MODERNISATION OF THE DESIGN MANUAL FOR ROADS AND BRIDGES (DMRB) VOLUME 7, PAVEMENT DESIGN & MAINTENANCE

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ABSTRACT

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A team of specialist engineers from TRL and its supply chain partners, working in close collaboration with Highways England, has updated the Design Manual for Roads and Bridges (DMRB) Volume 7. The DMRB contains the design and safety standards for pavements on the strategic road network. The work formed a key part of Highways England's requirement under its Licence and Protocol Agreement to update the whole of the DMRB by March 2020.

A new structure for Volume 7 was conceived that removes duplication and redundant advice and more closely aligns with assessment and design stages of the pavement management life-cycle. The new structure has also significantly reduced the number of documents, from 16 Standards and 5 Interim Advice Notes to 10 new Standards, as well as a dramatic reduction in page count. The documents are written in a style that clearly states what shall be done, following drafting rules that have been developed from international best practice on excellence in standards development. The redrafting has made the documents easier to read and understand and has brought them technically up to date by incorporating the latest developments in materials, pavement design and innovative assessment techniques.

This paper sets out the approach followed in developing the new 200 Series of pavements standards and presents the main changes incorporated in each of the new documents.

KEYWORDS: DMRB, pavement, design, maintenance, assessment, construction, standards, guidance, advice, requirements

INTRODUCTION

The Design Manual for Roads and Bridges (DMRB) sets out the design and safety standards for managing the motorways and all-purpose trunk roads across England, Wales, Scotland and Northern Ireland. First published in 1992, the DMRB consists of a suite of documents that cover all aspects of designing and managing the network. As well as being used for roads in the UK, the document is used widely across the world.

Over the years, the existing manual has become difficult to use due to the many revisions and variations in language and style. Further, the number of individual documents has increased significantly and many of the documents are long overdue an update from a technical perspective, not least to fully reflect current practice and innovations that have been adopted. This is illustrated in Figure 1 which shows how the number and average age of documents increased between 1980 and 2015. Note that this includes the documents that preceded the formal publication of the DMRB in 1992.

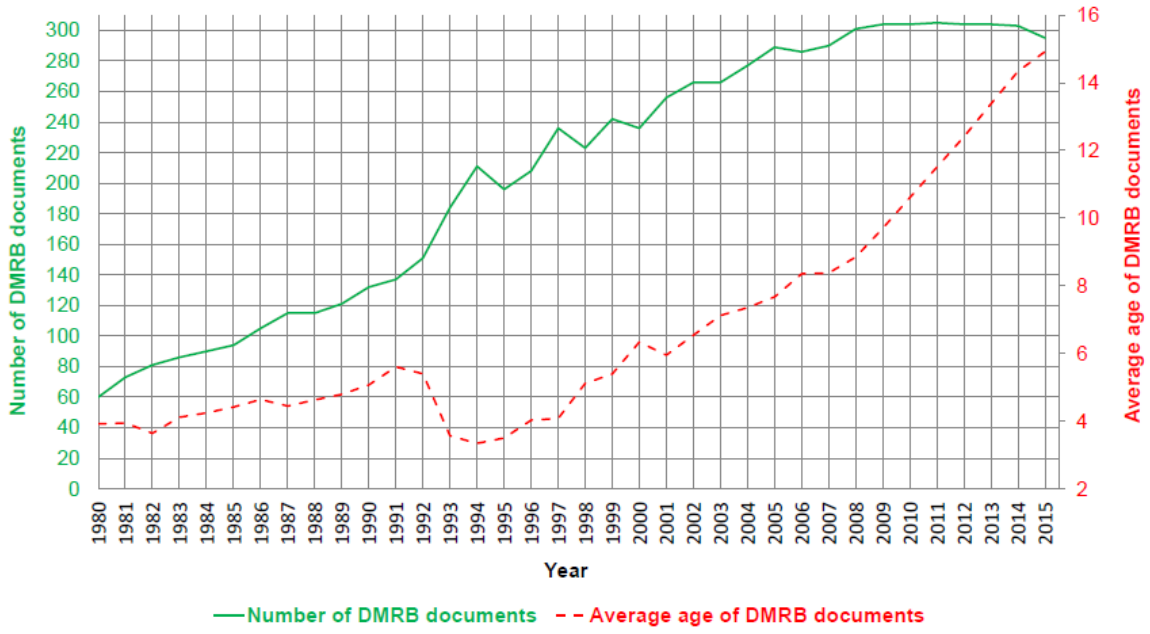

Figure 1. The number and average age of DMRB documents from 1980 to 2015

Following consultation with key stakeholders and users of the DMRB, a review of the document began in 2015 to assess its usability, content and structure. As a result of this review, Highways England committed to refreshing the whole of the DMRB by the end of March 2020. The main aims of the update included:

- reducing the volume of advice;
- adopting a consistent approach;
- making it more intuitive to use;
- using clearly-defined requirements;
- bringing it up to date; and
- addressing technical content that is frequently subject to Departures from Standard.

In order to do this, a new style and format for DMRB documents was developed along with a completely new structure for the entire DMRB document set, that incorporate the existing advice documents and Interim Advice Notes (IANs) into new documents with a new numbering system. In addition, to recognise the differences in approaches across England, Wales, Scotland and Northern Ireland, National Application Annexes were introduced so that nation-specific requirements can be clearly identified.

As part of the overarching update of DMRB, TRL and its supply chain partners worked in close collaboration with Highways England to update Volume 7 of the DMRB: Pavement Design and Maintenance. This paper sets out the approach followed in developing the new 200 Series of pavements standards and presents the main changes incorporated in each of the new documents.

DRAFTING RULES FOR THE NEW HIGHWAYS ENGLAND DMRB

Numbering of new DMRB documents

Detailed instructions for developing and drafting new DMRB documents are set out in the Manual for Development of Documents (MDD) (Highways England, 2019). The new documents, which are collectively referred to as Requirements and Advice Documents (RADs), follow a new structure and have a new numbering system aligned to technical discipline and the asset life-cycle stage. The life-cycle stages covered are appraisal, design, maintenance and operation, inspection and assessment, and disposal (as well as another series of documents providing "general information"). Another important change is that construction requirements are no longer included in the DMRB documents and these are instead to be covered in the Manual of Contract Documents for Highway Works (MCHW).

The coding system for the new DMRB documents is reproduced in Table 1. The first letter of the document relates to the discipline (G, L, C or T); the second letter the life-cycle stage (G, A, D, C, M, S or Z); and the (three-digit) number code relates to the asset type.

Table 1. Coding system for the new DMRB documents

		Part (discipline)								
		G	**L**	**C** (Civil Engineering)					**T** (Technology)	
		General Principles & Scheme Governance	Sustainability & Environment	Road Layout	Pavement	Structures & Bridges	Drainage	Geotechnics	Control & Comms. Technology	Road Lighting
Volume (life-cycle stage)		101-999	101-999	101-199	201-299	301-499	501-599	600-699	101-499	501-999
General Information	**G**				CG2xx					
Appraisal	**A**				CA2xx					
Design	**D**				**CD2xx**					
Construction*	**C**				-					
Maintenance & Operation	**M**				**CM2xx**					
Inspection & Assessment	**S**				**CS2xx**					
Disposal	**Z**				CZ2xx					
* Note – the "construction" row is currently a placeholder as construction requirements are to be moved into relevant MCHW documents.										

Since DMRB Volume 7 is specific to the pavement asset, the documents therefore all fall into the C_200 series of documents spread across design, maintenance & operation, and inspection and assessment i.e. CD, CM and CS. It should be noted that in the context of pavements, M (Maintenance and Operation) refers to regular or routine maintenance including activities such as patching and joint/crack repairs. The design of pavement renewal (maintenance) is covered by D (Design). More information on the specific document codes that have been assigned to the new DMRB documents and how these relate to the old DMRB standards is provided later in the paper.

Principles for drafting new DMRB clauses

The revised DMRB introduces a new approach to drafting clauses which places "requirements" at the core of the document. A requirement is a statement that conveys an action that needs to be followed i.e. is compulsory. This either reflects a legislative/statutory obligation that "must" be fulfilled or reflects an action that "shall" be followed in order to comply with the document (and requires a departure should there be a desire not to fulfil it). Requirements therefore use the verbs "must" and "shall" respectively.

Advice in the new documents uses the verb "should" to represent a recommendation and "may" to represent a permissible option. Advice always relates to a specific requirement and is therefore contained in a sub-clause to a requirement. Further clarification of a requirement or a recommendation can be presented as a note to a clause and uses the verb "can".

Appendices can be used to provide further advice and background, but these are not allowed to contain requirements.

Where requirements or approaches to fulfilling requirements vary between countries, National Application Annexes (NAAs) are used to reflect the differences. Where such variations in approach exist, the main document makes this clear.

The new approach is designed to allow updates and modifications to documents to be incorporated and issued far more quickly than the old DMRB. Consequently, Interim Advice Notes (IANs), that were temporary documents issued by Highways England to address early

and urgent needs, will no longer be produced. Instead, minor revisions to the original standard will be published.

A summary of the different verb forms and the clause numbering convention used in the new DMRB documents is given in Table 2.

Table 2. Verb forms and clause numbering used in the new DMRB documents

Description		**Verbal form**	**Clause numbering level**
Requirements (i.e. mandatory)	Legislative requirements	must	Top-level clause e.g. 2.1 or 4.5
	Other (non-legislative) requirements	shall	
Advice	Recommended approach	should	Sub-clause e.g. 2.1.1, 2.1.2, 4.5.1
	Permissible approach	may	
	Clarification of a concept or statement of fact	can	Presented as a NOTE

THE REVISION PROCESS

Clause by clause review

The first stage of the revision process involved a clause by clause review of each of the existing DMRB documents. Each clause was reviewed to assess:

- whether it contained any requirements
- whether it contained any advice
- whether its content was still technically appropriate
- which life-cycle stage it applied to
- whether it covered construction (to be moved to the MCHW)
- whether it belonged in another DMRB document or was already covered by another document.

As a result of this initial review, several of the existing documents were recommended for withdrawal as they didn't include any requirements, their content was out of date, they covered construction and/or the requirements were covered elsewhere within the DMRB. Withdrawn documents will be marked 'not for use on highway schemes' but will still be available in an online archive on the Standards for Highways website. The review also highlighted that the content of several of the existing documents spanned multiple life-cycle stages. For example, HD 32/16 Maintenance of concrete roads, covered virtually the whole life-cycle of a rigid pavement in a single document, something that the new DMRB structure does not allow.

In addition to reviewing the nineteen DMRB Volume 7 standards and Interim Advice Notes (IANs), TA 81/16 Coloured Surfacing in road layout and IAN 122/09 Rapid condition assessment of hard shoulder pavements were also reviewed, and relevant requirements captured.

Mapping the old to the new documents

The outcome of the review is summarised in Table 3. This shows the life-cycle stages covered by each document and, in broad terms, shows where the content covered by the old document has been incorporated within one of the new C_200 series documents.

Several of the old documents map directly to the new documents. For example, HD 24/06, which covers the calculation of traffic for pavement design, has been directly replaced by CD 224 and HD 28/15, skidding resistance, has been directly replaced by CS 228. For other documents, the mapping of old to new is less straightforward with some of HD 29/08 ending up in CS 229 and some in CS 230 and HD 30/08 being divided into CS 230 and CD 227.

Table 3. Results of the review of existing DMRB documents

Old DMRB document		**Life-cycle stage/s**	**Replacement document**
Volume 7 Section	**Document**		
1. Preamble	HD 23/99 General information	General	No requirements and out of date. Document withdrawn
	HD 35/04 Conservation and the use of secondary and recycled materials	General, Construction	No requirements and out of date. Document withdrawn
2. Pavement design and construction	HD 24/06 Traffic assessment	Design	CD 224 Traffic assessment
	IAN 73/06 Rev 1 Design guidance for road pavement foundations (draft HD25)	Design, Construction, Inspection & Assessment	CD 225 Design for new pavement foundations
	HD 26/06 Pavement design	Design	CD 226 Design for pavement construction
	HD 27/15 Pavement construction methods	Construction, Design	Content on pavement widening moved into CD 226. Other content covered by the MCHW.
	HD 39/16 Footway and cycleway design	Design, Construction	CD 239 Footway and cycleway pavement design
	IAN 194/16 Guidance on the management of risk when permitting traffic on planed asphalt surfaces	Construction	Very few requirements. Site practice beyond the scope of design documents, risk managed by GG 104.
3. Pavement maintenance assessment	HD 28/15 Skidding resistance	Inspection & Assessment	CS 228 Skidding resistance
	HD 29/08 Data for pavement assessment	Inspection & Assessment	CS 229 Data for pavement assessment Some of the text on traffic speed surveys has gone into CS 230.
	HD 30/08 Maintenance assessment procedure	Design, Inspection & Assessment	CS 230 Pavement maintenance assessment procedure CD 227 Design for pavement maintenance
	IAN 158/12 Maintenance assessment procedure	Design	Content out of date and deleted.
4. Pavement maintenance methods	HD 31/94 Maintenance of bituminous roads	Design, Construction, Maintenance, Inspection & Assessment	Most of the content deleted. Some clauses incorporated in CM 231 Pavement surface repairs
	HD 32/16 Maintenance of concrete roads	Design, Construction, Maintenance, Inspection & Assessment	Most of the text on assessment and treatment techniques has been incorporated in CD227. Some clauses incorporated in CM 231. Other text is covered elsewhere.
5. Surfacing and surfacing materials	HD 36/06 Surfacing materials for new and maintenance construction	Design	CD 236 Surface course materials for construction
	HD 37/99 Bituminous surfacing materials and techniques	Construction, Design	Very few requirements. Most of the content deleted as covered elsewhere.
	HD 38/16 Concrete surfacing and materials	Design, Construction, Maintenance, Inspection & Assessment	Very few requirements. Most of the content deleted as covered elsewhere.
	IAN 156/16R1 Revision of aggregate specification for pavement surfacing	Design	Content incorporated in CD 236
	IAN 157/11 Thin surface course system – installation and maintenance	Construction, Design	Very few requirements. Most of the content deleted as covered elsewhere.
DMRB Volume 6	TA 81/16 Coloured surfacing in road layout (excluding traffic calming)	Design	Mainly advice. Text on coloured surfaces incorporated in CD 236 (Rev 4)
Stand-alone document	IAN 122/09 Rapid condition assessment of hard shoulder pavements. Interim guide to data and maintenance advice	Design, Inspection & Assessment	Most of the text has been superseded by Major Projects design guidance. Some of the advice on assessment of previously untrafficked areas has been incorporated in CD 227.

THE NEW DOCUMENTS

This section summarises the scope of each of the new C_200 series documents and highlights some of the main changes that have been introduced over the old DMRB documents.

CD 224 Traffic assessment

CD 224 covers the calculation of design traffic (commercial vehicle pavement loading over the design period). It covers new trunk roads, including motorway schemes, and the maintenance of existing trunk roads, including motorways, and directly replaces HD 24/06. It has been updated and simplified. Some of the main changes include:

- For new pavement designs, the minimum percentage of Other Goods Vehicles 2 (OGV2) assumed in traffic flow calculations is now 70 per cent and Figure 2.1 of HD 24/06 has been removed. This simplifies the calculation and reduces the risk of underestimating the percentage of OGV2.
- Growth factors used for calculating future traffic have been updated based on 2015 Road Traffic Forecasts (HD 24/06 values were based on the 1997 National Road Traffic Forecast).
- Wear factors have been updated based on the latest vehicle traffic data.
- The method for calculating traffic flow after a specific number of years has been made far clearer than in HD 24/06 by the inclusion of a new equation and associated guidance. This will reduce the risk of inappropriate traffic flows being used for determining Polished Stone Values (PSVs) to achieve required skid resistance.

CD 225 Design for new pavement foundations

CD 225 replaces IAN 73/06 Revision 1 (2009) and HD 25/94. The full document has been extensively restructured, with corresponding updates to the MCHW Volume 1 Series 800 and MCHW Volume 2, Series 700 and Series 800. The document sets out the three permitted approaches that can be taken when designing a new pavement foundation:

- A restricted design approach that offers assurance of performance of the foundation through use of a limited palette of well understood materials.
- A performance design approach that gives flexibility to the designer in terms of the materials that can be used in the foundation conjunction with top of foundation testing to confirm performance requirements have been met.
- A widening design approach that utilises a restricted or performance design approach to assure the performance of the foundation whilst considering the additional requirements to provide sub-surface drainage continuity between the existing pavement and the widening.

CD 226 Design for pavement construction

CD 226 sets out the pavement design approaches to be used when constructing a new carriageway, widening an existing carriageway, upgrading an existing pavement or reconstructing an existing pavement. It directly replaces HD 26/06. Standard designs are presented that cover the permitted materials and design thicknesses required for various design traffic volumes and the requirements for designs using alternative procedures are set out. Some of the main changes include:

- A new standard design option which uses Roller Compacted Concrete (RCC) as the base material is introduced.
- Jointed concrete pavements are no longer included as a standard design for new pavements. Design curves and equations are still included for use when reconstructing or widening and existing jointed rigid pavement.
- The standard designs for flexible pavements have been rationalised. Designs with an asphalt base no longer include Hot Rolled Asphalt (HRA50) or Dense Bituminous Macadam (DBM125) equivalent materials.
- A new section covering on-line widening is included. This is based on requirements and advice that were previously contained in HD 27/15.
- The document includes expanded sections covering alternative design procedures and the use of cold recycled base materials.
- A new section on pavement design verification is introduced. This introduces (for England only at this stage) a new process to facilitate the technical governance of designs for new pavements or widening of an existing pavement. As part of this new process, a new Certified Pavement Engineer qualification has been introduced.

CD 227 Design for pavement maintenance

CD 227 describes the requirements for determining the need for maintenance and to design pavement renewals maintenance treatments on the UK motorway and all-purpose trunk roads. To reach this stage of the design process, the review of network surveys and safety inspection data (described in CS 230) will have shown that problems exist in the pavement surfacing and/or structure over a significant length and that substantial remedial works are probably needed. CD 227, along with CS 230, therefore supersedes HD 30/08. The document also includes guidance on retexturing techniques that was formerly in HD 31/94 and HD 37/99. It also incorporates requirements and guidance on treatments of rigid pavements that were formerly in HD 32/16. Some of the main changes introduced in CD 227 include:

- New requirements and advice that places the emphasis on collecting as much of the necessary condition data at traffic-speed as possible, reducing the need for closures and reducing exposure of road workers to risks.
- Improved processes for planning and reporting pavement maintenance investigations that maximise the use of existing condition data and minimise closures. This includes a requirement for an investigation plan setting out the proposed surveys and investigations to be undertaken as well as the reasons for collecting the data; and a

requirement to produce a pavement investigation report setting out the findings and recommendations of the investigation including proposed treatment options.

- A restructured section on interpretation of data and identification of maintenance needs with separate sub-sections dealing with each of the main pavement construction types.
- Detailed appendices dealing with defects and treatments for rigid pavements.
- Guidance on the need for Deflectograph and Dynamic Cone Penetrometer (DCP) surveys based on the results from TRAffic speed Structural Surveys (TRASS) undertaken with Highways England's Traffic Speed Deflectometer (England only).
- New requirements for determining the suitability of thin surface course systems for receiving preventative maintenance with an asphalt preservation treatment.
- New requirements for the appropriate use of geosynthetics and steel meshes as a maintenance treatment option for suppression of potential future reflective cracking, alongside a new corresponding MCHW clause in the 900 Series.

CD 236 Surface course materials for construction

CD 236 gives requirements for aggregates in surface course materials, which aim to ensure that appropriate skidding resistance is provided on roads. It applies to materials for both new and maintenance construction on both asphalt and concrete surfaces and supersedes both HD 36/06 and IAN 156/16. Some of the main changes introduced in CD 236 are:

- Updates to the permitted surface course material options.
- Designs based on traffic in individual lanes that allow more efficient use of higher PSV aggregates.
- Improved requirements for lay-bys, emergency areas, coloured surfacing and hardstanding locations (England only at this stage).
- Guidance on calculating the value for money of a "noise sensitive" departure approval (England only)

CD 239 Footway and cycleway pavement design

CD 239 contains requirements for the design of the pavement construction for new footways and cycleways. These can be surfaced with asphalt, concrete block or clay pavers, natural stone slabs or setts, pre-cast concrete flags or in-situ concrete and subject to pedestrian and/or cycle traffic and some overrun by vehicular traffic. It directly replaces HD 39/16. Some of the main changes introduced are:

- Pavement construction and thickness design options have been rationalised and cumulative traffic loadings, in terms of million standard axles (msa), have been introduced for "light-vehicle" and "heavy-vehicle" footway and cycleway categories.
- New requirements covering the skid resistance properties of surfaces have been introduced.
- Cold recycled base materials now permitted in footways and cycleways.

CS 228 Skidding resistance

CS 228 describes the requirements for the provision and management of appropriate levels of skid resistance on UK motorway and all-purpose trunk roads. It describes the requirements for making and interpreting measurements of skid resistance. It also provides a method to identify locations for treatment to improve skid resistance where that treatment is likely to reduce the risk of skidding related incidents in wet conditions. It directly replaces HD 28/15 which was substantially redrafted and updated in 2015. Consequently, technical changes to the document are limited, the main one being as follows:

- The use of the Highways England crash model has been made a requirement. This is used to assess the need for detailed investigation (England only).

CS 229 Data for pavement assessment

CS 229 describes the technical requirements for undertaking detailed scheme-level pavement investigations on the UK motorway and all-purpose trunk roads. It does not cover network-level surveys which are described in CS 230. The document includes sections on Visual Condition Surveys (VCS), Deflectograph surveys, Falling Weight Deflectometer (FWD) surveys, Ground-Penetrating Radar (GPR) surveys and invasive testing and therefore replaces much of HD 29/08. Several of the changes are designed to reduce exposure of road workers to risk and others introduce technical improvements. Some of the main changes include the following:

- It is now a requirement (in England) that VCS is undertaken using downward and forward-facing images collected at traffic speed as part of the TRACS4 (Traffic-speed Condition Survey) contract, or images of equivalent quality.
- New "contactless" methods for determining pavement temperatures for Deflectograph and FWD surveys are introduced that do not require holes to be drilled into the surface.
- Permitted and preferred temperature ranges for FWD testing are introduced that define the permitted use of FWD data collected at a range of pavement temperatures.
- New requirements for FWD testing of jointed pavements that are designed to capture more information about joint performance in a single hit.
- Clearer requirements on Quality Assurance and Accreditation for the FWD and Deflectograph.
- Improved guidance on the application of GPR and updated confidence ratings covering the different applications of GPR.
- Clearer requirements and improved guidance on invasive testing.

CS 230 Pavement maintenance assessment procedure

CS 230 sets out the requirements for reviewing routine/network level data in order to establish whether there is a pavement maintenance need that requires further investigation. The document has three main sections covering network level surveys, other sources of relevant data (including safety and routine inspections and records of unplanned maintenance) and review of the data, respectively. It replaces the parts of HD 30/08 and HD 29/08 that covered these topics. Given the differences in approach across the different countries, much of the content is covered in NAAs. Some of the main changes introduced in the English NAA (covering the Highways England network) are as follows:

- Updated requirements and guidance on the analysis of TRAffic-speed Condition Survey (TRACS) condition data.
- New requirements and guidance on the application of TRAffic-speed Structural condition Survey (TRASS) data as collected by Highways England's Traffic Speed Deflectometer (TSD).
- New requirements covering the assessment of rigid pavements into condition categories using visual defects identified from high resolution images collected at traffic speed.
- New requirements for identifying lengths suitable for receiving a preventative maintenance treatment from network condition data (to complement the testing of material samples set out in CD 227).
- Guidance on identifying schemes that are free of structural defects that can potentially be fast tracked for surface-only maintenance, "Technically Simple Schemes" (TSS).

CM 231 Pavement surface repairs

CM 231 provides requirements and guidance on methods to be used for minor repairs of both flexible and rigid pavements with sections covering patching and repairs to cracks and joints. Most of the content comes form HD 31/94 and HD 32/16 and reference is made to relevant MCHW clauses for selection of appropriate repair materials.

CONCLUSION

A comprehensive update of the DMRB Volume 7 has been completed with the final documents due to be released by the end of March 2020. While it may take some time for engineers to get used to the new style, the new language, and to navigate the documents that replace some standards that have been around for more than a quarter of a century, the authors are in no doubt that the new document is a big improvement on the previous incarnations of the DMRB.

REFERENCES

Highways England (2019). Manual for Development of Documents (MDD)