The use of the crack and seat treatment in the refurbishment of airfield pavements

Prepared for Defence Estates

P C Langdale, J F Potter and S J Ellis

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Executive Summary

This report is prepared for Defence Estates (DE) of the Ministry of Defence (MoD) under order number 17 of contract WS21/4013, ‘Term Commission for Specialist Research, Pavement Testing and Consultancy’. TRL Limited (formerly the Transport Research Laboratory) were commissioned by DE to prepare guidelines for crack and seat maintenance of pavements at DE airfields and thus disseminate the knowledge that has been gained through full-scale trials that have taken place at RAF Coningsby and RAF Lyneham. The overall purpose of the guide is to provide enough information to enable those engineers not familiar with crack and seat technology to be able to conduct effective maintenance of concrete pavements at airfields.

The rehabilitation of a jointed concrete airfield pavement is routinely performed by the application of a bituminous overlay. However, thermal movements in the underlying concrete slabs produce tensile stresses within the bituminous overlay and ultimately cause reflection cracks to be initiated in the surface of the asphalt above the joints in the concrete. Similarly, transverse reflection cracks can occur in the bituminous surfacing of flexible composite pavements due to thermal contraction in the cement bound base and when the pavement is overlaid, these cracks generally reappear in the new surfacing.

Defence Estates have conducted a number of trials at airfields to assess various techniques to minimise the occurrence of reflection cracking. The trials of ‘crack and seat’ before overlaying the concrete pavements have been successful and now the technique is being used more widely on airfields. Because the crack and seat method is new to DE project managers and engineers, guidance on how to specify and supervise the works is needed. This document provides a detailed background to crack and seat, an overlay design procedure, a draft specification for use on airfield pavements and detailed engineering guidance on the supervision of the work on site.

The guide is organised into four main chapters with greater detail given in appendices for reference purposes:

1 *Background*
An explanation of the causes of reflection cracking is given with information on the various maintenance options available. Details of the crack and seat methodology and procedures are presented including information on the specialised equipment needed for the cracking operation. The results of the trials on RAF airfields illustrate the success of the technique in minimising reflection cracking.

2 *Design*
An explanation through the DE ‘Guide to Airfield Pavement Design and Evaluation’ of the design procedure when using crack and seat will permit implementation of an appropriate design assessment.

3 *Specification*
A draft specification for crack and seat is given, based on experience from the trials and elsewhere. The specification is flexible and is illustrated by means of flow charts for use on jointed concrete and flexible composite runways and taxiways.

4 *Construction*
Detailed guidance is given for the project manager to supervise the works including advice on what to look for, what measurements need to be taken and how to assess the contractor’s operation. Photographic examples are provided to illustrate the operations and to show the results of good and poor practice.

Foreword – Defence Estates

This document is for the use of top level budget holders (TLBHs) for application by project sponsors and their project managers, property managers (PROMs), establishment works consultants (EWCs), works service managers (WSMs) and other parties involved with airfield pavement works.

This publication was prepared under the patronage of HQ Strike Command for application to airfield pavement works on the MOD Estate.

All queries relating to the application and content of this guide should be directed to:

Head of Airfield Pavements
Airfields and Bulk Fuels Group
Defence Estates
Blakemore Drive
Sutton Coldfield
West Midlands
B75 7RL

Tel: 0121 311 2119 or Sutton Coldfield MI 2119

1 Introduction

1.1 Background

The crack and seat technique has been used extensively on unreinforced jointed road pavements in North America and in Europe as a means of minimising the occurrence of reflection cracking in asphalt overlays on jointed concrete pavements. It was introduced into the UK in the early 1990s when trials were conducted on trunk roads to assess the performance of the treatment on both jointed unreinforced concrete and flexible composite pavements. These trials were successful and subsequently the technique has been further developed for UK conditions.

In 1995 and 1996, trials were carried out on MOD airfields using the crack and seat treatment for the purpose of developing a methodology for its use in airfield pavement refurbishment works. This document draws together the conclusions from those trials to provide guidance on the application of the crack and seat treatment for airfield pavement works for the purpose of minimising reflection cracking in the asphalt overlay.

1.2 Reflection cracking on MOD airfields

Many of the pavements on MOD airfields are of composite construction comprising 1940s and/or 1950s concrete pavements with multiple blacktop overlays that have periodically been applied as ‘low-cost’ maintenance measures. 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 (e.g. flexible composite construction) and also due to movement at cracks or lane joints in underlying age-hardened asphalt.

Reflection cracking has been identified as a major problem occurring at more than 85% of all MOD airfields (Ellis and Potter, 1998) and recurring frequently. Section 2 and Appendix A provide a more detailed description of the causes of reflection cracking. Also included in Section 2 and Appendix B is an outline of the various treatments that have been used in refurbishment work on MOD airfields and on UK trunk roads and motorways to delay or minimise reflection cracking. Conclusive evidence of their performance was not available at the time that this document was produced.

1.3 The crack and seat treatment

The crack and seat treatment is described in detail in Section 3. This includes information on the specialist equipment needed to carry out the cracking operation.

The performance of crack and seat trials being carried out in the UK is still being evaluated. Nevertheless, the indications are that the crack and seat treatment applied in accordance with the design and construction guidance and specification given in this document, with a minimum addition of a 100 mm of blacktop overlay, will substantially delay the onset and minimise the rate of occurrence of reflection cracking.

An obvious disadvantage of the crack and seat treatment is that it reduces the strength of the existing pavement. Hence its cost effectiveness depends on the need or otherwise for strengthening work as well as the implications for future maintenance. The latter should take into account not only the cost of future maintenance but also the interval between maintenance due to the progressive reduction in surface characteristics of the new surface course and the disruption to operations that future maintenance will incur.

The crack and seat treatment in conjunction with the provision of bituminous overlays can be used to rehabilitate jointed unreinforced concrete pavements. These are usually of single or two layer construction laid on a dry lean concrete (DLC), asphalt or unbound granular foundation or laid directly onto the subgrade. It is suitable for use on unreinforced concrete pavements constructed with or without load transfer dowel bars. The treatment is also suitable for refurbishing composite construction with PQC or cement bound layers after first removing the asphalt layers to expose the concrete prior to carrying out the cracking.

For the maintenance of reinforced concrete, the saw-cut, crack and seat (SCC&S) technique can be used. In this technique, transverse saw-cuts are made to sufficient depth to sever the longitudinal steel reinforcement. It is important that no saw-cut should be deeper than 50% of the slab thickness, in order to retain sufficient aggregate interlock across the saw-cut and crack. The pavement is then cracked as for the crack and seat technique, thus allowing the concrete to expand and contract at the saw-cut/cracks and hence minimising reflection cracking. It should be noted that this technique is much more expensive than the standard crack and seat technique. For this reason, the minimum saw-cut spacing is often set to 1m.

1.4 Pavement design using the crack and seat treatment

The use of the crack and seat treatment in pavement refurbishment work requires special consideration of its implications for structural design. Section 4 sets out a design procedure using the DE reference document for the design of airfield pavements ‘A Guide to Airfield Pavement Design and Evaluation’ (Property Services Agency, 1989).

1.5 Construction supervision for the crack and seat treatment

Section 6 provides guidance for the Project/Works Services Managers for supervision of the crack and seat treatment. This includes appraisal of trials, measurements and observations to be made throughout the main works. Photographic examples illustrate both good and poor practice.

1.6 Specification for the crack and seat treatment

A specification and associated notes for guidance for the crack and seat treatment are detailed in Appendix D. In completing the specification for specific projects, reference should also be made to Sections 3 to 6 of this document.

2 Reflection cracking on MOD airfields

2.1 Mechanisms of reflection cracking

This section deals with the theoretical background to the occurrence of reflection cracking. At RAF airbases, the MOD has, for many years, used jointed unreinforced 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.

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.

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 which is greater than that required for the structural strengthening. The thicker 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. Current DE design guidance (PSA 1989) specifies a minimum of 100mm of asphalt overlay and acknowledges that reflection cracking may still occur in overlays on jointed concrete pavements.

Reflection cracks are also a common occurrence in the asphalt surfaces of flexible composite construction, which is frequently used on taxiways. This type of construction employs a composite base, comprising a continuously laid cement bound layer, usually dry lean concrete (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 transverse reflection cracks to develop at the surface of the asphalt.

In the early stages of development, reflection cracks in asphalt above PQC slabs and in flexible composite constructions 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. Traffic loading and climatic changes exacerbate the situation. The likelihood of spalling at the cracks, and the potential for damage to aircraft engines from loose material, is of great concern on airfields.

Three mechanisms of reflection cracking were identified by Nunn (1989) and are illustrated in Figure 2.1.

The classical theory of the cause of reflection cracking is shown in Figure 2.1a. 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 2.1b 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 2.1c 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.

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.

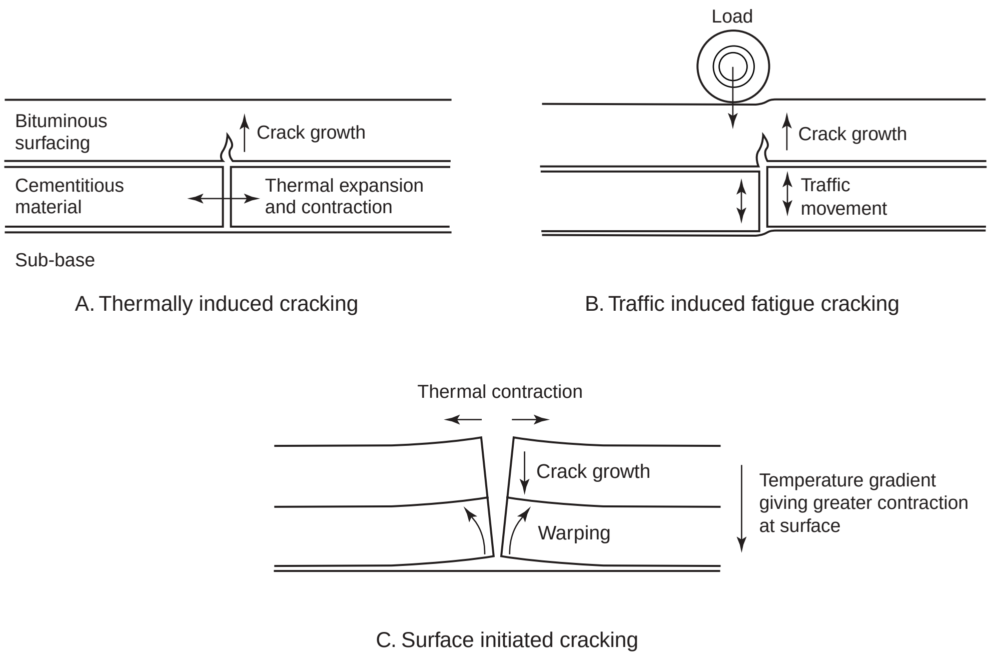

Figure 2.1 Mechanisms of reflection cracking

Several studies have concluded that crack propagation is dependent upon:

- low temperature exposure and brittleness of the surface course;
- thickness of the flexible layers;
- resistance of the bituminous binder to age hardening and climatic conditions; and
- temperature regime during construction and pavement life.

2.2 Pavement condition assessment

The routine airfield maintenance inspection records provide information on the type of pavements present on the airfield and their general condition. On the basis of these reports, recommendations are made identifying where remedial work is required and where minor and major maintenance might be needed in the future. A detailed pavement condition and structural assessment may then be established to investigate the condition more thoroughly and to make recommendations for specific immediate and future needs.

For composite pavements comprising asphalt overlays on PQC pavements or pavements with a DLC base and asphalt surfacing layers, (flexible composite), reflection cracking of the asphalt surface above joints or cracks in the PQC or DLC may be a problem. For badly deteriorated PQC pavements, an overlay is likely to be one of the maintenance options to be considered.

The assessment process relating to PQC and composite pavements should follow a general procedure such as that outlined in Figure 2.2.

As part of the structural assessment, the condition of the drainage system should be checked and any defects should be corrected as part of the remedial works. If the recommendation is for the pavement to be overlaid with asphalt then there is the potential for reflection cracking to

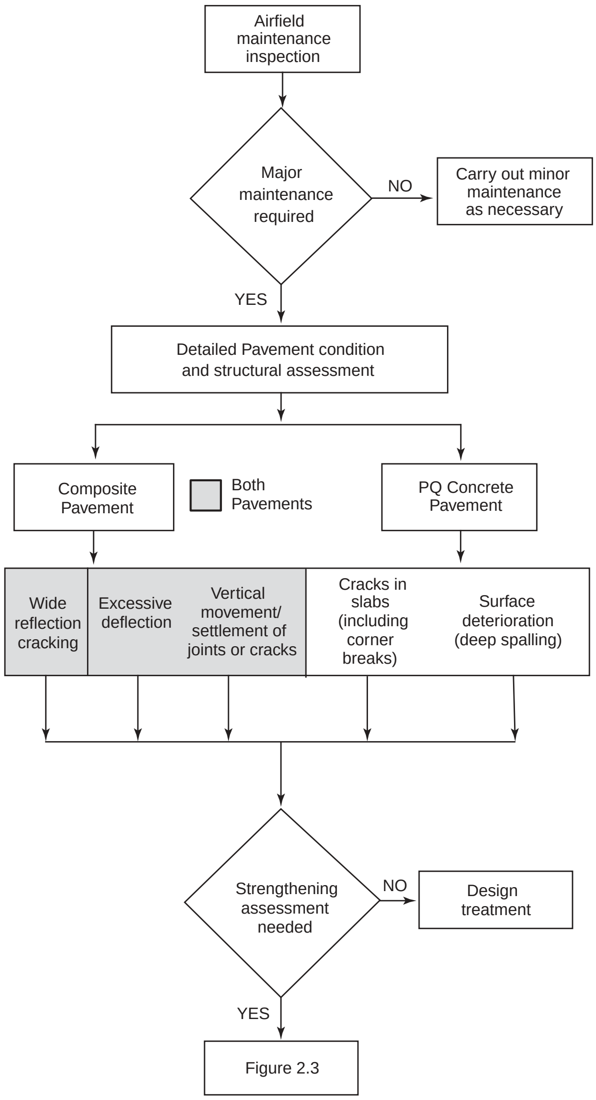

Figure 2.2 Assessment of airfield pavements

occur in future. Consideration should be given to applying an appropriate treatment to minimise this occurrence. There are various alternative treatments available and some of these are discussed in Section 2.3.

2.3 Remedial treatments

Since the 1960s, much research has been carried out on UK highways and airfields on minimising reflection cracking in asphalt overlays. There are a number of different maintenance options available for the control of reflection cracking:

- conventional asphalt overlay;
- modified asphalt overlay;
- concrete overlay;
- crack and seat treatment to unreinforced concrete;
- saw-cut, crack and seat treatment to reinforced concrete;
- saw-cut and seal the asphalt overlay above joints;
- geogrid reinforcement;
- stress absorbing membrane interlayers (SAMI);
- geotextile interlayer;
- asphalt inlay over concrete joints;
- combinations of the above treatments.

Figure 2.3 shows the options for strengthening rigid and composite pavements by the application of an overlay, possibly in combination with other treatments, to minimise reflection cracking. Not all treatments are applicable to both types of pavement. It is also important to fill any large voids under the slabs by pressure or vacuum grouting before overlaying to prevent slab rocking. In addition, it might be necessary to repair or replace cracked slabs and deteriorated joints when conventional overlays are being applied.

A brief description of each of the remedial treatments listed above is given in Appendix A. Further details are given by Vidal (2001). Also, in this Guide, reflection cracking on DE airfields is discussed.

3 Crack and seat maintenance

3.1 Introduction

The crack and seat technique is suitable for jointed unreinforced concrete pavements (JUCP) and composite pavements containing JUCP or cement bound material under asphalt surfacing layers. The technique produces shorter slabs while retaining satisfactory structural integrity by inducing fine, vertical, transverse cracks in the concrete thereby reducing the effective length of the slab

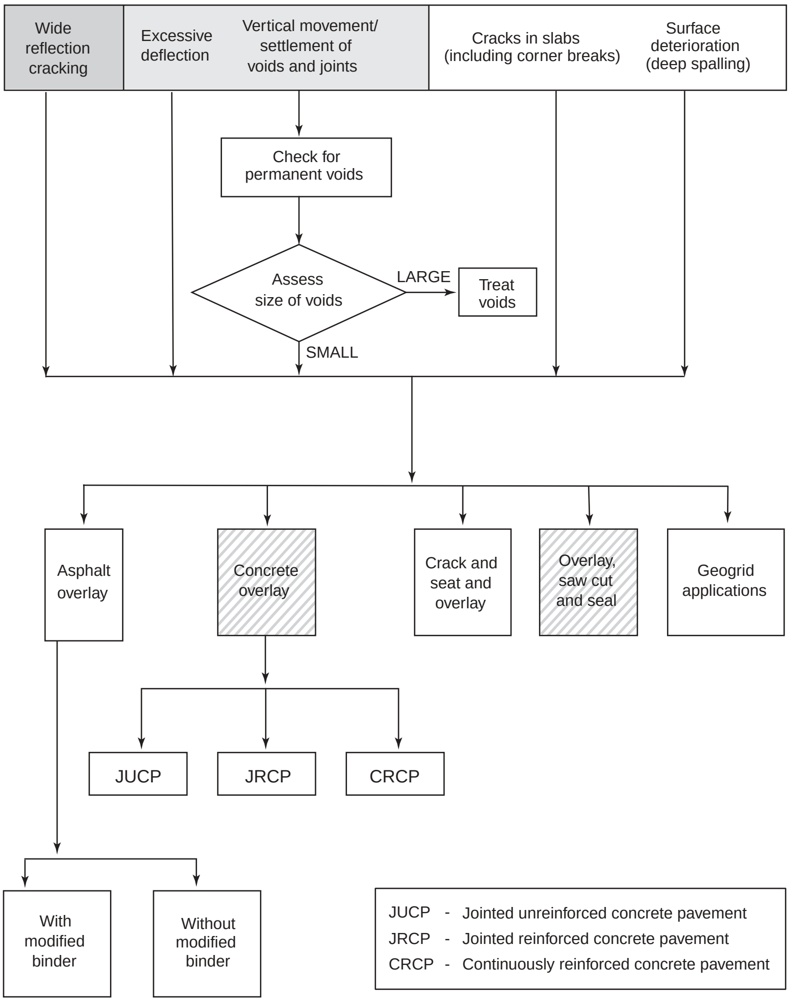

Figure 2.3 Selection of maintenance treatment

between the joints. The horizontal tensile strains resulting from thermal movements are distributed more evenly within the pavement and are therefore less likely to cause reflection cracks in the asphalt overlay. Provided that the cracks induced in the concrete are fine, then good aggregate interlock should be maintained and load transfer between the newly formed slabs should be satisfactory. After inducing cracks, the pavement is firmly seated by a heavy pneumatic tyred roller (PTR) to ensure that there are no voids under the concrete prior to overlaying.

Although a thinner asphalt overlay on a cracked and seated concrete pavement may be sufficient to inhibit reflection cracking, the extra cracks created in the concrete will reduce its load-spreading ability and this must be taken into account in the structural design (Potter and Mercer, 1996). Cracking of the concrete reduces its effective stiffness modulus, depending on the degree of interlock at the cracks and on the induced crack spacing. Consequently, it is necessary to establish the balance between the crack spacing, the reduction in stiffness modulus, the overlay thickness and the reduction of reflection cracks for typical designs of airfield pavements as shown in Figure 3.1.

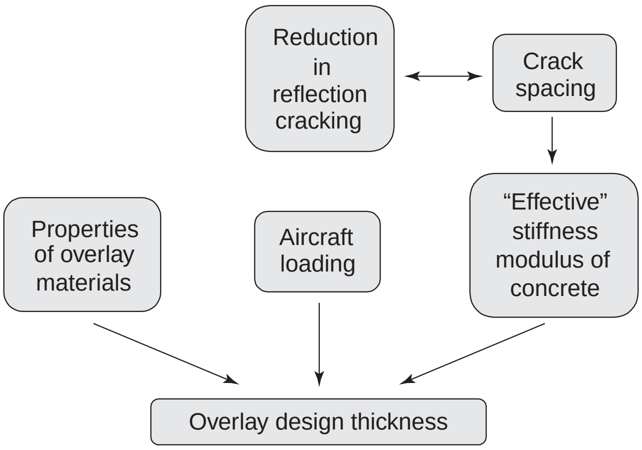

Figure 3.1 Crack and seat design of overlay thickness

3.2 Construction requirements and equipment

For cracking and seating of jointed concrete construction, it is usually not necessary to repair defective joints and cracks prior to overlay. This means that maintenance costs can be reduced. Also the complete maintenance operation should be carried out more quickly, not only because concrete repairs are not generally required, but also because no curing time is then necessary. The only remedial work that might be necessary is to fill any large voids under the slabs by grouting.

As with all pavement maintenance, it is important to ensure that the drainage is operating efficiently. Any deficiencies should be corrected as a matter of priority.

Effectively, the crack and seat process changes the jointed concrete pavement into a strong cement bound base with fine, closely-spaced cracks. Strong concrete does not tend to degrade at the cracks through mechanical abrasion resulting from heavy wheel loads, or from the opening and closing of the crack with changes in temperature.

For composite runways, taxiways and other airfield pavements comprising an asphalt surfacing on jointed unreinforced concrete or on a cement bound base, it is necessary to remove the asphalt prior to cracking and seating the concrete.

It is important that the cracking operation produces only fine vertical cracks in order to provide the good aggregate interlock needed for load transfer. However, it is also essential that the cracks penetrate to the full depth of the concrete layer so that small thermal movements can take place at each crack. Shattering of the concrete by using excessive force will reduce the effective stiffness and should be avoided.

In order to inspect the surface cracks following the cracking operation, it is usually necessary to wet the concrete and observe the crack pattern as the concrete dries. Cores are taken though a selection of the cracks to check that they are fine, vertical and penetrate the full depth of the concrete and to check that no shattering of the concrete occurs, which can contribute to a reduction in load-spreading ability of the overlaid pavement.

Two types of equipment have been used on MOD airfield pavements and on trunk roads and motorways in the UK for the cracking operation: guillotine devices and whiphammer devices. Whiphammer devices are no longer recommended, due to the large amount of random cracking caused. The guillotine devices that have been used and monitored are:

- Badger Breaker.
- Arrows Drophammer.
- Wirtgen BTZ 7000.

These are described as follows:

The Badger Breaker was introduced into the UK from the USA in 1996 where it had been used for some years for cracking and seating and also for rubblising concrete highway pavements. The equipment has been used on airfields and motorways in the UK. Construction monitoring has shown it to be capable of producing fine vertical cracks and a satisfactory crack pattern. Plates 3.1 and 3.2 show the machines in operation on a motorway and on an airfield.

The Badger Breakers monitored have four wheels with pneumatic tyres and are steered by the rear wheels. The guillotine blade weighs a little over seven tonnes and, for the models illustrated, is 2.4 metres wide. Models are available with a blade width of up to 3.65m. The blade is raised by a hydraulic system to a height of up to 2.75m although in normal operation for crack and seat the drop height is usually between 0.3m and 0.7m. The drop height is adjusted electrically and it can be raised and dropped up to 40 times a minute independent of the forward motion of the machine. The drop cycle can be set to run automatically or it can be operated manually to ensure accurate positioning of the blade. A striker plate is mounted on the bottom of the blade and this is normally about 50mm wide and the length is usually the width of

Plate 3.1 Badger Breaker working on a motorway

Plate 3.2 Badger Breaker initiating a slab halving crack on a taxiway

the blade. However, shorter striker plates can be welded to the blade to crack narrow slabs.

The Arrows D500 Drophammer used for crack and seat is shown in Plate 3.3. The machine has four wheels with pneumatic tyres and has rear wheel steering. The relatively small guillotine blade is mounted on a traversing head so that it can cover a width of 1.75m at any location. To cover wider widths, the machine makes parallel passes until the full width is achieved. The machine operates by raising the blade to a preset height of between 0.1m and 2.5m and releasing it to impact the surface of the pavement. The traversing head is moved sideways whilst the blade is being raised and the blade is dropped in the new location. This action is repeated across the required width of cracking with the blade impacting the pavement at intervals across the traverse to create the required transverse crack. The hammer weight is 612kg and it is able to apply between 30 and 120 impacts per minute. The cracking tool is a proprietary design with an impact area of about 100 square centimetres. It has been designed to prevent surface spalling and to ensure that vertical cracks are induced in the concrete. The Arrows D500 Drophammer is capable of producing transverse cracks in PQC slabs of any width with the same cracking tool.

Plate 3.3 Arrows D500 Drophammer guillotine action machine

The Wirtgen BTZ 7000 guillotine machine (no picture) was used in the initial trials of the crack and seat technique on highways in the UK. It has four wheels with pneumatic tyres and rear wheel steering. The guillotine blade is 1.75m wide and weighs approximately 5.5 tonnes. It can be dropped from a height of up to approximately 2.4m. In automatic mode the drop height and frequency are linked to the forward motion of the machine. Thus the drop height depends on the crack spacing being employed. On PQC slabs that are more than 3.5m wide, it is necessary to perform two passes of the machine to create a transverse crack across the full width of the slab.

Whichever machine is used for the cracking operation, it is necessary to adjust the impact force to produce the required fineness and depth of cracking, without any shattering of the concrete and without causing any undue spalling of the surface. The force applied is adjusted according to the strength and thickness of the concrete. For airfield pavements it is important that the induced cracks are predominantly vertical through the concrete because inclined cracks are likely to inhibit the thermal movements due to aggregate interlock enforced by the weight of the overlying pavement structure.

On PQC and composite construction, the cracked surface is seated using a pneumatic tyred roller (PTR) of at least 20 tonnes gross weight prior to application of the new bituminous overlay. A typical PTR is shown in Plate 3.4. This operation is carried out before the overlay is applied to ensure that the concrete slabs are securely seated into the foundation in order to prevent future rocking due to small voids.

For the main works on airfield pavements, guillotine action machines are specified for the cracking operation in order to produce the required pattern of cracking. Details of the specification for the treatment are given in Section 5 and Appendix D. The most important requirement is to create a fine full depth crack whilst preventing any shattering at the bottom of the concrete as a result of the cracking operation. This is checked during the work by examining cores taken through the impact points. The operation is fully described in Section 6 of this guide. The reason that the concrete could be

Plate 3.4 Pneumatic tyred roller (PTR)

shattered is shown in Figure 3.2. When the guillotine blade (or hammer action tool) strikes the surface of the slab, the concrete is deformed and horizontal tensile stresses are generated at the bottom of the concrete perpendicular to the blade. These stresses initiate the crack which propagates upwards to the surface of the concrete. If the force applied to the concrete is too high, then the concrete can shatter at the underside of the slab and it might also delaminate a few centimetres below the top surface of the concrete. This damage will reduce the load-spreading ability of the concrete substantially and will result in poor structural performance. Examples of shattering are shown in Section 6.

For jointed reinforced concrete pavements the longitudinal steel holds the concrete together, even if the concrete is cracked hence it will not allow the thermal contraction to take place at locations other than at the original construction joints. Hence the saw-cut crack and seat technique whereby the steel is cut with transverse saw-cuts (often at spacings equal to or greater than 1m) before cracking and seating is becoming increasingly popular. Other anti-reflection cracking treatments are also available for reinforced jointed concrete pavements, as outlined in Appendix A.

3.3 Measurements during the maintenance operation

As part of the crack and seat operation, it is necessary to conduct a small trial prior to the main production cracking to confirm that the cracking equipment can produce the required type of crack. Also, as part of the trial, Falling Weight Deflectometer (FWD) measurements are conducted to ensure that the effective stiffness of the cracked concrete exceeds the threshold value specified for structural design. During the main work it is necessary to assess the quality of the cracking and to monitor the effective stiffness of the cracked concrete using FWD measurements.

The quality of the cracking is assessed by visual inspection of the crack pattern on the surface of the concrete and by extracting cores through the cracks to ensure that the cracks comply with the specification. Details of the requirements are given in the specification in Appendix D and guidance on how to assess the cracks is given in Section 6.

The effective stiffness of the cracked concrete slabs is determined to enable an assessment of the effects of cracking and seating upon the load-spreading ability of the pavement. The effective stiffness is derived from the magnitude and shape of the deflection bowl generated under the loading plate of an FWD when the load is applied. Plate 3.5 shows an FWD being used to measure

Plate 3.5 Falling Weight Deflectometer (FWD)

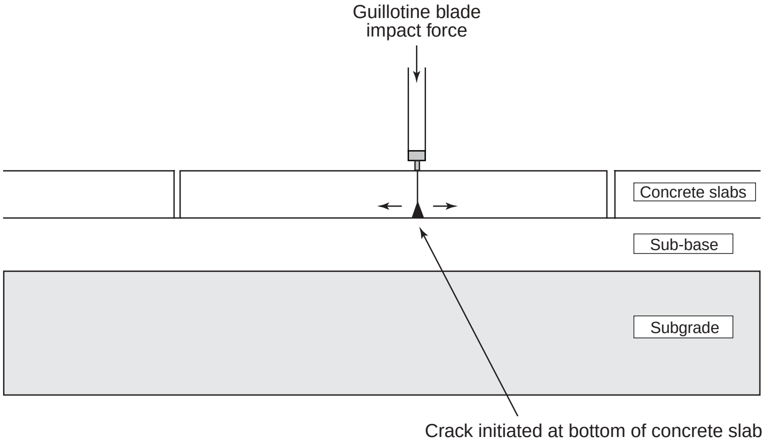

Figure 3.2 Generation of induced cracks by a guillotine action machine

deflections on an airfield taxiway. The shape of the deflection bowl and the magnitude of the deflections are controlled by the stiffness, thickness and position of the various layers within the pavement structure. To determine the effective stiffness of the cracked and seated concrete, the geophone transducers on the FWD should be positioned as shown in Figure 3.3.

By using a back-analysis technique, and knowing the thickness and position of the various pavement layers, it is possible to calculate a value for the effective stiffness of the materials within the pavement from the measured deflection bowl. This process can be carried out using various computer programs such as MODULUS developed by the Texas Transportation Institute, (1995).

Guidance on how to conduct the FWD surveys is given in Section 6. The responsibility for the FWD measurements and analysis resides with the project manager acting on behalf of DE as set out in the specification.

The FWD can also be used to measure the effectiveness of joint load transfer as a wheel passes from one slab to another. The load transfer efficiency (LTE) across joints or cracks in the concrete reflection cracking occurring in an asphalt overlay if an anti-reflection crack treatment is not employed. However, it is not a requirement of the crack and seat specification that LTE values are measured. Nevertheless, LTE measurements across cracks or across the joints between concrete slabs might be conducted as part of the pavement evaluation process prior to carrying out the pavement rehabilitation. Joints with poor LTE values are more likely to encourage the development of reflection provides an indication of the likelihood of cracking (see Figure 2.1b). LTE reduces with the temperature of the concrete and hence measurements should preferably be made in the winter when the joints are widest.

3.4 Crack and seat research trials

In summary, much progress has been made in understanding the causes and consequences of reflection cracking in PQC and DLC pavements. In particular, it has been established that crack and seat maintenance of jointed unreinforced concrete pavements is an effective means of minimising reflection cracking. This is illustrated by the success of full-scale trials that have been carried out on UK highways.

The research trials were designed to evaluate the effects of overlay thickness, crack spacing and the pattern of cracking, created by different types of cracking machine, on in-service roads. The performance of the test sections is being assessed by direct comparison with control sections of conventional overlay. During the construction of the research trials, measurements were made of the condition of the road before, during and after the various maintenance operations.

The performance of these trials was reported by Potter and Mercer (1996) and by Ellis (1997, 1998). Due to their success, the crack and seat and overlay technique has been used on many major structural maintenance schemes on trunk roads and motorways.

Figure 3.4 shows the performance of crack and seat on two jointed unreinforced concrete pavements, and Figure 3.5 shows the success on lean concrete pavements where the base has been exposed by planing off the existing asphalt. In these examples, the anti-reflection cracking performance is illustrated as a percentage of the total length of transverse joints or cracks in the test sections that has exhibited subsequent reflection cracking in the asphalt overlay.

Both Figures 3.4 and 3.5 demonstrate the success on UK highways of the crack and seat maintenance technique. It is expected that these results will be repeated at the current trials and maintenance projects at RAF Coningsby (1986) and RAF Lyneham (1987).

The anti-reflection cracking performance of different surfacing materials has also been illustrated by trials on airfield pavements. In particular, at RAF Finningley, the use of the edge strip to identify cracking has yielded results on the performance of a Friction Course and a Marshall asphalt surfacing. The trial indicates that a Friction Course surfacing is better at delaying the initiation of reflection cracking than Marshall asphalt.

Trials have been conducted on the northern taxiway at RAF Coningsby (Langdale and Potter 1996) and on an aircraft service platform at RAF Lyneham (Langdale *et al.*, 1997). On the basis of these trials, the crack and seat treatment was employed for maintaining two jointed unreinforced concrete taxiways at RAF Lyneham (Ellis and Langdale 1998). A brief description is given in Appendix B of the crack and seat works at RAF Coningsby and RAF Lyneham.

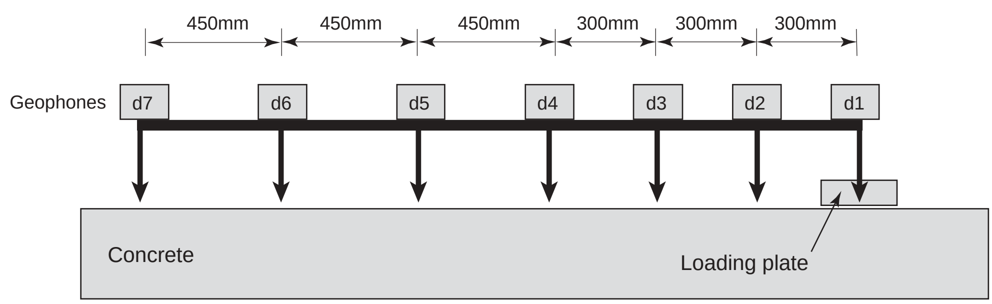

Figure 3.3 FWD geophone configuration

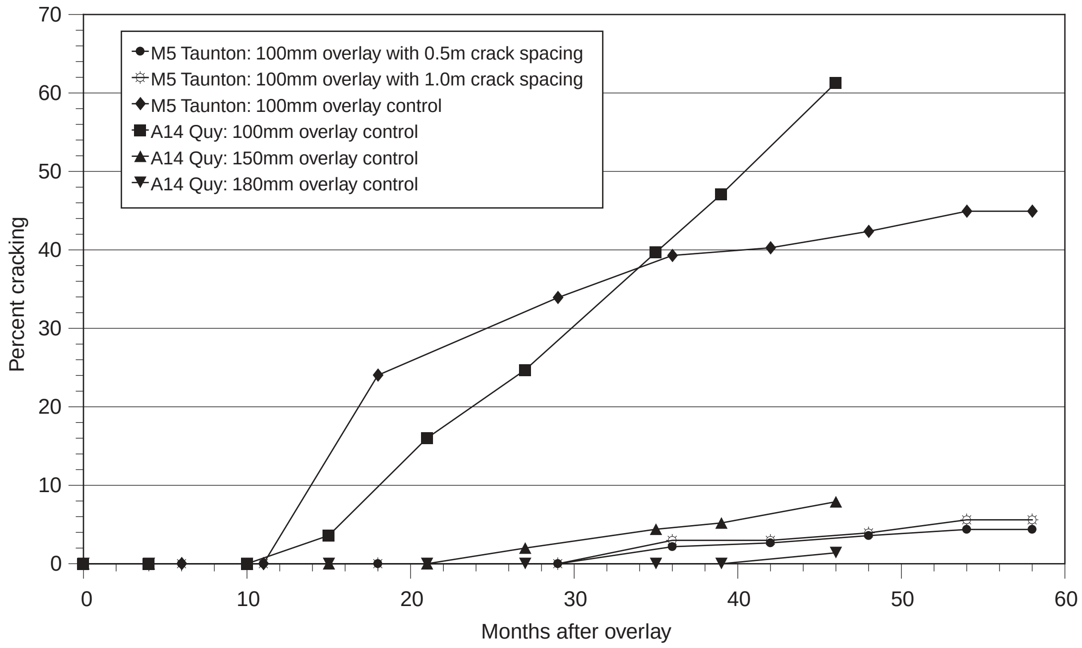

Figure 3.4 Performance of crack and seat on overlays to PQC pavements on UK highways (Ellis, 1997)

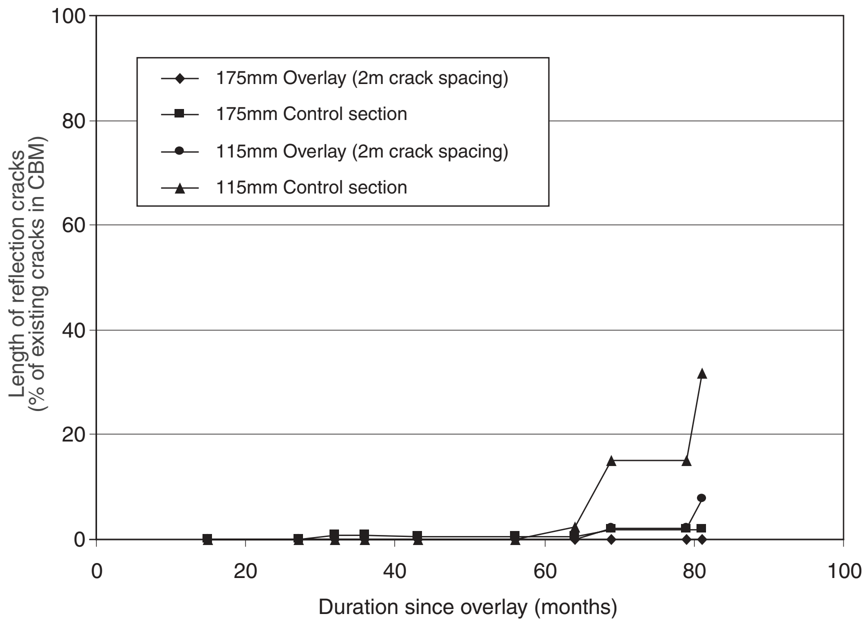

Figure 3.5 Performance of crack and seat on a UK highway with a lean concrete base (Ellis, 1998)

4 Design for crack and seat maintenance

4.1 General

The design guidance provided in this document is based on DE methods as provided in 'A Guide to Airfield Pavement Design & Evaluation' (PSA, 1989). General design considerations are repeated in this document so that design can be carried out with little cross-reference. Should further information be required then reference should be made to the PSA document.

4.2 Reason for maintenance

It may be necessary to reappraise the bearing capacity of a pavement to determine whether any strengthening is necessary. This would apply in any one of the following circumstances:

i A mid/end of life reassessment of the pavement to plan future maintenance and/or rehabilitation work.

ii The pavement has been unused for some time and is to be rehabilitated.

iii The pavement is to be strengthened for regular use by heavier aircraft.

iv The pavement has deteriorated in service.

v There has been a change in the classification system.

4.3 Types of pavement suitable for crack and seat

The design method presented in this document is applicable to the maintenance of two types of pavement; rigid or composite. To use crack and seat on composite pavements, the existing bituminous surfacing needs to be removed before cracking and seating.

A rigid pavement comprises, either wholly or partly, PQC concrete construction with a concrete running surface. For a jointed unreinforced concrete pavement, the standard crack and seat technique is used. For a jointed reinforced concrete pavement then the saw-cut, crack and seat technique should be used. Neither technique is suitable for continuously reinforced concrete pavement (CRCP).

A composite pavement consists of either an unreinforced concrete pavement that has been overlaid with bituminous material or a pavement that was constructed as composite with a cement bound base and bituminous surfacing layers. The latter type of construction is treated by DE as a flexible pavement for design and evaluation purposes because of the cracks that occur in the structure over time.

4.4 Design procedure for crack and seat maintenance

For design purposes, a cracked and seated concrete pavement with a bituminous overlay is treated as a flexible pavement. This is based on the concept that subsequent structural cracking in the underlying concrete will eventually lead to subgrade shear and rutting of the pavement before serious reflection cracking occurs in the bituminous surfacing.

The structural value of the cracked and seated concrete is considered to be the same as that for a bound base material (BBM) as defined in the PSA 'Guide to Airfield Pavement Design and Evaluation' (1989). For this purpose, the threshold value for the effective stiffness modulus is set at 5,000 MPa. To ensure compliance with the design concept, it is necessary to carry out a deflection survey using an FWD during the crack and seat works to determine and check the stiffness moduli of the cracked and seated concrete. The requirements are given in the specification in Appendix D and further guidance is given in Sections 3, 5 and 6.

The pavement design should accord with that given in the PSA Guide for flexible pavements utilising BBMs.

The steps necessary to carry out the design are:

a Determine the thickness of the existing BBM including any concrete or bituminous layers underlying the PQC. For existing flexible constructions with DLC bases, the thickness of BBM excludes the overlying bituminous surfacing layers because these will be removed before the crack and seat process.

b Determine the sub-base type and thickness.

c Determine the subgrade strength.

d Determine the design ACN.

e Determine the frequency of trafficking from:

- The design life.
- The pattern of trafficking and assessment of passes.
- Coverages and pass-to-coverage ratio.
- Mixed traffic analysis if there is more than one type of significant user aircraft.

f Determine the overlay thickness using Chart 4 from the PSA Guide (1989).

The following sections and the worked examples in Appendix C outline the various stages for design with some references to specific paragraphs in the PSA Guide to Airfield Pavement Design and Evaluation.

4.5 Evaluation of existing pavement

Before carrying out a structural design for strengthening or rehabilitating an existing pavement, it is necessary to determine its present condition. Structural deterioration of pavement layers will reduce their load bearing capacity and suitable allowances may have to be made in the evaluation or the overlay design.

If a pavement is being strengthened, the overlay thickness requirement should be calculated on the basis that it provides the required future design life. The evaluation of the existing pavement should therefore reflect its current condition. This will generally necessitate making due allowance for the deterioration of all layers in the existing construction. The reason for deterioration should be established and the causal factors, for example poor drainage, should be corrected as part of the strengthening works.

In this document it is assumed that the pavement evaluation indicates the need for overlaying with bituminous material after using the crack and seat treatment in order to minimise the occurrence of reflection cracking in composite pavements. If this is not the case, reference should be made to Chapter 7 of the PSA Guide (1989).

In order to design for crack and seat and overlay, information is required about the pavement construction and present condition. A record of its use may also be required. The specification and thickness of the various layers of construction need to be established. If records do not contain sufficient information, cores will need to be taken and trial pits may be required to provide information about the condition of the foundation and the subgrade.

For PQC and composite pavements, cores will provide information on the thickness and the condition of any concrete, asphalt or cement bound layers.

The CBR of the subgrade is required including, where possible, information on any variation with depth. This can be measured using a dynamic cone penetrometer (DCP). Information about the determination of CBR is given in paragraphs 7.2.4 of the PSA Guide to Airfield Pavement Design and Evaluation.

4.6 Subgrade strength

The determination of subgrade strength in terms of the California Bearing Ratio (CBR) is essential to the satisfactory design of a new or maintained pavement.

The value of CBR to be used for design is the value at the formation level for the pavement that is typically the lowest value. If there are no records of subgrade characteristics, a soil survey will be necessary through the pavement to determine soil properties. *In situ* CBR can be determined by simple site testing, for example using the Dynamic Cone Penetrometer (DCP).

If the CBR decreases with depth then an appropriate value needs to be considered for design. The appropriate value will always be greater than the lowest CBR value. Example C1 in Appendix C provides a worked example for determining equivalent CBR for a given aircraft loading.

4.7 The design aircraft classification number (ACN)

The method for determining the design aircraft classification number (ACN) for a pavement is given in Chapter 2 and Appendix B of the PSA Guide (1989). For crack and seat maintenance, appropriate values should be selected from the table in Appendix B for a flexible pavement subgrade.

The ACN of an aircraft expresses its relative loading severity on a pavement supported by a specified subgrade. The ACN used for pavement design is based on design aircraft, which is normally the aircraft with the highest ACN on the actual subgrade. ACN values should relate to the actual CBR value of the subgrade and can be calculated by linear interpolation from the design ACN values given in Appendix B of the PSA Guide.

4.8 Frequency of trafficking

While the magnitude and configuration of the wheel loads are the dominant factors in the structural design of airfield pavements, the effect of fatigue caused by load repetition is an important secondary consideration for both rigid and flexible pavements. Laboratory and full-scale tests clearly show that pavements subjected to high frequencies of trafficking need to be significantly thicker than those subjected to low frequencies.

The design methods given in this guide cater for three frequencies of trafficking: Low, Medium and High, as shown in Table 4.1.

Table 4.1 Design frequency of trafficking

Frequency of trafficking	*Nominal number of coverages* over design life of pavement*
Low	10,000
Medium	100,000
High	250,000

** The definition of 'coverages' is given in Section 4.11*

To determine the appropriate frequencies of trafficking, the total number of coverages, as defined in Section 4.11, during the design life should be calculated. This involves consideration of the design life, pattern of trafficking and mixed traffic use.

4.9 Design life

The design method and the frequencies of trafficking in Table 4.1 assume that aircraft movements are spread fairly evenly over the life of the pavement.

In normal circumstances pavement deterioration is gradual, becoming noticeable over a period of a few years. This deterioration can be due to surface weathering or structural fatigue or both. In deciding on an appropriate structural design life, the following considerations should be borne in mind:

i The need for major maintenance work on airfield pavements to be infrequent.

ii The likelihood of a change in aircraft use after a number of years.

iii Durability of pavement construction. Experience on airfields indicates that concrete pavements are more durable than bituminous pavements assuming both are constructed in accordance with the Department's specification. The surface serviceability of concrete with the aid of minor maintenance work, has been shown to be adequate for 25-35 years. On the other hand bituminous surfacings, as a result of surface weathering, generally require maintenance work, often in the form of slurry sealing, after 7-10 years, and more substantial restoration work after 20-25 years. In the case of friction course, resurfacing may be required after approximately 15 years.

With these factors in mind, it is recommended that the structural design for crack and seat and overlay should be for 20 years.

The design method assumes an increasing degree of minor maintenance (e.g. crack sealing) in the last few years of a pavement's life. Where such maintenance cannot be tolerated, the Engineer may wish to propose a structural design life beyond the expected life of the surfacing.

4.10 Pattern of trafficking and assessment of passes

An aircraft movement over a particular section of the pavement normally constitutes a pass. The total number of passes should be taken as the total number of movements and mixed traffic analysis should be used to consider the effect of aircraft operations at different weights. It is conservative to consider all movements at maximum ramp weight. If it is certain that actual operations (e.g. landings) will always be at weights lower than this figure then a more accurate weight can be used (e.g. for fast turn offs, accesses to maintenance areas and where runway length restricts maximum take off weight).

Runways and main taxiways leading to runway ends are the most heavily loaded pavements as they carry aircraft at their heaviest, when fuelled for take off. For these pavements, the number of passes can be taken as the number of departure movements only; landing movements are accounted for by assuming that all passes are at maximum ramp weight unless information indicates otherwise.

The outer portions of runways can be designed to a reduced loading regime. However, where an airfield does not have a parallel or perimeter taxiway, the assessment of the loading regime should include the additional use of the runway for taxiing operations. ‘Backtracking’ (taxiing) down the runway by departing aircraft will approximately double the coverages (as defined in Section 4.11) on the runway. In addition, the length of runway used by backtracking aircraft should be provided with the same full depth construction across the full width of the pavement to allow for taxiing being offset from the centre-line.

Reduction in construction thickness on the outer strips of runways, is particularly beneficial when strengthening existing runways which have an inadequate camber. The reduced thickness at the edge will allow improved transverse gradients and surface water drainage

On helicopter pads and Harrier VTOL pads, the dynamic effects of landing aircraft increase the loading factor. For these pavements, the passes should be taken as the number of take offs plus the number of landings at the ACN appropriate to the maximum weight; the pass-to-coverage ratio listed in Tables 4.2 and 4.3 should also be adopted.

Table 4.2 Pass-to-coverage ratios

*Main wheel gear type**	*Pass-to-coverage ratio*
Single	See Table 4.3
Dual	3.2
Dual-tandem	1.6

** Refer to the PSA guide, Appendix D (1989) for definition of landing gear arrangements.*

Table 4.3 Pass-to-coverage ratios with single main wheel gears

Tyre pressure (MPa)	*ACN of aircraft* Up to 10	11-20	21-40	Over 40
Up to 1.0	8	6	5	4
1.0 to 1.5	10	8	6	5
Greater than 1.5	12	10	7	6

4.11 Coverages and pass-to-coverage ratio

Coverages represent the number of times a particular point on the pavement is expected to receive a maximum stress as a result of a given number of aircraft passes. The relationship between passes and coverages depends on several factors, including the number and spacing of wheels on an aircraft’s main wheel gear, the width of the tyre contact area and the lateral distribution of the aircraft wheel paths relative to the pavement centre-line or guideline markings. The number of coverages is calculated using the pass-to-coverage ratio.

$$\text{Coverages} = \frac{\text{No. passes}}{\text{Pass-to-coverage ratio}}$$

Tables 4.2 and 4.3 give pass-to-coverage ratios for various main wheel gear arrangements on any pavement. These ratios assume channelised trafficking consistent with taxiing operations and the initial stage of a take off run. For the background to the derivation of the pass-to-coverage ratios see the PSA Guide, Appendix E (1989) which also sets out a procedure for calculating pass-to-coverage ratios for non-standard wheel gear arrangements.

4.12 Mixed traffic use

At a military airfield, the pavements are often designed for operations by a specific type of aircraft and this makes the calculation of the loading regime relatively straightforward. However, where traffic forecasts indicate operations by a variety of aircraft, the loading criteria will not be so readily assessed. In allowing for a variety of aircraft types it is necessary to be able to relate the loading severity of each type of aircraft to that of the design aircraft and thereby to calculate the number of Equivalent Coverages by the design aircraft.

The calculation of the loading regime for pavements subject to mixed traffic is explained with reference to Worked Example C2 in Appendix C:

i Decide on the required design life of the pavement.

ii Establish the aircraft types likely to use the pavement.

iii Establish the ACNs for each aircraft at the actual subgrade value and the appropriate weight.

iv Establish aircraft pass-to-coverage ratios from Tables 4.2 and 4.3.

v Establish the number of passes by each aircraft.

vi Establish the design aircraft.

vii Calculate the number of coverages by each aircraft during the design life of the pavement.

viii Calculate the ratio of the ACN of each aircraft to that of the design aircraft.

ix A pavement that is maintained by crack and seat methods is considered as a flexible pavement. For flexible pavements, use the PSA Guide Figure 10 to obtain flexible mixed traffic factors (FMTF) from the coverages found in step (vii).

x Calculate a modified FMTF for each aircraft by multiplying it by the respective ACN ratio and determine the number of Equivalent Coverages by the design aircraft.

xi Calculate the total coverages by the design aircraft.

xii From Table 4.1, select a frequency of trafficking to use as an input to the design charts.

4.13 Design of bituminous overlay

Worked Example C3 in Appendix C illustrates the overlay design procedure. The stages are as follows:

i The existing pavement construction is evaluated to determine the thickness and condition of the bound materials including the PQC. If additional cement bound or bituminous layers are under the concrete layer, then the BBM thickness will be the total thickness of all these layers. The bottom of the BBM will occur when a granular layer or subgrade is encountered.

ii Frequency of trafficking is calculated by determining the total Equivalent Coverages for the design aircraft, as demonstrated in Worked Example C2, Appendix C.

iii Design Chart 4 from the PSA Guide (1989) is then used to determine the required thickness of BBM for the desired design life. The ACN used is that for the design aircraft and for the established *in situ* CBR. For HIGH frequency trafficking, 8 per cent is added to the required BBM obtained for MEDIUM trafficking requirements. This is a nominal increase that has been selected without knowledge of the pavement performance at this level.

iv The total required BBM for the design aircraft is then determined as the value obtained from Design Chart 4 (plus 8 per cent for HIGH frequency trafficking, if necessary) plus 100mm of bituminous surfacing.

v To determine the overlay thickness, the existing pavement is included as part of the required BBM. The overlay thickness is determined as:

$(BBM_{required}) - (BBM_{existing})$, rounded up to the nearest 5mm.

5 Specification for the crack and seat treatment

5.1 General

The specification for the use of the crack and seat treatment on unreinforced PQC and composite pavements is set out in Appendix D. Sample Appendices to the specification are provided to detail the requirements for the specific project under consideration. In addition, Notes for Guidance are provided to assist the specifier in defining the detailed requirements.

The specification details the requirements necessary to successfully complete the crack and seat treatment. Before the main production work is commenced, a main trial cracking operation is carried out as part of the contract. Details of how this is achieved and assessed are included in the specification.

The responsibilities for checking and assessing compliance of the works are defined.

A pro-forma is included (Appendix 1.1) to maintain a progress record for the cracking operation.

A pro-forma is included (Appendix 1.2) to maintain a record of the cores extracted from the concrete.

6 Construction supervision of the crack and seat treatment

6.1 Introduction

This section is designed to help the Engineer to oversee the crack and seat works on airfield pavements. Guidance is given in the form of six flowcharts that take the process from the decision to use crack and seat through to approval of the cracked and seated surface ready for overlay.

Figure 6.1, Chart A, outlines the procedures required for crack and seat, while Charts B to E give outline guidance on the procedures to be followed in each phase of the works. Detailed guidance for each phase is given in the following sections.

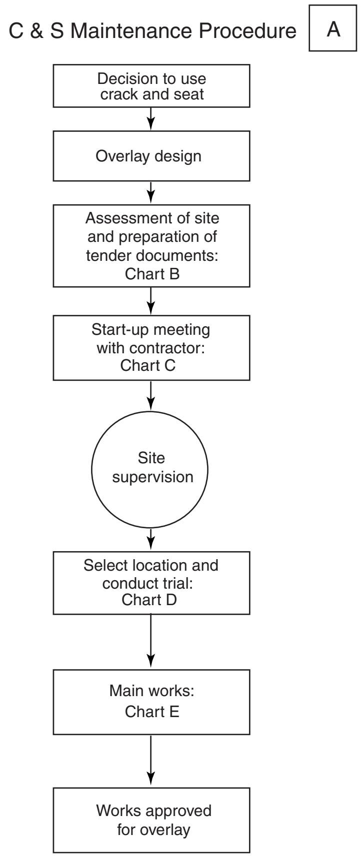

Figure 6.1 Chart A

6.2 Assessment of site and preparation of tender documents

Figure 6.2, Chart B, outlines the steps to assess the site and prepare the tender documents.

A visual condition survey should be available, or be carried out as part of the site investigation, to identify the numbers and sizes of the concrete slabs to be cracked and seated. Note that slabs wider than 5m or narrower than 3m may require a different cracking procedure if a wide blade guillotine is being used. Characteristics of such non-standard slabs that require special provision in the tender might be:

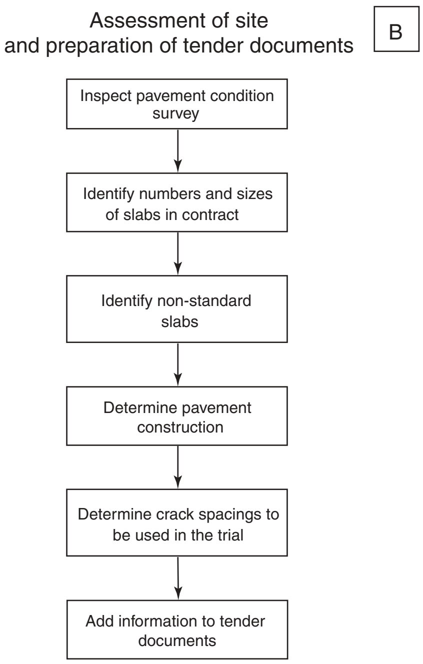

Figure 6.2 Chart B

- non-rectangular;
- less than 3m wide;
- greater than 5m wide;
- not flat, for example; shaped to form surface drainage channels;
- slabs over services.

A detailed visual condition survey will also allow the location of the trial to be determined before the hand-over of the site.

The construction of the pavement should be determined. If it is other than jointed unreinforced concrete of single-slab construction, then a feasibility trial should be considered to assess the applicability of the crack and seat technique. A feasibility trial would be conducted in a small area of pavement, ideally in the area of the proposed works, or in an area with similar construction. It should be cracked and seated to assess the effectiveness of the technique in the same way as for the main trial (see below) before crack and seat is incorporated into the tender documents for the maintenance works.

In the tender documents the overseeing organisation representing DE should provide information about the concrete contained in the scheme including its thickness, type of construction and whether DLC sub-base is present. The presence of any non-standard areas or slabs (as described previously) should be included, with approximate areas where possible.

The crack spacings to be assessed in the trial must be defined in the tender documentation. It is recommended to select a crack spacing that permits even division of slab length wherever possible; for example:

6m bays: 1m, 1.2m, 1.5m spacing,

5m bays: 1m, 1.25m, 1.7m spacing.

It is not recommended to use a crack spacing of less than 1m, as the risk of random cracking has been found to increase considerably below this threshold. It is suggested that the estimate of the cost of the main works is made on the basis of a 1m crack spacing.

6.3 Start-up meeting

Figure 6.3, Chart C, outlines the steps to be taken in preparation for and during the start-up meeting with the contractor.

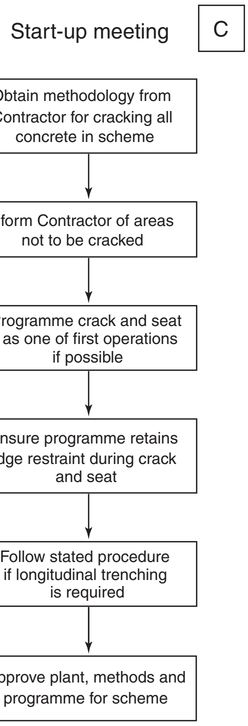

Figure 6.3 Chart C

The contractor shall inform the client as to his methodology for cracking all the concrete slabs within the scheme, with special regard to those slabs defined as non-standard in Section 6.2.

In addition, it is essential that the areas that are not to be cracked are clearly defined. Such areas will include slabs where services run underneath the pavement.

If the contractor’s plant cannot satisfy the requirements of the specification for some areas of the works, then alternative plant should be used, unless the overseeing organisation is prepared to accept the increased probability of reflection cracking in areas that are not fully cracked and seated.

Ideally, the crack and seat treatment should be one of the first operations carried out in the works, as the guillotine will operate most efficiently when it is allowed to work unimpeded.

The sequence of works should be confirmed with the contractor to ensure that side restraint to support the edges of the concrete slabs is maintained during the cracking and seating operation. This can be achieved by ensuring that either no works that remove side restraint are carried out before the cracking and seating, or that edge works are completed and fully reinstated to restore support before the cracking and seating treatment. If it is absolutely unavoidable to perform cracking and seating in small areas where the edge of the concrete to be cracked is unrestrained, then it will be necessary to carry out a controlled trial, in the affected area as defined in Section 6.4.

If trenching of the pavement is required as part of the works, for example for the installation of new AGL ducting (for lights), then the sequence of operations should be as follows:

1 Saw-cut limits of trench.

2 Crack and seat surrounding areas.

3 Excavate and reinstate trench.

The dangers of removing edge restraint before the cracking and seating operation is shown in Plate 6.1, where a trench to accommodate new AGL ducting was excavated before cracking and seating the adjacent slabs. The slab edge pieces have separated from the main slab, requiring localised reconstruction.

Plate 6.1 Cracking at excavated trench

It is advisable that the crack and seat operations are completed before the commencement of any other activities that will limit the possible overlay thickness, for example correcting drainage deficiencies, installing kerbs or ironwork. This is advisable in case the FWD testing shows areas that require an additional overlay thickness.

6.4 Trial area(s)

Figure 6.4, Chart D, sets out the steps necessary to conduct the trial which forms part of the specification for the crack and seat treatment.

A trial is required to identify the optimum drop heights for the guillotine, determine the required crack spacing and to establish the FWD test location to be used for the main works. The contractor must also demonstrate that the cracking plant can operate effectively in compliance with the specification. The trial assessment is carried out by a combination of visual inspection of crack patterns, cores and FWD measurements.

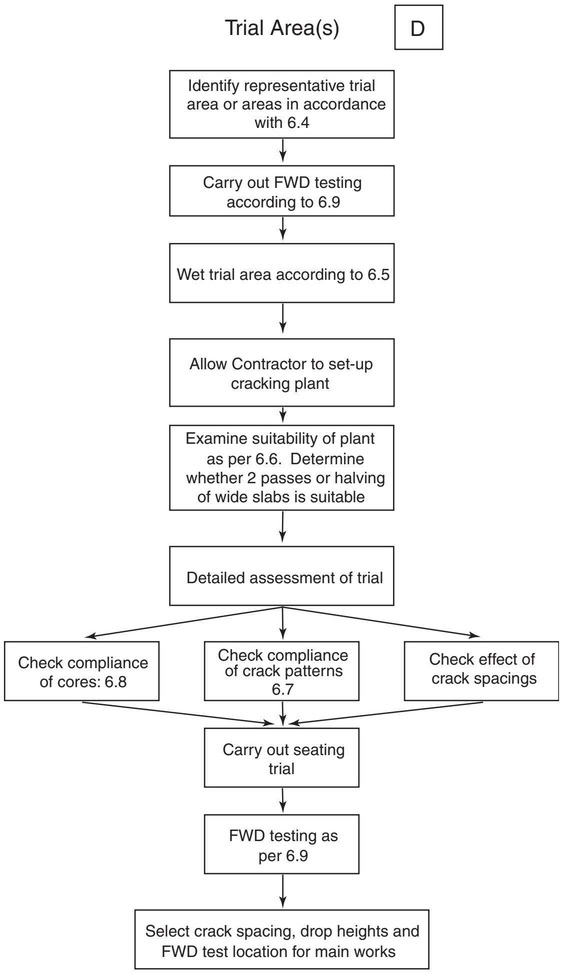

Figure 6.4 Chart D

The extent of a trial area should not be less than 300m^2 or greater than 420m^2. The overseeing organisation should identify the trial area(s), which should be representative of the whole of the main works. Special regard should be made to:

- Concrete thickness.
- Foundation strength, especially differing sub-base materials.
- Slab dimensions.

The overseeing organisation should identify areas that show differing levels of deterioration that might be indicative of different construction thicknesses or concrete or foundation strengths.

The outcome of the trial should ensure that there are ‘no surprises’ when the contractor starts on the main works. If the works contain areas of deterioration with, for example, transverse cracking, then the trial area should contain some similarly cracked slabs. On the other hand, the trial area should not consist only of cracked slabs when there are areas of pavement in generally sound condition, as it is likely that different impact forces will be required for each area.

If it is not possible to locate a single trial area that is generally representative of the site, then further trial areas should be added to ensure that a representative sample of the pavement is assessed in preparation for treating the main works.

6.5 Wetting the trial area

The trial area should be wetted to help identify the crack pattern. Ideally, a fine spray should be applied, e.g. from a road sweeper, since the cracks are most visible as the surface dries out. Alternatively, water may be applied from a bowser as shown in Plate 6.2. If too much water is applied, the cracks can still be seen upon impact, in the form of a bubble trail. The addition of water may be omitted if the surface is already sufficiently saturated by rainfall.

Plate 6.2 Wetting the trial area

6.6 Setting up cracking plant

In Stage 1 of the trial, the contractor shall be allowed to adjust the drop height of the guillotine blade of the cracking machine on an area of slabs as permitted in Appendix A1.0 of the specification. This adjustment is made at the crack spacing specified in Appendix 1.0 of the specification. The overseeing organisation should ensure that requirements can be met for positioning the guillotine with respect to slab edges etc. The guillotine blade should not cause excessive surface damage (spalling).

During this set-up period, the action of the cracking equipment should be closely examined:

- The blade should be flat across its whole width so that the impact force is evenly distributed across the full blade width. If uneven, or worn at the ends, a new strike bar should be fitted.
- The blade should be of a width capable of complying with the requirements of the specification.

When the contractor is satisfied with the performance of the cracking operations, further stages of the trial can be carried out according to the requirements of the specification, taking into account the guidance offered in the following sections.

6.7 Interpretation of crack patterns

To observe the production of cracks, it is best to stand at a distance of about 3m from the guillotine. From this distance the cracking can be seen as it is produced on the wet surface, and the effect of subsequent cracking can be seen on previously produced cracks. The position of cracks running from the end of the guillotine blade where it impacts the concrete to the edge of the pavement can be marked for possible subsequent core extraction.

The surface of the concrete should be viewed as the blade impacts the concrete and the creation of cracks should be seen if the surface is sufficiently wet. Cracks should be seen to run predominantly transversely to the edges of the slab. Frequently, cracks may be seen only after the adjacent drop has been performed. When cracking, bubbles can often be seen along the line of the impact when the surface has been fully saturated with water. It is useful to see cracks extending to the edge of the slabs, as it may be difficult to core at these positions.

The intention of the crack and seat process is to retain as much structural strength in the pavement as possible, while reducing the amount of thermal movement at the joints. Therefore, the ideal crack pattern comprises only transverse cracks that run across the full width of the slab. Plate 6.3 shows the transverse cracking desired by the specification. Plate 6.4 shows crack patterns often encountered while using the crack and seat technique, where sporadic ‘v’ cracking occurs when two cracks propagate from the end of the impact to the edge of the slab. This pattern of cracking is acceptable, unless the wedge-shaped area of concrete forming the ‘v’ appears to be detached from the main body of the slab.

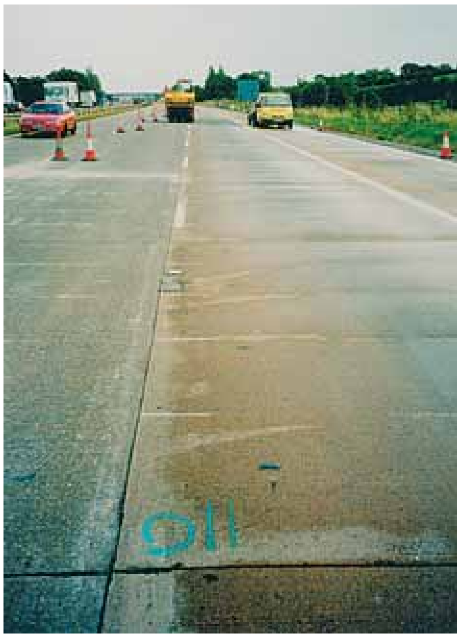

Plate 6.3 Transverse cracking

Plate 6.4 Typical satisfactory crack patterns at the edge of the slab

As soon as an appropriate number of slabs in each trial stage has been cracked, the slabs should be inspected as they dry to assess the pattern of cracking over the whole area.

The pavement should not appear to be cracked into 'crazy paving', like that shown in Plate 6.5; this was produced because a too small crack spacing, of less than 1m, was used. The majority of the concrete should remain crack-free with minimal longitudinal cracking, which should not extend for more than the distance between two impact lines. However, isolated instances of longitudinal cracking extending over the length of a bay should not require detailed investigation in the absence of any other non-compliance, as long as the majority of surrounding slabs are being cracked satisfactorily. On some occasions, internal stresses within the slabs are released when the guillotine blade impacts the concrete and these produce cracks that are outside the control of the contractor.

Plate 6.5 Unsatisfactory 'crazy paving' crack pattern

A sign of over-cracking is the production of curved cracks appearing as arcs around the ends of impacts. If such cracking is observed, then the cracking process should be halted and the guillotine drop height reduced until the crack pattern returns to the desired state. Cores will be required to verify the re-establishment of acceptable cracking; guidance on deciding where to take cores and how to interpret the cracking is given in Section 6.8.

Where slabs are wider than 5m, if a wide blade guillotine is being used and satisfactory crack patterns cannot be obtained by one pass of the guillotine, then the effect on the crack pattern of using two parallel passes should be assessed. If diagonal or randomly oriented cracking is seen to propagate over the uncracked half of the slab as a result of the first pass, it may be necessary to first 'halve' the slabs lengthways. This is achieved by using a reduced drop height in order to minimise random cracking. Also, after impacting the slab lengthwise with the guillotine, the longitudinal crack might not be visible. When the transverse cracks are induced, the longitudinal crack should appear. The presence of a single longitudinal halving crack should prevent the transverse crack from propagating into the other half of the slab. The halving of 6m square slabs and the resulting interim crack pattern is shown in Plate 6.6.

Plate 6.6 Halving large slabs

Special care must be taken to examine the area of concrete between parallel passes of the guillotine when two passes are used on a single wide slab, to ensure that it is not over-cracked due to overlapping impact forces. It is best to ensure that the second pass is no closer than 500mm from the edge of the adjacent line of impacts. In this situation, it might be better to use a lower impact force for the first line of transverse impacts. The second pass of impacts should line up with the first pass as closely as possible, and certainly within the tolerance specified for transverse alignment specified in Appendix A1.0 of the specification.

It should be borne in mind that some pavement constructions appear to have a 'natural' longitudinal plane of weakness, possibly associated with a drainage problem. In this case, at any chosen drop height, longitudinal cracking will often extend for the whole length of the slab and even run into adjoining slabs. In this situation, the drop height should be kept at the minimum required to crack the whole depth of the concrete in an attempt to minimise the severity of the longitudinal cracking. It should be noted that longitudinal cracks running to a free edge of a slab have a tendency to open up as cracking proceeds along the slab. Increasing the crack spacing may be appropriate in order to reduce the severity of the longitudinal cracks by reducing the number of impacts in each slab, and therefore the total impact force. Plate 6.7 gives an example of such longitudinal cracking outside the control of the contractor.

Plate 6.7 Longitudinal cracking due to internal stress or weakness within the slabs

6.8 Core extraction

As part of the main trial, cores of a minimum diameter of 150mm should be taken through cracks on each slab and inspected for cracking. Their locations should be along the impact positions of the guillotine, and also through the line of transverse cracks that can be seen running to the edge, which may not necessarily be in a direct line with the impacts.

Each core should contain cracks that are:

- Fine.
- Predominantly vertical.
- Through the full depth of the core.
- Non vertical branching.
- Not shattered at the bottom of the core.

Examples of cores complying with these criteria are shown in Figure 6.5 and in Plate 6.8.

Due to the nature of the cracking process, the crack will initiate from the bottom of the slab and propagate upwards,

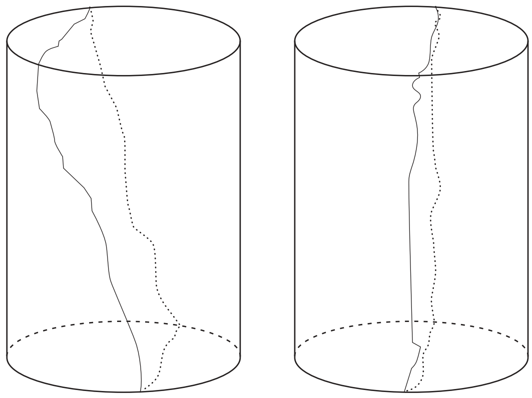

Figure 6.5 Fully compliant cores

Plate 6.8 Fully compliant core

as shown in Figure 2.1; therefore the crack will be at its widest at the bottom of the core. The width of the crack shall be defined as the width at the top of the core. Cores that are found to be in two distinct halves after extraction should be considered to comply with the specification in the absence of any other non-compliance, as the action of coring itself could open up any full-depth cracks. Inspection of the crack in the concrete pavement in the core-hole will normally show whether the crack width is fine in the body of the pavement itself.

A crack is considered to be predominantly vertical if the whole depth of the crack lies within the body of a 150mm diameter core. Cracks initiated directly under the centre of the impact of the blade are likely to be almost vertical, and parallel with the sides of the core. However, if the core is taken further away from the centre of the impact, it is possible that the crack will not be completely vertical, but will comply with the specification as defined above. A difficulty in assessment occurs when the core is not positioned centrally above the crack, for example 'A' in Figure 6.6 and 'C' in Figure 6.7.

Case 'A' should be treated as compliant in the absence of any other defect, as cracks are initiated from the bottom of the concrete and propagate upwards, the crack must be full depth. However, shallow diagonal cracks are not

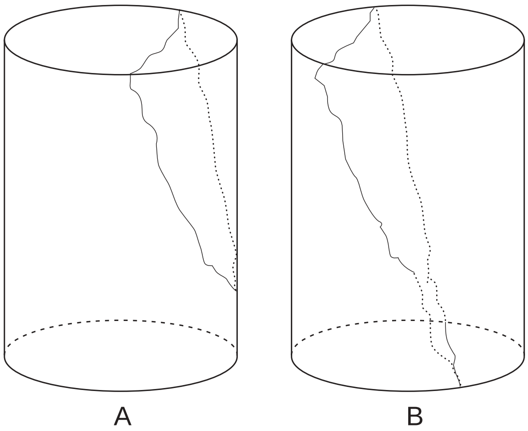

Figure 6.6 Compliant cracks cored off-centre

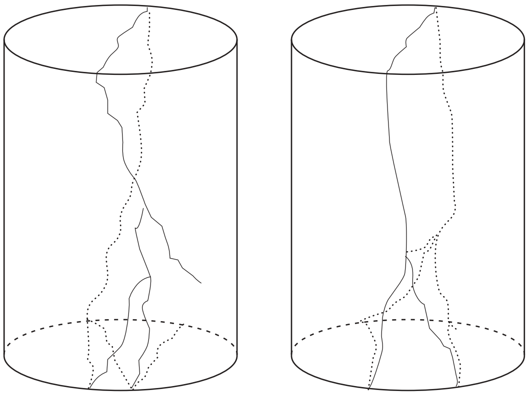

Figure 6.8 Vertically branching cracks

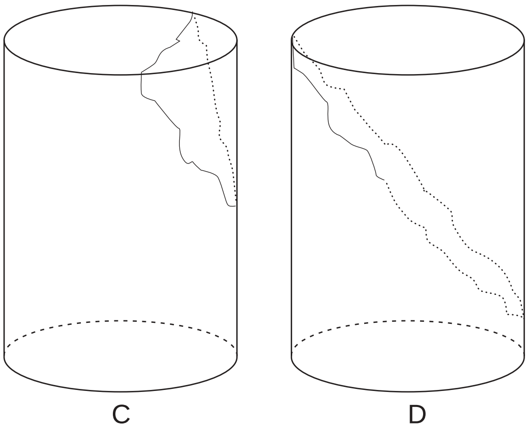

Figure 6.7 Non-compliant cracks cored off-centre

Plate 6.9 Over-cracked, vertically branching crack

considered to comply with the specification. The compliance of such cracks is best visualised by judging whether the whole of the depth of the crack could be contained within the whole of the 150mm diameter core. Case ‘A’ is acceptable because the crack would lie within the depth of the core if a different core position were used, as shown by crack ‘B’ in Figure 6.6.

Crack ‘C’ is not considered to comply with the specification because the crack is not ‘predominantly vertical’ as it cannot be contained within the depth of the core, as shown by crack ‘D’ in Figure 6.7. Clearly, the maximum angle of the crack with the surface is defined by the thickness of the core with respect to the core diameter. A judgement should be made to accept occasional cracks that form an angle of less than 60° provided that most cracks are within 10° of the vertical. However, the majority of cracks should be like those shown in Figure 6.5.

Cores taken from a pavement that has been struck with too much force can show multiple cracking or vertical branching of the cracks and will be automatically deemed to not comply with the specification. Such cores may have very poor interlock, and may separate into two or more large pieces with smaller fragments and might be difficult to remove from the core barrel.

Examples of such non-compliant cores are given in Figure 6.8 and Plates 6.9, 6.10 and 6.11.

Plate 6.10 Shattered core

Plate 6.11 Shattered core

Cores containing more than one crack or a crack branching in the horizontal plane will not necessarily fail to comply with the specification as they may be produced by other causes apart from over-cracking. Horizontally branching cracks in the absence of any other non-compliant defect are considered to meet the specification because cores taken on the ends of impacts may contain a horizontally branching crack. Similarly, if a core is taken on an impact at the intersection with a longitudinal crack, then as long as the longitudinal crack is acceptable, i.e. no longer than the distance between two consecutive impacts, the core is also acceptable. Examples of such cores are given in Figure 6.9.

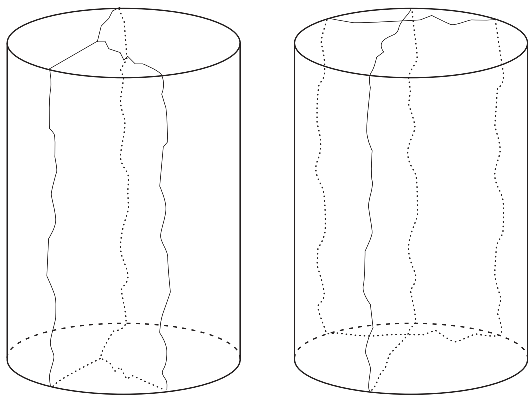

Figure 6.9 Compliant cores containing horizontally branching or multiple cracks

Cracking may not be immediately apparent on a wet, freshly extracted core. A crack will retain water from the action of coring, and therefore by allowing the core to dry naturally will normally enable the line of the crack to be seen, as the crack will show up as a dark line on the otherwise dry core. Also if the concrete was laid on a polythene layer during construction, then a fine crack can normally be observed on the smooth, shiny base of the core immediately after extraction.

When it is difficult to ascertain whether a crack extends completely through the full depth of the core, it should be borne in mind that the action of seating the pavement, and site traffic, is likely to complete the cracking to full depth. To determine whether there is sufficient cracking, the core should be dropped from waist height onto the pavement surface (so that the long side of the core is in contact with the pavement surface). This may be repeated until the core halves. Inspection of the two halves of the broken core while it is still wet will demonstrate whether the concrete was actually cracked through the full depth:

- If the crack did not extend through the full depth of the pavement then the top of the exposed surfaces will be dry, showing that halving was caused by dropping the core.
- If the exposed surfaces of the crack are wet right to the top of the core (dark) then the crack was full depth and aggregate interlock was holding the core together.

6.9 Seating

The contractor is responsible for conducting the seating trial required by the specification. The object of the trial is to determine the number of roller passes required until no further significant settlement of the slabs is detected. As a general rule, six passes of the PTR is normally sufficient, however this should be determined from the trial.

6.10 FWD testing

After the visual assessment of the cores and crack patterns has been performed, FWD measurements should be made on the trial area. The purpose of the FWD tests is to confirm that the effective stiffness values of the cracked and seated concrete exceed the required threshold value of 5 GPa that is used for the design. For the trial, the FWD measurements must be carried out before and after the crack and seat treatment to determine the reduction in effective stiffness of the concrete as a result of the cracking. It is essential that any debris is swept from the area before the FWD testing is carried out. The trial area should be marked up for FWD testing prior to wetting the pavement before starting the cracking operation.

It is recommended that the trial area be tested using the FWD at 0.5m spacings along the slab, starting at 1m from a transverse joint and extending for half the length of each slab along the centre line. However, if the slabs are wide and either two passes of the guillotine have been made or if a longitudinal halving crack has been induced, the FWD measurements should be made along a line one-third of the width in from a longitudinal edge.

The crack spacing to be used in the main works is determined from the calculated concrete stiffness modulus values after cracking and seating. The crack spacing to be used is the closest spacing that gives back-analysed stiffness values for the cracked and seated concrete that are consistently above the required design threshold, provided that the crack patterns and core inspections are satisfactory.

The FWD test location is determined from the back-analysed effective stiffness of the cracked concrete for the chosen crack spacing. Each FWD measurement on the trial at the chosen crack spacing is examined in relation to its position along the slab to determine the position of minimum effective stiffness of the concrete. From this, a position is identified that gives the most consistently low effective concrete stiffness value, e.g. 1m past the joint, 1.5m past the joint, etc. The FWD testing in the main works is then conducted at this location on each slab.

6.11 Assessment of main works

Figure 6.10, Chart E, sets out the procedure for conducting the crack and seat treatment on the main works.

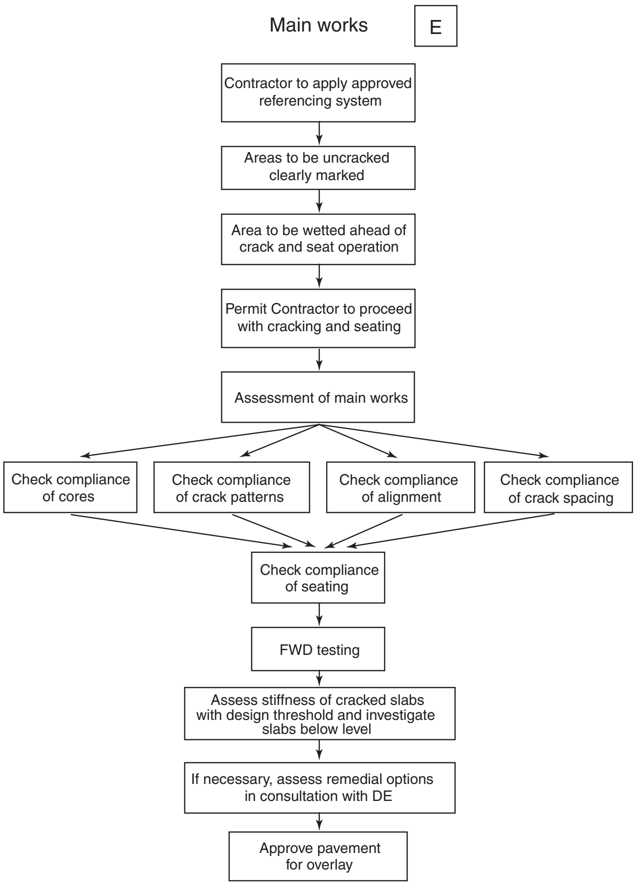

Figure 6.10 Chart E

The contractor must mark the pavement with a clearly visible referencing system for the slabs before the main works commence. The referencing can consist simply of chainage markers every 10m, or numbering of the slabs, but the system must be approved by the overseeing organisation. Marking individual slabs is preferable and allows them to be identified later and permits the accurate spacing of core locations. The referencing marks should be visible from the centre line of the pavement to be cracked and seated.

It is essential that areas that are not to be cracked and seated are clearly marked out before cracking commences. Such areas may include slabs where sensitive services run underneath the pavement.

The surface of the concrete should be wetted with water before commencement of cracking and seating operations. A distance of no more than 300 linear metres should be wetted to ensure that the surface is still wet when the surface is cracked.

The alignment of impact lines across the complete width of the pavement should be adjacent to the impacts in adjoining slabs, within the tolerances given in the specification. Close alignment might be a problem when a second pass is made in the opposite direction to the first pass on wide slabs. Manual alignment of the guillotine might be required to comply with the locational tolerance. Plate 6.12 shows an example of good alignment across the width of a taxiway consisting of six lanes of slabs.

Plate 6.12 Good alignment of cracking across width of taxiway

It is always necessary to ensure that that the longitudinal spacing of impact lines is maintained within the requirements of the specification. This applies, even if the contractor uses the guillotine in the automatic mode, i.e. the drop height and advance rate of the machine are set and the guillotine needs only to be steered, as there may be a tendency for the spacing to vary.

While monitoring the cracking it is prudent to check the crack patterns as they are produced by the guillotine and also at some distance behind the guillotine so that the final crack pattern can be observed on the drying surface. Some cracks will only be visible later, as the surface dries out.

As in the monitoring of the trial, observation of the production of cracks in the main works is best performed at a distance of about 3 metres from the guillotine. From this position the cracking can be most readily seen as it is produced on the wet surface. The effect of subsequent cracking on previously produced cracks can also be seen. The position of cracks running from ends of the impact positions to the edge of the slab can also be marked for subsequent coring.

If the crack patterns change to an undesirable state indicating that the slab is being either under or over-cracked, then the supervising engineer should continue for up to three further slabs to establish whether the required crack pattern returns. If the cracks (or cores taken from the cracked pavement) do not return to an acceptable pattern within the three further slabs with, if necessary, minor adjustments to the drop height of the guillotine, then a re-assessment trial (as defined in the specification) is required. Records should be made by the contractor and supervising engineer whenever the guillotine parameters are changed (drop height, spacing etc.) because of changes in the crack pattern or in the severity of cracks determined from the cores or by visual inspection or for any other reason. A proforma is provided in Appendix A1.1 of the specification.

Cores should be assessed as described in Section 6.3. The coring can be the slowest part of the crack and seat process, especially when the concrete contains flint gravel aggregate. For large and time-critical works, two coring rigs might be necessary. The supervising engineer should ensure that the guillotine does not proceed too far ahead of the coring operation, as defined in the specification. The engineer should halt the cracking process to allow the coring operation to ‘catch up’ or to give time for the surface to dry adequately in order to allow the full crack pattern to be observed. If the surface is sufficiently wet so that a satisfactory crack pattern can be seen as the guillotine proceeds, this surface drying requirement can be relaxed.

The information from each core should be logged to record the location, concrete thickness and crack details. An example of a core assessment form used for this purpose is given in Appendix 1.2 of the specification.

The supervising engineer and contractor should take care to ensure that cracking is not carried out within 0.5m of existing transverse cracks in the pavement. These cracks should be considered to constitute a pre-existing guillotine impact, and the impact spacing within the slab should be adjusted accordingly. Cracking across existing longitudinal cracks is not normally considered to constitute a problem.

Whilst marking up the site for locational referencing, a brief visual condition survey should be carried out to identify the locations of slabs that are already badly cracked prior to the crack and seat treatment. Note should also be made of slabs with joint replacements, bay replacements and slabs shorter than those generally present in the works. During the crack and seat process, the contractor or supervising engineer should record any slabs that appear to become over-cracked due to crack and seat. These procedures will greatly aid the assessment of the FWD survey carried out after the crack and seat treatment.

The seating of the cracked pavement should be carried out by a Pneumatic Tyred Roller (PTR), as defined in the specification, with the minimum required number of passes as established by monitoring the slab settlement as part of the main trial. The whole width of the cracked pavement should receive the minimum number of passes (normally six).

The FWD assessment survey can be carried out either before or after seating, as decided by the overseeing organisation. It is likely that the effective stiffness values will be higher after the seating operation, as the rolling should reduce slab movement. The FWD measurements should not be carried out within 100m of cracking operations in order to minimise the adverse effect that the guillotine impacts could have on the survey.

After the FWD survey of every cracked slab has been completed, the effective stiffness of each slab should be calculated and compared with the threshold stiffness used for the overlay design. The thickness of the cementitious layers used in the back-analysis must be taken from the thickness of the cores extracted as part of the compliance testing.

Where the thickness of the concrete is close to the nominal thickness of the pavement (± 10mm), then the average thickness of the slabs may be used for the stiffness calculations. If two or more distinct constructions are present in the works, then each construction should be analysed separately, using the average thickness for each construction.

If the thickness of the concrete pavement varies more than ± 10mm, then the 85^{th} percentile thickness (i.e. 85 % of values are lower than this) should be used in the back analysis in order to provide a safety margin for the stiffness of the cracked concrete.

A two layer model should be used to back analyse the FWD measurements to provide the effective stiffness of the concrete and the foundation layers for each slab tested. Slabs with concrete effective stiffness values below the design threshold should be identified. Each result below the threshold should be examined to determine whether the result is due to a poor fit of the deflection bowl. Some analysis programs will provide goodness of fit indicators such as AMD (Absolute Mean Deviation) and RMS (Root Mean Squared deviation), which will give an indication of whether the result can be discounted. If the result appears to be a good fit, then the slab or visual survey should be examined to determine whether there is an obvious cause for the low value.

From the visual survey carried out, those slabs for which there is a reason for the low stiffness other than over-cracking can be identified. Short slabs, extra thick slab replacements and bituminous patching can all contribute to lower than expected stiffness measurements. It is recommended that all slabs having a stiffness of more than 1 GPa below the threshold are re-inspected.

If there are no obvious alternative reasons for areas or groups of slabs with low stiffness other than over-cracking, or a local reduction in concrete thickness, then, depending on the size of the area affected, the proposed overlay thickness should be reconsidered in consultation with DE.

When the cracked and seated pavement has been assessed and any remedial action taken, the pavement can be approved for overly by the overseeing organisation.

7 Acknowledgements

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Appendix A: Remedial treatments for reducing reflection cracking

A.1 Geogrid reinforcement

Reinforcing grids are designed to enhance the tensile strength of an asphalt overlay by absorbing the horizontal tensile stresses above the concrete joints and distributing them over a wider area. As a result, the stress concentrations in the asphalt above the joints, caused when the concrete contracts with a reduction in temperature, should be reduced by the presence of the geogrid and hence reduce crack initiation and propagation of reflection cracking.

A.2 Stress absorbing membrane interlayer (SAMI)

A SAMI provides a flexible layer that is able to deform horizontally without breaking in order to allow movements to take place in the vicinity of the cracks or joints. Some SAMIS are supplied in the form of rolls or sheets that are applied to the concrete or existing surface over the joints or cracks before overlaying. Others are produced on site and consist of a layer of a proprietary mixture that is often inlaid and spread with single size chippings which are rolled in. SAMIS are generally waterproof which offers some protection to the pavement structure and foundation in the vicinity of the cracks should the surface of the overlay crack.

A.3 Geotextile interlayer

Geotextiles are installed as a blanket treatment onto the concrete slabs or onto the surface of a cracked flexible composite construction before overlaying. The geotextile is bonded to the underlying surface with bitumen which is spread at a rate to saturate the geotextile. The geotextile is able to extend horizontally without breaking and acts in a similar way to a SAMI to reduce the stress applied to the asphalt overlay. Geotextile interlayers also provide a waterproofing role protecting the pavement structure and foundation should the surface of the overlay crack.

A.4 Asphalt inlay over concrete joints

This is an alternative strategy that has met with some success on highways with a flexible composite construction or where an already overlaid jointed concrete pavement has suffered reflection cracking and is about to be overlaid again. The cracks in the original overlay above joints in the underlying concrete are milled out to a width of about 300mm to 500mm and inlaid with asphalt before applying a new surfacing. To give the best chance of minimising the future occurrence of reflection cracking, the asphalt inlay should be ductile to dissipate the stresses induced by thermal contraction at the crack or joint.

A.5 Modified asphalt

The resistance of asphalt to cracking depends mainly on the binder content and its elastic characteristics although the coefficient of expansion of the aggregate also contributes to the performance. The binder content and its characteristics affect the asphalt’s ability to absorb stresses generated at cracks and its self-healing properties as well as its resistance to ageing which reduces the risk of the asphalt becoming brittle with time. These properties are improved by the use of a viscous binder and a high binder content; one way of achieving this is by the use of polymer modified bitumen.

A primary objective of polymer modification is to reduce the temperature susceptibility of the binder. Other advantages often claimed for modified binders, are increased elasticity and reduced susceptibility to thermally induced and other forms of cracking.

The two most common families of polymers used for modifying bitumen are:

- Elastomeric polymers.
- Plastomeric polymers.

There are many varieties of polymers within each of these groups that can have diverse effects on different bitumens. Figure A1 illustrates, in a simplified way, the characteristics that modified binders are attempting to achieve to improve asphalt design.

When used in overlays on pavements with concrete layers a most desirable property is reduced susceptibility to reflection cracking. By minimising the occurrence of reflection cracking, the asphalt thickness may be reduced to offset the cost of the modifier and thereby reduce maintenance costs. The trials associated with these research projects have included the use of styrene-butadiene-styrene (sbs), an elastomeric modifier that improves the elasticity of the binder.

A.6 Crack and seat and overlay

The objective of the crack and seat technique is to induce fine cracks into unreinforced jointed concrete slabs or cement bound bases, after the removal of any bituminous surfacing. The fine cracks will then encourage the seasonal thermal movement in the concrete materials to occur at many of the induced cracks whilst at the same time providing adequate aggregate interlock. The induced cracks are at a closer spacing than the normal shrinkage cracks or joints, thus the thermal movements should be smaller and the occurrence of transverse reflection cracks in the asphalt overlay should be minimised.

A.7 Saw-cut crack and seat and overlay

The saw-cut crack and seat (SCC&S) technique is suitable for use on reinforced jointed concrete slabs after the removal of any bituminous surfacing. Transverse saw cuts are made, usually at spacings of 1.0 to 1.5m, to sufficient depth to cut the longitudinal steel reinforcement. The concrete is then cracked and seated at the saw cuts as for ordinary crack and seat. This process is more expensive and takes longer than ordinary crack and seat due to the large amount of saw cutting required. It is important that no saw cut is made deeper than half the slab thickness to allow adequate load transfer across the saw-cut and crack.

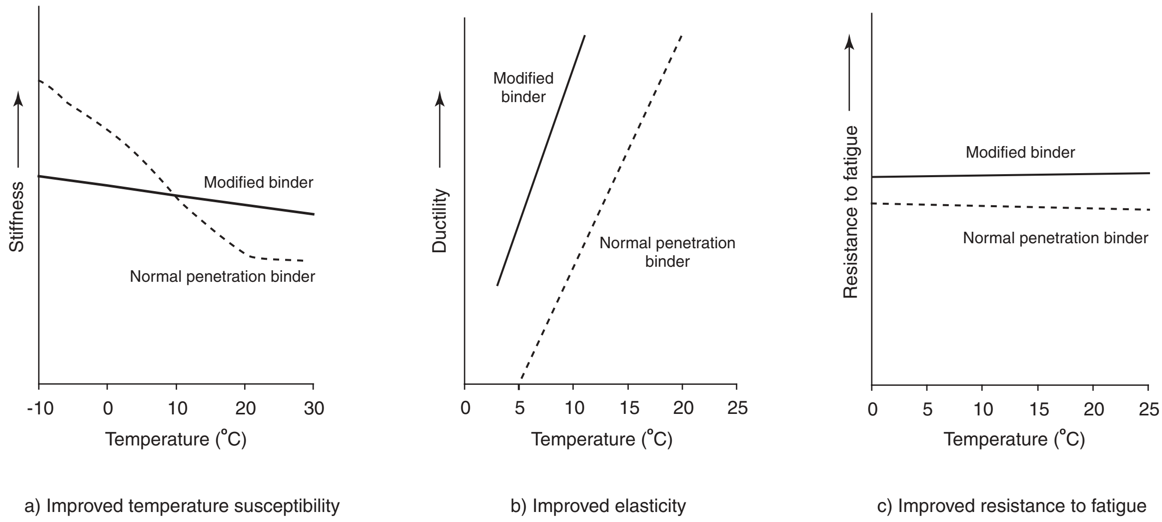


Figure A1 Characteristics of modified binders

Cutting the steel reinforcement and cracking the concrete into blocks allows many small thermal movements to occur at each crack in the concrete, rather than one large movement at the original joint thus minimising reflection cracking in the asphalt overlay.

A.8 Overlay, saw cut and seal

Overlay, saw cut and seal is a maintenance treatment suitable for PQC pavements overlaid with asphalt. It involves inserting a bituminous joint sealant in the asphalt surface above the joints where reflection cracks would occur. A schematic detail of the treatment, as constructed, is provided in Figure A2. As shown, 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. If the thermal movements in the PQC cause a crack to initiate, then it should propagate between the bottom of the initial saw cut in the asphalt and the joint in the concrete. The sealant should prevent water entering the crack. For the success of this technique, accurate marking out prior to overlay is essential, since the saw cut must be directly above the joint.

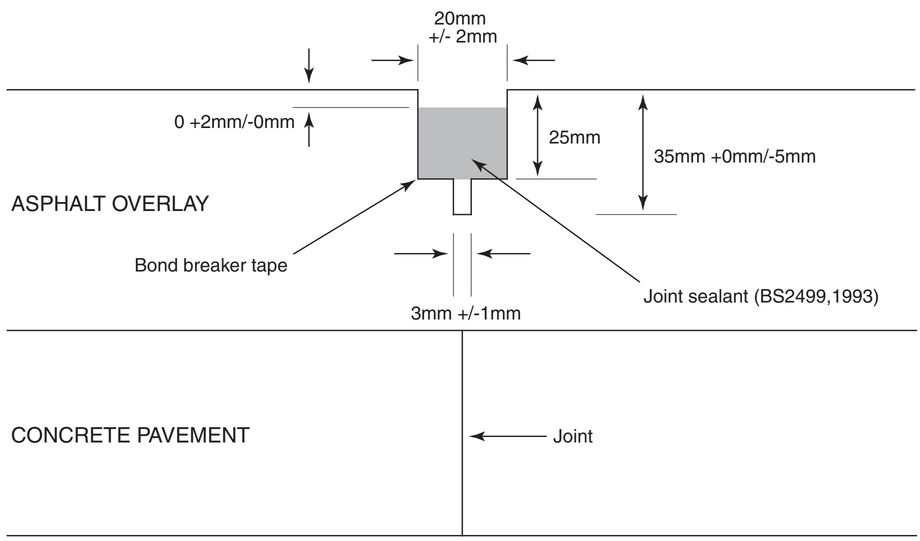


Figure A2 Schematic detail of saw cut and seal maintenance treatment

Appendix B: Previous crack and seat works on MOD Airfields

B.1 General

Following the success of the crack and seat trials constructed in the early 1990s on motorways and trunk roads (Potter and Mercer 1996), trials were conducted on the northern taxiway at RAF Coningsby (Langdale and Potter 1996) and on an aircraft service platform at RAF Lyneham (Langdale *et al.*, 1997). On the basis of the airfield trials, the crack and seat treatment was employed for maintaining two jointed unreinforced concrete taxiways at RAF Lyneham (Ellis and Langdale 1998). The treatment is becoming widely used on road pavements and the performance of the original trial sections continues to be good (Ellis 1997).

B.2 RAF Coningsby

A crack and seat trial was carried out in September 1995 as part of the maintenance operation to lay an asphalt overlay on the jointed unreinforced concrete on the northern taxiway. The trial area consisted of a section of the taxiway approximately 450m long by 18m wide (Figure B1). Three test sections were constructed with crack spacings of 1m, 0.75m and 0.5m together with a control section without crack and seat against which the performance of the test sections could be judged. The overlay was designed to be nominally 150mm of Marshall asphalt but in practice the crossfall was changed to improve the run-off of surface water and this increased the overlay thickness across the taxiway from 150mm to 210mm.

The unreinforced concrete (3m × 3m slabs) was of two-layer construction, nominally 200mm on 150mm, laid on a varying thickness of unbound granular foundation. Throughout the pavement, the transverse and longitudinal joints in the upper layer were constructed to overlay the midpoints of the lower layer slabs.

The cracking was carried out using two Arrows D500 Drophammers working in tandem. An Albaret Orthopactor PF2 pneumatic tyred roller (PTR) weighing 14 tonnes was used for the seating.

A visual survey was made before the start of the works so that any subsequent reflection cracking could be related back to the original joint and crack locations. A Falling Weight Deflectometer (FWD) was used to determine the stiffness modulus of the concrete before and after cracking and seating and also the load transfer efficiency across the transverse joints in the upper layer of concrete.

When this guide was drafted, the last visual inspection, carried out eight years after construction, showed that no reflection cracking had occurred in the trial area, however cracks had occurred in the control section (without crack and seat).

B.3 RAF Lyneham

Following the successful application of the crack and seat treatment at RAF Coningsby, a trial was carried out at RAF Lyneham on an aircraft service platform constructed with 370mm of jointed unreinforced concrete on an unbound granular foundation. The concrete slabs were 6m × 3m and 3m × 3m and the cracking was carried out using the Arrows D500 Drophammer. The purpose of the trial was to determine the effect of crack spacing on the effective stiffness modulus of the concrete prior to using the technique on the northeast taxiway (NET) and the southern taxiway (ST). The construction of the taxiways was similar to that of the aircraft service platform. Crack spacings of between 0.75m and 2m were investigated and

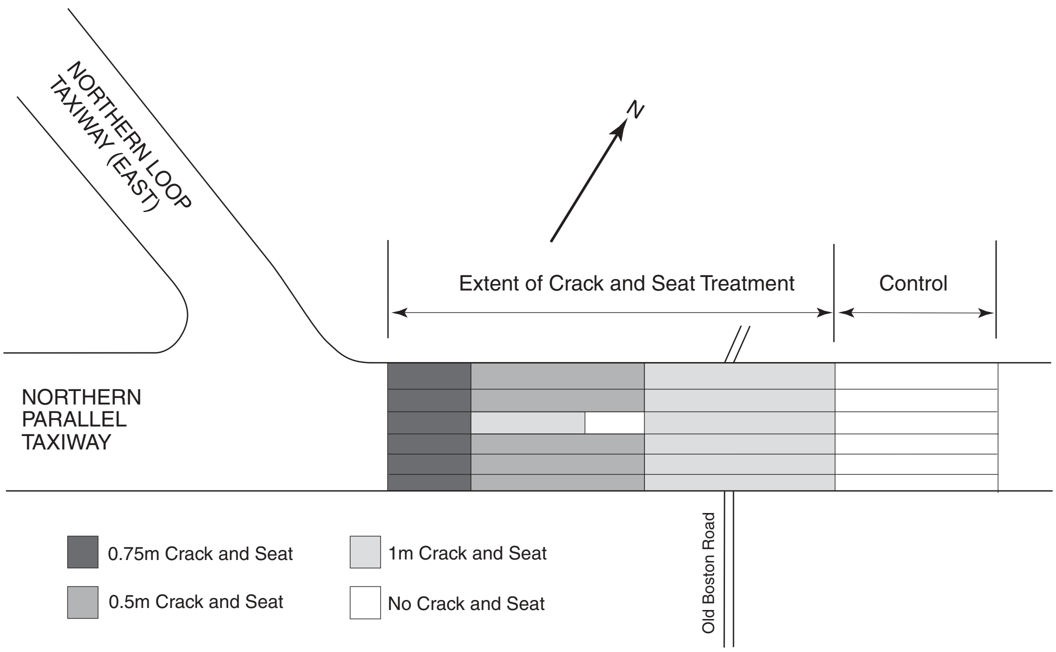


Figure B1 RAF Coningsby – layout and location of trial sections the threshold stiffness modulus needed for structural design was exceeded for crack spacings greater than 1m. The trial was carried out successfully and was reported by Langdale *et al.* (1997). At the end of the trial the cracked concrete was not overlaid as this was not required for structural purposes and, because the induced cracks were extremely fine, FOD was not considered to be a risk.

Following the trial, the north east and southern taxiways at RAF Lyneham were maintained using the crack and seat and overlay technique. For these works the contractor used a Badger Breaker guillotine with a single blade 2.4m wide. The existing construction comprised 380mm of jointed unreinforced concrete laid on a sub-base of lean concrete over part of the taxiways and an asphalt foundation elsewhere. The bay sizes were 6m × 6m, 6m × 4.5m, 6m × 3m and 6m × 1.5m as shown for the NET in Figure B2. It was necessary to develop a method to crack the 6m x 6m square slabs which involved applying a light impact in the longitudinal direction in the centre of the slab which did not create a crack at that stage. The guillotine then cracked each half of the slab with the blade transverse to the direction of the taxiway at the required crack spacing and this caused the longitudinal halving crack to form from the earlier impact. A Marshall asphalt overlay of 170mm was applied over the cracked and seated taxiways. The maintenance of the taxiways was described by Ellis and Langdale, (1998).

To-date no reflection cracking has been observed on either the north east or southern taxiways, six years after construction.

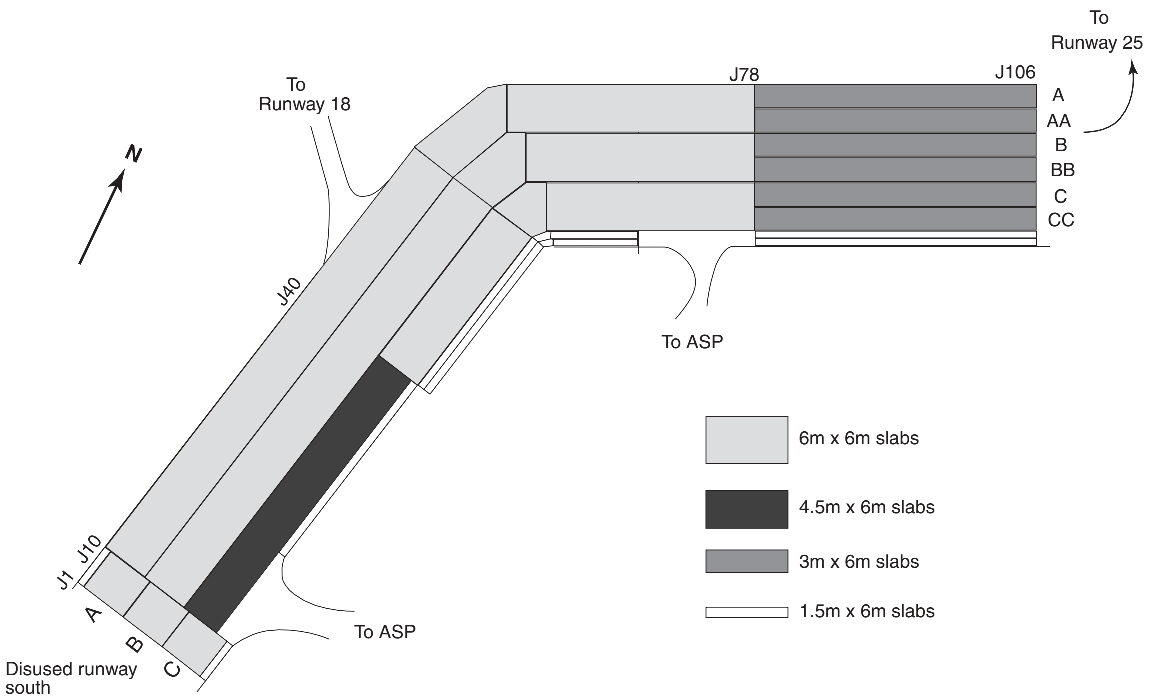


Figure B2 RAF Lyneham – north east taxiway crack and seat maintenance

Appendix C: Worked examples of pavement design using the crack and seat treatment

Example C1: Determination of equivalent CBR

A design has been carried out assuming an *in situ* CBR of 8 per cent. However, during further site investigation the CBR has been found to reduce with depth at one location. Determine the equivalent CBR for design purposes.

This example utilises Appendix B and Figures 5 and 6 from the PSA Guide (1989).

Pavement and aircraft data:

1 CBR of lower layer = 5 per cent.
2 CBR of upper layer = 13 per cent.
3 Depth of upper layer = 545mm (from formation to top of lower layer).
4 Aircraft to be considered: Hercules C130, VC 10 and Tristar.

Determine aircraft data (ACN) for different CBRs. (PSA Guide, Appendix B)

Table C1 ACN values on different CBR subgrades

	CBR				
Aircraft	*15*	*10*	*6*	*3*	*Main wheel gear*
Hercules C130	29	32	34	38	Tandem
VC10	44	47	58	73	Dual-tandem
Tristar	68	74	90	120	Dual-tandem

To determine the design CBR for a two-layer subgrade where the CBR of the upper layer is greater than the CBR of the lower layer:

1 Select the relevant undercarriage type.
2 Using Figure 5 in the PSA Guide, enter the CBR of the lower layer on the horizontal axis, make a vertical projection to meet the curve for the CBR of the upper layer to determine the equivalency factor (EF). In this example EF = 2.
3 Determine 't'. Where t = depth of upper layer/EF. In this example t = 545/2 = 272.5.
4 Using Table C1, determine ACN of the design aircraft for the CBR of the lower layer by linear interpolation.
5 Calculate t^2/ACN (see Table C2).
6 Using Figure 6(b) in the PSA Guide enter the CBR of the lower layer on the horizontal axis and the value of t^2/ACN on the vertical axis to determine the design CBR of the subgrade (see Table C2).

Table C2 Equivalent CBR values for given aircraft loading

Aircraft	*ACN (for lower layer)*	*t^2/ACN (where t^2=74256)*	*Design CBR for subgrade[1] (%)*
C130 Hercules	35.3	2104	9
VC10	63	1179	7.5
Tristar	100	743	7

[1] *PSA guide, Figure 6*

Example C2: Determination of frequency of trafficking

Determine the frequency of trafficking for mixed traffic loading in preparation for designing an overlay after cracking and seating an existing unreinforced PQC taxiway at an RAF airbase.

This example utilises Appendix B and Figure 10 from the PSA Guide (1989).

1 Design life = 20 years.
2 Expected departures:

Aircraft type	*Departures/Year*
Hercules C130	15,000
VC 10	52
Tristar	12

3 Determine aircraft data (ACN) for different subgrade CBRs (see Table C3).

Table C3 ACN values on different CBR subgrades (PSA guide, Appendix B)

	ACN					
Aircraft type	*CBR 15*	*CBR 10*	*CBR 6*	*CBR 3*	*Main wheel gear*	*Pass-to -coverage ratio*
Hercules C130	29	32	34	38	Tandem	1.6
VC10	44	47	58	73	Dual-tandem	1.6
Tristar	68	74	90	120	Dual-tandem	1.6

4 DCP survey shows subgrade CBR = 10%.
5 Design aircraft = Hercules C130. For setting out the information refer to Table C4. The table shows the aircraft (col. 1) and their ACNs (col. 2).
6 Establish aircraft pass-to-coverage ratios from Tables 4.2, 4.3 of Section 4.11 (col. 3, Table C4).
7 Calculate the number of coverages by each aircraft during the design life of the pavement (col. 5).
8 Calculate the ratio of the ACN of each aircraft to that of the design aircraft (col. 6).
9 A pavement that has been maintained by crack and seat methods is considered as a flexible pavement. For flexible pavements, use Figure 10 of the PSA Guide to obtain flexible mixed traffic factors (FMTF) from the coverages found in step 8. For each aircraft, select its respective number of coverages on the abscissa of Figure 10, then make a vertical projection until it intersects the curve. Make a horizontal projection and read off the FMTF from the left-hand ordinate (see results given in col. 7, Table C4).
10 Modify the FMTF for each aircraft by multiplying it by the respective ACN ratio (col. 8).
11 Select the Modified FMTF on the left-hand ordinate of Figure 10 (PSA Guide 1989). Using the graph in reverse, read off the number of Equivalent Coverages by the design aircraft (col. 9).
12 Column 9 gives the mixed traffic loading in terms of Equivalent Coverages by the design aircraft. Calculate the total coverages by adding these together.

Table C4 Flexible mixed traffic analysis example

(1) Aircraft	(2) ACN	(3) Pass-to-coverage ratio [Table 4.1]	(4) Annual departures	(5) Coverages during design life [20*(4)/(3)]	(6) ACN ratio [(2)/32]	(7) FMTF[2] [Figure 10[1]]	(8) Modified FMTF [(6)*(7)]	(9) Equivalent Coverages [Figure 10[1]]
Hercules C130	32	1.6	15,000	187,500	–	–	–	187,500
VC10	47	1.6	52	650	1.47	0.61	0.90	5,300
Tristar	74	1.6	12	150	2.31	0.42	0.97	8,500
Total coverages								201,300

[1] *PSA guide, Figure 10, Mixed traffic analysis – flexible pavements.*

[2] *FMTF = Flexible Mixed Traffic Factor.*

13 From Table 4.1 (see Section 4.8), select a frequency of trafficking to use in the design charts. For 201,300 Equivalent Coverages, the overlay design should be for HIGH Frequency of Trafficking.

Example C3: Pavement design using crack and seat treatment

Determine the thickness of a bituminous overlay for a cracked and seated concrete pavement.

1 Existing construction determined from pavement evaluation:

Material	*Thickness (mm)*	*Condition*
PQC	250	Some cracking; no voids underneath.
DLC	100	Sound.
Granular sub-base	100	Sound; Drainage in good order.
Subgrade		10% CBR.

2 Calculate the frequency of trafficking as illustrated in Worked Example C2. In this example high frequency of trafficking is assumed.

3 The overlay design is determined from Design Chart 4 in the PSA Guide (1989). Chart 4 requires knowledge of three design parameters:

- i The CBR of the subgrade.
- ii The design ACN.
- iii The frequency of trafficking.

4 To use Chart 4:

- i Select the frequency of trafficking.
- ii Select the ACN scale appropriate to the design aircraft's main gear type. Enter the chart with the design ACN and make a horizontal projection until it intersects the vertical projection of the appropriate CBR.
- iii From the intersection, trace a line parallel to the curves until it intersects the right hand ordinate. Read off the thickness of BBM required. The minimum surfacing thickness required on top of the base is 100mm.
- iv For high frequency design, the required thickness of BBM is increased to provide a total pavement thickness (BBM plus surfacing) that is 8% greater than that required for medium frequency design.

5 Design

Subgrade CBR	=	10%	*(determined by in situ measurement)*
Design Aircraft	=	Hercules C130	
Design ACN	=	32	*(see Worked Example C2)*
BBM	=	330mm	*(PSA Guide, Design Chart 4)*
Surfacing	=	100mm	*(PSA Guide, Design Chart 4)*
8% BBM	=	35mm	*(PSA Guide, Para. 6.9, HIGH = +8%)*
Total BBM required	=	330mm + 100mm + 35mm = 465mm.	
Overlay required	=	465mm – 350mm (existing BBM) = 115mm.	

Appendix D: Specification for the crack and seat treatment on airfield pavements

Cracking and Seating of Existing Jointed Unreinforced Concrete Pavements and CBM bases

[Clause 1.0: July 2003]

General

1 Where shown on the drawings listed in Appendix A1.0, the existing unreinforced cementitious pavement layers shall be cracked and seated with plant and equipment to which the overseeing organisation's consent has been given, and shall comply with this clause. This shall be done prior to overlaying with a bituminous material.

2 Prior to the commencement of operations to induce cracks, any existing bituminous overlay and surfacing shall be removed from the area to be treated up to the adjacent longitudinal joints. Removal of the overlay shall also be completed at a distance of not less than 30m ahead of the cracking operation. The contractor shall also ensure that adequate reference points based on the overseeing organisation's chainage, have been clearly marked and agreed with the overseeing organisation for purposes of accurately recording progress and locations of changes to equipment settings.

3 During cracking and seating operations adequate side restraint shall be maintained at pavement edges or within the pavement where service or other trenches are to be excavated. If other works are to be carried out at the pavement edges, the crack and seat operation can be completed before any excavation is undertaken or started only after any excavation is fully reinstated. Where lighting ducts or other services are to be installed within the pavement, saw cuts through the full depth of the concrete should be made before cracking and seating in the adjacent areas. The excavation works can then be completed without disturbing the cracked and seated pavement.

4 Compliance with this clause shall be assessed by (a) examining the generated crack pattern on the surface of the cementitious layer, (b) examining the depth and severity of cracking by means of core extraction, (c) measuring the spacing of the induced transverse cracks, (d) recording the number of passes of the seating roller. The overseeing organisation will calculate the effective stiffness modulus of the cracked cementitious layer from Falling Weight Deflectometer (FWD) measurements. An instruction shall be issued on any variation required in the method and pattern of cracking and also to subsequently confirm or otherwise the thickness of overlay required.

5 The sequence of operations shall be: (a) application of clean water to assist examination of the crack pattern, (b) inducing transverse cracks, (c) observation of the surface crack pattern, (d) extracting cores and (e) seating. The observation of the surface crack pattern and examination of the cores shall be carried out in daylight or under sufficient artificial light supplied by the contractor. FWD measurements by the overseeing organisation will follow the cracking operation and, subject to agreement with the contractor, may precede the seating operation. The pavement shall not be overlaid or re-opened to vehicle or aircraft traffic without the overseeing organisation's written confirmation and that the FWD measurements have been completed.

6 Before any of the main crack and seat work is commenced, a main trial cracking operation shall be carried out as specified in sub-Clause 14 of this clause. Once the main crack and seat operation has commenced, its efficacy shall be kept under review by the contractor in accordance with sub-Clauses 17, 18, 19 and 20 of this clause. If, due to variations in the strength or other physical characteristics of the cementitious pavement layer or of the foundation or otherwise, the crack pattern varies from that confirmed in the main trial, the equipment shall be adjusted as described in sub-Clauses 8 and 18 of this clause to produce the required crack pattern. If the crack pattern obtained in the main trial is not re-established within 4 bays for jointed unreinforced concrete pavements, or in the case of CBM bases within 20m, then the cracking operation shall stop immediately. The contractor shall report the circumstances to the overseeing organisation orally within 1 hour and confirm it in writing within 2 hours. A production cracking re-assessment trial shall then be carried out in accordance with sub-Clauses 24, 25 and 26 of this clause before any further cracking and seating work is carried out.

Cracking

7 Induced cracking of existing pavement layers shall be carried out in compliance with this clause including the particular requirements in Appendix 1.0.

8 For rectangular bays, transverse cracks at the required spacing shall be induced by suitable plant with a guillotine action capable of delivering variable preset impact loads to the concrete surface. The compressive strength of the existing concrete is within the limits stated in Appendix 1.0. If the unreinforced jointed concrete pavement is of two layer construction with a slip layer between the two layers of concrete, or is supported by a cement bound sub-base, it is not necessary to induce cracks in the lower layer of concrete or the sub-base. The required spacing of cracks to be used for the main trial in sub-Clauses 14, 15 and 16 of this clause shall be as specified in Appendix 1.0. The required spacing thereafter shall be as confirmed by the overseeing organisation on completion of the main trial. The contractor shall keep records of the settings to his plant and equipment and both the location and time at which each and every adjustment to it is made. Such records shall be in accordance with the proforma in Appendix 1.1 and

shall be available for inspection by the overseeing organisation on demand. Cracks shall be induced by one strike of the impacting head of such plant without producing undue surface shatter. The plant and impact head shall be of sufficient mass and geared to prevent both head bounce and any associated surface damage arising therefrom. The impact force shall be adjustable to achieve the cracking specified and the minimum force consistent with no surface shatter. Excessive impact forces which cause multiple cracking or shattering of the underside of the concrete slab, or to the underlying or adjacent layers shall not be permitted. If such damage does occur, the contractor shall carry out remedial measures in accordance with sub-Clauses 22 or 23 of this clause.

9 The induced cracks shall be predominantly vertical and shall be transverse to the direction of the pavement. They shall extend the full width of each concrete bay or the lane width of a CBM base. The generation of longitudinal cracks of length greater than the specified transverse crack spacing shall be prevented except when produced during the operation to halve wide slabs as permitted in sub-Clause 10.

10 Where the full width of any existing pavement layer cannot be adequately cracked transversely with one pass of the crack inducing plant as determined by the overseeing organisation, further parallel passes shall be made as necessary so that all subsequent transverse cracks are aligned with those from the preceding pass within the tolerances specified in Appendix 1.0. For slabs in excess of 5m wide it is permitted to halve the slabs by cracking in the longitudinal direction before inducing the transverse cracks in order to produce the specified crack pattern.

11 The contractor shall be responsible for (a) adjusting his equipment and methods so that the requisite crack pattern is maintained, (b) producing full depth fine vertical cracks in the cementitious layers, and (c) rendering treated areas suitable for overlaying, to the satisfaction of the overseeing organisation. The plant used to crack the cementitious pavement layers shall be self-propelled and have all wheels fitted with pneumatic rubber tyres. For all trials and for all production cracking operations the contractor shall provide clean water and shall saturate the surface area of the pavement that is to be cracked to the satisfaction of the overseeing organisation. The surface shall be allowed to dry naturally or shall be dried artificially so that it becomes surface dry before visual inspection is made of the induced crack pattern. The cracking operation shall not proceed more than 100 metres beyond the last accepted core in the assessment under sub-Clause 19 of this clause. All holes from which core samples have been extracted shall be filled with cementitious material equivalent to that in the surrounding pavement. This shall be well compacted in layers each not exceeding 50mm thickness.

Coring

12 The contractor shall take cores in accordance with sub-Clauses 15, 19, 20, 23 and 25 of this clause and with Appendix 1.0 at locations selected by the overseeing organisation.

Seating

13 Following cracking, all the cracked pavement layer shall be seated with a multi-wheeled pneumatic-tyre roller with a weight of not less than 12 tonnes with the number of passes specified in Appendix 1.0. The load including any ballast shall be distributed uniformly over all the wheels. The drive gear shall provide a progressive, variable speed, forward and reversing capability. Such compaction plant shall have articulating wheels on both front and rear axles. The wheel arrangement shall provide an overlap of not less than 40mm with the adjacent wheels. The internal pressure of the tyres shall be adjustable to provide variable ground contact pressure (GCP). The minimum GCP shall be as specified in Appendix 1.0. The contractor shall certify in an agreed form on a daily basis the exact extent of seating completed under this sub-clause and shall deliver each such certificate to the overseeing organisation before noon the next day.

Main trial

14 The contractor shall demonstrate that the plant, equipment and method proposed for the cracking and seating of the cementitious layers are capable of producing the required type and pattern of cracks. This shall be demonstrated by first executing a main trial over an area of neither less than 250 sq m nor greater than 420 sq m of existing pavement. The location of the trial shall be as directed by the overseeing organisation. The contractor shall demonstrate that the cracking operation can achieve consistent compliance with this sub-clause and with sub-Clauses 8 and 15 of this clause and with Appendix 1.0. If the pavement to be treated contains known areas where there are differences in the concrete thickness or strength or in the foundation conditions, then a main trial shall be conducted in each such area. The work on the main trial length shall proceed as follows:

i The surface shall be marked out.

ii Cracking shall proceed in stages as directed by the overseeing organisation in groups of four bays in jointed concrete pavements, or in lengths of 20m for CBM bases. Each group that is cracked and shall be seated and assessed in accordance with sub-Clause 15 of this clause.

iii In Stage 1 of the main trial the contractor, in consultation with the overseeing organisation, shall set up his plant and equipment and demonstrate that he can produce the required pattern and quality of transverse cracks in accordance with this clause including sub-Clause 10 and Appendix 1.0. This shall be assessed in accordance with sub-Clause 15 of this clause.

iv In Stage 2 and each subsequent stage of the main trial, a group of four bays in jointed concrete pavements, or a length of 20m for CBM bases, shall be cracked starting from one end to produce transverse cracks at one of the spacings stated in Item (v)(e) of Appendix 1.0. For each Stage, the settings of the cracking plant and equipment shall be recorded in accordance with the proforma in Appendix 1.1.

v The cracked pavement shall be seated with the number of passes of the roller specified in Appendix 1.0 as described in sub-Clause 13 of this clause.

Assessment of main trial

15 Compliance with the cracking and seating requirements for the main trial shall be assessed as follows:

i The surface pattern of cracking shall be checked before seating but after applying clean water and allowing to dry as specified in sub-Clause 11 of this clause.

ii Visual inspection: In Stage 1 of the main trial, the induced crack pattern shall be inspected by the contractor. In Stage 2 and in subsequent stages, visual inspection of the crack pattern shall be inspected by the overseeing organisation.

iii Crack spacing: In Stage 2 and in subsequent stages of the main trial, the spacing of transverse cracks shall be monitored by the overseeing organisation.

iv Coring: The depth and the vertical direction of cracking shall be determined by coring through the full depth of the cementitious pavement layers, including two layer construction and cement bound sub-bases, symmetrically at the crack position. Core diameter shall be in accordance with Appendix 1.0. In Stage 2 and in subsequent Stages of the main trial, the number of cores shall be in accordance with Table 1with not less than one core being taken from each slab or 5m length in CBM bases. This shall be at a location selected by the overseeing organisation. In cases where cracks are not visible in the surface, the locations of cores will be generally along the line of the impacts. If any shattering or multiple cracking is present in a core extracted from a single surface crack, then there is deemed to have been 'shattering failure'.

v Seating: The contractors certificates required under sub-Clause 13 of this clause shall be checked. The overseeing organisation may require the contractor to re-roll sample areas with not less than the number of passes of the roller specified in Appendix 1.0. If the number of roller passes required for seating is not in accordance with sub-Clause 13 of this clause, the contractor shall roll the entire area again with not less than the number of passes of the roller specified in Appendix 1.0.

vi The contractor shall make allowance in his programme for FWD measurements which will be made by the overseeing organisation after cracking or after cracking and seating in accordance with this clause. The contractor shall remove any mud or debris from the cracked pavement in the main trial lengths to the satisfaction of the overseeing organisation before FWD measurements are made.

Consent to the method and acceptance of the main trial

16 The contractor shall not proceed with the main works until the overseeing organisation has given its consent that the plant, equipment and methods used in the main trial are able to produce a cracked and seated slab that complies with the requirements in Table 1. Consent to the plant equipment and methods will be given by the overseeing organisation following a successful demonstration in the main trial that the cracking and seating complies with the requirements of this clause. When consent by the overseeing organisation to the method has been given, the plant, equipment and methods shall not be changed thereafter without the prior consent of the overseeing organisation except for normal adjustment and maintenance of plant. Should it be necessary for the contractor to otherwise change any plant, equipment and/or method the contractor may be required by the overseeing organisation to carry out a further main trial Stage.

Main works

17 The production cracking operation for the main works shall proceed at the crack spacing determined after the main trial, or from any relevant subsequent production cracking re-assessment trial. The production seating operation shall be completed by rolling the pavement for the number of passes determined from the main trial (not less than six). The main works shall be assessed in accordance with sub-Clause 20 of this clause.

18 The surface pattern of cracking shall be checked after applying clean water which shall be allowed to dry as specified in sub-Clause 11 of this clause. The contractor shall be responsible for the continuous observation of the crack pattern. Should the crack pattern vary from that to which consent was given in the main trial, or from any relevant subsequent production cracking re-assessment trial, with the consent of the overseeing organisation the contractor shall adjust the plant and equipment in order to produce the agreed crack pattern. The new settings of the plant and equipment shall be recorded by the contractor together with the chainage and the transverse location at which it was changed. These particulars shall be delivered to the overseeing organisation within not more than 24 hours of the changes being completed. If the agreed crack pattern is not restored within 4 bays in jointed concrete pavements or within 20m in CBM bases, production cracking shall cease in accordance with sub-Clause 6 of this clause. A production cracking re-assessment trial shall then be carried out in accordance with sub-Clauses 24, 25 and 26 of this clause before any further production cracking and seating work is carried out.

19 The depth and quality of the induced cracks shall be monitored by inspection of extracted cores. If there has been ‘shattering failure’ in accordance with sub-Clause 15(iv) of this clause, production cracking shall cease immediately. The extent of the area affected shall be determined as specified in sub-Clause 23 of this clause.

Assessment of the main works

20 Compliance with the cracking and seating requirements shall be assessed during the main works in accordance with the following criteria:

i The surface pattern of cracking of all areas that have been cracked and seated shall be checked after applying clean water and allowing to dry as specified in sub-Clause 11 of this clause.

ii Crack spacing: The spacing of transverse cracks shall be monitored.

iii Coring: The depth and the vertical direction of cracking shall be determined by inspecting cores extracted through the full depth of all the cementitious pavement layers at the crack position. Core diameter shall be in accordance with Appendix 1.0. Not less than one core shall be extracted in every 300 sq. m of cracked concrete at locations selected by the overseeing organisation.

iv Seating: The seating shall be assessed in accordance with sub-Clause 15 (v) of this clause.

v The contractor shall make allowance in his programme for FWD measurements which will be made by the overseeing organisation after cracking in accordance with this clause. The contractor shall remove debris from the cracked pavement to the satisfaction of the overseeing organisation before FWD measurements are made.

Acceptance of the main works

21 The main works under this clause shall be accepted when it complies fully with the requirements in Table 1.

Failure to comply and remedial works

22 The results of the crack and seat operations for any jointed unreinforced concrete slab, or any 5m length of CBM base, shall be rejected if it fails to comply with any of the criteria in sub-Clause 21 of this clause. If:

a shattering of cementitious material occurs within the extracted core; or

b the length of any longitudinal cracks in the aircraft wheeltrack areas, other than halving cracks in wide bays produced according to sub-Clause 10, are in excess of the specified crack spacing of the induced transverse cracks, then the following remedial measures shall be taken. The size of the affected area shall be determined and the rejected section(s) shall be broken out, excavated to full depth and reinstated with equivalent material, unless otherwise instructed by the overseeing organisation. If:

c the transverse crack spacing determined for the particular portion of the work is outside the specified tolerance; or

d the number of roller passes required for seating is not in accordance with sub-Clause 13 of this clause,then further cracking and/or FWD measurements shall be carried out and/or the contractor shall roll the entire area again with not less than the number of passes specified in Appendix 1.0 unless otherwise instructed by the overseeing organisation.

23 The extent of shattering or multiple cracking shall be determined by extracting and inspecting cores within the area between the position of the crack-inducing plant and the last core in which the cracking complied with the requirements of sub-Clause 21 of this clause. The extent of longitudinal cracking in the aircraft wheeltracks shall be determined by visual inspection.

Production cracking re-assessment trial

24 The production cracking re-assessment trial described in this sub-clause and in sub-Clauses 6, 18, 25 and 26 of this clause shall require the contractor to demonstrate that the plant, equipment and method to which consent was given by the overseeing organisation for use in the main works are capable of producing the required type and pattern of cracks in the existing cementitious layers by executing this trial over an area of not less than 75 sq m or greater than 120 sq m of existing pavement. The location of the trial shall be as directed by the overseeing organisation. The crack spacing(s) shall be as directed by the overseeing organisation within the tolerances specified in Appendix A1.0. The contractor shall demonstrate that the cracking operation can achieve consistent compliance with sub-Clause 26 of this clause. The contractor shall make programme allowance for FWD measurements which will be made by the overseeing organisation before and after cracking in accordance with this clause. The contractor shall remove debris from the cracked pavement in the re-assessment trial length before FWD measurements are made. The production cracking re-assessment trial length shall be seated with the number of roller passes used in the main works.

Assessment of production cracking re-assessment trial

25 Compliance with the cracking and seating requirements for the production cracking re-assessment trial shall be assessed as follows:

i The surface pattern of cracking shall be checked after applying clean water and allowing to dry as specified in sub-Clause 11 of this clause.

ii Visual inspection: The crack pattern will be monitored by the overseeing organisation.

iii Crack spacing: The spacing of induced transverse cracks will be monitored by the overseeing organisation.

iv Coring: The depth and vertical direction of cracking shall be determined by coring through the full depth of the cementitious pavement layer symmetrically at the crack position. Core diameter shall be in accordance with Appendix 1.0. The number of cores shall be in accordance with Table D1. Not less than one core shall be taken from each slab or 5m length in CBM base and this shall be at a location selected by the overseeing organisation. In cases where cracks are not visible in the surface, the locations of cores will generally be within the impact points.

v The contractor shall make allowance in the programme for FWD measurements which will be made by the overseeing organisation after cracking. The contractor shall remove debris from the cracked pavement in the trial length before FWD measurements are made.

Consent to the method and acceptance of the production cracking re-assessment trial

26 The contractor shall not resume the main works until the overseeing organisation has given its consent that the plant, equipment and methods used in the production cracking re-assessment trial comply with the requirements given in Table D1.

27 Consent to the plant equipment and methods will be given by the overseeing organisation following a successful demonstration in the production cracking re-assessment trial that the cracking and seating complies with the requirements of this clause. When consent to the method by the overseeing organisation has been given, the plant, equipment and methods shall not be changed thereafter without the prior consent of the overseeing organisation except for normal adjustment and maintenance of plant. Should it be necessary for the contractor to otherwise change any plant, equipment and/or method the contractor shall carry out a further production cracking re-assessment trial.

Table D1 Assessment criteria for acceptance for trials and for the main production works

	Criteria			
Type of trial or work category *Surface crack pattern*	*Transverse crack spacing*	*Coring to determine severity, depth and vertical direction of cracking*	*Seating*	*FWD monitoring within any bay length*
Main trial Stage 1				
i Fine (i.e. < 0.5mm wide). ii In a transverse direction. iii No longitudinal crack length > transverse crack spacing except for slab halving cracks. iv Monitored by the contractor.	i As specified in Appendix 1.0.	i Cores shall be taken at locations chosen by the contractor.	i Roll with the number of passes of the roller specified in Appendix 1.0. ii Monitored by the contractor.	None required. May be done by the overseeing organisation for the contractor on his request.
Main trial Stage 2 and subsequent stages				
i Fine (i.e. < 0.5mm wide). ii In a transverse direction. iii No longitudinal crack length > transverse crack spacing except for slab halving cracks. iv Monitored by the overseeing organisation.	i Each stage at one crack spacing as specified in Appendix 1.0. ii Monitored by the overseeing organisation.	i Cores shall be taken at locations chosen by the overseeing organisation. ii Not less than 5 cores in each stage with not less than 1 core from each bay or from a 5m length, as appropriate.	i Roll with the number of passes of the roller specified in Appendix 1.0. ii Monitored by the contractor.	i The overseeing organisation to determine and record the minimum effective stiffness modulus and its location from FWD measurements on every slab after cracking and/or seating. ii Not required for compliance monitoring.
Acceptance of main trial Stage 2 and subsequent stages				
i Crack pattern complies with i to iii above.	i Required tolerance on transverse crack spacing achieved.	i No multiple cracks or shattering within the core. ii Cores shall have a single crack to the full depth of the concrete. iii Cracks shall be predominantly vertical.	i Certification by the contractor that each point has been rolled with the number of passes of the roller specified in Appendix 1.0.	i Produce a record of the measured effective stiffness moduli for the concrete pavement and the foundation combination after the cracking and/or seating.
Main production works				
i Fine (i.e. < 0.5mm wide). ii In a transverse direction. iii No longitudinal crack length > transverse crack spacing except for slab halving cracks. iv Monitored by the contractor.	i Crack spacing determined from the main trial or from the re-assessment trial, as appropriate, to the tolerance specified in Appendix 1.0. ii Monitored by the contractor.	i Cores shall be taken at locations chosen by the overseeing organisation. ii Not less than 1 core every 300sq m. iii Monitored by the contractor.	i Roll each point with the number of passes of the roller specified in Appendix 1.0. ii Monitored by the contractor.	i Determine and record the effective stiffness modulus from FWD measurements on every slab after cracking and/or seating.

Continued ....

Table D1 (Continued) Assessment criteria for acceptance for trials and for the main production works

Type of trial or work category	*Criteria*			
Surface crack pattern	*Transverse crack spacing*	*Coring to determine severity, depth and vertical direction of cracking*	*Seating*	*FWD monitoring within any bay length*
Acceptance of the main production works				
i Crack pattern complies with (i) to (iii) above.	i Required tolerance on transverse crack spacing achieved.	i No multiple cracks or shattering within the core. ii Cores shall have a single crack to the full depth of the concrete. iii Cracks shall be predominantly.	i Certification by the contractor that each point has been rolled with the number of passes of the roller specified in Appendix 1.0.	i Not required for compliance monitoring. ii Required for confirmation of structural design.
Production cracking re-assessment trial				
i Fine (i.e. < 0.5mm wide). ii In a transverse direction. iii No longitudinal crack length > transverse crack spacing except for slab halving cracks. iv Monitored by the overseeing organisation.	i Crack spacing as specified by the overseeing organisation to the tolerance specified in Appendix 1.0. ii Monitored by the overseeing organisation.	i Cores shall be taken at locations chosen by the overseeing organisation. ii Not less than 5 cores with not less than 1 core from each bay or 5m length. iii Monitored by the overseeing organisation.	i Roll each point with the number of passes of the roller specified in Appendix 1.0. ii Monitored by the contractor.	i Determine and record the minimum effective stiffness modulus from FWD measurements on every slab after cracking and/or seating.
Acceptance of a production cracking re-assessment trial				
i Crack pattern complies with (i) to (iii) above.	i Required tolerance on transverse crack spacing achieved.	i No multiple cracks or shattering within the core. ii Cores shall have a single crack to the full depth of the concrete. iii Cracks shall be predominantly vertical.	i Certification by the contractor that each point has been rolled with the number of passes of the roller specified in Appendix 1.0.	i Produce a record of the measured effective stiffness moduli for the concrete pavement and the foundation combination after the cracking and/or seating.

Appendix 1.0: Notes for guidance sample-bituminous sprays

1 A tack coat shall be applied to all surfaces (bituminous and/or concrete) prior to resurfacing.

2 The tack coat shall be bitumen emulsion complying with either A1-40 or K1-40 of BS 434 applied at a rate of 0.35 litres to 0.55 litres per sq.m. as per sub-Clause 5.20 of Defence Works Functional Standard: Marshall Asphalt for Airfield Pavement Works.

Appendix 1.0: Notes for guidance sample-cracking and seating of jointed unreinforced concrete pavements and CBM bases

i *Location:* The drawing(s) to which reference is made in sub-Clause 1 are:

Drawings Nos. XXX [Compiler to complete]
YYY

A main trial area (or areas) of cracking and seating shall be carried out in accordance with sub-Clause 14 and shall be assessed in accordance with sub-Clause 15 at a location or at locations selected by the overseeing organisation. The purpose is to establish (i) the crack pattern, (ii) the depth and severity of cracking, (iii) the settings of the crack inducing equipment to produce the specified cracking, (iv) the spacing of the cracks for the main works. A production cracking re-assessment trial shall be carried out when necessary in accordance with sub-Clause 24 at a location selected by the overseeing organisation to re-establish (a) the crack pattern, (b) the depth and severity of cracking, (c) the settings of the crack inducing equipment to produce the specified cracking, and (d) the spacing of the transverse cracks for the main works remaining.

ii *Bituminous overlays to be removed:* Bituminous overlays are to be removed from surfaces to be cracked as follows:

a Chainage p to q ... mm nominal thickness

b Chainage x to y ... mm nominal thickness
[Compiler to complete]

iii *Existing cementitious pavement layer to be cracked:*

a Nominal thickness: xx mm
[Compiler to complete]

b Strength range: yy-zz MPa
[Compiler to complete]

iv *Existing sub-base and earthworks materials beneath the cementitious pavement layer:*

a Chainage e to f ... mm sub-base type xxx [Compiler to complete]
Subgrade - see data below

b Chainage f to g ... mm sub-base [Compiler to complete]
Subgrade - see data below

[Compiler to complete/ amend as appropriate]

See borehole and trial pit information [give name of document] listed in Appendix 1.2.

v *Cracking:*

a Tolerance on spacing of transverse cracks: +/- 5%

b Category of transverse cracks: Fine i.e. < 0.5mm wide

c Depth of cracks: Full depth of cementitious pavement layer.

d Type of crack:	The induced cracks shall be single, predominantly vertical through the layer with no shattering of the concrete.
e Spacing of transverse cracks for the main trial:	(1) xx m (2) xx m (3) xx m *[Compiler to complete]*
f Spacing of transverse cracks for the production cracking re-assessment trial:	As directed by the overseeing organisation
g Spacing of transverse cracks for the main works:	Determined from the main trial or from a production cracking re-assessment trial.
h Location of impacting head of the crack-inducing equipment:	No closer than 0.5m from any edge of the concrete slabs or CBM base.
j Tolerance of transverse alignment:	+/- 50mm
vi *Assessment of cracking:*	
(a) Core diameter:	Not less than 150mm diameter
(b) Depth of core:	Full depth of the cementitious layer(s)
(c) FWD measurements:	Carried out by the overseeing organisation
vii *Seating:*	
(a) Minimum ground contact pressure:	xx kPa *[Compiler to complete]*
(b) Number of passes on main work:	xx

Appendix 1.1: Cracking plant and equipment progress record

Contract: (Airfield) .... Sheet no.....

Pavement location: ....

Type of plant and Contractor's plant number......................

Blade length ....metres Blade weight.............kg

Month / year work commenced .... Runway / Taxiway plan reference

Date & time	Chainage and lane no. within runway / taxiway	Transverse crack spacing (m)	Height of Drop (mm)	Notes For example: Changes in crack pattern and reasons for any adjustments made to machine settings.

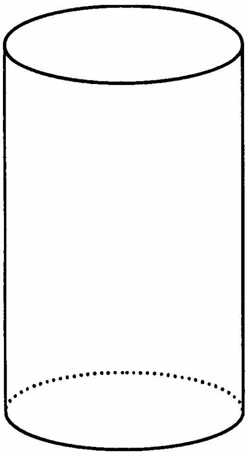
Name of Contractor____________________ *[Block capitals]*

Signature of Contractor's representative__________Date

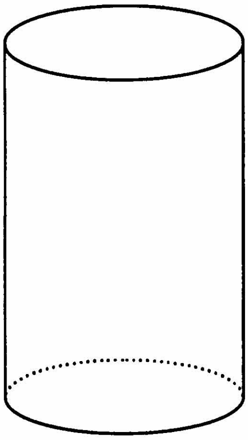
Name and post of signatory______________*[Block capitals]*

Appendix 1.2: Core assessment form

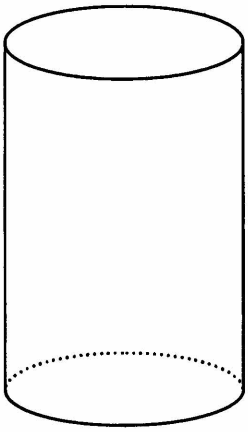
SCHEME: **DATE:**



Core Reference		Slab Number	
Core position		Chainage:	
Crack length		Core depth	
Drop height:		Crack width	
Comments:			
		Comply?	



Core Reference		Slab Number	
Core position		Chainage:	
Crack length		Core depth	
Drop height:		Crack width	
Comments:			
		Comply?	



Core Reference		Slab Number	
Core position		Chainage:	
Crack length		Core depth	
Drop height:		Crack width	
Comments:			
		Comply?	

NOTES FOR GUIDANCE

NG1.0 Cracking and seating of existing jointed unreinforced concrete pavements and CBM bases

1 In Appendix 1.0, the following values have been used successfully in the following sub-clauses:

v *Cracking:*

The prefixes (a), (b) etc. relate to the prefixes in Appendix 1.0 (v).

a The tolerance on the spacing of transverse cracks of +/- 5% is achievable. It may need to be based on average values over a slab length or a 5m run for cement bound bases.

b The width of the crack is that observed at the surface.

c On the main production work, cores should be extracted through all layers of cementitious material to provide data on thickness for the analysis of FWD measurements to calculate effective stiffness modulus. For unreinforced PQC of two layer construction with a slip layer between or of single layer construction on a DLC sub-base, it is only necessary that the cracks penetrate through the upper layer of the PQC. The lower cementitious layers will inevitably be cracked but not necessarily directly below the crack in the upper layer.

d Cores should ideally be taken through single induced transverse cracks and not where there is an intersection with a secondary crack nor where the surface crack might have bifurcated near the end of the guillotine blade impact. However, in some instances this is difficult to achieve and the cracking should not be considered as failed if a core has inadvertently been taken in such a location. The cracking does not comply with the specification if the concrete is shattered or the crack is bifurcated vertically; this type of cracking results from too high an impact force. (Examples are given in Section 6 of this Guide).

e The spacing of transverse cracks for the main trial should be specified as two or three alternatives in Item (v)(e) of Appendix 1.0, all of which should be trialled as required by sub-Clause 14(iii). From previous trials, the spacing of cracks should generally be between 1m and 2m. For PQC, the spacing alternatives to try in the main trial should be chosen such that the crack spacing divides evenly into the bay length. If the crack spacing on the main production work is closer than that specified following the main trial it might cause a reduction in the effective stiffness of the concrete as determined from the FWD measurements. Details of the locations where the crack spacing does not comply with the specification should be entered in the ‘Cracking Plant and Equipment Progress Record’ (Appendix 1.1) in accordance with sub-Clause 8 in order to enable the assessment of the effect on the stiffness modulus of the concrete.

f Where it is necessary to make two or more passes of the guillotine, the transverse alignment of the cracks should be within +/- 50mm. In this situation it might be necessary to apply a lighter impact load on the first pass in order not to over crack the concrete and then the second adjacent pass should ensure that the first crack penetrates the full depth of the concrete layer. For slabs wider than twice the guillotine blade width by 1m or more, inducing a longitudinal crack along the centreline of the slab to produce two narrower slabs that can be cracked transversely is an alternative procedure. The coring should be conducted on the trial slabs after the complete slab has been cracked and, where necessary, two or more passes of the guillotine have been completed.

vii *Seating:*

Minimum ground contact pressure: 550 kPa (80 psi).

A minimum of 6 passes of the roller has usually been found to be satisfactory.

2 In cases where the ‘cracked and seated’ pavement is re-opened and kept in use for a significant length of time before applying a bituminous overlay, cracks should be sealed as follows and these requirements should be included at the end of Appendix 1.0:

Sealing of cracks:

a Medium (> 0.5, < 1.5mm):	Overband with 50 or 70 pen bitumen.
b Wide (> 1.5mm):	Chase out and seal with 15D × 10W D3406 sealant.

3 The location of the main trial shall be as directed by the overseeing organisation in accordance with sub-Clause 14. This location should be representative of the main body of the work under this clause, e.g. it should be neither at the thickest part of the cementitious pavement layer nor at the part which is cracked already, nor over the worst formation.

4 If it is known that there are differing pavement constructions within the scheme, more than one main trial will be required and should be specified in Appendix 1.0.

Tack coat

5 The treated surface should be tack coated in accordance with Appendix 1.1 prior to overlaying.

Main trial in different lanes of the pavement

6 Experience has shown that the main trial should be conducted in bays away from the edge of the pavement and should include all the different size bays present in the pavement to be treated. This may necessitate more than one main trial. However, it may be prudent to carry out a production cracking re-assessment trial before resuming main work in an edge lane of the runway or taxiway.

Pre-contract feasibility trial

7 In cases where it is considered prudent to carry out a pre-contract feasibility trial, Clause 1.0 may be used providing that sub-Clauses 17 to 21 (approx.) are deleted and certain cross-referencing is checked and amended as necessary.

Glossary

Aircraft Classification Number	ACN	A number expressing the relative effect of an aircraft on a pavement for a specified standard subgrade strength.
Airfield Ground Lighting	AGL	Lighting on the runways or taxiways for aircraft guidance.
Asphaltic Concrete	AC	A mixture of continuously graded aggregate, filler and bituminous binder proportioned to produce a dense and impermeable surfacing.
Bay (of Concrete)		The area of slab bounded by adjacent pairs of longitudinal and transverse joints.
Bay Layout		The pattern of joints and grooves on a concrete pavement.
Binder		A material used for the purpose of holding solid particles together as a coherent mass.
Binder course (formerly basecourse)		The layer or layers of the bituminous surfacing immediately below the surface course.
Bitumen Emulsion		An emulsion in which bitumen is dispersed in water or in aqueous solution with the aid of suitable emulsifying agents.
Bituminous		Containing road tar, bitumen, pitch or mixtures thereof.
Bituminous Surfacing		The upper layers of the pavement structure which include the binder course, the surface course and, if applicable, the Porous Friction Course.
Bound Base Material	BBM	Any material equivalent to a granular sub-base or better, which uses a cement or bituminous binder.
British Standard	BS	A publication of the British Standards Institution.
California Bearing Ratio	CBR	An indication of the bearing capacity of a soil. Determined by comparing the penetration load of a soil to that of a standard material.
Composite Pavement		Any pavement consisting of both rigid and flexible layers.
Construction Joint		A joint separating areas of a concrete pavement slab placed during different pours, usually on different days. May be longitudinal, or lane, joint or a transverse joint across a lane.
Continuously Reinforced Concrete Pavement	CRCP	Concrete pavement containing steel reinforcement throughout its whole length with no transverse joints.
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 concrete lane by saw cutting so as to subdivide it into approximately square bays.
Coverage		The application of a maximum stress on a point in the pavement surface.
Defence Estates	DE	Organisation responsible for overseeing maintenance of military airfields.
Dense Bitumen Macadam	DBM	See Macadam.
Dry Lean Concrete	DLC	A cement bound granular material with low water content suitable for use as a base or sub-base. Unlike conventional concrete, it is usually compacted by rolling.
Dynamic Cone Penetrometer	DCP	Equipment used for the *in situ* determination of subgrade CBR.
Equivalent Coverages		The number of coverages by one aircraft which has the same damaging effect on the pavement as a given number of coverages by another aircraft.
Expansion Joint		Joint provided in a concrete pavement to accommodate the expansion that occurs when the temperature of the pavement rises.
Falling Weight Deflectometer	FWD	Pavement surveying equipment used to establish the material stiffness characteristics of pavement layers.
Flexible Pavement		A pavement which distributes the load primarily through the shear strength of the materials. May be wholly or partly constructed of bituminous material.
Foreign Object Damage	FOD	Potential damage to aircraft from misc. objects including debris on runway.
Formation		The surface of the subgrade in its final shape after completion of earthworks.
Frequency of Trafficking		The level of coverages for which the pavement is designed. There are three categories, High, Medium and Low.
Grading		Particle size distribution of an aggregate.
Heavy Duty Macadam	HDM	See Macadam.
Highways Agency	HA	
Hot Rolled Asphalt	HRA	A mixture of graded aggregate, filler and bitumen binder proportioned to a design or recipe to produce a dense and impermeable surfacing material.

Jointed Reinforced Concrete	JRC	Concrete with steel reinforcement and transverse joints (usually at approximately 20m-25m spacings).
Lane		A longitudinal strip of a pavement layer produced by one pass of a set of paving equipment.
Lane Joint		A construction joint between adjacent lanes.
Load Classification Group	LCG	A range of LCN values.
Load Classification Number	LCN	A number expressing the relative effect of an aircraft on a pavement or the bearing strength of a pavement.
Macadam		A graded aggregate coated with tar or bitumen. a. Dense Bitumen Macadam (DBM): A dense, relatively impermeable, macadam coated with a bitumen binder and with a filler content of between 2 per cent and 9 per cent. b. Heavy Duty Macadam (HDM): A dense bitumen macadam with 50 pen bitumen binder and a high filler content of 7 per cent to 11 per cent. c. Pervious Macadam: A layer of open-graded macadam with a maximum nominal size aggregate of 28 mm which acts as a topping to protect French drains whilst allowing surface water to pass freely through it.
Marshall Asphalt		An Asphaltic Concrete with graded bitumen bound aggregates designed to achieve specified stability, flow, voids and density characteristics.
Ministry of Defence	MOD	
Mixed Traffic		A mixture of aircraft types using a pavement, all of which produce a calculable effect on the fatigue life of a pavement.
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.
Pavement Quality Concrete	PQC	A Portland cement concrete designed within strict limits to give a durable material in pavement applications.
Performance Analysis of Road Infrastructure	PARIS	Collaborative European study of long term pavement performance.
Pneumatic Tyred Roller	PTR	Roller with rubber tyres used in crack and seat process.
Porous Friction Course		A relatively thin surfacing layer designed to have a high surface coefficient of friction and allow horizontal drainage of water within the layer.
Property Services Agency	PSA	A Government organisation looking after Government infrastructure – now disbanded.
Ramp		A section of pavement, usually laid at a gradient near the maximum permissible, which accommodates differences in the level between adjacent pavements. (Note that the US terminology, Ramp may also be used to indicate an aircraft parking area).
Reflection Crack		A crack in a pavement layer induced by a crack in the underlying layer.
Regulating Material		Bituminous material of variable thickness applied to an existing pavement to adjust the levels prior to resurfacing.
Rigid Pavement		A pavement which distributes the load by means of its high flexural stiffness. It comprises, either wholly or partly, PQC concrete construction with a concrete running surface.
Slurry Seal		A mixture of aggregates in a bitumen emulsion which, once the emulsion has broken, forms a seal to the surface of a pavement.
Subgrade		The natural or made-up ground supporting the pavement.
Surface course (formerly wearing course)		The layer of the bituminous surfacing which directly supports the traffic and, if applicable, is immediately below the Porous Friction Course.
Tack Coat		A thin film of binder to improve the adhesion between two courses of bituminous surfacing or between an existing surface and a new bituminous paving layer.
TRL Limited	TRL	UK National independent research centre for transport (formerly called the Transport Research Laboratory).
Unreinforced concrete pavement	URC	Concrete pavement containing no steel reinforcement. Usually has transverse joints at 5m or 6m spacings for highways, but these may be at approximately 3m spacings for airfields.

(NOTE. The project/works services manager should delete any terms not applicable to their project and should add any terms necessary due to the particular nature of their project.)

Abstract

This report is prepared for Defence Estates (DE) of the Ministry of Defence (MoD) under contract number WS21/4013: ‘Provision of research and consultancy services’. TRL Limited (formerly the Transport Research Laboratory) were commissioned by DE to prepare guidelines for crack and seat maintenance of pavements at DE airfields and thus disseminate the knowledge that has been gained through full-scale trials that have taken place at RAF Coningsby and RAF Lyneham. The overall purpose of the guide is to provide enough information to enable those engineers not familiar with crack and seat technology to specify and use the technique effectively for the maintenance of unreinforced concrete pavements and flexible composite pavements at airfields.

A background is provided which includes a description of the mechanisms that result in the occurrence of reflection cracking and options for maintenance. The crack and seat methodology and procedures are detailed and a specification and notes for guidance are given for the use of crack and seat on airfield pavements. Detailed guidance is given to help DE project managers supervise and check the works on site.

Related publications

TRL303 *The evaluation of tests for repair materials used on concrete pavements* by Chandler J W E and Mays G C. 1998 (price £35, code H)

RR349 *The performance of joint sealants in concrete pavements* by Franklin, R E and Savage, H E. 1992 (price £25, code E)

CT136.1 Road surfacing treatments update (1999-2001) *Current Topics in Transport: selected abstracts from TRL Library’s database* (price £20)

Prices current at September 2003

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