Guidelines on the Depth of Overlay to be used on Rural Regional and Local Roads

An Roinn Iompair Turasóireachta agus Spóirt
Department of Transport, Tourism and Sport

Second Edition
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1. Background

This document is a revision of the original '*Guidelines on the Depth of Overlay to be used on Rural Non-National Roads*' published by the (then) Department of the Environment and Local Government in 1999. It provides guidance on the depth of overlay to be used on Rural Regional and Local roads. Although the majority of the Rural Regional and Local road network still utilises unbound and bound granular material overlaid with surface dressing in its construction; the use of hot-mix bituminous materials has increased.

This document outlines pavement evaluation procedures to be undertaken in order to determine the need for overlay works or other remedial treatment measures. The design principles outlined in this document have been developed from site experience and best practice methods in preparing, carrying out and observing pavement works on Rural Regional and Local Roads and make reference to the NRA Design Manual for Roads and Bridges (NRA DMRB) and the associated pavement documents noted below. The construction guidance elements of this document originate from experience in the construction and monitoring of pavement works on the network along with the NRA Manual for Contract Documents for Road Works Volume 1 Specification for Road Works (NRA Specification for Road Works) [1], the '*IAT Guidelines for Surface Dressing in Ireland*' [2] and other general best practice methods. A 'Best Practice Guide' for pavement construction works on Rural Regional and Local roads is included in Appendix F.

For larger projects involving road realignment works, the NRA DMRB and Specification for Road Works should be used by Local Authorities. The approach adopted for the structural design of fully flexible road pavements in this document was developed from the UK Transport Research Laboratory report LR1132 '*The Structural Design of Bituminous Roads*' [3] (LR1132). This approach uses a linear, multi-layer elastic model of the pavement structure based on the material properties of the pavement layers and the load bearing capacity of the subgrade soil. This report also provides the basis for the design of flexible pavements contained in '*NRA HD 25-26 Pavement and Foundation Design*' [4] (NRA HD 25-26).

In compliance with the Construction Products Regulation (EU) No 395/2011 (CPR), all construction products covered by a harmonised European product standard (hEN) must have a Declaration of Performance (DoP) and be CE marked in order for them to be placed on the market within the EU. All parties working on schemes that utilise these guidelines must comply with the requirements of the CPR and the NRA Specification for Road Works.

It is necessary to establish the need for pavement overlay works before the design of such works can be considered. This need is established by implementing appropriate pavement evaluation procedures as part of an effective system of pavement management. The aims and objectives of pavement evaluation are outlined in the next Chapter.

2. Pavement Evaluation and Management

2.1 Pavement Evaluation

In April 2012, the Department of Transport, Tourism and Sport issued the *'Rural Flexible Roads Manual'* [5]. This manual provides guidance on methods used in visual pavement evaluation and on the determination of road pavement condition.

Each Local Authority is required to develop and maintain a Condition Assessment of its road inventory. The assessment is conducted at a network level and comprises of;

- Data issued as part of the *'Regional Road Network Pavement Condition Study Report'* [6].
- Visual surveys and ratings required under the *'Rural Flexible Roads Manual'*.

Using mechanical and visual data to carry out this network level assessment, each Local Authority can determine a rating, based on the Pavement Surface Condition Index (PSCI), for each road in its inventory and can select the optimum remedial treatment measure from Table 1 of the *'Rural Flexible Roads Manual'*. This table is duplicated below for ease of reference.

A road pavement project should be selected using the PSCI and, where available, machine data. Furthermore, annual programmes should be developed in accordance with available funding.

Periodic inspection of the road network is vital for the provision of relevant evaluation data and therefore PSCI should be updated regularly.

2.2 Condition Rating

To commence the process of a network level assessment, the Local Authority should use the *'Rural Flexible Roads Manual'*, mechanical data (where available) and previous records to evaluate the condition of their network.

Mechanical data may be sourced from such tests as the International Roughness Index (IRI) Test, the Side-Force Coefficient Routine Investigation Machine (SCRIM) Test and video surveys. The condition rating obtained with the use of the *'Rural Flexible Roads Manual'* can be used in conjunction with the mechanical surveys.

The *'Rural Flexible Roads Manual'* outlines the categories of common distress which can occur on a road pavement. These distresses are sub-divided into primary and secondary rating indicators which can be linked to ratings on the PSCI. Each road pavement segment can be assigned a rating on an index from 1 to 10. The objective is to rate the condition that represents the majority of the pavement over the segment surveyed.

Prior to carrying out condition assessment work, all personnel should have received approved training on details of distress identification and the PSCI rating system.

Overall Rating	Treatment Measures	Surface	Structure
10	**Routine Maintenance**	Excellent	
9		Very Good	
8	**Resealing & Restoration of Skid Resistance**	Fair	Good
7		Poor	
6	**Surface Restoration** — Carry out localised repairs and treat with surface treatment or thin overlay.	Fair	Fair
5		Poor	
4	**Structural Overlay** - Required to strengthen road. Localised patching and repairs required prior to overlay.	Poor Overall	
3			
2	**Road Reconstruction** - Needs full depth reconstruction with extensive base repair.	Very Poor Overall	
1		Failed Overall	

Figure 2.1: Treatment Measures (source: Rural Flexible Roads Manual)

2.3 Treatment Options

In general, where the condition rating is less than or equal to 8, some form of intervention is required. Treatment measures associated with ratings 9 and 10 relate to routine maintenance and therefore are not pertinent to this document. The overlay design guidelines described in this document should be used to select the material layers and thicknesses.

Once the Pavement Surface Condition Index rating is determined, Local Authority staff can define the category of treatment work to be carried out. These categories are summarised below:

- **Resealing and Restoration of Skid Resistance** shall maintain or restore waterproofing of the pavement surface and provide improved skid resistance to pavements with surface defects present.
- **Surface Restoration** in addition to surface dressing may, as necessary, include improvement of transverse and longitudinal drainage, pothole patching and restoration of road widths to those originally provided and local strengthening of weak road edges.
- **Structural Overlay** involves the regulation and overlaying of existing pavements with bound or sealed unbound materials and the provision of drainage, where necessary.
- **Road Reconstruction** involves the removal of existing layers of pavement, and their replacement with new structural layers of bound or sealed unbound materials along with the provision of drainage, where necessary.

If Structural Overlay and Road Reconstruction are proposed as treatment options, and with the strength and thickness characteristics of the existing pavement structure determined, the following overlay design options should be considered:

- New Granular Unbound Pavement
- Granular Unbound Overlay
- Bituminous Bound Overlay
- Combinations of the above

The Local Authority must evaluate these options having regard to the existing traffic demand regime (volume and loading), the condition of the road pavement, the design life required, expected design life and the available budget. Tables 5.1 and 5.2 in this document provide overlay design thicknesses for a 20 year design life with a specific growth rate and heavy goods vehicle content. At the project specific level, other technical data may be required for use with these design tables.

2.3.1 Staged Construction

Whilst noting that a Local Authority will seek to extract the longest possible life from a pavement, and try to maintain pavements such that they become 'long life pavements', the possibility of constructing the overlay works in stages may also be considered. Savings may be made by using staged construction if the reduction in cost of the initial construction is greater than the sum of the discounted costs of the overlays required during the total pavement life.

Single stage construction should be used for all flexible pavements of total design life up to 20 years as analysis detailed in TRL Report 1069 *'Economics of Staged Construction of Flexible Road Pavements'* [7] advises that this is the economical choice. Two-stage construction should be considered for flexible pavements having total designed lives between 20 years and 40 years as, for pavements designed to last between 35 and 40 years, two stage construction is cheaper than construction in one stage.

The use of more than one stage in the construction process may be attractive because the greater the number of stages of construction, the lower the actual cost of each stage. Each stage of the design can also be more accurately matched to the traffic. The disadvantages of increasing the number of stages of construction include the extra costs of delays to traffic incurred at the time of construction of each stage.

2.4 Materials

Materials to be considered in construction of pavement overlay or strengthening works is discussed in Chapter 4.

2.5 Assessment and Management Process

The process to be followed in evaluating the pavement condition, assigning an appropriate treatment option and assessing the works post-construction is shown in Figure 2.2. A network level assessment must first be carried out and progression to a project level assessment should only follow once the required funding has been identified.

2.6 Project Level Assessment

When the individual projects are identified each site should be inspected on foot to commence the process of detailed design of the road works. Such inspections should be carried out early in the year, well in advance of the 'surface dressing season', to enable any defects to be recorded and rectified prior to the commencement of pavement works.

The need for additional mechanical and ground investigation data, to aid the design of the pavement overlay, should be identified at this stage. Such data can be obtained from Falling Weight Deflectometer (FWD) tests, California Bearing Ratio (CBR) tests, site investigation cores and trial pits. Historical data for the project may be available from As-Built records.

At these project level inspections, the PSCI recorded during the network level assessment should be re-confirmed. Other issues to be examined include drainage (refer to Chapter 6), health and safety issues in the context of executing the works and the necessity, or otherwise, to enhance the road markings and signage.

- Issues regarding forward visibility should be identified.
- Areas prone to water damage or where there are steep gradients i.e., where road pavements are liable to be damaged by severe rainfall events, should be identified and recorded.
- Potential hazards such as junctions with the subject road, presence of schools, overhead power lines should be identified for the later preparation of a risk assessment.
- Statutory signage should be inspected to establish whether signs or poles are missing or need to be replaced. Similarly the necessity to either renew or provide road markings shall be determined.
- Any other site constraints should be identified and recorded.

If possible, design of the works should incorporate solutions to forward visibility problems detected. Treatment design should come from the options discussed in this Chapter. The pavement design should be developed from Table 5.1, Table 5.2 and the other approved analytical methods in this document.

Upon completion of the works, an assessment should be carried out to determine the new PSCI for the section of road treated.

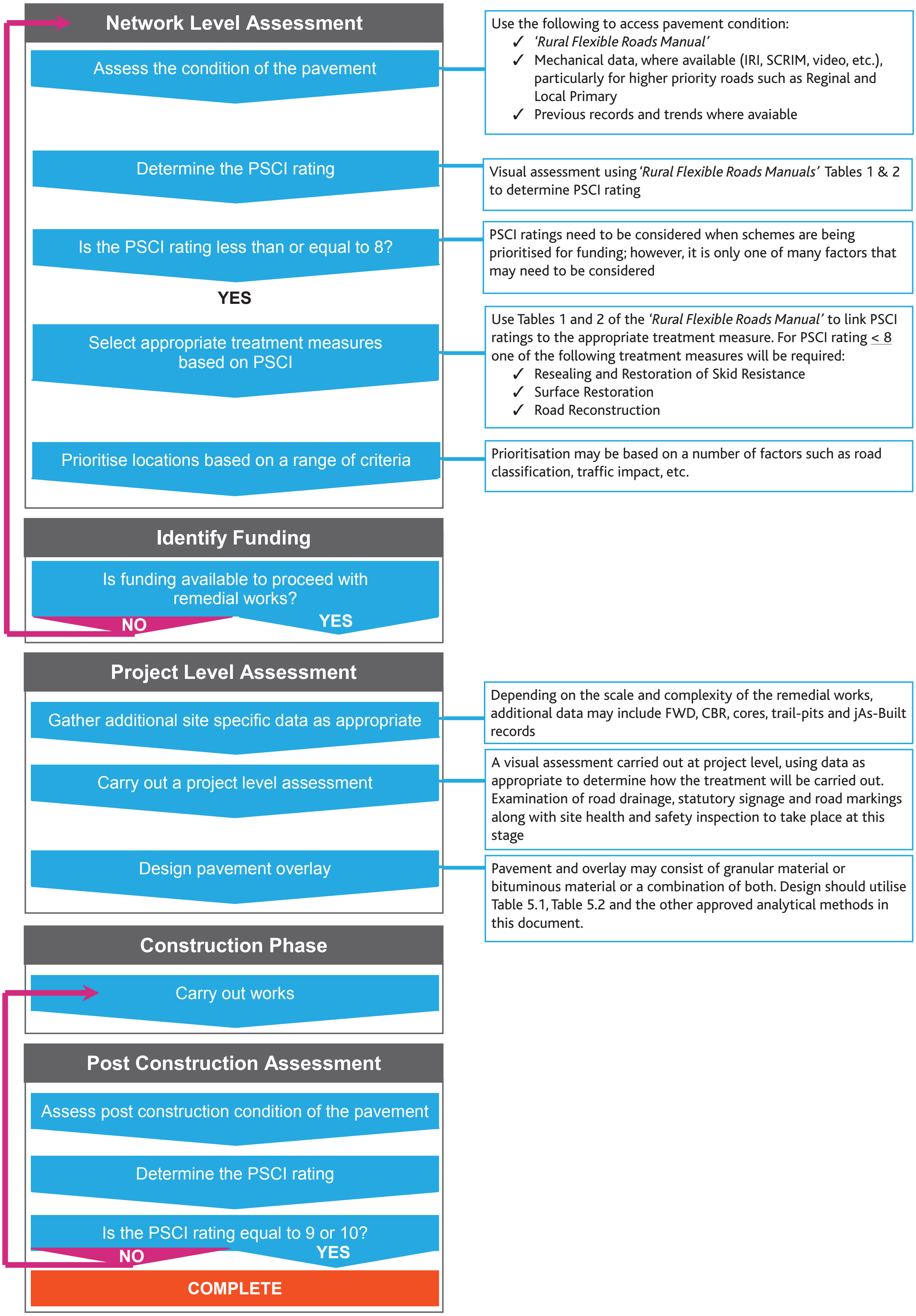

Figure 2.2: Pavement Evaluation and Management Flowchart

3. Design Principles

3.1 Design of New Granular Pavements

First published in 1980, the document entitled *'Thickness Design for Unbound Road Construction'* [8] (RC.218) proposes a method for determining the thickness of an unbound granular material layer required in design calculations. RC.218 advises that the document is relevant for CBR values in the range of 2 – 7% and for design traffic up to 2.5 million standard axles (msa). Design traffic is calculated using formulae presented in *'NRA Addendum to HD 24 Traffic Assessment'* [9] (HD 24). The inputs into this formula include the pavement design period, vehicle wear factors, growth factors and Annual Average Daily Traffic (AADT).

The NRA standard for combinations of materials and thicknesses relating to the design and construction of foundations and pavements is NRA HD 25-26. This standard is specific to National roads, including Motorways, with minimum design traffic of 1 msa. It is applicable to fully flexible pavements (based on LR1132), flexible composite pavements (based on TRL Report 615 *'Guidance on the development, assessment and maintenance of long-life flexible pavements'* [10]) and rigid pavements (based on TRL Report 630 *'New continuously reinforced concrete pavement designs'* [11]).

Therefore NRA HD 25-26 may not be relevant to Rural Regional and Local roads with low traffic volumes. Because of this, and as many Rural Regional and Local roads are constructed using unbound granular materials sealed with a surface dressing, RC.218 may be a more useful reference for pavement design on such roads.

The formula used in RC.218 to calculate the required depth of granular material equates the number of standard axles to be carried on the pavement and the thickness of the unbound granular material to be placed. The formula is as follows:

$$H = 635(E_2)^{-0.468} (N)^{0.117} \qquad (1)$$

Where H is the thickness of the unbound granular material, E_2 equals the stiffness modulus of the subgrade material and N represents the design number of standard axles.

3.1.1 Determination of Subgrade stiffness

The only variable in the above which cannot readily be measured in equation (1) is the subgrade stiffness modulus E_2. To rectify this RC.218 proposes two formulae for the estimation of subgrade stiffness modulus by determining the California Bearing Ratio (CBR) of the subgrade based on in-situ site tests. The two formulae are as follows:

$$E_2 = 10(CBR) \qquad (2)$$

$$E_2 = 17.9(CBR)^{0.66} \qquad (3)$$

RC.218 notes equation (2) to be a *"reasonable median line"* for data collected whilst also pointing out that this equation is unsuitable for Irish glacial tills. Equation (3) is referred to as being suitable for boulder clays, but this has not been validated in an Irish context. This is very close to the formula indicated in NRA HD 25-26.These formulae provide a quick method of estimating subgrade modulus. However, care must be taken with regard to sampling and moisture susceptibility of the soil.

Various forms of in-situ test methods to determine the strength of the foundation layers of a pavement are discussed in Chapter 3 of NRA HD 25-26. One such in-situ test, which is commonly used, is the Dynamic Cone Penetrometer. This test provides a quick approximate assessment of a subgrade CBR.

Another method for obtaining the CBR of a subgrade is to use NRA HD 25-26 Tables 3.1 and 3.2 which provide estimates of equilibrium long term CBR values. These tables are re-produced below.

Table 3.1 provides a simple means of assessing the equilibrium in-service i.e., long-term, CBR of the subgrade. The table should be used unless site or laboratory testing indicate otherwise. Considerable care is required in assessing the lower values of CBR. Values should be rounded down unless positive and consistent CBR determinations have been carried out. If the full information is not available for use with Table 3.1, certain assumptions can be made and Table 3.2 used instead.

TYPE OF SOIL	PI	HIGH WATER TABLE						LOW WATER TABLE					
		CONSTRUCTION CONDITIONS						CONSTRUCTION CONDITIONS					
		POOR		AVERAGE		GOOD		POOR		AVERAGE		GOOD	
		Thin	Thick	Thin	Thick	Thin	Thick	Thin	Thick	Thin	Thick	Thin	Thick
HEAVY CLAY	70	1 ½	2	2	2	2	2	1 ½	2	2	2	2	2 ½
	60	1 ½	2	2	2	2	2 ½	1 ½	2	2	2	2	2 ½
	50	1 ½	2	2	2 ½	2	2 ½	2	2	2	2 ½	2	2 ½
	40	2	2 ½	2 ½	3	2 ½	3	2 ½	2 ½	3	3	3	3 ½
SILTY CLAY	30	2 ½	3 ½	3	4	3 ½	5	3	3 ½	4	4	4	6
SANDY CLAY	20	2 ½	4	4	5	4 ½	7	3	4	5	6	6	8
	10	1 ½	3 ½	3	6	3 ½	7	2 ½	4	4 ½	7	6	> 8
SILT *		1	1	1	1	2	2	1	1	2	2	2	2
SAND (POORLY GRADED)		---	---	---	----	----	---20---		---	---	---	---	---
SAND (WELL GRADED)		---	---	---	----	----	---40---		---	---	---	---	---
SANDY GRAVEL (POORLY GRADED)		---	---	---	----	----	---60---		---	---	---	---	---
* estimated assuming some probability of material saturating													

Table 3.1: Equilibrium Subgrade CBR Estimation (source: NRA HD 25-26)

Type of Soil	PI	Predicted CBR %
Heavy Clay	70	2
	60	2
	50	2
	40	2 to 3
Silty Clay	30	3 to 4
	20	4 to 5
Sandy Clay	10	4 to 5
Sand (Poorly Graded)		20
Sand (Well Graded)		40
Sandy Gravel (Well Graded)		60

Table 3.2: Equilibrium Subgrade CBR Estimation (source: NRA HD 25-26)

3.1.2 New Granular Pavement Thickness

Following estimation of the CBR value of the subgrade on which the new pavement is to be constructed, the value can be input into equations (2) and (3) as required. Equation (1) can then be computed to determine the design thickness of the granular layer to be constructed. Below are separate tables summarising the design thickness values using equations (1) and (2), see Table 3.3, and equations (1) and (3), see Table 3.4. These tables may be used in the case of new road pavements or where road reconstruction is the chosen treatment.

		H (mm)				
CBR	E_2 (MN/m^2) using eq. 2	0.5 MSA	0.75MSA	1.0 MSA	2.0 MSA	2.5 MSA
2	20	730	760	790	850	880
5	50	470	500	510	560	570
7	70	400	420	440	480	490

Table 3.3: Design thickness of Granular material using equations (1) and (2)

		H (mm)				
CBR	E_2 (MN/m^2) using eq. 3	0.5 MSA	0.75MSA	1.0 MSA	2.0 MSA	2.5 MSA
2	28.3	620	650	670	730	750
5	51.8	470	490	500	550	560
7	64.7	420	440	450	490	510

Table 3.4: Design thickness of Granular material using equations (1) and (3)

As the tables illustrate, a very deep granular layer must be placed on a subgrade with a low CBR value. For these lower CBR values, equation (2) provides a more conservative depth of overlay thickness than those calculated using equation (3).

As the design traffic increases above 1 msa it may be more economical to consider using NRA HD 25-26. Figures 4.1 and 4.2 within NRA HD 25-26 provide guidance on depths of capping, subbase and combined asphalt layers, utilising known values of subgrade, CBR values and design traffic.

3.2 Overlay Design of Granular Pavements

Overlay design of granular pavements aims to increase the structural capacity of the granular layer by basing the design on controlling the amount of rutting to be experienced in the lifetime of the road. An overlay design for granular pavements can be carried out using the methods described in RC.218. The thickness of a granular overlay to be used can be estimated using an adaptation of equation (1) taking the thickness of the existing layer into account. The formula then becomes:

$$H_o = 635(E_2)^{-0.468} (N)^{0.117} - H_e \qquad (4)$$

Where H_o is the thickness of granular overlay, He equals the existing thickness of granular material and N represents the number of standard axles for overlay design life

The main disadvantage of this type of overlay design is that it does not take into account the quality of, or lack thereof, the existing granular material in the road structure. In the scenario that $H_o = H_e$ and it is found that the pavement structure is still failing an alternative approach such as stabilisation of the existing granular material would have to be considered. Alternative materials are discussed within Tables 4.1, 4.2 and 4.3.

3.3 Overlay Design by Computer Analysis of FWD Data

3.1.1 Falling Weight Deflectometer Test

The Falling Weight Deflectometer Test (FWD) is a non-destructive test used to determine the stiffness of the layers in a pavement, the ability of the pavement structure to distribute traffic loading and the stiffness of the subgrade layers. The FWD provides information on the bearing capacity of the pavement and subgrade layers being tested due to the action of wheel loads. Deflections are measured at the point of load application and at a number of locations remote from the applied load.

Refer to Appendix A for further information on the FWD test method.

3.1.2 Overlay Design using FWD Data

Linear elastic multi-layer analysis is used to model the pavement structure. This analysis applies a given load to the mathematical pavement model using assumed layer moduli values from which surface deflections are calculated. Layer stiffnesses are adjusted in the 'back analysis' approach until the theoretically predicted deflection bowl matches that measured on site.

Prior to obtaining the theoretical deflection bowl produced by the FWD test the pavement should be modelled. This involves considering the pavement structure as a number of horizontally infinite linear elastic layers with these layers being of finite thickness. UK DMRB *'HD 29 Data for Pavement Assessment'* [12] (HD 29) Chapter 5 details the rules that must be followed in how to model a pavement structure. The modelling usually involves limiting the number of layers within the structure to three. For typical Rural Regional and Local roads the pavement model would take the form as shown in Figure 3.1.

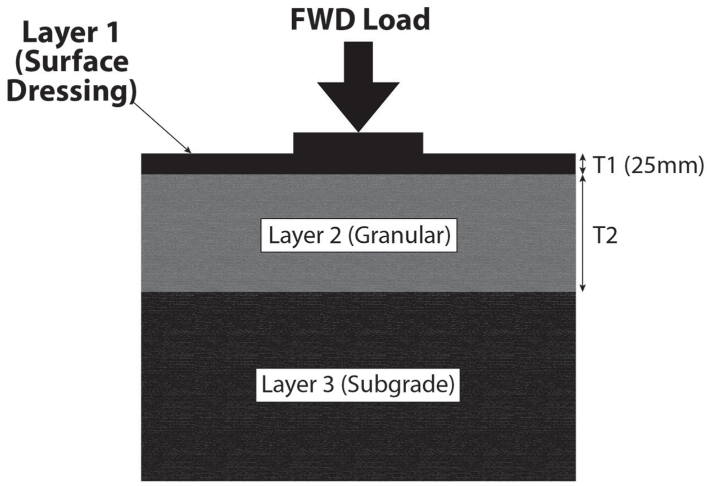

Figure 3.1: Typical Pavement Model for Rural Regional and Local Roads

In order for the correct modelling to be completed, accurate pavement layer thicknesses are essential. An under-estimate of as little as 15% in layer thickness, not uncommon given construction tolerances, can result in an over-estimate of over 50% in bound layer stiffness moduli values which would be enough to give the impression of good integrity in a poor layer.

Information on layer thicknesses can be obtained from sources such as As-Built construction records, coring, trial pits and Ground Penetrating Radar (GPR) tests. Details on the procedures of the GPR test are outlined in HD 29 Chapter 6. As detailed in Appendix A, plots produced from FWD data can be used to determine areas of weak pavement if further investigation on layer thickness is needed.

An indication of the stiffness of the pavement layers can be obtained directly by surface modulus equations. These equations are outlined in an NRA document entitled *'Guidelines for the use of the Falling Weight Deflectometer in Ireland'* [13] (NRA FWD Guidelines) Chapter 5.1 and HD 29 Annex 5B. Surface modulus plots give a good indication of the aggregate stiffness of the pavement layers at different equivalent depths. However more accurate estimates are obtained from 'back analysis'.

Chapter 5.2 of the NRA FWD Guidelines document provides advice on 'back analysis' by manual iteration, automatic iteration and interpretation of database information. HD 29 Chapter 5 outlines criteria for which the 'back analysis' should follow.

There are a number of different computer programs used for 'back analysis' in order to calculate the stiffness moduli of the layers. Assumed layer moduli are input into these computer programs and resulting deflections are calculated. These theoretical deflections are compared to the actual measured values and adjustments are made to the layer moduli such that the error between the measured and deflection bowls is reduced to an acceptable level. HD 29 Clause 5.38 outlines equations to indicate the degree of match achieved between the program output value and the measured value. HD 29 Clause 5.39 provides maximum guide values for the results of these equations. The final layer moduli are calculated once the values are normalised to an appropriate temperature, typically 20ºC, in accordance with HD 29 Clauses 5.34 – 5.37.

For typical Rural Regional and Local roads, the 'back analysis' process focuses on the granular material and the subgrade. UK DMRB *'HD 30 Maintenance Assessment Procedure'* [14] (HD 30) Table 6.1 gives reference stiffnesses values for FWD 'back analysis'.

The predicted traffic loading is also input into the program. HD 24 outlines the method for the estimation and calculation of traffic loading for the design of road pavements. An allowance may also be made for past traffic on the pavement which takes into account the number of equivalent standard axles since the construction or the last improvement works carried out on the pavement.

Once the pavement structure and design traffic volume is characterised, the computer program calculates the induced and compressive stresses and strains and overlay thickness for each test point.

The critical stresses and strains are analysed using formulae presented in Appendix E of LR1132 to quantify the number of axles to failure. Traffic data is then used to determine the residual life of the pavement. Computer programs can also determine the residual life based on the deflections measured. If the residual life determined is less than the desired value, pavement strengthening or overlay will be required to reduce the critical strains to the appropriate design level.

As advised in the NRA FWD Guidelines and HD 30 Chapter 6 Clause 6.6, the 85th percentile value of the plotted overlay depths is used to determine the design overlay depth for National roads. However, traffic volumes and speeds are generally lower on Rural Regional and Local roads than on National roads meaning that a lower value such as the 50th percentile value can be adopted.

In design philosophy terms, this implies that if all values chosen are truly accurate, 50% of roads strengthened will exceed their 20 year design life to failure and 50% will not. Failure in these circumstances is deemed to comprise a rut depth of 10 mm. Obviously 10 mm ruts on lower category Rural Regional and Local roads would not be deemed inordinate in most circumstances. For Rural Regional roads it is recommended that full road reconstruction be planned when the rut depth exceeds 25mm. Depending on specific conditions, rutting of up to 50mm may be acceptable on lower classes of road such as Local Secondary and Local Tertiary.

3.4 Integrated approach to Overlay Design

Two separate design methods have been described so far. The method described in RC.218 for granular unbound pavements is based on layer thickness and laboratory testing. The disadvantage of this approach is that it does not take into account the condition of the existing pavement structure. The FWD method is based on non-destructive site tests. An advantage of the FWD approach is that it takes account of the stiffness of the present structure.

FWD overlay calculations are usually based on the use of an overlay material with a high stiffness modulus such as Asphalt Concrete. Experience has shown that thin bituminous layers on weak pavements generally fail prematurely. Consequently, additional criteria are required to indicate where it is more practical to use a granular overlay or a combination of granular and bituminous overlays.

The Surface Curvature Index (SCI), which is obtained from FWD deflection data, is a measure of the load spreading properties of the upper bound layers and it is proposed that this parameter be used to identify when the use of granular or bituminous material is most suitable. A range of SCI criteria are shown in Table A.1 of Appendix A for Rural Regional and Local roads. From this table, SCI values in excess of 250 microns (normalised to a 40kN wheel load) indicate poor load-spreading ability. In such cases, a granular overlay should be the selected option so as to improve the overall bearing capacity of the road structure before consideration is given to the use of a composite Granular/Asphalt Concrete overlay. Asphalt Concrete material alone should not be used in these cases.

The thickness of the overlay design will also determine the material to be used. The previous edition of this document contained a summary of FWD test data using the Evaluation of Layer Modulus and Overlay Design (ELMOD) [15] computer program. This data is re-produced in Table 3.5. The computer program was used to calculate average bituminous overlay design thicknesses. A CBR value was then calculated from the ELMOD subgrade modulus using equation (2). This CBR value was then used to calculate granular overlay thicknesses using RC.218.

Review of Overlay Design Methods for Rural Regional and Local Roads Overlay Design for 1MSA							
	Average Deflection (microns)			Overlay Calculations			
Test Site	**D_1 (under loading plate)**	**D_1 - D_2 (= SCI)**	**D_7**	**Measured Granular Layer Thickness (mm)**	**Estimated Subgrade CBR (using ELMOD) (%)**	**Average Bituminous Overlay (ELMOD) (%)**	**Average Granular Overlay (using RC.218) (mm)**
A_1	1030	385	43	300	4	102	269
A_2	750	288	17	300	6	65	171
C_1	511	183	24	250	10	38	120
C_2	545	199	13	250	7	42	188
C_3	444	189	11	250	13	23	78
D	804	348	16	250	6	77	221
E_1	989	524	7	200	8	91	211
E_2	704	291	10	200	6	73	271

Table 3.5: Summary of Deflection and Overlay Calculations

Based on the data above, Figure 3.2 (which is sourced from the previous edition of this document) contains a plot of ELMOD versus RC.218 overlay design values. The best fit line through this data set is shown on the plot.

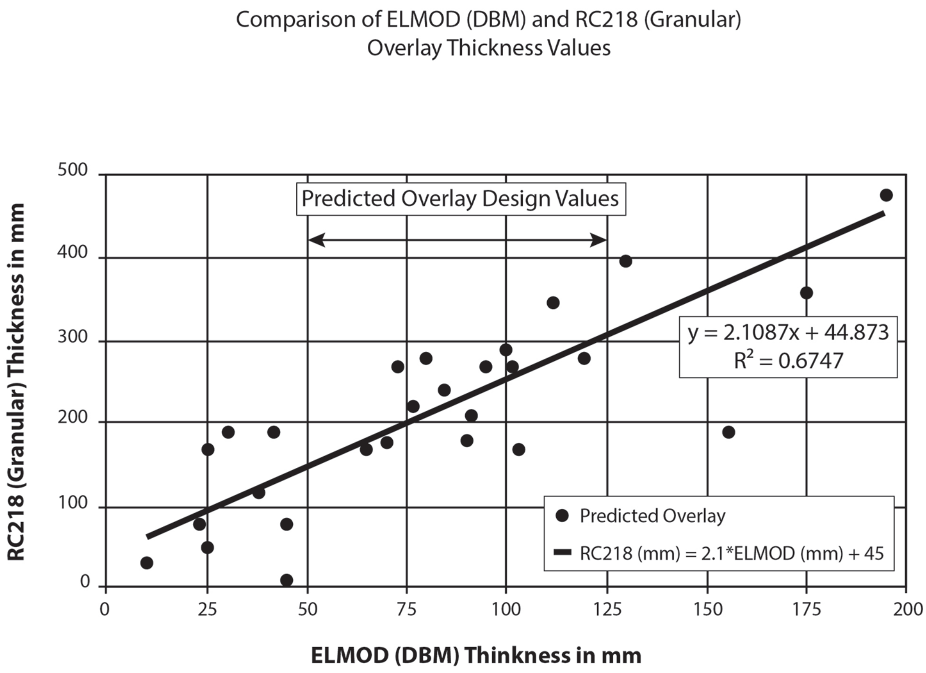

Figure 3.2: Overlay Design Results for Granular Pavements

Based on this graph, the relationship between overlay based on RC 218 and ELMOD is as follows:-

RC.218 [Granular] = ELMOD [AC] x 2.1 + 45 mm (6)

The coefficient of variation for this data set (R^2) is 0.6747.

4. Materials for use in Overlay Design

The following are the typical layers in a flexible pavement.

- The **subgrade** is the existing ground underlying the pavement. It consists of the native ground from that particular location or imported material if embankment construction is required.
- The **capping** layer, typically consisting of a crushed rock or gravel, acts as a support to the subbase and transfers load to the subgrade. The material is used to improve and protect weak subgrades. The capping should increase the stiffness modulus and strength of the formation. Subgrades with a CBR of 2.5-15% should be improved with a capping layer. Where subgrades have lower CBR values, capping with subbase may be insufficient to support the pavement and additional treatments may be required. Typically subgrades with a CBR of above 15% can be treated with a layer of subbase i.e., no capping is required. The top level of the capping is known as the formation.
- **Subbase**, typically consisting of high quality crushed rock, provides a surface on which paving machinery can lay the bituminous material. It is designed to evenly spread the load caused by the trafficking of the bituminous material above to the layers below. Subbase also allows sub-surface drainage of the pavement.
- The **base** layer is the main structural element of the pavement. It provides most of the load distribution for the pavement and distributes the wheel load stresses to levels with which the subgrade can cope. This layer is designed to resist structural deformation and fatigue cracking.
- The **binder course** layer helps distribute the load of traffic on the surface course above onto the base course and is designed to ensure that the top layer has an even surface on which to be laid.
- The **surface course** is the upper course of the pavement which is in contact with the traffic. It's is to provide a smooth running surface for traffic. It also transmits the contact stresses resulting from vehicles accelerating and braking to the layers below. The surface course must provide good skid resistance.
- The **geogrid** is used to reinforce pavements over soft soil, particularly pavements in need of rehabilitation over peat. There are options regarding type and its location in a road section, however for the purposes of illustration it is between the binder course and base.

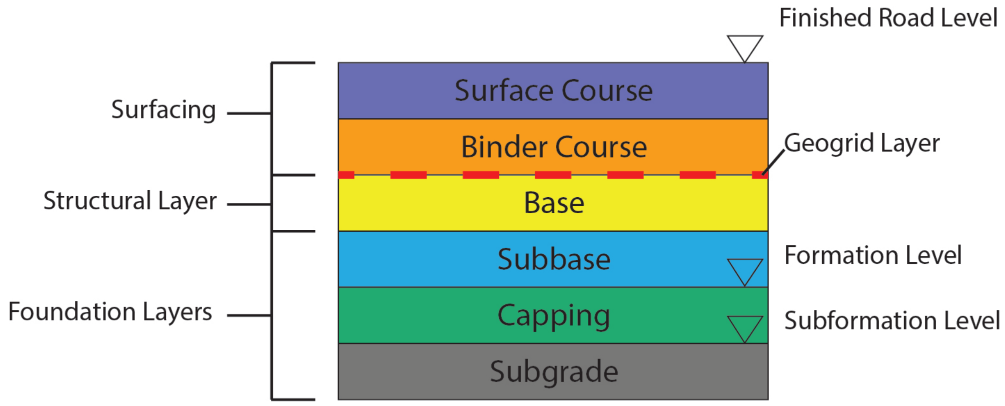

Fig 4.1: Typical layers in a Flexible Pavement

On Rural Regional and Local roads where surface dressing is the main surface course used there are several materials available to use in the sub-surface layers. Alternatives to surface dressing may also be considered.

Whilst noting the options available below, ultimately the overlay and the choice of material must be practical and balance the required design life against the traffic volumes that the pavement will encounter over that lifespan. The budget available to the Local Authority is also an important factor meaning improvement works may only be permitted to progress on an incremental basis.

Market rates and locally available materials will influence the choice of the material. Local terrain will also influence decisions. For example, on steep, high ground, granular material may be susceptible to damage by severe rainfall events. While drainage works are the primary response to this particular problem, if the risk of road loss remains after such works, then materials that can withstand occasional torrents should be considered for such specific isolated locations.

Granular Materials to be considered include:

- Typically known as **'Clause 804'**, this material consists of crushed rock and is defined as Granular Material Type B in Clause 804 of the NRA Specification for Road Works.
- **Wet Mix Macadam** consists of crushed rock pre-mixed with a controlled amount of water sufficient for adequate compaction. The material is defined as Granular Material Type D in Clause 806 of the NRA Specification for Road Works.

Bound Materials offer an alternative to unbound products:

- **Cement Bound Granular Mixtures (CBGM)** are granular hydraulically bound mixtures where cement acts as the binder. They are produced by mixing aggregates with cement and a reduced amount of water, enabling compaction with rollers. Such mixtures should comply with Clause 821, 822 or 823 of the NRA Specification for Road Works (depending on the requirements of the material).

Cold Bituminous Mixes available include:

- **Stabilised Wet Mix** is a bitumen emulsion bound crushed stone obtained by adding approximately 5% bitumen emulsion to Clause 806 material. The material has a final binder content of approximately 3-3.5%.
- **Grave Emulsion** is a material which originated in France. It consists of a graded mix of blended aggregates, water and approximately 7% bitumen emulsion. The material has a final binder content of approximately 4-4.5%.
- **Foam Mix Asphalt** is a mixture of aggregates and foamed bitumen. The foaming is caused by injecting water into hot bitumen.

Bituminous Mixtures for use as binder course include:

- **Asphalt Concrete**, formerly known as Dense Bitumen Macadam (DBM), is a material in which the aggregate particles are continuously graded or gap-graded to form and interlocking structure. Asphalt concrete should conform to Series 900 of the NRA Specification for Road Works

Surface Course materials offered include:

- **Surface Dressing** is a surface treatment consisting of successive laying of at least one layer of binder and at least one layer of chippings. Surface dressing works should be carried out in accordance with Series 900 of the NRA Specification for Road Works and the *'IAT Guidelines for Surface Dressing in Ireland'*.
- **Polymer Modified Stone Mastic Asphalt (PMSMA)** is a gap-graded asphalt mixture with bitumen as a binder, composed of a course crushed aggregate skeleton with a mastic mortar. It is typically defined by the parameters of Series 900 of the NRA Specification for Road Works as directed by the Department.
- **Hot Rolled Asphalt (HRA)** is a dense, gap-graded bituminous mixture in which the mortar of the fine aggregate, filler and high viscosity binder are major contributors to the performance of the laid material. The material should be in accordance with Series 900 of the NRA Specification for Road Works.

Geogrid is used to strengthen pavements constructed on weak or variable soils. Generally a geogrid is geosynthetic type material but can be a steel mesh. Soils pull apart under tension. Compared to soil, geogrids are strong in tension. This fact allows them to transfer forces to a larger area of soil than would otherwise be the case.

This distribution of force is due to stiffness created by aggregates in granular material locking into the apertures of the geogrid. The action of the aggregate causes it to form a stabilised layer with the geogrid. Ensuring that the correct size and shape of aggregate relative to the geogrid used is crucial to achieving an effective interlocking action. Suitable aggregate should be well graded and angular to produce interlock. Materials such as round gravels, moraines and large stones are not be suitable for use with geogrids. All geogrids used should comply with IS EN 13249 [16] and be CE marked in accordance with the Construction Products Directive.

Direct trafficking by construction vehicles can aid the interlocking process. The limiting thickness of a road construction layer, before another geogrid is required, is approximately 450mm as the stabilising effect between the aggregate and the geogrid diminishes at such depths. A 450mm thick initial layer is also normally considered to provide a good intermediate working platform for construction traffic.

A separator grade geotextile can be used if there is risk of fine material getting into the aggregate layer. If an assessment of aggregates in the top layer indicates that they are likely to generate fines under trafficking, which could subsequently be washed into sensitive water courses, the use of a separator grade geotextile should be considered.

A system of two geogrids can produce a stiffer road structure than that of a single geogrid to help limit differential settlement. This system is particularly relevant to design and construction of pavements across peat. When designing overlays on roads over peat the *'Guidelines on the Rehabilitation of Roads over Peat'* [17] should be used. The *'Works Methodologies on Non National Roads'* [18] and the ROADEX report entitled 'Floating Roads on Peat' [19] should also be consulted.

The use of **Recycled Materials** is another option to be considered. This process allows for the existing pavement structure to be directly re-used on site or to be treated off site and re-used at a later date.

Constructing pavement overlays using recycled materials can be achieved using the in-situ or ex-situ processes. The structurally rehabilitated layer that is created should be flexible and fatigue resistant.

- Cold in-situ recycling involves the re-use of the existing road pavement material. The binder used is a form of bitumen emulsion and the aggregate does not require heating. The process may require importation of suitably graded materials for strength and adhesion purposes i.e., Clause 804 material.

- The ex-situ process also extracts the existing road pavement material which is then screened and crushed to the required aggregate grading prior to mixing with binder(s) in a nearby plant. Laying of this material, in one or more layers, is conducted using a paver.

When considering this type of treatment a whole life cost approach should be adopted. This whole life cost approach should include the present cost of performing the treatment as well as all other discounted future maintenance costs associated with this treatment within a specified analysis period.

The *'NRA HD 37 Bituminous Surfacing Materials and Techniques'* [20] (NRA HD 37), provides guidance and specifications for the use of low-energy materials. This advice note is currently intended for maintenance of pavements with design traffic of less than 5 msa for a 20 year design life. It proposes that low-energy materials can be used as capping/ subbase material or as a substitute for standard hot-mix material. Further advice on the use of cold recycled materials is available in TRL Report 611 *'A guide to the use and specification of cold recycled materials for the maintenance of road pavements'* [21].

Clause 804 and Wet Mix Macadam are comparatively similar terms of unit (m^3) price. Aggregates bound with cement (CBGM) and bitumen emulsion (Stabilised Wet Mix, Grave Emulsion, etc.) will, by the nature of their constituents, be more expensive than unbound granular material. Unit rates for CBGM and cold bituminous mixtures are similar. Grave Emulsion is slightly more costly than Stabilised Wet Mix due to the higher binder content in the material.

The unit price of Asphalt Concrete used for binder course level is more costly than when it is used for base, due mainly to the finer aggregate content. When compared to PMSMA and HRA, Surface Dressing is considerably cheaper with PMSMA generally less expensive than HRA.

Summary tables outlining the advantages, disadvantages and factors/conditions needed for laying these and other materials are outlined below.

Material	Advantages	Disadvantages	Factors/Conditions to note
Clause 804 (Granular Material Type B)	• High quality material • Readily accessible • Provides sub-surface drainage and frost protection	• Poor construction can lead to water ingress and damage at pavement edge • Difficult to maintain road profile during compaction	• When using this material consideration must be given to specific site suitability • Refer to NRA SRW Clause 804 and Department requirements • Specific requirements for this material outlined in the NRA SRW Clause 804.3 (laying, compaction and maintaining the material within specified moisture content)
Wet Mix Macadam (Clause 806) (Granular Material Type D)	• High quality material • Low energy requirements - Cold applied material • Fast setting material (typically 15 – 20 minutes) • Cost effective • Excellent dry strength	• Poor wet strength • If placed at a moisture content above the optimum, material can become spongy and unstable • Poor construction can lead to water ingress and damage at pavement edge	• Refer to *'Guidelines on Construction Practice with Wet-Mix Macadam'* [22] (RC.342), NRA SRW Clause 806 and Department requirements • When using this material consideration must be given to specific site suitability. • Specific requirements for this material outlined in the NRA SRW Clause 806.4 (laying, compaction and maintaining the material within specified moisture content) • After laying, surface should be sealed with a cationic bitumen emulsion with chippings applied
Cement Bound Granular Material (CBGM)	• Can be produced from site arisings or recycled material thereby reducing transport costs • Compared to unbound granular materials, the material can provide an equivalent performance with reduced thickness when used as a subbase • Low energy requirements - Cold applied material	• Needs to be protected by one or more layers of asphalt in order to withstand trafficking • Period of construction is restricted within the requirements of Clause 813 of the NRA Specification for Road Works • Layer requires curing after compaction	• When using this material consideration must be given to specific site suitability. • Refer to NRA SRW Clause 813 and Department requirements • After initial compaction, requirements may determine that the material is induced with cracks and sealed

Table 4.1: Summary of ***Granular Unbound, Granular Bound and Cold Bituminous Mix materials*** *available for use on Overlay of Rural Regional and Local Roads*

Material	Advantages	Disadvantages	Factors/Conditions to note
Stabilised Wet Mix	• Can be stockpiled before use, a benefit on rural sites • Resists damage when saturated - fines are fully coated • Has greater resistance to deformation than Clause 806 material • Low energy requirements - Cold applied material • Same grading as Clause 806 wet mix macadam • Useful over peat embankments where reduced thicknesses with equivalent strengths are required	• Laying of material is prohibited when it may be subject to freezing before it matures – typically not permitted to lay material between October and March • More compaction required than hot-mix material, requires a combination of static and dynamic rolling • Difficult to maintain road profile during compaction • Surface course should be delayed until material has matured by drying	• Refer to *'Specification for Stabilised Wet Mix'* contained in Appendix E and Department requirements • When using this material consideration must be given to specific site suitability. • Typically laid using a hot mix paver or a road grader, but this is dependent on site suitability
Grave Emulsion	• Emulsion applied at low temperatures • Tighter grading envelope than stabilised wet mix macadam which provides more control of aggregate range • Less than 50% of the energy outlay than used for hot-mix material • Can be stockpiled before use, a benefit on rural sites • Suitable for use with all Irish aggregates	• Does not perform well when laid in damp/wet conditions • More compaction required than hot-mix material • After compaction using suitable rollers, traffic is relied upon to complete the compaction process as water escapes during curing.	• Refer to AFNOR (French standardization body) Standard NF P98-121 [23] (document in French) and Department requirements • Typically laid using a hot mix paver or a road grader, but this is dependent on site suitability • In France the material is used for roads with an equivalent maximum design traffic of 7 msa

Table 4.1 (contd.): Summary of ***Granular Unbound, Granular Bound and Cold Bituminous Mix materials*** *available for use on Overlay of Rural Regional and Local Roads*

Material	Advantages	Disadvantages	Factors/Conditions to note
Foam Mix Asphalt	• Foamed binder increases the shear strength and reduces the moisture susceptibility of granular materials • Can be used with a wider range of aggregate types • Reduced binder and transportation costs • Only the bitumen needs to be heated up so energy conserved, aggregates are cold-mixed	• The mixing of the foamed bitumen and aggregate must be done to a strict timeframe as the foamed bitumen dissipates in less than a minute and the bitumen resumes its original properties • Material is slow curing. Normally can only be trafficked one day after works completed	• Refer to *'Foamed Asphalt Mixes - Mix Design Procedure'* [24] document and Department requirements • Refer to NRA HD 37 • Initially the material will appear dull brown (because of the moisture present) but it will become black with time

Table 4.1 (contd.): Summary of ***Granular Unbound, Granular Bound and Cold Bituminous Mix materials*** *available for use on Overlay of Rural Regional and Local Roads*

Material	Advantages	Disadvantages	Factors/Conditions to note
Asphalt Concrete (AC) [formerly Dense Bitumen Macadam (DBM)]	• Finished surface provides a good ride quality	• Surface Course material (Surface Dressing, HRA, PMSMA) to be applied to Asphalt Concrete Binder Course as soon as is reasonably practicable after Binder Course has been laid	• Refer to Series 900 of the NRA SRW and Department requirements
Surface Dressing	• Cost effective • Provides good skid resistance • Seals the surface against the ingress of water • High daily outputs • Reduced traffic disruption due to the speed of the process	• Surface dressing does not strengthen the road structure • Period during which works are normally carried out is subject to suitable climatic conditions • Makes no improvement to the road profile • Makes no improvement to the ride quality	• For specific details, including aftercare, refer to *'IAT Guidelines for Surface Dressing in Ireland'*, Series 900 of the NRA SRW and Department requirements • Site works and construction technique shall match the surface dressing design • Several types of surface dressing available, such as single, double, sandwich, inverted and racked in dressings
Polymer Modified Stone Mastic Asphalt Surface Course	• Finished surface provides a good ride quality • Acts as a barrier to ingress of surface water to layers below • Better noise reduction capabilities than conventional surfacings • Quicker construction operation than HRA	• Specific parameters within which laying can occur	• Refer to Series 900 of the NRA SRW and Department requirements for permitted laying conditions and performance and testing requirements
Hot Rolled Asphalt (HRA)	• Durable material • High resistance to permanent deformation • Provides an impermeable layer for the pavement structure • Good ride quality	• Specific parameters within which laying can occur • Addition of chipping element lengthens work programme • On narrow roads may need closure / diversion to fit chipping machine	• Refer to Series 900 of the NRA SRW and Department requirements for permitted laying conditions

*Table 4.2: Summary of **Hot Bituminous materials** available for use on Overlay of Rural Regional and Local Roads*

Material	Advantages	Disadvantages	Factors/Conditions to note
In-Situ Recycling / Reclaimed Asphalt	• Existing pavement material is re-used so reduced demand for virgin aggregate and reduction of material disposed to landfill • Ex-situ process allows aggregates from sources other than the existing pavement to be used • Pavement structure improved without the need to import additional material • Lower mixing temperatures reduce the energy required to produce these materials (bitumen-bound materials typically heated to over 100ºC) • Environmentally friendly: less carbon emissions due to lower fuel and transport demand	• Time required to check the validity of the mix design between reclaiming the asphalt and using it as a component material • Works should only commence once the ideal moisture content and percentage of emulsion required for the new layer are determined • Surface course required to be laid over the recycled material • Remote locations may not be suitable for transporting specialist plant/machinery • On Rural Regional and Local Roads there may be insufficient depth of recyclable material in the existing pavement	• Refer to Series 900 of the NRA SRW and Department requirements • Refer to NRA HD 37 • Extensive site investigation required to mitigate risks in the design calculation of the pavement structure • To accommodate material variability, the depth of recycling to be removed should be 30-50mm more than design requires

*Table 4.3: Summary of **Recycled materials** available for use on Overlay of Rural Regional and Local Roads*

5. Rational Overlay Design Solutions

The important physical parameters in overlay design are existing traffic, existing granular thickness and subgrade CBR. This Chapter provides typical overlay thicknesses using the existing depth of granular material, determined on site, for a range of Annual Average Daily Traffic (AADT) bands and CBR values.

Data from FWD testing and AADT surveys will, realistically, not be available for many Rural Regional and Local roads in Ireland. From a practical point of view, Local Authority staff will need to approximate AADT figures for certain roads. These approximations can then be compared to the bands provided in Table 5.1 in order to calculate the overlay thickness required.

AADT is the total (in both directions) traffic count for a given road section and is usually divided in two for the purpose of pavement design as in Table 5.1. It is converted to Design Traffic, which is expressed in terms of million standard axles (msa), using formulae presented in HD 24. The AADT values quoted in Table 5.1 have been used to calculate the design number of standard 80 kN axles in each direction. This design is based on a 20 year design life at a growth rate of 3 per cent and a heavy commercial vehicle (HCV) content of 10 per cent. Rural Regional and Local roads with a disproportionate number of HCVs (above 10%) should be subject to further design analysis if deemed necessary by Local Authority staff.

However, in the case of narrow roads (≤ 4 m approximately), the driving lanes of the heavy commercial vehicles will overlap. In such cases, it is more appropriate to use the measured (total) AADT value when using Table 5.1.

As detailed in Chapter 3, the existing layer thicknesses can be obtained from various sources. If the existing materials are shown to be of poor quality, the measured thickness of existing granular material should be reduced to a suitable equivalent depth for use in Table 5.1. The subgrade soil should be sampled in order to establish its CBR value. Refer to Chapter 3 for testing methods to determine the CBR value. Where compressive subgrades exist, specialist advice should be sought. In the case where trial pits are used, refer to Appendix B for a sample trial pit record sheet.

Table 5.1 contains a range of sample overlay design thickness values for Wet Mix Macadam overlay with a double surface dressing (refer to Note 1 for equivalent Clause 804 thicknesses). The design data used in Table 5.1 is intended to cover the range of conditions encountered in practice on Rural Regional and Local roads. The overlay design values contained in Table 5.1 are typical of those estimated using 'back analysis' of FWD deflections. The design values using this method are often less than those calculated using methods in RC.218. This is due in part to the current use of higher quality granular materials compared to when RC.218 was published.

The minimum and maximum practical overlay design thickness values for granular unbound material (Clause 806 Wet Mix Macadam, Clause 804, etc.) are 150 and 300 mm respectively. On Rural Regional and Local roads with an AADT of less than 500, a minimum thickness of 100mm may be used in the circumstances defined in Table 5.1. Material of compacted thickness greater than 225 mm should be laid in two or more layers and the minimum compacted thickness of any such layer should be 110 mm. Table 5.2 contains equivalent thickness factors for granular material, stabilised wet mix, composite construction (wet mix macadam plus bituminous material) and bituminous bound material only. Series 800 of the NRA Specification for Road Works should be used when specifying the use of Wet Mix Macadam or Clause 804 for this purpose.

For higher trafficked roads, particularly where the current total AADT exceeds 8,000 (total in both directions), a project specific pavement design should be prepared as more economic, refined or better solutions can be achieved.

Existing Granular Thickness: 100 - 200mm				
	Current AADT (total in one direction)**			
Subgrade CBR	<500vpd	500 - 1000vpd	1000 - 2500vpd	2500 - 4000vpd
	< 1.1 MSA	1.1 – 2.3 MSA	2.3 – 5.8 MSA	5.8 – 9.3 MSA
1.5 - 3	150	200	300	-
3 - 5	100	150	250	300
> 5	100	150	200	250

Existing Granular Thickness: 201 - 300mm				
	Current AADT (total in one direction)**			
Subgrade CBR	<500vpd	500 - 1000vpd	1000 - 2500vpd	2500 - 4000vpd
	< 1.1 MSA	1.1 – 2.3 MSA	2.3 – 5.8 MSA	5.8 – 9.3 MSA
1.5 - 3	100	150	250	300
3 - 5	-	150	200	250
> 5	-	-	150	200

Existing Granular Thickness: 301 - 400mm				
	Current AADT (total in one direction)**			
Subgrade CBR	<500vpd	500 - 1000vpd	1000 - 2500vpd	2500 - 4000vpd
	< 1.1 MSA	1.1 – 2.3 MSA	2.3 – 5.8 MSA	5.8 – 9.3 MSA
1.5 - 3	-	150	200	250
3 - 5	-	-	150	200
> 5	-	-	150	150

Table 5.1: Typical Wet Mix Macadam Overlay Design Thickness Values for Rural Regional and Local Roads

** On roads narrower than 4m, use current AAD T (total of both directions)

Note 1: Clause 804 may be substituted for Wet Mix Macadam for current AADT ≤ 500. For current AADT > 500, Clause 804 thickness should be 50 mm greater than the indicated Wet Mix Macadam design thickness

Note 2: Where the existing granular layer thickness is less than 100 mm, the difference between the existing thickness and 100 mm should be added to the design overlay.

Note 3: This table is not applicable when subgrade CBR is less than 1.5. When this is the case, consideration should be given to the use of increased thickness and/or the use of geotextiles.

Note 4: This table is based on a 20 year design life, 3% per annum growth rate and 10% Heavy Commercial Vehicle content.

Note 5: **Good Drainage is essential in order to maintain road bearing capacity.**

Wet Mix Macadam (mm)	Stabilised Wet Mix (mm)	Wet Mix / Asphalt Concrete (mm)	Asphalt Concrete (AC) (mm)
150*	100	-	70**
200*	150	-	100**
250*	180	150 / 50	120**
300*	200	200 / 50	140**

Table 5.2: Approximate Equivalent Thickness values

* Clause 804 may be substituted for Wet Mix Macadam for current AADT ≤ 500. For current AADT > 500, Clause 804 thickness should be 50 mm greater than the indicated Wet Mix Macadam design thickness

** Asphalt Concrete alone should not be used for **SCI > 250 microns** (40 kN wheel load)

6. Drainage

Proper and functioning road drainage prevents flooding and ponding. Road drainage protects the bearing capacity of the pavement, subgrade material and road embankments from threat of erosion. When the road drainage system starts to become defective or ineffective, issues with the foundation of the pavement structure are likely to follow.

Prior to starting the detailed design of road works, the condition of the existing road drainage should be established. An inspection should identify the works necessary to rectify any drainage deficiencies. Such works should be programmed to take place in advance of the pavement works. Issues to note include:

- Water lodging on the road surface and whether it relates to an inadequate drainage system?

- Whether the drainage system is sufficient but poorly maintained or whether the retention of water on the roadway is due to the road having lost its shape?

Widening of an existing pavement increases the load on the road drainage system and potentially could reduce the space available for such a system. Widening should only be considered where the traffic regime requires it and should not in any event compromise the operation or effectiveness of the necessary road drainage system.

The *'Guidelines for Road Drainage'* published by the (then) Department of Environment, Heritage and Local Government [25] is the primary reference document on this issue. Series 500 of the NRA Specification for Road Works along with the relevant NRA Road Construction Details (RCD's) provide guidelines for the construction of piped and filter drainage systems. *'IAT Guidelines for Surface Dressing in Ireland'* also provides advice on recommended drainage practice to be carried alongside pavement works.

The most suitable type of drainage to be used will generally depend on the particular circumstances of the road. The main options available are open, piped and filter drainage systems.

6.1 Open Drainage

- This is the preferred system as open drains allow early (visual) detection of blockages, etc.
- This type of drainage requires adequate space along the verge for the open drain to fit.
- If sufficient space is not available, open drains are susceptible to damage caused by encroaching vehicles.

6.2 Piped Drainage

- Piped drainage can be used to good effect where there is limited width between the fence and road edge.
- These systems require regular maintenance of gullies, etc. to ensure free drainage paths.
- Load bearing pipes must be used for piped drainage.

6.3 Filter Drainage

- As per piped drainage, filter drainage systems can be used to good effect where space is limited.
- Regular maintenance is required, particularly to the Clause 505 (or equivalent) stone used to top-up the drainage layer.
- This stone can become contaminated by run-off liquids.
- The filter material can be made redundant if it compacts due to traffic or maintenance vehicles driving over or parking on the top layer of stone.

When undertaking maintenance works refer to the *'Guidelines for Road Drainage'* and, for open drains, the *'Drainage Maintenance & Standard Operating Procedures'* [26] which is published by the Office of Public Works.

7. General Recommendations

7.1 Recommended Approach for Local Authorities

(a) Approach Using FWD

- The extent of use of FWD testing should be appropriate to the type of road proposed for overlay. Generally FWD testing should be carried out on a sample of Rural Regional roads and priority Local Primary routes.
- Use data obtained from procedures such as FWD testing, coring and GPR testing along with soil maps and/or local knowledge to divide the County/Region into areas having assumed similar subgrades and depths of existing granular construction (refer to NRA FWD Guidelines Chapter 4.4 for guidance on subdivision of areas with similar deflection results).
- Undertake, as deemed appropriate, the testing listed above on a sample of roads representative of each subgrade type and construction depth.
- Utilise the results and analysis outlined in Chapters 3 and 5 of this document to develop plots and tables indicating the allowable overlay type (granular only, granular/bituminous or bituminous only) and wet mix overlay thickness required on each sampled road under various levels of AADT/% HCV.
- Utilise these local thickness tables as guides when developing five year programs of overlay work on Rural Regional and Local roads.
- Consider material data in Chapter 4 as a guide when choosing the most appropriate overlay design.

(b) Approach Using CBR Data

- Use data obtained from procedures such as Dynamic Cone Penetrometer testing, GPR testing and trial pits along with soil maps and/or local knowledge to divide the County into area having assumed similar subgrades and depths of granular construction as in (a) above.
- Use data from this testing in these areas to estimate typical values for existing construction depth and subgrade CBR.
- Utilise the CBR results and guidelines as set out in Tables 5.1 and 5.2 to develop tables indicating the allowable overlay type (granular only, granular/bituminous or bituminous only) and wet mix overlay thickness required on each sampled road under various levels of AADT/% HCV.
- Utilise these local thickness tables as guides when developing five year programs of overlay work on Rural Regional and Local roads as in (a) above.
- Consider material data in Chapter 4 as a guide when choosing the most appropriate overlay design.

7.2 Requirement for FWD Providers

- The software system used should be capable of recommending overlay thickness values for a variety of material types and combinations.
- From the magnitude of the recorded SCI values (Table A.1 of Appendix A), the software should indicate whether the present pavement is strong enough to allow the use of a bituminous overlay only and, if strong enough, also recommend overlay thickness in terms of asphalt concrete.
- Calculations to determine required overlay thicknesses, similar to that shown in Table 3.5, should be produced.
- Guidance for the use of a Falling Weight Deflectometer is available in an NRA document entitled 'Guidelines for the use of the *Falling Weight Deflectometer in Ireland'*.

7.3 Section overlay design value

- The average (50^{th} percentile) overlay design value is often used for Rural Regional and Local road test lengths. In effect, this means that some sections of the road under consideration will be under-designed. It is usually more cost effective to use this average value and replace/strengthen the most seriously disintegrated, cratered and badly cracked areas prior to full scale surfacing or overlay. This will have the effect of improving the most critical sections and so reduce the risk of premature failure.
- In general, the same overlay design thickness should be used for Rural Regional roads, by using the average traffic volume over its full length. Frequent changes to the overlay design should be avoided, particularly over short lengths of road.

7.4 Surface Course

- The thickness of surface course materials should not be factored in when calculating overlay design thickness values in the structural rehabilitation of Rural Regional and Local Roads. The choice of surface course, which must provide a sufficiently smooth running surface with sufficient skid resistance and seal the layers below from water ingress, should be decided on once the structural rehabilitation design is complete.

7.5 Design Thickness/Nominal Size Values

- The design thickness values used should be consistent with the nominal size of the material being used. This is important to ensure proper compaction of the layers. The nominal and minimum thickness values given in Tables 1A, 1B, 1C and 1D of BS 594987 [27] should be referred to when specifying the bituminous elements of the pavement build-up. Details of these tables are provided in Appendix C.

7.6 Drainage

- Adequate road drainage should be provided in conjunction with overlay works. This is to ensure that the bearing capacity of the road structure is maintained. Refer to Chapter 6 for further details.

7.7 Quality Control of Site Operations

- Quality Control should be itemised on a project/contract level. For guidance on Quality Control and Testing refer to Appendix F which contains a 'Best Practice Guide' for Pavement Works on Rural Regional and Local Roads.

7.8 Surface Dressing

- Design of the surface dressing is critical. Factors such as the existing surface condition, design traffic, road hardness, surface texture and site topography should be used to choose the type of surface dressing to be installed. Design procedures in the *'IAT Guidelines for Surface Dressing in Ireland'* should be then followed to determine the chipping size, rate of spread of binder and rate of spread of chippings.

- Where road widths are narrow and surface dressing is proposed as a treatment measure, it should be established whether a traditional surface dressing train can negotiate the road. If not an alternative, such as a combination sprayer/chipping spreader vehicle (combi unit) may be required.

- Surface dressing should be applied to asphalt concrete overlays as soon as is practicable for skid resistance purposes.

- Double surface dressing should be applied as soon as practicably possible after laying granular overlays i.e., two surface dressing passes as soon as practicable after laying Clause 804/Wet Mix Macadam. It is considered good practice to follow this double surface dressing with a further surface dressing when bedding in and initial settlement is deemed to have taken place.

7.9 Survey Data and Record Keeping

- Full details of all improvement and maintenance schemes should be recorded on the Local Government Management Agency (LGMA) MapRoad Pavement Management System (PMS) [28]. Full financial and technical records should be collected. Technical detail should include material types used, ambient conditions, thickness of each layer, testing carried out and test results.

- The data gathered shall form part of the on-going process of pavement management and the allocation of resources to the Rural Regional and Local road network.

- The importance of keeping these records is vital for future decision making on similar schemes and for monitoring the effectiveness of the works constructed.

7.10 Temporary Traffic Management

- For all road works on Rural Regional and Local Roads, traffic management should be planned, designed and installed in accordance with the Traffic Signs Manual Chapter 8 *'Temporary Traffic Measures and Signs for Roadworks'* [29] and *'The Guidance for the Control and Management of Traffic at Road Works'* [30].

- Traffic Management should be designed on the basis of a site specific risk assessment.

- With particular reference to surface dressing operations, a cautionary speed plate of 25 km/hr should be applied where newly laid surface dressing is exposed to live traffic. This control should be used to protect the quality of the surface dressing work until the binder has set and help develop a tight mosaic of chippings. In certain cases, convoy working may be a more appropriate means of protecting the works.

7.11 Safety and Health

- Road works can present a high risk unless adequate precautions are taken to ensure that the travelling public is adequately warned informed and directed past the works. Drivers may not expect to encounter standing or slow moving vehicles or people at work. Some Rural Regional and Local roads may fail to meet current sight distance requirements and design standards and in many cases the available carriageway width will be limited during works. Therefore risks involved in working on Rural Regional and Local roads must not be underestimated.

7.12 Best Practice for Works on Rural Regional and Local Roads

- A 'Best Practice' Guide for Pavement Works on Rural Regional and Local Roads is included in Appendix D. Guidance notes, similar to those in Appendix F, should be included in all specifications for overlay of Rural Regional and Local roads.

- All personnel should have completed the relevant DTTAS maintenance and improvement training courses such as 'Basic and Advanced Surface Dressing' and 'Basic and Advanced Road Strengthening'.

8. Conclusions

This document provides guidelines on the depth of overlay to be used on Rural Regional and Local roads. Often these road structures consist of unbound granular material sealed with surface dressing. The most scientific approach to overlay design is to base the design on load bearing capacity of the existing pavement structure.

This can be done in the following manner:

- Falling Weight Deflectometer (FWD) survey at 25 or 50m intervals in one direction except where highly variable subgrades are suspected.

- Examination of FWD plots to identify homogenous sub-sections.

- Ground Penetrating Radar (GPR) testing or trial pits in strategic locations to provide existing layer thicknesses.

- Overlay design using the 'back analysis' process based on layer stiffness moduli, calculated stresses and strains, and traffic data.

- Examination of overlay design thickness in conjunction with SCI values to determine most appropriate overlay strategy, i.e. SCI values greater than 250 microns (40 kN) require granular overlay or equivalent thickness of composite granular material/Asphalt Concrete overlay.

The alternative approach, using RC.218, is as follows:

- In-situ testing such as using GPR, trial pits and Dynamic Cone Penetrometer to determine existing thicknesses and subgrade CBR.

- Laboratory analysis including CBR, liquid and plastic limit tests to measure subgrade CBR.

- Design thickness of granular overlay using above information and formulae in RC.218.

In practice, Local Authorities should use either the FWD method or the CBR method, as outlined in Chapter 7, to determine the load bearing capacity of the existing pavement structure.

Once the existing pavement structure and conditions have been determined, appropriate treatment measures should be chosen as detailed in Chapter 2.

However, where the budget available does not permit this, an incremental solution may be required, whereby the pavement is strengthened and improved over one or more work programmes. In this case, the Local Authority should ensure that the road pavement is not allowed to fail or deteriorate before the final strengthening layers are added. Maintenance of roads is important as repair costs can rise to multiple times the maintenance costs over time if neglected.

All seriously disintegrated, cratered and badly cracked areas should be replaced with good quality material prior to full scale overlay e.g., regulation with bituminous material.

Good **drainage is essential** in order to maintain the bearing capacity of the road structure.

A named person should be indicated for the role of co-ordination of sampling and testing of materials to ensure that the works are carried out in accordance with the requirements of the relevant standards and contract specifications. This person must be given adequate access to IT and a test facility in order that quality control can be carried out on a daily basis.

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Appendix A – Description of FWD Analysis

A.1 Test Method

The aim of Falling Weight Deflectometer testing is to evaluate the structural condition of the road pavement.

The FWD test involves dropping a weight onto a damped spring system, mounted on a loading plate, which generates a load pulse. As specified in HD 29 Chapter 5, the load level for a FWD test on flexible and composite pavement is set at a nominal 50kN + 5kN. The NRA FWD Guidelines note that the target load pulse is usually either 40kN or 50kN. A different target load may be chosen to match the standard wheel load used in the pavement design or for other reasons. For example, the load may be increased to a nominal 75kN + 7.5kN for concrete pavements. The load pulse is applied through a circular loading plate of diameter 300mm. Uniform contact between the plate and the pavement surface is maintained by attaching a rubber pad (minimum thickness of 5mm) to the bottom of the loading plate.

Figure A.1: FWD loading plate (source COST 336)

Figure A.2: Deflection sensors of the geophone type (source COST 336)

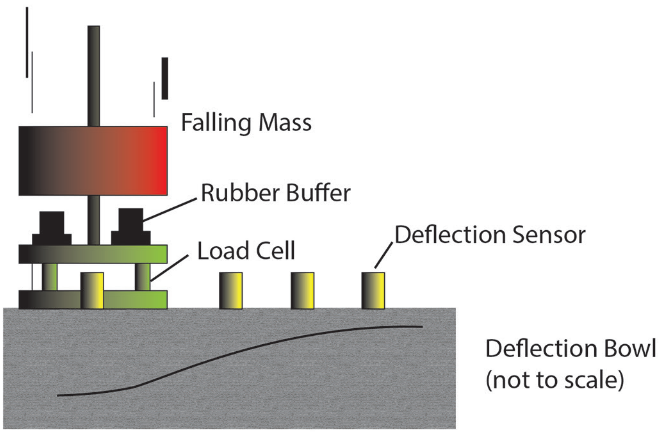

Figure A.3: Schematic diagram of a FWD in operation

The peak load is measured at the centre of the load plate with a minimum of six further sensors situated at radii of up to a distance of 2.25m, in accordance with HD 29 Clause 5.13, from the centre of the load plate. Refer to Table 5.1 of HD 29 for recommended deflection sensor positions or choose from the list outlined in the NRA FWD Guidelines. Deflections must be measured to a resolution of a least 1 micron over the range 0-2mm.

The road surface to be tested must be free of standing water. Also ensure that the whole area of the plate is in contact with the surface.

A small initial drop, to settle the load plate, followed by least three drops must be made at each test location. The first drop is usually omitted from the resulting calculations.

To quantify the greatest deterioration on a pavement structure the loading plate is typically located within the nearside wheel path of the heaviest loaded lane, typically the left hand lane. For comparison purposes, testing can also be carried out in the offside wheel path and between the wheel paths.

Pavement temperatures must be taken at the time of the test and normalised to a reference temperature. It is not necessary to carry out temperature measurements on surface dressed roads as the thickness of the bituminous material is such that it would not have any significant effect on the overall pavement structure. Refer to HD 29 Chapter 5 and NRA FWD Guidelines Chapter 3.4 for advice.

HD 29 and HD 30 recommend that visual condition surveys, deflectometer testing, coring and Dynamic Cone Penetrometer testing be carried out for scheme surveys. FWD testing is classed as an *"optional"* test.

As advised in HD 29 and NRA FWD Guidelines, all FWD equipment must be tested and approved in an annual FWD correlation trial to check their adequacy for road testing. Calibration procedures for FWD equipment are outlined in Chapter 2.4 of the NRA FWD Guidelines. The *'COST Action 336'* report (published by the European Commission Directorate General Transport in 2005) also provides advice on this issue.

A.2 Explanation of Plots

Once the FWD data is 'normalised' to a standard load, of 50kN or 75kN as appropriate, the deflection (in microns) is plotted against chainage. The three main deflection parameters used are the central deflection (D_1), an outer deflection (D_6) and deflection difference $D_1 – D_4$.

The central deflection D_1 relates to the overall pavement performance and structural strength. The deflection difference $D_1 – D_4$ indicates the condition of the bound layers and this parameter is an example of the Surface Curvature Index (SCI_x). SCI_x is the difference between the deflection recorded at the centre of the dynamic load and the deflection recorded at a nearby offset a distance Xmm away from the centre of the loading plate (usually up to 900 mm maximum). Low values of SCI suggest good load spreading ability of the layers. In cases where the plotted SCI profile takes the same shape as the D_1 plot, the upper bound layers have a large influence on the pavement structural condition.

Department of Transport, Tourism and Sport guidelines specify that bituminous-only overlays are not suitable where the SCI is calculated as being greater than 250 microns, as the possibility of premature cracking is too high.

Deflection D_6 gives an indication of the subgrade strength. Low values here indicate a stiff subgrade. In cases where this plot takes the same shape as the D_1 plot, the subgrade layer has a large influence on the pavement structural condition.

Figure A.4 below shows a typical plot of these three parameters while Tables A.1 and A.2 contain guideline deflection criteria for granular roads.

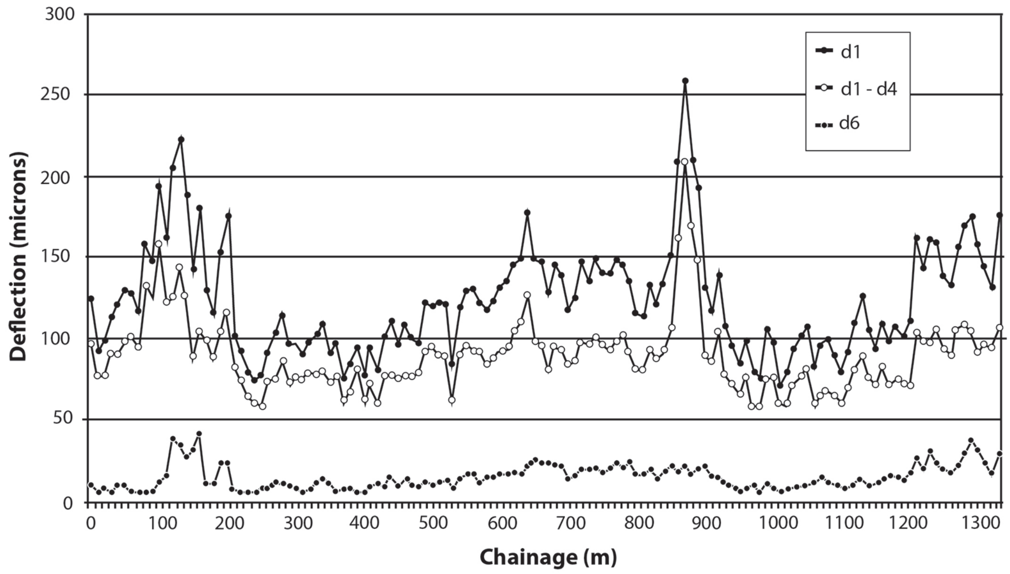

Figure A.4: Sample FWD Deflection Profiles (source: HD 29)

Central Deflection, D1 (microns)	SCI300 = D1 - D2 (microns)	Comment
< 300	< 150	Good Load Spreading Ability
300 - 500	150 - 250	Good to Poor Load Spreading Ability
501 - 800	251 - 400	Poor to Bad Load Spreading Ability
> 800	> 400	Bad Load Spreading Ability

Table A.1: Central and SCI Deflection Criteria for Rural Regional and Local Roads

(Note: All deflections normalised to 40kN load)

Outer Deflection @ 2.1m offset from centre of loading plate	**Comment**
< 15	Stiff Subgrade
15 - 30	Stiff to Moderate Subgrade
31 - 45	Moderate to Weak Subgrade
> 45	Weak Subgrade

Table A.2: Outer Deflection Criteria for Rural Regional and Local Roads

(Note: All deflections normalised to 40kN load

Appendix B – Sample Trial Pit Log

Sample Trial Pit Log			
Road Name, Number:	**Trial Pit No.**	**Date**	**Time**
Road Segment Number:			
Road Reference Number:			
Excavation Method:			
Description of Material	**Layer Thickness (mm)**	**Total Depth (mm)**	**Sample Depth (mm)**
1. Road Surface (Type, Cracking, etc.)			
2. Bituminous Bound Layers			
3. Granular Layers (Type, Grading, Cleanliness, etc.)			
4. Subgrade Soil (Type, Moisture Content, etc.)			
Other Remarks (surrounding Vegetation, etc.)			
Ground Water Conditions/Road Drainage			
Signed ______________________ on behalf of ______________ Co. Council			

Appendix C – Specified Nominal and Minimum Layer Thickness for Selected Bituminous Mixtures

Tables 1A, 1B, 1C and 1D of BS 594987:2010, with references to relevant Irish Standards included, are shown below:

Table 1A	**Nominal and minimum compacted layer thicknesses for asphalt concrete (AC) mixtures conforming to I.S. EN 13108-1 (see S.R. 28, Chapter 4)**			
Material description	**S.R. 28 reference**	**Size** mm	**Nominal layer thickness** mm	**Minimum thickness at any point** mm
Fine graded surface course	AC 4 Fine surf	4	15-25	10
Medium graded surface course	**AC 6 med surf**	**6**	**20-25**	**15**
Dense surface course	**AC 6 dense surf**	**6**	**20-30**	**15**
Open graded surface course	AC 10 open surf	10	30-35	25
Close graded surface course	**AC 10 close surf**	**10**	**30-40**	**25**
Open graded surface course	AC 14 open surf	14	35-55	30
Close graded surface course	**AC 14 close surf**	**14**	**40-55**	**35**
Open graded binder course	AC 20 open bin	20	45-75	40
Dense, heavy-duty and high-modulus binder course	**AC 20 dense/HDM/HMB bin**	**20**	**50-100**	**40**
Dense, heavy-duty and high-modulus binder course	AC 32 dense/HDM/HMB bin	32	70-150	55
Dense, heavy-duty and high-modulus base	**AC 32 dense/HDM/HMB base**	**32**	**70-150**	**55**
EME 2	AC 10 EME2 bin/base	10	60-100	50
EME 2	AC 14 EME2 bin/base	14	70-130	60
EME 2	AC 20 EME2 bin/base	20	90-150	80

Table 1B	Nominal and minimum compacted layer thicknesses for HRA mixtures conforming to I.S. EN 13108-4 (see S.R. 28, Chapter 6)			
Material description	**S.R. 28 reference**	**Size** mm	**Nominal layer thickness** mm	**Minimum thickness at any point** mm
HRA regulating and binder 50/10	HRA 50/10 reg/bin	10	25-50	20
HRA regulating and binder 50/14	**HRA 50/14 reg/bin**	**14**	**35-65**	**30**
HRA base and binder 50/20	HRA 50/20 bin/base	20	45-80	40
HRA base and binder 60/20	HRA 60/20 bin/base	20	45-80	40
HRA base and binder 60/32	**HRA 60/32 bin/base**	**32**	**60-150**	**55**
HRA surface course type F 0/2	**HRA 0/2 F surf**	**2**	**25**	**20**
HRA surface course type F 15/10	**HRA 15/10 F surf**	**10**	**30**	**25**
HRA surface course type F 30/10	HRA 30/10 F surf	10	35	30
HRA surface course type F 55/10	HRA 55/10 F surf	10	40	35
HRA surface course type F 30/14	**HRA 30/14 F surf**	**14**	**40**	**35**
HRA surface course type F 35/14	**HRA 35/14 F surf**	**14**	**50**	**45**
HRA surface course type F 55/14	HRA 55/14 F surf	14	45	40
HRA surface course type C 0/2	HRA 0/2 C surf	2	25	20
HRA surface course type C 55/10	HRA 55/10 C surf	10	40	35
HRA surface course type C 30/14	**HRA 30/14 C surf**	**14**	**40**	**35**
HRA Surface course type C 35/14	**HRA 35/14 C surf**	**14**	**50**	**45**
HRA surface course type C 55/14	HRA 55/14 C surf	14	45	40

Table 1C	Nominal and minimum compacted layer thicknesses for SMA surface course mixtures conforming to I.S. EN 13108-5 (see S.R. 28, Chapter 7)			
Material description	**S.R. 28 reference**	**Size** mm	**Nominal layer thickness** mm	**Minimum thickness at any point** mm
SMA 6	**SMA 6 surf**	6	20-40	15
SMA 10	**SMA 10 surf**	10	25-50	20
SMA 14	**SMA 14 surf**	14	35-50	30

Table 1D	Nominal and minimum compacted layer thicknesses for other SMA mixtures conforming to I.S. EN 13108-5 (see S.R. 28, Chapter 7)			
Material description	**S.R. 28 reference**	**Size** mm	**Nominal layer thickness** mm	**Minimum thickness at any point** mm
SMA 6	**SMA 6 reg**	6	15-40	10
SMA 10	**SMA 10 reg**	10	20-50	15
SMA 14	**SMA 14 bin/reg**	14	30-60	25
SMA 20	**SMA 20 bin/base/reg**	20	50-100	40

NOTE 1: Materials shown in **bold** in Table 1A to Table 1D are preferred mixtures as previously denoted in BS 4987 or BS 594.

NOTE 2: Thicknesses in excess of those given in Table 1A to Table 1D can provide better compaction if adequate equipment is used, but could lead to problems with surface irregularity and level control.

NOTE 3: A guide to the rates of spread likely to be obtained from different asphalt mixtures at different compacted thicknesses is given in Annex B of BS 594987:2010.

Appendix D – Specification for Clauses 801, 802, 804, 806, 810, 813, 821, 822, 823

Please note that the obligation shall be on the user of this document to have the most up-to-date version of these Specifications to hand.

The latest version of the NRA Specification for Road Works is available to download from the NRA standards website http://nrastandards.nra.ie/.

Notes:

- Appendix 7.1 of the Specification for Road Works deals with the permitted options for road construction

Road Pavements – Unbound and Cement Bound Mixtures

[March 2013]

801 General Requirements for Unbound Mixtures

1 Unbound mixtures shall be made and constructed to conform to IS EN 13285, the mixture and grading requirement categories in Table 8/1, and Clauses 802 to 809. The permitted alternatives for each part of the permanent Works shall be as described in Appendix 7/1. The Contractor shall ensure that the manufacturer of unbound mixtures has in place a system of factory production control that complies with the requirements of Annex C of IS EN 13242.

2 The properties of aggregates used in unbound mixtures shall comply with the selected requirements of IS EN 13242 listed in Table 8/2.

3 Where recycled coarse aggregate or recycled concrete aggregate is used in unbound mixtures in accordance with Clauses 803 and 807 as appropriate, the constituents of a sample of recycled aggregate shall be classified by hand-sorting the coarse aggregate particles in accordance with IS EN 933-11. The test shall be carried out by a suitably trained laboratory technician who has demonstrated competence in classifying the constituent classes in accordance with the test method. Recycled coarse aggregate and recycled concrete aggregate used in unbound mixtures in accordance with Clause 803 and 807 shall also comply with the additional requirements of Table 8/3.

Frost Heave

4 Subject to the tolerances given in Table 7/1 and unless otherwise stated in Appendix 7/1, material shall not be frost susceptible if it is used within 350 mm of the designed final surface of a road or paved central reserve.

5 Material shall be classified as non-frost susceptible if the mean heave is 15 mm or less, when tested in accordance with BS 812-124. Comparator specimens in accordance with Annex B of BS 812-124 shall be used.

6 Where unbound materials are to be placed adjacent to cement-bound materials or metallic structural components, refer to the additional requirements of Clauses 808 and 809.

Table 8/1: Mixture and Grading Requirement Categories for Unbound Mixtures

Unbound mixture	Type A	Type B	Type C (open graded)	Type D (wet mix macadam)	Type E (close graded)
Clause	803	804	805	806	807
Standard	IS EN 13285 Categories for unbound mixture properties				
Mixture requirement category	0/31,5 UF_7 OC_{80}	0/31,5 UF_7 OC_{80}	0/40 UF_7 OC_{80}	0/31,5 UF_7 OC_{80}	0/31,5 UF_7 OC_{80}
Grading requirement category	G_B	G_A	G_A	G_o	G_B

Table 8/2: Requirements for Aggregates Used in Unbound Mixtures for Subbase and Base

Unbound Mixture/Clause No.		803	804	805	806	807	808	809
Standard		IS EN 13242 Categories for aggregate properties						
Crushed or Broken and totally rounded particles		$C_{90/3}$ (See Note 1)	$C_{90/3}$	Not permitted	$C_{90/3}$	$C_{90/3}$	$C_{90/3}$	$C_{90/3}$
- Crushed Rock		C_{nr}	Not permitted	C_{nr}	Not permitted	Not permitted	Not permitted	Not permitted
- Gravel		C_{nr}	Not permitted	$C_{50/10}$	Not permitted	Not permitted	Not permitted	Not permitted
- Crushed Gravel								
Shape of course aggregate – Flakiness Index		FI_{50}	FI_{35}	FI_{50}	FI_{35}	FI_{50}	FI_{35}	FI_{35}
Resistance to fragmentation – Los Angeles test		LA_{30}						
Fines Quality – Methylene – Blue Test		MB (see Note 2)						
Resistance to freezing and hawing	Water Absorption	$WA_{24}2$ If water absorption is not greater than 2% then aggregate shall be assumed to be freeze – thaw resistant						
	Magnesium Sulphate Soundness	MS_{25}						
Sulphur Content							(See Note 5)	
All other IS EN 13242 aggregate requirements		Category $_{nr}$ (no requirement) (See Note 3)						

Notes:

1 IS EN 13242 assumes that crushed rock aggregates comply with category C90/3 without further testing.

2 It will be necessary to continue to specify Liquid limits and Plasticity index, where appropriate, until further data on the Methylene Blue test has been collected and reviewed.

3 The contractor/supplier shall furnish current Methylene Blue values on the material as supplied.

4 If required where signs of "Sonnenbrand" of basalt are known, the loss of mass and resistance to fragmentation shall be determined in accordance with EN 1367-3 and 1097-2 (see clause NG 800 sub-clause 5).

5 Refer to particular requirements in Clauses 808 and 809. A petrographer's detailed mineralogical examination may be required as described under section 3.4.2 of SR 21.

Table 8/3: Additional Requirements for Recycled Coarse Aggregate and Recycled Concrete Aggregate in Unbound Mixtures

Unbound Mixture	Type A	Type B	Type C	Type D	Type E
Clause	**803**	**804**	**805**	**806**	**807**
Component[1]	**Maximum Permitted Content (% by mass)**				
Asphalt (Class A)	50	0	0	0	5
Glass (Class G)	25	0	0	0	0
Other materials (Class X), including wood, plastic and metal	1				

Note 1: The constituents of a sample of recycled aggregate shall be classified by hand-sorting the coarse aggregate particles in accordance with IS EN 933-11. The test shall be carried out by a suitably trained laboratory technician who has demonstrated competence in classifying the constituent classes in accordance with the test method.

802 Transport, Laying, Compaction and Trafficking of Unbound

Mixtures

1 Unbound mixtures shall be protected from drying out and segregation both during transit to the point where it is to be laid and whilst awaiting tipping.

Laying

2 Unbound mixtures in a frozen condition shall not be incorporated in the Works but may be used, if acceptable, when thawed. Unbound mixtures shall not be laid on any surface which is frozen or covered with ice.

3 All unbound mixtures shall be placed and spread evenly. Spreading shall be undertaken either concurrently with placing or without delay. When laid beneath a pavement made up of three or less further layers unbound mixtures shall be spread using a paving machine or a suitable spreader box and operated with a mechanism which levels off the material to an even depth. Unbound mixtures may only be spread by grader when overlaid by at least four further pavement layers.

4 Except where otherwise stated in Appendix 7/1, material up to 225 mm compacted thickness shall be spread in one layer so that after compaction the total thickness is as specified. Material of compacted thickness greater than 225 mm shall be laid in two or more layers and the minimum compacted thickness of any such layer shall be 110 mm. Where the layers of unbound mixtures are of unequal thickness, the lowest layer shall be the thickest layer.

Compaction

5 Compaction shall be completed as soon as possible after the mixture has been spread and in accordance with the requirements for the individual mixtures.

6 Full compaction shall be obtained over the full area including in the vicinity of both longitudinal and transverse joints.

7 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.

8 The surface of any layer of material shall on completion of compaction and immediately before overlaying, be well closed, free from movement under construction plant and free from ridges, cracks, loose material, pot holes, ruts or other defects. All loose, segregated or otherwise defective areas shall be removed to the full thickness of the layer, and new material laid and compacted.

9 For the purposes of Table 8/4 the following shall apply:

(i) The number of passes is the number of times that each point on the surface of the layer being compacted shall be traversed by the item of compaction plant in its operating mode (or struck, in the case of power rammers).

(ii) The compaction plant in Table 8/4 is categorised in terms of static mass. The mass per metre width of roll is the total mass on the roll divided by the total roll width. Where a smooth-wheeled roller has more than one axle, the category of the machine shall be determined on the basis of the axle giving the highest value of mass per metre width.

(iii) For pneumatic-tyred rollers the mass per wheel is the total mass of the roller divided by the number of wheels. In assessing the number of passes of pneumatic-tyred rollers the effective width shall be the sum of the widths of the individual wheel tracks together with the sum of the spacings between the wheel tracks provided that each spacing does not exceed 230 mm. Where the spacings exceed 230 mm the effective width shall be the sum of the widths of the individual wheel tracks only.

(iv) Vibratory rollers are self-propelled or towed smooth-wheeled rollers having means of applying mechanical vibration to one or more rolls:

(a) The requirements for vibratory rollers are based on the use of the lowest gear on a self propelled machine with mechanical transmission and a speed of 1,5-2,5 km/h for a towed machine or a self-propelled machine with hydrostatic transmission. If higher gears or speeds are used an increased number of passes shall be provided in proportion to the increase in speed of travel.

(b) Where the mechanical vibration is applied to two rolls in tandem, the minimum number of passes shall be half the number given in Table 8/4 for the appropriate mass per metre width of one vibrating roll but if one roll differs in mass per metre width from the other, the number of passes shall be calculated as for the roll with the smaller value. Alternatively the minimum number of passes may be determined by treating the machine as having a single vibrating roll with a mass per metre width equal to that of the roll with the higher value.

(c) Vibratory rollers operating without vibration shall be classified as smooth wheeled rollers.

(d) Vibratory rollers shall be operated with their vibratory mechanism operating at the frequency of vibration recommended by the manufacturer. All such rollers shall be equipped, or provided with devices indicating the frequency at which the mechanism is operating and the speed of travel. Both devices shall be capable of being read by an inspector alongside the machine.

(v) Vibrating-plate compactors are machines having a base-plate to which is attached a source of vibration consisting of one or two eccentrically-weighted shafts:

(a) The mass per square metre of base-plate of a vibrating-plate compactor is calculated by dividing the total mass of the machine in its working condition by its area in contact with compacted material.

(b) Vibrating-plate compactors shall be operated at the frequency of vibration recommended by the manufacturer. They shall normally be operated at travelling speeds of less than 1 km/h but if higher speeds are necessary, the number of passes shall be increased in proportion to the increase in speed of travel.

(vi) Vibro-tampers are machines in which an engine driven reciprocating mechanism acts on a spring system, through which oscillations are set up in a base-plate.

(vii) Power rammers are machines which are actuated by explosions in an internal combustion cylinder; each explosion being controlled manually by the operator. One pass of a power rammer shall be considered to have been made when the compacting shoe has made one strike on the area in question.

(viii) Combinations of different types of plant or different categories of the same plant will be permitted; in which case the number of passes for each shall be such proportion of the appropriate number in Table 8/4 as will together produce the same total compactive effort as any one operated singly, in accordance with Table 8/4.

Table 8/4: Compaction Requirements for Unbound Mixtures

Type of Compaction Plant	Category	Number of phases for layers not exceeding the following compacted thickness: 110mm	150mm	225mm
Smooth-wheeled roller (or vibratory roller operating without vibration)	Mass per metre width of roll:			
	over 2700kg up to 5400kg	16	unsuitable	unsuitable
	over 5400kg	8	16	unsuitable
Pneumatic-tyred roller	Mass per wheel:			
	over 4000kg up to 6000kg	12	unsuitable	unsuitable
	over 6000kg up to 8000kg	12	unsuitable	unsuitable
	over 8000kg up to 1200kg	10	16	unsuitable
	over 12000kg	8	12	unsuitable
Vibratory roller	Mass per metre width of vibrating roll:			
	over 700kg up to 1300kg	16	unsuitable	unsuitable
	over 1300kg up to 1800kg	6	16	unsuitable
	over 1800kg up to 2300kg	4	6	10
	over 2300kg up to 2900kg	3	5	9
	over 2900kg up to 3600kg	3	5	8
	over 3600kg up to 4300kg	2	4	7
	over 4300kg up to 5000kg	2	4	6
	over 5000kg	2	3	5
Vibrating-plate compactor	Mass per metre of base plate:			
	over 1400kg/m2 up to 1800kg/m2	8	unsuitable	unsuitable
	over 1800 kg/m2 up to 2100kg/m2	5	8	unsuitable
	over 2100kg/m2	3	6	10
Vibro-tamper	Mass:			
	over 50kg up to 65kg	4	8	unsuitable
	over 65kg up to 75kg	3	6	10
	over 75kg	2	4	8
Power rammer	Mass:			
	100kg-500kg	5	8	unsuitable
	over 500kg	5	8	12

Use of Surfaces by Construction Plant and Other Traffic

10 Construction plant and other traffic used on pavements under construction shall be suitable in relation to the material, condition and thickness of the courses it traverses so that damage is not caused to the subgrade or the pavement courses already constructed. The wheels or tracks of plant moving over the various pavement courses shall be kept free from deleterious materials.

11 Where the Contractor proposes to traffic the unbound mixture layers with construction plant he shall improve these layers where necessary, to accommodate the method of construction and the type of plant and vehicles which he proposes to use, in order to avoid damage to the laid layer(s), any capping and the subgrade. Any permanent thickening shall be across the whole width of the pavement. Temporary thickening shall not impede drainage of any layer or the subgrade.

Trafficking Trial

12 When required by Appendix 7/1 for Type A or Type C materials, the Contractor shall undertake a Trafficking Trial incorporating the unbound mixture proposed for use in the permanent Works. A trial area shall be constructed, trafficked and assessed in accordance with the procedure described in sub-Clauses 13 to 18 of this Clause. The mean vertical deformation after 1000 equivalent standard axles shall be less than 30 mm when measured in accordance with the procedure stated in sub-Clause 17 of this Clause. Proposals for trafficking trials shall be submitted to the Employer's Representative five days in advance of construction.

Trial Procedure

13 The trial area shall be located on a formation prepared in accordance with the Specification. The trial area may be located so that it can be incorporated within the permanent Works if the resistance to wheel track rutting is demonstrated to comply with sub-Clause 12 of this Clause.

14 The trial area shall be at least 60 m long, and of sufficient width that when trafficked, the wheel paths of the test vehicle shall be at least 1 m from either edge of the top of the unbound mixture layer. The unbound mixture layer shall be compacted to the thickness specified in Appendix 7/1. The formation shall extend for a further 1 m either side of the unbound mixture layer.

15 A sufficient run off/run on area shall be constructed at each end of the trial area of the same width, and compacted to the same level, as the trial area, to ensure correct tracking by the test vehicle and minimise dynamic effects of the vehicle bouncing on its springs. Suitable guidance shall be given to assist the driver in maintaining the same track in each pass and to achieve channelled trafficking. Examples of suitable guides would be a string or painted line.

Mixtures

16 The unbound mixture used in the trial shall be transported, laid and compacted using the equipment proposed for use in the Works.

17 Maximum vertical deformation shall be measured in both wheel tracks using optical or laser levels at pre-determined monitoring points on five transverse lines spaced equally along the length of the trial bay. The transverse lines at the ends of the trial area shall be at least 5 m from the run off/run on areas. The average deformation of the two wheel tracks after 1000 standard axles shall be recorded.

Reporting and Acceptance of Trafficking Trial Area

18 A report on the Trafficking Trial, stating how the use of the unbound mixture was validated shall be submitted to the Employer's Representative, who shall raise any objection within two working days of receiving the report.

804 Granular Material Type B

1 Type B granular material shall be crushed rock. The mixture shall comply with Clause 801 and with the following sub-clauses. The overall grading requirements for the mixture are summarised in Table 8/6.

2 The material passing the 0,425 mm BS sieve shall have a liquid limit, determined in accordance with the cone penetrometer method (definitive method) in BS 1377: Part 2, not greater than 20 for limestone and 21 for all other rock types.

3 The material shall be laid and compacted at a moisture content within the range of the optimum to 2 percent below the optimum percentage determined in accordance with the vibrating hammer method test in (IS EN 13286-4), and without drying out or segregation.

4 The material shall be maintained within the moisture content range specified in sub-clause 804.3 whilst awaiting overlaying.

Table 8/6: Granular Material Type B

IS EN 13285 Categories -				
Mix Designation:		**0/31,5**		
Oversize Category:		**OC_{80}**		
Overall Grading:		**G_A**		
Sieves for Grading / Fines Category	**ISO Sieve Size (mm)**	**Percentage by Mass Passing**		
		Overall Grading Range	**Supplier Declared Value Grading Range**	**Tolerance on the Supplier Declared Value**
2D	63	100	**No Requirement**	**No Requirement**
D	31,5	80 - 99		
A	16	55 - 85	63 - 77	±8
B	8	35 - 65	43 - 57	±8
C	4	22 - 50	30 - 42	±8
E	2	15 - 40	22 - 33	±7
F	1	10 - 35	15 - 30	±5
G	0,5	0 - 20	5 - 15	±5
UF_7	0,063	0 - 7	**No Requirement**	**No Requirement**
LF_N	NR	NR		

Grading of individual batches – differences in values passing selected sieves

Retained sieve size, mm	**Passing sieve size, mm**	Percentage by mass passing	
		Not less than	Not more than
8	16	10	25
4	8	10	25
2	4	7	20
1	2	4	15

NOTE: The particle size shall be determined by the washing and sieving method of IS EN 933-1

806 Granular Material Type D (Wet Mix Macadam)

1 Wet-mix macadam shall be made and constructed in the following manner.

Aggregate

2 The mixture shall comply with Clause 801 and with the following sub-clauses. The coarse and fine aggregate shall consist of crushed rock. The overall grading requirements for the mixture are summarised in Table 8/8.

3 The material passing the 0,425 mm BS sieve shall have a liquid limit, determined in accordance with the cone penetrometer method (definitive method) in BS 1377: Part 2, not greater than 20 for limestone and 21 for all other rock types.

Moisture Content

4 The material shall be transported, laid and compacted at a moisture content within the range 0.5 to 1.5 percent below the optimum percentage determined in accordance with the vibrating hammer method test in (IS EN 13286-4) and without drying out or segregation.

Laying and Compaction

5 The compacted thickness of each layer shall not be more than 150 mm.

6 Compaction of wet-mix macadam shall be carried out in accordance with the requirements of Clause 802, using vibrating rollers having a mass per metre width of vibrating roll of at least 1800 kg.

7 The material shall be protected from weather during transit to the site, whilst awaiting tipping and during laying.

8 On completion of compaction the surface of the material shall be sealed with cationic bitumen emulsion (70 per cent bitumen) sprayed at a rate between 1.1 and 1.4 litre/m2, covered with 2/6 mm chippings at a rate of spread of 6 to 8 kg/m2, and lightly rolled.

Table 8/8: Granular Material Type D (Wet Mix Macadam)

IS EN 13285 Categories -				
Mix Designation:		**0/31,5**		
Oversize Category:		**OC_{85}**		
Overall Grading:		**G_0**		
Sieves for Grading / Fines Category	**ISO Sieve Size (mm)**	**Percentage by Mass Passing**		
		Overall Grading Range	**Supplier Declared Value Grading Range**	**Tolerance on the Supplier Declared Value**
1,4D	40	100	No Requirement	No Requirement
D	31,5	85 - 99		
A	16	50 - 78	58 - 70	±8
B	8	31 - 60	39 - 51	±8
C	4	18 - 46	26 - 38	±8
E	2	10 - 35	17 - 28	±7
F	1	6 - 26	11 - 21	±5
G	0,5	0 - 20	5 - 15	±5
UF_7	0,063	0 - 7	No Requirement	No Requirement
LF	NR	NR		

Grading of individual batches – differences in values passing selected sieves

Retained sieve size, mm	Passing sieve size, mm	Percentage by mass passing	
		Not less than	Not more than
8	16	10	25
4	8	10	25
2	4	7	20
1	2	4	15

NOTE: The particle size shall be determined by the washing and sieving method of IS EN 933-1

810 General Requirements for Cement Bound Mixtures

1 Cement bound mixtures (hereafter referred to by the generic term HBM, Hydraulically Bound Mixture) shall be produced, constructed and tested in accordance with the following Clauses. The permitted alternatives for each part of the Works shall be as described in Appendix 7/1.

2 Attributes shall be deemed to have a "No Requirement" classification unless stated otherwise.

3 The terms listed below shall apply to the HMB Clauses of this specification:

CBGM cement bound granular mixture

CBR California bearing ratio

E modulus of elasticity

Gv_{xx} volumetric expansion category

HBM hydraulically bound mixture

IBI immediate bearing index in accordance with IS EN 13286-47

Imm_{xx} immersion category

IPI_{xx} immediate bearing category

LA Los Angeles coefficient

MCV moisture condition value

NR no requirement

OWC optimum water content

$Pulv_{xx}$ pulverisation category

R_c compressive strength

R_t direct tensile strength

R_{it} indirect tensile strength

R_t,E method of performance classification based on the combination Rt and E. Classes of R_t,E are designated T0 to T5, in IS EN 14227, where T designates R_t,E and the number indicates the performance class

SC soil cement time (hours) at constant temperature in defining maturity for calculating the construction period T°C ambient air temperature in defining maturity for calculating construction period

W_{xx} water content category

Conditions of cement supply

4 In accordance with the note to clause 1 of IS EN 197-1, the exchange of additional information between the manufacturer and the user should be made in accordance with, but not limited to the following:

Identification

Cement should be identified on the bag or the delivery note, and on any test report, with the following particulars:

(i) the name, trade mark or other means of identification of the manufacturer to facilitate traceability to the factory in which the cement was manufactured;

(ii) the designation/name, the notation / type and strength class of the cement; e.g. Portland cement CEM I 42,5N; Portland-limestone cement CEM II/A-LL 42,5N; Blastfurnace cement CEM III/A 42,5N;

(iii) the number and date of the Irish Standard e.g. IS EN 197-1:2007;

(iv) the standard notation of any admixture, where applicable;

(v) the CE marking plus associated information; and in the case of bagged supply only:

(vi) the weight of a bag packed with cement.

Packed/bagged cement

Where cement is supplied in a bag for manual handling, the weight should be 25 kg, or less, within permitted tolerances.

Testing

5 HBM shall be tested in accordance with Clause 825 and the test methods specified in the following clauses.

Mix designation

6 The Contractor shall submit a statement to the Employer's Representative that includes:

(i) The information detailed in the 'Designation and Description' clause of the relevant IS EN Standard for the specified HBM, confirming compliance with the requirements of this Series and Appendix 7/1.

(ii) Target proportions of constituents, including water.

(iii) Mixture design details and results, in accordance with Clause 826.

(iv) Method statement in accordance with Clause 817.

813 General Requirements for Production and Construction

1 HBM shall be produced and HBM layers constructed using one of the following methods:

(i) mix-in-plant method of construction using batching by mass in accordance with Clause 814;

(ii) mix-in-plant method of construction using volume batching in accordance with Clause 815;

(iii) mix-in-place method of construction, in accordance with Clause 816.

2 Restrictions on the construction period for HBM are defined in degree hours, being the summation of the products of the average air temperature above 3ºC (T ºC) and time for each period (t hours): i.e. construction period limit =ƒ°(T.t). The air temperature during the interval, t, shall not fluctuate by more than 4°C.

3 Construction of layers, including multiple lift layers, and any reworking and reuse, shall be completed within the lesser of 8 hours, the construction period specified in Table 8/11 or the mixture setting time. The time shall be measured from the addition event defined in Table 8/11 to completion of compaction.

4 Mixtures used in base layers shall be batched by mass and paver laid in a single lift. Construction of bases by other methods shall only be permitted when alternative proposals are submitted to the Employer's Representative to address confined spaces where it is impracticable for a paver to operate.

5 Laying shall be carried out in a way that avoids segregation and drying of the surface. The temporary intermediate surfaces within a multiple lift layer shall be sprayed with water to prevent surface drying.

6 The minimum compacted lift thickness in a multiple lift layer shall be 150 mm.

7 Making-up of level after initial compaction shall not be permitted for single lift working or the uppermost lift of multiple lift working.

8 The edge of previously compacted HBM or other material shall be vertical and straight before fresh HBM is laid against it.

9 Compaction of HBM layers, including the intermediate lifts of multiple lift working, shall be completed without drying out and before setting of any part of the layer and shall meet the requirements for density in clause 825.

10 Compaction of HBM shall be carried out by vibrating roller and/or pneumatic-tyred roller (PTR).

11 On completion of compaction the surface shall be closed, free from ridges, cracks, loose material, visible voids, ruts, shear planes and other defects. All defective areas shall be rectified within the time period specified in sub-Clause 813.2. If rectification is not completed within the specified time period, the defective area shall be removed to the full thickness of the layer, and new mixture laid and compacted.

Table 8/11: Construction Period for HBM Layers

Binder	Addition event defining the start time for calculating maximum construction period	Maximum construction period (°C hours)
Cement	Addition of cement	35

Cold and Wet Weather Working

12 During cold weather:

(i) the temperature of HBM shall not be less than 5°C at the time of laying;

(ii) HBM shall not be laid on a frozen surface;

(iii) laying of HBM shall cease when the air temperature falls below 3°C, and laying shall not be resumed until the rising air temperature reaches 3°C;

(iv) the laying of HBM using binders containing less than 3% of CEM 1 cement, by dry mass of mixture, shall be restricted in use to the period from 1 May to 30 November, unless otherwise agreed by the Employer's Representative.

13 In the case of heavy or persistent rain, production shall cease and any laid material shall be compacted immediately.

Curing, Protection and Trafficking

14 On completion of compaction the layer shall be cured to prevent loss of moisture by:

(i) application of a bitumen emulsion spray complying with Class C40B4, as specified in the IS EN 13808 to produce an even and complete coverage of at least 0.2 kg/m2 of residual bitumen. Before spraying commences, the surface shall be free of all loose material and standing water. The curing membrane shall be protected from any damage until the construction of the overlaying layer;

(ii) application of a mist/fog/light spray of water, sufficient to keep the surface continuously wet until the specified strength of the HBM has been developed or the layer is overlaid.

15 Trafficking of HBM layers shall comply with the requirements set out in Table 8/12 and sub- Clause 813.16. Should any HBM layer exhibit signs of damage, trafficking shall cease immediately and shall only be resumed once the layer has gained sufficient stability to resist damage.

16 CBGM shall not be trafficked for 7 days unless the layer complies with the following:

(i) the layer is compacted by both vibrating roller and PTR in accordance with sub-Clause 813.10 to comply with the requirements of sub-Clause 813.11;

(ii) the mixture contains at least 50% by mass of coarse aggregate complying with IS EN 13242, Category C90/3 for "crushed or broken particles";

(iii) test specimens made at the same time as the specimens required in Clause 825 but cured under the same conditions as the in-situ CBGM have achieved an average strength of at least Class C3/4.

Table 8/12: Trafficking of HBM Layers

HBM Designation	Clause reference	Trafficking
CBGM	821, 822 and 823	Sub-Clause 813.16
SC	824	Not restricted provided that the IBI requirements of Table 8/14 are satisfied. For mixtures containing cohesive soil or chalk, the test specimens made at the same time as the specimens required in Clause 825 but cured under the same conditions as the insitu treated soil shall also have achieved an average strength of at least Class C0.8/1.0.

17 Surface contamination shall be avoided as far as is practicable and any unavoidable contamination shall be removed prior to overlaying. Reworking and re-compaction of the layer shall only be permitted within the construction period set out in Table 8/11. Reworking shall only be permitted when the water content requirements of the reworked material are maintained within the limits stated in the method statement required under Clause 817.

18 Before overlaying, any loose material shall be removed and replaced to the full depth of the layer or, if within the construction period set out in Table 8/11, reworked as specified in sub-Clause 813.17.

19 Daily record sheets complying with sub- Clause 817.4 shall be submitted to the Employer's Representative by start of work on the next working day, detailing:

(i) spread rate/batching record results;

(ii) depth measurements;

(iii) density test measurements;

(iv) sample and test locations;

(v) construction period records showing the time(s) of mixing, water addition, completion of compaction and application of curing membrane.

Work may proceed during the period for objection, which shall be 24 hours.

821 Cement Bound Granular Mixtures A (CBGM A)

1 Cement bound granular mixtures A (CBGM A) shall comply with IS EN 14227-1 and have binder constituent proportions complying with the requirements of Clause 811.

2 Aggregate shall comply with the requirements of Clause 820 and shall have a combined grading that complies with Envelope A from IS EN 14227-1, Figure 1.

3 The strength after immersion shall be at least 80% of the non-immersed strength, when tested in accordance with the laboratory mixture design requirements specified in Clause 826.

4 The method of construction shall be in accordance with Clause 813 and either Clause 814, Clause 815 or Clause 816.

5 The laboratory mechanical performance shall comply with the requirements of Appendix 7/1, when sampled and tested in accordance with Clause 825.

822 Cement Bound Granular Mixtures B (CBGM B)

1 Cement bound granular mixtures B (CBGM B) shall comply with IS EN 14227-1, and have binder constituent proportions complying with the requirements of Clause 811.

2 Aggregates shall comply with the requirements of Clause 820 and shall have a combined grading that complies with Envelope B from IS EN 14227-1, Figure 1. Alternatively, the total mixture grading shall comply with the grading envelope Category G2 from IS EN 14227-1, Annex B, Figure B2.

3 The strength after immersion shall be at least 80% of the non-immersed strength, determined in accordance with the laboratory mixture design procedure specified in Clause 826.

4 The method of construction shall be in accordance with Clause 813 and Clause 814.

5 The laboratory mechanical performance shall comply with the requirements of Appendix 7/1, when sampled and tested in accordance with Clause 825.

823 Cement Bound Granular Mixtures C (CBGM C)

1 Cement bound granular mixtures C (CBGM C) shall comply with IS EN 14227-1, and have binder constituent proportions complying with the requirements of Clause 811.

2 Aggregates shall comply with the requirements of Clause 820 and shall have a total mixture grading that complies with grading envelope Category G1 from IS EN 14227-1, Annex B, Figure

3 B2 for 0/20 size mixtures, Figure B3 for 0/14 mm size mixtures or Figure B4 for 0/10 mm size mixtures.

4 The compacity of the mixture shall be at least 0.8, when calculated in accordance with IS EN 14227-2, Annex C. The maximum dry density value used for the calculation shall be determined in accordance with IS EN 13286-50, using the modified Proctor (4.5 kg rammer) procedure from IS EN 13286-2.

5 The strength after immersion shall be at least 80% of the non-immersed strength, when tested in accordance with the laboratory mixture design requirements specified in Clause 826.

6 The method of construction shall be in accordance with Clause 813 and Clause 814.

7 The laboratory mechanical performance shall comply with the requirements of Appendix 7/1, when sampled and tested in accordance with Clause 825.

Appendix E – Specification for Stabilised Wet Mix

Stabilised Wet Mix

1 Stabilised Wet Mix shall be designed, manufactured and laid in accordance with the recommendations in the French Ministry of Equipment Specification *"Directive Pour la Realisation des assiser de chaussée en grave-émulsion"* and comply with the following sub-clauses and with the appropriate requirements set down in Series 700 of the NRA MCDRW Volume 1 Specification for Road Works.

Aggregate

2 The coarse and fine aggregate shall consist of crushed rock complying with the requirements of IS EN 12620 as regards quality and cleanliness. In addition the fines passing the 425 micron sieve shall be non-plastic. The aggregate shall have a ten per cent fines value of 130 kN or more when tested in a soaked condition in accordance with IS EN 1097-2.

Filler

3 If filler is required it shall consist of crushed rock, Portland cement or other material approved by the Engineer. The quality of filler shall comply with the requirements of IS EN 13043.

Binder

4 The binder shall be Cationic Bitumen Emulsion (63% Nominal Bitumen content) and shall comply with the requirements set out in Table E.1. The bitumen used in the emulsion shall comply with the NRA Specification for Road Works for penetration grade petroleum bitumens and be within the grade range of 170-230 penetration. The Bitumen Content of the Stabilised Wet Mix shall be within the range 3.3%±0.3% by mass of total mixture excluding moisture content.

Materials

5 Before coating the aggregate shall be clean, free of organic matter or contamination from clay. The aggregate shall be stockpiled on a hard clean base and in such a manner to enable the stockpile to drain quickly. The moisture content of the combined aggregate shall not be greater than 3.5%, before mixing with the emulsion. All aggregates used in the mix shall not be susceptible to frost.

Table E.1: Specification for Cationic Bitumen Emulsion (63 per cent Bitumen Content) for use in Stabilised Wet Mix

GRADE OF CATIONIC EMULSION (Binder content - nominal percent by Mass) 63%			
Property	**Test Method**	**Specification**	
		Minimum	**Maximum**
Particle Charge Test	ASTM D 244-09	Positive	
Viscosity °Engler 20°C	IP 212	6	12
Storage Stability Test 1 day (% by mass)	ASTM D 244-09	-	1
Sieve Test (% by mass 850 micron sieve)	ASTM D 244-09	-	0.10
Distillation Oil distillate by volume of emulsion %	ASTM D 244-09	-	1.0
Residue % by mass	ASTM D 244-09	61	-
Test on Residue from Distillation Test			
Penetration at 25°C (100 g 3 sec.)	IP 49	100	250
Solubility in Trichloroethylene % by weight	IP 47	99	-

General: The emulsifying agent should not exert any deleterious effects on the bitumen deposited and should be such that any drainage, washings or the like passing from the work into streams, ponds, rivers, etc. should not after dilution in water have any toxic effect upon plant, animals or fish life.

Test methods will be in accordance with the current edition of the Energy Institute standards or, where stated, in accordance with the current edition of the American Society for Testing and Material (ASTM) standards.

Mixing

6 The materials including any added filler shall be accurately weighed or measured into a mechanical mixer of approved type and thoroughly mixed. The weighing or measuring mechanism shall at all times be maintained within the accuracies recommended by the manufacturer.

Composition of Mixed Material

7 The material, to the nominal size of aggregate described in the Contract Specification Appendices, shall consist of an intimate mixture of coarse aggregates, fine aggregate, filler if necessary, and binder, combined in proportions to lie within the limits set out in Table E.2.

The mixture shall satisfy the following criteria when compacted and tested accordance with the French standard NF EN 13108-1.

Immersion - Compression Test at 18°C	**Not less than**
Compactivity LCPC (geometric measurement)	> 85%
Resistance to compression - using 120 mm diameter moulds	> 30 kN
Immersion/Compression Ratio	> 0.55

Acceptance of Design Mix

8 At least four weeks before laying is to commence, the Contractor shall submit details of the mixture he intends to use to the Engineer for approval. These details shall include the following information:

(i) Grading curve (per cent by mass passing)

(ii) Bitumen content (per cent of total mass excluding moisture content)

(iii) Composition of mixture (percentages of constituents)

(iv) Emulsion type (Bitumen Content and specification)

(v) Mix design data showing compactivity, resistance to compression and immersion/ compression ratio

The type of emulsion, the type of aggregate used in the mix and the moisture content of the mix are important factors in the break of the emulsion, the adhesion of the residual binder, the compactability and resistance to compression of the mix and its immersions/compression ratio. It is therefore necessary to examine the behaviour of different emulsions and aggregates formulations in order to obtain the optimum mix.

Table E.2: Stabilised Wet Mix

Nominal Maximum Size (mm)	37.5
Range of thickness of compacted course (mm)	60-120
Binder Grade 0 Cationic bitumen emulsion (63% bitumen content)	170-230 penetration bitumen
Bitumen Content (percentage by mass of total mixture excluding moisture content)	3.0-3.6
Moisture Content (before compaction percentage by mass of total mixture)	3-5
Aggregate Grading (*percentage by mass passing) BS Sieve Size 50 mm 37.5 mm 20 mm 10 mm 5 mm 2.36 mm 600 µm 75 µm	 -100 95-100 60- 80 40- 60 25- 40 15- 30 8- 22 0 – 8

*In addition to complying with the above grading envelopes at least 4 per cent by mass shall be retained between any consecutive sieves.

Acceptance of Plant Mixes

9 Before full scale laying commences the Contractor shall prove to the Engineer by the laying of a preliminary trial length at a location approved by the Engineer that the Stabilised Wet Mix he intends to supply complies with the specified requirements. For the trial the Contractor shall use the materials, mix proportions, mixing, laying, compaction plant and construction procedure that he proposes for the main work. The Stabilised Wet Mix and its job-mix formula will be agreed after verification of the specified requirements, texture and appearance of coating at this trial.

Tolerance Limits

10 Agreement will be reached between the Contractor and the Engineer on the job mix material, its composition shall comply with the requirements of Table E.2 and with the job tolerance specified in Table E.3.

Table E.3: Tolerance for Stabilised Wet Mix Job-Mix Formula

BS Sieve Size	Job tolerance per cent by mass
37.5 mm	± 6
20 mm	± 6
10 mm	± 6
5 mm	± 6
2.36 mm	± 4
600 µm	± 4
75 µm	± 1.5
Binder Content	± 0.5

Acceptance of Compaction

11 The average compacted dry density shall be not less than 95% of the Duriez dry density obtained in the laboratory for the approved mix. Measurements of in-situ dry density will be made daily and the results compared with the reference value. No individual result shall be less than 90% of the Duriez dry density.

Compaction should be carried out using a combination of a vibrating roller and a pneumatic tyred roller. The mass per metre width of roll of the vibrating roller should not be less than 2000 kg. The vibrating roller should operate at a speed at about 2 km/hr. The mass per wheel of the pneumatic tyred roller should not be less than 300 kg and the inflation pressure of the tyres should not be less than 7 bars. The pneumatic roller should be operated at a speed of about 6 km/hr.

Cold and wet weather

12 The laying of Stabilised Wet Mix is prohibited during frost, heavy rain or in the period of the year when it may be subject to freezing before it matures (i.e. before the escape of added water and water contained in the emulsion). Unless permitted by the Engineer Stabilised Wet Mix Macadam should not be laid in the period of the year between October and March.

The laying of Stabilised Wet Mix shall cease when descending air temperature in the shade falls below 3°C and shall not be resumed until the ascending air temperature in the shade reaches 3°C. Matured Stabilised Wet Mix should be overlaid by a bituminous carpet or by a surface dressing before the winter

Appendix F – 'Best Practice Guide' for Pavement Works on Rural Regional and Local Roads

Introduction

This Appendix is intended as a guide for use by Local Authority site staff during pavement works on Rural Regional and Local Roads.

Irrespective of the construction method adopted, it is always of utmost importance that the correct construction standards are adhered to in order to ensure the works are as effective and durable as possible.

Construction to an appropriate standard also reduces the time and money spent on remedial measures post-completion of the works, be they of a minor or major nature. Fewer repairs mean fewer closures, traffic management and new construction costs and minimises disruption for the general road user.

This 'Best Practice Guide' has been developed from practical experience and is designed to be consistent with existing Department Guidelines and Standards as well as the *NRA Design Manual for Roads and Bridges* (NRA DMRB) and the *NRA Manual of Contract Documents for Road Works* (NRA MCDRW).

This 'Best Practice Guide' takes the form of general notes which detail items to be aware of at various stages of the pavement construction process.

Best Practice Notes

1. **Prior to Commencement of Pavement Works**
2. **Subgrade**
3. **Capping**
4. **Granular Unbound Material**
5. **Compaction of Granular Unbound Material**
6. **Granular Bound Mixtures**
7. **Surface Dressing**
8. **Cold Milling (Planing)**
9. **Preparation prior to laying Bituminous Material**
10. **Bituminous Joints**
11. **Laying Bituminous Material**
12. **Laying Bituminous Material at Structures**
13. **Compaction of Bituminous Material**
14. **Tack/Bond coat**
15. **Placing Chippings on Hot Rolled Asphalt**
16. **High Friction Surfacing**
17. **Pavement Widening**
18. **Kerbing**
19. **Other Pavement Works**
20. **Quality and Testing**
21. **Completion Checks**
22. **Miscellaneous Notes**

1. Prior to Commencement of Pavement Works

- Prior to commencing works, traffic management should be designed and installed in accordance with the Traffic Signs Manual Chapter 8 *'Temporary Traffic Measures and Signs for Roadworks'* and *'The Guidance for the Control and Management of Traffic at Road Works'*.
- For safety reasons on narrow roads a formal road closure may be required. All relevant parties should be consulted and informed relating to proposed Traffic Management details.
- Treatment of the existing surface with a suitable weed killer may be required prior to overlay works on some Rural Regional and Local Roads.
- Has the Network Level Rating (PSCI) of the existing pavement been determined and recorded as the 'before the works' value?
- Has a Project Level Assessment been carried out? Has a site inspection been carried out on the existing drainage, statutory signage and road markings? Have all site specific health and safety hazards been identified?
- For Rural Regional and certain Local Roads has the International Roughness Index (IRI) of the road surface been measured? (IRI test is typically carried out using a Road Surface Profiler).
- Drainage and edge support works, along with any necessary hedge cutting (within permitted season), should be completed prior to the commencement of overlay on Rural Regional and Local Roads.
- Superelevation should be provided where necessary.

2. Subgrade

- Subgrade should be even and rolled with one pass of a smooth-wheeled roller.
- Subformation should not be trafficked by site plant other than that directly involved in the subgrade/capping operation.
- Subgrade should be covered with capping (Class 6F1 / Class 6F2 / Class 6F3) or subbase (Clause 804 / Clause 806) material as soon as possible after it is prepared and should not be left exposed to rain or exposed overnight.
- The excavation to subformation should not affect any existing drainage or utilities, if they are to be retained.

3. Capping

- Material supplied to site should conform to the specified requirements and be kept free of contaminants.
- Material should be compacted with the required number of passes from a compactor of appropriate mass.
- Capping should not be laid in heavy rain. Wet subgrade and capping are susceptible to rutting when rolled or trafficked.
- Capping should not be trafficked by site plant other than that directly involved in the preparation of the formation.
- The final level of the capping should be within the required tolerances relative to design level.

4. Granular Unbound Material

- Material supplied to site should conform to the specified requirements and be kept free of contaminants.
- The use of a paver to lay unbound materials, as opposed to a grader, results in a better finished ride quality. Where site conditions allow, unbound materials should only be spread with a grader where the unbound materials will be overlaid by at least four more pavement layers. However on Rural Regional and Local Roads with site constraints e.g., limited road width, the use of a paver may not be practical.
- The thickness of granular overlays should not be less than 150mm on Rural Regional and Local roads except on roads with less than 500 current AADT where 100mm can be used in the circumstances defined in Table 5.1 of this document.

- Material of compacted thickness greater than 225 mm should be laid in two or more layers and the minimum compacted thickness of any such layer should be 110 mm.
- Subbase should be laid on a clean, dry and even surface of capping material.
- Subbase should not be laid in heavy rain. Wet subbase is susceptible to rutting when rolled or trafficked.
- Materials placed within 500mm of cement bound materials (such as concrete pavements, concrete structures or concrete products) should comply with Clause 808 of the NRA Specification for Road Works.
- Materials placed within 500mm of metallic structural elements forming part of the works should comply with Clause 809 of the NRA Specification for Road Works. As stated in the Clause these requirements do not apply to metallic items protected by concrete and ancillary metallic items such as tops of chambers and gullies.
- The final level of the subbase should be within the required tolerances relative to design level.
- If rectification of the newly placed unbound layer is required, the top 75mm should be scarified, reshaped with material added or removed as necessary, and re-compacted. Area to be treated should not be less than 20m long and 2m wide.

5. Compaction of Granular Unbound Material

- Compaction should be carried out with a roller whose category is suitable for the layer thickness and the required number of passes should also be achieved.
- Compaction should be completed as soon as possible after the material has been spread.
- Special care should be taken to obtain full compaction in the vicinity of both longitudinal and transverse joints.
- Compaction of any layer of material should continue until the material is free from movement under compaction plant. The surface of any layer of material should, on completion of compaction and immediately before overlaying, be sufficiently closed, free from movement under compaction plant and from ridges, cracks, loose material, pot holes, ruts or other defects.
- Care should be taken on embankment edges.
- Rollers should lead with the driving axle on new strips, and change strips on compacted material. Rollers should not brake at end of passes and should not vibrate when static, or downhill on steep inclines.
- Rollers should work from the lower to upper side of the layer to maintain the design camber/crossfall.

6. **Granular Bound Mixtures**

- Hydraulically Bound Material (HBM) should be transported directly to the point where it is to be laid in covered trucks and protected from the weather both during transit and whilst awaiting tipping.
- Mixtures used in base layers should be batched by mass and paver laid in a single lift. In confined spaces where it is impracticable for a paver to operate, construction of bases by other methods should only be permitted when alternative proposals are submitted to the Employer's Representative.
- The construction period (measured in degree hours) should meet the requirements of the product specification.
- During cold weather the temperature of HBM should not be less than 5°C at the time of laying.
- The minimum compacted lift thickness in a multiple lift layer should be 150 mm.
- The edge of previously compacted HBM or other material should be vertical and straight before fresh HBM is laid against it.
- Compaction of HBM layers, including the intermediate lifts of multiple lift working, should be completed without drying out and before setting of any part of the layer and should meet the required density.
- Compaction of HBM should be carried out by vibrating roller and/or pneumatic-tyred roller (PTR).

- On completion of compaction the surface should be inspected to ensure it is closed, free from ridges, cracks, loose material, visible voids, ruts, shear planes and other defects. All defective areas should be rectified within the required time period specified. If rectification is not completed within the specified time period, the defective area should be removed to the full thickness of the layer, and new mixture laid and compacted.
- On completion of compaction the layer should be cured to prevent loss of moisture by application of a bitumen emulsion spray or application of a mist/fog/light spray of water.
- If required in the Contract, cracks should be induced in fresh material after initial compaction. These should be at a maximum longitudinal spacing of 3 m ± 5%.
- If the HDM layer is constructed in widths exceeding 4.75m, longitudinal cracks should be induced at not more than 4.75m centres. Longitudinal construction joints or induced cracks should not be located more than 150mm from the lane line, or edge line marking.
- Bitumen emulsion should be poured or sprayed into the grooves prior to final compaction, to form a crack inducing membrane.
- Before overlaying, any loose material should be removed and replaced to the full depth of the layer or reworked if within the construction period specified. Reworking should only be permitted when the water content requirements of the reworked material are maintained within the limits stated in the Contractor's method statement.
- HBM should not be trafficked during curing period. Any trafficking should be agreed with the Employer's Representative after confirmation of the actual strength achieved from test cubes is obtained.
- Daily record sheets should be submitted to the Employer's Representative by start of work on the next working day, detailing:
  - Spread rate/batching record results;
  - Depth measurements;
  - Density test measurements;
  - Sample and test locations; and
  - Construction period records showing the time(s) of mixing, water addition, completion of compaction and application of curing membrane. Work may proceed during the period for objection, which should be 24 hours.

7. Surface Dressing

- Surface dressing should be designed and constructed in accordance with the guidelines of the Institute of Asphalt Technology, Irish Branch as outlined in the 'IAT Guidelines for Surface Dressing in Ireland'.
- Chippings should be spread at the required spread width and rate by a mechanical spreader. Hand laying chippings can lead to an uneven distribution and should be avoided to the extent possible.
- Surface dressing should be carried out within the recognised 'surface dressing season', in frost free conditions.
- Spraying should not commence if surface is wet, if it is raining or if rain is forecast. Refer to Section 11 for further guidance.
- Chippings should be free of any dirt, dust which will inhibit adhesion, mud or foreign material when loaded for spreading onto the sprayed area.
- During spraying the chipping spreader should not fall more than 30m behind the sprayer.
- Overlap areas of spray should only be chipped once. The lap between sprays should be swept by hand. Otherwise a gap or ridge may form at a joint in the pavement which will interfere with road drainage.
- Rolling should commence immediately after chippings are applied. A pneumatic tyred roller should be used. A minimum number of four passes should be given to all sections.
- Excess chippings should be swept off the surface dressing as soon as is practicable, provided that chippings are not dislodged and the chipping mosaic is not disturbed. In normal circumstances, light sweeping can be carried out on the morning following completion of the surface dressing.
- Post-completion, the surface dressing should be checked on the day after the works and after the first heavy frost.

8. Cold Milling (Planing)

- Prior to placing new bituminous material on a planed surface, the area should be even with groove depths not greater than 10mm and free of loose laminate of existing material.
- Existing ironwork should not be disturbed in planing operations.
- When planing works are carried out, the full depth of surface course, binder course and top layer of base should be removed.

9. Preparation prior to laying Bituminous Material

- Bituminous material should be laid on a surface that is clean of all loose material, free of standing water, unfrozen and treated with the relevant bonding agent i.e., tack coat or bond coat. Carrying out an inspection on this prior to application of tack/bond coat is essential. Inadequate bonding between layers can lead to pavement defects such as delamination, cracking, potholes and rutting that all greatly reduce the lifespan of the pavement. A road-sweeper should be used to clean all bituminous surfaces with a power washer required if deemed necessary.
- Diesel spills should be treated prior to application of tack coat/bond coat.

10. Bituminous Joints

- Surface course transverse joints at tie-in locations to existing surfaces should allow for a smooth transition such that there is no bump or hollow when driving over it.
- All transverse joints should have a cut vertical face, be clean of all loose material (power-washed if necessary) and be treated with hot bitumen (except for porous asphalt) prior to new bituminous material being laid against it.
- Transverse joints should not be stacked i.e., one layer directly on top of another, as this will cause a weakness in the new pavement. When tying into existing pavements a minimum offset of 1m should be allowed from the step below.
- Longitudinal joints should be vertical (planed if necessary to provide the ‘key-in’ step), clean of all loose material (power-washed if necessary) and treated with hot bitumen (except for porous asphalt) prior to laying of new bituminous material against it.
- Longitudinal joints should not be stacked on top of one another. A minimum offset of 150mm should be allowed from parallel joints in the layer below.
- Longitudinal joints should be such that there is a constant gradient across each layer.
- Longitudinal joints should be located outside the ‘Wheel-Track Zones’ of each lane. Wheel track zones are the areas of the lane most liable to direct contact loading from a vehicle’s wheels. If longitudinal joints are located within these zones it will cause a weakness in the pavement structure.
- Unless echelon paving is used the longitudinal joint of the surface course should be cut vertically with the cutting wheel of the roller and treated with bitumen, except for porous asphalt, prior to the fresh material being laid against it.
- Ideally surface course joints are located such that they will be directly under or along one side of the new road marking on the road surface (this will vary depending on lane widths and the Contractor’s method of laying).
- If joints are being trafficked for a period prior to laying new material a temporary ramp should be placed against them as a means of protection. Temporary ramps should be completely removed back down to the level of the layer below prior to laying of new material.
- Within 24 hours of the joint being formed, the top surface of all base and binder course joints should be sealed such that there is not less than 0,50kg/m² of residual bitumen 75mm either side of the joint.

11. Laying Bituminous Material

- If so required, minor longitudinal irregularities should be eliminated by regulation with selected material prior to overlay.
- Bituminous material should be delivered and rolled within the required temperature parameters.
- The final level of the respective bituminous layers should be within the required tolerances relative to design level. Notwithstanding the tolerances permitted in surface levels of pavement courses, the cumulative tolerance should not result in a reduction in the asphalt thickness of the pavement of more than 15 mm from the specified thickness. There should not be a reduction in the thickness of the bituminous surface course by more than 5 mm from that specified.
- Paving in the surface course operation should be as continuous as possible with a constant supply of material required. This reduces the amount of transverse joints on the final surface.
- Surface course should only be laid within the weather (including wind speed) and temperature parameters of the specified material. In general, laying of road pavement materials containing bitumen binders may proceed provided the temperature of the surface to be covered is 2°C or more, the air temperature is at or above 0°C and rising.
- When laying surface course, wind speed, air temperature, delivery temperature and rolling temperature (start and finish) should be checked to ensure compliance against the respective specification requirements of the material.
- Laying of material should not occur when standing water is present. As far as practicably possible, laying of bituminous material should be avoided during heavy rain. If wet weather is likely to be prolonged, laying should be suspended.
- Hand placing and hand-raking of bituminous material is only allowed in certain circumstances.
- If rectification of the newly placed bituminous bound layer is required, the full width of the paving laid in one operation should be removed for a length of 5m (base and binder courses) or 15m (surface course) and replaced with fresh material.

12. Laying Bituminous Material at Structures

- Care is needed when laying bituminous material into bridge decks or transition slabs; the waterproofing and sand asphalt protection layer can be damaged quite easily at this interface.
- When laying bituminous material over existing structures, existing waterproofing should be left undisturbed or replaced if required. If a sand asphalt protection layer (typically red or black in colour) is required this material should not be laid during rain and should have a secure bond to the waterproofing layer.
- Vibratory rollers should not be used in vibrating mode on bridge decks.

13. Compaction of Bituminous Material

- Is the correct roller being used for the works? Smaller rollers may not be able to provide adequate compaction for deep layers of material. If in doubt check the specification sheet of the roller in question.
- Material should be compacted firstly adjacent to the joint, working from lower to upper side of the layer, in order to maintain design camber/crossfall. Rollers should overlap on successive passes by at least half the width of the rear roll.
- Rollers should not be allowed to stand on material that is still hot nor should they travel too slowly. If this happens over-compaction of the layer may occur resulting in fines and/or water rising to the surface too fast, which may lead to ripples on the finished surface.
- Bituminous material should be properly compacted along kerbs, around manhole/inspection chamber lids and piers/bases of structures. In such tight areas a roller may not achieve sufficient compaction. In this case the use of a compacting plate or tamping rod may be required.
- If constructing a pavement close to a bridge abutment, bridge pier or gantry base have all the layers been correctly compacted? Insufficient compaction may leave to a failure in the pavement at a later stage.

- Compaction within a trench reinstatement should be carried out with care. Insufficient compaction may lead to a failure in the pavement at a later stage.
- Compacting equipment used within a trench should be narrower than the trench width.
- Over-compaction of HRA surface course can lead to cracking of chippings.

14. Tack coat/Bond coat

- The rate of spread of tack coat/bond coat should meet the design requirements. The material should be sprayed on a clean surface which is free of standing water and should be sprayed over the full width to be laid.
- Tack coat/bond coat sprayed on a bituminous layer should be given sufficient time to break as per the manufacturer's instructions. Otherwise tyres on the paver and tipper trucks will 'pick up' the fresh adhesive material off the bituminous material. Temperature and humidity will affect the 'break rate' of the tack coat/bond coat.
- Tack coat/bond coat may not be required where bleeding (fatting up) is evident in the base or binder course.

15. Placing Chippings on Hot Rolled Asphalt

- Hand laying chippings can lead to an uneven distribution across the width being laid.
- When laying pre-coated chippings monitor that the chipping spread (measured in kg/m^2) meets the required texture depth and is even across the width being laid.
- Chipping spreader and roller must remain tight behind the paver at all times.
- Chippings should be free of any dirt, dust which will inhibit adhesion, mud or foreign material when loaded for spreading onto the hot asphalt.

16. High Friction Surfacing

- High Friction Surfacing should only be applied onto a surface course which is dry and clean of all dust, oil and loose material.
- All road markings, road studs and ironwork should be masked to avoid contact with the binder and aggregate.

17. Pavement Widening

- Roads should be restored to their original width, and edges strengthened where necessary. The provision of additional width should only be countenanced where traffic considerations warrant it.
- Prior to excavation for widening works, the Contractor should confirm that all existing utilities have been diverted.
- When excavating a verge area for pavement widening works care should be taken so as not to undermine the existing pavement if it is being retained.
- Widening works should not compromise the existing surface drainage and sub-surface drainage.

18. Kerbing

- Kerbing/kerb drainage (if required) should be installed prior to bituminous material is placed in order for the pavement to have a definitive edge. If the kerbs are installed afterwards, the edge of the new bituminous material may have to be removed with an infill piece required.
- Kerbing provides a definitive longitudinal edge for the new pavement. Poorly constructed pavement edges and verges can lead to deformation of the pavement edge once the road is trafficked.
- Haunching or foundation for kerbing should not encroach out into the pavement structure.
- Similar to joints, kerbs should be treated with hot bitumen prior to laying of bituminous material.

19. Other Pavement Works

- Ironwork within the carriageway width should be set to the final design level after laying of binder course and prior to surface course works.
- Core holes left after samples taken should be cleaned out, dried, treated with hot bitumen, then filled and compacted correctly with a tamping rod before the next bituminous layer is laid.
- Pin holes, left in the pavement after the removal of temporary traffic management barrier, should be cleaned out and filled with a high-strength grout before the next bituminous layer is laid.
- The pavement design may call for new capping or subbase to be placed on existing bituminous material. If so ensure that holes are 'punched' in the existing pavement to allow the new granular layer to be adequately drained.

20. Quality and Testing

- If the product is covered by a harmonised European Standard, does the Declaration of Performance meet the intended use of the product on site? If appropriate, is the product CE marked?
- Are the materials coming from a source that complies with all relevant regulations?
- Records of products and suppliers used on a scheme should be maintained to ensure traceability.
- Does the material conform to the applicable Specification?
- If applicable, has the Contractor submitted the proposed target mixture with supporting data from trial mix results and/or historic records?
- Is the Contractor adhering to the material, quality and testing requirements of the Contract? Is testing been carried out at an INAB-accredited laboratory?
- All pre-coated chippings used in HRA, coarse aggregates for surface coarse and surface dressing should be from a single source. This is to mitigate issues relating to durability, Polished Stone Values, Aggregate Abrasions Values and colour of the chips.
- Is the Contractor carrying out inspections to ensure individual layer thicknesses are correct and within tolerance?
- Is the Contractor conducting visual inspections at the various stages of pavement construction? Such inspections can identify issues relating to condition and texture of the material, diesel spills, muck, loose material, water ponding and broken joints. Any such issues should be addressed prior to placing the next pavement layer.
- Is compaction being carried out with a suitable roller that is achieving the correct density?
- Is the rate and accuracy of spread of the tack coat/bond coat/binder material and chippings in accordance with the relevant specifications and requirements?
- Has Nuclear Density Gauge testing been carried out to check the pavement density?
- Has a rolling straight edge test been carried out on the binder course?
- The supervising engineer should visit each site each day of the works to ensure that quality control, level control and other required checks are being carried out.

21. Completion Checks

- Once laid, the surface course should be protected as much as practically possible prior to opening to live traffic. No construction materials should be stored on it. Excavators – apart from those with rubber wheels or rubber tracks – should not be used on it and protective pads should be placed under any trailer/crane/wheeled excavator props.
- Newly laid bituminous layers should only be trafficked once the material has sufficiently cooled and hardened.
- As soon as the bond between the binder and the chippings will allow, traffic at controlled speeds should be allowed onto a newly surface dressed road in order to achieve the best mosaic possible.
- Are there any noticeable bumps/hollows/depressions in the surface upon driving on it?
- Monitor during and after rainfall: is there any ponding on the new surface?
- Has the required crossfall been achieved?
- How does the material look on visual inspection?
    - o In the case of HRA/surface dressing is the chipping rate of spread in accordance with the design requirements?
    - o Has loss of chippings occurred?
    - o Have the chippings become totally embedded in the binder i.e., has the surface fatted up?
    - o Is there any cracking evident on the surface? This might occur if the bituminous material is rolled too soon after laying or trafficked too soon after rolling.
    - o Are there any gouges or visible marks on the surface?
    - o Are there any distinct roller marks left on the surface after compaction is complete?
- How is the surface course around drainage lids performing? In some cases surface course is liable to breaking up around lids located within the carriageway. A common remedial measure is to place hot bitumen and chippings around the lid.
- Ensure accurate record keeping is collated and recorded as outlined in Chapter 7.9.
- Has the Condition Rating of the pavement been updated to reflect the works carried out?
- For Rural Regional and priority Local roads has the new surface course been analysed for the 'after the works' IRI value?
- Has a macrotexture depth test (commonly known as the 'sand patch test') been carried out on the surface course?
- If required, the skid resistance of the new surface should be checked using the Sideway-force Coefficient Routine Investigation Machine (SCRIM) test or equivalent. [May be carried out after a period of time to allow for some trafficking of the new surface].
- Road signs, road markings and road studs should be provided, replaced or renewed as soon as practicable and installed in accordance with the Design drawings, Traffic Signs Manual, etc.? Ideally the construction joints should be located directly under or along one side of the lining.
- Defects that develop in the works carried out should be rectified in consultation with the Local Authority.

22. Miscellaneous Notes

- Particular attention should be paid to drainage and road crossfall (min. 2.5%) in the interests of maintaining the life of the pavement. Refer to Chapter 6 of this document for further guidance.
- If overlay works have created a significant difference in level between the finished road level and the existing verge this should be addressed before the scheme is considered complete. The level difference should be addressed by placing granular crushed stone material for a minimum width of 300mm from the pavement edge.
- For roads traversing peat refer to the "*Guidelines on the Rehabilitation of Roads over Peat*". This document recommends the most suitable forms of road rehabilitation over peat in Ireland.

Postal Address: Department of Transport, Tourism and Sport, 44 Kildare Street, Dublin 2, Ireland
Website: www.dttas.ie
E-mail: info@dttas.ie
Telephone: LoCall 0761 001 601 or +353 1 670 7444 (outside Ireland)

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