Design Manual for Roads and Bridges

Drainage
Design

CD 523
Determination of pipe roughness and assessment of sediment deposition to aid pipeline design

(formerly HA 219/09)

Revision 1

Summary
This document sets out the optimum design of highway drainage pipelines, based on sediment transport, in terms of roughness coefficient and velocity. It provides an assessment of the volume of sediment deposition that can occur in proposed and existing pipelines.

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
1	Mar 2020	Revision 1 (March 2020) Revision to update references only. Revision 0 (June 2019) CD 523 replaces HA 219/09. This full document has been re-written to make it compliant with the new Highways England drafting rules.

Foreword

Publishing information

This document is published by Highways England.

This document supersedes HA 219/09, which is withdrawn.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 document examines the key parameters used in the hydraulic design of pipelines and provides further guidance in determining optimum design, based on sediment transport, in terms of roughness coefficient and velocity.

The structural design of pipes for road drainage is described in CD 533: Determination of pipe and bedding combinations for highway drainage CD 533 [Ref 2.I].

The introduction of sumpless gullies, see CD 527 [Ref 4.I], led to a change of drainage philosophy to reduce maintenance where practical and improve the quality of surface water run off from the carriageway. The elimination of the gully sump can lead to an improvement in water quality but can potentially increase the amount of sediment entering the drainage system. By improving the ability of the pipeline to transport sediment, there is scope to reduce the number or frequency of catchpits and to trap sediment at more centralised locations where it can be removed without recourse to the major traffic management associated with lane closures.

In pipes with no sediment deposits, the pipe discharge capacity may be reduced by up to 4% due to increased energy losses caused by the movement of sediment along the pipe invert (see Construction Industry Research and Information Association (CIRIA) Report CIRIA R141 [Ref 1.I]).

Sediment deposition in the pipe has a more pronounced impact resulting from the combination of reduced cross-sectional area and an increase in bed roughness. Where the depth of deposition represents a small proportion of the pipe diameter, then the in loss of discharge capacity is primarily due to the increased bed roughness.

The sediment loads monitoring study Sediment Loads [Ref 3.I] confirmed that land use has a significant effect on the volume of sediment entering the drainage system, and that there is a marked difference in volume between rural and urban locations. However existing land use is a changeable factor, both in terms of time and distance along a road. During the life of a road, adjacent rural areas may easily change from being grazing grounds (grassland) to forested areas, for example. It is unwise to base the design of the drainage system on factors that cannot be controlled.

Assumptions made in the preparation of this document

The assumptions made in GG 101 [Ref 1.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 GG 101 [Ref 1.N].

Symbols

Symbols

Symbol	Definition
D	Pipe diameter (mm)
d	Sediment size (mm)
d_h	Hydraulic diameter (m)
d_{50}	Nominal sediment size (mm)
k_b	Roughness coefficient of deposited bed (mm)
k_c	Composite roughness coefficient (mm)
k_g	Value of k_s associated with particles deposited in sediment bed
k_0	Roughness coefficient of pipe walls (mm)
k_s	Colebrook-White equation roughness coefficient
mg/l	Milligrams per litre
P_0	Length of pipe wall exposed to water
R	Hydraulic radius (flow area divided by the wetted perimeter)
Re	Reynolds number (dimensionless)
s	Specific gravity of sediment particles
T	Temperature
u	velocity based on pipe cross section area (m/s)
v_m	Minimum flow velocity
W_b	Width of deposited bed (mm)
y	Depth of deposited bed (mm)
λ	Darcy Weisbach flow friction factor
λ_b	Sediment bed friction factor
λc	Composite friction factor
λ_0	Pipe wall friction factor

Terms and definitions

Terms

Term	Definition
Darcy Weisbach	An equation relating head loss due to friction to average flow velocity for an incompressible fluid.
Froude number	The ratio between inertial and gravitational forces.
Head loss	Loss of energy in the flow within a pipeline due to deviations from a straight line or obstructions.
Reynolds number	The ratio between inertial and viscous forces.
Sediment load	The amount of sediment accumulating on the paved surface and expressed in g/m^2/annum.
Sediment concentration	The amount of sediment contained within the pipe flow expressed as mg/l.
Self cleansing velocity	The minimum velocity required to prevent sediment deposition in pipes.
Specific gravity	The ratio between the weight of a substance and the weight of an equal volume of water at 4^oC.

1. Scope

Aspects covered

1.1 The requirements contained in this document shall be applied to the design of piped drainage for use on motorway and all-purpose trunk roads.

1.2 The design shall determine the optimum design for sediment transport in terms of pipe roughness coefficient and velocity.

Implementation

1.3 This document shall be implemented forthwith on all schemes for road drainage on the Overseeing Organisation's motorway and all-purpose trunk roads according to the implementation requirements of GG 101 [Ref 1.N].

Health and safety

1.4 Safety risk mitigation measures shall follow the ERIC hierarchy - eliminate, reduce, isolate and control for each identified safety risk.

Use of GG 101

1.5 The requirements contained in GG 101 [Ref 1.N] shall be followed in respect of activities covered by this document.

2. Sediment transport

Design

Sediment load

2.1 Pipelines shall be designed to transport sediment.

NOTE *Urban roads, which have been found to create more sediment than rural roads, generate maximum values in the order of 200 g/m² per annum, about 90 g/m² per annum of which is retained in gully pots Sediment Loads [Ref 3.I].*

Sediment concentration

2.2 A value of sediment concentration shall be inserted into the assessment calculation based on evidence or the default value of 50 mg/l, refer to the note below.

NOTE *The value of sediment concentration obtained for rural roads corresponds approximately to the 'medium concentration' recommended in CIRIA CIRIA R141 [Ref 1.I] for sewer design, that is 50 mg/l, whereas for urban roads it is approximately 115 mg/l, a value that is still well below the 'high concentration' value given in CIRIA (200 mg/l). This indicates that sediment concentration levels in UK road drainage are comparable with the average values associated with other surface water sewers.*

Methodology to assess sediment load

2.3 The methodology adopted to assess sediment load shall use sediment sizes as surrogate parameters for the type of location factor, i.e. urban versus rural.

NOTE *Measurements of sediment loads at these two types of location showed that sediment from urban roads has an average sizes of 0.5 mm whereas sediment coming from rural surrounds tends to be larger, with an average size of 0.9 mm.*

2.4 Sediment sizes of 0.5 mm for urban locations and 0.9 mm for rural locations shall be used in the calculation the sediment volumes.

2.5 Carrier pipes shall be designed to achieve 'self-cleansing' conditions that either prevent sediment from depositing or allow a certain amount of deposition, that is not detrimental, and produce a balance between the processes of deposition and erosion during a specified period.

2.5.1 A simplified approach given in CIRIA CIRIA R141 [Ref 1.I] may be used which assumes a bed deposit equal to 2% of pipe diameter.

Sediment transport

2.6 Highway drainage pipelines shall be designed to transport sediment.

NOTE *A thorough evaluation of the various sediment transport equations has been carried out and presented in CIRIA CIRIA R141 [Ref 1.I] . This shows that the equation 2.6N1, developed from data collected in pipes with diameters in the range 150 to 450 mm, gave prediction values that were closer to the six sets of laboratory data than most of the other equations and produced smaller standard deviations. Calculations using this equation involve two stages:*

1) *the roughness of the sediment bed is first determined and then used to calculate the hydraulic resistance of the pipe;*
2) *the sediment concentration is calculated from the known flow conditions. The resistance of the bed (which is composed of grain resistance and of form resistance caused by the development of dunes) was found to be dependent on the grain mobility factor and on the Froude number of the flow.*

Equation 2.6N Minimum flow velocity

$$v_m = \sqrt{\frac{(8k_g)(s-1)d}{\lambda}}$$

2.6.1 To calculate the sediment transport capacity of the pipe, the particle Reynolds number should be determined using equation 2.6.1.

Equation 2.6.1 Calculation of Reynolds number

$$Re = u\frac{d_h}{v}$$

NOTE This equation has been adopted in the simplified guidance given in Part B of CIRIA CIRIA R141 [Ref 1.I] . In effect, this 'equation' requires the determination of a long set of parameters using iterative procedures which are only practical to carry out by means of a computer program. For details of the full equation and its associated parameters see CIRIA CIRIA R141 [Ref 1.I]

3. Pipe roughness coefficients

General

3.1 The hydraulic design of pipelines shall allow for a depth of deposited sediment equivalent to 2% of the pipe diameter.

3.1.1 The effect of the bed roughness should be accounted for in the design of pipelines to include the overall roughness of the pipe, or its composite roughness k_c .

NOTE The presence of sediment increases the roughness coefficient to a value above the one associated with the pipe material only, k_0 .

3.1.2 The roughness coefficient of the sediment bed, k_b, may be estimated using an equation developed from laboratory tests on pipe full flows:

Equation 3.1.2 Roughness coefficient of the sediment bed

$$k_b = 5.62R^{0.61}d_{50}^{0.39}$$

NOTE Of the various methods used for calculating the composite roughness, the most reliable is probably that which uses the perimeter weighting of the Darcy-Weisbach friction factors for the bed and pipe walls. This takes into account the proportional weights of the two types of roughness and their hydraulic contribution to friction losses and is given as:

Equation 3.1.2N Composite friction factor

$$\lambda_c = \frac{\lambda_o P_o + \lambda_b W_b}{P_o + W_b}$$

3.1.3 Where the composite friction factor λ_c is known, the composite roughness k_c may be calculated from the following simplified formula:

Equation 3.1.3 Composite roughness

$$k_c = 3.7D\left[10^{-\left(\frac{1}{4}\lambda c\right)0.5}\right]$$

NOTE 1 The values of composite roughness coefficient obtained for two different assumptions of pipe wall roughness can be found in Tables 3.1.3Na and 3.1.3Nb.

NOTE 2 The two different assumptions of pipe wall roughness:

1) *the design condition k_0 = 0.6mm*
2) *deteriorated condition due to pipe ageing and misalignment k_0 = 2.1mm.*

Table 3.1.3N2a : Values of composite roughness for design condition k_o = 0.6mm

d_{50} (mm)	D (mm)	y (mm)	W_b (mm)	k_c (mm)
0.5	150	3	42	2.1
0.5	200	4	56	2.2
0.5	225	4.5	63	2.3
0.5	250	5	70	2.3
0.5	275	5.5	77	2.4
0.5	300	6	84	2.4
0.5	350	7	98	2.5
0.5	375	7.5	105	2.5
0.5	400	8	112	2.5
0.5	450	9	126	2.6
0.5	500	10	140	2.6
0.5	525	10.5	14	2.7
0.5	600	12	168	2.7
0.5	675	13.5	189	2.8
0.5	700	14	196	2.8
0.5	750	15	210	2.8
0.5	800	16	224	2.9
0.5	825	16.5	231	2.9
0.5	900	18	252	2.9
0.9	150	3	42	2.6
0.9	200	4	56	2.7
0.9	225	4.5	63	2.8
0.9	250	5	70	2.8
0.9	275	5.5	77	2.9
0.9	300	6	84	2.9
0.9	350	7	98	3.0
0.9	375	7.5	105	3.1
0.9	400	8	112	3.1

Table 3.1.3N2a : Values of composite roughness for design condition k_o = 0.6mm (continued)

d_{50} (mm)	D (mm)	y (mm)	W_b (mm)	k_c (mm)
0.9	450	9	126	3.2
0.9	500	10	140	3.2
0.9	525	10.5	147	3.2
0.9	600	12	168	3.3
0.9	675	13.5	189	3.4
0.9	700	14	196	3.4
0.9	750	15	210	3.5
0.9	800	16	224	3.5
0.9	825	16.5	231	3.5
0.9	900	18	252	3.6

Table 3.1.3N2b : Values of composite roughness coefficient for deteriorating condition (ageing and misalignment) k_o = 2.1mm

d_{50} (mm)	D (mm)	y (mm)	W_b (mm)	k_b (mm)	k_c (mm)
0.5	150	3	42	39.1	4.2
0.5	200	4	56	46.6	4.4
0.5	225	4.5	63	50.1	4.5
0.5	250	5	70	53.4	4.6
0.5	275	5.5	77	56.6	4.7
0.5	300	6	84	59.7	4.7
0.5	350	7	98	65.5	4.9
0.5	375	7.5	105	68.4	4.9
0.5	400	8	112	71.1	5.0
0.5	450	9	126	76.4	5.1
0.5	500	10	140	81.5	5.2
0.5	525	10.5	147	83.9	5.2
0.5	600	12	168	91.1	5.4
0.5	675	13.5	189	97.8	5.5
0.5	700	14	196	100	5.5
0.5	750	15	210	104.3	5.6
0.5	800	16	224	108.5	5.6
0.5	825	16.5	231	110.6	5.7
0.5	900	18	252	116.6	5.8
0.9	150	3	42	49.2	4.8
0.9	200	4	56	58.6	5.1
0.9	225	4.5	63	63.0	5.2
0.9	250	5	70	67.1	5.3
0.9	275	5.5	77	71.1	5.4
0.9	300	6	84	75	5.5
0.9	350	7	98	82.4	5.6
0.9	375	7.5	105	86	5.7
0.9	400	8	112	89.4	5.8

Table 3.1.3N2b : Values of composite roughness coefficient for deteriorating condition (ageing and misalignment) k_o = 2.1mm (continued)

d_{50} (mm)	D (mm)	y (mm)	W_b (mm)	k_b (mm)	k_c (mm)
0.9	450	9	126	96.1	5.9
0.9	500	10	140	102.5	6.0
0.9	525	10.5	147	105.6	6.1
0.9	600	12	168	114.5	6.2
0.9	675	13.5	189	123	6.3
0.9	700	14	196	125.8	6.4
0.9	750	15	210	131.2	6.5
0.9	800	16	224	136.5	6.5
0.9	825	16.5	231	139.1	6.6
0.9	900	18	252	146.6	6.7

4. Head loss in hydraulic design

4.1 The design of pipelines for highway drainage shall allow for the head losses in the pipeline.

4.1.1 The velocities required to maintain sediment transport and minimise deposition are a function of pipe gradient and should be expressed as either a minimum velocity or a minimum gradient.

NOTE 1 Minimum velocities have been determined on the assumption of continuous straight pipelines. However, as part of the design, changes in direction of the pipe are necessary and these result in a reduction in flow velocity or head loss.

NOTE 2 Loss of energy or head loss occurs wherever there is an impact on the flow within the pipe or channel. Local losses that occur in highway drainage systems can typically be associated with the presence of bends and junctions in pipes, entry to and exit from manholes/chambers/gully pots and exit at outfalls.

NOTE 3 Local losses are approximately proportional to the square of the flow velocity, V, and it is common practice to assign to them a non-dimensional loss coefficient K, which results from the division of the head loss by the velocity parameter $V^2/2g$ (kinematic head).

Table 4.1.1N3 Values of K

Inlet	
straight run	0.50
angled 90º	1.50
angled 60º	1.25
angled 45º	1.10
angled 22.5º	0.70
Manhole	
straight run	0.15
angled 90º	1.00
angled 60º	0.85
angled 45º	0.75
angled 22.5º	0.45

NOTE 4 Tables 4.1.1N4a to 4.1.1N4d present the minimum velocities and associated pipe gradients for the various cases/conditions of straight pipe runs. The procedure followed in the production of these tables is contained in Appendix A.

Table 4.1.1N4a Urban - Design conditions k_o = 0.6mm

Pipe diameter (mm)	Minimum V (m/s)	Slope
150	0.47	1/304
200	0.52	1/362
225	0.54	1/387
250	0.56	1/411
275	0.58	1/433
300	0.60	1/455
350	0.63	1/496
375	0.65	1/515
400	0.66	1/534
450	0.69	1/570
500	0.72	1/603
525	0.73	1/619
600	0.78	1/640
675	0.84	1/641
700	0.86	1/640
750	0.90	1/638
800	0.94	1/635
825	0.96	1/633
900	1.02	1/625

Table 4.1.1N4b Rural - Design Conditions k_o = 0.6mm

Pipe diameter (mm)	Minimum V (m/s)	Slope
150	0.41	1/363
200	0.44	1/463
225	0.45	1/511
250	0.46	1/558
275	0.47	1/603
300	0.48	1/646
350	0.50	1/730
375	0.51	1/771
400	0.52	1/810
450	0.53	1/887
500	0.55	1/961
525	0.56	1/997
600	0.58	1/1100
675	0.60	1/1190
700	0.60	1/1212
750	0.62	1/1256
800	0.63	1/1298
825	0.64	1/1319
900	0.66	1/1379

Table 4.1.1N4c Urban - Deteriorated conditions k_o = 2.1mm

Pipe Diameter (mm)	Minimum V (m/s)	Slope
150	0.45	1/256
200	0.50	1/306
225	0.52	1/328
250	0.54	1/349
275	0.56	1/369
300	0.58	1/388
350	0.61	1/424
375	0.63	1/441
400	0.64	1/457
450	0.67	1/488
500	0.70	1/518
525	0.71	1/532
600	0.76	1/550
675	0.82	1/551
700	0.84	1/551
750	0.88	1/549
800	0.92	1/546
825	0.94	1/544
900	1.00	1/537

Table 4.1.1N4d Rural - Deteriorated Conditons k_o = 2.1mm

Pipe Diameter (mm)	Minimum V (m/s)	Slope
150	0.40	1/304
200	0.43	1/391
225	0.44	1/433
250	0.45	1/473
275	0.46	1/512
300	0.47	1/550
350	0.49	1/623
375	0.50	1/659
400	0.51	1/694
450	0.52	1/760
500	0.54	1/825
525	0.54	1/856
600	0.56	1/947
675	0.59	1/1025
700	0.59	1/1045
750	0.61	1/1083
800	0.62	1/1120
825	0.63	1/1138
900	0.65	1/1190

NOTE 5 *Data collected during the Sediment Loads Monitoring Study Sediment Loads [Ref 3.I] revealed that, within the various rural locations, there was a wide range of average sediment sizes depending on the land use of the surrounding areas. The maximum average sediment size measured corresponded to adjacent grassland and had d_{50}=2.15mm. Additional computer simulations were carried out to assess the effect of the larger sediment size on minimum velocities and pipe gradients and these are summarised in Table 4.1.1N5.*

Table 4.1.1N5 Rural - design conditions: d_{50} = 2.15mm k_o = 0.6mm

Pipe Diameter (mm)	Minimum V (m/s)	Slope
150	0.41	1/316
200	0.46	1/363
225	0.49	1/383
250	0.51	1/402
275	0.53	1/429
300	0.54	1/461
350	0.56	1/524
375	0.57	1/554
400	0.58	1/584
450	0.59	1/641
500	0.61	1/696
525	0.62	1/723
600	0.64	1/802
675	0.66	1/876
700	0.66	1/900
750	0.68	1/947
800	0.69	1/993
825	0.69	1/1016
900	0.71	1/1081

NOTE 6 When compared with similar conditions, but having smaller sediment size (see Table 4.1.1N4b), the larger sediment particle size necessitates higher minimum flow velocities and steeper pipe gradients.

5. Assessment of sediment deposition

5.1 The requirements of the Overseeing Organisations shall be followed for assessing the volume of sediment that can enter the drainage system.

NOTE Overseeing Organisation specific requirements related to assessment of the volume of sediment that can enter the drainage system can be found in the National Application Annexes.

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	Highways England. GG 101, 'Introduction to the Design Manual for Roads and Bridges'

7. Informative references

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

Ref 1.I	CIRIA. CIRIA R141, 'Design of sewers to control sediment problems'
Ref 2.I	Highways England. CD 533, 'Determination of pipe and bedding combinations for drainage works'
Ref 3.I	Atkins Ltd. Sediment Loads, 'Monitoring of Sediment Loads from High Speed Roads'
Ref 4.I	Highways England. CD 527, 'Sumpless gullies'

Appendix A. Procedure to develop tables for the design of pipes in average and deteriorated condition

A1 Pipe roughness coefficient (k_0):

Determination of a suitable baseline value for the pipe roughness coefficient, k_0, to be used in the design, and which is representative of any pipe material likely to be used in road drainage: Although a wide range of materials is available, a value of k_0 = 0.6 mm is commonly used to represent the pipe roughness average conditions when new.

Determination of a suitable value for the pipe roughness coefficient, k_0, which is representative of the deteriorated pipe condition (ageing plus misalignment): The effect of ageing was taken into account by increasing the roughness coefficient to 1.5 mm and an additional increase of 0.6 mm for misalignment. This corresponds to a step of 14-18 mm at the pipe joint and raises the total value of the coefficient to 2.1 mm.

A2 Composite pipe roughness k_c:

Sediment load and type of location (rural versus urban) was represented by using a sediment size of 0.5 mm for urban roads and 0.9 mm for rural roads: The corresponding values of composite pipe roughness, k_c, due to the presence of the sediment, were calculated for the range of pipe sizes typically available for use in road drainage (150 mm to 900 mm).

A3 Temperature value T and specific gravity:

A suitable temperature value for the water needed to be stated as this affects the value of viscosity and friction losses in the pipes. A value of T=15ºC was adopted. Also an appropriate value for the specific gravity of the sediment needed to be determined. From the Sediment Loads Monitoring Report Sediment Loads [Ref 3.I], the average particle density was determined as being 2,220 kg/m^3 for both rural and urban locations. A value of specific gravity of 2.22 was subsequently used in all simulations.

A4 Transport equation for deposited bed:

Refer to equation 1 in Chapter 3 of CIRIA R141 [Ref 1.I] to obtain minimum flow velocities V and associated pipe gradients.

Drainage
Design

CD 523
England National Application Annex to CD 523 Determination of pipe roughness and assessment of sediment deposition to aid pipeline design

(formerly HA 219/09)

Revision 1

Summary
This National Application Annex sets out the Highways England specific requirements for estimating the volume of sediment that accumulates on the carriageway surface and potentially enters the drainage system.

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
1	Mar 2020	Revision 1 (March 2020) Update to references only. Revision 0 (June 2019) Highways England National Application Annex to CD 523.

Foreword

Publishing information

This document is published by Highways England.

This document presents the Highways England-specific requirements in relation to the assessment of sediment deposition within the context of DMRB document CD 523, and replaces any such reference to this subject in HA 219/09, which is 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 amount of sediment that may accumulate on the carriageway and be washed into the drainage system. The parameters in this document have been derived from site trials in England. The derived geographical factors are based on rainfall, soil type and general topography and hence only apply to England.

Assumptions made in the preparation of the document

The assumptions made in GG 101 [Ref 1.N] apply to this document.

Abbreviations and symbols

Abbreviations

Abbreviations

Abbreviation	Definition
HADDMS	Drainage Data Management System

Symbols

Symbols

Symbol	Definition
B_p	Primary Bed Load
B_s	Specific Bed Load
F_g	Geographical Location
F_l	Land Use
F_p	Profile
F_r	Road Size
$\tau_{deposition}$	Critical stress for deposition
$\tau_{erosion}$	Critical stress for erosion

E/1. Assessment of the sediment deposition in existing drainage to prioritise maintenance

E/1.1 The volume of sediment entering the drainage system shall be assessed.

NOTE A method of assessing the sediment load in existing pipelines is provided in Appendix E/A and worked examples included in Appendix E/B.

E/2. 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. GG 101, 'Introduction to the Design Manual for Roads and Bridges'

E/3. Informative references

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

Ref 1.I	Highways England. MCHW, 'Manual of Contract Documents for Highway Works'
Ref 2.I	Atkins Ltd. Sediment Loads, 'Monitoring of Sediment Loads from High Speed Roads'
Ref 3.I	Highways England. CD 532, 'Vegetated drainage systems for highway runoff'

Appendix E/A. Assessment of the sediment deposition in existing drainage to prioritise maintenance

E/A1 General

The parameters below have been derived from site trials in England. The derived geographical factors are based on rainfall, soil type and general topography and hence only apply to England.

E/A1.1 Sediment deposition in pipes

The volume of sediment deposited in the pipeline, the primary bed load (B_p), is the volume of sediment annually generated by an area of road and is taken to be 0.05 kg/m^2 per annum according to the report "Monitoring of sediment loads from high speed roads" Sediment Loads [Ref 2.I].

To determine the predicted sediment load for a section of road, the specific bed load (B_s), the primary bed load is multiplied by the sum of four weighted factors.

These factors are:

1) Land use (F_l);
2) Geographical location (F_g);
3) Road size (F_r); and
4) Profile (F_p).

A coefficient, or weighting, is then applied in the formula to represent the influence these factors have on sediment deposition.

The figures are then inserted into the following equation (in kg/m^2):

Land uses and factors (F_l) are:

1) Rural general (adjacent land has a mixture of uses): 1.0
2) Rural grassland (adjacent land is predominantly covered with grassland): 0.9
3) Rural arable (adjacent land is used for arable farming): 0.1
4) Rural forested (adjacent land has a very high number of trees): 0.35

A weighting of 50% is applied to the land-use factors.

Geographical location and factors (F_g) are:

1) South West: 1.0
2) London, South and SE: 0.1
3) East Anglia: 17.0
4) Midlands: 4.2
5) NE and Yorkshire: 6.2
6) Lancs, Cumbria and NW: 1.5

A weighting of 35% is applied to the geographical location factors.

Road size and factors (F_r) are:

1) 2-lane carriageway: 0.4
2) 3-lane carriageway: 1.0
3) 4-lane carriageway: 12

A weighting of 10% is applied to the road size factors.

Profile and factors (F_p) are:

1) level: 56.0
2) cutting: 1.0
3) embankment: 1.2.

A weighting of 5% is applied to profile factors.

Equation E/A.1 Total site specific bed load

$$B_s = B_p(F_l + F_g + F_i + F_p)$$

To calculate the total site specific bed load, insert the weighted factors into the following equation (in kg/m^2):

Equation E/A.2 Weighted site specific bed load

$$B_s = B_p[(0.5F_l) + (0.35F_g) + (0.1F_i) + (0.05F_p)]$$

The proportion of the generated sediment that enters the gully (B_{sg}) has been measured as being 40% of the total sediment load, hence (in kg/m^2):

Equation E/A.3 Gully retained sediment proportion

$$B_{sg} = 0.4B_s$$

For sediment removal refer to Clause 521 MCHW [Ref 1.I] .

This procedure provides an indication of the volume of sediment that may enter a section of pipeline. Refer to the sediment predictor spreadsheet and input the particular pipe line characteristics to determine whether or not sediment deposition is likely to occur. This suggests the cleaning frequency for the pipeline. Note this does not indicate that the pipeline needs replacing.

E/A1.2 Sediment predictor spreadsheet

This spreadsheet contained in the drainage data management system (HADDMS) offers a simple way to determine the likelihood of sedimentation in a piped network. It is based on a simple shear stress calculation, as bed shear stress has been found to be linked to the erosion and deposition of solids in pipes, each of which are initiated at critical shear stresses, which depend on the characteristics of the solids concerned.

Note that this method is only applicable to circular pipes. It does not predict sedimentation in gullies.

Bed shear stress is linked to velocity of flow. Erosion of existing sediment is initiated when the velocity rises and the bed shear stress exceeds the critical stress for erosion, $\tau_{erosion}$. Similarly, sediment is deposited when the shear stress falls below the critical stress for deposition, $\tau_{deposition}$, at lower flows. In between the two, sediment remains in suspension (Bouteligier et al.). The spreadsheet compares bed shear at various depths of flow with the critical values to indicate susceptibility to erosion or deposition.

This view is simplified, largely because it ignores whether there is sediment available to be deposited or eroded, and the capacity of the flow to transport solids. This, however, is the province of a detailed time-stepping model and is beyond a simple spreadsheet solution.

The inputs needed are simple:

1) pipe reference (text),
2) pipe diameter (in mm),
3) pipe roughness (equivalent sand roughness k_s in mm),
4) pipe gradient (decimal),

5) sediment particle size (d_{50} in mm),
6) sediment specific gravity (dimensionless).

These can be input manually or copied from another source such as the output of a design model. Two other pieces of data are needed:

Deposition and erosion factors (dimensionless, defaults provided)

These factors:

$\gamma_{deposition}$ = 0.08;

$\gamma_{erosion}$ = 0.28

are used to calculate the critical shear stresses, and can be varied to calibrate the spreadsheet in particular cases where the critical values are known from laboratory tests or other sources such as published literature for similar solids.

The results are presented in 'traffic light' form. Detailed instructions are included in the spreadsheet.

The spreadsheet should be used as part of a risk assessment. The first stage of this would be to identify whether the catchment is at risk of causing significant washoff of solids. If so, the representative particle size and specific gravity need to be determined, preferably using samples collected on site. If site-specific data are not available, a range of values should be used.

The spreadsheet then identifies any pipe lengths that are susceptible to deposition. If possible, these should be redesigned to eliminate the risk, generally by steepening the gradient. If this is impractical or excessively expensive, it may be worth commissioning a more detailed model to identify the risk and any improvements needed in greater detail.

Should the potential for sediment deposition remain following redesign, then alternative methods of preventing or reducing the volume of sediment entering the pipeline, need to be investigated. It may be that, in these circumstances, a pipeline is not the most appropriate drainage system.

Appendix E/B. Sediment prediction - worked examples

Removal of sediment from the drainage system is a routine maintenance activity that needs to be programmed. Being able to assess the volume of sediment that may enter the drain at certain locations should assist in this programming. The volume of sediment entering the piped system can be estimated from the formulae in Appendix E/A.

E/B1 Example 1 (an extreme case)

To estimate the volume for a 2.5 km section of 3-lane motorway constructed at grade through a rural arable site in Essex.

The land use factor for rural arable is 0.1

The geographical location factor for East Anglia is 17.0, the road size factor for a 3-lane carriageway is 1.0 and the profile factor for a road at grade is 56.0.

The appropriate weightings are applied to the factors and inserted into the equation.

The total site specific bed load is calculated from:

$B_s = B_p(F_l + F_g + F_r + F_p)$ kg/m^2

$B_s = 0.05$ x([0.1x50%] + [17x35%] + [1x10%] + [56x5%]) kg/m^2

$B_s = 0.445$ kg/m^2 per annum

Paved area = 30.3m (29+paved c/r) x 2,500 m

Sediment load = 0.445 x 30.3 x 2,500 kg/m^2

Sediment load = 33,931.25 kg

or

33.9 tonnes per annum

or

13.6 kg/m run or 13.6 tonne/km

The proportion entering the gullies is 40%

$B_{sg} = 0.4 \times B_s$

$B_{sg} = 0.4 \times 33.9$ Tonnes

$B_{sg} = 13.56$ Tonnes

E/B2 Example 2

To estimate the volume of sediment generated for a 1.8 km section of 2-lane motorway on embankment through grassland in Shropshire.

The land use factor for rural grassland is 0.9

The geographical location factor for Shropshire is 4.2, the road size factor for a 2-lane motorway is 0.4 and the profile factor for a road on embankment is 1.2.

The appropriate weightings are applied to the factors and inserted into the equation.

The total site specific bed load is calculated from:

$B_s = B_p(F_l + F_g + F_r + F_p)$ kg/m^2

$B_s = 0.05$ x([0.9x50%] + [4.2x35%] + [0.4x10%] + [1.2x5%]) kg/m^2

B_s = 0.101 kg/m^2 per annum

Paved area = 22.8m (21.5 + paved c/r) x 1,800m

Sediment load = 0.101 x 22.8 x 1,800 kg/m2

Sediment load = 4,145.04 kg

or

4.14 tonnes per annum

or

2.3 kg/m run or 2.3 tonnes per km

The proportion entering the gullies is 40%

B_{sg} = 0.4 x 4.14 tonnes = 1.66 tonnes

This volume of sediment will either be deposited in the pipe system, or, if not intercepted by a vegetative treatment system, CD 532 [Ref 3.I], enter the receiving water course.

Drainage
Design

CD 523
Northern Ireland National Application Annex to CD 523 Determination of pipe roughness and assessment of sediment deposition to aid pipeline design

(formerly HA 219/09)

Revision 0

Summary
There are no specific requirements for Department for Infrastructure, Northern Ireland supplementary or alternative to those given in CD 523.

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

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Version	Date	Details of amendments
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Drainage
Design

CD 523
Scotland National Application Annex to CD 523 Determination of pipe roughness and assessment of sediment deposition to aid pipeline design

(formerly HA 219/09)

Revision 0

Summary
There are no specific requirements for Transport Scotland supplementary or alternative to those given in CD 523.

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

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Llywodraeth Cymru
Welsh Government

Drainage
Design

CD 523
Wales National Application Annex to CD 523 Determination of pipe roughness and assessment of sediment deposition to aid pipeline design

(formerly HA 219/09)

Revision 0

Summary
There are no specific requirements for Welsh Government supplementary or alternative to those given in CD 523.

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

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