GUIDELINES ON THE REHABILITATION OF ROADS OVER PEAT

An Roinn Iompair
Department of Transport

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Guidelines on the Rehabilitation of Roads Over Peat

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CONTENTS

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Chairperson

Mr. Dominic Mullaney, formerly Department of Transport

Members

Mr. Pat Baker, Clare County Council,
Mr. Mark Sweeney, Donegal County Council,
Mr. Brian O'Connor, Kerry County Council,
Mr. Conrad Harley, Mayo County Council,
Mr. Kevin West, Monaghan County Council,
Mr. Barry Lennon, Offaly County Council,
Mr. Damien Grennan, Westmeath County Council,
Mr. Edward Winterlich, Transport Infrastructure Ireland,
Mr. Brian Burke, Road Management Office,
Mr. Henry Spratt, Road Management Office,
Mr. Brian Cross, Department of Transport Support Office,
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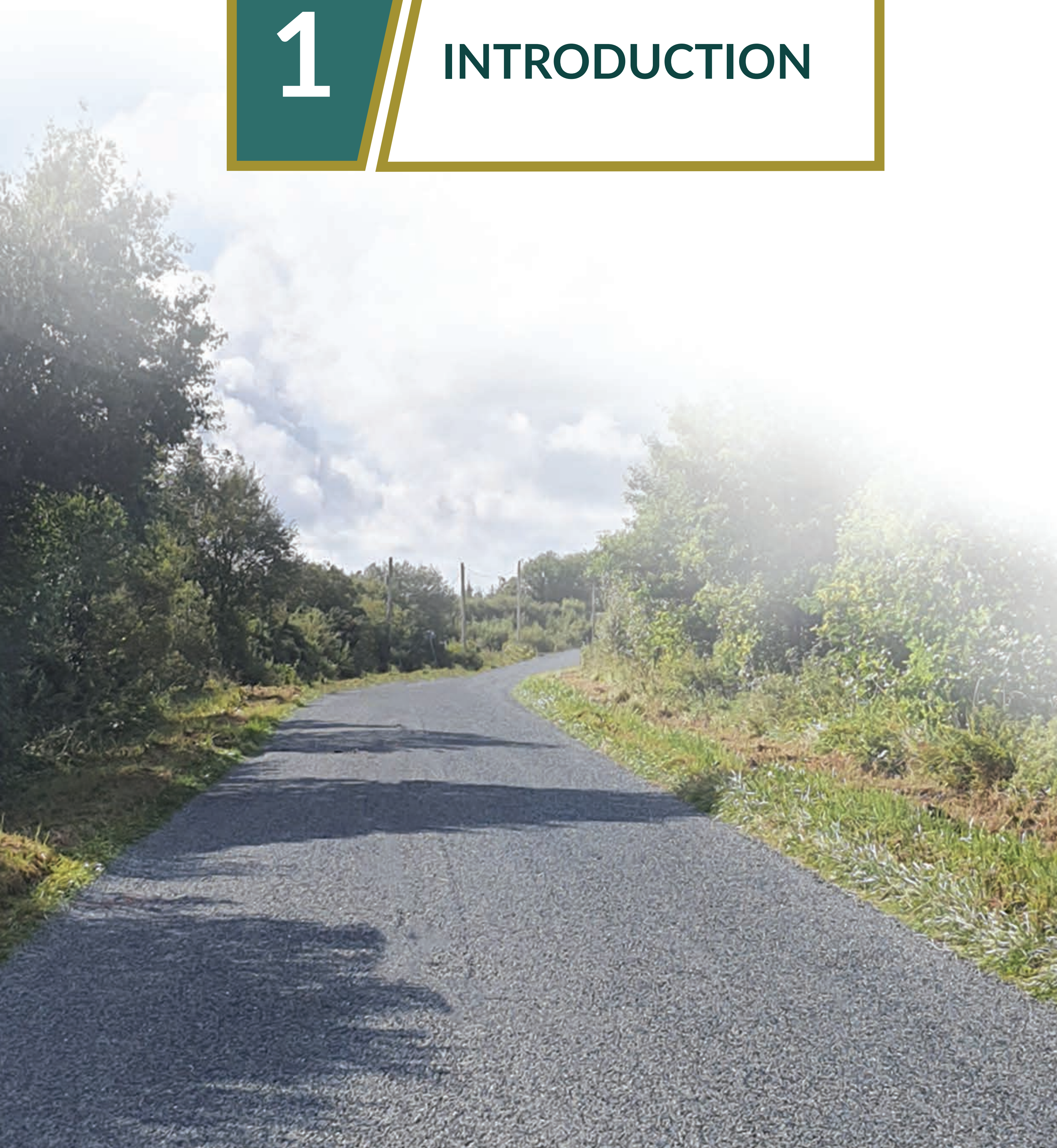
1 INTRODUCTION



1 INTRODUCTION

A guidelines document on the rehabilitation of roads over peat was issued by the Department of the Environment and Local Government in May 2000. As roads oversight function has since moved to the Department of Transport it is considered appropriate to update that document to take account of developments since it was first issued. This revised document is part of a larger suite of Departmental guidelines that includes documents regarding road pavement design, trench reinstatement and drainage, amongst others.

1.1 Policy Context

Project Ireland 2040 was launched in February 2018. It sets out the Government's vision for Ireland's social, economic, planning, and environmental development. It comprises two main documents:

- An overall National Planning Framework, which extends to 2040, and
- A National Development Plan (NDP), which is a 10-year investment program.

The NDP is reviewed periodically and sets out the proposed investment in respect of ten National Strategic Outcomes (NSOs). The following NSOs are particularly relevant to roads:

NSO 2: deals with Enhanced Regional Accessibility; National Road Funding is a key component.
NSO 3: has regard to strengthening rural economies and communities and sets out the importance of properly maintaining (and upgrading where appropriate) the Regional and Local Road network.
NSO 8: deals with the planned transition to a Climate-Neutral and Climate Resilient Society.

In this context and considering the Climate Action Plan, it is important to minimise the environmental impact of the road network. This can be achieved through adopting a sustainable approach to the design of pavement maintenance and rehabilitation works that minimises waste and conserves resources through empirical and/or mechanistic design approaches and the recycling of existing materials. This becomes increasingly important in relation to roads sited over peat.
These roads, be they designed roads or legacy roads, may require more frequent interventions to mitigate rutting and differential settlement caused by weak sub-grades and to maintain transverse and longitudinal gradients.

As required by the Climate Action Plan, road maintenance activities must incorporate energy efficient practices and technologies, to assist in reducing the overall carbon footprint of road maintenance activities, such as:

- Low-carbon construction methods,
- Pavement recycling techniques, and
- Waste minimisation.

The National Investment Framework for Transport in Ireland (NIFTI) is the Department of Transports framework for prioritising future investment in the land transport network and is fully aligned with Project Ireland 2040 and the Climate Action Plan. NIFTI establishes four Investment Priorities: De-carbonisation, Protection and Renewal, Mobility of People and Goods in Urban Areas, and the Enhanced Regional and Rural Connectivity that projects must align with in order to be considered for funding. The four NIFTI Investment Priorities are supplemented by Modal and Intervention Hierarchies. The framework encourages the use of active travel and public transport ahead of solutions reliant on private transport. Maintenance or optimisation of existing assets, including through demand management, is also preferred to extensive enhancements or outright new infrastructure.

1.2 Peatland's and the Road Network

1.2.1 Formation of Peatland's of Ireland

The formation of Ireland's peatland's occurred over the past 10,000 years in the post-glacial Holocene period (Hammond, R.F. 1981: The peatland's of Ireland, 2nd. Edition, Dublin: An Foras Taluntais). According to Hammond, the formation of peat in Ireland was influenced by many factors including, climate, drainage, hydrology, geomorphology, nutrient status, and glacial geology. The most common types of peatland's in Ireland include both raised and blanket bogs. These bogs formed at a rate of a few millimetres per year and are predominantly formed by the accumulation of dead vegetation in various stages of decomposition. The depositional/growth environment also affect the nature and composition of the peat. Both Raised bogs and Blanket bogs get nutrients from rainwater (defined as ombrotrophic) and are therefore almost entirely made of organic material. Fen bogs, however, are fed by groundwater or flowing water sources and tend to be present at the base of the Raised and Blanket bogs. A significant engineering challenge in the genesis of the raised bog is that they can be underlain by depths of very soft silts and clays which can complicate engineering solutions to improve roads constructed over these areas. In calcareous regions, peats can also include layers of very soft marl which is formed by the photo-reduction of dissolved carbon dioxide by submerged green plants.

The Formation of the Raised Bog

Raised Bog typically form in areas of high groundwater levels and low nutrient supply which limits the growth of trees and other vegetation. Vegetation is generally dominated by Sphagnum mosses which are acidic in nature and this type of bog is characterized by dome shaped mounds which can reach thicknesses of greater than 10m. Examples of raised bogs in Ireland include the Bog of Allen, Co. Kildare, Clara Bog, Co. Offaly, and the Connemara bog complex SAC in Co. Galway.

(A) Raised bogs began to develop 10,000 years ago in depressions occupied by shallow lakes, usually left behind by retreating glaciers after the Ice Age.

(B) At the time, the land was washed by nutrient-rich ground water and anaerobic conditions occurred. At first, reed beds developed but then died off, and their dead remains began to accumulate and a Fen appeared as the fen peat accumulated.

(C) The growth and subsequent decay of rushes, sedges, grasses, herbs and wild-flowers, trees and shrubs and this process added to the accumlation of the dark and fibrous fen peat.

(D) The thickness of the fen peat layer increased and the roots of plants growing on the surface lost contact with the calcium-rich groundwater. Rainwater then provided the only source of minerals for plants and this provided a very poor source of minerals for plant growth.

(E) Raised bog species, such as Sphagnum mosses begin to take hold and eventually the fen becomes a raised bog. The Sphagnum mosses can survive on mineral-poor rainwater alone and the spongy-peat which forms over the fen is above the influence of ground water. The fen plants are replaced completely by plants which can survive in the much poorer, acidic conditions and as the mosses accumulate and plants die, a raised bog is formed. The flattened dome of a raised bog is slightly higher than the surrounding countryside, hence the name.

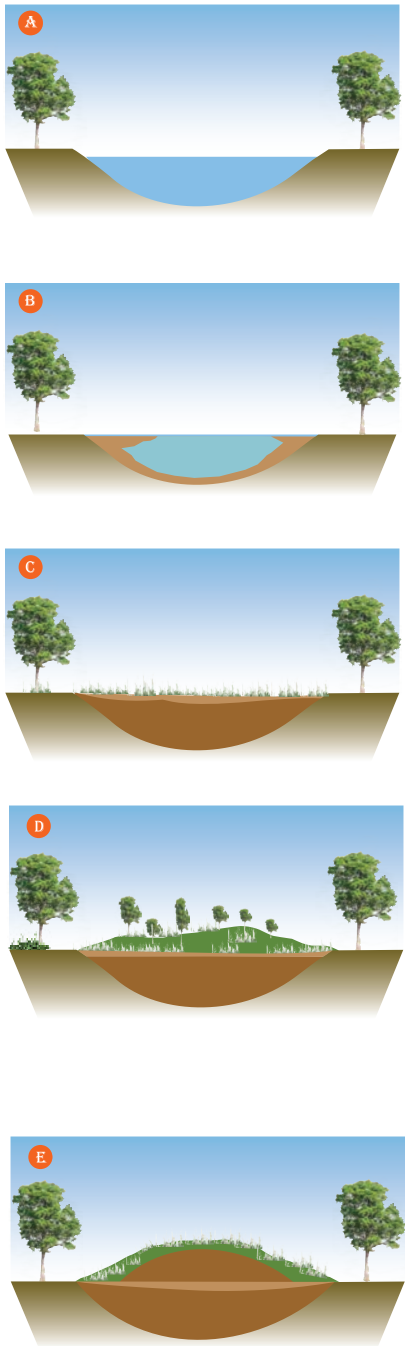


Figure 1.1 - The formation of a Raised Bog

The Formation of a Blanket Bog

In Ireland, blanket bogs typically occur along the western seaboard such as the Owenduff/Nephin Complex SAC and the Bellacorick Bog Complex SAC in Co Mayo. As with raised bogs, blanket bog formation began at the end of the last period of glaciation. Initially, peat formation was confined to shallow lakes and wet hollows, but over time the formation of acid peat resulted in the blanket bog habitat we find today.

(A) Blanket bogs are formed in a similar way to raised bogs, directly on the original soil, and develop in areas with poor drainage where water accumulates due to impermeable underlying subsoil or geological features in areas of flat or gently sloping land.

(B) Heavy rainfall resulted in washing out or leaching of minerals, such as iron, in a process know as paludification, from the surface layers to form a hardpan layer.

(C) This hardpan layer prevented drainage, and gave rise to formation of a very weak, but generally thin, lower layer of fen peat.

(D) A continuous layer of peat developed covering the landscape, and the vegetation was dominated by heathers and purple moor grasses. Depths of blanket bogs tend to be less than raised bogs and can vary from a few centimetres to several meters.

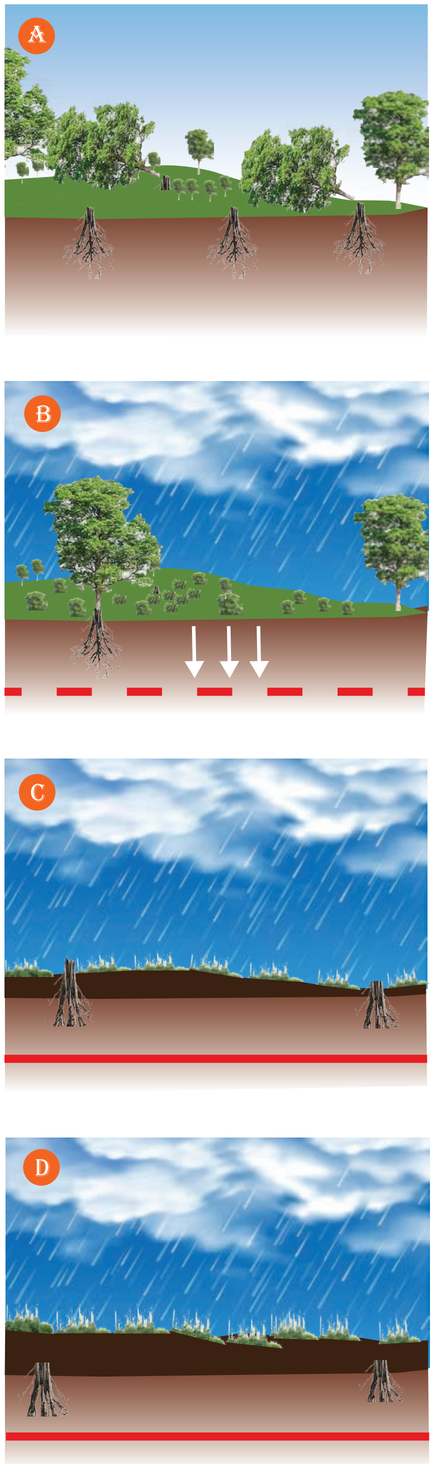


Figure 1.2 - The formation of a Blanket Bog

1.2.2 Ireland's Road Network

Ireland's present road network had its origins in the 18th and 19th centuries. Osorio (2008) details the genesis, development, and current performance of bog roads in Ireland over the past 150 years. The paper discusses typical construction procedures utilised for the construction of these roads in the middle part of the nineteenth century. This construction process included the initial drainage of the road alignment by opening transverse and parallel drains, which dried the surface layers of the peat, increasing the initial bearing capacity and stability of the bog foundation, which, in turn, allowed the road builders to place and compact a layer of stiff clay, followed by a cover of stone or gravel forming the road surface layer over the peat soil sub-grade.

The majority of existing roads over peat consist of these legacy roads from the 18th and 19th centuries, which have been adapted and repaired to accommodate modern traffic requirements as best as possible. The original roads have been supplemented over the years with layers of stone to make up for settlements and to improve ride quality. Furthermore, the presence of these roads has facilitated the extraction of peat with the result that the road pavement now generally exists at a higher elevation than that of the surrounding and remaining unharvested ground, thus forming rampart roads which appear as being on embankments today.

The Regional and Local Road network, which constitutes approximately 94% of the total network, is a legacy network in nature and has had minimal interventions in respect of the overall alignment. The strengthening and maintenance of these roads, in particular those sections with peat sub-grades, poses a major challenge to Road Authorities with ever-increasing traffic volumes and axle loads which these roads must carry.

1.2.3 Extent of Roads over Peat

Peatland's of Ireland constitute approximately 19% of Ireland's total land area. See Figure 1.4, detailing the peatland's Ireland. These locations contain 15% of the total road network. A summary of the lengths of roads over peat and percentage of the overall network by road classification is presented in Table 1 below. Appendix A contains a breakdown by Local Authority. A view of the Regional Road network over peat can be seen in Figure 1.3 below

Road Classification	Length of Road Over Peat (km)	Percentage of Overall Network
National Primary	202	0.2%
National Secondary	536	0.5%
Regional	1,826	1.8%
Local Primary	3,412	3.4%
Local Secondary	4,885	4.8%
Local Tertiary	4,447	4.4%
Total	15,308	15.1%

Table 1 – Distribution of Roads over Peat by Road Classification

Of all road classes, 14.4% of the total network is represented by Regional and Local roads over peat. When considering maintenance and rehabilitation of the road network over peat for the Regional and Local road network there are several distinctive aspects of roads over peat which need to be addressed when designing maintenance or rehabilitation works. These include:

- Assessment of weak sub-grade strength resulting in pavement failures;
- Assessment of ground settlement, which can lead to problems of flooding;
- Long term creep settlements which can lead to undulations in the vertical alignment of roads over peat and formation of transverse cracking;
- Narrow road widths associated with rampart roads over peat;
- The impact of seasonal changes in ground water and moisture changes leading to edge failure on existing carriageways, and leading to transverse ground movement and the development of longitudinal cracking in a pavement centreline.

It is, therefore, crucial that ground and pavement investigations, appropriate to the scale and complexity of the proposed scheme, are undertaken to gather sufficient data to enable the most effective design solution to be developed for that given project location.

Peat and Regional Roads

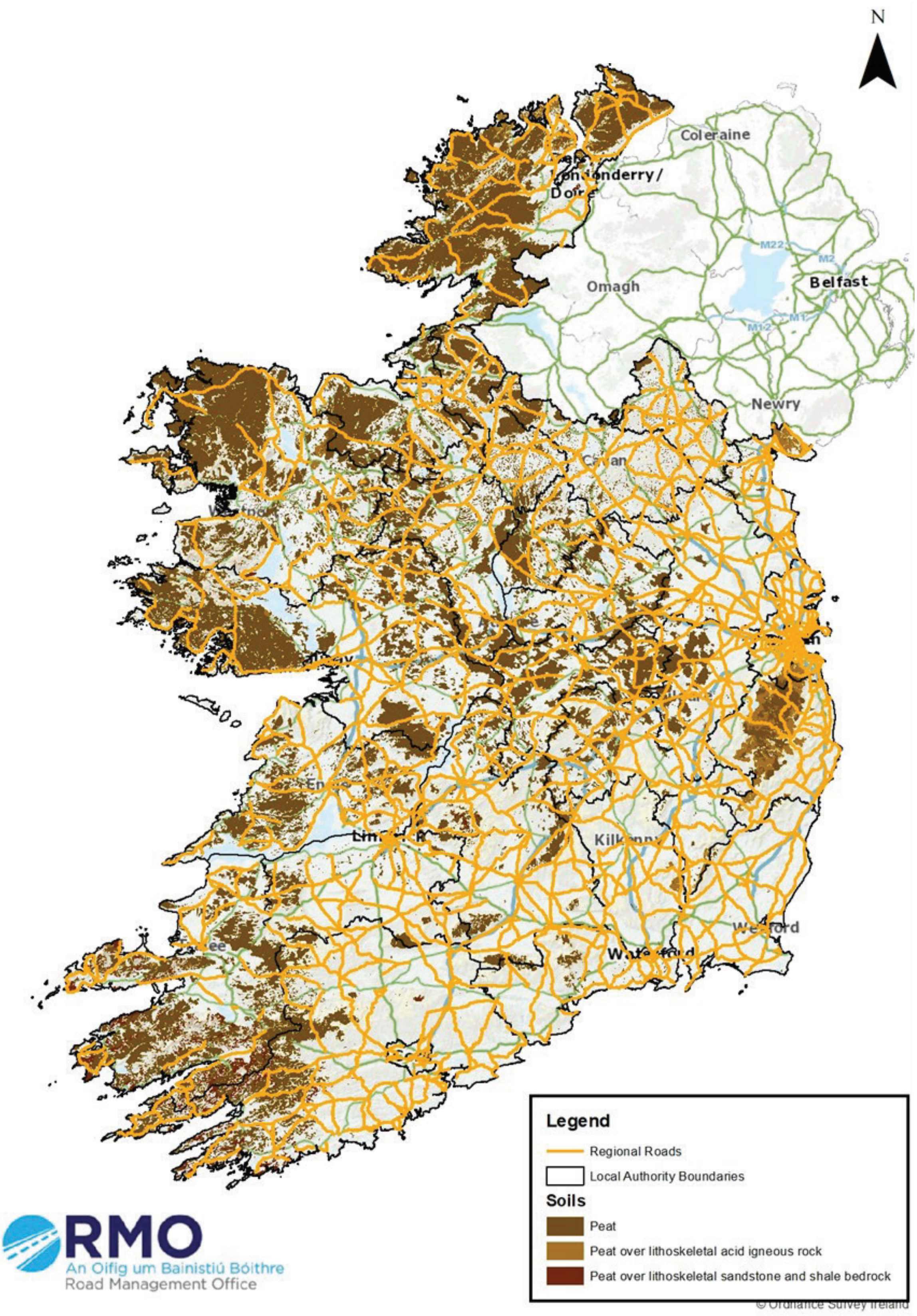


Figure 1.3 - Extent of Regional Road Network over Peat

Peatland Map of Ireland

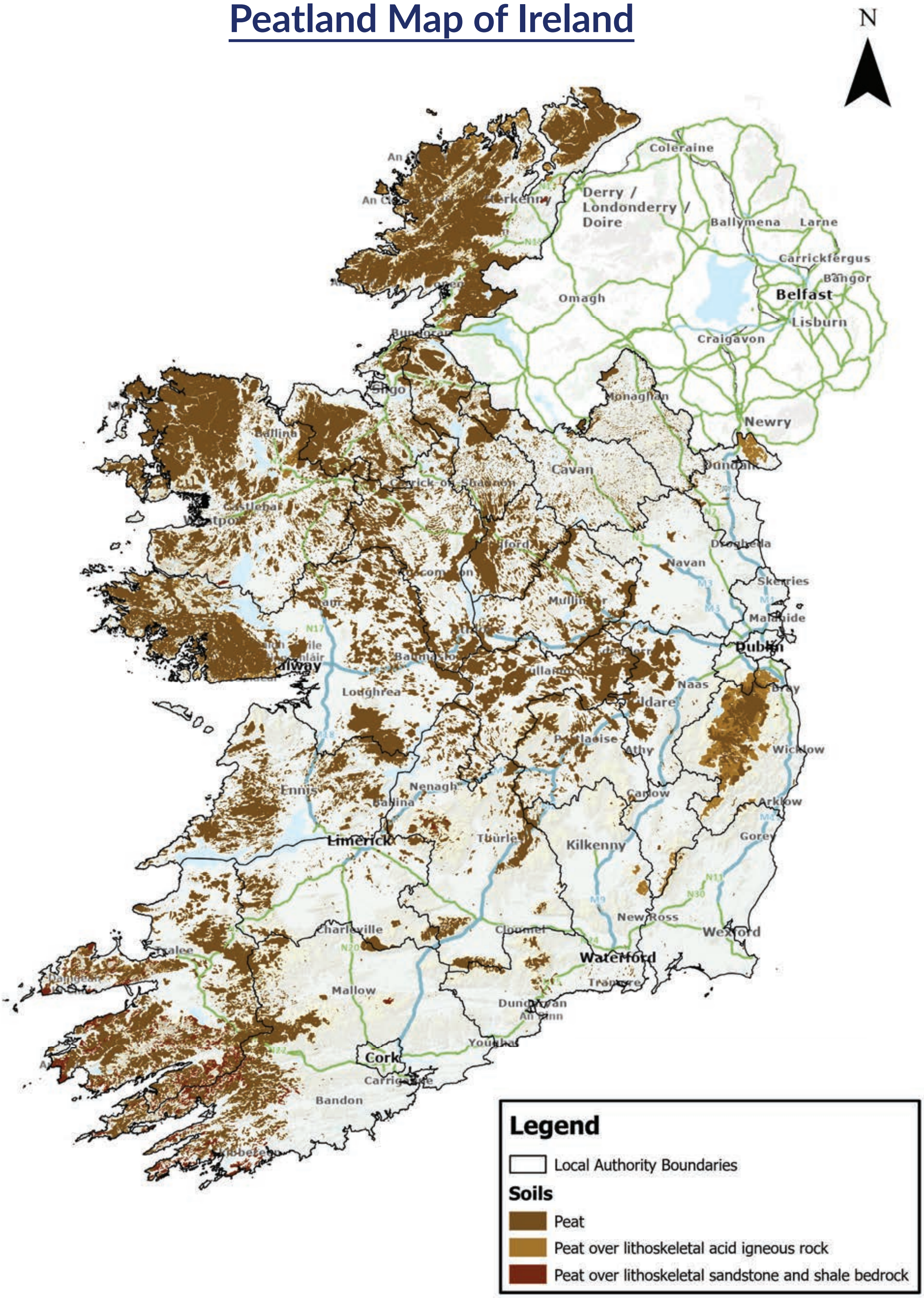


Figure 1.4 - Peatland Map of Ireland

2 OBJECTIVES

2 OBJECTIVES

This document provides guidance to those involved in the design, maintenance, and rehabilitation of roads over peat. The document is not intended to be a design standard, rather aims to provide guidance to the user to help inform their decisions when dealing with roads over peat.

Document purpose:

- Provide guidance for the process and issues that should be addressed when dealing with the maintenance and rehabilitation of roads over peat.
- Provide guidance on the issues that need to be considered for the construction of roads over peat.
- Provide guidance on intervention strategies.
- Provide case studies to inform practitioners of previous experiences in dealing with the maintenance and rehabilitation of roads over peat.

3 DESIGN PROCESS

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3.1 Desktop Study

A desktop study should be undertaken in advance of carrying out a visual inspection of a site's location, its condition and constraints. The study should seek information on the existing site topography, geological and hydrological conditions, maintenance history, existing services and utilities, traffic volumes, potential construction and environmental constraints. The findings of a desktop study should be followed by a site visit and visual assessment of the existing pavement condition and its surrounding environment to determine the need and extent of any further ground and/or pavement investigations. A typical desktop study should consider the following:

- Site details, maintenance history and ground conditions,
- Ground related hazards and constraints, such as topographic, geological or man made hazards,
- Hydrological hazards and constraints, such as increased runoff, erosion and flooding,
- Previous ground investigation information,
- Previous pavement investigations and existing PSCI (Pavement Surface Condition Index) rating or available machine survey data,

The desktop study should include information regarding existing services in the area. Use of mapping from Eircom, ESB, EPA Geo Portal, Tailte Éireann Geohive, and free open-source online mapping should also be assessed prior to attending the site for the purpose of a visual inspection. When consulting with service providers, it is advisable to ascertain whether any future works are planned. This may allow planning the works to mitigate excavation of pavement sections after the pavement rehabilitation works have been completed but potential planned works should not be used to put the improvement or rehabilitation scheme on hold for a protracted length of time.

Consultation with the local Municipal District Area Office is vital. Local knowledge of historical maintenance measures that had previously been implemented, and their subsequent performance, may yield valuable information and assist in the decision-making process. Further to this, local information regarding winter maintenance programmes and the impact of adverse winter weather on sites at higher altitudes should be sought.

3.1.1 Regional & Local Road Asset Management System

Ireland's Regional and Local Road infrastructure is the largest asset managed by Local Authorities. MapRoad Asset Management System (AMS), supported by the Department of Transport and the Road Management Office (RMO), is a single technology system established to manage and standardise processes for the wide-ranging asset functions across the entire network. The key elements are:

- Asset Management of the annual Department of Transports Regional & Local Roads Investment Programme,
- Recording of as-constructed details of National Road Pavement Asset Repair and Renewal (PARR) Schemes.
- Pavement Survey Condition Index (PSCI),
- Mechanical road network data, Rut Depth, International Roughness Index (IRI), Sideways-Force Coefficient Routine Investigation Machine (SCRIM), Cracking etc.,
- Active Travel Infrastructure Management,
- Bridges and Structures Management,
- Speed Limits,
- Annual Average Daily Traffic (AADT) Bands and Traffic Data,
- Public Lighting Inventory,
- Viewable 3rd Party datasets, Subsoils (Teagasc mapped peat locations) etc.
- Importing of maps from external mapping services https://gis.epa.ie and https://maps.environ.ie, these services include, to name a few the SIS National Soils, Special Area of Conservation (S.A.C) and Special Protection Area (S.P.A) maps,
- Viewable background map types, OSI Premium, OSI Ariel, OSI Discovery, Google Ariel, etc.
- Integrated Google Street Viewer,
- The customisation and export of reports from MapRoad.

MapRoad AMS is a dynamic platform which can be utilised to best assist users in overseeing the management of the network. In terms of roads over peat, users can isolate any given location on the network and determine asset management data such as the history and details of projects, current PSCI values, measured rut depth or cracking, presence of mapped peat soils, ground topography etc., where captured data allows. The goal of any asset management process is to use a system-wide approach to improve operations, making an organization more effective by considering the full investment requirements and life cycle of its assets.

3.1.2 The Three Key Principles of Asset Management.

The following are three key principles of asset management:

I. Inventory and Facilitating Data Collection

As interventions are carried out on the network it is imperative that those interventions are captured and recorded in their entirety. MapRoad AMS has the functionality to capture precise spatial locations of said intervention, and also has the functionality to store documents (pdf, word, excel, jpg images) against each project, thus allowing the user to document and archive useful project information and any gathered investigatory or test results. The output of this level of asset management is anchored in the lessons learned process. The insights gained from the outcomes of past projects shared through the MapRoad platform can be applied to current projects locally and nationally. The recommended process for capturing pavement projects in MapRoad AMS for Roads Over Peat (ROP) are:

- Prefix all project Names with the code ROP to allow easier identification of these projects for future analysis, at a micro and macro level.
- Ensure all elements of the intervention are accurately captured in 'Works Grid' of the projects form.
- Locations of specific elements of the intervention i.e. a geotextile type, can be spatially located to the metre within the start and end chainages of a project's length, width and depth.
- Archive all useful documentation in the 'Files' tab of the project form. Visual Inspection records, Falling Weight Deflectometer (FWD), California Bearing Ratio (CBR), Slit trenches or trial pits, images before and after or specification details on geosynthetics materials etc.

II. Improving Efficiency, Performance, and Utilization

Ensuring that the quality of data collected for future roads over peat projects will provide the backbone of intervention performance analysis and inform the future improvement of interventions nationally. Data-driven methods and tools can help identify, gaps, root causes, and trends.

III. Maximizing Return on Investment

As well as measuring the impact and return on investment of improvement actions, data can be used to inform future surveys and reporting. As detailed above, MapRoad AMS has the functionality to spatially record locations, quantities and material types used in the construction of road improvement schemes on the road network. This type of asset management provides the ability to then identify and analyse all pavement intervention types per location, thus enabling the four key concepts of circular economy listed below:

- Designing for durability,
- Reuse,
- Re-manufacturing, and
- Recycling, with the aim to preserve value in the form of energy, labour, and materials expenditure.

3.1.3 National Roads Pavement Asset Management System

Transport Infrastructure Ireland's (TII) Pavement Asset Management System (PAMS) is a comprehensive database that contains information about the National Road network in Ireland. It includes annual pavement condition surveys and a network inventory that informs decisions with respect to pavement improvements and renewals on National Roads. It serves as a repository for site-specific survey data and pavement works information, enhancing the ability to predict deterioration rates and target and prioritise investment. Various surveys are conducted annually, providing data on pavement conditions, such as surface types and texture, skid resistance, cracking, rutting and ride quality. Deterioration models are used to analyse survey data and predict deterioration rates, guiding prioritisation of pavement repair and renewal interventions.

Potential interventions include surface replacement, overlay, strengthening, and reconstruction, each aimed at improving pavement characteristics and functionality. The specific interventions chosen are influenced by factors such as cost, funding availability, and overall network management objectives. The Implementation Authority prepares a Pavement Asset Repair and Renewal (PARR) proposal, outlining the reasons for pavement deterioration and recommended repair and renewal actions. These are now uploaded to MapRoad AMS.

3.1.4 Tailte éireann - Geohive

The GeoHive service is an online platform that provides access to various geospatial datasets and services in Ireland. It serves as a hub for geospatial information and offers users the ability to access, visualize, and analyse data related to topics such as demographics, land use, transportation etc. The platform is managed by Tailte Éireann and the Central Statistics Office (CSO), ensuring the reliability and quality of data made available to the public. This site is a useful portal to access environmental and transport data and includes geology, flood mapping, environmental monitoring, environmental sensitivity mapping, the TII Geographic Information System (GIS) Portal and open data, amongst other datasets. Use of the service can assist in the desktop study phase and provide support tools in decision making for higher cost maintenance or construction schemes.

3.1.5 Soils Mapping

Mapping of soils in Ireland is undertaken by several organisations including Teagasc, the Environmental Protection Agency (EPA) and the Geological Survey of Ireland (GSI). Each organisation has differing responsibilities in relation to soil, with Teagasc being the main organisation responsible for operating the Soil Information System (SIS). The SIS is a digital soil mapping system based on the National Soil Database, which was last published in 2014, and was created through the collection of soil samples from across the country. It provides a range of information including soil type, depth, drainage characteristics, texture etc.

According to information in the SIS, peat soils cover approximately 19% of the land area of Ireland, shown in Figure 1.4 - Peatland Map of Ireland. This figure is slightly above the original estimate of 17% provided by R.F. Hammond in 1981. More detailed information on the occurrence of peat soils can be obtained from the County series of the National Soil Survey of Ireland, available from Teagasc. The Environmental Protection Agency (EPA) Geo Portal (https://gis.epa.ie/EPAMaps/) is a geographic information system which provides access to various environmental related data for Ireland. It provides a substantial dataset for environmental issues including Corine, soils and sub-soils, water and water framework directive information, water quality and historical mines data. Recent work undertaken by the RMO in the MapRoad AMS will enable Local Authorities to detail the occurrence of roads over peat in their administrative areas.

Data Collection

It is imperative that accurate and timely data is collected during the desktop study process. The data must be as up to date as possible, with particular attention when capturing the following:

- PSCI data – this data must be current and ideally the PSCI rating should be taken as part of the desktop study process when dealing with roads over peat.
- Traffic data – this data must be current and ideally should be taken as part of the desktop study process. Estimated traffic data is not acceptable.
- Pavement data – this data should be recorded, for example, the depth of base, binder or surface course or the inclusion of a geosynthetic material within the pavement should recorded accurately on MapRoad. Where accurate historical data is available, this should be recorded in MapRoad also.

3.2 Visual Inspection

3.2.1 Introduction

The purpose of the visual inspection is to provide more detailed information in respect of the site and any site constraints. In addition, the visual inspection will assist in determining the location, nature and extent of pavement distress and information regarding the associated drainage. Pavement distress can be categorised into surface defects, pavement deformation, cracks, patching, potholes and disintegration. Some typical defects common on roads over peat include:

- Surface undulations or permanent deformations caused by creep settlements of the peat,
- Pavement edge failures due to seasonal moisture changes, and
- Longitudinal cracking forming along the centreline of the pavement.

Further details, including photographs of typical defects, can be accessed in the Rural Flexible Roads Manual Volume 1, on the RMO website. Identification of these parameters will enable a more targeted approach to further site investigation if required. The Guidelines for Road Drainage should be consulted for detailed guidance on drainage assessments for consideration during a site visual inspection.

3.2.2 How to go about the Visual Inspection

Guidance can be found in the Rural Flexible Roads Manual with respect to Pavement Survey Condition Ratings (PSCI) for use on the Regional and Local Road network. For works on the National Road network, refer to TII publications for details on the requirements of a visual inspection. Appendix G provides an example of a pavement visual survey inspection record sheet and a non-exhaustive list of items to consider when undertaking a visual inspection for the rehabilitation of a road constructed over peat. The information in Table 2 provides some items for consideration when making on site observations during the visual inspection. To aid in the collection of accurate data during the visual inspeactions the following items may be considered:

- Divide the site segments into sections of homogeneous characteristics using AMS or PAMS data and initial visual identifications;
- Note the extent and condition of the category elements set out in Table 2 below and the visual survey checklist found in Appendix G.
- If a Vehicle Restraint System (VRS) exists on site, then consultation with the overseeing authority regarding condition and planned works is advised.
- Check for evidence of collisions and consider collision history at the site.

- Determine if the site is an Invasive Alien Plant Species (IAPS) location. Where appropriate consult TII publications on the Management of Invasive Alien Plant Species on National Roads.

	Category	Elements
1	The carriageway pavement	Surfacing type, geometry, PSCI rating.
		Pavement structure integrity – defects and distresses
2	Footways and cycle tracks	Locations, geometry, materials, condition
3	Covers, gratings, frames etc.	Number, locations (carriageway or verges), conditions, types
4	Kerbs, edging, preformed channels, road signs and lines and vehicle restraint systems	Misalignment, dislocation, damage, heights, tie-in arrangements and decreased conspicuity
5	Road drainage network including outfalls	Types, cross falls, culverts, bridges, blockages, outfalls etc.
6	Utilities	Locations, underground, overhead, crossings, planned future works
7	Traffic	AADT and % HGV, identify nearby industry such as quarries etc.

Table 2 - Visual Inspection Survey Categories and Elements

3.2.3 Specific Problems Related to Roads over Peat

Normal pavement failures such as alligator cracking, edge breakup, rutting, etc. can arise due to either poor pavement layers or poor sub-grade. The rehabilitation of roads experiencing normal pavement failures are covered elsewhere through standard procedures. There are some unique aspects of roads over peat that can lead to specific problems or failure types that should be considered when carrying out a visual inspection. Some of the more common specific problems or failure types that can arise on a road over peat are:

- Undulations due to creep settlement of peat;
- Edge failure and excessive subsidence due to seasonal moisture changes;
- Longitudinal tension cracks presenting as centreline opening;
- Transverse cracking of rampart roads;
- Narrow carriageway.

Some examples of the specific problems or failure types are shown in Figures 3.1 and 3.2

Figure 3.1 - Example of Centreline Opening on Road Over Peat

Figure 3.2 - Example of Undulations & Edge Failure on Road over Peat

3.3 Pavement Investigation

A pavement investigation is a comprehensive process to determine the factors which cause distress and deterioration within a pavement structure. The investigation should allow a designer to develop an optimal intervention, considering financial and project specific constraints. As discussed in the previous sections, a combination of the Desktop Study and Visual Inspection should assist the designer in assessing proposed works, such as utility repairs or realignments, which may affect the proposed pavement rehabilitation or maintenance works. A scheme-level pavement structural assessment may typically involve the use of both invasive and non-invasive investigative techniques to both test and confirm the pavement properties. The use of each method will be at the discretion of the designer and should be based on the size and complexity of the proposed scheme. Typical methods include:

- Falling weight deflectometer (FWD),
- Ground penetrating radar (GPR),
- Coring of pavement materials,
- Laboratory testing of pavement materials.

3.3.1 Falling Weight Deflectometer (FWD)

The use of the Falling Weight Deflectometer (FWD) is a non-invasive testing method and is essential for understanding pavement layer stiffness properties, and the sub-grade strength, especially for existing pavement confirmation or for the design of strengthening measures. It should be noted, however, that there are limitations to the use of the FWD on roads with peat sub-grades due to the unique characteristics of peat. Factors such as the high moisture content of peat and high compressibility can lead to significant deformation under applied test loads which can make it difficult to accurately measure the structural response of a pavement over peat when subjected to the FWD test.

Figure 3.3 - Falling Weight Deflectometer Testing Device

3.3.2 Ground Penetrating Radar (GPR)

GPR proves highly valuable in assessing changes in pavement construction, measuring layer thickness's, and identifying defects or features within the pavement. This non-invasive testing method is especially advantageous for older pavements that may have undergone changes in their structure over many years, as it allows engineers to gain insights into the pavement's composition without the need for excavation. By providing valuable information about the subsurface conditions, GPR helps in making informed decisions regarding pavement maintenance, rehabilitation, and structural assessments.

Figure 3.4 - Ground Penetrating Radar

3.3.3 Coring

The use of coring techniques can assist in determining the pavement material type, thickness and overall integrity at the location of the core. The core will provide a visual assessment of the depth of any cracking. The core sample retrieved can also be subject to laboratory analysis, and in-situ DCP test may be conducted to assess the condition of the unbound granular and subgrade layers of the pavement at the location of core extraction.

3.3.4 Laboratory Testing

Before proceeding with laboratory testing, it is crucial to assess relevant field data (depth of peat, composition of peat, depth of pavement layers, any cores from the bound pavement layers and drainage arrangements) and then determine if further tests are required in order to analyse pavement behaviour. Comparing field data between failed and intact areas can be particularly beneficial in understanding the underlying issues.

In most cases where roads are located over a peat sub-grade, pavement problems such as an undulating surface or pavement cracks, are caused by creep settlements of the weak peat sub-grade and drainage issues rather than materials which are not to specification. Where it is suspected that that either the bound or unbound materials in the existing failed road pavement are not in accordance with the appropriate specification it is possible to undertake various tests on the bound or unbound materials or both. Details of possible tests are set out in Appendix E.

3.4 Drainage Considerations

The efficient discharge of surface water from a road pavement to an adjacent drainage network is an important preventative maintenance measure which preserves and maintains the lifespan of a road pavement. Drainage is one of the most important initial factors to be considered when undertaking road pavement intervention measures. Surface water ingress through a road pavement structure, either through cracks, potholes or the road verge can reduce the lifespan of the pavement by jeopardising the performance of the bound and unbound pavement materials and encouraging deterioration of the pavements founding sub-grade materials.

The efficient control and removal of surface water from the road, through regular planned drainage maintenance tasks such as reopening water cuts, ditch and culvert clearance, is therefore of particular importance for roads over peat to assist in prolonging the lifespan of the pavement.

The recent impacts of climate change have had a serious and detrimental effect on roads over peat. This became apparent in the summer of 2018, with the formation of longitudinal cracks in the surface of road pavements caused by shrinkage of peat after prolonged periods of hot dry weather. Conversely, in periods of persistent and heavy rainfall events, the risk and problems associated with flooding, increased runoff and erosion has resulted in heave and subsidence caused by the erosion of soil and pavement material in some areas.

Figure 3.5 - Showing maintenance, opening of water cuts

3.4.1 Drainage Considerations for Roads over Peat - General

Where drainage networks do not facilitate the efficient displacement of surface water from a road surface, the risk of potential problems caused, such as unsafe driving conditions, pavement and sub-grade deterioration, embankment failure, erosion, flooding or structural damage is greatly increased. In areas where roads are constructed over peat, regular monitoring of the performance of the drainage network to identify any issues which may begin to emerge is vital to ensure that the operation of the drainage network is not compromised, and the lifespan of the road can be increased. Planned drainage maintenance works required to be undertaken on a regular basis will ensure that existing drainage infrastructure operates to its optimum capacity and will mitigate those potential risks mentioned above.

Table 3 provides details of typical maintenance works for roads over peat. Note that general guidance on road drainage can be found in Departmental guidelines published in March 2022. In the case of open drains adjacent to the roadway edge, these collect both surface and ground waters from roads over peat.

Care should be taken during maintenance of these drains to ensure that road drainage patterns are not altered resulting in excessive drainage of the peat foundation beneath the road structure which may lead to differential settlements and surface deformation of the road above.

Planned Drainage Maintenance Works on Roads over Peat		
Works	Reason	Comments
Repair potholes	Stop water ingress into road structure	On-going maintenance as often as necessary
Open Water Cuts Drainage Inlets	To remove standing water from surface	
Clear roadside drains	Ensure drainage channels are kept operational	Care to be taken that excess clearing is avoided to ensure that there is no significant change to drainage patterns which may result in the drying out of the peat underneath the road structure
Upgrading/replacing Culverts	Ensure drainage channels are kept operational	Particular attention is needed if geosynthetics are present. Recommend adhering to manufacturers recommendations on lap details for the reinstatement of same

Table 3 - Planned Drainage Maintenance Works on Roads over Peat

Where maintenance works are undertaken on a road over peat, such as pavement and or drainage maintenance, restoration or improvement, a system of regular monitoring and reporting on the performance of the drainage network during and after construction should be considered. These records should assess the performance of the network to ensure that surface water discharge into the network is managed, to avoid uncontrolled or concentrated discharge points into drains mitigating the potential for local erosion points and potential global instabilities on a road embankment or rampart.

3.4.2 Drainage Considerations when using Geosynthetics

The use of geosynthetic in road pavements over peat sub-grades can extend the service life of that road pavement by reducing surface deformation (less cracking and rutting) and this in turn may reduce the number of road maintenance cycles associated with that road.

In a scenario where a geosynthetic is being used as an intervention measure to prolong the life of a road over peat, the design and installation of the geosynthetic should be in accordance with the manufacturers instructions. The use of a geosynthetic in these cases will prevent or eliminate fines from migrating into the clean capping aggregate layer from the sub-grade below with the permeability of the geotextile ensuring that ground water can continue to migrate upwards through the geosynthetic material and allow consolidation to take place.

> In a scenario whereby the use of a geosynthetic has been considered as an intervention measure to prolong the life of a road over peat, then the design and installation of these geosynthetic shall be undertaken in accordance with the manufacturer's recommendations.

3.5 Ground Investigation

Undertaking a ground investigation for roads constructed over peat is of great importance to properly inform the design process for pavement rehabilitation and maintenance measures. The ground investigation should be tailored to suit the size and complexity of the project, but regardless of the size of the project, all roads constructed over peat should be subject to at least a level of basic probing investigation, to establish the depth of peat.

The aim of ground investigation, in its simplest form, is to collate information about the depth and consistency of the peat, the type of peat present whether fibrous, pseudo fibrous or amorphous with simple testing to verify its moisture levels. Neglecting the simplest form of site investigation for roads constructed over peat for the sake of time or cost is not advised as the collation of this basic data can assist experienced design engineers in providing the most effective design solution for the specific site.

Conducting a cost-effective ground investigation involves selecting the appropriate methods for each specific site location. The level of ground investigation will be dependent on the scale of the project. From low-cost, low priority schemes on minor roads with low traffic volumes a simple probing exercise to establish the depth and consistency of the peat may be sufficient, however, for more significant works on roads with higher traffic volumes, higher costs can be expected with more detailed ground investigation works required.

A low-cost ground investigation probing technique was trialled on the L-3210, Mountbellew, Co. Galway. The trial used peat probes to establish the depth of peat, hand-held field vane to provide an estimate of peat soil strength, and a Russian peat core sampler to retrieve samples for visual inspection of the peat, Von Post classification and moisture content testing. Details of the trial, the equipment used, and the results are provided in Appendix D. The trial suggests that the methods proposed are beneficial in obtaining initial depths of peat and preliminary properties of the peat in a relatively low-cost and quick manner with works undertaken by Local Authority Municipal District Staff.

> It is imperative, at a minimum, that the depth of peat below the section of road in question is known and accurately recorded. An understanding of the depth of peat can allow a greater understanding of how a road behaves when founded on soft sub-grade.

A more detailed form of preliminary ground investigation is to combine dynamic probes (DPH) at approximately 25m intervals, either side of the road, with windowless sampling to give an indication of the nature of the soil. Coordinates of the locations should be reported, along with the Ordnance Datum (OD) elevation. This investigation can identify the depth of peat and any underlying soft/firm soils and can be very useful when planning a detailed investigation. For high-cost schemes, where complex ground investigations are planned, advice should be sought from appropriately qualified and experienced geotechnical engineer. A detailed investigation would typically include cable percussion boreholes with piston sampling, in-situ penetration or vane tests and rotary coring to greater depths if piling were considered as an optimal design solution.

For ground investigation works, guidance and information can be accessed in the Engineers Ireland – Specification and related documents for ground investigation in Ireland and on the TII Publications website. Further requirements for planning ground investigations can be found in IS EN1997-2: Planning of Ground Investigations. Table 4 provides a summary of more complex intrusive investigation techniques and these are discussed in detail in Appendix C of these guidelines.

Note on the moisture content of peat

The simple moisture content test is a very useful indicator of the engineering properties of a peat. Typically peats would have moisture contents in excess of about 400% whereas mineral soils would have moisture contents less than 100%. Marls are special and have moisture contents of about 150%. Note that there is a big difference between the definition of moisture content used by agriculturists and engineers. The former refers to the mass of water to the mass of soil and water and therefore cannot exceed 100%, whereas in engineering the moisture content is the mass of water to the mass of the soil particles only.

Investigation Technique	Description & Equipment	Application & Data Collation	Advantages & Limitations	Suitable Site Conditions	Cost & Time Considerations	Maintenance Works (M) or New Works (N)
Peat Depth Probes	12mm Fibreglass rods with 17mm steel tip. Threaded connections & 20cm Fibreglass T-piece handle	Offers rapid assessment of depths of peat and soft to very soft alluvium soils In-situ depth of soft soil	Rapid assessment of depth of peat and soft soil via manual application Offers no confirmation of soil types and strength.	Peat and very soft to soft soils.	Low cost, Rapid results	M
Hand Vane	Hand-held vane consisting of torque head with reading gauge, extension rods and cruciform vane	In-situ measurement of soil strength Provides an estimate of the un-drained soil shear strength	Suitable for soft soils, portable for use in the field Not suitable for granular soils. Provides an estimate of the soil strength and should be used with caution in fibrous peat soils	Soft soils, areas of cohesive soft ground	Low cost, Rapid results	M
Russian Peat Core Sampler	Side filling chambered-type sampler for collection of uncompressed cores in peat soils	Collection of uncompressed cores in peat soils. Soil sample for visual and laboratory analysis	Suitable for shallow investigations. Quick retrieval of uncompressed peat soil cores	Peat and very soft soils	Low cost, Rapid results	M
Trial Pits & Slit Trenches	Shallow excavations to depths typically 4 to 5m with mechanical excavator	Direct visual inspection & sampling of shallow surface soils Visual inspection of soil profile	Suitable for shallow investigations. Limited depth, safety of edges and potential collapse of excavations can be unsuitable in soft soils due to stability. Stability of excavators in soft ground.	Firm ground conditions.	Medium cost, Quick results.	N

Table 4 - Summary of intrusive ground investigation techniques

Investigation Technique	Description & Equipment	Application & Data Collation	Advantages & Limitations	Suitable Site Conditions	Cost & Time Considerations	Maintenance Works (M) or New Works (N)
Dynamic Probes	Penetration testing using hammer to drive steel rods into the ground Self-propelled rig with anvil and hammer raised and dropped specific height to drive rods into ground	Offers rapid in-situ assessment of soils density and strength Penetration resistance. Blow count per increment of penetration	Quick setup, rapid assessment of soils. Depths up to 25m in soft soils Super heavy probe unsuitable for soft soils	Loose to dense granular soils, soft cohesive soils	Medium cost Rapid results	M & N
Dynamic Cone Penetration (DCP)	Manual operated DCP with steel rods, conical tip, drop hammer and steel rule	Evaluation of soil strength and compaction. Penetration resistance data. Blow counts per driven incremental length	Quick setup, minimal disturbance Suitable for granular soils, less suitable for cohesive or soft materials	Typical use in pavement investigations	Low cost, Quick result	M & N
Mackintosh Probe	A hand-held probe to measure ground resistance and retrieve small samples	Offers a semi quantitative assessment of soils strength Penetration resistance, sub-surface strata sampling	Quick portable, minimal equipment Only suitable for use in loose or soft soils	Loose or soft soils	Low cost, Rapid results	M

Table 4 - Summary of intrusive ground investigation techniques

Investigation Technique	Description & Equipment	Application & Data Collation	Advantages & Limitations	Suitable Site Conditions	Cost & Time Considerations	Maintenance Works (M) or New Works (N)
Window Samples	Small diameter boreholes for retrieval of soil samples by driving hollow tubes into the soil.	Offers visual inspection of soil layers and sample recovery. Visual profile of soils for descriptive purposes, retrieval of small samples for index testing.	Quick test with minimal disturbance, provides visual of sub-surface layers. Limited sample size, may not recover undisturbed samples.	Shallow investigations, preliminary site assessments.	Medium cost, Quick results.	M & N
Borehole – Cable Percussive	Cable percussion rig, drilling tools, steel casing. Use of heavy bit or chisel attached to cable and winch to create borehole.	Provides visual description of soil profile. Soil samples and descriptions. Groundwater levels and monitoring.	Good for deep penetration in soft soils, sample recovers and GWL monitoring. Slow, labour intensive, limited to accessible locations, disturbance to surroundings.	Best suited for soft soils, suitable for all soil types.	High Cost, Dependent on-site conditions, including mobilisation, setup TTM etc. along with testing and sampling requirements, refusal depths etc.	N
Borehole – Rotary Core	Drilling method using a rotating bit to extract continuous cylindrical rock core samples. Rotary drilling rig, core barrel, drilling fluids.	Offers detailed visual inspection of solid geology, rock types, fracturing etc. Continuous core samples of rock allowing description, classification etc.	High quality samples, effective in hard strata locations. Requires specialist equipment, not suitable for soft soils.	Typically used for mineral exploration and geotechnical investigations for projects considering significant interventions.	High cost, Dependent on-site conditions, including mobilisation, setup TTM etc. along with testing and sampling requirements, refusal depths etc.	N

Table 4 - Summary of intrusive ground investigation techniques

3.6 Environmental Considerations

According to information published on the Irish Peatland Conservation Council's website, Ireland's peatland's are estimated to store 1085Mt (mega tonnes) of carbon which corresponds to 53% of all soil carbon stored in the island, in 16% of the land area. Globally, peatland's are estimated to hold 30% of all soil carbon while covering an estimated 3% of the land area of the planet. Drainage of peatland's can disrupt the process of accumulation of carbon in peat and can lead to release of carbon and other green house gases into the atmosphere. It is therefore important to carefully drain and avoid excavation of the peat to lessen the environmental impact of roads over peat where possible.

Given the environmentally sensitive site-specific conditions that must be considered when selecting an intervention on a road constructed over peat sub-grades, the following may be considered based on the project size:

- Climate change effects on roads constructed over peat;
- The application of an environmental management checklist for the project;
- Material selection;
- Carbon footprint calculation.

3.6.1 Climate Change Effects on Roads over Peat

The effect of severe weather events, including prolonged dry spells, periods of prolonged and persistent wet weather accompanied by intense rainfall events can have a negative impact on roads over peat, and may require intervention depending on the severity of impact of the event. The Climate Adaptation Strategy for Regional and Local Roads, published in February 2023, sets out how Road Authorities can improve the resilience of assets on the Regional and Local Road network to the impacts of climate change. Reference to the Strategy should be made when assessing and risk rating of any roads constructed over peat within a Local Authority area to ensure a structured and consistent approach nationally. When assessing the effects of climate change on any road constructed over peat, it is important to review the historical records in order to assess the effectiveness of interventions in terms of the frequency and cost of each method or type employed.

3.6.2 Project Environmental Management Checklist

For large scale, road construction projects, an Environmental Management Plan is required to ensure successful delivery. In most cases, interventions on roads constructed over peat are localised and small. It is, therefore, suggested that an Environmental Management Checklist be implemented to ensure schemes are delivered in accordance with the client's statutory environmental compliance responsibilities prior to commencement of works. The checklist is proposed to ensure that any scheme has been considered in the context of the following environmental considerations.

- Water Quality, Surface Water and on site Drainage systems;
- European Communities (Waste Directive) Regulations 2011 – Article 27: By-products;
- European Communities (Waste Directive) Regulations 2011 – Article 28: End-of-waste;
- Material Management Plan;
- Pollution Control;
- Appropriate Assessment Screening, where applicable;
- Environmental Impact Assessment, where applicable.

3.6.3 Material Selection

Due consideration should be given to the selection of appropriate materials and intervention types for roads over peat. Incorporation of locally sourced recycled materials, such as Reclaimed Asphalt Pavement (RAP), and the selection of cold or warm mix plant or in-situ recycling techniques can reduce the demand for natural and energy resources. Where these considerations are accompanied by modern pavement design techniques and the selection of geosynthetic materials for improved performance and durability of a pavement foundation, the lifespan can be increased reducing the overall environmental impact of the pavement lifecycle.

The location of and the environmental constituents of any geosynthetic layer and the net environmental impacts of this decision-making process should be considered prior to selecting an intervention. Placement of a selected geosynthetic within the pavement layers will dictate the level of construction required in the first instance and more importantly may limit options with regards to maintenance interventions in the future. Therefore, material selection may have a long-term impact on the environmental risks associated with any pavement and the associated carbon footprint of the road.

3.6.4 Carbon Footprint Calculation

The Climate Action Plan sets out targets for carbon reduction in relation to the construction sector. Under the Climate Action Plan, energy efficient practices and technologies must be incorporated to assist in the reduction of the overall carbon footprint of road maintenance activities. A carbon footprint is the total amount of greenhouse gases that are generated as a result of using resources for production or in the provision of services and can be expressed as a carbon dioxide equivalent (CO_2e). Greenhouse gas emissions associated with an organisation's activities are generally expressed as kilogrammes of carbon dioxide equivalent ($kgCO_2e$).

Calculating the carbon footprint for road maintenance activities can be a complex process, particularly in relation to roads over peat. There are a number of calculation tools that can be used to calculate the carbon footprint of construction works, such as the TII Carbon Tool for Road, Greenway and Light Rail Projects. Care should be taken when calculating the carbon footprint for maintenance activities for roads over peat to ensure that all aspects of the maintenance process are captured and reflected accurately in the calculation.

Particular attention should be given to the reduced duration between interventions that are experienced in the rehabilitation of roads over peat compared to roads with stronger sub-grades when considering carbon footprint calculation. The reduced duration between interventions can lead to increased maintenance and rehabilitation works leading to an increase in use of materials, increased construction activities and an increase in carbon. It is important that a maintenance technique or treatment type is selected to help maximise the duration between interventions and minimise the amount of carbon produced. Minimising the amount of materials to be excavated, appropriate reuse of existing materials and the use of warm mix asphalt instead of hot mix asphalt are some examples of how the overall carbon footprint of maintenance activities on a road over peat may be minimised.

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4 INTERVENTION STRATEGIES

4 INTERVENTION STRATEGIES

The unique nature of roads constructed over peat, in particular the sub-grade, leaves them susceptible to detrimental effects that can arise due to environmental changes and traffic impacts. Such impacts can have an amplifying effect on the deterioration of a road over peat when compared to the performance of roads constructed over stronger sub-grades such as glacial soils.

In general, early intervention on roads experiencing initial defects, is recommended, as a minimal low-cost intervention can produce the best value for money. However, when considering interventions on roads over peat, an early intervention may not necessarily represent the most prudent approach. The problems associated with roads over peat may be more fundamental in nature than just initial surface defects and can deteriorate quickly over relatively shorter periods of time. In fact, it may be necessary to accept a lower level of service in terms of ride quality to ensure that roads over peat do not consume a disproportionate percentage of a road maintenance budget.

Chapter 4 provides guidance to Roads Authorities on how they may prioritise their network of roads over peat for intervention and how they may set the appropriate intervention level based on a system of prioritisation. Road Authorities are reminded of the commitments made in the Climate Action Plan to transition from the environmentally and economically unsustainable 'Take-Make-Waste' model towards a circular economy that offers a sustainable alternative. A circular economy reduces consumption and maximises efficiency of use of materials through behaviours such as recycling and reuse.

When considering intervention strategies and construction solutions for dealing with roads over peat, a balance may need to be drawn between an intervention that provides the greatest return in terms of prolonged pavement lifecycle and the impact in respect of carbon emissions and waste generated through the construction process. The remedial treatment for roads over peat will differ from "normal roads" as the proposed remedial works need to take account of the low strength peat sub-grade.

4.1 Priority Matrix

Figure 4.1 below shows the priority matrix and how a road authority may prioritise their network of roads over peat for intervention. The matrix requires data gathering by the road authority in terms of the current Pavement Survey Condition Index (PSCI) rating (see Figure 4.2) and the traffic levels on a road in question expressed as Annual Average Daily Traffic (AADT).

Priority

Current PSCI			
7-8	L	L	M
5-6	L	M	H
1-4	M	H	H
0	501-<2,000	2,001-<5,000	5,001+
	AADT		

Figure 4.1 - Priority Matrix

It is imperative that when assessing the need for an intervention on a road or part of a network, that data being used is of the highest accuracy possible. For the purposes of roads over peat, the PSCI rating date and the traffic survey must be as close to the assessment date as possible and ideally within the same calendar year of the intervention works.

Once the AADT data and PSCI rating are known then their positions on the X-Axis and Y-Axis respectively can be determined and the priority intervention of a road over peat established. The matrix sets out three levels of priority, Low (L), Medium (M) and High (H).

L - Low Priority.

Priority has initially been determined as low. These projects may be addressed by Local Authorities in their annual Regional & Local Roads Programme. Where L is horizontally aligned with a PSCI of 5-6, then the intervention should take consideration of the AADT and the frequency of interventions.

M - Medium Priority.

Priority has initially been determined as medium. Other site-specific details, like frequency from last intervention coupled with cost of last intervention may mean that a cost benefit analysis results in the road improvement being carried out under an improvement funding programme. However, improved materials and techniques such as the use of geosynthetics may be required to extend the life of the improvement works. Where M is horizontally aligned with a 7-8 PSCI value, then the condition value indicates only surface defects and thus a surface dressing treatment is likely to be the appropriate intervention. Where the PSCI is 6 or less then consultation with the funding authority may result in the commencement of a full design process.

H - High Priority.

Priority has initially been determined as high. In this case commencement of a design process, laid out in chapter 3 may apply. Consultation with the funding authority may be required. Once fully informed the funding authority may provide approval and funding for a capital investment project.

Overall PSCI Rating	Primary Rating Indicators*	Secondary Rating Indicators*
10	**No Visible Defects.**	Road surface in perfect condition.
9	**Minor Surface Defects[1].** **Ravelling or Bleeding <u><10%</u>.**	Road surface in very good condition.
8	**Moderate Surface Defects[1].** **Ravelling or Bleeding <u>10% to 30%</u>.**	Little or No Other defects.
7	**Extensive Surface Defects[1].** **Ravelling or Bleeding <u>> 30%</u>.**	Little or No Other defects. **Old surface with aged appearance**.
6	**Moderate Other Pavement Defects[2].** **Other Cracking <u>< 20%</u>.** **Patching generally in Good condition.** **Surface Distortion requiring some reduction in speed.**	Surface defects[1] may be present. No structural distress[3].
5	**Significant Other Pavement Defects[2].** **Other Cracking <u>> 20%.</u>** **Patching in Fair condition.** **Surface Distortion requiring reduction in speed.**	Surface defects[1] may be present. **Very localised structural distress**[3] (< 5 m^2 or a few isolated potholes).
4	**Structural Distress[3] Present.** **Rutting, Alligator Cracking or Poor Patching for <u>5% to 25%</u>.** **Short lengths of Edge Breakup/Cracking.** **Frequent Potholes.**	Other defects may be present.
3	**Significant Areas of Structural Distress[3].** **Rutting, Alligator Cracking or Poor Patching for <u>25% to 50%</u>.** **Continuous lengths with Edge Breakup/Cracking.** **More frequent Potholes.**	Other defects may be present.
2	**Large Areas of Structural Distress[3].** **Rutting, Alligator Cracking or Very Poor Patching for <u>> 50%</u>.** **Severe Rutting (<u>> 75mm</u>).** **Extensive Very Poor Patching. Many Potholes.**	Very difficult to drive on.
1	**Extensive Structural Distress[3].** **Road Disintegration of surface. Pavement Failure.** **Many large and deep Potholes.** **Extensive Failed Patching.**	Severe Deterioration. Virtually undriveable.

** Individual pavements will not have all the types of distress listed for any particular rating. They may have only one or two types.*

Note 1: Surface Defects = Ravelling or Bleeding.
Note 2: Other Pavement Defects = Other Cracking (longitudinal, transverse, reflection or slippage), Surface Distortion (Shape problems, depressions/sags, shoving, bumps, settlement or heave), Good/Fair Patching.
Note 3: Structural Distress = Load-related defects comprising Rutting, Alligator Cracking, Edge Breakup/Cracking, Poor/Failed Patching, Potholes or Road Disintegration.

Figure 4.2 - Pavement Survey Condition Rating System

4.2 Intervention Types

The most basic level of planned maintenance is the provision of a surface dressing layer. This is applicable when the PSCI rating is 7 or 8 and when the surface needs to be resealed and/or the skid resistance needs to be improved.

When the PSCI is 6 or less a range of remedial treatments can be considered, and the selected treatment type will depend upon the following:

- The actual PSCI
- Longevity of previous interventions
- Depth of peat
- Depth of road pavement (and depths of different layers within the Pavement)
- Cost
- Traffic levels

It is important to review the alternative treatment types having assessed a road over peat using the guidance in Chapter 3 and the taking account of the items set out above.

Some suggested remedial works options are set out as follows:

4.2.1 Treatment Type 1

Where the use of crushed stone overlays followed by a double surface dressing has proved successful in the past then this practice should continue because of the ease of application, minimal disturbance to traffic and moderate cost. Experience in many counties has shown that the addition of regulation layers is preferable to causing disturbance to the existing pavement.

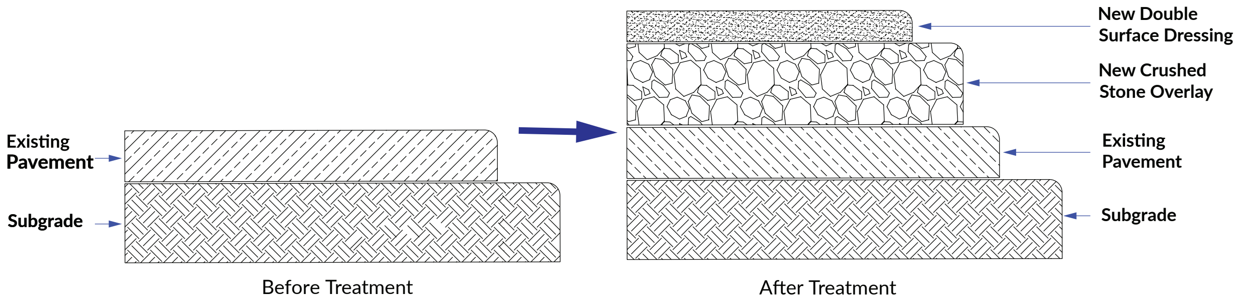

Figure 4.3 : Treatment Type 1

4.2.2 Treatment Type 2

Where crushed stone overlays have been noted to perform poorly and have given a poor lifespan of less than five years, an alternative is to retread the existing road by scarifying and recycling the existing pavement to a depth of about 100mm to 150mm, reshape the road surface and if necessary add sufficient new crushed stone to produce a dense smooth profile. The new surface should be double surface dressed. This technique should only be applied where there is a minimum depth of 200mm of high quality crushed stone in the base. The main advantage of this technique is that it minimises the extra pavement weight

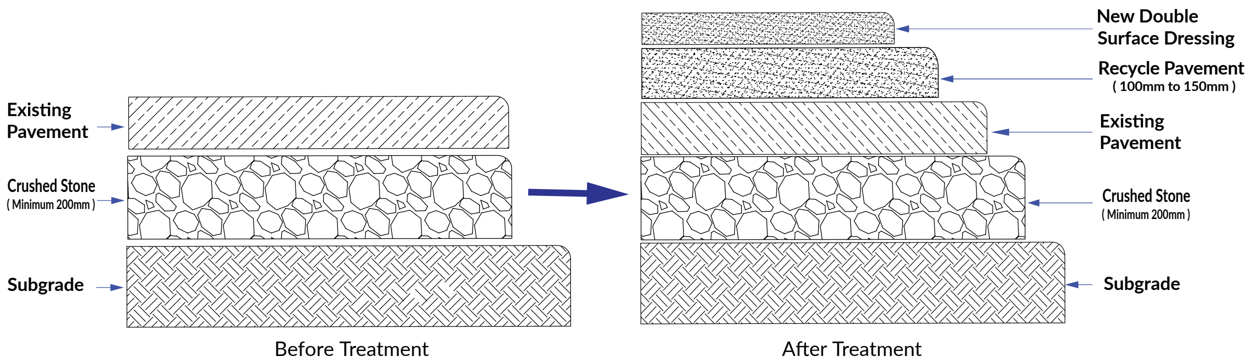

Figure 4.4 : Treatment Type 2

4.2.3 Treatment Type 3

An alternative to treatment type 1 is to overlay the existing pavement with a lesser depth of hot-mixed or cold-mixed bituminous material. This option will be more attractive where the cost of bituminous material is competitive, and where experience has shown that this technique gives a longer lifespan than that given by unbound stone overlays. The use of a Hot Rolled Asphalt surface course should be avoided due its rigid properties and consequent higher likelihood of cracking in the event of differential settlement of sub-grade.

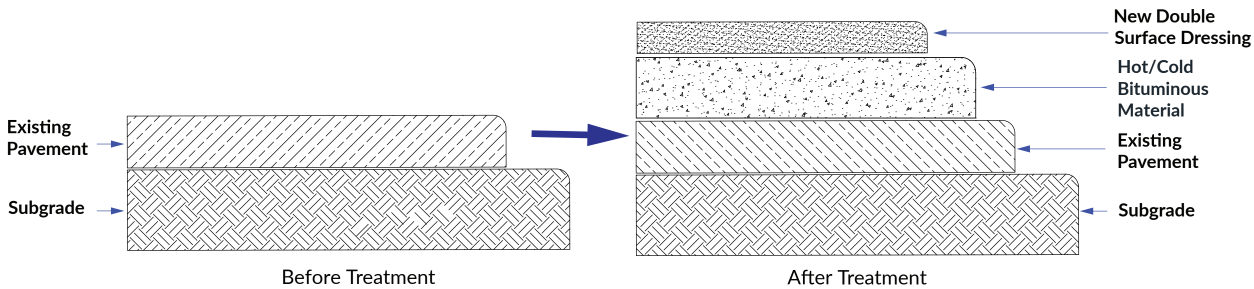

Figure 4.5 : Treatment Type 3

4.2.4 Treatment Type 4

Where some sections of road have given rise to particular problems which are unlikely to be resolved by treatment types 1 to 3 then consideration can be given to the installation of a geosynthetic. The use of a geosynthetic material can be installed in combination with a crushed stone overlay of 150mm or a bituminous material overlay of 100mm. While the latter is more expensive it minimises the extra weight of road pavement and thus minimises the stress transmitted to the weak sub-grade.

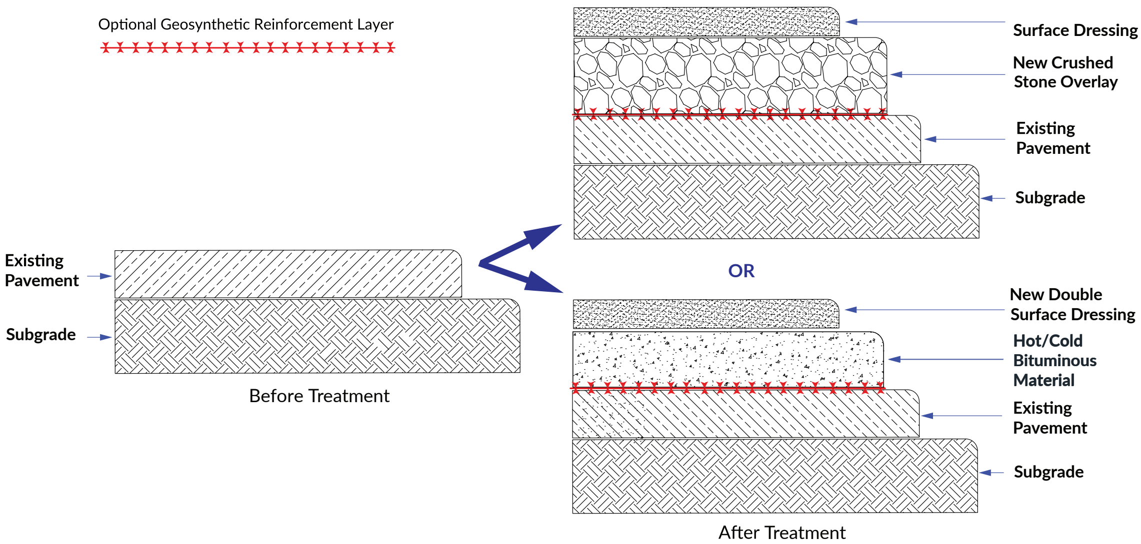

Figure 4.6 : Treatment Type 4

4.2.5 Treatment Type 5

Some problem sections of roads over peat already have a considerable depth of road pavement which has been built up over many years. Where the pavement depth is in excess of 500mm the option of reducing the finished road level by 100mm to 150mm could be considered. Sufficient material should be removed to allow a new layer of crushed stone followed by a double surface dressing or a layer of bituminous material to be provided. Where appropriate the new layer can be provided in association with a geosynthetic. Consideration may be required in respect of the strength of the remaining pavement layers once the finished road level has been reduced.

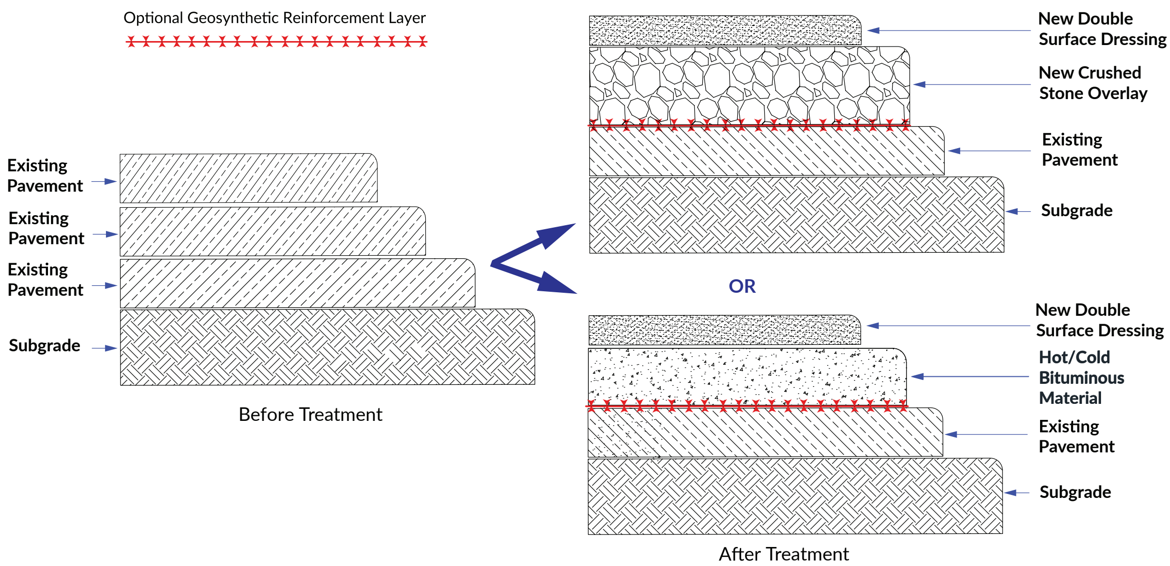

Figure 4.7 : Treatment Type 5

4.2.6 Treatment Type 6

Where the following criteria apply:

- Short sections of road over peat which have proven particularly difficult to maintain.
- Previous remedial works have had very limited life spans.
- The depth of peat is not excessive.

Subject to Department/TII (as appropriate) approval the possibility of removing the full road pavement and the underlying peat material can be appraised and considered. This option will require a full appraisal in terms of environmental, drainage and geotechnical matters.

4.3 Use of Geosynthetics

An analysis was conducted of improved sections of roads over peat where geosynthetics were used in past years. In some cases the geosynthetics were immediately below or within the bituminous layers. In other cases the geosynthetics were laid on a smooth surface immediately below the unbound layer; that is at formation level and below the unbound crushed stone material. Examples of each use of geosynthetics are given below and referenced in Appendix B.

4.3.1 - R347, Cloonascargh, Co. Galway

A 500m section of the R347 Tuam Road in County Galway was rehabilitated in 2018 where a mesh geogrid was laid between a sealed regulating layer and an 80mm layer of asphalt. The asphalt layer was then surface dressed. The depth of peat below the road is unknown. The section of the R347 has performed reasonably well with current PSCI rating of 7 and a current IRI rating of 3.7. The section of road was resealed in 2024.

4.3.2 - R390, Annaghortagh, Co. Westmeath

Approximately 1,000m of the R390 in County Westmeath was rehabilitated in 2001 with an asphalt reinforcement geogrid placed between the base and the binder layers. The depth of peat below the road is unknown. The section of the R390 has been overlaid twice and surface dressed once in the intervening years with an additional overlay completed in 2024. The PSCI rating has varied over the years to a current rating of 5 and a current IRI rating of 2.85.

4.3.3 - R476, Kilfnora, Co. Clare

A 250m section of the R476 Kilfenora Road in County Clare was rehabilitated in 2006 where a mesh geogrid was laid between a regulating layer and a 200mm layer of crushed rock. The 200mm layer of crushed rock was sealed and overlaid with a 100mm layer of asphalt and surface dressing. The depth of peat beneath the road was approximately 4m. No works have been carried out on this section of the R476 since 2006. The section of the R476 has performed well with a current PSCI rating of 7 and a current IRI rating of 3.5.

4.3.4 - Observations on the use of Geosynthetics

The examples suggest that the approach used on the R476, where the geosynthetics is immediately under the crushed stone layer may achieve better overall pavement longevity. This approach is also advisable, where possible, when considering the future maintenance and rehabilitation of regional and local roads over peat Experience has shown that where geosynthetics have been placed in pavement layers, particularly near the surface, that maintenance operations required to plane out the pavement and geosynthetic in advance of installation of new pavement may result in the removal of excessive levels of acceptable pavement from the road. The removal of layers of acceptable pavement materials and intact geosynthetics is not fully compatible with the circular economy model to reduce consumption and maximise efficiency of use of existing materials.

For these reasons it is recommended that where a geosynthetics is required and where it can be installed at reasonable cost in problem roads then it should be laid at as low a level as possible and ideally at formation level. It is likely that this approach will be more readily achievable in new build roads over peat or in situations where a road over peat is being widened. Where a geosynthetic may be required and it is not possible to install at low levels within the pavement or at formation level then an assessment of the cost of installing the geosynthetic within the pavement layers and the resulting return period between interventions may need to be undertaken.

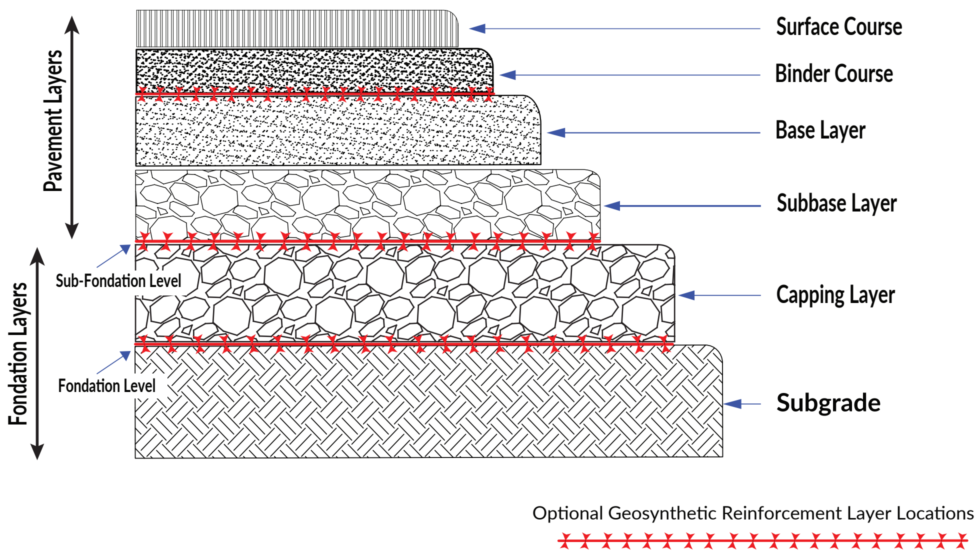

Figure 4.8 : Optimal Reinforcement Locations for Fully Flexible Pavements

For all regional and local roads it is vital that MapRoad data capture be fully and accurately recorded to aid future analysis, it is also vital that the depth of peat underlying the road is accurately captured. Accurate and up to date data is vital to avoid anomalies and allow a more in depth understanding of the network.

The example of the R347 Tuam Road suggests that the geosynthetic may be helping with respect to strengthening the pavement but there may be issues with the ability of the pavement to remain sealed against the ingress of water. Similarly the example of the R390 suggests that the geosynthetic may have helped improve the life of the pavement but hasn't fully reduced the number of interventions required.

4.4 Types of Geosynthetics

Geosynthetics are generally polymeric products used to solve geotechnical problems in civil engineering projects. Geosynthetics come in many types and are used to solve specific problems by providing stabilisation, reinforcement, separation, filtration, drainage or containment. The main types of geosynthetics used in road construction are as follows:

- Geogrids
- Geotextiles
- Geocomposites

4.4.1 Geogrids

Geogrids are open grids or meshes made up of polymeric, steel or glass materials. Geogrids are generally used for stabilisation or reinforcement of soils and road foundations. The majority of geogrids are made from polymeric materials such as polyester, polypropylene and polyethylene. Polyester and polypropylene grids are generally installed in combination with a dense bitumen macadam overlay. The polyester grids are more flexible than the polypropylene grids and the latter require a high standard of contact between the grid and the underlying road surface which has to be regulated.

Figure 4.9 - Installation of transverse woven white geogrid (A), and longitudinal biaxial polypropylene type geogrid (B) on the R400 in Co. Offaly in October 2024

Bitumen coated polyester grids are considered easier to install than polypropylene grids The more rigid polyethylene grids are often installed in combination with a crushed stone overlay. They are usually installed at formation level or in the lower part of the overall pavement layer.

4.4.2 Geotextiles

Geotextiles are permeable fabrics made of polymeric fibres such as polyester or polypropylene that are contained in woven, knitted or non-woven textiles. Geotextiles are commonly used as a separation and filtration layer to prevent migration and mixing of materials whilst allowing the free movement of water. Geotextiles are commonly placed at formation level to act as a sub-grade sub-base separator.

4.4.3 Geocomposites

Geocomposites are combinations of two or more geosynthetic materials to perform multiple geosynthetic functions. The most common form of geocomposites used in road construction is a combination of geogrids and geotextiles to provide stabilisation / reinforcement with separation / filtration respectively.

4.5 Passing Bays

It is sometimes appropriate to provide passing bays on what are effectively single lane roads, regardless of whether the road is over peat or not. Passing bays can allow narrow rural roads with low traffic volumes to be improved at reasonable cost whilst assisting in regulating traffic and in improving traffic safety. The following points should be noted in respect of passing bays:

- They should be provided at regular intervals with approximately 5 to 6 bays per kilometre.
- The sighting should be arranged so that from any point on the road at least one bay is visible and adjacent bays are inter-visible.
- On sharp bends a two-lane carriageway is desirable.
- Information traffic signs should be provided on approaches to passing bays.
- It is useful to provide a special standard marker post at each passing bay to improve inter-visibility of bays.

The provision of passing bays (where feasible) instead of providing extra width along the full length of a road has particular advantages where a road is constructed on a peat foundation for the following reasons:

- It reduces the initial cost of widening by minimising road area.
- It minimises future maintenance.
- Geosynthetics can be utilised in the provision of passing bays whereby a strip of geosynthetic may be placed in the pavement layers to reinforce the joint between the existing pavement and the new passing bay pavement construction.

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5 SIGNIFICANT IMPROVEMENT WORKS

5 SIGNIFICANT IMPROVEMENT WORKS

Chapters 2 to 4 of this document provide guidance on the maintenance of roads over peat. There may be scenarios where maintenance of an existing road over peat is not applicable such as minor realignments or new-build schemes where a more significant intervention may be required. It is expected that these interventions would be very limited and would be subject to robust scrutiny to ensure the correct option has been selected to address the problem identified. The guidance provided in sections 2 to 4 may be used as a starting point when considering a significant intervention, but it is highly likely that a more in depth analysis and assessment will be required to verify that a significant intervention is needed. A non-exhaustive list of Items that should be considered when assessing a significant intervention is as follows:

- Desktop study, visual inspection and detailed site surveys such as topographical surveys;
- A full detailed pavement investigation where appropriate (see Appendix E for guidance);
- A full ground investigation (see Chapter 3, Table 4 and Appendix C for guidance)
- Environmental assessments including screening for Environmental Impact Assessment and Appropriate Assessment, and the subsequent carrying out of these assessments when screened in;
- Carbon lifecycle assessment. Guidance can be found through TII publication Climate Guidance for National Roads, Light Rail, and Rural Cycleways (Offline & Greenways). Overreaching Technical Document and ISO 14040 Environmental Management - Lifecycle Assessment - Principles and Frameworks;
- Options and benefits assessments in line with the latest guidance on public spending;
- Landowner matters and accommodation works;
- Detailed design;
- Planning requirements and implications;
- Affordability assessment.

Appendix F provides a number of possible options that are available depending on the problem(s) identified when considering a significant intervention in respect of a road over peat. Guidance on the main points that should be considered regarding construction and the pros and cons of each option are also provided.

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APPENDICES

Appendix A - Length of Road Over Peat by County

County	National Primary	National Secondary	Regional	Local Primary	Local Secondary	Local Tertiary	Total
Carlow	0	0	0	2	2	1	5
Cavan	6	8	30	60	77	27	208
Clare	6	36	94	199	299	214	848
Cork	5	24	122	280	504	325	1260
Cork City	0	0	0	0	0	0	0
Donegal	15	89	359	855	941	787	3046
Dun Laoghaire - Rathdown	2	0	16	10	14	14	55
Galway	8	86	206	278	480	418	1476
Galway City	0	0	1	2	4	8	15
Kerry	12	97	122	310	268	463	1272
Kildare	11	1	40	34	99	58	243
Kilkenny	2	0	8	4	10	9	33
Laois	1	12	36	54	38	58	199
Leitrim	16	0	61	154	144	144	519
Limerick	5	0	20	31	87	41	184

Appendix A - Length of Road Over Peat by County

County	National Primary	National Secondary	Regional	Local Primary	Local Secondary	Local Tertiary	Total
Longford	16	19	56	102	132	127	452
Louth	6	1	14	30	29	44	124
Mayo	17	73	196	280	483	721	1770
Meath	0	6	11	6	16	58	97
Monaghan	7	9	33	54	48	80	231
Offaly	3	22	110	91	116	141	483
Roscommon	16	27	69	142	365	284	903
Sligo	12	9	64	187	351	275	898
South Dublin	1	0	7	1	13	1	23
Tipperary	0	9	39	73	78	48	247
Waterford	2	0	5	10	11	3	31
Westmeath	33	8	40	912	130	70	373
Wexford	0	0	0	0	3	2	5
Wicklow	0	0	67	71	143	26	307
Total	**202**	**536**	**1826**	**3412**	**4885**	**4447**	**15308**

Appendix B – Case Studies

During the revision of these guidelines the working group investigated a number of locations across the Regional and Local Road network to assess the historic performance of pavement interventions using geosynthetics. Locations where geosynthetics were placed between the bound and unbound layers and locations where the geosynthetic was placed within the pavement layers were investigated. A selection of some of these locations are provided in the following pages.

B.1 Regional Road R347, Cloonascragh, Co. Galway

Local Authority	Galway County Council
Municipal District	Tuam
Road Number	R347
AADT	3000
% HGV	12-15%
Speed Limit	80 km/h
Depth of Peat	Unknown
Year of Works	2018
Length of Works	500m
Width of Works	6.3m
Road Construction	DBM Regulation Mesh Geogrid Slurry Seal 80mm DBM 10mm Surface Dressing
Current PSCI	7
Current IRI	3.5
Interventions since construction	2024 – surface dressing works

Image Credit Google Sreet View

B.2 Regional Road R390, Annaghgortagh, Co. Westmeath

Local Authority	Westmeath County Council
Municipal District	Athlone-Moate
Road Number	R390
AADT	1900
% HGV	5%
Speed Limit	80 kph
Depth of Peat	Unknown
Year of Works	2001
Length of Works	1000m
Width of Works	6m
Road Construction	Asphaltic reinforcement geogrid located between base and binder course
Current PSCI	5
Current IRI	2.85
Interventions since construction	2010 – overlay works 2014 – overlay works 2018 – surface dressing works 2024 – overlay works

B.3 Regional Road R476, Kilfenora, Co. Clare

Local Authority	Clare County Council
Municipal District	West Clare
Road Number	R476
AADT	1500-2000
% HGV	2%
Speed Limit	80 kph
Depth of Peat	4m
Year of Works	2006
Length of Works	250m
Width of Works	5.5m
Road Construction	Cl 804 Regulation Mesh Geogrid Cl 804 – 200mm thick layer Cl 804 layer sealed Blacktop – 100mm thick layer Surface Dressing
Current PSCI	7
Current IRI	3.5
Interventions since construction	None

Appendix C – Ground Investigation Techniques

C.1 Boreholes

The two main methods for subsurface investigation boreholes are Cable Percussion and Rotary Core.

C.1.1 Cable Percussion:

This type of borehole is considered the most reliable method for obtaining ground condition information. They typically have a diameter of 200mm, though variations can be used. The standard rig consists of a steel tripod with a two-tonne capacity winch and is driven by a diesel engine. Boreholes are formed using a 'clay cutter' for cohesive soils or a 'shell' for non-cohesive materials, with a chiselling tool available for hard ground or obstructions. A steel casing is driven into the borehole to support its sides during the drilling process. Disturbed samples can be collected from both the clay cutter and the shell. This method enables piston sampling in peat and soft/organic soils, U100 sampling in firm soils, and Standard Penetration Tests (SPTs) to some extent in soft ground. In-situ vane testing can also be performed either within the borehole or adjacent to it to determine the undrained shear strength of soft soils. Additionally, piezometers can be installed in the boreholes to monitor groundwater levels.

Figure C .1.2

C.1.2 Rotary Core-holes:

Rotary core-holes are used to investigate rock and drill through overburden beyond the refusal depths of cable percussive boreholes. The method uses double-tube rotary drilling with water, air mist, or polymer gel to cool the drilling head. A powered rotary cutting head (drill bit) is attached to a rotating shaft to drill into the ground. The typical core diameter is 75mm. Geobor 'S' core-holes are used to obtain high-quality samples of the overburden and underlying rock. This technique is suitable for obtaining samples from firm to hard cohesive soils. A triple-core barrel system is used in this method, with a non-rotating inner barrel containing a removable tube or liner. While this method may provide information on the overburden depending on the depth of penetration below the soft ground, it is primarily used for rock exploration and is not well-suited for soft ground investigation.

C.2 Trial Pits & Slit Trenches

Trial pits are excavated using a tracked or wheeled excavator. The maximum excavation depths are limited to approximately 4 to 5 meters in depth, but the risk of side wall collapse may occur at shallow depths with higher risks in areas of soft ground. While trial pits offer a cost-effective and quick method of investigation, they may not penetrate the full depth of soft ground. Obtaining high-quality samples for triaxial tests or oedometer tests from trial pits is not possible and therefore, piston samples from boreholes are recommended where retrieval of such samples has been specified as part of the ground inverstigation. However, in-situ shear vanes, such as Geonor H-60 or similar, can be conducted in soft soils and this can be achieved in a safe manner by testing undisturbed bulk pieces from the excavator bucket when placed on the ground arising from the excavation. Caution must be exercised while interpreting the results obtained from these tests. In some cases, accessing trial pit locations may require the use of bog mats or wide tracked excavators to ensure safe entry and exit.

C.3 Probing

The use of ground probing methods are quick methods to establish the depth of peat, and depending on the type of probe used, details of the strength profile can also be established. Furthermore, the use of probing can assist in the calibration of non-invasive geophysical methods in determining the sub-surface ground conditions. In its simplest form, probing involves pushing or driving a steel rod with a conical tip and threaded ends into the ground until resistance of a hard strata is encountered. These probes would typically be used to determine the depths of softer materials to relatively shallow depths and can produce a good indication of the thickness of peat deposits. Some challenges associated with probing can present where there are soft compressible layers present with the peat, such as silt, clay or gravel deposits from historical flooding events, or fragments of wood. In these situations, more complex probing methods such as Dynamic Probing or Dynamic Cone Penetrometer may be required.

C.3.1 Dynamic Probing (DP):

This type of test involves using a free fall hammer to drive a conical point, with area of 10, 15 or 20cm^2, attached to drive rods, into the ground. The test records the number of hammer blows (N) required to drive the point a fixed distance into the ground, typically 10cm, which creates a graph of blow count vs depth of penetration. The selection of the mass of the hammer, the drop height and diameter of the conical point are to be in accordance with IS EN ISO 22476-2: 2005. Hammer mass ranges from 10kg for the DP Light to 65.5kg for the DP Super Heavy and drop height of 0.5m or 0.75m are used. A motorised device with an automatic latch and release mechanism is used to avoid operator errors. The test is stopped at 1m intervals for the addition of rods to the achieve the required depths of penetration.

C.3.2 Dynamic Cone Penetrometer (DCP)

Appendix E discusses the use of the DCP in determining CBR values of sub-grade and unbound granular materials in accordance with TII Standard Publications. As stated in the code of practice for ground investigations there is no formal standard for this test however a description of the test is provided in the design manual for roads and bridges.

C.3.3 Mackintosh Probe:

The Macintosh prospecting tool is composed of interconnected rods and barrel connectors. These rods typically have a driving point at their base and a manually operated driving hammer at their top. This tool offers a cost-effective means of determining the thickness of soft deposits like peat. The streamlined driving point has a maximum diameter of 27mm. The drive hammer weighs a total of 4kgs, while the rods are 1.2m long with a 12mm diameter. To establish a depth profile, the device is used by driving the point and rods into the ground with consistent blows from the full drop height provided by the hammer. The number of blows required for every 150mm of penetration is recorded. When dealing with small areas of stiff clay, the driving point can be replaced with an auger or core tube. By using a box spanner and a Tommy-bar, the rods can be rotated clockwise at ground level. Additionally, tools can be inserted into and extracted from the soil using the lifting driving tool. Due to the light weight of the hammer, the Macintosh probe has limitations in terms of depth and the materials it can effectively penetrate.

C.4 Hand Vane Testing:

Field vane testing in soil exploration can use either the “field vane” or “hand vane,” especially for fine soils. The test involves inserting a solid rod with a cruciform vane into the soil and rotating it at a constant rate, usually between 6°/min and 12°/min. Results from the field vane test can be correlated to the soil’s shear strength and extended to measure its remoulded strength. To determine remoulded strength, the vane undergoes ten complete rotations, followed by a 5-minute wait before repeating the test. Examples of Field Vanes include the Geonor H-10 field vane and this test should be in accordance with BS 1377-9:1990, section 4.4. Hand-held shear vanes, such as Genor H-60 or the Pilcon hand vane, provide quick indication of a soils shear strength. They have a calibrated scale providing a direct estimate of the soil’s shear strength. However, they have a fast failure rate and could potentially overestimate the un-drained shear strength of the soil.

While acknowledging that shear vane readings are not reliable for determining the actual strength of peat (landva, 1980), they can still be utilized to qualitatively indicate relative variations in strength at a specific location’s depth (McFarland, 1969, Dykes & Kirk, 2006). When undertaking vane tests on peats and soft soils it is recommended to use larger vanes, typically 65mm x 130mm. As detailed in BS 5930, testing standards BS EN ISO 22476-9 and BS1377-9:1990 do not explicitly cover the hand vane equipment or test procedure, however more information and guidelines on the test can be found in the New Zealand Geotechnical Society’s guideline, which provides a suggested specification item and test method.

C.5 Window Samples:

Window sampling is a dynamic soil sampling technique used in ground investigations and soil sampling. It involves driving a hollow steel tube into the ground using a percussive hammer or drop weight to collect soil samples. The method is divided into two types: window sampling and windowless sampling, depending on the design of the sampling tube. In window sampling, the tube has longitudinal slots or “windows,” allowing the recovered soil to be examined within the steel tube and disturbed samples to be taken through these windows.

On the other hand, windowless sampling tubes do not have slots; instead, a plastic liner is inserted to retain the soil sample or disturbed samples. Both approaches provide reasonably complete soil profiles and are popular for shallow soil investigations due to minimal spoil, compact equipment, and relatively low cost. Despite the advantages, windowless sampling has limitations. The recovered samples are generally disturbed, limiting the precision of obtaining undisturbed soil properties. Windowless sampling is best suited for dry cohesive soils and may not be as effective in gravelly or soft ground conditions. When considering windowless sampling in peat or soft ground, the stability of the borehole is critical. In peat, where the ground has limited strength and cohesion, the borehole could squeeze and collapse during sampling, making windowless sampling more suitable. In soft ground conditions, the method can be useful if the borehole can remain open unsupported. However, it's important to note that in soft ground, soil disturbance during sampling may affect the accuracy of certain soil parameters.

C.6 Geophysical Surveys:

Geophysical investigations are invaluable tools in ground investigations, providing crucial data for subsurface mapping and assessing physical properties. These techniques can efficiently complement intrusive methods and offer a non-intrusive approach, minimizing disturbance to sensitive ground areas, like peat and soft ground. Rapid data acquisition allows coverage of large areas efficiently, providing a broad overview of subsurface conditions. Where the use of geophysical methods of investigation are being considered advice should be sought from appropriately qualified and experienced geophysical engineers.

C.7 Sampling:

For general soil sampling during ground investigation, two main types of soil sampling techniques are employed, each involving the retrieval of either disturbed or undisturbed samples. Disturbed soil samples undergo remoulding during the sampling process, typically obtained from augers or trial pits, and are collected in bulk form, ranging from 0.5 to 25kg, depending on the specified tests. On the other hand, undisturbed samples are carefully retrieved using thin-walled tubes with sharp cutting ends, ensuring slow penetration into soft ground. This type of sampling utilizes piston samples during the execution of exploratory boreholes.

C.8 Ground Water Monitoring

Groundwater monitoring is essential for understanding groundwater levels and pressures in soft ground. Several methods can be used for this purpose, including standpipes/piezometers, Casagrande piezometers, and vibrating wire piezometers. Standpipes or piezometers are installed in soft ground to assess groundwater levels, with the option to specify response zones over the full length of the borehole or within specific strata. Casagrande piezometers consist of a porous tip attached to a smaller-diameter riser pipe, making them more sensitive to water level changes, particularly in low permeability soils. Vibrating wire piezometers use a magnetic, high tensile strength wire to measure pore water pressure, offering a quick response time and the ability to measure small negative pore pressures. All of these methods provide valuable data for effective groundwater management.

C.9 Laboratory Testing

This section provides general information on the requirements for laboratory testing forming part of geotechnical ground investigations. Any tests which are specified for establishment of design parameters shall be conducted according to the requirements of existing IS EN, EN ISO or British Standard documentation for those tests. Typical laboratory tests conducted on peat and soft ground include water or water content, Atterberg Limits, and particle size distribution tests. For peat soils in particular, organic and fibre contents along with degree of humidification are also recommended. Care should be taken when specifying Atterberg Limit tests for peat soils as the presence of organics in peat materials can impact these results, see O'Kelly, 2014.

For undisturbed piston samples, un-drained shear strength (Cu) can be measured through the Unconsolidated Un-drained (UU) Triaxial Compression Test, and Consolidated Un-drained (CU Triaxial Compression Tests. It should be noted that these more complex and expensive laboratory test should only be specified under the consultation of an appropriately experienced geotechnical engineer, where complexities for scheme maintenance or rehabilitation design solutions result in those schemes falling into higher cost brackets.

The test methods employed along with equipment and any deviations from standard procedures should be reported along with all test results. These results should then be presented in accordance with the requirements of standard documentation. As with laboratory testing of pavement materials, before proceeding with laboratory testing, it is crucial to assess the field data and determine the appropriate type and number of tests required to establish design parameters for the pavement foundation layers.

Note on Water Content testing of peat soils:

A Water Content test generally involves oven drying a soil sample at 105°C to 110°C for a period of 24 hrs. According to Head, for peat soils containing organic matter, a drying temperature of 60°C is preferred to prevent oxidation of the organic content. This lower temperature may therefore require a longer drying period and check weighing should be made at 2-to-4-hour intervals. Further information on the determination of Water or Water Content can be found in BS 1277-2:2022 and ISO 17892-1:2014

Note on Engineering Properties & Behaviour of Peat:

Further and more detailed information on peat characteristics, index properties and behaviour can be found by visiting the Roadex Network website and navigating to the e Learning section.

See https://www.roadex.org/

Appendix D - Low Cost Ground Investigation GI: Probing Trial

As part of the review and update of these guidelines, a proof-of-concept pilot low-cost ground investigation was undertaken on the L-3210, near Mountbellew, Co. Galway. This location was chosen as it was the location of a pilot scheme, undertaken in 1986, which was referenced in the previous iteration of these guidelines. Some key details of those works are as follows:

- Maximum peat depths 8.8m.
- Pavement depths ranging from 375mm to 2.35m.
- Works included installation of geogrid, surface dressing and dense bituminous wearing course.

The pilot works for this probing Ground Investigations technique sought to establish the peat depth, preliminary estimate of the peats un-drained shear strength values and the retrieval of samples for the determination of Water Content and Von Post classification of the in-situ peat. Furthermore, with the use of GPS surveying equipment, it was proposed to generate a depth of peat/soft ground plan, and from this information to build a model of the critical section for the road investigated. It should be noted that no investigation of the pavement structure itself was carried out as part of these works, but that this information could be added to the investigated section when undertaken. The proposal for the low-cost probing ground investigations included the use of the following equipment:

D.1 Peat Probes

The peat probe was used to establish the depth of peat at each planned probe location. The depth recorded was an average of three probe depth measurements taken at each location. The peat probes themselves consist of 12mm diameter fibreglass rods with the initial rod having a 17mm diameter steel tip. The rods are light weight in construction and both penetration and extraction of the rods into and out the peat deposit is achieved by manual handling technique.

Figure D.1.1 – Photograph Showing Manual Peat Depth Probing.

D2. Hand-held field shear vane

The hand-held shear vane was used to investigate the preliminary un-drained shear strength of the peat soils. The apparatus consists of three interchangeable vanes with height to diameter ratios of 2. Test depths of up to three metres below ground level are achievable with the hand-held shear vane by means of the addition of the 10mm diameter, 500mm long extension rods. It is recommended to use the larger of the vanes, typically 25.4mm x 50.8mm, for testing the peat. Caution is advised in the use of the vane and the results obtained should be considered as an estimate of the soils strength and reviewed by an experienced ground engineering professional where results are relied upon for characterisation of the existing ground conditions

D.3 Russian peat core sampler

The Russian type of peat core sampler consists of a stainless-steel peat borer and retrieves samples which are 50cm in length, 5cm in diameter and semi-cylindrical in cross section. Penetration of the peat surface is achieved through manual handling techniques and depths of 2.4m to 7.2m can be achieved, depending on the strength and consistency of the peat and the manual effort applied. A visual description and Von Post classification of the peat sample retrieved is possible, This also allows the determination of the peat water content to be established at an accredited laboratory.

Figure D.1.2 – Photographs Showing Russian Peat Core Sampler.

D.4 Pilot investigation works

The investigation works took place in August 2023 on the L3210, near Mountbellew on the county Galway-Roscommon border. The works included establishment of a traffic management plan in line with the requirements of Chapter 8 of the Traffic Signs Manual. This consisted of traffic lights with traffic movements restricted to one lane of the carriageway while the investigation works took place on the opposite verge.

As part of the works, a rubber wheeled backhoe excavator was on site to remove verge overgrowth and any hard verge fill where encountered. The works investigated a 200m section of the road and consisted of peat depth probes at five locations. The works on this section were completed within a three-hour time frame.

Average peat depths recorded ranged from 2.9m to 4.9m. Results of the hand-held shear vane ranged from 19kPa to 35kPa at a depth of 0.5m below ground level, and 15kPa to 23kPa at a depth of 1.5m below ground level. A total of five samples were retrieved using the peat core sampler, typically at depths between one and two metres with one sample being taken below two metres.

Recommendations

It would be recommended to initially undertake a probing investigation to establish the sections of road with the deepest underlying peat. Once established, the investigation should focus on retrieving samples at these deepest locations to log the condition of the peat in half metre intervals and to supplement the samples with preliminary undrained shear strengths using the hand-held vane. These deepest or critical sections can then be considered for any possible design solutions for the section of road to be maintained, or to further inform requirements for a detailed ground investigation and subsequent testing requirements.

Appendix E - Purpose & Approach for Scheme Level Surveys

Name of Survey/ Test	Purpose and Approach
Falling Weight Deflectometer (FWD)	FWD Testing should be carried out when it is important to know the material properties of the pavement layers and the strength of the underlying subgrade. This is particularly important to either confirm the strength of an existing pavement or for the design of pavement strengthening measures. The FWD simulates the wheel load of a moving vehicle by using a falling-weight loading system to create a temporary deflection basin on the tested surface which is measured by a series of geosensors that are located at set distances from the weight. FWD readings are normally taken at set intervals and are used to develop a longitudinal deflection profile along the road pavement which can be analysed to provide information on the strength of the pavement layers and sub-grade. The test method for the Structural Evaluation of Road Pavements is detailed in DN-PAV-03060.
Ground Penetrating Radar (GPR)	GPR is a Technique that uses radio waves for the purpose of detecting or obtaining images of buried objects or determining the physical properties beneath the ground. GPR can be used to provide information about changes in pavement construction, layer thicknesses and defects/features within the pavement. GPR is particularly useful in older pavements which may have a pavement structure which has evolved over a number of years. A detailed description of GPR is provided in AM-PAV-06050.
Coring	When assessing pavements, coring of the bound layers is normally required for one or more of the following purposes: (a) Determination of layer and total pavement thicknesses (usually in conjunction with GPR). (b) Determination of the material type and condition of the layers. (c) Determination of the depth of cracking. (d) Provision of samples for compositional or physical tests. (e) Provision of access for carrying out DCP tests in granular foundation layers. Cores are normally taken from a rig. Care is required to check for the presence of any services prior to coring operations being carried out. Coring and trial pitting is described in more detail in AM-PAV-06050.
Dynamic Cone Pentrometer (DCP)	The DCP is recommended as the most suitable method for use in the bottom of core holes and trial pits to indicate the strength and thickness of the foundation layers. The equipment is simple to use, is of low cost and is a quick procedure to carry out. The DCP uses a drop hammer and the number of blows between readings will vary depending on the strength of the layer being penetrated. Where there are significant surface defects, high deflections, or thin pavement thicknesses, it is desirable to test at every core hole to assess the contribution of the foundation to overall pavement strength. Where defects appear non-structural and FWD deflections are low, testing at every third core hole would be acceptable. The DCP procedure is described in detail in AM-PAV-06050.

Name of Survey/ Test	Purpose and Approach	
Laboratory Testing	Decisions on the type and number of laboratory tests should be made after the assessment of the field data. Testing of materials to compare results between failed and intact areas may be particularly useful. Laboratory testing and the range of available tests is considered in detail in AM-PAV-06050.	
Laboratory Testing of Bituminous Materials	Indirect tensile test	Indirect tensile tests may be carried out to confirm the stiffness of the pavement layers and to quantify the load spreading ability of the pavement material.
	Wheel tracking tests	Wheel tracking tests may be carried out on areas of pavement which exhibit rutting to determine the root cause of the rutting.
	Compositional Analysis	Compositional analysis provides information about the particle size distribution and binder content of asphalt. The information obtained can, for example, be used to assess whether the material is too rich or too lean in binder which may help to explain higher than expected material deformation.
	Recovered Binder Tests	The recovered binder may also be tested to determine the Penetration and Softening Point. This can be helpful to identify where binder is particularly soft (prone to deformation) or particularly hard which may be associated with cracking or excessive loss of chippings from Hot Rolled Asphalt (HRA) surfaces. Binder properties will be required if recycling is being considered.
Laboratory Testing of Unbound Materials	Laboratory testing of the foundation layers, sub-base or subgrade, should not normally be necessary as the FWD and DCP measurements should indicate the general condition and strength. However, tests may occasionally be necessary to explain the reasons for high or low strength or stiffness or to compare the material properties with specification standards. The most useful of these are: • Grading • Liquid Limit, plasticity index and linear shrinkage • Water Content. • Water condition value.	

Name of Survey/ Test	Purpose and Approach
CBR Testing	Where pavement failure is believed to be caused primarily by a weak foundation, a laboratory CBR test of the material may be carried out, preferably by removing an undisturbed CBR mould-sized sample. (A disturbed CBR sample will also require an in-situ density test to be carried out so that the CBR material can be re-compacted to the in-situ density). An in situ CBR test is generally not very practical as it requires a large- plan trial pit and takes considerable time, both of which add considerably to the cost. CBR testing is discussed in greater detail in AM-PAV-06050.
Trial Pits	Excavating trial pits is a much slower and more expensive method of obtaining pavement information compared to coring and should therefore be used only when necessary and data cannot be obtained by other means. Trial pitting is normally required for one or more of the following purposes: • Obtaining bulk samples of the bound or unbound layers for laboratory testing. • Detailed examination of the unbound layers or sub-grade including density measurement. • Investigating the causes of rutting. Investigating drainage problems within or beneath the pavement. • Trial pits normally require at least a lane closure and plant to open up the pit. The trial pit reinstatement is a significant task and should be reinstated in accordance with the TII Specification for the Reinstatement of Openings in the National Roads. Trial pits are discussed in greater detail in AM-PAV-06050.

Table E.1 – Purpose & Approach for Scheme Level Surveys (TII Publication Extract)

DYNAMIC CONE PENETRATION (DCP)

The DCP test is recommended for assessing formation layer strength and can be correlated empirically to the California Bearing Ratio (CBR) through the relationship developed by the TRL as outlined in TII publications. The DCP is recommended as the most suitable method for use in the bottom of core holes, trail pits or slit trenches to indicate the strength and thickness of the foundation layer.

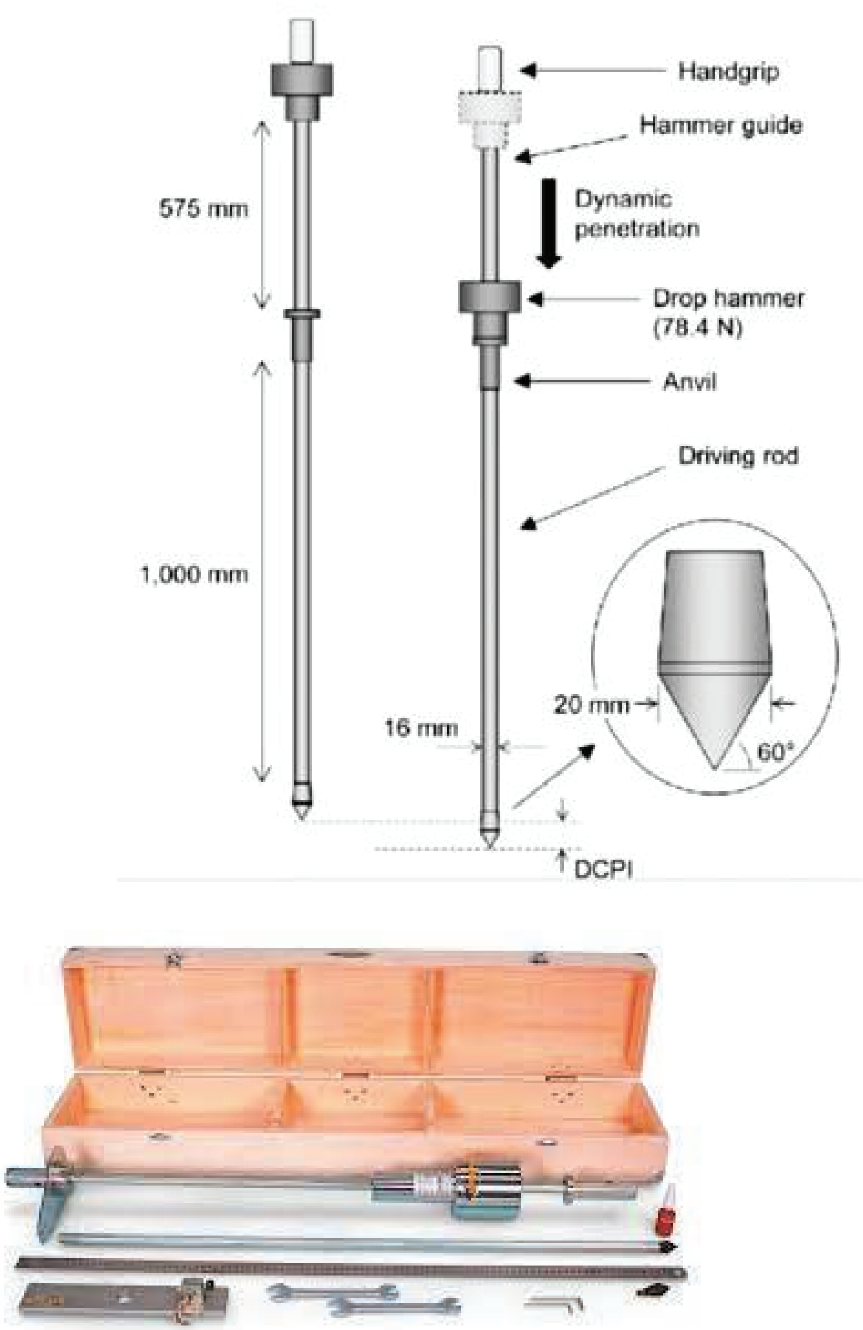

Figure E.1.1 – Dynamic Cone Penetration Test Kit

Trial Pits & Slit Trenches

The excavation of trial pits is a costlier method of obtaining pavement information in comparison with coring and this option should be considered when essential data cannot be obtained by any other means. The execution of a trial pitting investigation requires significant planning as these works will require at least a lane closure to safely position excavators to ensure segregation from traffic and the public. Requirements for temporary traffic management shall be in accordance with the requirements of Chapter 8 of the traffic signs manual and the necessary method statements and risk assessments shall be put in place prior to undertaking the works, including but not limited to the identification of both underground and overhead services.

The use of trial pits will allow the designer to obtain bulk samples of the bound and unbound layers for laboratory testing and allow for a detailed visual examination of these layers and the sub-grade material. The visual examination may provide information into causes for rutting and explore drainage issues within or beneath the pavement. Once completed, the reinstatement process shall be carried out in accordance with the requirements of the purple book for Regional and Local Roads.

Figure E.1.2 – Trial Pit (left) and Slit Trench (right)

Appendix F - Possible Options for Significant Interventions

Option No.	Construction Method	Remarks
1A	Full Excavate and Replace of Soft Ground	• Typically cost effective for excavation depths up to 3-4m. • The base of the excavation needs to extend to equivalent a 1H:1V line from the crest – land take requirements would be relatively high. • Good construction methods are necessary in soft ground and particularly in peat, with the fill being kept close to the excavation face to reduce the risk of collapse of the side of the excavation. • Sheet piles may be required along the excavation to ensure stability of deep excavation slopes and to ensure long-term stability of the proposed embankment. Thus, this may not be a cost effective solution in deeper soft ground areas. • De-watering of the excavation is not necessary if Class 6A material is used. Class 6A Fill can be placed under water and this reduces the risk of instability of the sides of the excavation • The excavated material has to be transported from the site and a suitable repository sourced. • No stockpiling is permitted on the soft ground strata. • No maintenance would be required post construction, other than standard road maintenance. • Impact on SAC, SPA and PNHA areas would need to be considered.
1B	Excavate and Replacement of Peat, Leave Marl and Alluvium in place where soft Ground is present	• Typically cost effective for excavation depths of approximately < 3-4m. • There may be difficulty in excavating out the existing road and peat where there is underlying very soft Marl and Alluvium which could make construction impractical and dangerous. • Overall stability to Eurocode 7 may not be achieved in deeper soft ground areas. • Should vertical drains be required to speed up primary consolidation in underlying soft marls and alluvium, pre-drilling through fill may be required which adds to the costs. • The base of the excavation needs to extend equivalent to a 1H:1V line from the crest-landtake requirements would be relatively high. • Good construction methods are necessary in peat, with the fill being kept close to the excavation face to reduce the risk of collapse of the side of the excavation. • De-watering of the excavation is not necessary if Class 6A material is used. Class 6A Fill can be placed under water and this reduces the impact on SAC, SPA and PNHA areas would need to be considered. • Risk of instability of the sides of the excavation. • The excavated material has to be transported from the site and a suitable repository sourced. • No stockpiling is permitted on the peat stratum. • May not be suitable for road widening due to differential settlements between widened and existing • On-going road maintenance would be required over the lifetime of the road.

Appendix F - Possible Options for Significant Interventions

Option No.	Construction Method	Remarks
2	Staged construction, generally with vertical drains and if required, basal reinforcement and berms	• The embankment is constructed in stages, allowing the excess pore water pressures to dissipate at each stage. • Vertical drains can be installed to increase the rate of consolidation but their effectiveness in peat is questionable. • Basal reinforcement and berms may be used to improve stability and to increase the rate of construction. • Berms would require additional space adjacent to the road which would need to be considered. • Need to consider long term creep issues and differential settlements which would be relatively high if constructed on peat. • May not be suitable for road widening due to differential settlements between widened and existing road. • On-going road maintenance would be required over the lifetime of the road. • Does not require excavation of soft ground, however, impact on SAC, SPA and pNHA areas would need to be considered.
3	Option 2 + Lightweight Fill	• The use of lightweight fill could be used effectively to make staged construction more effective. However, sourcing the material may be difficult. • May be more cost effective in deeper soft ground areas • Basal reinforcement and berms may be used to improve stability and to increase the rate of construction. • Berms would require additional space adjacent to the road which would need to be considered. Settlements would be lower than if using general fill (i.e. Option 2). • Need to consider long term creep issues and differential settlements which would be relatively high if constructed on peat. • May not be suitable for road widening due to differential settlements, particularly if the widened road extends onto the road pavement. • On-going road maintenance would be required over the lifetime of the road. • Flotation under flood conditions has to be considered • Impact on SAC, SPA and pNHA areas would need to be considered.

Appendix F Possible Options for Significant Interventions

Option No.	Construction Method	Remarks
4	Option 2 + Ultra Lightweight Fill (Polystyrene blocks, Leca, rubber tyres)	• The embankment fill is made up of polystyrene blocks which have an effective unit weight of about 3kN/m2. • The use of ultra lightweight fill would reduce the risk of instability in the very soft ground and also reduce the settlement but would be unlikely to be cost effective. • Usually found to be expensive • Flotation under flood conditions has to be considered • Need to consider long term creep issues and differential settlements which would be relatively high if constructed on peat. Although the use of Ultra lightweight fill would reduce the settlements in comparison to lightweight fill (Option 3). • Does not require excavation of soft ground, however, impact on SAC, SPA and pNHA areas would need to be considered.
5	Piled supported reinforced concrete slab	• Generally considered to be expensive but may be more cost effective in deeper soft ground area. • Would need to control development close to the embankment to ensure that there is no lateral failure induced by adjacent construction. • Concrete slab generally only used where the embankment is low
6	Basally reinforced pile supported embankment	• Generally considered to be expensive. • Would need to control development close to the embankment to ensure that there is no lateral failure induced by adjacent construction. • This would not be suitable for the low embankment heights required for this scheme (i.e. <2m) as pile would have to be at close spacing to achieve arching.

Appendix G - Pavement Visual Survey Inspection Form

Visual Inspection Survey		Date of Survey	
Road Number		Start Time	
Segment ID		Weather Conditions	

Page 1 of 2

Chainage	Lane	Carriageway	Footway & Cycletrack	Ironwork	Kerb/Edging/Channel	Drainage & Outfalls	Utilities	Traffic or Other	Defect Condition	Description	Image No.

Appendix G - Pavement Visual Survey Inspection Form

Chainage	Lane	Carriageway	Footway & Cycletrack	Ironwork	Kerb/Edging/Channel	Drainage & Outfalls	Utilities	Traffic or Other	Defect Condition	Description	Image No.

An Roinn Iompair
Department of Transport