

Reflection cracking on airfield pavements – a design guide for assessment, treatment selection and future minimisation

Design & Maintenance Guide 33

Reflection cracking on airfield pavements – a design guide for assessment, treatment selection and future minimisation

1ST EDITION – JULY 2005

CONSTRUCTION SUPPORT TEAM
DEFENCE ESTATES

DMG 33
Reflection Cracking on Airfield
Pavements - A Design Guide for
Assessment and Treatment

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Foreword

This guide has been prepared for Defence Estates to provide guidance on the identification, categorisation and treatment of reflection cracking in airfield pavement structures. The information provided in this is based on the Department's experience which includes a substantial programme of research and trial projects at various locations

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ACKNOWLEDGEMENTS

This report was prepared by John Cook (Defence Estates) and Sally Ellis (TRL Limited) at TRL Limited.

Furthermore, this report represents a culmination of an extensive research programme that DE and TRL have been investigating since the early 1990s. Significant contributions that must be reported are those of John Potter and Peter Langdale from TRL Limited. In addition to the authors, the key players in the research team at TRL also included: Craig Coley, Kevin Green, Ian Carswell and Nigel Hewitt.

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1 Introduction

1.1 BACKGROUND

1.1.1. Many of the pavements on MOD airfields are of composite construction comprising 1940s and/or 1950s pavements with multiple blacktop overlays that have periodically been applied as expedient maintenance treatments. As a consequence of movements at the joints or cracks in the underlying concrete slabs, reflection cracking has progressively occurred through many of the blacktop overlays. Reflection cracking of a less pronounced nature has also occurred in blacktop surfacings due to movement in underlying cement-bound bases (eg.: pavements with 'flexible composite' construction) and also due to movements at cracks or lane joints in underlying age-hardened asphalt.

1.1.2. Reflection cracking affects pavements to a greater or lesser extent at over 85% of MOD airfields (Ellis and Potter, 1998). This in turn necessitates a substantial amount of recurring maintenance/ restoration works in order to ensure safe aircraft ground operations.

1.1.3. The cost of maintenance/restoration treatments for reflection cracking can vary considerably depending on several key factors. These include the severity and extent of reflection cracking, the operational requirements and the performance of the various remedial/restoration treatments. Further complications are: the degree of proven performance of treatments which is somewhat variable; new treatments continue to be developed; and the extent and severity of pavement defects other than reflective cracking. This document provides guidance on the use of various cost-effective treatments for minimising reflection cracking based on the Department's experience which includes a substantial programme of research and trial projects at various locations (Ellis & Langdale, 2005).

1.2 THE DESIGN CONCEPT

1.2.1. Procedures for the assessment and maintenance of airfield pavements in respect of reflection cracking are provided in the guide as follows:

- Site investigation of surface cracking in existing blacktop.
- Assessment of severity of a reflection cracking problem.
- Selection and design of maintenance treatments.

1.2.2. The development and propagation of reflection cracking is affected by a number of variables. This is especially so in the case of the old evolutionary multi-layer pavements that predominate on MOD airfields.

1.2.3. Before carrying out a diagnostic check on the pavement it is first necessary to have an appreciation of the mechanisms of reflection cracking (Chapter 2). Site investigation procedures for assessing the nature and extent of a reflection cracking problem are detailed in Chapter 3. For the purpose of design of asphalt overlays a procedure for rating reflection cracking is described in Chapter 4. This rating scale is an assessment of the relative stage of development of reflection cracking in a pavement and its potential rate of future crack propagation through any maintenance treatment.

1.2.4. As stated in para. 1.1.3, there are a number of factors affecting the selection of restoration treatments. Having regard to this and the current state of the art (Vidal, 2001)

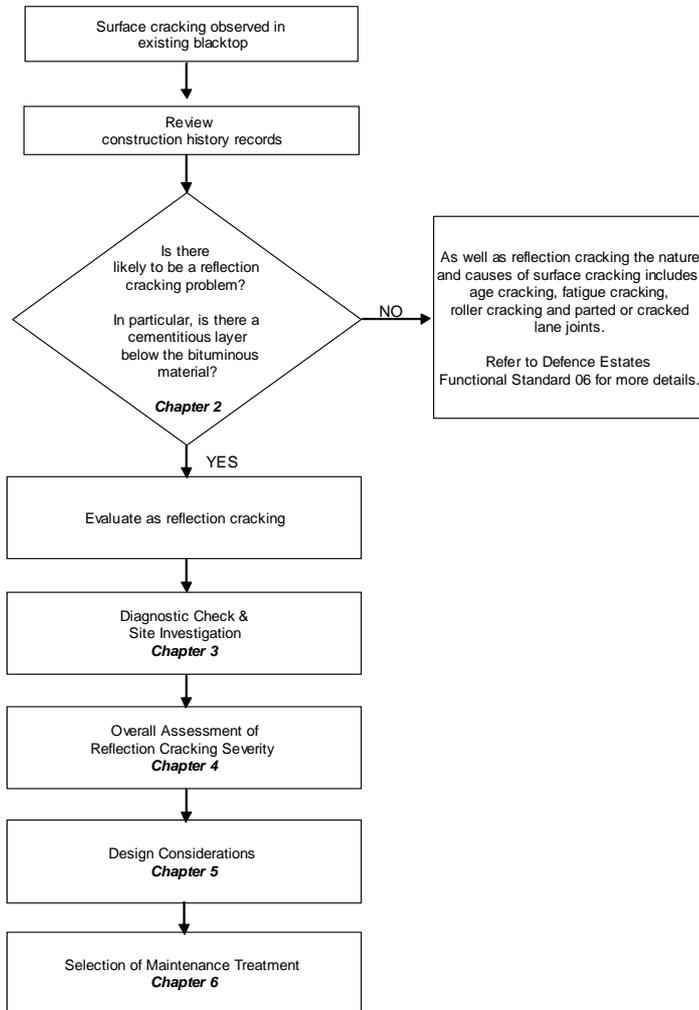
design guidance is provided in relation to four categories of severity of reflection cracking and design/operational requirements.

1.2.5. Chapters 5 and 6 provide guidance on the design and selection of maintenance/restoration treatments for reflection cracking. Figure 1 summarises the step-by-step approach adopted for this guide.

1.3 RESEARCH AND DEVELOPMENT

1.3.1. New treatments for reflection cracking continue to be developed. Also monitoring of performance of existing treatments and research into the development of more systematic methods of designing treatments for reflection cracking continues. Defence Estates should be contacted for information on the latest developments.

Figure 1 Maintenance Planning Procedure



2 Mechanisms of Reflection Cracking

2.1 THE THEORY

2.1.1. This section deals with the theoretical background to the occurrence of reflection cracking. At military airfields, the MOD has, for many years, used jointed unreinforced concrete (URC) - pavement quality concrete (PQC) - without dowel bars, tie bars or keys on a rolled dry lean concrete (DLC) to construct airfield runways and taxiways. It was not considered necessary to use traditional mechanical load transfer devices because good base support was provided by the DLC. Also, the aggregate interlock at the transverse contraction joints was considered to be sufficient to ensure satisfactory load transfer between adjacent PQC slabs, particularly when supported on DLC foundations. This undowelled rigid pavement design also simplified the construction procedures on site. Although single-slab construction was usually employed, in the 1950s twin slab construction was sometimes specified for use at airfields from which heavy aircraft operated. In the twin-slab construction, the joints in the top layer were generally offset to those of the bottom layer and a separation membrane was usually laid between the two layers.

2.1.2. The gradual reduction of load transfer at the joints with time increases the loads on the foundation. The action of aircraft wheel loads can lead to settlement at the joints and even pumping of fines from the underlying materials. Aircraft loading and climate effects, particularly seasonal temperature changes, can cause the slabs to crack and spalling to occur at the joints. To improve the serviceability of concrete pavements, asphalt overlays have provided an economic means of extending pavement life.

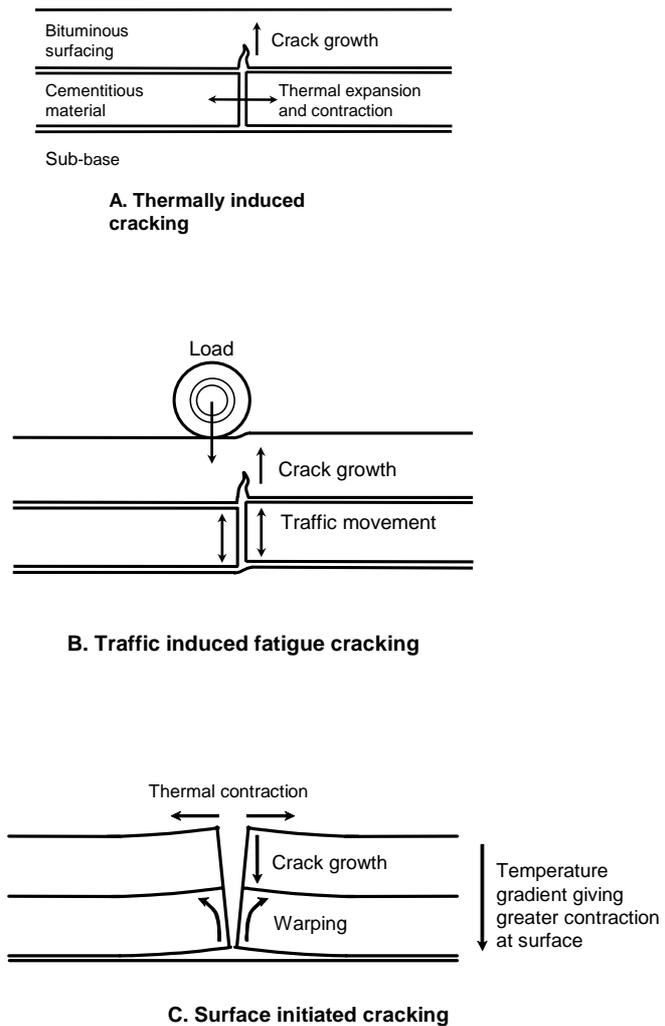
2.1.3. It is common practice to overlay the pavement with Marshall asphalt after carrying out selected repairs to the concrete. Although the overlay strengthens the pavement, it is also applied to improve the riding quality, increase durability and, in particular, to minimise the risk of foreign object damage (FOD). Once overlaid with asphalt, cracks can occur in the overlay above the joints in the concrete layer. This is due to the horizontal tensile stresses induced in the asphalt by the thermal expansion and contraction of the underlying concrete resulting from daily and seasonal temperature changes. In order to reduce the occurrence of reflection cracking, a minimum thickness of asphalt overlay is considered necessary and this could be more than might be required for the structural strengthening. Although a greater thickness of asphalt provides the added benefit of better thermal insulation to the concrete this helps to reduce daily thermal movements and still permits the movements due to seasonal temperature changes. However, increasing the thickness of asphalt surfacing increases the cost of the pavement rehabilitation. Previous DE design guidance (PSA 1989) specified a minimum of 100mm of asphalt overlay and acknowledges that reflection cracking may still occur in overlays on jointed concrete pavements.

2.1.4. In the early stages of development, reflection cracks in asphalt above PQC slabs and in flexible composite constructions, where there is a dry lean base layer, may be barely visible and are not considered to be a structural problem. However, when they propagate completely through the asphalt, infiltration of water can weaken the foundation and fine material may be pumped to the surface, resulting in the creation of voids beneath the concrete. Also water trapped in cracks and underlying porous layers can subsequently cause blistering in new

blacktop overlays. Traffic loading and climatic changes exacerbate the situation. The likelihood of spalling at the cracks formed, and the potential for damage to aircraft engines from loose particles, is of great concern on airfields.

Three mechanisms of cracking were identified by Nunn (1989) and are illustrated in Figure 2.

Figure 2 Mechanisms of reflection cracking



2.1.5. The classical theory of the cause of reflection cracking is shown in Figure 2A. Reflection cracks can be produced as a result of horizontal movements between adjacent concrete slabs when they expand and contract under the influence of daily and seasonal temperature changes. These movements induce high tensile strains in the asphalt directly above joints or cracks in the underlying concrete that may initiate a crack in the asphalt, which then propagates to the pavement surface. Figure 2B illustrates how a reflection crack can be induced as a result of vertical movement between adjacent concrete slabs under the action of a wheel load, due to a lack of foundation support. Shear stresses are generated in the asphalt that could cause the crack to propagate to the surface. Clearly, in both mechanisms where cracks propagate upwards, the rate of propagation depends on the thickness of the asphalt overlay and on the foundation support. For many years, it was widely accepted that reflection cracking was caused solely by a combination of these two mechanisms. Figure 2C shows how cracks starting at the surface of the asphalt can be caused by a combination of

thermal contraction and warping of the pavement under cold winter conditions, when the asphalt is brittle and least able to accommodate tensile strain caused by thermal contraction. This effect increases with time because the asphalt near the surface ages and becomes more brittle.

2.1.6. Extensive investigations into reflection cracking in flexible composite and overlaid jointed concrete road pavements by coring demonstrated that, in the UK, cracks initiate at the surface of the asphalt and propagate downwards to join up with the underlying joint or crack in the concrete (Burt 1987, Nunn 1989). The initiation of cracks was found to depend on the temperature cycle, thickness of the asphalt and on the properties of the asphalt surface layer. More ductile surfacing materials, with a higher yield strain and higher recovered binder penetration, were found to contain fewer reflection cracks. In many instances, particularly for overlays thicker than 150mm, reflection cracks visible at the surface often do not penetrate the full depth of the asphalt layer.

2.1.7. The studies concluded that crack propagation was dependent upon:

- Low temperature exposure and brittleness of the wearing course.
- Thickness of the flexible layers.
- Resistance of the bituminous binder to age hardening and climatic conditions.
- Temperature regime during construction and pavement life.

2.2 REFLECTION CRACKING ON COMPOSITE PAVEMENTS

2.2.1. Reflection cracks are also a common occurrence in the asphalt surfaces of flexible composite construction, which is frequently used on taxiways, and in the blacktop overlays on concrete slabs. This type of construction employs a composite base, comprising a continuously laid cement-bound layer, usually DLC, under an asphalt upper base and an asphalt surfacing. Shrinkage cracks develop in the cement-bound layer in its early life and, under the action of seasonal changes in temperature, these widen and impose horizontal tensile stresses in the overlying asphalt which cause reflection cracks to develop at the surface of the asphalt.

2.3 REFLECTION CRACKING FROM SUB-SURFACE ASPHALT LAYERS

2.3.1. There is an additional feature of reflection cracking that has been observed on airfields. The phenomenon is that reflection cracking occurs in fully asphaltic pavements in the same way as it does for those with cementitious layers at depth. The reason being that cracks exist in sub-surface asphalt layers as construction joints, lane joints or age cracking and the thermal loading on the pavement creates movement at these cracks or joints that will initiate the reflection cracking mechanism. This defect is more likely to occur in extreme climates where the effects of age and cracking are likely to be severe.

2.4 TOP-DOWN AND BOTTOM-UP CRACKING ON AIRFIELD PAVEMENTS

2.4.1. The extensive reflection cracking research program conducted by DE (Ellis & Langdale, 2005) has concluded that the evidence found on road pavements can also be found on military airfields in the UK. In particular, the thicker asphalt overlays, of the types typically used on airfields, clearly follows the mechanism illustrated in Figure 2.1C. Surface initiated cracking is caused by the thermal expansion and contraction of the underlying concrete, and by the age hardening of the asphalt surface. However, the thicker asphalt overlay helps to insulate the concrete and therefore there is a greater degree of contraction at the top of the joint than at the bottom, this leads to the concrete slabs warping with the greatest tensile strain being at the surface of the pavement. At the same time the asphalt has aged and become more brittle. The reflection crack therefore initiates at the surface and propagates down through the full thickness of the overlay, until it meets the joint or crack in the concrete. Due to the temperature related aspects of the thermal contraction and expansion crack initiation commences in prolonged cold periods during Winter, evidence of this is can be found in core samples (Figure 3). However previous common practice on MOD airfields of applying successive but relatively thin asphalt overlays has in many instances resulted in progressive full depth cracking via the mechanism illustrated in Fig 2A.

Figure 3 Top-down reflection cracking through asphalt
surfacing



3 Site Investigation and the Diagnosis for Reflection Cracking

3.1 GENERAL

3.1.1. The Biennial Airfield Maintenance Inspections carried out on MOD airfields should provide an indication of significant reflection cracking together with information on maintenance measures taken. If either such maintenance is becoming problematic or impractical or not cost effective or in danger of failing to control FOD risk or giving rise to sub-standard friction characteristics, then a further more detailed site investigation will be needed. The aim of such an investigation would be to assess the short, medium and long term outlooks and in particular the options for continuing maintenance and the need of appropriate timing for any major restoration works. Typically such an investigation would form part of an Assessment Study carried out to scope a major airfield pavement refurbishment project. This Chapter sets out guidance for the identification of reflection cracking including the appropriate and necessary site investigation requirements.

3.2 INITIAL INSPECTION OF SURFACES

3.2.1. The observation of surface cracking in blacktop pavements is a skilled discipline and personnel experienced in the observation of surface cracking are a pre-requisite for this task. The nature and causes of surface cracking are varied and include: age cracking, fatigue cracking, roller cracking and parted or cracked lane joints as well as reflection cracking. Defence Estates Functional Standard 06 gives more details on the nature and causes of these various surface cracking defects. There are some simple rules; for example, it is easiest to identify surface cracks on a drying surface after rainfall. In addition, cracking is more likely to occur in winter as materials contract due to the reduction in temperature, therefore it is in winter and spring that surface cracking, is most likely to be identified. In the Summer and Autumn materials thermally expand and therefore, in their initial life, surface cracks are likely to close up and be harder to identify. When inspecting surface cracks the severity should also be identified. In the first stage cracks are only just visible to the naked eye and the importance of an experienced surveyor cannot be underestimated. If there is cementitious material at depth and the surface cracking is regularly spaced it indicates a potential reflection cracking problem and further investigation will be required. Figure 4 shows overband sealing repairs to reflection cracks in composite pavements with concrete slabs beneath the blacktop.

Figure 4 Overband sealing of typical reflection cracks



3.2.2. Special attention should be given to the shoulders and at the edges of runways because, as discussed further in para. 3.4.2, there is an increased likelihood of reflection cracking occurring where the surfacing thickness is most likely to be lower. Hence reflection cracking will initiate at an earlier time in the pavement life. Moreover, it is also quite common for the shoulders of runways not to receive the full surfacing treatment, of say a porous friction course, which will be restricted to the runway surface width where actual aircraft manoeuvres will take place.

3.3 REVIEW OF CONSTRUCTION RECORDS

3.3.1. The structure of all pavements at all airfields is identified in the construction history records of the Biennial Airfield Maintenance Inspection Reports. During each Biennial Airfield Maintenance Inspection the inspector is responsible for ensuring that the construction history record is updated with any pavement maintenance that has been carried out in the preceding period. The record identifies the age, thickness and type of all materials within the pavement structure.

3.3.2. A review of the construction history records should enable a quick consideration of whether reflection cracking is the likely cause of the problem that is being investigated. Most specifically the review should be able to ascertain whether there is a cementitious layer at depth, and provide an initial guide to the thickness of the asphalt layers. The area of runway or taxiway under consideration will be made up of several identified areas in the construction history. It is important to view all the areas that are appropriate to appreciate all the materials that may be present in a pavement structure at depth. A cementitious layer at depth could be identified by all the following terms: concrete, dry lean concrete, DLC, pavement quality concrete, PQC.

3.4 DETAILED INSPECTION OF SURFACES

3.4.1. Unless already ascertained a more detailed survey will need to be carried out to quantify the cracking. This should be done with a measuring wheel to determine the length and spacing of cracks, and measuring tape to record the precise size (length), and severity (width and shape) of the cracks. For a typical reflection cracking problem the location of the cracks will relate to the joints or cracks in the concrete slabs at depth and will assist with confirmation of the reflection cracking deterioration mode.

3.4.2. Every effort is made to ensure accuracy of construction records in the Biennial Airfield Maintenance Inspection Reports but for various reasons as indicated below there can be discrepancies between these and actual materials present, in particular the thickness of the asphalt layers/overlays. Therefore it is important to verify the pavement construction as one of the first steps towards understanding the reason for failure. This is ascertained by taking core samples through the entire bound pavement depth to confirm bituminous and cementitious thickness'. The crossfall of the pavement should also be considered as it may have been formed in the foundation, in the concrete layer or in the surfacing material, the latter having a large effect on overlay thickness'. In addition, it is not unusual for the crossfall to have been altered during a pavement rehabilitation contract and this information is unlikely to be available in the construction history record.

3.5 CORING AND/OR TRIAL PITS

3.5.1. As described in para. 3.4.2, core samples are necessary to establish the thickness of the pavement layers, as the construction history record is unable to record changes in pavement thickness due to design features such as cross fall and changes thereof during maintenance treatments.

3.5.2. The number of core samples to be taken will depend upon the scale of the observed problem. It is essential that at least three cores in a transverse line, with one at the centre-line and one close to each edge of the pavement width ascertain a complete cross-section of the runway. Longitudinally the core samples will in the main need to be close to and at the location of the surface cracks. It is also necessary to take some core samples along the pavement edges at non-surface crack locations to check the variation in surface thickness.

3.5.3. When it is suspected, either from the construction history record, existing knowledge, or the core samples that may have already been taken, that there is a wide range in the variation of asphalt thickness a ground penetrating radar survey (para. 3.6) is required.

3.5.4. Core samples are also required through the observed surface cracks to determine the crack depth and the reflection initiation mechanism i.e. joint in PQC slabs, crack in reinforced concrete, natural crack in dry lean base, lane-joint in asphalt etcetera. It is also important to measure the crack depths and record such information as: top down cracking only, extent of cracking, cracking is contained within the top asphalt layer, cracking is full depth, cracking includes top down and bottom up, extent of bottom up cracking i.e. is it always present, and depth of cracks.

3.5.5. In addition, by taking core samples it is possible to undertake laboratory testing of the bituminous materials to ascertain compositional and structural properties. These will be important when it is considered that the surface cracking has occurred earlier in its life than would reasonably be expected. This being the case, there may be cause to investigate the contract that laid the surfacing material.

3.5.6. Furthermore, once a core sample has been extracted to full-depth, the core hole can be used to conduct a dynamic cone penetrometer (DCP) test to establish the pavement foundation CBR. This information will be particularly useful when considering pavement strengthening as part of the maintenance treatment.

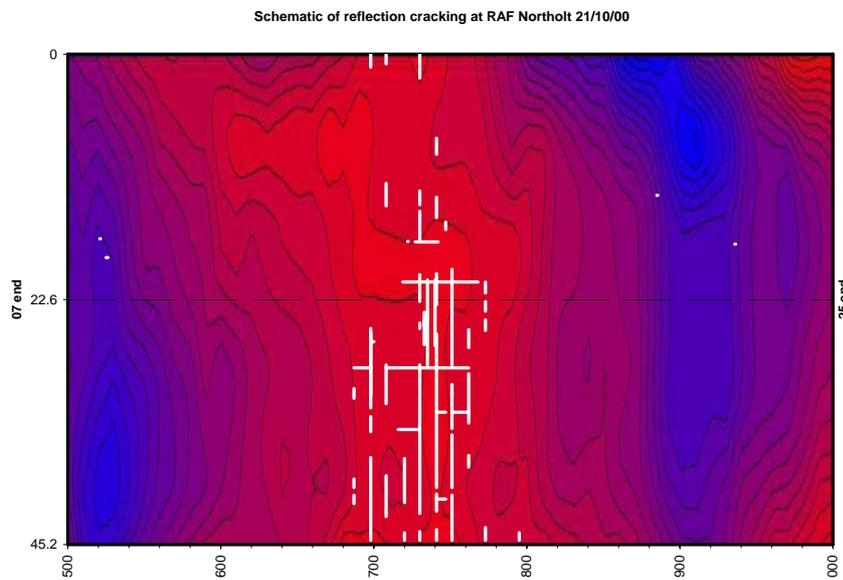
3.5.7. This information will not affect the severity rating in Chapter 4 however it is likely to affect the design of the overlay/restoration works at Chapter 6.

3.6 GROUND PENETRATING RADAR (GPR)

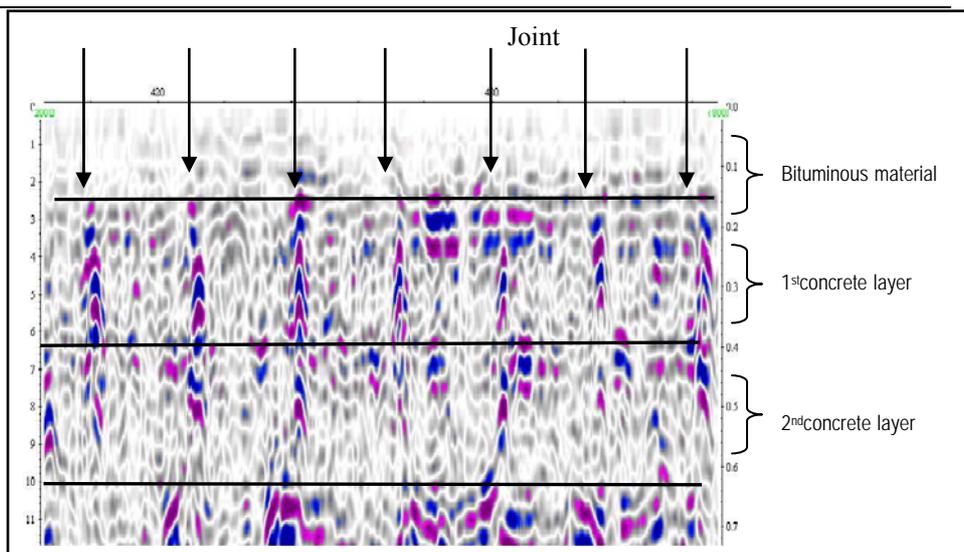
3.6.1. This section provides information on the use of the Ground Penetrating Radar (GPR) as a site investigation tool. DE has conducted a number of detailed site investigations using GPR and concluded that the equipment can provide detailed information to establish (see Figure 5).

- Thickness of layers.
- Location of joints in PQC (i.e. bay size).
- Presence and depth of reinforcement.

Figure 5 Survey results from GPR Investigation



(a) Visual survey superimposed on GPR asphalt thickness contour plot



b) GPR to estimate PQC bay sizes

3.6.2. Background

3.6.3. Radar is an echo sounding method where a combined transmitter/receiver is passed over the surface at a controlled speed. Short duration pulses of radio energy are transmitted into the pavement and reflections from material boundaries and embedded features, such as rebars or voids, are detected by the receiver. Sampling is so rapid that the collected data is effectively a continuous cross section, enabling rapid assessment of thickness and condition over large areas. By assessing the strength, phase and the scatter of signals it is often possible to find cracking and changes in compaction, bond and moisture content.

3.6.4. This method inevitably involves the collection of a large body of information - not all of which is of engineering significance. Analysis involves identifying the main elements of the structure under investigation and establishing the characteristics of its base condition.

Variations in construction and condition can then be identified, enabling significant features to be mapped.

3.6.5. The arrangement and condition of structural components can be identified by analysing a combination of three main variables in the radar data:

- the **amplitude, phase and velocity** of the signals from within the material and from the material boundaries which give an idea of material type and condition.
- the continuity of the signal which gives an idea of the shape of the component.
- the **travel time** of radio pulses through the material gives an indication of the layer thickness or depth to embedded features.

3.6.6. In order to provide a reliable definition of material type and to provide a definitive calibration of radio frequency velocity, core and trial pit information is usually required. The more core information that is made available, the greater the reliability that can be expected from the results of the radar investigation.

3.6.7. A precise match between processed radar thickness data and core logs from the same stretch of airfield pavement is not always achievable. Typically, the accuracy to which the thickness of bound materials can be measured is approximately double that of unbound or open textured materials. In these circumstances, the likely accuracy of thickness measurements is:

- +/- 8% for bound layers
- +/- 15% for unbound layers.

3.6.8. As a rule, variations in moisture content and void ratio are greater in the unbound materials compared to bound materials. Since the radio frequency (RF) velocity in water is one third that of typical pavement construction materials, and three times faster in air compared to the same, unbound material velocities can be expected to vary more along the same length of road compared to those in bound layers.

3.6.9. Survey procedure

3.6.10. Surveys can be conducted between scheduled air traffic where necessary. The radar recording equipment (GSSI SIR10H multi-channel digital radar system) is operated from an appropriately marked survey vehicle and linked to the transducers (operating at centre frequencies of 1.5GHz, 900MHz and 400MHz) via three 5m cables. The transducers are suspended directly below the vehicle, and housed within a sled. This enables the transducers to be positioned directly on the pavement surface. The test equipment can be seen in Figure 6.

3.6.11. The scan rate at which the Radar control system gathers information can be controlled by an external survey wheel mounted at the rear of the survey vehicle. The Radar control system is set to collect around 20 scans per metre i.e. one scan every 50mm. This close scan rate allows small changes within the pavement to be resolved, giving greater confidence to the interpretation.

3.6.12. The survey wheel attached to the survey vehicle provides an independent distance measurement system linked to the radar equipment. This records the position of each individual radar scan relative to a fixed starting point. Working in this way a longitudinal relocation accuracy of better than $\pm 2\%$ measured from the nearest fixed point can be expected.

Figure 6 Ground Penetrating Radar survey equipment



4 Categorisation of Reflection Cracking Severity Level

4.1 GENERAL

4.1.1. This Chapter provides a procedure for the categorisation of severity of reflection cracking as part of the methodology for the design of asphalt overlays in conjunction with the procedures outlined in Chapters 5 and 6. The rating system of Severity of Reflection Cracking in this Chapter represents an assessment of the relative stage of development of reflection cracking in a pavement and its potential rate of future crack propagation through any maintenance treatment/overlay. There is not always a single Severity Level for a particular pavement because this rating can be affected by the design solution. In particular removal of the top cracked layer(s) or alternatively, deep repairs to all primary cracks prior to the provision of a new overlay will affect the reflection cracking Severity Level for purposes of design of an overlay. Hence the process of determination of Severity Level(s) must be carried out in conjunction with consideration of design requirements (refer to Chapter 5) and design solutions/options (refer to Chapter 6). The levels of severity are identified in Figure 7.

4.1.2. To determine the design options and the associated reflection cracking Severity Level(s), the following data on the pavement is required:

- Underlying concrete bay size (m).
- Potential length of reflection cracking, ascertained from the bay size (m).
- Actual length of reflection cracking (m).
- Proportion of reflection cracking occurrence (actual/potential) (%).
- Depth of surface cracking (mm) or top down cracking and bottom up cracking, or whether cracking is full depth above the cement bound layer.
- Width (mm) and nature of surface cracking eg. bifurcating and or ravelling.

4.1.3. Figure 7 sets out the reflection Cracking Severity Levels.

4.1.4. Reflection cracking induced solely by underlying cracks/joints in asphalt layers is uncommon in temperate climates. This defect is more likely to occur in extreme climates. Where this defect is considered significant the determination of Severity Level will need to be assessed on a case by case basis and advice should be sought from Defence Estates.

Figure 7 Determination of reflection cracking Severity Level by proportion of cracking observed

Severity Level	Proportion of Reflection Cracking			
	Composite Pavements with DLC as the Primary Lower Layer See notes 3, 4, 5 and 6	Composite Pavements with PQC as the Primary Lower Layer See notes 1, 2 and 6 (concrete bay size, B [m])		
		B < 3.5	3.5 ≤ B < 6.5	B ≥ 6.5
Low	≤15%	≤15%	n/a	n/a
Medium	>15% wide scale surface cracking	>15%	≤15%	n/a
High		n/a	>15%	n/a
Very High		n/a	n/a	See note 7

Note:

- The proportion of reflection cracking where the lower layer is PQC (%) = $\frac{\text{(length of reflection cracks observed)}}{\text{(potential length of reflection cracking)}}$
- The proportion of reflection cracking for PQC surfaces/pavements to be provided with an asphalt overlay equals 100% (ie > 15%).
- The proportion of reflection cracking where DLC is the primary lower layer should be calculated using an assumed 10m crack spacing unless there are multiple occurrences where the spacing is observed as less than 10m. In this instance the observed crack spacing shall be used to calculate the potential for the entire paved area.
- The determination of the Severity Level where DLC is the primary lower layer and where wide scale surface cracking has occurred (ie > 15%) should be based on a quasi PQC bay size of < 3.5m unless there is strong evidence to the contrary that rates of crack propagation are equivalent to that induced by larger PQC bays.
- The determination of the Severity Level for new composite construction with DLC as the primary lower layer should be based on a quasi PQC bay size of < 3.5m with >15% cracks, unless the performance of similar constructions in similar climates indicates otherwise.
- Where reflection cracking is minimal or localised a Severity Level determined in accordance with the above may not be justified for the purposes of the overall pavement design/refurbishment. In such cases consideration should be given to localised crack treatments as part of the refurbishment works together with either a down rating or zero rating of the reflection cracking Severity Level for purposes of the overlay design.
- Consult Defence Estates.

5 Design Considerations

5.1 GENERAL

5.1.1. In this Chapter those design considerations that would typically apply to maintenance/restoration works on MOD airfields are discussed with regard to reflection cracking.

5.1.2. For a particular situation there will invariably be a number of design factors (eg: pavement defects other than reflection cracking, strength and surface characteristic issues and any site possession constraints). These will have a bearing on the design/ maintenance concept, but are outside the scope of this document.

5.1.3. Reflection cracking in itself does not normally create a FOD risk to aircraft. However, subsequent fretting/ spalling of cracks due to frost action and trafficking will give rise to a FOD risk. Wide or bifurcating cracks are more prone to fretting and spalling and wide cracks can be a 'FOD trap' for loose materials. Fine 'clean' cracks do not pose a FOD risk in the short term although maintenance work would eventually be required to prevent fretting and spalling.

5.2 MINOR MAINTENANCE

5.2.1. Minor maintenance can in many situations provide a cost effective means of maintaining surface serviceability when pavements are subject to reflection cracking. DE 'Functional Standard 06 – Guide to Maintenance of Airfield Pavements' (1994) gives guidance on minor maintenance treatments. However in considering the cost effectiveness and viability of ongoing minor maintenance treatments the following factors will need to be taken into account:

- Overband sealing is a common and effective minor maintenance treatment for reflection cracking.
- It should be noted that once overbanded the development of reflection cracking may become difficult to see by visual inspection. However, it is likely that the reflection cracking will be extending at the existing crack ends. Therefore, during subsequent inspections it is important to pay close attention to the ends of overband sealed cracks.
- Minor maintenance treatments all have limited life spans and will probably need to be reapplied every 4-8 years depending on severity of reflection cracking, material type and performance.
- The applications of these treatments are likely to be an ongoing process as reflection cracking develops in a pavement.
- Reflection cracking can sometimes take the form of close parallel and/or bifurcating cracks. This makes minor maintenance treatments more problematic and costly.
- The FOD risk on highly sensitive areas such as primary runways regularly used by jet aircraft is difficult to contain with minor maintenance treatments when reflection

cracking becomes extensive.

- Wet weather runway friction values can be significantly reduced and also the aquaplaning risk increased as a result of extensive minor maintenance works (overband sealing) of reflection cracking. Extensive overband sealing can, dependant on pavement profiles, cause shallow ponding.
- The frequency of useage and the relative importance of a pavement area on an airfield may severely restrict access for carrying out maintenance work. Hence ongoing minor maintenance on heavily used main runways and and key sections of associated main taxiways is likely to be unrealistic when reflection cracking is extensive.
- Pavements subject to regular useage and high risk of fuel spillage are likely to be problematic when reflection cracking is extensive.

5.3 MAJOR RESTORATION WORKS - MINIMISE REFLECTION CRACKING FOR LIFE OF PAVEMENT (IE NOMINAL MAXIMUM OF 15% REFLECTION CRACKING FOR PAVEMENT DESIGN LIFE OF 20 YEARS)

5.3.1. Major restoration works for a pavement becomes necessary when it is not cost effective or viable to maintain surface serviceability using minor maintenance techniques. The design requirements in respect of aircraft operations (refer to para. 5.2) may be such as to necessitate a scope of restoration work which ensures minimum reflection cracking for the anticipated life of the new surfacing. For the purpose of reflection cracking design considerations the life of a new asphalt surfacing is taken as 20 years. As explained in para. 5.2 this design concept is most likely to apply to primary runways and sometimes principal taxiways.

5.3.2. Unless major pavement strengthening work is being considered, it is most likely that the scope of works required to meet the above reflection cracking criteria will be somewhat more substantial and costly than that required to restore typical surface weathering and traffic abrasion defects. Guidance on treatment selection to meet the above requirement is given in Chapter 6.

5.4 MAJOR RESTORATION WORKS - MINIMISE REFLECTION CRACKING UP TO MID LIFE OF PAVEMENT (IE NOMINAL MAXIMUM OF 15% REFLECTION CRACKING FOR FIRST 8-11 YEARS) WITH INCREASING BUT VIABLE MAINTENANCE REGIME/CRACK REPAIRS FOR BALANCE OF PAVEMENT LIFE.

5.4.1. The design requirements for major restoration works may be such that a less substantial and less costly solution in respect of reflection cracking compared with that at para 5.3 above is viable. This will largely depend on considerations in respect of functional requirements of aircraft operations and maintenance issues as discussed at para 5.2. Such circumstances would typically arise in the case of restoration works for taxiways and secondary runways.

5.4.2. This design concept is unlikely to be valid in cases where reflection cracking in the existing pavement is categorised as High Severity in accordance with Chapter 4. This is because in such cases progressive cracking in the 'second' half of the pavement life would be very aggressive and beyond the scope of minor maintenance techniques.

5.4.3. Guidance on the design of blacktop overlays and reflection crack treatments to account with the above concept is given in Chapter 6. As for the long term design requirement at para. 5.3 it is likely that the scope of works required to meet the above reflection cracking criteria will be somewhat more substantial and costly than that required to restore typical surface weathering and traffic abrasion defects.

5.5 OTHER DESIGN CONSIDERATIONS

5.5.1. A long term strategy in respect of aircraft operations and maintenance costs may determine that one of the requirements for a restoration project is to negate future reflection cracking in a pavement. Having regard to the current state of the art including the proven

track record of the various treatments, the only reliable solutions are likely to involve reconstruction of the existing pavements or the provision of a thick concrete overslab. The costs of works for either of these options is likely to be somewhat in excess of restoration works required to comply with the design concepts at paras. 5.3 and 5.4.

5.5.2. Preventative maintenance/ restoration works can often provide the lowest whole life pavement costs. This could be considered for reflection cracking whereby a blacktop wearing course is planed off during the early stages of top-down cracking and is replaced.

6 Selection of Maintenance / Restoration Treatment

6.1 GENERAL

6.1.1. This Chapter provides the design information for maintenance and rehabilitation treatments with regard to reflection cracking. The need or otherwise for maintenance/restoration works either wholly or partly as a consequence of reflection cracking must necessarily take account of such factors as the FOD risk (ie crack widths, fretting of cracks and bifurcating cracks, rate of crack development, extent of and durability of ongoing maintenance treatments), practicalities of ongoing maintenance, any significant deterioration in the friction/drainage characteristics and budget constraints. Chapter 5 gives further details regarding the design considerations and criteria

6.1.2. A brief description of treatment options is given in Section 6.2. Defence Estates can be contacted for information on latest developments.

6.1.3. A design procedure for standard restoration treatments incorporating blacktop overlays based on the Department's experience is given in section 6.3. This procedure is linked to design considerations (Chapter 5) and a rating system for severity of reflection cracking (Chapter 4).

6.2 MAINTENANCE / RESTORATION TREATMENTS

6.2.1. The treatments to select from when considering either structural maintenance of a jointed URC pavement; or maintenance of the asphalt surfacing to an overlaid jointed URC pavement, are as follows:

- minor maintenance;
- complete reconstruction;
- concrete overslab;
- crack and seat and overlay;
- thick asphalt overlay;
- alternative asphalt surfacing;
- geogrid;
- recycling of existing overlays; and
- overlay, saw cut and seal.

6.2.2. These techniques are described in more detail in the paragraphs below and in particular the factors that contribute to the inhibition of reflection cracking are discussed.

6.2.3. It is important to take into account both the costs of construction and for future maintenance over the whole life of the pavement. In this Section, actual costs are not presented because they depend on local circumstances and timing. The economic statements are based on general costs for the different operations. The design requirements in terms of Aircraft Classification Number (ACN) and aircraft frequency loading have not been defined and therefore the information provided is based on considerations of following factors:

- maintenance treatment cost and programme implications;
- structural design life;
- reflection cracking design life;
- interim maintenance requirements; and
- pavement rehabilitation at the end of maintenance treatment design life.

6.2.4. It is also important to compare like with like. For example, rehabilitation of pavements could be for a structural design life of 20 years, or, if total reconstruction in PQC is being considered as an option, a longer initial design life that may be more economic. Consequently, the maintenance treatments described in the following sections are considered on their own merits.

6.2.5. Minor Maintenance.

Refer to Chapter 5 para 5.2 and DE 'Functional Standard 06 - Guide to Maintenance of Airfield Pavements' (1994).

6.2.6. Complete reconstruction

Whether the reconstruction is in PQC, fully flexible or composite construction the cost of the raw materials and the construction works are likely to be substantially greater than those associated with the innovative alternatives. In addition, the disruption to aircraft operations and any associated delay costs are likely to be much greater. Furthermore the sustainability of the planet and the national drive to achieve sustainable development makes total reconstruction a less attractive option.

6.2.7. Concrete Overslab

This option will provide a long term solution for most cases of reflection cracking. However in cases of High and Very High severity reflection cracking careful consideration will need to be given to slab design, bay layout and joint details. Refer to DE Airfield Pavement Design Guide for further details on overslab design. Other comments as for "Complete Reconstruction".

6.2.8. Crack and seat and overlay

The most progressed of all the anti-reflection cracking treatments in the UK is to crack and seat and overlay. The technique was developed on UK highways, where it is now the favoured option for maintenance of rigid and composite pavements. DE have also undertaken successful trials at RAF Coningsby and RAF Lyneham, and applied crack and seat and overlay as the maintenance treatments on full-scale pavement rehabilitation contracts. The undisputed success of this technique has also led to the publication of TRL Report 590 (Langdale et al, 2003) and DMG21 (Defence Estates, 2003) that provides comprehensive guidance for the selection, design, specification and site supervision of the crack and seat and overlay treatment.

In general, at the present time, to crack and seat and overlay is considered to be the most economic whole life solution for maintenance of PQC or DLC pavements.

6.2.9. Thick asphalt overlay

A thick asphalt overlay is considered to be greater than 200mm thick. Evidence from UK roads does support the concept of a thicker surfacing inhibiting the development of reflection cracking. However, the increased thickness will only contribute to a delay in the initiation of reflection cracking and will not eliminate it completely.

From experience, the cost of crack and seat methods are equivalent to about 20mm of asphalt overlay, depending on the size of the scheme. This cost is certainly less than the reduction in asphalt thickness that can be considered when a crack and seat maintenance method is applied. In addition, it is necessary to repair defective joints and extensive spalling etc before any overlay is placed and the cost of this could be high. Finally, the associated effects on the airfield layout (i.e. lighting and drainage) would be less for a thinner asphalt overlay.

6.2.10. Alternative asphalt surfacing

Standard designs for asphalt overlays include Marshall Asphalt (MA) surfacing. Also available for surfacing is a Porous Friction Course (PFC), and there is a specification giving details of its mix design 'Specification 040, Porous Friction Course for Airfields', (Defence Estates, 2005). Through the research programme conducted by DE and TRL there is extensive evidence that supports the selection of PFC surfacing as opposed to MA if there is a likelihood that reflection cracking could occur. This is because PFC has demonstrated that it can substantially delay and/or eliminate the initiation of reflection cracking (Ellis et al, 2001 and Ellis & Langdale, 2005).

In addition, there is also the possibility to use Stone Mastic Asphalt (SMA). DE has also conducted research including trials using SMA as the surfacing material and to date it has proved to perform as well as conventional surfacing and is also expected to outperform the currently accepted MA and HRA. A Specification for SMA has been developed 'Specification 049' (Defence Estates, 2005) and latest recommendations for the design of SMA can be obtained from DE.

Besides the choice between the four currently accepted surfacing materials, MA, HRA, PFC and SMA, it may also be worth considering the incorporation of an asphalt modifier. In this case the asphalt is modified by the addition of a polymer to the bituminous binder in order to modify the rheological properties of the binder and improve its performance. Polymer modified binders in asphalt surfacing may be used to improve elastic recovery and the fatigue cracking properties of the asphalt. For reflection cracking, an improved elastic recovery may help to delay the initiation of the cracks.

The addition of a modifier to the surfacing course increases the cost disproportionately but if, as a result, the overlay thickness could be reduced some of this increase could be offset.

DE is continuing to evaluate the performance of modified asphalt materials. Until design and specification advice is published, guidance should be requested from DE.

6.2.11. Geogrid solutions

The terminology for geogrid solutions has varied both with time and type. In this instance, the term geogrid refers to SAMIs (stress absorbing membrane interlayer), geotechnical reinforcements, geotextiles and geogrid applications. The most extensive information in maintenance treatments for the prevention of reflection cracking is that available for geogrid solutions. Since the late 1980s full-scale trials and maintenance schemes have been carried out using geogrid solutions. Uniquely, as compared to the other treatments, there is much information available on the application of geogrids to airfield problems world-wide. More details of the experience of geogrids can be found in Ellis and Potter (1998), Vidal (2001), Ellis et al (2002) and Ellis and Langdale (2005).

DE have conducted research and constructed trial sections to evaluate geogrid performance. To date, most treatments have performed well in the initial period, providing a delay to the initiation of reflection cracks. Subsequently the performance of different products has varied. Some products do continue to perform well, whereas in other cases, the delayed appearance of reflection cracks has been followed by rapid crack growth to match that experienced by PQC pavements with overlays and no anti-reflection cracking treatment.

Initial costs of geogrid products can vary between high and low compared to crack and seat. Considering the treatments together it must also be noted that geogrids are likely to require increased maintenance. In addition, the progress rates during construction are generally lower as difficulties can be encountered in the placement of geogrids. There is the potential for material wastage due to complications between construction plant and the geogrid materials.

DE has increasing confidence in certain geogrid products and is continuing to evaluate the performance of geogrids in general. Until design and specification advice is published, guidance should be requested from DE when considering the use of geogrids in any airfield pavement maintenance contract.

6.2.12. Recycling of existing overlays

Recycling of asphalt materials is known to help conserve natural resources and to reduce the energy used in production. In countries where there is a shortage of road-building aggregate, or no indigenous bitumen, recycling is the standard approach for both construction and maintenance. The UK enjoys a plentiful supply of good quality aggregate and a comprehensive infrastructure to transport materials over the relatively short distances between quarry, mixer and site but, nevertheless, the momentum for recycling materials that can be used in road building has been growing rapidly in recent years. Conservation of resources has become an extremely important issue and the road construction industry is one of many that Government is setting targets for a move to sustainable development.

Through the Highways Agency (HA) sponsored research, TRL has investigated the technical feasibility of reusing a wide range of materials in pavement structures. One area of study is to recycle asphalt arising into new hot-mix asphalt. Wearing courses can be recycled in-situ using specialised plant which heats, scarifies and remixes the old wearing course with new material which is relaid on the pavement in one pass of the machine or can be recycled in centralised mixing plants. However, for roadbase and base course layers it is more cost effective to recycle asphalt in central mixing plants because a greater percentage of reclaimed asphalt can be used in the mix and thicker layers of asphalt are required for the main structural elements of the pavement. It is considered likely that a similar approach will be suitable for overlays on airfield pavements where reflection cracking has occurred and necessitates rehabilitation of an existing pavement.

DE has not extensively investigated the application of the recycling techniques described above. Nevertheless, DE too are keen to deliver to the Government's targets for sustainable development. As such DE will consider the use of recycling techniques for overlay rehabilitation. Until design and specification advice is published, guidance should be requested from DE.

6.2.13. Overlay, saw cut and seal

Overlay, saw cut and seal is a maintenance treatment which works on the philosophy of inserting a bituminous joint sealant in an asphalt overlay at the location where reflection cracks would occur. A groove is sawn into the asphalt surface directly above the joint in the PQC. The groove is then filled with an approved joint sealant to just below the surface of the overlay. Any thermal movements in the PQC are then allowed for by the material characteristics of the sealant and space provided for expansion and contraction.

Monitoring of trial sections on UK roads has proved the technique to be successful and the technique is now a standard anti-reflection cracking treatment applied to UK motorways and trunk roads.

The costs associated with the saw cut and seal are likely to be similar to or less than those for crack and seat. However, it would still be a requirement to repair defective joints and to ensure that the cracks occurred over each joint. Furthermore, it has also been identified that the success of the treatment relies on top quality workmanship. The trials have shown that it is essential that the saw cut is directly above the PQC joint, and that the groove cut and joint sealant insertion is to the dimensions shown in the schematic layout.

DE has not extensively investigated the application of the overlay, saw cut and seal technique described above. Until design and specification advice is published, guidance should be requested from DE.

6.3 DESIGN PROCEDURE FOR STANDARD RESTORATION TREATMENTS INCORPORATING BLACKTOP OVERLAYS

6.3.1. Figure 8 sets out recommendations for blacktop overlays/restoration treatments in relation to two design criterion as defined in Chapter 5 (i.e. in outline terms - minimise reflection cracking up to the mid-life or full life of pavements) and for four Severity Levels of reflection cracking as defined in Chapter 4. As discussed in Chapter 4 there may not be a single Severity Level for a particular pavement as this rating may be affected by the design solution. The determination of a Severity Level is therefore an integral part of the design process. The following sets out some of the key factors to consider in formulating the design options:

- a) Surface reflection cracking confined to the top layer with no associated 'bottom-up cracking'.

In these circumstances it can be reasoned that the overall thickness of blacktop above a cement bound base/concrete slab is generally adequate and that replacement of the top layer only will suffice.

- b) Full depth reflection cracking, or existing concrete surface slabs or new pavement incorporating cement bound bases.

All three cases will have a single Severity Level for purposes of design of blacktop overlay.

- c) 'Top-down' (confined to the wearing course/top layer) and 'bottom-up' cracking (not extending into the uppermost blacktop overlay/restoration treatment).

Provided that the life of the last restoration treatment/overlay has been realised (ie 15-20 years) then it is realistic to use the same design concept as applied at "a" above.

- d) 'Top-down' and 'bottom-up' cracking - bottom-up cracking extends into the last blacktop overlay/restoration treatment.

One design option to consider is a new blacktop overlay based on a severity rating of reflection cracking of the pavement surface. Another option is a blacktop overlay design based on removal of the cracked surface layer, a reflection cracking Severity Level assuming widespread (ie > 15%) 'bottom-up' cracking and the new blacktop overlay equal to the thickness from figure 7 minus the un-cracked depth of existing blacktop. The depth of 'bottom-up' cracking and hence the determination of depth of un-cracked blacktop will need to be assessed from cores mostly taken at positions of 'top-down' cracking.

- e) Where reflection cracking is minimal a Severity Level determined in accordance with Figure 7 may not be justified for the purpose of the overall pavement design/refurbishment. In such cases consideration should be given to localised crack treatments as part of the refurbishment works together with a down rating of the Severity Level.

Figure 8 Design options for minimisation of reflection cracking in the medium term and long term

Severity Level (Figure 7)	Medium Term (Para 5.4)	Long Term (Para 5.3)
Low	80mm Marshall Asphalt (MA) overlay	150mm MA overlay or 80mm MA asphalt + Porous Friction Course (PFC)
Medium	150mm MA overlay	220 MA asphalt or 150mm MA asphalt MA + PFC
High	220mm MA overlay	300mm MA asphalt or 220mm MA + PFC or Crack and seat and overlay (MA/PFC)
Very High	Crack and seat and overlay or Geogrid + overlay (MA/PFC) Consult DE.	Crack and seat and overlay (MA/PFC)
<p>Notes & References</p> <ol style="list-style-type: none"> 1. Design life is based upon the occurrence of reflection cracking remaining at less than 15% of the total potential for reflection cracking. 2. Alternate surfacing such as SMA are discussed in 6.2.10. 3. Crack and seat, design, specification and construction guidance can be found in TRL 590 (Langdale et al, 2003), or Design and Maintenance Guide 21 (Defence Estates, 2003). 4. For further information on pavement maintenance also refer to Functional Standard 06 'Guide to Airfield Pavement Maintenance' 5. Attention is drawn to note 6 of Figure 6 regarding the determination of the Reflection Cracking Severity Level when existing reflection cracking is minimal and of the option to use localised crack repairs together with either a down rating or zero rating of the reflection cracking Severity Level for purposes of the overlay design. 6. Key factors identified as points a) to e) in para. 6.3.1 should be referred to before finalising any design option. 		

7 References

The documents identified below have been used in the development of this Guide. Any unpublished TRL reports may be purchased from TRL Limited with prior permission from Defence Estates.

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Glossary

<p>Added Filler Filler aggregate that is additional to that inherent in the course and fine aggregate</p>	<p>Bitumen Binder obtained from crude oil by refinery processes.</p>	<p>Cutback Bitumen Bitumen whose viscosity has been reduced by the addition of a suitable volatile diluent.</p>	<p>Foreign Object Damage (FOD) Damage sustained by aircraft as a result of foreign objects striking the aircraft or being ingested into jet engines. Potential sources of damage are generally referred to as FOD hazards.</p>
<p>Aggregate / Cement Ratio The ratio between the total mass of aggregate, including the mass of any absorbed water, in a concrete mix and the mass of cement in the mix.</p>	<p>Bitumen Emulsion An emulsion in which bitumen is dispersed in water or in aqueous solution with the aid of suitable emulsifying agents.</p>	<p>Dense Bitumen Macadam (DBM) See 'Macadam'.</p>	<p>Free Water/Cement Ratio The ratio between the mass of water, less any water absorbed by the aggregates, in a concrete mixture and the mass of cement in the mixture.</p>
<p>Asphalt A mixture of coarse and fine aggregate, filler aggregate and bituminous binder used in the construction of flexible pavements for roads and airfields.</p>	<p>Bitumen Macadam See 'Macadam'.</p>	<p>Drylean concrete A cement bound granular material with low water content suitable for use as a Base or subbase. Unlike conventional concrete, it is usually compacted by rolling.</p>	<p>Friction Course See 'Porous Friction Course'.</p>
<p>Asphalt Concrete An asphalt mixture consisting of continuous graded aggregate, filler aggregate and bituminous binder proportioned to produce a dense and impermeable surfacing.</p>	<p>Bituminous Containing bitumen. (Previously included road tar, pitch or mixtures thereof).</p>	<p>Edge Restraint Device that serves to prevent sideways movement of paving units and prevents loss of material from the laying course, base or subbase.</p>	<p>Grading Particle size distribution of an aggregate.</p>
<p>Asphalt Surfacing A porous friction course, surface course, or a combination of these, and a binder course.</p>	<p>Bituminous Surfacing Alternative name for 'Asphalt Surfacing'.</p>	<p>Expansion Joint Joint provided in a concrete pavement to accommodate the expansion which occurs when the temperature of the pavement rises.</p>	<p>Heavy Duty Macadam (HDM) See 'Macadam'.</p>
<p>Asphaltic Concrete Alternative name for 'Asphalt Concrete'.</p>	<p>Bond Coat Proprietary Tack Coat that is guaranteed to provide additional adhesion and, therefore, bond between layers, when applied at the rate of application recommended by the proprietor for the particular situation.</p>	<p>Filler Aggregate For asphalt, aggregate, most of which passes a 0.063 mm sieve as permitted in BS EN 13043, which can be added to construction materials to provide certain properties. For concrete and block making, aggregate, most of which passes a 0.063 mm sieve as permitted in BS EN 12620, which can be added to construction materials to provide certain properties.</p>	<p>Hot Rolled Asphalt (HRA) An asphalt mixture of gap-graded aggregate, filler aggregate and bitumen binder proportioned to a design or recipe to produce a dense and impermeable surfacing material.</p>
<p>Base Structural layer(s) of a pavement immediately below the Binder Course that are bound.</p>	<p>Coarse Aggregate For asphalt, aggregate mainly retained on a 2.0 mm test sieve and containing no more finer material than is permitted for the various sizes in BS EN 13043. For concrete and block making, aggregate mainly retained on a 4.0 mm test sieve and containing no more finer material than is permitted for the various sizes in BS EN 12620.</p>	<p>Fine Aggregate For asphalt, aggregate mainly passing a 2.0 mm test sieve and containing no more coarse material than is permitted for the various gradings in BS EN 13043. For concrete and block making, aggregate mainly passing a 4.0 mm test sieve and containing no more coarser material than is permitted for the various gradings in BS EN 12620.</p>	<p>Interlock Effect of frictional forces between concrete blocks that prevent them moving vertically in relation to each other.</p>
<p>Basecourse Previous name for 'Binder Course'.</p>	<p>Crushed Aggregate Aggregate produced by crushing rock or gravel.</p>	<p>Fines Any solid material passing a 0.063 mm test sieve.</p>	<p>Intermediate Restraint Device that is used to provide restraint of concrete block paving units at intervals in the paved surface.</p>
<p>Bay (of Concrete) The area of slab bounded by adjacent pairs of longitudinal and transverse joints or grooves.</p>	<p>Construction Joint A joint separating areas of a concrete pavement slab placed during different pours, usually on different days. May be a longitudinal, or lane, joint or a transverse joint across a lane.</p>	<p>Foreign Object Damage (FOD) Damage sustained by aircraft as a result of foreign objects striking the aircraft or being ingested into jet engines. Potential sources of damage are generally referred to as FOD hazards.</p>	<p>Joint Filling Material Material used to fill the joints between concrete blocks. Often referred to as 'joint filling sand'.</p>
<p>Bay Layout The pattern of joints and grooves on a concrete pavement.</p>	<p>Contraction Groove A groove formed in the surface of a concrete slab, either during or soon after laying, in order to induce shrinkage cracking to occur in a controlled manner. Usually formed transversely at regular intervals along a lane of concrete by saw cutting so as to subdivide it into approximately square bays.</p>		<p>Joint Width The distance between adjacent concrete blocks or concrete blocks and restraint.</p>
<p>Binder A material used for the purpose of holding solid particles together as a coherent mass.</p>			<p>Laitance On a concrete pavement, a thin layer with poor durability formed of fine aggregate, cement and water brought to the surface, usually by overworking.</p>
<p>Binder Course The layer or layers of the asphalt surfacing immediately below the surface course. (Previously called 'Basecourse').</p>			<p>Lane A longitudinal strip of a pavement layer produced by one pass of a set of paving equipment.</p>

<p>Lane Joint A construction joint between adjacent lanes.</p> <p>Laying Course Material Layer of material on which concrete blocks are bedded. Often referred to as the 'bedding sand' or 'laying course sand'.</p> <p>Laying Face Working edge of the wearing surface when concrete blocks are being laid out.</p> <p>Laying Pattern An arrangement of concrete blocks to form specific patterns for structural requirements.</p> <p>Macadam An asphalt mixture (nominally an Asphalt Concrete) consisting of graded aggregate coated with bitumen.</p> <p>a. Dense Bitumen Macadam (DBM): A dense, relatively impermeable, Macadam coated with a bitumen binder and with a filler aggregate content of between 2 % and 9 %.</p> <p>b. Heavy Duty Macadam (HDM): A dense bitumen Macadam with 40/60 pen grade bitumen binder and a high filler aggregate content of 7 % to 11 %.</p> <p>c. Pervious Macadam: A layer of 0/32 mm Porous Asphalt which acts as a topping to protect whilst allowing free penetration of the surface water to French drains.</p>	<p>Marshall Asphalt An Asphalt Concrete designed to achieve specified stability, flow, voids and density characteristics.</p> <p>Particle Size Fraction That portion of aggregate which passes one sieve but is retained on the adjacent smaller sized sieve in the sequence of sieves used to specify that grading.</p> <p>Pavement A structure consisting of a layer or superimposed layers of selected materials, whose primary purpose is to distribute the applied load to the Subgrade.</p> <p>Pavement Quality Concrete (PQC) A cement concrete of a suitable quality for use as the surfacing on airfield pavements.</p> <p>Pervious Macadam See 'Macadam'.</p> <p>Petroleum Bitumen See 'Bitumen'.</p> <p>Porous Asphalt An asphalt mixture consisting of gap-graded aggregate and binder with a relatively open structure that is pervious to air and water.</p> <p>Porous Friction Course A relatively thin layer of 2/10 mm aggregate sized Porous Asphalt that allows free penetration of the surface water to the underlying impervious surface course.</p>	<p>Ramp A section of pavement, usually laid at a gradient near the maximum permissible, which accommodates differences in level between adjacent pavements. (Note that, in US terminology, 'Ramp' may also be used to indicate an aircraft parking area).</p> <p>Regulating Material Asphalt of variable thickness applied to an existing pavement to adjust the shape preparatory to resurfacing.</p> <p>Road Tar A viscous liquid derived from crude tar obtained by the destructive distillation of coal which was, but is no longer, used as a component in asphalt.</p> <p>Roadbase Previous name for 'Base'.</p> <p>Sand (for making concrete) Now called 'Fine Aggregate'.</p> <p>Sieved Fraction Previous name for 'Particle Size Fraction'.</p> <p>Stone Mastic Asphalt (SMA) A dense gap-graded asphalt with aggregate-to-aggregate interlock that includes fibres as a stabilising additive to carry the binder without drainage.</p>	<p>Subgrade Upper part of the soil, natural or constructed, that supports the loads transmitted by the overlying pavement.</p> <p>Surface Course The layer of the asphalt surfacing immediately below the porous friction course or which directly supports the traffic. (Previously called 'Wearing Course').</p> <p>Tack Coat A thin film of bitumen emulsion to improve the adhesion between two courses of asphalt or between an existing surface and a new asphalt layer.</p> <p>Thin (Asphalt) Surfacing System A proprietary asphalt product with suitable properties to provide a surface course that is laid at a nominal depth of less than 50 mm (previously limited to 40 mm).</p> <p>Uncrushed Aggregate Aggregate resulting from the natural disintegration of rock.</p> <p>Wearing Course Previous name for 'Surface Course'.</p>
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(NOTE: This glossary is common to all DE Functional Standards for asphalt, block paving and concrete pavement materials and the Project Manager should delete any terms not applicable to a particular project and should add any terms necessary due to the particular nature of that project.)

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