Pavement Structural Evaluation Viewing and Interpretation

Deflectometer (FWD/TSD/MSD)

Introduction

The files in this set are for preliminary evaluation of pavements on which Falling Weight Deflectometer (FWD) testing with full bowl analysis or Traffic Speed Deflectometer testing has been carried out, using either the Austroads empirical method or the widely recognised mechanistic-empirical method. For Multi-Speed-Deflectometer (MSD) screening, empirical methods are often appropriate, but systems are being developed to create equivalent FWD files if required.

The raw FWD data file is initially checked for bowl errors and a layer model is defined, preferably using supplied information, or by assuming default layer thicknesses. The file is then back-analysed through ELMOD to obtain moduli. If no layer information has been supplied, the thicknesses are modified so that the resulting model has decreasing moduli with depth.

Once the model has been defined, a series of calculations are performed providing a suite of output parameters including rehabilitative options, remaining life, and structural numbers. The road is then divided into uniform segments for construction that are used to calculate the sectionalised overlays and reconstruction depths.

An automatically generated graphical PDF report is produced assuming an overlay of the existing surface material. Statistical parameters are calculated and shown in summary pages to assist with the design.

It is most important that the client has provided:

- Purpose – what the desired use of the FWD data is in terms of construction QA, rehabilitation or network data collection. This is essential because for old pavements the rehabilitation requirements are of relevance while for newly constructed pavements the structural quality and expected life are usually required.
- Design Traffic and Design Life – check that the design life and design traffic (usually 25-year ESA) assumed in the analysis are as required for each road before adopting overlays or residual lives. This is critical if using Austroads GMP.
- Precedent Overlay Parameters – if using the Precedent overlay design methods, check that the key parameters are supplied, namely the ratio of future to past ESA and percentage of road in a terminal condition. If remaining life is an issue, check to see that distress information is also supplied (i.e. HSD rutting and roughness).

- As-built Information – verify the model conclusions by checking reliable as-built information (if available) or carry out at least one test pit (after FWD) at the weakest point. By carrying out destructive tests after the FWD information is received, the number of test pits may be substantially reduced (by targeting the critical areas only).

Personnel with appropriate local experience should verify that detailed visual assessment of pavement distress is fully consistent with this interpretation. If otherwise, it is important to contact us, as in a minority of cases there can be alternative analysis techniques that could be more appropriate for the situation.

Interpretation

Preliminary analyses are based on vertical strain accumulation in unbound granular pavements, and further processing with good as built layer information will be required to assess solutions for any bound layers (e.g. AC or stabilised basecourse) where horizontal tensile strains will lead to cracking. Overlay for AC surfacing assumes any cracking is first removed and replaced.

New pavements will generally increase in stiffness over the first year of trafficking. For unbound granular layers, if moduli do not consistently decrease with depth, preliminary results may be overly conservative; hence adapting layer thicknesses and remodelling to ensure there are no moduli inversions will usually give more appropriate life predictions.

To get detailed background on the use of deflection data, please see our FWD information and interpretation website: Pavement Analysis

Provided Data

Excel spreadsheets may be viewed which contain all of the raw and processed data. Each column heading in the Detail spreadsheet has a comment providing more information about that parameter.

A standard PDF report is provided which is intended for rehabilitation evaluation (focussing on only one of the various overlay options) with summary tables, per point data tables and colour graphs.

The MSD has been developed locally because unbound pavements with high deflections are widespread. The MSD is not as accurate as the TSD, but readings can be made in both wheel-paths and at 1 m centres. Moreover, it can test at any speed, wet or dry conditions and can also record deflections on unsurfaced gravel roads if the surface is compact. This means the MSD can also be used during construction of either cohesive or compact granular materials as each layer is placed. It can also be used for maintenance dig-outs to test the effective stiffness of each repair prior to surfacing. After placing and compacting any layer, a contractor may collect over 100 tests and determine stiffnesses all within 2 minutes. Therefore, the MSD usefully fills gaps that up until now have only been provided by slower or less readily available FWD, LWD or Beam (more testing higher quality). For MSD screening with empirical outputs, the equivalent Adjusted Structural Number (SNP) may be generated for dTIMS users, but this method is overly simplistic and loses much of the recovered information when it is condensed in this "one size fits all" approach. MSD output can be converted to any of the FWD empirical parameters, but can now be provided as a more general set of structural indices: SLI, BLI and LLI (Surface, Base and Lower Layer Index) obtained from beneath a large-single wheel in a similar manner to those reported by Horak (2008) for dual wheels and NZTA RR401 for FWD. It should be noted that traditional 2-D deflection measurements between the wider load spacing of dual wheels are well suited to pavements that reach a terminal condition due to excessive strains at depth, i.e. those with thick structural asphaltic layers. On the other hand, where a thin surfacing is used on an unbound granular basecourse, then determining the 3-D deformations directly beneath a heavily loaded large-single enables much more relevant properties to be characterised in that upper layer. NZTA, contractors and researchers (Bailey, Patrick & Jackett et al 2006), commonly consider that the great majority of NZ unbound pavements reach a terminal condition due to upper layer distress. In other words, subgrade rutting is seldom the reason for rehabilitation. The large-single wheel indices for MSD are available now, although development is in progress. In future, having 3 parameters empowers users who prefer to continue with empirical parameters, to be more informed regarding which is the layer that governs the life of the pavement, rather than losing this information in a single number which is the critical disadvantage of SNP. The layer which is terminal will usually dictate the most practical and economic form of rehabilitation treatment. Trying to relate SNP to remaining life, given that the prediction may be out by an order of magnitude either way, cannot help but be problematic. The most positive incremental step for dTIMS users who find SNP inadequate, is to adopt multiple structural indices, as promoted using any of the above 3 methods. It is important these empirical methods are confined to network structural evaluation of low volume roads. Full mechanistic evaluation (i.e. 4th generation TSD in the long term, short term FWD) should always be adopted for project level design or for QA of any marginal cases for new construction.

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FWD Pavement Structural Evaluation
PROJECT: Granular Pavement

Job Number:
Test Date: 15/06/1994
Overlay: Granular (mm)

Ave Surf Temp: #DIV/0!
Seasonal Factor: 1.00
Isotropic Modulus: 330 MPa

Layering Data Source: Analyst Inferred
Traffic Data Source: Client AADT
Distress Data Source: Site Inspection

Pavement Model

Chainage		Surfacing		Layer Types / Depths								Traffic Parameters			Design	
From	To	Type	Thick.	1		2		3		4		AADT	ESA_0	Grow.	Life	Traffic
(km)			(mm)		(mm)		(mm)		(mm)		(mm)			(%)	(yrs)	(ESA)
0.010	2.404	CS	25	UB	125	UB	150	UB	150			1366	3.E+04	3.0	25	1.00E+06
2.404	3.100	CS	25	UB	125	UB	175	UB	175			1366	3.E+04	3.0	25	1.00E+06

Structural Evaluation (ELMOD) & Sub-Sectioning of Uniform Treatment Intervals

Chainage		Layer 1 Mod.		Subgrade Mod.		Subgrade CBR		Central Defl.		Curvature		Life		SNP	Critical Layer
From	To	50%	10%	50%	10%	50%	10%	50%	95%	50%	95%	50%	10%	50%	
(km)		(MPa)		(MPa)				(mm)		(mm)		(yrs)			
0.010	0.163	952	662	85	52	17.6	11.9	0.531	0.713	0.165	0.233	99	96	4.4	5
0.163	0.488	504	334	44	33	9.6	6.5	0.912	1.330	0.277	0.544	52	24	3.5	5
0.488	0.823	772	371	75	60	15.5	12.8	0.672	0.983	0.211	0.375	99	79	4.0	5
0.823	1.410	505	327	41	26	8.4	4.2	1.019	1.594	0.309	0.540	41	9.6	3.3	5
1.410	2.263	1008	681	56	19	8.4	2.7	0.680	1.211	0.176	0.275	86	18	3.8	5
2.263	2.763	561	373	19	11	2.7	1.2	1.146	2.363	0.298	0.536	18	0.001	2.3	5
2.763	2.913	417	194	7	6	0.6	0.5	1.164	2.496	0.324	0.576	2.8	0.001	0.6	5
2.913	2.963	279	279	4	4	0.2	0.2	1.215	1.380	0.311	0.336	0.001	0.001	0.0	5
2.963	3.100	537	383	15	11	1.9	1.2	1.360	2.146	0.320	0.489	8.8	0.1	2.0	5

Recommendations for Rehabilitation

Strain Criteria: Austroads GMP-Rigorous (All Layers)

#	Chainage		Length	Granular Overlay	Minimum Reconstruction or Widening Depth
	From	To			
	(km)		(km)	(mm)	(mm)
2	0.010	0.163	0.153	0	430
3	0.163	0.488	0.325	0	460
4	0.488	0.823	0.335	0	430
5	0.823	1.410	0.588	50	510
6	1.410	2.263	0.853	0	570
7	2.263	2.763	0.500	110	700
8	2.763	2.913	0.150	170	840
9	2.913	2.963	0.050	220	999
10	2.963	3.100	0.138	110	680

Note - overlay thickness is determined as 90 percentile strengthening for each section to accommodate the design traffic, but greater thicknesses may be required for shape correction or to meet minimum basecourse thickness and subbase drainage requirements.

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FWD Pavement Structural Evaluation
PROJECT: Granular Pavement

Job Number: 0
Test Date: 15/06/1994
Overlay: Granular (mm)

Ave Surf Temp: #DIV/0!
Seasonal Factor: 1.00
Isotropic Modulus: 330 MPa

Layering Data Source: Analyst Inferred
Traffic Data Source: Client AADT
Distress Data Source: Site Inspection

FWD Data Summary

Loc.	Lane	Path	Resilient Moduli					CBR	Life	Layer Depths				Crit. Layer	Cent. Defl.	Curv. Func.	SNP	Depth RCN	Gran. OVL
			E1	E2	E3	E4	Esg			1	2	3	4						
(km)			(MPa)						(yrs)	(mm)					(mm)	(mm)		(mm)	(mm)
0.010	CL		965	217	120		55	12	99	125	150	150		5	0.66	0.19	4.0	430	0
0.025	CL		800	320	177		74	18	99	125	150	150		5	0.53	0.16	4.4	430	0
0.050	CL		1533	276	152		165	26	99	125	150	150		5	0.41	0.12	4.8	430	0
0.075	CL		952	321	177		87	18	99	125	150	150		5	0.50	0.16	4.5	430	0
0.100	CL		1200	227	126		118	21	99	125	150	150		5	0.51	0.16	4.5	430	0
0.125	CL		697	221	122		85	16	99	125	150	150		5	0.66	0.23	4.1	430	0
0.150	CL		662	243	134		52	12	96	125	150	150		5	0.71	0.22	4.0	430	0
0.175	CL		334	111	61		40	8	25	125	150	150		5	1.23	0.42	3.1	430	0
0.200	CL		504	260	143		83	18	99	125	150	150		5	0.64	0.25	4.2	430	0
0.220	CL		414	176	97		37	8	48	125	150	150		5	0.96	0.30	3.3	440	0
0.225	CL		590	286	158		75	16	99	125	150	150		5	0.62	0.22	4.2	430	0
0.250	CL		232	110	61		39	8	24	125	150	150		5	1.33	0.54	3.0	430	0
0.275	CL		464	131	73		23	4	15	125	150	150		5	1.19	0.35	2.5	530	50
0.325	CL		514	134	74		33	7	33	125	150	150		5	1.05	0.32	3.1	460	0
0.350	CL		725	152	84		44	10	66	125	150	150		5	0.86	0.25	3.6	430	0
0.375	CL		623	120	66		63	13	64	125	150	150		5	0.91	0.28	3.7	430	0
0.400	CL		849	193	107		68	13	93	125	150	150		5	0.71	0.21	4.0	430	0
0.420	CL		392	178	98		101	17	91	125	150	150		5	0.84	0.36	3.8	430	0
0.425	CL		748	247	136		106	17	99	125	150	150		5	0.61	0.21	4.2	430	0
0.450	CL		678	105	58		57	11	52	125	150	150		5	0.97	0.26	3.5	430	0
0.475	CL		449	136	75		43	9	42	125	150	150		5	1.03	0.33	3.3	430	0
0.500	CL		700	199	110		91	16	99	125	150	150		5	0.67	0.24	4.1	430	0
0.525	CL		1112	253	140		104	18	99	125	150	150		5	0.53	0.16	4.4	430	0
0.550	CL		825	323	178		164	27	99	125	150	150		5	0.45	0.19	4.7	430	0
0.575	CL		883	199	110		91	17	99	125	150	150		5	0.62	0.20	4.2	430	0
0.600	CL		803	290	160		84	16	99	125	150	150		5	0.57	0.20	4.3	430	0
0.625	CL		852	199	110		67	13	96	125	150	150		5	0.70	0.21	4.0	430	0
0.650	CL		660	172	95		67	13	86	125	150	150		5	0.78	0.24	3.9	430	0
0.675	CL		366	172	95		50	10	50	125	150	150		5	0.98	0.38	3.4	430	0
0.700	CL		772	201	111		75	15	99	125	150	150		5	0.68	0.22	4.0	430	0
0.725	CL		796	252	139		99	18	99	125	150	150		5	0.58	0.20	4.3	430	0
0.750	CL		947	233	129		85	16	99	125	150	150		5	0.59	0.19	4.3	430	0
0.775	CL		371	199	110		62	14	79	125	150	150		5	0.86	0.36	3.8	430	0
0.800	CL		700	130	72		72	16	93	125	150	150		5	0.80	0.26	3.8	430	0
0.820	CL		581	162	90		60	14	87	125	150	150		5	0.80	0.27	3.8	430	0
0.825	CL		496	149	82		43	10	53	125	150	150		5	0.96	0.32	3.5	430	0
0.850	CL		737	112	62		35	7	38	125	150	150		5	1.02	0.28	3.2	450	0
0.875	CL		505	87	48		34	6	17	125	150	150		5	1.28	0.39	2.9	460	50
0.900	CL		563	130	72		32	6	32	125	150	150		5	1.06	0.31	3.0	470	0
0.925	CL		703	99	55		39	8	41	125	150	150		5	1.04	0.29	3.3	430	0
0.950	CL		505	112	62		25	4	14	125	150	150		5	1.25	0.33	2.6	520	50
0.975	CL		383	79	44		26	4	4.4	125	150	150		5	1.59	0.44	2.3	510	70
1.000	CL		311	99	55		32	5	9.6	125	150	150		5	1.44	0.49	2.6	470	50
1.020	CL		261	78	43		16	2	0	125	150	150		5	2.07	0.55	1.4	600	110
1.025	CL		817	151	84		44	9	60	125	150	150		5	0.86	0.22	3.5	430	0
1.050	CL		455	133	74		33	6	26	125	150	150		5	1.13	0.34	3.0	470	0
1.075	CL		564	157	87		39	8	44	125	150	150		5	0.97	0.28	3.3	440	0
1.100	CL		588	152	84		38	6	34	125	150	150		5	1.02	0.28	3.2	460	0
1.125	CL		410	170	94		35	7	34	125	150	150		5	1.05	0.35	3.1	460	0
1.150	CL		496	187	103		115	22	99	125	150	150		5	0.70	0.31	4.1	430	0
1.175	CL		367	135	74		55	12	54	125	150	150		5	1.02	0.40	3.5	430	0
1.200	CL		677	238	131		75	16	99	125	150	150		5	0.65	0.23	4.1	430	0
1.220	CL		497	142	79		51	10	51	125	150	150		5	0.96	0.32	3.5	430	0
1.225	CL		868	201	111		95	18	99	125	150	150		5	0.61	0.20	4.2	430	0

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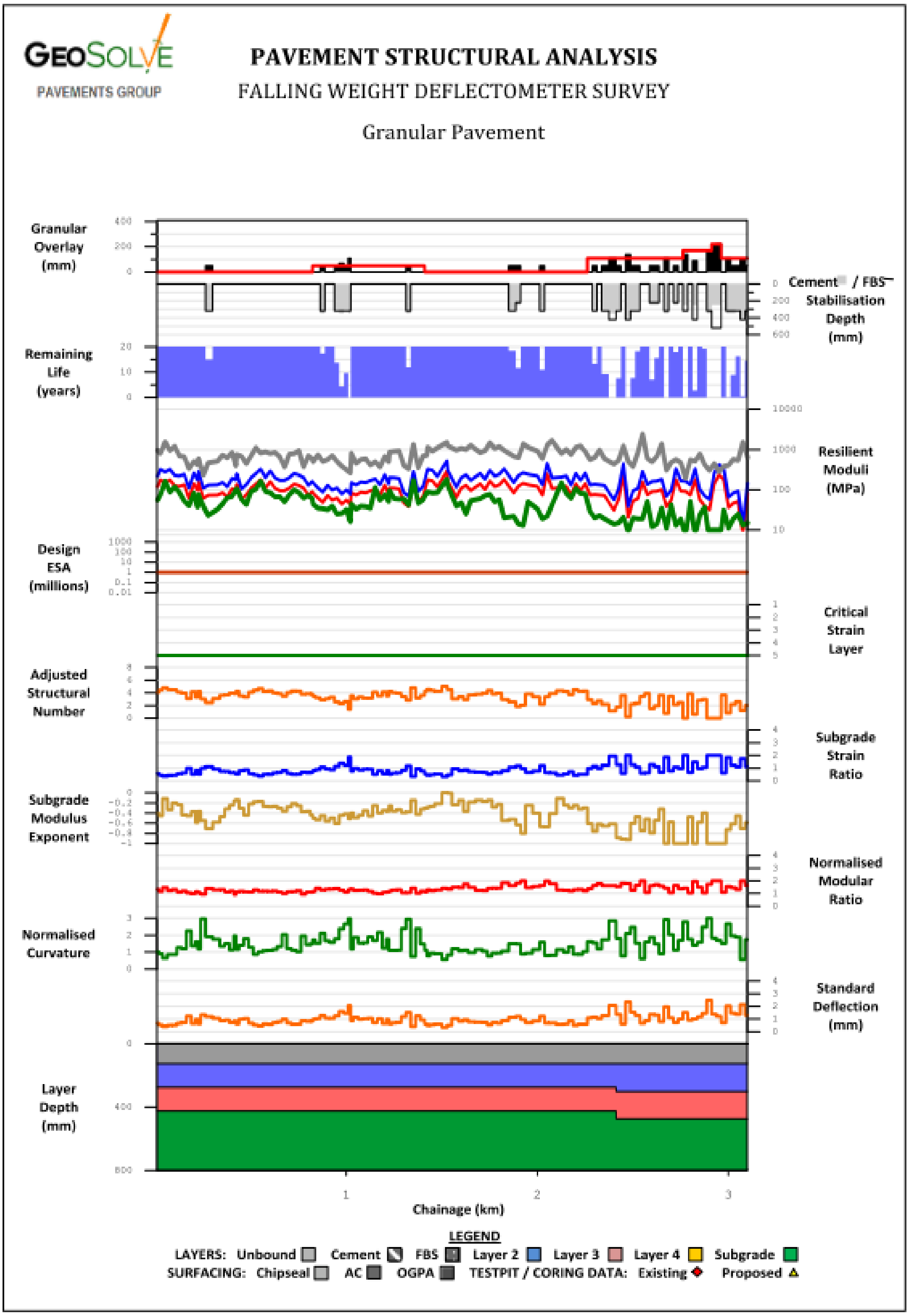
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PAVEMENT STRUCTURAL ANALYSIS
FALLING WEIGHT DEFLECTOMETER SURVEY
Granular Pavement
Granular Overlay (mm)
Cement / FBS Stabilisation Depth (mm)
Remaining Life (years)
Resilient Moduli (MPa)
Design ESA (millions)
Critical Strain Layer
Adjusted Structural Number
Subgrade Strain Ratio
Subgrade Modulus Exponent
Normalised Modular Ratio
Normalised Curvature
Standard Deflection (mm)
Layer Depth (mm)
Chainage (km)
LEGEND
LAYERS: Unbound Cement FBS Layer 2 Layer 3 Layer 4 Subgrade
SURFACING: Chipseal AC OGPA TESTPIT / CORING DATA: Existing Proposed

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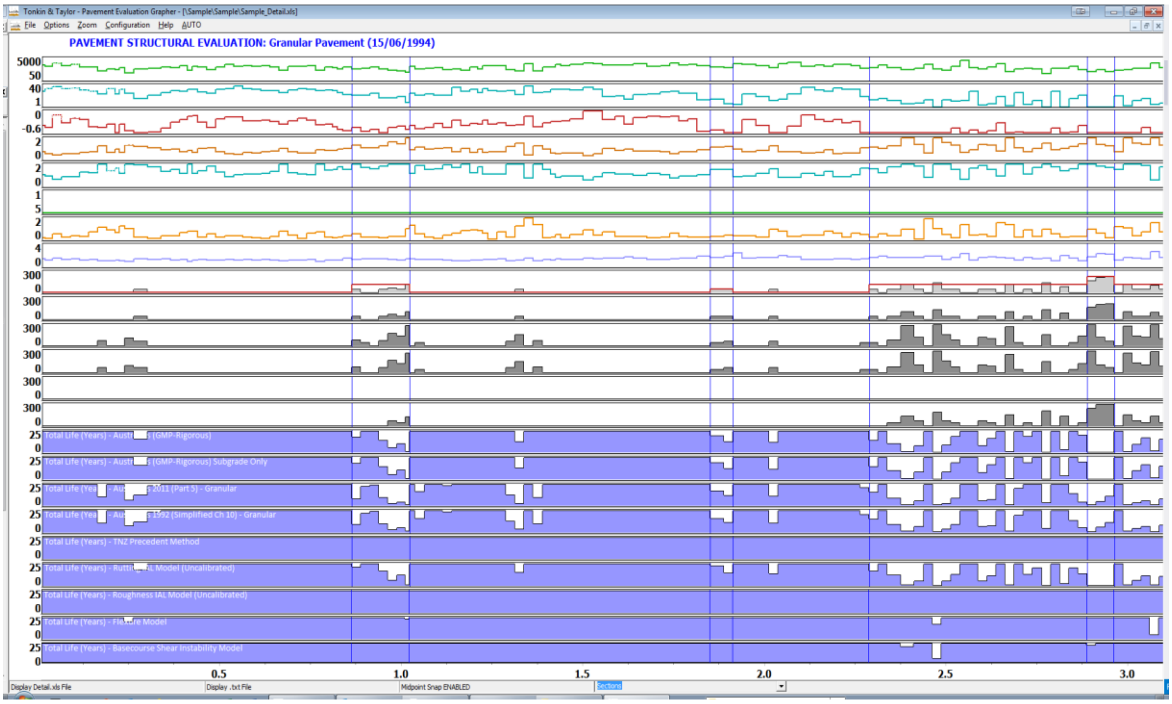
Pavement Analysis Software

Special graphical and data interrogation software (complimentary to our clients) can be downloaded from: https://www.pavementanalysis.com/s/PEGrapherInstaller.exe

This lets you easily look at any parameters and readily see critical information such as the remaining life (using a variety of recognised methods) and likely ultimate distress mode for each section of road.



NOTES:

- **The software is in beta at the moment, but it is currently being used by our Pavement Analysis team.**
- **This software is completely free and will not install any Adware/Malware/Third Party Software.**
- **A "publisher cannot be verified" warning will/may pop-up - it is safe to click Install.**
- **The application will install a shortcut in your Start menu under "All Programs > WinPEGrapher > WinPEGrapher".**
- **It can be removed by using the "Uninstall a program" link in the Control Panel and scrolling down to WinPEGrapher.**

We would appreciate hearing if you have any suggestions for improvements to the software, such as additional parameters, or if you are having any problems. This software is a beta release which is continually being updated with new features. If applicable, we would appreciate getting a copy of the debugger dialog so we can improve it.

GeoSolve Limited
Email: fwd@geosolve.co.nz, Website: www.pavementanalysis.com

Please feel free to send any feedback/suggestions/error logs through to pegrapher@geosolve.co.nz.

Support

- Frequently asked questions: click on the FAQ menu at http://www.pavementanalysis.com/
- Email us at: fwd@geosolve.co.nz
- For an urgent response, please feel free to contact us on 021 341 851 for support on any aspect.

References

1. Rims B0K Network Level
2. RIMS BoK Project Level
3. Ullidtz, Per (1998), Pavement Analysis, Elsevier.
4. Tonkin & Taylor (1998), Pavement Deflection Measurement and Interpretation for the Design of Rehabilitation Treatments, Transfund Research Report No. 117.

Part 2, Multi-Speed Deflectometer (MSD)

The MSD has developed locally because unbound pavements with high deflections are widespread. The MSD is not as accurate as the TSD, but readings can be made in both wheelpaths and at 1 m centres. Moreover, it can test at any speed, wet or dry conditions and can also record deflections on unsurfaced gravel roads if the surface is compact. This means the MSD can also be used during construction of either cohesive or compact granular materials as each layer is placed. It can also be used for maintenance dig-outs to test the effective stiffness of each repair prior to surfacing. After placing and compacting any layer, a contractor may collect over 100 tests and determine stiffnesses all within 2 minutes. Therefore, the MSD usefully fills gaps that up until now have only been provided by slower or less readily available FWD, LWD or Beam. For MSD screening with empirical outputs, the equivalent Adjusted Structural Number (SNP) may be generated for dTIMS users, but this method is overly simplistic and loses much of the recovered information when it is condensed in this "one size fits all" approach. (The US originators of this parameter now regard it as too "nebulous" and have replaced it with the NCHRP mechanistic method). MSD output can be converted to any of the FWD empirical parameters, but can now be provided as a more general set of structural indices: SLI, BLI and LLI (Surface, Base and Lower Layer Index) obtained from beneath a large-single wheel in a similar manner to those reported by Horak (2008) for dual wheels and NZTA RR401 for FWD. These 3 indices have been tailored to span the same range as SNP (i.e. 0 to 8 corresponding to very weak to very stiff) for the ease of adoption by dTIMS users. It should be noted that traditional 2-D deflection measurements between the wider load spacing of dual wheels are well suited to pavements that reach a terminal condition due to excessive strains at depth, i.e. those with thick structural asphaltic layers. On the other hand, where a thin surfacing is used on an unbound granular basecourse, then determining the 3-D deformations directly beneath a heavily loaded large-single enables much more relevant properties to be characterised in that upper layer. NZTA, contractors and researchers (Bailey, Patrick & Jackett et al 2006), commonly consider that the great majority of NZ unbound pavements reach a terminal condition due to upper layer distress. In other words, subgrade rutting is seldom the reason for rehabilitation. The large-single wheel indices for MSD are available now, although development is in progress. In future, having 3 parameters empowers users who prefer to continue with empirical parameters,

Informational Links:

MSD RIMS Presentation 2018

MULTI-SPEED DEFLECTOMETER

COMPARISON OF TSD/MULTI-SPEED DEFLECTOMETER

TSD + MSD WITH NETWORK EXEMPLAR