow train passes over the tunnel the protective waterproofing layer is further strengthened by the addition of another layer of **MINERAL TESTUDO** which, as usual, is heat bonded. The ballast is then laid directly on this extra **MINERAL TESTUDO** sheet. Since certain parts of the tunnel had to be totally covered with soil to allow plant growth, the building mamagemt used INDEX membranes treated with the antiroot additive Preventol BAYER.

The technical specifications can be summarised as follows:
before applying the waterproofing layer the whole surface must be coated with INDEVER bituminous primer. This is a bituminous solution containing oxidized bitumen additives and solvents with a 50% solid content and viscosity FORD No. 4 at 25° C for 20-25 sec. Once the primer has dried a polymer-bitumen polyester waterproofing **TESTUDO SPUNBOND 25 of 5 mm** thickness is fully heat bonded to the outside of the tunnel roof and the covering is continued for at least 1m down the vertical sides. The membrane is reinforced with a polyester non woven fabric of 250 gr/M², having a resistance to traction (Soc. Autostrade - The Italian Motorway Company) equal to L: 180 kg/8 cm, T: 125 kg/8 cm; ultimate elongation (Soc. Autostrade), L/T of 50%; resistance to hot puncture 12 kg; resistance to puncture with a punch of 0.3 mm in diameter at a speed of 500mm/min. at 20° C which is equal to 10.0 daN and at -10° C which is equivalent to 31/1 daN ; a dynamic pucture resistance on asbestos cement (UNI 8202 re-verified at 0,1 atm) of over 30 kg; cold flexibility (UNI 8202) of -10° C.
The material will also resist thermal shock of (LCPC -140° C × 10 mins.) and be resistant to a fissure test carried out at -10° C (LCPC) before and then after thermal shock; it will also resist frost-defrost cycles and de-icing salts. The waterprrofing mass is treated with the BAYER ® PREVENTOL antiroot additive. The antiroot test must comply with DIN 40062 requirements, no root must either perforate the lower face of the membrane **OR PENETRATE INTO THE UPPER FACE.** All membranes should be laid to allow side laps of 100 mm and end laps of 150 mm which will be fully bonded. After the installation of the first membrane a second one should be laid. The second waterproofing membrane should be fully bonded astride the laps of the first layer. This membrane, a **MINERAL TESTUDO SPUNBOND** polyester 4,5 which is manufactured from polymer bitumen modified with elastomers and plastomers and reinforced with non woven fabric of continuosly extruded spunbond polyester, has the upper face self-protected by a layer of slate granules. Weighing 4.5 kg/M² the sheet meets the UNI 8202 requirements and has an ultimate longitudinal breaking point of 75 kg/5 cm, transversal of 65 kg/5 cm, an ultimate elongation of 50% at -10° C and resistance to static puncture of ▷ kg.
The first layer will have been treated with BAYER PREVENTOL B2 anti-root additive. When subjected to a test this membrane will resist root attack to both the upper and lower surfaces in accordance with DIN 4062. It is vital that side laps of 100 mm are allowed and these must be fully bonded.

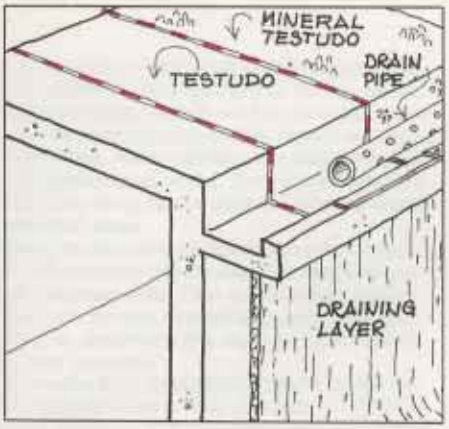
LATER PROTECTION FO THE TGV TUNNEL

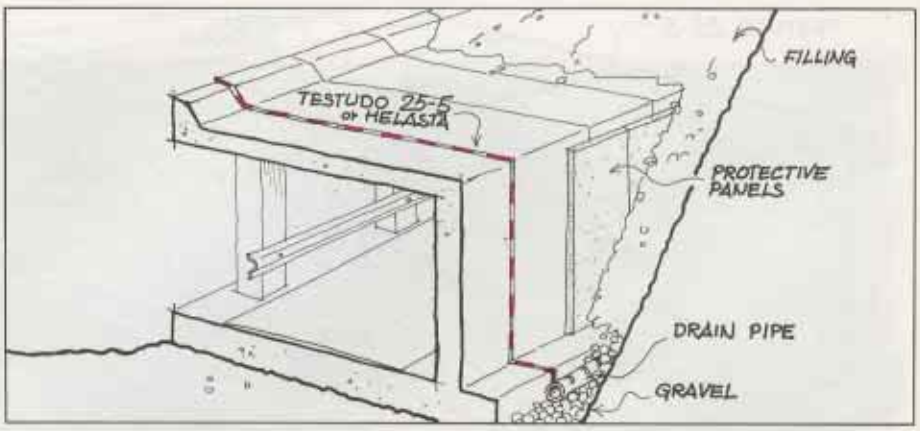
Bayer Material Protection

Antiroot treatment with
® PREVENTOL B2

® PREVENTOL is a registered trade mark of BAYER AG Leverkusen.

2 APPLICATIONS





TECHNICAL SPECIFICATIONS

WATERPROOFING TUNNELS ON THE PARIS METRO

A STATION BUILT UNDER A PUBLIC GARDEN

The waterproofing system is almost identical to the one used for the TGV line tunnel. The only difference in that on the side of the wall against the soil a gutter was built to carry water to drains.

WATERPROOFING UNDER HOT APPLIED ASPHALT

In this case the waterproofing element was obtained using a single layer of **TESTUDO SPUNBOND 25-5**; this was not treated with anti-root additive. The membrane was laid fully bonded after the concrete had been primed. Asphalt was then applied to the area which was planned for vehicular use.

TECHNICAL SPECIFICATIONS

ANTI-LANDSLIP OR ANTI-AVALANCHE GALLERY

Generally the protective surface (''the roof'') will be waterproofed with a membrane as will the vertical wall of the structure against the mountain side. The inner wall will have vertical drainage through gravel from which the water is collected by draining pipes.

The technical specifications can be summarised as follow:

The surfaces which will receive waterproofing must first be treated with a coat of bituminous primer, type INDEVER, which is a bituminous solution made of oxidized bitumen, additives and solvents, with 50% sold contents and viscosity FORD No. 5 at 25° C at 20 -25 sec.

THE TESTUDO SYSTEM

When the primer has become completely dry on the roof and vertical walls (the inner wall) a waterproofing membrane of type **TESTUDO SPUNBOND** polyester 25 will be applied. This membrane is made of polymer bitumen modified with elastomer and plastomers and reinforced with a non woven (isotropic) fabric of continuosly extruded spunbond polyester. The membrane, when tested to UNI 8202, has the following characteristics: ultimate breaking point Long. 80 kg/5 cm, Trans. 70 kg/5 cm; ultimate elongation L/T of 50%; dynamic puncture resistance to perforation on asbestos cement equal to PD4 the static resistance is equal to PS4.

The cold temperature flexibility is -10° C. The membrane has a resistance to hydraulic pressure (thickness 5 mm) on free discs × 188 cm^2 (F.S.) to bursting point. It also has a resistance to fatigue of 1,000 cycles on active fissure opening 3 mm in both directions (Index).

The membranes must be laid to allow side laps of 100 mm and they must be fully bonded with a suitable propane gas torch on the lower (outside) retainer wall, and cover all its surface starting from the bottom and continuing to the top.

In mountain areas affected by particularly cold weather, **HELASTA P** can be used as the alternative to Testudo membrane. The instructions for use can be summarised as follows:

THE HELASTA SYSTEM

When the primer has become completely dry on the roof and vertical walls a waterproofing layer of Felasta P membrane 4 mm thickness will be applied fully bonbed using a suitable propane gas burner. **HELASTA P** is a modified bitumen membrane made of a mixture of distilled polymer bitumen and thermoplastic styrene butadiene copolymers (SBS) reinforced with a ''non woven'' fabric produced with a continuosly extruded **SPUNBOND** fibre; the bitumen compound will achieve elongation of 2000%. The technical characteristics of the membranes when tested to UNI 8202 are:

- Resistance to traction: Long. 90 kg/5 cm, Trans. 80 kg/5 cm
- Elongation to breaking point (ultimate elongation) L/T 50%
- Flexibility at low temperature -25° C
- Resistance to dynamic puncture on asbestos cement PD4
- Resistance to static puncture on asbestos cement PS4
- Resistance to fatigue at least 10,000 cycles at 0°C and at least 1,000 cycles at -10° C.

The membrane applied by heat bonding should always have side laps of 100 mm width. The waterproof covering should be completed as for the Testudo solution.

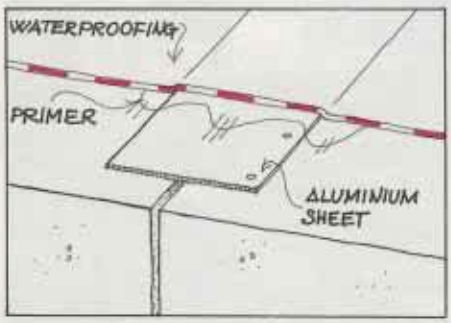
Bayer Material Protection

ANTIROOT TREATMENT WITH PREVENTOL B2
PREVENTOL IS A REGISTERED TRADE MARK of BAYER AG LEVERKUSEN.

3 DETAILS

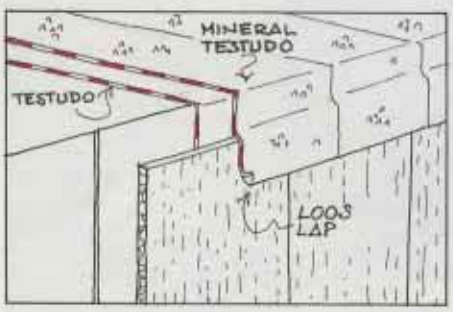
1 - FLAT JOINT (TGV ATLANTIQUE)

On the roof of the TGV tunnel there are transverse joints in the concrete every 9 - 10 m. Each joint has been covered with an aluminium plate 20 - 25 cm in width which has been fixed on one side only and then covered with the waterproofing layer.



2 - JOINING WITH THE VERTICAL WATERPROOFING (TGV ATLANTIQUE)

The top end of the layer of **MINERAL TESTUDO** runs down from the roof to the upper part of the wall for a lenght of 40-50 cm to form a square loose overlap which rests on the draining fabric.

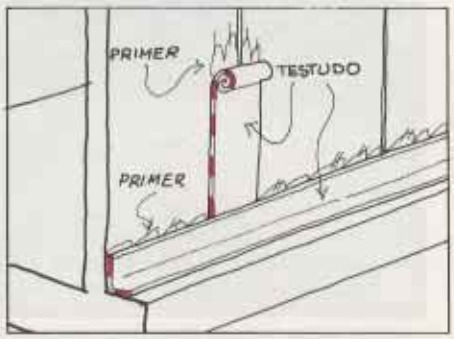


3 - BRIDGING THE JOINTS BETWEEN THE PANELS

Strips of **TESTUDO SPUNBOND** 25-30 cm wide have been bonded over the joints of the vertical panels which form the curtain wall. The point where the vertical surface meets the horizontal beam at the base of the wall 50 mm wide strips of **TESTUDO SPUNBOND 25-5** have been applied fully bonded.

VERTICAL DRAINING LAYER

For draining purposes a special draining mat-



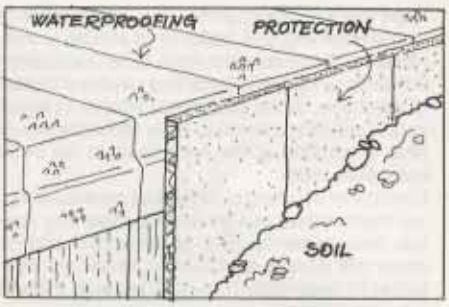
tress is used. It is made of two distinctive layers: the first is composed of 20 mm non woven fabric; the second is a geotextile frabric weighing about 150 gr/M^2 which is fixed along the top and on one lateral side only of the draining fabric. The draining coverage is applied to the structure starting from the top and is continued until the draining pipes are completely covered.

DRAINING PIPE

On the TGV tunnel, draining pipes with boles along the sides were used, while draining pipes made of a porous concrete were used for the Metro.

PROTECTION DURING THE REFILLING OF THE TUNNEL

Vertical panels of 1-2 cm thickness made of compressed cellulose fibres were installed to protect the waterproofing applied to the walls of the TGV tunnel. Then the exposed side of the tunnel was covered with earth.



REFILLING OPERATIONS

Altough the membranes used have an extremely high degree of resistance to puncture the refilling operation has to be carried out carefully.

The first layer of earth should be free from stones. After completion of the first layer of earth, a second layer made with suitable pebbles can be added. Those vertical areas covered with waterproofing membranes are best refilled with material capable of carrying out a drainage function whilst offering adeguate mechanical protection. If only mechanical protection is required panels of polystyrene foam or compressed fibre panels can be used.

INDEX's production uses exclusive industrial patents covering secret processes employed during manufacturing.

MEMBER NSP

TOTAL QUALITY

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advanced waterproofing systems, insulations and refurbishment

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