INTERIM ADVICE NOTE 96/07

GUIDANCE ON IMPLEMENTING RESULTS OF RESEARCH ON BRIDGE DECK WATERPROOFING

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Summary This interim advice note provides guidance on improving the performance of surfacing to bridge decks, particularly for surfacing less than 120mm thick, and provides advice on the application of bridge deck waterproofing systems to concrete aged less than 28 days. This advice is based on the results of recent research carried out on bridge deck waterproofing.

Instructions for Use
This IAN takes immediate effect.

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1. Introduction

Highways Agency (HA) requirements relating to bridge deck surfacing and waterproofing are contained in Departmental Standard BD 47/99 "Waterproofing and Surfacing of Concrete Bridge Decks" (Design manual for Roads and Bridges, Volume 2, Section 3, Part 4). These requirements relate to the total thickness of the surfacing (a minimum of 120mm), the material that directly overlays the waterproofing system (at present sand asphalt), the bond of the surfacing to the waterproofing system and the sub-surface drainage.

While the performance of surfacing is generally satisfactory if the total thickness is at least 120mm (as specified in BD47/99), premature failures have occurred when the thickness has been reduced. Although this reduction is outside current standards there may be good practical and/or economic reasons for considering reducing the thickness of the surfacing. Part 1 of this IAN reviews research carried out to understand the performance of surfacing to bridge decks, particularly where it is less than 120mm thick and provides guidance on reducing the risk of failure by emphasising the importance of sub-surface drainage, strengthening the bond requirements, specifying deformation requirements and specifying maximum air voids on all asphalt mixtures.

BD 47/99 also specifies the requirements relating to the application of bridge deck waterproofing which leads to waterproofing systems being normally applied a minimum of 28 days after decks are cast. Recent research has shown that the performance of waterproofing systems should not be adversely affected by application to concrete aged 7 days or more. Therefore, Part 2 of this IAN provides advice on the application of bridge deck waterproofing systems to concrete aged less than 28 days.

The risks associated with these proposals can be mitigated by careful planning and observing the advice/procedures within this advice note. However as these risks will be taken by the Highways Agency contractors must seek formal approval from the HA Project Manager for that particular scheme.

Project Managers should confirm that proposals comply with the requirements of this IAN and that the identified justification (cost/time savings) are appropriate. Project Managers should be aware that significant benefits can be realised by the reduction in programme offered by this IAN and these should be reflected in the magnitude of the identified benefits.

The decision to implement these procedures is at the discretion of individual HA Project Managers.

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2. Improving Surfacing Performance

2.1 Introduction

BD 47/99 requires waterproofing systems on concrete bridge decks to be overlaid with a 20mm thick sand asphalt protection layer and binder and surface courses so that the total thickness of the three layers is 120mm. This minimum thickness should always be aimed for, however the total thickness on some bridges has to be reduced for practical and/or economic reasons and in such cases, a number of premature failures have occurred when the asphalt has broken up and potholes developed. The failures have been attributed to several factors, including:

- The accumulation of sub-surface water in the asphalt
- Poor bond of the asphalt layers to the waterproofing system
- Excessive thickness of the waterproofing membrane
- Low compressive modulus of the waterproofing system
- Low fatigue resistance of the asphalt layers

Research has been carried out to investigate these failures and develop guidance to improve the performance of bridge deck surfacing. This research has highlighted several changes that are necessary to existing HA guidance, including:

- Emphasis on the importance of sub-surface drainage
- Strengthening bond requirements
- Specifying deformation limits for all mixtures within 100mm of the surface
- Specifying maximum air void contents for all asphalt mixtures.

The revised guidance is summarised below and is intended to develop further the existing HA advice for bridge deck surfacing.

2.2 Surface and sub-surface drainage

- Surface drainage systems, longitudinal gradients and cross falls should be provided to minimise the amount of water that can enter and accumulate in the surfacing on bridges.

- Edge drains should be provided to drain the full depth of relatively permeable surface courses (e.g. air void content > 6%) (i) at the low points of the deck and (ii) where the flow of sub-surface water though the surface course is impeded, e.g. at expansion joints that are not the buried type.

- Sub-surface drainage should be provided at the level of the waterproofing system as specified in BD 47/99 at all locations were water may accumulate.

- The vertical faces of the joints between adjacent laid widths (rips) of asphalt are normally sealed with bitumen to prevent water ingress. However, a fully sealed joint will prevent the horizontal flow of water through the asphalt layers. Provision must be made to ensure good bond between the adjacent laid widths, but in a way that does not allow water to accumulate in parts of the asphalt layers. The upper surface of a surface course joint should never be coated with bitumen after it has been compacted.

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2.3 Surface preparation and application of the waterproofing system

- Any new waterproofing system to be provided shall be a BBA certified product in accordance with the Specification clause 2003.

- After the waterproofing membrane has been applied, there should be no hollows or depressions of maximum dimension 150mm in plan and depth greater than 2mm in trafficked areas of the deck that are not drained naturally by the longitudinal gradient or cross fall, or by the provision of subsurface drainage.

- The waterproofing system must be uniformly bonded to the deck and it must not be applied if there is any contamination of the deck, or the environmental conditions, threaten to compromise the bond. It is expected that grit blasting may be necessary on most existing decks where the waterproofing system is being replaced. On new concrete decks it is important to ensure all laitance is removed. Pressure washing is not generally recommended as additional time has to be allowed for this water to evaporate from the concrete substrate. All waterproofing systems require a good bond and require the same level of preparation to the concrete substrate. Any proposals for application to a deck with a reduced level of preparation must be submitted formally through the Departures procedure.

- The nominal thickness of spray applied waterproofing membranes should not be greater than 3mm.

- Concrete repair materials should be compatible with the waterproofing system and have similar properties to the deck concrete (strength, coefficient of thermal expansion and elastic modulus). Repair materials less than 5mm thick should be avoided as they are more likely to de-bond. Repairs of lower thickness should be used only if a durable bond can be demonstrated.

2.4 Surfacing and waterproofing system

- An additional protective layer (APL) of sand asphalt should only be used when required by the individual waterproofing system. A separate British Board of Agrément (BBA) assessment is required for each type of asphalt overlay that can be used with a proprietary waterproofing system.

- Unless an APL is necessary, the waterproofing system should be overlaid with a layer of hot rolled asphalt binder course to Clause 943 of the Specification for Highway Works (MCHW 1) (SHW). A uniform thickness, not less than 45mm, is recommended. Variations in the total surfacing thickness over bridges should be accommodated in the upper layers, and tapered areas should be trimmed to remove asphalt too thin to be sufficiently well compacted.

- Care should be taken to minimise damage to the waterproofing system after it has been applied and before it has been overlaid with asphalt, especially when an APL is not laid. Any damage to the system should be repaired in accordance with the BBA method statement for that system.

- The hot rolled asphalt binder course directly overlaying the waterproofing system should have a Class 2 deformation resistance measured using the wheel-tracking test (BS 598-110), all in accordance with Clause 952 of the SHW. Coring for test samples should not be undertaken from asphalt laid over the waterproofing membrane.

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- The asphalt layer directly overlaying the waterproofing system should have a design air void content of no more than 4% so that the amount of sub-surface water that enters the layer is low.

- When the asphalt layer directly overlaying the waterproofing system contains coarse aggregates, the waterproofing system should have a thick tack coat that fills the voids at the base of the layer and prevents them from interconnecting.

- The flow of sub-surface water into the binder course(s) (and APL if present) should be minimised by specifying:

  (i) a thin surface course system (TSCS) with a thick bond or tack coat that will help to seal the binder course and
  (ii) binder course(s) which have a low void content.

- Contractors should give details of

  (i) the temperatures at which the surfacing should be laid and compacted to ensure that the tack coat of the waterproofing system is activated and
  (ii) how stripping of the tack coat is to be minimised and repaired before and during surfacing.

- The asphalt directly overlaying the waterproofing system should be laid and compacted at temperatures that are sufficiently high:

  (i) to form a dense layer and
  (ii) to activate the tack coat so the asphalt is uniformly and well bonded to the system.

  The temperature at the level of the waterproofing system should be measured immediately after the asphalt has been laid, and when compaction is essentially completed. Laying and compaction temperatures should be chosen to take into account the requirements to form a dense layer that is firmly bonded to the waterproofing system. The objective should be to exceed the minimum temperatures required to activate the tack coat by at least 10°C. If necessary a site trial should be carried out to ensure that the minimum temperatures can always be achieved. If recorded temperatures are below the required level then the surfacing must be removed and the waterproofing prepared again.

- When an APL is required, consideration should be given to using black sand asphalt.

- The laying of an APL of sand asphalt by hand should be discouraged because of the difficulties of laying and rolling such a thin layer at sufficiently high temperatures to achieve a good bond and form a dense layer.

- If the surfacing is to be laid and compacted at temperatures that exceed those permitted by the SHW, it must be demonstrated before works commence on site that this will not damage the waterproofing system.

- A stronger and thicker layer than sand asphalt should be used in verges and footways to prevent utility companies from damaging waterproofing systems, e.g. 50mm thick no-fines concrete.

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2.5 Bond of surfacing to the waterproofing system

- The minimum adhesion and bond strength requirements in BD 47/99 should apply only to surfacing of thickness 120mm or more including an APL of sand asphalt.

- Higher minimum values should be specified when the waterproofing system is overlaid with asphalt with coarse aggregates. The minimum tensile adhesion and shear and tensile bond strength requirements given in Table 1 are recommended.

Table 1 Minimum adhesion and bond strengths for waterproofing systems when overlaid with coarse mixtures

Surfacing thickness		**≥120 mm**	**< 120 mm; ≥ 90 mm**	**< 90 mm ≥ 60 mm**
Tensile adhesion test (waterproofing system to concrete)	@ -10°C	0.30MPa	0.50MPa	0.70MPa
	@23 °C	0.30MPa	0.50MPa	0.70MPa
	@40 °C	0.20MPa	0.30MPa	0.30MPa
Shear bond test (surfacing to waterproofing system)	@ -10°C	0.30MPa	0.30MPa	0.40MPa
	@23 °C	0.30MPa	0.30MPa	0.40MPa
	@40 °C	0.10MPa	0.15MPa	0.15MPa
Tensile bond test (surfacing to waterproofing system)	@23 °C	0.40MPa	0.45MPa	0.50MPa

2.6 Deformation resistance

- During prolonged periods of hot weather, asphalt overlays to suspended structures experience the highest temperatures and their deformation resistance should be specified accordingly.

- The deformation resistance of the thin surfacing course should comply with the requirements of Clause 942 of the SHW.

- The deformation resistance of all binder course layers (and base if applicable) should comply with the Class 2 deformation resistance requirements in accordance with Clause 952 of the SHW, measured using the wheel-tracking test (BS 598-110). Coring for test samples should never be undertaken from asphalt layers laid above the waterproofing membrane.

- Where materials are nominally laid at a thickness less than 40mm, testing is permitted to composite samples made up of more than one of the different layers to be used in the pavement, provided no part of the layer has a thickness less than twice its maximum aggregate size.

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3. Lapping onto existing waterproofing systems

Problems can arise when lapping waterproofing systems with significant differences in adhesion levels. For example, there are significant differences in bond strengths when a spray membrane is applied to a sheet membrane. Guidance on what should be done when carrying our repairs to, or partially replacing, existing waterproofing systems with significant differences in bond strengths is given below.

- Carry out pull off tests on the existing waterproofing system and record the adhesion achieved (to be done before the breakout of concrete).

If the adhesion is of similar magnitude to the proposed system then prepare joint and overlap with new system, in accordance with the BBA method statement. The minimum overlap is to be as specified by the waterproofing contractor.

Where the adhesion is significantly different the procedure below should be used.

- The new BBA certified waterproofing system is to be butted up to the existing waterproofing system.
- Provide a protective banding layer that laps a minimum of 150mm onto both the new and existing waterproofing systems.
- Where the existing waterproofing system on the deck has been formed using mastic asphalt there will be a significant difference in thickness between the new and existing waterproofing systems. In order to facilitate the lapping of the protective banding layer on to both new and existing waterproofing systems, a 45° chamfer in the mastic asphalt should be formed. If this is not possible, due to either break up of the mastic asphalt or poor adhesion to the deck, this chamfer shall be formed in concrete. Where concrete is to be used to form the required chamfer, record the presence of the concrete chamfer on both the as-built record drawings and within SMIS.
- Record the structure in SMIS as ‘At Risk’ to failure of the waterproofing system and monitor for signs of failure at routine future inspections.

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4. Waterproofing Systems Applied to 'Young' Concrete

4.1 Introduction

Waterproofing systems that have satisfied the requirements of the certification tests as specified in BD 47/99 are considered suitable for use on bridge decks where the concrete is aged 28 days or more. Therefore, currently, waterproofing is normally applied a minimum of 28 days after decks are cast. Any decrease in the age at which concrete can be waterproofed would be beneficial as it may reduce congestion on the road network and realise cost benefits from a reduced construction programme.

Recent research has been carried out to investigate the factors that affect the performance of waterproofing systems applied to concrete less than 28 days old. This research has shown that the performance of waterproofing systems should not be adversely affected by application to concrete aged 7 days or more. The findings of the research and guidance on the application of waterproofing systems to concrete 7 to 28 days old are given below.

4.2 Factors affecting performance

The most significant differences in the performance of a waterproofing system applied to 28 day old and younger concrete are likely to be dependent on:

- the resistance to blow/pin holing and blistering of the system;
- the bond of the system to the concrete;
- the effect of the moisture content of the concrete on the curing of components of the system; and
- shrinkage and load induced cracking.

These factors are dependent on:

- the type of concrete
- the surface finish of the concrete
- the moisture content of the concrete when the waterproofing system is applied
- the temperature of the concrete when the waterproofing system is applied
- the type of the waterproofing system, in particular the type of primer
- the temperature history after the waterproofing system has been applied, including the
- temperature of surfacing materials

Blow/pin holes and blistering are formed by out-gassing when air, water vapour or solvents in primers within voids in concrete are expelled due to changes in temperature or, sometimes, barometric pressure. Pin/blow holes are formed only when liquid-applied systems are curing – the longer it takes for them to cure, the greater the likelihood that they will form. Blisters may form any time after installation.

Out-gassing is most likely to occur when the temperature of a deck changes rapidly due to solar radiation or due to the application of hot surfacing materials. As concrete ages, the size of the pores decreases, therefore concrete aged less than 28 days may be more prone to out-gassing than older concrete.

A waterproofing system should remain uniformly bonded to a concrete deck throughout its service life. Almost all membranes can have small defects through which chloride ions can

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pass. If the membrane is firmly bonded to the concrete, the number of chloride ions that can pass through a defect is normally low and the ions can reach only a small area of the deck. However, if the membrane has a defect where it is not bonded to the deck, many chloride ions can pass through the membrane and the likelihood that they can penetrate the concrete and cause reinforcement corrosion is much higher.

The initial bond of most waterproofing systems to concrete is dependant on the surface moisture content of the concrete during waterproofing. The bond strength will be reduced if surface moisture is present, especially if it impairs the curing of liquid applied components. Over time, even if out-gassing does not form blisters, it may weaken the bond of the system to the concrete. The bond may also change as the concrete ages and cures.

Shrinkage and load induced cracking may be significant in the hogged regions of continuous multi-span decks. A waterproofing membrane and its overlaying structure may be subjected to larger tensile strains if they are applied to the deck before the onset of cracking.

4.3 Guidance on the application of waterproofing to 'young' concrete

The performance of waterproofing systems should not be adversely affected by application to early aged concrete (i.e. 7 to 28 days), provided they are applied in accordance with the guidelines given below.

- Any new waterproofing system to be provided shall be a BBA certified product in accordance with the Specification clause 2003.

- 'Young' concrete tends to have higher surface moisture contents; therefore extra care is needed to ensure that the required moisture content has been achieved before application of the waterproofing system. Considerable flame drying may be required. After a period of sustained rainfall it is likely that the substrate will be saturated, flame drying may dry the immediate surface but a significant amount of moisture may remain. Care should be taken to establish that the substrate has an acceptable moisture content before application of waterproofing. Moisture content should be measured and be found to be below 6%.The accuracy of measurement should be accounted for. (i.e. hand held moisture meters have an accuracy ± 2%)

- Extra care is required when using primers on early-age concrete and that these must be fully cured prior to application of the waterproofing system. (This does not relate to concrete curing compounds or surface impregnates which must be removed/treated before application of waterproofing but to the primer that is part of the BBA registered procedure for that waterproofing system)

- Tensile adhesion is particularly important when applying sheet membranes at high ambient temperatures. The minimum tensile adhesion and bond strengths given in Table 1 shall apply.

- Pull-off tests should be conducted on site after the installation of the membrane and before surfacing to confirm that the condition and dryness of the surface of the concrete is sufficiently dry to give adequate initial tensile adhesion of the waterproofing system to the concrete. Any requirements for acceptability of adhesion should reflect the properties of the systems being used. For example, 0.3 MPa is too low for spray applied membranes and would be indicative of a potential problem if recorded on a site trial. Advice should be sought from the manufacturer prior to commencing trails.

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- Bond tests have shown that the tensile bond strength of the surfacing to the waterproofing system and/or the tensile strength of the surfacing can be weakened by wheel loading when the surfacing is saturated. A thick tack coat should be applied to limit the amount of water that can accumulate on the surfacing at the interface with the waterproofing system.

5. Implementation

The decision to implement these procedures is at the discretion of individual HA Project Managers.

6. References

"The performance of surfacing overlaying bridge deck waterproofing systems", R W Jordan, K Nesnas and M G Evans, Published Project Report Number PPR 221

"The performance of surfacing overlaying bridge deck waterproofing systems: appendices" R W Jordan, K Nesnas and M G Evans, Unpublished Project Report Number UPR/IE/001/06.

"Application of bridge deck waterproofing to concrete aged from 3 to 28 days", A J J Calder, M G Evans and R W Jordan, Published Project Report Number PPR 154.

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