23E CONGRÈS MONDIAL DE LA ROUTE PARIS 2007

Comité Technique 4.2 « Interactions Route / Véhicule »
Technical Committee 4.2 « Road / Vehicle Interactions »
Groupe de travail D / *Working Group D*

Evaluating the performance of automated pavement cracking measuring equipment

Michel BOULET

- LCPC (France)
- Directeur Technique Routes /Technical Director for Roads
- Michel.Boulet@lcpc.fr

- On behalf Mathieu Grondin (MTQ, Can-Qc) Paul Harbin (Roadware, Can), Pietro Bumma (METW, Be)
- Thanks to Brian Ferne (TR, UK), Leif Sjögren (VTI, SE), John Laurent (INO, Can-Qc), Keizo Kamiya (Nexco ERI, JP), Steve Brown (ARRB, Aus)

Evaluating the performance of automated pavement cracking measurement equipment

Background : Former committee C1 “Surface Characteristics”

1996 – 2005 (Montreal) : “Pavement Distresses Surveys”

1) **Inventory of existing (visual) procedures : network or project level**

2) **Distresses types – Methods for quantification of extent and severity**

3) **Calculation of (global) distresses indices**

4) **Inventory of existing (semi of fully) automated systems**

5) ***Dedicated workshop during the Montreal Congress***

Evaluating the performance of automated pavement cracking measurement equipment

Background : Former committee C1 “Surface Characteristics”

1996 – 1999 (Kuala Lumpur) : “Surface distress assessment”

1) PIARC efforts towards harmonization

Main recommendations :

- dimension of extent
- classes of severity
- reporting (research, project and network level)

Article in Routes/Roads journal

2) Use of pavement surface conditions parameters in pavement maintenance management systems

Evaluating the performance of automated pavement cracking measurement equipment

Background : Former committee C1 “Surface Characteristics”

2000 – 2003 (Durban) : “Automated pavement cracking assessment equipment – State of the art”

1) Identification of harmonization feasibility

2) Status of technologies (2D and 3D)

3) Evaluating the performance of automated equipment

- *Many test experiments are not complete (representativity of test sites, repeatability not measured, etc.)*
- *Many factors limit the possibility to compare the results (reference sites, human intervention, etc.)*
- *A test standard to compare and evaluate the automated equipment reliability should be necessary (or very desirable)*

4) Experience with measuring distresses at network level

Evaluating the performance of automated pavement cracking measurement equipment

TC 4.2 “Road / Vehicle Interactions”

2004 – 2007 (Paris) : “Evaluating the performance of the automated pavement cracking measurement systems”

1) Inventory of pavement cracks detection and identification methods in order to improve the reproducibility of the measurements

2) Designing an methodology for evaluating and classifying the performances of automated cracking measurement systems in terms of reliability (bias and repeatibility)

3) Inventory of the methods to characterize and to record surface distresses on unpaved roads (presentation Yves Provencher)

Evaluating the performance of automated pavement cracking measurement equipment

TC 4.2 “Road / Vehicle Interactions”

2004 – 2007 (Paris) : “Evaluating the performance of the automated pavement cracking measurement systems”

WHY ??

1) Pavement surface distresses are the main pavement condition data for pavement maintenance management systems

2) More and more automated systems in the future

3) To share existing national practices or experiences : Australia (ARRB), Canada-Québec (MTQ), Belgium (METW,..), European Commision (COST actions 325/354), France (SETRA, LCPC), Germany (BASt), Japan (PWRI), Netherlands (DWW), Sweden (VTI), United Kingdom (HA, TRL), USA (DOT, AASHTO PP 44-00, ASTM E-1656-94, TRB),….

4) To evaluate the interests and the feasibility for further harmonization

HOW ??

➔ *PIARC International Workshop in Quebec on August 2006*

Evaluating the performance of automated pavement cracking measurement equipment

Measurement Methods or Procedures

1) In situ visual inspections

2) Visual analyses of (digital or photographic) images of pavement surfaces

3) Off line (in laboratory) automated analyses of digital images of pavements surfaces (semi-automated systems)

4) On line automated recording of surface conditions data (fully automated systems)
   - 2D images
   - 3D images

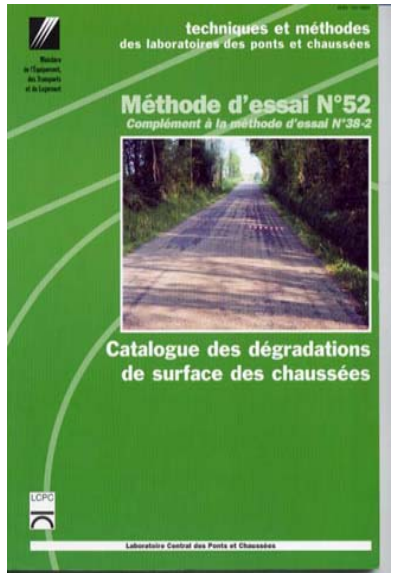
Summary

Benefits from Automation

- Objective, repeatable (measured vs estimated)
- Reduced cost & improved safety of operators

Performance to suit needs

- Width detection threshold (1mm)
- Survey frequency & network sampling



Standards & Documents

- Defined data specifications & test method
- Validation & repeatability procedures
- Reporting (type, severity, extent – definitions & limits)

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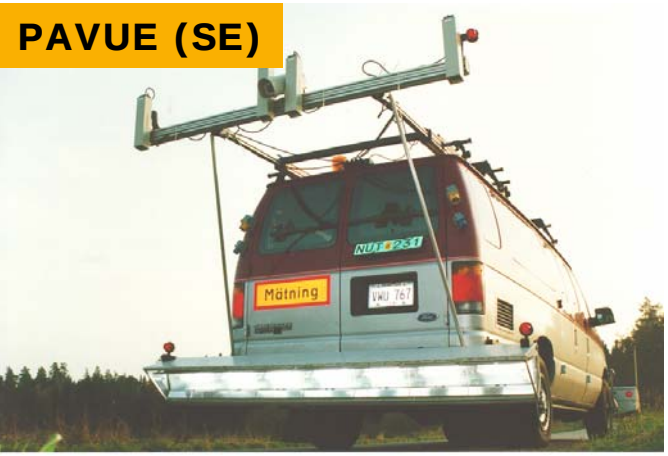
Some examples of equipment (ref. PIARC inventory)

PAVUE (SE)



ROADCRACKS (AUS)

NEXCO ERI (JP)

RAV and HARRIS (UK)

INO (CAN-QC)

ARAN (CAN)

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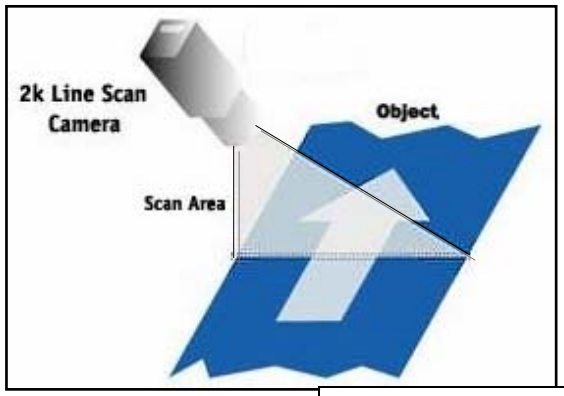
Technology Advances

Collect



2D

3D

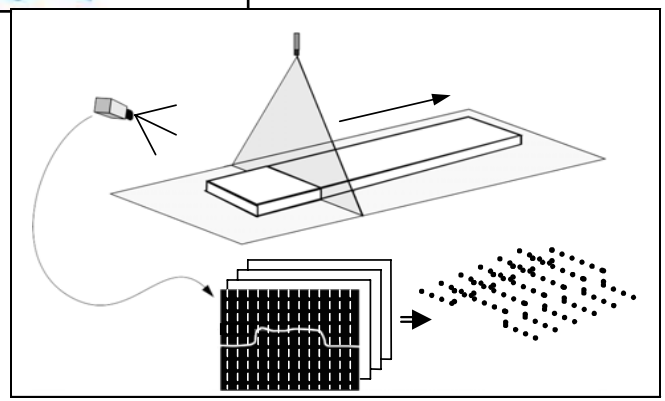


Diagram 1—How a 3D laser triangulation sensor operates

Record

- Today, high-quality images are easily available
- However, the storage capacity of the collected information is limited
- So the challenge is to implement analysis in real time

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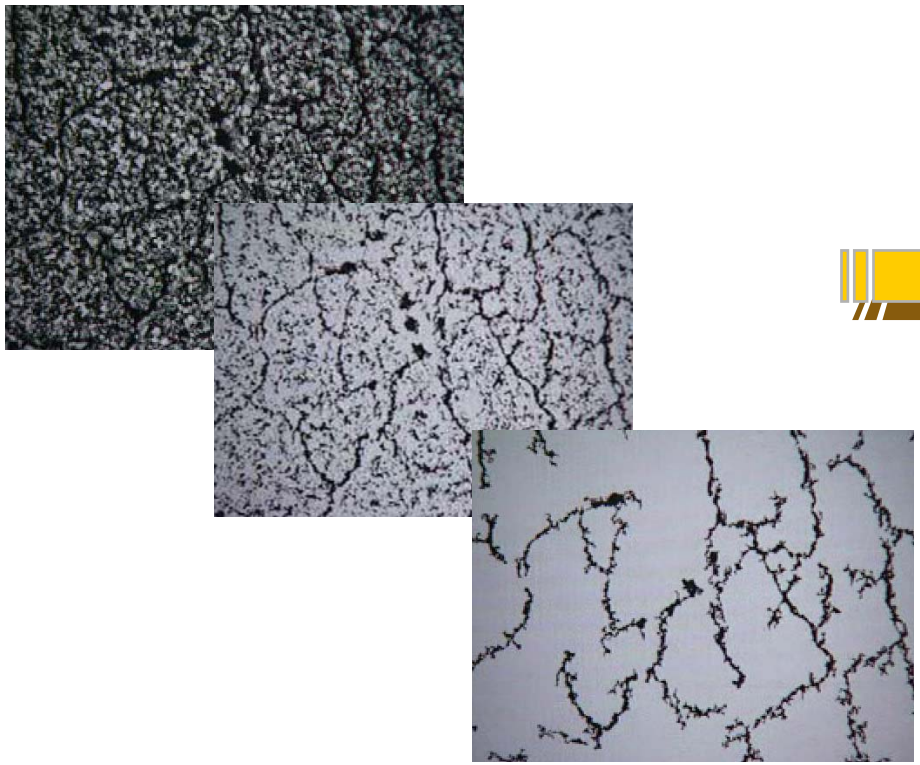
Technology Advances

Analysis



Classification

Challenge:

- Respect numerous protocols

- Recognize all distress types (actually : only cracks)

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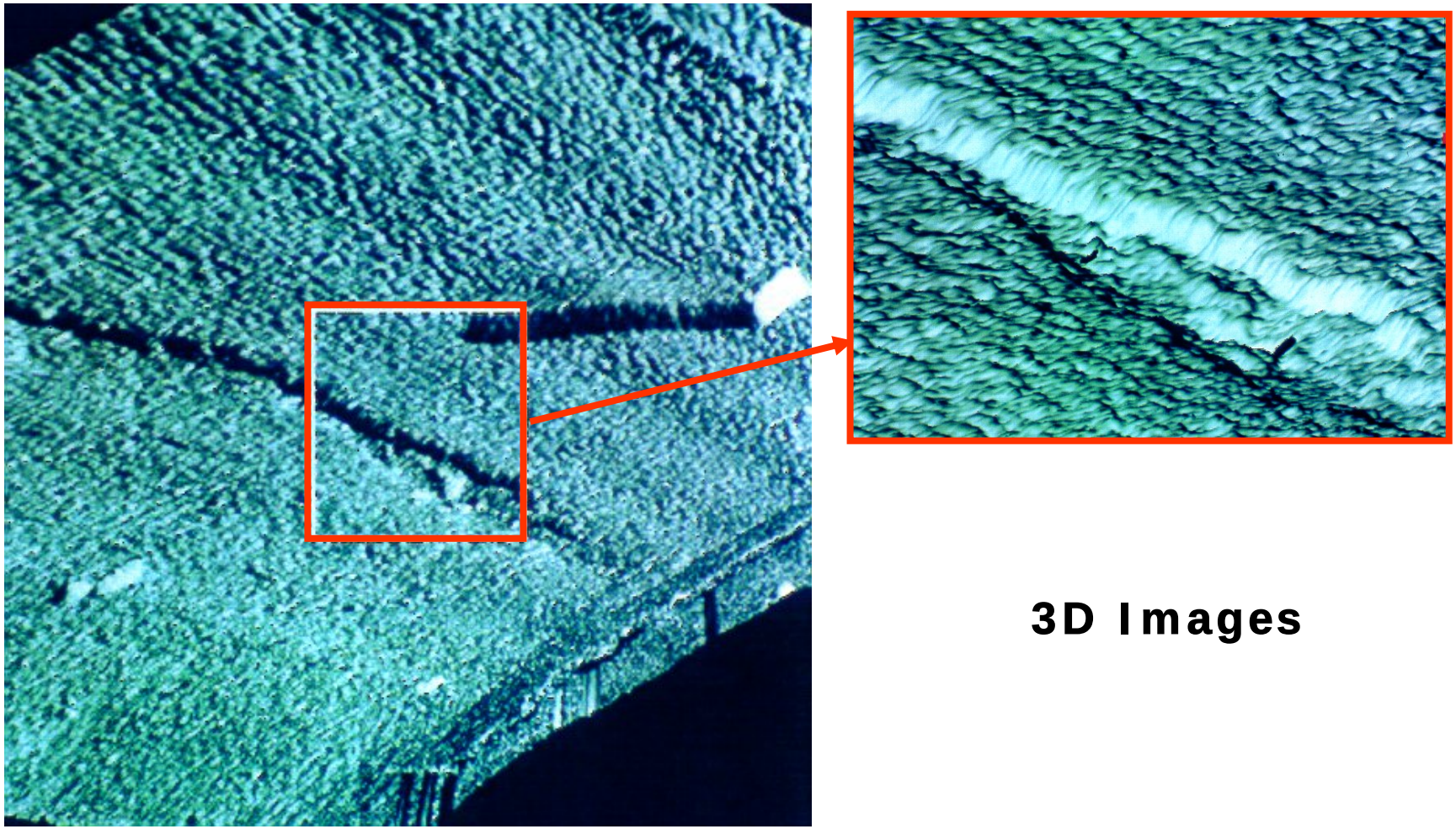

3D Images

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PIARC Methodology concept to increase the reproducibility of the cracks measurements : A- Delimitation of the analyzed zone

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PIARC methodology concept : Cracks definition

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What's a crack ??

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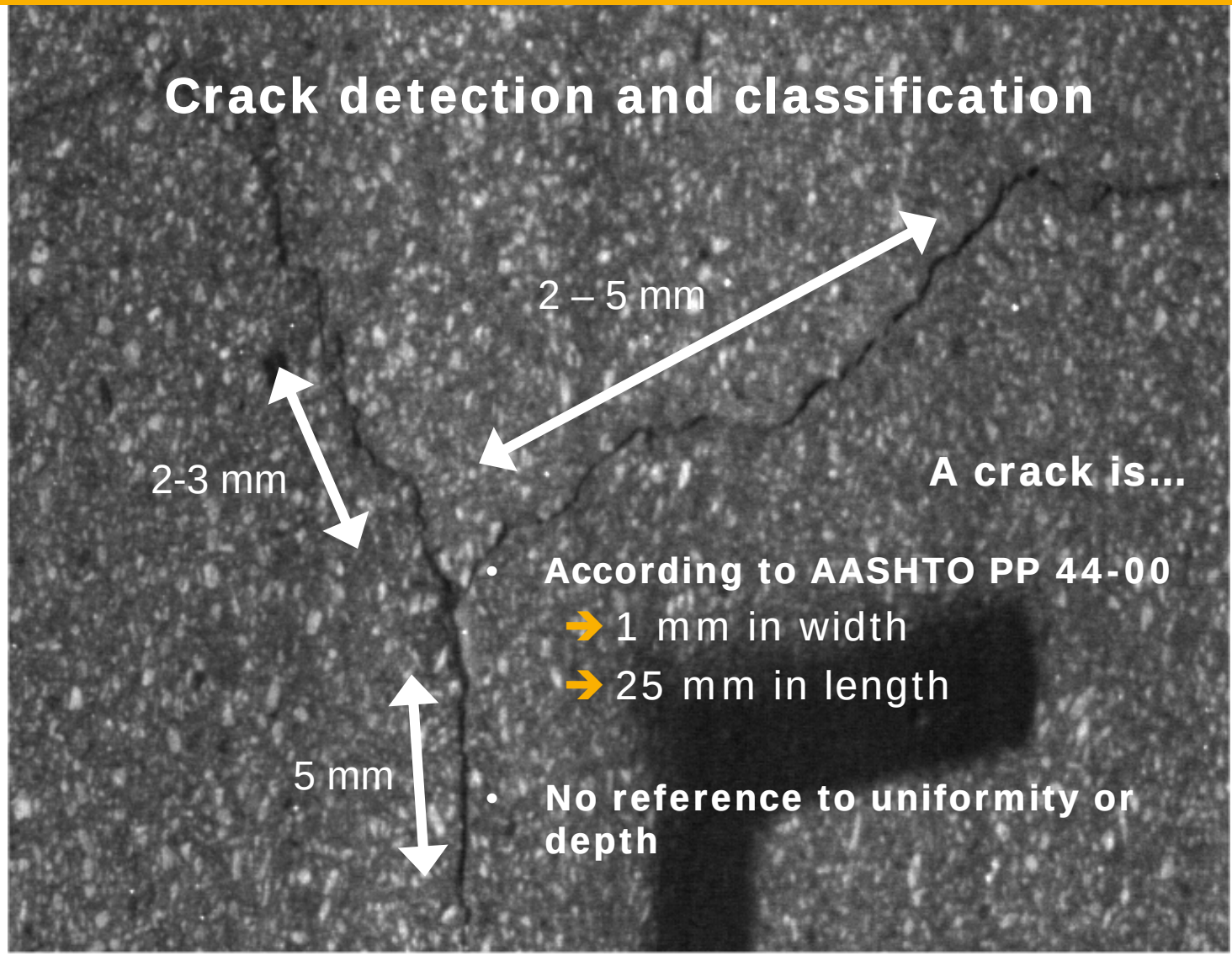

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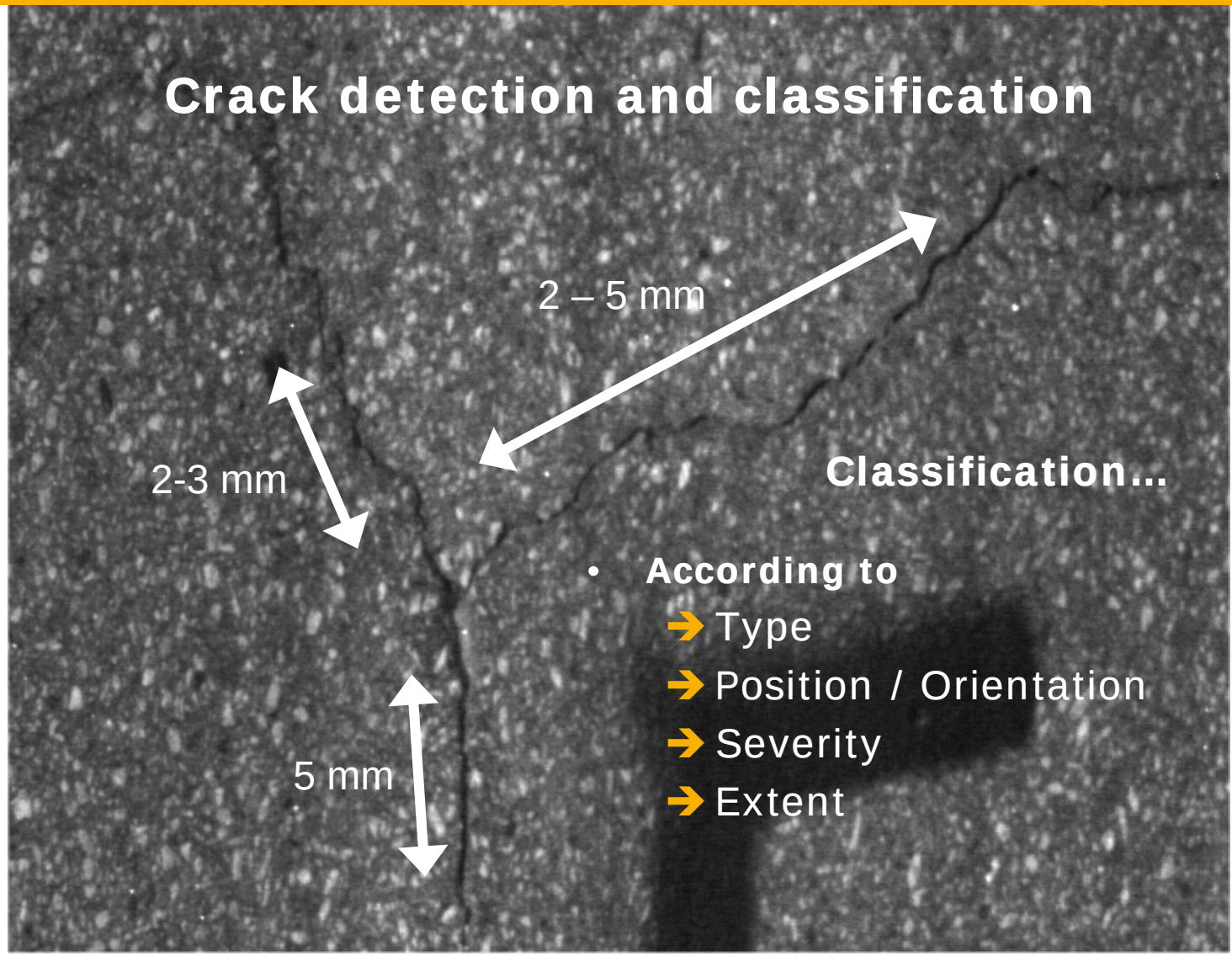

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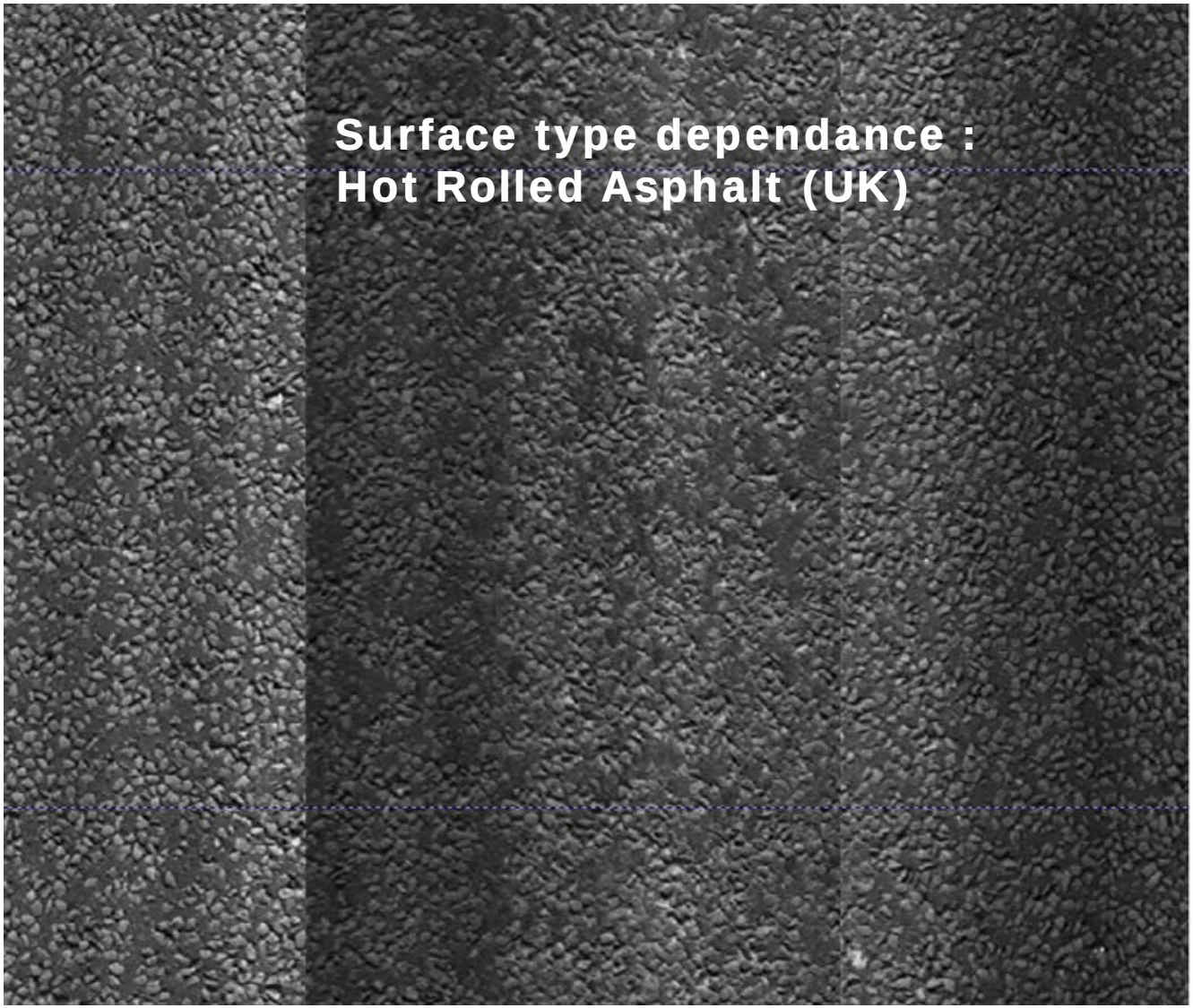

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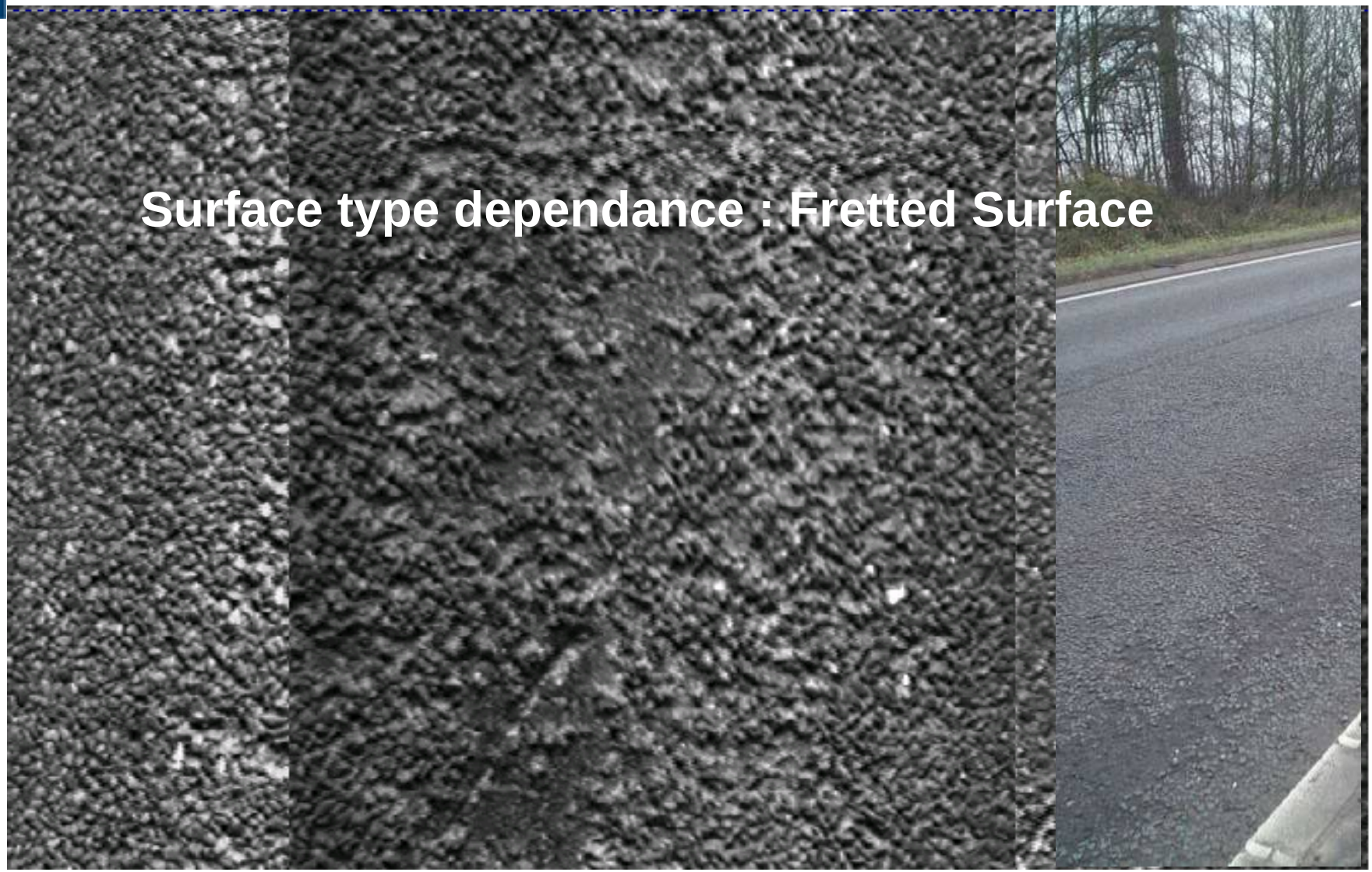

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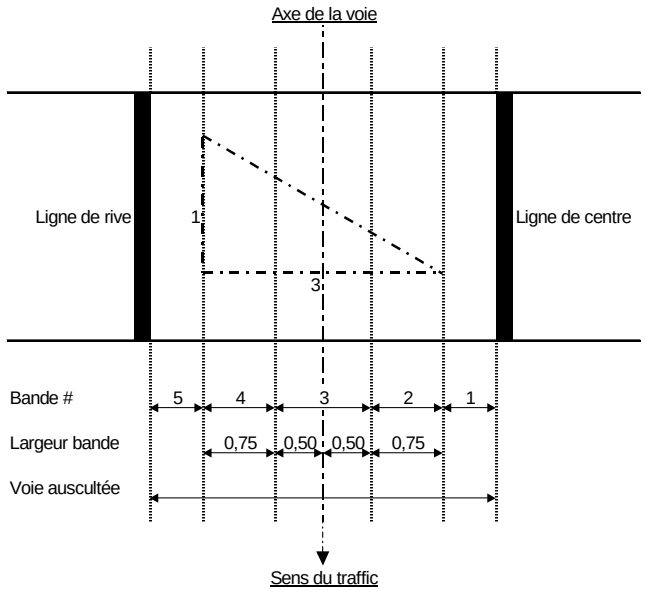
PIARC Methodology concept to increase the reproducibility of the cracks measurements : B – Crack description and type

Type	Description	Scheme or picture
Crack definition	*Minimum length: 0,15 m* *Minimum width: 1 mm*	
Transversal cracking	*Crack with an orientation ≤1:3 (1 parallel et 3 perpendicular to the road axis) and which is present on 2 or more longitudinal strips.*	
Longitudinal cracking	*Crack with an orientation > 1:3 (1 parallel and 3 perpendicular to the road axis).*	
Edge cracking	*Longitudinal crack distant less than 0.25 m from the edge of the road.*	

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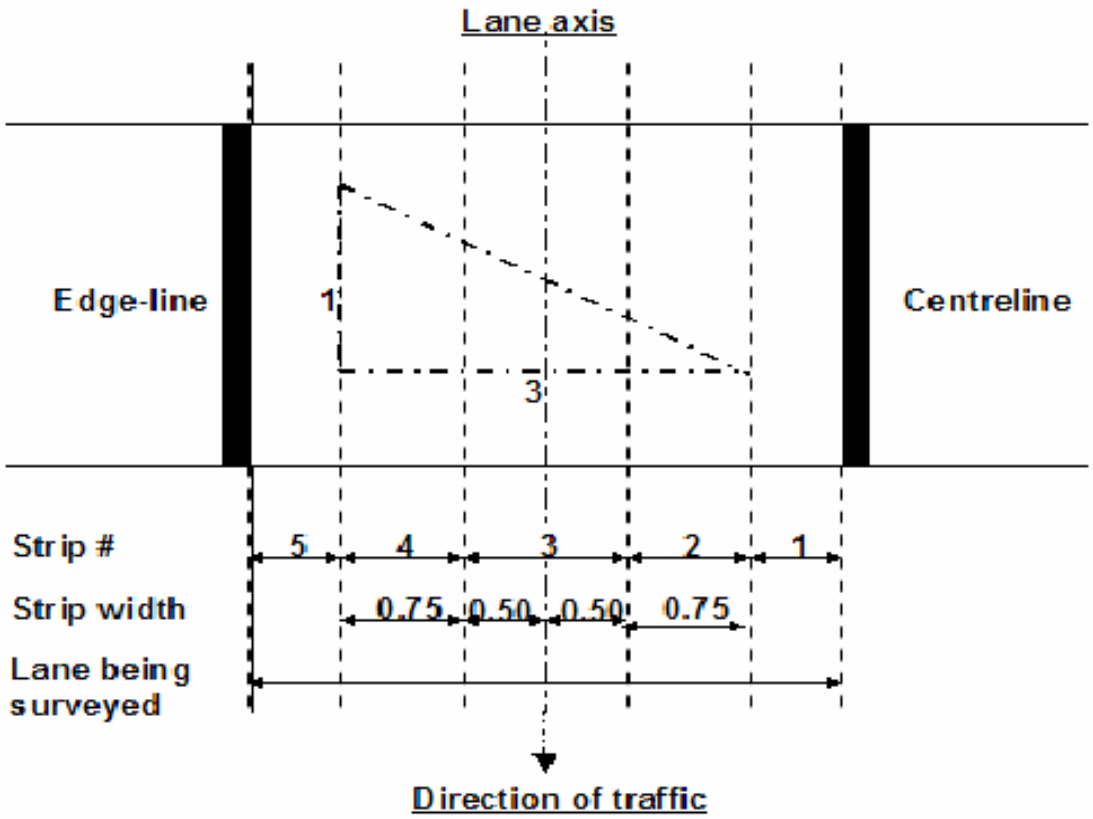
PIARC Methodology concept to increase the reproducibility of the cracks measurements : B – Crack description (orientation)



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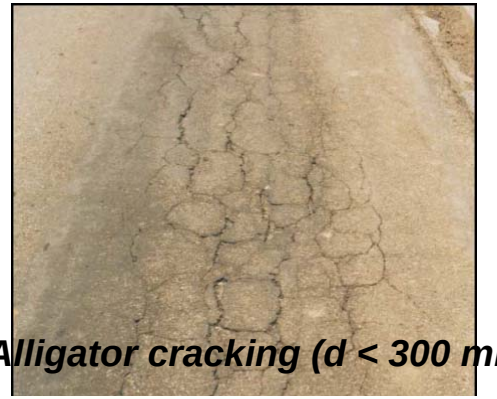
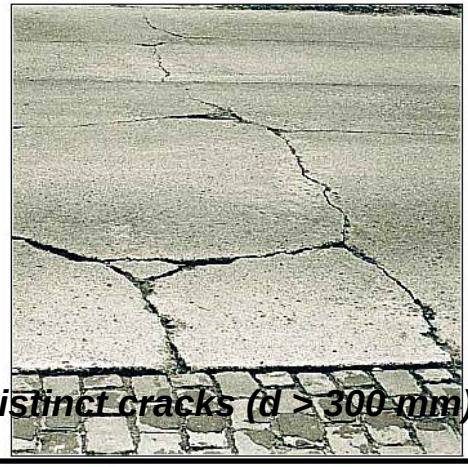
Alligator cracking	***Agglomeration of pavement cracks in the form of a grid, with at least 3 pieces in each direction, and where the diameter of each piece is less than 300 mm.*** ***If the diameter of the pieces is greater than 300 mm, then the cracks are considered as distinct.***	 ***Alligator cracking (d < 300 mm)***  ***distinct cracks (d > 300 mm)***
Multiple cracks	***Agglomeration of pavement cracks that run parallel and that are less than 300 mm apart.*** ***If they are more than 300 mm apart, then the cracks are considered as distinct.***	

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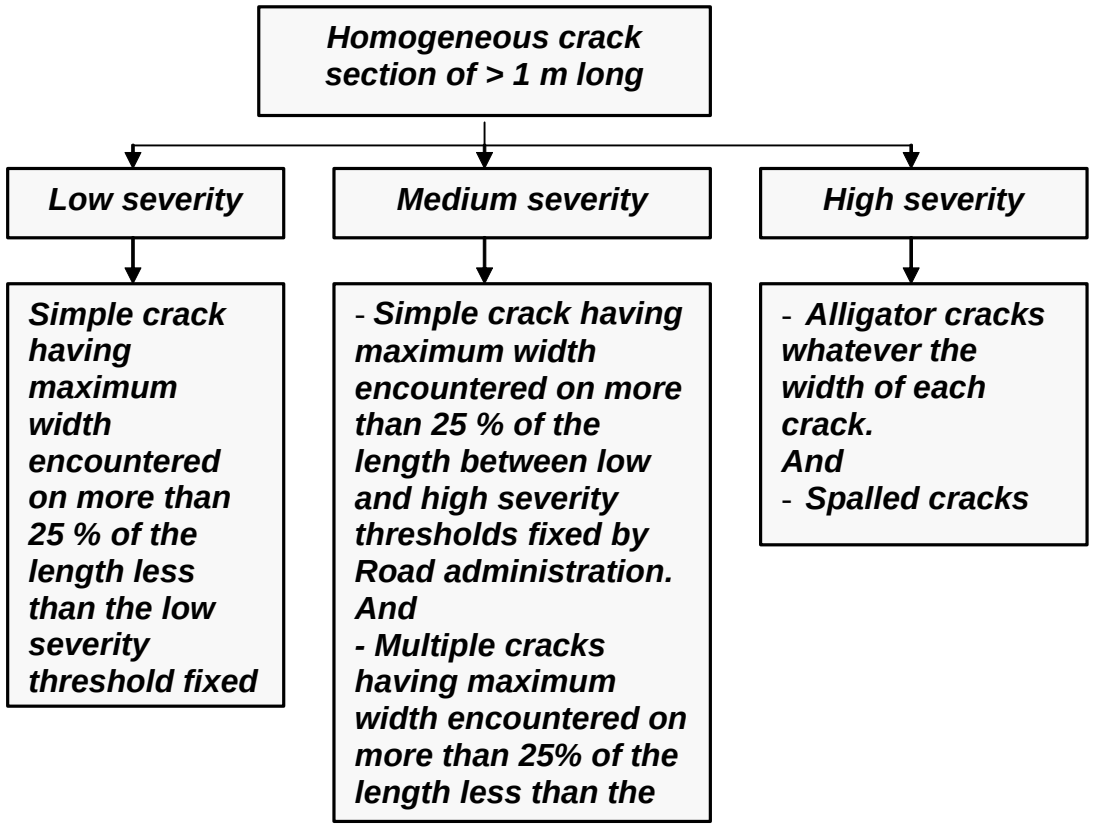
PIARC Methodology concept to increase the reproducibility of the cracks measurements : C- Severity level



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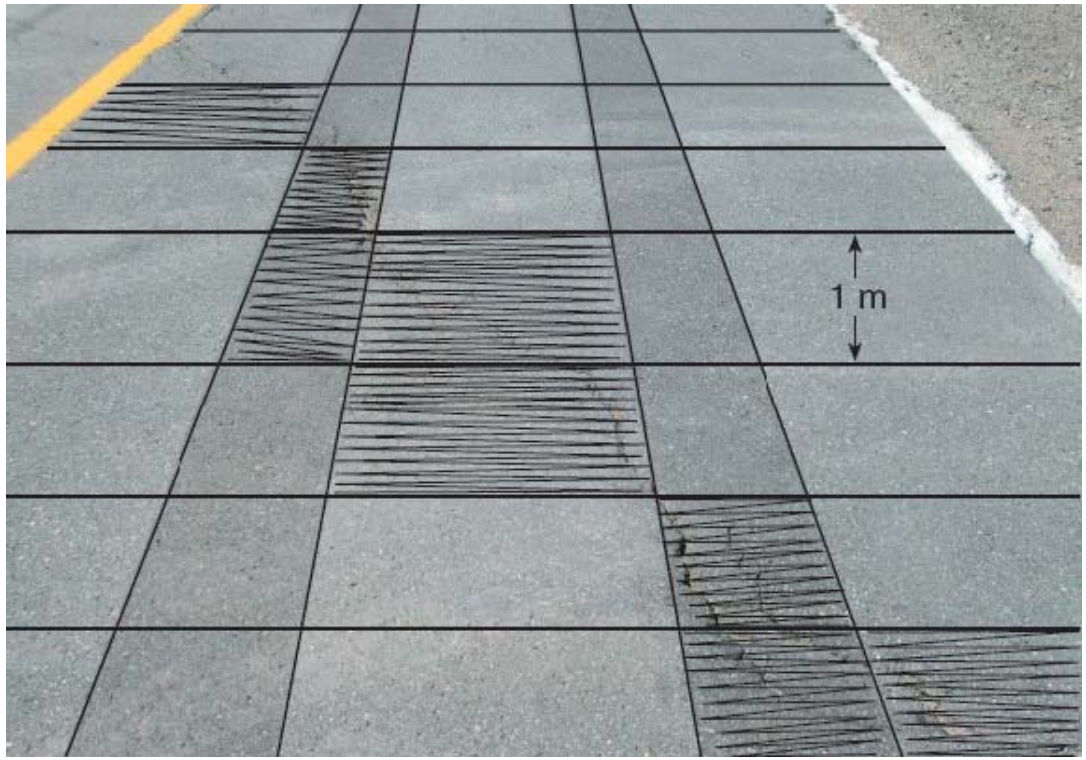
PIARC Methodology concept to increase the reproducibility of the cracks measurements : D – Crack extent by the mean of cells



For project level validation test

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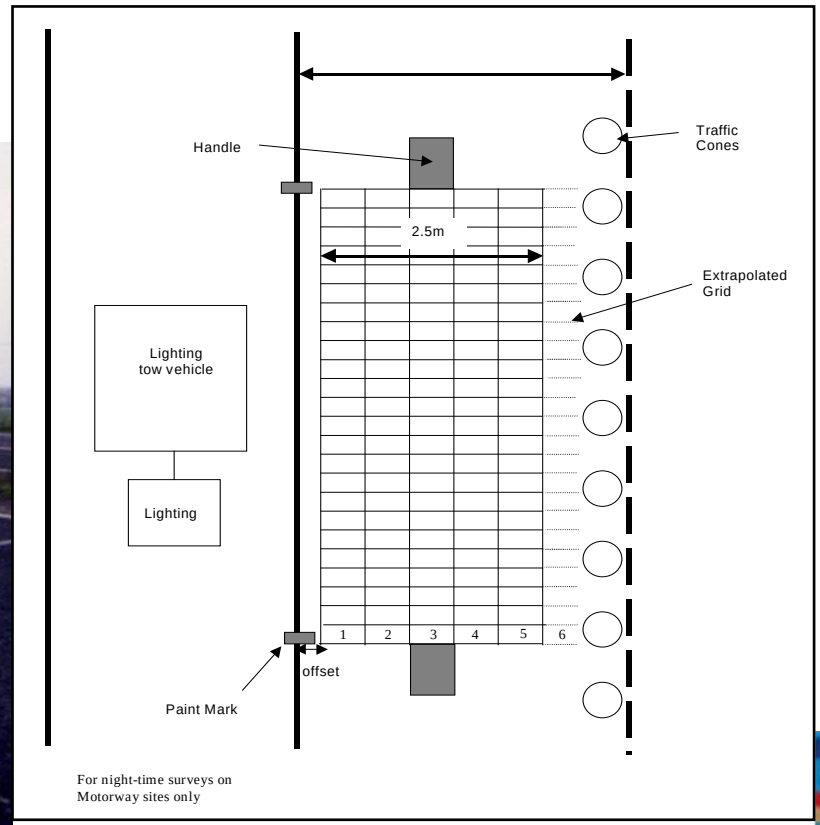
Visual inspection using wire grid to establish reference crack data (UK)



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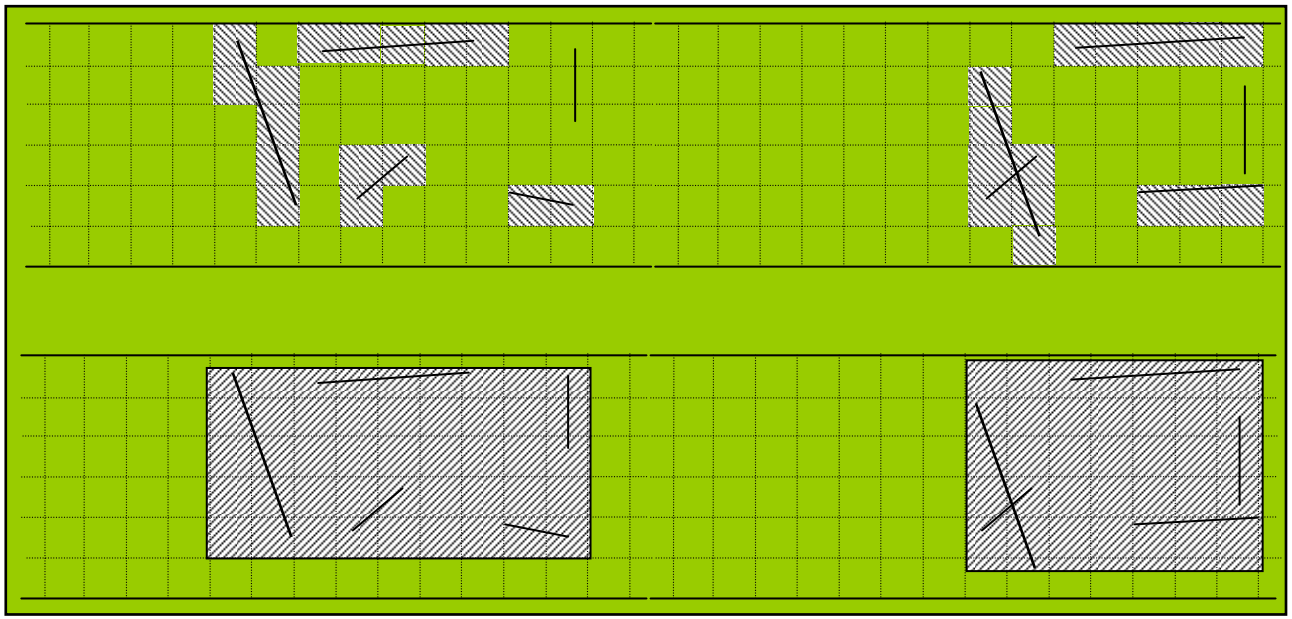

Automatic survey

with the grid

“Manual Survey”

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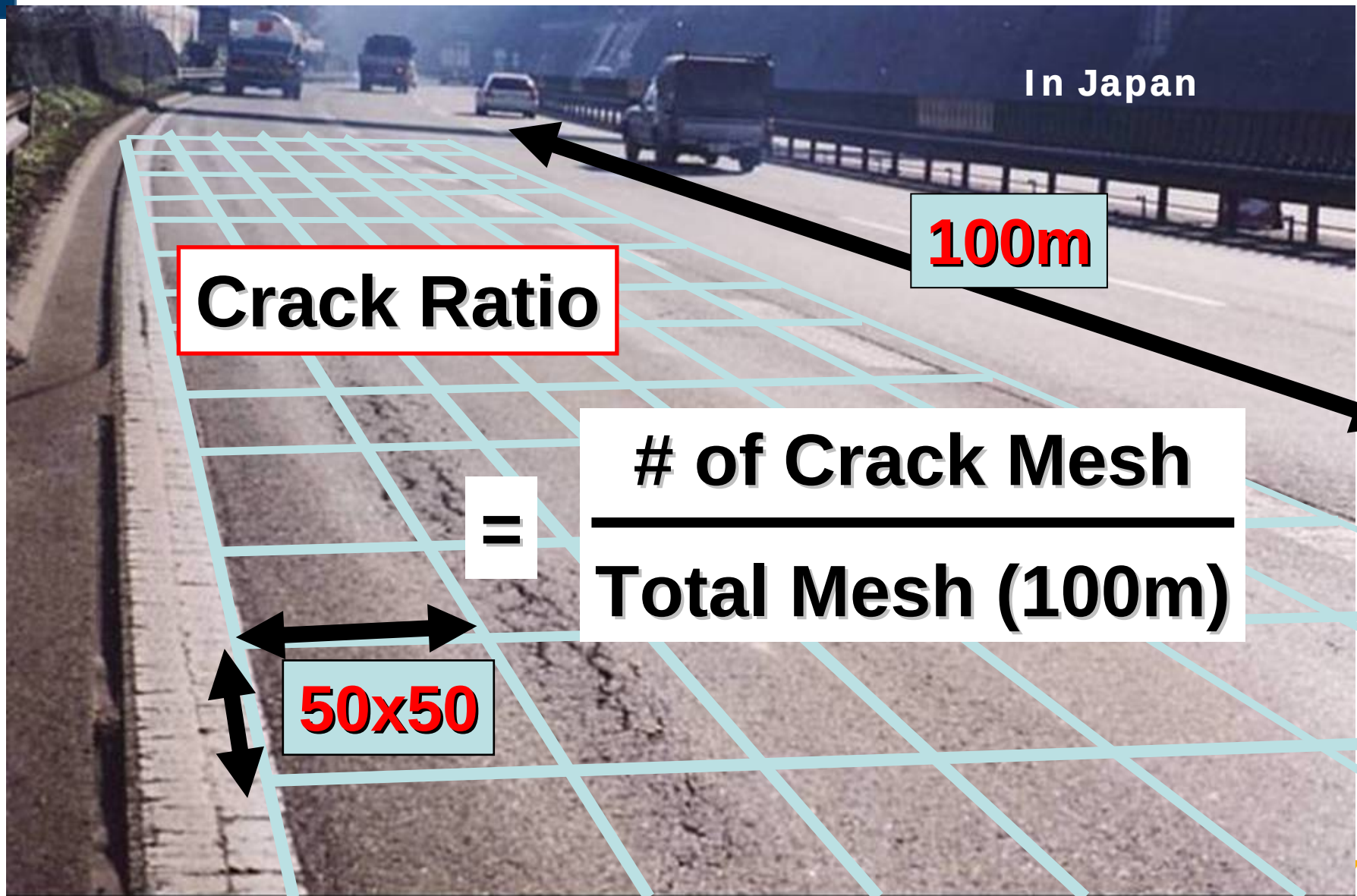

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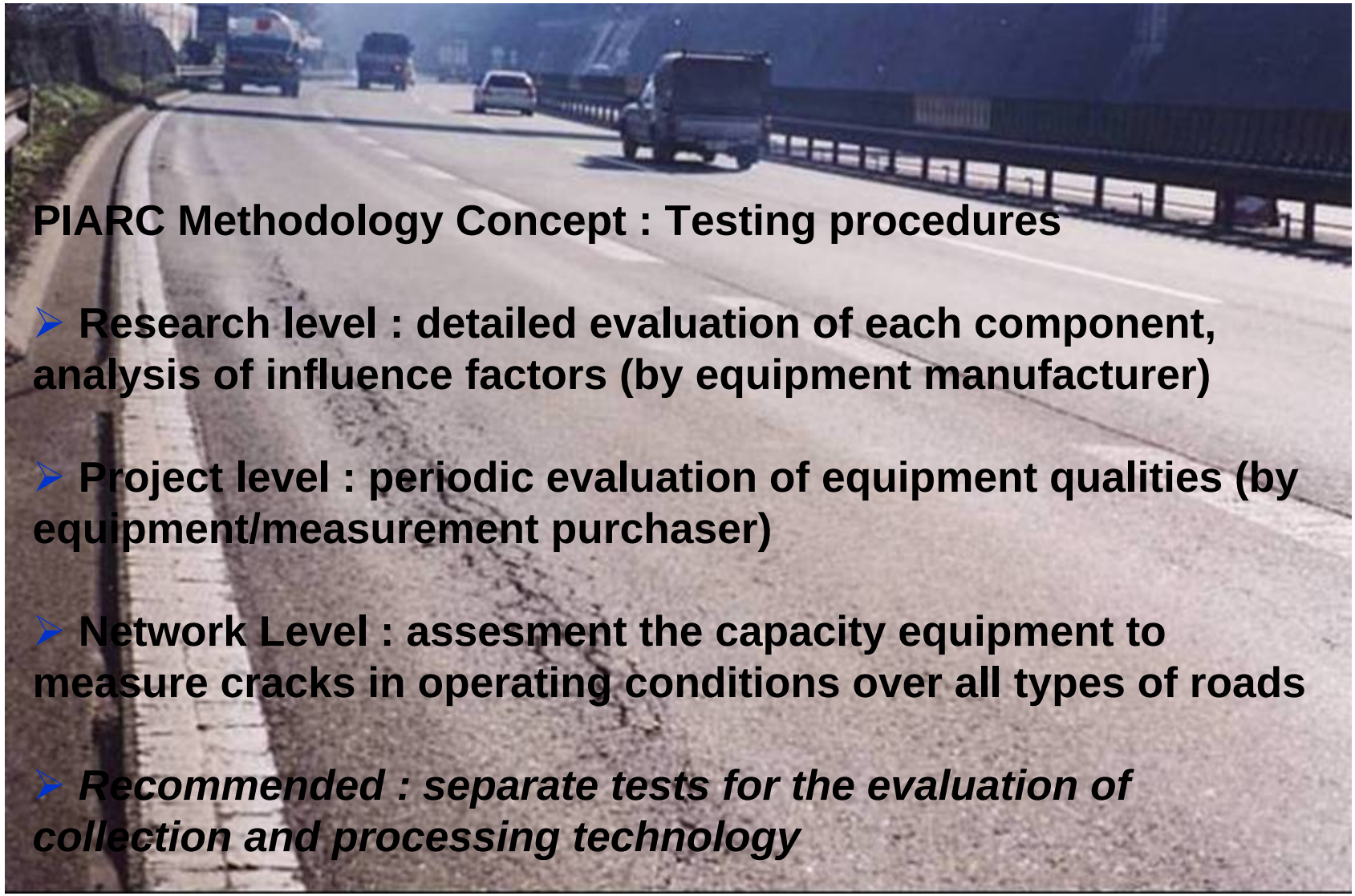

PIARC Methodology Concept : Testing procedures

- **Research level : detailed evaluation of each component, analysis of influence factors (by equipment manufacturer)**
- **Project level : periodic evaluation of equipment qualities (by equipment/measurement purchaser)**
- **Network Level : assesment the capacity equipment to measure cracks in operating conditions over all types of roads**
- ***Recommended : separate tests for the evaluation of collection and processing technology***

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Phase 1 – Research level validation test (under controlled conditions)

Description of artificially fissured test tracks

Sampling unit	Crack
Number of tracks	1
Number of cracks per tracks	170
Number of longitudinal cracks	150 (1 cell)
Number of transversal cracks	20 (5 cells)
Track length	600m
Available cells	300
Used cells	250
Number of repetitions	5

Crack severity : 2mm, 3 mm, 5mm, 8 mm width
Crack length : 3m, 5m, 8m for longitudinal, and 3,6 m for transverse
Crack depth : x1 and x2 macro texture depth
Levels of macrotexture : 2 at less

Evaluating the performance of automated pavement cracking measurement equipment

Phase 1 – Research level validation test

Classification thresholds for detection and bias

Class	Correctly detected cracks	Length (cracks with relative bias < 7.5 %)	Severity (Cracks with relative bias < 20 %)
AAA	100 %	100 %	100 %
AA	≥ 90 %	≥ 90 %	≥ 85 %
A	≥ 80 %	≥ 80 %	≥ 70 %
B	≥ 70 %	≥ 70 %	≥ 60 %
C	< 70 % and ≥ 50 %	< 70 % and ≥ 50 %	< 60 % and ≥ 50 %

Class C : lower limit for « suitable » equipment

Evaluating the performance of automated pavement cracking measurement equipment

Phase 1 – Research level validation test

Classification thresholds for repeatability

Class	Length (cracks with C.V. < 0.1 %)	Severity (Cracks with C.V. < 0.5 %)
AAA	100 %	100 %
AA	≥ 90 %	≥ 85 %
A	≥ 80 %	≥ 70 %
B	≥ 70 %	≥ 60 %
C	< 70 % and ≥ 50 %	< 60 % and ≥ 50 %

(C.V. : Coefficient of Variation)

Evaluating the performance of automated pavement cracking measurement equipment

Phase 2 – Project level validation test

Objective : to regularly check the equipment performances

Description of the road trafficked test sections

Sampling unit (cell length)	1m sub-sections
Number of test sections	10
Number of cracks per section	Variable
Number of longitudinal cracks	Variable
Number of transversal cracks	Variable
Length of the test sections	50m
Cells per test sections	250
Total number of cells	2500
Repetitions for bias	3
Repetitions for repeatability	5

(Variable = representative of surveyed network conditions)

Evaluating the performance of automated pavement cracking measurement equipment

Phase 2 – Project level validation test

Data and data analysis

- Reference : in situ visual (manual) inspections
- Detection and quantification according to the “Grid protocol”
- Minimum length of detected crack : 0,15 m
- Cracking rate : number of allocated (presence of cracks) cells divided by 250 (total number of cells);
- Concordance with the reference :
    - Position of the allocated cells;
    - Severity of allocated cells.

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Phase 2 – Project level validation test

Classification thresholds for detection and bias

Class	Cracking rate (from reference)	Cells with crack Concordance with reference	Crack severity Concordance with reference
AAA	± 1 %	100 %	100 %
AA	± 2.5 %	95 %	90 %
A	± 5 %	90 %	80 %
B	± 10 %	80 %	70 %
C	> 10 % and < 30%	< 80 % and ≥ 50 %	< 70 % and ≥ 50 %

Class C : lower limit for suitable equipment

Evaluating the performance of automated pavement cracking measurement equipment

Phase 2 – Project level validation test

Classification thresholds for repeatability

Class	Cracking rate	Crack presence (cells concordance)	Crack severity (cells concordance)
AAA	C.V. < TBD	C.V. < TBD	C.V. < TBD
AA	C.V. < TBD	C.V. < TBD	C.V. < TBD
A	C.V. < TBD	C.V. < TBD	C.V. < TBD
B	C.V. < TBD	C.V. < TBD	C.V. < TBD
C	C.V. < TBD	C.V. < TBD	C.V. < TBD

TBD = to be determined
Classification for all types of cracks

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Phase 3 – Network level validation test

Objective : to assess the capacity of equipment to measure crack over all types of road surfaces and conditions

Description of the road trafficked test sections

- total length of test sites : up to 100 km
- surfaces of test sites representative of network surfaces : types, texture, colour,..
- various test operating conditions (sun, dry/wet, …)

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Phase 3 – Network level validation test

Data and data analysis

Reference : visual analyses of digital images (resolution : 1 pixel = 2 mm x 2 mm)

- Detection and quantification according to the “Grid protocol”
- Calculation total area of grid tiles containing crack within 50 m sub-sections , Calculation of a Normalised Reference Area and a Normalised Automatic Area for each 50 m long sub-sections
- NRA/NAA >1.75 : sub-sections with high level of cracking
- NRA/NAA < 0.2 : sub-sections with low level of cracking
- If concordance of NRA and NAA for more than 75 % sub-section for the two levels of cracking, then automated system suitable for network survey. If not, to investigate the reasons

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Conclusions – Recommendation

- **The PIARC method still needs to be completed, experienced, validated**
- **To constitute a worldwide users (of equipment, of data provided by the equipment) group aiming at to continuing to exchange information, to share experiences** : PIARC, FEHRL/CEDR (EU), TRB/AASHTO (North America), ARRB (AUS),
- **To evaluate the benefits of new technologies (2D → 3D)**
- **Is Cracking always the main or more relevant information for any type of pavement ?? What's about other distresses : potholes, bleeding, ravelling, repairs, ...??**
- **To define suitable requirements (strictly necessary, sufficient, desirable), in terms of types of distresses to be detected and recorded,**

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Merci pour votre attention!

Thank you for listening !

Michel.Boulet@lcpc.fr