Design Manual for Roads and Bridges

Pavement
Design

CD 227
Design for pavement maintenance

(formerly HD 30/08, HD 32/16)

Revision 0

Summary
This document describes the requirements to determine the need for maintenance and to design pavement renewals maintenance treatments on the UK motorway and all-purpose trunk roads. This document, along with CS 230, supersedes HD 30/08 and HD 32/16 which are withdrawn. This document includes guidance on retexturing techniques that was formerly in HD 31/94 and HD 37/99. This document, along with CM 231 and CD 236, therefore supersedes HD 31/94 and HD 37/99 which are withdrawn.

Application by Overseeing Organisations
Any specific requirements for Overseeing Organisations alternative or supplementary to those given in this document are given in National Application Annexes to this document.

Feedback and Enquiries
Users of this document are encouraged to raise any enquiries and/or provide feedback on the content and usage of this document to the dedicated Highways England team. The email address for all enquiries and feedback is: Standards_Enquiries@highwaysengland.co.uk

This is a controlled document.

Contents

Release notes

Version	Date	Details of amendments
0	Mar 2020	CD 227 partially replaces HD 30/08. This full document has been re-written to be compliant with the new Highways England drafting rules.

Foreword

Publishing information

This document is published by Highways England.

This document, along with CS 230, supersedes HD 30/08 and HD 32/16 which are withdrawn.

This document includes guidance on retexturing techniques that was formerly in HD 31/94 and HD 37/99. This document, along with CM 231 and CD 236, therefore supersedes HD 31/94 and HD 37/99 which are withdrawn.

Contractual and legal considerations

This document forms part of the works specification. It does not purport to include all the necessary provisions of a contract. Users are responsible for applying all appropriate documents applicable to their contract.

Introduction

Background

Road pavements do not last indefinitely. At some stage in their lives signs of wear such as polishing, rutting, fretting and cracking may show on the surface. Maintenance is required when the deterioration is judged to affect the standards of service provided to the road user and the integrity of the pavement structure.

The Overseeing Organisations use a hierarchical approach to assessing the needs of the motorways and all-purpose trunk roads.

Network-level surveys, undertaken on a regular or routine basis, are used to identify lengths of pavement that potentially require maintenance. Wherever possible these surveys are undertaken at traffic speed. The requirements for this process are set out in CS 230 [Ref 11.N].

Once a length has been identified as requiring maintenance then a detailed investigation is required to determine the maintenance need and to provide the information required to design the appropriate maintenance treatments. The requirements for this process are set out in this document. Requirements and associated advice for collecting the data required to support this process are set out in CS 229 [Ref 3.N].

To accomplish this task in the most cost-effective manner, it is necessary to use a logical assessment procedure to enable the correct maintenance treatment to be carried out at the most advantageous time. This is to ensure that the strengthening is warranted and is of the right degree, and to avoid re-surfacing being laid on a structurally inadequate pavement.

In-service roads, even those built up over very many years, usually conform to one of the flexible or rigid construction types described in CD 226 [Ref 4.N]. This document describes a uniform approach to the collection of condition information, its presentation and assessment. This can be applied to all these pavement types, although detailed procedures can vary depending on the specific type of construction present.

Assumptions made in the preparation of this document

The assumptions made in GG 101 [Ref 7.N] apply to this document.

Pavement deterioration can be caused by a combination of factors and this document is not intended to be a substitute for the expertise and judgements of the designer.

Mutual Recognition

Where there is a requirement in this document for compliance with any part of a "British Standard" or other technical specification, that requirement may be met by compliance with the Mutual Recognition clause in GG 101 [Ref 7.N] Introduction to the Design Manual for Roads and Bridges.

Abbreviations

Abbreviations	Definition
AC	Asphalt concrete
BWC	By weight of cement
CBR	California bearing ratio
CRCB	Continuously reinforced concrete base
CRCP	Continuously reinforced concrete pavement
CSO	Crack, seat and overlay
DBM	Dense bituminous macadam
DCP	Dynamic cone penetrometer
DLP	Determinate life pavement
EME	Enrobés á module elevé
FWD	Falling weight deflectometer
GPR	Ground-penetrating radar
HBM	Hydraulically bound mixture
IT-CY	Indirect tension test on cylindrical specimens
JRC	Jointed reinforced concrete
LLP	Long-life pavement
LTE	Load transfer efficiency
msa	Million standard axles
PAK	Polycyclic aromatic hydrocarbon [marker]
PFT	Pavement friction tester
PRD	Percentage refusal density
SM	Surface modulus
TTBM	Total thickness of bituminous material
ULLP	Upgradeable to long-life pavement
URC	Unreinforced jointed concrete
VCS	Visual condition survey
VI	Void intercept

Terms and definitions

Term	Definition
Deeper treatment	A treatment that either extends below the depth of the surface course or strengthens the pavement.
Evolved pavement	A pavement where the original construction has been strengthened, widened or reconstructed over a period of years.
Full reconstruction	A maintenance treatment that involves replacement of all the bound layers and extends into the foundation.
Partial reconstruction	Replacement of all the bound layers.
Plane off and inlay	Replacement of some of the bound layers.
Surface treatment	A treatment intended to rectify defects confined to the surface course of pavements with an asphalt surfacing or shallow defects in rigid pavements with a concrete surfacing.

1. Scope

Aspects covered

1.1 The requirements in this document shall be used to design pavement renewals maintenance treatments on the Overseeing Organisations' motorway and all-purpose trunk roads.

NOTE 1 This document does not cover routine or minor maintenance. Minor surface repair techniques are covered in CM 231 [Ref 12.N].

NOTE 2 To reach this stage of the design process, the review of the network surveys and safety inspection data, described in CS 230 [Ref 11.N], has shown that problems exist in the pavement surfacing and/or structure over a significant length of pavement and that substantial remedial works are probably needed. Further detailed surveys or investigations are necessary to determine the causes of the defects and the appropriate remedial works.

1.2 This document also sets out the requirements that shall be used to interpret the various pavement surveys and investigation techniques.

NOTE 1 The requirements for undertaking detailed pavement investigations are set out in CS 229 [Ref 3.N].

NOTE 2 The details of routine testing for skidding resistance are contained in CS 228 [Ref 13.N].

1.2.1 This document does not deal with the assessment of road pavements where contractual warranties are in force e.g. substantial defects appearing very early in the expected life of the pavement. Where contractual warranties are in force, the investigation and assessment methods should reflect the specific circumstances and be based on the practices of CS 229 [Ref 3.N] and this document.

1.3 Rigid pavements that are only exhibiting signs of surface defects (e.g. low skidding resistance, low texture, shallow spalling) shall not be subject to detailed structural investigation.

Implementation

1.4 This document shall be implemented forthwith on all schemes involving the design of pavement renewals on the Overseeing Organisations' motorway and all-purpose trunk roads according to the implementation requirements of GG 101 [Ref 7.N].

Use of GG 101

1.5 The requirements contained in GG 101 [Ref 7.N] shall be followed in respect of activities covered by this document.

2. Development and execution of an investigation plan

2.1 This section summarises the procedures that shall be followed for developing an investigation plan to collect the scheme level data needed to verify pavement construction and design suitable maintenance treatments.

2.2 Where a design is being undertaken that results in a realignment of the wheel paths then the investigation plan shall be revised or augmented to take account of this.

NOTE The requirements in this section are intended for investigation and design of renewals maintenance schemes where the positions of the wheel paths remain unchanged.

Investigation plan

2.3 The investigation plan shall set out the proposed surveys and investigations, the reasons for collecting the data and how the data is to be used.

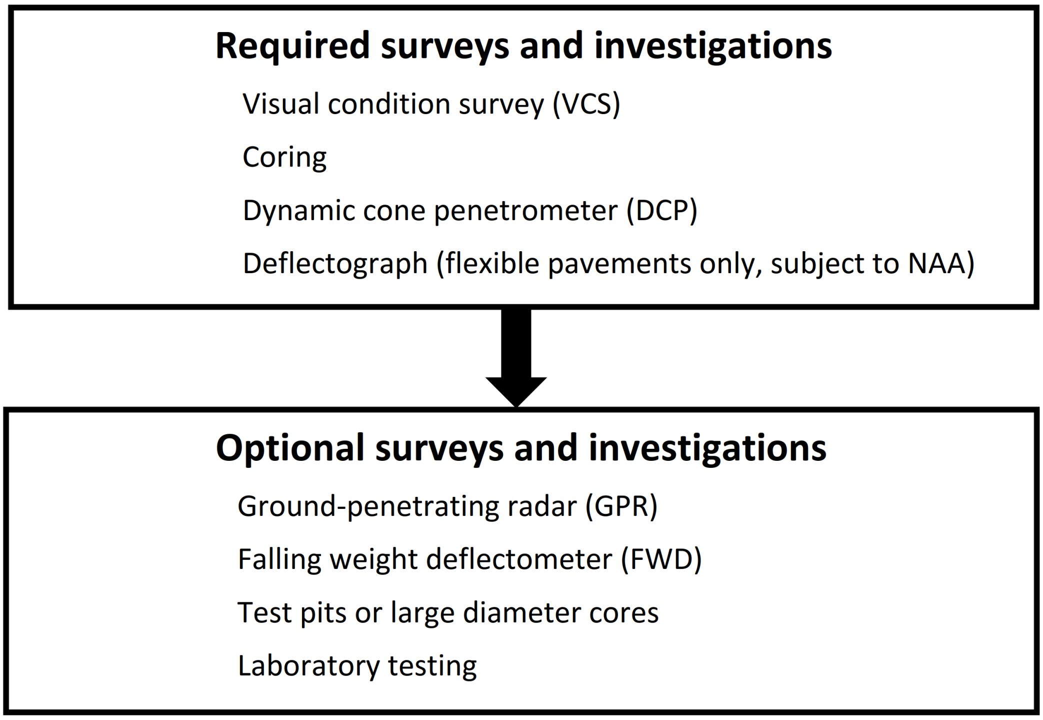
2.4 An investigation plan shall be produced after the visual condition survey (VCS) and prior to the commencement of the detailed investigations.

NOTE The investigation plan can be used by the Overseeing Organisation to review the proposed approach and confirm its appropriateness.

Surveys and investigations

2.5 The types of surveys and investigations that shall be used are identified in Figure 2.5.

Figure 2.5 Scheme level surveys and investigations



NOTE 1 Deflectograph surveys apply to flexible pavements only and are subject to criteria in the appropriate NAA.

NOTE 2 *The scheme-level surveys and investigations are intended to:*

1) *determine or confirm the construction type/s and thicknesses present;*
2) *determine or confirm the type of pavement deterioration (surface defects and/or loss of structural integrity);*
3) *provide information to enable any strengthening, resurfacing and other maintenance works to be designed effectively and economically.*

2.6 The network level survey data and additional data used to identify the scheme, described in CS 230 [Ref 11.N] , shall be used to inform and tailor the development of the investigation plan.

2.7 Where condition data has been collected as part of a previous investigation, the data shall be used to inform and tailor the development of the investigation plan.

2.7.1 Data from previous surveys may be used to reduce or increase the scope of the investigation in certain areas depending on how much the condition has changed and how well those areas were characterised previously.

2.8 The types of survey and investigation that shall be carried out for scheme-level pavement assessments on all pavement types are:

1) VCS;
2) coring;
3) dynamic cone penetrometer (DCP).

2.9 The need for deflectograph surveys shall be determined in accordance with the relevant national application annex (NAA).

2.10 Where further information is needed to support the scheme design, the optional surveys and scheme-level pavement assessment techniques shall be chosen from the following:

1) ground-penetrating radar (GPR);
2) falling weight deflectometer (FWD);
3) test pits or large diameter cores;
4) laboratory testing.

2.11 The required and optional surveys selected for the investigation shall be planned to make efficient use of road space and traffic management and minimise disruption to road users.

2.11.1 Surveys should be planned to ensure that the data is collected within the appropriate time of year and/or pavement temperature limits.

NOTE *Some surveys, such as deflection surveys, have time of year and/or pavement temperature limits that define the usage of the data.*

2.11.2 Wherever possible, surveys should be undertaken at traffic speed.

NOTE *The scheme-level surveys and investigation can involve stationary or slow moving vehicles and personnel on foot occupying part or all of a carriageway for several hours.*

2.12 All measurements shall be undertaken in accordance with CS 229 [Ref 3.N].

2.13 The investigation plan shall be designed:

1) to confirm the type/s of pavement constructions that are present;
2) to collect condition data appropriate for the type/s of constructions that are present.

NOTE 1 *Structural deterioration mechanisms are very different in flexible pavements with an asphalt base, flexible pavements with an hydraulically bound mixture (HBM) base, and rigid pavements.*

NOTE 2 *Information on how to deal with rigid pavements that have been overlaid with asphalt including cracked, seated and overlaid rigid pavements, is given in Section 3 of this document.*

2.14 Where a lane that has not previously been trafficked is to be re-purposed to carry significant future traffic, the investigation plan shall take account of the increased risk that there may be weak, brittle or rut-susceptible material present that may not necessarily be identified by non-invasive methods.

Required surveys and investigations:

Visual condition surveys (VCS)

All pavement types

2.15 VCS shall be carried out in accordance with CS 229 [Ref 3.N].

2.16 VCS shall cover all running lanes.

2.16.1 The VCS should cover the hard shoulder and/or hard strip, and laybys and refuge areas, where present.

2.17 VCS shall be carried out in advance of all other surveys and investigations.

NOTE The visual survey normally provides the most useful information in determining the causes of failure, deciding on the appropriate treatment and targeting of subsequent investigations.

2.18 The results of the VCS shall be used to plan the subsequent investigations.

NOTE Rigid pavements that are only exhibiting signs of surface defects (e.g. low skidding resistance, low texture, shallow spalling) do not require detailed structural investigation.

Coring

Flexible pavements

2.19 Coring on flexible pavements shall be carried out in accordance with CS 229 [Ref 3.N].

NOTE 1 Coring can provide detailed information on the structure and condition of the pavement layers. This information is important for understanding the defects present and in designing maintenance treatments.

NOTE 2 Coring also provides access for DCP testing of the foundation layers.

2.20 Cores shall be taken in areas which are representative of all the defective or weak areas, but biased to the worst areas where remedial works are likely to be more substantial.

NOTE The strategy for deciding the locations for coring depends on the specifics of each site.

2.20.1 Cores should be located both in undamaged areas and also on a representative sample of defects, including cracks.

NOTE When taking a core on a defect, it can be useful to take a core in an intact location close by for comparison.

2.20.2 In lanes with visible defects, at least one core per 200 m should be taken.

NOTE 1 The process of coring is destructive and time-consuming and therefore a balance needs to be struck between the collection of sufficient data and the impact of the investigation.

NOTE 2 In areas of multiple defects such as intersecting cracks or cracks where the adjacent asphalt or concrete is disintegrating, successful core recovery can be a problem.

2.20.3 Evolved pavement thicknesses and materials can be very variable which can lead to a variety of defects and also variable deflections. In such circumstances, investigations can be complicated and more cores should be taken than in homogeneous constructions.

NOTE Pavements where the original construction has been strengthened, widened or reconstructed over a period of years are referred to as evolved pavements.

2.20.4 Ruts or areas of deformation may be assessed by a set of three cores to determine which of the asphalt layers have deformed (see CS 229 [Ref 3.N]).

Rigid pavements

2.21 Coring on rigid pavements shall be carried out in accordance with CS 229 [Ref 3.N].

2.21.1 In rigid pavements, cores should be located both in undamaged areas and also on a representative sample of defects, including cracks.

2.21.2 In rigid pavements, cores should primarily be used to determine the presence and location of steel reinforcement, to determine the depth of spalling, slab thickness and condition, and to confirm the presence and condition of a bound subbase.

2.21.3 Coring in rigid pavements may also be used to determine the degree of interlock across cracks and to provide access for DCP testing of the foundation layers.

2.21.4 In lanes with visible signs of defects, at least one core per 200 m should be taken.

Dynamic cone penetrometer (DCP)

All pavement types

2.22 DCP testing shall be carried out in accordance with CS 229 [Ref 3.N].

2.23 The frequency of DCP testing shall be in accordance with the relevant NAA.

NOTE DCP testing is a way to determine the approximate strengths of the foundation layers.

Optional surveys and investigations

Deflectograph

Flexible pavements

2.24 When a deflectograph survey is required, it shall be carried out in accordance with CS 229 [Ref 3.N].

NOTE Deflectograph surveys are only applicable to flexible pavements.

Falling weight deflectometer (FWD)

Flexible pavements

2.25 When an FWD survey is to be undertaken on a flexible pavement, it shall be carried out in accordance with CS 229 [Ref 3.N].

2.25.1 An FWD survey may be useful to confirm and explain high or variable deflectograph deflections.

2.25.2 An FWD survey may be useful where defects are complex and the pavement construction is expected to be variable.

NOTE Back-analysis of FWD data needs accurate pavement thickness information (see CS 229 [Ref 3.N]).

2.25.3 Where FWD surveys are being undertaken on a flexible pavement, testing should be undertaken in one wheel path only (normally the near side wheel path) and at 20 m intervals.

2.25.4 On flexible pavements with HBM base, some close spaced testing (0.2 to 1.0 m intervals) may be carried out to assess crack frequency and severity in the HBM.

Jointed rigid pavements

2.26 When an FWD survey is to be undertaken on a jointed rigid pavement, it shall be carried out in accordance with CS 229 [Ref 3.N].

NOTE 1 The primary use of the FWD on jointed rigid pavements is to assess the performance at joints or cracks. The load transfer efficiency (LTE) test can be used to assess the efficiency of joints and void intercept (VI) can be used to investigate potential voiding beneath the edge of slabs.

NOTE 2 FWD layer stiffness evaluation testing on concrete slabs is generally of limited usefulness.

2.26.1 Where there is evidence of structural defects, an FWD survey to evaluate the performance of joints and cracks, where present, in jointed concrete pavements should be carried out.

NOTE 1 The joint condition in jointed concrete pavements contributes significantly to pavement performance. Assessment of the joints provides information that is useful in selecting the most appropriate treatments.

NOTE 2 Signs of structural defects include cracking in slabs, deep spalling at joints, stepping/differential movement, evidence of pumping and lack of adhesion of joint seals.

2.27 Joint performance evaluation testing shall include both LTE and VI testing.

2.27.1 Joint evaluation testing should be undertaken in the most heavily trafficked lane, normally lane 1.

2.27.2 Joint evaluation testing may be undertaken in additional lanes if the VCS indicates that there are structural defects present.

2.27.3 Where joint performance evaluation is undertaken, every joint should be tested.

Continuously reinforced concrete pavements (CRCP)

2.28 When an FWD survey is to be undertaken on a continuously reinforced concrete pavement, it shall be carried out in accordance with CS 229 [Ref 3.N].

2.28.1 An FWD survey may be useful on a continuously reinforced concrete pavement to provide information on the stiffness and condition of the layers.

NOTE Back-analysis of FWD data needs accurate pavement thickness information (see CS 229 [Ref 3.N]).

2.28.2 Joint evaluation testing (LTE and VI) may be appropriate for assessing wide cracks and termination slab joints in continuously reinforced concrete pavements.

2.28.3 Where FWD surveys are being undertaken on a continuously reinforced concrete pavement, testing should be carried out in all lanes exhibiting structural defects.

2.28.4 Testing should be undertaken in one wheel path only (normally the near side wheel path) and at 20-m intervals.

Ground-penetrating radar (GPR)

All pavement types

2.29 When a ground-penetrating radar (GPR) survey is to be undertaken, it shall be carried out in accordance with CS 229 [Ref 3.N].

2.29.1 A GPR survey should be carried out on sites where pavement thickness or type of construction is uncertain, including evolved pavements.

2.29.2 A GPR survey may be carried out where it is suspected that voiding and/or moisture are present and are potentially compromising the pavement performance.

2.29.3 GPR surveys should be carried out at traffic speed.

NOTE There can be occasions where a slow speed GPR survey is needed. See CS 229 [Ref 3.N].

2.29.4 GPR surveys should be carried out at an early stage of the investigation.

NOTE 1 The results of a GPR survey can be useful in determining core locations.

NOTE 2 There can be occasions where the need for a GPR survey is identified at a later stage in the process e.g. post coring.

2.29.5 For rigid pavements, GPR surveys may be used to determine the depth and presence of reinforcement and the location of dowels at joints.

2.30 GPR surveys shall cover all running lanes.

2.30.1 The GPR survey should cover the hard shoulder where present.

2.31 The results of the GPR survey shall be used to inform the subsequent investigations.

Test pits

All pavement types

2.32 When test pits are to be undertaken, they shall be carried out in accordance with CS 229 [Ref 3.N].

2.32.1 Test pits should only be used where data cannot be obtained by any other means.

NOTE 1 Test pitting is not encouraged for general use as it is a much slower and more disruptive method of obtaining pavement information than coring and DCP tests.

NOTE 2 A decision on whether test pits are required is usually taken after all the network data and the essential types of scheme data have been assessed. Consequently, any test pits are likely to be excavated as a separate, later operation.

NOTE 3 Large diameter (300 to 450 mm) cores can be used as an alternative to pits.

Laboratory testing

All pavement types

2.33 When laboratory testing is undertaken, testing shall be in accordance with the European and British Standards by laboratories accredited to carry out those tests.

2.34 Cores and other samples shall be retained for at least three months following the investigation.

2.35 The number and type(s) of laboratory tests shall be specified after the assessment of the field data.

NOTE Depending upon the nature of the materials found and the type of distress evidenced by the pavement, laboratory testing can provide valuable data for the evaluation process.

2.36 Laboratory testing of pavement material shall be targeted for specific design reasons rather than being undertaken routinely.

NOTE 1 Laboratory testing can be helpful when distress or a defect in the pavement is observed/suspected that requires further investigation, or where characteristics of the existing material are required for design purposes.

NOTE 2 Laboratory testing can be helpful for identifying potentially weak, brittle or rut-susceptible asphalt materials in previously untrafficked areas that are to be repurposed to carry significant future traffic.

NOTE 3 Testing of materials to compare results between failed and intact areas can be useful. Core retention allows any requirement for laboratory testing to be assessed.

NOTE 4 The state of compaction of bound materials can be assessed through density measurements.

NOTE 5 For asphalt concrete materials, the percentage refusal density (PRD) test can be used to compare the achieved level of compaction with the maximum achievable level.

NOTE 6 It is often only possible to test material of good integrity and this can introduce a bias into the results.

NOTE 7 An assessment of the quality of bound materials can usually be made from a visual examination of the cores to judge voids, gradation and binder content.

2.36.1 Where there is doubt over the adequacy of asphalt layers it may be useful to carry out indirect tension tests on asphalt core samples.

NOTE The stiffness moduli from indirect tension tests can be used to quantify the load spreading ability of the material as well as to help to confirm or explain measured deflection values or FWD derived layer moduli.

2.36.2 Where sets of cores across ruts have failed to identify the layers which have deformed, it may be useful to carry out wheel-tracking tests on samples taken from asphalt cores to judge the deformation of each of the suspect layers.

2.36.3 Poor wheel-tracking results should not normally be used to attribute poor rutting resistance to asphalt layers when no actual rutting has occurred on the pavement.

2.36.4 Analysis of asphalt materials may be useful to help explain why a particular layer has deformed excessively.

2.36.5 Where there is doubt over the condition of HBM, it may be useful to undertake cylindrical strength testing and to determine density.

NOTE 1 Cylindrical testing can be used to derive cube strength and to estimate flexural strength.

NOTE 2 Density can be used to assess the degree of compaction achieved, particularly if an estimate of the relative density of the aggregate is available.

NOTE 3 Stiffness modulus can be measured on either beam or cylindrical specimens.

2.37 Testing of layers that are performing well shall not be undertaken purely to check compliance with current specifications, or those at the time of construction, if known.

NOTE Materials not complying fully with specifications can often be performing satisfactorily.

2.38 Where asphalt material recycling is being proposed, the layers to be recycled shall be tested for compositional analysis and binder properties in order to assess their suitability for the process.

2.39 Where polycyclic aromatic hydrocarbon marker (PAK) testing of a core indicates that tar is present and where removal of the material is being proposed, further tests to determine the nature and composition of the material shall be undertaken.

NOTE 1 Guidance on sampling and testing for tar-bound materials is given in Managing Reclaimed Asphalt Managing Reclaimed Asphalt 2016 [Ref 8.N].

NOTE 2 The Environment Agency's position with regard to asphalt waste containing tar is set out in RPS 075 [Ref 15.N].

2.40 Recovery of unbound foundation layers and laboratory testing shall only be undertaken where there is clear evidence that the foundation has failed and where full depth reconstruction is proposed.

NOTE 1 Recovery of unbound materials can be achieved using a window sampling technique.

NOTE 2 DCP measurements can normally be used to indicate the general condition and strength of unbound foundation materials.

2.40.1 The following tests may be used on unbound materials in order to explain the reasons for high or low strength or stiffness or to compare the material properties with specification standards:

1) grading;
2) liquid limit, plasticity index and linear shrinkage;
3) moisture content.

2.40.2 Laboratory California bearing ratio (CBR) testing of unbound material may be carried out, preferably by removing an undisturbed CBR mould-sized sample.

NOTE 1 A disturbed CBR sample also needs the in situ density to be determined so that the CBR material can be re-compacted to the in situ density.

NOTE 2 In situ CBR tests are generally not very practical as they require a large-plan test pit and take considerable time.

3. Origin of defects and identification of maintenance type

3.1 This section summarises the procedures that shall be followed for interpreting the scheme level data assembled during the surveys and investigations.

3.2 During the interpretation stage of the process, the following shall be determined:

1) the construction types and layer thicknesses present;
2) the nature, extent and severity of defects;
3) the probable cause of defects;
4) whether the defects are confined to the surface or extend deeper into the pavement structure;
5) the types of remedial treatment needed.

Determination of construction type

3.3 The results from existing construction records, cores and, where available, GPR shall be reviewed and used to determine the construction types and layer thicknesses present on the site.

3.3.1 Where it is apparent that multiple construction types are present within the potential scheme, they should each be dealt with separately.

3.4 Where an investigation has identified construction thicknesses or types that are different to those held in the Overseeing Organisation's records, the construction records shall be updated in accordance with the Overseeing Organisation's requirements.

3.5 Pavement construction type shall be categorised as:

1) flexible with an asphalt base;
2) flexible with an HBM base;
3) jointed rigid;
4) continuously reinforced rigid; or
5) evolved, not fitting any of these construction types.

NOTE 1 Construction types are defined in CD 226 [Ref 4.N].

NOTE 2 Pavements originally constructed as flexible with HBM base but with ≥275 mm of intact asphalt are considered as flexible with asphalt base.

3.6 Rigid pavements with up to 50 mm of asphalt overlay shall be regarded as rigid.

3.7 For formerly rigid pavements with between 51 mm and 179 mm of asphalt overlay or previously cracked, seated and overlaid pavements, specialist advice for assessment and treatment shall be sought from the Overseeing Organisation.

NOTE The behaviour, assessment and design of treatment options for formerly rigid pavements with between 51 mm and 179 mm of asphalt overlay or previously cracked, seated and overlaid pavements, require special consideration.

3.8 Formerly rigid pavements with 180 mm or more of asphalt overlay shall be assessed in accordance with the guidance for flexible pavements with HBM base, except for the analysis of deflectograph data.

NOTE Deflectograph analysis cannot be carried out on pavements containing pavement quality concrete.

3.9 For continuously reinforced concrete pavements (CRCP) (with or without a thin surfacing), or continuously reinforced concrete bases (CRCB), specialist advice for the design of deep treatments shall be sought from the Overseeing Organisation.

Presentation of data

3.10 All the relevant data collected from the surveys and investigation shall be assembled in a form that allows data to be compared at all locations within the investigation length.

NOTE 1 A major part of the interpretation process is the comparison of the different types of data, observing where they support or conflict with each other.

NOTE 2 Guidance on the analysis and presentation of condition data is given in CS 229 [Ref 3.N].

3.10.1 The data to be assembled should include:

1) VCS presented in the form of a strip plan;
2) the network-level data collected as described in CS 230 [Ref 11.N];
3) deflectograph results for flexible pavements – both residual life and temperature corrected deflection profiles;
4) core information - layer type, thicknesses, condition and bond between layers;
5) DCP results;
6) GPR results (if available);
7) summary values of the most important in situ and laboratory tests (if available);
8) FWD profiles for flexible pavements (if available);
9) joint evaluation test results (FWD) for jointed rigid pavements (if available);
10) FWD profiles for continuously reinforced concrete pavements (if available).

3.11 All survey or investigation data shall be referenced to the Overseeing Organisation's network referencing system.

3.12 Data from all of the different surveys and investigation methods shall be reviewed and used to assess the structural condition of pavements.

Skid resistance

3.13 Where an investigation carried out in accordance with CS 228 [Ref 13.N] has recommended that the skid resistance of the pavement needs to be improved, surface only maintenance shall be proposed (see Section 4).

3.14 Where a length recommended for treatment to improve skid resistance has defects that extend below the surfacing then a deeper treatment shall be proposed (see Section 5).

Assessment of data: flexible pavements with asphalt base

Deflectograph

3.15 Deflectograph data shall be processed in accordance with CS 229 [Ref 3.N].

3.16 The most recent traffic and construction data shall be used for the analysis with the results of coring and GPR used to update the construction records.

NOTE The precision of determination of pavement life type or estimates of residual life is limited by the accuracy of the input data including construction and traffic details.

3.17 The pavement category and/or residual life of the pavement shall be determined.

NOTE The results of the analysis can categorise pavements into determinate (including upgradable to long-life) or long-life and, for the former, provide an estimate of the residual life of the pavement. This information can be used to help determine the most likely nature and extent of the deterioration. Further information is given in Appendix A.

3.17.1 Deflectograph deflection profiles should be used to provide information about the structural condition of the pavement.

Cores

3.18 The condition of each of the bound layers shall be determined by reviewing the core logs.

NOTE 1 *Deterioration in asphalt such as cracking, debonding of layers or stripping of the binder if present can affect road performance.*

NOTE 2 *Where laboratory tests have been undertaken, the results can provide additional information on the condition of materials.*

Dynamic cone penetrometer (DCP)

3.19 DCP results shall be reviewed in order to assess the depth and strength of the unbound layers.

NOTE *A lack of support can be caused by:*

1) *poor quality materials;*
2) *inadequate compaction;*
3) *ingress of water (indicating possible drainage problems).*

Falling weight deflectometer (FWD)

3.20 Where FWD testing has been undertaken, the data shall be analysed in accordance with CS 229 [Ref 3.N].

3.21 FWD deflection profiles shall be used to provide information about the condition of pavement layers.

3.21.1 Back-analysis of FWD data may provide estimates of layer stiffnesses.

3.22 Where back-analysis of FWD data has been undertaken, the reference values of layer stiffnesses in Table 3.22 shall be used to interpret the results.

Table 3.22 Indicative condition related to layer stiffness in flexible pavements with asphalt base

Material type	Layer stiffness derived from FWD		
	Poor integrity throughout	**Some deterioration**	**Good integrity**
Asphalt (at 20ºC)	< 3 GPa	3 - 7 GPa	> 7 GPa
Unbound foundation	<0.1 GPa		≥ 0.1 GPa

NOTE 1 *The bound layer stiffnesses apply to layers consisting of only one material type.*

NOTE 2 *Layers which fall into the 'Some deterioration' stiffness category are not always unserviceable. Depending on the other indicators, they can remain in the pavement with or without further strengthening.*

NOTE 3 *For the foundation layers of flexible pavements with asphalt base, a minimum layer stiffness of 0.1 GPa (=100 MPa), has been found to be associated with good performance. It is also a reasonable criterion for the unbound foundation layers of flexible pavements with HBM base.*

NOTE 4 *Some of the factors that can influence layer stiffness of various materials are listed in Table 3.22N4.*

Table 3.22N4 Factors affecting layer stiffness

Material or layer	Stiffness decreases	Stiffness increases
Asphalt	High voids Cracking Layer debonding Stripping High moisture	Low voids Binder-hardening
Granular	High moisture Clay contamination	Low moisture Natural-cementing
Subgrade	High moisture	Low moisture

NOTE 5 *Layer stiffnesses of bound materials from FWD back-analysis can also appear lower close to discontinuities (such as joints in concrete or full depth cracks in HBM) or when measurements are taken towards the unconfined edge of a pavement.*

3.23 Conclusions regarding layer condition shall always be supported by more than one type of observation or measurement.

3.23.1 FWD layer stiffnesses should be checked for correlation with pavement visual condition, the layer condition evident in cores, deflectograph and DCP results, and any laboratory test results that have been undertaken.

3.23.2 When comparing asphalt layer stiffnesses at 20ºC from FWD back-analysis with indirect tensile (IT-CY) test values at 20ºC, IT-CY values should be multiplied by 1.5.

NOTE *This adjustment factor only applies to estimates of stiffness from intact layers. The presence of cracking or debonding can reduce the effective stiffness of the layer calculated from back-analysis.*

Defects

3.24 The results of the investigation shall be used to determine the causes of the defects.

NOTE 1 *Knowledge of the cause of the defects provides a good basis for the design of structural maintenance. The primary factors to determine treatments are the condition of the layers and the causes of defects.*

NOTE 2 *A comparison of properties of materials taken from areas of minor or major surface defects can often help to explain the reasons for the difference in performance.*

NOTE 3 *Defects in the wheel-tracks can indicate either structural damage to the base caused by traffic alone or environmental damage to the surfacing, exacerbated by traffic. Where the defects occur over the whole lane or carriageway and not just in the wheel-tracks, the cause is probably not traffic related.*

NOTE 4 *For multi-lane roads, differences in the condition and deflection levels between different traffic lanes can help to determine the contribution of traffic loading to the overall deterioration. This information also helps to optimise maintenance treatments across the carriageway width.*

NOTE 5 *Sometimes there is no clear correlation between deflections and other indicators of pavement condition (visual survey and cores). This can be due to a number of factors:*

1) *errors in the measurement of road temperature;*
2) *deterioration of the road surface, which is only superficial and does not significantly increase the deflections;*
3) *slight deterioration of the road surface resulting in some degree of detachment or debonding of the surface course or binder course resulting in increased deflections;*
4) *pavement supported on an unusually strong subgrade;*
5) *temporarily higher or lower than normal subgrade moisture contents reducing or increasing the pavement strength relative to normal.*

Treatments

3.25 Where deterioration is confined to the surface layers, this confirms that the pavement is structurally sound and surface only maintenance shall be proposed (see Section 4).

3.26 Where deterioration extends downwards into the lower layers, and is affecting the performance of the pavement, or an increase in design life is required then a deeper treatment shall be proposed (see Section 5).

NOTE 1 *Deterioration affecting the performance of the pavement can include cracked and rutted materials that are either affecting the serviceability or structural integrity of the pavement or, if left untreated, can compromise the integrity of the pavement e.g. by allowing water to enter the structure.*

NOTE 2 *Some weak or partially disintegrated materials found at depth within old pavements, e.g. tar-bound slag, could have been in this state for a considerable length of time. Where there are no associated surface defects then such weak materials can often be left in place. The cause of such low strength is usually poor aggregate grading, high voids and low binder content.*

Assessment of data: flexible pavements with HBM base

Deflectograph

3.27 Deflectograph data shall be processed in accordance with CS 229 [Ref 3.N].

3.28 The most recent traffic and construction data shall be used for the analysis with the results of coring and GPR used to update the construction records.

NOTE *The precision of estimates of residual life is limited by the accuracy of the input data such as measured deflection, construction and traffic details, as well as experimental error within the empirical relationships used.*

3.29 The pavement category and/or residual life of the pavement shall be determined.

NOTE *The results of the analysis can categorise pavements into determinate (including upgradeable to long-life) or long-life pavements. For determinate pavements the analysis can provide an estimate of the residual life of the pavement. This information can be used to help determine the most likely nature and extent of the deterioration. Further information is given in Appendix A.*

3.29.1 Deflectograph deflection profiles should be used to provide information about the structural condition of the pavement.

Cores

3.30 The condition of each of the bound layers shall be determined by reviewing the core logs.

NOTE 1 *The condition of the HBM and the presence and frequency of cracking is particularly important for the evaluation of flexible pavements with HBM base.*

NOTE 2 *Where laboratory tests have been undertaken, the results can provide additional information on the condition of materials.*

Dynamic cone penetrometer (DCP)

3.31 DCP results shall be reviewed in order to assess the thickness and estimated CBR of the unbound layers.

NOTE *A lack of support can be caused by:*

1) *poor quality materials;*
2) *inadequate compaction;*
3) *ingress of water (indicating possible drainage problems).*

Falling weight deflectometer (FWD)

3.32 Where FWD testing has been undertaken, the data shall be analysed in accordance with CS 229 [Ref 3.N].

3.33 FWD deflection profiles shall be used to provide information about the condition of pavement layers.

3.33.1 Back-analysis of FWD data may be used to provide additional information about layer stiffnesses.

3.34 Where back-analysis of FWD data has been undertaken, the reference values of layer stiffnesses in Table 3.34 shall be used to interpret the results.

Table 3.34 Condition related to layer stiffness in flexible pavements with HBM base

Material type	Layer stiffness derived from FWD		
	Poor integrity throughout	Some deterioration	Good integrity
Asphalt (at 20ºC)	< 3 GPa	3 - 7 GPa	> 7 GPa
Hydraulically bound mixture(HBM)	< 8 GPa	8 - 15 GPa	> 15 GPa
Unbound foundation	<0.1 GPa		≥ 0.1 GPa

NOTE 1 *The bound layer stiffnesses apply to layers consisting of only one material type.*

NOTE 2 *Layers which fall in the 'Some deterioration' stiffness category are not necessarily unserviceable. Depending on the other indicators, they can remain in the pavement with or without further strengthening.*

NOTE 3 *For the foundation layers of flexible pavements with asphalt base, a minimum layer stiffness of 0.1 GPa (=100 MPa), has been found to be associated with good performance. It is also a reasonable criterion for the unbound foundation layers of flexible pavements with HBM base.*

NOTE 4 *Some of the factors that can influence layer stiffness of various materials are listed in Table 3.34N4.*

Table 3.34N4 Factors affecting layer stiffness

Material or layer	Stiffness decreases	Stiffness increases
Asphalt	High voids Cracking Layer debonding Stripping High moisture	Low voids Binder-hardening
HBM	Cracking Debonding Poor compaction	-
Granular	High moisture Clay contamination	Low moisture Natural-cementing
Subgrade	High moisture	Low moisture

NOTE 5 *Layer stiffnesses of bound materials from FWD back-analysis can also appear lower close to discontinuities (such as joints in concrete or full depth cracks in HBM) or when measurements are taken towards the unconfined edge of a pavement.*

3.34.1 For flexible pavements with HBM base, FWD analysis should also be carried out with all the bound layers (asphalt and HBM) combined as a single layer and results compared to the stiffness values given in Table 3.36.2.

3.35 Conclusions regarding layer condition shall always be supported by more than one type of observation or measurement.

3.35.1 FWD layer stiffnesses should be checked for correlation with pavement visual condition, the layer condition evident in cores, deflectograph results, DCP results and any laboratory test results that have been undertaken.

3.35.2 When comparing asphalt layer stiffnesses at 20ºC from FWD back-analysis with indirect tensile (IT-CY) test values at 20ºC, IT-CY values should be multiplied by 1.5.

NOTE *The adjustment factor of 1.5 only applies to estimates of stiffness from intact layers. The presence of cracking or debonding can reduce the effective stiffness of the layer calculated from back-analysis.*

Defects

3.36 The results of the investigation shall be used to determine the causes of the defects.

NOTE 1 *Knowledge of the cause of the defects can provide a good basis for the design of structural maintenance. The primary factors to determine treatments are the condition of the layers and the causes of defects.*

NOTE 2 *A comparison of properties of materials taken from areas of minor or major surface defects can often help to explain the reasons for the difference in performance.*

NOTE 3 *Defects in the wheel-tracks can indicate either structural damage to the base caused by traffic alone or environmental damage to the surfacing, exacerbated by traffic. Where the defects occur over the whole lane or carriageway and not just in the wheel-tracks, the cause is probably not traffic related.*

NOTE 4 *For multi-lane roads, differences in the condition and deflection levels between different traffic lanes can help to determine the contribution of traffic loading to the overall deterioration. This information also helps to optimise maintenance treatments across the carriageway width.*

NOTE 5 *Sometimes there is no clear correlation between deflections and other indicators of pavement condition (visual survey and cores). This can be due to a number of factors:*

1) *errors in the measurement of road temperature;*
2) *deterioration of the road surface is only superficial and does not significantly increase the deflections;*
3) *slight deterioration of the road surface resulting in some degree of detachment or debonding of the surface course resulting in increased deflections;*
4) *pavement is supported on an unusually strong subgrade;*
5) *temporarily higher or lower than normal subgrade moisture contents reducing or increasing the pavement strength relative to normal.*

3.36.1 The condition class/es for flexible pavements with HBM base should be determined in accordance with Table 3.36.2.

NOTE 1 *The primary transverse shrinkage cracks, which form in a layer of medium to high strength HBM at the time of construction, often cause reflection cracks in the road surface. The timing of the appearance of such cracks in the surface is partly influenced by the age and thickness of the overlying asphalt layers and partly by other factors such as strength of mix, subgrade strength, weather conditions during and immediately after construction and traffic loading.*

NOTE 2 *With HBM, defects first develop in the vicinity of cracks, the pavement structure on either side retaining high structural stiffness. Deflection measurements on flexible pavements with hydraulically bound base tend to be very low (less than 0.15 mm) unless they happen to coincide with cracks.*

NOTE 3 *Forecasts of long residual lives which are derived for flexible pavements with HBM base in combination with low deflections and moderate traffic loadings can be misleading, because these forecasts depend on the pavement remaining substantially uncracked.*

NOTE 4 *When HBM is used for more than one layer of the pavement structure, shorter lives can be achieved for a given deflection than might be indicated by deflection analysis. Much depends on the condition of the lower hydraulically bound layer. Deflections can be kept low by the undamaged lower layer concealing progressive deterioration of the upper layers.*

NOTE 5 *The principal determining factor for each class is the type, extent and severity of cracking in the HBM base. The table also gives details of the type of treatment likely to be appropriate. The FWD stiffnesses apply to the combined asphalt and hydraulically bound base layers at less than or equal to 20^{o}C.*

3.36.2 The determination of condition classes should be based on all the criteria in Table 3.36.2 and not just on one, e.g. FWD layer stiffness.

Table 3.36.2 Assessment of treatment of flexible pavements with HBM base

	Class A	Class B	Class C	Class D
Visual observation	Surface cracking not evident or confined to widely spaced minor transverse cracks unless associated with construction joints in the HBM.	Surface transverse cracking confined to left hand lane. No, or very minor, longitudinal cracking in the wheel-tracks.	Transverse and longitudinal cracking in the wheel-tracks are both evident.	Extensive transverse and longitudinal cracking in the wheel-tracks are both evident.
Deflection profile	Consistent, low deflection values (typically <100 microns) with no regular peaks.	Deflections are low (typically <100 microns) but there are regular isolated peak values.	Deflections are variable with mean values typically between 100 and 200 microns with regular peak values.	Deflections are consistently high with mean values typically >200 microns.
Crack severity (see notes below)	Transverse crack severity generally 1.	Transverse crack severity generally 2.	Transverse crack severity 2 or 3, longitudinal crack severity generally 1.	Transverse and longitudinal crack severity generally 3.
HBM strength	≥ 10 MN/m^2	≥ 10 MN/m^2	≥ 10 MN/m^2	≥ 10 MN/m^2
Cores	Consistent sound HBM with no wide cracks.	Some occasional cracking in HBM but material generally sound.	Wide longitudinal cracks but material between cracks is sound.	Wide cracks for the full depth of some cores.
FWD - mean pavement layer stiffness modulus surveyed at close intervals (< 20 ^{o}C)	Consistent results >10 GPa with a few individual results below 7 GPa	>10 GPa with some individual results below 7 GPa	Variable results average >10 GPa with successive results below 7 GPa	<7 GPa
Probable HBM condition	Little deterioration beyond initial transverse cracking due to early shrinkage and thermal warping, with good load transfer across transverse cracks.	Deterioration has gone beyond initial transverse cracking. HBM slabs are large with movement at transverse cracks. Longitudinal cracking is slight or absent, with good load transfer across cracks	HBM slabs are large with significant movement at transverse cracks. Longitudinal cracking is present.	HBM slabs are small, probably < 4 m maximum dimension. Multiple transverse and longitudinal cracks with poor load transfer.

Table 3.36.2 Assessment of treatment of flexible pavements with HBM base (continued)

Implications for treatment	Structure has very little deterioration and pavement can have a potential traffic capacity of between 20 and 80 msa. Surface defects require treatment (see Section 4)	Structure has some deterioration and there is a significant risk of reflection cracking. See Section 5 for treatment design.	See Section 5 for treatment design.	Pavement can require reconstruction. See Section 5 for treatment design.

General notes:
Note 1: Crack severity ratings are as follows:

1) widely spaced cracks (>10m), generally ≤0.5 mm wide, without fretting, and no evidence of vertical movement;
2) regularly spaced cracks (5-10 m), generally ≤1.0 mm wide, with some fretting, and evidence of horizontal and/or vertical movement;
3) regularly and irregularly spaced cracks, generally >1.0 mm wide, with some fretting, and evidence of horizontal and vertical movement.

Note 2: The deflection guide values in Table 3.36.2 are based on deflectograph or FWD (normalised to 50 kN).
Note 3: Further information on the interpretation of Table 3.36.2 is provided in TRL publication TRL RR189 [Ref 7.I] .

3.36.3 The condition classes should be used to inform treatment type for flexible pavements with HBM base.

Treatments

3.37 Where deterioration is confined to the surface layers, this confirms that the pavement is structurally sound and a surface treatment shall be proposed (see Section 4).

3.38 Where deterioration extends downwards into the lower layers, and is affecting the performance of the pavement, or an increase in design life is required then a deeper treatment shall be proposed (see Section 5).

NOTE 1 Deterioration affecting the performance of the pavement can include cracked and rutted materials that are either affecting the serviceability or structural integrity of the pavement or, if left untreated, can compromise the integrity of the pavement e.g. by allowing water to enter the structure.

NOTE 2 Some weak or partially disintegrated materials found at depth within old pavements, e.g. tar-bound slag, could have been in this state for a considerable length of time. Where there are no associated surface defects then such weak materials can often be left in place. The cause of such low strength is usually poor aggregate grading, high voids and low binder content.

Assessment of data: jointed rigid pavements

Cores

3.39 The core logs shall be reviewed to determine the following:

1) condition and thickness of each of the bound layers;
2) the presence and location of steel reinforcement;
3) the depth of spalling;
4) the presence and condition of a bound sub-base (where present).

NOTE 1 Cracking in rigid pavement slabs is normally found to extend to the full depth of the concrete layer.

NOTE 2 Coring in rigid pavements can be used to assess the degree of mechanical interlock across cracks.

NOTE 3 Where laboratory tests have been undertaken, the results can provide additional information on the condition of materials.

NOTE 4 Guidance on obtaining the compressive strength from cores is given in Series 1000 of MCHW [Ref 9.N].

Dynamic cone penetrometer (DCP)

3.40 DCP results shall be reviewed in order to assess the thickness and estimated CBR of the unbound layers.

NOTE A lack of support can be caused by:

1) poor quality materials;
2) inadequate compaction;
3) ingress of water (indicating possible drainage problems).

Falling weight deflectometer (FWD)

3.41 Where FWD testing has been undertaken, the data shall be analysed in accordance with CS 229 [Ref 3.N].

3.42 Where load transfer efficiency (LTE) testing of joints or cracks has been undertaken, the results shall be assessed by benchmarking the LTE values against condition information from the VCS and from cores.

NOTE 1 Joints or cracks with perfect load transfer can give a LTE of just under 100%.

NOTE 2 LTE significantly below 50% can be regarded as indicating unsatisfactory load transfer.

NOTE 3 *The LTE value above which all joints or cracks can be considered to be performing satisfactorily varies from site to site and depends on temperatures through the depth of the slab at the time of testing.*

3.43 Where void intercept (VI) testing has been undertaken, the results shall be reviewed in order to identify locations where a lack of slab support is indicated.

NOTE *VI values of ≥50 microns are indicative of under-slab voiding.*

3.44 Where mid-slab layer stiffness evaluation measurements have been taken, the deflection profiles shall be used to provide information about the condition of pavement layers.

3.45 Where back-analysis of FWD data has been undertaken, the reference values of layer stiffnesses in Table 3.45 shall be used to interpret the results.

Table 3.45 Condition related to layer stiffness in jointed rigid pavements

Material type	Layer stiffness derived from FWD		
	Poor integrity throughout	**Some deterioration**	**Good integrity**
PQ concrete	< 20 GPa	20-30 GPa	> 30 GPa
Hydraulically bound mixture (HBM)	< 8 GPa	8-15 GPa	> 15 GPa
Unbound foundation	<0.1 GPa		≥ 0.1 GPa

NOTE 1 *The bound layer stiffness applies to layers consisting of only one material type.*

NOTE 2 *Factors that can reduce the stiffness of a jointed rigid pavement are cracking, proximity to joints, debonding and poor compaction.*

NOTE 3 *Layer stiffnesses of bound materials from FWD back-analysis can also appear lower close to discontinuities (such as joints in concrete or full depth cracks in HBM) or when measurements are taken towards the unconfined edge of a pavement.*

3.46 Conclusions regarding layer condition shall always be supported by more than one type of observation or measurement.

3.46.1 FWD layer stiffness should be checked for correlation with pavement visual condition, the layer condition evident in cores, DCP results and any laboratory test results.

Defects

3.47 The results of the VCS and the investigation shall be reviewed and used to identify the observed dominant defects.

NOTE 1 *Defects in rigid pavements can be broadly categorised as being surface or structural. Tables C1 and C2 in Appendix C to this document provide information on the possible cause of each defect, appropriate testing to verify the diagnosis, and available treatment options.*

NOTE 2 *Details and background information on defects in rigid pavements can be found in the CS CPMM 2001 [Ref 1.N].*

NOTE 3 *Knowledge of the cause of the defects provides a good basis for the design of surface or structural maintenance. The primary factors to determine treatments are the condition of the layers and the causes of defects.*

NOTE 4 *A comparison of properties of materials taken from areas of minor or major surface defects can often help to explain the reasons for the difference in performance.*

NOTE 5 *For multi-lane roads, differences in the condition and deflection levels between different traffic lanes can help to determine the contribution of traffic loading to the overall deterioration. This information also helps to optimise maintenance treatments across the carriageway width.*

3.48 For pavements where the defects are structural, the residual life of the pavement shall be determined using the methodology described in Chapter 7 of the Concrete Pavement Maintenance Manual CS CPMM 2001 [Ref 1.N].

NOTE 1 *The CPMM methodology for determining the residual life of the pavement is based in part on relationships between the total traffic (in million standard axles (msa)) the pavement could have been expected to carry when first open to traffic, the cumulative past traffic based on traffic counts and the future traffic growth rate (obtained from CD 224 [Ref 18.N]). It also takes account of the actual condition of the pavement based on the VCS, cores, DCP and FWD data, defects, the percentage of failed bays and the contribution of the tied hard shoulder.*

NOTE 2 *The design method used when the pavement was constructed is not necessarily relevant to assessing its expected life, as the underlying design methods have been revised over time.*

NOTE 3 *Information on failure criteria for rigid pavements is described in TRL publication TRL RR87 [Ref 17.N].*

NOTE 4 *Current concrete pavement design (based on TRL RR87 [Ref 17.N]) allows the thickness of the concrete slab to be reduced if there is a tied shoulder (or tied adjacent lane) to the lane being trafficked (see CPMM Figure 7.3, CS CPMM 2001 [Ref 1.N]). Where traffic is moved to the hard shoulder without an existing tied shoulder (e.g. a SMART motorway), there is the possibility of damage to the nearside edge of the slab and this can affect the design life calculation.*

Treatments

3.49 Where the dominant defect is surface and/or the residual life of the pavement is five years or greater, then surface maintenance treatments shall be proposed (see Section 4).

3.50 Where the residual life of the pavement is less than 5 years, or an increase in design life is required, then a deeper treatment shall be proposed (see Section 5).

Assessment of data: continuously reinforced rigid pavements (CRCP)

Cores

3.51 The core logs shall be reviewed to determine the following:

1) condition and thickness of each of the bound layers;
2) the presence and location of steel reinforcement;
3) the depth of spalling;
4) the presence and condition of a bound sub-base (where present).

NOTE *Where laboratory tests have been undertaken, the results can provide additional information on the condition of materials.*

Dynamic cone penetrometer (DCP)

3.52 DCP results shall be reviewed in order to assess the quality of the unbound layers.

NOTE *A lack of support can be caused by:*

1) *poor quality materials;*
2) *inadequate compaction;*
3) *ingress of water (indicating possible drainage problems).*

Falling weight deflectometer (FWD)

3.53 Where FWD testing has been undertaken, the data shall be analysed in accordance with CS 229 [Ref 3.N].

3.54 FWD deflection profiles shall be used to provide information about the condition of pavement layers.

3.54.1 Back-analysis of FWD data may provide estimates of layer stiffnesses.

3.55 Where back-analysis of FWD data has been undertaken, the reference values of layer stiffnesses in Table 3.55 shall be used to interpret the results.

Table 3.55 Table of layer stiffness for CRCP

Material type	Layer stiffness derived from FWD		
	Poor integrity throughout	Some deterioration	Good integrity
PQ concrete	20 GPa	20-30 GPa	30 GPa
Hydraulically bound mixture (HBM)	< 8 GPa	8-15 GPa	> 15 GPa
Unbound foundation	< 0.1 GPa		≥ 0.1 GPa

NOTE 1 The bound layer stiffness applies to layers consisting of only one material type.

NOTE 2 Factors that can reduce the stiffness of a jointed rigid pavement are cracking, proximity to joints, debonding and poor compaction.

NOTE 3 Layer stiffnesses of bound materials from FWD back-analysis can also appear lower close to discontinuities (such as joints in concrete or full depth cracks in HBM) or when measurements are taken towards the unconfined edge of a pavement.

3.56 Conclusions regarding layer condition shall always be supported by more than one type of observation or measurement.

3.56.1 FWD layer stiffness should be checked for correlation with pavement visual condition, the layer condition evident in cores, DCP results and any laboratory test results.

Defects

3.57 The results of the VCS shall be reviewed and the number of significant defects in each 100 m per lane identified.

NOTE 1 Significant defects in CRCPs, indicating a weakened structure or need for maintenance, include:

1) *transverse cracks at spacings of less than 1 m;*
2) *transverse cracks with widths greater than 1 mm;*
3) *longitudinal cracks;*
4) *areas of polygonal cracking;*
5) *loose or missing blocks of concrete (punchouts);*
6) *crack bifurcations;*
7) *failing repairs;*
8) *spalling.*

NOTE 2 "Normal" cracks in CRCPs are exclusively transverse with no spalling or bifurcations, are less than 1 mm in width and are spaced at least 1 m apart.

NOTE 3 The CS CPMM 2001 [Ref 1.N] provides further information and photographic illustrations of each defect.

3.57.1 Multiple visual condition surveys should be used to determine the rate of development of significant defects in CRCPs.

NOTE 1 Significant defects in CRCPs are defined in Table C.3 in Appendix C of this document.

NOTE 2 There is no standard methodology for assessing the residual lives of continuously reinforced rigid pavements. An increase in the number of significant defects is likely to be an indicator that the pavement is failing.

Treatments

3.58 Where significant defects are present, options for the treatment shall be provided.

NOTE Treatment options for CRCPs are set out in Table C.3 in Appendix C of this document.

3.59 Where the defects are limited in number and are confined to the surface then surface maintenance treatments shall be proposed (see Section 4).

NOTE Surface treatments can be used to extend the life of a continuously reinforced concrete pavement.

3.60 Where defects are widespread and/or not confined to the surface or the pavement needs strengthening, then a deeper treatment shall be proposed (see Section 5).

NOTE Defects in CRCPs can be considered widespread where the number of significant defects reaches 10 per carriageway km or the number of punchouts reaches 4 per carriageway km.

Report

3.61 The findings and recommendations of the investigation shall be stated in a report that includes a summary of the following:

1) the network-level data;
2) the results of the detailed investigations in graphical and/or tabular from;
3) the main defects that are driving the need for treatment;
4) the broad treatment options that are likely to be needed.

4. Design of surface only maintenance

4.1 This section provides details of the design of surface treatment options that shall be used for maintaining flexible and rigid pavements.

4.2 Where a new or replacement surface course is being proposed, this shall be designed in accordance with CD 236 [Ref 14.N].

4.3 Surface only maintenance treatments shall be designed to rectify the defects present.

4.4 Where a treatment that results in an increase in pavement height is being considered, an assessment shall be made of the consequential impact on the following:

1) headrooms at structures, gantries and overhead lines;
2) carriageway surface geometry;
3) kerb and vehicle restraint system heights;
4) drainage and ironwork;
5) heights of copings and parapet walls adjacent to retaining walls and underbridges;
6) overloading at under-bridges and adjacent to retaining walls.

NOTE Requirements for headrooms are set out in CD 127 [Ref 2.N].

Pavements with an asphalt surfacing

4.5 Where defects are confined to the surfacing, replacement of the surfacing shall be undertaken.

4.5.1 Where the proposed treatment is only to address low skid resistance and the existing surface is free of other defects, an overlay may be applied.

4.5.2 Retexturing may be used to provide a temporary improvement in skid resistance and texture, pending replacement of the surface.

NOTE The use of retexturing is set out in CD 236 [Ref 14.N] and further guidance on retexturing asphalt surfacings is provided in Appendix B.

4.5.3 Crack sealing may be used for isolated lengths of cracking and deteriorated construction joints within the surface.

4.6 Where crack sealing is being undertaken, this shall be done using materials specifically designed to bond with asphalt and to prevent water ingress.

NOTE More information on crack repairs is given in CM 231 [Ref 12.N] and Series 700 of the MCHW [Ref 9.N].

Preventative maintenance

4.7 Where a preventative maintenance treatment is to be used, this shall be designed in accordance with the relevant national application annex (NAA).

Jointed rigid pavements (with a concrete surfacing)

4.8 Where the only defect is shallow cracking (confined to the top 50 mm), then crack sealing using materials specifically designed to bond with concrete and prevent water ingress shall be used.

4.8.1 Thin bonded repairs may be used on areas of cracking up to 1 m^2.

4.8.2 Slab replacement may be used to treat larger areas of cracking.

NOTE 1 Guidance on treatment options for jointed rigid pavements is given in Appendix C of this document.

NOTE 2 More information on crack repairs is given in CM 231 [Ref 12.N] and Series 700 of the MCHW [Ref 9.N].

4.9 Where there are missing or defective joint seals, they shall be replaced with a compatible hot or cold applied sealant or compression seal, installed in accordance with the manufacturer's instructions.

NOTE 1 Due to ageing, joint seals typically need replacing every 5 to 10 years.

NOTE 2 More information on joint seals is given in Series 1000 of the MCHW [Ref 9.N].

4.10 At locations vulnerable to contamination by fuel or oil, e.g. bus stops, laybys or parking areas, a fuel resistant sealing material shall be used.

4.11 Overbanding materials shall not be used to seal joints or cracks in concrete pavements.

4.12 Where the defects are limited to shallow spalling, surface scaling, cobweb crazing, aggregate pop out or surface irregularity then thin bonded concrete repairs shall be carried out.

4.12.1 Shallow spalling should be repaired before the joint seal is affected to the extent that it permits water and detritus to penetrate the joint.

NOTE 1 Guidance on the treatment options for jointed rigid pavements is given in Appendix C of this document.

NOTE 2 More information on thin bonded repairs is given in CM 231 [Ref 12.N] and Series 1000 of the MCHW [Ref 9.N].

4.12.2 Slab replacement may be used to treat larger areas of cracking.

4.13 Where the only defect is low skid resistance or low texture then retexturing (where permitted) or an overlay shall be applied.

NOTE 1 The use of retexturing is set out in CD 236 [Ref 14.N].

NOTE 2 Guidance on retexturing concrete surfacings, including surface reprofiling, is provided in Appendix B of this document.

4.14 Treatments that result in a reduction in the thickness of the concrete surface layer shall not be used where the reduction in thickness reduces the structural life of the pavement below 20 years or results in inadequate cover above reinforcement.

NOTE 1 Details of minimum cover to reinforcement can be found in Series 1000 of the MCHW [Ref 9.N].

NOTE 2 Guidance on the treatment options for jointed rigid pavements is given in Appendix C of this document.

Continuously reinforced concrete pavements (with a concrete surfacing)

4.15 When designing surface treatments for continuously reinforced concrete pavements an assessment shall be made of the extent and depth of significant defects.

NOTE 1 Significant defects in continuously reinforced rigid pavements are defined in Section 3 of this document.

NOTE 2 Surface treatments can, if applied at the right time, be used to extend the life of a continuously reinforced concrete pavement.

NOTE 3 Guidance on the treatment options for continuously reinforced concrete pavements is given in Table C.3 in Appendix C of this document.

4.15.1 Where the defects are limited to shallow spalling then thin bonded repairs should be carried out.

NOTE More information on thin bonded repairs is given in CM 231 [Ref 12.N] and Series 1000 of the MCHW [Ref 9.N].

4.15.2 Where significant cracking is present then crack sealing using materials specifically designed to bond with concrete and prevent water ingress may be used.

NOTE 1 Significant cracking in CRCPs is defined in Section 3 of this document.

NOTE 2 More information on overband and inlaid crack sealing systems is given in Series 700 of the MCHW [Ref 9.N].

4.15.3 Where multiple defects are present, an overlay may be applied.

4.16 Overbanding materials shall not be used to seal joints or cracks in concrete pavements.

4.17 Where the only defect is low skid resistance or low texture then retexturing (where permitted) or an overlay shall be applied.

NOTE 1 The use of retexturing is set out in CD 236 [Ref 14.N].

NOTE 2 Guidance on retexturing concrete surfacings, including surface reprofiling, is provided in Appendix B of this document.

4.18 Treatments that result in a reduction in the thickness of the concrete surface layer shall not be used where the reduction in thickness reduces the structural life of the pavement below 20 years or results in inadequate cover above reinforcement.

NOTE 1 Details of minimum cover to reinforcement can be found in Series 1000 of the MCHW [Ref 9.N].

NOTE 2 Guidance on the treatment options for continuously reinforced concrete pavements is given in Table C.3 in Appendix C of this document.

4.19 Where the presence of alkali-silica reaction is suspected, consultation with the Overseeing Organisation shall be undertaken.

NOTE Alkali-silica reaction can be inferred from the presence of areas of crazing containing a white or creamy powdery material which streaks the surface after heavy rainfall.

5. Design of deeper maintenance treatments

5.1 This section provides details of the design of deeper maintenance treatment options that shall be used for maintaining flexible and rigid pavements.

NOTE Deeper treatments are treatments that either extend below the depth of the surface course or strengthen the pavement.

5.2 For all treatments, the surface course shall be designed in accordance with CD 236 [Ref 14.N].

5.3 Where a treatment that results in an increase in pavement height is being considered, an assessment shall be made of the consequential impact on the following:

1) headrooms at structures, gantries and overhead lines;
2) carriageway surface geometry;
3) kerb and vehicle restraint system heights;
4) drainage and ironwork;
5) heights of copings and parapet walls adjacent to retaining walls and underbridges;
6) overloading at underbridges and adjacent to retaining walls.

NOTE Requirements for headrooms are set out in CD 127 [Ref 2.N].

5.4 Where the existing pavement has sufficient structural strength but has defects below the surface course that are affecting the performance of the pavement, the treatment shall be designed to rectify those defects (i.e. non-strengthening treatments).

NOTE For flexible and jointed rigid pavements, a residual life of ≥5 years can be taken as being indicative of sufficient structural strength.

5.5 Geosynthetic or steel mesh interlayers shall only be used as a maintenance treatment option for suppression of potential future reflective cracking in:

1) jointed concrete pavements that are being overlaid with asphalt;
2) flexible pavements with hydraulically bound bases that are being inlaid;
3) asphalt layers that are being placed over a discontinuity in construction.

NOTE Discontinuities can occur where a pavement has been widened or where there is a longitudinal change in construction type.

5.6 Where a geosynthetic or steel mesh interlayer is specified, this shall be in accordance with Series 900 of the MCHW [Ref 9.N] and BS EN 13249 [Ref 6.N].

5.7 A geosynthetic or steel mesh interlayer shall be placed sufficiently deep within the bound layers so that it is not removed when the surface course is replaced.

5.8 Where a geosynthetic or steel mesh interlayer is specified, it shall not be used to reduce the design thickness of asphalt material.

5.9 Where drainage faults are found that have led to a weakening of the foundation, these shall be rectified and action taken to prevent recurrence.

NOTE Failure to rectify drainage faults can result in a requirement to reconstruct both the drainage system and the pavement.

5.9.1 The design of pavement treatments should be finalised after the effect of the drainage measures on pavement performance has been assessed.

Flexible pavements

Non-strengthening treatments

5.10 In a flexible pavement, non-strengthening treatments shall involve planing off to the depth of the defects and inlaying back to existing levels.

Strengthening treatments

5.11 Where a treatment is required to strengthen a flexible pavement, the designs presented shall include options to:

1) strengthen the pavement to provide a minimum structural life of 20 years after treatment;
2) upgrade to an LLP.

5.12 Flexible pavements shall be strengthened using one of the following methods:

1) overlay;
2) plane off and inlay (replacement of some of the bound layers);
3) partial reconstruction (replacement of all the bound layers);
4) full reconstruction (extending into the foundation).

NOTE Guidance on the selection of strengthening treatments is given in Appendix D.

5.13 The design of strengthening treatments for flexible pavements shall not be based on deflection results alone.

5.14 Where reconstruction (partial or full) is proposed, the design shall be in accordance with CD 226 [Ref 4.N].

Jointed rigid pavements

Non-strengthening treatments

5.15 Non-strengthening treatments for jointed rigid pavements shall include:

1) isolated bay replacement;
2) localised full depth repair (e.g. to repair extensive cracking or deep spalling at a joint);
3) slab lifting and pressure or vacuum grouting;
4) crack treatment at gully and manhole covers.

5.16 Permanent full depth repairs shall be made in concrete.

NOTE Repairs incorporating bituminous mixtures have a shorter design life than repairs made using concrete.

5.16.1 Concrete slabs may be replaced with bituminous mixtures as a temporary measure, but need to be replaced during the next planned maintenance period, or as a consequence of a defect (whichever occurs soonest).

NOTE 1 Non-strengthening treatments can be used to treat defects in jointed rigid pavements where an increase in structural life is not required.

NOTE 2 Guidance on the non-strengthening treatment options for jointed rigid pavements is given in Appendix E of this document and Series 1000 of the MCHW [Ref 9.N].

5.17 Where a rapid cure concrete mix is to be used, it shall be subject to off-site trials to ensure a sufficient strength is achievable in the time available.

NOTE 1 An example of a rapid cure concrete mix design which achieves adequate strength to be trafficked in 3 hours can be found in Table E.1 in Appendix E.

NOTE 2 Maturity curves for strength gain against temperature and time can be utilised during the concrete mixture design.

NOTE 3 An alternative to rapid cure concrete is roller compacted concrete. This is described in CD 226 [Ref 4.N].

Strengthening treatments

5.18 Where a treatment is required to strengthen a jointed rigid pavement, the design shall provide a minimum structural life of 20 years.

5.19 Jointed rigid pavements shall be strengthened using one of the following methods:

1) reconstruction (partial or full);
2) fractured slab techniques;
3) overlay using concrete or asphalt.

NOTE 1 Fractured slab techniques comprise 'crack, seat and asphalt overlay' (for jointed unreinforced concrete), 'saw cut, crack, seat and asphalt overlay' (for jointed reinforced concrete) or 'rubblisation and asphalt overlay'.

NOTE 2 Guidance on the strengthening of jointed rigid pavements is given in Appendix E of this document.

5.20 Fractured slab techniques ('crack, seat and asphalt overlay' and 'saw-cut, crack, seat and asphalt overlay') shall be designed in accordance with the appropriate National Application Annex.

5.21 Where reconstruction is proposed, the design shall be in accordance with CD 226 [Ref 4.N].

Continuously reinforced concrete pavements (CRCP)

5.22 Where there are isolated 'punchouts' or deep spalling present in CRCP, a full depth repair shall be undertaken.

NOTE 1 Significant defects in continuously reinforced rigid pavements are defined in Section 3 of this document.

NOTE 2 More information on full depth repairs is given in Series 1000 of the MCHW [Ref 9.N].

NOTE 3 The continuity of the reinforcement needs to be maintained where necessary by adequate laps.

NOTE 4 Table 8.6 in the CS CPMM 2001 [Ref 1.N] provides the procedure for undertaking this repair.

5.23 CRCPs shall be strengthened (or widespread defects treated) using one of the following methods:

1) reconstruction (partial or full);
2) overlay using concrete or asphalt.

5.24 Where reconstruction or overlay of CRCP is being assessed, consultation with the Overseeing Organisation, over the circumstances when each are to be considered, shall be undertaken.

NOTE Guidance on overlays and full depth repairs for CRCP is given in Appendix C Table C.3 and Appendix E.

6. Normative references

The following documents, in whole or in part, are normative references for this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

Ref 1.N	Concrete Society (on behalf of Highways England and Britpave). CS CPMM, 'Concrete Pavement Maintenance Manual' , 2001
Ref 2.N	Highways England. CD 127, 'Cross-sections and headrooms'
Ref 3.N	Highways England. CS 229, 'Data for pavement assessment'
Ref 4.N	Highways England. CD 226, 'Design for new pavement construction'
Ref 5.N	Highways England. CD 225, 'Design for new pavement foundations'
Ref 6.N	BSI. BS EN 13249, 'Geotextiles and geotextile-related products. Characteristics required for use in the construction of roads and other trafficked areas (excluding railways and asphalt inclusion)'
Ref 7.N	Highways England. GG 101, 'Introduction to the Design Manual for Roads and Bridges'
Ref 8.N	ADEPT. Managing Reclaimed Asphalt, 'Managing Reclaimed Asphalt – Highways & Pavements' , 2016
Ref 9.N	Highways England. MCHW, 'Manual of Contract Documents for Highway Works'
Ref 10.N	Highways England. SHW, 'Manual of Contract Documents for Highway Works, Volume 1 Specification for Highway Works'
Ref 11.N	Highways England. CS 230, 'Pavement maintenance assessment procedure'
Ref 12.N	Highways England. CM 231, 'Pavement surface repairs'
Ref 13.N	Highways England. CS 228, 'Skidding resistance'
Ref 14.N	Highways England. CD 236, 'Surface course materials for construction'
Ref 15.N	Environment Agency. RPS 075, 'The movement and use of treated asphalt waste containing coal tar'
Ref 16.N	Transport Research Laboratory. Sanders, PD, McRobbie, S, Morgan, P, Muirhead, M & Greene, M. TRL PPR 822, 'The performance of re-textured concrete pavements'
Ref 17.N	TRL. Mayhew, HC & Harding, HM. TRL RR87, 'Thickness design of concrete roads'
Ref 18.N	Highways England. CD 224, 'Traffic assessment'

7. Informative references

The following documents are informative references for this document and provide supporting information.

Ref 1.I	BSI. BS EN 13108-1, 'Bituminous mixtures – Material specifications. Asphaltic concrete.'
Ref 2.I	BSI. BS EN 13108-5, 'Bituminous mixtures. Material specifications. Stone Mastic Asphalt.'
Ref 3.I	Transport Research Laboratory. Nunn, ME, Brown, A, Weston, D & and Nicholls, JC.. TRL 250, 'Design of long-life flexible pavements for heavy traffic'
Ref 4.I	TRL. Coley, C & Carswell, I. TRL 657, 'Improved design of overlay treatments to concrete pavements. Final report on the monitoring of trials and schemes'
Ref 5.I	Transport Research Laboratory. Sanders PD, Wayman M, Dunford A, & Viner HE. TRL PPR 607, 'Long term friction performance of longitudinally diamond ground concrete'
Ref 6.I	Transport Research Laboratory. P G Roe and S A Hartshorne. TRL 299, 'Mechanical retexturing of roads: an experiment to assess durability'
Ref 7.I	Transport Research Laboratory. Goddard, RTN. TRL RR189, 'Structural investigation of roads for the design of strengthening'
Ref 8.I	Transport Research Laboratory. Sanders, PD & Brittain, S. TRL PPR 677, 'Surface treatment options for concrete roads'

Appendix A. Pavement deterioration mechanisms

A1 Introduction

Although there are many common factors, there are also some differences in the surface and structural deterioration mechanisms of pavements depending on whether they are, generally, of flexible or rigid construction.

The surfaces of all pavements eventually suffer from loss of skidding resistance. Loss of texture and rutting can also occur, particularly for surfacing materials which have relatively high binder contents. For surface courses which lose aggregate as a result of environmental deterioration (see section A2) the texture depth may not decrease, indeed it may even increase. The deterioration mechanisms of specific types of pavement, commonly found on the road network are discussed below.

A2 Flexible pavements with asphalt base

Deterioration in flexible pavements with asphalt base is generally associated with traffic loading and/or with environmental factors. Deterioration due to traffic loading is normally associated with the following mechanisms:

1) Repeated cycles of tensile strains generated within the bound layers under vehicle loading cause fatigue cracks to initiate in the asphalt. Classical pavement analysis indicated that these cracks generally initiate at the underside of the asphalt base and then propagate upwards through the material. However, the view of how this mechanism operates in practice on the thick pavements that comprise the greater part of the trunk road and motorway network has been revised following extensive observation and investigation, and is further discussed in sub-section A3.
2) Rutting due to the permanent, cumulative deformation of one or more of the various layers within the pavement structure including the foundation. Where the rutting emanates from the subgrade or pavement foundation and the entire pavement structure is deformed, this is referred to as structural deformation. Rutting that is confined to the asphalt layers is termed non-structural.

The main environmental causes of pavement deterioration are as follows:

1) The asphalt binder can harden over time with consequent effect on the fatigue resisting properties of the mixture. One of the principal mechanisms of binder hardening is oxidation of the bitumen, and this predominantly occurs at the surface of the pavement exposed to air and solar radiation. Strains at the pavement surface caused by both thermal cycling and vehicle loading can eventually lead to cracks appearing at the surface. Over time these can propagate downwards and ultimately reach the base of the bound layers. The hardening of the bitumen may also affect the cohesion of the mixture and may lead to the loss of aggregate in the surfacing (fretting or surface disintegration).
2) As bitumen is a viscoelastic material the performance of asphalt mixtures is influenced by temperature and the rate of loading. The risk of the accumulation of permanent deformation in the surfacing (non-structural rutting) is, therefore, increased during periods of hot weather and further exacerbated by slow moving and/or stationary traffic. This risk can be mitigated by the selection of appropriate, well-designed and placed materials.

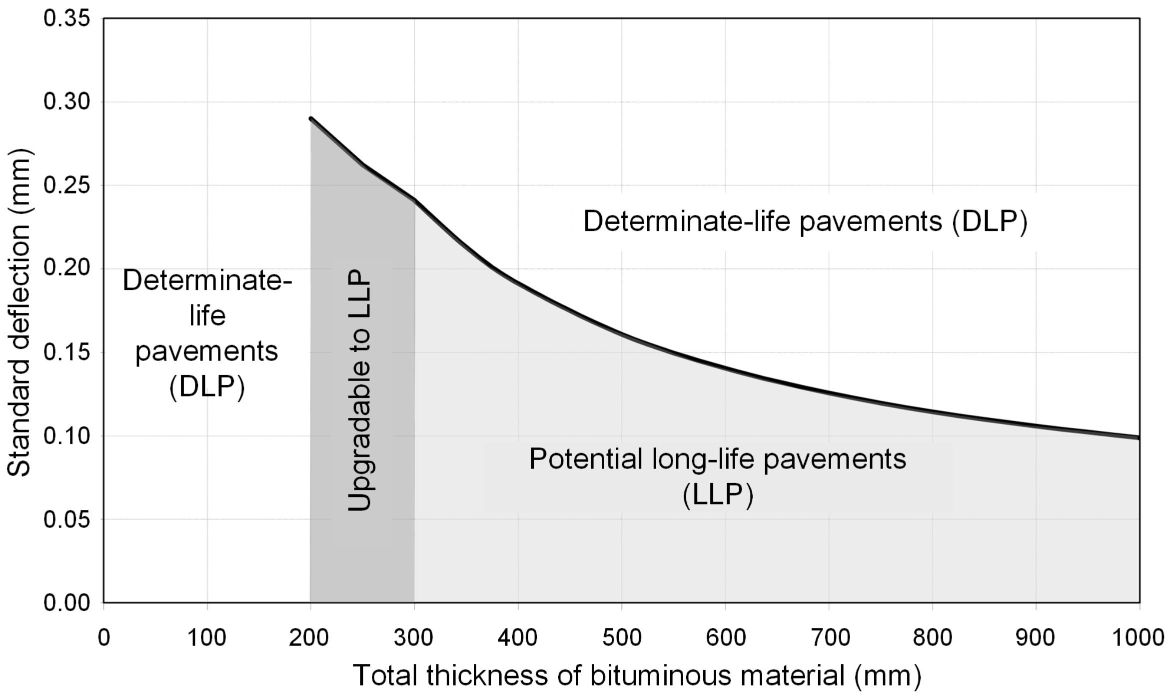
Less common environmental causes of pavement deterioration include the variation in foundation strength caused by seasonal changes in moisture levels and the action of freeze-thaw cycles, particularly on cracked pavements of thin construction.

A3 Long-life flexible pavements with asphalt base

Thick, well-constructed flexible pavements with asphalt base on strong foundations do not suffer bottom-up, fatigue cracking of the base or structural deformation TRL 250 [Ref 3.I]. Environmental factors can cause cracking to develop at the surface, which gradually increase in depth. Deformation in these pavements also tends to be limited to the surfacing layers (i.e. is non-structural). Very long pavement lives can be achieved by the removal of any cracked or severely rutted material, before the defect has progressed too deeply, and its replacement with new material.

Criteria based on measured deflection and total thickness of bituminous material may be used to identify flexible pavements with asphalt base with the potential for long life. This identification is carried out as part of deflectograph data processing. The criteria, see Figure A.1, are conservative in that pavements which plot just above the boundary curve, in the determinate-life pavements (DLP) zone, may also be either upgradeable to long-life (ULLP) or potential long-life pavements (LLP).

Figure A.1 Deflectograph-based pavement life categories



The total thickness of bituminous material (TTBM) shown in Figure A.1 is the combined thickness of all the contiguous intact asphalt layers present in the pavement, subject to the following criteria:

1) Asphalt layers within the top 100 mm of the existing pavement are included in TTBM regardless of their condition.
2) Asphalt layers which are known to be severely deteriorated and whose upper surface is at a depth greater than 100 mm are not included in TTBM.
3) Any intact asphalt (or deteriorated surfacing material) that is separated from other intact asphalt materials by either a severely deteriorated asphalt layer or any granular layer (either of which are greater than 25 mm thick and have their upper surface at a depth greater than 100 mm) is not to be included in TTBM.

Although the pavement life categorisation in Figure A.1 can be applied to individual deflections, the classification of a length of pavement as long-life should normally be based on the 85th percentile of the maximum deflection of both wheel-tracks within each 100 m length.

A4 Determinate-life flexible pavements with asphalt base

Flexible pavements with asphalt base that do not meet the 'long-life' criteria in Figure A.1 are subject to both traffic induced and environmental deterioration. These pavements are referred to as determinate life as their life to investigatory condition may be estimated using the deflectograph-based design method described in CS 229 [Ref 3.N].

A5 Flexible pavements with hydraulically bound base

These pavements consist of a lower base of hydraulically bound mixture (HBM) designed to withstand traffic induced stresses and an asphalt upper base and surfacing which insulate the HBM and contribute to load spreading. The strength and thickness of the HBM layer has a significant influence on the progression of deterioration, which is also associated with the effects of traffic and the environment as described above.

Thermal effects in this type of pavement usually give rise to primary transverse shrinkage cracks in the HBM during construction. In time, these cracks can lead to cracking in the overlying asphalt, known as reflective cracking. Generally, reflective cracking starts in the surfacing, like environmental cracking, and does not necessarily penetrate to the full depth of the asphalt layers. Reflective and environmental cracks may, if left untreated, allow the ingress of water to materials beneath the surface which may be moisture susceptible. Transverse cracks in the base which are wide enough to significantly reduce granular interlock can give rise to poor load transfer which can cause significant pavement deterioration.

The asphalt surfacing may also develop environmentally induced defects such as surface cracking and loss of aggregate due to hardening of the bitumen.

In flexible pavements with hydraulically bound base,surfacing failures occasionally occur as a result of incorrectly installed reinforcing grids or separation membranes appearing at the surface.

A6 Rigid pavements

These include the following types, which are detailed in CD 226 [Ref 4.N]:

1) unreinforced jointed concrete (URC);
2) jointed reinforced concrete (JRC);
3) continuously reinforced concrete pavement (CRCP), which may have been surfaced with an asphalt thin surface course system;
4) continuously reinforced concrete base (CRCB), which have an asphalt overlay of at least 100 mm.

The major surface-only defect in rigid pavements without asphalt surfacing, in addition to loss of skidding resistance and texture, is surface spalling. This is related to the durability of the concrete but is not normally indicative of structural deterioration of the pavement.

Structural deterioration mechanisms in rigid pavements are very different to those in flexible pavements with an asphalt base. Horizontal tensile stresses are generated by the combined effects of wheel loading and thermally induced internal and warping stresses. These stresses can, under certain conditions, lead to cracking. This is often associated with poor support of the slab caused by drainage problems or water ingress at joints.

A7 Jointed rigid pavements

The two types of jointed concrete pavement, unreinforced (URC) and reinforced (JRC), both incorporate joints which are designed to minimise the occurrence of uncontrolled, random cracking. Cracking in unreinforced pavements is a major problem as there is no reinforcement to hold the material together. Reinforced pavements can tolerate small amounts of transverse cracking provided that good load transfer is maintained.

Structural defects manifest themselves mainly in the form of various types of cracking. Settlement or failure of joints to operate properly may also occur, problems which, if not remedied, can lead to the development of cracks and subsequent failure.

Where expansion joints have lost their capacity to absorb movement 'blow ups' may occur in hot weather. Two consecutive slabs rise up in an inverted 'V' as a result of debris filling the expansion gaps or dowels becoming locked.

A8 Continuously reinforced rigid pavements

CRCP and pavements with CRCB effectively contain continuous longitudinal reinforcement with no intermediate expansion or contraction joints. Internal thermally-induced stresses within the concrete slab are relieved by transverse cracks which normally occur at 1-2 m spacings and are held tightly closed by the reinforcement. The central portion of a long slab of CRCP does not move when subjected to changes in temperature; longitudinal movement takes place only at the ends. This end-movement can be partly restrained by ground beams in a ground beam anchorage or accommodated by a special joint.

One form of defect that can occur in CRCP is punchouts. These can occur when closely spaced transverse cracks are connected by parallel longitudinal cracks causing small blocks of concrete to become loose and eventually detach from the pavement under repeated traffic load applications.

Where the concrete has asphalt surfacing this may also develop the environmental defects of surface cracking and loss of aggregate due to hardening of the bitumen, see Section A5.

Appendix B. Retexturing techniques

B1 Retexturing of asphalt surfacings

The wet skidding resistance of asphalt surfacings is generated primarily by the microtexture of the aggregate in the surface. This microtexture is gradually polished by traffic until an equilibrium level is reached. CD 236 [Ref 14.N] provides advice on the choice of aggregate and CS 228 [Ref 13.N] on the standards for the skidding resistance of in-service roads.

The ability of a surface to maintain adequate skidding resistance at high speeds is governed by the macrotexture of the surfacing. As a surfacing ages, the macrotexture may fall as chippings are embedded into the asphalt matrix or substrate or excess binder comes to the surface. In some circumstances, for example overrolling, the chippings in a new surfacing may be embedded too far and the requirements for texture depth of a new road may not be met.

Retexturing is the mechanical reworking of a sound road surface to restore either skidding resistance, texture depth or both.

The most appropriate technique to be employed in any given situation depends upon the nature of the existing surface and the fault or faults to be remedied. It should be noted that all retexturing treatments are different and that technique selection should always be made on a site specific basis.

B1.1 Retexturing techniques

The suitability and effectiveness of a retexturing treatment depends on the condition of the road prior to treatment. Some treatments can increase both skidding resistance and texture depth; others may increase skidding resistance but reduce texture depth. There are also treatments which increase texture depth with little effect on skidding resistance.

Advantages of retexturing techniques include:

1) conservation of natural resources by reworking an existing surface;
2) retexturing may be more economical than some traditional resurfacing methods, especially where small areas are to be treated;
3) most processes can be carried out at any time of year in all but the most severe weather conditions;
4) traffic disruption is reduced compared with conventional treatments because of short lead-in times and the speed of the processes;
5) can be used as a 'stop-gap' measure to treat small, high-risk sites;
6) reduced carbon footprint and minimal waste.

Disadvantages include:

1) retexturing should not be used on unsound roads where there is cracking or surface irregularities, or on roads with sealing or overbanding;
2) some processes cannot treat roads with severe transverse deformation, such as heavily rutted surfaces;
3) road surfacing features such as ironwork, white lining and traffic detection loops may have to be avoided or protected.

On an asphalt road surface, the durability of the results of a treatment can be influenced by the type and geometry of road, the quantity and behaviour of the traffic, polishing stresses on the aggregate and the rate of spread of chippings, where used, in the surfacing. However, just as a new surfacing can polish under the action of traffic, the aggregate on a retextured surface can eventually polish back to an equilibrium skidding resistance level, close to that of the original surfacing. Further information on retexturing of asphalt surfaces is given in TRL 299 [Ref 6.I].

The following paragraphs give some comments on available methods and suggestions on their application for restoring skidding resistance and/or surface texture depth. Table B.1 gives a summary of these methods and suggestions.

Table B.1 Appropriate circumstances and treatments for retexturing asphalt surfacings

Surface type	Original condition: effect required from treatment		Suitability of treatment processes: Bush hammering	Shot blasting	Grooving / grinding	Longitudinal scabbing	Fine milling	Hydro-retexturing
Chipped rolled asphalt	Polished aggregate: recovery of skidding resistance	good[1] texture	Yes	Yes	Yes	Yes	Yes	O
		poor[1] texture	Yes	Yes	Yes	X	Yes	O
	Embedded chippings: recovery of texture depth	good[2] SR	O	Yes	O	X	Yes	Yes
		poor[2] SR	O	Yes	O	X	Yes	Yes
	Excessive noise/ excessive texture	good SR	Yes	X	O	Yes	X	X
Surface dressing	Polished aggregate: recovery of skidding resistance	good texture	Yes	Yes	X	O	O	X
		poor texture	Yes	Yes	X	X	O	X
	Fatted-up: recovery of texture depth	good SR		X	X	X	O	Yes
		poor SR	X	X	X	X	O	Yes
Thin surfacings	Polished aggregate: recovery of skidding resistance	good texture	Yes	Yes	Yes	Yes	O	X
		poor texture	Yes	Yes	Yes	X	O	X
	Removal of binder film	good SR	O	O	X	X	Yes	O
Asphalt concretes	Polished aggregate: recovery of skidding resistance	good texture	Yes	Yes	O	Yes	Yes	X
		poor texture	Yes	Yes	O	X	Yes	X
	Removal of binder film	good SR	O	O	X	Yes	Yes	Yes

Key: SR - skidding resistance
Yes - appropriate treatment
X - not recommended
O - treatment may be appropriate in some circumstances but effects can be limited and depend on surfacing condition

Table B.1 Appropriate circumstances and treatments for retexturing asphalt surfacings (continued)

Notes: 1) When referring to texture in this context. 'good' and 'poor' are approximately the following respectively: SMTD > 1.2 mm (good); SMTD <0.6 mm (poor), where SMTD = sensor measured texture depth. 2) When referring to skidding resistance, 'good' and 'poor' denote above or below investigatory level respectively.

B1.2 Impact methods

Processes in this category involve striking the road surface with either hard-tipped tools or hard particles. These treatments are effective where the loss of skidding resistance is due to polishing and affect mainly the aggregate particles and the weathered asphalt matrix.

1) Shot blasting: The impact is by steel shot projected at high speed from a rotating wheel. As the surface is scoured, both shot and arisings are recovered and separated, with the steel shot stored for reuse. This process improves both skidding resistance and surface texture depth of chipped rolled asphalt surfacings by removing the weathered asphalt matrix and leaving the chippings (with renewed faces) exposed. There is a risk of chippings that are not properly embedded, such as in surface dressing, becoming loosened by this process, as the supporting matrix is removed.
2) Fine milling: Fine milling (following surface profile) involves the creation of longitudinal grooves using tungsten tipped cutting tools set at 6 mm spacing. The process removes the top 2-6 mm of the road to achieve a new running surface. This can also be used to provide a key for an overlay treatment. This process improves microtexture and macrotexture, thereby improving skid resistance and increasing texture depth.
3) Bush hammering: The road surface is struck by a number of impact heads with chisel-ended hammers with hardened tips. This process enhances skidding resistance, but can sometimes reduce texture depth, depending on the condition of the existing road surface and the severity of the treatment.

B1.3 Cutting and scabbling/flailing

This category includes cutting, sawing, grooving, grinding and scabbling/flail grooving. In the latter case, the cutting action is combined with impact on the cutting heads.

1) Grooving/grinding: Using diamond-tipped blades assembled in configurations to suit the patterns of cutting required. This process can be used to provide either discrete grooving patterns or for bump cutting. The treatment affects macro-texture and can reduce texture if the blades are in a close-spaced configuration. Microtexture is often unaffected because the plateaux between grooves are the original surface.
2) Longitudinal scabbling: Hardened tips set into the edges of steel washers are loosely mounted side-by-side and drawn across the road surface whilst being hydraulically loaded. This process enhances skidding resistance, by removing material from the tops of particles to expose new aggregate faces, but it reduces surface texture depth by the same process.

B1.4 Fluid action

This involves the surface being subjected to the action of a fluid at high temperature or pressure. These treatments are not mechanical reworking of the road surface to expose new aggregate surfaces, and as a result do not restore skidding resistance lost through the polishing action of traffic.

B2 Retexturing of concrete surfacings

The wet skidding resistance of a road is dependent on the tyre interacting with the microtexture of the road surfacing. On concrete surfacings, microtexture comes primarily from the sand and fine aggregate in the concrete surface layer. Microtexture is gradually polished by traffic until an equilibrium level of skidding resistance is reached. The laitance containing the fine aggregate may be worn away to expose the coarse aggregate which may be unable to maintain adequate microtexture. CS 228 [Ref 13.N] provides advice on standards for the skidding resistance of in-service roads. Microtexture is essential to maintain an adequate skid resistance level at all speeds. The ability of a surface to maintain adequate skidding resistance at high speeds is also governed by the macrotexture of the surfacing. As a surfacing ages, the level of macrotexture may fall as the ridges created by brushing, are worn away.

Retexturing is the mechanical reworking (except water jetting) of a sound road surface to restore either skidding resistance, texture depth or both. The surface levels of an area which has been retextured should remain the same as the surrounding surface. The suitability and effectiveness of a retexturing treatment depends on the condition of the road prior to treatment.

Most processes can be carried out at any time of year in all but the most severe weather conditions. Retexturing can be used as an interim measure to treat high-risk sites and most processes are repeatable. Retexturing is most effective on a concrete road surface that is generally sound but caution is needed with some treatments where there are joints within the concrete surface. In some circumstances reinstatement of the joints may also be required. Further advice should be sought from the contractor as to limitations concerning a particular process.

Improved skidding resistance can be achieved by roughening the worn surface by the use of various retexturing techniques summarised in Table B.2. The durability of an increase in skid resistance level and texture depth can depend on the type and geometry of road, the quantity and behaviour of the traffic and the raw materials which make up the surface, in particular the aggregate. The durability of macrotexture and microtexture improvements may also differ.

Some retexturing treatments can be accompanied by an increase in the volume or a change in the characteristic of traffic/tyre noise, the nature of which can depend on the type of treatment that is adopted.

Table B.2 Overview of retexturing techniques for concrete surfacings

Technique	Maintenance	Application	
Flailing transverse	Restoration of macro texture (for high speed skid resistance) on suitable intact structures, with suitability dependent on characteristics of coarse aggregate and concrete.	Suitability assessed on site specific basis.	Improves microtexture and macrotexture, but there is potential for a change in traffic tyre noise.
Fine milling (shallow)			
Bush hammering			
Shot blasting			
Fine milling (deep)			
Grinding with longitudinal grooving (following surface profile)			
Water jetting			Removes aggregate surface polish and contaminants to expose existing microtexture.

B2.1 Transverse grooving

Transverse grooving in accordance with the 1000 series of MCHW [Ref 9.N] involves creating a macrotexture on concrete surfaces by sawing grooves typically between 2 and 5 mm wide, using diamond or abrasive cutting discs.

The sawed grooves are cut at right angles to the direction of traffic; restoring macrotexture, providing improved high speed skid resistance and improving drainage pathways for surface water. This technique also has the potential to increase tyre/road noise.

Transverse grooving is not required to be a continuous process and areas where other defects may be created should be avoided. An example of this is stopping short (typically 300 mm) of white lines demarking lanes and also joints. The risk of continuing grooving up to joints is that the angles may slightly differ, resulting in the creation of tapering 'wedges' which can be susceptible to deterioration under trafficking.

B2.2 Flailing transverse

Flailing-transverse improves macrotexture and removes polish from aggregates by mechanical impact on the concrete road surface. The technique involves hardened tips set into the edges of steel washers loosely mounted side-by-side and drawn across the road surface while being hydraulically loaded. Surface texture depth can be reduced as the material from tops of the particles is removed.

B2.3 Bush hammering

During bush hammering the concrete surface is struck by a number of impact heads with chisel-ended hammers with hardened tips. This technique improves macrotexture and microtexture of the road surface.

B2.4 Shot blasting

Steel shot blasting is an abrasive system that impacts the surface of the pavement with high velocity steel particles.

This technique improves macrotexture and microtexture of the road surface and equipment is available which is suitable for treating both large and small areas.

B2.5 Grinding with longitudinal grooving (following surface profile)

Grinding with longitudinal grooving (following surface profile) involves the creation of longitudinal grooves using diamond tipped saw blades. The closely spaced saw blades cut longitudinal grooves at a predetermined width and depth and this process follows the profile of the surface. The surface levels of the treatment area remain the same as the surrounding surface and the treatment is repeatable. This technique improves microtexture and macrotexture, thereby improving skid resistance and increasing texture depth, and has the potential to reduce tyre/road noise. The treatment causes no damage to joints and road markings, road studs and ironwork do not have to be removed prior to treatment.

B2.6 Water jetting

This process involves the controlled jetting of water through a series of nozzles at high or ultra high pressure onto the road surface. This treatment does not involve a mechanical reworking of the surface to expose new aggregate surfaces and, as a result, does not restore skidding resistance lost through the polishing action of the traffic. This technique thoroughly cleans the surface and removes surface contaminants and rubber deposits to expose the existing microtexture.

B2.7 Fine milling (shallow)

Fine milling can be used to provide an enhanced texture depth only if the planer is set to scarify the surface to a nominal depth of 1mm. This can also be used to provide a key for an overlay treatment.

B2.8 Surface reprofiling

Restoration of macrotexture and potential to reduce tyre/road noise can be achieved by surface reprofiling of concrete surfaces. Where these techniques are used, the thickness of the concrete surface layer can be reduced. Therefore, surface reprofiling is only suitable for concrete pavements which exhibit a generally good structural condition.

Assessment is required prior to maintenance design to check both cover to reinforcement and structural capacity.

With surface reprofiling, it is important that concrete bays remain largely intact, that joint performance is good and that support from the foundation is suitable to prevent significant differential movement under or between slabs

The mechanical hardness of the aggregate used in the concrete mix can affect the speed at which the reprofiling process can progress; for example a flint gravel has a greater resistance to diamond cutting than limestone, and may require slower movement with a greater load applied to the cutting drum. Fine milling (deep) and grinding with longitudinal grooving are two techniques for surface re-profiling. Significant reduction in concrete thickness from deeper or multiple treatments can give rise to a structural failure. CD 226 [Ref 4.N] should be used to assess any reduction in capacity after treatment.

B2.8.1 Fine milling (deep)

Fine milling can also be used to provide an improved ride quality by increasing the depth of scarification above 1 mm.

Texture measurements undertaken following fine milling are typical of that required for a trafficked asphalt pavement surface. The mechanical hardness of the aggregate used in the concrete mix can affect the speed at which the fine milling process can progress; a harder stone having a greater resistance may require slower movement with a greater load applied to the milling drum.

Fine milling of concrete surfaces produces a milled surface which provides an improved level as surface irregularities are generally removed by the process hence resulting in an improvement of ride quality but it has been found to increase road/tyre noise. The process results in a significantly roughened surface.

B2.8.2 Grinding with longitudinal grooving

Grinding with longitudinal grooving involves the removal of a thin layer of concrete using diamond tipped saw blades. A level surface is achieved by running an assembly of closely spaced blades across the pavement surface. This produces saw cut grooves which provide a relatively constant level as any stepped joints or surface irregularities are removed by the process hence resulting in a significant improvement of ride quality and tyre/road noise reduction. The cutting process exposes a clean, un-polished aggregate face which helps to restore texture and enhance skid-resistance characteristics.

Grinding with longitudinal grooving can be used also following removal of thin overlay, subject to analysis of geometry tolerances.

The long term performance of diamond ground concrete surfaces is further detailed in TRL reports TRL PPR 607 [Ref 5.I], TRL PPR 677 [Ref 8.I] and TRL PPR 822 [Ref 16.N].

B2.9 Summary of surface treatment options for concrete surfaces

The expected service life in Table B.3 is defined as the period over which the intended performance for the treatment is likely to be achieved. The expected service lives quoted in Table B.3 are for over 50 msa designs. Where the traffic is lower than 50 msa, then the service life for each surface treatment is likely to be higher than the quoted upper limit. For most retexturing treatments the service life refers to the period of elevated skid resistance as measured by sideway-force coefficient routine investigation machines and/or the pavement friction tester (PFT).

Table B.3 Surface treatment for concrete surfaces

Surface treatment		Range of expected service life	Installation issues	Road surface benefits & issues
Transverse grooving in accordance with Clause 1029 of MCHW		20-40 years	Very slow process to install.	Produces a very noisy surface.
Retexturing	Flailing	2-3 years	These processes can be noisy during installation requiring vacuum sweepers. Considerations required to mitigate exposure to local residents.	The resultant surface is likely to be slightly more noisy than before treatment.
	Bush hammering	2-3 years		Little change in surface noise from pre-treatment levels.
	Fine milling (shallow)	4-5 years		Little change in surface noise from pre-treatment levels.
	Shot blasting	2-3 years	Dust production can be significant and should therefore be controlled.	Little change in surface noise from pre-treatment levels.
	Water jetting	< 3 months	Possible contaminants in run off from process.	Achieves little more than removal of surface contaminants.
Surface re-profiling	Fine milling (deep)	Insufficient experience in UK	The process is noisy. Considerations required to mitigate exposure to local residents.	The resultant surface may be noisier than before and can exhibit a noticeable change in noise tone.
	Grinding with longitudinal grooving	4-6 years	The process is noisy. Considerations required to mitigate exposure to local residents. Arisings need to be disposed of in the proper manner or recycled.	A very low noise surface is produced which has a smooth ride quality, eliminating stepping at joints and slab distortions.

Appendix C. Defects in rigid pavements

Table C.1 Surface defects in jointed rigid pavements (including possible causes and suggested maintenance options)

Surface defects				
No.	**Type of visual defect**	**Possible cause/s**	**Maintenance options and relevant MCHW [Ref 9.N] series**	**CS CPMM 2001 [Ref 1.N]pages**
1.1	Defective joint seals	Adhesion/cohesion failure, age of sealant.	Reseal joints. Series 1000 (ST).	Page 22
1.2	Surface irregularities (poor surface profile)	Bumps and/or depressions. For pop-outs, punchouts and stepping see 1.4, 2.7, 2.8 below.	Remove high areas by bump cutting (and retexture if necessary) ensuring that adequate cover is maintained above reinforcement. Series 1000 (ST). Regulate low areas using thin-bonded surface repairs. Series 1000 (ST).	Page 29
1.3	Surface scaling	Frost attack on concrete that was too workable, had inadequate cement content or entrained air. Vehicle fire or acid attack from spillage.	Retexture surfacing ensuring that adequate cover is maintained above reinforcement (ST). For small areas (typically $\leq$ 1 m^2) thin-bonded repair. Series 1000 (ST). In severe cases replace the slab. Series 1000 (DT).	Pages 30, 76 (8.3)
1.4	Pop-outs (isolated loss of a small area of surface material)	An aggregate particle expands and fractures as a result of a physical action or a chemical reaction.	Carry out thin-bonded repair Series 1000 (ST). Plug single particle pop-outs with resin mortar. Series 1000 (ST).	Page 32
1.5	Shallow joint spall (spall extends < 50 mm from joint and depth is < one third of slab depth). (depth of spall can be established by coring through the joint).	Weaker concrete, trafficking, failed repair, ingress of material into joint groove, etc.	Widen joint sealant groove (maximum width 40 mm) - recut & seal joint. Series 1000 (ST). Thin-bonded repair Series 1000 (ST).	Pages 23, 24

Table C.1 Surface defects in jointed rigid pavements (including possible causes and suggested maintenance options) (continued)

Notes:
1) Defects are listed in increasing order of seriousness.
2) When the pavement is approaching the end of its life or needs strengthening, fractured slab techniques and overlays are available. See Appendix E.
3) ST = surface only treatment. See Section 4.
4) DT = deeper treatment. See Section 5.

Table C.2 Structural defects in jointed rigid pavements (including possible causes and suggested maintenance options)

Structural defects				
No.	**Type of visual defect**	**Possible cause/s**	**Maintenance options and relevant MCHW [Ref 9.N] series**	**CS CPMM 2001 [Ref 1.N]pages**
2.1	Corner crack(s) (0.3 - 2 m long)	Poor slab support and/or load transfer, dowel bar issues. Often starts as a single crack, but can quickly develop to form multiple corner cracks or further cracks across corner segment. If larger than 2 m, consider as a diagonal crack. If less than 0.3 m, consider as a shallow/deep joint spall. Acute angles in non-rectangular slabs.	No immediate treatment if crack is < 0.5 mm wide. Full-depth joint repair. Series 1000 (DT).	Page 36
2.2	Cracks around gully or utility cover	Discontinuity and associated stresses caused by gully/utility cover within a slab, particularly at corners of slab adjacent to gully/utility cover.	No immediate treatment if slab is reinforced and crack < 0.5 mm wide. Relocate gully/utility cover in verge and replace full or partial slab. Series 1000 (DT).	Page 37
2.3	Diagonal cracks (excluding corner cracks or cracks associated with gully/utility cover) (condition can be investigated by coring the crack and an FWD survey to evaluate the performance of the cracks)	Differential settlement.	No treatment initially, but monitor crack (e.g. reinforced concrete single crack < 0.5 mm wide). For wider crack, form groove and seal. Series 1000 (ST). Full-depth repair. Series 1000(DT). Replace slab (this will depend upon the severity of the defect). Series 1000 (DT).	Page 35

Table C.2 Structural defects in jointed rigid pavements (including possible causes and suggested maintenance options) (continued)

2.4	Transverse cracks (condition can be investigated using an FWD survey to evaluate the performance of the cracks)	At construction: excessive slab length, late sawing of joint grooves, displaced bottom joint former or inadequate reinforcement lap. Post construction: poor or variable support (foundation), poor load transfer to adjacent slab or joint lock-up (crack is usually near the transverse joint).	No treatment for cracks <0.5 mm wide. Monitor. Epoxy treatment (crack width 0.5 to 1.5 mm). Series 1000 (DT). Full-depth repair for unreinforced slabs or reinforced slabs with corroded steel (crack width >1.5 mm). Series 1000 (DT). Replace slab (crack width > 1.5 mm or multiple longitudinal & transverse cracks). Series 1000 (DT).	Pages 33, 26
2.5	Longitudinal cracks (condition can be investigated by coring the crack and an FWD survey to evaluate the performance of the cracks)	Constructed with excessive slab width, differential support across slab (e.g. by water penetration to foundation), misaligned or locked-up dowel bar(s) or induced by the cumulative effects of traffic.	Monitor (if reinforced and crack <0.5 mm wide). Full-depth repair for unreinforced slabs or reinforced slabs with evidence of corroded steel (crack width >1.5 mm). Series 1000 (DT). Replace slab (crack width > 1.5 mm or multiple longitudinal & transverse cracks). Series 1000 (DT).	Page 34
2.6	Deep joint spall (where spall extends more than 50 mm from edge and more than one-third of slab depth) (condition can be investigated by coring the spall and an FWD survey to evaluate the performance of the joints)	Weakened foundation at joint, dowel bar issues, weaker concrete, trafficking (more prevalent in wheelpaths), failed repair, etc.	Full-depth joint or slab end repair (full width). Series 1000 (DT).	Pages 25, 26
2.7	Punchouts	Localised defect in reinforced concrete where multiple cracks have joined up. The fragments of concrete generally appear to have been 'punched' downwards.	Full-depth repair. Series 1000 (DT).	Page 40

Table C.2 Structural defects in jointed rigid pavements (including possible causes and suggested maintenance options) (continued)

2.8	Slab rocking / Slab settlement / Joint Stepping (where step > 3 mm between adjacent slabs) (condition can be investigated by coring the joint to examine dowels & tie bars [after locating with GPR, metal detector, etc], DCP to examine foundation and an FWD survey to evaluate the performance of the joints)	Reduced sub-base support (often due to water penetration) and/or corroded tie bars/dowel bars. Rocking (i.e. visible vertical movement of slab edge) may be observed particularly when trafficked by heavy vehicles. Rocking is often identified from mud pumping stains from a joint.	Inject grout under slabs / slab lifting. Series 1000 (DT). Remove high areas by bump cutting and retexture if necessary, ensuring that adequate cover is maintained above reinforcement (ST). Improve under slab drainage where necessary prior to pavement maintenance being undertaken. Series 500 (DT). Full-depth slab end repair Series 1000 (DT). Replace slab (and sub-base if required) as appropriate. Series 1000 (DT). Retrofit additional tie bars to adjacent lanes if required. Series 1000 (DT).	Pages 27, 38
2.9	Compression failures (known as 'blow ups'). These usually occur in jointed pavements during periods of prolonged hot weather. (condition can be investigated by an FWD survey to evaluate the performance of the joints)	Substantial build-up of detritus in joint grooves as a result of poor joint sealing and/or inadequate number of expansion joints formed during construction. This failure is more likely in jointed pavements greater than 8 years old with evidence of poor sealant condition/ build up of detritus in joint grooves/ a significant number of temporary joint repairs or sealing grooves that cannot be sealed properly and/or at least two consecutive locked-up joints.	Repair or replace 'blown up' slabs (or slab ends) to full-depth. Series 1000 (DT). To prevent future blow-ups, install new dowelled expansion joints in all lanes at 2 50 m centres over the relevant lengths. Series 1000 (DT).	Page 39

Table C.2 Structural defects in jointed rigid pavements (including possible causes and suggested maintenance options) (continued)

Notes:
1) Defects are listed in increasing order of seriousness.
2) When the pavement is approaching the end of its life or needs strengthening, fractured slab techniques and overlays are available. See Appendix E.
3) ST = surface only treatment. See Section 4.
4) DT = deeper treatment. See Section 5.

Table C.3 Defects in CRCP (including possible causes and suggested maintenance options)

Defects				
No.	**Type of visual defect**	**Possible cause**	**Maintenance options and relevant MCHW [Ref 9.N] series**	**CS CPMM 2001 [Ref 1.N] pages**
3.1	Normal (transverse) cracks ('Normal' cracks in CRCPs are exclusively transverse with no spalling or bifurcations, are $\leq$ 1 mm in width and are spaced at least 1 m apart)	It is normal for fine transverse thermal contraction/shrinkage cracks to develop every 1-4 m soon after construction. Over the next 4 years or so, further transverse cracks slowly develop between the wider spaced cracks, resulting in a typical crack spacing of 1-2 m. These cracks are an inherent feature of continuously reinforced concrete.	No treatment	Pages 46, 84
3.2	Crazing	The presence of any crazing (referred to as 'map cracking' in the CPMM) should be noted, particularly any containing white or cream powdery material that streaks over the surface after heavy rain as such a deposit may indicate an alkali-silica reaction.	Seek guidance from the overseeing organisation.	Page 46
3.3	Spalled cracks (depth of spall may be established by coring through the crack)	Weakened foundation at crack, weaker concrete, trafficking (more prevalent in wheelpaths), failed repair.	Shallow spall - Thin-bonded repair Series 1000 (ST). Monitor and record locations of spalling for future reference. Deep spall - Full-depth repair (one lane at a time to minimise stress in the pavement) Series 1000 (DT).	Pages 25,26, 8 4-87
3.4	Punchouts	Localised defect in reinforced concrete where multiple cracks have joined up. The fragments of concrete generally appear to have been 'punched' downwards.	Full-depth repair Series 1000 (DT).	Pages 40, 87

Table C.3 Defects in CRCP (including possible causes and suggested maintenance options) (continued)

3.5	Significant transverse cracks (Significant transverse cracks in CRCPs include any of the following: 1) spacings of less than 1 m; 2) >1 mm wide; 3) bifurcated; 4) polygonal.)	These can be caused by a design fault, a construction fault, poor quality concrete or a lack of foundation support. For cracks $\leq$ 1.5 mm wide, the reinforcement may not have yielded completely. If left untreated, water ingress can lead to corrosion and spalling. At wider cracks, the reinforcement has almost certainly yielded. In effect the cracks are likely to be acting as either undowelled or untied joints.	Isolated cracks ($\leq$ 1.5 mm wide) may be sealed. Series 700 (ST).Wide cracks (> 1.5 mm), or where significant defects are widespread, full depth repair. Series 100 0 (DT).	Pages 77, 84-87
3.6	Longitudinal cracks	Longitudinal cracks are not expected. Possible causes include shallow cover to reinforcement, slab design is too thin and/or poor foundation support. Longitudinal cracks may well deteriorate and develop further unless remedial action is taken. Where longitudinal and transverse cracks cross there is a risk of spalling particularly if they cross obliquely. When sealing cracks, a sawn groove is preferred because it is much more regular and can be made narrower.	Seal isolated cracks > 0.5 mm. Series 700 (ST). Full-depth repair depending on severity. Series 1000 (DT).	Pages 87 CPMM

Notes:
1) Defects are listed in increasing order of seriousness.
2) Isolated significant cracks may be treated using surface treatments (crack sealing and thin bonded repairs). See Section 3 for definition of significant defects in CRCP.
3) Where significant defects are widespread i.e. the number of significant defects reaches 10 per carriageway km or the number of punchouts reaches 4 per carriageway km, the pavement should be strengthened using a full depth repair.
3) ST = surface only treatment. See Section 4.
4) DT = deeper treatment. See Section 5.

Appendix D. Strengthening treatments for flexible pavements

D1 Overlay

Several options for the design of strengthening by overlay exist for flexible pavements.

D1.1 Deflectograph

A first indication of the range of thicknesses of material required along the site can be obtained from the analysis of deflectograph data. The 85th percentile deflection applicable to each 100 m length should be used for this purpose, see CS 229 [Ref 3.N].

For flexible pavements with an asphalt base and with a TTBM of 200-299 mm, overlays may also comprise the additional thickness of material required to upgrade a determinate life pavement (with low deflections) into a long-life pavement. More details are given in Appendix A of this document.

D1.2 Comparison with new design

Another approach to overlay design is to compare the thickness of the existing pavement structure with that required for new construction designed to carry both past and future traffic in accordance with CD 226 [Ref 4.N]; the difference in thickness is an estimate of the necessary overlay. Allowance can be made for any deterioration or initial deficiencies, as well as the varying materials in the existing pavement.

D1.3 Analytical design

A third method is to use an analytical design approach to calculate the stresses and strains at key points within the pavement structure and to use strain/fatigue relationships to determine the required overlay. This approach normally uses stiffnesses calculated from FWD back-analysis. There are many different methods of analysing FWD measurements and there is currently no standard approach for estimating overlay thickness (or residual life) using FWD results. Analytical processes, and in particular the high sensitivities of the fatigue relationships used in this process can produce very different results for the same data, depending on the method used and assumptions made.

D1.4 General

Overlay design should not be based on deflection results alone. The analysis of deflection data is a starting point, not an end point as analysis does not take into account all factors relating to pavement performance. There should be confirmatory evidence of surface defects and material condition.

Where the existing surfacing shows signs of surface deterioration, which is usually the case, it is generally advisable to plane the surface to a depth of 15 to 20 mm before overlaying, particularly where the overlay is less than 100 mm. This is to remove material with hardened bitumen and provide a sound, uncracked surface to which the new asphalt can firmly bond. Where the existing surfacing is cracked or damaged to a depth greater than 20 mm, the defective material should be removed and replaced with new material before the overlay is applied. This is to prevent these defects affecting the performance of the pavement. Damaged or sub-standard asphalt layers lower in the pavement may be left in place depending on the degree of damage and the depth relative to the new surface.

For flexible pavements, overlay design thicknesses are based on the use of traditional dense bitumen macadam (DBM125) material. This type of asphalt is now designated "AC 20 dense bin 100/150 rec" or "AC 32 dense base 100/150 rec" as defined in BS EN 13108-1 [Ref 1.I] If stiffer asphalt materials are used, such as EME2, then some reduction in overlay thickness is possible, except in the case of flexible pavements with hydraulically bound base. An assessment of the potential reduction in thickness can be gained from a comparison of the recommendations given in CD 226 [Ref 4.N] for the design of new roads.

Where some of the lanes of a carriageway have substantial remaining life and do not require strengthening, the consequences of overlaying these lanes needs to be considered. For this reason, as well as the many other consequences of increasing pavement height, inlays are often used for strengthening flexible pavements.

D1.5 Concrete overlays as a renewal treatment

Concrete overlays have not been widely used in the UK. However, a thick concrete overlay or inlay can provide improved strength, longer life and improved surface characteristics and can benefit from a good foundation provided by the existing pavement.

Concrete overlays may be designed using the rigid pavement design chart in CD 226 [Ref 4.N]. The surface modulus (SM) of the pavement to be overlaid is used in place of the foundation class shown on the chart. The SM is measured using the FWD as described in CS 229 [Ref 3.N]. A representative value for the SM is obtained for each section of road being considered for treatment, with values being taken from both across and along the carriageway. Generally, the 15th percentile modulus value (i.e. the value exceeded by 85% of the sample values) should be used for each treatment length.

Thick concrete overlays can be considered for flexible pavements that would otherwise require reconstruction. The existing pavement and foundation are retained to form part of the foundation of the new road structure.

D2 Inlays

When designing strengthening inlays on flexible pavements, the depth of inlay and choice of material used depends on the condition and thickness of all of the existing pavement layers.

Where strengthening by inlay, it is recommended to remove only those layers which are defective and to retain as much of the sound existing material as possible. This not only saves materials and time, but also provides a firm base for the new layers. Retained layers should be left undisturbed. However, the dual constraints of finished pavement level and design thickness may require the removal of some sound material. The amount of sound material removed may be minimised by using stiffer replacement materials such as EME2 where technically viable.

Where total bound layer thickness permits, pavements may be upgraded to long-life by use of deep inlays comprising an asphalt thickness equivalent to 300 mm of "AC 20 dense bin 100/150 rec" or "AC 32 dense base 100/150 rec" as defined in BS EN 13108-5 [Ref 2.I].

Where tar-bound materials are encountered it is desirable to leave these in situ, even if they are not in very good condition, to avoid the complications of the proper disposal of this material. Further guidance on dealing with tar-bound materials is given in Managing Reclaimed Asphalt – Highways & Pavements (ADEPT, 2016) Managing Reclaimed Asphalt 2016 [Ref 8.N].

D3 Reconstruction

Where the inlay thickness required to convert a flexible pavement with an asphalt base into a long-life pavement corresponds to removal of all of the bound layers (partial reconstruction), the design should be carried out using the appropriate standard (chart-based) approach in CD 226 [Ref 4.N]. It may be prudent to retain a thin layer of asphalt to protect the subbase and/or to enhance the foundation. In such cases the remaining material should be classed as part of the foundation. The resulting composite foundation class should be established in a manner consistent with the MCHW SHW [Ref 10.N].

Where the subbase is considered satisfactory and the stiffness modulus provided by the foundation as a whole is adequate, there is no need to excavate, even if the subgrade itself is of low CBR. This is because the provision of capping in the construction of new roads is primarily to enable the subbase and upper layers to be adequately laid and compacted, and to ensure that no damage to the subgrade occurs as a result of construction phase trafficking.

When there are defects in the subbase (e.g. low CBR, contamination, etc) and there is low stiffness then the subbase may need to be replaced (full reconstruction). The reconstruction required should be designed wholly in accordance with CD 225 [Ref 5.N] and CD 226 [Ref 4.N]. Where the subgrade cannot provide a satisfactory platform for reconstruction then capping may also be required.

D4 Additional guidance for flexible pavements with a hydraulically bound base

It should be noted that flexible pavements with hydraulically bound bases which have thick (circa 300mm) asphalt cover generally behave more like a flexible pavement with an asphalt base. This is also true of some cracked, seated and overlaid pavements. This should be taken into account both when analysing deflection data and when considering strengthening options.

Implications for strengthening of flexible pavements with hydraulically bound bases are given in the categorisation described in Table 3.36.2 of this document and in Figure 5.3 of TRL 657 [Ref 4.I]. Pavements in Class A require no action except where it is desirable to increase the original design life of the road.

Flexible pavements with hydraulically bound bases in Classes B and C of Table 3.36.2 generally require an overlay, but are also likely to need local reconstruction at severe cracks in the HBM. The treatment selection chart in TRL 657 [Ref 4.I] may be used to decide the appropriate treatment. For flexible pavements with hydraulically bound bases, an asphalt overlay provides additional thermal insulation to the HBM layer, as well as preventing ingress of water to the HBM layer and the foundation.

In the case of inlays to flexible pavements with a hydraulically bound base, the structure may be converted to a long-life pavement by using a thickness of new asphalt inlay that provides an overall pavement structure that is consistent with an 80 msa life according to the standard (chart-based) approach in CD 226 [Ref 4.N]. It may be necessary to treat cracks in the HBM base prior to laying the asphalt to reduce the risk of reflection cracking. Alternatively, crack and seat may be used.

Where the HBM base is severely deteriorated (Class D of Table 3.36.2), reconstruction may be necessary. However where possible, consideration should be given to retaining all or part of the HBM and using it as part of the foundation for a new flexible pavement with an asphalt base. The design in such cases can be carried out using the standard (chart-based) approach in CD 226 [Ref 4.N]. The effective foundation class of the HBM base should be established in a manner consistent with CD 225 [Ref 5.N].

Appendix E. Deeper treatments for rigid pavements

E1 Non-strengthening treatments for jointed rigid pavements

The treatments described in this section are deeper treatments for rigid pavements that are estimated to have a residual life of more than 5 years. See Tables C.1 and C.2 in Appendix C for information on where these treatments may be appropriate.

E1.1 Bay replacement

The procedure for bay replacement, as well as information regarding the most suitable time of year to remove slabs, is given in Series 1000 of MCHW [Ref 9.N]

E1.2 Localised full depth repair

Rapid cure concrete is a pragmatic potentially beneficial option for full depth repairs using concrete. Modifying concrete using water reducer, accelerator and additives can be carried out to achieve the required strengths in a very short amount of time and within a single night's possession.

An example of a rapid cure concrete mix design which achieves adequate strength to be trafficked in 3 hours is provided in Table E.1

Table E.1 Example design for rapid cure concrete

Constituent	Quantity
Cement	500 kg/m^3 (minimum)
Coarse aggregate 4 - 20 mm	912 kg/m^3
Fine aggregate 0 - 4 mm	876 kg/m^3
Super plasticiser	0.77 litres
Accelerator	4.0 % BWC (by weight of cement)
Free water	140 litres
Water/cement ratio	0.28

To make available as much time as possible for curing and to enhance the curing process, operational practices such as pre-saw cutting and mechanical slab lifting (as opposed to breaking and excavating), use of volumetric mixers, heat blankets and space heaters, should be considered.

Small bays of 2 m length (along the carriageway) constructed over a granular sub-base may fail around the dowel bars and settle due to heavy traffic loading and lack of compaction of the sub-base. It is recommended that when the existing sub-base is granular the length of bay is increased to at least 2 m so that re-compaction of the sub-base is easier and the traffic load is spread over a longer bay, so eliminating the punch down effect on a short bay.

Further detail on this treatment can be found in the CS CPMM 2001 [Ref 1.N] and MCHW [Ref 9.N].

E1.3 Slab lifting & pressure or vacuum grouting

Raising the level of slabs by slab lifting is a very controllable process in which the slab is connected to a lifting frame which straddles the bay and is raised to the required level in increments of a few millimetres at a time by the operation of hydraulic jacks (the CS CPMM 2001 [Ref 1.N] provides further details). Whilst the slab is still connected to the lifting frame, the void that has been created underneath should be filled by either pressure or vacuum grouting.

Further detail on this treatment can be found in Series 1000 of the MCHW [Ref 9.N].

E1.3.1 Pressure grouting

Pressure grouting is used either to fill small voids stabilising dynamic movement of the slab, or to fill the voids that are created when slabs are raised to correct settlement or stepping at joints and cracks.

Further detail on this treatment can be found in Series 1000 of the MCHW [Ref 9.N].

E1.3.2 Vacuum grouting

In this process, normally a low viscosity resin grout is induced to flow into voids beneath the slab by the application of a vacuum. Holes are drilled through the slab to provide the vacuum suction and grout injection points.

The advantages of this process are that any water beneath the slab is drawn off before the grout is injected and the use of low viscosity grout enables very small voids to be penetrated. There is also little danger of inadvertently filling service ducts.

Further detail on this treatment can be found in Series 1000 of the MCHW [Ref 9.N].

E2 Strengthening treatments for jointed rigid concrete

The treatments described in this section are deeper treatments for rigid pavements that need strengthening.

Strengthening of an existing pavement may be required to extend its life where it is deemed to have a residual life of less than five years. Figure 11.1 in the CS CPMM 2001 [Ref 1.N] illustrates the opportune time for strengthening techniques to be implemented.

Where an overlay is being considered, the existing slabs should be retained provided they are relatively intact. The existing slabs can be brought up to a relatively uniform standard by replacing failed bays or rectifying joint defects, for example, prior to being overlaid.

See Appendix C for details of defects where these treatments can be appropriate.

E2.1 Full depth reconstruction

Strengthening can be achieved by the demolition and reconstruction of the existing pavement. This can be necessary when the existing slab has deteriorated structurally to the extent that it is considered unsuitable for use as the sub-base or base beneath a new overlay or in those cases where an increase in surface level of the road cannot be accommodated.

For fast-track slab replacement, compression type joint seals can be installed as soon as the groove is sawn. If hot or cold applied sealants are to be used they can be applied after the concrete has reached sufficient strength for grit blasting without damage occurring to the joint grooves. Further details can be found in Series 1000 of the MCHW [Ref 9.N].

Consideration should be given to recycling the excavated slabs by crushing and recycling the aggregate. Further details can be found in Series 700 of the MCHW [Ref 9.N]

E2.2 Fractured slab techniques

Where the existing pavement is too distressed and variable to repair to a relatively uniform condition then cracking and seating in situ may be appropriate prior to overlaying.

E2.2.1 Crack, seat and overlay (CSO) (for jointed unreinforced concrete)

This technique involves the existing pavement layer(s) being cracked and seated prior to being overlayed. Further details can be found in Series 700 of the MCHW [Ref 9.N].

E2.2.2 Saw cut, crack, seat and overlay (for jointed reinforced concrete)

This technique involves the longitudinal steel reinforcement being saw cut completely through prior to the crack, set and overlay processes being undertaken. Further details can be found in Series 700 of the MCHW [Ref 9.N].

E2.3 Overlay Options - concrete or asphalt

Overlaying of concrete pavements (excluding continuously reinforced concrete) represents greater difficulties than overlaying bituminous pavements due to the discontinuities which occur at joints or wide cracks. Joints (and wide cracks) represent a source of concentrated movement in the pavement brought about by a combination of:

1) load induced movements;
2) long term temperature induced movements (seasonal);
3) short term temperature induced movements (diurnal);
4) drying shrinkage movements.

Report TRL 657 [Ref 4.I] provides information on treatment options for overlays to jointed unreinforced and jointed reinforced rigid pavements.

An overlay placed over existing jointed concrete slabs can be subjected to a concentration of strain at locations of joints (and wide cracks) in the underlying pavement. Therefore the overlay needs to be designed to accommodate this movement.

For concrete overlays this can be carried out in two basic ways:

1) by forming joints in the overlay at the same location as joints (and wide cracks) in the underlying pavement;
2) by separating the overlay from the underlying pavement using, say, a regulating layer of bituminous material.

It should be noted that a concrete overlay that is sufficient to strengthen the road may be of inadequate thickness to provide cover to reinforcing steel, and may therefore need increase in depth.

To help delay/resist reflection cracking of bituminous overlays one or more of the following measures are required:

1) using thicker bituminous layers than required for the predicted traffic loading only;
2) creating a 'joint' in the bituminous surfacing by sawing and applying a suitable sealant (saw cut and seal Series 700 MCHW [Ref 9.N]);
3) using modified binder to improve the elastic recovery and fatigue cracking properties of the bituminous materials;
4) using stress-absorbing or 'reinforcing' materials to distribute strains above joints (or wide cracks) by partial debonding or other mechanisms.

In method 2) reflection cracks do not always follow the line of the formed joint and several parallel cracks can be created. To help overcome this, a band of surfacing material is sometimes removed, and replaced with a modified bituminous material.

Modified bitumen binders with polymer used within asphalt layers (including surfacing) have been shown to have improved resistance to deformation and fatigue of the asphalt and to provide better adhesion between bitumen and aggregate compared with conventional bitumen. The effectiveness of the modified bitumen in the asphalt is dependent on the base bitumen, level and type of modification and design of the asphalt mixture. Stress-absorbing or "reinforcing" materials can be used in lower layers and are relatively new with insufficient evidence to date to prove their long term effectiveness and overall economy.

E2.4 Concrete overlays

E2.4.1 Bonded concrete overlay

Bonded concrete overlays are only appropriate for existing concrete pavements in good condition and where structural and level considerations dictate that only a thin overlay is required. A relatively small increase in slab thickness can greatly increase pavement life, but is not considered worthwhile to apply overlay thicknesses less than 50 mm since the material cost is only a fraction of the overall strengthening cost. Any assessment of increased life should be based on the properties (for example strength) of the existing slab, making allowance for fatigue damage to date due to past traffic.

It is essential that a good bond is achieved between the overlay and the existing concrete, since bond failure can lead to major distress, with cracking and spalling of the concrete across the carriageway width. Special surface treatment is therefore required, the extent depending on the existing surface condition, aggregate type and so on.

This may consist of two passes of a grit or shot blaster, the second one just prior to overlaying. A cement grout may be used to assist in creating the bond, but, if used, this needs to be applied immediately before the overlay concrete is placed, otherwise premature setting of the grout may create a slip layer. The existing joints also need be cleaned and resealed and any spalling at joints repaired prior to overlaying.

Joints and wide cracks in the underlying pavement should be reproduced in the bonded concrete overlay, ensuring that the appropriate joint type (for example contraction or expansion) is used. There are problems in achieving this in practice which means that the work is labour intensive and requires close supervision.

Consideration should be given to using a limestone aggregate in the overlay since this has a lower coefficient of thermal expansion than, say, flint gravel or granite aggregates and can therefore shrink less during curing. Use of fabric reinforcing mesh in the overlay may be required to help control shrinkage induced cracking.

Since there is no reduction in the total number of joints, this method of overlaying can lead to continuing maintenance expenditure, and associated traffic delays, in the future.

E2.4.2 Unbonded concrete overlay

When structural and level consideration dictate that a thicker overlay is required, then an unbonded overlay may be used. Such concrete overlays may be either unreinforced, jointed reinforced or continuously reinforced slabs. Reinforced concrete overlays are suitable for strengthening of existing pavements that have deteriorated to a considerable degree as well as those that are still in good structural condition.

Prior to the construction of the overlay it is necessary to stabilise any vertical movement that can be occurring at joints or cracks in the existing slab by grouting or full depth reconstruction. Spalling at joints can need to be rectified with bituminous or cementitious materials and the surface levels regulated if necessary. A partially unbonded overlay should not be attempted since this cannot be specified nor produced in a uniform manner in practice.

Use of an unbonded overlay does not constrain the designer to the same slab shape and size as the underlying pavement. Therefore continuously reinforced concrete may be used.

For an unbonded overlay in jointed reinforced concrete, joints need not be reproduced in the same locations as the existing slab. However, the pavement design needs to ensure that debonding occurs by some positive means (for example by use of a bituminous regulating layer of nominal thickness 40-50 mm).

The minimum practical thickness recommended to achieve cover of reinforcement, to enable proper compaction and to help prevent reinforcement ripple (for continuously reinforced concrete overlays) is 200 mm.

E2.5 Asphalt overlays

The thickness of bituminous overlays is determined not only by structural requirements but also by the need to minimise or avoid reflection cracking which may result from movement in joints or cracks in the underlying slab.

Considerable care needs to be taken before the overlay is applied. Joints can require checking and remedial works carried out if necessary. Depressions and potholes can require filling and all cracks sealed. In particular, measures need to be taken to limit the amount of horizontal and vertical movements at joints and wide cracks.

Where a thin bituminous overlay is required, it may be appropriate to saw-cut and seal the concrete prior to the overlay. Further details are given in Series 700 MCHW [Ref 9.N].

E3 Continuously reinforced concrete pavements (CRCPs)

Guidance on the treatment options for CRCPs is given in Table C.3 in Appendix C of this document.

CRCPs, and in particular those which have a concrete running surface, are generally more difficult and costly to repair than other types of rigid pavement because of the large quantity of heavy steel reinforcement in the slab and the high levels of stress that are generated in it. The most appropriate time of the year to carry out work requiring part of the slab to be demolished (i.e. full depth repairs), is during the Spring and Autumn months, which avoids working during particularly hot weather when compressive stresses are high and the slab may buckle, or during cold weather when the slab is in tension.

Preventive maintenance to prolong the structural life of the slab is highly desirable. Measures such as the sealing of medium to wide cracks, repair of spalled cracks, and grouting to stabilise vertical slab movement may all be necessary.

Designs for new CRCB pavements assume that 15 mm of concrete is equivalent to 100 mm of asphalt which makes allowance for the different thermal stresses generated in an asphalt overlaid concrete pavement. This equivalence may be used for asphalt overlay design over intact CRCPs, using the design charts in CD 226 [Ref 4.N].

Further information regarding defects and maintenance of continuously reinforced concrete can be found in the CS CPMM 2001 [Ref 1.N].

Pavement
Design

CD 227
England National Application Annex to CD 227 Design for pavement maintenance

(formerly HD 30/08 and HD 32/16)

Revision 0

Summary
This National Application Annex sets out the Highways England-specific requirements for determining the need for deflectograph surveys and the frequency of dynamic cone penetrometer (DCP) testing when developing and executing a scheme-level pavement investigation, and design requirements for fractured slab techniques.

Feedback and Enquiries
Users of this document are encouraged to raise any enquiries and/or provide feedback on the content and usage of this document to the dedicated Highways England team. The email address for all enquiries and feedback is: Standards_Enquiries@highwaysengland.co.uk

Contents

Release notes

Version	Date	Details of amendments
0	Mar 2020	Highways England National Application Annex to CD 227.

Foreword

Publishing information

This document is published by Highways England.

This document supersedes HD 30/08 and HD 32/16, which are withdrawn.

Contractual and legal considerations

This document forms part of the works specification. It does not purport to include all the necessary provisions of a contract. Users are responsible for applying all appropriate documents applicable to their contract.

Introduction

Background

This National Application Annex gives the Highways England-specific requirements for determining the need for deflectograph surveys and the frequency of dynamic cone penetrometer (DCP) testing when developing and executing a scheme-level pavement investigation, testing to confirm whether a pavement is suitable for receiving a preventative maintenance treatment and design requirements for fractured slab techniques.

Assumptions made in the preparation of this document

The assumptions made in GG 101 [Ref 7.N] apply to this document.

Mutual Recognition

Where there is a requirement in this document for compliance with any part of a "British Standard" or other technical specification, that requirement may be met by compliance with the Mutual Recognition clause in GG 101 [Ref 7.N].

Abbreviations

Abbreviation	Definition
DCP	Dynamic cone penetrometer
NSC	Network structural condition
TRASS	Traffic speed structural survey
TSCS	Thin surface course system

E/1. Development and execution of an investigation plan

Need for deflectograph surveys (CD 227, 2.10)

E/1.1 A deflectograph survey shall be undertaken as part of the scheme-level investigation on all flexible pavements unless the traffic speed structural survey (TRASS) results for the entire length are all in network structural condition (NSC) categories 1 and 2 and there is no other evidence of structural deterioration.

NOTE 1 More information on TRASS is given in CS 230 [Ref 1.I].

NOTE 2 Examples of evidence of structural deterioration include longitudinal wheel-track cracking, pumping and settlement in flexible pavements of any base type, and transverse cracks with crack severity ratings of 2 and 3 as defined in CD 227 [Ref 6.N] Table 3.36.2 in flexible pavements with a hydraulically bound base.

E/1.2 Where the scheme has any reporting length in NSC categories 3 or 4 (or has no TRASS data less than three years old available) or there is any other evidence of structural deterioration then a deflectograph survey shall be undertaken on the whole scheme.

E/1.2.1 Where a deflectograph survey has been undertaken in the last three years then the results of this may be used instead.

E/1.2.2 Testing should be undertaken in all lanes where the TRASS results are in NSC categories 3 and 4 and/or in lanes where there is evidence of structural deterioration.

Frequency of dynamic cone penetrometer (DCP) testing (CD 227, 2.22)

Flexible pavements

E/1.3 For flexible pavements, DCP testing of the foundation shall be undertaken in accordance with Table E/1.3.

Table E/1.3 Frequency of DCP testing on flexible pavements

NSC category	Any other evidence of structural deterioration present?	DCP frequency
Categories 1 and 2 only	No	DCP at least one third of the core holes
Categories 1 and 2 only	Yes	DCP at least two thirds of the core holes
Some in categories 3 or 4	N/A	DCP at least 90 percent of the core holes

Rigid pavements

E/1.4 For rigid pavements, DCP testing shall be undertaken in at least one-third of the core holes.

E/1.4.1 Where there is any evidence of structural deterioration being present in a rigid pavement then DCP testing should be undertaken in at least 90 percent of the core holes.

NOTE See CD 227 [Ref 6.N] for more information on evidence of structural deterioration in rigid pavements.

E/2. Design of surface only maintenance

Preventative maintenance (CD 227, 4.7)

E/2.1 Lengths identified at network level as being suitable for receiving a preventative maintenance treatment shall be subject to the following investigations in order to confirm their suitability.

NOTE Guidance on the identification of suitable sites at network level is given in CS 230 [Ref 1.I].

Coring

E/2.2 Coring, in accordance with CS 229 [Ref 4.N], shall be undertaken in order to provide representative samples of thin surface course system (TSCS) material for laboratory testing.

E/2.3 Where more than one type of TSCS is present within the length (or where the same TSCS laid at different times is present), representative samples of each TSCS material (type or age) shall be obtained and each material considered independently.

E/2.4 At least three cores per TSCS material (type or age) shall be taken, or three cores per lane-km of each TSCS material, whichever is greater.

NOTE Three cores can normally provide sufficient quantity of recovered binder from the TSCS to allow rheological testing to be undertaken.

E/2.5 Where the core logs reveal the presence of deteriorated material that indicates the need for a renewal maintenance treatment then the site shall not be considered suitable for a preventative treatment.

Binder recovery and rheological testing

E/2.6 Binder from the TSCS shall be recovered from each core in accordance with BS EN 12697-3 [Ref 3.N].

E/2.7 Where the TSCS contains additives or polymer modifiers, the additional guidance in PD 6692 [Ref 1.N] shall be followed.

E/2.8 The binder recovered from each core shall be subjected to rheological testing to BS EN 14770 [Ref 2.N] including test frequencies of 0.4 Hz and 1.59 Hz and covering the temperature range 0ºC to 60ºC.

E/2.9 The temperature ($T_{(VET)}$) and complex modulus ($G^*_{(VET)}$) at which the phase angle value (δ) is equal to 45º when tested at a frequency of 0.4 Hz shall be reported for each sample.

E/2.10 The $T_{(VET)}$ and $G^*_{(VET)}$ results shall be assessed against the categories in Table E/2.10 in order to determine whether a preventative maintenance treatment is suitable.

Table E/2.10 Suitability for a preventative maintenance treatment treatment

Category	$T_{(VET)}$ °C	$G^*_{(VET)}$ MPa	Condition	Recommendation
A	< 17	> 10	Sound condition. Low risk of fretting.	No action needed. A preventative maintenance treatment may be applied.
B	$17 \geq [T_{VET)}] \leq 20$	≤ 10	Some age hardening. An increased risk of fretting.	Ideal condition. A preventative maintenance treatment should be applied.
C	> 20	≤ 10	Severely age hardened. High risk of fretting.	Preventative maintenance treatment not recommended.

Preventative maintenance treatment

E/2.11 Where the decision is taken to apply an overlay treatment, this shall be designed in accordance with CD 236 [Ref 9.N].

E/2.12 Where the decision is taken to proceed with an asphalt preservation treatment, it shall be specified in accordance with Series 900 of the MCHW [Ref 8.N].

NOTE If asphalt preservation systems are used for preventative maintenance, they can result in a short-term reduction in skidding resistance.

E/3. Design of deeper maintenance treatments

Fractured slab techniques (CD 227, 5.20)

E/3.1 Fractured slab techniques comprise 'crack, seat and asphalt overlay' and 'saw-cut, crack, seat and asphalt overlay', and shall be designed using the analytical design approach in CD 226 [Ref 5.N].

E/3.2 The designs shall have a minimum asphalt thickness of 150mm.

E/3.3 Fractured slab techniques shall not be used on rigid pavements with an unbound subbase.

NOTE Specifications for fractured slab techniques are set out in the 700 series of the MCHW [Ref 8.N].

E/4. Normative references

The following documents, in whole or in part, are normative references for this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

Ref 1.N	BSI. PD 6692, 'Asphalt. Guidance on the use of BS EN 12697 "Bituminous mixtures. Test methods"'
Ref 2.N	BSI. BS EN 14770, 'Bitumen and bituminous binders. Determination of complex shear modulus and phase angle. Dynamic Shear Rheometer (DSR)'
Ref 3.N	BSI. BS EN 12697-3, 'Bituminous mixtures. Test methods. Bitumen recovery: Rotary evaporator'
Ref 4.N	Highways England. CS 229, 'Data for pavement assessment'
Ref 5.N	Highways England. CD 226, 'Design for new pavement construction'
Ref 6.N	Highways England. CD 227, 'Design for pavement maintenance'
Ref 7.N	Highways England. GG 101, 'Introduction to the Design Manual for Roads and Bridges'
Ref 8.N	Highways England. MCHW, 'Manual of Contract Documents for Highway Works'
Ref 9.N	Highways England. CD 236, 'Surface course materials for construction'

E/5. Informative references

The following documents are informative references for this document and provide supporting information.

Ref 1.I	Highways England. CS 230, 'Pavement maintenance assessment procedure'

Design Manual for Roads and Bridges

Pavement
Design

CD 227
Northern Ireland National Application Annex to CD 227 Design for pavement maintenance

(formerly HD 30/08, HD 32/16)

Revision 0

Summary
This National Application Annex sets out the Department for Infrastructure, Northern Ireland-specific requirements for determining the need for deflectograph surveys and the frequency of dynamic cone penetrometer (DCP) testing when developing and executing a scheme-level pavement investigation, and design requirements for fractured slab techniques.

Feedback and Enquiries
Users of this document are encouraged to raise any enquiries and/or provide feedback on the content and usage of this document to the dedicated team in the Department for Infrastructure, Northern Ireland. The email address for all enquiries and feedback is: dcu@infrastructure-ni.gov.uk

This is a controlled document.

Contents

Release notes

Version	Date	Details of amendments
0	Mar 2020	Department for Infrastructure, Northern Ireland National Application Annex to CD 227.

Foreword

Publishing information

This document is published by Highways England on behalf of the Department for Infrastructure, Northern Ireland.

This document supersedes HD 30/08 and HD 32/16, which are withdrawn.

Contractual and legal considerations

This document forms part of the works specification. It does not purport to include all the necessary provisions of a contract. Users are responsible for applying all appropriate documents applicable to their contract.

Introduction

Background

This National Application Annex gives the Department for Infrastructure, Northern Ireland-specific requirements for determining the frequency of dynamic cone penetrometer (DCP) testing when developing and executing a scheme-level pavement investigation, and design requirements for fractured slab techniques.

Assumptions made in the preparation of this document

The assumptions made in GG 101 [Ref 3.N] apply to this document.

Mutual Recognition

Where there is a requirement in this document for compliance with any part of a "British Standard" or other technical specification, that requirement may be met by compliance with the Mutual Recognition clause in GG 101 [Ref 3.N].

Abbreviations

Abbreviation	Definition
DBFO	Design, build, finance and operate
DCP	Dynamic cone penetrometer
NSC	Network structural condition
OGV	Other goods vehicle

NI/1. Development and execution of an investigation plans

Need for deflectograph surveys (CD 227, 2.10)

NI/1.1 Network level deflectograph structural condition surveys on the Department for Infrastructure trunk road network shall be undertaken in accordance with the project contract, for design, build, finance and operate (DBFO) managed roads and departmental policy for all other roads.

NOTE 1 A knowledge of the trend of average deflection can be very useful in the assessment of the condition particularly when the deflections predict low or negative residual values.

NOTE 2 If the residual life assessment is valid, deflections measured one year later are expected to show a deterioration.

NI/1.2 On multi-lane roads surveys shall be carried out in lane 1 in both directions.

NOTE Surveys of the other lanes can be necessary where:

1) *visual defects are markedly different;*
2) *there is a significantly different construction;*
3) *the traffic loadings in these lanes are greater than in lane 1.*

NI/1.2.1 On single lane carriageways where other goods vehicle (OGV) traffic is split approximately 50:50 in each direction, a deflection survey in at least one direction should be undertaken for maintenance planning purposes.

NI/1.3 The requirements of traffic management, including lane closures, can restrict the working day for survey purposes. Any such limitations on access shall be determined at the planning stage.

NI/1.4 For discrete new build schemes a deflectograph survey shall be undertaken under the contract on the whole scheme at the frequency specified in the particular scheme contract.

Frequency of dynamic cone penetrometer (DCP) testing (CD 227, 2.22)

NI/1.5 For flexible pavements, DCP testing of the foundation shall be undertaken in accordance with Table NI/1.6.

Table NI/1.5 Frequency of DCP testing on flexible pavements

Network structural condition category	Any other evidence of structural deterioration present?	DCP frequency
Categories 1 and 2 only	No	DCP at least one third of the core holes
Categories 1 and 2 only	Yes	DCP at least two thirds of the core holes
Some in categories 3 or 4	N/A	DCP at least 90 percent of the core holes

Rigid pavements

NI/1.6 For rigid pavements, DCP testing shall be undertaken in at least one-third of the core holes.

NI/1.6.1 Where there is any evidence of structural deterioration being present in a rigid pavement then DCP testing should be undertaken in at least 90 percent of the core holes.

NOTE See CD 227 [Ref 2.N] for more information on evidence of structural deterioration in rigid pavements.

NI/2. Design of surface only maintenance

Preventative maintenance (CD227, 4.7)

NI/2.1 Where the decision is taken to apply an overlay treatment, this shall be designed in accordance with CD 236 [Ref 5.N].

NI/3. Design of deeper maintenance treatments

Fractured slab techniques (CD 227, 5.20)

NI/3.1 Fractured slab techniques comprise 'crack, seat and asphalt overlay' and 'saw-cut, crack, seat and asphalt overlay', and shall be designed using the analytical design approach in CD 226 [Ref 1.N].

NI/3.2 The designs shall have a minimum asphalt thickness of 150 mm.

NI/3.3 Fractured slab techniques shall not be used on rigid pavements with an unbound subbase.

NOTE Specifications for fractured slab techniques are set out in the 700 series of the MCHW [Ref 4.N].

NI/4. Normative references

The following documents, in whole or in part, are normative references for this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

Ref 1.N	Highways England. CD 226, 'Design for new pavement construction'
Ref 2.N	Highways England. CD 227, 'Design for pavement maintenance'
Ref 3.N	Highways England. GG 101, 'Introduction to the Design Manual for Roads and Bridges'
Ref 4.N	Highways England. MCHW, 'Manual of Contract Documents for Highway Works'
Ref 5.N	Highways England. CD 236, 'Surface course materials for construction'

Design Manual for Roads and Bridges

Pavement
Design

CD 227
Scotland National Application Annex to CD 227 Design for pavement maintenance

(formerly HD 30/08, HD 32/16)

Revision 0

Summary
This National Application Annex sets out the Transport Scotland-specific requirements for determining the need for deflectograph surveys and the frequency of dynamic cone penetrometer (DCP) testing when developing and executing a scheme-level pavement investigation, and design requirements for fractured slab techniques.

Feedback and Enquiries
Users of this document are encouraged to raise any enquiries and/or provide feedback on the content and usage of this document to the dedicated Transport Scotland team. The email address for all enquiries and feedback is: TSStandardsBranch@transport.gov.scot

This is a controlled document.

Contents

Release notes

Version	Date	Details of amendments
0	Mar 2020	Transport Scotland National Application Annex to CD 227.

Foreword

Publishing information

This document is published by Highways England on behalf of Transport Scotland.

This document supersedes HD 30/08 and HD 32/16, which are withdrawn.

Contractual and legal considerations

This document forms part of the works specification. It does not purport to include all the necessary provisions of a contract. Users are responsible for applying all appropriate documents applicable to their contract.

Introduction

Background

This National Application Annex gives the Transport Scotland-specific requirements for deflectograph surveys and the frequency of dynamic cone penetrometer (DCP) testing when developing and executing a scheme-level pavement investigation, and design requirements for fractured slab techniques.

Assumptions made in the preparation of this document

The assumptions made in GG 101 [Ref 4.N] apply to this document.

Mutual Recognition

Where there is a requirement in this document for compliance with any part of a "British Standard" or other technical specification, that requirement may be met by compliance with the Mutual Recognition clause in GG 101 [Ref 4.N].

Abbreviations

Abbreviation	Definition
DBFO	Design, build, finance and operate
DCP	Dynamic cone penetrometer
NSC	Network structural condition
OGV	Other goods vehicles

S/1. Development and execution of an investigation plan

Need for deflectograph surveys (CD 227, 2.10)

S/1.1 Network level deflectograph structural condition surveys on the Transport Scotland trunk road network shall be undertaken as part of the Transport Scotland Road Condition Survey Contract, centrally managed by Transport Scotland.

S/1.2 The network shall be covered every four years.

NOTE 1 A knowledge of the trend of average deflection can be very useful in the assessment of the condition particularly when the deflections predict low or negative residual values.

NOTE 2 If the residual life assessment is valid, deflections measured one year later are expected to show a deterioration.

S/1.3 On multi-lane roads surveys shall be carried out in lane 1 in both directions.

S/1.3.1 Surveys of the other lanes may be necessary where:

1) visual defects are markedly different;
2) there is a significantly different construction;
3) the traffic loading in these lanes are greater than in lane 1.

S/1.3.2 On single lane carriageways where other goods vehicle (OGV) traffic is split approximately 50:50 in each direction, a deflection survey in at least one direction should be undertaken for maintenance planning purposes.

NOTE The deflectograph operates at a nominal speed of 2.5 km/h. Seasonal and temperature constraints allow a period of about 100 days in a calendar year for surveys in categories 1 and 2, and in this period a typical deflectograph output on continuous lengths of road, using an experienced operating team, is unlikely to exceed 1000 lane km.

S/1.4 The requirements of traffic management, including lane closures, can restrict the working day for survey purposes. Any such limitations on access shall be determined at the planning stage.

S/1.5 For discrete new build schemes and design, build, finance and operate (DBFO) contracts, deflectograph surveys shall be undertaken in accordance with the requirements of the contract.

Frequency of dynamic cone penetrometer (DCP) testing (CD 227, 2.22)

Flexible pavements

S/1.6 For flexible pavements, DCP testing of the foundation shall be undertaken in accordance with Table S/1.6.

Table S/1.6 Frequency of DCP testing on flexible pavements

Network structural condition category	Any other evidence of structural deterioration present?	DCP frequency
Green	No	None required
Amber	No	DCP at least one third of the core holes
Amber	Yes	DCP at least two thirds of the core holes
Red	N/A	DCP at least 90 percent of the core holes

Rigid pavements

S/1.7 For rigid pavements, DCP testing shall be undertaken in at least one-third of the core holes.

S/1.7.1 Where there is any evidence of structural deterioration being present in a rigid pavement then DCP testing should be undertaken in at least 90 percent of the core holes.

NOTE 1 See CD 227 [Ref 2.N] for more information on evidence of structural deterioration in rigid pavements.

NOTE 2 The Concrete Pavement Maintenance Manual CS CPMM [Ref 1.I] provides guidance.

S/2. Design of surface only maintenance

Preventative maintenance (CD227, 4.7)

S/2.1 Where the decision is taken to apply an overlay treatment, this shall be designed in accordance with CD 236 [Ref 6.N].

S/3. Design of deeper maintenance treatments

Fractured slab techniques (CD 227, 5.20)

S/3.1 Fractured slab techniques comprise 'crack, seat and asphalt overlay' and 'saw-cut, crack, seat and asphalt overlay', and shall be designed using the analytical design approach in CD 226 [Ref 1.N].

S/3.2 The designs shall have a minimum asphalt thickness of 150 mm.

S/3.3 Fractured slab techniques shall not be used on rigid pavements with an unbound subbase.

S/3.3.1 A simplified design method developed for crack, seat and asphalt overlay that may be used is set out in TSIA 44 [Ref 3.N].

NOTE Specifications for fractured slab techniques are set out in the 700 series of MCHW [Ref 5.N].

S/4. Normative references

The following documents, in whole or in part, are normative references for this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

Ref 1.N	Highways England. CD 226, 'Design for new pavement construction'
Ref 2.N	Highways England. CD 227, 'Design for pavement maintenance'
Ref 3.N	Transport Scotland. TSIA 44, 'Introduction of Simplified Design Method for Crack and Seat and Overlay'
Ref 4.N	Highways England. GG 101, 'Introduction to the Design Manual for Roads and Bridges'
Ref 5.N	Highways England. MCHW, 'Manual of Contract Documents for Highway Works'
Ref 6.N	Highways England. CD 236, 'Surface course materials for construction'

S/5. Informative references

The following documents are informative references for this document and provide supporting information.

Ref 1.I	Concrete Society (on behalf of Highways England and Britpave). CS CPMM, 'Concrete Pavement Maintenance Manual'

Design Manual for Roads and Bridges

Llywodraeth Cymru
Welsh Government

Pavement
Design

CD 227
Wales National Application Annex to CD 227
Design for pavement maintenance

(formerly HD 30/08, HD 32/16)

Revision 0

Summary
This National Application Annex sets out the Welsh Government-specific requirements for determining the need for deflectograph surveys and the frequency of dynamic cone penetrometer (DCP) testing when developing and executing a scheme-level pavement investigation, and design requirements for fractured slab techniques.

Feedback and Enquiries
Users of this document are encouraged to raise any enquiries and/or provide feedback on the content and usage of this document to the dedicated Welsh Government team. The email address for all enquiries and feedback is: Standards_Feedback_and_Enquiries@gov.wales

This is a controlled document.

Contents

Release notes

Version	Date	Details of amendments
0	Mar 2020	Welsh Government National Application Annex to CD 227.

Foreword

Publishing information

This document is published by Highways England on behalf of the Welsh Government.

This document supersedes HD 30/08 and HD 32/16, which are withdrawn.

Contractual and legal considerations

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Introduction

Background

This National Application Annex gives the Welsh Government-specific requirements for determining the need for deflectograph surveys and the frequency of dynamic cone penetrometer (DCP) testing when developing and executing a scheme-level pavement investigation, and design requirements for fractured slab techniques.

Assumptions made in the preparation of this document

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Abbreviations

Abbreviation	Definition
DCP	Dynamic cone penetrometer
NSC	Network structural condition
TRASS	Traffic speed structural survey

W/1. Development and execution of an investigation plan

Need for deflectograph surveys (CD 227, 2.10)

W/1.1 Network level deflectograph condition surveys on the Welsh Government Strategic Road Network shall be undertaken as part of the Welsh Government Condition survey Contract.

W/1.2 Deflectograph shall be carried out on feasible sections of the network with an aim of full coverage every four years.

W/1.3 Residual life assessment can give an indication of structural condition and shall be used in support of visual survey assessment to indicate requirement for further investigation.

W/1.4 On multi-lane roads surveys shall be carried out in lane 1 in both directions.

W/1.5 The requirements of Traffic Management, including lane closures, can restrict the working day for survey purposes. Access limitations shall be determined at the planning stage.

Frequency of dynamic cone penetrometer (DCP) testing (CD 227, 2.22)

Flexible pavements

W/1.6 For flexible pavements, DCP testing of the foundation shall be undertaken in accordance with Table W/1.6.

Table W/1.6 Frequency of DCP testing on flexible pavements

Network structural condition category	Any other evidence of structural deterioration present?	DCP frequency
Green	No	DCP at least one third of the core holes
Amber	Yes	DCP at least two thirds of the core holes
Red	N/A	DCP at least 90 percent of the core holes

Rigid pavements

W/1.7 For rigid pavements, DCP testing shall be undertaken in at least one-third of the core holes.

W/1.7.1 Where there is any evidence of structural deterioration being present in a rigid pavement then DCP testing should be undertaken in at least 90 percent of the core holes.

NOTE See CD 227 [Ref 2.N] for more information on evidence of structural deterioration in rigid pavements.

W/2. Design of deeper maintenance treatments

Fractured slab techniques (CD 227, 5.20)

W/2.1 Fractured slab techniques comprise 'crack, seat and asphalt overlay' and 'saw-cut, crack, seat and asphalt overlay', and shall be designed using the analytical design approach in CD 226 [Ref 1.N].

W/2.2 The designs shall have a minimum asphalt thickness of 150 mm.

W/2.3 Fractured slab techniques shall not be used on rigid pavements with an unbound subbase.

NOTE Specifications for fractured slab techniques are set out in the 700 series of the MCHW [Ref 4.N].

W/3. Normative references

The following documents, in whole or in part, are normative references for this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

Ref 1.N	Highways England. CD 226, 'Design for new pavement construction'
Ref 2.N	Highways England. CD 227, 'Design for pavement maintenance'
Ref 3.N	Highways England. GG 101, 'Introduction to the Design Manual for Roads and Bridges'
Ref 4.N	Highways England. MCHW, 'Manual of Contract Documents for Highway Works'