Delivering a safe and sustainable highway network

County Surfacing and Structural Maintenance Strategy – 2009

Strategic Director **Paul Galland**

Approved for use May 2009 **Graeme Fitton** Head of Engineering and Highways

This strategy shall be implemented by the Environment and Economy Directorate with immediate effect

Project Team: Tony Iwanikiw, Chris Horn and Nigel Chetwynd

Compiled by Charles Catt FIAT MIHT MEI

Published 2009

Contents

0 Introduction

Background

0.1 The strategy was last fully revised in 2006

0.2 The strategy covers the construction, structural maintenance and resurfacing of the highway network together with footways, cycleways and cycle paths and associated untrafficked but surfaced areas. It does not include the construction and maintenance of bridges.

0.3 This is an amended version of the 2006 strategy to take into account changes to the Specification for Highway Works up to August 2008, Design Manual for Roads and Bridges and the introduction of EN standards. There is a significant emphasis on safety, sustainability, environment and minimisation of resource use. This is achieved by, in order of priority:

- Reducing material usage
- Reuse of road structure
- Recycling road materials

0.4 Material usage can be reduced by using thinner but stronger constructions, longer life construction, more durable materials and processes and ensuring construction processes optimise the performance of any material used in the construction. It can also include a reduction in the use of high cost materials where cheaper alternatives will perform sufficiently well.

0.5 The road structure can be reused optimally by timely surface treatments which prevent deterioration of the existing structure. This can include resurfacing with structurally competent materials to extend the design life of the structure or resurfacing with systems that keep water out of the pavement. This maintains the integrity of the structure and prevents foundation weakening or the stripping of binder from aggregate that can occur as binder is exposed to air and water.

0.6 Materials can be recycled either in situ or ex situ but the former minimises haulage of materials off and back on to site. Recycling should only be resorted to after reuse of the structure has been proved to be not feasible. The need for more than local reconstruction is an indication that there has been a failure in the management of maintenance (in a few cases this may be unavoidable due to lack of funds). Failure may be due to lack of timely maintenance or the depredations of those who dig holes in roads to obtain access to services.

0.7 The main changes are to the specification of bituminous materials and to the sub-base specification. These specification changes do not significantly alter the materials.

Layout and use of this strategy document

0.8 The document is divided into 20 chapters in 2 parts, together with 6 annexes. Part 1 covers new construction and Part 2 covers maintenance. The chapters are, as far as possible, freestanding and for any process such as resurfacing only one section usually needs to be referred to and there is inevitably a degree of repetition as a result. The annexes cover the specification of Warwickshire special materials which are not specified in nationally available standards or specifications. Other Annexes cover the likely changes in the next few years as a result of changes to external specifications and standards that are likely to be implemented in the near future, the specification for a number of asphalt mixes such as 45/10F in EN 13108-4 format and a list of abbreviations and acronyms.

0.9 There are also a number of supporting papers, held by Network Management (Nigel Chetwynd). They include papers on:

- Binder grade in structural layers
- Polished stone values and effect of aggregate size
- Effect of ride quality on pavement life
- Noise

- Structural contribution of thin surfacing
- Patching – causes and investigation of reasons for its need
- Environmental assessment of maintenance operations
- BBA/HAPAS system and use of certificates
- Reasons for changing the sub-base specification

0.10 Wherever possible existing national specifications and standards are used in preference to specifically local ones. The main ones that are used are:

- Specification for Highway Works volume 1 – Specification
- Specification for Highway Works volume 2 – Notes for Guidance
- Design Manual for Roads and Bridges – volume 7; Pavement Design and Maintenance including IAN 73 rev 1
- BS EN 13108 Bituminous mixtures – material specifications
- BS PD 6691 Guidance on the use of BS EN 13108
- BS 594987 Asphalt for roads and other paved areas – Specification for transport, laying and compaction and type testing protocols.
- IAN 96: Bridge deck surfacing
- Road Note RN42: Best practice guide for durability of asphalt pavements
- BBA/HAPAS guidelines and certificates
- Well Maintained Highways – Code of practice for highway maintenance management

Other standards and specifications will be referred to where needed and a full list is given in the Chapter 20.

0.11 Warwickshire County Council policies and strategies which are relevant to this document are:

- Warwickshire Highway Maintenance – Policy Document
- Road Safety Strategy
- Transport and Roads for Developments: The Warwickshire Guide 2001
- Local Transport Plan (LTP)

0.12 The strategy document is divided into chapters which may be updated independently. The date at which the individual chapter was last revised is included at the end of that chapter. The master document is kept on the WCC system. The currency of the section must always be checked before use. The frequency of updating will vary from section to section but the document will be reviewed on an annual basis but any sections influenced by the publication of relevant external or internal documents will be revised as required. For example the Specification for Highway Works may be revised every three months.

0.13 The testing strategy is published separately.

0.14 A skidding strategy strategy is published separately.

0.15 It is not permitted, under the public procurement directive, for any public body to require the use of a particular proprietary product. All such requirements must be specified in performance terms, hence the use of BBA/HAPAS certification for proprietary highway materials. Statements such as: ‘example product or similar’ are also not permitted as they are deemed to steer towards a particular product giving unfair advantage. Additional requirements can be added on a contract by contract basis but they must have technical justification, must be specified in performance terms and must not conflict with published European Standards.

0.16 References are given in the form [Catt 1983]; ie authors surname followed by the year of publication. Where the author is unknown the commissioning authority is given instead eg [HA 2002]. The complete list of references can be found in Chapter 20.

0.17 **Users of this document are reminded of their responsibilities under the Construction Design and Management (CDM) regulations to provide designs that are safe to construct, safe to use and safe to maintain.**

Last amendment May 2009

1 Guiding Principles

1.1 The main guiding principles are:

- To have minimum environmental impact
- To have appropriate and balanced levels of safety to minimise casualties
- The minimisation of hazards during installation and maintenance
- To maximise the durability of the pavement structure

Environmental impact

General

1.2 As stated in the introduction the priority order of processes to reduce environmental impact are

1. Reduce material usage
2. Provide good ride quality
3. Reuse road structure
4. Recycle road materials

Reduce material usage

1.3 In the history of road construction and maintenance two directly opposed philosophies have been used to try and achieve minimum material usage: build a road as thin as possible or build it strong enough to last a long time. Over a lifetime the latter has been demonstrated repeatedly to have the lowest use of raw materials, the lowest maintenance costs and the lowest impact on the travelling public. Some have argued that roads do not last 60 or more years but many of Warwickshire's road have foundations that predate World War 2 and indeed those with Roman origins (eg A5 and B4455) still have remnants of Roman foundations. Therefore this strategy is based on the provision of long life pavements. In order to achieve this durable materials must be used which must be properly installed; it is no good having durable components if inadequate installation means early failure and high maintenance need.

1.4 The long life philosophy does not only apply to the structure of the road but applies equally to such matters as traffic management surfaces and road markings.

1.5 In the context of resurfacing the thinnest surface consistent with other requirements will be chosen.

Ride quality

1.6 Ride quality has a number of effects on the sustainability of the network and the general environment:

- good ride quality maximises the life of the pavement as it minimises impact loading from vehicles
- good ride quality minimises fuel consumption
- good ride quality minimises noise generation (for any given surface type)

Reuse of road structure

1.7 When structural maintenance is being planned making the maximum use of the existing pavement structure should be the main principle. This means that where there are no level constraints the existing structure will be left in place and an appropriate overlay designed and installed using, where it will improve economy, local reconstruction. Reuse, on most of the county's roads, will have a lower environmental cost than recycling as, usually, a relatively thin overlay will increase the life of a road significantly and a recycled road will need a new surface anyway. The other advantage of reuse

is that virtually all roads in the county (as is the case nationally) includes old, hard, tar bound materials. Tar is not a problem if left in situ (this is normally also true when recycled in situ and cold) but can be if removed from site; it certainly is a problem if it is recycled using a hot process. Reuse can be more problematic in urban areas where highway level constraints are much more frequent. To strengthen a road where levels are constrained it is necessary to remove the existing and replace with a thicker or a stronger material. Even in these situations it is sometimes possible to remove a part thickness and replace with a stronger material or remove part thickness and recycle the remainder and resurface.

Recycling

1.8 Recycling consists of breaking up the existing road, treating the broken material using one of a number of processes and relaying it either in the same place or on another section of road. It is always carried out by a specialist contractor and specialised plant is usually required. Advice should be sought from suitable contractors into the feasibility of recycling a particular section of pavement. Because tar is usually present only cold in situ recycling should be considered. This may use either emulsion binder or foamed bitumen. Cement recycling must not be used as it cracks and unless a considerable thickness of bituminous material is placed on top the cracks reflect through to the surface and allow water to penetrate the pavement structure. Many sub-grades in the County are clays which shrink and expand as their moisture content falls or rises so that any structure must be flexible, again leading away from rigid cement based recycling. Emulsion or foamed bitumen recycling sometimes use small amounts of cement – this is not a problem,

Balanced safety levels

Skidding resistance

1.9 This strategy follows the philosophy of the HA (HD28 paragraph 1.3). ‘The objective … is to manage the risk of skidding accidents in wet conditions so that the risk is broadly equalised across the network.’ This means that adequate levels of PSV of aggregate combined with aggregate size are provided at each site. Advice on the implementation of HD28/04 is given in CSS Guidance note on skidding resistance dated May 2005. Warwickshire’s strategy for skidding and skidding resistance is published separately.

Macro-texture

1.10 At high speed it is necessary to provide either high macro-texture to maintain adequate skidding resistance or, on low texture materials, to increase the measured skidding resistance to compensate for the fall off in skidding resistance with speed. This was shown, indirectly, in old research but recent work has demonstrated this clearly. Advantage is taken of these findings to enable the use of known durable surfacing materials on lightly trafficked roads. Over 95% of the County’s network is classed as lightly trafficked (under 250 cv/l/d)

Casualty reduction

1.11 The minimisation of casualties over the whole network is contributed to by the provision of appropriate skidding resistance at all sites. Unnecessarily high values of PSV should not be used as above a certain value crash frequency is not reduced. This follows from research carried out many years ago by TRL showing that once the skidding resistance level has a certain value (different for each type of site) any further increase does not reduce the frequency of crashes summarised in [Hosking 1992] and [Catt 1983]. This finding has been confirmed by recent research by the same organisation [Parry and Viner 2005]. In some cases an increase in skid resistance results in increased crash rates.

Installation and maintenance hazards

Manual handling

1.12 Regard is paid to the manual handling regulations. Examples of possible problems are lifting of kerbs and slabs, hand laying bituminous materials and screeding of high friction surfaces and

screeded road markings where heavy buckets of hot materials (often over 200°C) are carried and poured.

Vibration avoidance

1.13 Vibration white finger can result from the use of hand held vibrating tools. Due regard is paid to the minimisation of the use of such tools.

Toxic materials

1.14 The main source of toxic materials in road construction materials are pigments. Increasing use of coloured surfaces indicate that much care is needed to ensure that any pigments used are non-toxic. Many pigments are based on heavy metals such as cadmium, chromium and lead; all of which are toxic. There are two major problem areas with their use: as they wear dust is generated which is often fine enough to be included in the 'PM10' count which means it is breathable and therefore has a high level of toxicity. The second is when it is removed from the road. By then the records of what materials were used have often been lost or they are not communicated to the contractor removing the surfaces thus raising the likelihood of spreading toxic materials uncontrollably. Non-toxic pigments are available but are usually less durable and more expensive. Where a coloured surface is required the use of natural coloured aggregates is always preferred as the colour is very durable and aggregate is non-toxic.

Services

1.15 As far as possible utility companies should be persuaded to place their equipment outside the construction of the pavement as this reduces hazards during maintenance of the pavement structure. This also eliminates the damage caused to the pavement structure when the services are accessed in the future. It is accepted that placing sewers outside the highway structure is not usually feasible and in such cases they should, as far as possible be placed between the wheel tracks.

Last amendment May 2009

Part 1 New Construction

2 Foundations, drainage and sub-base

Drainage

2.1 This strategy does not deal with the design of drainage systems. They are, however, extremely important and the pavement designs strategyassume that the subgrade is properly drained by a system that keeps the subgrade free of water for the life of the pavement; ie the system shall not only function initially but must either be maintained on a regular basis or designed not to need maintenance so that it functions at all times. Environment Agency requirements should be followed. There has been significant consideration of drainage recently in connection with major flooding. The most recent guidelines should be followed.

Proper functioning of drainage of all types is now more important than was traditionally the case as pavements are now designed for long life – in excess of 40 years is usual for new roads. RN42 highlights the need for fully functioning drainage throughout the life of the pavement

Note: If the drainage fails the life of a pavement can be more than halved and indeed nearly 100% of all failures of a road structure include water as the main or a significant contributor cause.

2.2 It is also important that storm water drainage is properly designed, constructed and maintained as poor disposal of surface water will increase the amount of water entering the structure and this will reduce the life of the road. It is recommended that, as far possible, gullies and other devices to collect run-off should be kept out of the main carriageway as they seriously weaken the structure. Evidence is beginning to be gathered showing that irregularities in the running surface (particularly those affecting one wheel track such as those formed be depressed gullies) can be a cause of crashes.

Sub-base

2.3 The foundation specification for trunk roads was totally revised in IAN 73 and is no longer considered to be merely a construction platform for the structural layers. The specifications for both capping and sub-base should logically be in the 800 series and it has been confirmed with the Highways Agency that this is the intention when resources allow. It is therefore appropriate that strategy the traditional description of sub-bases, Wxx is used rather than variations on the 600 series description of 6Fxx for the lower layer. The strength of capping has been downgraded when compared to earlier designs of foundation layers. Also the total thickness of foundation has generally been increased. Warwickshire has a long history (over 40 years) of using permeable sub-bases and capping layers.

2.4 Permeable sub-bases have significant advantages when it is proposed to use recycled materials:

- they are stable in all moisture conditions including full saturation (the normal state on clay subgrades after a number of years when no drainage maintenance is carried out)
- no frost heave testing is needed for either the open graded material or for the thin layer of regulating material used on top as there is no capillary path for water to migrate to form ice-lenses. This is a great advantage when using recycled type 1 for regulating as otherwise a frost test (very expensive) would be needed for each source which might consist of relatively small quantities.
- They do not require much compaction which minimises breakdown of materials that may be relatively soft.
- The actual grading is not critical provided the fines content is very low and the materials are very permeable. The maximum size should be compatible with the size of the equipment used to place the material.
- Warwickshire sub-bases have traditionally been thinner than the foundations for Highways Agency

2.5 The specification for Warwickshire sub-bases, W150 and W75 are given in Annex A. It has been written in terms of minimum permeability with a ‘deemed to comply’ grading limit, which limits the amount of fines in the product. This enables easy use of recycled materials particularly those of

WCC's own production. Within the overall thickness the maximum thickness of the larger 'W' materials shall be used with a minimum thickness of type 1 or type 3 from SHW which is used as a regulating layer to give a good even surface to the sub-base on which to lay the bituminous base layer. Type 2 may be used but only those containing at least 80% of bituminous planings. W75 is normally used only where space is limited such as in strip widening and where significant proportion of the materials has to manhandled. W150 is preferred where machine placing is used such as half lane widths or more.

2.6 Figure 1 shows the design process for sub-base thickness. The process used depends on whether or not a site investigation has been carried out. On small schemes the saving in amount of sub-base is unlikely to cover the cost of carrying out even a simple site investigation together with a sufficient number of plasticity indices and the necessary testing of CBRs on site. It is thought that the size of scheme for breakeven is likely to be around 1000 sq m or more depending on saving of sub-base thickness and obviously its cost and the cost of disposing of arisings.

2.7 The sub-base is classified as a class 2 foundation in HD26/05. Table 2.1 gives the relevant thicknesses using default values of CBR. Table 2.2 gives the CBR for common sub-grade materials, which should be used in the design in most cases.

2.8 The substitution of Types 1, 2 or 3 sub-base (in SHW these are called 'unbound mixtures) for W150 or W75 shall not be permitted as none of them are sufficiently permeable. Table 2.2 is extracted from HD25/94 to cover the soil types found in Warwickshire and simplifies it to summer or winter construction. If the CBR measured at the time of construction is lower than that given in the table then the lower figure shall be used for design. A measured CBR higher than that indicated by the table shall be ignored. All the caveats and warnings in IAN73 regarding CBRs shall be noted and considered.

2.9 The sub-base shall be laid in layers with a thickness not exceeding 4 times the nominal size of the material (this is called 'D' in European Standards)

Note 1: bituminous planings are now included in type 2 unbound mixtures

Note 2: for the background on W150 and W75 see supporting papers (held by Network Management)

3.0 Type 1 unbound mixture shall be placed at a moisture content between optimum and optimum-2% measured using the vibrating hammer test in BS 5835 part 1 :1980.

Figure 1 Design Process for Sub-Base Thickness

Site investigation carried out?			
No		**Yes**	
Use thickness given in Table 2.1 for the obvious soil types (default values)		Use thickness given in table 2.3 on the basis of CBRs determined from table 2.2 using soil parameters determined as a result of a site investigation	
		Measure CBR immediately prior to placing sub-base	
		Is CBR at or above design CBR?	
		Yes	**No**
Construct sub-base at the default thickness.*		Use design thickness	Increase thickness to that required for the measured CBR

*it is good practice to measure the CBR at this stage to check that it is not below the low limit of CBR for the thickness. If it is then use additional thickness.

NEVER, NEVER reduce the sub-base thickness below the design thickness as a result of measuring the CBR. The design thickness is determined using the long term stable CBR.

Table 2.1 Default sub-base Thicknesses

CBR	Total sub-base thickness (nominal)	W sub-base	Type 1 or 3 Sub-base or bituminous road planings (type 2)
%	mm	mm (minimum)	mm (maximum)
<2 (Lias clay)	750	600	150
2-5 (Keuper Marl)	500	350	150
5-15 (non-plastic sands)	300	150	150
>15 (non-plastic gravels)	200	0	200

See paragraph 2.5 for method of choosing between W75 and W150.

The thickness of the 'W' sub-bases should be maximised within each category with types 1 - 3 reduced to the role of a regulating layer.

Table 2.2 Design CBR

Soil type	**PI**	**Construction period**	
	%	**Winter**	**Summer**
Heavy Clay (typically Lias)	70	1.5	2
	60	1.5	2
	50	1.5	2
(typically Mercia mudstone (marl))	40	2	2.5
Silty Clay	30	2.5	3
Sandy Clay	20	2.5	4
	10	1.5	3
Silt		1	1
Non-plastic Sands		10	20
Sandy Gravels		20	40

PI is plasticity index - see BS 1377:1990

Table 2.3 Design Sub-base Thicknesses (for 'large' contracts)

CBR	Total sub-base thickness (nominal)	W sub-base	Type 1 or 3 Sub-base or bituminous road planings (type 2)
%	mm	mm (minimum)	mm (maximum)
<2	750	600	150
2	500	350	150
2.5	450	300	150
3	410	260	150
4	360	210	150
5	320	170	150
6-8	300	150	150
8-10	250	100	150
10-15	225	0	225

3 Structural layers for new roads (except adoptable roads)

3.1 The structural layers of all new roads shall be asphalt concrete using 100/150 grade bitumen. The layer thickness shall be as shown in table 3.1 The assumed design life is 40 years. This section does not include the design of adoptable roads, see section 7 for the design for these roads.

Table 3.1 Construction thickness for new roads

Traffic level	Base thickness mm	Binder course thickness mm
Up to 1 msa (this includes all HAUC type 4 roads, and all roads carrying up to 100 cv/l/d). All of these will have 55/10F surfacing.	100*	60
1 to 5 msa (this includes all HAUC type 3 roads, and all roads carrying up to 500 cv/l/d) with 55/10F surfacing	150*	60
Above 5 msa (ie HAUC type 0, 1 or 2 roads and roads carrying more than 500 cv/l/d). A traffic count is required. (Or for new roads an estimate)	As figure 2.2 of HD 26 less thickness of structural surfacing	

* the base thicknesses assume 40 mm of HRA 55/10F surf 100/150 surfacing. Where a different thickness of structural surfacing is used these thicknesses shall be adjusted to maintain overall structural thickness.

NOTE 1: The levels of traffic for the HAUC categories have been doubled compared to those given in the specification for reinstatements in Highways as the design life is 40 years and not 20 assumed by HAUC.

NOTE 2: The HAUC classification can be obtained from the Street Works Register team

3.2 The base shall be AC 32 dense base 100/150 recipe mixture to BS EN 13108-1 and PD 6691. Where a new road is being built that does not have any underlying utilities, **and** will not have any in its lifetime, 40/60 binder may be used in place of 100/150 binder with the design thickness in accordance with Figure 2.2 of HD 26. Design mixtures may be used but only with express written permission of Warwickshire County Council after the provision of all relevant information. The use of gravel aggregate is not permitted. EME is not suitable for use on WCC roads as its design costs are high and it would only be useable where 40/60 pen binder is useable and the saving in thickness would be marginal with WCC traffic levels.

3.3 The binder course shall be AC 20 dense bin 100/150 recipe mixture to BS EN 13108-1 and PD 6691. Where a base using 40/60 binder is used then the binder course shall likewise use 40/60 binder. Design mixtures may be used but only with express written permission of Warwickshire County Council after the provision of all relevant information. The use of gravel aggregate is not permitted.

3.4 A bond coat in accordance with clause 920 of the Specification for Highway Works shall be used between all structural layers. Clause 920 requires that all bond coats are applied using a spray bar. More information is given in BS 594987.

NOTE: A bond coat is a polymer modified emulsion although there are likely to be developments in binder technology which will permit modified hot binders without flux to be used (A tack coat is an unmodified emulsion such C40B2 or C69B2; these are no longer permitted.)

3.5 Cementitious materials shall not be used for structural layers on any grade of road.

NOTE: all cementitious materials crack. To prevent the cracks propagating to the surface it is necessary to overlay the cement bound layer with a minimum of 175 mm of bituminous material. On major trunk roads this would be within the design thickness but for all County roads it uses extra high cost materials compared to an all bituminous design.

3.6 The level of compaction shall be measured by means of void content. The void content shall not exceed 6% for either the base layers or the binder course for the mean of each set of 6 cores; regardless of whether the Asphalt Concrete is recipe or design. The compaction close to a joint as defined in clause 903 shall be such that the air voids shall be not more than 2% above that specified for the main mat. The specification, based on clause 929 of the SHW is in the WCC standard document as 973AR which is reproduced in Annex C.

3.7 Resistance to deformation for the binder course should not be specified for roads carrying less than 500 cv/l/d. For roads carrying more than this the deformation resistance shall be class 1 when tested in accordance with BS 594987. No requirements for the deformation resistance of the base should be specified on any county road.

Last amendment May 2009

4 Surfacing new roads

4.1 Surfacing shall be one of two types. A summary of the type to be used, and where, is given in table 4.1. This table uses commercial vehicles per lane per day (cv/l/d) as defined in HD 24 and the speed limit as the parameters affecting the material choice.

Table 4.1 Summary of preferred surfacing for new work

<table>
<tr><th>Speed limit (mph)</th><th>Traffic 100 cv/l/d and below</th><th>Traffic above 100 cv/l/d</th><th>Traffic above 100 cv/l/d where noise is a problem</th></tr>
<tr><td>20</td><td rowspan="6">Hot Rolled Asphalt 55/10F surf 100/150 (see para 4.2)</td><td rowspan="3">Hot Rolled Asphalt 55/10F surf 100/150 (see para 4.3)</td><td rowspan="2">Hot Rolled Asphalt 55/10F surf 100/150 (see para 4.3)</td></tr>
<tr><td>30 and roundabouts and traffic lights on roads with higher limits</td></tr>
<tr><td>40</td><td rowspan="4">BBA/HAPAS 0/10 thin surfacing with noise reduction stated in the certificate of 2.5 dB(A) or more (see para 4.4)</td></tr>
<tr><td>50</td><td rowspan="3">BBA/HAPAS 0/10 thin surfacing (see para 4.4)</td></tr>
<tr><td>60</td></tr>
<tr><td>70</td></tr>
</table>

Note: where a new section is being inserted into an older road (eg a right turn lane) it is usually appropriate to match the surfacing type with the existing except where the existing is surface dressing.

4.2 On all roads carrying less than 100 cv/l/d the surfacing material shall be Hot Rolled Asphalt HRA 55/10F surf 100/150 to BS EN 13108-4 as described in PD 6691.

NOTE: this has traditionally been called medium temperature asphalt (MTA) in Warwickshire

4.3 On roads carrying more than 100 cv/l/d with a speed limit of 40 mph or less the surfacing material shall be Hot Rolled Asphalt HRA 55/10F surf 100/150 to BS EN 13108-4 as described in PD 6691. This surfacing shall also be the first choice for new roundabouts and traffic light junctions on roads with higher speed limits; however, if these are part of a larger scheme then the surfacing chosen for the whole scheme may be carried through. Thin surfacing on the circulation area of small roundabouts should be used with caution and the supplier specifically asked to demonstrate its suitability in such locations.

4.4 On roads carrying more than 100 cv/l/d with a speed limit above 40 mph the surfacing material shall be a 0/10 thin surfacing with a BBA/HAPAS certificate and the material used shall be chosen from those that have a stiffness stated in the certificate in excess of 2GPa. A material without a claimed stiffness may be used but its thickness shall not count towards the overall structure of the pavement and the difference should be made up by increasing the base thickness. Where noise is a problem, the thin surfacing shall be chosen from those that have a noise reduction of at least 2.5 dB(A) stated in its BBA/HAPAS certificate; this is level 2 as defined in NG 942 of the SHW. Higher levels of noise reduction shall not be specified. Further advice on selecting and using these materials can be found in ‘Best practice guidelines for specification of modern negative texture surfaces (NTS) on local authority roads’ [DfT/UK Roads Board 2006].

4.5 The polished stone value shall be specified in accordance with the table in Annex B. Higher values shall not be specified unless a written justification is lodged with Network Management prior to issuing a contract. The values in Annex B include a sufficient safety margin and using higher values will not further reduce skidding crashes except in exceptional circumstances.

NOTE 1: if skidding crashes still occur with high values of skidding resistance the layout of the road is probably at fault.

NOTE 2: recent research has shown that very high skid resistance values can be associated with increased crash frequency.

4.6 The resistance to surface abrasion shall be AAV_{10}.

4.7 The level of compaction for the hot rolled asphalt surfaces shall be in accordance with the requirements given in clause 973AR in Annex C.

4.8 The level of compaction for the BBA/HAPAS surfacing materials cannot be directly specified but the supplier and laying contractor shall be required to demonstrate that the level of compaction achieved on site is commensurate with that obtained on the BBA trial site(s). Durability, stiffness, and deformation resistance are all closely related to compaction level and inadequate levels of compaction will result in reduced life. The means of demonstration is the prerogative of the supplier but should give confidence that adequate compaction has been achieved.

4.9 All the usual requirements for surfacing performance such as compliance with straightedge requirements (SHW 701), texture depth and finished level must be achieved for all surfacing. The texture to be specified should follow the guidance given in NG 942 of the SHW; ie level 1 for urban sites and level 2 for all but the heaviest trafficked dual carriageways of which there are very few in the County. There is no requirement for texture depth when 55/10F HRA is used but this is allowed for by using higher PSVs for this material compared to others, see Annex B for details.

4.10 Regardless of the type of new surfacing, ironwork within the carriageway shall be reset to its final level before the surface course is laid. If for some very good reason this not done then the area around the ironwork which is cut out in order to reset it shall be reinstated with a BBA/HAPAS certificated inlaid crack sealing system (eg Permatrack). On no account shall the hand laying of thin surfacings be attempted as they always fail very early.

NOTE: 'Permatrack' is given here as an example for information. It cannot be specified as such as that would contravene the Public Procurement Directive (PPD)

Last amendment May 2009

5 New footways and cycleways

Footways

5.1 The footway design should accord with HD 39 for the traffic level chosen. Light vehicle design will be the most common. Untrafficked design shall not be used when sweepers or other maintenance vehicles are used that are not pedestrian controlled. Footways combined with cycleways shall have the same construction as the cycleway.

NOTE: There should be no step between the cycleway and footway when they use the same route and are immediately adjacent to each other. Separation should be by means of a white line only. A longitudinal step of less than 25 mm can 'throw' a cyclist if it is crossed at a narrow angle to avoid pedestrians for example.

5.2 HD 39 gives a two course surfacing design. As an alternative 50 mm of asphalt may be used in a single layer; the asphalt shall be 55% stone content when machine laid or 45% stone content when hand laid. Machine laying of all bituminous surfacing materials on footways is the default option. Permission shall be sought from the Warwickshire County Council to lay the surfacing by hand.

NOTE: the specification for 45% hot rolled asphalt, both 45/10F and 45/6F, are given in Annex D.

Cycleways

5.3 Cycleways included as part of the carriageway shall have the same construction as the carriageway.

NOTE: for safety reasons cycleways as part of the carriageway should be avoided in new works.

5.4 Cycleways are normally maintained using ride on vehicles and therefore they shall always be constructed using the light vehicle design, or any of the heavier options. The preferred option shall be bituminous construction as the ride quality is always better than segmental paving. Concrete shall never be used. The bituminous material shall always be machine laid as the ride quality of hand laid material is usually very poor and is never comfortable.

5.5 Although HD 39 is for footways the construction for light vehicles is suitable for cycleway use. It gives a two course surfacing design. As an alternative 50 mm of asphalt may be used in a single layer; the asphalt shall be Hot Rolled Asphalt 55/10F surf 100/150.

Last amendment May 2009

6 Cycle paths and trails

6.1 These are routes for cyclists that are constructed of unbound aggregate. Standards are being developed nationally for these and the county cycling officer shall be consulted to determine the latest position if paths or trails are constructed by the County Council.

Last amendment May 2009

7 Adoptable roads

7.1 The majority of these are for residential development. In previous editions of this document the various types of road eg type 4 collector roads were described in the estate road design guide and the structural design was given for each. The current planning guidance has done away with these classifications and this document follows the current planning guidance in giving different designs depending on the width of carriageway and the use to which the road is put. All designs are, as recommended by the CSS [1994] in ENG6/94, for a structural life of 60 years; maintenance of the surfacing being carried out as required during that lifetime. Achieving this structural life requires the provision of adequate thickness of structure and good workmanship when constructing the road, in particular proper compaction. The intention behind this long life requirement is that existing council tax payers should be in no worse position than they would have been had the development not taken place. As part of this it is essential that the design, execution and workmanship are checked and tested before committing the County to adopting the road or footway for maintenance.

7.2 The construction thicknesses given below relate to the 'optimum' widths given in the 'Transport and Roads for Developments: The Warwickshire Guide 2001'. Roads for the same class built narrower than optimum shall be constructed to the same thickness as it can be expected that the traffic carried will not be less. In summary the carriageway widths are as follows:

- 7.3 m – this is for large industrial developments and other roads carrying significant numbers of heavy vehicles
- 6.7 m – small scale industrial developments, business parks, most bus routes in residential streets
- 6.1 m – business parks and bus routes in residential streets; in either case where no demand for on street car parking is anticipated.
- 5.5 m – residential roads serving more than 50 dwellings
- 5.0 m – residential roads serving up to 50 dwellings and where the traffic speed is expected to exceed 10 mph
- 4.5 m – residential roads serving less than 12 dwellings, traffic does not exceed 10 mph and pedestrians and those with impaired mobility have absolute priority.

Sub-base

7.3 The construction thickness for these is as given in chapter 2. The thicknesses relate purely to the bearing capability of the soil and are independent of the traffic level.

Pavement construction

7.4 Construction requirements shall be as for new roads given in chapters 3 and 4 of this strategy but with increased thickness to allow for the higher design life. From the maintenance viewpoint the bituminous options given in tables 7.1 – 7.3 are preferred. Any other construction and surfacing (including coloured) shall be assessed for maintenance liability and in the probable event of it being higher an appropriate commuted sum will be charged; experience has shown that in virtually all cases the bituminous option gives the lowest long term maintenance costs.

NOTE: as an example segmental paving always costs more to maintain – not because the segments are less durable (they are not) but they often need relaying, which is expensive, often at intervals of less than 10 years.

7.5 Safety is paramount. In addition to the speed reduction measures dealt with in 'Transport and Roads for Development' it is a requirement that the road surface presents a safe interface to all users. As a minimum the Polished Stone Values given in Appendix C must be adhered to; care should be taken to ensure that all the higher values needed because of sharp bends and junctions are considered.

7.6 *7.3 m and wider single carriageways*

Table 7.1

Layer	Thickness	Material
Surface Course	40 mm	Hot Rolled Asphalt 55/10F surf 100/150 to BS EN 13108-4 (PD 6691) with a PSV_{60} and AAV_{10} aggregate
Binder course	60 mm	AC 20 dense bin 100/150 recipe mixture to BS EN 13108-1 (PD 6691).
Base	200 mm	AC 32 dense base 100/150 recipe mixture to BS EN 13108-1 (PD 6691)

Where the traffic density is such that a dual carriageway is required then the construction shall be determined in consultation with the County Council but is likely to be thicker, in total, than that given above. The surfacing in this case may be a BBA/HAPAS thin surfacing with at least 2.5 dB(A) noise reduction and a structural stiffness of more than 2 GPa. (both as stated in the appropriate certificate)

7.7 *6.7 m and 6.1 m wide roads*

Table 7.2

Layer	Thickness	Material
Surface Course	40 mm	Hot Rolled Asphalt 55/10F surf 100/150 to BS EN 13108-4 (PD 6691) with a PSV_{60} and AAV_{10} aggregate
Binder course	60 mm	AC 20 dense bin 100/150 recipe mixture to BS EN 13108-1 (PD 6691).
Base	150 mm*	AC 32 dense base 100/150 recipe mixture to BS EN 13108-1 (PD 6691)

* If the developer wishes to lay the base in two layers then AC 20 dense bin 100/150 may be used in place of the AC 32 dense base 100/150

7.8 *5.5 m wide and narrower roads and areas with shared use*

Table 7.3

Layer	Thickness	Material
Surface Course	40 mm	Hot Rolled Asphalt 55/10F surf 100/150 to BS EN 13108-4 (PD 6691) with a PSV_{60} and AAV_{10} aggregate
Binder course	60 mm	AC 20 dense bin 100/150 recipe mixture to BS EN 13108-1 (PD 6691).
Base	125 mm*	AC 32 dense base 100/150 recipe mixture to BS EN 13108-1 (PD 6691)

* If the developer wishes to lay the base in two layers then AC 20 dense bin 100/150 may be used in place of the AC 32 dense base 100/150.

7.9 Segmental paving may be permitted for these roads with the following provisos: only rectangular pavers 200 mm x 100 mm and 80 mm thick in accordance with BS EN 1338 or BS EN 1344 are permitted. The paving shall be carried out in accordance with BS 7533. Special shaped blocks may be used provided the developer or his supplier can guarantee the future provision of replacement blocks for at least 20 years from the date of construction to enable the area to be maintained in case of damage.

NOTE: although blocks normally have a long life as a block the surface in which they are used often does not unless the workmanship is of very high quality; this means they can be relaid but at high cost. However carefully this is done there is always some loss of block especially as cut blocks. It is probable that where pavers other than those defined above are used a high commuted sum would be required.

7.10 There is a serious safety problem using pavers to BS EN 1338 or BS EN 1344. There is no equivalent to the polished paver value (PPV) test (included in BS 6677 and BS 6717 which are now

obsolete) which ensured that adequate skidding resistance was maintained during the life of the pavers. If a developer wants to use block paving on these roads then he must provide evidence in the form of a PPV test result for the paver in question before he is permitted to do so. The pavers shall have a minimum polished paver value (PPV) of 55. As an alternative, for concrete pavers only, all the constituents shall be from quarries having an aggregate with a polished stone value (PSV) of at least 55.

NOTE 1: there have been occasions in the past when a PPV has not been specified and a high level of skidding accidents have ensued after a couple of years wear even where the initial skidding resistance was adequate.

NOTE 2: the advice given in HD 39 (DMRB volume 7), which is accepted as best practice, is that only standard rectangular pavers should be used. Although the durability of elements is not a problem, areas constructed with them often have fairly short lives. Using other than standard blocks may commit the Authority to a higher than expected maintenance charge in the future if, in order to repair a failure, all the blocks in an area need to be replaced. The likelihood is that if the paving fails it will be taken out and replaced with bituminous materials.

NOTE 3: no local authority can require the use of any particular brand of paver as to do so would contravene the requirements of the public procurement directive, however it is permissible to require additional performance characteristics where they can be justified..

7.11 The construction shall be as shown in Table 7.4

Table 7.4

Layer	Thickness	Material
Surface Course	110 mm	80 mm thick pavers on 30 mm sand bed
Base/binder course	160 mm	AC 20 dense bin 100/150 recipe mixture to BS EN 13108-1 (PD 6691) laid in two layers

This construction permits site traffic to use the top of the base/binder course layer during construction of the housing.

Footways and cycleways

7.12 Footways shall be constructed in accordance with table 7.5 which consists of appropriate extracts from HD 39 amended to use more durable materials. The construction for residential areas assumes light vehicle use and occasional overrun by goods vehicles and is therefore suitable for drive accesses. The construction for non-residential roads assumes occasional overrun by HGVs. Where higher traffic levels are anticipated, eg crossings into large distribution warehouses, then a full highway pavement design appropriate to the anticipated traffic will be needed. Sub-bases shall be type 1, type 3 or planings with above 80% asphalt content. Particular care should be given to evenness of the final surface for both footways and cycleways as many vehicles, for example child's buggies, wheel chairs and bicycles, that use these surfaces do not have suspension. At least the final surface shall be machine laid. Machine laying is preferred for the binder course as overall quality is usually better and it also minimises thickness variations in the surfacing..

7.13 For safety reasons only pavers which have been demonstrated to have adequate long term skidding resistance either by means of a PPV test or by using aggregate with a PSV in excess of 50 (concrete pavers only) shall be used.

Table 7.5 footway and cycleway construction

Footways and cycleways in residential areas			
Surface course	40 mm thick Hot Rolled Asphalt 55/10F surf 100/150 to BS EN 13108-4 (PD 6691)[1] with a PSV_{50} and AAV_{10} aggregate	65 mm thick pavers[3] or 400 mm x 400 mm slabs or mix all with a PPV of 50 minimum on 30 mm sand bed	
Binder course	60 mm AC 20 dense bin 100/150 recipe mixture to BS EN 13108-1 (PD 6691)	60 mm AC 20 dense bin 100/150 recipe mixture to BS EN 13108-1 (PD 6691)	
Sub-base			
CBR of subgrade	≤ 2%	2-5%	> 5% (rare in Warwickshire)
Sub-base thickness[2]	250 mm	200 mm	150 mm
Footways and cycleways in industrial and other non-residential areas			
Surface course	40 mm thick Hot Rolled Asphalt 55/10F surf 100/150 to BS EN 13108-4 (PD 6691) [1] with a PSV_{50} and AAV_{10} aggregate	80 mm thick concrete pavers[3] with a PPV of 50 minimum on 30 mm sand bed	
Binder course	100 mm AC 20 dense bin 100/150 recipe mixture to BS EN 13108-1 (PD 6691)	100 mm AC 20 dense bin 100/150 recipe mixture to BS EN 13108-1 (PD 6691)	
Sub-base			
CBR of subgrade	≤ 2%	2-5%	> 5% (rare in Warwickshire)
Sub-base thickness[2]	365 mm	250 mm	200 mm

Note 1: 55% is the normal stone content but where it impossible to machine lay the material 45% stone material may be used in limited areas (the specification can be found Annex D)

Note 2: where the sub-grade is frost susceptible the sub-base thickness shall be increased to bring the total construction thickness to 450 mm. Where the sub-base thickness is above 200 mm a combination of W75 with type 1 or type 3 may be used. (road planings to type 2 and containing at least 80% bituminous materials may used in lieu of types 1 or 3)

Note 3: the same constraints on shape shall apply as for pavers used on roads

Note 4: 25 mm of 55/6F may be used as a surfacing instead of 40 mm of 55/10F provided the binder course thickness is increased by 15 mm to maintain the structural life.

Part 2 Maintenance

8 Maintenance design process

Information gathering and assessment

Introduction and background

8.1 A wide range of information is needed, from various sources, to enable the optimum amount and type of maintenance to be carried out. If too little is done then the highway network will deteriorate, both structurally and in safety, with increasing rapidity. If too much, or the wrong sort, then resources, both financial and material, will be wasted.

8.2 The standard process of management is changing from a simple, needs based, approach to a much longer term asset management approach. At the simplest level Warwickshire has the following lengths of the various classes of highway (July 2003 figures):

- A roads 430 km
- B roads 430 km
- C roads 860 km
- D roads 1990 km
- E roads (metalled) 110 km

8.3 The asset value of the network has been roughly estimated at about £2billion. A more exact figure cannot be determined without a full inventory of the network which would include at least the following:

- The total area of each class of road
- The construction of individual sections
- The number and type of bridges
- Length, width and construction of footways
- The drainage network, including gullies, pipe work, culverts etc
- The sign inventory
- Street lighting inventory
- The value of the street scene
- Value of the land used

Each section or group would need to have its age, life expectancy and replacement cost assessed.

8.4 In addition to the human suffering caused, road casualties represent a financial cost to the community. Potential savings from casualty reduction should be taken into account in the maintenance design process. 'Road Casualties Great Britain' published by DfT assesses the financial benefit of preventing the different severities of casualties are shown in table 8.1 (2006 values).

Table 8.1 savings from prevention of casualties

Casualty type	Potential saving (2006 prices)	Potential savings(estimated for 2007 using update formula)
Fatal	£1,489,450	£1,522,218
Serious	£167,360	£171,042
Slight	£ 12,900	£13,184

In addition the value of damage only crashes cost an estimated £1697 in built up areas (speed limit 40mph or less) and £2515 on other roads (2007 prices). In addition there are delay costs to other

motorists and these are likely to rise as traffic levels increase and the Police treat more crashes as ‘scenes of crime’ which means a road is closed for longer periods of time.

The total cost of the 2,999 road casualties in Warwickshire in 2004 was £161 million. In 2007 the total number of casualties on Warwickshire roads reduced to 2677 at a cost of £141 million thus saving £20 million for UK plc.

The main source of data on road casualties is the database maintained by the Intelligence Team in the Road Safety Unit.

8.5 The main advantage of asset management is that the cost of maintenance is calculated on a whole life basis and the maintenance option which maximises the asset value with the lowest total expenditure over the life of the pavement can be determined. Even if it were not possible to carry out all the optimised maintenance the penalties for not so doing can be calculated. Also calculable would be whether the total asset value were increasing or decreasing.

Data sources

8.6 The main sources of data used to assess maintenance needs are:

- SCANNER
- Coarse visual inspections
- SCRIM
- Deflectograph
- Serviceability inspections
- Collision data
- Information from the public

8.7 The main sources of data used to design maintenance treatments are:

- Deflectograph
- Collision data
- Road Note 39 (for surface dressing)
- Traffic flows
- Records of historic maintenance treatments
- Various parts of Design Manual for Roads and Bridges (DMRB) volume 7
- SCRIM
- This document

Last amendment May 2009

9 Maintenance options

General

9.1 Maintenance covers a wide range of possibilities ranging from a minimum intervention of 'patch and make do' to a significant structural overlay, or, on rare occasions, total reconstruction. Different treatments have different properties and the choice will depend on the required final outcome. Availability of finance should not be part of the initial decision making process. If insufficient funds are available and a lower level of maintenance is carried out than is justified technically then the fact should be recorded and the site monitored to determine, for future use, the cost effectiveness of the reduced maintenance. A summary of the options is given in table 9.1 together with a summary of their properties. More information is given in HD31 for flexible roads and HD 32 for rigid ones.

9.2 Each option should be considered on a cost benefit analysis. An assessment should be made of the street scene amenity value so that it can be included in the analysis.

9.3 The optimum treatment will depend on what the need is. For example if the need is simply to restore skidding resistance then surface dressing is likely to have the highest benefit to cost ratio. Another example would be if the structure had failed then either an overlay or a recycling treatment could well be optimum. Experience and good historical records will reduce the need for numerical calculations.

9.4 Good records are also required to provide the knowledge of how long different treatments last in different situations. Table 9.1 gives some general guidance on the durability of treatments and also what they can and cannot do.

9.5 When the structure of the road is being improved it is difficult to forecast what improvement in life a given overlay provides unless the work is being carried out following a Deflectograph survey when the extension of life for a given overlay or the overlay for a given life extension can be determined using LR 833 [Kennedy and Lister 1978]. It may seem surprising to use such an old document but deflectograph still uses the research published in it and modern computer systems only compute the overlay required for a given traffic level and not the inverse. Further information on the structural contribution of thin surfacing is included in the supporting papers.

9.6 A useful flow chart that can be used to assist in choosing options can be found in HD 30/99 Figure 7.1.

Last amendment May 2009

Treatment	Thickness range	Increase pavement strength?	Texture depth	improve Skid resistance	Reduce permeability of pavement	Improve ride quality	Initial cost	Speed of construction	Re-profile	Noise reduction	Expected life	Level of sustainability
	mm	Yes/no	mm								years	Range -- 5 to + 5
Patch (with no other treatment)	Any	No	No	No	No	No	Very high	Slow	No	No	0-3	-- 2 to -- 4
Retexturing	0	No	1.5	Yes in medium term	No	No	Low	Fast	No	No	3 then re-do	+ 3 to + 4
Surface dressing	6-14	No	1-3	Yes	Yes (best)	No	Low	Fast	No	No	10-15*	+ 4
Slurry surfacing	6-15	No	0.5-1.5	Yes	A bit	Can do	Moderately low	Fairly fast	Yes	No	5	+ 2
HAPAS thin surfacing	15-50	Some do	0.5-2	Yes	Usually	Yes	Medium to high	Moderate to fast	Yes	Yes	10-15	+ 2
55% hot rolled asphalt	30-70	Yes	0.3-1	Yes	Yes	Yes	Medium	Moderate	Yes	Yes	10-15	+ 2
High friction systems	3-5	No	0.5-1	Yes (best)	A bit	No	Very high	Slow	No	No	3-10	-- 4
Structural overlay	80+	Yes	Depends on surfacing	Yes	Yes	Yes	High	Slow (to moderate)	Yes	Depends on surfacing	20+ for structure	+ 4
Haunching	80+	Yes, locally	Depends on surfacing	Depends on surfacing	Yes	Yes	Medium to high	Slow (to moderate)	Yes	Depends on surfacing	20+ for structure	--2 to + 2
Retread with 2 surface dressings	75-100	Yes	About 1	Yes	Yes	Yes	High	Fairly fast	Yes	No	10+ (as structure)	+ 3
Deep recycling with foamed bitumen	150-250	Yes	Depends on surfacing	Depends on surfacing	Yes	Yes	Very high	Moderate	Yes	Depends on surfacing	20+ for structure	+ 4

*when done to current Warwickshire standards

Table 9.1 Treatment options

10 Surfacing and overlaying

Introduction

10.1 Surfacing is required to perform four main functions in various combinations. Each surfacing type has its own strengths and weaknesses and no single surfacing type is best in all situations. The four functions are:

- to waterproof the pavement structure,
- to add strength to the pavement structure,
- to provide good ride quality and
- to provide adequate skid resistance (this includes macro-texture where required).

For more details on these subjects see appendix A to this chapter and for a short discussion on skidding resistance see Appendix B. For the specification of PSV and Aggregate size combinations see Annex B to this strategy.

10.2 The County has a limited budget for road maintenance and the aim should always be to maximise the long term value obtained from that budget. The first choice maintenance option should always be surface dressing as it is the pre-eminent surfacing for waterproofing the structure and is equal to any for providing skidding resistance. Only if it is necessary to add strength to a pavement structure or to improve ride quality would a paver laid surface be considered. For residential roads slurry surfacing can improve ride quality but not as well as paver laid surfaces and does not improve the pavement strength.

Surfacing on lightly trafficked roads

10.3 Lightly trafficked roads are those categorised as type 4 in the New Roads and Street Works Act; ie those carrying up to about 100 cv/l/d. In the normal road hierarchy this type will include virtually all D (unclassified) roads (98.4%) and many C roads (87%). As can be seen from the summary table the preferred surfacing type on these roads is 55/10F hot rolled asphalt for all the different options of rural or urban situations. Other surfacings may be used but only where there is justified need which shall be recorded as part of the design process. This is most likely where there are particularly onerous environmental considerations.

Surfacing on other roads

10.4 The usual surfacing on more heavily trafficked roads shall be either 55/10F hot rolled asphalt or a thin surfacing with a BBA/HAPAS certificate. Proprietary surfacings without a BBA/HAPAS certificate shall not be used. Other surfacings may be used but only where there is justified need which shall be recorded as part of the design process. Where a BBA/HAPAS thin surfacing is used due consideration should be given to IAN 49/03

NOTE : IAN 49/03 does not apply to BBA/HAPAS thin surfacing based on slurry surfacing or surface dressing.

Overlaying

10.5 Where more than a single layer of surfacing is required a number of options are open depending on the category of road and the thickness required. For roads carrying significant traffic the overlaying will normally be carried out in 2 or more layers with the surfacing as above but the additional layers would normally be 20 mm DBM125. On very lightly trafficked roads a combined layer consisting of either 55/10F hot rolled asphalt (up to about 70 mm maximum) or, currently being trialled, 20 mm Masterflex which may be used for a single structural/surfacing layer between 50 and 100 mm thick. With current knowledge it should be limited to roads carrying less than 100 cv/l/d. When Masterflex is used due consideration should be given to IAN 49/03, there have also been reported problems with horses slipping on it so care should be taken when using Masterflex on horse routes.

High friction surfacing

10.6 ***There is rarely justification for this type of surfacing in Warwickshire***. High friction surfacing shall only be used for reduction of skidding crashes and not for any other purpose; it is very

expensive, often has the shortest life of any surfacing and has a very high environmental cost. Before using high friction surfacing on an existing road (eg where the site category has been increased by installation of a pedestrian crossing) the existing skidding resistance shall be checked, either from existing data or a specific Grip Tester survey and repeated in the summer following installation; only if there is a demonstrated need should high friction surface be used although there may be need for some enhancement of skidding resistance. Surface dressing could usually be used to provide this enhancement with a suitable design. See chapter 16 for more information on specifying and laying High Friction Surfacing. See also the Skid Resistance Strategy for the procedures to be used to assess skid resistance.

NOTE: draft CSS guidance states the High friction surfaces are rarely needed

Coloured surfaces

10.7 Coloured surfaces are useful for various traffic management purposes but they should only be used where their need is demonstrable. More information on ways of obtaining coloured surfaces in given in Appendix C to this chapter.

If it is necessary to provide a coloured surface there are a number of naturally occurring coloured aggregates in the UK that could be used and these provide colours that are not bright and glaring and they could be incorporated in surfacing materials which would have long life and would maintain their colour throughout their lives. [Nicholls 1998].

10.8 Calcined bauxite shall not be used in a coloured surface unless its high friction performance is required.

NOTE: some authorities are removing coloured surfaces from areas such as bus lanes and cycle paths and are finding that this has no effect on their use.

Table 9.1 Summary of first choice surfacing types to be used (other than surface dressing)

	Traffic level	**0-20 cv/l/d**	**20-100 cv/l/d**	**More than 100 cv/l/d**
Speed limit	*Road type*	*HAUC type 4*	*HAUC type 4*	*HAUC type 3 or above*
50-60	*Single track*	55/10F-125	55/10F-125	n/a
50-60	*Two lane*	55/10F-125	55/10F-125	55/10F-125**
50-70	*Dual carriageway*	55/10F-125	55/10F-125	HAPAS Thin surfacing
40	*Two lane*	55/10F-125	55/10F-125	55/10F-125**
40	*Dual carriageway*	55/10F-125	55/10F-125	HAPAS Thin surfacing
20-30	*Cul de sac*	55/10F-125 or slurry surfacing*	55/10F-125	n/a
20-30	*Residential*	55/10F-125	55/10F-125	55/10F-125
30	*Through route*	55/10F-125	55/10F-125	55/10F-125

* the slurry surfacing shall be to clause 918 of SHW with the appropriate specification of performance related parameters and shall be designed to take a high proportion of slow speed (including stationary) power steering..

** where noise reduction is required a BBA/HAPAS thin surfacing with a noise reduction level of at least 2.5 dB(A) should be used.

Note: where a structural contribution is required the BBA/HAPAS certificate should provide a value of claimed stiffness above 2GPa.

55/10F-125 is short hand for: Hot Rolled Asphalt 55/10F surf 100/150.

Surface dressing may be used on any class of road provided it is correctly designed and if structural improvement is not required

10.9 When resurfacing with hot paver laid materials any ironwork within the carriageway shall be reset to its final level before the surface course is laid. If for some very good reason this not done then the area around the ironwork which is cut out in order reset it shall be reinstated with a BBA/HAPAS certificated inlaid crack sealing system (eg Permatrack – BBA/HAPAS certificate number 02/H072). On no account shall the hand laying of thin surfacings be attempted as they always fail very early.

NOTE: 'Permatrack' is given here as an example for information. It cannot be specified as such as that would contravene the Public Procurement Directive (PPD)

Last amendment May 2009

Appendix A to Chapter 10

Surfacing Capabilities

Waterproofing the pavement structure

10.A.1 It is very important to keep water out of the pavement structure. The first line of defence in this respect is the surface course. Surface courses vary considerably in their ability to waterproof the pavement. In general the richer the mixture and the lower the void content the better the waterproofing ability of the material. The pre-eminent surfacing in this regard is surface dressing because it has a continuous thick binder film across the whole road; it is almost totally waterproof unless there are unbridgeable cracks in the existing road. Hot rolled asphalt, of any stone content, is also very good. The thin surfacing materials are very variable in this respect; some are very good either because they have low voids or they have a thick bond coat whereas others are quite permeable. Asphalt concrete surfacings are poor in this regard which is a factor contributing to their non-use in Warwickshire. Even the so called dense macadam surfacing is quite permeable and the close textured ones certainly are. Slurry surfacings are also relatively permeable as they need moderately high voids to allow the water involved in their binder to escape. Porous asphalts by their nature are very permeable.

Adding strength to the pavement

10.A.2 Most hot dense surfacing materials add strength to the pavement structure. Surface dressing and slurry surfacing do not add any strength. Thin surfacings are very variable in this regard, some add significantly to the pavement structure while others have no significant effect. Hot rolled asphalt also adds strength. What is indisputable is that these strengthening effects are only valid where the pavement is in a sound structural state. **No surfacing of any type can rescue a failed road**. Resurfacing a failed road may hide the defects for a few weeks, a year at the outside for lightly trafficked roads. The structural contribution from porous asphalt and asphalt concrete surfacing should be ignored.

10.A.3 If a higher level of strength improvement than is given by a standard surfacing is required then either a thicker layer of 55/10 asphalt or a thick layer of proprietary strengthening surfacing (eg Masterflex) may be used. As an alternative a binder course plus surfacing combination may be used.

NOTE: where a BBA/HAPAS thin surfacing is used only those with claimed stiffness above about 2GPa may be considered as part of the structural thickness.

Improving ride quality

10.A.4 Only paver laid surfacings provide good ride quality. Surface dressing has no effect on this parameter. Slurry surfacing can improve the quality where the irregularities are short wavelength such as on roads where utility reinstatements are numerous and poor. Paver laid thin surfacing is particularly good in this regard as they are usually quieter than traditional materials and are usually perceived by motorists as more comfortable than a noisier surface with the same level of irregularity.

Providing adequate skid resistance

10.A.5 This is the surface parameter that contributes most to road safety. There are two fundamental misconceptions with this parameter: PSV is usually thought to be synonymous with skidding resistance – it is **NOT**; and that the higher the skidding resistance the lower the accident risk. This latter is only true at low levels of skidding resistance; once the skid resistance level reaches a threshold (which varies from site to site) skidding accident rates do not reduce further and may increase. Too high a skidding resistance usually means that resources have been wasted. PSV contributes to skidding resistance but aggregate size, traffic

flows, time of year and site layout contribute usually more variability to the skidding resistance of a site. PSV and aggregate size are controllable inputs whereas all the others are beyond the control of the maintenance engineer but can be designed for. Site layout is changeable in the long term but is an expensive option.

Other factors

10.A.6 The above factors are not the only ones to be considered although they are the main technical ones. Other factors that need to be taken into account are:

- Appearance – particularly in town centres, villages, conservation areas and other environmental sensitive situations. Evenness of appearance comes high on the list of priorities for acceptability of a road surface (public consultation exercise – see Tim Bowtell); it is higher than ride quality for residential areas where heavy traffic is uncommon. Multiple patching has very low acceptability even when very well done.
- Colour is also part of appearance but can be determined separately. The most durable colours are those where the aggregate is used to provide the colour rather than using pigments. Colours provided by aggregates are much more easily matched for repairs or extension of the surfacing as they are inherent in the material and do not degrade with time and aggregate from the same source is normally of the same or a closely toning colour. See also Appendix C to this chapter.
- Time of year – some surfacings cannot be laid in winter – eg surface dressing. Others, such as high friction surfacing, **should not** be laid in Winter.
- Noise – in noise sensitive areas the likely noise generation should be part of the design process. 55/10F HRA is a reasonably quiet surface and for lightly trafficked roads and those with a 30 mph speed limit or lower there is no noise justification for using a thin surfacing; there could just be a marginal justification on more heavily trafficked roads where the 30 mph speed limit is routinely exceeded. Poor reinstatements can excite high levels particularly when traversed by empty lorries
- Cost is obviously a consideration, but only in conjunction with expected life, all the other factors should be considered first and a **best value** surfacing should be arrived at.

Appendix B to Chapter 10

Summary of factors affecting skid resistance

10.B.1 There are a number of factors affecting the skidding resistance of any particular location of which polished stone value is only one, and not always the most important one.

10.B.2 The major ones with an estimate of their potential relative effect on skid resistance is given in table B.10.1

Table B.10.1 Relative effect on skid resistance of various factors

Factor	Relative effect - range	Notes
Time of year	15 or more, the extreme so far is 28	Skidding resistance is lowest in mid to late summer. Weathering in winter, polishing in summer
Aggregate size	20	3 mm highest, 14 and 20 mm lowest
Speed (low texture) eg 55/10 asphalt	9	Drop in skidding resistance from 30 mph to 60 mph. Below 30 mph skidding resistance increases with low texture
Speed (high texture) eg racked in surface dressing	2	Drop in skidding resistance from 30 mph to 60 mph
Traffic level (0-250 cv/l/d)	14	This is the drop between no traffic and 250 cv/l/d. additional polishing due to increased commercial traffic. Little change above this level.
Turning and braking	6	Difference between no stress and turning and braking due to additional polishing action
PSV	10	Range normally used in surface courses (55-65)

10.B.3 A more detailed paper in included within the supporting papers.

Appendix C to Chapter 10

Coloured surfacings

10.C.1 There are many coloured surfacings on the market. They are based on one of two means to provide it: either by the use of pigments or by the use of coloured aggregates; sometimes both methods are used.

10.C.2 When made with uncoloured binders pigmented materials are often brighter initially but are prone to fading unless inorganic pigments are used. However many inorganic pigments are based on heavy metal compounds eg chromium or cadmium salts which are toxic. The traditional coloured materials are coated bituminous materials pigmented with iron oxide (non-toxic) but this gives a muddy red brown colour because of the black binder used. They are relatively durable although usually somewhat less so than the equivalent unpigmented materials; this is due to the higher fine filler content. Any pigmented material that is used must use non-toxic pigments as there is always wear to the surface which generates respirable dust and disposal when the coloured surface is removed is very difficult and expensive and getting more so.

10.C.3 Organic pigments are usually non-toxic and when used with clear binders can be initially very bright but often fade very quickly. Because of this fading it is very difficult to match colours if remedial works have to be carried out. Pigmented materials are often hand screeded which exacerbates the matching problem as texture can vary from screed to screed and this has an apparent effect on colour. Screeded materials usually have poor durability as they tend to debond early with the process often starting in less than a year. They are also very expensive both in first cost and maintenance cost. All pigmented materials and particularly screeded ones should be avoided unless no other process is usable.

10.C.4 Whether pigments are used or not the ultimate colour of any surfacing is that of the aggregates that are contained within the material. the colours of aggregates do not fade (they are geologically old) and matching is easy – as long as the aggregate comes from the same source – the blending in is usually very good. They can also be used in durable materials and processes such as surface dressing (preferred as the colour is there from day 1) or coated materials. If the coated materials are made with a clear resin the colour is again available from day 1. The cheapest and most durable option is to use a coloured aggregate in a conventional bituminous material but the colour takes time to develop; this option is of limited use for traffic management but may be of use in developments.

10.C.4 Where a particular colour is not required, eg as part of speed reduction measures then it is possible to use aggregates entirely from local sources. For example: on the usual dark grey of Warwickshire's road using either Bardon Hill or Bayston Hill aggregate a contrast can be obtained using Croft which is a reddish colour. This is a procedure used in Northamptonshire for many years where the rural roads were done in grey and speed limited areas in villages were done in 'red' (usually Croft). A trial has been done on the B4453 at Weston under Wetherley at the village gates at both ends of the village. The aggregate used was Castle an Dinas (very light grey) and was done at the same time as the main run of standard surface dressing through the village thus adding very little to the cost..

10.C.5 There are a number of coloured aggregates available and the currently known sources are summarised in table 10.C; there are probably others

Table 10.C Summary of coloured aggregates

Colour	Source	PSV	Comments
Green	Criggion, Shropshire	60*	This aggregate has been used in the County for many years and is still visible in many areas
Green	Ghyll Scaur, Millom, Cumbria	67	This has been used a few times in County and thought to be still extant in one location
Red	Harden, Northumberland	52	
Red	Brindister, Shetland Islands. (Imported into Kings Lynn)	64	Very little known about this source
Reddish	Croft, Leicestershire	56	
Pinkish red	Wick, Near Bath	60	
Buff	China	70	Calcined bauxite, very high environmental cost. Use only where high friction is required
Light grey	Castle au Dinas, Cornwall	55	Other quarries in Cornwall may also have very light coloured aggregate
Various	Natural gravels	45 typical	May be suitable on very lightly trafficked roads.

* often behaves as if the PSV were lower than this

NOTE: The drive of Compton Verney House is an example of the use of natural gravel (although the workmanship could have been better).

11 Haunching and strip widening

11.1 Haunching is a very useful technique as it is often the case, particularly in rural areas, that the edge of a pavement fails long before the rest of the road. When the technique is used to add width to a road it is known as strip widening but the requirements are identical. It is usually very uneconomical, both financially and materially, to overlay the whole carriageway with enough material to prevent failure in these weakest areas at the edge of the carriageway. The cause of such failures is usually creeping widening of the carriageway over the years with material being placed in ruts at the edge where traffic has overrun and then subsequently surface dressed and patched and surface dressed again. Haunching is always built to full construction depth for new work even though this is usually thicker than the existing. The existing has usually had many years of compaction and adjustment to construction which the new work has not and also the new work forms a support for the rest of the road width.

11.2 Haunching consists essentially of the reconstruction of about a metre width (usually between 0.5 m and 2.0 m) along the edge of the carriageway cutting back into sound construction. The edge of the excavation should be stepped so that when the haunch is rebuilt the new work is married into the old in such a way as to minimise the likelihood of water penetration. The outer edge of the excavation must be wide enough so that when it is backfilled with stone the final carriageway is supported at an angle not less than 45º to the horizontal; ie if the excavation is 700 mm deep it shall extend at least 700 mm beyond the final edge of the carriageway. If this is not done failure of the new edge will occur fairly rapidly after reconstruction. This width shall take into account any additional thickness added by means of an overlay over the whole width.

11.3 Once the sub-base is in place – the thickness required shall be that described in Chapter 2 under ‘new construction’ – all further layers shall be laid by machine (except for the rare instances where this is impossible). The surface course of the haunching shall always be machine laid even when subsequent overlaying is expected. The steps against the old construction shall be coated in bond coat both on the horizontal and vertical faces to ensure that the whole construction becomes a monolithic whole.

11.4 Overbanding shall not be used unless the existing surface is fretting (this is fairly rare) when a narrow overband, not exceeding 40 mm wide may be used with the bulk of the width on the old surface. Overbanding shall never be used if the carriageway is to be surface dressed within the next two years. Overbanding can be a hazard to motorcyclists as its skidding resistance is poor. Its joint sealing is also poor as it will crack in the first winter due to thermal movement, good treatment of the vertical joint is much more effective as a seal.

NOTE: overbanding always reflects through surface dressing forming a fatty and potentially slippery strip significantly wider than the original overbanding thus forming a hazard to road users, particularly those on 2 wheels.

Last amendment May 2009

12 Patching

12.1 Within Warwickshire patching is used in two distinct ways. The first is to make the road safe and this is often done by the safety inspection teams who cover the county highway network in a standard manner or as result of information received from the public. The other is planned patching which takes place where a road is showing signs of distress but is not dangerous. Whenever a road needs patching a record of the cause or causes and the likelihood of further patching in the vicinity must be undertaken.

Safety

12.2 Small areas of loss of material must be filled quickly if they constitute a hazard. These are defined in the county maintenance policy. Where the pot hole is in a place where the road is habitually crossed by pedestrians – eg at junctions, outside churches, chapels, meeting halls etc the possibility of a pothole also being a trip hazard should be considered and perhaps a speedier response than would normally obtain may be necessary. Alternatively the filling of potholes smaller than would normally be the case may be needed. Either bagged material or deferred set materials may be used. Often these have short life (although this seems to be improving, particularly with bagged materials) and the patches may need redoing at intervals until the proper planned patch or other treatment is carried out. In any case good compaction will prolong the life of the patch, rolling with the wheels of a vehicle may well provide better compaction than a hand punner provided that care is taken to maintain reasonable surface regularity.

Planned patching

12.3 Planned patching may be carried out for a number of reasons:

- Prior to surface dressing or other resurfacing
- To rectify problems with utility reinstatements
- To extend the life of the pavement structure. A benefit/cost assessment, including the likely cost of further patching from the same cause, should always be carried out before this reason is acceptable as patching is often a very expensive exercise in terms of unit cost.
- When resetting ironwork that has sunk, is rocking or has failed in some way and is being replaced.

12.4 Planned patching should be carried out as early as possible after marking out – our customers are not impressed by yellow lines fading with time and nothing being done. The patch shall be set out so as to include all of the pothole plus any area likely to fail within the foreseeable future. The outer edge of reinstatement shall be at least 100 mm beyond the edge of the current pothole. If there has been any delay in carrying out the reinstatement the area shall be reassessed immediately prior to reinstatement and if the pothole has enlarged, as is likely if the reinstatement has been delayed by more than a week or two, then a larger area shall be treated to include the whole of the damaged surface.

12.5 All vertical faces shall be sawn and the layer removed up to the saw cut. The preferred option is to remove the material using a planer to avoid the use of vibrating hand tools. A planer removes a more consistent thickness which improves the quality of the reinstatement. Where a planer is used it is not necessary to saw cut as a planer leaves a sufficiently neat edge. Where more than one layer is being reinstated the surface course shall be cut through and removed and then the binder course layer saw cut at least 75 mm smaller all round and then the failing binder course should be removed. Again both layers can be taken out by a planer but still leaving a 75 mm wide step at the base of the surface course.

12.6 Where saw cutting takes place as a separate operation ahead of the reinstatement it should not be done more than a few days in advance as the cuts allow ingress of water into the structure. If a two course patch is required then the advance cutting shall be one shallow cut (approx 40 mm) around the outside and a concentric deeper cut 75 mm (or more) inside it to the depth of the bottom of the binder course. Where determinable, whole layers shall be removed with a minimum of 40 mm for surface course patches.

12.7 The whole of the horizontal and vertical faces shall be coated with a suitable bond coat. Overbanding shall not be used except where the existing surface is in danger of fretting when a band not exceeding 40 mm wide may used with at least two thirds of its width on the existing surface course. Its purpose is purely to assist in preventing further deterioration; Overbanding does not seal a joint for very long as the joint propagates through and the overbanding cracks. Overbanding shall never be used if the road is going to be surface dressed within the next two years.

12.8 Reinstatements, when hand laid, shall use hot rolled asphalt 45/10F surf 160/220 (Annex D). This may be used for the whole depth of a reinstatement provided that it is laid in layers not exceeding 60 mm and each shall be fully compacted before the next layer is placed. Where the material in a layer is still warm to the touch when the next layer is placed there is no need to use a bond coat between layers. However if, for example, the binder course is left overnight before the surface course is laid the binder course shall be sprayed with tack coat or bond coat before placing the next layer. Where patching is extensive it may be better, technically and visually, to use a mini-paver for laying material in which case hot rolled asphalt 55/10F surf 100/150 should be used.

12.9 Permanent reinstatements shall not use deferred set or cut back materials. asphalt concretes to EN 13108-1 shall not be used as surfacing. Although they often appear to be more workable than 45/10 asphalt they are much more permeable even when well compacted and do not match any surfacing used in Warwickshire for over 20 years. If used prior to surface dressing macadams, even close textured or dense ones, are more porous than existing surfaces whether they are asphalt or surface dressing and it is likely that a local failure over the patch will ensue as there will be insufficient binder to retain the chippings within the area of the patch. There is currently no suitable patching material which will give reasonable match to any of the BBA/HAPAS thin surfacings and on no account shall hot thin surfacing material be hand laid as they are totally unsuitable for this purpose because of their very high stone content and hard binder.

12.10 New patching materials are being developed but are as yet unproven. Their use shall be limited to fully monitored trials unless they have a BBA/HAPAS certificate when they may be used within the certificated limits.

12.11 Where there is a structural failure then the patch shall consist of 200 mm of bituminous material or the thickness of the existing pavement if greater. This material may be 45/10F or 55/10F asphalt (as appropriate to the laying method) but if the area is extensive it may be better to use 2AC20 dense bin 160/220 for all but the surface course.

Patching on pavement edges

12.12 Patches at the edge of unkerbed pavements shall follow the general requirements for patching given above but care shall be taken to ensure that the road width is not increased, ie the outer edge of the patch shall be in line with the rest of the road edge. If it is necessary to add support to the edge of the road because traffic has overrun and caused significant rutting then the ruts shall be excavated to a depth of 300 mm and to a minimum width of 300 mm and backfilled with suitable free draining crushed rock such as W75 or coarse bituminous planings to a level approximately level with the road edge and then some verge material shall be placed on top so that it does not look like a widened pavement.

Patching round ironwork

12.13 Patching around ironwork is probably the most difficult type to do successfully and durably. The most important factor is to ensure that the cover is properly and firmly but resiliently set. If this is not done and there is even the slightest degree of rock the reinstatement will fail rapidly. Therefore stage one is to reset the ironwork in a sound manner. By far the best is to use a resilient material to set the frame. There are a number of proprietary systems on the market, not all of which are suitable for maintenance purposes. If the traditional cement mortar approach is used then it shall not be made too strong and thin pieces of build up such as tile shall not be used as they cause rapid failure.

12.14 Once the frame has been set and any build up material set sufficiently to carry traffic without movement (this may be overnight with cement based materials) the reinstatement of the surrounding area may be undertaken. It is most important that this is done in such a manner as to minimise any possible ingress of water. The whole of the surface of the iron frame shall be fully coated in a suitable bond coat – both vertical and horizontal surfaces, the vertical face of the surrounding pavement

structure and any visible horizontal pavement structure shall likewise be coated. The reinstatement shall be carried out using hot rolled asphalt 45/10F surf 160/220 (Annex D). On heavily trafficked roads or where the ironwork is in a wheel path 100/150 grade binder may be used to limit deformation. Even more likely to be durable are BBA/HAPAS inlaid sealing materials certificated for the thickness and width to be used.

NOTE 1: 'heavy' in this context means HAUC types 0 or 1 roads.

NOTE 2: on roads less than 6.7 m wide even gullies are in the wheelpath of heavy vehicles.

12.15 There are number of new processes coming on to the market specially designed for ironwork reinstatement and trials should be carried out on a representative selection of suitable ones.

Last amendment May 2009

13 Traffic safety

13.1 Traffic safety interventions includes various modes of traffic management introduced for purposes such as accident reduction, speed reduction, and environmental improvement. These are all regarded by the public as being aspects of traffic calming regardless of the reason for the intervention.

13.2 When traffic calming is introduced on a site the design should be based on the whole life cost of the scheme and not just the initial cost. This is in line with asset management principles.

13.3 Examples of factors that shall be taken into account are:

- Initial cost
- Decreases in structural life downstream of humps, cushions and transverse road markings due to increased dynamic loading
- Increased routine maintenance costs due to factors such as the need to sweep by hand between 'build outs' and existing kerbs
- Need for higher PSV aggregates because of the increase in investigatory level caused by turning and braking
- Maintenance costs such as need to replace road markings on a regular basis (life expectancy of white lines about 4 years or less) and the need to remove them in their entirety before resurfacing.
- Damage levels to street furniture and signs which in some cases can be frequent.

NOTE: The multiplicity of teams dealing with these types of matters should get together to work up a practice document which can be used to assist in the determination of whole life costs.

13.4 There is guidance within the 'Transport and Roads for Developments: The Warwickshire Guide 2001' [WCC 2001] on the use of traffic calming on new estates.

13.5 High friction surfacing should be used where its skid resistant properties can be demonstrated as likely to reduce casualties but not otherwise. With the traffic levels on Warwickshire's roads it is very rare that high friction surfacing is needed. For further information on specifying and laying High Friction Surfacing see Chapter 16. See also CSS guidance (currently in draft) which says the need for HFS is rare of Local Authority roads.

13.6 A full justification in terms of accident reduction shall be carried out before high friction surfacing is used. Annex B gives the equivalent Polished Stone Values for different aggregate sizes for various situations. As can be seen the use of aggregate smaller than the standard 20 mm on which Highways Agency advice is based can be used to provide more than adequate skidding resistance. For example the use of 6 mm size promotes a 60 PSV aggregate to the equivalent of about 74 which is more than adequate for virtually all sites, although a more conservative value is used in Annex B.

13.7 Sections using coloured surfacing are frequently used within these areas particularly as passive speed control devices within villages (Village speed limit review). Currently these are often provided using a screeded surface which usually incorporates calcined bauxite utilising either buff bauxite to provide colour contrast or are pigmented in addition to highlight a possible hazard. Calcined bauxite has the highest environmental cost of any aggregate (and possibly of any material) used on UK roads. The calcining process takes place at 1700ºC which is obviously very energy hungry and the process itself, particularly that used in China, is also heavily polluting of the local area in terms of smoke generation (serious health problems have been unofficially reported). Therefore, wherever possible, naturally occurring UK aggregates shall be used, there are a number of suitable aggregates available which would contrast with the normal dark grey which is used most often Warwickshire. See also Appendix C to Chapter 10.

NOTE: for example pink granite from Croft could be used to contrast with the grey of Bardon Hill.

13.8 Pigments also carry a risk as some are toxic and care must be exercised to ensure that toxic pigments are never used. The problems arise in the production of dust as they wear and their removal at the end of their life which can spread toxic materials far and wide.

13.9 Whenever a high friction surface has been used for colour and not its high friction properties there is a significant risk of poor safety. Examples of unsafe use are: use on part width of a road such

as in a cycle way at a side junction or it has a significant area of white marking on it. The aim should be to maintain an even level of skidding resistance across the whole lane (or potential lane – eg where traffic can move into a cycle way).

13.10 Where a full lane width is not treated it is quite likely that a vehicle braking will have one side of the vehicle on a normal surface and one side on a high friction surface which could induce a spin on heavy braking or even, in the case of an articulated vehicle, jack knifing. Similarly screeded markings, whether white, red or yellow, have relatively low skid resistance and where they are placed on a high friction surface there could be the possibility of differential braking. There is a further hazard in this case and that is to motorcycles. If there is straight line braking then there could be sudden loss of grip as the front wheel moves from high friction surface to white marking possibly causing the rider to fall. It is possible that a sudden increase from low skidding resistance to high could also be a hazard. If this combination of high friction surfacing with low friction markings is used on a bend then a motor-cycle rounding the bend could slide on the white line and this would inevitably be hazardous [IHIE 2005]. A very high level of skidding resistance can increase the rate of crashes caused by skidding.

13.11 In all cases a full risk analysis, by a team independent of the design team, must be carried out to determine the overall safest combination of engineering measures.

Last amendment May 2009

14 Surface dressing

14.1 Surface dressing is the major maintenance operation, by area, carried out within the county. Warwickshire has a very good record of successful surface dressing and has one of the lowest failure rates of any local authority or contractor. This is due to the very close liaison between the client and the contractor which has developed over many years. Almost all the failures that have occurred have been when the rules have been broken; for example when work has carried on into September or the work has been carried out when the weather has become unsuitable in order to finish a section. It has been calculated that rectifying a failure can cost between 5 and 10 times the original cost of the dressing. Risking failure can be very costly.

NOTE: There is scope for improving the durability of surface dressing by increasing the rate of spread of binder above that given in Road Note 39. There is very little record of fatted up surface dressings in Warwickshire since the switch to polymer modified binders and the more binder there is on the road the more durable is the dressing going to be. The overall aim should be an equal number of ultimate failures which are due to fatting up and to fretting although the majority should always be by overall wearing out.

14.2 Generally the guidance given in Road Note 39 shall be used. (It is heavily based on Warwickshire experience over the years as WCC had some of the best records of what was done and how it performed.) Provided that the surface dressings are properly designed they may be used on all categories of site although great care must be taken when considering its use on the circulation areas of small roundabouts. If they carry heavy vehicles with multiple rear axles in significant numbers surface dressing may not be suitable as the rear wheels of these vehicles often have a significant sideways component to the direction of travel which can destroy the dressing before it has fully stabilised. Mini-roundabouts where the path of such traffic is over the central roundel do not generally cause problems as the turning radius is greater.

14.3 Not all the options given in Road Note 39 are now permitted in Warwickshire. The main limitations being:

- Only emulsion binders shall be used
- Only polymer modified binders shall be used (intermediate, premium or super-premium grade as appropriate)
- No single layer dressings using 6/10 mm or 8/14 mm chippings shall be used
- 10 mm dressing shall be either racked in or double with the latter being used on higher stressed sites.
- 14/6 double dressings shall only be used where absolutely necessary – usually only lane 1 of heavily trafficked dual carriageways (eg Bedworth Bypass)
- 14/6 racked in surface dressing shall not be used.

14.4 Successful trials have been carried out over the last three years into the use of the first sweepings from 10 and 6 mm dressings (mixed) on very minor rural roads. This should continue with great care being taken to ensure that the chippings are adequately clean for the purpose.

14.5 Where surface dressing is to be carried out over road markings they should normally be removed unless they are thin and outside the normally trafficked area. Surface dressing does not adhere well to thermoplastic lines. Not removing them in trafficked areas will result in a significantly reduced life as well as an uncomfortable ride which can lead to early structural failure because of increased dynamic loading. They shall always be removed in the following cases:

- Where new or revised traffic management is being carried out and traffic will travel over the area of the old markings – if this is not done traffic will try to avoid the unpleasant level of roughness and stray – for example – into a new cycleway included within the carriageway (eg B439, Evesham Road, Stratford).
- Zigzag lines, whether the ones outside schools or the no stopping ones adjacent to pedestrian crossings.
- Any other marking within the normal lane width if it has been applied more than once since last resurfacing – examples in this category include ‘slow down’ lines approaching roundabouts and junctions, dragons teeth, 30 mph roundels.

14.6 For many years virtually all the surface dressing binder has been obtained from a single source (Lanfina, now Total Bitumen). This has been a partnership that has served Warwickshire well but there has been significant changes in their organisation and they no longer have spray bars. It would be advantageous for other sources of binder to be trialled to provide a back-up source of at least equal quality and consistency.

NOTE: Total's intermediate grade binder normally complies with premium grade requirements, therefore care must be taken when trying other sources to ensure they are are as robust.

Last amendment May 2009

15 Slurry surfacing

15.1 Slurry surfacing is the generic term for surfacing materials which are mixed on site in the form of a slurry and are then screeded out to form a new surface. The thinnest options are sometimes called slurry seals and the thicker ones are usually called microasphalts. The main ingredients are graded aggregates and bitumen emulsion which is often polymer modified. Other minor constituents, used for modifying the mix for different substrates or different weather conditions are water, cement, 'dope' and fibres.

15.2 Considerable development has taken place in this type of material in the last few years and at the highest performance level a BBA/HAPAS certificate has been achieved by at least one material as a fully fledged thin surfacing and, at the other end of the spectrum, are simple volume batched materials suitable for footways. Most frequently slurry surfacings have been used successfully on footways and lightly trafficked, low speed roads. Most of the successful ones contain either polymer modified binder or fibres or both.

Road use

15.3 Slurry surfacing using 0/6 mm (or larger) aggregate may be used on lightly trafficked residential roads. The roads shall be limited to culs de sac and residential roads where the traffic is limited to that accessing properties along the road only. The material shall be specified and laid in accordance with clause 918 of the Specification for Highway Works. The requirements in table 15.1 shall be specified. See also PD 6689:2009 [BSI 2009]

15.4 Microasphalt has been used on a number of roundabouts in the last two years, early performance seems to be good but there is little information on the long term performance and durability in this type of situation. When more sites are treated they should be monitored together with those already done so that an appraisal of the economics of the process can be built up.

Table 15.1 Requirements for slurry surfacing for roads

Requirement	SHW table	Class or category
Macrotexture	NG 9/1	No requirement
Defect classification – area, P_1 to P_4 inclusive	NG 9/2	Category 2 for all P
Defect classification – linear	NG 9/3	Category 2
Transverse regularity	NG 9/4	Category 1
Longitudinal regularity	NG 9/6	Category 1

15.5 The slurry surfacing may be laid in one or more layers in order to achieve the required surface regularity, the lower layer or layers need not be complete but the final layer shall be laid over the entire area in widths one lane wide. Where the lane is too wide to lay in one width the joint shall be between the wheel tracks (ie in the 'oil lane').

Footway use

15.6 Slurry surfacing may be used for all grades of footway that have a bituminous surfacing. Preference shall be given to those processes that have a BBA/HAPAS certificate for footway use. The material shall be specified and laid in accordance with clause 918 of the specification for highway works. The requirements in table 15.2 shall be specified:

Table 15.2 Requirements for slurry surfacing for footways

Requirement	SHW table	Class or category
Macrotexture	NG 9/1	No requirement
Defect classification – area, P_1 to P_4 inclusive	NG 9/2	Category 2 for all P
Defect classification – linear	NG 9/3	Category 2
Transverse regularity	NG 9/4	Category 0
Longitudinal regularity	NG 9/6	Category 0

15.7 Where the slurry surfacing is used to seal the footway or to arrest fretting it may be laid in a single layer. Where regulation is required the slurry surfacing shall be laid in two or more layers with the final layer being placed using a screed of suitable width. The minimum thickness, at any point) of material in the final layer shall be not less than 1.5 times the upper aggregate size (eg for 0/6 mm material the minimum thickness shall be 9 mm). The target thickness shall be at least twice the upper aggregate size.

Last amendment May 2009

16 High Friction Surfacing

16.1 **It will be very rare for this surface type to be needed; it will have to be a very difficult site carrying more than 500 cv/l/d in any lane (in itself a rare traffic level in Warwickshire).** See also guidance from the CSS (currently in draft). All high friction surfacing shall have a BBA/HAPAS certificate. All materials shall be laid by a BBA/HAPAS approved installer. As stated in 13.5 high friction surfacing should only be used where its skid resistance is demonstrably required, this is because it is very expensive and tends to fail 'catastrophically'; ie it delaminates from the underlying surface often within a year or two of laying. Maintenance will only be carried when the skidding resistance falls below the appropriate investigation level and then only if the collision criteria are met.

16.2 High Friction Surfacings use calcined bauxite as the skid resistant aggregate which is either glued to the road surface using an adhesive such as epoxy resin or is incorporated in a resin based mixture which is screeded onto the road surface. Calcined bauxite uses huge amounts of energy in its production as the calcining process takes place at 1700ºC and the process used in China (the commonest source) is highly polluting. Guyana uses a cleaner process but both are produced a long way from UK and therefore they incur a high environmental penalty of long haulage. The properties of Brazilian bauxite are no better than some UK natural aggregates and, therefore, shall not be permitted.

16.3 High friction surfaces shall only be laid between May and September inclusive. It is an absolute requirement that they adhere strongly to the underlying surface (by definition they are subject to very high horizontal forces). Even a surface that is only very slightly damp (but which can be visually dry) reduces the likelihood of this happening very significantly.

16.4 The ideal of naturally occurring complete dryness occurs only rarely between October and April. During this wetter period temperatures are also low which necessitates the use of screeded material. These have significant Health and Safety concerns which are such that Warwickshire should not be specifying them (even indirectly) as it may be in default of CDM regulations. WCC cannot stop a contractor using them but the safer option of sprayed and chipped versions of high friction surfacing should be available. It should also be remembered that screeded versions are often considered to have a poor appearance (important for good quality street scene)

NOTE recent research at TRL has confirmed earlier research that most of the advantage of calcined bauxite arises from its small size and the use of these smaller sizes of suitable UK aggregate could be incorporated into suitable surfacing thus improving sustainability and reducing cost.

16.5 There is currently no national specification for workmanship on these products as there is for surface dressing and slurry surfacing. A combination of the visual assessments that are used for those two products shall be used for the assessment of High Friction Surfacing in Warwickshire. The test procedures to be used are set out in Appendix A of this chapter and the specification to be achieved is set out in Table 16.1.

16.6 The tests measure various factors of surface loss and fatting. Since these materials are, by definition, safety critical it is essential that they meet these requirements and any faults rectified.

Table 16.1 Specification for visual assessment of High Friction Surfacing

Parameter	Requirement in the wheel track*	Requirement outside the wheel track*
Fatting up after 2 weeks and any time up to 2 years; P_1	Not more than 0.5 %	Not more than 2.0%
Delamination at 2 years; P_2	Not more than 0.5 %	Not more than 2.0%
Chipping loss at 2 years; P_3	Not more than 3%	Not more than 6%
'Grinning' at 2 years; P_4	Not more than 3%	Not more than 6%

* where the location of the wheel track is indeterminate, as on roundabouts, the whole area shall meet the wheel track criteria.

Last Amendment May 2009

Appendix A to Chapter 16

Test methods for visual assessment of High Friction Surfacing

These are based on tests from BS EN 12272-2 and EN 12274-8 for surface dressing and slurry surfacing respectively which are already in use in the SHW for those materials. Minor modifications are needed to enable their use for high friction surfacing.

The four tests to be used are:

1. for fatting up – the test for fatting up EN 12274-8 (P_1 in that standard)
2. for delamination – the delamination test from EN 12274-8 (P_2 in that standard)
3. for chipping loss – the fretting test from BS EN 12272-2 (P_3 in that standard)
4. for 'grinning'* - the test for groups of small repetitive defects from EN 12274-8 (P_4 in that standard) except that the minimum defect size shall be 10 mm and not 10D.

* 'grinning' is where the high friction surface has worn off the top of chippings in the underlying surface and they are 'grinning' through the high friction surfacing.

17 Recycling

17.1 Any road in Warwickshire that was not constructed completely new in the last 25 years can be assumed to contain tar in one form or another either as the binder on base, binder course or surface course materials or as the binder in surface dressing. The last tar bound coated material was used on the A446 on Grimstock Hill on Coleshill Bypass around 1980 and the last surface dressing binder containing tar was used in diminishing quantities until 1989. From 1990 emulsion binders have been used exclusively. Therefore only in situ recycling shall be used unless the absence of tar can be demonstrated or a system and process used that takes the presence of tar into account.

NOTE 1: The Environment Agency has been known to permit ex situ cold recycling of tar bound materials but this should be checked with the local EA office (they are not known for consistency). One site where it was permitted was A38 in Devon and the contractor was Carillion.

NOTE 2: there are simple tests [Vansteenkiste and Verhasselt 2004] which can detect tar in cores taken from a road but they are not particularly sensitive ie when tar is detected it is definitely there; but at relatively low levels (although still above the threshold) the tests may not pick up the presence of tar.

17.2 It has been shown that cement based recycling is prone to severe cracking on clays and particularly on the Lias Clays of south Warwickshire whereas bitumen based ones tend to become wavy but remain intact. Therefore only fully flexible recycling procedures shall be used. The use of very low proportions of cement in combination with bituminous binders would constitute a flexible system.

NOTE: other binders are being developed such as various combinations of PFA/GGBS/Lime (hydraulic binders) most of which have intermediate flexibility but are very slow to gain strength and can fail if loaded early in their life.

17.3 On lightly trafficked roads the retread process has proved to be satisfactory over many years use both on residential roads and on rural roads when properly protected by at least two surface dressings or an impermeable surfacing like 55/10F hot rolled asphalt. It is essentially a simple process which involves breaking up the existing road structure to a depth of 75 mm to 100 mm (with modern plant it may be possible to treat up to 150 mm) adding bitumen emulsion and possibly some additional aggregate and mixing the whole together, screeding it out and compacting the whole and then covering immediately with a 6 mm surface dressing. It is best if a further 6 mm surface dressing is carried out in the following surface dressing season. If necessary a subsequent surface of 55/10F hot rolled asphalt may be applied. On rural roads without constraints on final levels it is likely that reusing the existing structure with a structural surfacing will be both cheaper and have a lower environmental cost over the long term.

NOTE: the ride quality is best if the breaking up of the existing road is done with a planer rather than with the more traditional harrows or tines.

17.4 This process is always carried out using specialist contractors as the experience of the gang doing the work and particularly that of the foreman is critical in making the difference between an adequate job and a good job. This is because the addition of binder and aggregate is a matter of judgement and not an exact science.

17.5 On more heavily trafficked roads, or where a thicker treatment is needed, a foamed bitumen process may be used. This is in essence similar to retread but uses heavier plant similar to a road planer to break up the existing road and a heavy recycler which adds the foamed bitumen through an integral spray bar while the mixing process is taking place. As in the retread process the material is graded out and rolled. It is normally completed by placing a surfacing layer of 55/10F hot rolled asphalt at least 40 mm thick on top. In urban areas it will usually be necessary to remove some 50 mm of the existing road structure otherwise the final surface will be too high. This process is only carried out by a limited number of specialist contractors. The equipment is heavy and expensive to move so it is only economical where a suitably large area can be treated as a single contract.

17.6 In urban areas where there has been significant activity by the utilities care must be take to assess the suitability of a multitude of materials for use in the process.

18 New materials and processes

18.1 Warwickshire has a long and proud history of trialling new and innovative materials and processes. Some of the highlights are:

- 1965 Open graded sub-bases – W150 and W75 started life on Warwick Bypass as 4½" (112 mm) crushed concrete which was won primarily from a wartime airfield at Atherstone on Stour just outside Stratford. This was also a major recycling exercise returning some 75 acres of land to agricultural use.
- 1967 Laying dense bases in thick layers was trialled on what is now the B4632 at Willicote bends – a comparison of the density achieved using two 75mm layers of 40 mm dense base and one 150 mm layer. The latter had a far superior density. Warwickshire always encouraged the use of thick layers thereafter.
- 1968 Airfield friction course (10 mm porous asphalt) – late 1960s and early 70s – although initially very successful and producing good quiet surfaces it proved to lack durability and was dropped. The cause of the poor durability is now better understood but other surfacing materials have taken its place. (BBA/HAPAS thin surfacings)
- 1974 Delugrip was the first of the proprietary thin surfacing materials which was developed at Birmingham University in conjunction with Dunlop. It was potentially a good surfacing material but never took off because of its cost.
- 1978 Medium temperature asphalt (55/10F) was first laid on the C43 outside Mallory Court Hotel and its use spread throughout the County. It then spread to the UK Midlands and beyond and became a British Standard Material. It is now included in EN 13108-4.
- 1982 Racked in, Double and Sandwich surface dressing – Warwickshire were early adopters of these techniques which, together with polymer modified binders, transformed the potential for long life surface dressing on all roads and levels of site difficulty. Trials of innovative techniques in this field continue.
- 1994 Some of the first trials of thin surfacing on non-trunk roads took place in Warwickshire in 1994 at the entrance to Tarmac Nuneaton quarry and is now in frequent use on appropriate sites.
- 2002 First trials of the reuse of clean sweepings of surface dressing chippings. This proved successful and has continued; 100,000 sq m were done in 2004. it was reported in 'Surveyor' in 2004.
- 2004 Use of Tarmac's Masterflex which is a thick single layer structural surface course with a sustainability benefit. Not only does it have good structural and ride qualities it also uses a polymer modified binder allowing it to flex in sympathy with underlying ground movements.
- 2009 Masterlayer is a lower texture version of Masterflex with potential for crack bridging.

18.2 The trialling of new materials and techniques shall be encouraged but they must be formally and properly monitored by means of suitable tests and visual assessments. For surfacings one of the best technique is to take photographs from the same position at regular intervals.

Last amendment May 2009

19 Improving Sustainability

19.1 There are number of materials and processes used in the County which have very poor durability and/or sustainability compared to what is possible. Some of these are listed below and it is County policy to improve on the sustainability of these materials and processes.

19.2 Road marking materials – white and yellow lines. It is noticeable that the life of these materials is extremely variable. Some such as on C43 between Fosse Way and Harbury (probably 'Rainline') have been in place for several years (probably since 1999 when it was last surface dressed) and are still virtually complete and very visible in the dark and wet whereas others seem to last a very short time and have poor visibility in the dark and wet. Comparative trials should be carried out to determine the most sustainable options.

19.3 The use of calcined bauxite merely for its colour has a very high environmental cost which is not balanced either by its durability or any engineering properties. Trials should be carried out to determine suitable contrasting aggregates from natural sources which can be used as 6 mm surface dressing to form the coloured patches. There are number of green, red, pink and light grey aggregates from UK sources which could prove suitable; see Appendix C to Chapter 10.

19.4 Many patching materials have poor durability – whether this is inherent in the materials or is a function of poor installation is a matter of conjecture. Trials should be carried to determine whether better installation would improve the life of the patch, for example by removing material to a greater depth so that the patch is structurally adequate. Efforts should also be made to source more durable materials that are suitable for patching and that are tolerant of adverse conditions particularly for safety patching which must be carried out in any weather conditions.

19.5 Another area where early failure is endemic is the reinstatement around ironwork whether or not it has been reset. Trials should be carried out on potentially suitable materials and/or systems.

19.6 Although the current source of surface dressing binder has served the County well for it would be advantageous to have alternative sources trialled and approved to enable continued long life of this very sustainable process. A new type of binder has recently become available which uses a flux derived from plant materials. Traditional fluxes evaporated leaving behind a binder which gradually hardened. These new fluxes work by themselves polymerising which enables a fluid binder to be used which quickly becomes strong with no volatile organic compounds. They also have the advantage of being less weather susceptible than any previous type of binder.

19.7 With the advent of new manual handling regulations various new ideas for kerbs such as permanent plastic moulds or hollow concrete kerbs, each of which are filled with concrete on site, are being introduced. Pressed concrete kerbs are very durable products and have often been reused. The question arises, therefore, whether these new ideas are similarly durable and is there any scope for reuse or recycling. Trials should be carried out.

Last amendment May 2009

20 References and Bibliography

Table 20.1 gives the list of the supporting papers held by Network Management, Table 20.2 gives the list of direct references and Table 20.3 gives a bibliography of other documents and publications which give useful background

Table 20.1 Supporting papers

Number	Title
1	Binder grade in structural layers
2	Polished stone values
3	Effect of aggregate size on skidding resistance
4	Roughness and ride quality – effects on structural life
5	Noise – what affects it
6	Structural contribution of thin surfacings
7	Patching – causes and their investigation
8	Environmental assessment of maintenance works
9	BBA/HAPAS system
10	Capping layers and sub-bases – an assessment

Table 20.2 References

Author	Title and source
	Re-using surface dressing chippings. Surveyor 2004
Anon	CDM regulations
BBA/HAPAS	Guidelines and certificates for high friction surfacing (SG1), inset and overband crack seals (SG2), thin surfacing (SG3), polymer modified binders (SG4) and permanent cold lay surfacing materials (SG8). See www.bbacerts.co.uk for more details
BSI	BS 594987:2007 Asphalt for roads and other paved areas – Specification for transport, laying and compaction and type testing protocols
BSI	PD 6691:2007 Guidance on the use of BS EN 13108 Bituminous mixtures – Material specifications. (the references to the various parts of BS EN 13108 can be found in this document but it will be very unlikely for practitioners to need to use the standards themselves)
BSI	EN 13043:2002 Aggregates for bituminous mixtures and surface treatments for roads, airfields and other trafficked areas
BSI	BS EN 13242:2002 Aggregates for unbound and hydraulically bound materials for use in civil engineering work and construction
BSI	PD 6682-2:2003 Aggregates for bituminous mixtures and surface treatments for roads, airfields and other trafficked areas – Guidance on the use of BS EN 13043
BSI	BS 1377-2:1990; Method of test for soils for civil engineering purposes. Classification tests.
BSI	BS 5835-1:1980; recommendations for testing aggregates. Compactibility test for graded aggregates
BSI	BS 6677-1:1986. Clay and calcium silicate pavers for flexible pavements.

	Specification for pavers (withdrawn)
BSI	BS 6717-1:1993. Precast concrete paving blocks. Specification for paving blocks (withdrawn)
BSI	BS 7533 parts 1-12. Pavements constructed with clay, natural stone or concrete pavers. See BSI website for details of each of coverage of each part.
BSI	BS EN 12697-5:2002. Bituminous mixtures. Test methods for hot mix asphalt. Determination of maximum mix density
BSI	BS EN 1338:2003. Concrete paving blocks. Requirements and methods of test
BSI	BS EN 1344:2002. Clay pavers. Requirements and test methods
BSI	BS EN 12271:2006 Surface dressing – Requirements
BSI	BS EN 12273:2008 Slurry surfacing – Requirements
BSI	BS EN 12272-2:2003 Surface dressing – test methods – Part 2 Visual assessment of defects
BSI	BS EN 12274-8:2005 Slurry surfacing – test methods – Part 8 Visual assessment of defects
BSI	PD 6689:2006 Guidance on the use of BS EN 12271:2006 Surface Dressing – Requirements
Catt C	An Alternative view of TRRL's Research into skidding resistance. Asphalt Technology no 33, July 1983
CSS	ENG6-94; Pavement design manual; CSS 1994
CSS	Guidance note on skidding resistance; CSS, 2005
Department for Transport	Road casualties in Great Britain – Annual publication
Highways Agency	IAN 49/03: Use of warning signs for new asphalt road surfaces. Interim advice note, 2003
Highways Agency	IAN 73/06 rev 1. Design guidance for road pavement foundations (draft HD 25) 2009
Highways Agency	Design manual for Roads and Bridges – volume 7; Pavement Design and Maintenance; continually updated (Includes HD23 to HD 40)
Highways Agency	Specification for Highway works volume 1 – Specification; continually updated
Highways Agency	Specification for Highway works volume 2 – Notes for guidance; continually updated
Hosking R	Road Aggregates and skidding, TRL state of the art review/4; HMSO 1992
IHIE	Guidelines for motorcycling. Improving safety through engineering and integration. IHIE 2005
Kennedy C K and N W Lister	LR833. Prediction of pavement performance and design of overlays. TRL 1978
C Roberts and J C Nicholls	Design guide for road surface dressing; Road Note 39 6th edition. Highways Agency/TRL 2008
Nicholls J C (ed)	Asphalt surfacings. A guide to Asphalt Surfacings and Treatments used for the surface course of Road Pavements. E & F N Spon 1998
Parry A and H Viner	Accidents and the skidding resistance standard for strategic roads in England. TRL 622; 2005
Roads Liaison	Well Maintained Highways – code of practice for Highway Maintenance

Group	Management; www.roadscodes.org 2005
Roads Liaison Group	Best practice guidelines for specification of modern negative texture surfaces (NTS) on local authority highways. www.roadscodes.org 2006
Vansteenkiste S O and A F P Verhassalt	Comparative study of rapid and sensitive screening methods for tar in recycled pavements. Road Materials and Pavement Design Volume 5; proceedings of first EATA conference Nottingham 2004
WCC	Local Transport Plan; 2005
WCC	Road Safety Strategy
WCC	Skid Testing Strategy
WCC	Testing Strategy
WCC	Transport and Roads for Development: The Warwickshire Guide; 2001
WCC	Village speed limit review
WCC	Warwickshire Highway Maintenance – Policy document

Table 20.3 Bibliography

Author	**Title and source**
Anon	Bituminous Materials in Road Construction. Road Research Laboratory 1962*
Atkinson K	Highway maintenance handbook, 2nd edition. Thomas Telford 1997
Cebon D	Handbook of Vehicle-Road Interaction, Swets and Zeitlinger 1999
Croney D and P Croney	The design and performance of road pavements; 2nd edition. McGraw Hill 1991
Dawson A	Water in Road Structures. Springer 2008**
Hosking R	Road Aggregates and Skidding. State of the Art Review / 4. TRL 1992
Hunter R (editor)	Bituminous mixtures in road construction. Thomas Telford 1994
Lilley A	A Handbook of segmental paving. E & FN Spon 1991
Nichols J C (editor)	Asphalt surfacings – A guide to asphalt surfacings and treatments used for the surface course of road pavements. E & FN Spon 1998
Read J and D Whiteoak	The Shell Bitumen Handbook, 5th edition. Thomas Telford for Shell Bitumen 2003
Thom N	Principles of pavement design. Thomas Telford 2008

*Although very old this is still one of best books for explaining how bituminous roads work

** This is a pan European review of latest research on the effects and movement of water in pavements

Annexes

A W150 and W75 sub-base

The aim of this specification is to maximise the use of recycled materials and also use materials that are produced in quarries as part of their normal processes without unnecessary processing. It is particularly aimed at recycled aggregates produced by Warwickshire.

A1.1 The sub-base shall be known as W150 (D=150) or W75 (D=80) as appropriate depending on the maximum size of the aggregate permitted. The previous designations 6F72 or 6F71 shall not be used as they cause confusion for suppliers.

NOTE: although the main sieve size is now 80 mm for W75 the designation has not been changed as the material is essentially the same and there will be no need to re-educate users and suppliers

NOTE: for explanation and definition of 'D' and 'd' see PD 6682-2

A1.2 The sub-base shall consist of crushed rock, crushed slag, crushed concrete or crushed recycled aggregates. The permeability coefficient shall be not less than 10^{-1} m/s for D = 150 mm or less than 10^{-2} m/s for D = 80 mm. Materials complying with the limits given in Table A1 are deemed to comply with this requirement.

NOTE: If suppliers wish to demonstrate that a finer grading complies they shall demonstrate this using the test method for permeability in HA 41/90 A Permeameter for road drainage layers

A1.3 The material passing the 425 um BS sieve, when tested in accordance with BS 1377 shall be non-plastic.

A1.4 The aggregates used shall conform with clause 801 of the Specification for Highway Works for Type 1 unbound mixtures except that proven materials, eg ironstone, are acceptable as are crushed and screened recycled materials.

Note: it can be assumed that materials with these coarse gradings will be non-frost susceptible, it is not possible to carry out the test on these materials.

A1.5 The material shall be laid and compacted in accordance with clause 802 of the Specification for Highway Works with the following exceptions:

Layer thickness may be up to 4 times the upper aggregate size (D) – ie 320 mm for W75 and 640 mm for W150. The minimum layer thickness shall be 2D.

Where the materials comply with the limits given in Table A1 compaction by means of the placing and spreading plant is usually sufficient particularly when using ironstone or Cotswold stone which are prone to breakdown.

Segregation shall be kept to a minimum.

Table A1 Sub-base

	W75	**W150**
Sieve size	**% passing**	**% passing**
200* mm		100
150* mm	100	80-100 [D]
90 mm	90-100	0-50
80 mm	0-100 [D]	
31.5 mm	0-40	0-20
8 mm	0-15	0-5
0.5 mm	0-5	
0.063 mm	0-2	0-1

* non-standard sieve sizes

It should be noted that in effect there is no limit to how coarse the material can be ; for example W150 can be all retained on a 100 mm sieve.

For recycled materials the simplest way of obtaining W75 is to set the crusher at about 90 mm and screen the crushed material on a 20 mm screen. The retained material will be

acceptable as W75 and a thin layer of the fines (providing there is little or no soil or clay in the original material) can be used to regulate.

Notes on W75 and W150

A1.6 The first use in Warwickshire of open graded sub-bases was on Warwick Bypass which was built between 1965 and 1967. (It is possible that it was also used on Meriden bypass). Warwick bypass used crushed concrete from two World War 2 airfields; Honiley and Atherstone on Stour. The latter was just south of Stratford. About 80 acres (32 ha), mainly at Atherstone, were returned to agriculture. The concrete runways were put through a mobile crusher with jaws set at 4.5" (115 mm) and the resultant crushed material screened over a ¾" (20 mm) screen. The coarse material was placed first and the fine material used to regulate the surface to provide a sound platform for the rest of the construction. This material has performed well even where the sub-base had been fully waterlogged. The open texture of material ensured good particle interlock even when saturated thus preventing pumping of the fines and damage to the clay sub-grade.

A1.7 Following this early use it was found that the material grading used on Warwick Bypass was too coarse for strip widening and similar constrained sites and a smaller material following the same philosophy was developed which became W75 and as quarry plant increased in size it was convenient to increase the size of the larger material to 150 mm (and even larger material was used when reconstructing the M6).

A1.8 The precise grading is unimportant so materials that do not comply with the grading limits may well be suitable particularly if the non-compliance is on the coarse side provided it can be handled and placed where required. The important factor about these materials is that they have high to very high levels of permeability with k at least 10^{-2} m/sec in Darcy's law and for the coarsest ones k=1 m/sec approximately. The intention at all times was and is to use materials that the quarries produced with a minimum amount of energy, preferably as part of or a by-product of other production. This became more difficult over time as suppliers wished to know the precise specification against which they were supplying. It should now be possible, with the advent of supply chain partnering, to return to this style of agreement which could benefit both producer and user.

A1.9 It is important to connect these materials to the drains in an efficient manner either by ensuring good connection to filter drains or by laying a separate drain in a chase on the low side which is connected to a drainage system at suitable intervals. Any upstands of impermeable materials must be prevented from forming as these would form a barrier to free drainage.

A1.10 Type 1 has gained credibility over the years as a 'strong' sub-base – this is only correct when it has been placed at optimum moisture content and compacted to something approaching its maximum density. It seems surprising, therefore, there is no requirement for it to be placed and compacted at optimum moisture content, which would also reduce its tendency to segregate. The open graded Warwickshire sub-bases have over the years been shown to remain adequately 'strong' under any moisture regime. Recent research at Nottingham University has shown that open graded unbound materials are stiffer then well graded ones and hence better at load spreading. Another problem with type 1 is that it is never free draining as when it is compacted to a dense mass it has a measurable suction of about 200 mm; this is sufficient to draw water in from the sides of the sub-base across about 8m or two lanes when laid at 1 in 40 crossfall.

A1.11 Sub-bases and capping layers spread load and as such shear forces and potential tensile forces are generated. As unbound materials cannot accept tensile forces the limit is reached when any compressive stresses induced in the material by overlying layers and the traffic load have been overcome. With type 1 positive pore water pressures can be generated when it is saturated and this destroys any ability to spread load. Type 1, therefore is intolerant of inadequacies in construction and maintenance. Conversely the open graded WCC sub-base do not suffer from pore water pressures and aggregate interlock remains good even under water. Therefore they are fairly tolerant of poorer drainage maintenance.

Last amendment May 2009

B Minimum Polished Stone Value of Chippings

The minimum polished stone values given in the table are for 10 mm aggregate in surface dressing, thin surfacing and, where the speed limit is 30 mph or less for 55/10F asphalt.

The minimum PSVs given in the table shall be **increased by 5** where 14 mm or 20 mm aggregate is used in any surfacing and where 55/10F asphalt is used on roads with 40 mph or higher speed limits.

NOTE: 65 will be increased to 68+

The minimum PSVs given in the table shall be **decreased by 5** where 6 mm aggregate is used in the any surfacing. (for this purpose only 68+ is assumed to be 70)

Site group	Site Description	Minimum PSV required for given IL, traffic level and type of site							
		Risk rating	IL	Traffic (cv/lane/day) at design life					
				0-20	21-100	101-250	251-500	501-750	751-1000
1	Dual carriageways and single carriageways where traffic is generally free-flowing on a relatively straight line.	3	0.40	50	50	50	50	50	55
		4	0.45	55	55	55	55	55	60
3	Approaches to major and minor junctions or other hazards on all-purpose dual carriageways and single carriageways where frequent or sudden braking occurs but in a generally straight line, mini-roundabouts	4	0.45	55	55	55	60	60	65
		5	0.50	55	55	60	65	65	68+(70)
		6	0.55	50	60	65	68+(70)	68+(70)	68+(70)
4	Steep Gradients (>5%) longer than 50 m	4	0.45	55	55	55	55	55	60
		5	0.50	55	55	60	65	65	68+(70)
		6	0.55	60	60	65	68+(70)	68+(70)	68+(70)
5	Bends on all types of road (<500 m radius [note 1]); roundabout circulation areas except mini roundabouts; approaches to hazards that require combined braking and cornering.	4	0.45	55	60	60	60	65	65
		5	0.50	60	60	65	65	68+(70)	68+(70)
		6	0.55	65	65	68+(70)	68+(70)	HFS(75)	HFS(75)

Notes:
1. Shaded lines are the default risk rating/Investigatory levels for that group except that for bends with a radius between 250 and 500 m when the default risk rating is 4 and the required PSV is in highlighted text
2. Where '68+' material is listed in this Table, none of the three most recent results from consecutive tests relating to the aggregate to be supplied shall fall below 68.
3. HFS means that high friction surfacings complying with MCHW 1 Clause 924 will be required.
4. Investigatory Level (IL) is defined in Chapter 3 of HD 28 (DMRB 7.3.1)

Last amendment May 2009

C Compaction Specification for Bituminous Materials

Table C.1 Air Void Limits

	Mean of 6 cores		**Mean of pairs**	
Material	Min	Max	Min	Max
	%	%	%	%
Asphalt concrete base EN 13108-1	2	6	1	8
Asphalt concrete binder courses EN 13108-1	2	6	1	8
All asphalt materials, ie base, binder course and surface course EN 13108-4	2	5	1	6
Enriched asphalt concrete binder course used as surface course and proprietary equivalents (eg Masterflex)	2	5	1	7

Where materials are laid on a weak substrate they may need to designed (within EN 13108 limits) to be easier to compact. The simplest method to do this is to increase the binder content. On weak substrates the durability gained from good compaction is far more important than any increased risk of rutting. In any case these roads are typically lightly trafficked and rutting is not a problem anyway.

C.1 The adequacy of compaction of bituminous materials will be judged against the air void levels given in table C.1. The following procedure shall be used.

C.2 Compliance shall be judged from the determination of air voids for areas of 1000 m^2 or from the area laid in one day where the area is less than this, where a number of small areas are laid in a day the client shall determine whether these are to be grouped into one site for testing purposes. Three 100 mm nominal diameter core pairs shall be taken from each area. At least 2 of the core pairs shall be from the wheel track zones of the completed carriageway. For the purposes of this clause the wheel track zones shall be taken to be between 0.5 m and 1.1 m and between 2.55 m and 3.15 m from the nearside edge of the road or where lane markings are provided, from the centre line of those markings.

C.3 The density D_0 corresponding to 0% air voids shall be determined using BS EN 12697-5. One core from each set of six shall be taken for the determination of the maximum density; where only one set is taken then the determination shall be carried on 2 cores from the set.

C.4 When the material contains applied chippings the void content shall be calculated for the whole layer including chippings.

C.5 The air void content shall be calculated as $100(1 - D_m/D_o)\%$, where D_m is the measured density and D_o is as described in C.3, and will be quoted to the nearest 1%.

C.6 Where these requirements for the air voids are not met the Contractor shall determine the full extent of the area of the defective material to the satisfaction of the Client. The full depth of the layer, the full width of the paver and a minimum of 15 m long, of the defective material shall be removed and replaced with fresh material laid and compacted to this Specification.

C.7 Cores shall be taken near unsupported edges of each mat as defined in clause 929 every 250 m. The mean of any pair shall have an air void content not more than 2% above that for core pairs given in the table and the mean of any consecutive sets of 3 pairs shall be not more than 2% above that for mean of 6 cores given in the table.

D Specification for non-standard Hot Rolled Asphalts

D.1 These HRA types have a long history of use in Warwickshire. The following types are shown:

1. Hot rolled asphalt 55/6F surf 100/150 (used for machine laid surfacing to footways and cycleways)
2. Hot rolled asphalt 45/6F surf 160/220 and Hot rolled asphalt 45/10F surf 160/220 (used for hand laying). These two specifications were developed in Warwickshire specifically for hand laying and were taken up by the Highways Agency in HD 39, the advice note for footways, where the pre EN 13108 specifications may be found.

55% Stone Hot Rolled Asphalt Surface Course (for machine laying)

1. 55% stone hot rolled asphalt shall comply with sub-Clauses 2, 3, 4 and 5 of this Clause, and the requirements of Appendix 7/1 or 11/1 as appropriate.
2. Materials of designation 55/10F surf and 55/14 F surf shall comply with PD 6691 Table C2A columns 6 and 12 respectively. 55/6F surf shall comply with the target grading and binder content in the table

BS Test sieve	Target % by mass of total aggregate passing BS test sieve
Designation	55/6F
10mm	100
6.3mm	90-100
2mm	41
0.5mm	29-43
0.25mm	9-31
0.063mm	6.0
Minimum target binder content % by mass	5.5
The tolerances on the target gradings are as given in PD 6691	

3. In carriageways, the coarse aggregate shall be crushed rock with a minimum polished stone value of 55, unless otherwise stated in Appendix 7/1.
4. In cycleways, the coarse aggregate shall be crushed rock with a minimum polished stone value of 50, unless otherwise stated in Appendix 11/1.
5. The binder shall be 100/150 grade bitumen.

45% Stone Content Hot Asphalt Surface Course (for hand laying)

1. 45% stone content hot rolled asphalt surface course shall comply with sub-Clauses 2, 3, 4, 5 and 6 of this Clause, and the requirements of Appendix 7/1 or Appendix 11/1 as appropriate.
2. Materials shall comply with BS EN 13108-4, shall have the following target gradings and binder content , and shall be recipe type F.

BS Test sieve	Target % by mass of total aggregate passing BS test sieve	
Designation	45/6F	45/10F
14mm	-	100
10mm	100	95-100
6.3mm	90-100	-
2mm	51	51
0.5mm	37-53	37-53
0.25mm	13-38	13-38
0.063mm	7.0	7.0
Minimum target binder content % by mass	6.3	6.3
The tolerances on the target gradings are as given in PD 6691		

3. In carriageways the coarse aggregate shall be crushed rock with a minimum polished stone value of 55 unless otherwise stated in Appendix 7/1.

4. In cycleways, the coarse aggregate shall be crushed rock with a minimum polished stone value of 50, unless otherwise stated in Appendix 11/1.

5. In footways, the coarse aggregate shall be crushed rock with a minimum polished stone value of 50, unless otherwise stated in Appendix 11/1.

6. The binder shall be 160/220 grade bitumen and the temperature shall not exceed 160^{o}C at any time.

E Foreseeable changes

Most of the changes foreshadowed in the 2006 edition have now taken place. The updates to DMRB have been slower than expected mainly due to decimation of staff at the Highways Agency. There are a number of changes to specifications and advice that are expected in the next 2-3 years:

- DMRB volume 7 is currently being revised in its entirety. several parts have already been published and others are due out within the next year or two.
- There is a possible change from patch texture to machine measured texture being the default method – this is still being debated
- There is a major research project funded jointly by HA/MPA/RBA into the effects of aggregate size on skidding resistance. The early results have been quoted as being ‘interesting’. Further enquiries have been answered very guardedly but the indications are that the Warwickshire take on this (see Annex B) is conservative.

F Abbreviations and Acronyms

The following acronyms and abbreviations have been used in this strategy.

Acronym	Meaning
AAV	Aggregate Abrasion Value
BBA	British Board of Agrément
BS	British Standard
CBR	California Bearing Ratio (a measurement of soil bearing capacity)
CDM	Construction, Design and Management regulations
CSS	County Surveyors Society
Cv/l/d	Commercial vehicles per lane per day
dB(A)	Decibels, A weighted
DBM	Dense Bitumen Macadam
DfT	Department for Transport
DMRB	Design Manual for Roads and Bridges
EN	Euro norm (European Standard)
GPa	GigaPascals
HA	Highways Agency
HAPAS	Highway Authority Product Assessment Scheme
HAUC	Highway Authority and Undertakers Committee
HD	Highways Agency Advice Note
HDM	Heavy duty macadam
HRA	Hot Rolled Asphalt
IL	Investigation level
ISO	International Standards Organisation
ITSM	Indirect tensile stiffness modulus
LTP	Local Transport Plan
msa	Million standard axles
MSSC	Mean summer SCRIM coefficient
MPA	Mineral Products Association (was QPA)
MTA	Medium Temperature Asphalt (historical name for 55/10 HRA with 125 pen binder
NG	Notes for Guidance (in volume 2 of SHW)
PANDEF	Standard method of reporting Deflectograph data (nearly obsolete)
PI	Plasticity Index
PM10	A measurement of respirable dust (less than 10 μm diameter)
PPV	Polished Paver Value
prEN	Draft (provisional) European Standard
PSV	Polished stone value
QPA	Quarry Products Association (now MPA)
SATS	Saturated ageing tensile stiffness (a test for water sensitivity for bituminous materials)
SCANNER	Traffic speed survey method
SCRIM	Sideway-force Coefficient Routine Investigation Machine
SHW	Specification for Highway Works
TRL	Transport Research Laboratory
TRRL	Transport and Road Research Laboratory (predecessor name of TRL)
WCC	Warwickshire County Council