Life Cycle Cost Efficient Asphalt pavements – Research programme 2013-2017

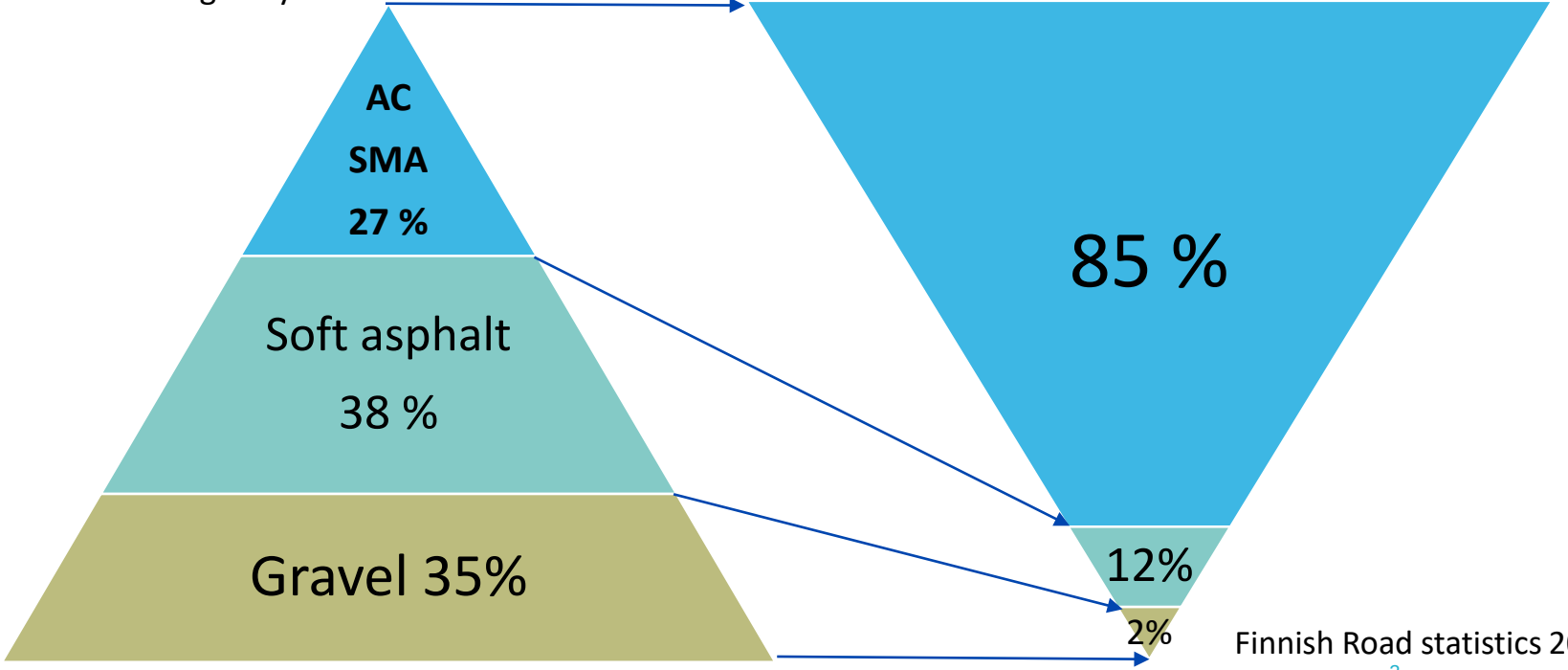
Transport Research Finland

31.5.2018 Katri Eskola

Contents:

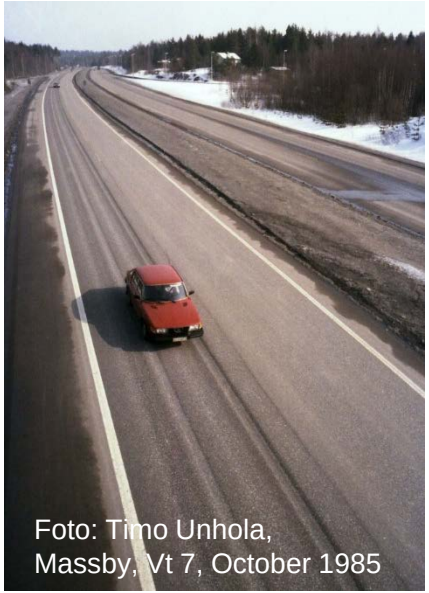
1) Asphalt pavement maintenance on highways in Finland

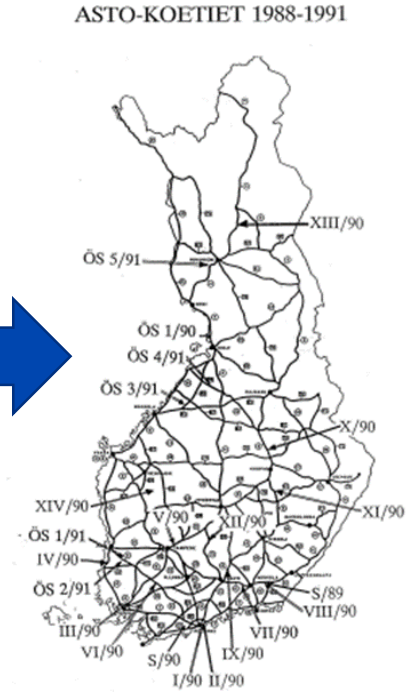
Challenge of Highway's maintenance in Finland



Finnish Road statistics 2016

Wearing caused by studded tyres on high-volume roads



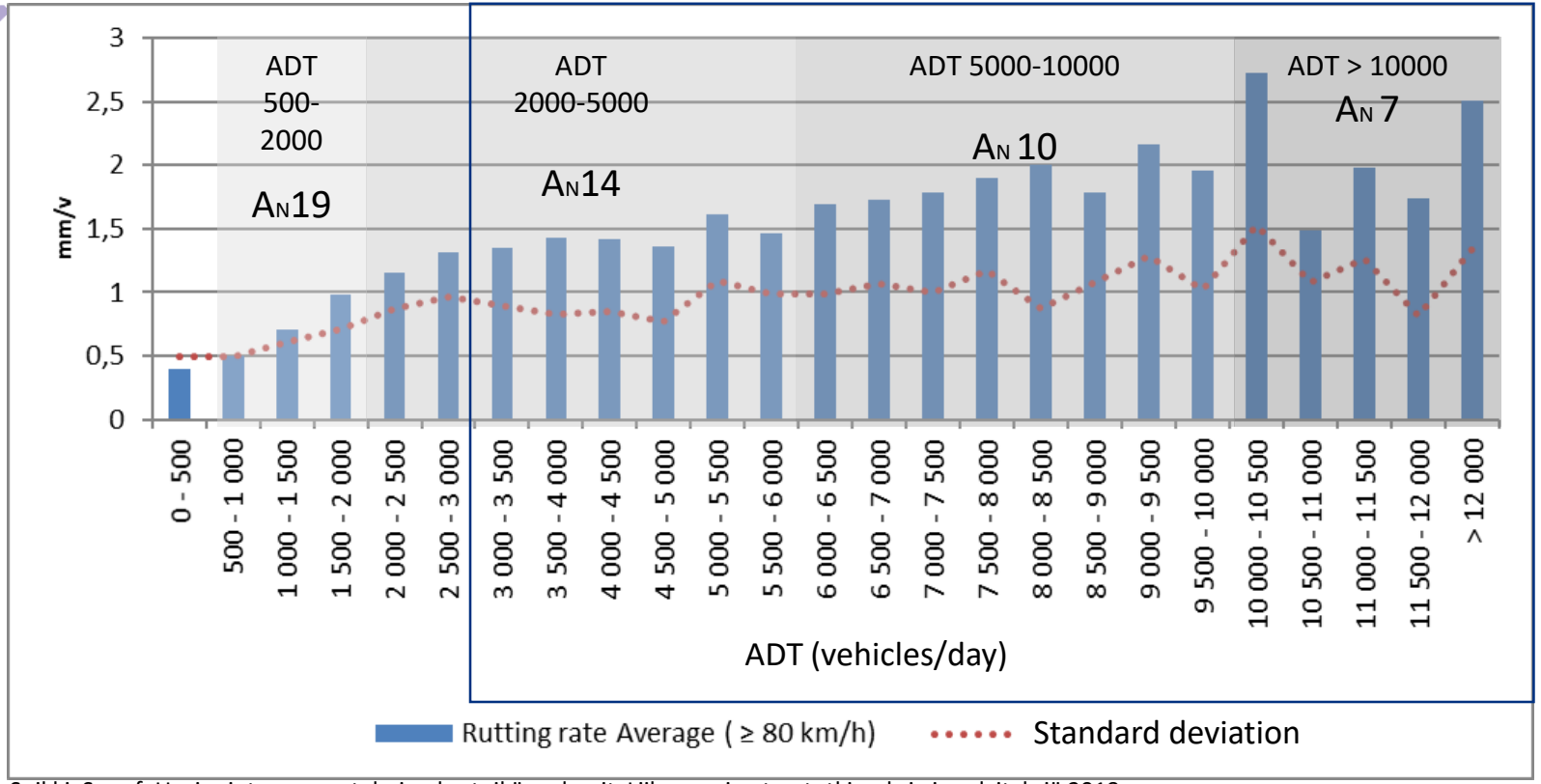


SMA

$$Ura = \begin{Bmatrix} 2mm \\ 4mm \end{Bmatrix} + \frac{0.3}{46} \cdot p.ikä \cdot \frac{(2 \cdot KVL_{kaista})^{1.00}}{1000} \cdot \begin{Bmatrix} 1{,}0, kun\_tien\_lev.\_l \le 10.5m \\ \left(\frac{l}{10}\right)^{-0.75}, kun\_tien\_lev.\_l > 10.5m \end{Bmatrix} \cdot \begin{Bmatrix} 0.85, kun\_talvinop.\_w = 60 \\ 1.0, kun\_talvinop.\_w = 80 \\ 1.0, kun\_talvinop.\_w = 100\_(1ajorata) \\ 1.1, kun\_talvinop.\_w = 100\_(2ajorata) \end{Bmatrix} \cdot MT \cdot (9.4 + 2.21 \cdot KM)$$

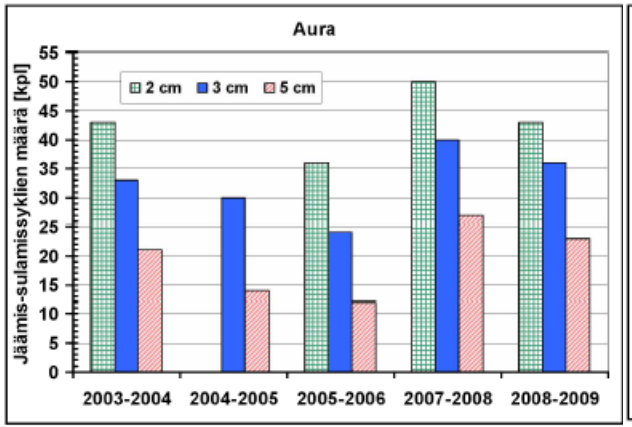
Elinkaarikustannuslaskentoja ST-urakan arvonvähennysten määrittämiseksi. Tiehallinnon sisäisiä julkaisuja 25/ 2007

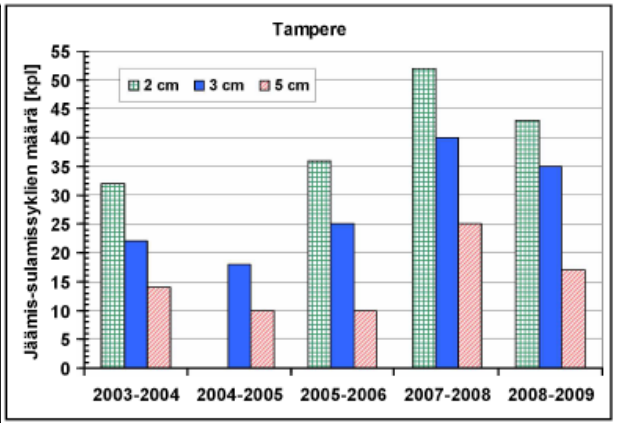
Average rutting rate based on road profile measurements 2010 - 2015 [When winter speed limit ≥ 80 km/h]

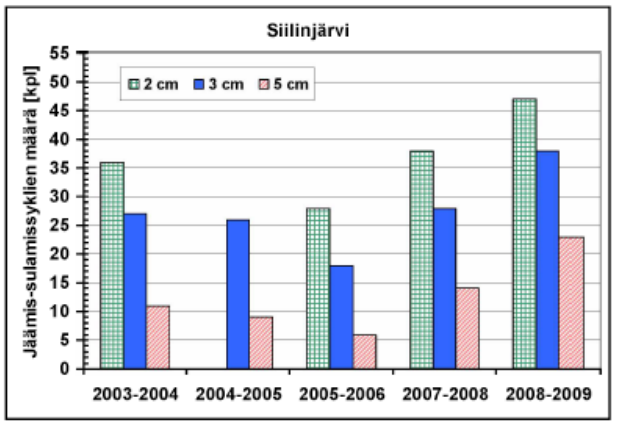


Suikki, Spoof: Uusiopintausmenetelmien kestoikäanalyysit. Liikenneviraston tutkimuksia ja selvityksiä 2018

Water in winter time causes a need of research

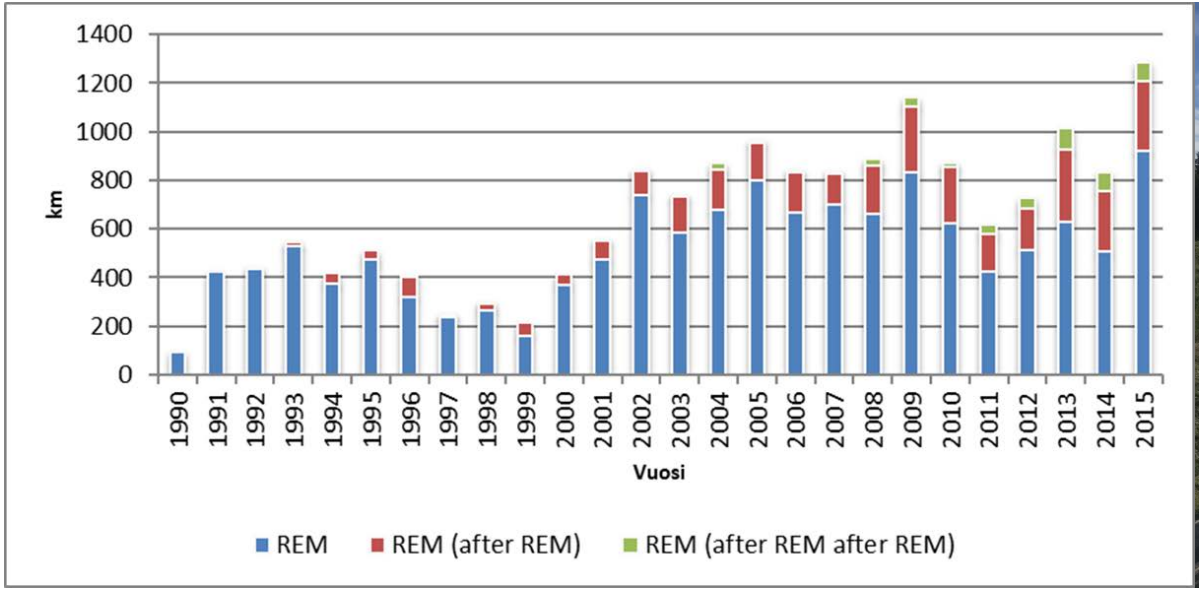






Laukkanen, Halonen, Pyy: Asfalttimassan kestävyys jäätymis-sulamista sekä veden ja kuormien yhteisvaikutusta vastaan. Liikenneviraston tutkimuksia ja selvityksiä 20/2012

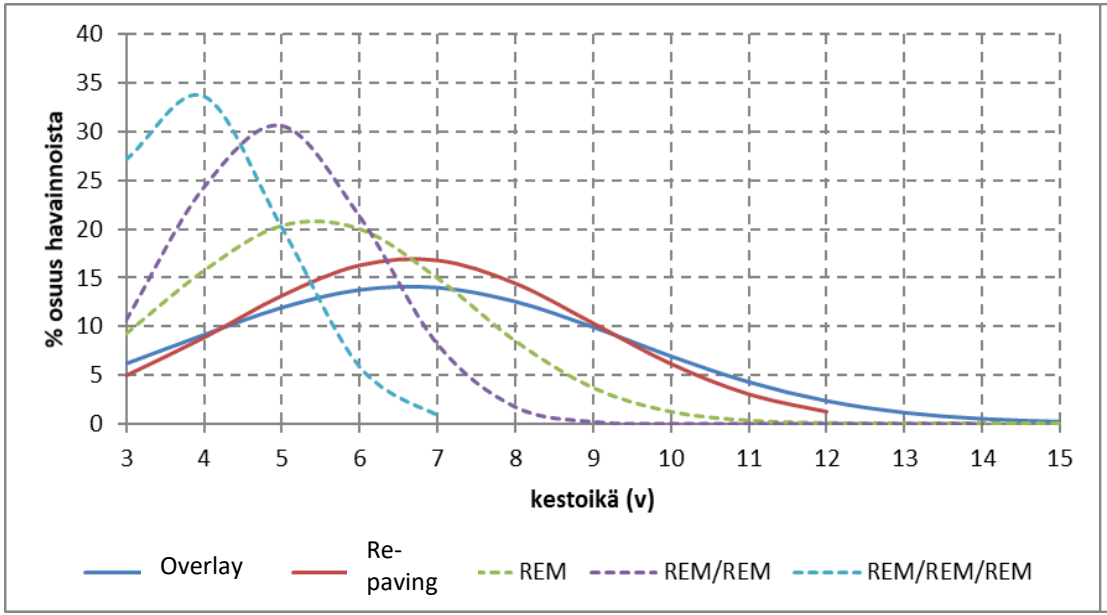
Remixing (REM) = Hot-in-place recycling on High volume roads in Finland

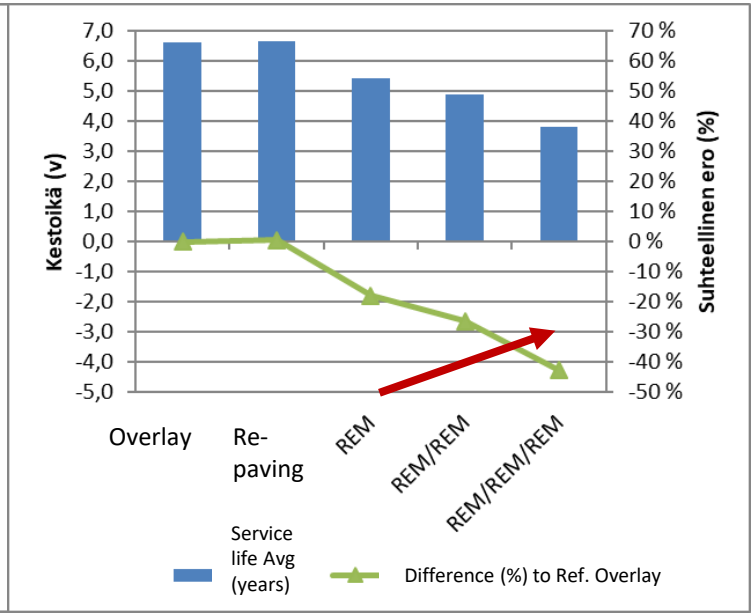


Suikki, Spoof: Uusiopintausmenetelmien kestoikäanalyysit. Liikenneviraston tutkimuksia ja selvityksiä 2018

Service life time comparison between
Remixed surface course (REM) and Overlay/Repaving

e.g. Highways with ADT 10 000 – 25 000:





Suikki, Spoof: Uusiopintausmenetelmien kestoikäanalyysit. Liikenneviraston tutkimuksia ja selvityksiä 2018

Maintenance cost (€/year)
Difference (%) to Ref. Overlay

2) Research Program 2013 - 2017:

How to maintain service life of surface course ?
How to maintain Life Cycle of Surface course by Remixing ?

Execution

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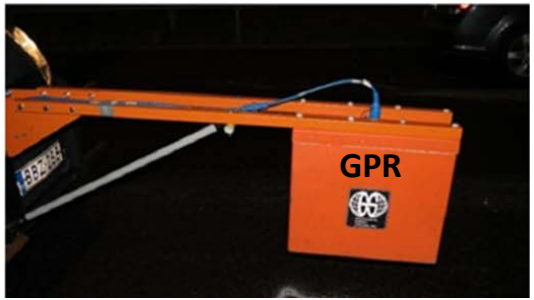
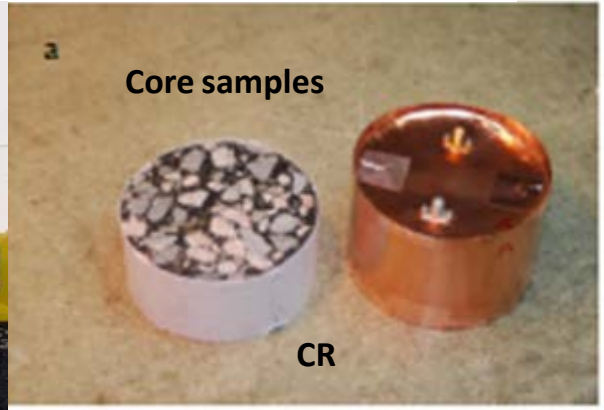
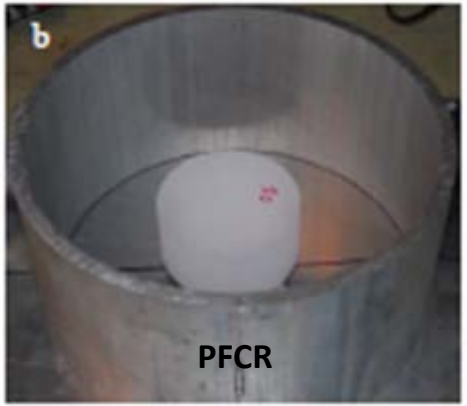
Project 1(2): Assessment of Asphalt pavement density - How to measure that new asphalt layer is dense enough?



Research In Aalto University collaboration between the Civil Engineering Department PI Prof. Terhi Pellinen and the Department of Electrical Engineering and Automation Prof. Pekka Eskelinen





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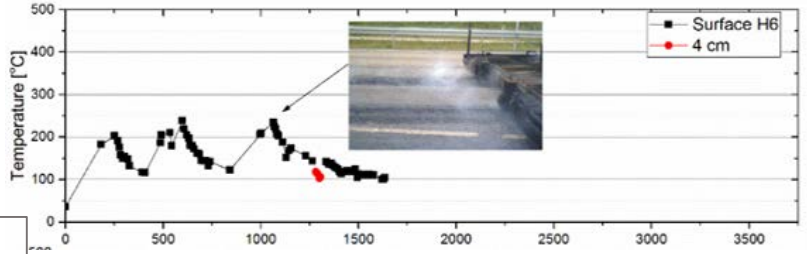
Project 1 (2): Assessment of Asphalt pavement density - Test sites and laboratory tests

Test sites	Year	Laboratory test samples	Laboratory tests Aalto	GPR and other site measurements Contractors + Aalto	(Number of) samples made and tested in laboratory: - Void content (SSD /DRY, Parafilm, CoreLok) , - Aggregate density , - Binder Content + Grading, - Volumetric properies: VMA, VFB Mitta Oy + Aalto	CR Asphalt core samples: DRY/ Saturated with water Aalto	PFCR Asphalt core samples: DRY / Saturated with water Aalto
Vt 3 Vt 12	2013	36 cores 2 slabs 8 material samples	VC of cores by methods SSD & DIM VNA measurements	GPR: - Before - Static: 4 points after 20 h - After: (20 h, 6 days, 40 days, 2 years)			
Vt 5	2014	16 cores	VC of cores: SSD, DRY, DIM, Parafilm Aggregate density VNA measurements	Thermal camera during work GPR Microwave radar	12	12 / 6	12 / 6
Mt 210	2014	24 cores	VC of cores: SSD, DRY, DIM, Parafilm Aggregate density VNA measurements	GPR Microwave radar			
Vt 7 Hamina	2014	10 cores	30 * VC of cores: SSD, DRY, DIM Aggregate density VNA measurements	GPR / surface layer Microwave radar /each layer			
Kosken kylä	2015			GPR 1 GHz & 2 GHz on crushed rock layer, metal plate and reference material			

Test sites Year 2016	GPR (km)	(Number of) Core samples tested in laboratory: - Void content (SSD /DRY, Parafilm, CoreLok) , -Aggregate density , - Binder Content + Grading, - Volumetric properies: VMA, VFB Aalto + contractor	CR Asphalt core samples Aggregate Core samples Aalto	PFCR Asphalt core samples Agregate core samples Aalto
12	299	50 + 36 Aggregate core sample density: 45	52 45	52 45

Project 2 (2): Remixing - Test sites and Laboratory tests

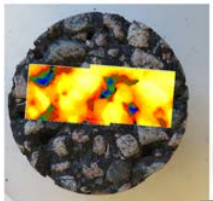


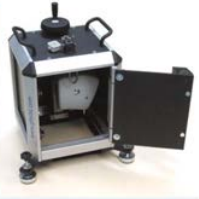
Research in the Civil Engineering Department of Aalto University: PI Prof. Terhi Pellinen and Dr. Michalina Makowska

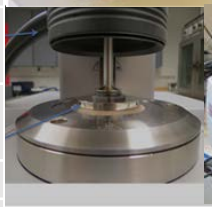
TEST ROADS

Tie Nro	Year
VT1	2013
Kt52	2015
VT4	2015
VT4	2016
VT5	2016
VT6	2016
VT7	2016
VT12 ja MT307-KT57	2016
VT25	2017

(Number of) Samples		Aalto	Contractor	Total
Core samples from the road		248	28	276
Samples made in the laboratory		64	-	64
Bitumen	Binder content and grading	112	15	127
	Bitumen samples	42	5	47
	Laboratory-blended bitumen and rejuvenator	10	8	18
	References (bitumen and rejuvenator)	13	4	17
Mechanical tests		228	-	228
Aggregate	Surface area	43	-	43
	Density	67	-	67
	Grading	112	20	132
FT-IR	Bitumen and filler	4085	-	4085







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New knowledge - New experts

Pellinen, Terhi ; Huuskonen-Snicker, Eeva ; Olkkonen, Martta-Kaisa ; Eskelinen, Pekka (2014)
Civil Engineering Applications of Ground Penetrating Radar in Finland
Vol. 16, EGU2014-6274, 2014 EGU General Assembly
pdf

Huuskonen-Snicker, Eeva ; Pellinen, Terhi ; Olkkonen, Martta-Kaisa ; Eskelinen, Pekka (2014)
Asphalt quality evaluation with GPR and the effect of aggregate permittivity properties
1st National Colloquium of Geosciences, Espoo, 19-20 March 2014

Eskelinen, Pekka ; Pellinen, Terhi ; Olmos Martinez, Pablo (2014)
Dielectric measurements of stone materials with a wideband microwave sweep
International Radar Symposium 2014 (IRS 2014), Gdansk, Poland, 16-18 June 2014

Olkkonen, Martta-Kaisa ; Eskelinen, Pekka ; Huuskonen-Snicker, Eeva ; Pellinen, Terhi ; Olmos Martinez, Pablo (201
A New Microwave Asphalt Radar
RADAR 2014 (International Radar Conference 2014), 13-17 October, Lille, France

Nevalainen, Niklas, diplomityö (2014)
Lämpökamera päällystystöiden laadunvarmistuksessa
http://urn.fi/URN:NBN:fi:aalto-201408292556

Nevalainen, Niklas, erikoistyö (2014)
Lämpökameran käyttö päällystystöissä, jatkotutkimus
pdf

Huuskonen-Snicker, Eeva (2016)
Radar in non-destructive testing of thin granular dielectric layers
(Ohuiden rakeisten dielektristen kerrosten ainetta rikkomaton testaus tutkalla)
http://urn.fi/URN:ISBN:978-952-60-7228-9

Hartikainen, Ari ; Pellinen, Terhi ; Eskelinen, Pekka Eskelinen (2017)
Quantification of asphalt inhomogeneity
The 29th Baltic Road Conference, 27-30 August 2017, Tallinn
pdf

Hartikainen, Ari ; Pellinen, Terhi ; Huuskonen-Snicker, Eeva ; Eskelinen, Pekka (2018)
Algorithm to process the stepped frequency radar signal for a thin road surface ap
https://doi.org/10.1016/j.conbuildmat.2017.10.075

Pellinen, Terhi ; Eskelinen, Pekka ; Hartikainen, Ari (2018)
Asfalttipäällysteen tyhjätilan mittausmenetelmien arviointia - Vuosien 2016-2017 k
http://urn.fi/URN:ISBN:978-952-60-7825-0

I. Thesis and Dissertations

1. Aromaa, Kalle, diplomityö (2016)

Bitumin vanhenemisen ja elvyttämisen vaikutukset sen reol
The effects of ageing and rejuvenation on bitumen rheology

http://urn.fi/URN:NBN:fi:aalto-201603291573

2. Ahmed, Fawad, Master's thesis (2016)
Diffusion of the rejuvenators into bitumen studied by FTIR-A

http://urn.fi/URN:NBN:fi:aalto-201612085849

3. Makowska, Michalina, Doctoral dissertation (2017)

The physicochemical influence of the inorganic phase on the aging and performance of a

http://urn.fi/URN:ISBN:978-952-60-7645-4

II. Articles in the international peer-review journals

M. Makowska, T. Pellinen, P. Olmos Martinez and O. Laukkanen, "Analytical Methodology to Determine the Composition of Filler Used in Hot-Mix Asphalt. Case Study," Transportation Research Record: Journal of the Transportation Research Board, No. 2445, pp. 12-20, 2014. DOI: 10.3141/2445-02 View at Publisher Pre-print copy

M. Makowska and T. Pellinen, "Etchable iron content (FETCH) proposed as the missing parameter for the better prediction of asphalt mastic stiffening," Construction and Building Materials, vol. 93, pp. 528-541, 2015. DOI: 10.1016/j.conbuildmat.2015.05.099 View at Publisher Author's pre-print copy

Makowska M., Aromaa K., Pellinen T., "The rheological transformation of bitumen during the recycling of repetitively aged asphalt pavement", EATA2017, Zurich, Switzerland, 12-14 June 2017, Road Materials and Pavement Design, Volume 18, 2017, Issue sup2: EATA 2017, pp. 50-65. DOI: 10.1080/14680629.2017.130426 Author's copies/View at publisher

Makowska M., Hartikainen A., Pellinen T., "The oxidation of bitumen witnessed in-situ by infrared spectroscopy", Materials and Structures, 50: 189, 17 pages, 2017. DOI: 10.1617/s11527-017-1058-y View at Publisher

T. Blomberg, M. Makowska and T. Pellinen, "Laboratory simulation of bitumen aging and rejuvenation to mimic multiple cycles of reuse," in Transportation Research Arena, Warsaw, Poland, 2016., Transportation Research Procedia, Vol. 14, 2016, pp. 694-703. Fulltext at Aaltodoc: http://urn.fi/URN:NBN:fi:aalto-201610134987. DOI: 10.1016/j.trpro.2016.05.335 View at Publisher

Olkkonen, Martta-Kaisa ; Eskelinen, Pekka ; Huuskonen-Snicker, Eeva ; Pellinen, Terhi ; Olmos Martinez, Pablo (2014)
An evaluation of permittivity of two different rock types with microwave resonator and waveguide cutoff principl
http://dx.doi.org/10.1515/freq-2014-0040

Pellinen, Terhi ; Huuskonen-Snicker, Eeva ; Eskelinen, Pekka ; Olmos Martinez, Pablo (2015)
Representative volume element (RVE) of asphalt pavement for electromagnetic measurements
http://dx.doi.org/10.1016/j.jtte.2015.01.003

Huuskonen-Snicker, Eeva ; Eskelinen, Pekka ; Pellinen, Terhi ; Olkkonen, Martta-Kaisa
A New Microwave Asphalt Radar Rover for Thin Surface Civil Engineering Applica
http://dx.doi.org/10.1515/freq-2015-0034

Pellinen, Terhi ; Eskelinen, Pekka ; Huuskonen-Snicker, Eeva ; Hartikainen, Ari (2015)
Assessment of air void content of asphalt using dielectric constant measuremen
http://urn.fi/URN:ISBN:978-952-60-6288-4

Eskelinen, Pekka (2016)
A Simple Permittivity Calibration Method for GPR-Based Road Pavement Measure
https://doi.org/10.1515/freq-2015-0269

Hartikainen, Ari ; Pellinen, Terhi ; Eskelinen, Jussi ; Huuskonen-Snicker, Eeva (2016)
Road pavement density evaluation - a case study
Functional Pavement Design: Proceedings of the 4th Chinese-European Workshop

Pellinen, Terhi ; Eskelinen, Pekka ; Hartikainen, Ari ; Huuskonen-Snicker, Eeva ; Eskelinen Jussi (2016)
Assessment of air void content of asphalt using dielectric constant measurements by GPR and with microwave radar
http://urn.fi/URN:ISBN:978-952-60-6879-4

Olkkonen, Martta-Kaisa (2016)
Studies on characterization of dielectric composite materials using radar and other microwave sensors
(Dielektristen komposiittimateriaalien mikroaaltomittauksia)
http://urn.fi/URN:ISBN:978-952-60-6950-0

III. Publications in Finnish press

Alustavia tutkimustuloksia asfalttipäällyste

Bitumin vanhenemisen ja elvyttämisen vai

Tiepäällysteiden kestävyys ja rakenteellinen

IV. Conference proceedings

Development of specifications and guidelines for hot in-place recycling in Finland--outline and framework Makowska, M., Pellinen, T., 26 Sep 2016, 8th RILEM International Symposium on Testing and Characterization of Sustainable and Innovative Bituminous Materials., Canestrari, F. & Partl, M. N. (eds.). Vol. 11, p. 851-862 12 p. (RILEM Bookseries; vol. 11)

The "false positive" on the antiaging properties of asphalt fines investigated by RTFO laboratory aging of mastics
Makowska, M., Pellinen, T.
29 Jun 2016, Functional Pavement Design: Proceedings of the 4th Chinese-European Workshop on Functional Pavement Design ., Erkens, S., Lu, X., Anupam, K. & Yiqiu, T. (eds.). p. 54-54

ASSESSMENT OF RISKS IN THE HOT IN-PLACE RECYCLING IN FINLAND DURING THE SUMMER OF 2016 Makowska M., Pellinen T., Solowski W., Baltic Road Conference 2017, 27-29 August 2017, Tallin, Estonia

V. Supplementary

Curing and ageing of biofluxed bitumen: a physicochemical approach Markus Simonen, Timo Blomberg, Terhi Pellinen, Michalina Makowska, Jarkko Valtonen

Aalto Open Learning
Course home page:

https://openlearning.aalto.fi/course/view.php?id=31

- Open Access
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- Research documentation

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3) Research Program 2013 - 2017:

How to maintain service life of recycled surface course ?
How to maintain Life Cycle of surface course by Remixing ?

Main results

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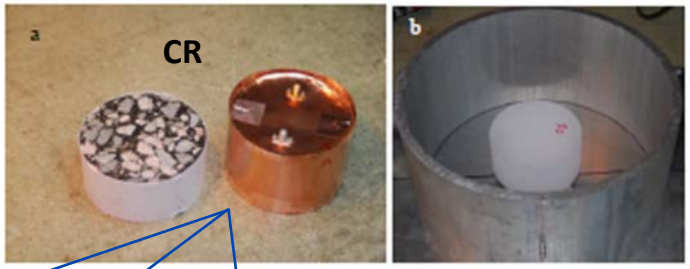
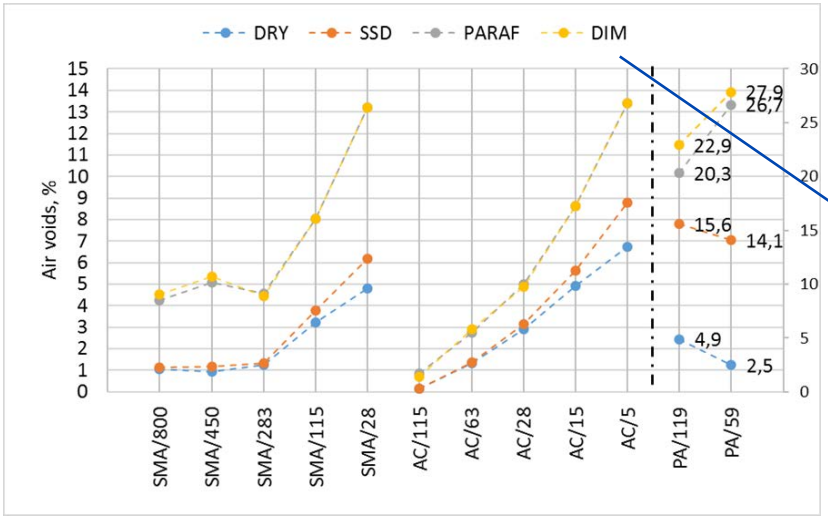
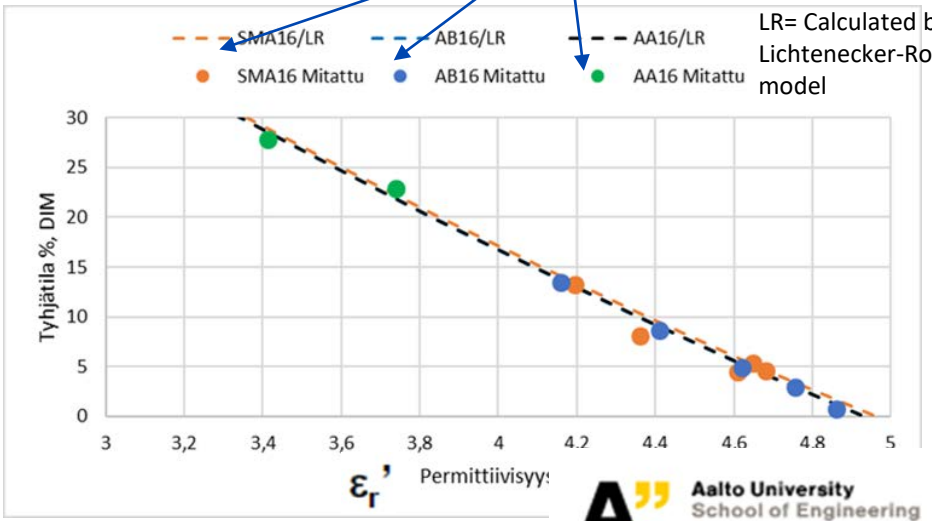
Assessment of Asphalt pavement density: Correlation in laboratory made samples

- No variation of aggregate's permittivity ε_r'
- Void content measured by dimensions (DIM/Parafilm)
- Density ρ_p and permittivity ε_r' is measured from core samples
- No water in sample



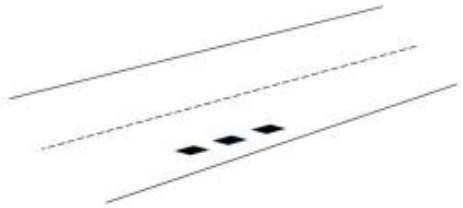


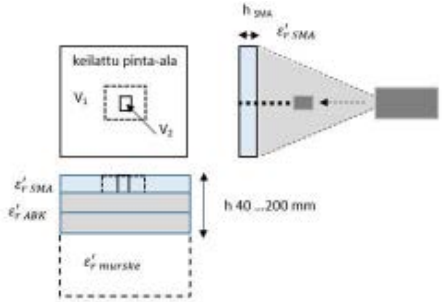


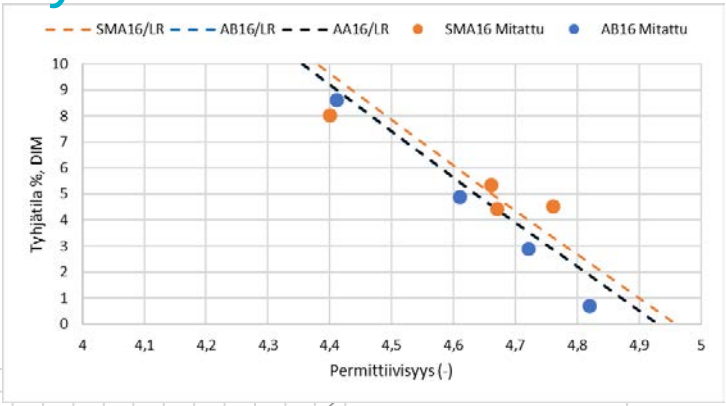
LR= Calculated by Lichtenecker-Rother-model

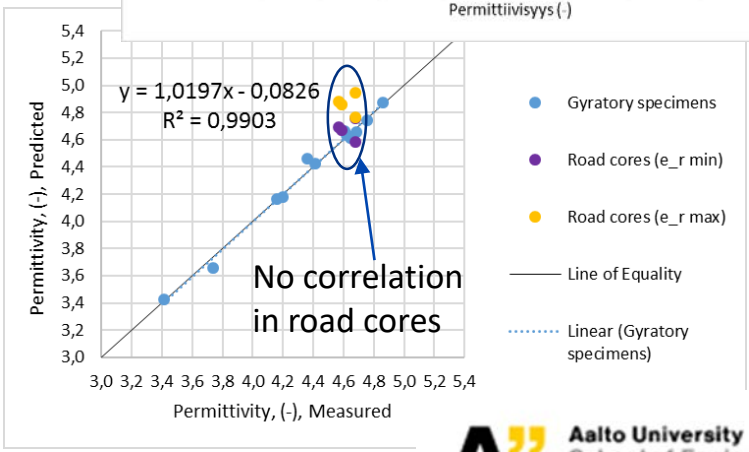
Assessment of Asphalt pavement density measurements on road by GPR

- Variation of Aggregate's ε_r' is included
- Changes in volumetric properties changes Void content but is not seen in the asphalt's ε_r'
- Water is affecting to measurement results
- Representative volume element is not equal in GPR and core sample used in calibration









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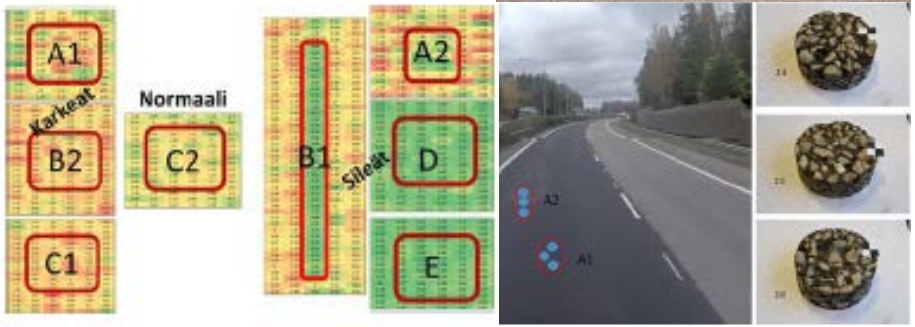
The more efficient and reliable method is needed to ensure the new asphalt layer is dense enough

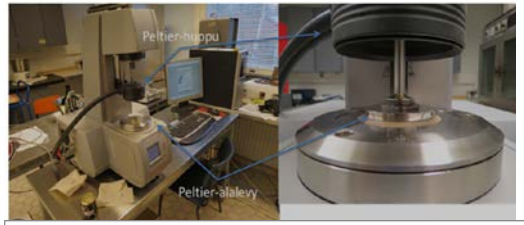
New asphalt layer's Homogenity will be monitored by MPD measurements

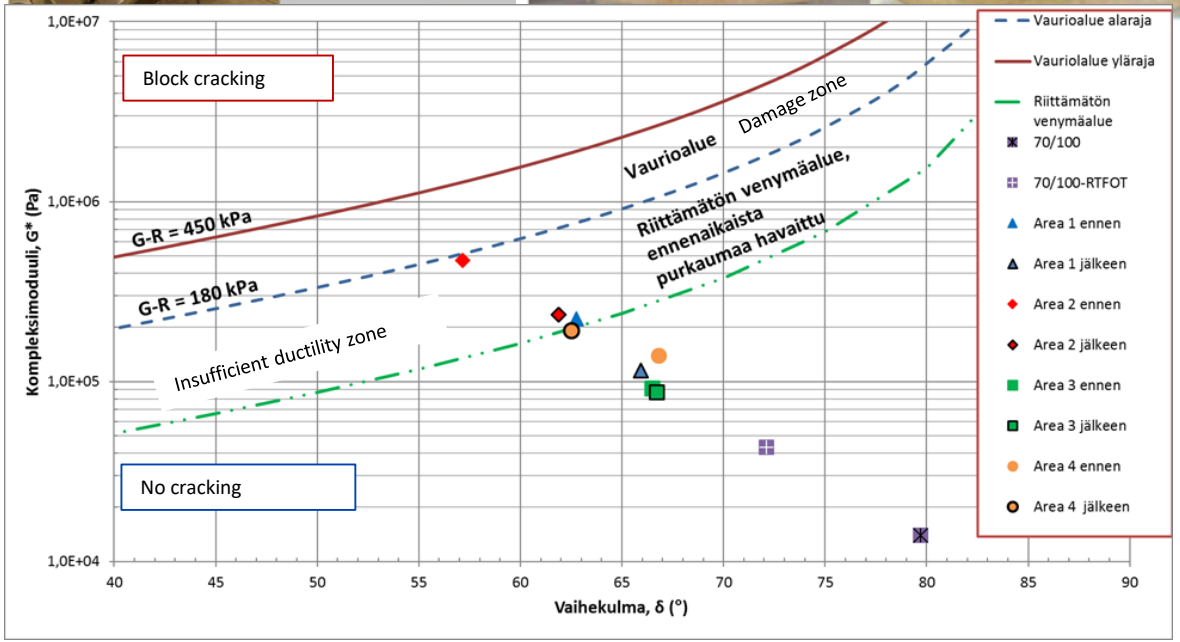


New technologies will be guiding to and reporting the results of intelligent compaction ? - TEST SITE 2018

https://julkaisut.liikennevirasto.fi/pdf8/lts_2017-01_paallysteen_lajittumavirheiden_web.pdf

How to increase recycling and a service life ? - Better/new test methods are needed into use





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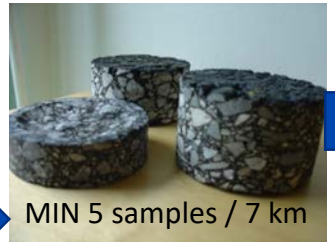
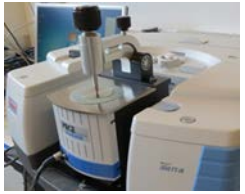
How to increase recycling and a service life ?
- Better Design is needed

2) PRE-Testing:

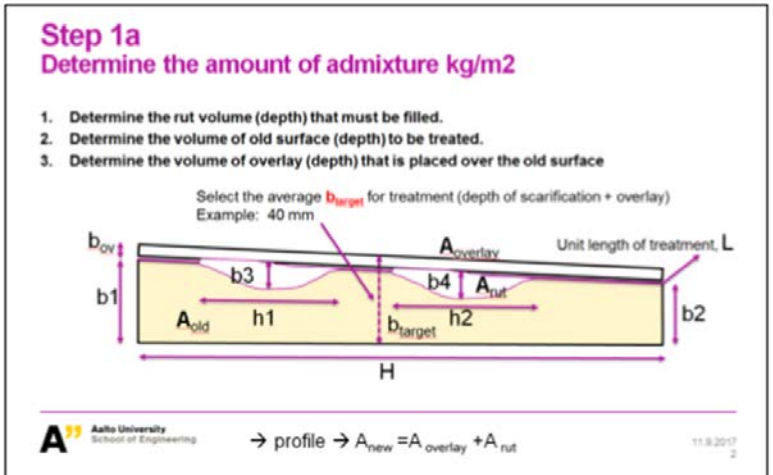




- Void content
- Maximum Density
- Grading and Binder content
- QC of Recovered Binder (FT-IR)
- Bitumen penetration >> Complex Modulus and Phase Angle (DSR)

1) Road measurements:

- Rut Depth data
- Rut volume data



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4) Research Program 2013 - 2017:

How to maintain service life of (remixed) surface course ?
How to maintain Life Cycle of Surface course by Remixing ?

Implementation of results

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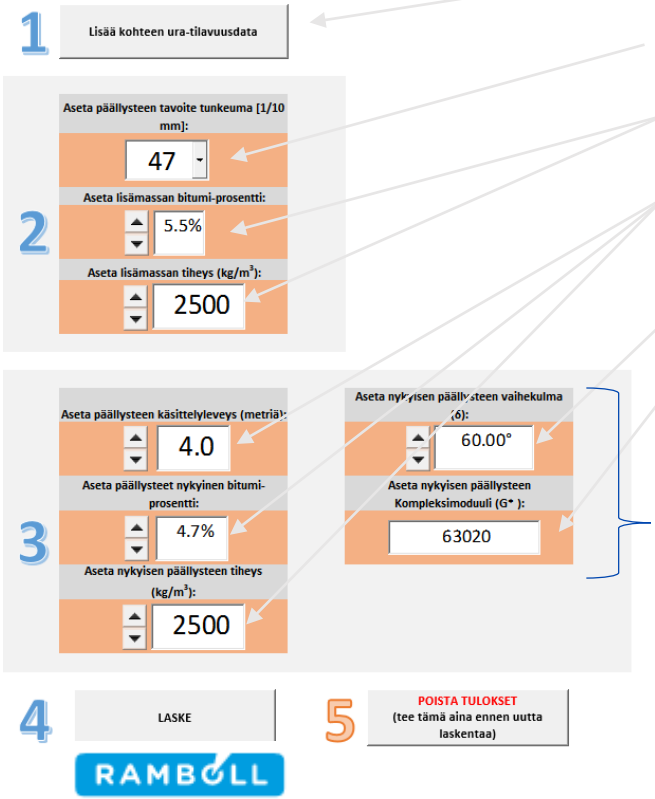
Excel Tool for Remix Design : Road profile data is combined to bitumen rheological data

Input data (Example):



- Input: Rut volume data
- Set the Rheological target ($40 \frac{1}{10\ mm}$, $47 \frac{1}{10\ mm}$ ja $76 \frac{1}{10\ mm}$)
- Set the bitumen content (%) and density ($\frac{kg}{m^3}$) of admixture
- Set the bitumen content (%) and density ($\frac{kg}{m^3}$) of old surface course and working width (m)
- Set the Phase angle of old bitumen(°) [Phase Angle, δ; 0,01 Hz T=25°C]
- Set the Complex Modulus of old bitumen [G*] (Pa) [Complex Modulus ; 0,01 Hz T=25°C]

In Version 2 Penetration data can be used

Bitumen of admixture: 70/100

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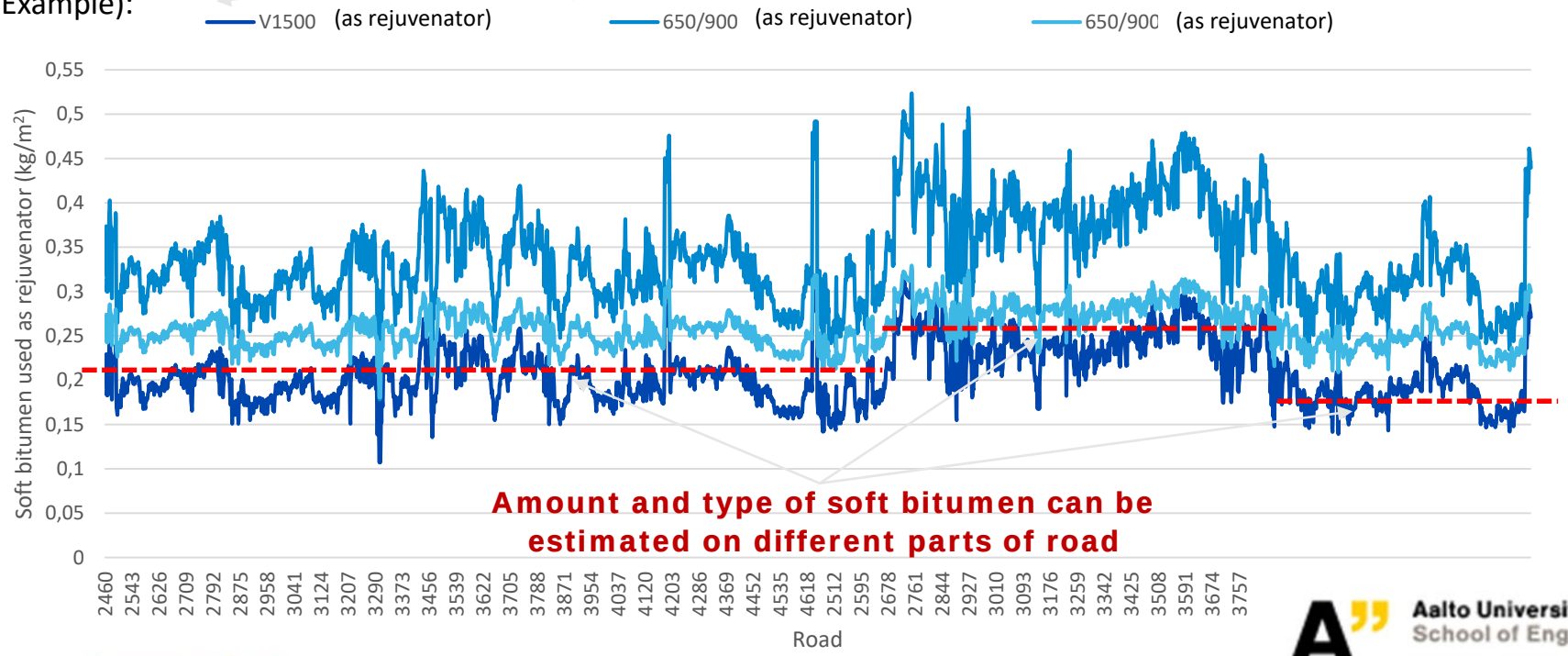
Excel Tool for Remix Design: Calculation results

Calculated by amount of admixture based on Rut volume

43

Fixed amount of admixture, e.g. 35 $\frac{kg}{m^2}$

Output data (Example):



Amount and type of soft bitumen can be estimated on different parts of road

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Better performance by Better process

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https://www.liikennevirasto.fi/documents/20473/431718/Remix_Digipilottiraportti.pdf/0f86c1c8-6aed-4307-8af0-ef7b1ca87cc4

The planning-execution-quality control process

In the future this can be predicted or simulated, choice of PRE-sampling sites based on POST-sampling

Aging process

PRE-sample

Historical database and other NDT

Design process

First approximation from ELY

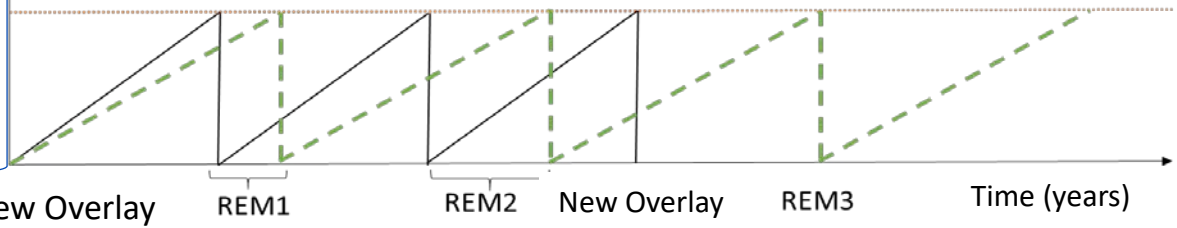
POST-sample

Quality control, gathering of the data

Execution

Fine-tuning by Contractor

Maximum rut depth, mm



Estimated cost-savings by better design on High volume roads in Finland