MATERIALS ENGINEERING BRANCH

GUIDELINES FOR THE APPLICATION OF WATERPROOF MEMBRANES TO BRIDGE DECKS

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## Revision Status Record

<table>
<thead>
<tr>
<th>Section No.</th>
<th>Latest Revision No.</th>
<th>Latest Revision Date</th>
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<tbody>
<tr>
<td>New document</td>
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<tr>
<td>Clause 5.1 and 5.2</td>
<td>1</td>
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<td>Clause 5.1 curing changed to 5.2. Clause 5.2 surface finish changed to 5.1. New clause 5.1 surface finish reworded.</td>
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1. PURPOSE

The aim of this document is to provide guidance on the preparation and application of a waterproofing system to a bridge deck. The guidelines are intended to assist practitioners understand and successfully implement relevant contract specifications used by Main Roads Western Australia (Main Roads).

2. SCOPE

The guidelines apply to bridge decks on new construction where the final surfacing is asphalt. It describes each stage of the process of applying a waterproofing system including products used, preparation, surface finish, air drying and curing times of the concrete, and application of the strip membrane, sprayed binder and asphalt.

3. BACKGROUND

Main Roads has used preformed strip membranes and sprayed rubber treatments for at least 30 years to waterproof the decks of bridges where the final surfacing on a structure is asphalt. Until recent times most bridges were constructed with a continuously poured upper structure. With this method of construction the preformed strip membrane sheeting was used underneath the footpath, kerbline and median areas to provide waterproofing. Outside of those areas the deck was covered with a tack coat, sprayed rubber treatment and asphalt. Information on the function of each component of the waterproofing system is explained in detail in later sections of this document.

In recent years there have been a number of defects occurring in the surfacing treatments on new concrete bridges within the first year or two after construction. The defects have in the main been deformation of the asphalt and to a lesser extent cracks in the asphalt. The defects occurred in high stress areas where traffic is braking or turning, eg. slip lanes, or over construction joints such as piers or deck segments. Investigations indicated that the defects were most likely due to stresses in the asphalt layer as a result of the condition of the substrate. Aside from the asphalt itself factors that could lead to this mode of failure may include slippage, excess bitumen from the sprayed binder, finish of the concrete, blisters in the sheet membrane, cutters in the sprayed binder, remnant curing agent inhibiting the bond or moisture in the concrete, or use of incorrect membrane.

With the adoption of new technologies for constructing the upper structure of bridges designers have used preformed strip membrane applied transversely across the deck. It is important that a preformed strip membrane has a good bond to the concrete and has no or minimal blisters below the membrane. The size of any blisters is important and is discussed in detail in this document.

4. REFERENCES

Main Roads WA Specifications
- Specification 503 – Bituminous Surfacing
- Specification 509 – Polymer Modified Bituminous Surfacing
- Specification 820 – Concrete for Structures
- Specification 875 – Waterproof Membrane
5. CONCRETE

5.1 Surface Finish

The finish on the concrete deck can influence how well a subsequent waterproofing membrane performs. A suitable finish to facilitate a bond between a preformed strip membrane and the deck is a smooth mechanical steel trowel finish. This maximises the contact area between the flat strip material and the concrete. Concrete finished with a wood float may also provide a suitable surface finish for a strip membrane. Regardless for the surface finish the area to be covered with a strip membrane should be consistent without significant depressions or high spots.

However a smooth finish is not ideal for those parts of the deck where a bituminous binder is to be applied. It is preferable that the surface finish not be smooth but has some irregularities to improve bonding and lessen any likelihood of slippage of surfacings. A sprayed bituminous membrane can be successfully applied to a concrete deck finished with either wood float or mechanical steel trowel, provided that the mechanical steel trowel finish is undertaken in a manner to produce a similarly textured surface finish similar to a wood float. However, if the mechanical steel trowel finish is too smooth it should be lightly broomed prior initial set.

A broomed finish is not suitable for a preformed strip membrane as it will be unable to flow sufficiently into the grooves in the concrete as a result of the brooming process. A concrete deck that has both preformed strip membranes and sprayed bituminous membranes may have different surface finishes suited to each membrane type or alternatively have a uniform surface finish suited to both membrane types.

It is critical to the performance of the waterproofing membrane system and subsequent surfacing treatments that the surface of the concrete be free from surface pitting, cavities, ridges, abrupt discontinuities, loose aggregates and sharp protrusions. Any of these defects will increase the chance of air entrapment between the deck and the membrane with the potential for vapour pressures from the trapped air causing enlargement of blisters and bubbles.
5.2 Curing

Curing is the process of controlling or preventing the loss of moisture from the concrete after its placement and compaction. It prolongs hydration of the cement which increases strength and durability of the concrete. Water forms an essential part of a concrete mix for both workability and to hydrate the various minerals in the cement beginning the hardening process that binds the concrete into a solid mass, although more water is usually required for workability than is needed for the effective hydration of the concrete.

How well the waterproofing membrane and overlying asphalt performs is dependent, in part, on the effectiveness of the processes undertaken during and at the completion of the concrete placement, finishing and curing.

5.2.1 Method of Curing

Freshly placed concrete should be protected from the sun, wind and rain and prevented from drying out too quickly. In accordance with Specification 820 all concrete surfaces shall be cured by one of the following methods:

- By covering with sand or hessian or foam which is kept permanently wet
- By wrapping with polythene or similar film to provide an airtight cover
- By maintaining the formwork in position for the required curing period
- By spraying with an approved curing compound complying with the requirements of AS 3799 (such curing compound shall be applied in accordance with the Manufacturer's published recommendations).

5.2.2 Duration of Curing

The period of curing depends on the type of cement used in the concrete. In accordance with Specification 820 the curing shall commence immediately after the concrete has achieved its final set. The minimum curing period for structural concrete shall be 7 days. The minimum curing period for concrete Class S50M and any other concrete incorporating ground granulated blast furnace slag, silica fume or fly ash shall be 14 days.

6. PREPARATION OF CONCRETE DECK

6.1 Removal of Curing Method

Curing compounds containing wax, oil, silicone or pigment can interfere with the bond between the concrete and the strip membrane. Therefore it is vital that all remnant curing compounds be removed prior to the application of the waterproof membrane. It is also necessary to completely remove the curing compound or system to allow the deck to dry sufficiently prior to the application of the waterproofing membrane.

6.2 Cleaning and Repair

The concrete surface should be properly prepared prior to the application of the waterproofing membrane system, which includes removal of all dirt, dust, loose materials and any oil or diesel spills. Before applying a waterproof system the concrete deck should be inspected and repaired as necessary to a uniform defect free surface.
6.3 Drying

Once concrete is placed and cured a portion of water is chemically bound by the hydration process. The remaining water should be allowed to evaporate prior to the application of the waterproofing membrane. The concrete surface should be properly air dried to reduce the potential for moisture vapour to cause blistering of the waterproofing membrane system.

Specification 875 includes a hold point which requires the Contractor to demonstrate to the Superintendent that all of the curing agent film or matter has been removed and that the concrete deck has dried sufficiently to meet the requirements of the strip membrane application procedures. The specified minimum air drying times are detailed in specification 875.

7. APPLICATION OF THE STRIP MEMBRANE

7.1 Location

Preformed strip type membranes are applied at various locations on a bridge structure in accordance with Specification 875 and the Drawings. The preformed strip membrane applied to the top surface of the bridge deck must be compatible with subsequent surface treatments such as hot sprayed rubber or polymer modified bituminous seals and hot asphalt.

Preformed strip membranes are applied transversely across the deck directly over areas where crack widths exceeding micro cracking may occur. This area requires a waterproofing material that has the ability to span larger crack widths that may occur in this area of the deck. All joints in the strip membrane must have a minimum overlap of 75 mm.

7.2 Products

The specified preformed strip membrane applied to the top surface of the bridge deck is Bituthene 5000 or equivalent. Bituthene 5000 is made from a high strength heat resistant polypropylene mesh embedded in a layer of self adhesive rubberised bitumen and has been specifically designed for concrete structures that that have asphalt as a wearing course. Where an alternative product is proposed the supplier must demonstrate that it has the same properties as Bituthene 5000 and that the Manufacturer has published requirements for its application. An alternative product must be approved for use by the Superintendent.

7.3 Surface Treatment

To promote good adhesion with the concrete the surface shall be treated with a primer following the procedures described in the Manufacturer's published requirements. The Bituthene 5000 system has the option of either a solvent based or water based primer, as follows:

- Bituthene primer B2, solvent based primer,
- Bituthene primer WP-3000, water based primer.

Where strip membrane systems other than Bituthene 5000 are used the primer must be compatible for use with the membrane system and applied in accordance with the Manufacturer's published requirements.

7.4 Air Drying

The deck must be air dried prior to the application of the strip membrane system. The period of air drying must take into account the proposed membrane system and primer, the specific requirements of the Manufacturer and the prevailing weather conditions.
7.4.1 Solvent Based Primer

Where a solvent based primer is to be used as part of the strip membrane system the specified minimum air-drying period for the concrete is 7 days.

7.4.2 Water Based Primer

Where a water based primer is to be used as part of the strip membrane system the specified minimum air-drying period for the concrete is 14 days.

7.4.3 Alternative Products

Where “alternative” products require longer air-drying time than specified above then the minimum air-drying time shall be in accordance with the Manufacturer’s published requirements.

7.5 Blistering

Korhonen et al. (1999) produced Special Report 99-11 for the US Army Corps of Engineers. The Report states that blisters in the strip membrane are caused by the expansion of air pockets trapped between the membrane and the concrete during application. Roughness of the surface of the concrete, unevenly applied or inadequately cured primer, debris and moisture in the concrete are among a number of factors that can impair adhesion. A strip membrane with good adhesion to the concrete is unlikely to blister.

Larger blisters in a strip membrane will move under traffic loadings, creating an unstable substrate for the asphalt surfacing. The consequences of the movement will be fatigue cracking of the asphalt or movement of the asphalt resulting in a deformation failure. Special Report 99-11 further states that it can be mathematically shown that some voids (blisters) are acceptable. When blisters form, they appear as slightly bloated lumps about 50-300 mm in diameter. They often occur after the membrane is laid or immediately after the sprayed membrane or asphalt is placed on top of the preformed strip membrane.

Special Report 99-11 explains that the presence of voids (air pockets) between the membrane and the concrete could result in the formation of larger blisters and the smaller the void the less likely it is to develop into a blister. The Report includes equations to determine the propensity of a void on a deck to expand. This concept is demonstrated in four graphs copied from the Report and shown below as Figure 3. Please note that Figure 3 has been copied as it appears in Special Report 99-11, therefore Figures 1 or 2 do not exist in this document.

Special Report 99-11 states that the smaller the size of a void the less likely it is that the void would develop into a blister. The following italicised text quotes from the Report and explains this concept.

Figure 3... consists of 4 graphs, each composed of 3 curves, where each curve represents peel strength plotted against temperature and critical size. Each graph defines the smallest void expected to blister. For example, if an air pocket beneath a membrane adhered to a deck at 5 lbf/in. (875 N/m) is heated from 70°F to 140°F (24°C to 67°C) [sic] [21°C to 60°C], a 5.2-in. (13.2-cm) [sic] radius would be the smallest void that could blister (Fig. 3a). However, if the air beneath the membrane is continually water saturated, the critical void would reduce to 2.25-in. (5.7-cm) [sic] radius (Fig. 3b). Of course, higher bond strengths are more resistant to blistering, but one must realise that heat, the driving force of blisters, softens the adhesive and diminishes the peel strength. Thus, the 5 lbf/in. (875 N/m) force [sic] used in the above analogy is considered to be conservative, even though some membranes adhere more tightly to concrete at room temperature.
The situation changes as soon as the membrane is topped with hot pavement. In this case, the void immediately heats up to 250°F (146°C) [sic][121°C] or more and its overburden increases more than 20-fold (a membrane weighs between 0.002 to 0.008 lb/in.² [1.4 to 5.6 kg/m²] whereas a 2-in. [5.1 cm] thick asphalt pavement weighs approximately 0.168 lb/in² [118 kg/m²]). In this situation we see that the critical size changes from a 2.1 in. (5.3-cm) [sic] radius when the void space is dry (Fig. 3c) to a 0.30-in. [sic] [8 mm] radius when it is wet (Fig. 3d). Moreover, blisters do not expand once, they continually increase in size, Korhonen (1986) found this to be true for roof blisters as did Hironaka and Holland (1986) for pavement blisters. Thus, once a blister initiates, no matter how small it may be, it eventually grows large enough to become a big problem.

Though Figure 3 represents idealized situations (a blister is rigid and self-contained), clearly a non-porous membrane exposed to the sun will remain blisterless if its voids are smaller than 5.5 in. (14 cm) across (Fig. 3b). When exposed to the intense heat of freshly laid pavement, approximately quarter-sized voids (0.9 in., or 2.4 cm [sic] [2.3 cm]) (Fig. 3d) can lead to problems. Other scenarios are possible for blisters but the quarter coin size should be a useful rule of thumb for bridge inspectors to distinguish when a membrane is being inadequately adhered to the deck.

7.5.1 Protection

It is good practice to ensure strip membrane shall not be exposed to direct sunlight during periods of hot weather. A suitable reflective foil laminate can be used to protect the strip and reduce the likelihood of blisters and bubbles developing in the membrane.
7.5.2 Repair

If blisters or bubbles are evident in the strip membrane they must be repaired before the application of surfacing treatments.

Blisters can be repaired by puncturing the top of the membrane and forcing out trapped air. Small punctures should self seal whilst larger tears and damaged areas may require the placement of a patch of strip membrane over the tear or damaged area.

The removal of blisters is essential to ensure the successful performance of the asphalt surfacing on a bridge deck.

8. APPLICATION OF THE SPRAYED SURFACING

8.1 Binder selection

8.1.1 Perth Metropolitan Area and Environs

Within Perth and its environs Main Roads requires that the sprayed membrane be a modified binder using 20% by mass of rubber in accordance with Specification 503. The rubber binder is covered to excess with a 5 mm aggregate such that the aggregate is rolled into the rubber binder to create a binder/stone mastic of about 3 to 4 mm in thickness. This creates a thicker waterproofing membrane than would be achieved from a traditional sprayed seal covered with aggregate on the surface. An important aspect of the rubber treatment is that the viscosity of the rubber binder must be reduced with cutting oils to ensure:

- The binder is sprayed evenly and
- That the 5 mm aggregate is able to penetrate into the rubber binder.

Sprayed membranes applied using polymer modified binders are unlikely to achieve the same outcome as a sprayed rubber treatment, i.e. creating a thick mastic type membrane.

8.1.2 Distant and Remote Sites

At distant sites it may not be practical to transport and use a rubber binder that has been produced in Perth, within the time limits set in Specification 503. In this situation Main Roads would require the production of the rubber binder on site or allow the application of a sprayed membrane using a polymer modified binder (PMB), in accordance with Specification 509. Where used a PMB must be a S15E or S20E binder produced in a plant, to be covered with a 7 mm sealing aggregate. S25E binders are more heavily modified and far more viscous and not suited to this application without the addition of significant quantities of cutting oil. At more remote sites where it is not practical to transport and store hot PMB, due to withholding times, a PMB suited to being blended on site from a concentrate may be used. Where a PMB is used the binder application rate should be designed as a SAMI seal, refer to Specification 509.

8.2 Timing (Tack Coat and Seal)

After preparation of the surface of the deck has been completed, a prime (tack coat) must be applied using diluted cationic slow setting emulsion (Grade CSS/170-60) at a rate of 0.6 L/m². The time for the prime to cure will vary depending upon the prevailing conditions, however it is typically a minimum of 4 hours. If using a cutback prime allow days for curing unless in very hot conditions when the curing time may be reduced. When cured the prime must be evenly coloured and sticky.

After the application and curing of the prime, a bitumen/scrap rubber binder is applied at the specified application rate and then a single size 5 mm aggregate is quickly spread and rolled to
create a mastic type membrane. The bitumen/scrap rubber membrane is cutback with between 7 and 10% medium curing cutter according to pavement temperature. The treatment is not intended to carry traffic and does take some time to cure. This period varies according to conditions but a minimum of 2 weeks is normally recommended and can be programmed to avoid delaying subsequent treatments. However, where the minimum amount of cutter is used and/or the seal is cured in hot conditions the time for curing can be reduced but should not be less than 1 week.

If a PMB is used the amount of cutter may vary between 0 to 8% dependant upon prevailing conditions. The curing time should be as above. However, where there is a tight timeframe to place the asphalt the quantity of cutter used in the PMB may be reduced.

### 8.3 Tack Coat

The function of the tack coat is not dissimilar to that of a prime on a granular basecourse, to seal off surface dust and to promote an effective bond between the waterproofing membrane and the concrete deck. Without a tack coat the more viscous rubber binder or PMB will develop significant pinholes due to the surface tension of the cement dust. The impact of this is that the bridge deck will not have a complete covering of a sprayed bituminous membrane.

Specifications 503 and 509 describe the application of a diluted cationic slow setting emulsion (Grade CSS/170-60) at a rate of 0.6 L/m². In many circumstances it is not practical to apply the emulsion using the bar of a sprayer, but rather applying it by hand and spreading excess binder with a squeegee. In this situation the rate of application cannot be demonstrated other than being an average rate for the area sprayed by hand. What is important is that the final tack coat must cover all of the concrete and leave an even black sticky coating.

No subsequent binder shall be applied on the prime until the emulsion has broken and has evaporated. Tack coating using emulsion is usually done the day before the hot sprayed membrane is applied. At distant or remote sites where it may not be practical to use a small quantity of emulsion, consideration can be given to tack coating the concrete using a cutback bitumen such as 40/60 bitumen/MC cutter at a rate of 0.6 L/m². If using a cutback bitumen for this purpose a longer curing time may be required before the subsequent sprayed membrane is applied.

### 8.4 Rubber Binder

#### 8.4.1 Binder

The binder is a blend of 79% Class 170 bitumen, 20% granulated rubber by mass and 1% adhesion agent. The membrane should be applied at the locations as shown on the relevant contract drawings and must completely overlap the preformed strip membranes.

#### 8.4.2 Cutting

Medium Curing Cutting Oil shall be added to the rubberised seal binder depending on surface temperature at the time of sealing. The minimum proportion of cutter is 7% as shown in Specification 503, however the Superintendent may allow a lower quantity of cutting oil. Refer to the notes in Section 8.2 on the timing of works in relation to the sprayed membrane.

#### 8.4.3 Aggregate

The material is a 5 mm single sized crushed aggregate precoated with distillate. The aggregate is spread to excess and rolled into the rubber binder to create a matrix of aggregate and binder.

#### 8.4.4 Application
The application of the binder and aggregate shall be in accordance with Specification 503.

8.5 Polymer Modified Binder

8.5.1 Binder

At distant sites an S15E or S20E binder may be used in accordance with Specification 509. The S15E or S20E binder must not be held at elevated temperatures for longer than that specified. Where it is not practical to transport a PMB from Perth the use of a site blended PMB from concentrate may be allowed. Advice should be sought from PMB producers on the appropriate class of PMB suitable for field blending.

8.5.2 Cutting

Medium Curing Cutting Oil should be added to the PMB, depending on surface temperature at the time of sealing, in accordance with Specification 509.

Specification 509 provides guidance on the addition of medium curing cutting oil to the PMB. Where the treatment is to be covered by asphalt within a short period of time, it is not desirable to add cutter oil. In this scenario if cutter oil is considered necessary, it should be limited to a maximum of 2% by volume of binder.

8.5.3 Aggregate

The cover material should be a 7 mm single sized aggregate precoated with distillate. Where 7 mm aggregate is not available a 10 mm single sized aggregate may be used. The aggregate must not be spread to excess as this will result in binder being forced to the top of the aggregate layer. The aggregate spread rate must be determined in accordance with the design procedure within Specification 509.

8.5.4 Application

The application of the binder and aggregate shall be in accordance with Specification 509.

9. APPLICATION OF ASPHALT

Prior to the application of the asphalt surfacing the waterproof membrane must be inspected for blisters or bubbles. If blisters or bubbles are evident prior to the application of the asphalt on the bridge deck they shall be repaired prior to the application of the asphalt. TDP Specification 875 requires that the asphalt not be applied to the bituminous seal if blistering is evident in areas of the bridge deck subject to vehicle movements.

Selection of asphalt surfacing shall be in accordance the guidelines for the selections of surfacings document. Usually 50 mm of 14 mm nominal sized asphalt is placed in one layer on a new bridge. This increases the likelihood that the layer of asphalt is relatively impermeable due to the extra thickness, with the thickness of the asphalt layer being nearly 4 times its nominal size (asphalt becomes less permeable as thickness of a layer increases). In addition the 50 mm thickness of asphalt reduces the likelihood that the sprayed membrane beneath the asphalt would be damaged during future maintenance operations to replace the asphalt on the bridge.
Unlike placing asphalt on sprayed seals or existing asphalt layers the temperature of the concrete deck is likely to have a greater impact on the rate at which asphalt cools. Typically more heat flows from the asphalt mat into the concrete base than up into the air, therefore the concrete deck temperature has more impact on the available time to compact the asphalt than the air temperature. The asphalt can be produced at a temperature of 5-10°C higher than usual mixing temperatures. The minimum recommended temperature for compaction of asphalt over a waterproofing membrane is 135°C.
## 10. CHECKLIST

### BRIDGE DECK WATERPROOFING CHECKLIST

<table>
<thead>
<tr>
<th>Guideline Clause</th>
<th>Process</th>
<th>Comment</th>
<th>TDP Specification Reference</th>
</tr>
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<tbody>
<tr>
<td>5.1</td>
<td>Surface finish</td>
<td>An appropriate surface finish applied to the concrete surface in accordance with the specification.</td>
<td>820</td>
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<tr>
<td>5.2.1</td>
<td>Curing method</td>
<td>The concrete shall be cured by an appropriate method in accordance with the specification.</td>
<td>820</td>
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<tr>
<td>5.2.2</td>
<td>Duration of curing</td>
<td>The concrete shall be cured for the minimum time in accordance with the specification.</td>
<td>820</td>
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<tr>
<td>6</td>
<td>Surface preparation</td>
<td>Ensure the complete removal of the curing method by suitable means.</td>
<td>875</td>
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<td></td>
<td></td>
<td>Ensure adequate cleaning of the deck surface and repair of defects and irregularities.</td>
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<td>Ensure the deck receives sufficient air drying (Clause 7.4)</td>
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<tr>
<td>7</td>
<td>Application of strip membrane</td>
<td>Ensure that the membranes are located on the bridge decks as per drawings and specifications.</td>
<td>875</td>
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<td>Ensure only specified or approved product/s are used.</td>
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<td>Ensure the deck receives sufficient air drying.</td>
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<td>Check for presence of any blisters or bubbles in the membrane and rectify by appropriate means, as required</td>
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<td>7.5</td>
<td>Blisters and bubbles</td>
<td>Protect membrane from direct sunlight during periods of hot weather</td>
<td>875</td>
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<td></td>
<td>Assess strip membrane for the presence of bubbles and blisters and remediate immediately prior to the application of the sprayed membrane.</td>
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<tr>
<td>8</td>
<td>Selection and application of sprayed surfacing</td>
<td>Ensure only rubberised binder is used for structures located in Perth and Environs.</td>
<td>503 or 509</td>
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<td>Polymer modified binder may be used for Remote and/or distant sites.</td>
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<td></td>
<td>Application of sprayed surfacing:</td>
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<td></td>
<td></td>
<td>- Surface preparation</td>
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<td>- Application (tack coat)</td>
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<td>- Application of membrane</td>
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<td>- Curing of membrane</td>
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<tr>
<td>9</td>
<td>Asphalting</td>
<td>Assess the area of the strip membrane under the sprayed membrane for the presence of bubbles and blisters and remediate immediately prior to the application of the asphalt.</td>
<td>875 &amp; 504</td>
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<td>Ensure correct period of curing for the sprayed membrane is applied prior to the application of the asphalt.</td>
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<td>Check the temperature of substrate is above the minimum specified value prior to the application of the asphalt – increase the temperature of the asphalt if necessary.</td>
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<td>Ensure that the rollers are of sufficient mass to adequately compact the asphalt.</td>
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