Norfolk Partnership Laboratory
Part of the Norse Group

Pavement design and construction Guide for Estate Roads (Section 38) and Section 106/278 Works

Date Published: 17 May 2022

Introduction:

Norfolk Partnership Laboratory (NPL) is part of (Norse Highways) Norse Eastern Limited, a subsidiary of the Norse Group, a company wholly owned by Norfolk County Council. NPL has produced these notes as guidance for developers to aid them in the design of the pavements for adoption by Norfolk County Council.

If a developer wishes to put forward designs not covered by this guidance document, they shall be considered along with the other relevant documentation, this shall then be treated as a departure from standard and will require approval from Norfolk County Council before the works take place.

This document shall be read in conjunction with the various British & European Standards and also Highways England's Specification for Highway Works (SHW) and Design Manual for Roads and Bridges (DMRB). It should be noted that the DMRB has been up-dated as of the 1st April 2020, references in this document refer to those within the new design manual.

The Developer is required to demonstrate that the construction of the pavement is carried out as specified. The Developer shall demonstrate this with the relevant levels of testing and can demonstrate that they have achieved satisfactory results. In addition, the developer shall supply or make available the results to the Highway Authority (Norfolk County Council).

Any costs incurred in respect of sampling/testing shall be at the expense of the developer. All testing shall be carried out by a UKAS accredited laboratory holding accreditation for the relevant tests. Testing shall be carried out to the relevant British standard.

The County Highways Laboratory (i.e. Norfolk Partnership Laboratory) may be able to offer assistance to developers in undertaking sampling/testing work by arrangement (Tel **01603 578389**)

Developers are strongly advised to discuss all aspects of the work with the highway authority.

Once construction drawings are approved by the Highway authority, designs **shall only be changed by exception from that, of the approved submitted drawings**, when this does happen **approval from the overseeing authority is required.** If the overseeing authority approves the developer's request, the developer shall resubmit new amended drawings to the overseeing authority for its records.

Norfolk Partnership Laboratory
Part of the Norse Group

Table of Contents

Table of Amendments:

- February 2019 - Incinerator Bottom Ash Aggregate Section 3 - S Shearwood
- May 2019 - Up-date to testing requirements for sub-bases Section 9 - S Shearwood
- May 2019 - Up-date to PM5 and PM6 with regards to EME2 - S Shearwood
- June 2019 - Permeable pavements added to section 3 - S Shearwood
- June 2019 - Testing For adoption, Section 9, up-date on testing certificate requirements for capping's and sub-bases - S Shearwood
- June 2019 - Clarifications to trench testing - M Bumstead
- April 20 - References updated in line with the new Design Manual for Roads and Bridges (Pavements Volume) and the up-dated MCHW 800 series - S Shearwood
- June 2020 - Addition of Design guide for block paving to BS7533 - S Shearwood
- August 2020 - Addition of road widening detail, for construction outside the confines of the existing carriageway - S Shearwood
- June 2021 - Up-date to testing regime in section 10 - S Shearwood
- June 2021 - Additional IBAA test added to section 4 - S Shearwood
- July 2021 - Modification to trench testing, section 10.2 - M Bumstead
- July 2021 - Requirement for contractor to provide as-built drawings added Section 11 - S Shearwood
- May 2022 – Updated document to make it accessible for all readers – A Thorburn

1. Highway Condition Survey

The Developer shall, prior to implementation of the development, submit to the Council for its approval a Highway Condition Survey, which will identify the current condition of the Highway in the vicinity of the site to include:

A plan which identifies the area covered by the survey.

- A written report detailing the current condition of the roads and footways in the vicinity of the site.
- A list of Highway defects, prior to implementation of the development, including specific photographs, identifying the individual defects.
- A photographic overview of the roads and footways in the vicinity of the site.
- An estimate of the size, types, numbers and route of construction traffic expected to service the site, during the development period

Prior to first occupation of the development (trigger will vary according to phasing), the Developer will submit to the Council for its approval a post-development Highway Condition Survey of the area outlined in the Highway Condition Survey, to identify any damage to the highway caused during the development period, and a list of repairs which are subsequently required.

The Developer shall secure and agree the repairs with Norfolk County Council, in line with the Councils quality standards and rectify any damage caused to the highway during the period of the development. The repairs shall be completed by either the Developer or by procuring works through a contribution paid to the Council.

If the Developer chooses to carry out the work, the Developer will complete the repairs no later than the date approved in writing by the Council, as detailed in the post-development Highway Condition Survey.

If the Developer wishes not to procure the works then the Developer will pay to the Council an agreed contribution to pay for the repairs detailed in the agreed post development Highway Condition survey. The financial contribution shall be payable prior to first occupation of the development or on a date to be agreed by the Council.

It should be noted that Norfolk County Council are within their rights to (at approval of the pre or post Highway Condition survey reports) ask that a highway is renewed at the Developers expense to a depth, width and length as appropriate if that highway is:

- pre-construction, deemed inappropriate for the volume of Construction traffic expected

or.

- Post construction damaged beyond what localised repair methods can adequately resolve.

For post construction this would generally be when defects are present in greater than 40% of a given length/width resulting in localised repairs giving poor drainage/ride quality and/or an inadequate post works life. The depth of this repair would depend on whether there is surface and/or structural damage present.

2. Subgrade Assessment:

- Formation:

All sites should have had a ground investigation carried out for other aspects of the development. This should be consulted to assess likely soil types.

The primary input parameter for the design of pavement foundations is the Stiffness Modulus (Sm) of the sub grade. Sm is the standard method of measurement within the DMRB (CD225) and the standard method within the County of Norfolk.

Like a topographical survey, a Site Investigation (SI) is an essential pre-requisite for highway design, and it is a mandatory requirement in NHBC standards, see Chapter 4.1 clause D4. An SI will inform the soil type at formation level and ensure that soft and/or compressible soils are not present beneath formation level. For sites where a SI does not exist, a rapid and economical assessment of the latter can be made with the Dynamic Cone Penetrometer supplemented with window samples, hand augers, trial pits or a combination to a minimum depth of 3.0 meters below existing ground level.

Sub-grade Surface modulus (Sm) should be carried out at the assumed formation level to determine the thickness of the proposed road to be adopted. The Sm value should be established from the material in its Equilibrium condition (see CD225 CL2)

The Sub-grade surface modulus results should be presented to Norfolk County Council before the foundation of the pavement is formed. In order to prove the designed construction depths, this should be carried out at design stage so that the ground works are not delayed during the construction.

The Sm value for a particular type of soil commonly experiences seasonal variation. During dry conditions in the summer months, it may have a high value which may dramatically reduce during the wetter winter months. The value used to design a pavement foundation is a conservative value that takes account of: -

- Seasonal variation
- Long term equilibrium moisture conditions.
- Unfavourable moisture conditions during construction.
- The end-of-life condition when moisture ingress through a deteriorating pavement may be expected.

The following tables provide estimated values for long term Sm. Table CBR1 is generic and Table CBR2 refers to soils commonly found in Norfolk. Chart CBR3 shows the process for determining testing requirements.

- Table CBR1: Generic, Estimated Values of Equilibrium CBR.

(Table 5.1 of IAN 73/06 withdrawn)

Soil	PI (%)	Construction Thickness	Construction Thickness
		Thin (Estimated Sm)	Thick (Estimated Sm)
Heavy Clay	70	25	25
Heavy Clay	60	25	25
Heavy Clay	50	25	30
Heavy Clay	40	30	35
Silty Clay	30	35	44
Sandy Clay	20	45	50
Silt	Not applicable	<25	<25
Sand (poorly graded)	Not applicable	120	120
Sand (well graded)	Not applicable	140	140
Sandy gravel (well graded)	Not applicable	160	160

Note 1: Thick construction is a depth to sub grade of 1200mm, thin is a depth to sub grade of 300mm.

- A Guide to Determining Equivalent Sm values as derived from CD225

CBR (%)	<2	2	2.5	3	4	5	6	7	8	10	15	20	30	50
Subgrade modulus (MPa)	<25	25	30	35	45	50	55	60	65	75	100	120	155	215

Equation 2.4 CBR to subgrade surface modulus conversion (CD225)

$E = 17{:}6(CBR)^{0{:}64} MPa$

where:
E = estimated subgrade surface modulus
CBR = California bearing ratio (CBR) of the subgrade
NOTE Equation 2.4 is valid for CBR values in the range 2 to 12 per cent

- Table CBR2: Estimated Values of Equilibrium CBR.

(For Soils Commonly Found in Norfolk).

Soil	Estimated Sm
Alluvium (including Peat, Terrington Beds, Barroway Drove Beds and Breydon Formation)	<25 Invariably requires special consideration
Cover Silt	<30
Corton Till Member (Formally Corton Till, Happisburgh Till, Cromer Till or Brickearth)	25
Crag (cohesive)	25
Lowestoft Till (Boulder Clay)	35 to 45
Corton Formation Sand (Single sized sand with significant proportions of silt)).	50
Head	<25 to 100 Depending on the proportion of clay and/or silt.
Crag (non-cohesive)	65 to >100
Glacial Sands and Gravels inc Lowestoft Formation, Sheringham Cliffs Formation etc. (Graded sand and gravel)	>100
Chalk, dry and unworked.	>100
Chalk, worked and/or wet	<25 to 50 If it is allowed to dry the CBR will recover to >100

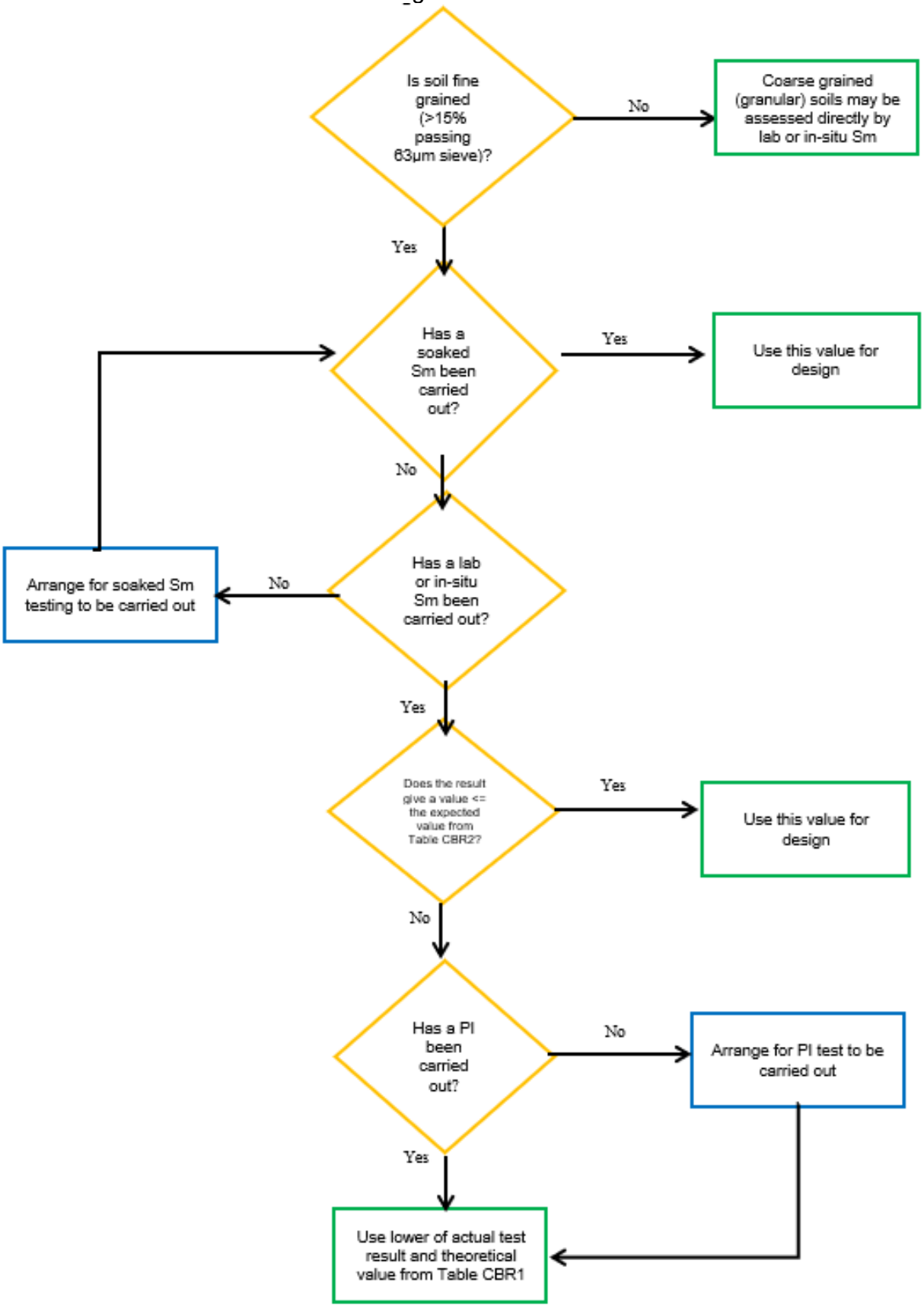
The use of un-soaked Sm values alone for pavement design on fine grained soils (clay and silt) should generally be avoided. This can lead to unrepresentatively high values in dry weather and unrepresentatively low values in wet weather.

To determine the appropriate Sm value for any site the procedure in flowchart CBR3 shall be adopted. All testing shall be carried out by a UKAS accredited testing laboratory.

Note: The use of soaked Sm shall be carried out unless **either** it can be shown that the soil is coarse grained **or** a thorough SI has been carried out that has identified the level of the water table, proven the material above the water table will not allow capillary attraction to formation level, Limits testing and Laboratory Sm's (or In-situ) have been carried out and the data correctly interpreted

.

- Chart CBR3 - Assessment of Subgrade Surface Modulus value



NOTE: This is not applicable where either alluvium or peat is present beneath site.

The following number of tests are considered appropriate for most sites (See Notes **1 and 2 below):**

Length of carriageway being designed	No of tests required
Less than 50 metres	2
50 to 150 metres	3
150 to 500 metres	Every 50 metres max.
500 to 1000 metres	At least 10 evenly spaced
Over 1000 metres	Every 100 metres max.

Note 1: Additional testing will be required if the geology is complex (more than 2 materials) or if unexpected soft spots are revealed.
Note 2: If the ground investigation indicates that peat or other soft alluvial deposits underlie the site special measures are likely to be needed. Sm's may not be required under these circumstances, Norfolk Partnership Laboratory should be consulted.

3. Pavement Design:

Although it has become common practice, the structure of new build sections of the highway network should not be taken from NCC standard details.

NCC standard details are intended for highway maintenance and Edge strengthening (haunching) schemes on established sections of the highway network; and not used for widening or new construction. Where construction is undertaken by NCC's contractors it will be supervised by NCC's client teams.

New build sections of the highway network (including haunches) should be designed using established design protocols. The most common procedures are described in 'The Design Manual for Roads and Bridges, Pavement's volume, CD225 Design of new pavement foundations and CD226 Design for new pavement construction.' Documents referred to can be downloaded from http://www.dft.gov.uk/ha/standards/dmrb/index.htm: In brief the procedure is:-

- Design the Highway Foundation:

Determine the equilibrium[Note1] surface modulus (Sm) of the sub grade and follow the procedure described in CD225 [Note2] to design the highway foundation.

For small schemes a 'Restricted Design' is required For larger schemes a 'Designed Foundation' is usual. On most S278 schemes a 'Restricted Design' is acceptable.

When the equilibrium Sm is less than 30 the sub grade must be improved. Common methods of sub grade improvement are:

The inclusion of a capping layer

- The inclusion of a Geogrid.
- Improvement by the addition of lime and/or cement.
- Additional capping

The underlying Geology and economics will determine which of the above methods are most suitable for a particular site.

- Design the Pavement:

Obtain the traffic flow [Note3] expressed as commercial vehicles/ lane/day (cv/lane/day). Calculate the design traffic using the method described in CD224 and follow the design procedure in CD226 to design the 'pavement'. Typically, the pavement consists of the asphalt base, binder course and surface course.

The Polished Stone Value (PSV) of the chippings in chipped surface courses or the coarse aggregate in unchipped surface courses should be determined from CD236 for A roads, Table PD11 for all other categories and comply with NCC's policy on PSV's held within this document.

Notes – Pavement Design:

1. The equilibrium Sm of the sub grade is the minimum that will be achieved on site; it is usually achieved during the winter months when the moisture content of the soil is greatest. (See Section 2 of this document for further information).
2. CD225 was formally Interim Advice Note 73/06 (IAN73/06) a draft of HD25.
3. Traffic flows are obtainable from Norfolk County Council's Traffic Survey Team on; trafficsurveys@norfolk.gov.uk
4. Traffic flows can also be found on Gov.uk
5. CD236 was formally Interim Advice Note 156/12 (IAN156/12)
6. CD226 was formally HD 26/06 - Pavement Design

- Permeable Pavements

Permeable pavements would generally not be permitted in the public highway and is only considered in exceptional circumstances upon the approval of a senior member of the Asset management team. The use of a permeable pavements will also carry the need for a large commuted sum for the continued maintenance of the system which will need to be programmed through the Asset management team.

4. Foundation Materials and Design**:**

Unbound Subbase: Unbound subbase is specified in the Specification for Highway Works (SHW). Brief descriptions appear in Table FD1.

- Table FD1: Unbound Subbase

Type	Specification	Permitted Aggregates
Type 1	SHW clause 803	Crushed rock, crushed slag, crushed concrete, recycled aggregates or well burnt non-plastic colliery shale
Type 2	SHW clause 804	Natural sands & gravels, crushed rock, crushed slag, crushed concrete, recycled aggregates or well burnt non-plastic colliery shale
Type 3	SHW clause 805	Blast furnace slag
Type 4	SHW clause 807	Recycled aggregates containing asphalt arising's.

Notes:

- Crushed flint gravel is not normally a permitted constituent of Type 1 subbase.
- Type 2 mixtures containing natural sands & gravels are not permitted on developer schemes administered by NCC.
- Where Recycled aggregate or recycled concrete is used in unbound mixtures in accordance to Cl 802to 807 (SHW) as appropriate, it shall have been tested in accordance with Cl 710(SHW) and Shall comply with the requirements of Table 8/3 (SHW).
- All materials shall meet the manufactures declared grading limits for the product

Bound Subbase and capping's: bound sub-base and Capping's are specified in the Specification for Highway Works (SHW). Brief descriptions appear in Table FD2.

- Table FD2: Bound Subbase's and Capping's

Specification	Description
SHW clause 614	Cement Stabilisation to Form Capping
SHW clause 615	Lime Stabilisation to Form Capping
SHW clause 643	Lime and Cement Stabilisation to Form Capping
SHW clause 821	Cement Bound Granular Mixtures A
SHW clause 822	Cement Bound Granular Mixtures B
SHW clause 823	Cement Bound Granular Mixtures C (CBGM C)
SHW clause 840	Soil Treated by Cement (SC), Soil Treated by Slag (SS), Soil Treated by Fly Ash (SFA) and Soil Treated by Hydraulic Road Binder (SHRB)

- Incinerator Bottom Ash Aggregate (IBAA):

The use of IBAA should meet with the requirements of the Environment Agency's RPS 247 which **regulates the use of IBAA.** Where the use of all IBAA (or blends of IBAA) is used in the construction, its location shall be recorded and will be issued to the **overseeing** authority.

The use of IBAA should not be used in footpath areas unless it has over 100mm of **asphalt** above it. The IBAA shall have had a three-week mellowing period after leaving the incinerator or have a pH no greater than 10.5 Before it can be used.

All Aggregate shall comply with BS EN 13242 and the relevant Clauses in the 800 series of the Specification for Highway Works. In addition to this, the following test should be carried out:

- Aluminium particles

Mixtures containing manufactured aggregates, other than air-cooled blast furnace slag and steel slag, covered with less than 150mm asphalt shall meet the requirements of table 4.1 below:

- Table 4.1 Requirements for mixtures containing manufactured aggregates

Constituent	Requirement	Test Procedure
Aluminium particles	Non-Retained on the 14mm sieve	

The following test procedure shall be followed:

I. Obtain a test portion in accordance with BSEN932.-1 1997, with a minimum mass of 10kg.

II. Pass the test portion over a 14mm test sieve conforming to BSEN932-2 1999, discard particles passing the 14mm sieve.

III. Spread the particles retained on the 14mm sieve onto a clean flat surface.

IV. Separate by hand any aluminium particles and agglomerated particles that contain a portion of aluminium.

   a. Discard non-aluminium particles and agglomerated particles that do not contain a portion of aluminium.

   b. Place any aluminium particles in a tray.

V. Separate the aluminium fraction from the agglomerated particles.

   a. Add any non-separated agglomerated particles to the tray

   b. Discard any resulting non-aluminium fraction.

   c. Re-pass any resulting aluminium fraction over the 14mm sieve and discard particles passing the 14mm sieve.

d. Any resulting aluminium fraction retained on the 14mm sieve to the tray.

VI. Particles in the tray are classified as aluminium particles retained on the 14mm sieve.

VII. The test report shall include the following information:

a. Reference to this clause, Or that of the 800 Series in the SHW.

b. Name and location of the sample source.

c. Date of sampling

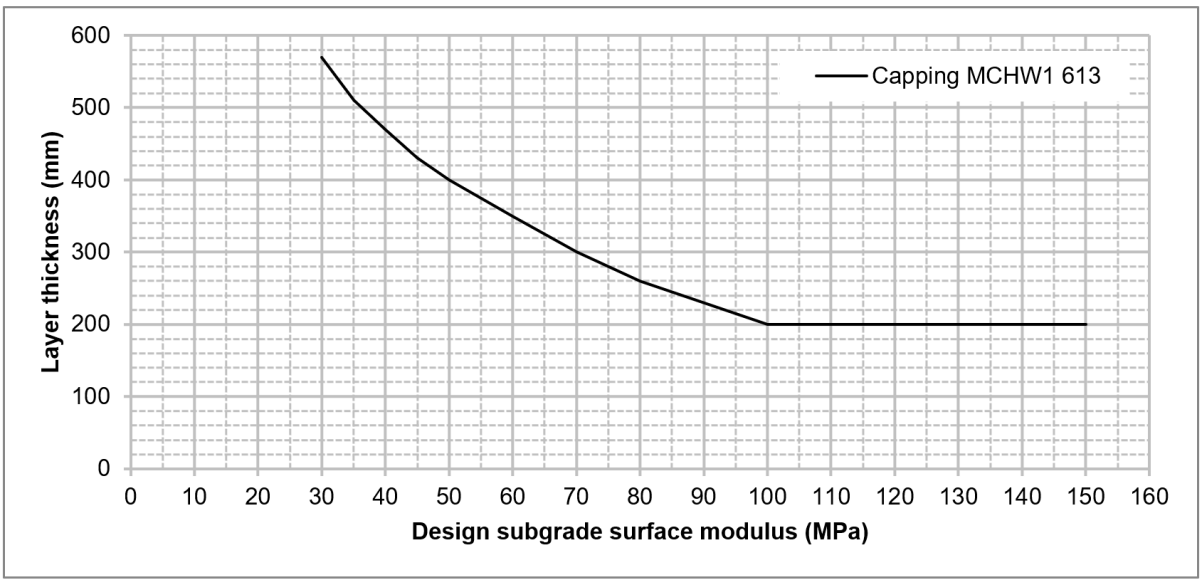
d. Mass of test portion (kg)

e. Date of Test

f. Number of aluminium particles retained on the 14mm sieve

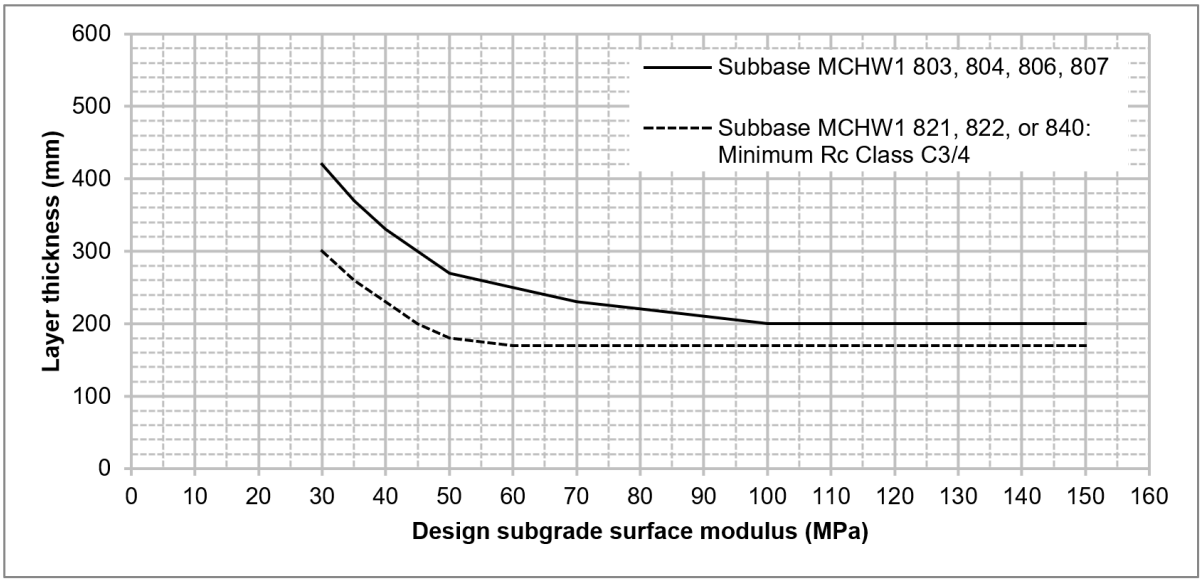
g. Description of any retained particles

- Table FD3: Restricted design options - class 1 capping only



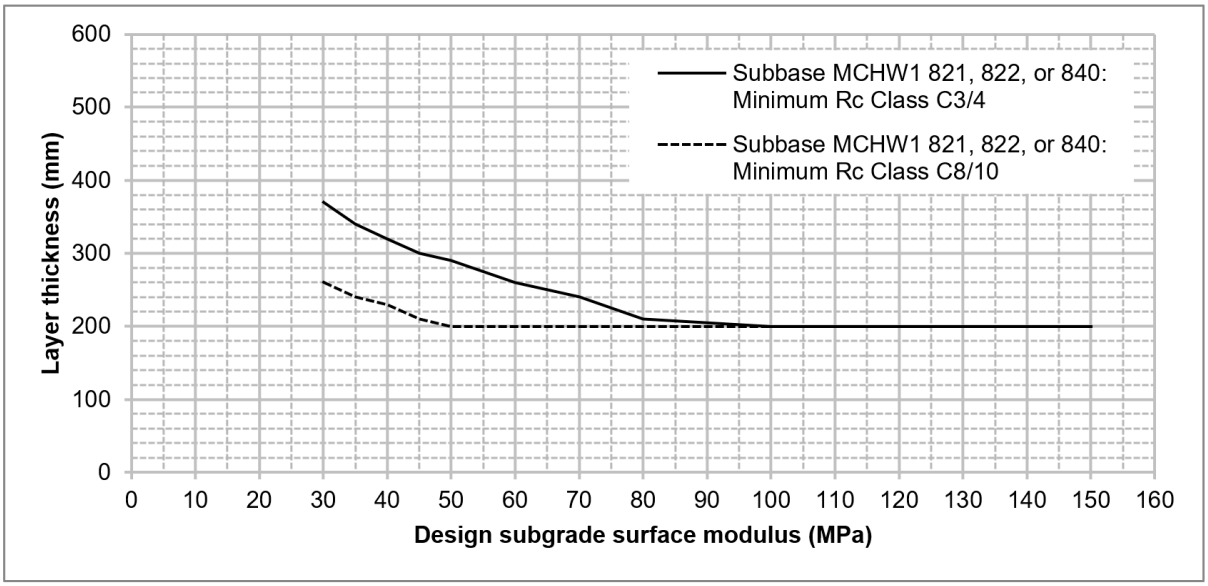
Where the design subgrade surface modulus is lower than 30 MPa, improvement of the subgrade shall be undertaken. Options for improvement of the subgrade include excavation and replacing between 500 to 1000 mm of the soft subgrade with granular fill, mechanical stabilisation (geogrids and/or geotextiles) and soil stabilisation.

- Table FD4: Restricted design options - class 2 subbase only



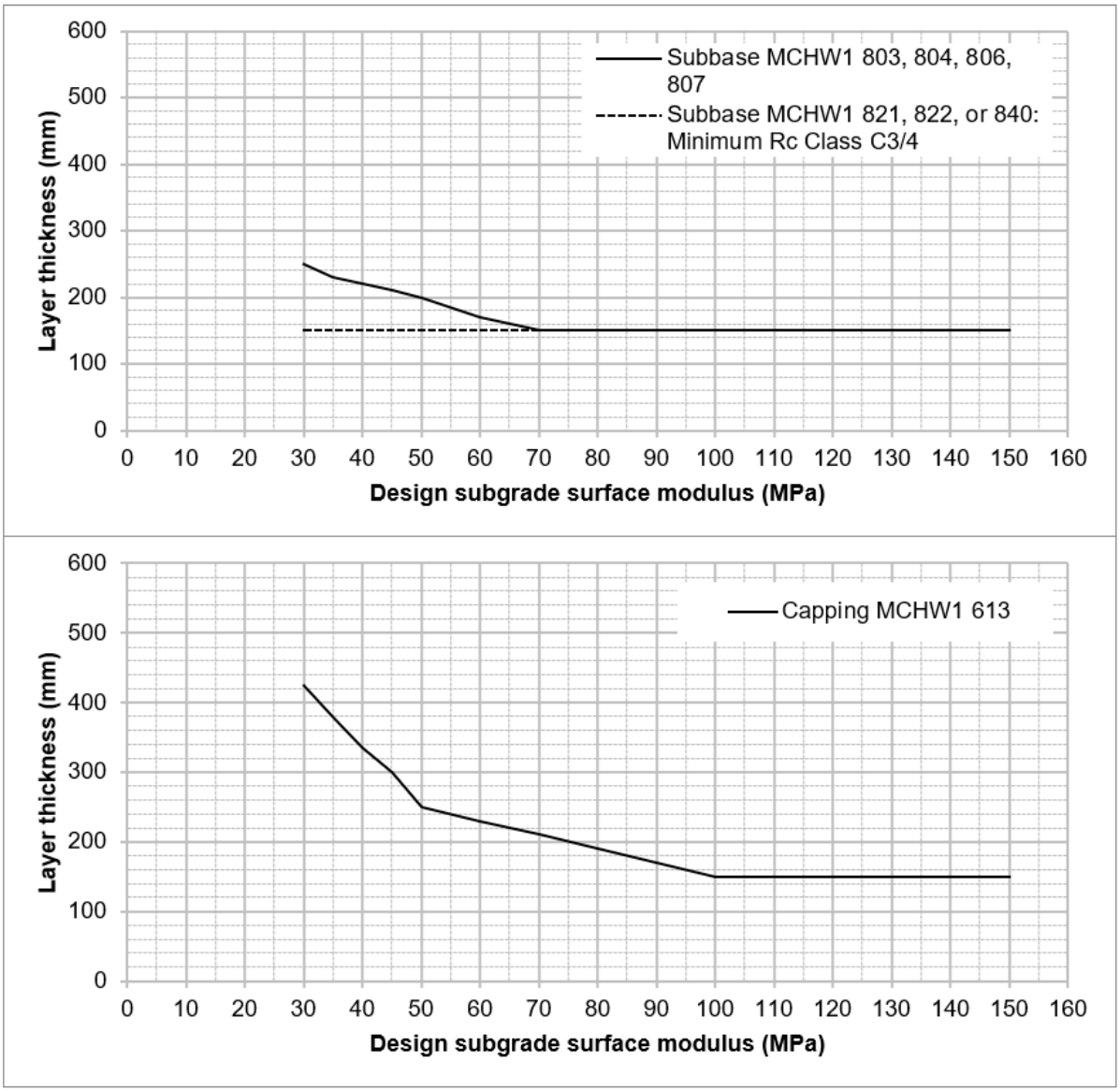
Where the design subgrade surface modulus is lower than 30 MPa, improvement of the subgrade shall be undertaken. Options for improvement of the subgrade include excavation and replacing between 500 to 1000 mm of the soft subgrade with granular fill, mechanical stabilisation (geogrids and/or geotextiles) and soil stabilisation.

- Table FD5: Restricted design options - class 3 subbase only



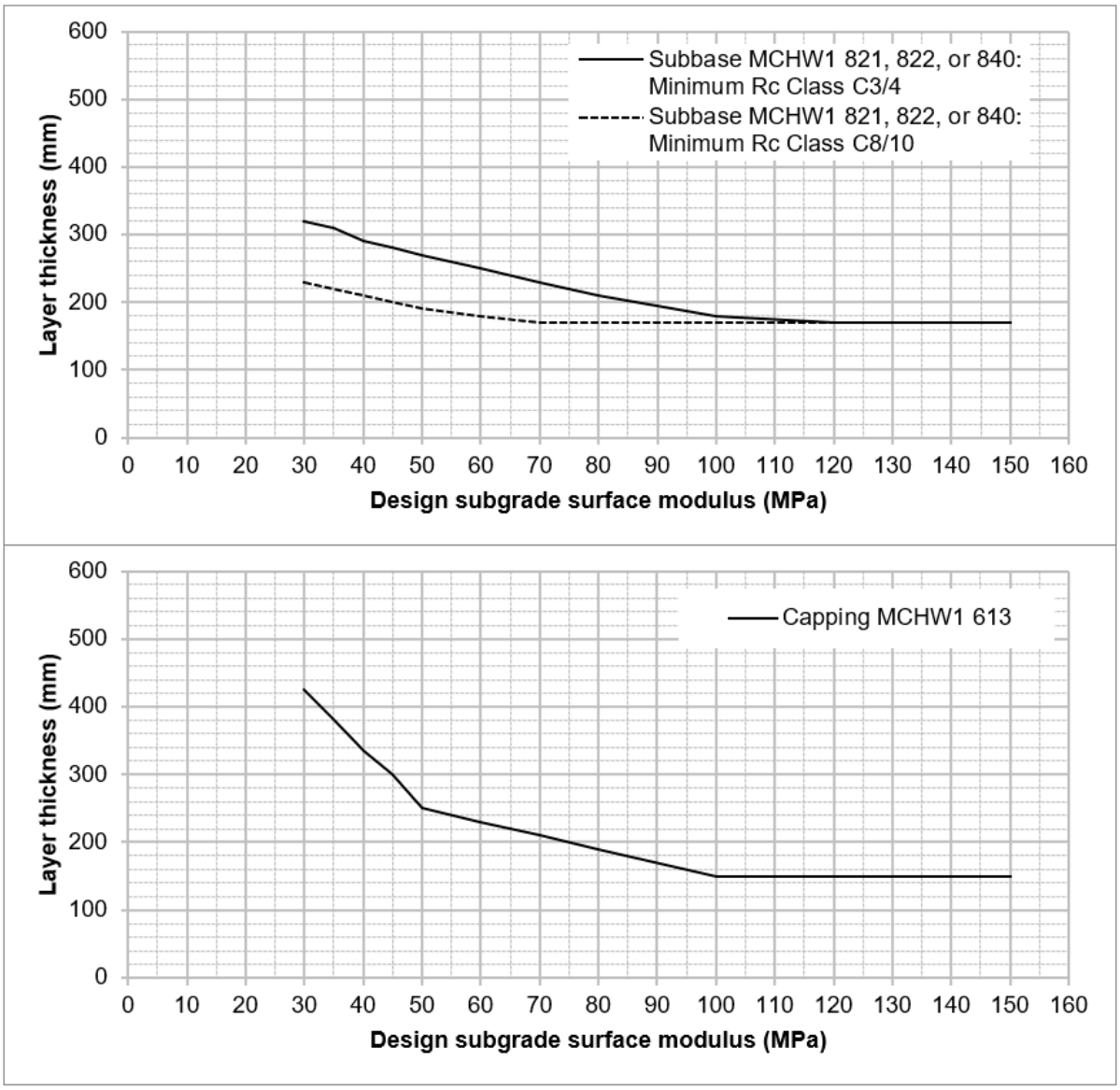
Where the design subgrade surface modulus is lower than 30 MPa, improvement of the subgrade shall be undertaken. Options for improvement of the subgrade include excavation and replacing between 500 to 1000 mm of the soft subgrade with granular fill, mechanical stabilisation (geogrids and/or geotextiles) and soil stabilisation

- Table FD6: Restricted design options - class 2 subbase on capping



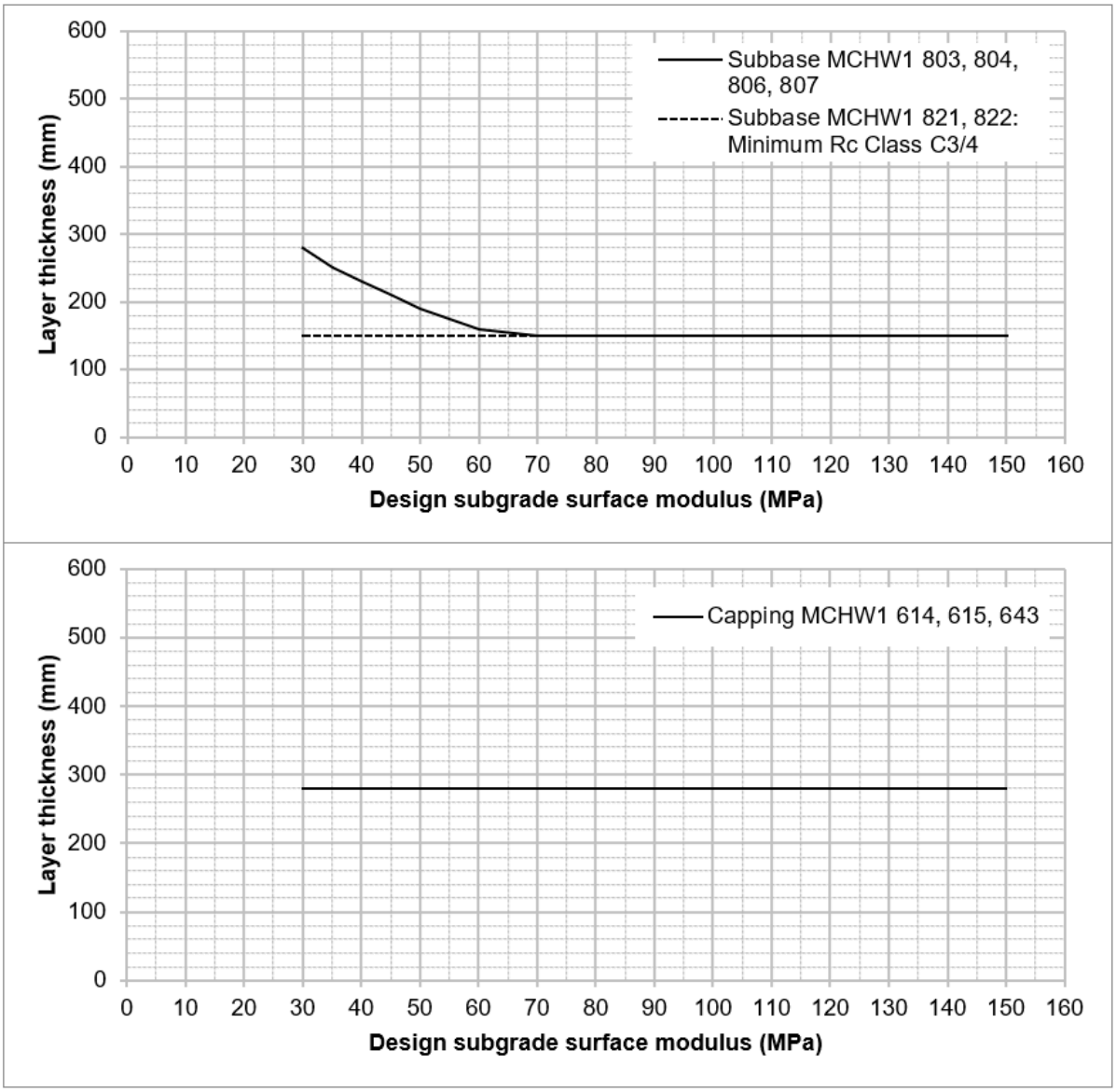
Where the design subgrade surface modulus is lower than 30 MPa, improvement of the subgrade shall be undertaken. Options for improvement of the subgrade include excavation and replacing between 500 to 1000 mm of the soft subgrade with granular fill, mechanical stabilisation (geogrids and/or geotextiles) and soil stabilisation.

- Table FD7: Restricted design options - class 3 subbase on capping



Where the design subgrade surface modulus is lower than 30 MPa, improvement of the subgrade shall be undertaken. Options for improvement of the subgrade include excavation and replacing between 500 to 1000 mm of the soft subgrade with granular fill, mechanical stabilisation (geogrids and/or geotextiles) and soil stabilisation

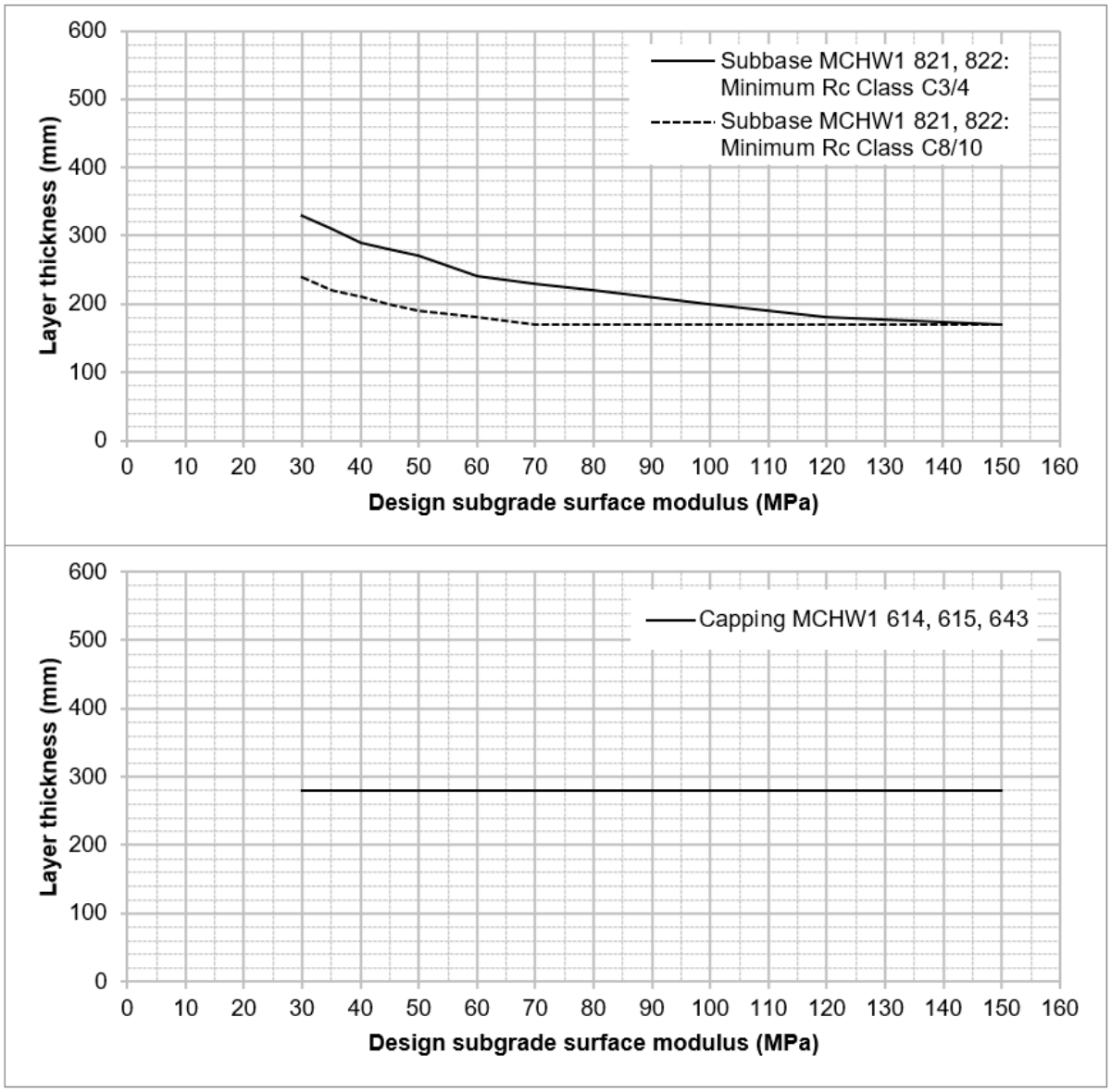
- Table FD8: Restricted design options - class 2 subbase on bound capping



Where the design subgrade surface modulus is lower than 30 MPa, improvement of the subgrade shall be undertaken. Options for improvement of the subgrade include excavation and replacing between 500 to 1000 mm of the soft subgrade with granular fill, mechanical stabilisation (geogrids and/or geotextiles) and soil stabilisation

Where a restricted design is proposed with a bound capping and unbound sub-base, the designer needs to consideration how the unbound sub-base will drain, where the foundation is confined within kerbs or similar.

- Table FD9: Restricted design options - class 3 subbase on bound capping



Where the design subgrade surface modulus is lower than 30 MPa, improvement of the subgrade shall be undertaken. Options for improvement of the subgrade include excavation and replacing between 500 to 1000 mm of the soft subgrade with granular fill, mechanical stabilisation (geogrids and/or geotextiles) and soil stabilisation

➢ Foundation Design: **Performance** foundations

Foundations can be designed as per the charts above (FD3-9) as a restricted design. Restricted designs are thicker but have factors of safety built in that require less site testing on the end product but can cost more to construction costs.

A developer can propose a performance foundation in line with those set out in CD225 CL3.24-3.39. These designs need more thought but can in the long term save the developer money.

To achieve a performance design, continuous testing will be required to prove that the foundation has achieved the foundation class set out by the developer and their designers. Continuous testing methods are set out Series 800 of the MCHW.

Where a performance design is proposed with a bound capping and unbound sub-base, the designer needs to consider how the unbound sub-base will drain, where the foundation is confined within kerbs.

The highway authority will require developers to have firstly established a trial section, with the relevant testing carried out on the performance foundation to prove that the foundation meets the requirements before construction work begins. Once the trial section is built, data **SHALL BE** submitted for checking to the County Laboratory at the developers cost. Once approved by the laboratory, works may begin with the continuous testing methods in place to prove at any time that the foundation meets the requirement for the whole site.

➢ Foundation Design: Grids in foundations

The foundation design shall be carried out in accordance with CD225, or the design can include the use of a grid system. If a grid system is the chosen route by the developer, a design shall be submitted by the developer. The design shall have been carried out by the grid supplier and shall be presented to the Highway Authority for approval before construction. Where a grid is to be used, all utilities shall be in place before the grid is laid, or ducts provided through which the services can later be fed. The design document shall also lay out procedures where under exceptional circumstances a utility has to be placed after the grid has already been placed. In this event, moleing techniques should be used wherever possible. If not possible then the procedure shall layout the method of reinstatement of the grid and any minimum overlaps required of the grid system. Alternatively, in the event of shared surface carriageways, the grid shall be designed to be placed deep enough so that the utilities can be placed on top of the grid, therefore avoiding future cutting of the grid, this is to avoid legacy issues

N.B it should be noted that all services which are planned to be beneath the grid system shall be installed before the placement of the grid.

Where services are placed at a later point (or service connections) the grid system shall be placed back in the pavement foundation, over the service with suitable overlaps of the grid with the minimum width as required by the grid supplier.

In the event that services are to be laid in shared surfaces, it shall be agreed with the Highway Authority as to how the grid is to be positioned, this is so that the pavement foundation is not compromised continuously.

- Haunches construction:

Care should be taken where haunch widths are <0.8m. Thought should be given to the compaction of the new foundation and the asphalt layers by the designer at design stage (e.g. does compaction equipment suitable to achieve compaction fit into the widening?).

NCC standard for widths <0.8m is to use ST1 for the foundation and the base, the design should represent this in such occasions, based on the sub-grade stiffness modulus.

It is strongly advised that an asphalt reinforcement grid is placed into any road widenings, the grid should be place equal distance over the longitudinal joint between the old and new construction at a depth where it shall be effective. The idea of the grid is to reduce longitudinal cracking where a haunch is added to the edge of the exiting carriageway

The location of longitudinal surfacing joints shall comply with MCHW Cl 903 (excerpt below)

- Longitudinal joints

The following should be followed regarding the location of longitudinal joints

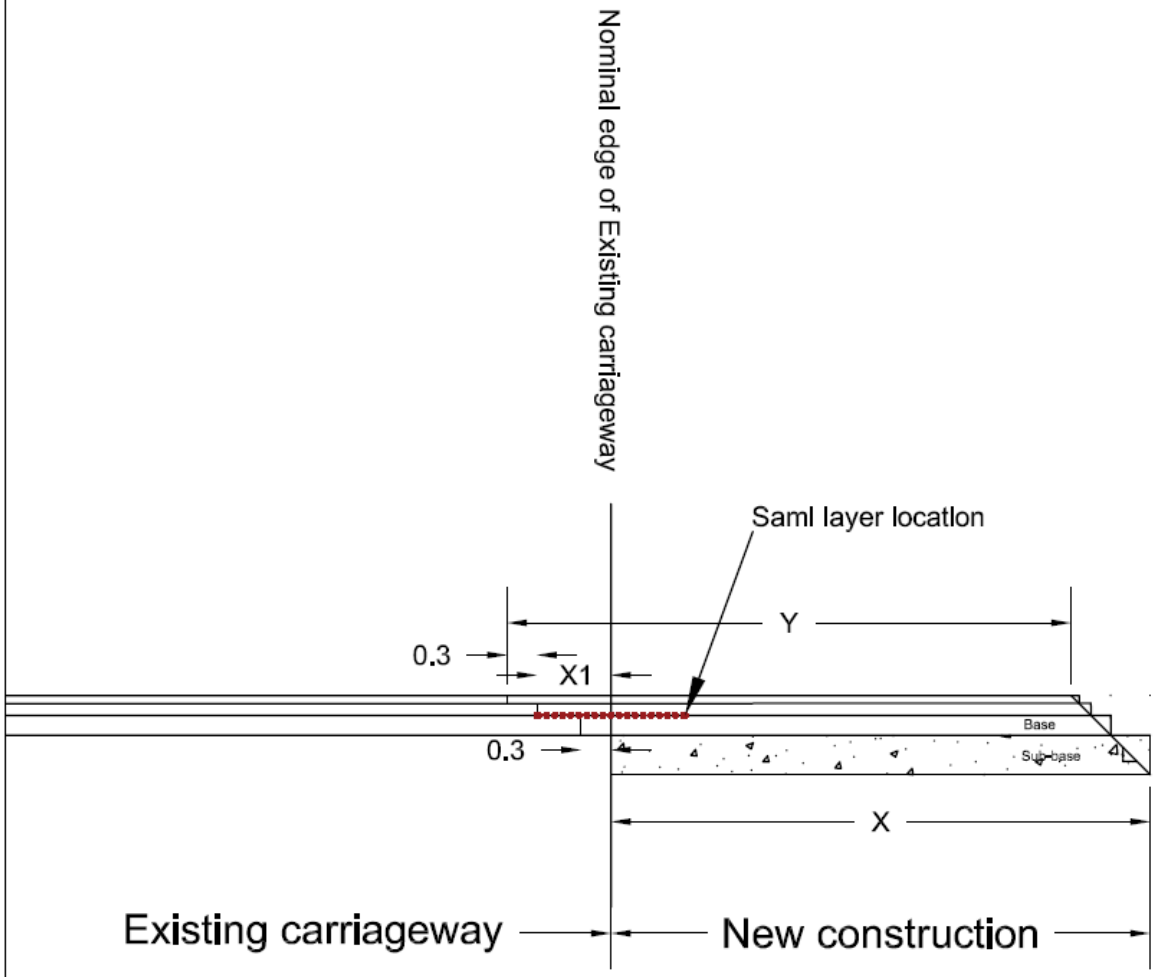
(05/18) ***Joints***

21 *(05/18) For new pavement construction, all longitudinal joints in all layers shall be situated outside wheel track zones. Where an existing road pavement is resurfaced, joints in the surface course shall coincide with either the lane edge, the lane marking, or the middle of a traffic lane, whichever is appropriate. Joints shall not coincide*

with the wheel path. For the purposes of this Clause, the wheel-track zones shall be taken to be between 0.5 m and 1.1 m and between 2.55 m and 3.15 m from the centre of the nearside lane markings for each traffic lane (or, in the absence of lane markings, lane edges). All joints shall be offset at least 300 mm from parallel joints in the layer beneath.

Norfolk Partnership Laboratory
Part of the Norse Group

Typical Road Widening Detail



Notes:

1) Foundatlon thlckness should be deslgned In accordance with this document, based on the equlllbrlum value of Sm. where a grld ls proposed for the foundation, the design shall be slte speclflc based on the Equlllbrlum value of Sm.
2) Where the foundatlon wldth (x) ls less than 0.8m, consideration should be given to using ST1 rather than sub-base to achieve compaction of the foundation.
3) Where no kerb is to be installed at the new edge of the carriageway, New edge of carriageway is to be stepped at a ratio of 1:1.
4) The Base layer may be also substituted with ST1 where the width is less than 0.8m, this will requlre the base layer thlckness to be redeslgned.
5) A Stress Absorbing Membrane Interlayer (SAMI) should be laid on the base layer at a point, which was the previous edge of the carriageway to delay/stop a longitudinal reflectlve crack appearlng In the future.
6) The step width of "X1" should be wide enough to accommodate the SAMI layer Into the existing pavement.
7) Layer steps shall be a minimum of 0.3m per layer at the tle-In polnts.
8) The location of the joint at "Y" should be located to comply with Cl903, Sub-clause 21.
9) Bond coats shall be placed on all bound layers in accordance with the rates specified in BS594987.
10) All material specifications shall be supplied, Includlng the penetratlon of the blnder and the PSV of the surface course material.

Foundation Worked Examples

Example 1 Restricted Design:

Long term Sm =25MPa (Equilibrium value)

Short term Sm=50MPa (value at construction)

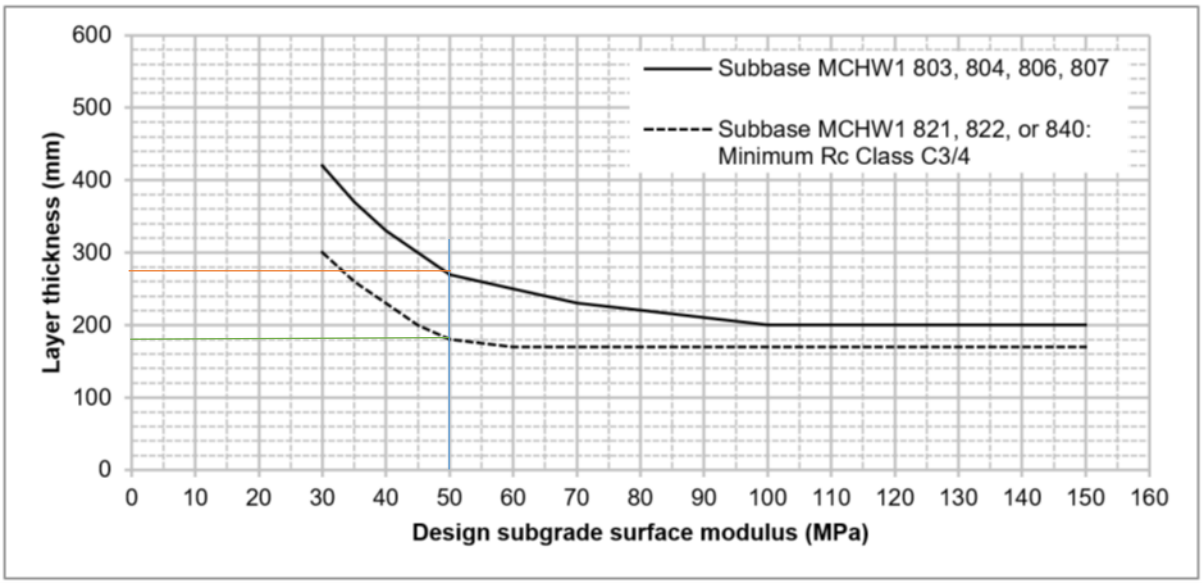
Therefore, design Sm =25MPa

Designing a class two restricted foundation as per FD4

This would require an improvement layer (cl2.7 (CD225))

An improvement layer of 500mm of capping is carried out, Sm is measured on top of the improvement layer and found to be 75MPa.

The foundation then can be redesigned using a design subgrade surface modulus of 50MPa. As of note 2 after Cl3.12, (CD225) (even though it measures 75MPa). As note 2 implies you can go back to a one-layer foundation after ground improvements is carried out, as the value is now at 50MPa



Therefore, sub-base is either

- 280mm of Cl 803,804,806 or 807

Or

- 180mm of C3/4 Cl 821, 822 or 840

On a layer of capping 500mm thick, tested to prove it achieves 50MPa

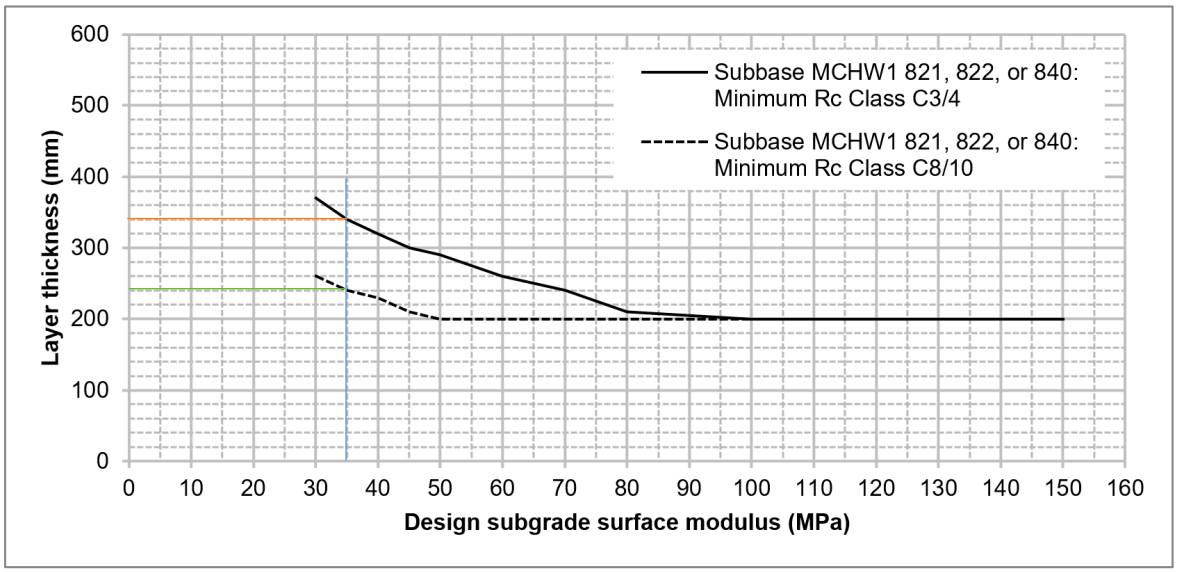
Example 2 Restricted design

Long term Sm =35MPa (Equilibrium value)

Short term Sm=60MPa (value at construction)

Therefore, design Sm =35MPa

Designing to a class three restricted foundation as per table FD5



Therefore, sub-base is either

- 340mm of C3/4 Cl 821, 822 or 840
- Or
- 240 of C8/10 Cl 821, 822 or 840

N.B. Where strengths exceed 8/10Nmm² at 28 days, crack induction shall take place as per clause 818 of the MCHW

5. Pavement Construction Materials and Design**:**

In recent years British Standards have been replaced by European Standards and materials technology has seen significant improvements/changes. Drawings and documents issued by NCC and Consulting Engineers do not always reflect these changes.

- Asphalt – Terminology:

A comparison between current and historic terminology appears in Table PD1.

- Table PM1 – Current Asphalt Terminology

Former UK (British Standard) Terminology	**Curent Terminology**	**Standard**
Bitumen Macadam	Asphalt Concrete (AC)	BSEN 13108-1 & PD6691(Annex B)
Hot Rolled Asphalt	Hot Rolled Asphalt (HRA)	BSEN 13108-4 & PD6691(Annex C)
Stone Mastic Asphalt	Stone Mastic Asphalt (SMA)	BSEN 13108-5 & PD6691(Annex D)
Thin Surface Course to the Specification for Highway Works, Clause 924. This material is commonly confused with SMA and only permitted on the Norfolk network by exception.	Not strictly specified in European Standards. Certified in the UK under the BBA/HAPAS approval scheme.	Specification for Highway works Cl 942
Not applicable	Enrobé Module Elévé 2 (EME2)	BSEN 13108-1 & PD6691(Annex B)

Asphalt – Standards: The composition of asphalt is described in BS EN 13108, it is divided into parts, see Table PD2 for the parts in common use in Norfolk.

- Table PM2 – Current British/European Standards

BS EN 13108 Part Number	Contents
Part 1	Specifies the composition of Asphalt Concrete (AC) (previously known as Bitumen Macadam in UK practice)
Part 4	Specifies the composition of Hot Rolled Asphalt (HRA)
Part 5	Specifies the composition of Stone Mastic Asphalt (SMA)

Because BS EN 13108 is problematic for designers & specifiers, *PD6691 'Guidance on the use of BS EN 13108 Bituminous Mixtures – Material Specifications'* should be used to specify bituminous mixtures.

Transport, laying and compaction of asphalt is specified in BS 594987. Nominal and minimum compacted thicknesses appear in Tables 1A, 1B, 1C and 1D.

Asphalt Surface Course: Historically chipped, 30/14 HRA surface course has proved to be a durable product. However, SMA is as durable and often preferable because:-

- It is quicker to install.
- A chipping gang is not required, and this may lead to cost savings.
- Health and Safety requirements may be less onerous.
- Traffic Management may be less onerous.
- It has greater deformation (rut) resistant.
- It provides a quieter surface than HRA.
- It can be laid thinner than HRA providing there is a commensurate increase in the thickness of the binder course e.g. a traditional build-up of 40mm of HRA surface course on 60mm of binder course could be specified as 35mm of SMA surface course on 65mm of binder course. Although this is likely to realise a cost saving, such a thin surface course **may not be practical** during the winter months.

Thin Surface Course (TSC) complying with the Specification for Highway Works is commonly confused with SMA. TSC is not usually as durable as SMA and TSC is **only permitted on the Norfolk network by exception** & site-specific approval.

Although surface course Asphalt Concrete (Dense Bitumen Macadam [DBM]) may be used on cycle ways and footways, **it is not an acceptable** material for use as a carriageway surface course. 6mm SMA will provide greater durability than DBM on a cycleway or footway.

- Asphalt – Allowable Materials and Nominal Thickness.

The following materials are specified for use on adoptable highways within Norfolk and should be installed to BS594987 & should comply with PD6691 Bituminous mixtures - material specification:

- Table PM3: Allowable asphalt materials

BS594987 reference	Nominal target Layer thickness	Additional notes
AC 32 dense/HDM/HMB Base/Bin	70–150	Base & binder course
AC 20 dense/HDM/HMB Base	50-100	Binder course
AC 10 EME2 base/bin	60–100	Base & binder course
AC 14 EME2 base/bin	70–130	Base-binder course
AC 20 EME2 base/bin	90–150	Base-binder course
HRA 50/10 reg/bin	25–50	Regulating & binder course
HRA 50/14 reg/bin	35–65	Regulating & binder course
HRA 50/20 bin/base	45–80	Base & binder course
HRA 60/20 bin/base	45–80	Base & binder course
HRA 60/32 bin/base	60–150	Base & binder course
AC 6 Dense Surf	20-30	Foot/Cycle Path only
HRA 15/10 F surf	30	Footpath only
HRA 30/10 F surf	35	Footpath only
HRA 55/10 surf	40	Carriageway
HRA 30/14 surf	40	Carriageway with PCC[1]
HRA 35/14 surf	45–50	Carriageway with PCC[1]
HRA 55/14 surf	45	Carriageway
SMA 6 surf	20–40	Foot/Cycle path and Carriageway
SMA 10 surf	25–50	Cycle path and Carriageway
SMA 14 surf	35–50	Carriageway
SMA 6 reg	15–40	Regulating course
SMA 10 reg	20–50	Regulating & binder course
SMA 14 bin/reg	30–60	Regulating & binder course
SMA 20 bin/base/reg	50–100	Base & binder course

Notes:

- PCC =Pre-coated Chips are required for 30/14 HRA and 35/14 HRA only.
- The use of Flint gravel Pre-coated chippings is strongly discouraged due to the poor affinity to bitumen and their low Polished Stone Values, other natural coloured chippings are available from suppliers in a higher PSV.
- Bond Coats conforming to BS594987 shall be applied between **all** bound layers of the carriageway pavement at the rates of spread specified in BS594987.
- HRA in areas of bus stops shall be avoided in the whole pavement construction due to the poor deformation resistance they offer from repeat loading.
- When using Imprinted thermoplastic, approval **shall be** gained by the overseeing authority's laboratory before use, the material shall be installed to comply with the manufacturer's instructions, and not laid thicker than specified by the manufacture.
- All unsupported Asphalt edges shall be either cut back or edge compacted using an edge compaction wheel.
- Texture depths shall be specified by the designer on the contract documents.
- Void Contents shall comply with those specified in PD6691.
    - SMA Binder = Core pairs = $V_{max\ 6.0,}$ Set of six cores = $V_{max\ 4.0.}$
    - SMA Surf = Vmin 1.5: Vmax 5.0
- Gravel mixtures shall have the appropriate adhesion agents in accordance with PD6691 C2.3.5 or C2.4 It should be noted that in the new DMRB CD226, Highways England have dropped Hot Rolled Asphalt binder and base course, it is **not** the intention of Norfolk County Council to follow suit.

- Joints

For new pavement construction, all longitudinal joints in all layers shall be situated outside wheel track zones. Where an existing road pavement is resurfaced, joints in the surface course shall coincide with either the lane edge, the lane marking, or the middle of a traffic lane, whichever is appropriate. Joints shall not coincide with the wheel path, the wheel-track zones shall be taken to be between 0.5 m and 1.1 m and between 2.55 m and 3.15 m from the centre of the nearside lane markings for each traffic lane (or, in the absence of lane markings, lane edges). All joints shall be offset at least 300 mm from parallel joints in the layer beneath.

- Warm Mix Asphalt

The use of warm mix Asphalt is allowable with the use of Straight run penetration grade bitumen's. Materials shall comply with Clause 903 (MCHW) "Warm Mix Asphalts (WMA)". Where Warm mix Asphalt is proposed to be used with a Polymer Modified Bitumen (PMB), then written conformation shall be required from the asphalt supplier that they are agreeable, and that it is within a suitable delivery distance.

Warm mix asphalt shall not be used in Hot Rolled Asphalt With pre-coated Chippings Applied.

Stone Mastic Asphalt Surface Course May also be mixed warm when they comply with the above.

A selection of surface course descriptions, designations and specification references appear in Table PM4; **others can be found in BS594987 tables 1A, 1B, 1C and 1D**.

- Table PM4: Examples of Surface Course Descriptions etc

Material Description	Designation	Specification
6mm dense surface course, 100/150 pen bitumen	AC 6 dense surf 100/150	PD6691 Annex B
10mm close graded surface course, 100/150 pen bitumen	AC 10 close surf 100/150	PD6691 Annex B
15/10 HRA surface course type F, recipe mixture 40/60 pen bitumen	HRA 15/10 F surf rec 40/60	PD6691 Annex C
30/14 HRA surface course type F designed mix, 40/60 pen bitumen	HRA 30/14 F surf des 40/60	PD6691 Annex C
55/14 HRA surface course type F designed mix, 40/60 pen bitumen	HRA 55/14 F surf des 40/60	PD6691 Annex C
6mm Stone Mastic Asphalt surface course with 40/60 pen bitumen and 60psv coarse aggregate	SMA 6 surf 40/60 psv60	PD6691 Annex C
10mm Stone Mastic Asphalt surface course with 40/60 pen bitumen and 65psv coarse aggregate	SMA 10 surf 40/60 psv65	PD6691 Annex C

N.B Values above are examples of the types of descriptions expected from the designer. Each site should be site specific and within the guidelines of this document and BS59987

Asphalt Binder Course: Historically HRA binder course has been used but Asphalt Concretes' (AC) such as designed DBM50 or designed HDM are preferable because: -

- AC has a higher Stiffness Modulus and hence, better load spreading characteristics.
- AC has greater resistance to deformation (rutting).
- AC may be cheaper than HRA

Where there is a significant risk of deformation (rutting) Stone Mastic Asphalt (SMA) binder courses are preferable.

Enrobé Module Elévé 2 (EME2) binder course is also acceptable, but it is likely to be too expensive for most developer led schemes. **EME2 comes in two binder types 10/20 and 15/25 only**.

A selection of binder course descriptions, designation and specification references appear in Table PM5; **others can be found in BS594987 tables 1A, 1B, 1C and 1D**.

➢ Table PM5: Examples of Binder Course Descriptions etc

Material Description	Designation	Specification
20mm dense binder course, 40/60 pen bitumen, designed mix.	AC 20 dense bin 40/60 des	PD6691 Annex B
20mm heavy duty binder course, 40/60 pen bitumen, designed mix.	AC 20 HDM bin 40/60 des	PD6691 Annex B
50/14 HRA binder course, 40/60 pen bitumen	HRA 50/14 bin 40/60	PD6691 Annex C
60/20 HRA binder course, 40/60 pen bitumen	HRA 60/20 bin 40/60	PD6691 Annex C
10 or 14 or 20mm Enrobé Module Elévé binder course, 15/25 or 10/20pen bitumen, designed mix	AC 10 or 14 or 20 EME2 bin 15/25(or 10/20) des	PD6691 Annex B
20mm Stone Mastic Asphalt binder course with 40/60 pen bitumen.	SMA 20 bin 40/60	PD6691 Annex C

N.B Values above are examples of the types of descriptions expected from the designer. Each site should be site specific and within the guidelines of this document and BS59987
Some of the products listed above can be used as both Binder course and Base, but SMA is not an option in the base layer

A selection of Base course descriptions, designation and specification references appear in Table PM6; others can be found in BS594987 tables 1A, 1B, 1C and 1D.

- Table PM6: Examples of Base Course Descriptions etc.

Material Description	Designation	Specification
32mm dense base, 40/60 pen bitumen, designed mix.	AC 32 dense base 40/60 des	PD6691 Annex B
32mm heavy duty base, 40/60 pen bitumen, designed mix.	AC 32 HDM base 40/60 des	PD6691 Annex B
60/20 HRA base, 40/60 pen bitumen	HRA 60/20 base 40/60	PD6691 Annex C
60/32 HRA base, 40/60 pen bitumen	HRA 60/32 base 40/60	PD6691 Annex C
10 or 14 or 20mm Enrobé Module Elévé base, 15/25 or 10/20 pen bitumen, designed mix	AC 10 or 14 or 20 EME2 base 15/25 (or 10/20) des	PD6691 Annex B

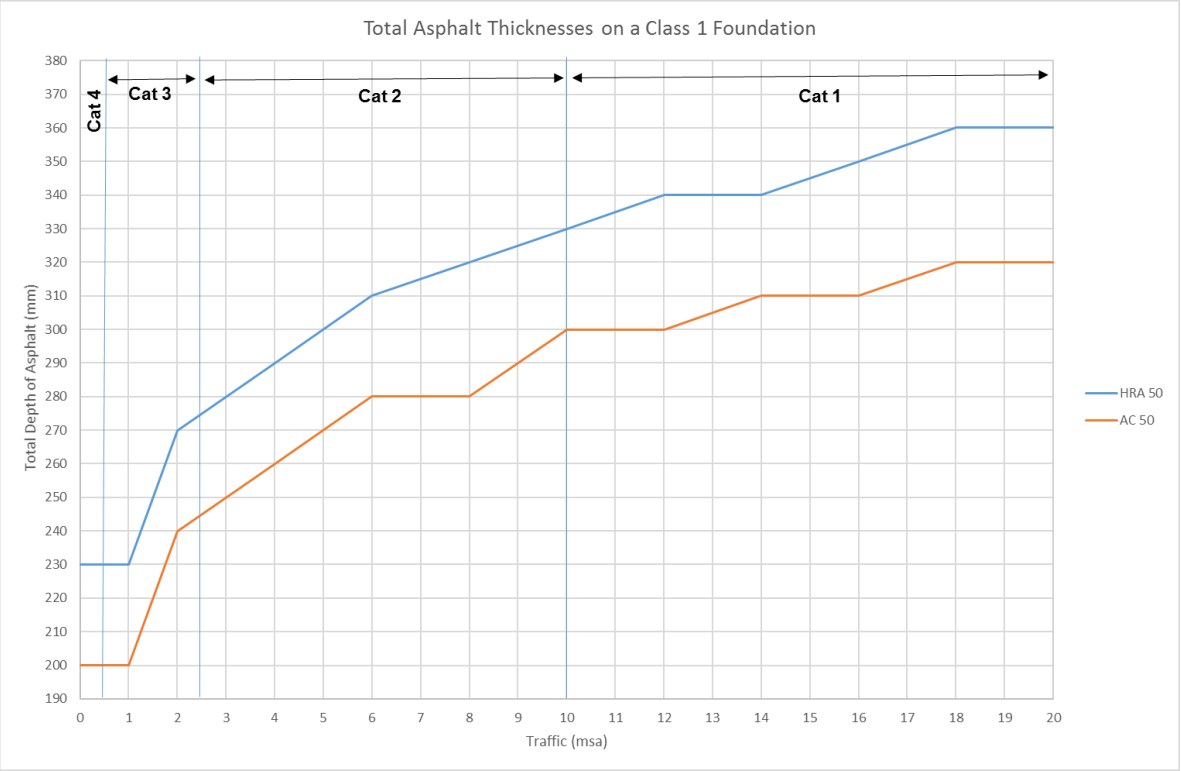
N.B Values above are examples of the types of descriptions expected from the designer. Each site should be site specific and within the guidelines of this document and BS59987
Some of the products listed above can be used as both Binder course and Base, but SMA is not an option in the base layer

Note 1: It should be noted that in the new DMRB CD226, Highways England have removed Hot Rolled Asphalt binder and base course, it is not the intention of Norfolk County Council to follow suit.

Note 2: Longitudinal joints should not be placed in the wheel paths to avoid undue applied stresses on the joint.

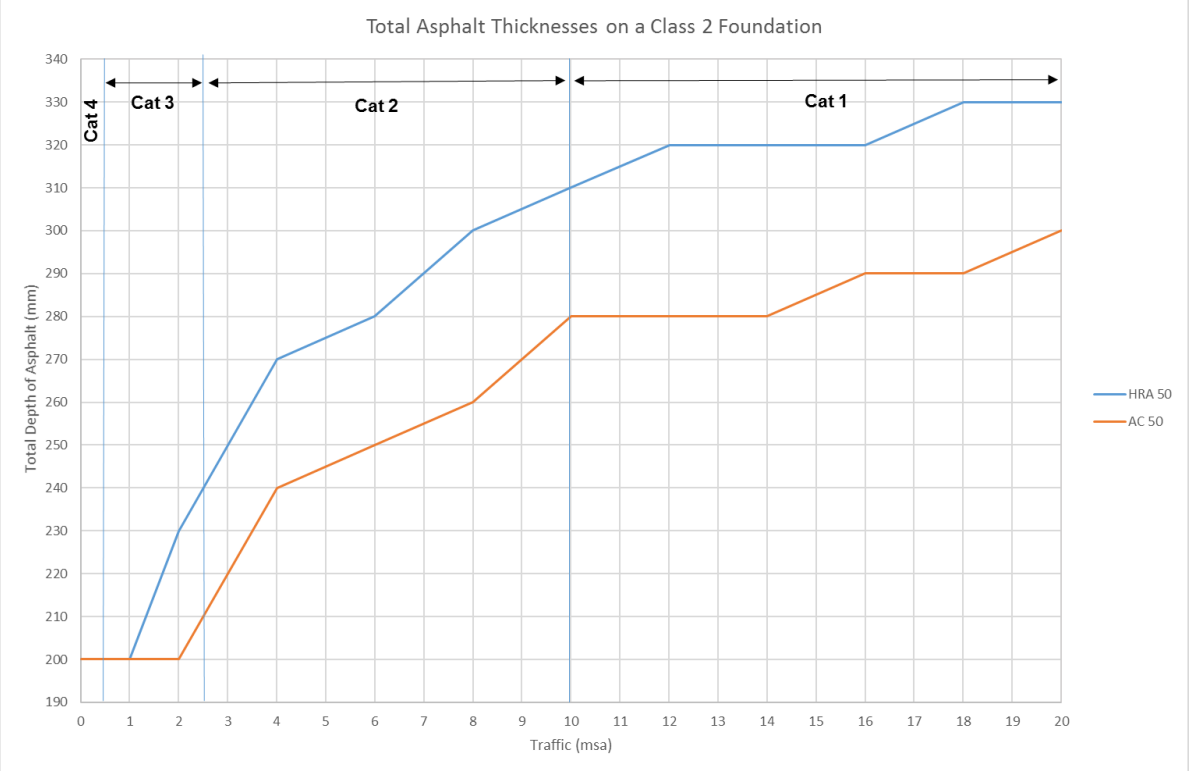
Note 3: the joints in different pavement layers should not coincide, this is to avoid water being able to travel through several layers without being impeded. The minimum lateral distance between joints in adjacent layers is generally specified as 300mm, but the distance should be the maximum practical.

- Table PM7: Typical total thickness of Asphalt on a class 1 foundation



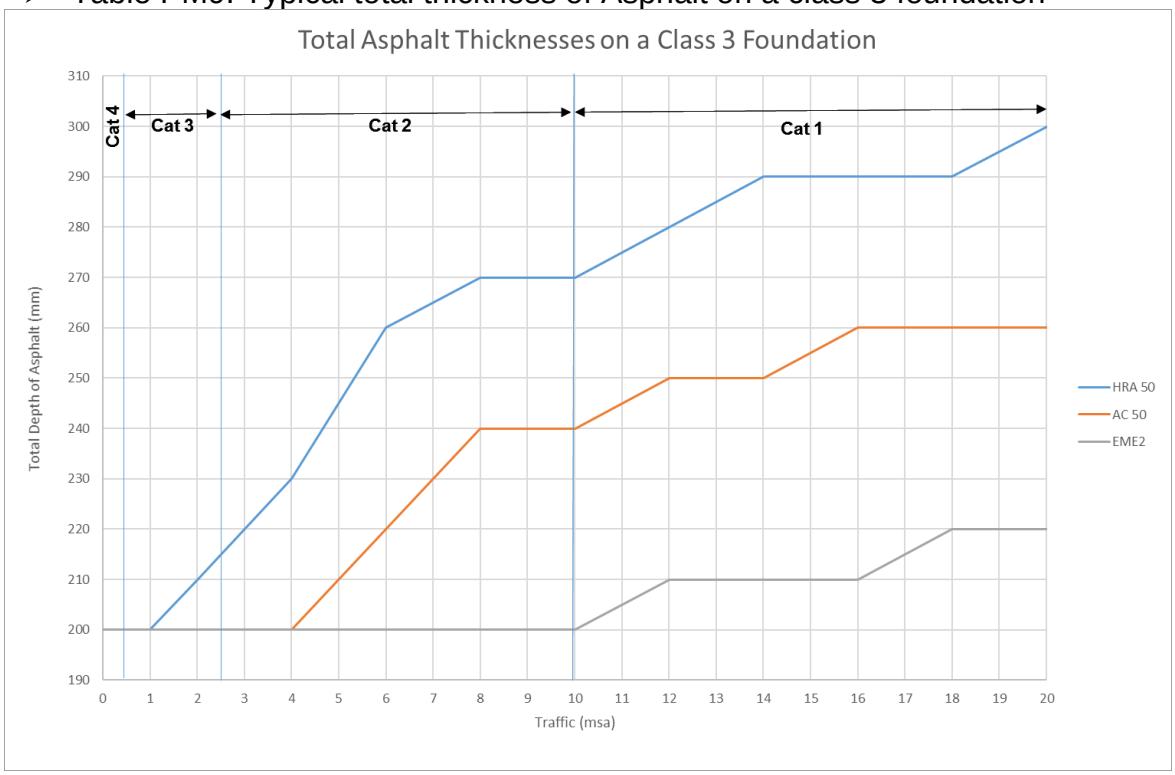
N.B. EME^2 can not be used on a class one foundation

- Table PM8: Typical total thickness of Asphalt on a class 2 foundation



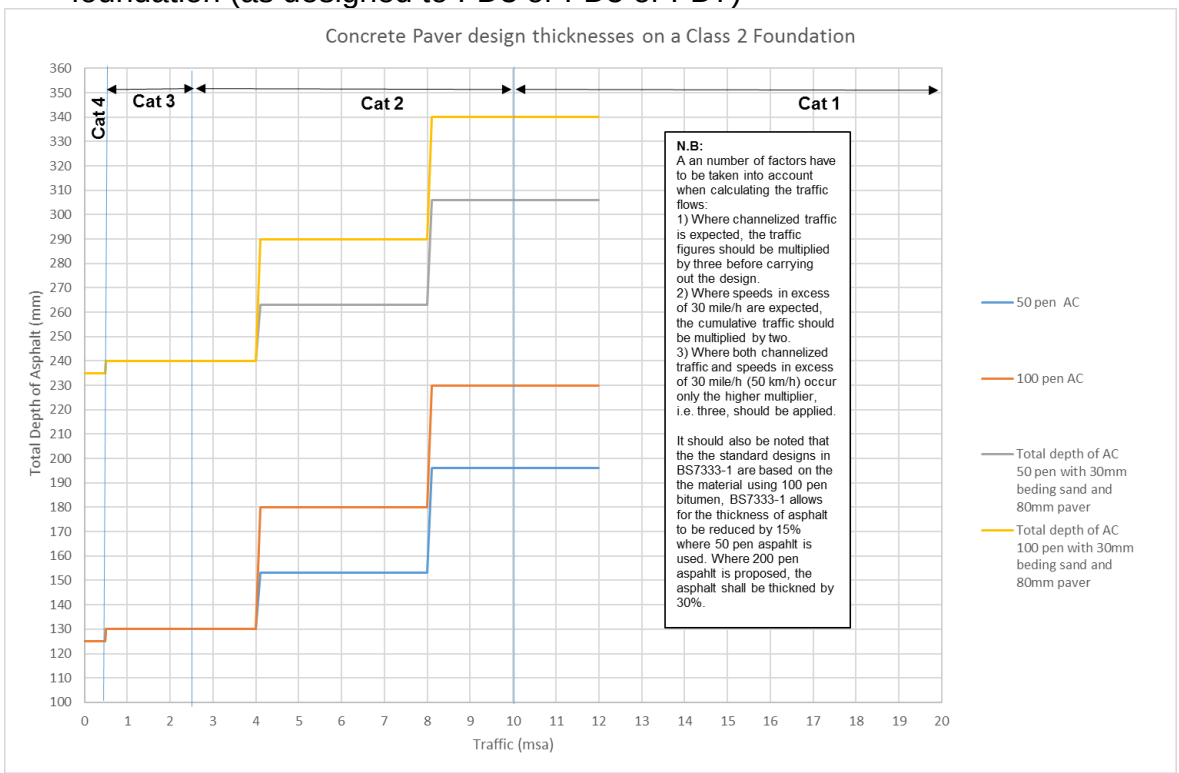
N.B. EME^2 can not be used on a class two foundation with a surface Stiffness Mondulus of <120Mpa

- Table PM9: Typical total thickness of Asphalt on a class 3 foundation



Note 1: It should be noted that in the new DMRB CD226, Highways England have removed Hot Rolled Asphalt binder and base course, it is **not** the intention of Norfolk County Council to follow suit.
Note 2: For traffic flows higher than 20msa, please refer to DMRB CD226

- Table PM10: Typical construction depth of concrete pavers on a class two foundation (as designed to FD3 or FD5 or FD7)



Foundation designs for pavers should be to CD225, pavement design should be to BS7333-1 or -2

Examples of Estate Road Specifications that comply with current practice appear in Tables PM11 and PM12.

- Table PM11 Example of an Estate Road Specification.

Thickness (mm)	Material Description & Designation	Specification
40	10mm Stone Mastic Asphalt surface course with 40/60 pen bitumen and 55psv coarse aggregate (SMA 10 surf 40/60 psv55)	PD6691 Annex C
60	20mm dense binder course, 40/60 pen bitumen, designed mix. (AC 20 dense bin 40/60 des)	PD6691 Annex B
100	32mm dense base, 40/60 pen bitumen, designed mix. (AC 32 dense base 40/60 des)	PD6691 Annex B
225	Type 1 unbound sub-base	SHW clause 803

Note 1: PD6691 – BSI Standards Publication, Published Document, Guidance on the use of BS EN 13108 Bituminous Mixtures – Material Specifications
Note 2: SHW – Specification for Highway Works.
Note 3: Bond coat complying with BS594987 shall be applied to all bound substrates.

Guidance on the above:

- The example above is based on a class two foundation for sub-base only (Table FD3) on a sub-grade surface modulus material with an equilibrium Sm of 100Mpa.
- 200m of asphalt of asphalt is place on the class 2 foundation (PM8), with traffic flows up to 2msa.
- The Base and binder course are made up with Asphalt Concrete material, with a 55psv SMA surface course. 55 PSV has been chosen on this minor road as there are several junctions along it (PM13).

- Table PM12: Example of an Estate Road Specification.

Thickness (mm)	Material Description & Designation	Specification
80	Concrete block pavers should conform to BS 6717-1. (psv55)	BS7333-1
30	Laying course and jointing material	BS 7533-3.
130	32mm dense base, 40/60 pen bitumen, designed mix. (AC 32 dense base 40/60 des)	PD6691 Annex B
200	Type 1 unbound sub-base	SHW clause 803
250	Capping	SHW clause 613
500	Capping	SHW clause 613

Note 1: PD6691 – BSI Standards Publication, Published Document, Guidance on the use of BS EN 13108 Bituminous Mixtures – Material Specifications
Note 2: SHW – Specification for Highway Works.
Note 3: Bond coat complying with BS594987 shall be applied to all bound substrates.

Guidance on the above:

- The example above is based on a class two foundation using Type 1 and capping (Table FD5) on a sub-grade surface modulus material with an equilibrium Sm of <30Mpa. As the Sm is lower than 30Mpa, additional foundation improvement is required to support the pavement in construction (500mm)
- Under clause 2.8 (CD225 DMRB), the thickness of ground improvement is taken to have risen to 50MPa
- 200m is required to be placed on the class two foundation, with traffic flows of up to 2msa
- Traffic speeds are <30mpH, so no multiplication factor applicable to Cl 4.2 BS7333-1 and the location is not a pinch point (so no channelized traffic), and again no multiplication factor applicable.
- Asphalt thickness is reduced by 15%, by using 50 pen bitumen (Cl5.3.5 BS733-1(this cannot be reduced below 130mm, therefore not applicable)
- 30mm laying course in accordance with BS7333-1
- 80mm concrete pavers

6. PSV requirements on all but A Class networks

- Table PM13: PSV requirements on the network excluding “A” class roads.

Speed		**<40MPH**	**<40MPH**	**≥ 40MPH**	**≥ 40MPH**	**All**
	Site Cat	Hot Rolled Asphalt	Stone Mastic Asphalt	Hot Rolled Asphalt	Stone Mastic Asphalt	Brick Paving
Event						
Single carriageway, generally free flowing on a relatively straight line	C	53	50	55	53	55
Roundabout circulation area	R	50	50	50	50	58
Approach to Pedestrian crossing and other high-risk sites Note 1, Note 2	NCC policy	60 Note 3	60 Note 3	60 Note 3	60 Note 3	60
Approach to major and minor junctions where frequent and sudden breaking occurs Note 2	Q	58	55	58	55	58
Bends (<500m radius	S1/S2	58	55	58	55	58

- Note 1 this is dictated by the NCC policy set out within this document in (Chapter 6)
- Note 2, Approach lengths are set out within our policy for approach to controlled crossings and are based on stopping distances set out within the Highway Code, these should also be applied to category Q sites also.
- Note 3, the PSV increases to 65 when the traffic flows exceed 1000 cv/l/d as per NCC policy
- The Aggregate Abrasion value should be no greater than 14
- The PSV requirements for all A class roads should comply with the skidding resistance requirements of CD236 (DMRB)
- The Categorisation of Sites is set out in CD 228, appendix A
- PSV requirements for the A class network shall comply with those set out in CD 236
- On the A class network, seek approval for any categories that required High Friction Surfacing from the overseeing authority before installation (NCC Asset management team.)

7. Use of Surface Treatments on Pedestrian Crossing Approaches:

Norfolk County Council has a policy for surfacing on the approach to controlled pedestrian crossing, this policy is outlined below

- Procedure SP03-07-P04

  Revision 01 (16 March 2015)

  Requirements:

- Purpose

The purpose of this procedure is to ensure an appropriate surface treatment is provided in advance of pedestrian crossings on Norfolk County Council roads for the safety of road users, whilst ensuring best use of resources and minimising environmental degradation.

Local Transport Note 2/95 *Design of Pedestrian Crossings* states “It is recommended that high skid resistance surfaces be provided on carriageway approaches to pedestrian crossings”. In Norfolk this led to designers specifying use of calcined bauxite High Friction Surface (HFS) treatments at almost all crossings including pedestrian refuge islands.

Due to the high cost and variable durability of HFS it is now specified by exception at formal pedestrian crossings in Norfolk. This would generally be on the recommendation of a safety audit due to factors such as high approach speeds or downhill gradient approach to stop line.

However, the need for high skidding resistance on approach to crossings (as recommended by LTN 2/95) remains. Introduction of a formal crossing changes the previously non-event status of the road, thereby bringing the adequacy of the existing surface friction into question.

In response to LTN 2/95 we therefore need a robust process that can stand up to scrutiny without being too onerous.

- Method / Specific requirements:

- A-Roads

Table 4.2 in CS228 specifies Investigatory Levels (ILs) for various situations on Trunk Roads. ILs relate to the Mean Summer SCRIM Coefficient (MSSC). NCC Skidding Resistance Policy (Appendix D (iv)) adapts the values in CS228 for the county A-class network (the only part of the network regularly subject to SCRIM testing). On approach to pedestrian crossings and other high-risk areas an IL of 0.5 is specified.

If the latest annual SCRIM results indicate that this is not met, the designer, taking Laboratory advice, decides what remedial treatment to carry out. Plane/ inlay with appropriate PSV aggregate is generally preferred to HFS due to longevity of treatment.

Using table 3.1 of CD236 the required IL can be related to minimum required PSV of aggregate for the type of site and traffic level. For 0.5 IL on approach to crossings a minimum PSV of 65 is specified for commercial vehicle flows up to 750 per lane per day (which covers the large majority of county A-roads). A minimum PSV of 68 should be specified for levels of commercial vehicle use above this level.

- Non-A-Roads

NCC has not adopted Investigatory Levels for the County non A-class network and these roads are not routinely SCRIM tested. Without the ability to relate IL's to PSV of existing aggregate, an alternative procedure has been developed.

Resurfacing the approaches to all new crossings on non A-class roads is considered an appropriate way forward. Site specific Laboratory advice would be sought on the treatment but generally this would involve plane/inlay with an appropriate asphalt surfacing with aggregate PSV of 60. In the rare instance that the level of traffic use exceeds 1000 commercial vehicles per lane per day, an aggregate of 65 PSV should be used

In order to minimise costs, the optimum length of surfacing needs consideration. CS228 gives the length of site category for approach to a pedestrian crossing as 50m, irrespective of speed of approach. However braking distance is clearly dependant on speed so the length over which enhanced skid resistance is required should relate to this. Typical braking distances are given in the Highway Code, but distances increase significantly in the wet, particularly with tyre tread depths close to the legal limit. Therefore these distances are doubled to:-

20mph and 30mph	28m
40mph	48m
50mph	76m
60mph	110m

Ideally this resurfacing should be carried out as part of major resurfacing works to reduce the overheads/rates. However, if it is to be a standalone scheme, the designer should consider the cost bandings for small surfacing schemes (e.g. resurfacing less than 500m² is more expensive per m² than doing 501m²). The enhanced skid resistance is only required on the approach half of the carriageway, although it may be appropriate to resurface the full width.

This procedure would apply to all new formal crossings on non A-roads, but it should also be considered when undertaking major upgrades to existing crossings and resurfacing adjacent to existing crossings. There are unlikely to be many formal crossings on the U-class network (due to light traffic flows) so this would primarily apply to B- and C-roads. Current practice for new formal crossings on A-roads would remain.

The need for resurfacing should be established at feasibility stage as it would affect the cost benefit of the scheme and enable adequate budget to be included within the design brief.

Exceptions

None

8. Footpath construction and cycle path construction:

- Table FP1: Footpath/Cycle path construction.

Type	Surface course thickness	Binder/Bedding course thickness	Sub-base Thickness	Description
Standard Norfolk Treatment for footpaths	25mm	25mm	100mm (150mm in accesses)	Pedestrian Use Only – Hot rolled asphalt with 10mm aggregate surface course 50mm thick (two 25mm thick layers)
Cycle paths and shared routes	20mm (70mm)	50mm (0mm)	100mm (150mm in accesses, sub-base should be increased to 300mm where heavy vehicles are likely to overrun)	20mm of 6mm SMA with a 50mm of AC 20. The mix should be with 50 Pen bitumen and machine laid with a machine paver for improved ride ability Alternatively The use of an Enhanced Asphalt Concrete product, with the ability to be laid in one layer. Using 50 Pen bitumen, laid with a machine paver for improved ride quality
Footpath with: possible HGV traffic overrun or Regular over-run	30mm 30mm	40mm 85mm	If Sm = 25-45 = 300mm, If Sm = 45-50 = 200mm If Sm=>50 = 150mm	Enhanced Asphalt Concrete product, with the ability to be laid in one layer. may be used with a suitable Penetration binder to resist the HGV traffic
Block Pavers	See design chart in table PM10	See design chart in table PM10	Foundation thickness as per the adjacent carriageway foundation.	The use of block paving is not encouraged by the Highway authority. Alternatively, the use of asphalt with coloured chippings could be used

N.B Proprietary footpath materials are acceptable with the overseeing authority's laboratory's permission

- Block Paving – Construction detail.

CONCRETE BLOCKS FOR PAVING

Concrete blocks shall comply with the requirements of BS 7533. Concrete blocks shall be a minimum 80mm thick for use in carriageways, footways, footpaths and cycle tracks.

The skid resistance of concrete blocks shall be determined by the polished stone value (PSV) test.

The minimum polished stone value (PSV) of any product shall be 55 unless specified otherwise.

LAYING PATTERN

Block surfacing shall be laid in a 45° or 90° herringbone pattern with two stretcher courses adjacent to kerbs and a single stretcher course around ironwork unless directed otherwise by the NCC client team.

LAYING COURSE FOR BLOCK PAVING

The laying course material shall comply with the requirements of BS 7533 and detailed in MCHW, Pavement Design CD239.

The laying course shall be within + 1% of its optimum moisture content determined in accordance with test 12 of BS 1377.The laying course shall be such that after compaction it forms a uniform layer 30mm thick below the blocks.

The laying course shall be screeded to produce a uniform surface to correct design profiles and falls at a uniform degree of compaction.

COMPACTING BLOCK PAVING

The surface course shall be compacted by use of appropriate equipment in order to ensure the filling of the lower portion of the block to block joint by the laying course material. Two or three passes of the compacting equipment will normally be required to achieve this condition.

Compaction shall follow block laying as soon as possible but shall not be carried out within one metre of the laying face.

Apart from this edge strip no area of paving shall be left un-compacted at the completion of the day's work.

JOINT FILLING

After compaction of the surface course, dry silver sand shall be spread over the surface and brushed into the joints.

The blocked surface shall then be vibrated as before in order to encourage the filling of the upper part of the block to block joint by the surface applied sand.

Top filling and final compaction shall be completed as soon as practicable after laying and in any case prior to the termination of work on that day.

N.B Pavers shall be concrete, 80mm in thickness

9. The use of in-situ Stabilisation to form Capping and Sub-bases:

- Pre works testing:

Pre-works testing should be carried out as outlined below:

- Trial pitting, to establish material depths through the site. Samples should be sufficiently large and retained to allow for mix designs to be carried out.
- Foundation testing should be carried out in the trial holes to establish sub-grade surface modulus
  Testing should be carried out in the form of:
  - Dynamic Cone Penetrometer (Note: care should be taken in areas where utilities are present)
  - Ex-situ Sm values (for fine grained materials these should be soaked)
  - Light weight deflectometer testing (at different depths through the trial pit to cover all soil layers to be retained/stabilised)
- A mix design should be carried out with percentage of binders (and different powders if required)
- Cubes/cylinders should be made from all mix designs over a variety of ages.
- Grading of laboratory mix material
- Determination of the optimum moisture content (OMC).
- Determination of organic matter
- Immediate Bearing Index, where deemed necessary by the design - Immediate stability shall be determined at selected water contents and binder contents measured in accordance with BS EN 13286-47, this should be taken as an average of 3 test specimens.
- Elastic modulus in compression of three samples per mix to BS13286-43
- Resistance to Water – Strength after Immersion. The strength after immersion in water shall be assessed by comparing the average strength and condition of:
  - 3 specimens initially cured in a sealed condition for 14 days at the test temperature; and then removed from their moulds and immersed in aerated water for 14 days at the same test temperature.
  - 3 specimens cured in sealed condition for 28 days at the same test temperature.
  - The immersed specimens shall be unconfined and have water in contact with all surfaces. On completion of the immersion stage of the test the specimens shall show no signs of cracking or swelling.
  - Curing temperature shall comply with Table 8/15 (SHW vol. 1).
- Chemical testing to BRE SD1 should be carried out to check for Sulphates etc. within the material to be stabilised.
- HBM shall be deemed to be resistant to frost heave where the compressive strength class is C2/2.5 (BS9227) or greater, or Rit is greater than 0.25 MPa., when cured in accordance with Table 8/15 (SHW vol. 1).

- Pavement Design:

The pavement design should be formally submitted prior to construction works being issued for approval

- With the trial pit data, trial mix data and the submitted foundation design, listing the thickness of the foundation design, class of foundation (1,2,3 or 4), and if cracking is to be induced and how.
- Foundation class requirement CD225 (class 1 = >50MPa, Class 2 =>100Mpa, Class 3 =>200MPa, Class 4=>400MPa.
- Asphalt thickness shall be determined in accordance with predicted traffic flows (Ref: CD226)
- The introduction of induced cracking should happen for any material where strengths exceed 8/10Nmm^2. Crack induction shall take place as per cl818 (Volume 1 SHW 800)
- All stabilised Pavement layers shall not be covered within 7 days unless they can be proven to have reach the requirements within Table 8/16 and CL NCC 884 & NCC885 (10.4.1 & 10.4.2 of this document)
- Outline procedure of how the Stabilised surface will be sealed after compaction Cl813/15 (Volume 1 SHW 800)

The stabilised material **shall not** be trafficked except for construction traffic placing the next layer of stabilised material, or the first layer of asphalt, once Sm has been achieved in accordance with the clause above.

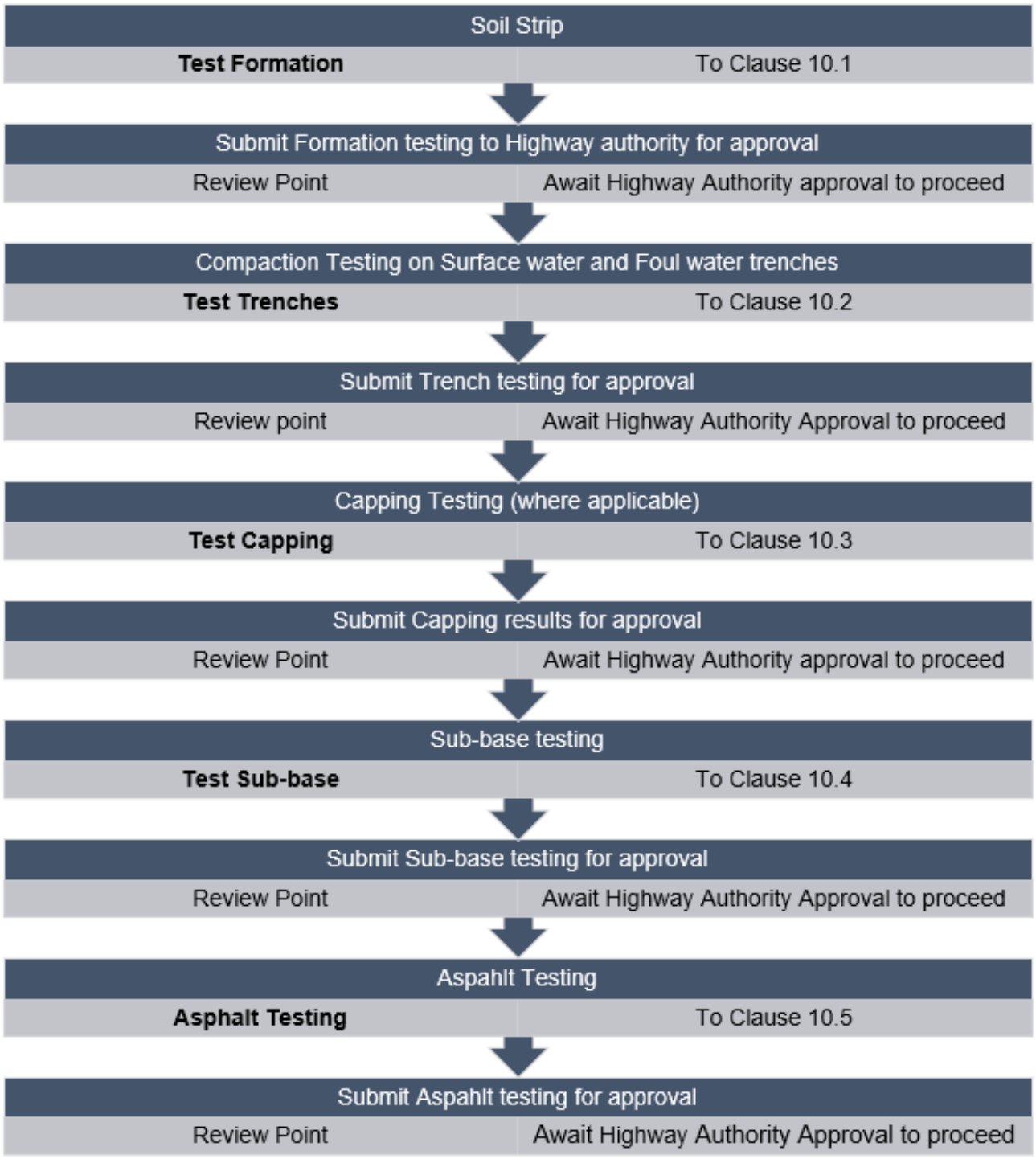
Drainage and ducting for all other services shall have been placed beneath the carriageway before the pavement foundation is formed. The stabilised material shall not be excavated once placed and compacted.

Test results shall be submitted throughout the development to the overseeing authority to enable signoff and adoption to take place.

10. Construction testing for Adoption:

These notes have been written to give guidance to the developers of roads they wish to be adopted by Norfolk County Council. These guidance notes provide a level of testing by the developer for presentation to Norfolk County Council. It should be noted that any testing carried out should be carried out by a UKAS accredited Laboratory**,** and all equipment should comply with the relevant British standards and calibrations.

Development phase process chart



10.1. Formation:

The Formation shall be assessed by determining the long-term equilibrium value of stiffness modulus Sm, see Section 2 of this document (determination of equilibrium value of Sm (CBR) and frequency on page 10). This should be carried out in advance of any road construction works (this is also used to validate the design values submitted and to correlate with those established during the construction phase). Not establishing Sm before the site works begin, may result in the site works not starting in a timely manner until Sm is established.

At the start of construction, the formation shall be checked to ensure that it is at or above the Design CBR (long term value reported in Surface modulus) which was determined at design stage. Where this falls below this at construction (short term Value), a foundation redesign will be required. Where the value is higher than the long-term design value, the long-term value **SHALL** be used.

Short Term Testing shall be carried out as set out below:

10.1.1. NCC882 Determination of the Construction Subgrade Surface Modulus (Short Term Values)

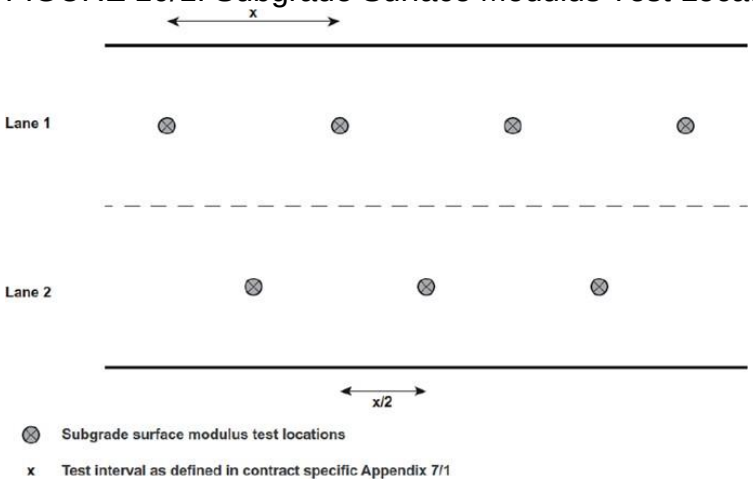
Scope

1 The test methods described in this Clause shall be used for the determination of the subgrade surface modulus of the foundation prior to the commencement of construction of the overlying layers.

Procedure

2 The construction subgrade surface modulus shall be determined in accordance with this Clause at intervals suitable for the type of subgrade material and its condition, with a maximum spacing of 60 m along each lane of prepared subgrade and staggered to the mid-point between adjacent lanes, see Figure 10/1.

FIGURE 10/1: Subgrade Surface Modulus Test Locations



3 At least 10 tests shall be carried out for each prepared foundation area.

4 The measurement of the construction subgrade surface modulus shall be taken at formation level or at sub-formation level if capping is part of the foundation design.

5 The test site shall be free from standing water, ice and snow.

6 Where the construction subgrade surface modulus is found to be less than the design subgrade modulus, the area shall either be improved, or the foundation redesigned in accordance with CD 225 (DMRB).

Construction Subgrade Surface Modulus Measurement

7 The subgrade surface modulus shall be determined using one of the following devices:

(i) Dynamic Cone Penetrometer (DCP).

(ii) Falling Weight Deflectometer (FWD); or

(iii) Lightweight Deflectometer (LWD).

Dynamic Cone Penetrometer (DCP) Testing

8 Dynamic Cone Penetrometer (DCP) testing shall be undertaken following the procedure outlined within CS 229 (DMRB).

9 Result expressed as mm/blow shall be converted to a California Bearing Ratio (CBR) value, expressed as a percentage, using the following relationship:
EQUATION 8/1: (03/20) DCP (mm/blow) to CBR Relationship
$Log_{10}(CBR) = 2.48 – 1.057 * Log_{10}(mm/blow)$

10 The CBR value obtained at design stage (long term value) shall then be converted to surface modulus (E) using the following equation:
EQUATION 8/2: (03/20) CBR to Subgrade Surface Modulus Equation
$E = 17.6(CBR)^{0.64}$ MPa

Falling Weight Deflectometer (FWD) Testing

11 FWD testing shall be undertaken using a calibrated FWD in accordance with BS 1924-2.

Lightweight Deflectometer Testing (LWD)

12 LWD testing shall be undertaken using a calibrated LWD in accordance with BS 1924-2.

13 In accordance with BS 1924-2, an LWD device shall only be used with a site-specific correlation versusa FWD or if it has an annual correlation certificate.

14 Testing shall either be undertaken to:

(i) Procedure A – the standard target stress as per BS 1924-2; or

(ii) Procedure B – a range of target stresses centred around 100 KPa to determine stress dependency.

N.B. from October 2021it is expected that all light weight Deflectometers used on pavements in the county of Norfolk shall comply with BS1924 and shall hold a correlation certificate in compliance with BS1924-2.

10.2. Trenches:

Where Trenches are excavated beneath the carriageway (proposed or existing), compaction testing should be carried out to confirm that the material is compacted throughout its entire depth. The minimum amount of testing is set out in the table at the end of 10.2

The Developer shall be responsible for achieving compactions that comply with a) and either b) or c) as appropriate from the following:

a) *Formations and Earthworks within 200mm of formation level*: Compaction to a dry density of not less than 95% of the optimum dry density obtained by the BS 1377 vibrating hammer method for coarse grained (granular) material or 2.5kg rammer method for fine grained (cohesive) material.

b) *Narrow trenches (no more than 750mm wide) Trench Backfill greater than 200mm below formation level*:

Compaction, as measured in accordance with BS 1377 Part 9 Cl. 3.2 (1990) DPSH method, shall either:

i) Comply with the formula:

$N = 3 + D$

Where:

N = Number of blows to achieve 100mm penetration

D = Depth of test in metres (rounded to nearest metre).

NOTE: This method shall not be used where the trench fill contains large quantities of medium to coarse gravel and cobbles (d_{60}>6.3). If d_{60} is greater than 6.3 method ii) below shall be used for site derived fill. For imported fill where d_{60}>6.3 site trials are needed, and methodology should be agreed in advance.

D_{60}= Particle diameter in mm at which 60% of the soil by weight is finer.

ii) Or comply at all depths with the formula:

$N_t >= N_u$

Where:

N_t = Number of blows to achieve 100mm penetration in the trench.

N_u = Mean number of blows to achieve 100mm penetration in the undisturbed soil perpendicular to the trench on each side at between 1 and 3m distant.

c) For e*arthworks and wide trenches (more than 750mm wide) (including where two narrow trenches are contiguous and should be treated as one trench) Trench Backfill greater than 200mm below formation level*:

Compaction, as measured in accordance with BS 1377 Part 9 Cl. 3.2 (1990) DPSH method, shall comply with the requirements of b) and in addition In-situ Sm shall be carried out on the trench backfill to ensure the fill has a value of Sm greater than or equal to that of the natural soil used in the design.

The following number of trench tests are considered appropriate for most sites**:**

Length of trench being reinstated	No of tests required
Less than 50 metres	2
50 to 150 metres	3
150 to 500 metres	Every 50 metres max.
500 to 1000 metres	At least 10 evenly spaced
Over 1000 metres	Every 100 metres max.

10.3. Capping:

The use of a capping layer is fundamental to the construction process. where the formation has a long-term value of Sm <30Mpa improvement to the subgrade needs to take place. This materials function is to provide a good working platform on which the pavement can be built and does not form part of the pavement.

Capping layers shall meet the requirements of Cl 613,614, 615, 643 typically 6F1, 6F2, 6F3, 6F4 or 6F5 materials are used as Specified in the 600 series of the Specification for highway Works

Hydraulically Bound Mixtures:

The use of hydraulically bound mixtures is encouraged on schemes which are large enough to be commercially viable. Site material can be used for capping. Testing to confirm the appropriate foundation stiffness, strength and density should be carried out to (NCC884 & NCC885 of Cl 10.4 of this document to validate the design before the sub-base is laid, covering the material) and design should be carried out using the principles in Clause 614/615 or 643 in the Manual of Contract Documents for Highway Works. Design methods and testing have been outlined in the previous Section.

Test certificates shall be submitted to the overseeing authority to show that the materials supplied as capping meets the required specification. Test certificates shall be relevant to the materials supplied to the site and should be no more than Three months old

Testing of capping

- Determination of short term Sm on formation to check appropriateness of design at 60m intervals staggered in alternate lanes (NCC882 of this document)
- LWD's for foundation compliance at 20m intervals staggered in alternate lanes. Rolling mean of 5 results shall be used for compliance as per NCC884 & NCC885 Excerpt below
- Sets of cubes/cylinders to determine strength compliance. Pair of cubes/Cylinders at 60m intervals to coincide with Sm values to determine 28-day strength, additional cubes/cylinders for early testing if required.
- Nuclear Density Testing for compaction compliance. At 60m intervals to coincide with Strength/density locations.
- Nuclear Density Box Calibration every 1000 tonnes.

10.4. Sub-base:

Material: Sub-base materials should comprise and comply of either Type 1, 2, 3 or 4 as per the Specification of Highway Works Clause 803, 804, 805 and 807. Current certificates for any material supplied to the site should be supplied to the overseeing authority. Generally, Class 804 Materials are not used in Norfolk because of the high Silica sand content. Other materials may be put forward for approval by the developer to be used as Sub-base; these should be submitted well in advance of the works and approved by Norfolk Partnership Laboratory.
Minimum requirements for the use of material on the site shall be:

- Grading to meet the specification of the material (manufactures declared values)
- Clause 710 to meet the requirements of table 8/3 (SHW V1)
- Los Angles testing to Table 8/2 (SHW V1)
- NCC also requires PH values to Below 10 on all recycled product.
- NCC will require any products containing IBAA to have the additional test specified in section 4, Page 14.

Test certificates shall be submitted to the overseeing authority to show that the materials supplied as Sub-base meets the required specification. Test certificates shall be relevant to the materials supplied to the site and should be no more than Three months old

Testing of Sub-base:
Compaction of sub-base materials should be carried out to Clause 802 of the Specification for Highway Works (Clause 802 states that “compaction of unbound mixtures shall be carried out by a method specified in Table 8/4, unless the Contractor demonstrates at site trials that a state of compaction achieved by an alternative method is equivalent to or better than that using the specified method.) Records shall be kept demonstrating compliance (the ground works contractor is to clarify before works begins how they will achieve this)

Surface Modulus testing shall be carried out at the developers cost to NCC884 & NCC885 of this document and measured to prove the pavement is satisfactorily constructed to the foundation design class.

Where the use of stabilised materials is used, the following testing regime will be carried out:

Compliance testing for hydraulically bound foundations

- Determination of short term Sm on formation to check appropriateness of design at 60m intervals staggered in alternate lanes (NCC882 of this document)
- LWD’s for foundation compliance at 20m intervals staggered in alternate lanes. Rolling mean of 5 results shall be used for compliance as per NCC884 & NCC885 Excerpt below
- Sets of cubes/cylinders to determine strength compliance. Pair of cubes/Cylinders at 60m intervals to coincide with Sm values to determine 28-day strength, additional cubes/cylinders for early testing if required.

- Nuclear Density Testing for compaction compliance. At 60m intervals to coincide with Strength/density locations.
- Nuclear Density Box Calibration every 1000 tonnes.

N.B. from October 2021it is expected that all light weight Deflectometers used on pavements in the county of Norfolk shall comply with BS1924 and shall hold a correlation certificate in compliance with BS1924-2.

10.4.1. NCC884 Permanent Works Assessment for Foundations:

Scope

1. This Clause outlines the performance testing required when constructing all foundations in addition to other compliance testing outlined in this specification.

Information Required

2. For each foundation area, records of the performance test results for each construction stage, referenced to the following condition details shall be stored and presented on request to the Overseeing Organisation in a digital spreadsheet format:
    I. Subgrade surface modulus value immediately before foundation construction.
    II. Date and time of mixing (for stabilised and slow-setting materials).
    III. Date and time of placing and compaction.
    IV. Date of performance testing.
    V. Values of foundation surface modulus recorded.
    VI. Values of material properties including density and layer thickness.
    VII. Weather conditions including temperature; and
    VIII. Sampling and testing records.

Assessment

3. Within 48 hours prior to construction of the overlying pavement layers, the foundation surface modulus shall be tested in accordance with CL NCC885 at 20 m intervals along each lane, staggered by 10 m between adjacent lanes. Tests shall coincide with subgrade surface modulus and density tests where appropriate.
4. The foundation surface modulus values achieved shall meet or exceed that detailed in Table 8/16 for the corresponding material and foundation class.
5. A foundation containing unbound materials that fails to comply with the performance requirements detailed in Table 8/16 when the recorded moisture content is in excess of that in the demonstration area, may be re- tested for compliance when the foundation moisture content has reduced to that in the demonstration area.
6. Where surface modulus performance values do not meet the requirements detailed in Table 8/16 the foundation is required to be re-designed. Where detailed in contract specific documents, the Contractor shall redesign the foundation in accordance with the requirements of this document
7. Ruts that develop under construction traffic, measured in accordance with this Clause, shall nowhere exceed the limits in Clause 886 (SHW Volume 1).

10.4.2. NCC885 Top of Foundation Assessment

Scope

1. The procedure described in this clause is for establishing the foundation surface modulus of newly constructed foundation.

Foundation Surface Modulus Measurement

2. The foundation surface modulus shall be measured using either:
    i. FWD; and
    ii. LWD based on a site-specific correlation versus an FWD.
3. FWD testing shall be undertaken using a calibrated FWD in accordance with BS 1924-2.
4. LWD testing shall be undertaken using a calibrated LWD in accordance with BS 1924-2 and requires a site-specific correlation versus a FWD undertaken in the performance foundation demonstration area.
5. The site-specific correlation for an LWD shall be established in accordance with BS 1924-2.
6. Where a Lightweight Deflectometer is being used, testing shall either be undertaken to:
    I. Procedure A – the standard target stress as per BS 1924-2; or
    II. Procedure B – a range of target stresses centred around 100 kPa specified in order to determine stress dependency.
7. Table 8/16 gives the mean foundation surface modulus and minimum foundation surface modulus values, for each foundation class, and for different categories of materials, that shall be met at the top of foundation level immediately prior to the construction of the overlying pavement layers.

Table 8/16 Foundation Surface Modulus Requirements

Foundation Class		Class 1	Class 2	Class 3	Class 4
Mean of 5 foundation surface modulus tests (MPa)	Unbound mixtures	40	80	N/A	N/A
Mean of 5 foundation surface modulus tests (MPa)	Fast-setting mixtures	50	100	300	600
Mean of 5 foundation surface modulus tests (MPa)	Slow-setting mixtures	40	80	150	300
Minimum of any foundation surface modulus test (MPa)	Unbound mixtures	30	50	N/A	N/A
Minimum of any foundation surface modulus test (MPa)	Fast-setting mixtures	30	50	150	300
Minimum of any foundation surface modulus test (MPa)	Slow-setting mixtures	30	50	75	150

The use of hydraulically bound mixtures is encouraged on schemes which are large enough to be commercially viable. Site materials can be used for sub-base. Testing to confirm the appropriate foundation stiffness, density and strength should be carried out to SHW 800 series.
Design should be carried out using the principles in Manual of Contract Documents for Highway Works Cl. 810, 814, 815 and 816.

Design methods and testing have been outlined in the previous Section of this document
Testing for Surface Modulus at each intermediate foundation level where compaction is carried out is recommended to identify any areas of concern as soon as possible and to ensure that the completed foundation will meet the requirements. Results for testing at intermediate layers will permit checks to be made against expectations as work proceeds.

Test certificates shall be supplied to the overseeing authority to show that the material supplied as sub-base meets the specified material, and if required has met the specified foundation class before the asphalt has been applied. Test certificates shall be relevant to the materials supplied to the site and should be no more than Three months old

10.5. Asphalt:

Asphalt testing should be carried out at a rate of at least one sample per material per days laying. This is to establish the correct material has been laid as per the specified material on the site design. Testing results should be presented to the overseeing authority.

Where disputed, bonds and depths of Asphalt should be confirmed (at the developer's expense) by means of coring. 150mm cores shall be taken vertically through the construction at locations agreed with the overseeing authority and should achieve a torque >300kPa using the Torque bond test set out in BBAHAPA A3 to confirm bond where disputed.
Rolling Straight Edge and Texture depths shall be used in dispute override quality and surface texture.

Where required by the overseeing authority, bulk density and void content measurements shall be measured on Asphalt concrete (inc EME2) and SMA binder courses & bases in accordance with BS 594987.

Compaction: Continuous compliance testing shall take the form of that laid out is BS594987 Cl 9.4.2

Test certificates shall be supplied to the overseeing authority to show that the installation and materials supplied is that which has been specified on the approved site-specific drawings.

All testing shall be at the developer's expense and it is strongly advised that the developer (and their ground worker) regularly communicate with the highway authority to ensure that the Highway authority is able to pass comment in good timing and avoid abortive costs.

11. As Built documentation.

At the end of construction works, an as-built drawing (preferably electronic) for the site shall be made available to the NCC site supervisor, this data shall be handed over to the asset management team within NCC to be placed on the as built register.

12. Reference documents:

- CD224 – Traffic Assessment
- CD225 – Design for new pavement foundations
- CD226 – Design for new pavement construction
- CD236 – Surface course materials for construction
- CD239 – Footway and cycleway pavement design
- CS228 – Skidding resistance
- CS 229 - Data for pavement assessment
- TRRL LR1132 – The structural design of bituminous roads
- BSEN 13108 series – Bituminous mixtures. Material Specifications.
- BS594987 - Asphalt for roads and other paved areas. Specification for transport, laying, compaction and product type testing protocols.
- BS1924-2 Hydraulically bound and stabilized materials for civil engineering purposes
- BS EN 13286 - Unbound and hydraulically bound mixtures
- BS7533 Series - Pavements constructed with clay, natural stone or concrete pavers
- PD6691 - Guidance on the use of BS EN 13108, Bituminous mixtures. Material specifications.
- Specification for highway works 600 series – Earthworks
- Specification for highway works 700 series - Road Pavements General
- Specification for highway works 800 series - Road Pavements - Unbound, Cement and Other Hydraulically Bound Mixtures
- Specification for highway works 900 series - Road Pavements - Bituminous Bound Materials
- Specification for highway works 1100 series - Kerbs, Footways, Cycleways and Paved Areas