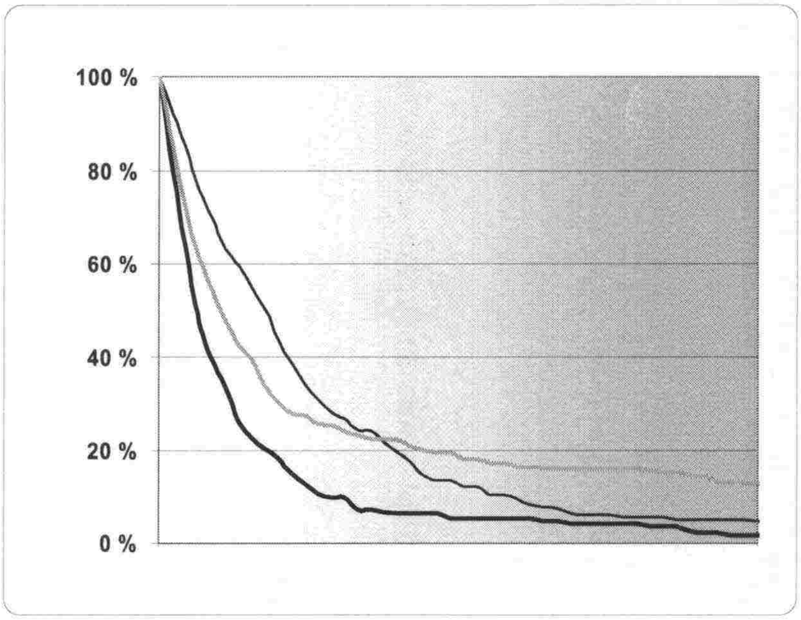
TIEHALLINTO

Juha Äijö

Automated Crack Measurement Test in Finland 2004

Finnra Reports 5/2005



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Finnish Road Administration
Opastinsilta 12 A
P.0.Box 33
FIN-00521 HELSINKI
Telephone: Int. +358 204 2211

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Keywords: Pavement cracks, automatic crack survey
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Aiheluokka: 33 Päällysteet

TIIVISTELMÄ

Tiehallinto järjesti kesälle 2004 automaattisten vauriomittauslaitteiden vertailutestin. Siinä kerättiin käytännön kokemuksia nykyisistä mittalaitteista, niiden käytöstä ja tuloksista. Testikohteita oli Etelä-Suomen vähäliikenteisiltä teiltä yhteensä 100 km, jotka jakautuivat tasan kesto- ja kevytpäällysteteihin. Muita valintakriteerejä olivat päällysteenleveys ja vauriomäärä. Määrällisesti eniten testikohteita oli luokassa kestopäällystetiet, leveys yli 7 m ja vaurioita alle 40 m^2 33 km sekä kevytpäällysteteitä, leveys alle 7 m ja vaurioita yli 40 m^2, 35 km.

Kohteilla oli tehty normaali vaurioinventointi keväällä 2004 ja ne inventointiin toiseen kertaan heinäkuussa 2004. Testiin osallistui kaksi laitteistoa:

1. Ramboll RST Ab:n laite "Laser RST PAVUE, vers 13"
2. Tieliikelaitoksen Adhara Inc'n valmistama laitteisto versio 1.0 sekä UniANALYZE ohjelmisto kuvatulkintaan.

Testikohteiden mittausten tuloksina havaintoaineisto muodostui:

- kahdesta mittauksesta jokaiselta kohteelta
- mittaushavainto jokaiselle 100 m
- mittaushavainto jokaiselle 10 m
- kohteiden referenssiaineisto videona
- kolme erilaista vauriomittausmenetelmää
- Ramboll RST:n aineisto hankekohtaista tarkastelua varten

Tarkastellut vauriomuuttujat ovat vauriosumma (ja siihen liittyvät vauriotyypit), Cracked Surface indeksi, CS, jota Ramboll RST käytti sekä Unified Crack Index, UCI, jota Tieliikelaitos tuotti.

Verrattaessa tuloksia vaurioinventoinnin tuloksiin voidaan tyypillisenä piirteenä todeta, että automaattiset mittarit keräävät tiedon selkeistä päällystevaurioista. Vähäiset vauriomäärät jäävät tallentamatta, esimerkiksi inventointituloksen ollessa 0-5 m^2, kuvatulkinta antaa yleensä tulokseksi ehjän kohteen. Kun tarkastellaan kohteita, joiden vauriomäärä on lähellä nykyistä "huonokuntoisen tien" vauriorajaa, (kestopäällysteillä 60 m^2 ja kevytpäällysteillä 115 m^2), ovat kuvatulkinnan tulokset hyviä ja toistettavia.

Mittaustulosten toistettavuus onkin etu siirryttäessä automaattiseen mittausmenetelmään. Teknisen toteutuksen ratkaisu vaikuttaa myös toistettavuuteen ja esimerkiksi puuttuva valaistusjärjestelmä heikensi toisen mittalaitteen tuloksia. Mahdollisuus mittaustulosten jatkokäsittelyyn antaa huomattavan hyödyn automaattisten laitteiden käyttäjille. Vaurion sijainti ajoradalla, vaihtoehtoisten kuvatulkintaparametrien käyttö sekä yhdistäminen muihin tiestömittauksiin ovat tekijöitä, joita tarvittaisiin päällystettyjen teiden toiminnan suunnittelussa.

Hankesuunnittelussa tarvittavan vauriotyypin tunnistaminen on vasta kehitteillä. Vauriokartat ja uudet tunnusluvut auttavat suunnittelijaa määrittämään

vaurioitumisen syitä, mutta nämä ominaisuudet tarvitsevat mittauksia, kehitystyötä ja ajallista seurantaa ennen kuin ne muodostuvat rutiineiksi.

Testin tulosten perusteella on mahdollista asettaa laatuvaatimuksia mittalaitteiden toistettavuudelle ja tulosten sisällön suhteen. Tuotantomittauslaitteiden tulee pystyä vähintään näiden laitteiden laatutasoon.

Suosituksena voidaan sanoa, että automaattisen mittausmenetelmät pystyvät korvaamaan nykyisin käytössä oleva vaurioinventoinnin. Vaikka vauriomuuttuja muuttuu nykyisestä, saadaan uuden menetelmän mukana lisätietoja, kuten vaurion sijaintiajoradalla. Uusi menetelmä tulisi ottaa käyttöön mahdollisimman nopeasti, jotta siitä saatavat hyödyt olisivat toiminnansuunnittelun käytössä mahdollisimman pian.

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SAMMANFATTNING

Vägverket utförde under sommaren 2004 ett test för de automatiska sprickmätningar. Målsättningen var att få en konkret uppfattning om hurudana förväntningar man kan ställa på de nya mätmetoderna samt sprickvariablerna. Resultaten har framställts på samma sätt som tillståndsdata inom Vägverket.

Testobjekten representerar typiska låg-trafikerad vägar i Södra Finland. Av vägarna är 52 km belagda med asfalt och 56 km med mjukasfalt. Samtliga testobjekt har granskats på följande sätt:

- Visuella sprickinventeringar i maj
- Visuella sprickinventeringar i juni/juli
- Framställning av referensmaterial bl.a. video, tillståndsregisterdata och fältbesök
- Automatiska sprickmätningar, Ramboll RST Ab, 2 resultatdataset för varje testobjekt
- Automatiska sprickmätningar, Vägverket Produktion, 2 resultatdataset för varje testobjekt.

Den gamla sprickvariabeln, Sprickindex (VS), jämfördes med nya variabler som entreprenörerna framställde, Sprick Index (Ramboll RST) och "Unified Crack Index" (Vägverket produktion). På enskilda objekt granskades möjligheterna att definiera olika spricktyper och olika mått av en spricka (bredden, längden, betydelsen).

När man granskar resultat som tillståndsfördelningar på vägnätsnivå, kunde båda utrustningarna framställa resultat med bra kvalitet. Om vägen har tydliga sprickor samlar automatiska mätutrustningar informationen. Sensitiviteten är någonting som man kan justera och kalibrera. Visuell inventering samlar mera små sprickmänger jämfört med automatisk mätning. Det ena utrustningen hade inte ljussystem på mätbilen och det minskade sensitiviteten också i resultaten. Repeterbarheten var särskilt bra med Ramboll RST:s utrustning.

På objektnivå finns mycket att utveckla. Vägverket Produktion kunde inte framställa spricktyper och Ramboll RST har inte färdiga rutiner för definitioner av olika spricktyper. Det finns många möjligheter att analysera rådatat. I denna rapport framställs resultaten som olika grafiska polygoner samt bilder från testobjekten. Det ges också en studie av 10 m data.

Testet bevisade att existerande mätteknik kan ersätta visuell inventering vid tillståndsmätningar av vägnätet. Nya mätmetoder ger:

- Förbättrad kvalitet på data
- Möjlighet att få information om sprickornas läge i körfältet
- Möjlighet att utveckla nya resultatvariabler (t.ex. kumulativ spricksumma i tvärsled)

Rekommendationerna till följd av detta test är att vägverket borde övergå till automatiska sprickmätningar så snabbt som möjligt för att få ett sprickdata, som kan utnyttjas effektivt.

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SUMMARY

The Finnish Road Administration (Finnra) organized in 2004 a test for automated crack measuring systems. The goal was to get a concrete experience from the existing measurement systems. The test sites were chosen from typical low volume roads in Southern Finland. The total length of measured test sites were 100 km asphalt roads, soft asphalt roads, road with under and over 7 m with different type of cracks.

Finnra is conducting each year 10 000 km of manual crack inventory with methodology called PVI. All test sites were measured manually (according to the PVI methodology) in normal production type measurement in May 2004 and second time in July 2004.

Finnra was able to get two service providers to the test:
1. Ramboll RST, with system Laser RST PAVUE, version 13
2. Finnish Road Enterprice, with system from Adhara Inc, version 1 and UniAnANALYZE software.

The data from test objects consists for each methodology:
- Two measurement run
- Measurement observation for each 100 m section
- Measurement observation for each 10 m section
- Reference material as front video at low speed
- Material from Ramboll RST for object level analysis

The crack variables in the test were chosen and provided by service providers: Existing PVI variable "Vauriosumma, VS", "Cracked Surface Index, CS" provided by Ramboll RST and "Unified Crack Index, UCI" provided by Finnish Road Enterprice.

When the results are used to present the condition distribution of the network or the differences of condition on different roads the quality of automated measuring systems was good. If the road is cracked, both systems could record that automatically. Repeteability of the results was clearly best with the Ramboll RST's system.

The development issues concentrates to the definition of the type or the severity of crack. There exist a lot of possibilities to develop a common definition for different cracks in co-operation with other road administrations.

The conclusions from the test in Finland 2004 were:
New measurement methodologies provide increased data quality
Location of crack in lane is an important new information about cracking
New methodology provides good possibilities to develop new crack variables for different purposes

The recommendation is that Finnra should change the crack inventory methodology as soon a possible to automated measuring.

INTRODUCTION

The Finnish Road Administration (Finnra) is conducting a Road Asset Management Research Program and one key aspect for the research is data collection and management. In year 2003 Finnra started a state of art project to study possibilities to change from the manual pavement crack inventory to fully automated crack measuring methodology.

Encouraged with the findings Finnra decided to fully test different measuring devices. Finnra tested two measuring devices during period June – July 2004 and was able to compare those results with crack inventory results. With the help of these results Finnra received a practical understanding about the limits and prospects of these new technologies.

The crack measurement technology has made a huge development step during the last five years. The industry needs testing, verification and possibilities for product measurements to be able to provide good solutions for clients. Also, it is useful to demonstrate the different techniques to use crack data from the network level condition distributions through project design and procurement.

Helsinki, January 2005

Finnish Road Administration

Content

1 METHODOLOGY

The basic idea of this study is to gather a very practical view about the new measuring methodologies and to be able to compare the results with the existing crack inventory practices called PVI (a visual manual method).

The crack inventory program of the Finnish Road Administration is annually about 10 000 km. The test sites were chosen from this program (year 204) and marked on the road. The service providers for the measurement systems were free to choose the best time frame to conduct the measurements on the test sites during the best time period June – July 2004. The testing procedure required 2 complete runs on each test site. The companies were allowed to do as many repetitions they wanted to do. All variables were reported for each 10 meter and 100 meter sections.

The reference material were, video film from the test sites at very low speed, several field inspections were done to control the results against the data from Road Data Bank and data from condition data bank contain other relevant measurements. Also a second crack inventory was done for each test site. It was done in 2 phases, in sample 1 the second inventory was done in June and in sample 2 the second inventory was done in July. About half of the roads have the results from Laser-RST measurements (IRI, max rut, roughness etc.).

Results are studied from two perspectives:

1. Description of condition of network; network level
2. Cracks on specific site; project level

On network level we studied the results grouped for Asphalt Concrete roads (AC) and for Soft Asphalt roads (SA) and on the project level we tried to specify the different types of cracks.

1.1 Criteria's to choose test sites

The test sites were chosen with the following criteria:

- Road width, under and over 7 m. On narrow roads the traffic trends to drive only on three wheel paths and this changes the cracking.
- Existing cracks in terms of the PVI crack index: under and over PVI 40 m^2. This is the average of whole test section.
- On AC roads the depth of ruts, under and over 10 mm. The fatigue cracking starts from the bottom of deep cracks.

Altogether the study consist 17 test sites 52 km AC roads, 56 km SA roads and 3 km roads that were constructed 7 years ago and no action has been done under that time. This kind of sample was planned in order to be able to estimate the correlations between different crack observation methods on different kind of Finnish low volume roads.

On the table 1 can be seen how these criteria's were met on the test sites.

Table 1. Different types of test sites

AC	**Road width**	
Length, km	**Over 7 m**	**Under 7 m**
PVI under 40 m²	33	2
PVI over 40 m²	7	10
SA	**Road width**	
Length, km	**Over 7 m**	**Under 7 m**
PVI under 40 m²	5	11
PVI over 40 m²	5	35

Ruts over 10 mm were on 6.5 km of AC roads.

1.2 Test sites

Test sites located in the district of Uusimaa and Turku.

Table 2. Road addresses for test sites

Pavement Type	Test Site Number	Road number	Section number	Section length	Measured Length
AC	1	1215	1	5520	5500
AC		1215	2	5176	5100
AC	2	1221	1	5371	5000
AC	3	1222	1	2249	2200
AC	4	1331	1	4622	4500
AC		1331	2	4057	4000
AC	5	11225	1	6742	5000
SA	6	11201	2	5940	1900
SA	7	1223	1	3031	2800
SA	8	280	1	2244	2000
SA		280	2	4690	4600
SA		280	3	5778	5700
AC	9	282	1	6780	2500
SA	10	2810	3	4070	2000
SA		2810	4	5571	3000
SA		2810	5	7855	2000
SA	11	2260	7	4523	4300
SA		2260	8	4941	4900
SA		2260	9	4748	4700
SA	12	2262	1	7879	3500
SA	13	2253	1	5215	5000
SA		2253	2	3245	3200
SA		2253	3	7050	3000
SA	14	12455	1	8220	3800
SA	15	11319	1	2667	2500
SA		11319	2	4808	4700
7 years	30	133	1	6590	2200
7 years	31	132	4	5561	1600
7 years		132	5	2188	2000
Summary:	17 sites			147331	103200

1.3 Information from each 100 m section

The variables of information for each 100 m section from Finnra's Condition Data Bank (KURRE) are presented on table 3. RST Data exists for test sites 1, 2, 4, 8, 9, 14 and 31.

Table 3. Data variables for test sites.

Variable_ID	Condition Information
Kohde_nro	Test site number
TIE	Road number
AR	Lane
AOSA	Section, beginning
AET	Distance, beginnig
LOSA	Section, end
LET	Distance, end
PIIRI	Region
MITTAUSAIKA	PVI measurement time
M_AR	Measured lane
VERKKOHALK	Alligator crackking
K_SAUMAHALK	Certerline crack, narrow
L_SAUMAHALK	Certerline carck, wide
Kapea_PITUUSHALK	Longitudinal crack, narrow
L_PITUUSHALK	Longitudinal crack, wide
K_POIKKIHALK	Tranverse crack, narrow
L_POIKKIHALK	Transverse crack, wide
REIKA	Pothole
PURKAUMA	Ravelling
PAKKASKATKO	Tranverse crack, climate
REUNAPAINUMA	Edge drop
VAURIOSUMMA	Crack Index
KUORMITUSVAURIO	Fatigue distress
SAAVAURIO	Climate distress
MUUNNETTU	change date
VANHENTUNUT	old data
MITTAUSKOHDE_ID	Measurement ID
TAPAHTUMA_AIKA	Time
NOPEUS	Speed limit
KVL_RASKAS	ADT_heavy
KVL	ADT
KVL_KAISTA	ADT_lane
KKL_KUMUL	Equivalent standard axle loads
Paal_LEV	Pavement width
PAAL_LUOKKA	Pavement class
PAAL_TYYPPI	Pavement type
TEKN_PVM	Date for heavy action
TP_PVM	Action date
TP_PINTA	Type of action
TP_RAE	Stone size(max)
TP_massa	Amount of mass
TP_TYOMEN	Methodolofy of action
URA_AIKA	Tiem for rut measurement
URA	Max rut depth
KESA_IRI_AIKA	Time for IRI meas in summer
KESA_IRI	IRI_summer
KEVAT_IRI_AIKA	Time for IRI meas in springtime
KEVAT_IRI	IRI_spring
POIK_EPATAS	Transversal roughness
KVKANT	Beasring Capacity, spring
SCI	Surface Condition Index from BC
BCI	Base Condition Index from BC
KANT_MITTAUS_AIKA	Time forBC measurement
PAAL_CM	Pavement thickness
VESIURA	Water depth in rut
DRI	DRI variable by Finnra
POIKKEAMA	
HARJANNE	Height between wheelpath
HARJANNE_MAX	Max height between wheelpath
KAARTEISUUS_ALKU	Curvature
MAKISYYS	Hilliness
RMS_MEGA_OIK	RMS_MEGA_right
RMS_MEGA_KESKI	RMS_MEGA_middle
RMS_KARKEA_OIK	RMS_KARKEA_right
RMS_KARKEA_KESKI	RMS_KARKEA_middle
RMS_HIENO_OIK	RMS_HIENO_right
RMS_HIENO_KESKI	RMS_HIENO_middle
RMS1_OIK	RMS1_right
RMS3_OIK	RMS3_right
RMS10_OIK	RMS10_right
RMS30_OIK	RMS30_right
Päällyste	Pavement

Visual inventory, PVI, crack variable VS (vauriosumma)

The crack inventory methodology used in Finland is called as PVI. It is a semi manual inventory of cracks over both lanes. The inventory is done with very low speed and the driver tells to the operator what kind of cracks he can visually see on the pavement. The operator uses a panel connected to computer and feeds the different measurement types to the database. The road address and distance measurement comes automatically to the database.

The PVI index, "vauriosumma, VS", is calculated with the help of weight factor for each crack type. The unit is m^2.

All results are stored per 100 meter sections. The crack types used in VS variable are:

Crack type	Weight factor
• Transversal Cracks	
▪ Narrow	0.5
▪ Wide	1
▪ Freeze	0.1
• Longitudinal Cracks	
▪ Narrow	0.5
▪ Wide	1
• Centerline Cracks	
▪ Narrow	0.5
▪ Wide	1
• Alligator Cracks	1
• Holes and raveling	1

The basic data for all test sites comes from the current crack inventory methodology. PVI inventory data from the normal production measurements were collected in May 2004. We call this dataset in the analysis PVI (May).

The second PVI inventory was done for each test site in two phases and we call these datasets in the analysis as PVI_sample 1 or PVI_sample 2. Sample 1 was conducted in May and June and sample 2 in May and July. In general the procedure for the second measurement is the same as the inventory in May but for practical reasons the second measurement is done more accurately, roads addresses are controlled and the inventory is conducted with very experienced personal.

The length for the different samples and pavement types were:

AC roads	
PVI_sample 1	14.5 km
PVI_sample 2	37.5 km
SA roads	
PVI_sample 1	5 km
PVI_sample 2	47 km

1.4 Other Crack variables

The crack variables presented in this report were:
Cracked Surface percentage, CS, A grid of 20 x 20 cm is put on top of the measured section and each grid containing a crack segment is rated cracked. The percentage of cracked surfaces for each 100 and 10 meter section is calculated (chapter 2.3).

Cracked Surface percentage in the wheel path, CSiwp, is the percentage of the road surface affected by cracking in the wheel path area (chapter 2.2).

Unified Crack Index, UCI, is the percentage of the road surface affected by cracking and patching.

1.5 Reference video

The test sites were filmed on video at very low speed and compiled with distance data to digital video files /Appendix B.

Example from the video figure is from test site 5, 1075 m from the beginning.

Figure 1. Example from the video, screen dump from the player.

To verify the validity of the automatic crack measurements some individual cracks were picked from the measuring data to compare the polygon data with the actual physical measures from road and from images.

1.6 Combination of data from the test sites

The data from different sources were combined for each 100 meter section. Results can be compared per 100 meter as actual values or differences between two measurements. For the statistical analysis observations for AC and Soft asphalt roads were combined for datasets per 100 meter (PVI; CS and UCI) and per 10 meter (CS and UCI).

The crack index results from both PVI inventory runs are presented in figure 2.

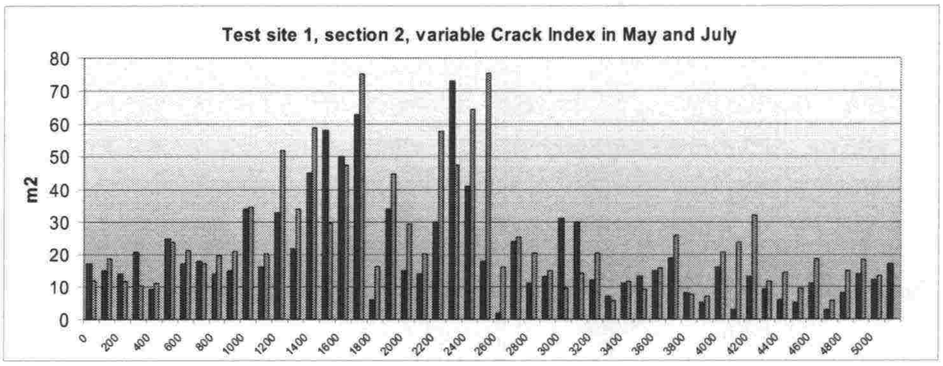


Figure 2. Example from test site data, PVI(May) and PVI(July) results.

All results are reported in similar way and it is possible to compare chosen variables on each test site.

The macro texture in the right wheel path for AC sections and soft asphalt (SA) sections are shown in the figures 3 and 4, measured by Ramboll RST.

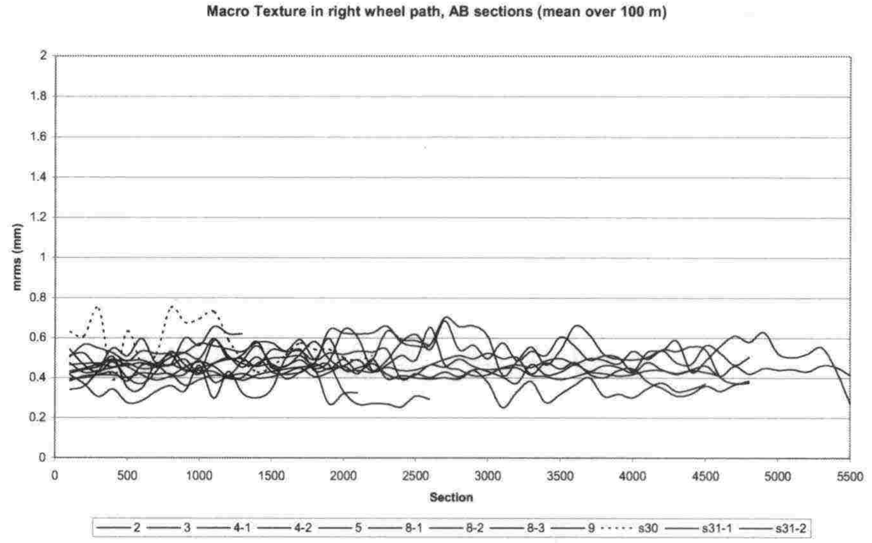


Figure 3. Macro texture in the right wheel path for AC sections.

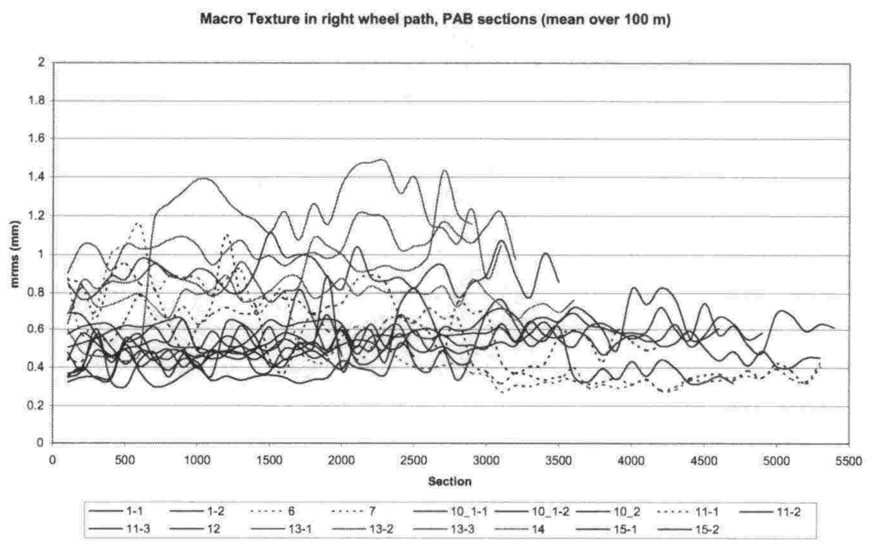


Figure 4. Macro texture in the right wheel path for SA sections.

The texture varied a lot for the SA sections while for the AC sections, the macro texture were rather uniform between road objects. Refer to figure 4. Especially test site 13 has very high roughness values.

2 SYSTEM R

2.1 Overview

Ramboll RST provided to the test a measurement device called Laser RST PAVUE, version 13. The company, Ramboll RST has currently a 5 year contract to measure the road surface features of the Finnish public road network, which includes automatic measurements of rutting, unevenness, texture etc. Ramboll RST has a long experience in road surface measurements and together with Ramboll OPQ (a part of Ramboll RST), the company has a complete array of techniques and equipment for the automatic crack measurements with production capability beginning in 2005.

Figure 5. Ramboll RST measuring vehicle, version 2004.

2.2 Measuring Instrumentation

The measuring instrumentation used in this test was a Laser RST vehicle that was equipped with 4 cameras on the back side of the vehicle, facing the road surface and collecting images at highway speed limits. The vehicle also has a video camera directed forward to gather a pictorial overview of the road section measurements. The report of the measurements is on appendix D (Offrell 2004).

Additional lightning equipment is located at the back of the car, close to the pavement.

Figure 6. Cameras and the lightning system.

A generator is located at the rear of the vehicle as a temporary solution for the electricity supply.

Texture was measured simultaneously using Laser RST technique. The texture was varying over the sections and between different sections within the same overlay. This information is used to distinguishing cracks from the pavement background image (this is referred to as segmentation).

Wheel path areas were defined in the following manner:

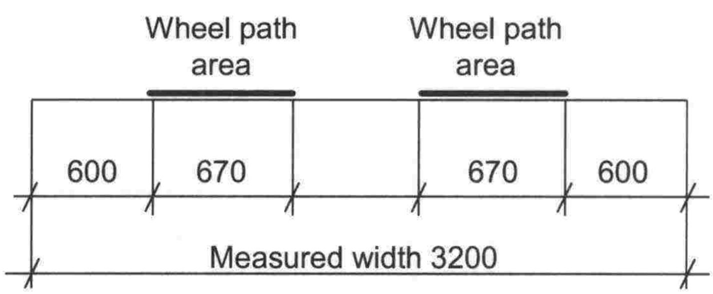


Figure 7. Theoretical positioning of the wheel path areas.

The analyses of the video recordings are performed using an off-line analysis station in the office environment. The software is developed by OPQ Ab.

For repeatability of the processing data in the office there are a few issues to address. The analysis is fully automated after the settings based on overlay type and macro texture. The settings are defined and evaluated individually for the surface group types.

- The result is dependent on the macro texture, for example, some crack segments can be expected to be missed on surfaces with high macro texture.
- Also, the result is dependent on the amount of cracking, for example, on a road with high cracking one can expect to have a data overload with subsequent data loss on shorter sections of a few meters. This normally does not influence the capability of estimating the status of the road.
- This overload can be different at different measurements, up to 5m in a 100m section.

- The analysis settings are very important input variables for the automated analysis: First analysis with the test data was done with too wide analysis area. The current system can not automatically adjust the edge of pavement, so too wide area was chosen to the first set of results. It gave a lot of cracks from the right hand side of the road. In the second analysis was the last 40 cm left out from the right side of the lane and 20 cm from the left side of the lane. The difference is shown in figure 8.

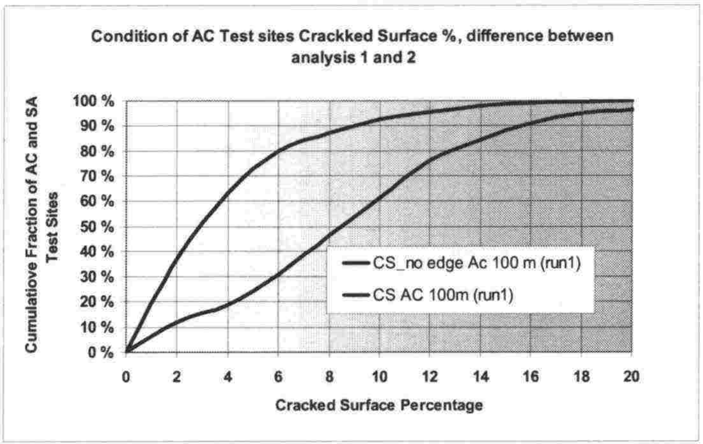


Figure 8. Difference between analysis settings 1 and 2.

The second analysis settings (blue line) gave a good result about the difference between AC and SA test sites.

2.3 Crack variables provided by System 1

System R (Ramboll RST) provided the following crack variables for this test:

Cracked Surface %

A grid of 20 x 20 cm is put on top of the measured section and each grid containing a crack segment is rated cracked. The percentage of cracked surfaces for each 100 and 10 meter section is calculated.

- Cracked Surfaces based on the grid model.
- Cracked Surfaces inside the wheel path areas.

The size for the grid is free to define according to the need.

Crack Status presentation according to English TTS specification model.

This crack index is modeled by TRL Limited for the acceptance testing for automatic crack measurement in England.

The method is developed for road objects containing varying extent of cracking along the measured section. The following procedure is used:

For each set of data (e.g. a single run with the crack data collection vehicle):

1. Sum the cracked 20 x 20 cm area of cracking over 50m lengths.
2. Calculate the average of the detected cracks
3. Divide all values by this value to get a new dataset having an average value of 1, each of these is now the relative intensity.
4. Use this data to decide on the level for each 50m length (low 0-0.2; medium 0.5-1.25 and high >1.75)
5. Compare each section with the corresponding section of the reference to see if the level match (requires; low and high 75% match, medium 50% match).

The allocation of level (high, medium, low) is dependent on the dataset itself. TRL uses a manually rated data set (filmed by a reference vehicle) as the reference. The limits for the different levels chosen by TRL (based on a test section specially chosen for it's variation in cracking) are normally not representative for road sections were the cracking is generally rather uniform.

These results are presented in the Appendix C. This methodology is developed according to the needs of Highway Agency to manage the high volume trunks roads in England. To use the definitions in Finnish low volume roads some re-engineering must be done to establish the useful limits for the definition of high, medium and low severity.

Crack Maps

The crack maps are presented as 100 meter on each page (see below). Each crack segment is described with a polygon based on x- and y-coordinates in the local reference, i.e. a straight road of the measured length.

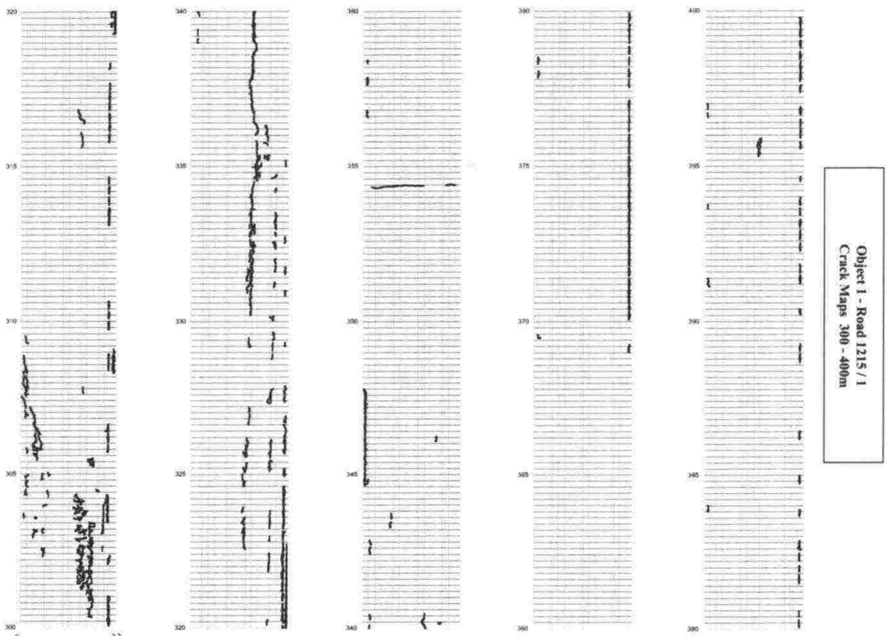


Figure 9. *Example of a crack map.*

Polygon data

It is possible to calculate additional parameters from the raw polygon data files. There are also a number of predefined parameters that are calculated automatically in the analysis. For example:

- Crack length (Lt). The crack length is calculated as the perimeter of the individual crack polygon divided by 2.
- Accumulated longitudinal (L) or transversal (W) crack extent. The crack extent is calculated as the height or width of the box which inscribes the individual polygon.
- Position. It is defined by the position of the X- and Y-coordinates describing the individual polygon.
- Direction. The direction is defined by the angle (a) between the diagonal of the box which inscribes the individual polygon and the driving direction.
- Shape (S). The shape can be defined by the length of the polygon divided by the diagonal of the box which inscribes the individual crack polygon. A high value would impose a crack with many branches.
- Percentage of cracked area (P). It is defined as the area covered by crack pixels in a section divided by the total area of the same section. This can be calculated for different section intervals.

In Figure 10 the definitions of the crack measures are illustrated.

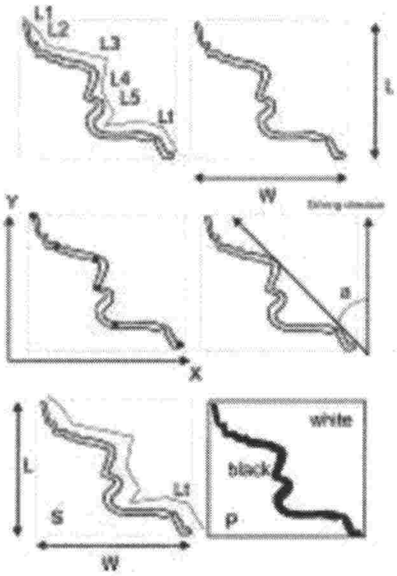


Figure 10. Definitions of the crack measures.

2.4 Development plans

Ramboll RST is going to integrate the Crack Imagination instruments to the Laser RST vehicle. This means the possibility to collect effectively surface condition data with one measurement run.

The present the overall information of the crack status can be done by generalization of amount of cracks by the percentage of the cracked surface. A proposal is to divide the CS percentage into classes. As an example: 0-2% no cracks, 2-5% crack starts, 5-10% medium cracked, >10% heavily cracked road section.

3 SYSTEM T

3.1 Overview

The Finnish Road Enterprise provided a second measurement device for the test. The Enterprise has done semi-manual PVI inventory since the methodology was introduces in the beginning of 1990's. The Finnish Road Enterprise has followed the development of the automated systems for a long period and was one of the main participants for the previous crack measurements test in 1998 with the GIEtech Inc. The Finnish Road Enterprise can also provide a wide range of measurement services for network and project level measurements.

Figure 11. Crack measuring device, The Finnish Road Enterprise, version 2004

3.2 Measuring Instrument, version 2004

The measuring instrument was installed on a van and one person was able to conduct all the analysis work needed. The System was provided by Adhara Systems Inc. The system includes Digital camera, unit to steer camera with the speed of the vehicle and computer to store images and the software to analyze the images.

The vehicle does not have any lightning devices for imaging. See Figure 11 for a pictorial view of the vehicle.

3.2.1 UniANALYZE Software

UniANALYZE software loads all pavement images related to a particular section. It allows the user to continuously measure the distress over an entire section of pavement. Figure 12 shows the image load dialog box.

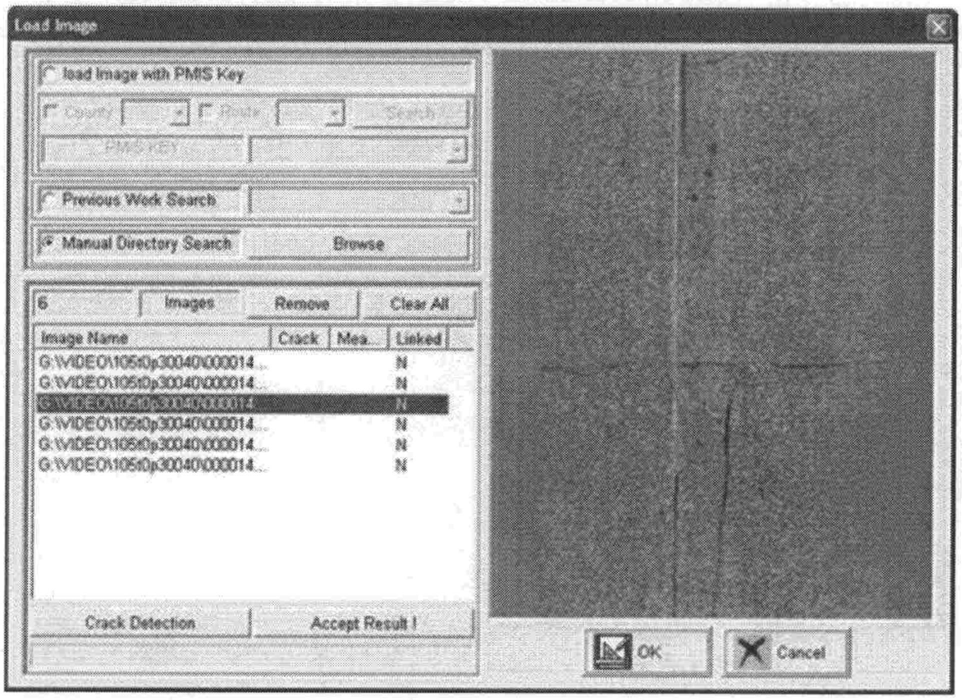


Figure 12. Image load dialog box

Automatic Pavement Distress Condition Rating

UniANALYZE uses state-of-the-art digital image processing technology to analyze figures taken from various types of pavement surfaces. uniANALYZE has two main image processing steps:

- **Image Segmentation**: A common problem in automated pavement image evaluation, is distinguishing cracks from the pavement background image (this is called segmentation). uniANALYZE employs the following automated crack image segmentation procedure:
  - The pavement image is divided into user specified grids to compensate for the various lighting condition in pavement surface.
  - A noise filter is applied to the image to remove the background noise caused by the pavements rough texture while maintaining minimal degradation of sharp crack edges.
  - A white line detection filter is applied to reduce the errors caused by the distinctive edges of any white line using statistical properties of pavement images.
- **A crack detection analysis** is applied to each grid to distinguish the cracked grids from the background grids.

3.3 Crack variables provided by System T

Since there are many definitions of different distress categories, uniANALYZE currently adopts two different crack classification standards: Unified Crack Index and AASHTO provisional standards. Custom standards can also be implemented based on client's requirements.

Unified Crack Index

Unified Crack Index (UCI) is the percentage of the road surface affected by cracking and patching. Dr. H. Lee first introduced the Unified Crack Index classification standard (Pavement Management Implementation, ASTM STP 1121). uniANALYZE counts the number of cracked grids. Then, it divides the counted number by the total number of grids to compute a unified crack index for each pavement image. The size of grids can be chosen by the customer in this test we have used 20 cm x 20 cm grid. Figure 13 shows a sample of the unified crack index.

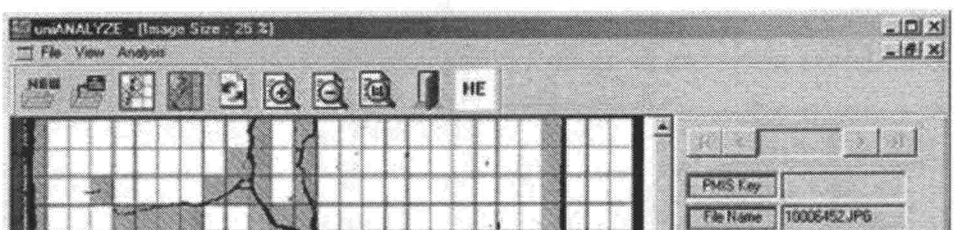


Figure 13. *The Unified Crack Index analysis window displaying a processed unified crack index of 73. 03 % (100 – 233 cracked grids out of 972 total grids)*

AASHTO Provisional Cracking Standards

AASHTO provisional cracking standard have been adopted into uniSURVEY and have been used in a systematic and rational manner since 2000. uniSURVEY can determine the crack type for each image based on the AASHTO protocols. After defining the crack types, uniSURVEY can then calculate the extent and severity of the crack. This is measured by either length or area of crack depending on crack types. Figure 14 shows a sample of the AASHTO standard analysis result.

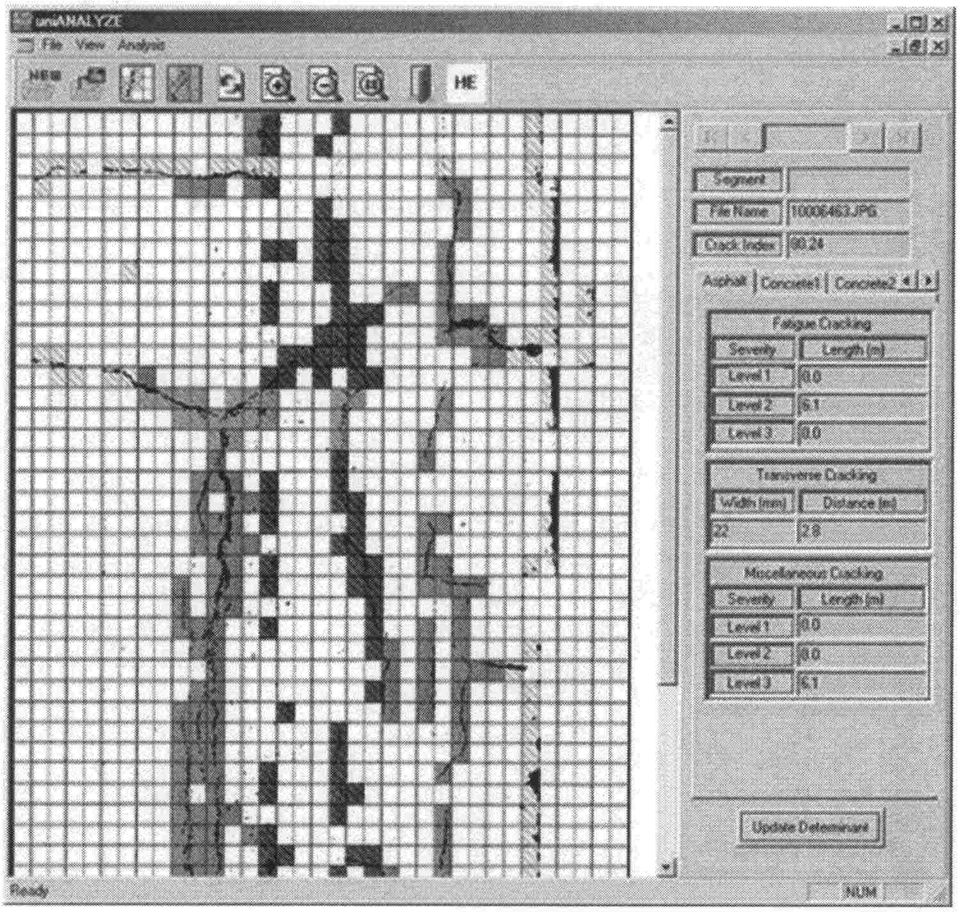


Figure 14. The AASHTO image analysis window displaying a level 2 severity 6.1 meter fatigue, 22mm in width with a 2.8 meters long transverse, and a level 3 severity 6.1 meter long miscellaneous cracks.

The AASHTO variable was provided as three result range inside, between and outside wheel path. For each range the average crack width and severity class was provided as average of 10 meter and 100 meter section. With the current system the user could not define the severity or crack width definitions, so it was not possible to verify effect of different settings. Because the analysis procedure basically is the same as with the UCI definition, 100 Gen concentrated to present the UCI values.

Basically the software gives the result values for each picture and the procedure to define the representative value for 10m or 100 m section must do. It cannot be average value of several pictures as the first suggestion was.

In the table 4 is presented the basic AASHTO type result from 5 images.

Table 4. AASHTO results per image (test site 3, appendix A)

Image	Variable	1322.jpg	1327.jpg	1329.jpg
IW	(Intensity)	0,00	0,19	0,00
IW	(Width)	0,67	9,19	0,00
IW	(Severity)		3	
BW	(Intensity)	0,00	0,00	0,00
BW	(Width)	0,00	0,00	0,00
BW	(Severity)			
OW	(Intensity)	1,06	1,35	1,15
OW	(Width)	7,58	7,54	8,74
OW	(Severity)	3	3	3

Data variables are the following:

Segment ID	Shows the road address
File Name	The files are automatically named according to the distance measurement system
IW	IW means inside wheel path (side of centerline),
BW	BW means between wheel paths
OW	OW means outside wheel path (side of centerline)
(Intensity)	Intensity is the AASHTO definition for amount of cracks in the image (m/m^2).
(Width)	Width shows the average width of cracks in an image
(Severity)	Severity is the AASHTO classification according to the crack width (1 if the width is less than 3 mm, 2 when width is from 3 mm to 6 mm and 3 when width is over 6 mm)

Some examples of the images are presented in appendix A (CD vol 1.).

AASHTO definitions are potential variables for Finnra if the user can study the effect of different settings to the results.

3.4 Development plans

The Finnish Road Enterprise has intended to actively provide the crack measurement services in Finland. This will include the development of measuring methods and variables for planning, design and quality control purposes.

The possibility to combine the crack measurement with other road surface measurements is going to be an important issue.

If the automated system can not define patches, should the information be manually added to the system.

4 RESULT

4.1 Overview

The current practice of crack inventory data is concentrated for pavement management purposes on network level. This includes presentation of current condition, development of crack deterioration models, presentations for condition changes and quality control analysis.

The crack information is needed for the design, planning and quality control purposes. The type of a crack can reveal the reason for pavement deterioration and the type of action needed and it can be used as functional requirements for the contractor over longer period. The measuring method should meet the demands for an objective variable to follow up these functional requirements.

There are two main questions where the road condition measurements are needed and the crack definitions are one important part of the possibilities to describe the road condition:

- What is the level of service for the specific road?
- What is the strength or the remaining life time for the specific road?

Table 5. Test results

Results	Variable	Pavement	Observations	Crack Inventory	System 1	System 2
Condition distribution	Vauriosumma	AC & SA	10m & 100m	X		
	Cracked Surface	AC & SA	10m & 100m		X	
	Unified Crack Index	AC & SA	10m & 100m			X
Distributions of observations	Vauriosumma	AC & SA	100m	X		
	Cracked Surface	AC & SA	100m		X	
	Unified Crack Index	AC & SA	100m			X
Repeatability (absolute difference)	Vauriosumma	AC & SA	10m & 100m	X		
	Cracked Surface	AC & SA	10m & 100m		X	
	Unified Crack Index	AC & SA	10m & 100m			X
Reliability, 95 %	Vauriosumma	AC	100m	X		
	Cracked Surface	AC	100m		X	
	Unified Crack Index	AC	100m			X
Repeteability (low, medium and high relative difference)	Vauriosumma	AC	100m	X		
	Cracked Surface	AC	100m		X	
	Unified Crack Index	AC	100m			X
Crack Types	*Longitudinal*	AC & SA	10m & 100m	X	(X) not compeleated	
	Transversal	AC & SA	10m & 100m	X	(X) not compeleated	
	Allicator	AC & SA	10m & 100m	X	(X) not compeleated	

Results from this test are presented in a similar way that is used in the Finnish Road Administration's (Finnra's) planning processes. The three different measuring methodologies are providing three different approaches to describe the cracking status on test sites. In principal the basic definition for cracked surface and Unified crack index is the same, but the solutions are so much different that the variables do not represent each other. The reader cannot directly compare the different values from different methodologies, but it is possible to estimate the basic message from each variable; how badly the test sites are cracked?

4.2 Condition distributions according to different crack variables

The presentation of condition distribution is the most important result from the condition measurements. The cracks are behaving differently on AC and SA (soft asphalt) roads because of the traffic volume and the structural differences. The test results are presented separately for AC and SA test sites to demonstrate the most common usage of the PVI data, condition distributions. The figure 15 presents the PVI distribution 1.1.2004 on all Finnra's AC and SA roads.

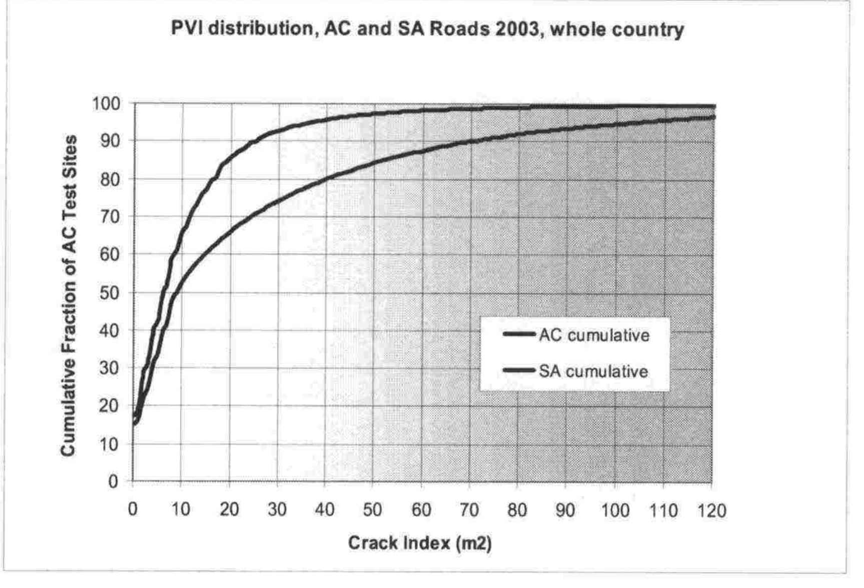


Figure 15. *The condition distribution for AC and SA (soft asphalt) roads with PVI variable.*

This condition distribution is much better than the distribution from the test sites (Figure 16). All results are presented as 100 m observations, because the PVI results are presented per 100 m section. To get more precise results the automatically collected data is presented also in 10 m sections. This provides more observations for statistical analysis and also bigger variation for results than the averages for 100 m.

PVI measurements are covering both lanes and automated variables are covering only images from one lane.

4.2.1 Asphalt Concrete Roads (AC test sites)

Bold lines are PVI measurements in May, 52.1 km, bold line with square is the distribution of all AC test sites and the narrow lines with dots are measurement pair May – June, 12.5 km.

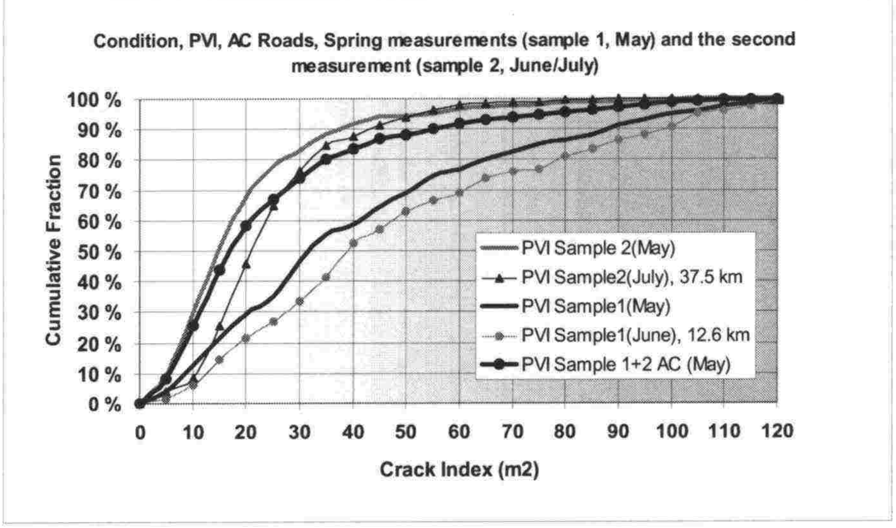


Figure 16. The condition distribution for AC roads with PVI variable.

Second PVI measurement found more cracks from the test sites that the inventory in May. 10 % of all roads have crack index over 60 m^2 (limit to "poor road" definition). 95 % of all roads have crack index below 80 m^2.

Same test sides presented with System R, 52 km, two runs results as averages for 100 meter and 10 meter sections.

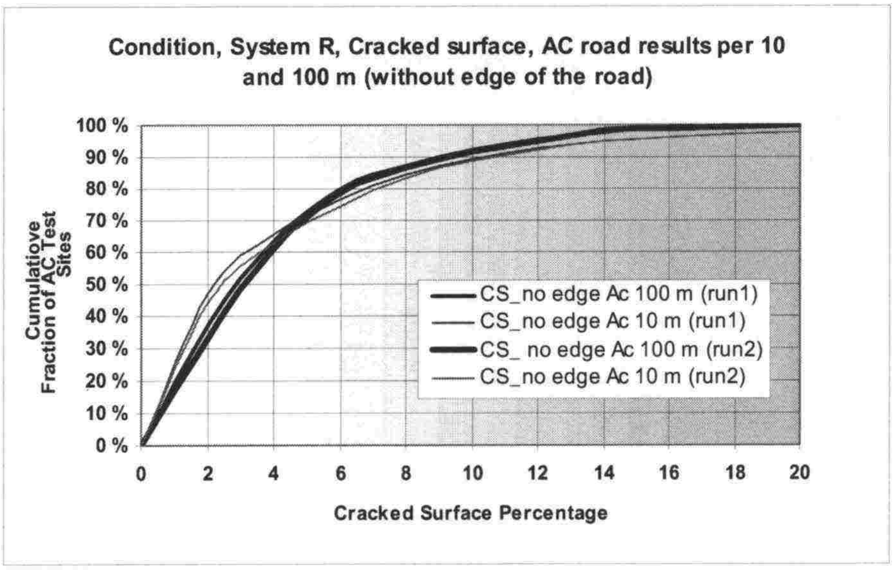


Figure 17. The condition distribution for AC roads with System R, unit Cracked Surface Percentage.

10 m results show greater variability and are logical. Both measurement runs are giving very similar results. 95 % of observations are below CS 12 %. Condition of AC test sites presented with System T, 52 km. Results from two different runs are very similar to each other.

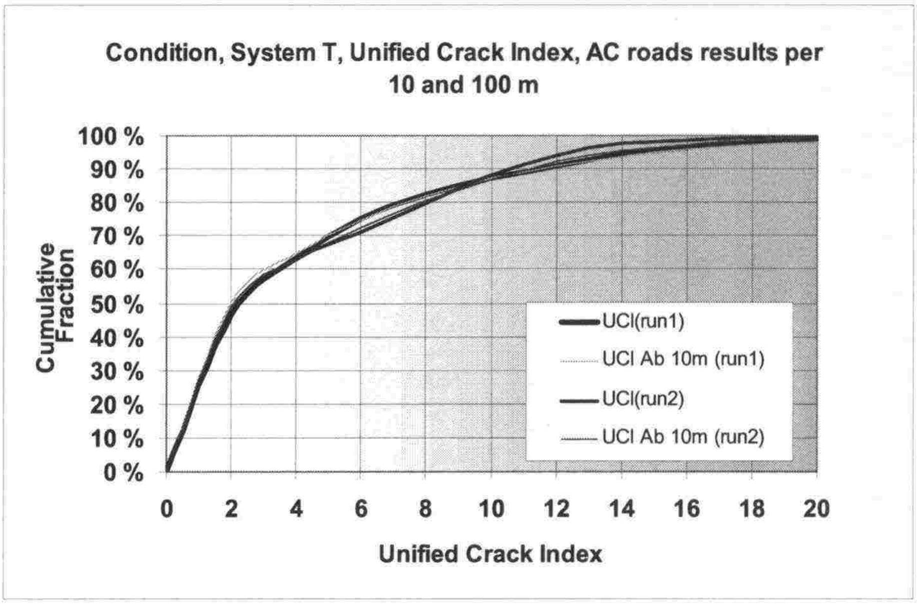


Figure 18. *The condition distribution for AC roads with System T, unit Unified Crack Index.*

The variability between 10 and 100 meter results is very small, but it exists. 95 % of observations are below UCI 14 %.

System R is the year 2004 version of Ramboll RST measuring instrument and System T is the year 2004 version of the Finnish Road Enterprice's measuring instrument. This means that these results and condition variables are representing the measuring instrumentation and software used in 2004 test.

4.2.2 Soft Bitumen Roads (Soft Asphalt (SA) test sites)

Only one test object had a PVI measurement in June (5 km) so these results are presented together with other SA results. In Figure 19 is presented results from the SA test sites, 52 km.

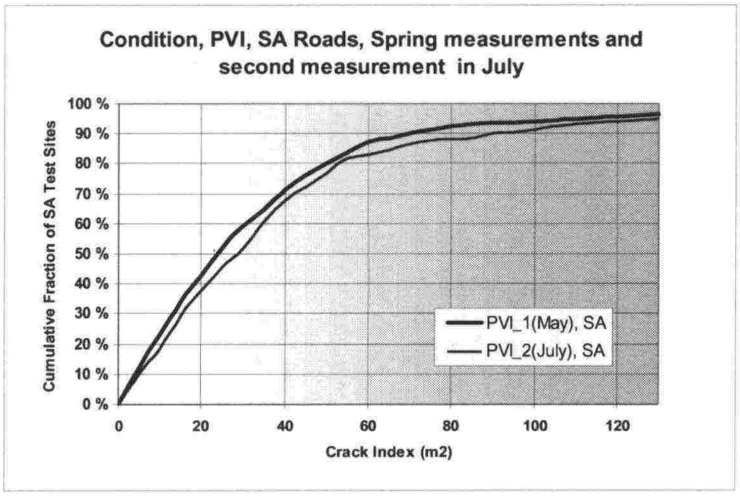


Figure 19. The condition distributions for Soft Asphalt (SA) roads with PVI variable.

The July measurement shows more cracks than the measurement in May. The limit for "poor roads" is on this type of roads 115 m^2 . On this data we have 5 % of roads that have more cracks that 115 m^2 .

Same test sites are presented with Cracked Surface % with 10 and 100 meter sections in Figure 20. 5 % of roads have more cracks CS value 18 %.

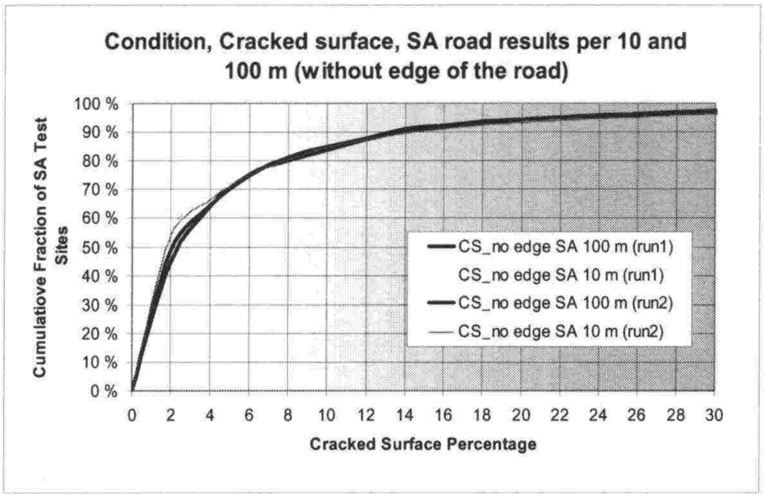


Figure 20. The condition distribution for AC roads with Unified Crack Index variable, System R.

The difference between 2 measurement runs is very low. Results per 10 m sections have more variability.

Same test sites are presented with Unified Crack Index % with 10 and 100 meter sections in Figure 21.

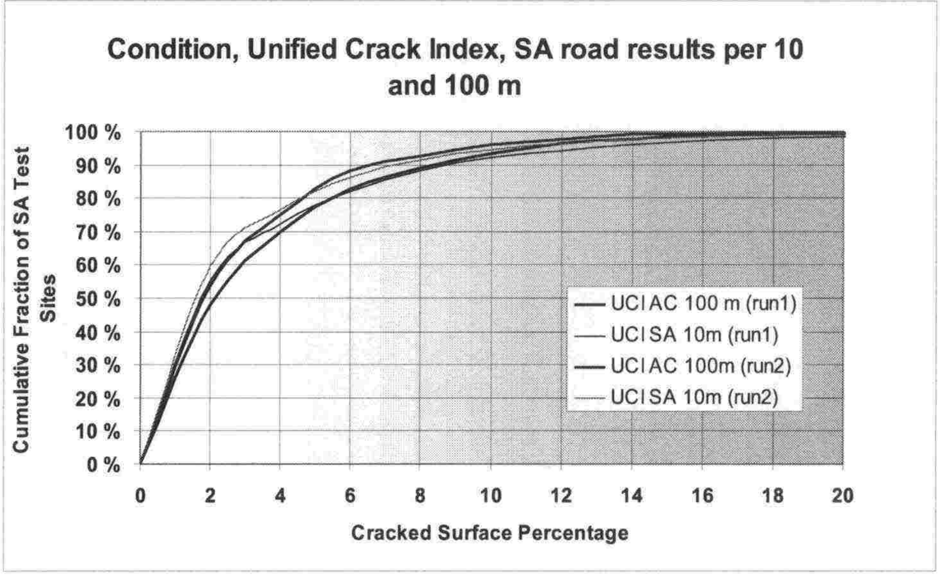


Figure 21. *The condition distribution for soft asphalt (SA) roads with Unified Crack Index variable, System T.*

5 % of roads have more cracks UCI value 12 %.

Comments

The condition distribution curve for both automated measuring systems is steeper that the inventory results. This happens especially on small crack level.

4.2.3 Comparison of the cracking on different types of roads

To illustrate how the results are used to present the crack status on different type of networks we present the AC and SA distributions on same figure. How the different methodologies succeed to present the more poor condition on SA roads?

The traditional result from PVI shows the difference in Figure 22.

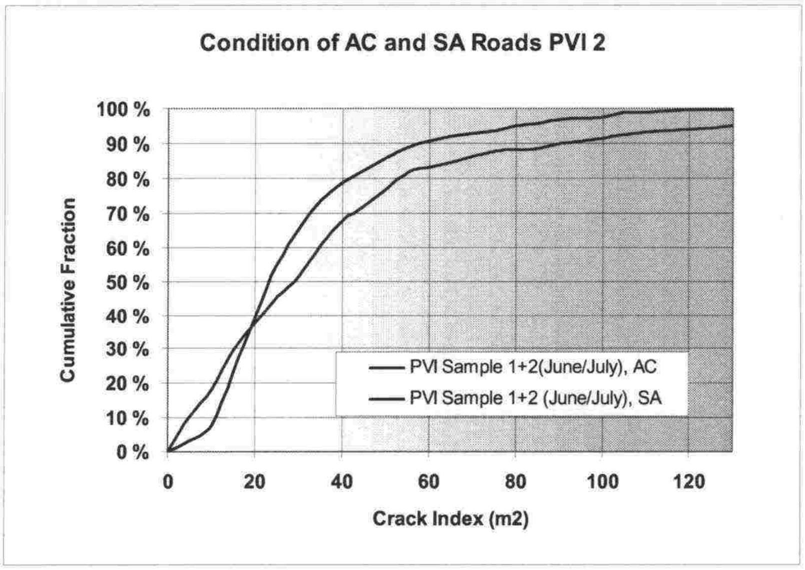


Figure 22. *The condition distributions for AC and SA roads with PVI variable.*

SA test sites have less little cracked and a lot more very cracked sections.

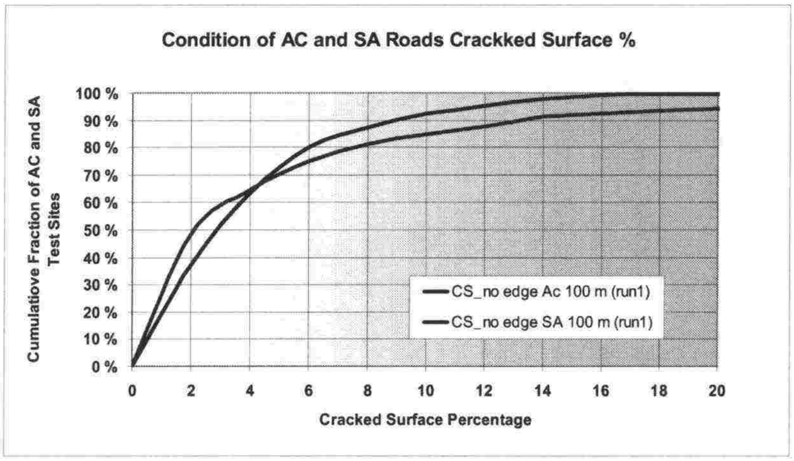


Figure 23. *The condition distributions for AC and SA roads with Cracked Surface variable by System R.*

System R, Cracked Surface percentage, shows similar trend than PVI variable. For example the crossing of AC and SA lines.

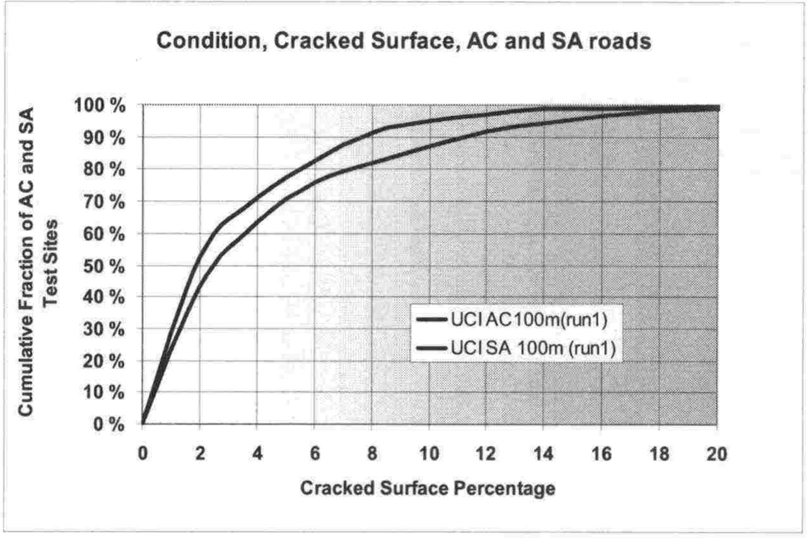


Figure 24. *The condition distributions for AC and SA roads with Unified Crack Index variable by System T.*

Also the System T, UCI, variable shows that SA test sites have worse condition than the AC sites.

Comments

Cracks from wheel path area can be presented separately. The result is similar to the condition distribution but the user can find precisely those sections where wheel path cracking exists. The Figure 25 shows that SA roads have more cracks on wheel paths.

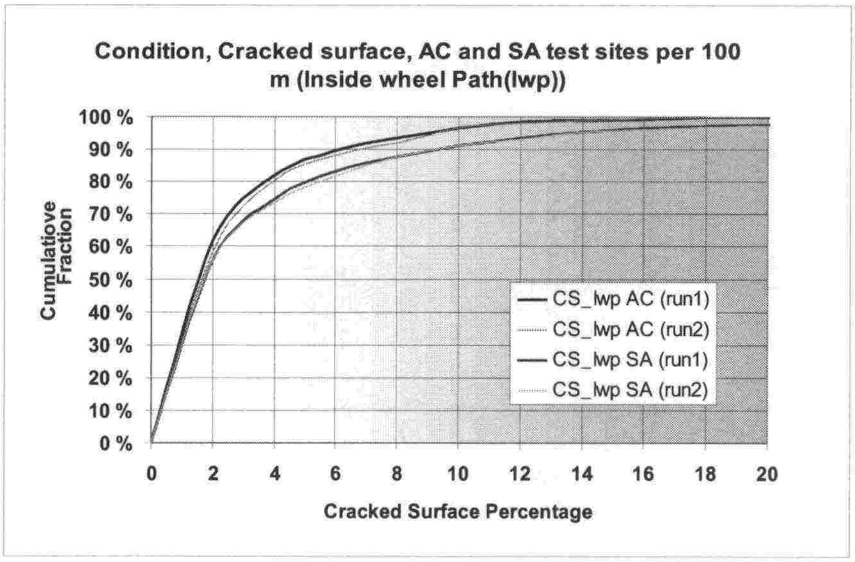


Figure 25. *Cracked Surface % in wheel path area from AC and SA test sites, run 1 and 2 by System R.*

4.2.4 Distributions for the test site observations

Another way to look the distributions from different measurement methodologies is to look all observations from AC and Soft Asphalt (SA) test sites (Figures 26 and 27) and estimate the best function to describe the results.

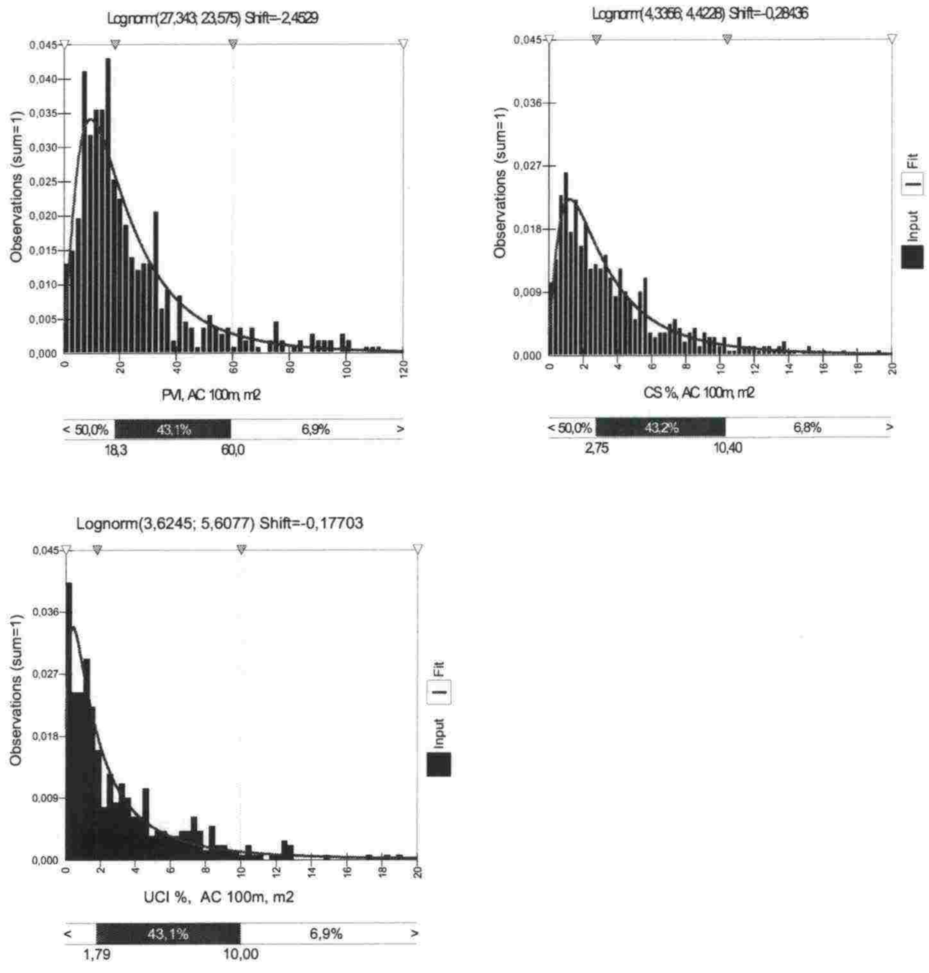


Figure 26. *AC observations from PVI, CS and UCI analysis.*

At the limit value for "Poor roads", VS 60 m^2, means that 6.9 % of PVI observations are over this limit. The corresponding CS value is 10.4 % and UCI value is 10 %.

The median of crack PVI inventory results from AC roads is 18.3 m^2 (VS) and the median for both measuring systems is at very low level, CS value is 2.7 and UCI value 1.8. This gives a hint that the analysis systems skip small and low severity cracks. After the severity is medium or high the system can collect the cracking. This can be seen as a positive feature when the road keeper is using the data to estimate the need for actions. UCI analysis finds most of the figures clean in this test.

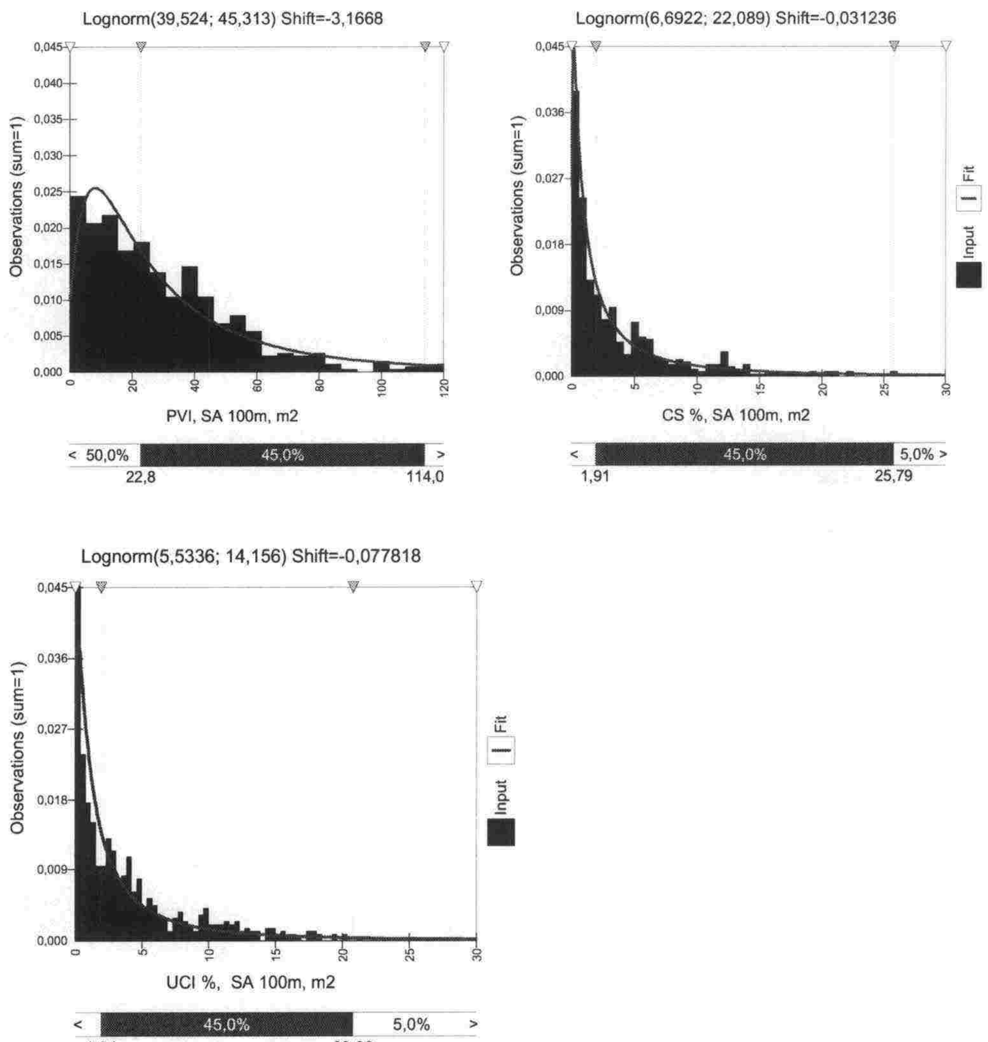


Figure 27. *SA observations from PVI, CS and UCI analysis.*

The limit for "poor roads" on SA is quite high 115 m^2 which means that only 5 % of observations from SA test sites were over it. Comparable CS value for that is 26 % and UCI value 21%.

On Soft Asphalt roads are very much observations without any crack for both measuring systems.

4.3 Repeatability on network level measurements

Overview

Repeatability is presented by calculating the difference between run 1 and run 2 for each 10 or 100 meter section. This absolute difference is classified and the cumulative distribution of these errors shows the repeatability of the measurement. Often the quality demands are presented as accepted values at certain level of reliability, for example 50 % and 95 % of observations must be under chosen percentage.

Repeatability of PVI inventory.

All observations from run 1 and run 2 are presented in Figure 28 for AC and Soft Asphalt, SA, test sites.

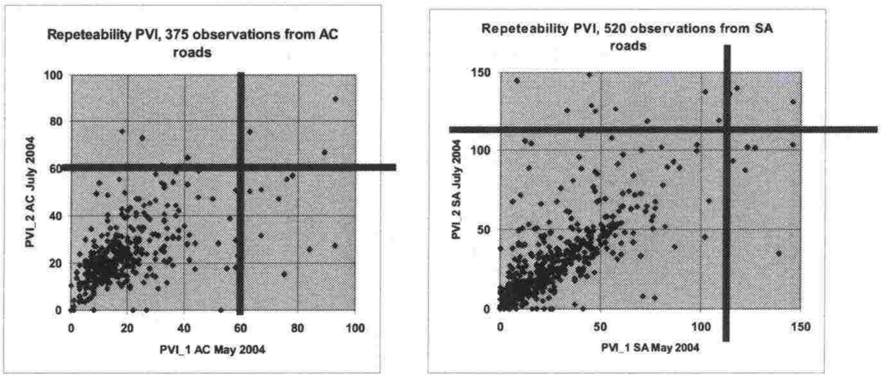


Figure 28. PVI observations from AC and SA test sites.

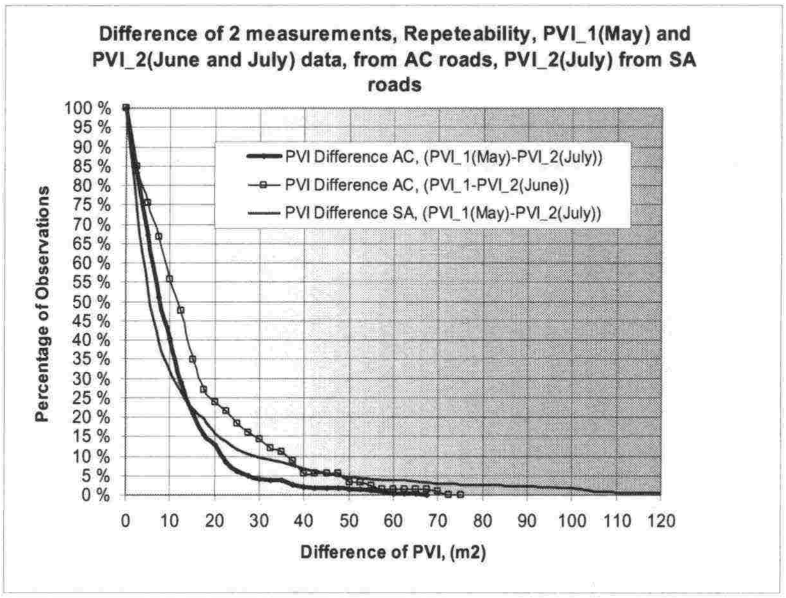


Figure 29. PVI repeatability AC and SA test sites.

Repeatability of PVI measurements in July was much better than the repeatability in the June measurements. 50 % of AC PVI measurements were +/- 5 m^2 from each other and 95 % reliability was at PVI value +/- 20 m^2.

Repeatability of System R measurements (variable Cracked Surface percentage)

All observations from run 1 and run 2 are presented in Figure 30 for AC and SA 100 meter observations.

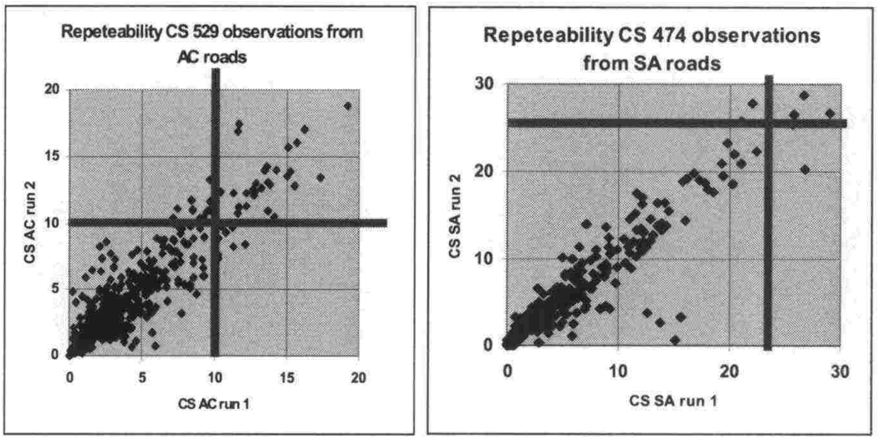


Figure 30. *System R observations (CS) from 2 runs, AC and SA test sites.*

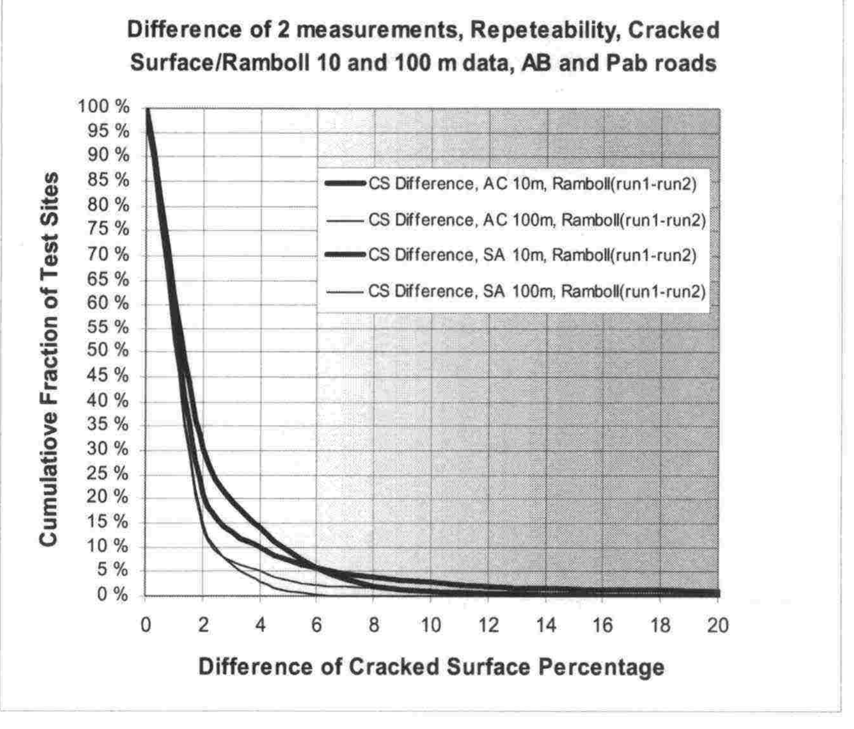


Figure 31. *System R (Ramboll 2004) repeatability AC and SA test sites.*

The System R (CS) repeatability can be described as: 50 % of AC CS(100m) measurements were +/-0.5 % m^2 and the 95 % reliability was for CS(100 m) value +/- 2 %

Repeatability of system T measurements (variable Unified Cracked Index)

All observations from run 1 and run 2 are presented in Figure 31 for AC and SA 100 meter observations.

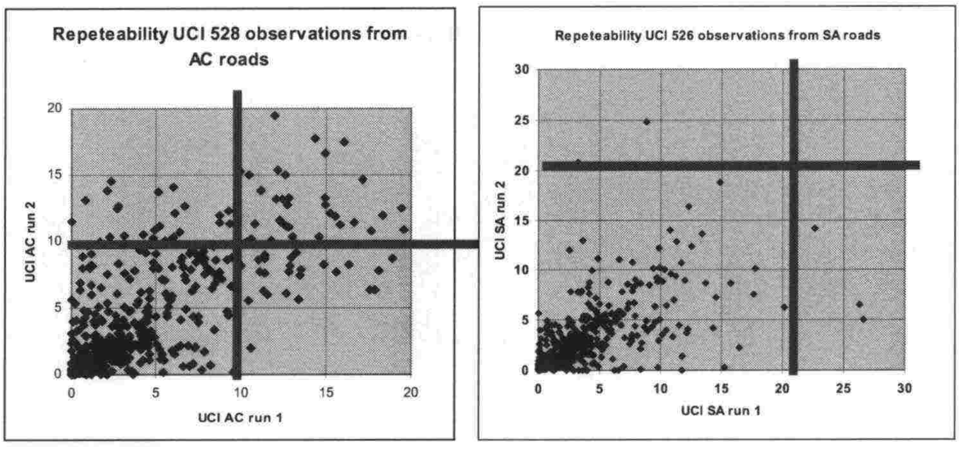


Figure 32. System T (UCI) observations from 2 runs, AC and SA test sites.

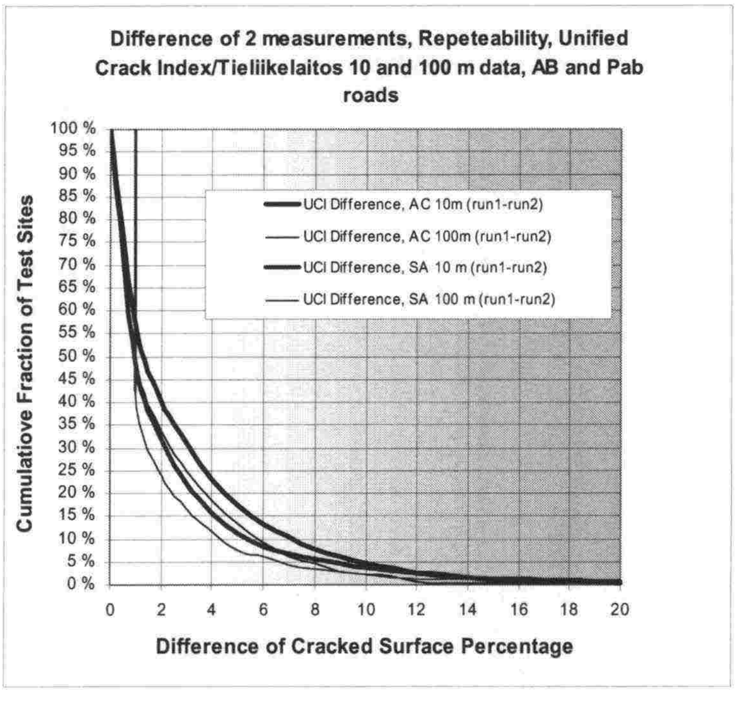


Figure 33. System T (UCI) repeatability AC and SA test sites.

The repeatability of System T, version 2004, (UCI)) repeatability can be described as: The 50 % of AC UCI measurements were +/-0.5 % m^2 and the 95 % reliability was for UCI value +/- 4 %. The AC pavements were more difficult to analyze than the SA test sites (the difference of 2 runs is bigger on AC test sites than on SA sites).

This quality information can be used to estimate the effect of used method in planning. In figures 34 – 36 we present the condition distribution for AC test sites when the initial crack value is low, medium or high. These ranges are roughly estimated from the test sample:

- Low is 40 % of observation (PVI value is <= 15 m^2 and CS and UC values <= 2).
- Medium are 30 % of observations (PVI value is 15-30 m^2 and CS and UC values 2-5).
- High is 30 % of observation (PVI value is > 30 m^2 and CS and UC values > 5).

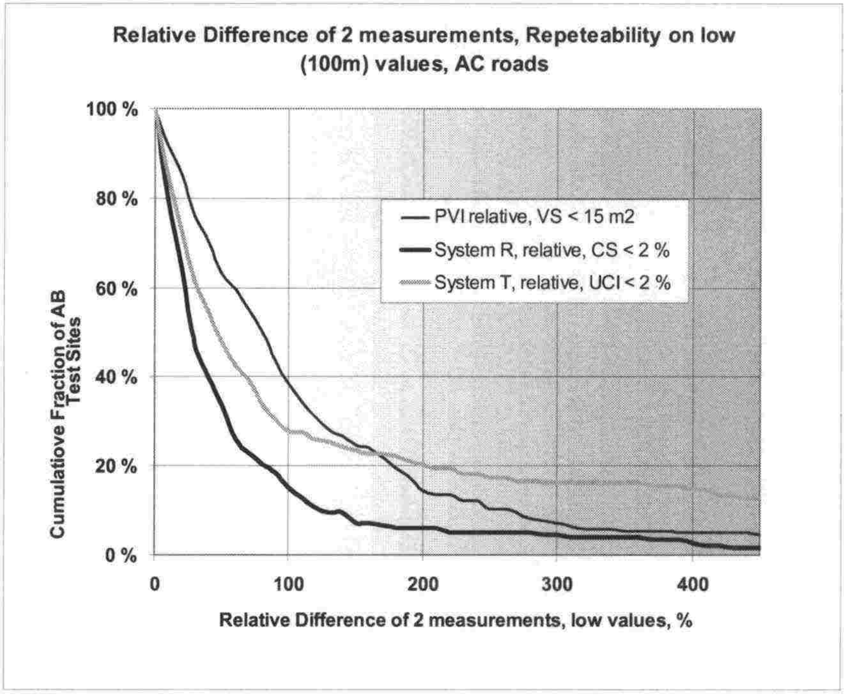


Figure 34. Relative difference on AC test sites with low cracking.

Relative percentage is very high on these low values, for example system R & T difference 100 % is CS/UCI value difference only 2 units per observation.

System T is better than the inventory but has more very big errors that the PVI methodology. System R gives quite good repeatability.

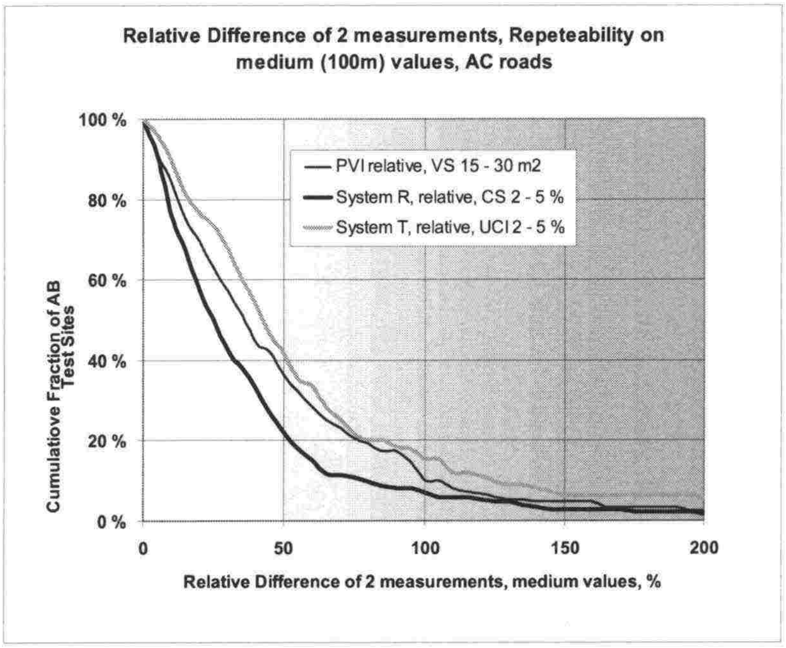


Figure 35. *UCI condition distribution and the reliability on AC test sites with medium amount of cracks.*

On medium (PVI value is 15-30 m2 and CS and UC values 2-5). System 2 behaves similar way as the PVI.

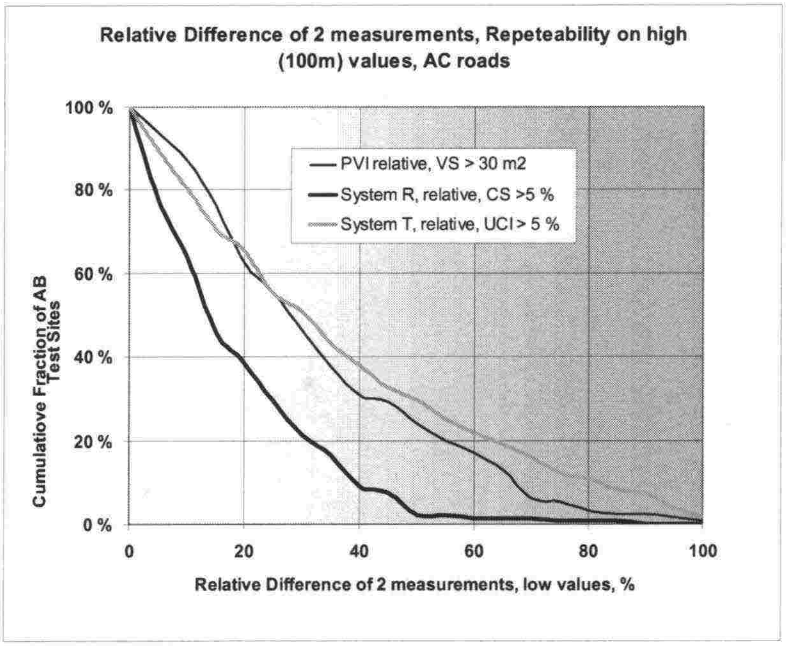


Figure 36. *UCI condition distribution and the reliability on AC test sites with high amount of cracks.*

On high is 30 % crack level (PVI value is > 30 m2 and CS and UC values > 5). System 1 gives clearly better result than the PVI. This is the most important crack level when planning the maintenance actions.

Reliability

The figures 37 - 39 show the range for 95 % reliability of each variable. The curve has defined separately for previous presented low, medium and high crack samples. In Figures 37 – 39 is presented the condition curve (from chapter 4.1) and upper limit (97.5 % observations are below the light red curve) and lower limit (2.5 % of observations are above to brown curve). At the limit for "poor road", PVI 60 m^2, the reliability of the variable is between 83 % and 96 %.

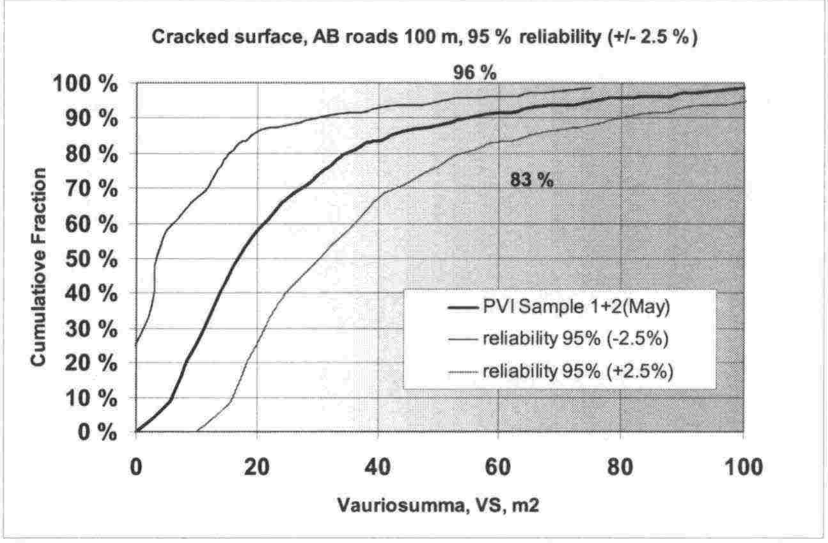


Figure 37. PVI condition distribution and the reliability on AC test sites.

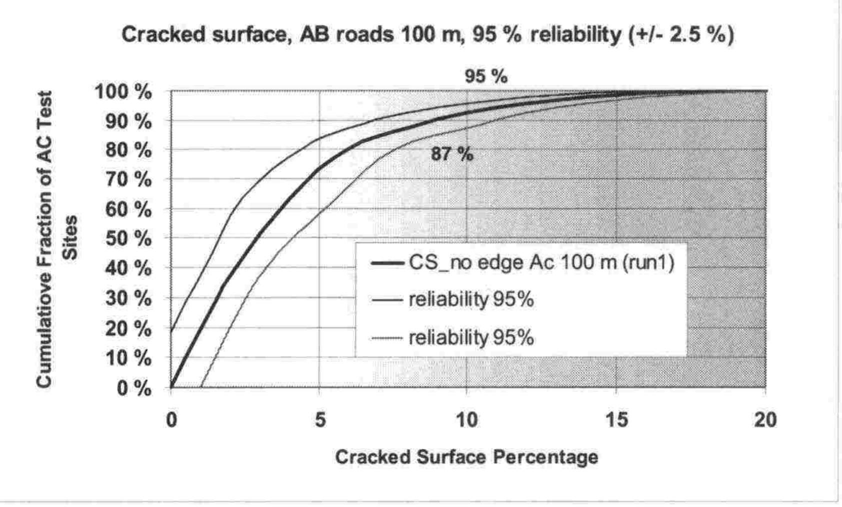


Figure 38. System 1 CS condition distribution and the reliability on AC test sites.

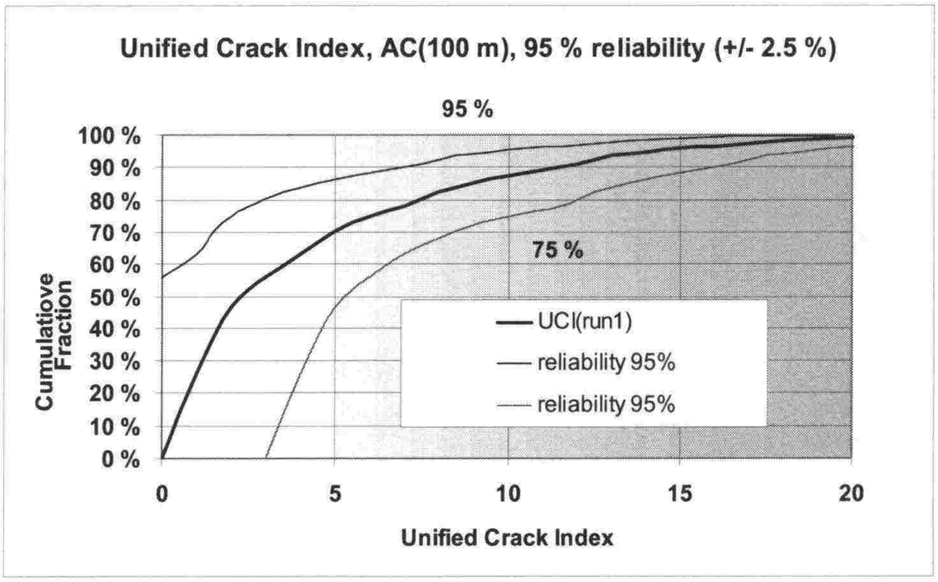


Figure 39. System 2 UCI condition distribution and the reliability on AC test sites.

The result is the range for 95 % accurate result at the "poor condition" limit is:

- PVI 83 – 96 %, 13 % variability range.
- System 1 / CS 87 – 95 %, 9 % variability range
- System 2 / UCI 75 – 95 % 20 % variability range.

In this test, the System 1 (CS variable), provides better reliability than PVI. System 2 (UCI) gives a little wider range than other methods. The result is dependent on the level where the reliability of the system will be studied.

4.4 Object level results and definition of Crack Types

4.4.1 Overview

The Finnish Road Enterprise was not able to provide the classification of different crack types with the current version of UniAMS software (Adhara 1.0). The following principles and results are from the procedure provided by Ramboll RST. Although the methodology is the same that is used in most of the automated crack measuring systems in England by WDM limited and Babtie Group.

The new existing and available information from automated measurements is the location of cracks on the lane (in the wheel path, between wheel paths or edge of the road), example on chapter 5.4, Cumulative cracked surface index.

4.4.2 Identification of different Cracks Types

The crack types are defined to help the designer or pavement engineer to be able to estimate if the deterioration is climate or fatigue related. It is not easy to produce good definitions for different crack types and this is one task to be done with the further development of the crack measurement system.

There are a few basic measures to define the crack type:

- Direction
- Length
- Width

These geometrical values are not easy defined for cracked pavement. If there are a lot of cracks you are not interested of each individual crack, but the total area. Also, there are many decisions to make about the width of one crack /Offrell 2004:

> Crack width is always an interesting measure as this is often used to define the severity of the cracks. However, crack width is a very complicated measure because a single crack seldom shows only one width, and there is no simple way of defining which width is the important one (see Figure 14). For example, it is questionable if the maximum width should be used as it is only representative for a short section of the crack length, and whether the medium width is a representative measure for the crack. Furthermore, the width of the crack is generally altered in the process of removing noise from the images and converting the images into crack polygons. The precision after analysis is therefore too low to give a representative value for the width.

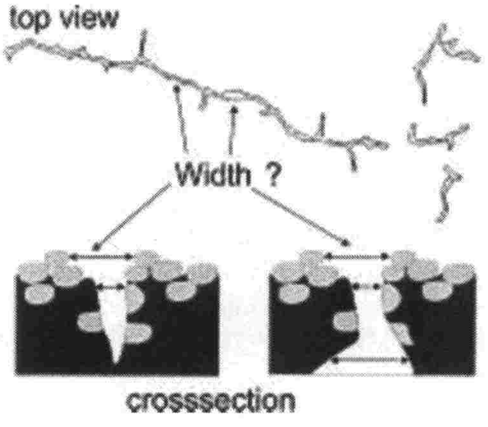


Figure 40. How to define the width of a crack.

According to the chosen variables Finnra can make decisions on how to define the severity of certain crack types. This needs a new test program.

4.4.3 How to define Crack type

The basic information for crack definition is at this moment depended on the software used for the image processing. Ramboll RST is using the software developed by the Swedish company OPQ (The Digital Image Processing Software's, DIP). It uses the parallel processing technique to handle the images. This process contains several steps and the result is a set of data to describe the cracks in terms of polygons. Each polygon describes in principle one crack on road. The DIP software determines 40 data variables for each polygon and it gives a user interface to handle the raw (polygon) data.

In Figures 41 and 42 are presented some decision rules to define the crack type.

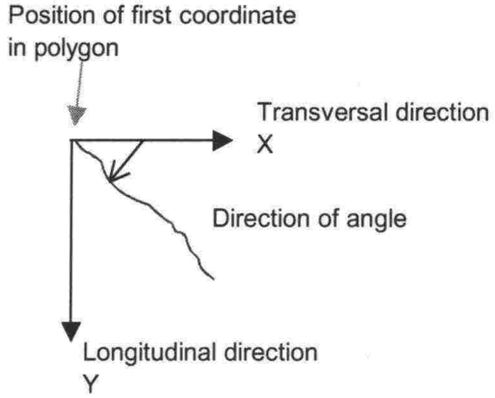


Figure 41. Basic information for one crack.

With the help of information about outstretches and direction it is possible to classify if the crack is longitudinal or transversal.

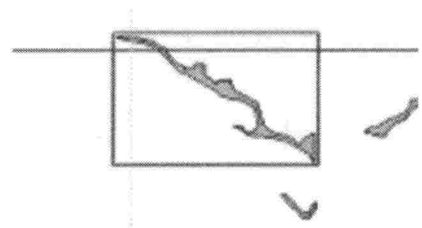
Indication of features

Outstretchness	
<0.2	longitudinal outstretch
0.8-1.2	squared
>2	transversal outstretch

Direction	
<20°	Transversal
30°-60°	Diagonal
>70°	Longitudinal

Polygon with

Outstretchness	1.6	
Polygon Area	1.7dm^2	
Direction	35°	
Coverage	7 %	



Polygon with

Outstretchness	8.0	
Polygon Area	0.7dm^2	
Direction	4°	
Coverage	23 %	

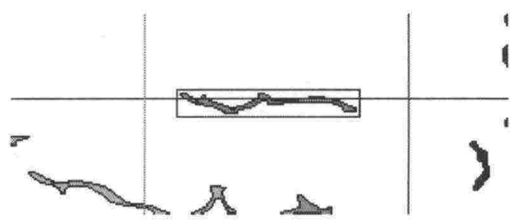


Figure 42. Polygon data usage.

4.4.4 Examples for Crack detection

The first example is from the end of test site 5 where we have raveling pavement on a bridge. This is typically a very difficult type of deterioration for automated crack systems. The analysis steps are:

1. The overview image from video
2. Compiled images from Ramboll PAVUE vehicle
3. Polygon data after the DIP(digital image process) analysis
4. Black and white crack map report
5. Grid for definition of cracked surface

Figure 43. Video image from the test site 5.

In the picture we can see the overview from the bridge deck and raveled asphalt pavement surface.

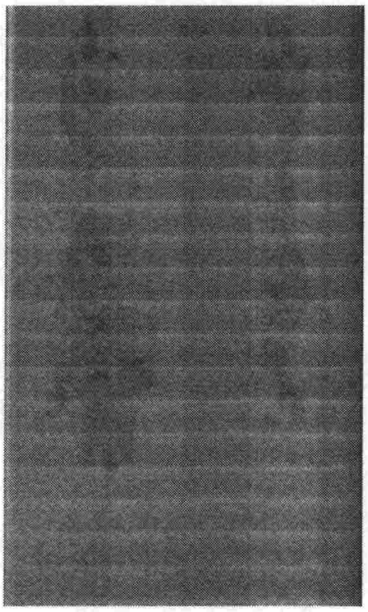


Figure 44. Compiled images from Ramboll PAVUE vehicle.

PAVUE system compiles the pictures from 4 video cameras to an adjacent digital picture from the road. There can be seen the more illuminated areas closer to the lightning system.

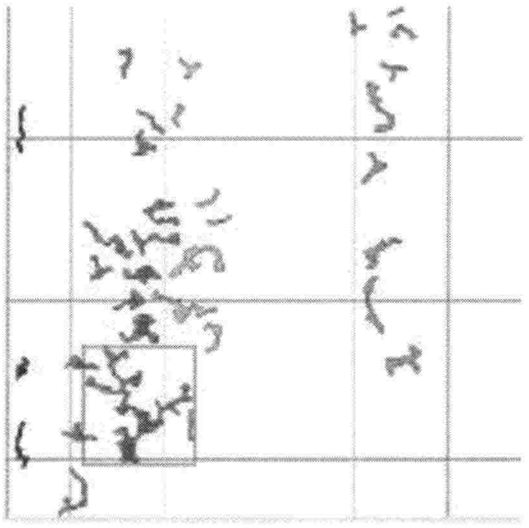


Figure 45. Polygon data after the DIP analysis.

Figure 42 is visualization for polygon data available to the crack type and extends analysis after the Digital Imaging Process (DIP).

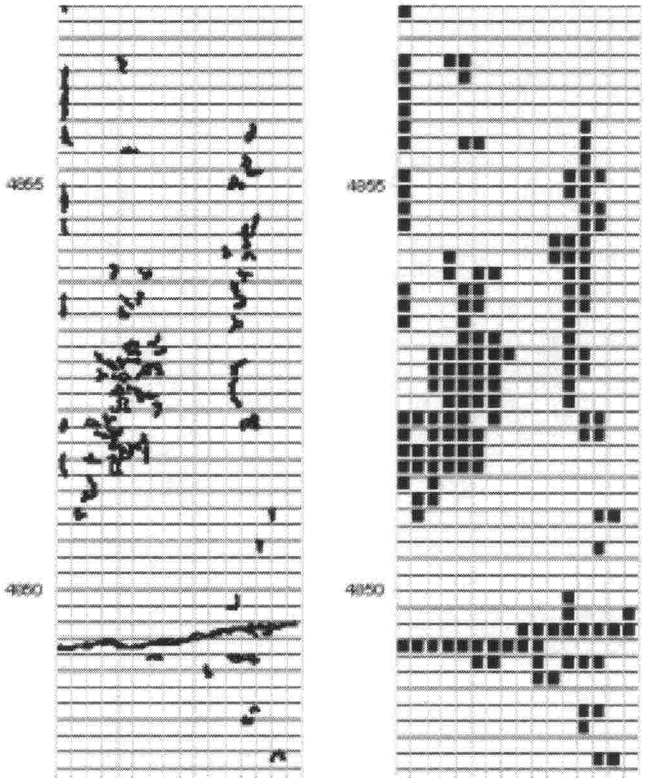


Figure 46. Crack Map and grid for definition of cracked surface.

Crack Map is an illustration for cracks. It is done in early phase of the DIP process and it is a question only about black and white pixels. This gives a very good overview about the cracks founded by the measuring unit. The grid picture is similar presentation of tiles included to the cracked surface variable.

Example 2, test site 5, 1075 meters from the beginning. Cracked area wide cracks:

The analysis steps are:

1. The first figure shows the overview image from video
2. Compiled images from Ramboll PAVUE vehicle
3. Polygon data after the DIP analysis
4. Black and white crack map report
5. Grid for definition of cracked surface

Figure 47. Polygon data usage.

We have the beginning of an alligator crack in the wheel path and the transversal crack over the lane. Typical low volume AC road in southern Finland.

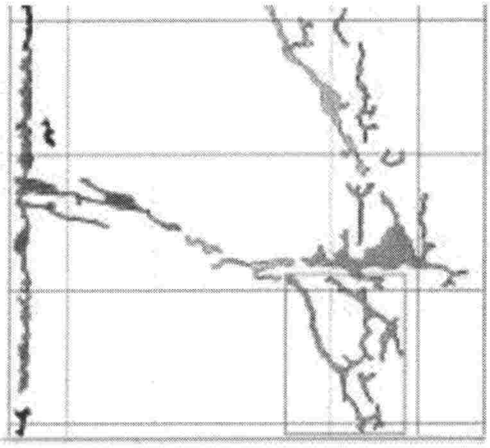


Figure 48. Polygon data usage.

Polygon visualization, colors are presenting the location of cracks on the lane. Also the centerline crack is collected.

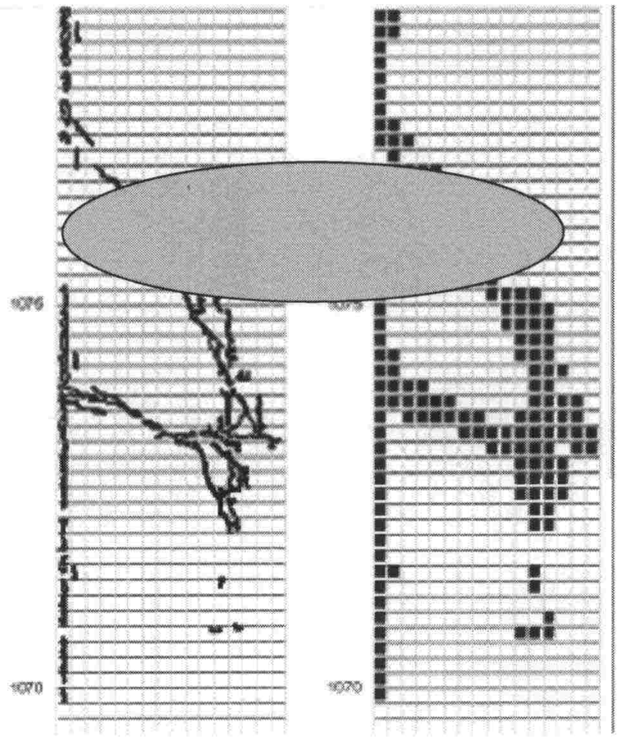


Figure 49. Crack Map and grid for definition of cracked surface.

The grey are shows some problem for Digital Imaging Process for camera 2 signal when creating the continuous image.

The Figure 50 shows the combinations of RST laser data with the crack detection. On the right hand side we have the cross profile for the lane (colors in from -20 mm to + 20 mm) and the outmost color "Blue" graphic shows the index value for the transversal profile index.

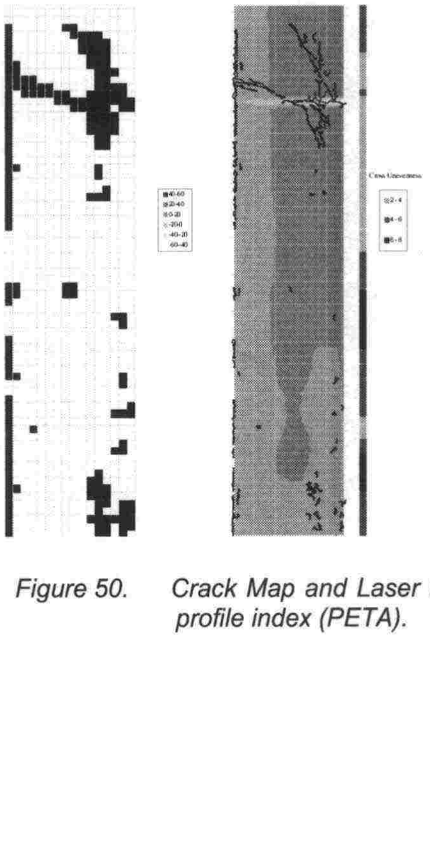


Figure 50. Crack Map and Laser RST data, height profile and transversal profile index (PETA).

4.4.5 Object Level data summary

The work data contains the Excel file “3011 APVM Object Data variables.xls” witch gives the possibility to compare different variables with each other. The example is given in Figure 51 from test site 14, 2 kilometers from the beginning. We have also the Laser RST measurements from condition database.

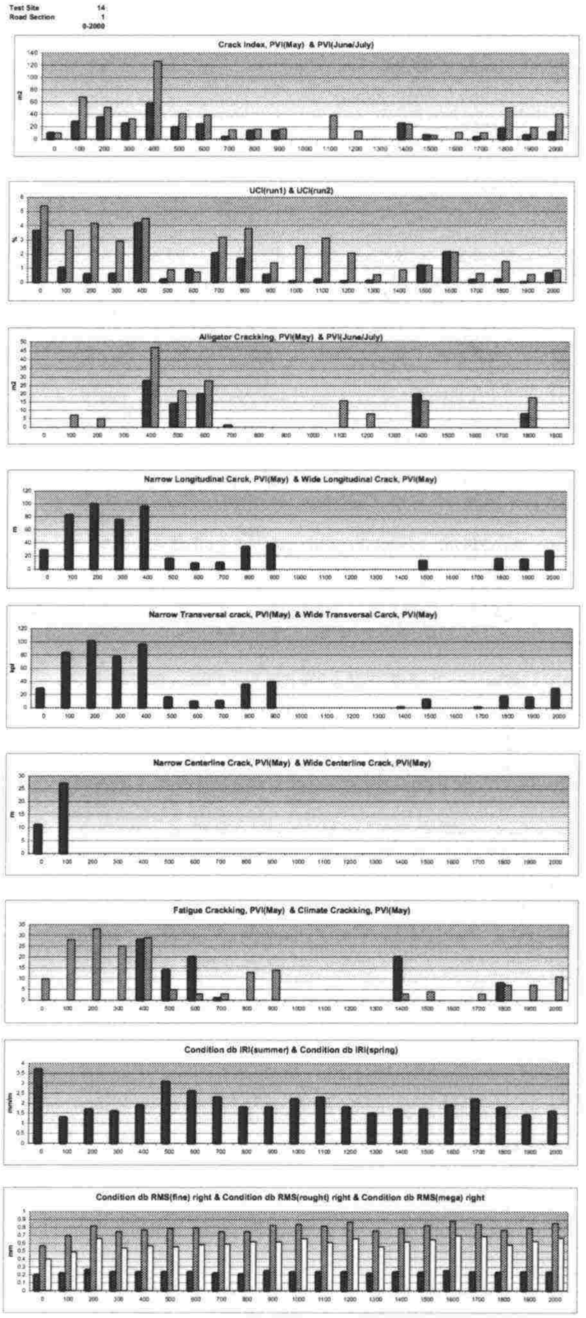


Figure 51. Object data (100 m) summary

Appendix A contains results from more detailed summary based on 10 m data. The Road Enterprise provided an extra dataset 10 m PVI results. With help of that data 100 Gen Oy have picked 20 individual crack and presented the reference data (video overview) with PVI and other data provided by Ramboll RST and Road Enterprise.

5 OTHER ISSUES

5.1 The effect of measuring time

The difference with PVI(May) and PVI(June), sample 1, measurements compared with PVI(May) and PVI(July), sample 2, were very difficult to interpret. The difference with PVI(July) was greater than the differences with PVI(June) on all roads. This means that it was not possible to present the effect of self healing on low volume roads after the spring – thaw period. Cracks were not sealed during the 2 month period May – July, according to the PVI methodology.

Conclusion is that this phenomenon cannot be studied with 100 m PVI variable.

5.2 Types of requirements in different countries

5.2.1 Highway Agency, UK

Highway Agency (HA) /Päällystettyjen teiden vauriomittauksen kehittäminen/ gave out a four year (2001-2005) measuring contract in 2000. The quality demands was set in two phases: 1. Acceptance Test and 2. Production Quality Test.

The acceptance test is done by authorized test organization (TRL limited) and it is based on certain visually selected test sites. The different quality limits are set for test observations with High, Medium and Low crack amounts. The variable is the amount of cracked observations from different measurements.

The production quality test is based on images collected with TRL's HARRIS system and invented with TRL's staff. The results from production measurements are compared at the level of 65 % of test observations. The tested variable (amount of cracked or not cracked observations) can differ maximum 70 % from the reference data.

5.2.2 Maryland Department of Transportation

Maryland DOT focused their QA/QC (Quality Assuarance/Qualitys Controll) efforts by requiring 80% crack detection rate. Maryland DOT uses the manual crack inventory procedure as "ground-truth" data to perform QA/QC for their automatically collected crack data. After the images had been QC'ed and QA'ed, cracks were classified and rated. / Groeger 2003/

5.2.3 National Park Service (NPS)

National Park Service (NPS) made a condition measurement contract in USA 2003 for all paved roads administrated by the NPS. Automated crack measurement was one parameter which was included to the contract. ERES consulting company was chosen to create the quality demands the crack measurement process /Selezneva et.al. 2003/.

The recommendation for quality control procedure has 7 steps:

1. Randomly select n frames (for large parks, n =93 for 95% confidence and reliability level). It is advisable to sample as many roads as practically possible.
2. Test the first n_0 frames in the selected sample against the specified QA pass/fail criterion (for large parks, n_0 =58 for 95% confidence and reliability level).
3. If none of the n_0 frames fails the QA pass/fail criterion, the quality standard is met –results from automated crack detection system are accepted for the park.
4. If two or more of the n_0 frames fail the QA pass/fail criterion, the quality standard is not met – results from automated crack detection system are rejected for the park.
5. If one frame of the n_0 frames fails the QA pass/fail criterion, test the rest of the frames in the sample n.
6. If all the remaining frames in the sample of n frames pass the QA pass/fail criterion, the quality standard is met – results from automated crack detection system are accepted for the park.
7. If one or more of the remaining frames in the sample of n frames fail the QA pass/fail criterion, the quality standard is not met – results from automated crack detection system are rejected for the park.

5.3 How the old PVI data can be used with new crack variable

The recommendation is based on the crack measurement tests conducted by Road Administration in 1998 /GIE/ and 2004. The Crack Index variable from PVI inventory is so uncertain variable that the correlation function between the new measured variable and old PVI can be created with existing precision.

The recommendation is to use A simple function with a couple decision rules to converge the PVI variable to the new crack variable.

During the Crack test 1998 different type functions between PVI and measurement data were developed. Results showed that the models based only on the Crack Index variable were as good as the models based on crack type information.

The main issue is to take account the current use of Crack Variable in the Finnra's Management by Objectives process. It is important to be able to diminish the yearly variability with regional data.

5.4 Development Issues

Dynamic definition of the wheel path areas. The get the real figure of traffic related cracking the location of ruts should be defined dynamically based on the transversal profile. This is important especially on narrow road with a lot of curves.

The Crack Type definitions are needed to help the designer or pavement engineer to estimate the reason for the deterioration, climate or fatigue related. It is not easy to produce good definitions for different crack types and this is one task to be done with the further development of the crack measurement system.

The combination of crack information with other road condition variables is needed.

Cumulative cracked surface index is a new way to look the crack data. In the Figure 52 we show the cumulative amount of cracked tiles in the transversal cross section. The figure is calculated for 100 m but it can also present a10 m, 1 000 m, road section or road class result. Do the problems exist in wheel paths, edge or on centerline?

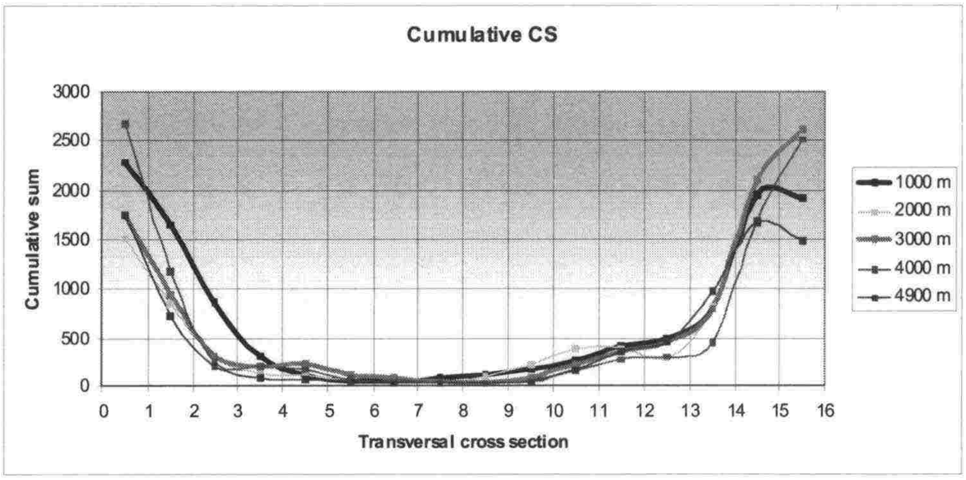


Figure 52. Cumulative CS in the transversal cross section by 100 m.

5.5 The use of the Crack Data

The Finnish Road Administration has used the Crack inventory data since the beginning of 1990's. All paved roads have been inspected on regular basis and the results are used with planning and management purposes. Cracks have been one of the condition variables used in the Finnra's management by objectives system.

The definition of "poor roads" has been introduced and it has been used to allocate maintenance and rehabilitation funding to Regions. Also crack information is part of the definition of level of service provided to the users.

The main need has been to find the poor road sections for planning of the rehabilitation actions.

There exists also a need to use crack data in design phase of the planning. The type of crack is important information for the engineer to be able to estimate reason of the occurring crack. Already the information of the location of crack in lane is an improvement to the old methodology.

Prediction models for deteriorating are an essential part of good management of roads. Reliable models are based on reliable measuring information. It is important to use the best possible methodology for crack data collection, because otherwise the used measuring budget is not used efficiently. It is possible to estimate the cost of poor quality data and how much the improvements means to the future total costs. The structural strength varies a lot on road network. The models to estimate the lice cycle of different structures are needed to the future procurement procedures.

6 CONCLUSIONS

The test results showed that the automated measurement systems can provide new and better possibilities to use crack data than the manual PVI inventory. The transition to new crack measuring methodology should be done as soon as possible. The main benefits from the measurement methodology are:

- Quality of data
- Repeatability of measurements
- The location of a crack can be determined precisely
- Possibility to develop new usage of crack data in planning and procurement process
- The crack measurements can be done at the same time as the other condition measurements (benefit to get different condition variables at the same time + cost savings).

A clear difference exists with the tested measurement devices. Some improvements must be done in both systems before the production type measurements can be started. It is important that the measuring device has a lightning system of its own (as it has been stated in literature and test in 1998).

Tested automated measurement methodologies are not especial sensitive for low crack levels or small amounts of cracks. These cracks can be determined with visual inventory. On the other hand small crack amounts are not interesting as a point of view maintenance planning.

AC pavements were more difficult to analyze than SA (soft asphalt) test sites and this can be seen when the differences of 2 runs (repeteability) are bigger on AC test sites than on SA sites.

The main development issues with the automated measurement methodologies are:

- Identification of Crack width
- Identification of Crack types
- Improvement of repeteability
- Combination of cracks, longitudinal and transversal surface condition

The future promises great improvements to the crack information and there is possibility to get more useful and better quality data at lower cost than the current inventory methodology can provide.

LITTERATURE

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Selezneva, O., Mladenovic, G., Speir R., Amenta J. and Kennedy J., "QA Sampling Considerations for Automated Distress Data Collection and Processing for National Park Service Road Inventory Program", the 82nd Annual TRB Meeting, Washington, D.C., January 2003

UK Roads Board, TRACKS –type survays of the principal Road Network, Advice note and specifications Version 1.0 My 200.

APPENDIX

CONTENT

App A **Individual Crack Observations, 10 m data**
DVD volume 1
File: APVM Test_report Appendix A.doc & *.pdf

App B **Excel files**
DVD volume 1
0611 APVM ObjektData.xls
Contains the possibility to compare two input data variables on one test site section.
3011 APVM ObjectData variables.xls (English version)
Contains the possibility to choose different datasets for 100 m section.

App C **Reference video**
DVD volume 2 & 3
The files can be viewed with a DivX player mpegable4, Installation package on DVD vol 1 / VideoPlayer. It can be loaded from web address: http://www.mpegable.com .

App D **Data provided by Ramboll RST**

DVD volume 1, App D:
Document Test measurements in Finland 082004.doc
Contains a full report of the Ramboll measurements and repeatability presentation according to TRL.
Datafile folders: "Crack Data Collection CD 1 & 2

DVD vol 4, Ramboll front video

App E **Data provided by the Finnish Road Enterprice**

DVD volume 1
UCI results and detail files

AASHTO results, excel file 2510 Aashto10 summaries.xls
Summary per test site AASHTO 10 m result
APVM manuaaliset vertailumittaukset 10m.xls

DVD volume 5 to 10
Collected images from test sites (in *.jpg format)

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Juha Äijö

Automated Crack Measurement Test in Finland 2004

Appendix A

[redacted]

INDIVIDUAL CRACK OBSERVATIONS, 10 M DATA

Explanation of the following observations

Test site refers to the number of the test site in the study 2004.
Road section, is the section number on the test site
Number is the distance from the beginning of the section

Left side
Comments about the 10 m observation
and
Some comments about the inventory result
and
about the result from system 1 / Ramboll RST
and
about the result from system 2 / Finnish Road Enterprise

Crack types used in the current inventory methodology

Right side
Image from the reference video, overview image from the 10 m observation

Left side
Inventory result PVI(July) by crack types
As the index value, VS m2

Result from system 1, Cracked surface, CS, index
Run 1, run 2 and relative difference % between the 2 runs.

Result from system 2, Unified Crack Index, UCI
Run 1, run 2 and relative difference % between the 2 runs.

Some relative variables for the comparison of different methods:
Average CS divided by PVI, and average UCI divided by PVI and average CS divided by average UCI

AASHTO result from images used in the UCI value (in the middle of the page)
IW wheelpath inside the lane (by centerline)
BW between wheelpaths
OW wheelpath outside the lane
Intensity amount of the cracks in the image m/m2
Width average width of the cracks in the image
Severity class according to the aashto classification 1,2 or 3 (rep. under 3 mm, 3 – 6 mm or over 6 mm)

Middle of the page jpeg images from the system 2

Right side
Crack map by system 1

Test Site 1
Road Section 1
960

10m Results

Several crack types:
Alligator crackking
Longitudinal Crack
Transversal Crack
PVI: All detected, VS 10
System1: Similar results with PVI
System 2: Similar results with PVI

Crack Types:	
Transversal	
Longitudinal	
Centerline	
Alligator	All.
Pothole	Pot.
Ravelling	Ravell.
Edge	
Freeze-Thaw	Fre.

Transversal		Longitudinal		Centerline	
narrow	wide	narrow	wide	narrow	wide
1	0	9	0	0	0

Alligator	Pothole	Ravell.	Edge	Fre.
4	0	0	0	0

PVI (July) VS
10,2

System 1 CS		
Run 1	Run2	delta%
22,7	23,9	2,5

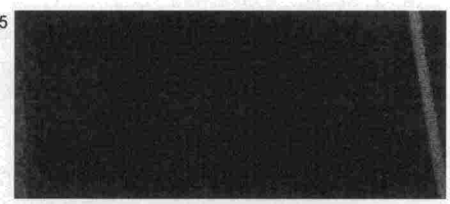
System 2 UCI		
Run 1	Run2	delta%
19,6	10,7	29,4

Relative variables:

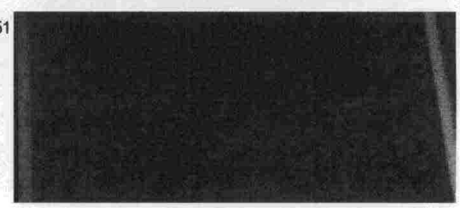
average CS / PVI	average UCI / PVI	average CS / average UCI
2,3	**1,5**	**1,5**

Image	Variabl	945	947	951	955
IW	(Intensi	0,00	0,67	0,48	0,00
IW	(Width)	1,06	8,09	9,12	0,00
IW	(Severi	7,61	3	3	0
BW	(Intensi	3,00	2,31	2,02	0,00
BW	(Width)	0,00	17,09	18,39	0,00
BW	(Severi	0	3	3	0
OW	(Intensi	0,00	0,86	0,77	1,54
OW	(Width)	0,00	9,62	10,29	13,93
OW	(Severi	0	3	3	3

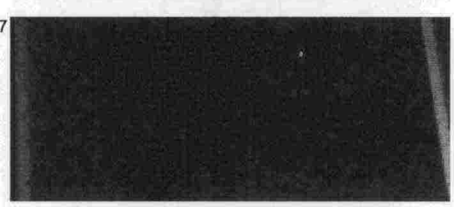
955



951



947



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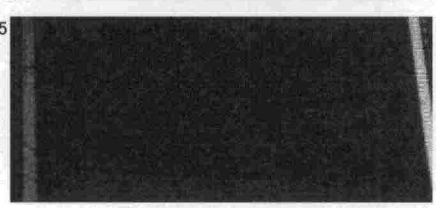
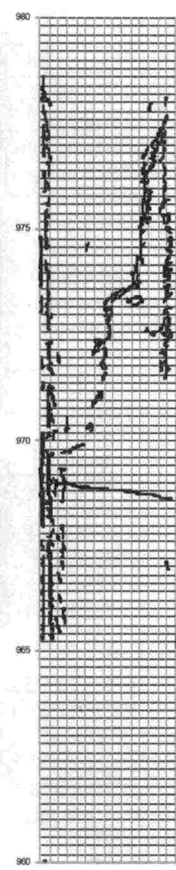




Automated Crack Measurement Test in Finland 2004

INDIVIDUAL CRACK OBSERVATIONS, 10 M DATA

Test Site 3
Road Section 1
140

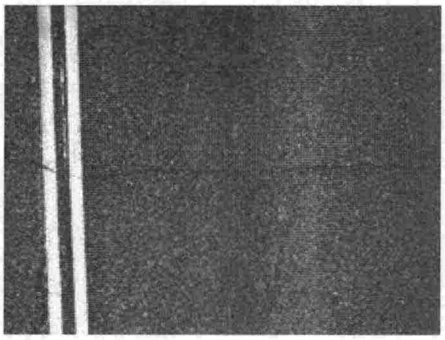
10m Results

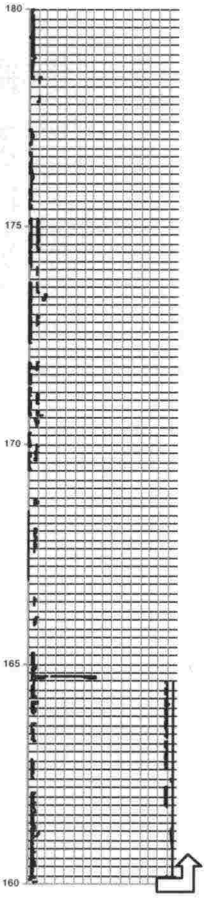
Transversal Crack
Centerline crack
PVI: narrow transversal carcak on smooth AC pavements
System1: Only half of the crack was detected, similar result with PVI
System 2: Most of the small cracks were not detected

Crack Types:	
Transversal	
Longitudinal	
Centerline	
Alligator	
Pothole	
Ravelling	Ravell.
Edge	
Freeze-Thaw	Fre.

Transversal		Longitudinal		Centerline	
narrow	wide	narrow	wide	narrow	wide
1	0	2	0	10	0

3174





Alligator	Pothole	Ravell.	Edge	Fre.
0	0	0	0	0

PVI (July) VS
5,1

System 1 CS		
Run 1	Run2	delta%
3,6	5,7	23,1

System 2 UCI		
Run 1	Run2	delta%
0,6	0,5	14,3

Relative variables:

average CS / PVI	average UCI / PVI	average CS / average UCI
0,9	**0,1**	**8,8**

Image	Variable	3174
IW	(Intensity)	0,00
IW	(Width)	0,00
IW	(Severity)	0
BW	(Intensity)	0,00
BW	(Width)	0,00
BW	(Severity)	0
OW	(Intensity)	0,00
OW	(Width)	0,10
OW	(Severity)	4,375

Test Site 3
Road Section 1
1100

10m Results

Longitudinal Crack
PVI: Good result
System1: Good result
System 2: Good result

Crack Types:	
Transversal	
Longitudinal	
Centerline	
Alligator	All.
Pothole	Pot.
Ravelling	Ravell.
Edge	
Freeze-Thaw	Fre.

Transversal		Longitudinal		Centerline	
narrow	wide	narrow	wide	narrow	wide
0	0	10	0	5	0

Alligator	Pothole	Ravell.	Edge	Fre.
0	0	1	0	0

PVI (July) VS
4,5

System 1 CS		
Run 1	Run2	delta%
7,4	8,9	8,8

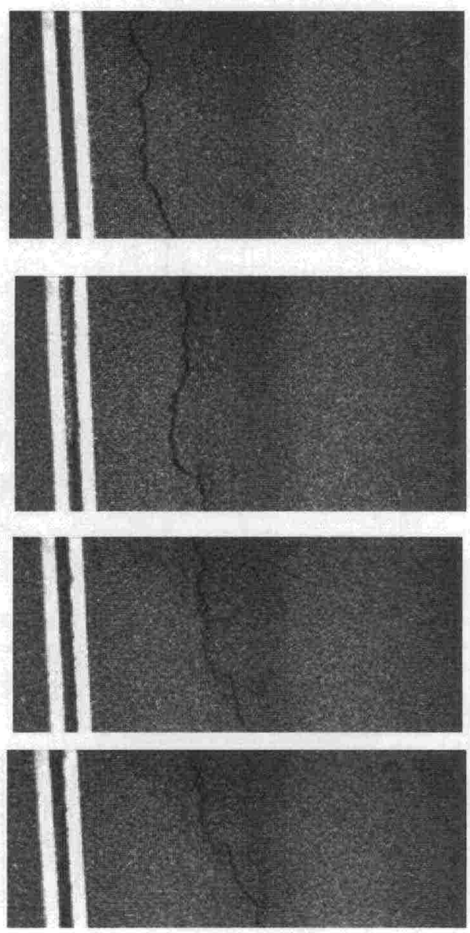
System 2 UCI		
Run 1	Run2	delta%
5,4	4,3	11,7

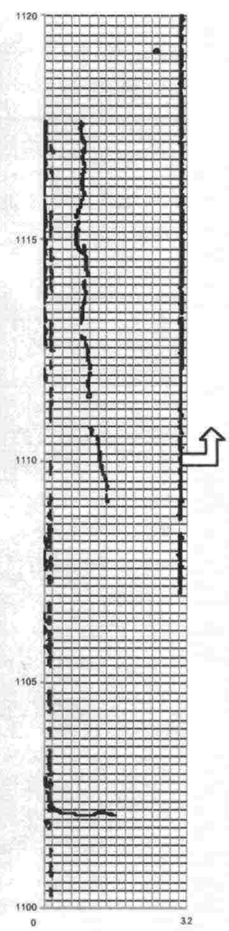
Relative variables:

average CS / PVI	average UCI / PVI	average CS / average UCI
1,8	**1,1**	**1,7**

Image	Variabl	1117	1120	1123	1127
IW	(Intensi	0,00	0,00	0,10	1,15
IW	(Width)	0,00	0,00	9,67	17,94
IW	(Severit	0	0	3	3
BW	(Intensi	0,00	1,06	1,06	0,10
BW	(Width)	1,06	12,75	18,21	12,78
BW	(Severit	9,173	3	3	3
OW	(Intensi	3,00	0,00	0,00	0,00
OW	(Width)	0,00	0,00	0,00	0,00
OW	(Severit	0	0	0	0

1127
1123
1120
1117





Test Site **3**
Road Section **1**
1280

10m Results

Alligator crack intiates in wheelpath
PVI: Defined as one longitudinal crack
System1: Good result
System 2: Good result

Crack Types:
Transversal
Longitudinal
Centerline
Alligator
Pothole
Ravelling Ravell.
Edge
Freeze-Thaw Fre.

Transversal		Longitudinal		Centerline	
narrow	wide	narrow	wide	narrow	wide
0	0	7	0	10	0

Alligator	Pothole	Ravell.	Edge	Fre.
0	0	0	0	0

PVI (July) VS
3,1

System 1 CS		
Run 1	Run2	delta%
10,6	11,9	5,7

iwp

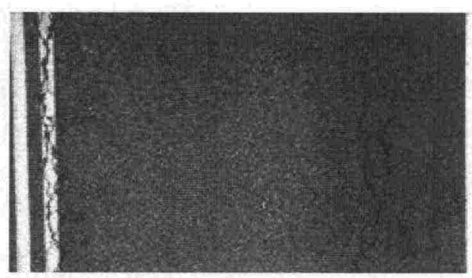
System 2 UCI		
Run 1	Run2	delta%
6,9	7,5	3,7

Relative variables:

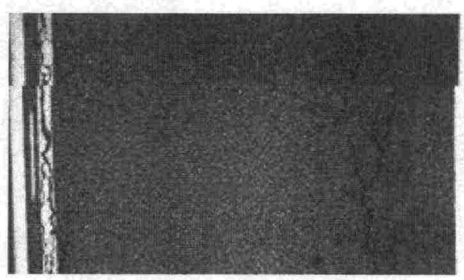
average CS / PVI	average UCI / PVI	average CS / average UCI
3,6	**2,3**	**1,6**

Image	Variabl	1.322	1.327	1.329	1.332
IW	(Intensi	0,00	0,19	0,00	0,10
IW	(Width)	0,00	9,19	0,00	5,43
IW	(Severity)		3		2
BW	(Intensi	0,00	0,00	0,00	0,19
BW	(Width)	0,00	0,00	0,00	5,32
BW	(Severity)				2
OW	(Intensi	1,06	1,35	1,15	0,00
OW	(Width)	7,58	7,54	8,74	0,00
OW	(Severi	3	3	3	

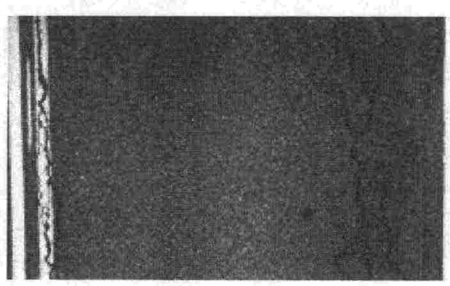
1329

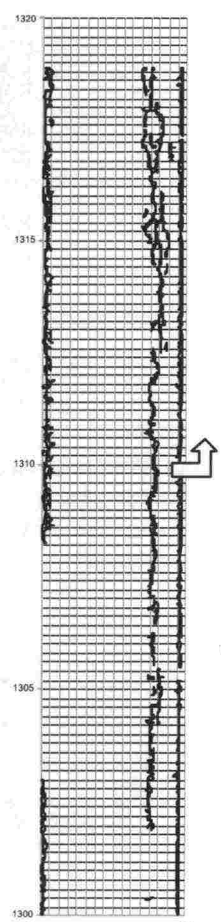


1327



1322





Test Site **3**

Road Section **1**

1610

10m Results

Alligator crackking
Transversal Crack
PVI: Good detection of allicator crackking (8meters)
System1: A lot of craccked tiles, crack detection better on second run
System 2: Allicator cracks were in images but were not detected

Crack Types:

Crack Types	
Transversal	
Longitudinal	
Centerline	
Alligator	
Pothole	
Ravelling	Ravell.
Edge	
Freeze-Thaw	Fre.

Transversal		Longitudinal		Centerline	
narrow	wide	narrow	wide	narrow	wide
1	0	4	0	10	0

Alligator	Pothole	Ravell.	Edge	Fre.
8	0	0	0	0

PVI (July) VS
13,7

System 1 CS		
Run 1	Run2	delta%
13,4	23,0	26,3

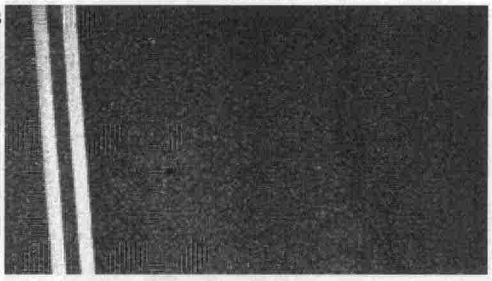
System 2 UCI		
Run 1	Run2	delta%
1,4	0,3	63,6

Relative variables:

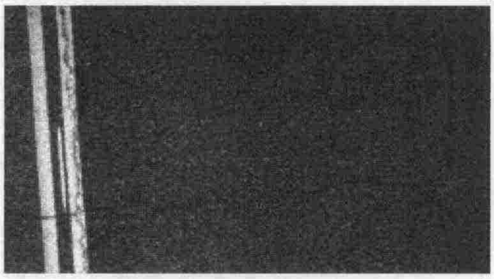
average CS / PVI	average UCI / PVI	average CS / average UCI
1,3	**0,1**	**22,1**

Image	Variable	1630	1635	1638
IW	(Intensity	1,25	0,10	0,00
IW	(Width)	18,69	4,58	0,00
IW	(Severity)	3	2	0
BW	(Intensity	0,00	0,00	0,10
BW	(Width)	0,00	0,00	7,11
BW	(Severity)	0	0	3
OW	(Intensity	0,00	0,00	0,00
OW	(Width)	0,00	0,00	0,00
OW	(Severity)	0	0	0

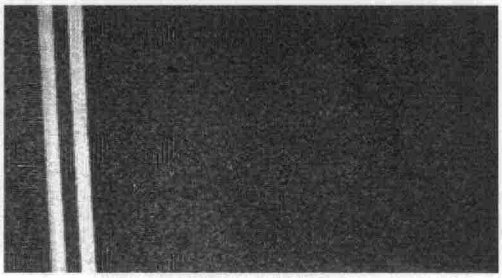
1638

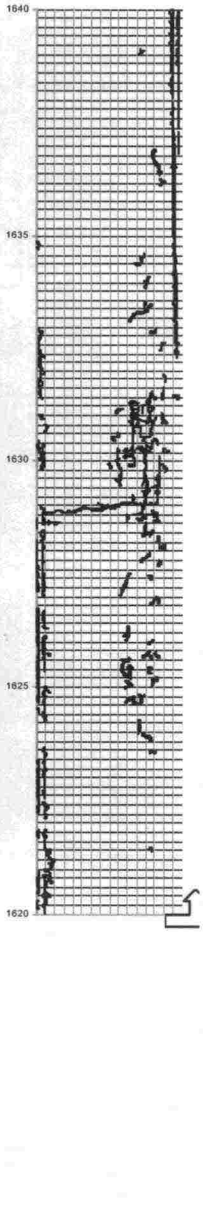


1635



1630





Test Site 3
Road Section 1
2090

10m Results

Wide Longitudinal Crack
PVI: Crack defined as narrow
System1: Good result
System 2: Crack was not detected

Crack Types:

Transversal	
Longitudinal	
Centerline	
Alligator	
Pothole	
Ravelling	Ravell.
Edge	
Freeze-Thaw	Fre.

Transversal		Longitudinal		Centerline	
narrow	wide	narrow	wide	narrow	wide
0	0	10	0	0	0

Alligator	Pothole	Ravell.	Edge	Fre.
0	0	0	0	0

PVI (July) VS
3

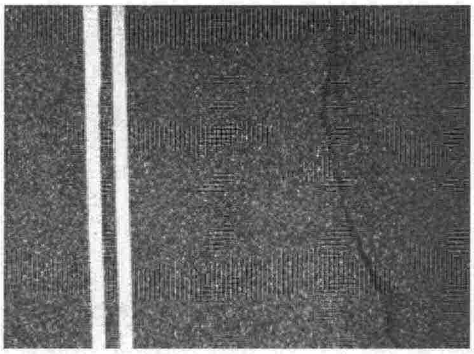
System 1 CS		
Run 1	Run2	delta%
4,0	4,0	0,0

System 2 UCI		
Run 1	Run2	delta%
0,5	0,2	50,3

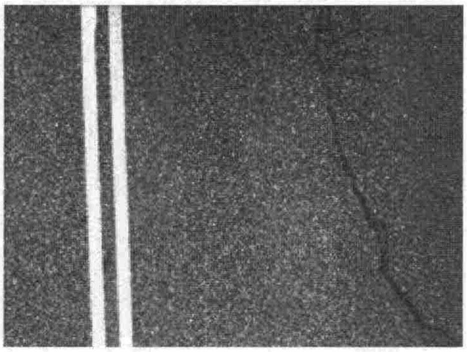
Relative variables:

average CS / PVI	average UCI / PVI	average CS / average UCI
1,3	**0,1**	**13,3**

2130



2127



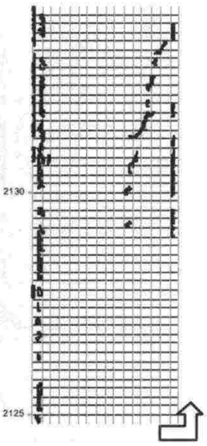


Image	Variabl	2127	2130
IW	(Intensi	0,00	0,00
IW	(Width)	0,00	0,00
IW	(Severit	0	0
BW	(Intensi	0,00	0,00
BW	(Width)	0,00	0,00
BW	(Severit	0	0
OW	(Intensi	0,00	0,00
OW	(Width)	0,00	0,00
OW	(Severit	0	0

Test Site 4
Road Section 1
1540

10m Results

Longitudinal Crack
PVI: Many cracks, one meter alligator crack
System1: Good result on both runs
System 2: A lot of cracks were not detected

Crack Types:	
Transversal	
Longitudinal	
Centerline	
Alligator	
Pothole	
Ravelling	Ravell.
Edge	
Freeze-Thaw	Fre.

Transversal		Longitudinal		Centerline	
narrow	wide	narrow	wide	narrow	wide
0	0	9	0	5	3

Alligator	Pothole	Ravell.	Edge	Fre.
1	0	0	0	0

PVI (July) VS
5,7

System 1 CS		
Run 1	Run2	delta%
15,6	13,7	6,3

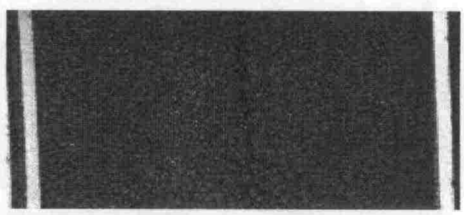
System 2 UCI		
Run 1	Run2	delta%
0,8	1,1	16,6

Relative variables:

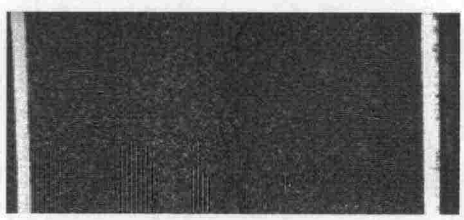
average CS / PVI	average UCI / PVI	average CS / average UCI
2,6	**0,2**	**16,2**

Pituushalkeama

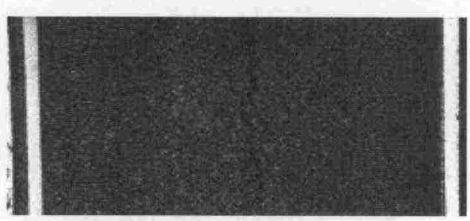
1567



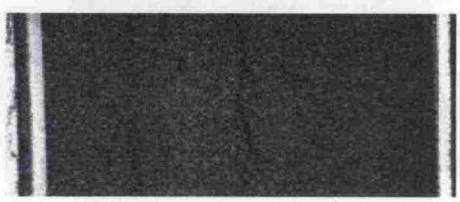
1564



1559



1556



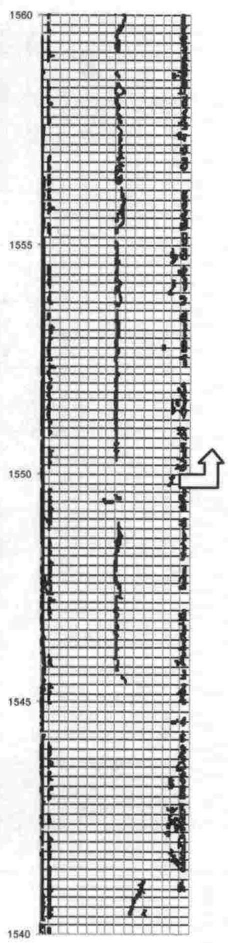


Image	Variabl	1556	1559	1564	1567
IW	(Intensi	0,00	0,00	0,00	0,00
IW	(Width)	0,00	0,00	0,00	0,00
IW	(Severi	0	0	0	0
BW	(Intensi	0,00	0,58	0,00	0,29
BW	(Width)	0,77	6,25	0,00	6,14
BW	(Severi	7,229	3	0	3
OW	(Intensi	3,00	0,00	0,00	0,00
OW	(Width)	0,00	0,00	0,00	0,00
OW	(Severi	0	0	0	0

Test Site 4
Road Section 1
1820

10m Results

Longitudinal Cracks or initiating Alligator cracks
PVI: Not very useful definition, VS only 6.7
System1: Good result on both runs
System 2: Rough surface was not detected as cracks

Crack Types:	
Transversal	
Longitudinal	
Centerline	
Alligator	
Pothole	
Ravelling	Ravell.
Edge	
Freeze-Thaw	Fre.

Transversal		Longitudinal		Centerline	
narrow	wide	narrow	wide	narrow	wide
0	0	19	0	10	0

Alligator	Pothole	Ravell.	Edge	Fre.
0	0	0	0	0

PVI (July) VS
6,7

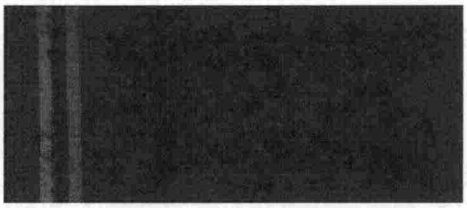
System 1 CS		
Run 1	Run2	delta%
57,4	56,1	1,1

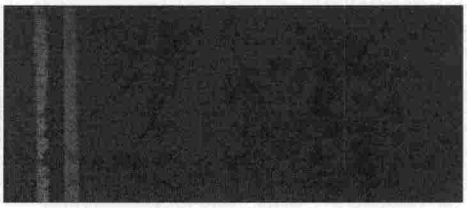
System 2 UCI		
Run 1	Run2	delta%
0,9	0,8	9,0

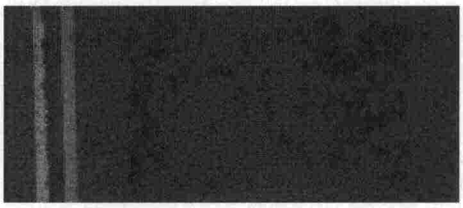
Relative variables:

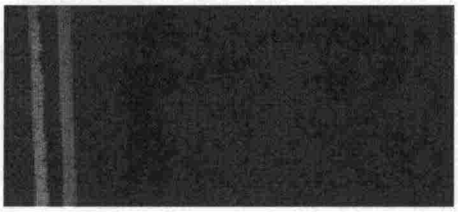
average CS / PVI	average UCI / PVI	average CS / average UCI
8,5	**0,1**	**68,6**

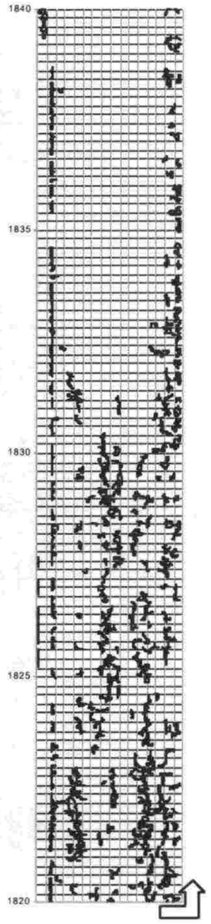
Image	Variabl	1824	1827	1829	1832
IW	(Intensi	0,00	0,00	0,19	0,19
IW	(Width)	0,00	0,00	64,12	70,24
IW	(Severit	0	0	3	3
BW	(Intensi	0,00	0,00	0,00	0,00
BW	(Width)	0,19	0,00	0,00	0,00
BW	(Severit	5,811	0	0	0
OW	(Intensi	2,00	0,00	0,00	0,00
OW	(Width)	0,00	0,00	0,00	0,00
OW	(Severit	0	0	0	0

1832


1829


1827


1824




Test Site 4
Road Section 1
2150

10m Results

Alligator crackking
PVI: 50 % crackked
System1: Detected a lot of these cracks
System 2: Crack was not detected

Crack Types:
Transversal
Longitudinal
Centerline
Alligator
Pothole
Ravelling — Ravell.
Edge
Freeze-Thaw — Fre.

Transversal		Longitudinal		Centerline	
narrow	wide	narrow	wide	narrow	wide
0	0	0	0	0	0

Alligator	Pothole	Ravell.	Edge	Fre.
5	0	0	0	0

PVI (July) VS
5

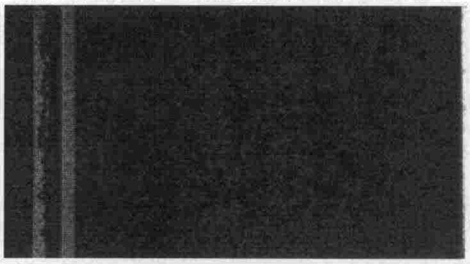
System 1 CS		
Run 1	Run2	delta%
27,7	34,3	10,6

System 2 UCI		
Run 1	Run2	delta%
0,2	0,2	20,0

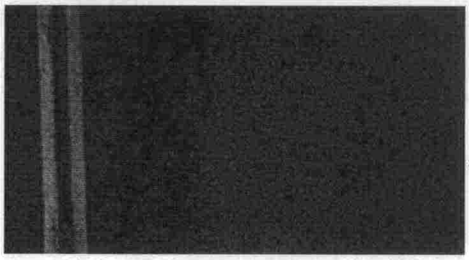
Relative variables:

average CS / PVI	average UCI / PVI	average CS / average UCI
6,2	**0,0**	**165,3**

2159



2156



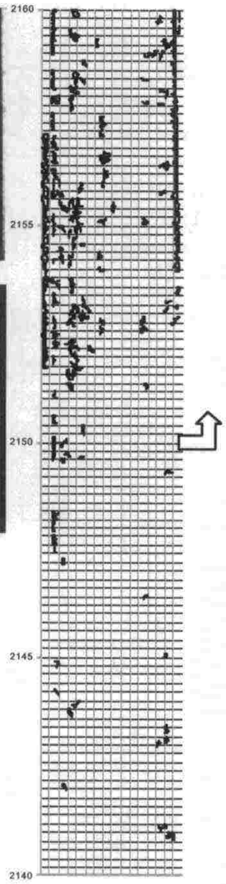


Image	Variabl	2156	2159
IW	(Intensi	0,00	0,00
IW	(Width)	0,00	0,00
IW	(Severi	0	0
BW	(Intensi	0,00	0,00
BW	(Width)	0,00	0,00
BW	(Severi	0	0
OW	(Intensi	0,00	0,19
OW	(Width)	0,00	7,14
OW	(Severi	0	3

Automated Crack Measurement Test in Finland 2004

INDIVIDUAL CRACK OBSERVATIONS, 10 M DATA

Test Site **4**
Road Section **1**
2240

10m Results

Several crack types:
Alligator crackking
Transversal Crack
Centerline Cracks
PVI: All detected, VS 11
System1: Similar results with PVI
System 2: Cracks were not detected

Crack Types:	
Transversal	
Longitudinal	
Centerline	
Alligator	
Pothole	
Ravelling	Ravell.
Edge	
Freeze-Thaw	Fre.

Transversal		Longitudinal		Centerline	
narrow	wide	narrow	wide	narrow	wide
1	0	0	0	10	5

Alligator	Pothole	Ravell.	Edge	Fre.
4	0	0	0	0

PVI (July) VS
11

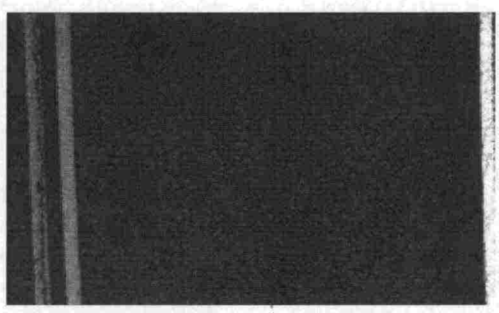
System 1 CS		
Run 1	Run2	delta%
34,4	32,9	2,3

System 2 UCI		
Run 1	Run2	delta%
0,3	0,9	50,3

Relative variables:

average CS / PVI	average UCI / PVI	average CS / average UCI
3,1	**0,1**	**55,8**

2248



2245

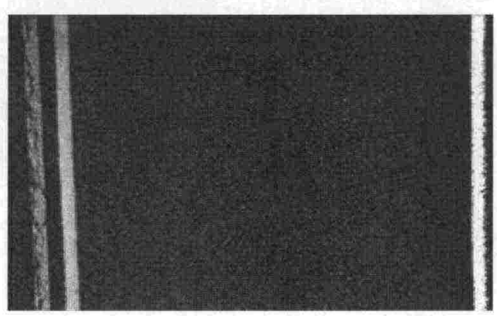
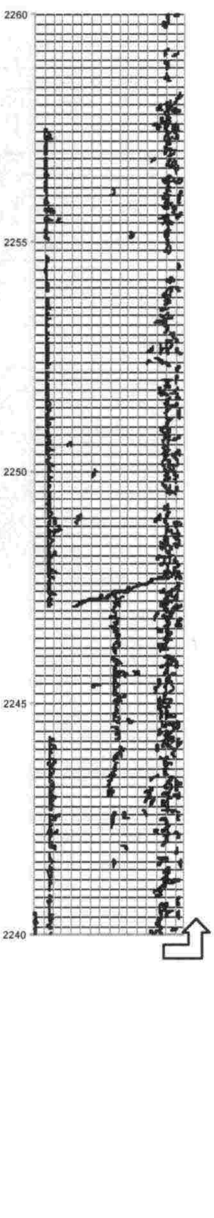


Image	Variabl	2245	2248
IW	(Intensi	0,00	0,00
IW	(Width)	0,00	0,00
IW	(Severi	0	0
BW	(Intensi	0,00	0,00
BW	(Width)	0,00	0,00
BW	(Severi	0	0
OW	(Intensi	0,00	0,00
OW	(Width)	0,00	0,00
OW	(Severi	0	0



Test Site 4
Road Section 1
3250

10m Results

Unsucceeded patch
Wide longitudinal Crack
PVI: Shows longitudinal cracks, VS only 6.1
System 1: Good result
System 2: Good result

Crack Types:	
Transversal	
Longitudinal	
Centerline	
Alligator	All.
Pothole	Pot.
Ravelling	Ravell.
Edge	
Freeze-Thaw	Fre.

Transversal		Longitudinal		Centerline	
narrow	wide	narrow	wide	narrow	wide
0	0	17	0	10	0

Alligator	Pothole	Ravell.	Edge	Fre.
0	0	0	0	0

PVI (July) VS
6,1

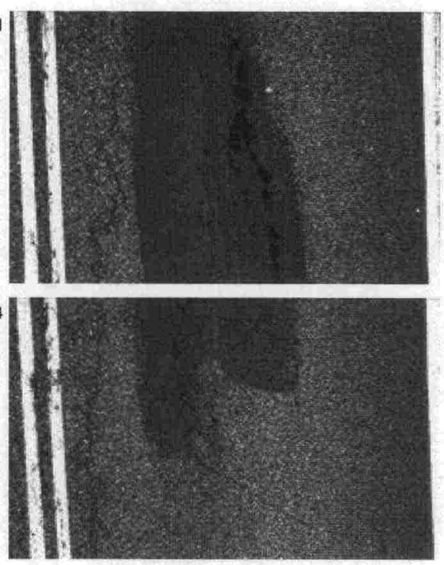
System 1 CS		
Run 1	Run2	delta%
26,6	22,4	8,5

System 2 UCI		
Run 1	Run2	delta
7,2	7,1	1,0

Relative variables:

average CS / PVI	average UCI / PVI	average CS / average UCI
4,0	**1,2**	**3,4**

3261



3254

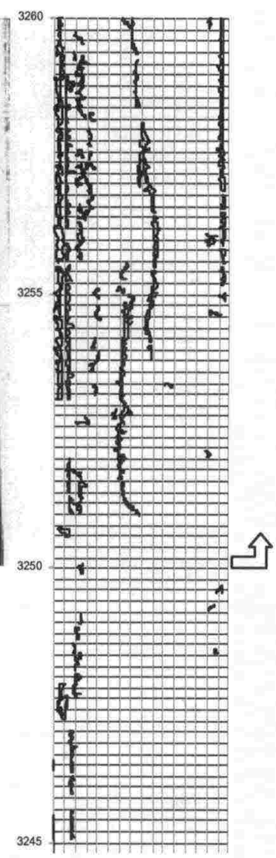


Image	Variable	3254	3261
IW	(Intensitv	0,00	0,00
IW	(Width)	0,00	0,00
IW	(Severity	0	0
BW	(Intensity	0,00	1,44
BW	(Width)	0,77	19,63
BW	(Severity	9,665	3
OW	(Intensity	3,00	0,48
OW	(Width)	0,00	18,44
OW	(Severity	0	3

Test Site **8**
Road Section **2**
3150

10m Results

Wide Longitudinal Crack
Centerline Crack
PVI: Crack is classified as narrow !
System1: Similar result with PVI
System 2: Similar result with PVI

Crack Types:	
Transversal	
Longitudinal	
Centerline	
Alligator	
Pothole	
Ravelling	Ravell.
Edge	
Freeze-Thaw	Fre.

Transversal		Longitudinal		Centerline	
narrow	wide	narrow	wide	narrow	wide
0	0	20	0	10	0

Alligator	Pothole	Ravell.	Edge	Fre.
0	0	0	0	0

PVI (July) VS
7

System 1 CS		
Run 1	Run2	delta%
10,3	8,1	11,6

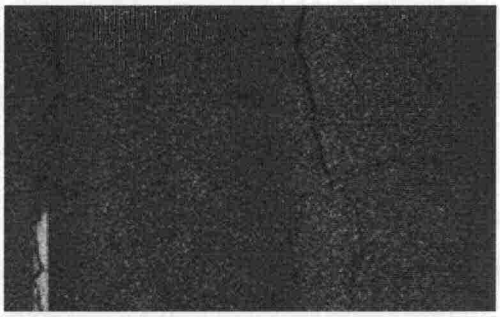
System 2 UCI		
Run 1	Run2	delta%
5,3	6,0	6,7

Relative variables:

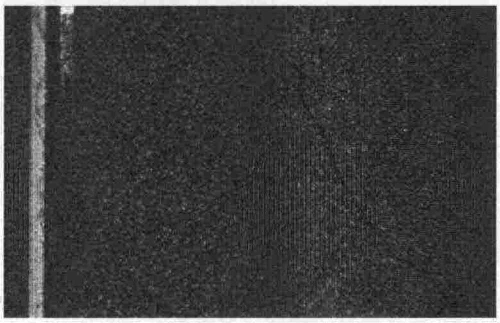
average CS / PVI	average UCI / PVI	average CS / average UCI
1,3	**0,8**	**1,6**

Image	Variabl	3143	3150	3159
IW	(Intensi	0,00	0,00	0,00
IW	(Width)	0,00	0,00	0,00
IW	(Severi	0	0	0
BW	(Intensi	0,00	0,00	0,00
BW	(Width)	0,00	0,00	0,00
BW	(Severi	0	0	0
OW	(Intensi	0,00	0,86	1,25
OW	(Width)	0,00	9,72	9,75
OW	(Severi	0	3	3

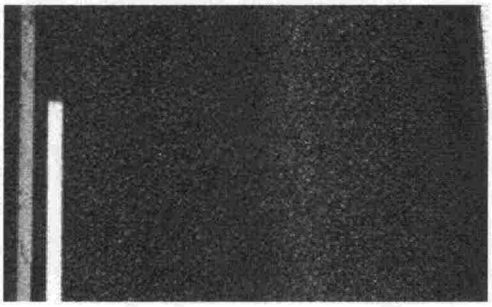
3159

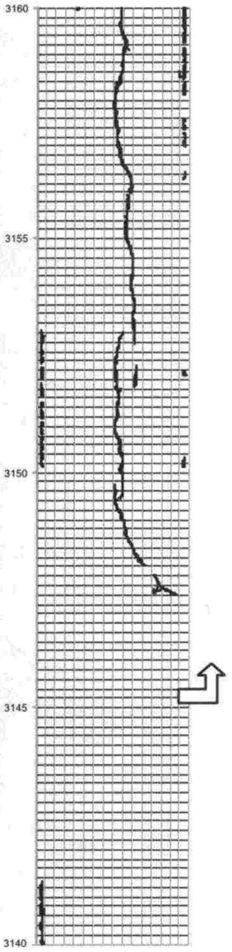


3150



3143





Test Site 8
Road Section 2
3180

10m Results

Wide Longitudinal Crack
Centerline Crack
PVI: Crack is classified as narrow !
System1: Similar result with PVI
System 2: Similar result with PVI

Crack Types:

Transversal	
Longitudinal	
Centerline	
Alligator	
Pothole	
Ravelling	Ravell.
Edge	
Freeze-Thaw	Fre.

Transversal		Longitudinal		Centerline	
narrow	wide	narrow	wide	narrow	wide
0	0	8	0	10	0

Alligator	Pothole	Ravell.	Edge	Fre.
4	0	0	0	0

PVI (July) VS
7,4

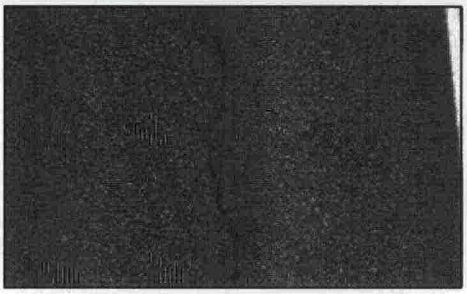
System 1 CS		
Run 1	Run2	delta%
11,0	14,7	14,4

System 2 UCI		
Run 1	Run2	delta%
9,4	8,4	5,1

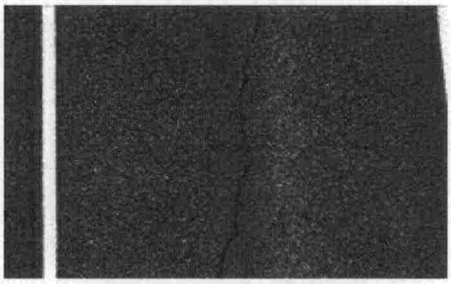
Relative variables:

average CS / PVI	average UCI / PVI	average CS / average UCI
1,7	**1,2**	**1,4**

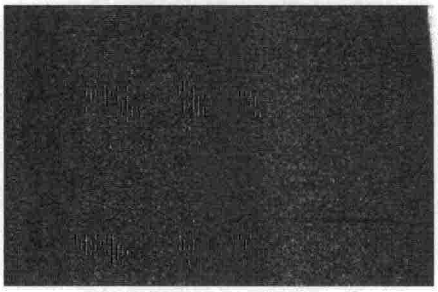
3199



3190



3186



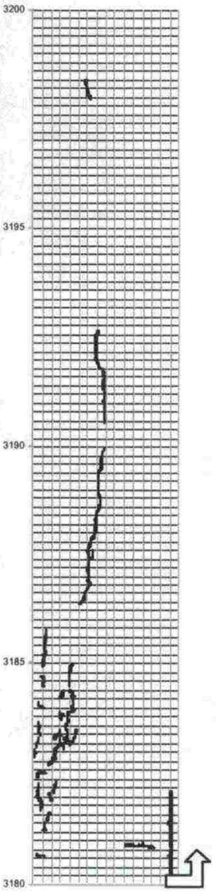


Image	Variable	3186	3190	3199
IW	(Intensity	0,00	0,00	0,00
IW	(Width)	0,67	0,00	0,00
IW	(Severity	8,399	0	0
BW	(Intensity	3,00	1,35	1,44
BW	(Width)	0,00	12,22	11,53
BW	(Severity	0	3	3
OW	(Intensity	0,00	0,00	0,00
OW	(Width)	0,29	0,00	0,00
OW	(Severity	8,249	0	0

[redacted]