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Analytic Pavement & Foundation Design

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DN Design

Standards

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TII Publications

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Contents

Updates to TII Publications resulting in changes to
Analytic Pavement & Foundation Design DN-PAV-03021

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Amendment Details:

The new DN-PAV-03021 introduces the Irish Analytic Pavement Design Method (IAPDM) software as part of the pavement design process for new pavements and existing pavement overlay/strengthening. Pavement designs will now be carried out using the IAPDM web-based software. The IAPDM allows for the consideration of actual material performance characteristics within the design method. This document also provides requirements related to the assessment and evaluation of existing pavement data and the determination of a suitable pavement overlay/strengthening intervention.

Contents Table

1. Introduction

This publication will guide a pavement designer through the design process for new pavements and the strengthening / overlaying of existing pavements. All pavement designs are to be carried out using the Irish Analytic Pavement Design Method (IAPDM). The design of flexible and flexible composite pavement types only are considered within this publication.

This publication will detail the following aspects of the pavement design process to be followed by the pavement designer:

i. Irish Analytical Pavement Design Method (IAPDM)
ii. New Pavement Design
iii. Existing Pavement Strengthening / Overlay Design
iv. Departures from Standard

1.1 Irish Analytic Pavement Design Method (IAPDM)

The design process detailed in this publication is implemented through the web-based IAPDM software. The IAPDM is a Mechanistic-Empirical (ME) pavement design method developed specifically for Irish conditions.

The ME design approach provides a means of customising a pavement design for locally available materials, innovative materials and construction methods in an attempt to maximise the whole life value of the pavement.

The philosophy of ME design is that the pavement should be treated in the same way as a civil engineering structure, the procedure for which is detailed in this publication.

The IAPDM uses a Multi-Layer Linear Elastic (MLLE) model to calculate the pavement response to traffic loads. This pavement response is then correlated to an expected long-term performance using empirical models to assess the capacity of the pavement structure to carry predicted future traffic loads.

Design models incorporated within the IAPDM work on the basis of an 85th percentile level of reliability. Design reliability relates to the probability of the actual occurrence of the modelled pavement performance under the specified design traffic loading. This level of design reliability is suitable for the National Road network.

To request access to the IAPDM please send your email address and mobile phone number to iapdm@tii.ie.

2. New Pavement Design

2.1 Overview

An overview of the design process for new pavement structures on a greenfield site is depicted in Figure 2.1 below. Each of the processes depicted are discussed in subsequent sections.

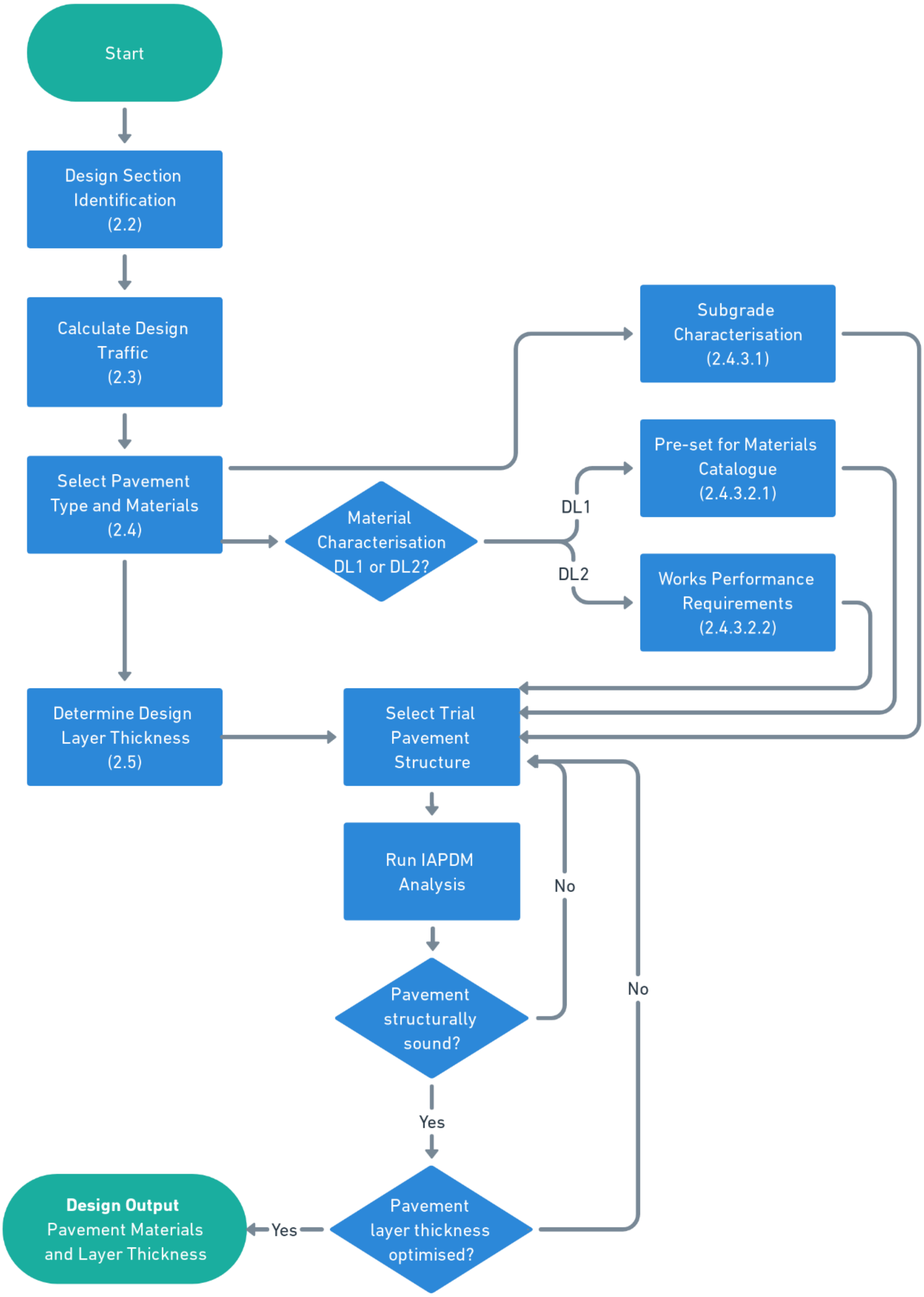


Figure 2.1 New Pavement Design Process

2.2 Design Section Identification for New Pavements

Design sections are extents of pavement within a project which will operate under similar conditions throughout the pavement lifecycle. Pavement designs will be carried out for each design section considering each section’s particular conditions.

The start and end chainages of design sections for new pavements are to be defined based on the following conditions:

a) Lane configuration

b) Traffic loading in design lane / most heavily trafficked lane

c) Subgrade design stiffness

2.3 Design Traffic

The design traffic is the quantification of vehicle loading applied to a pavement structure in the design lane over the specified design period. The design lane is defined as the lane most heavily trafficked by commercial vehicles within a carriageway.

All lanes, including auxiliary lanes plus the hard shoulder and hard strips, shall be designed to carry the design traffic.

The design period for a pavement structural analysis is the number of years from the time of opening the road to traffic, that the pavement structure is required to provide an acceptable level of service to the road user.

The design period for a new pavement shall be 40 years. Other design periods may be used in circumstances where a different design period of the pavement asset is required. Use of a design period other than 40 years for a new pavement shall require a TII Departure from Standard.

The design traffic, expressed as a number of standard axles, is determined for each design section. The design traffic and number of standard axles is calculated by the procedures detailed in PE-SMG-02002 Traffic Assessment. The minimum design traffic for a National Road shall be 1 million standard axles in order limit the risk of premature pavement failure related to very thin pavement structures.

The standard axle shall be characterised within the IAPDM as a single wheel with 40kN half axle load and a tyre pressure of 559kPa.

The IAPDM has the inbuilt functionality to facilitate the calculation of the design traffic in line with PE-SMG-02002 as shown in Appendix C.

2.4 Selection of Pavement Type and Materials

2.4.1 Overview

A pavement structure comprises of pavement layers constructed from the materials as described in Table 2.1 below. The function of each layer within the pavement structure and materials typically used for each are also described. Guidance on the selection of suitable pavement materials is provided in TII Publication DN-PAV-03024 Bituminous Mixtures, Surface Treatments, and Miscellaneous Products and Processes.

Guidance in the selection of suitable surfacing materials for a project is provided in TII Publication DN-PAV-03023 Surfacing Materials for New and Maintenance Construction for Use in Ireland.

Table 2.1 Pavement Layers, Materials and their Function

Layer	Pavement Material	Function
Surface Course	Bituminous	Road user skid resistance and ride quality.
Binder Course	Bituminous	Level control and improved ride quality. Provides structural capacity.
Base Course	Bituminous Hydraulically Bound Materials Unbound Granular	Main structural pavement layer ensuring long term pavement performance and the required pavement structural capacity.
Subbase	Unbound Granular	Provides improved pavement level control and structural capacity.
Capping	Unbound Granular	Provides a working platform for construction vehicles to construct upper pavement layers. Also provides structural strength / capacity to the pavement structure using lower quality, cheaper materials. A capping layer is not always required where subgrade conditions are sufficient to provide adequate construction vehicle support and pavement drainage.
Subgrade	In-situ / Imported Materials	Lowest layer of the pavement foundation.

Pavements constructed with either a bituminous or unbound granular material base are referred to as Fully Flexible pavement structures. Pavements constructed with a combination of Bituminous and Hydraulically Bound bases are referred to as Flexible Composite pavement structures.

The pavement foundation is defined as the combined structure of the subgrade, subbase and capping layers where required.

The full range of material types and mixtures currently available for use is provided in the TII Publications Specification of Road Works documents and are tabulated below.

Table 2.2 TII Publications Specification of Road Works

Pavement Material	TII Publication
Bituminous	CC-SPW-00900 - Specification for Road Works Series 900 - Road Pavements - Bituminous Materials
Hydraulically Bound Granular Unbound Granular - Subbase	CC-SPW-00800 - Specification for Road Works Series 800 - Road Pavements - Unbound and Cement Bound Mixtures
Unbound Granular - Capping	CC-SPW-00600 - Specification for Road Works Series 600 - Earthworks

2.4.2 Selection Criteria

The designer shall select the most suitable pavement type materials, and / or combination of materials for each pavement design. Some of the aspects that should be considered by the designer when considering pavement types and materials are listed below:

i. Traffic loading type
ii. Material availability
iii. Material cost
iv. Maintenance requirement throughout the pavement lifecycle
v. Material embodied carbon
vi. Possibility for material re-use / repurposing at asset end of life

2.4.3 Material Characterisation and Design Inputs

2.4.3.1 Subgrade

Where the pavement is to be constructed in cuttings, the subgrade is the in-situ material on which the new pavement structure is to be constructed. Where the pavement is to be constructed on embankment the subgrade is the top of the structural fill incorporated into the works to achieve the required vertical profile.

The subgrade long term performance is considered within the IAPDM in terms of stiffness and resistance to deformation. The subgrade related performance characteristic design input to the IAPDM is the design subgrade stiffness.

The design subgrade stiffness shall be determined per design section as follows:

a) Select a long term stiffness based on subgrade material type and conditions from Appendix A. The selected long term stiffness is used within the IAPDM as the initial subgrade design stiffness.

b) Prior to construction, the short term stiffness of the subgrade shall be determined by either of the test methods listed in Table 2.3 below.

c) The short term stiffness determined by testing shall be compared to the long term stiffness determined as per (i) above. Where the short term stiffness of the subgrade at any test location is less than the long term stiffness, the subgrade will require treatment and improvement to meet the long term stiffness or the pavement design adjusted to incorporate the determined short term stiffness of the subgrade.

d) An improved subgrade within the design section will be re-tested to ensure the short term stiffness is greater than or equal to the long term stiffness.

Table 2.3 Subgrade characterisation test methods

Test Method	Reference	Output	Test Frequency
Falling Weight Deflectometer (FWD)	Appendix B of AM-PAV-06050 and CC-GSW-04008	Surface modulus (MPa) from surface deflection measurements.	50m alternate intervals in each lane.
Dynamic Cone Penetrometer	Appendix D, AM-PAV-06050	CBR% from penetration rate converted to stiffness modulus.	

A Departure from Standard will be required in the following circumstances:

a) Where subgrade treatment and improvement is proposed.

b) An alternative design CBR / Stiffness value is proposed based on testing or previous experience

c) The use of specific geosynthetics / processes and materials are incorporated into the pavement or foundation.

The use of any of the above shall not prevent the reusability or recyclability of the pavement structure at its end of life.

2.4.3.2 Pavement Materials

The long term performance characteristics of pavement materials to be considered within a new pavement design shall be input into the IAPDM as outlined in Table 2.4 below based upon the Design Level

Table 2.4 New Pavement Material Performance Characteristics

Pavement Material	Performance Characteristic
Bituminous	• Stiffness • Resistance to Fatigue (Cracking),
Unbound Granular	• Stiffness
Hydraulically Bound Granular	• Stiffness • Resistance to Fatigue (Cracking)
Low Energy Bound Material	• Stiffness • Resistance to Fatigue (Cracking)

Pavement materials are characterised within the IAPDM as defined below.

2.4.3.2.1 Design Level 1 (DL1) Material Characterisation

The IAPDM provides a pre-existing catalogue of pavement material mixtures for the designer to select from and include within a pavement design. The range of pavement material mixtures available within the catalogue aligns with those available within the TII Specification of Road Works documents. The long term performance characteristics of the materials selected from the catalogue are pre-set within the IAPDM.

DL1 materials are characterised during production and construction based on their constituent and mixture requirements as detailed in the relevant TII Publication Specification for Road Works.

2.4.3.2.2 Design Level 2 (DL2) Material Characterisation

The IAPDM provides the designer with an opportunity to better characterise the long term performance characteristics of a pavement material through additional performance tests. Within the IAPDM the designer creates a new material within the materials database and specifies a level of performance of a material which the Works are required to meet. This new material creation process is detailed in Appendix C.

The performance levels and related works requirements tests per material type are detailed in Appendix B.

The performance related works requirements of a material are in addition to the constituent and mixture requirements as specified in the relevant TII Publication Specification for Road Works.

2.5 Determination of Design Layer Thicknesses

Once the pavement type and materials for the project have been selected, the required pavement layer thicknesses to carry the predicted construction and design traffic load are determined.

The determination of the required pavement design layer thicknesses is carried out through an iterative process within the IAPDM software.

A trial design pavement structure is defined and is structurally evaluated to assess whether the trial foundation and pavement structural system are adequate for the construction and design traffic loading.

Foundation and pavement design layer thicknesses are adjusted until the modelled pavement structure meets the structural capacity requirements.

The design layer thicknesses input to the IAPDM for a material shall align with the minimum nominal layer thickness requirements as per the relevant TII Specification for Road Works. Pavement layer design thicknesses shall be rounded up to the nearest 5mm.

Different pavement material types may also be introduced as part of the design iteration process to assess the impact on design layer thicknesses and material quantities required to adequately withstand design traffic loading.

The central reserve pavement shall consist of the same pavement thickness and material as the adjacent hardstrip and carriageway.

An example of a design iteration and analysis is provided in Appendix C.

3. Existing Pavement Strengthening/Overlay Design

3.1 Overview

TII's Pavement Asset Management System (PAMS) analyses a range of pavement condition indicators collected annually from pavement surveys on the National Road network. From the PAMS analysis, sections of road which may require a maintenance intervention are identified. The PAMS identified sections of road require further scheme level detailed investigations to confirm the PAMS analysis output and to determine a detail design for the section of road which can be specified for construction. This publication details the determination of the scheme level existing pavement capacity and maintenance intervention design process.

The determination of the required maintenance intervention for an existing pavement structure is a complex process. A number of pavement related performance indicators must be collated and analysed to determine homogenised design sections within a project and, if required, a suitable maintenance intervention. Pavement designs shall be carried out for each design section considering each section's particular conditions. This process requires careful consideration and the application of engineering judgement and experience in determining the most suitable maintenance intervention.

The existing pavement assessment and intervention design process is depicted in Figure 3.1 below.

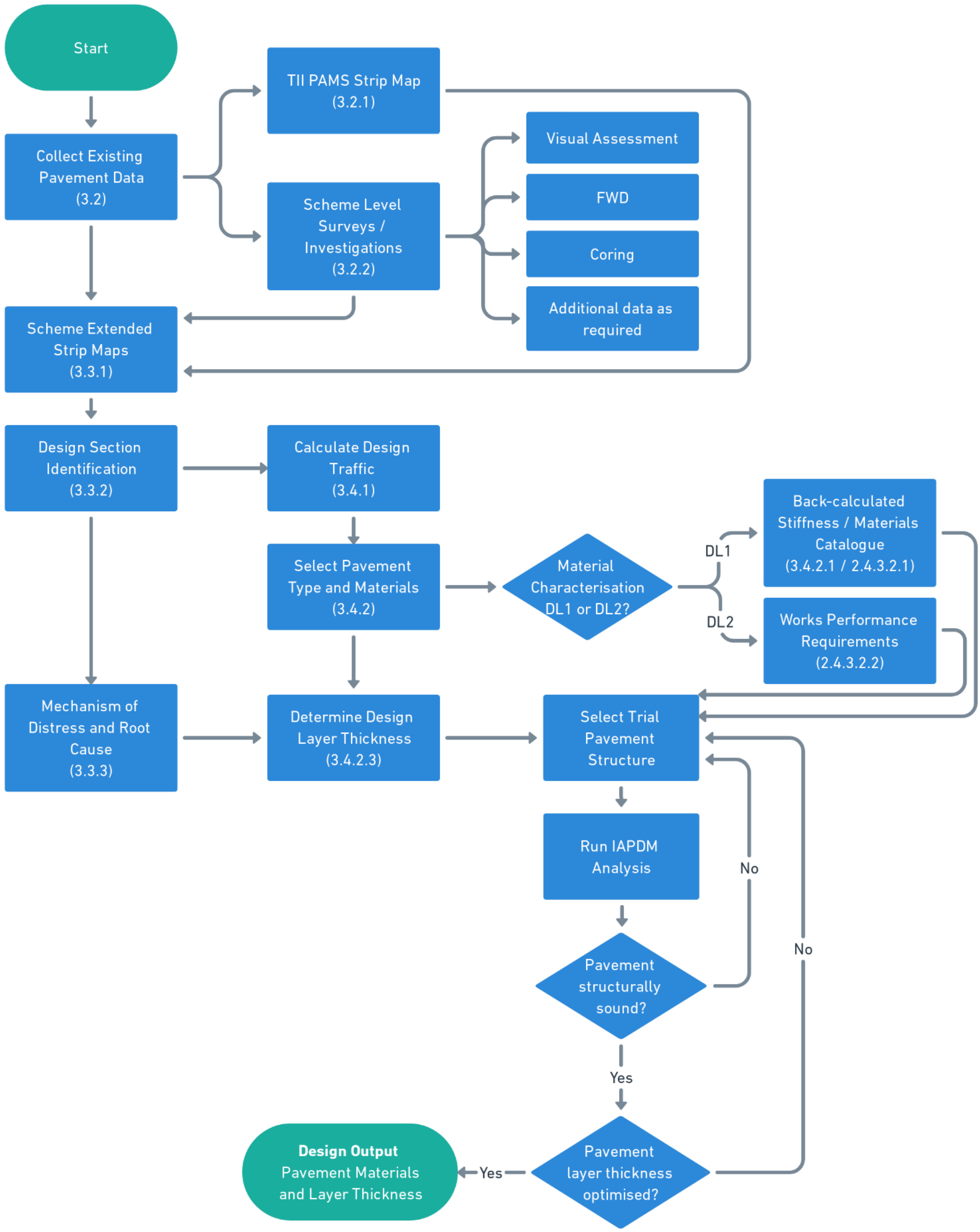


Figure 3.1 Existing Pavement Assessment and Maintenance Intervention Design Process

3.2 Existing Pavement Condition

3.2.1 Overview

Information from the PAMS and Scheme level surveys are to be used in the assessment of the existing pavement capacity and maintenance intervention design process. The information sources and the detailed data to be collected, assessed and analysed are detailed below.

3.2.2 Pavement Asset Management System (PAMS)

The network level survey pavement condition data used within the PAMS to identify the section of pavement for rehabilitation available from TII Network Management in the form of PAMS Strip Maps shall be used as part of the scheme level, existing pavement capacity detailed assessment and maintenance intervention design.

The survey instruments, relevant data outputs and practical consideration for the detailed pavement assessment are tabulated below. The existing pavement related performance data outlined below is the minimum required to be interrogated as part of the existing pavement assessment and maintenance intervention design process.

Table 3.1 PAMS data

Survey Instrument	Performance Indicator	Practical Consideration
Road Surface Profilometer (RSP)	Rutting in left wheel path (mm)	Permanent deformation in wheel paths indicating structural distress and impacting pavement surface drainage and ride quality
	Longitudinal Profile Variance at 3 metres (LPV3) lane width average	Road User Ride Quality / Experience
	International Roughness Index (IRI) lane width average	
Laser Crack Measurement System (LCMS)	Percentage area covered by: Alligator cracking Longitudinal cracking Transverse cracking	Pavement structural distress and structural deterioration
Ground Penetrating Radar (GPR)	Bituminous material layer thickness Granular material layer thickness	Pavement structure composition and layer thickness
As-built records	Pavement layer thicknesses Material specifications	Pavement structure composition and layer thickness

Detailed information relating to the survey instruments and data collection procedures referred to above is provided in AM-PAV-06050.

3.2.3 Mandatory Scheme Level Surveys / Investigation

The pavement performance data and analysis to be collected and undertaken as part of specific scheme level investigation are detailed below.

3.2.3.1 Visual Inspection

The pavement designer shall carry out an in person visual assessment of the pavement being investigated. The visual assessment process will provide vital first-hand information to the designer as to the pavement condition and environment in which the pavement exists.

The minimum information to be collected as part of the visual inspection is detailed in Table 3.2 below.

Table 3.2 Visual condition data

Performance Indicators	Practical Consideration	Frequency
Ravelling	**Assess deterioration in surfacing condition and skid resistance**	**Degree and extent per 100m section[1]**
Bleeding		
Rutting	**Permanent deformation in wheel paths indicating pavement structural distress and impacting pavement surface drainage and ride quality**	
Surface Distortion		
Alligator Cracking	**Pavement structural distress and structural deterioration**	
Longitudinal Cracking		
Transverse Cracking	Pavement shrinkage/expansion cracks increasing risk of pavement structural deterioration through moisture ingress	
Edge breaks/cracking	Reduced lateral restraint impacting ride quality and	
Patching	Reduced performance. Indication of pavement structural deterioration, and structural failure	
Potholes		
Road Disintegration		

[1]Degree and extent to be report as Very Poor / Poor, Fair, Very Good / Good

3.2.3.2 Falling Weight Deflectometer (FWD)

Data collected from an FWD survey shall be used to assess the structural condition of the existing pavement structure.

The minimum information to be considered from the FWD survey is detailed in Table 3.3 below.

Table 3.3 FWD deflection bowl parameters data

Performance Indicators	Practical Application	Frequency
D0 - Central Deflection in microns	**Overall pavement response and structural condition**	**Minimum of 50 metre intervals per lane[1]**
SCI - Surface Curvature Index in microns (D1-D2)	**Upper pavement structural response and condition**	
D7 - Deflection 1800mm from load plate in microns	**Lower pavement and subgrade structural response and condition**	

[1] Project specific station spacing to be agreed with TII Network Management

The procedures for carrying out FWD surveys and the collection of pavement deflection data is detailed in AM-PAV-06050, Appendix B.

3.2.3.2.1 Back-calculation of Pavement Layer Stiffness

The FWD back-calculation process is an iterative process used to determine existing pavement layer stiffnesses by varying the existing pavement layer stiffnesses within a theoretical pavement linear elastic model until the modelled pavement deflection bowl replicates the FWD measured deflection bowl. The existing pavement layer stiffness is used in the IAPDM as part of an existing pavement strengthening / overlay design.

The following requirements are to be met within the back-calculation process used:

a) Layer thicknesses within the structural model shall be based on actual data from the site investigation process or as built pavement structure data.

b) A Multi-layer linear elastic mechanistic model using specialist software shall be used.

c) Back-calculated layer stiffnesses for bituminous materials shall be temperature corrected according to the procedures set out in AM-PAV-06050 and CC-GSW-04008.

The back-calculation process shall be carried out and results provided by FWD survey service providers.

3.2.3.3 Coring

Cores shall be drilled in bound material pavement layers at selected locations along the pavement under investigation. The core samples will be used to assess the following aspects of the bound pavement layers condition:

a) Layer thickness

b) Stripping of bitumen in bituminous materials

c) Degree of binding in hydraulically bound materials

d) Bond between layers

e) Assessment of the depth of cracking into the pavement layer

Procedures for the drilling of cores is detailed in AM-PAV-06050, Appendix C

3.2.4 Additional Scheme Level Surveys / Investigation

3.2.4.1 Overview

In addition to the mandatory scheme level survey / investigations, additional pavement performance data and analysis methods are available

3.2.4.2 Trail Pits

Trial pits may be required to be carried out at selected locations along the pavement under investigation in order to understand in greater detail the existing pavement structure layer thickness and the composition of the layers making up the pavement structure. Samples of pavement material shall be taken during trial pitting for possible further laboratory investigations (see Section 3.2.4.3)

The selection of the locations for the excavation of trial pits and/or drilling of cores into the existing pavement structure shall be based on a review of available data including:

a) PAMS
   i) IRI lane average
   ii) Rut depth in left wheel path (mm)
b) FWD
   i) Deflection bowl parameters
   ii) Back-calculated stiffnesses
c) Visual condition
d) Severity of condition / Intervention type
e) As-built pavement structure data (if available)

3.3.3 The information, observations and frequency to be collected at each trial pit is detailed below.

i. Identification of pavement layers and material types present
ii. Thickness of each layer present in millimetres
iii. Depth of cracking in bound layers
iv. Deformation in the pavement layers
v. High water table

Further in-situ tests may be required to be carried out on the pavement layers identified within each trial pit is detailed in Table 3.4.

Table 3.4 In-situ tests within trial pits

Performance Indicators	Practical Application	Frequency
Dynamic Cone Penetrometer – Penetration rate	**Penetration rate can be used to estimate layer CBR% and layer stiffness.**	**Per test pit in unbound granular material and subgrade layers**
In-situ Density by Sand Replacement	**Used to assess the degree of compaction of the layer in-situ when compared with the laboratory Maximum Dry Density.**	

Procedures for the digging and sampling of materials from trial holes is detailed in AM-PAV-06050, Appendix C.

3.2.4.3 Laboratory testing of materials

Materials sampled from existing pavement layers as part of trial pit excavations or cores may require further laboratory testing to assess their condition and their suitability for use as part of the proposed strengthened/overlaid pavement structure.

Table 3.5 sets out the range of laboratory tests that may needed to be carried out on materials sampled from the existing pavement. Guidance is provided on the selection of the required tests based on the likely re-use or recycling of the existing pavement materials.

The extent of sampling and laboratory testing of existing materials carried out for a project depends on the environment and the sub-network within which the section of road falls. This requirement shall be discussed and agreed with TII Network Management.

Table 3.5 Laboratory testing per material type

Material Type Sampled	Sample source	Test Method	Practical Application	When required?
Bituminous	Bulk sample from trial pit	Compositional grading	Mixture identification	Re-use in-situ or RAP
		Binder content	Mixture identification	
		Penetration	Mixture identification and performance	
		Softening point	Mixture identification and performance	
		Presence of coal tar (depending on pavement age and sub-network)	Environmental compliance	
	Core	ITSM	Mixture performance	Undisturbed re-use in-situ
		Wheel tracking		
		Void content		
Unbound granular and subgrade	Bulk sample from trial pit	Compositional grading	Mixture identification	Undisturbed re-use in-situ
		Atterberg limits	Mixture identification and performance	
		In-situ moisture content	Mixture in-situ performance	
		Optimum moisture content and Maximum Dry Density	Mixture performance	

3.3 Data Analysis and Interpretation

3.3.1 Overview

The level of data analysis and interpretation to be carried out as part of the existing pavement assessment and rehabilitation design process is dependent on the environment and the sub-network within which the section of road falls. The level of data analysis and interpretation shall be discussed and agreed with TII Network Management.

3.3.2 Strip Maps

Strip maps are an important tool to visually interrogate large amounts of data from different sources. TII PAMS creates TII PAMS Strip Maps from the Network Survey data. However, forscheme level pavement design more detailed Extended Scheme Design strip maps shall be developed to identify design sections and to assist in determining the root cause of existing pavement distress. The Extended Scheme Design Strip Maps shall include scheme survey data collected and detailed in Section 3.2 to the extent agreed with TII Network Management.

Extended scheme design strip maps shall be prepared and include the following minimum data:

a) TII PAMS Strip Map data

b) Deflection bowl parameters

c) Back-calculated layer stiffnesses

d) Visual assessment data

e) Pavement structure data (coring)

Colour coding for the assessment of deflection bowl parameters and back-calculated stiffnesses are presented in Table 3.6 and Table 3.7.

Table 3.6 Deflection Parameter (microns) Traffic Light Categories

Stiffness Category	Traffic Light Assessment	D1	SCI	D7
Very Low	RED	>700	>300	>50
Low		500 to 700	200 to 300	40 to 50
Reasonable	YELLOW	350 to 500	140 to 200	30 to 40
Moderate		200 to 350	80 to 140	20 to 30
Very High	GREEN	100 to 200	40 to 80	10 to 20
High		<100	<40	< 10

Table 3.7 FWD Back-calculated Layer Stiffness (MPa)Traffic Light Categories

Stiffness Category	Traffic Light Assessment	Bituminous	HBM	UGM
Very Poor	RED	<3000	<3000	<250
Fair	YELLOW	3000 to 7000	3000 to 12000	250 to 500
Very Good	GREEN	>7000	>12000	>500

An example of an extended strip map including both PAMS and Scheme survey data is provided in Appendix D.

3.3.3 Design Section Identification for Existing Pavements

Sections of existing pavement with similar characteristics are required to be identified / homogenised into design sections. The extended scheme design strip maps detailed in Section 3.3.2, depicting the various pavement condition indicators shall be used to identify design sections.

Pavement designs shall be carried out for each design section considering each of the sections particular characteristics. These characteristics include, and are not limited to the following:

i. Traffic loading in design lane / most heavily trafficked lane

ii. Lane configuration

iii. Existing pavement structure

iv. Pavement condition

Each design section will be defined by a start and end chainage per carriageway. Pavement designs shall be developed across the full width of the carriageway

3.3.4 Mechanism of Distress and Root Cause

The root cause and mechanism of observed pavement performance per design section shall be determined based on the interrogation of existing pavement survey/investigation information and condition data. There are two mechanisms of pavement structural distress which are significant cause of pavement failure and poor levels of service. These are permanent deformation and bound material fatigue. These mechanisms can occur separately within different layers and materials or as a result of mechanism interaction such as asphalt concrete upper pavement material fatigue, moisture ingress to UGM layers and resulting pavement deformation and poor service level performance. The process of identifying these distress mechanisms, their root cause and required intervention is detailed in Appendix E. Where the observed pavement distress is limited to the pavement surfacing, a resurfacing of the pavement only may be the optimal solution.

The extent to which the mechanism of distress and root cause of pavement failure shall be interrogated is dependent on the level of project risk and extent of existing pavement data available. The assessment detailed in Appendix E shall be carried out to the greatest extent possible based on the extent of existing pavement data available or collected.

The interrogation of pavement data and condition to determine the pavement distress mechanism and the root cause may not correlate exactly and conflicting indicators can sometimes be observed. It is therefore required to use engineering judgement and experience to identify the pavement failure mechanism and root cause.

3.4 Maintenance Intervention Design

3.4.1 Overview

Once the root cause of the pavement distress has been identified, a suitable intervention to strengthen / overlay an existing pavement structure to meet an expected future traffic loading can be designed for using the IAPDM. This design process is detailed in the following sections. Each carriageway lane shall be assessed based on the extent of pavement data available for that lane.

3.4.2 Design Traffic

The design traffic is the quantification of vehicle loading applied to a pavement structure within a carriageway lane over the specified design period.

The design period for a pavement structural analysis is the number of years from the time of opening the road to traffic that the pavement structure is required to provide an acceptable level of service to the road user. The design period to be used in an existing pavement rehabilitation design analysis will be dependent on the pavement intervention required based on the assessment of the existing pavement asset condition. The design period will be agreed with TII Network Management.

3.4.3 Pavement Type and Materials

For an existing pavement structure analysis and maintenance intervention determination both new and existing pavement materials shall be characterised to allow for their long term performance consideration within the IAPDM. The process for material characterisation of both new and existing pavement materials is detailed below.

3.4.3.1 Existing Pavement Materials

Existing pavement materials are characterised based on pavement condition data collected as part of scheme level surveys as detailed in Section 3.2.

A significant input to the design process is the determination of the representative back-calculated stiffnesses of each pavement layer within the existing pavement structure for each design section, see Section 3.2.3.2.1.

The representative back-calculated stiffnesses for a design section pavement structure shall be determined from the deflection bowl measured at the 85th percentile D1 (deflection measured at the FWD load plate) station within a design section.

The design section representative back-calculated layer stiffnesses shall be used for the determination of the required pavement structural maintenance intervention.

3.4.3.2 New Pavement Materials

New pavement materials to be considered within the pavement strengthening design shall be characterised as detailed in Section 2.4.

3.4.3.3 Pavement structural intervention required

Subsequent to the determination that a structural intervention is required for the existing pavement structure, through the process detailed in Section 3.3.4, the structural intervention design for the existing pavement shall be carried out using the IAPDM.

The various structural pavement intervention options shall be considered within the IAPDM. These interventions include:

i. Overlays / Strengthening
ii. Inlays/Partial Reconstruction
iii. Whole Pavement Reconstruction

Each of the above pavement strengthening options may be considered within the IAPDM through the inclusion of new pavement material layers and the replacement of existing pavement layers within the pavement structural model.

Each lane shall be strengthened to carry its design traffic. However, the design must ensure continuity of drainage both in and below the pavement layers and across the carriageway width.

A worked example of a Pavement strengthening / overlay design is provided in Appendix C.

4. Departures from Standard

Where an alternative design method to IAPDM is proposed for the design of a pavement structure for a National Road, this shall be considered a Departure from Standard.

The Departure application should include the following information to assist TII in evaluating the suitability of the design method, its inputs and outputs.

i. Detailed information on the mechanistic model used in determining the pavement layers response under traffic loading e.g. stresses and strains.

ii. Detailed information relating to the empirical models used to characterise the long term performance characteristics of the materials considered e.g. resistance to fatigue. This information should include data or research references to long term performance trials for the selected materials.

iii. Detailed information relating to the selected material design layer stiffnesses used in the alternative design method. This information should include data or research references to long term performance trials for the selected materials.

iv. Information supporting the application of the models and materials characterisation used in the alternative design process are applicable to Irish conditions.

Appendix A:

Selection of Long Term Subgrade Stiffness Modulus

Table A1 Guidance on Long Term Subgrade Stiffness (MPa)

Type of Soil	Plasticity Index	High Water Table						Low Water Table					
		Construction Conditions						Construction Conditions					
		Poor		Average		Good		Poor		Average		Good	
		Thin	Thick	Thin	Thick	Thin	Thick	Thin	Thick	Thin	Thick	Thin	Thick
Heavy Clay	70	22	27	27	27	27	27	22	27	27	27	27	31
	60	22	27	27	27	27	31	22	27	27	27	27	31
	50	22	27	27	31	27	31	27	27	27	31	27	31
	40	27	31	31	35	31	35	31	31	35	35	35	39
Silty Clay	30	31	39	35	42	39	49	35	39	42	42	42	55
Sandy Clay	20	31	42	42	49	46	61	35	42	49	55	55	66
	10	22	39	35	55	39	61	31	42	46	61	55	76
Silt		17	17	17	17	27	27	17	17	27	27	27	27
Sand (Poorly Graded)		119											
Sand (Well Graded)		186											
Sandy Gravel (Well Graded)		241											

Notes:

A `high' water table is one within 300mm of formation (or sub-formation if a capping is present). A `low' water table is 1 metre down. `Thick' construction represents a 1200mm pavement (including capping); a `thin' pavement is 300mm of construction. The construction condition referred to relates to whether the subgrade is allowed to become wet, i.e. protection from rain, and the quality of drainage provided. More detailed advice is given in LR1132 (1984).

The long term subgrade stiffness values tabulated above may be converted to an equivalent long term subgrade CBR (%) using the following relationship. The use of this relationship should be limited to stiffness values between 27 MPa and 86 MPa:

$CBR = (E/17.6)^{1.5625}$

Where E is the selected long term subgrade stiffness in MPa.

Appendix B:

Design Level 2 Material Characterisation and Works Performance Requirements

B1.1 Bituminous Bound Materials

Table B1 Bituminous Bound Material Works Performance Testing for Design Level 2

C	Test Method[1]	Performance	Performance Category
Stiffness[1]	Indirect Tensile Stiffness Modulus (MPa) EN 12697-26:2018 Annex C IT-CY 20ºC	≥1800	S1
		≥2500	S2
		≥4500	S3
		≥6500	S4
Resistance to Fatigue	ε_6 (failure strain level at $1x10^6$ load repetitions) EN 12697-24:2018 Annex E, IT-CY at 20ºC	<130	F1
		≥130	F2
		≥190	F3

Notes:

1. The above limits relate to the minimum of the average of the results from a set of test specimens.

2. Works testing frequencies to be agreed with TII Network Management on a project specific basis.

B1.2 Hydraulically Bound Granular Materials

Table B2 Hydraulically Bound Granular Material Performance Testing for Design Level 2

Performance Characteristic	Test Method	Performance	Performance Category
Stiffness	Elastic Modulus (E_c) (Cylindrical specimen, compression) IS EN 13286-43	≥20 MPa	S1
		≥28 MPa	S2
		≥33 MPa	S3
Fatigue	Indirect Tensile Strength (R_{it}) IS EN 13286- 42	≥1.2 MPa	F1
		≥1.8 MPa	F2
		≥2.4 MPa	F3

Notes:

1. The above limits relate to the minimum of the average of the results from a set of test specimens.

2. Works testing frequencies to be agreed with TII Network Management on a project specific basis.

B1.3 Low Energy Bound Materials (LEBM) / Stabilised Granular Materials

Table B3 LEBM / Stabilised Granular Material Performance Testing for Design Level 2

Performance Characteristic	Test Method[1]	Performance	Performance Category
Stiffness	Indirect Tensile Stiffness Modulus (MPa) EN 12697-26:2018 Annex C, IT-CY 20ºC	≥1000	S1
		≥1750	S2
		≥2500	S3

Notes:

1. The above limits relate to the minimum of the average of the results from a set of test specimens.

2. Works testing frequencies to be agreed with TII Network Management on a project specific basis.

B1.4 Unbound Granular Materials

Table B4 Unbound Granular Material Performance Testing for Design Level 2

Performance Characteristic	Test Method	Performance		Performance Category
		Rolling Average[1]	Minimum	
Stiffness	Surface Modulus (MPa) Falling Weight Deflectometer as per CC-GSW-04008 / AM-PAV-06050, Appendix B	≥100	≥70	S1
		≥200	≥120	S2
		≥300	≥175	S3

Notes:
[1]Rolling average of 5 consecutive FWD stations

Appendix C:

IAPDM Guidance

C1.1 IAPDM Pavement Design Guidance

In order to access the IAPDM web-based software a request shall be made to TII. An email address and mobile phone number are required to be provided to TII to setup a user and provide access.

C1.2.1 Project Dashboard

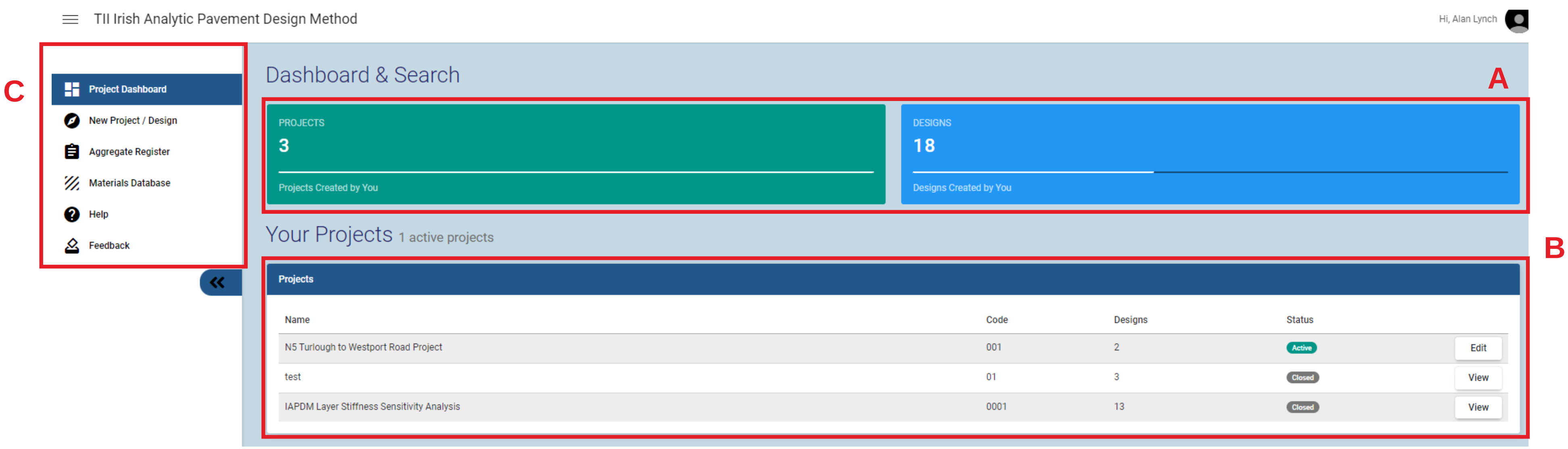


Figure C.1 Project Dashboard

The landing page of the IAPDM web-based software is shown in Figure C.1 above.

This page shows the number of projects and designs which have been created by the user (A).

The names of each project and number of pavement designs carried out under that project are shown. The user also has the functionality to edit existing designs within a project. (B).

Access to the pavement design system are shown on the left of the page (C).

C1.2.2 New Pavement Structure

C1.2.2.1 Project/Design Naming

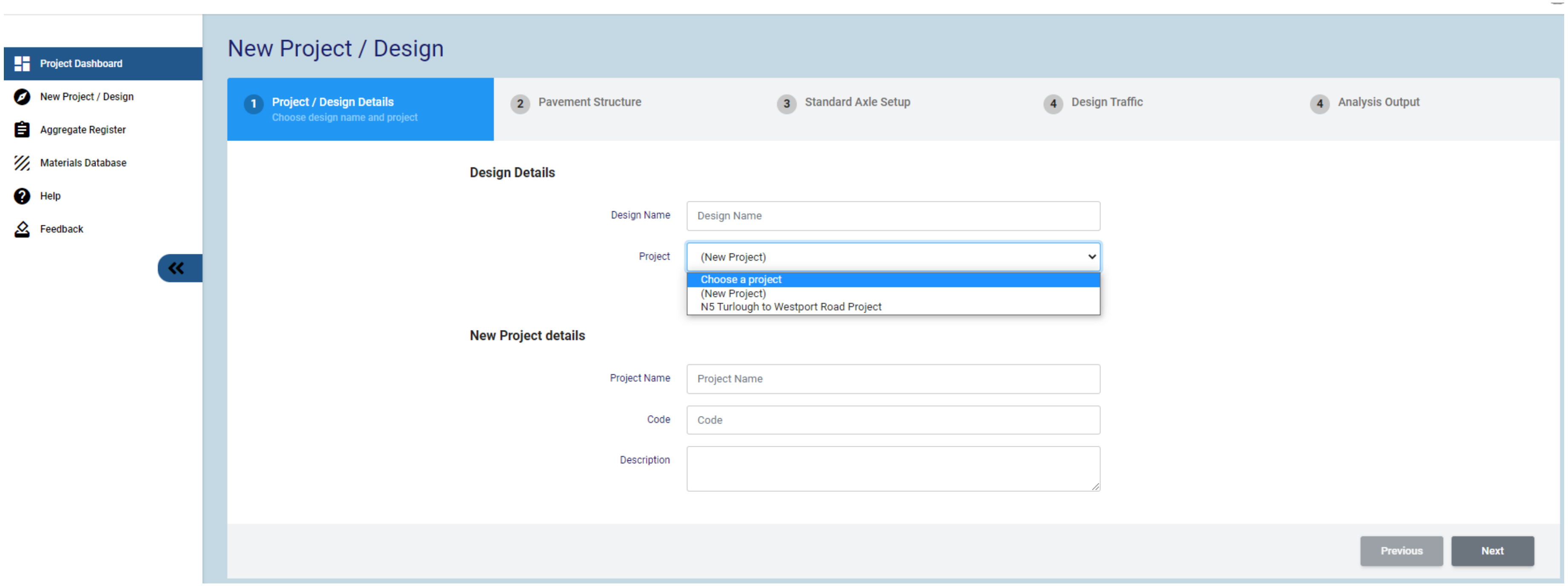


Figure C.2 New Project / Design page

To initiate the pavement design process the user shall select ‘New Project/Design’ on the left hand taskbar. When this link is selected the page as shown in Figure C.2 will be displayed.

This page allows for the naming of a project and a pavement design analysis under the project.

Where a new design is being developed under a project which has already been created, this project name can be selected from the ‘Project’ drop down menu.

Project Name input is the name of the overall project or contract for which a pavement design is required to be carried out. An example of a project name would be ‘N5 Westport to Turlough Road Project’.

Code is a user defined alpha numeric input which can align with an organisation's internal quality management system and project numbering systems.

Description input allows for the input of more detail on a project. An example input for this is:

'Design and construction of new national primary road (approximately 23km long), new national secondary road (approximately 2.5km long) and all ancillary works.'

Design Name identifies a pavement design analysis within a project. For a new pavement structure there may be a number of pavement designs for various sections of pavement sections along the new road alignment due to, for example varying subgrade conditions.

For existing pavements requiring rehabilitation, different pavement designs may be required to respond to changes in the existing pavement condition for homogenous sections of existing pavement.

An example input for the design name is 'Section 1_km0.0 to km10_Option 1'

Once the project and design naming has been complete the 'Next' button is selected to move to the pavement structure definition page.

C1.2.2.2 Pavement Structure Definition

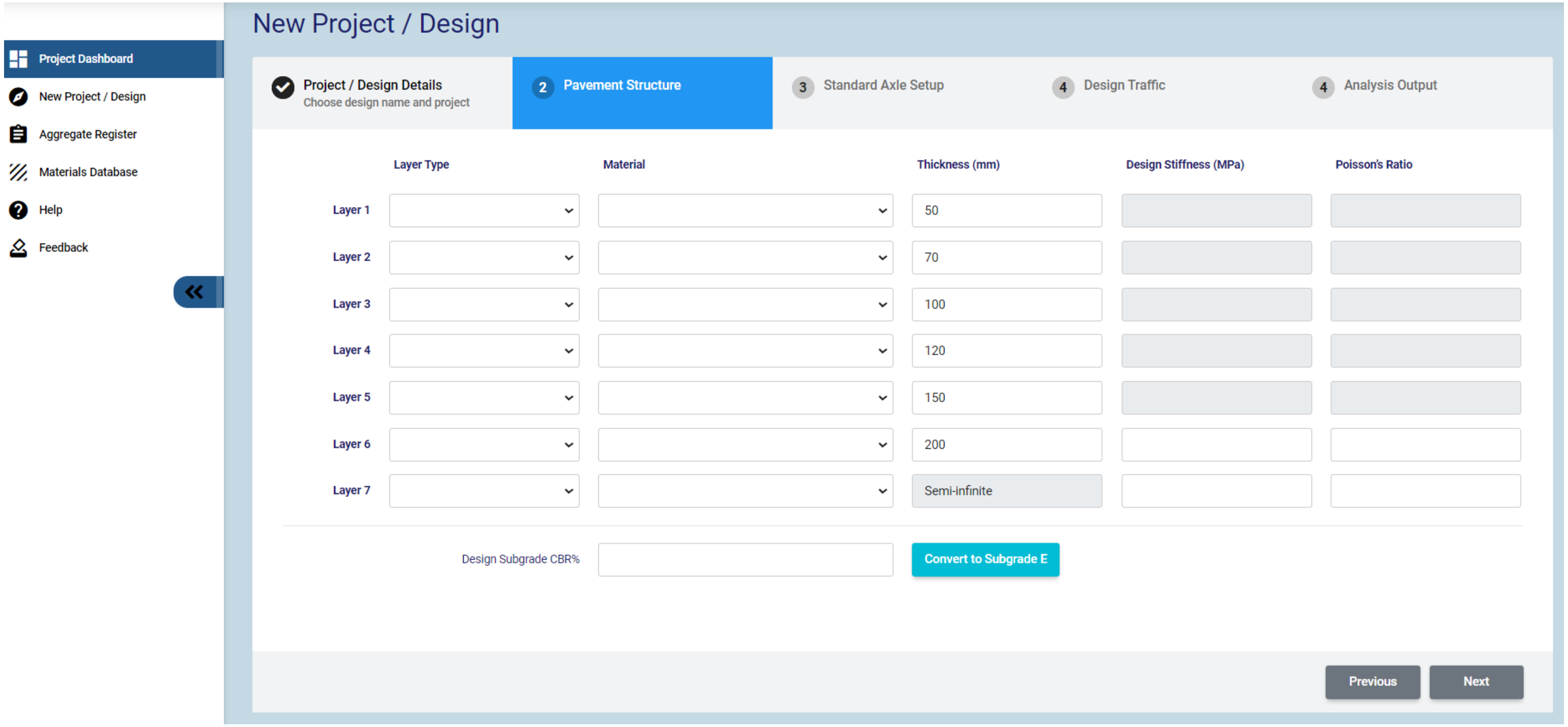


Figure C.3 Pavement Structure Definition page

The 'Pavement Structure' tab allows the user to define a pavement structure build-up of up to a maximum of 7 layers. The pavement structure build-up is defined by the user through the following inputs.

Layer Type dropbox allows the user to define the layer type as per the nomenclature used in Ireland e.g. surfacing, binder, base, subbase, capping and subgrade. There must be at least one subbase or capping layer on top of the subgrade within the design model.

Material dropbox allows the user to select for use within a pavement layer, a material type and its related performance characteristics. The material name and performance characteristics are defined within the Material Database (See section xx). The user can select DL1 or DL2 materials.

Design Stiffness and **Poisson's Ratio** fields are automatically populated with data from the materials database once a material has been selected.

Subgrade stiffness and Poisson's ratio are defined by the user here either by inputting a design CBR or a design stiffness based on in-situ plate load tests as discussed in DN-PAV-03021.

Once all fields are completed, the 'Next' button will access the 'Standard Axle Setup' tab.

C1.2.2.3 Selecting a Standard Axle Loading

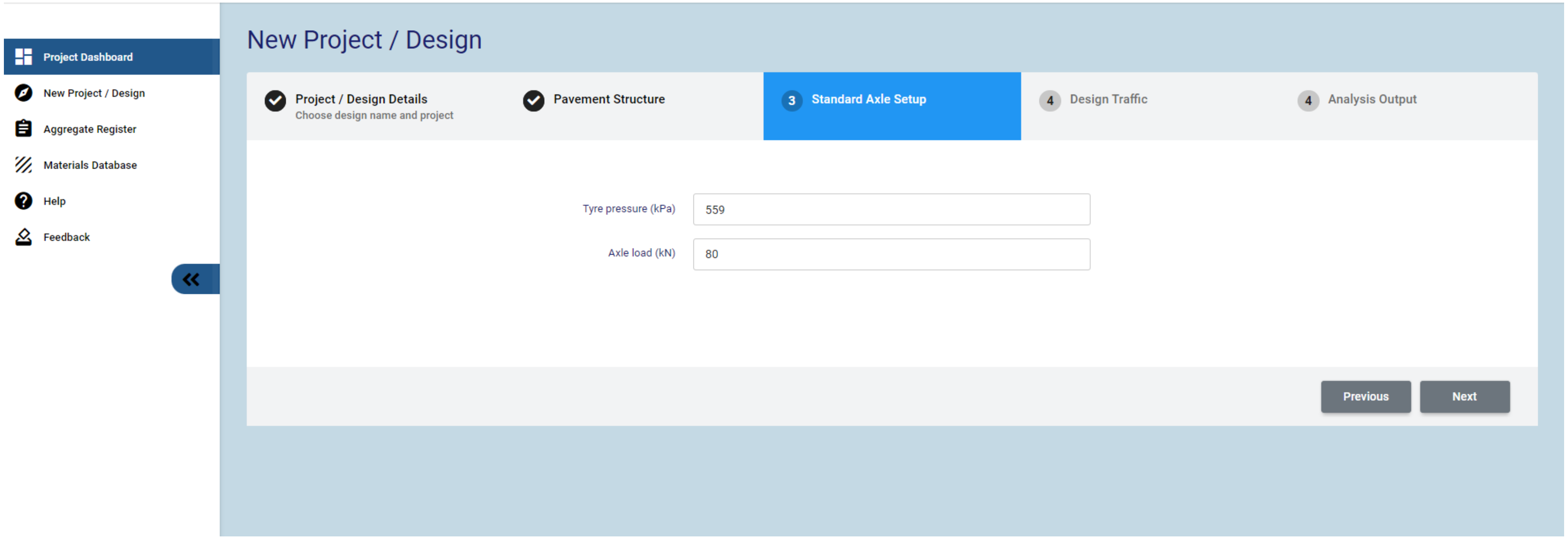


Figure C.4 Standard Axle Load setup page

This tab details the standard axle load considered within the pavement design analysis. For TII projects the default values shown above are pre-set and are automatically input when the tab is opened. The functionality of changing the standard axle load setup is provided for unusual events such as overloading assessment or abnormal vehicle loadings.

The next button will access the 'Design Traffic' tab.

C1.2.2.4 Design Traffic Calculation

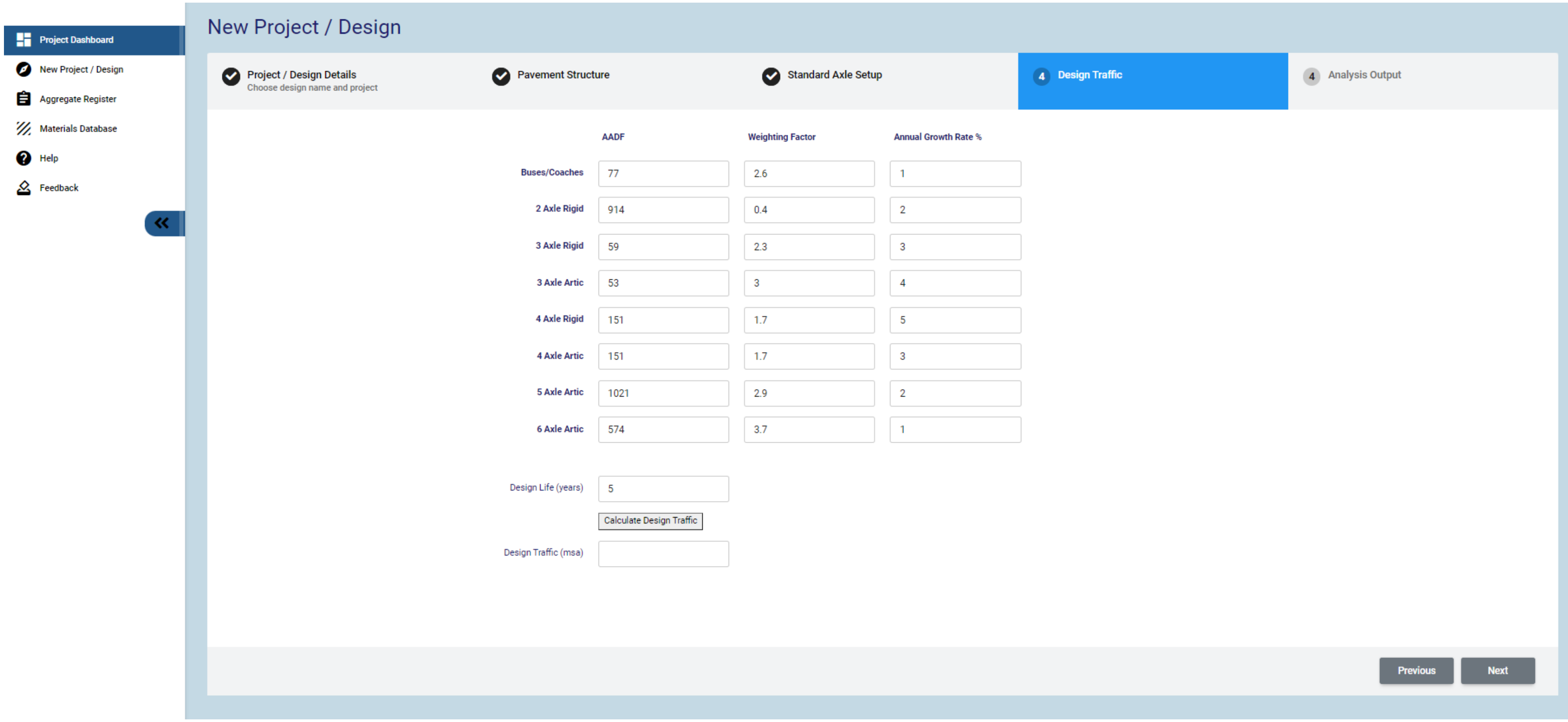


Figure C5 Design Traffic input page

The input to the design traffic tab are the inputs required for a design traffic calculation as per PE-SMG-02002.

Annual Average Daily Flows (AADF) is the annual average daily flow (one direction) of commercial vehicles travelling on the design lane.

Wear Factors relate to the structural wear to a road associated with each vehicle that passes and increases significantly with increasing axle load.

Annual Growth relates to traffic growth. Guidance on growth rates is provided in PE-PAG-02017-03.

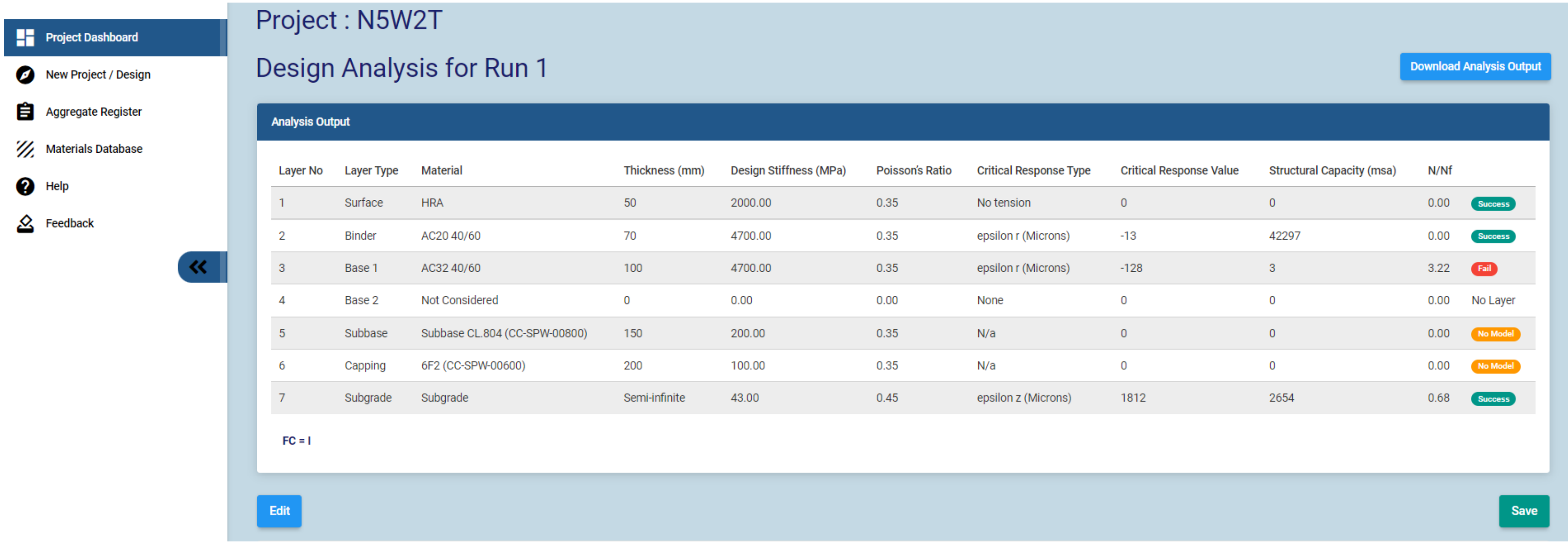
<u>Design Life</u> (Period) is the number of years from the time of opening the road to traffic, that the pavement structure is required to provide an acceptable level of service to the road user.

The design period for a new pavement structural analysis will shall be 40 years.

<u>Design Traffic</u> the result of design traffic calculation is shown here when the 'Calculate Design Traffic' button is pressed. The user also has the option to directly input a required design traffic loading in million standard axles (msa) in this textbox.

When the design traffic input and analysis is completed the 'Next' button will request the user to save their design inputs and analysis and then view the analysis results.

C1.2.2.5 Design Analysis and Outputs



Layer No	Layer Type	Material	Thickness (mm)	Design Stiffness (MPa)	Poisson's Ratio	Critical Response Type	Critical Response Value	Structural Capacity (msa)	N/Nf	
1	Surface	HRA	50	2000.00	0.35	No tension	0	0	0.00	Success
2	Binder	AC20 40/60	70	4700.00	0.35	epsilon r (Microns)	-13	42297	0.00	Success
3	Base 1	AC32 40/60	100	4700.00	0.35	epsilon r (Microns)	-128	3	3.22	Fail
4	Base 2	Not Considered	0	0.00	0.00	None	0	0	0.00	No Layer
5	Subbase	Subbase CL.804 (CC-SPW-00800)	150	200.00	0.35	N/a	0	0	0.00	No Model
6	Capping	6F2 (CC-SPW-00600)	200	100.00	0.35	N/a	0	0	0.00	No Model
7	Subgrade	Subgrade	Semi-infinite	43.00	0.45	epsilon z (Microns)	1812	2654	0.68	Success

Figure C.6 Analysis Output

The 'Analysis Output' page provides the result of the pavement design analysis as well as summarises of the defined pavement structure, standard axle load setup and the design traffic calculation.

The outputs of the design analysis are shown below.

Critical Response Type is the pavement structural response which determines the life of the particular layer within the pavement structure system. This is dependent on the material type considered. The material types and their critical responses are tabulated below.

Table C.1 Critical Responses Modelled

Material Type	Critical Response Type	Description
Bituminous Material	Epsilon r	Maximum horizontal strain at the bottom of the layer
Low Energy Bound Materials	Epsilon r	Maximum horizontal strain at the bottom of the layer
Hydraulically Bound Material	Sigma r	Maximum stress at the bottom of the layer
Top of Foundation	Deflection	Deflection at the top of the foundation when directly loaded
Subgrade	Epsilon z	Vertical strain at the top of the subgrade when the foundation is directly loaded

The Critical Response Value provides the modelled critical response within a layer and is input into the empirical, long term performance model for that particular material.

Structural Capacity is the output of the empirical long term performance model of a particular layer / material considering the critical response value calculated. Where the structural capacity of the particular layer equals or exceeds the calculated design traffic loading, a green ‘Success’ symbol is shown at the end of the results table. Where the structural capacity of the particular layer is less than the calculated design traffic loading, a red ‘Fail’ symbol is shown at the right end of the results table. Where a selected material/layer’s long term performance is not modelled an orange ‘No Model’ symbol is shown.

N/Nf shows the ratio of the structural capacity of a pavement layer within the pavement system to the design traffic loading. Values greater than 1 indicate layer failure. Values less than or equal to one indicate sufficient structural capacity.

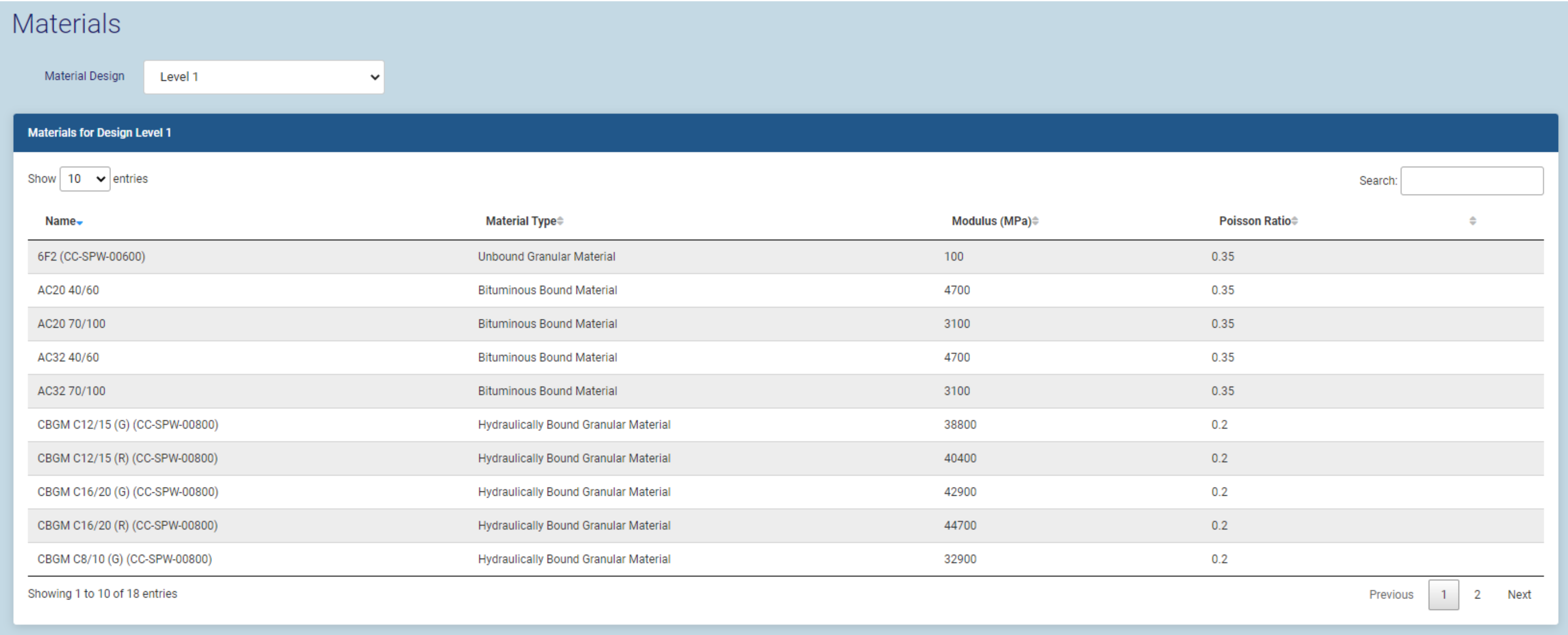
C1.2.2.6 Material Database

The material database allows for the definition of a pavement material for use as a layer within a pavement structure. Within the IAPDM there are two levels of sophistication of pavement material definition and long term performance characterisation. Pavement materials can be defined to Design Level 1 or Design Level 2.

Design Level 1 (DL1)

DL1 materials are characterised during production and construction based on their constituent and mixture requirements as detailed in the relevant TII Publication Specification for Road. Pavement materials characterised to DL1 have long term performance characteristics which are pre-set within the IAPDM. A list of DL1 pavement materials are available for selection by the user within the 'Pavement Structure' tab where the pavement layers, associated materials and layer thickness are defined. These materials are specified predominantly based on requirements for constituent materials and mixture composition however some performance related specifications are required for bituminous bound and hydraulically bound materials.

The materials available to the user under Design Level 1 are shown within the 'Material Database' as depicted in Figure C.7 below.



Name	Material Type	Modulus (MPa)	Poisson Ratio
6F2 (CC-SPW-00600)	Unbound Granular Material	100	0.35
AC20 40/60	Bituminous Bound Material	4700	0.35
AC20 70/100	Bituminous Bound Material	3100	0.35
AC32 40/60	Bituminous Bound Material	4700	0.35
AC32 70/100	Bituminous Bound Material	3100	0.35
CBGM C12/15 (G) (CC-SPW-00800)	Hydraulically Bound Granular Material	38800	0.2
CBGM C12/15 (R) (CC-SPW-00800)	Hydraulically Bound Granular Material	40400	0.2
CBGM C16/20 (G) (CC-SPW-00800)	Hydraulically Bound Granular Material	42900	0.2
CBGM C16/20 (R) (CC-SPW-00800)	Hydraulically Bound Granular Material	44700	0.2
CBGM C8/10 (G) (CC-SPW-00800)	Hydraulically Bound Granular Material	32900	0.2

Figure C.7 Material Database - Design Level 1 Materials

Design Level 2 (DL2)

The IAPDM provides the designer with an opportunity to better characterise the long term performance characteristics of a pavement material through additional performance tests. This gives the user the ability to consider the measured performance of a material rather than an assumed performance based on material constituents and mixture composition.

Within the 'Materials Database' the user can select Level 2 from the Material Design dropdown at the top of the page. Once Level 2 is selected a list of user defined DL2 materials will be shown. The user can add a new DL2 material by pressing the 'Add Material' button at the top of the page.

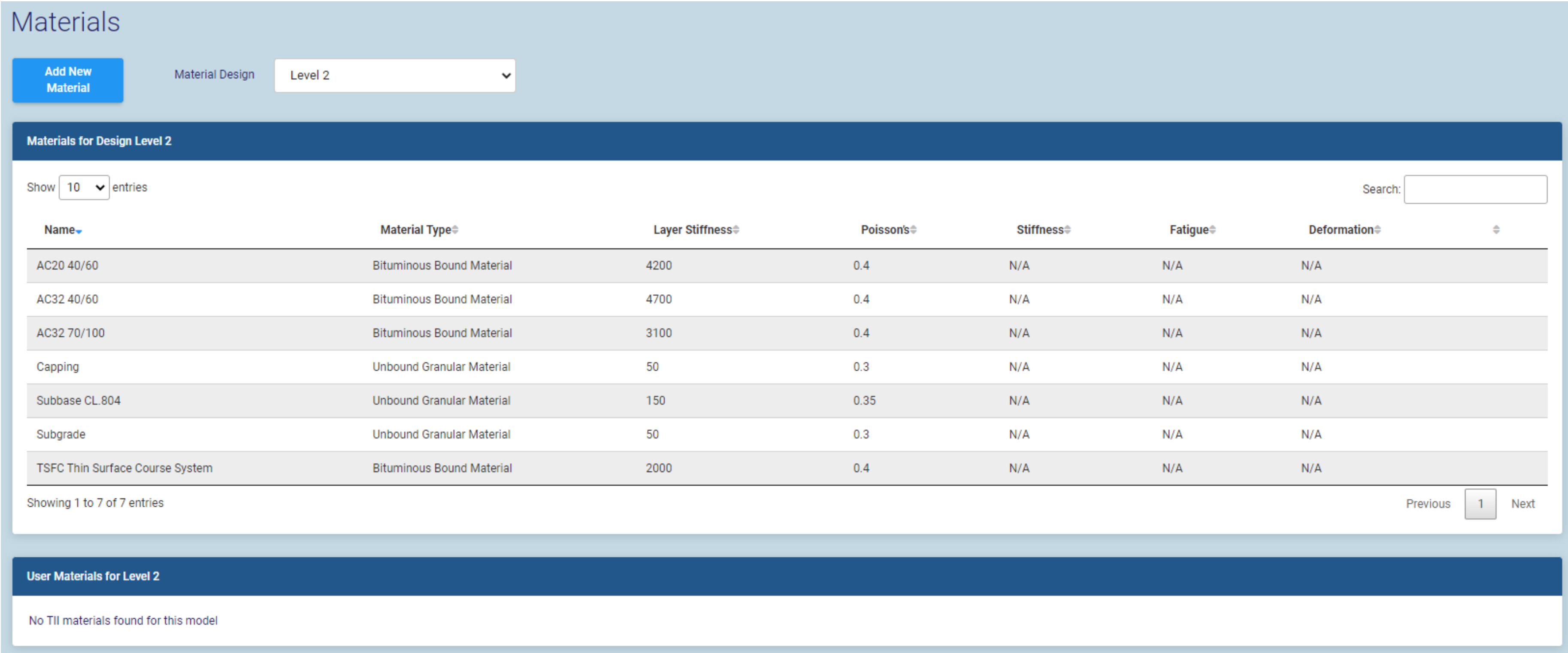


Figure C.8 Materials Database - Design Level 2 Materials

The add material popup is shown below. The user defines the naming of the material and the long term performance of the material based on a combination of laboratory testing of the materials and experience with the product from previous projects. Guidance on the inputs is provided below.

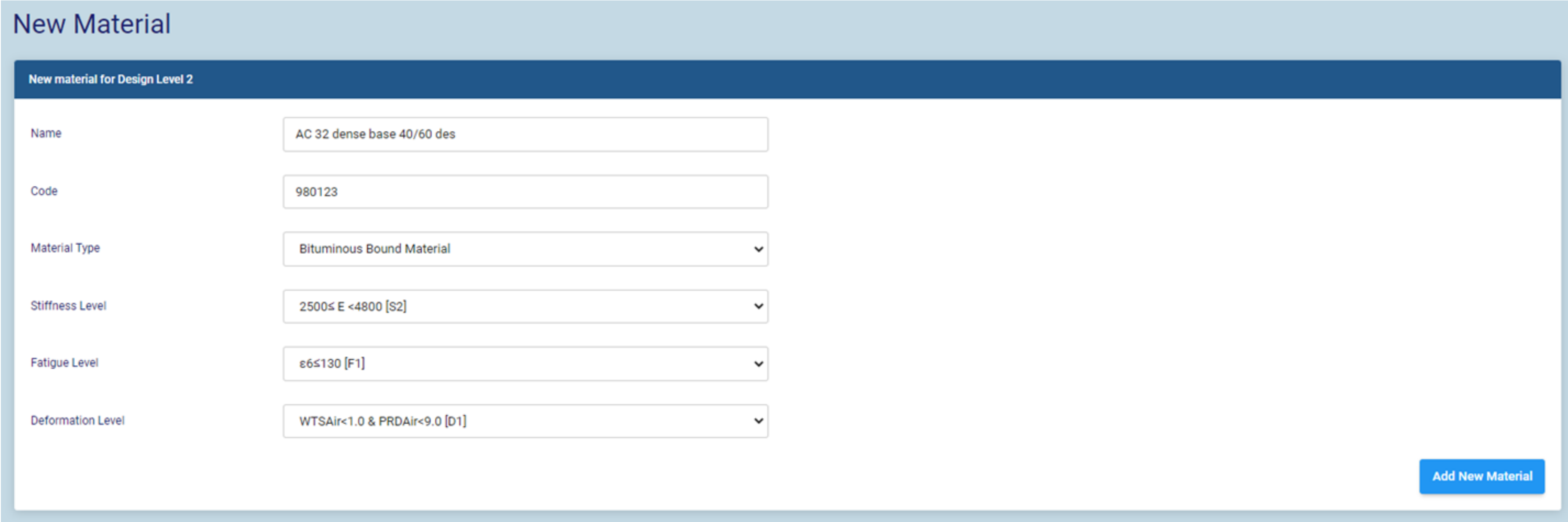


Figure C.9 Materials Database - DL2 Materials Input Form

Name as per the material naming structure used in the relevant material type TII Specification for Road Works document. For example asphalt concrete materials specified in CC-SPW-00900 are named in the following manner, ‘AC 32 dense base 40/60 des’. Additional suffixes will be added to the user defined named based on the performance levels selected for Stiffness, Fatigue and Deformation Levels.

Code is a user defined input which is typically a unique identifier for the material.

Stiffness Level is the stiffness category of the material defined by the user based on laboratory testing and pervious experience with the material. The selected stiffness parameters shown for each level relate to the performance limits the construction pavement layer / material are required to realise after construction.

Fatigue Level is the fatigue category of the material defined by the user based on laboratory testing and pervious experience with the material. The selected fatigue parameters shown for each level related to the performance limits the construction pavement layer / material are required to realise after construction.

Pavement materials designed to DL2 have additional works requirements related to the performance testing of the Works / constructed pavement layer. Limits with respect to the performance of the works are set based on the level of performance set when defining the DL2 material as described above. Appendix B details the list of performance categories, performance tests and required performance limits for each pavement material type.

C1.3 Worked Examples

C1.3.1 New Pavement Structure Design

C1.3.1.1 Background:

The Designer is tasked with designing a new pavement structure for the following design scenario:

f) Design Traffic for 40-year design period: 25 msa

g) Design Subgrade CBR (%): 4%

Step 1 – Project and Design Setup:

Create a new Design within an existing or new Project as shown in Figure C.10.

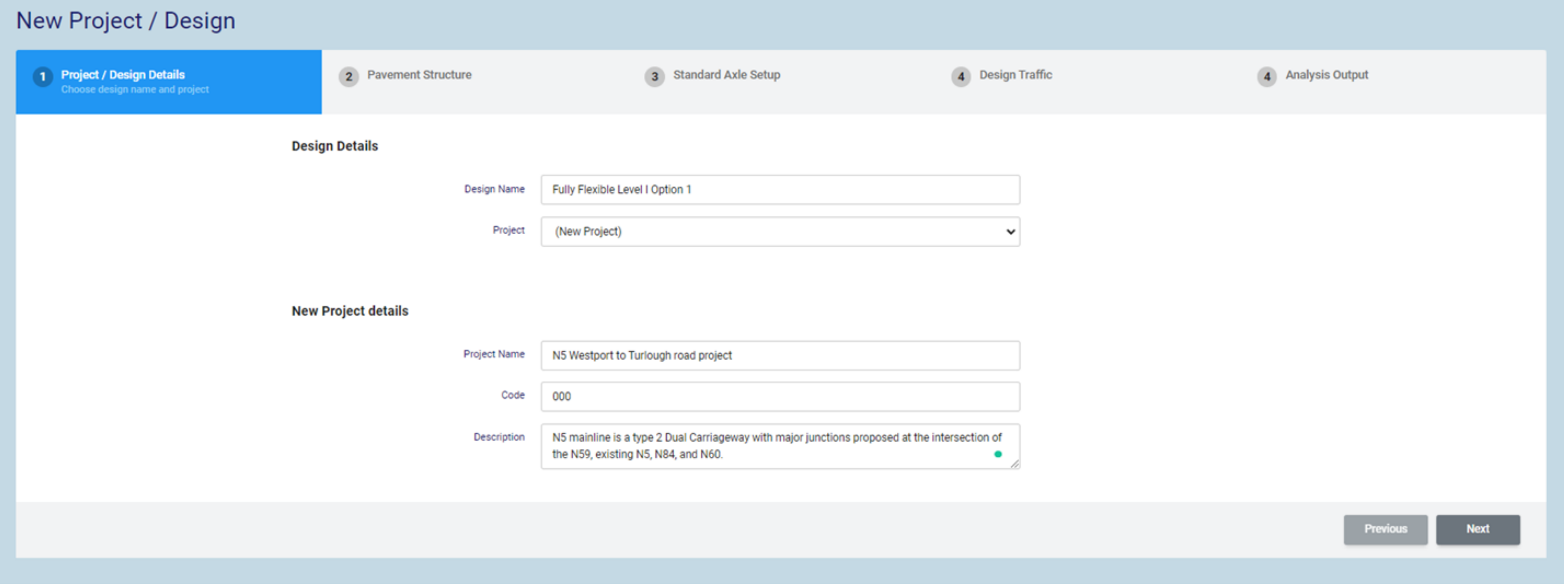


Figure C.10 IAPDM Screenshot - Step 1

Step 2 – Pavement Structure Definition:

The pavement structure build-up to be analysed within the IAPDM is defined through the form depicted in Figure C.11. An initial flexible pavement structure is inputted shown in Figure C.11 as a first iteration of a pavement design. In this example only Level 1 materials are considered.

For the subgrade design stiffness, the designer has the option to input the stiffness directly or the design CBR which will be converted to a design stiffness. Guidance on subgrade design stiffness and CBR is provided in DN-PAV-03021 Pavement and Foundation design.

The first pavement structure definition iteration can be seen below. Note that a design CBR of 4% is input which is equivalent to a subgrade design modulus of 43MPa.

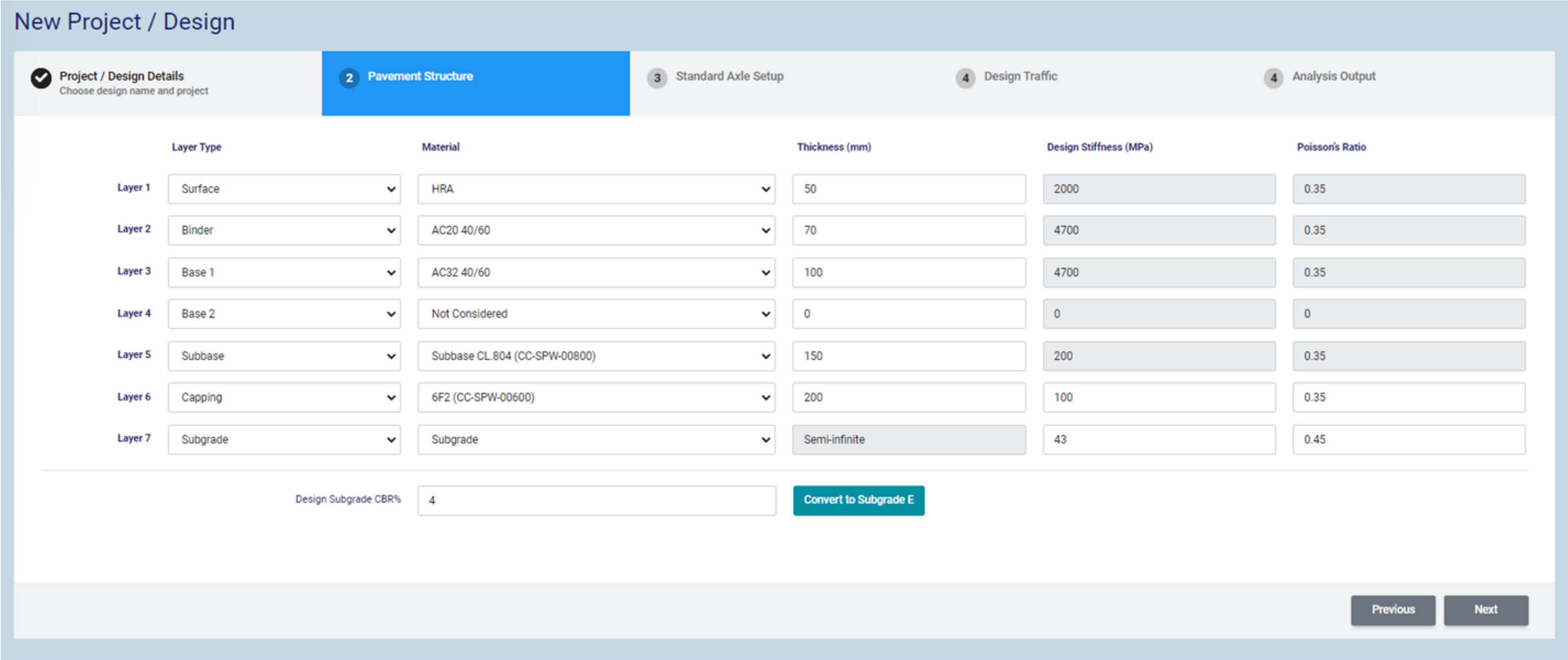


Figure C.11 IAPDM Screenshot – Step 2 Pavement Structure Definition

Step – 3: Determine the Axle Setup:

For this example the standard set up will be used as it is illustrated below:

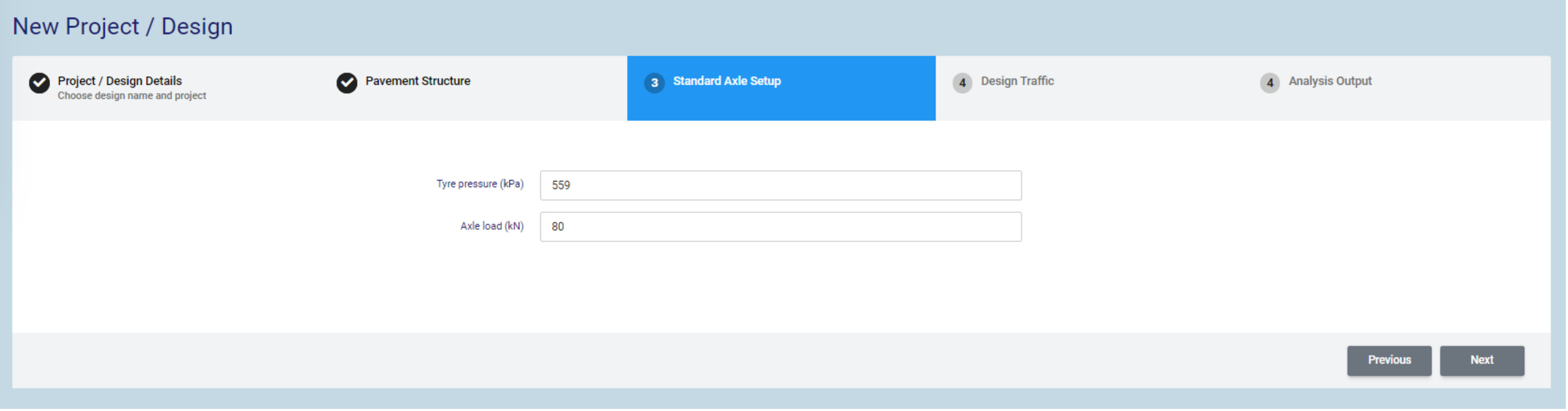


Figure C.12 IAPDM Screenshot – Step 3 Axle Setup determination.

Step – 4: Determine the Design Traffic

The Design Traffic for this example is equal to 25 MSA and it is inputted in the corresponding textbox.

Step – 5: Run the Analysis of the selected Structure

The result analysis for the first iteration can be seen in the figure below. The structural capacity of this pavement is 3 MSA. Because the expected traffic is 25MSA a second iteration is necessary where the capping layer will be increased by 100 mm and the base thickness will be increased by 85 mm.

Project : N5 Westport to turlough road project

Design Analysis for Fully Flexible Level 1 Option 1

Download Analysis Output

Analysis Output

Layer No	Layer Type	Material	Thickness (mm)	Design Stiffness (MPa)	Poisson's Ratio	Critical Response Type	Critical Response Value	Structural Capacity (msa)	N/Nf	
1	Surface	HRA	50	2000.00	0.35	No tension	0	0	0.00	Success
2	Binder	AC20 40/60	70	4700.00	0.35	epsilon r (Microns)	-13	42297	0.00	Success
3	Base 1	AC32 40/60	100	4700.00	0.35	epsilon r (Microns)	-128	3	8.04	Fail
4	Base 2	Not Considered	0	0.00	0.00	None	0	0	0.00	No Layer
5	Subbase	Subbase CL.804 (CC-SPW-00800)	150	200.00	0.35	N/a	0	0	0.00	No Model
6	Capping	6F2 (CC-SPW-00600)	200	100.00	0.35	N/a	0	0	0.00	No Model
7	Subgrade	Subgrade	Semi-infinite	43.00	0.45	epsilon z (Microns)	1812	2654	0.68	Success

FC = I

Edit Save

Pavement Structure

Standard Axle Setup

Design Traffic

Figure C.13 IAPDM Screenshot - Step 5 Results of the first iteration.

The second iteration of the pavement design analysis results can be seen below:

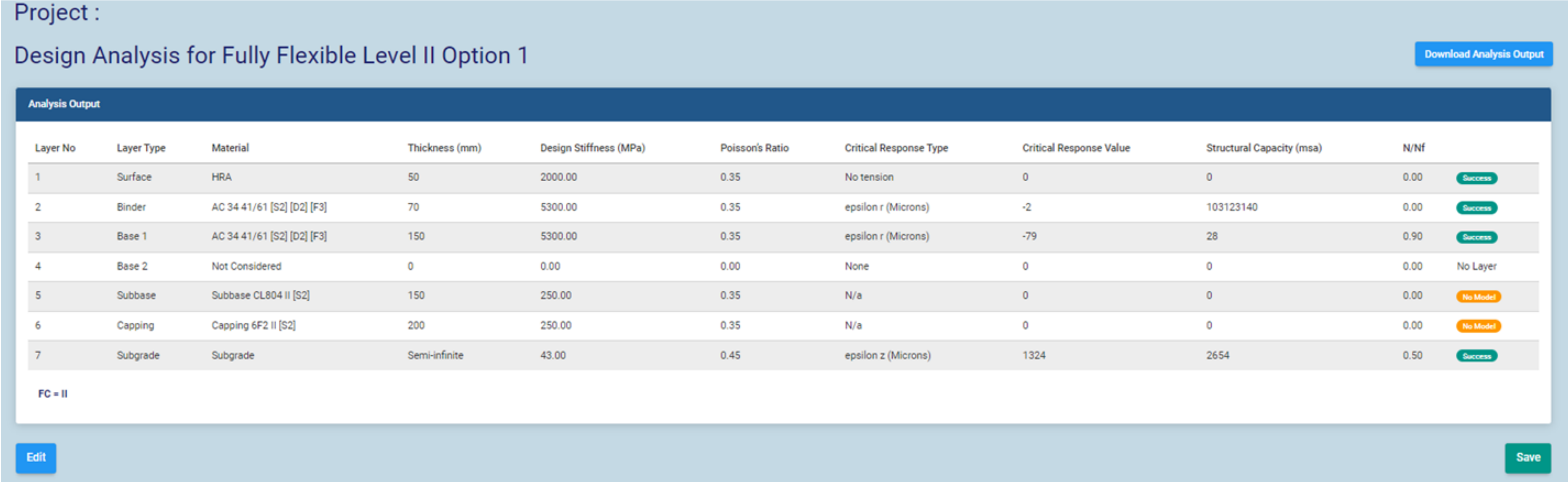
Layer No	Layer Type	Material	Thickness (mm)	Design Stiffness (MPa)	Poisson's Ratio	Critical Response Type	Critical Response Value	Structural Capacity (msa)	N/Nf	
1	Surface	HRA	50	2000.00	0.35	No tension	0	0	0.00	Success
2	Binder	AC20 40/60	70	4700.00	0.35	epsilon r (Microns)	-2	69915821	0.00	Success
3	Base 1	AC32 40/60	185	4700.00	0.35	epsilon r (Microns)	-77	26	0.95	Success
4	Base 2	Not Considered	0	0.00	0.00	None	0	0	0.00	No Layer
5	Subbase	Subbase CL.804 (CC-SPW-00800)	150	200.00	0.35	N/a	0	0	0.00	No Model
6	Capping	6F2 (CC-SPW-00600)	300	100.00	0.35	N/a	0	0	0.00	No Model
7	Subgrade	Subgrade	Semi-infinite	43.00	0.45	epsilon z (Microns)	1221	2654	0.46	Success

Figure C.14 IAPDM Screenshot Step 5 Results of Second iteration.

The structural capacity of the layer is 26MSA which is acceptable as it is above the required 25MSA.

The next step will be the solution of the same problem with the use of Level II materials. This will be done in order to showcase the savings of material between Level I and Level II.

The considered Level II pavement after analysis can be seen below:



Project :

Design Analysis for Fully Flexible Level II Option 1

Download Analysis Output

Analysis Output

Layer No	Layer Type	Material	Thickness (mm)	Design Stiffness (MPa)	Poisson's Ratio	Critical Response Type	Critical Response Value	Structural Capacity (msa)	N/Nf	
1	Surface	HRA	50	2000.00	0.35	No tension	0	0	0.00	Success
2	Binder	AC 34 41/61 [S2] [D2] [F3]	70	5300.00	0.35	epsilon r (Microns)	-2	103123140	0.00	Success
3	Base 1	AC 34 41/61 [S2] [D2] [F3]	150	5300.00	0.35	epsilon r (Microns)	-79	28	0.90	Success
4	Base 2	Not Considered	0	0.00	0.00	None	0	0	0.00	No Layer
5	Subbase	Subbase CL804 II [S2]	150	250.00	0.35	N/a	0	0	0.00	No Model
6	Capping	Capping 6F2 II [S2]	200	250.00	0.35	N/a	0	0	0.00	No Model
7	Subgrade	Subgrade	Semi-infinite	43.00	0.45	epsilon z (Microns)	1324	2654	0.50	Success

FC = II

Edit Save

Figure C.15 IAPDM Screenshot – Results of Level II materials pavement

A total of 100mm savings in Capping material as well as 35mm savings in bituminous material.

C1.3.2 Existing Pavement Structural Evaluation and Strengthening Design

C1.3.2.1 Background

The Designer is asked to assess an existing pavement structure and, if required, design a pavement rehabilitation intervention that will allow the pavement to carry an additional 10 MSA for a 20 year design period.

The designer should follow the procedures detailed in AM-PAV-06050 for the overall assessment of an existing pavement structure. Guidance provided here focuses on the process to carry out a remaining life and rehabilitation design analysis for an existing pavement using the IAPDM.

For a pavement rehabilitation design, the designer is required to consider a wide range of pavement condition and materials data in order to determine the most suitable pavement intervention. As part of this assessment the designer is required to identify design sections / homogenous sections of pavement. A rehabilitation design is carried out per design section. Design sections are identified based on the interrogation of existing pavement data and condition typically presented through strip maps.

In order to carry out an existing pavement remaining life and rehabilitation design in the IAPDM, the designer requires the following information per design section:

i. Pavement structure layer thicknesses and material types – determined from trial hole, coring and/or Ground Penetrating Radar (GPR) investigations.

ii. Pavement layer stiffnesses back-calculated from the homogenous section 85th percentile deflection bowl. Note bituminous materials require temperature correction to 20°C from the temperature of the bituminous material at the time of FWD testing.

For the example analysis presented here the existing pavement structure data is used is provided in Table C.2.

Table C.2 Existing pavement structure information

Layer	Material Type	Thickness (mm)	Stiffness (MPa)
1	Bituminous	155	3250*
2	Unbound Granular	500	354
3	Subgrade	Semi-inf	291
*Temperature corrected			

The remaining life and rehabilitation design procedures within the IAPDM software are detailed through the following steps.

C1.3.2.2 Insert the Characteristic values of the existing pavement.

Add the new materials of the existing pavement for the bituminous and subbase part in the library.

Figure C.16 IAPDM Screenshot – Insert Existing Material with characteristic values.

The new pop up window is shown in Figure C.17:

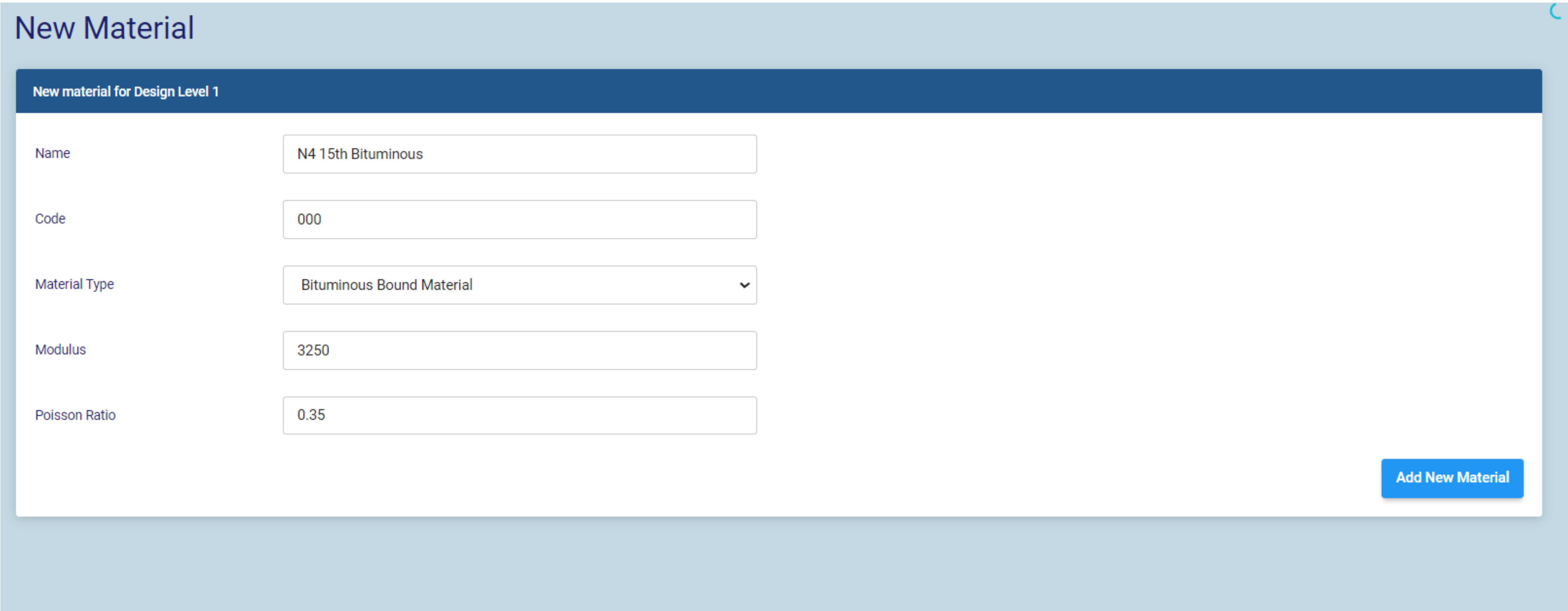


Figure C.17 IAPDM Screenshot – Pop Up material to insert the existing Material as level I.

Two new materials must be added, one for characterising existing bituminous layers and another for the existing subbase of the pavement structure. The subgrade modulus can be changed directly in the pavement structure definition tab.

C1.3.2.3 Create a new design and project

Create the design and project to save the work similar to the previous example in order to estimate the remaining of the existing pavement.

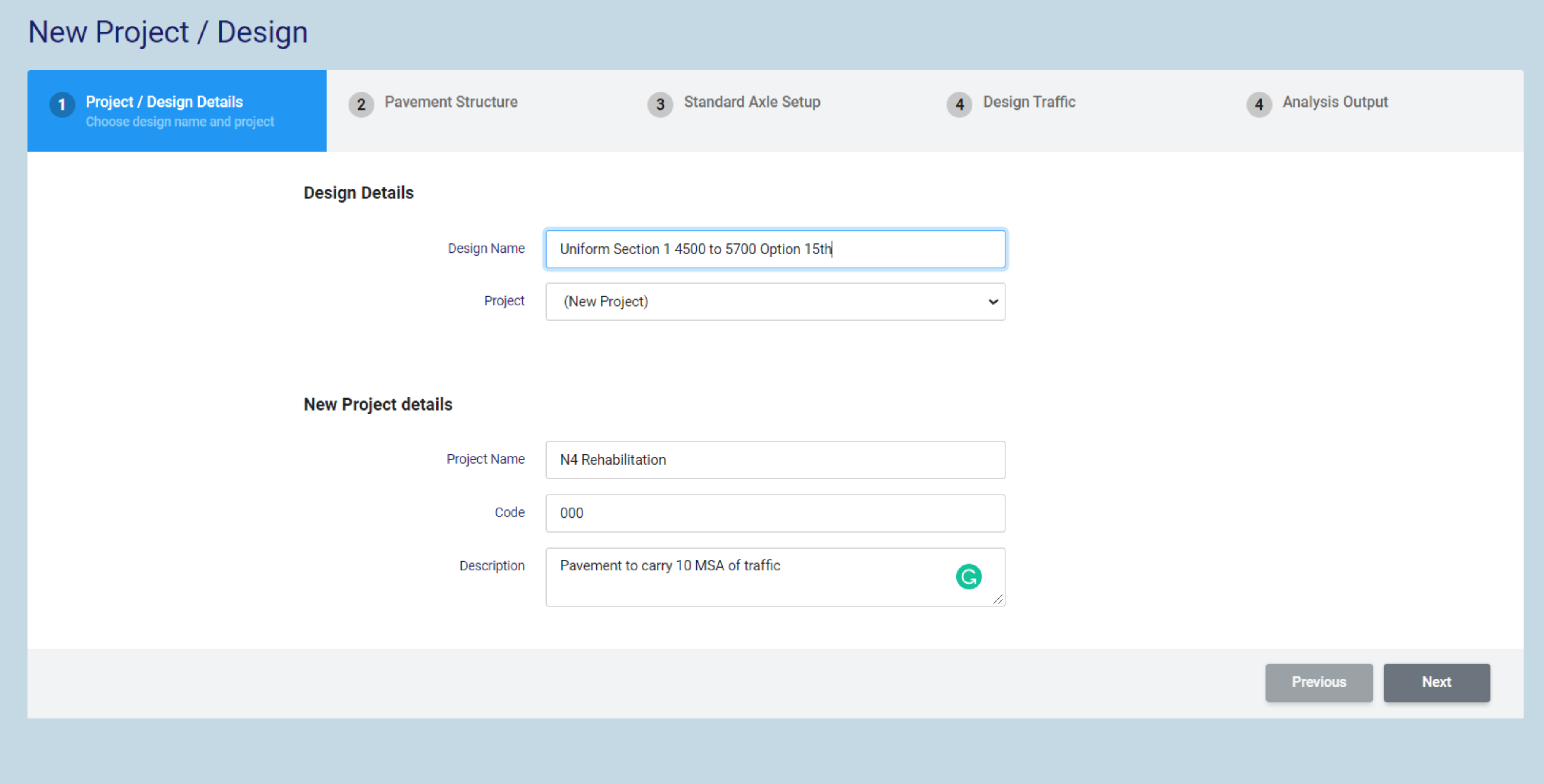
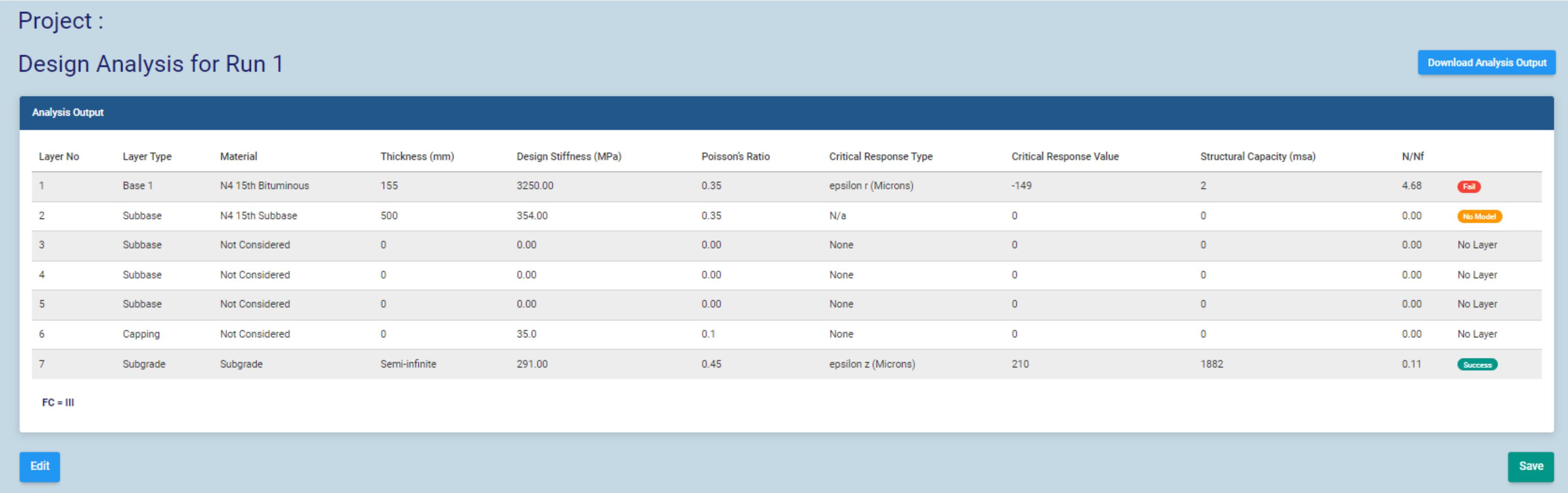


Figure C.18 IAPDM Screenshot – Creation of the new design and project.

C1.3.2.4 Estimate the remaining life

Create a pavement design analysis incorporating the existing pavement structure information provided in Table C.2. The existing pavement structure analysis is shown in Figure C.19 below. A remaining life of 2 MSA is calculated by the tool which indicates the pavement structure is not structurally sufficient to carry the predicted future traffic loads.



Project :

Design Analysis for Run 1

Download Analysis Output

Analysis Output

Layer No	Layer Type	Material	Thickness (mm)	Design Stiffness (MPa)	Poisson's Ratio	Critical Response Type	Critical Response Value	Structural Capacity (msa)	N/Nf	
1	Base 1	N4 15th Bituminous	155	3250.00	0.35	epsilon r (Microns)	-149	2	4.68	Fail
2	Subbase	N4 15th Subbase	500	354.00	0.35	N/a	0	0	0.00	No Model
3	Subbase	Not Considered	0	0.00	0.00	None	0	0	0.00	No Layer
4	Subbase	Not Considered	0	0.00	0.00	None	0	0	0.00	No Layer
5	Subbase	Not Considered	0	0.00	0.00	None	0	0	0.00	No Layer
6	Capping	Not Considered	0	35.0	0.1	None	0	0	0.00	No Layer
7	Subgrade	Subgrade	Semi-infinite	291.00	0.45	epsilon z (Microns)	210	1882	0.11	Success

FC = III

Edit

Save

Figure C.19 IAPDM Screenshot - Results of remaining life of existing pavement.

C1.3.2.5 Create a new design and project

Create the rehabilitation design and project to save the work similar to the previous example.

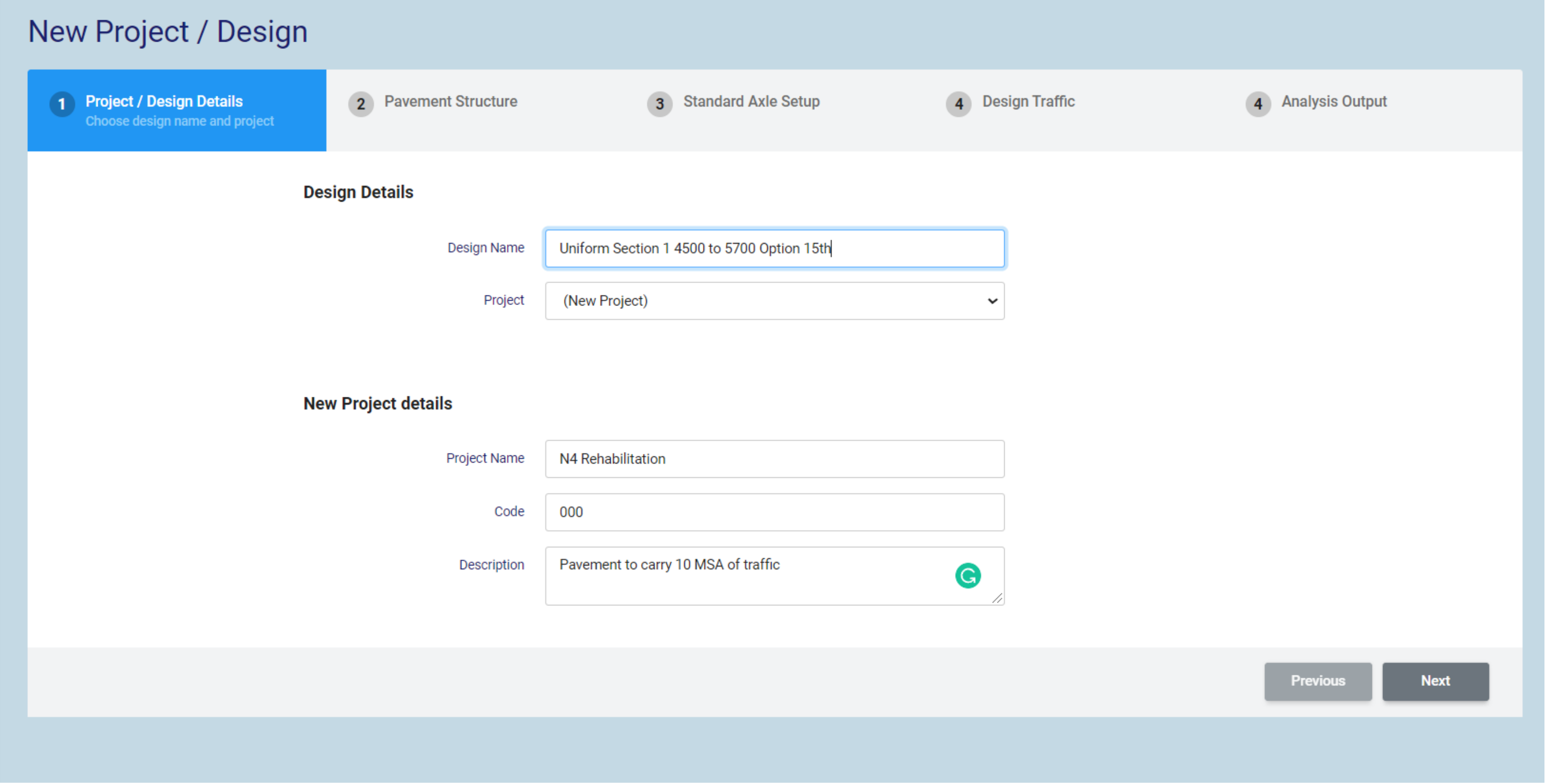


Figure C.20 IAPDM Screenshot – Creation of the new design and project.

C1.3.2.6 Overlay Design first iteration.

Determine the build-up for the first iteration. Analysis of the surface course determines that it should be milled out to a depth of 50mm.The layer one will be for the surfacing of the overlay and will be equal to 35mm, the layer 2 will be the second layer of the overlay and equal to 55 mm while layer 3 will represent the bituminous layer of the existing pavement minus the 50mm that will be milled out. Finally layer 4 will represent the subbase of the existing pavement.

First analysis for the characteristic values:

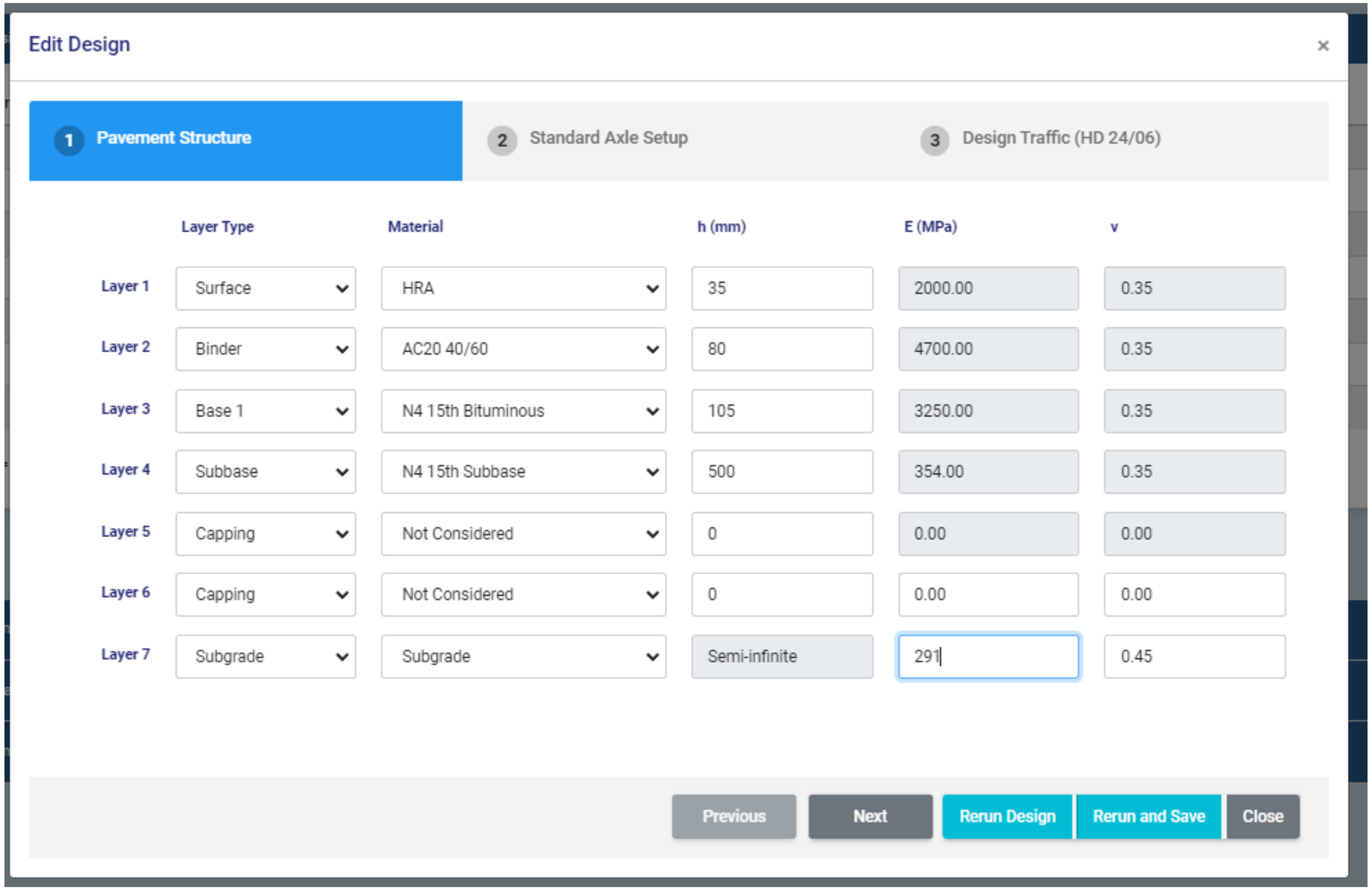


Figure C.21 IAPDM Screenshot – Build-up of overlay in the existing pavement

C1.3.2.7 Input Design Traffic

Determine the axle setup, for this example the standard set up will be used.

The design traffic for this example is equal to 10 MSA and it is inputted in the corresponding textbox.

C1.3.2.8 Pavement Strengthening Design Output

The result analysis for the selected overlay structure can be seen below:

Analysis Output

Layer No	Layer Type	Material	Thickness (mm)	Design Stiffness (MPa)	Poisson's Ratio	Critical Response Type	Critical Response Value	Structural Capacity (msa)	N/Nf	
1	Surface	HRA	35	2000.00	0.35	No tension	0	0	0.00	Success
2	Binder	AC20 40/60	80	4700.00	0.35	epsilon r (Microns)	-32	1058	0.01	Success
3	Base 1	N4 15th Bituminous	105	3250.00	0.35	epsilon r (Microns)	-101	11	0.91	Success
4	Subbase	N4 15th Subbase	500	354.00	0.35	N/a	0	0	0.00	No Model
5	Capping	Not Considered	0	0.00	0.00	None	0	0	0.00	No Layer
6	Capping	Not Considered	0	35.0	0.1	None	0	0	0.00	No Layer
7	Subgrade	Subgrade	Semi-infinite	291.0	0.45	epsilon z (Microns)	210	1882	0.11	Success

FC = III

Edit   Save

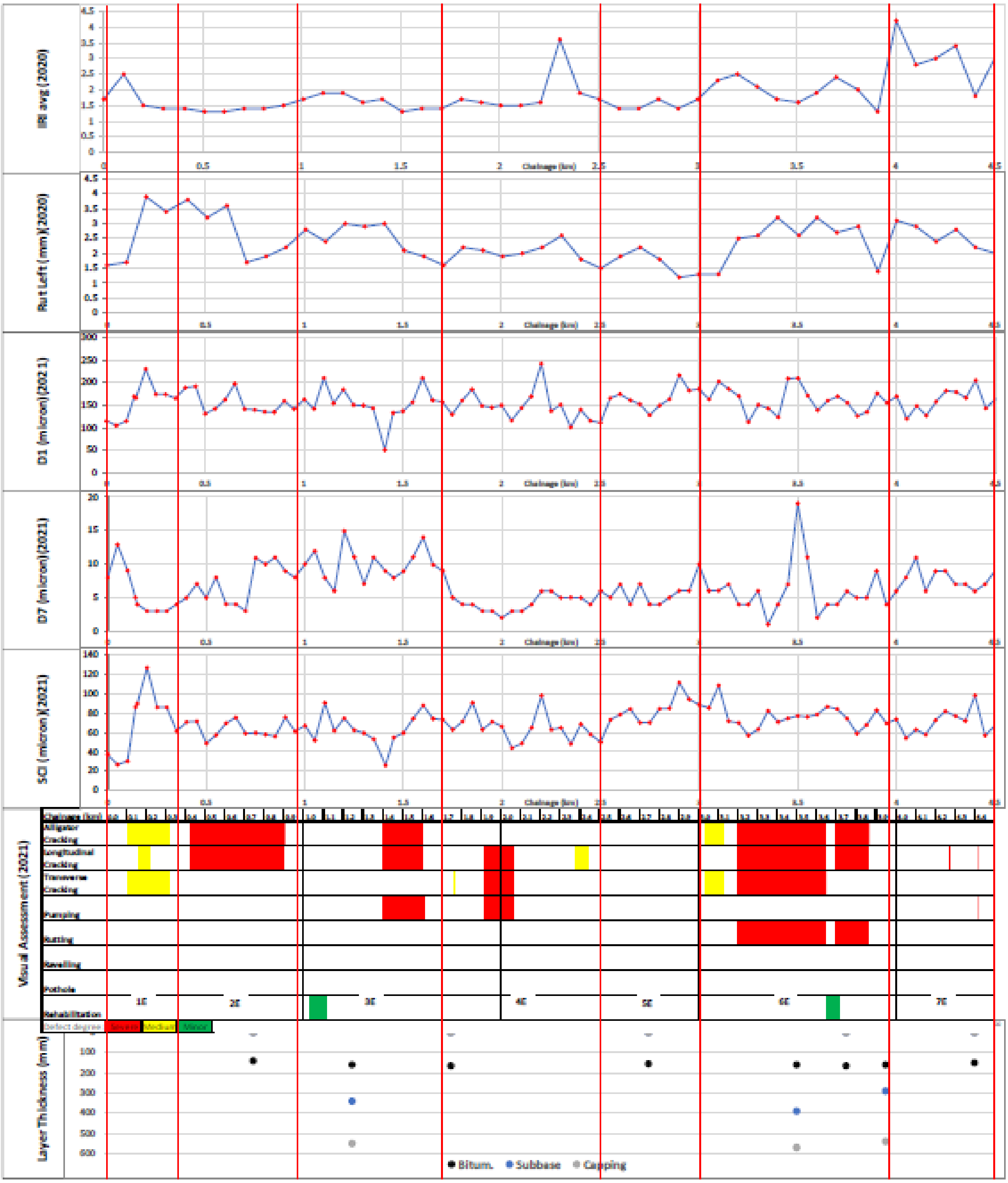
Figure C.22 IAPDM Screenshot – Results of the selected Overlay design

The structural capacity of the layer is 11MSA which is acceptable as it is above the required 10MSA.

Note: As detailed in AM-PAV-06050, it is important for the designer to consider a range of pavement condition indicators when assessing the remaining life and determining a rehabilitation intervention of an existing pavement structure. For example the presence of alligator cracking or excessive rutting may indicate that the existing bituminous layer should be removed and that an overlay alone may not be a suitable solution.

Appendix D:

Extended Scheme Design Strip Map Example


IRI avg (2020)
Rut Left (mm)(2020)
D1 (micron)(2021)
D7 (micron)(2021)
SCI (micron)(2021)
Chainage (km)
Visual Assessment (2021)
Alligator Cracking
Longitudinal Cracking
Transverse Cracking
Pumping
Rutting
Ravelling
Pothole
Rehabilitation
Defect degree
Severe
Medium
Minor
1E
2E
3E
4E
5E
6E
7E
Layer Thickness (mm)
Bitum.
Subbase
Capping

Appendix E:

Distress Mechanism, Cause and Intervention Guidance

Table E1 Bound material fatigue failure mechanism assessment

Distress Consideration	Observation	Outcome	Reference
Mechanism	Is alligator or longitudinal cracking present?	If 2/3 observations are confirmed then the bound pavement layers can be described as having fatigue cracking.	3.2.3.1
	Is the depth of cracking through the full depth of the bound layers?		3.2.3.3 and 3.2.4.2
	Are bound back-calculated stiffnesses within the red/poor category?		3.3.2
Cause	Are the bound layer mixtures samples within grading, voids and binder content SPW requirements?	If 1/2 observations are confirmed then the bound material quality may be a contributing factor to development of the observed distress.	3.2.4.3
	Is bituminous material binder penetration significantly lower than expected material SPW requirements?		
	Are supporting layers back-calculated stiffness with the red/poor category?	If yes, then the bound layers may have insufficient structural support.	3.3.2
	Has the pavement structure carried its expected design traffic loading?	If none of the above causes are positively identified the pavement may have reached the end of its design life.	3.4.2
Intervention	Do cores and trial pit observations indicate cracking is predominantly full depth?	If the bound layer is fatigued or of poor quality through the full depth of the layer then full depth replacement of the layer should be considered.	3.2.3.3 and 3.2.4.2
	Are the bound layer mixture samples within grading, voids and binder content SPW requirements?		3.2.4.3
	Is the extent of alligator and longitudinal cracking greater than 15% of the design section length?	If the extent of the observed distress is greater than 15% of the design section length consideration should be given to applying the required intervention to the full length of the pavement section.	3.2.3.1
	Is the rut depth in the left wheel path in the red/poor category?	If yes then observed fatigue cracking may be inducing moisture ingress and permanent deformation in supporting unbound granular layers.	3.3.2

Table E2 Permanent deformation failure mechanism assessment

Distress Consideration	Observation	Outcome	Data Reference
Mechanism	Is the rut depth in the left wheel path in the red/poor category?	If 2/4 observations are confirmed then the pavement can be described as having significant permanent deformation within the pavement structure.	3.3.2
	Has the visual assessment identified deformation in the wheel paths?		3.2.3.1
	Do cores across the observed deformation indicate deformation in bound layers i.e. varying heights?		3.2.3.3
	Do trial pit profile observations indicate deformation in unbound granular layers?		3.2.4
Cause	Are the unbound granular mixtures sampled within SPW requirements for the expected material type?	If observations are confirmed then the material quality may be a contributing factor to development of the observed distress.	3.2.4.3
	Is bituminous material grading significantly outside of the material SPW requirements?		
	Is bituminous material binder content or penetration significantly greater than the expected material SPW requirements?		
	Are supporting layers back-calculated stiffness within the red/poor category?	If yes, then the layers may have insufficient structural support.	3.3.2
	Has the pavement structure carried its expected design traffic loading?	If none of the above causes are positively identified the pavement may have reached the end of its design life.	3.4.2
Intervention	Has deformation been identified in the bituminous bound layers only?	If the bituminous material is not fatigued, the layer may be reprofiled and overlain if required for strengthening. If the layer is fatigued, the layer will be replaced.	3.2.3.3 and 3.2.4.2
	Has deformation been identified in the unbound bound granular layers, including subgrade, only?	A pavement overlay or inlay should be considered to protect the unbound granular materials. If high moisture contents have been noted in the UGM and subgrade then drainage issues should be investigated and remedied.	

Distress Consideration	Observation	Outcome	Data Reference
		High moisture contents due to moisture ingress through a fatigued bound layers will be rectified when the bound layers are replaced.	

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