Irish Analytical Pavement Design Method (IAPDM)

The case for IAPDM
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Mechanistic Empirical Pavement Design
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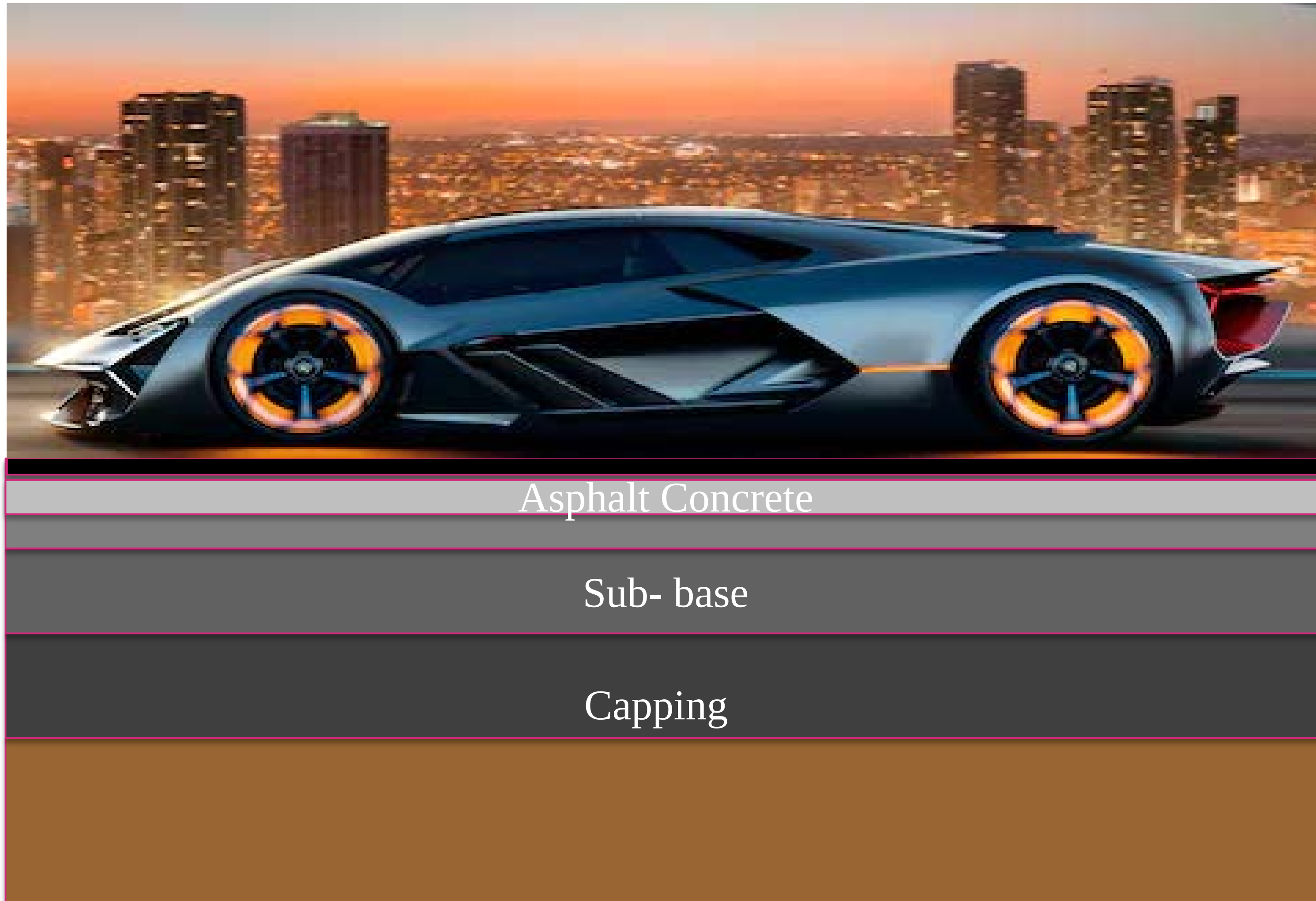
TII Roads Conference - 28th September 2018

ARUP

Principles of road pavement



WHY?

Here is WHY?

- Pavement Design should be based on sound engineering principles.

- The current Design Method contained within TII Publications does not allow the Designer to properly capture and use the inherent mechanical properties of either the constituent materials or the mixes.

- Research has shown Ireland is behind the curve of other many other countries

- It is estimated that the Mechanistic Empirical method may reduce the thickness of a new long life pavement by on average 15% saving approximately **€8M** for a 25km Irish Road scheme and approximately **€1.5M** per annum on road maintenance schemes

It is a sustainable solution

Targeted Designs using the mechanical properties of the Constituent Materials and the Products

Less Materials

Less Transport

Less Congestion/Less Disruption

TII Publications

GE PE DN CC OP AM RE

Current Design (TII Publications)

Traffic Assessment PE-SMG-02002

TRL Report PPR 066 (2006)

Pavement & Foundation Design DN-PAV-03021

TRL Report LR 1132 (1984)

TRL Report LR 1132

$$CAM = \frac{1}{NPL}\left[\sum_{i}\sum_{j=1}^{3} k_j n_{ij}\left(\frac{P_i}{P_0}\right)^{\alpha}\right]$$

TRL Report 615

$$Ti = W \times P \times 10^{-6} \times 365 \times Fo \times Y \times G \text{ (msa)}$$

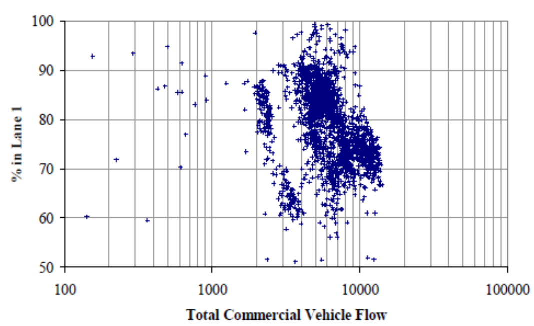
2.4 The factors used to calculate the Design Traffic (T) are as follows:

- Commercial Vehicle Flow at opening (F);
- Design Period (Y);
- Growth Factor (G);
- Wear Factor (W); and
- Percentage of vehicles in the heaviest loaded lane (P).

Multi Layer Linear Elastic modelling

$$AWF = \left(1 + 6(DLC)^2 + 3(DLC)^4\right) \times \left(WC \times CP \times LE \times AC \times S\right)^4$$

Pavement Wear Factors



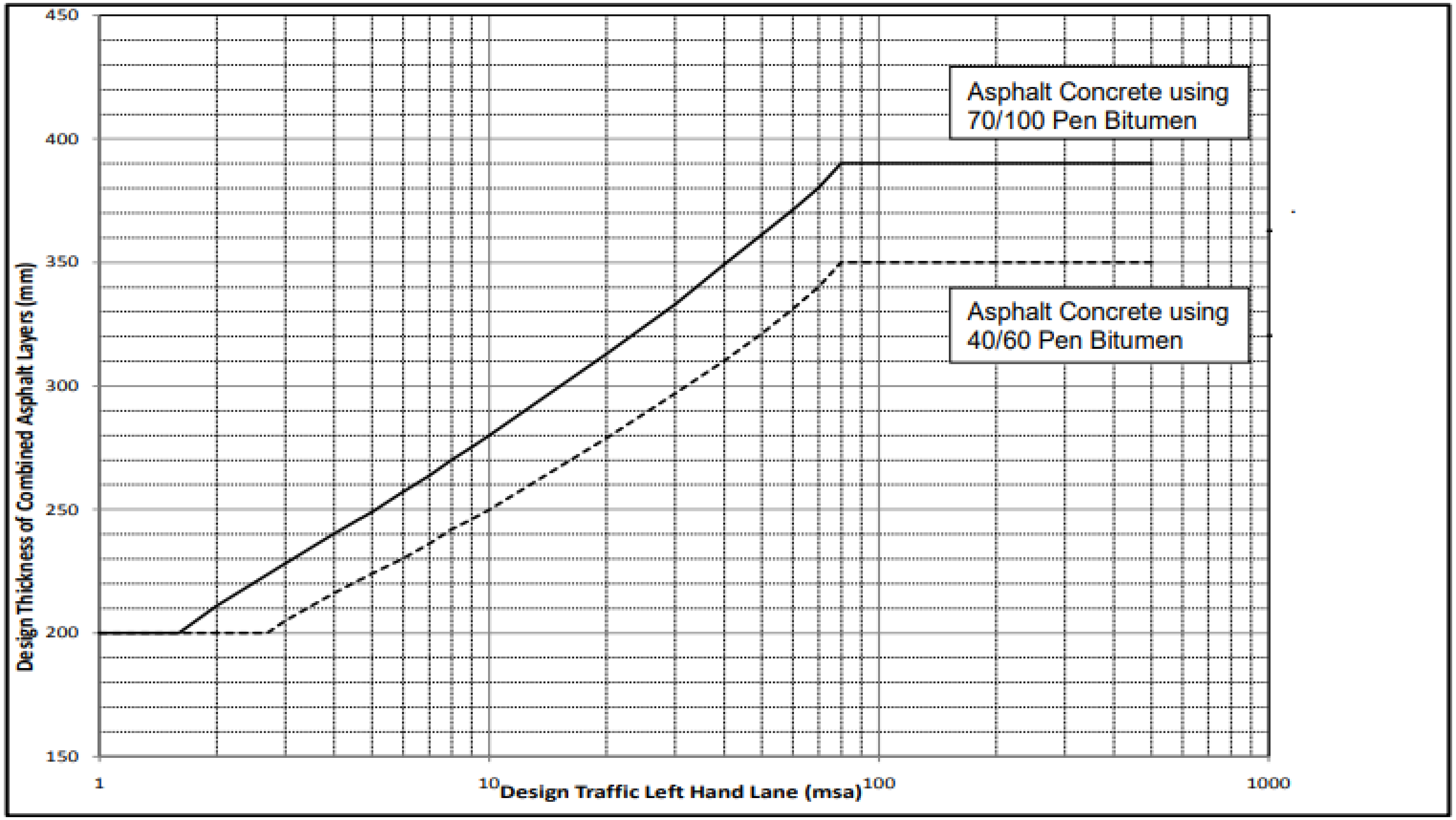
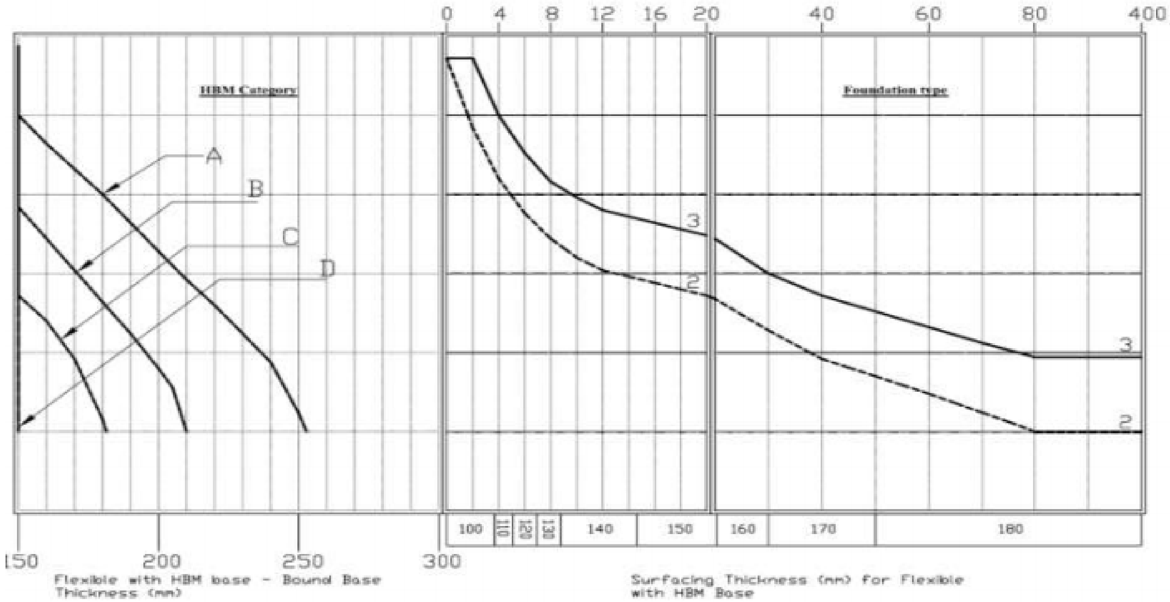


Figure 4.2 Design chart for fully flexible pavement



Hydraulic Bound Base Material Category

HBM Category	A	B	C	D
Crushed Rock Coarse Aggregate: (with coefficient of thermal expansion < 10x10-6 per °C)	-	CBGMB - C8/10 (T3)	CBGMB - C12/15 (T4)	CBGMB - C16/20 (T5)
Gravel Coarse Aggregate: (with coefficient of thermal expansion ≥ 10x10-6 per °C)	CBGMB - C8/10 (T3)	CBGMB - C12/15 (T4)	CBGMB - C16/20 (T5)	-

We can do better!!!!

Irish Analytical Pavement Design Method

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Mechanistic Empirical Pavement Design

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Features of the Mechanistic Empirical Pavement Design Method (MEPDM)

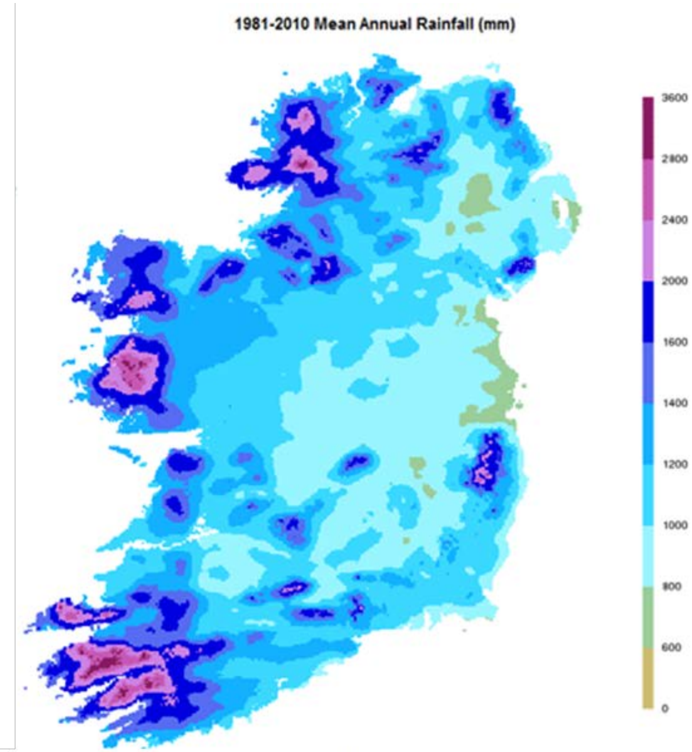
- Input Traffic, Environmental, and Material Properties
- Response Model based on Engineering Mechanics
- Distress Model and Transfer Functions to relate critical parameters to failure mechanisms

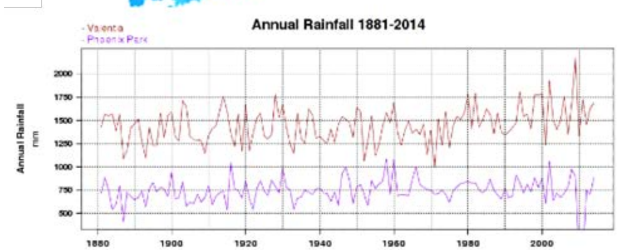
Modern International Approach

- MEPDM has been adopted in the USA, France, Sweden, South Africa, New Zealand, Australia and many other countries
- Road Pavement Design is based on actual measured material properties
- Actual recorded data from WIM surveys, meteorological records and traffic forecasts can be used to optimise life cycle road pavement design

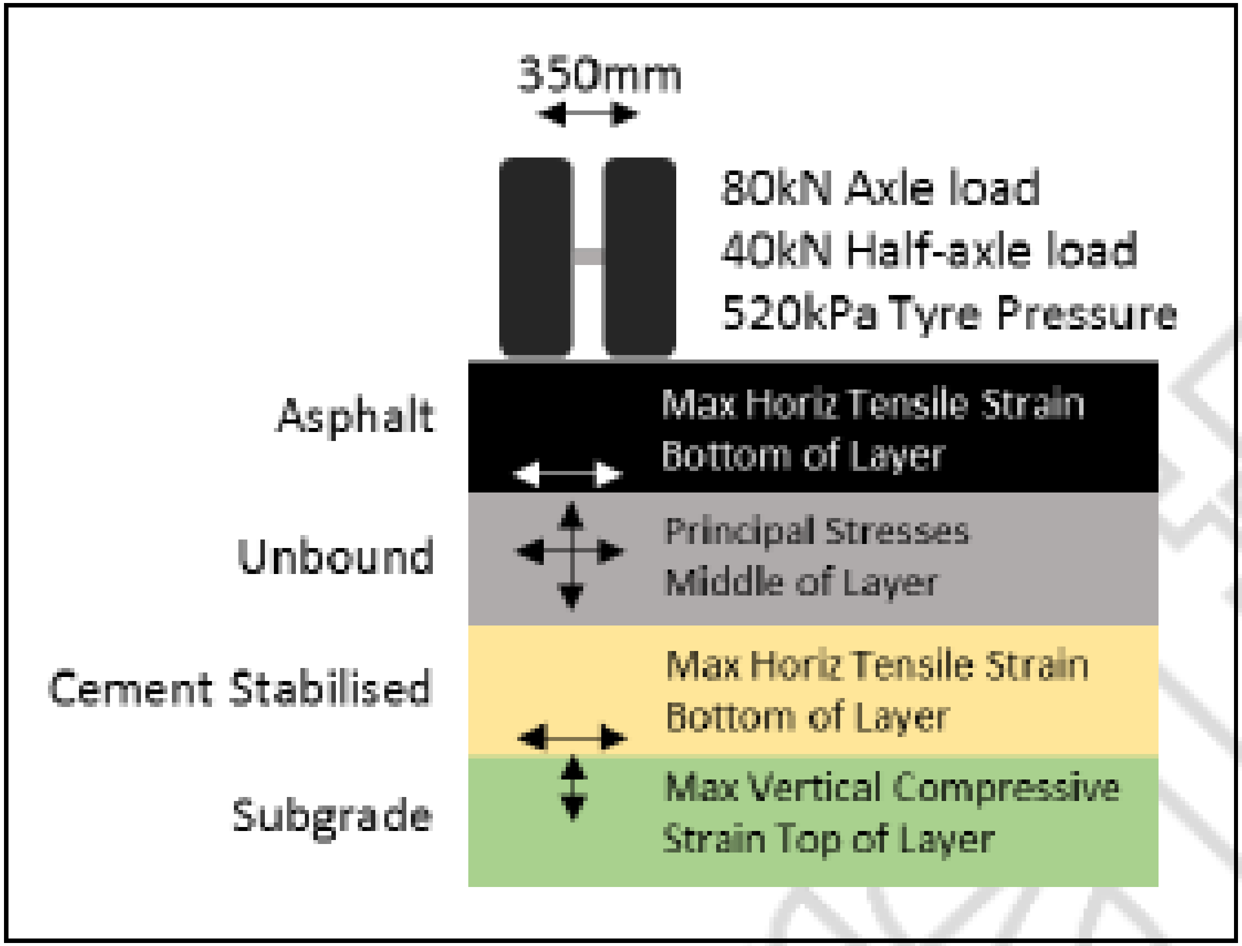
Mechanistic Empirical Pavement Design Method (MEPDM)

Traffic Load & Climatic Data



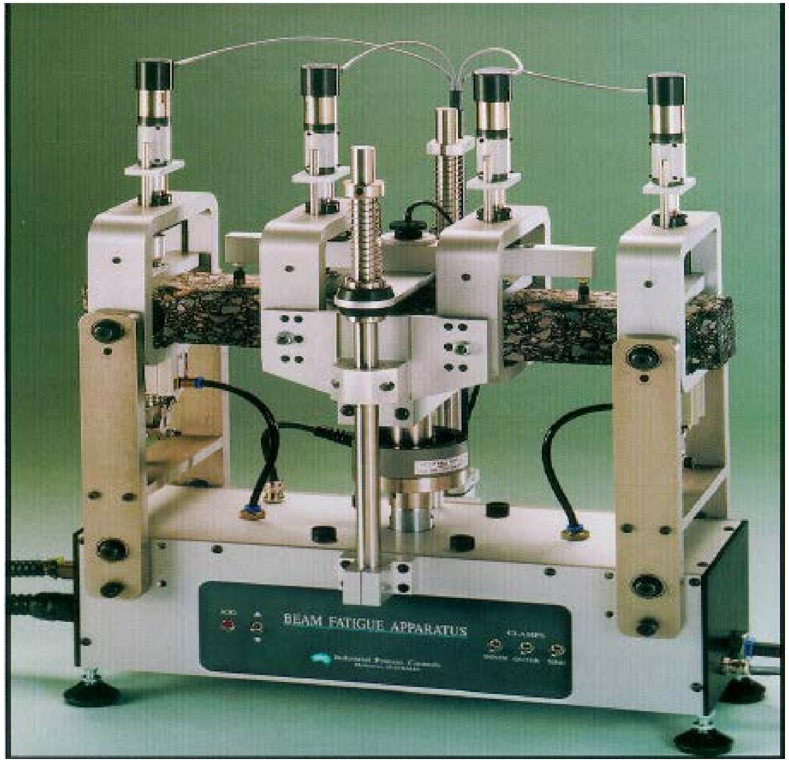


Pavement Structure



Example of Material Characterisation for Bituminous Layer

- Different frequencies to simulate different traffic speeds
- Different temperatures to consider climatic effects
- Different strain levels



AMADEUS - Response Models

Software Name	Method Used in response model	Type *	Non Linearity	Rheology	Anisotropy	Interface	Climatic effects	Dynamic loading	Axle spectrum	Tyre characteristics	Stochastic	Crack propagation	Thermal effects	Cumulated damage	Fatigue	Permanent Def
APAS-WIN	Multilayer	3					Y		Y	Y			Y		Y	
AXYDIN	Axi-symmetric FEM	1						Y								
BISAR/SPDM	Multilayer	3				Y	Y		Y						Y	Y
CIRCLY	Multilayer	3			Y	Y			Y	Y				Y	Y	
CAPA-3D	3D-FEM	3	Y	Y	Y	Y		Y		Y		Y	Y	Y	Y	Y
CESAR **	3D-FEM	3	Y	Y	Y	Y	Y	Y		Y	Y	Y		Y	Y	Y
ECOROUTE **	Multilayer	1				Y				Y				Y		
ELSYM 5	Multilayer	1														
KENLAYER	Multilayer	2	Y	Y		Y		Y		Y				Y	Y	Y
MICHPAVE	Axi-symmetric FEM	1	Y												Y	
MMOPP	Multilayer	2	Y				Y	Y	Y	Y	Y	Y		Y	Y	Y
NOAH	Multilayer	3			Y	Y	Y		Y		Y				Y	Y
ROADENT/WESLEA ***	Multilayer	2				Y	Y		Y	Y						
SYSTUS	3D-FEM	2	Y	Y	Y	Y		Y		Y		Y				
VAGDIM 95	Multilayer	3					Y						Y	Y	Y	Y
VEROAD	Multilayer	1		Y					Y	Y	Y					
VESYS	Multilayer	3					Y		Y	Y	Y			Y	Y	Y

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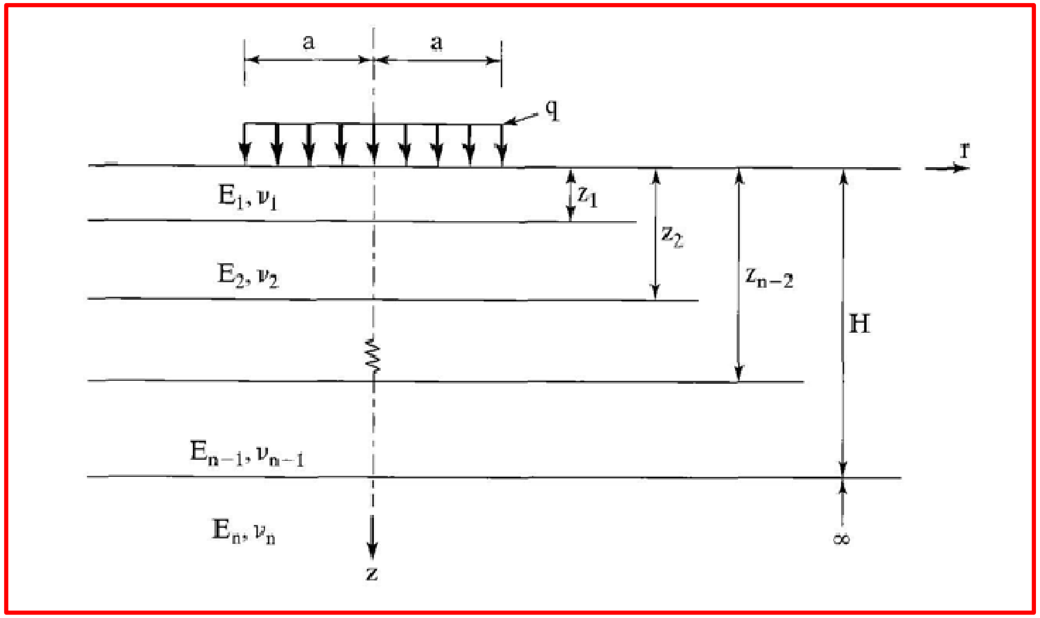
IAPDM - Response Model (TIIPAV)

- Based on Multi-Layer Linear Elastic (MLLE) theory
- Wheel load can be single or dual wheel
- Layer *n* is a semi-infinite elastic half-space
- E_i & v_i denotes Modulus of Elasticity & Poisson's Ratio of each layer *i*



Distress Models & Calibration

- Transfer/Distress Functions
  - Example Bitumen
    - $N_t=10^{-3.083}*\varepsilon_t^{-3.291}*E^{-0.854}$

Calibration of distress models with measured response in Irish roads is in progress

Iterative Recursive Analyses

- Miner's Law in relation to varying stress is:

$$\sum_{i=1}^{k} \frac{n_i}{N_i} = C$$

where

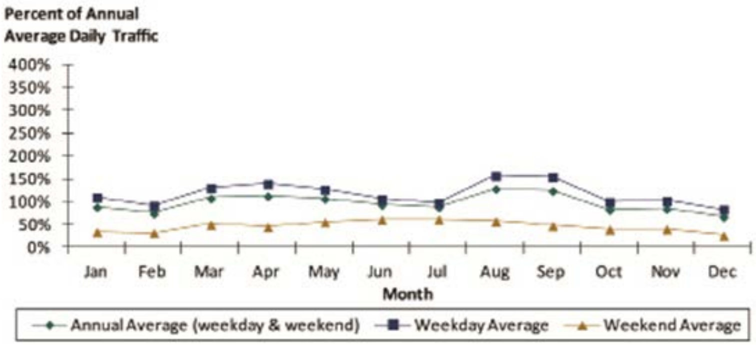
k = different stress magnitude

n_i = number of cycles applied at stress level Δ

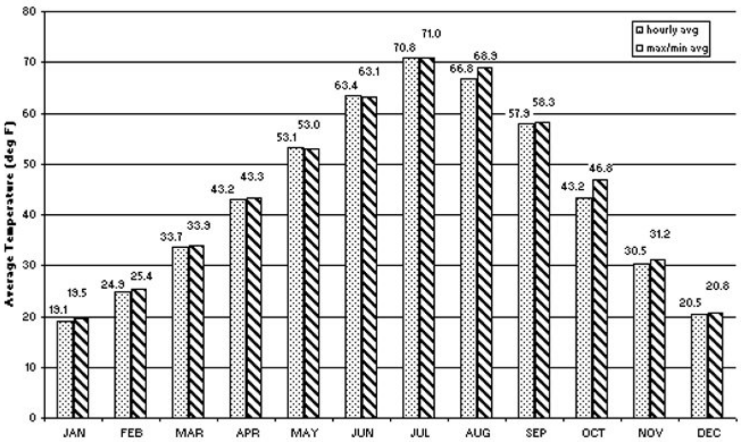
N_i = number of cycles to failure at stress level Δ

C is normally taken as 1

Traffic Variation



Temperature Variation



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Failure Modes

Ref. No	Description of Mechanism	M-E Analysis
1	Deformation in the bituminous layers;	Yes
2	Cracking initiated at the surface;	Yes
3	Longitudinal unevenness;	Yes+geotechnical & workmanship
4	Loss of skid resistance;	
5	Cracking initiated at the bottom of the base course;	Yes
6	Surface cracking;	Yes?
7	Ravelling;	
8	Deformation in the subgrade;	Yes
9	Frost heave;	
10	Wear due to studded tyres;	
11	Low temperature cracking;	
12	Permanent deformation from unbound layers.	Yes

Hierarchical Input to Response Model

- Input level 1 - Input parameters measured directly, site or project specific
- Input level 2 - Input parameters estimated from correlations or regression equations which are based on previous experience
- Input level 3 - Best estimated or default values

THANK YOU