Eliminate the Deduct Staircase

Towards Continuous Distress Severity Measurement

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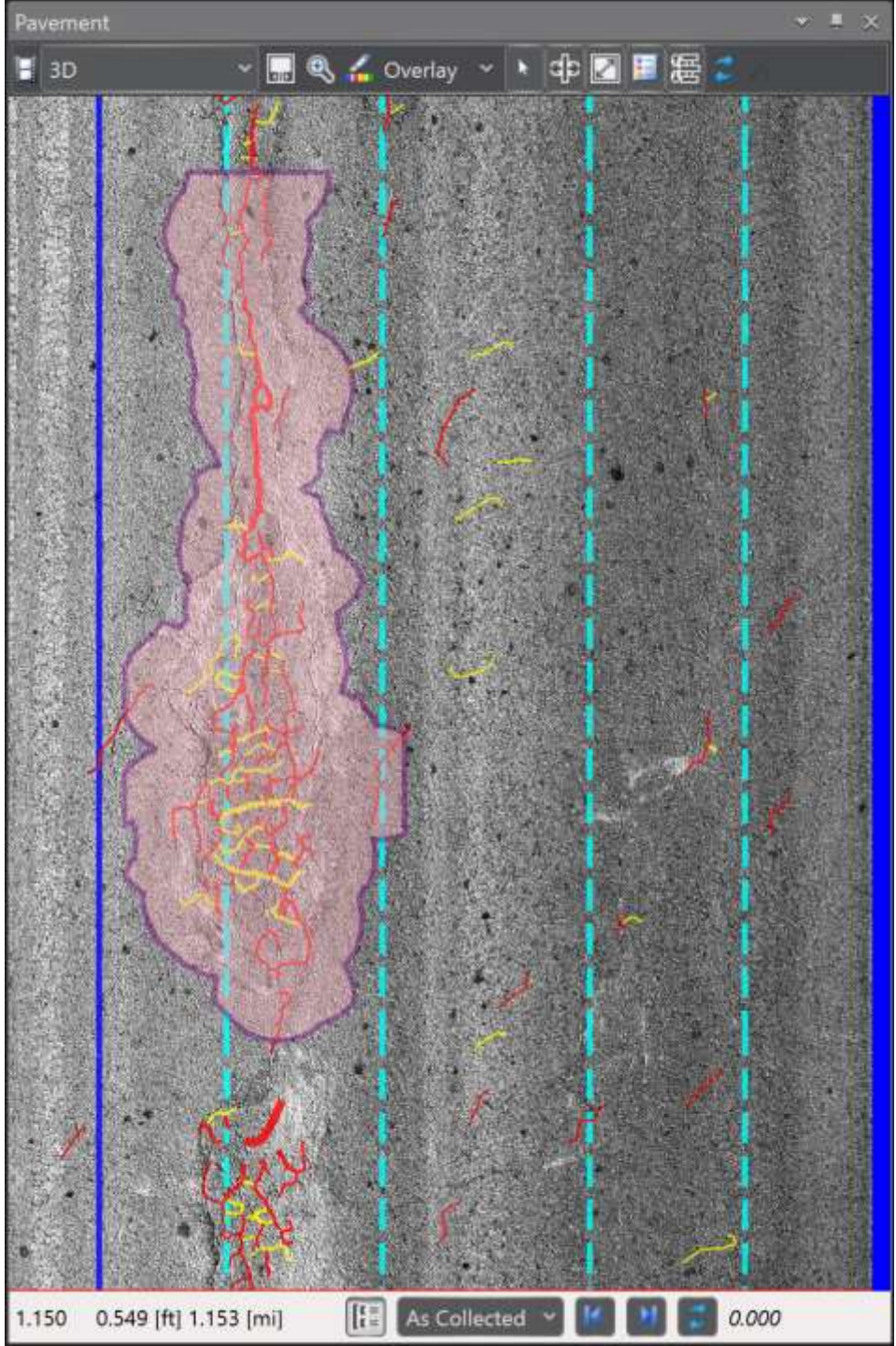
Outline

- Problem definition
- Suggested solutions
- Test results: variability of condition data on repeat runs

Condition Measurement

- Three fundamental questions
  - What kind of distresses are present?
  - How much is there?
  - How bad is it?
- Also important: how do you summarize (aggregate) the data to determine overall condition indices?



Severity Levels and Deduct Curves

- Most distress protocols in use today were inspired by ASTM D6433
- Measurements have been difficult to automate repeatably
- Distress protocols have not been designed around what can be measured
- Challenges:
  1. Too many distress types, overlapping definitions
  2. Distress types not amenable to mathematical/geometrical definition
  3. Metrics like crack length and area are too variable
  4. Binning of distresses into severities causes discontinuities in output data
- Repeatability of “PCI” is difficult to achieve:
  - Sometimes, big change in cracking data causes little change to PCI
  - Sometimes, little change in cracking data causes big change to PCI

Proposed Solutions

Problem	Solution
Too many distress types, overlapping definitions	Reduce number of distress types; essentials only
Distress types not amenable to mathematical/geometrical definition	Introduce quantitative definitions, such as rules by road zone
Metrics like crack length and area are too variable	**Switch to metrics that are less sensitive to small changes in the input data, like projected lengths and length of road affected**
Binning of distresses into severities causes discontinuities in output data	**Move to continuous severity measurement and eliminate multiple deduct curves**

HPMS Cracking is one example

Problem	How It is Addressed (on asphalt pavements)
Too many distress types, overlapping definitions	Only one distress type: cracking
Distress types not amenable to mathematical/geometrical definition	Clear definition: only consider wheelpath cracking
Metrics like crack length and area are too variable	Simple metric: % of wheelpath area with [fatigue] cracking
Binning of distresses into severities causes discontinuities in output data	No severity measurement

Test Runs

- 114th Avenue: 2 runs collected 3 days apart (Feb 5 & 8, 2019)
- Staley Rd: 3 runs collected within 1 hour (Mar 11, 2019)

- System: ICC road survey van with LCMS-2 sensor

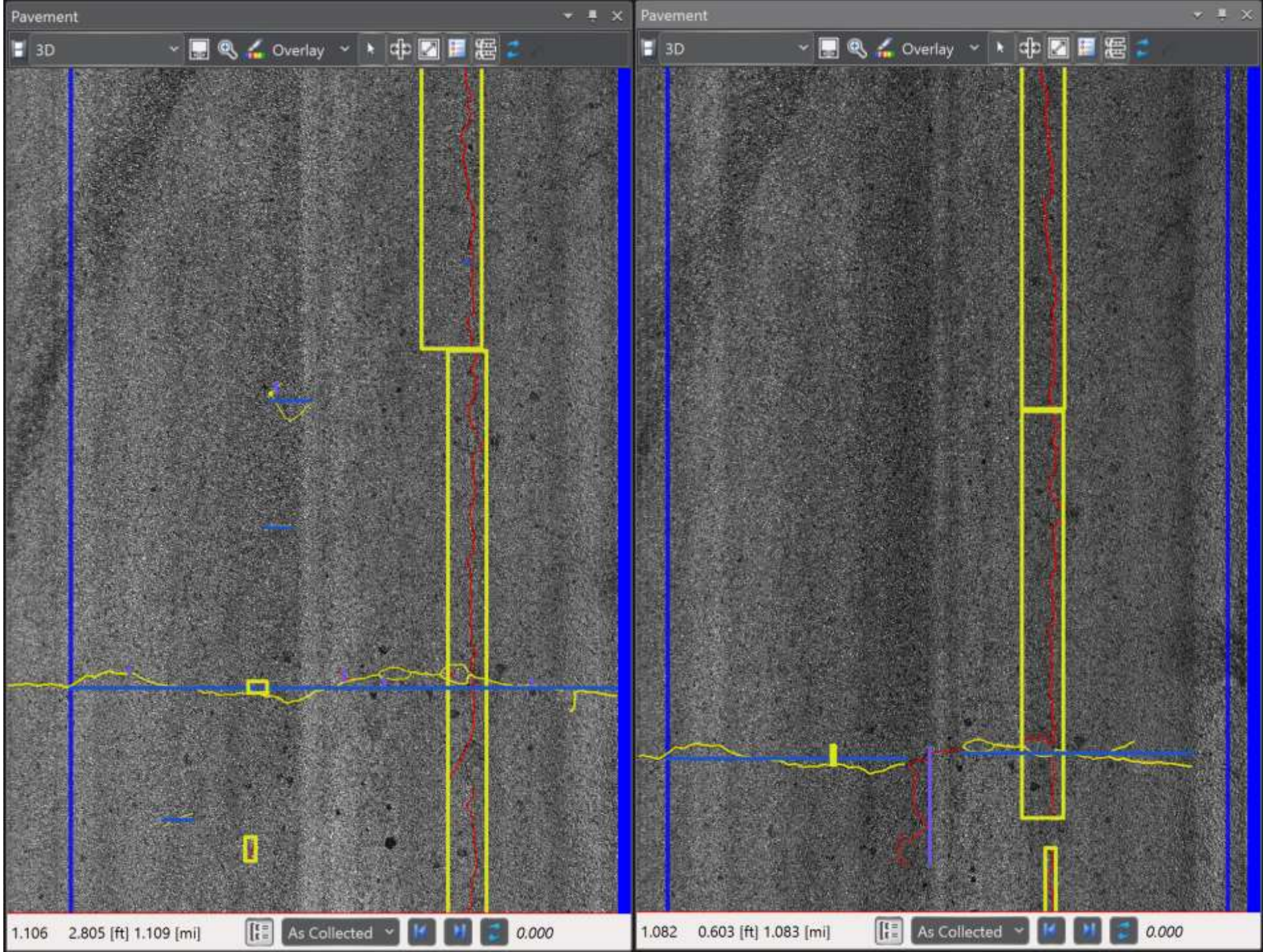
Test Runs

114th Avenue

Staley Road

Linear Cracking

Projected lengths are more repeatable than crack lengths.



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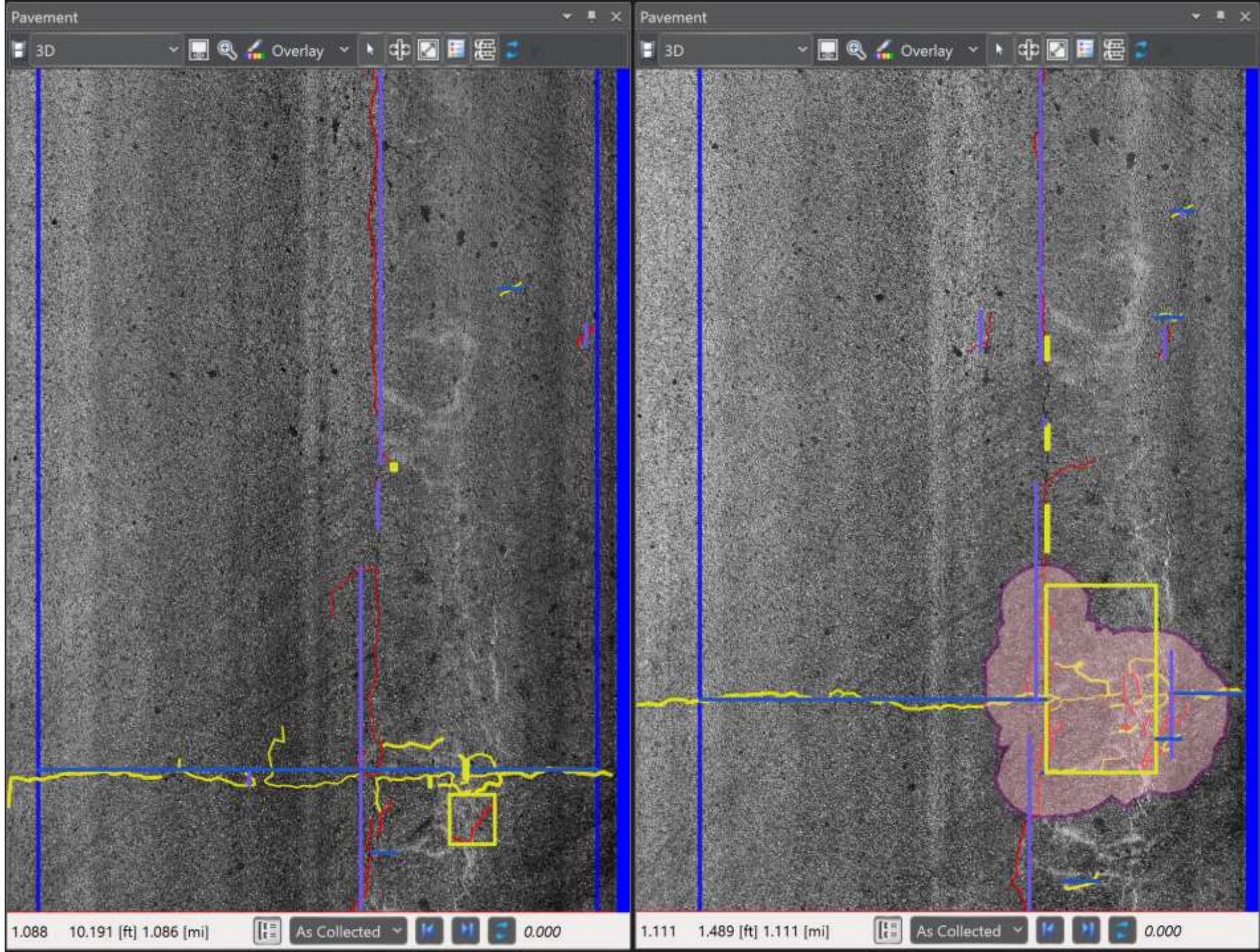
Linear Cracking

Pattern detection can introduce variability.

Use road zones to limit what you are looking for.



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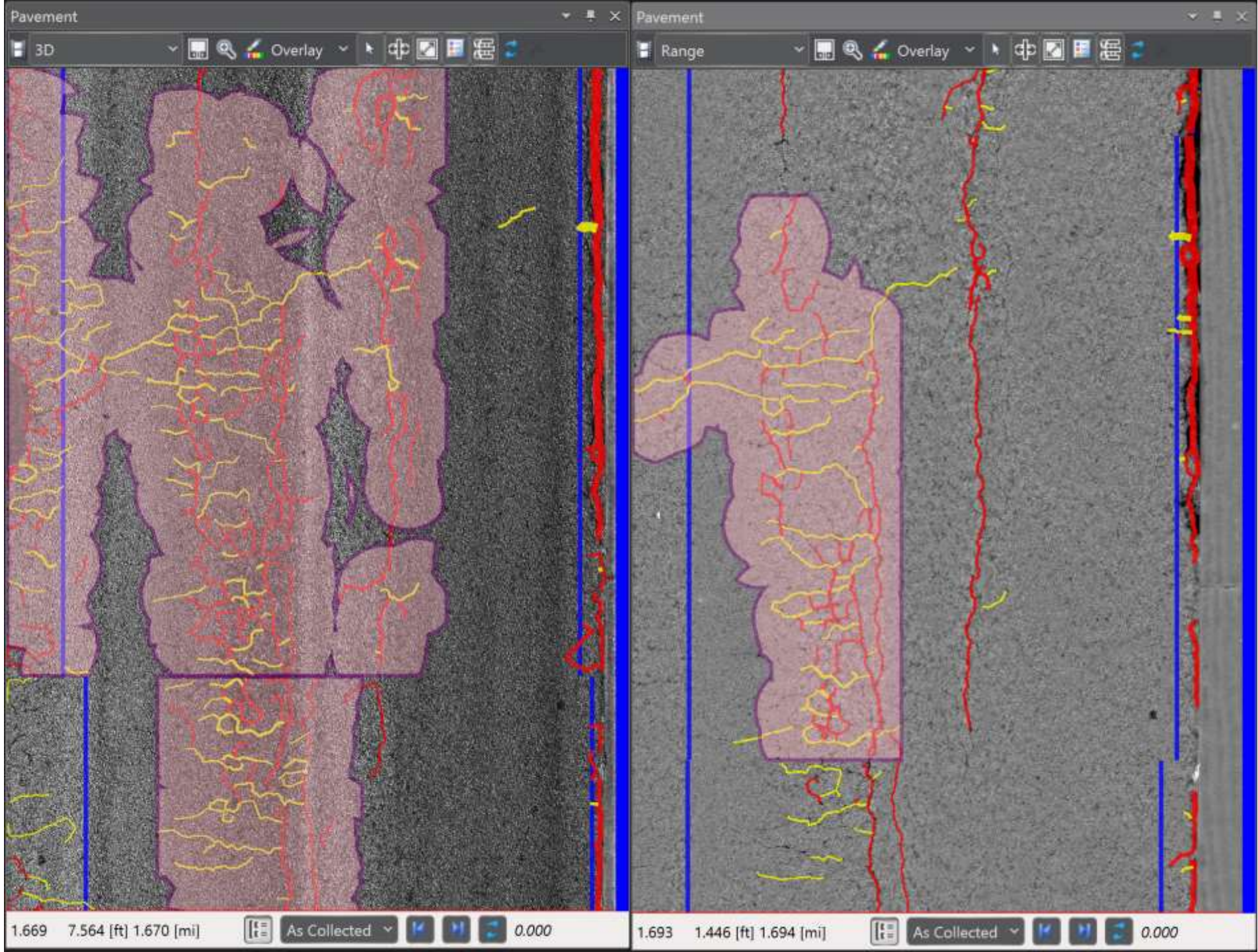
Alligator Cracking

Pattern detection is affected by missing portions of crack.

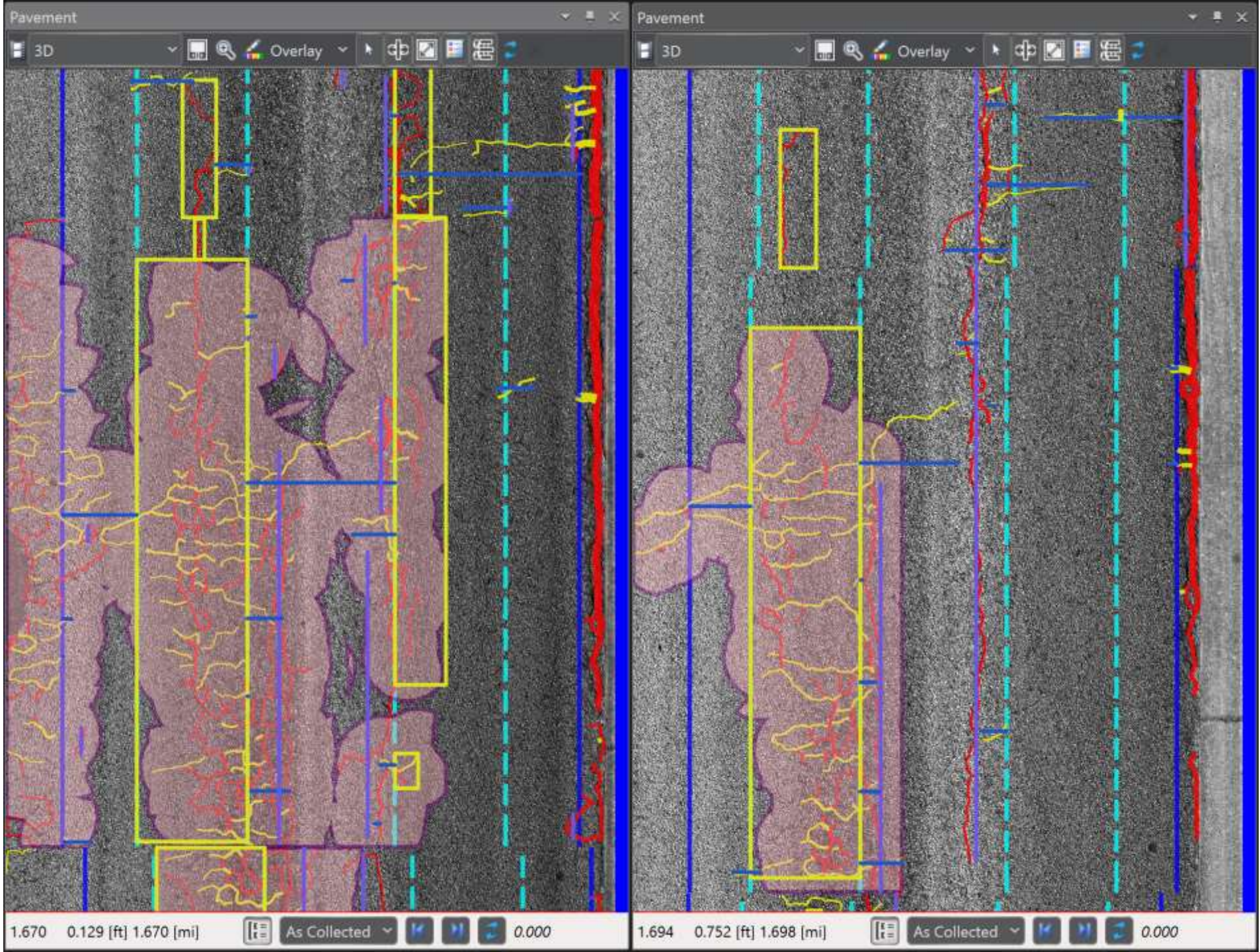
Note: RH image shows range data.



Alligator Cracking

Projected length or length of road affected metrics will be more repeatable.

Run	1	2
Avg crack width (mm)	7.50	8.46



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Common practice: 3 severity curves

EXAMPLE

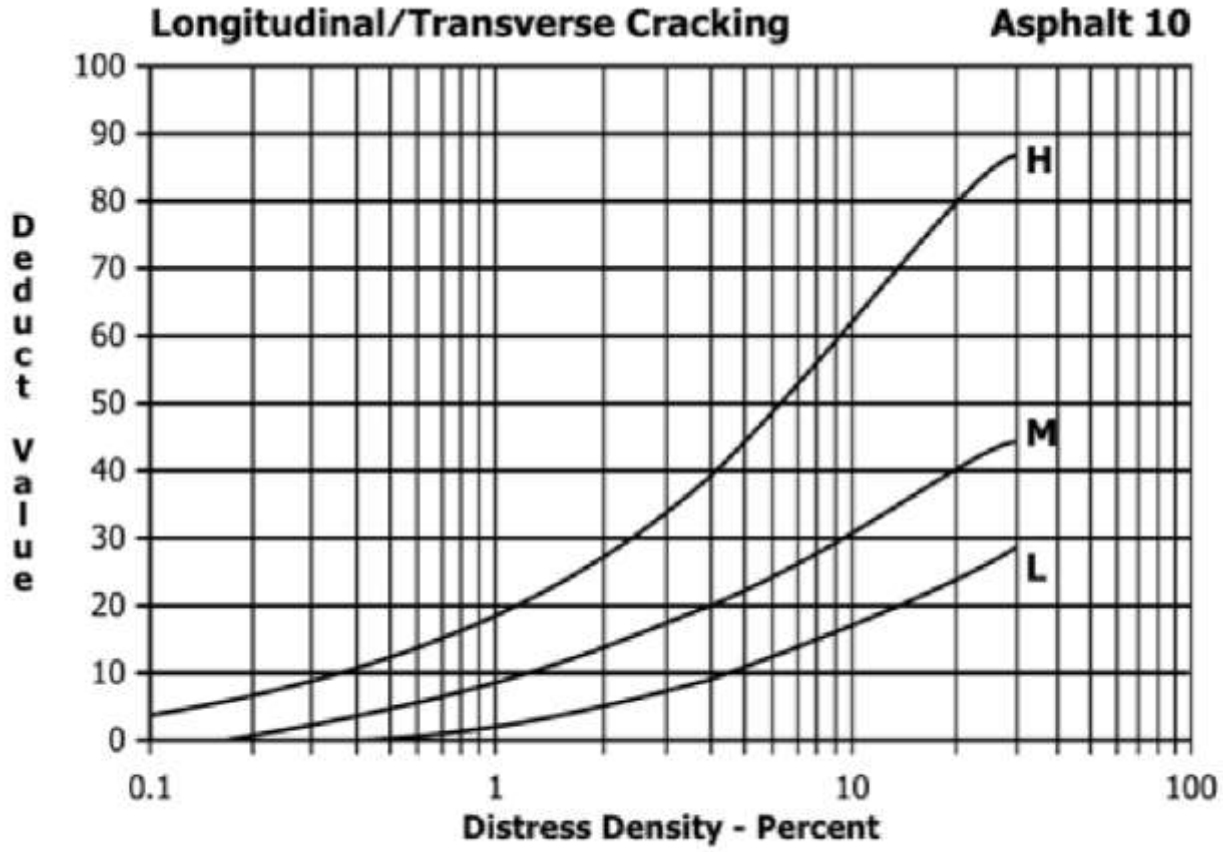

FIG. X3.14 Longitudinal/Transverse Cracking

Severity	Non-filled Crack Width*
Low	< 10mm
Moderate	10-75 mm
High	> 75mm

*ASTM D6433. Severity definition also considers surrounding cracking and whether crack is filled or unfilled.

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Case 1: Distribution of crack widths within bins

Consider two different roads with different distributions of long/trans cracking.

	Average Crack Width (mm)			Distress Extent		ASTM Deduct Value		
Case	**Avg**	**Low**	**Moderate**	**Low**	**Moderate**	**Low**	**Moderate**	**Total**
1A	10.0	9.9	10.1	4.0	4.0	8.6	18.9	**27.6**
1B	6.7	3.3	10.1	4.0	4.0	8.6	18.9	**27.6**

Big change in input causes no change in deducts

Case 2: Slight variance in crack width measurement

Consider the same road section collected twice.

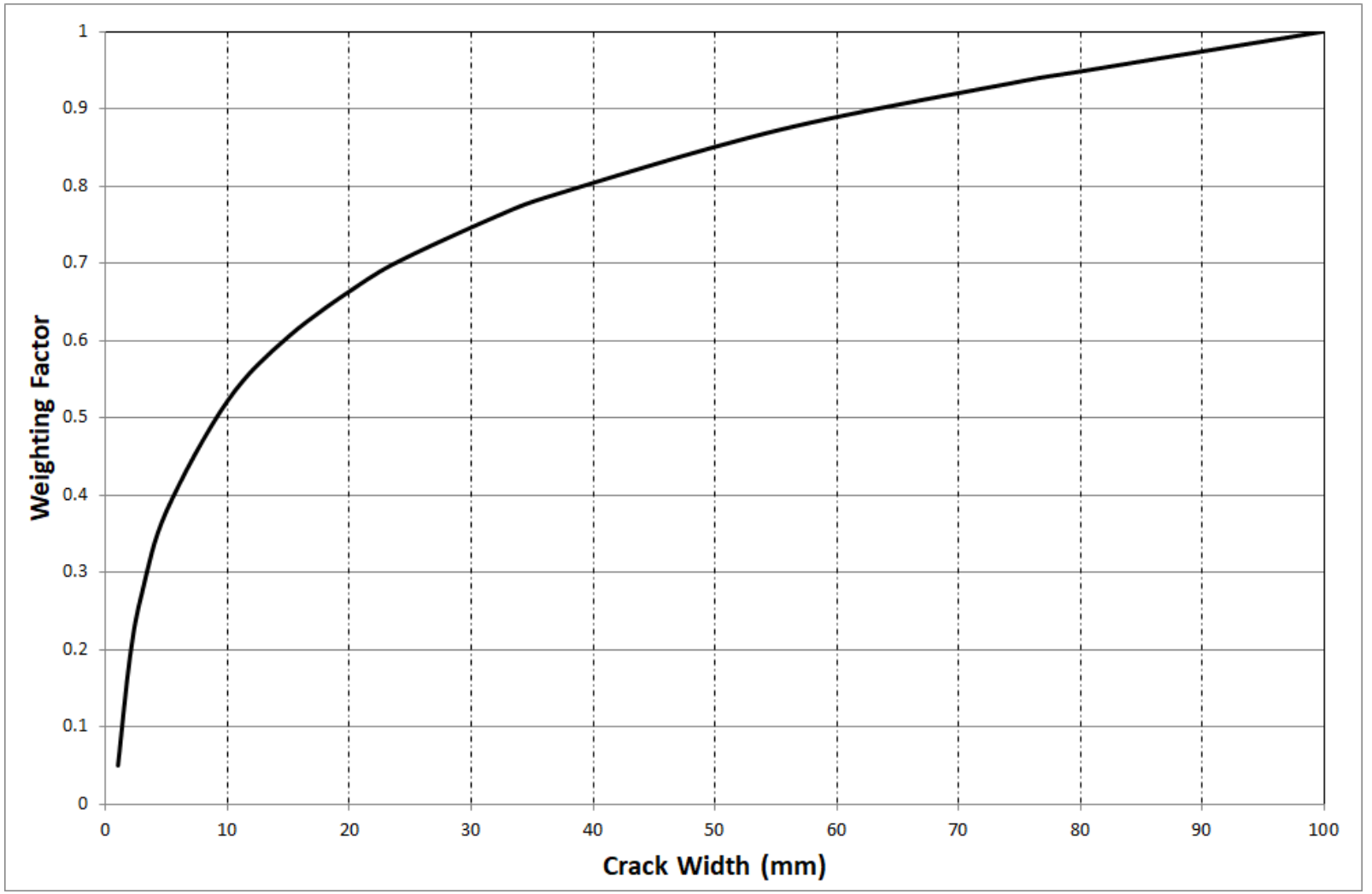
	Average Crack Width (mm)			Distress Extent		ASTM Deduct Value		
Case	**Avg**	**Low**	**Moderate**	**Low**	**Moderate**	**Low**	**Moderate**	**Total**
2A	9.9	9.9	10.1	10.0	3.0	17.8	15.5	**33.2**
2B	9.9	9.9	10.1	13.0	0.0	21.0	2.6	**23.5**

Small change in input causes big change in deduct

Proposal

- Eliminate discrete severity levels for distresses
  - Instead, adopt continuous severity measurement to match real-life distress propagation pattern
- Weight distress extent by the severity of each distress in the sample
- Calculate overall extent by summing weighted extents in the sample
- Use a single deduct curve (with formula) to determine deduct value for each distress type in the sample
- Proceed with deduct adjustment and section PCI calculation from sample(s)/lane(s) as usual

Continuous Severity (Proposed)



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One Deduct Curve (Proposed)

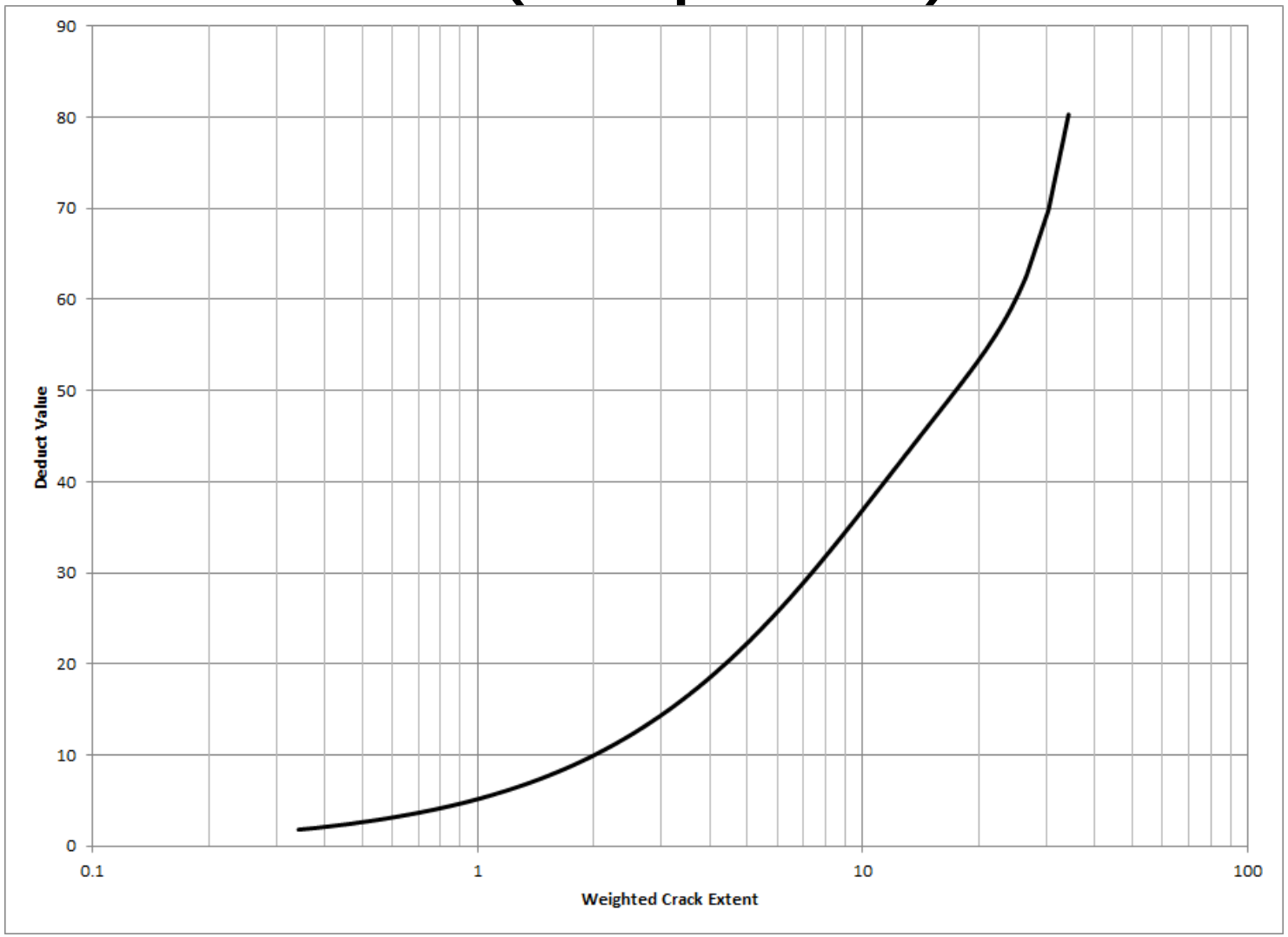
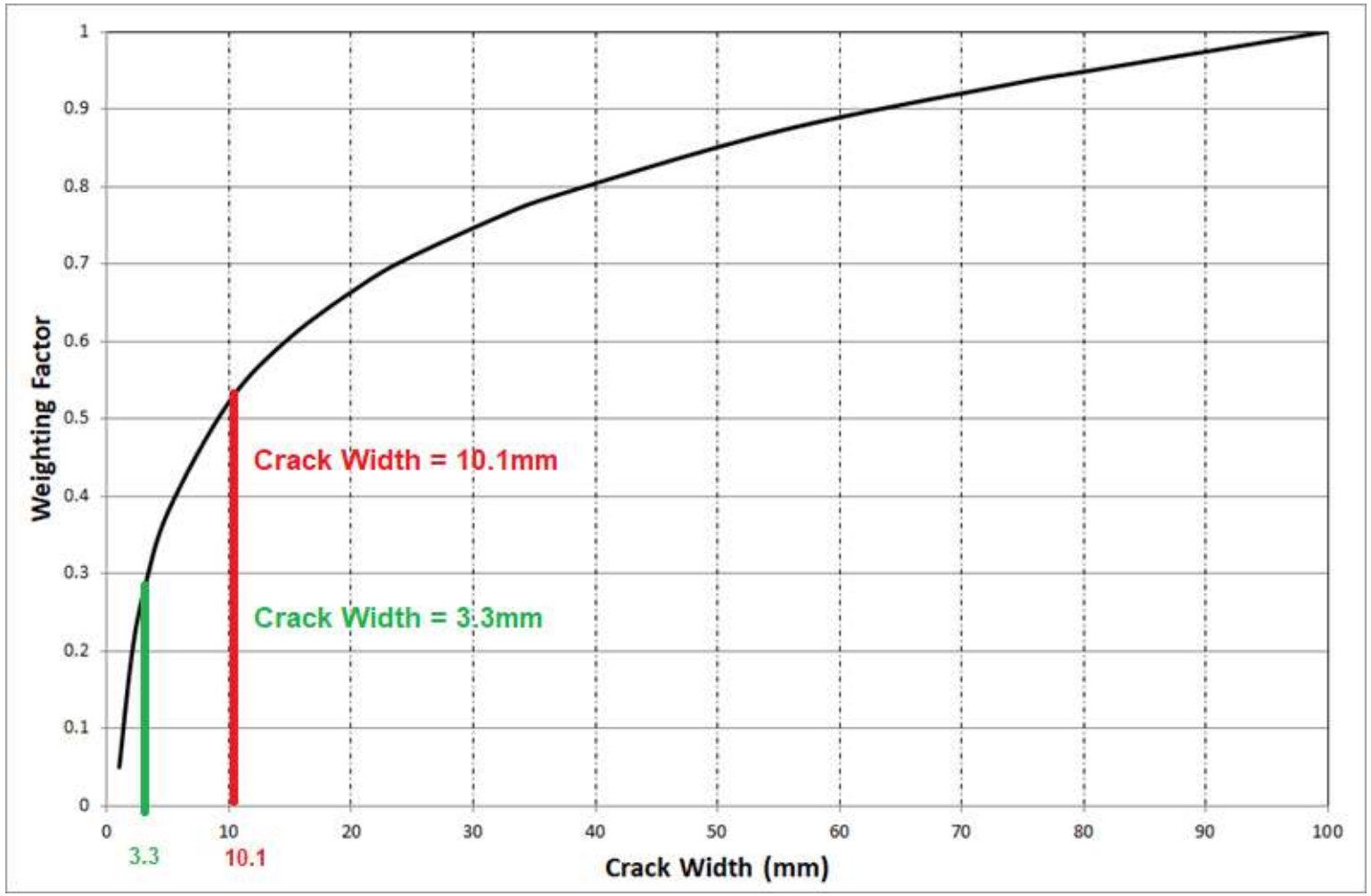


Illustration with Cases 1 & 2

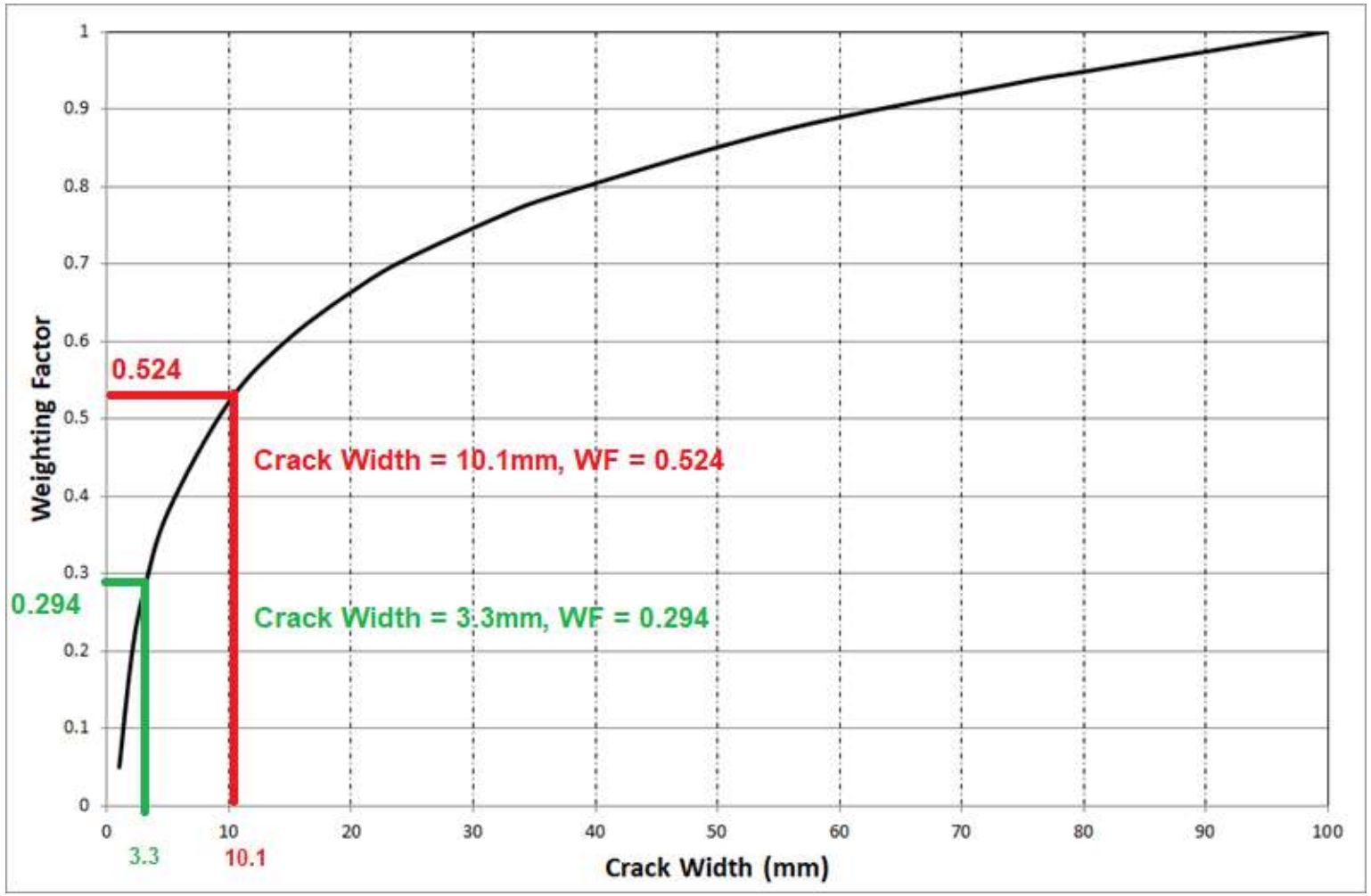
	Average Crack Width (mm)			Distress Extent		ASTM Deduct Value			Proposed Method	
Case	Avg	Low	Moderate	Low	Moderate	Low	Moderate	Total	W. Crack Extent	W. Deduct
1A	10.0	9.9	10.1	4.0	4.0	8.6	18.9	**27.6**	**4.2**	**19.20**
1B	6.7	3.3	10.1	4.0	4.0	8.6	18.9	**27.6**	**3.3**	**15.57**
2A	9.9	9.9	10.1	10.0	3.0	17.8	15.5	**33.2**	**6.8**	**28.22**
2B	9.9	9.9	10.1	13.0	0.0	21.0	2.6	**23.5**	**6.8**	**28.19**

The deducts now match what we expect

Worked Example – Case 1B



Worked Example – Case 1B



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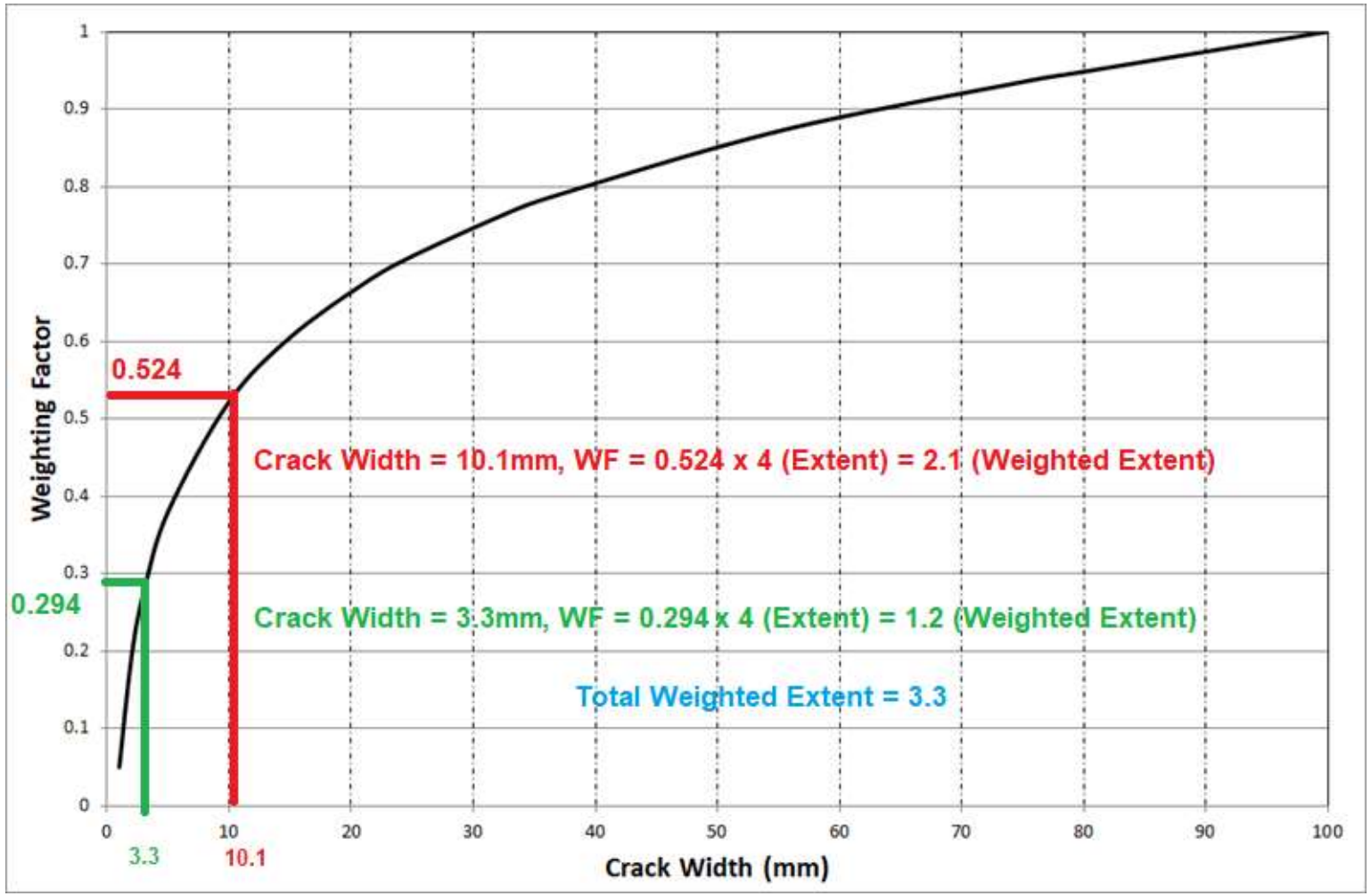
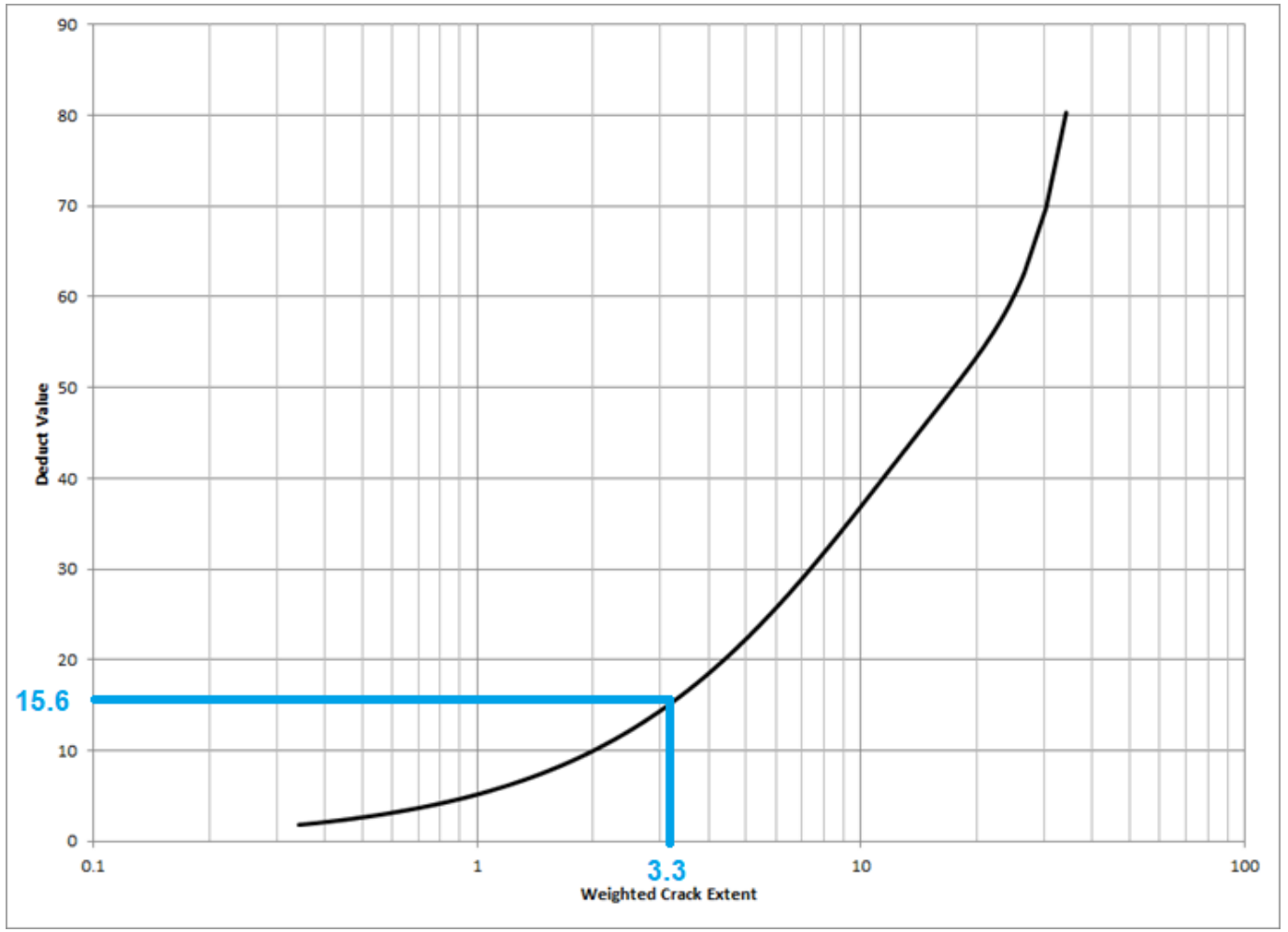
Worked Example – Case 1B

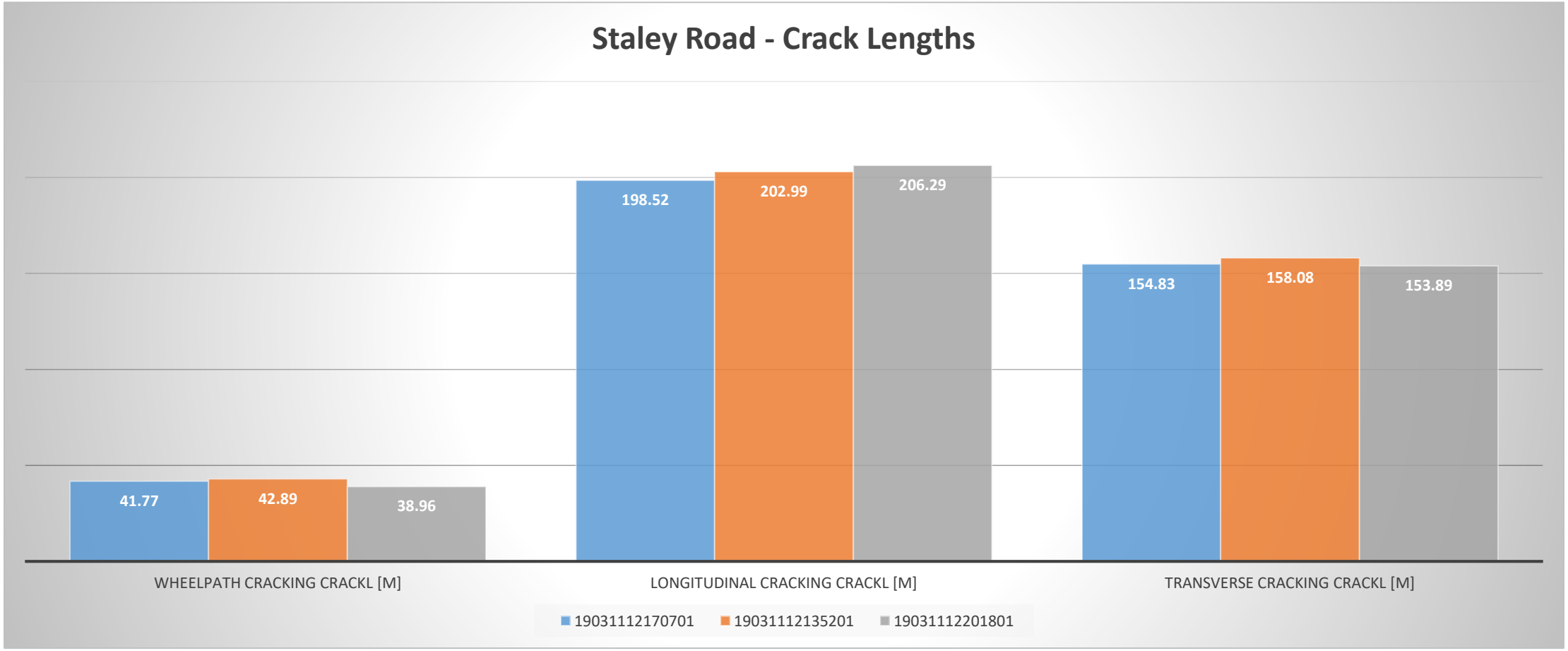


Worked Example – Case 1B



Test Results

Good



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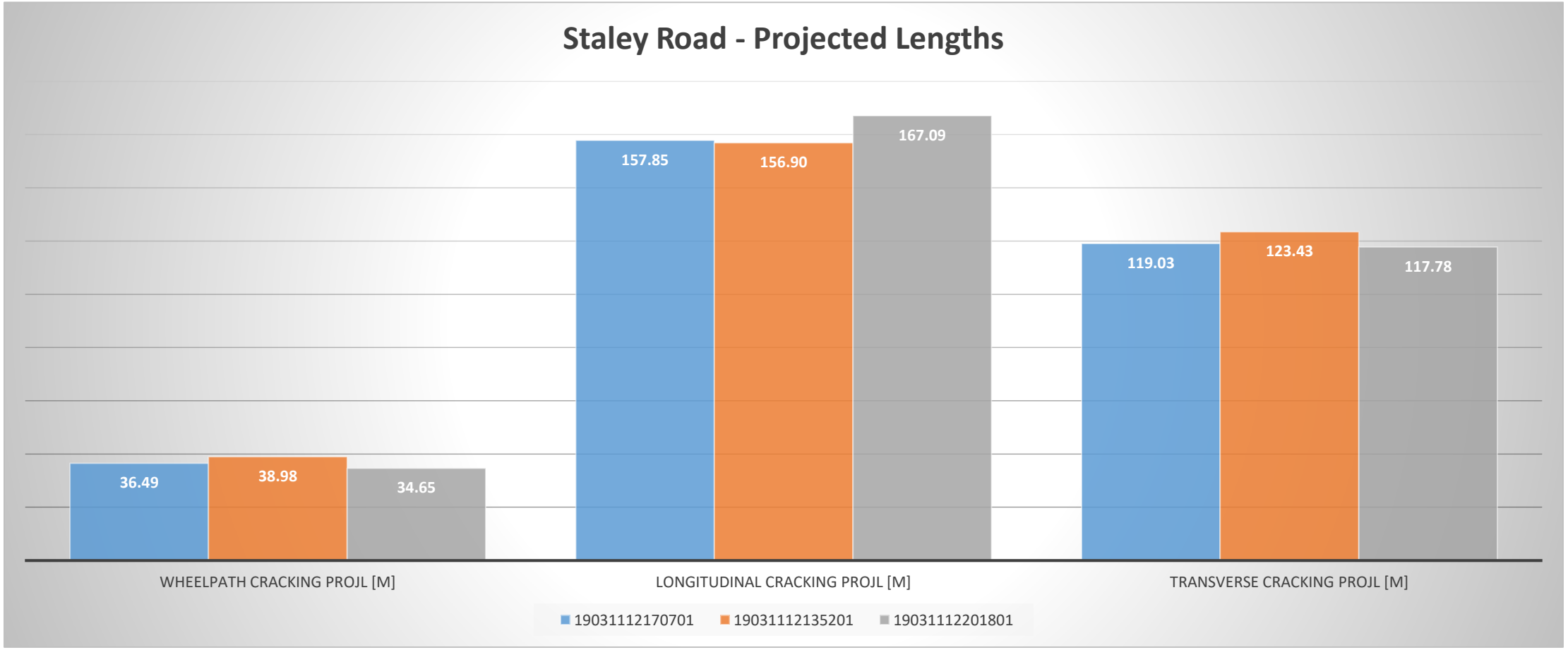
Test Results

Good (little change)



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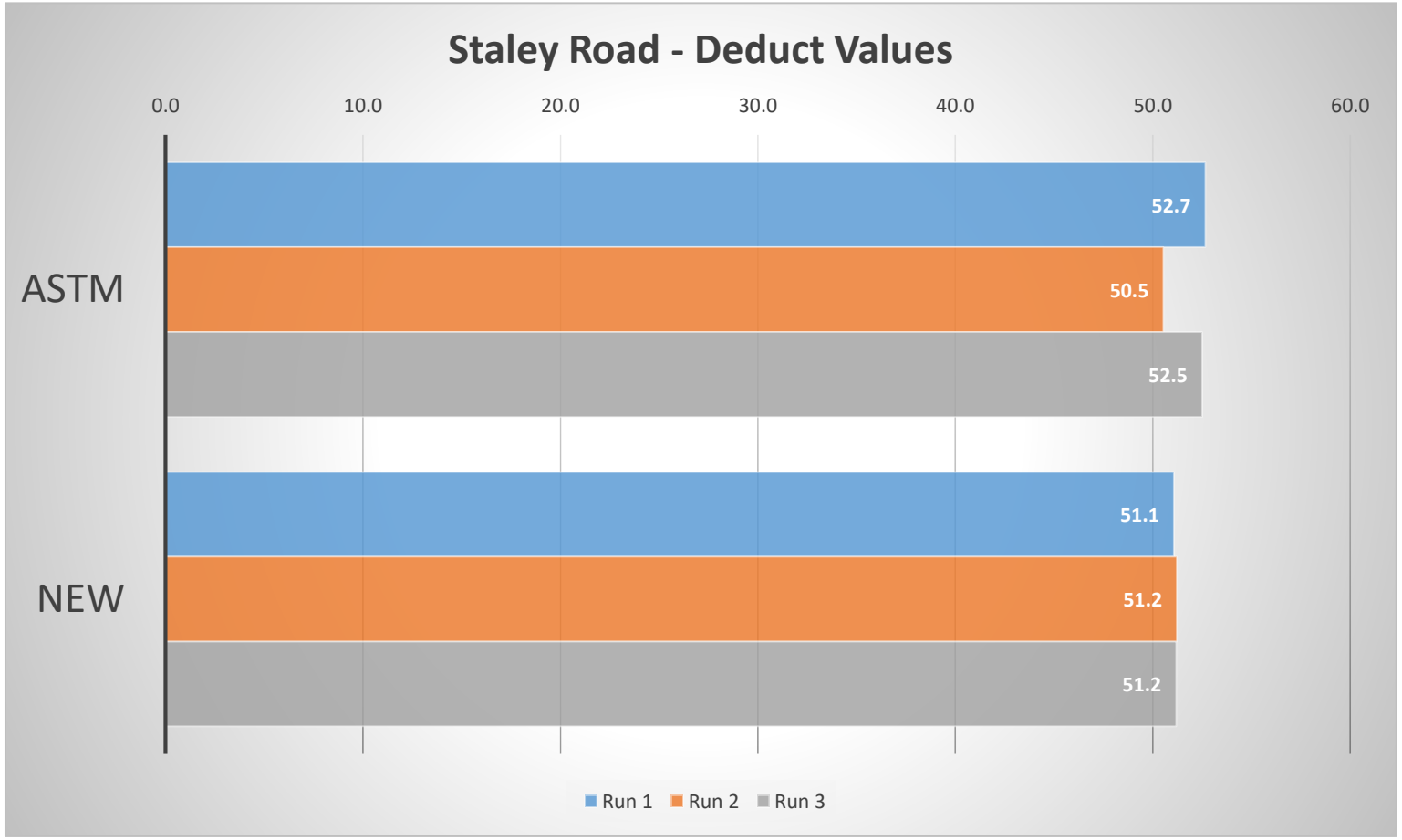
Test Results



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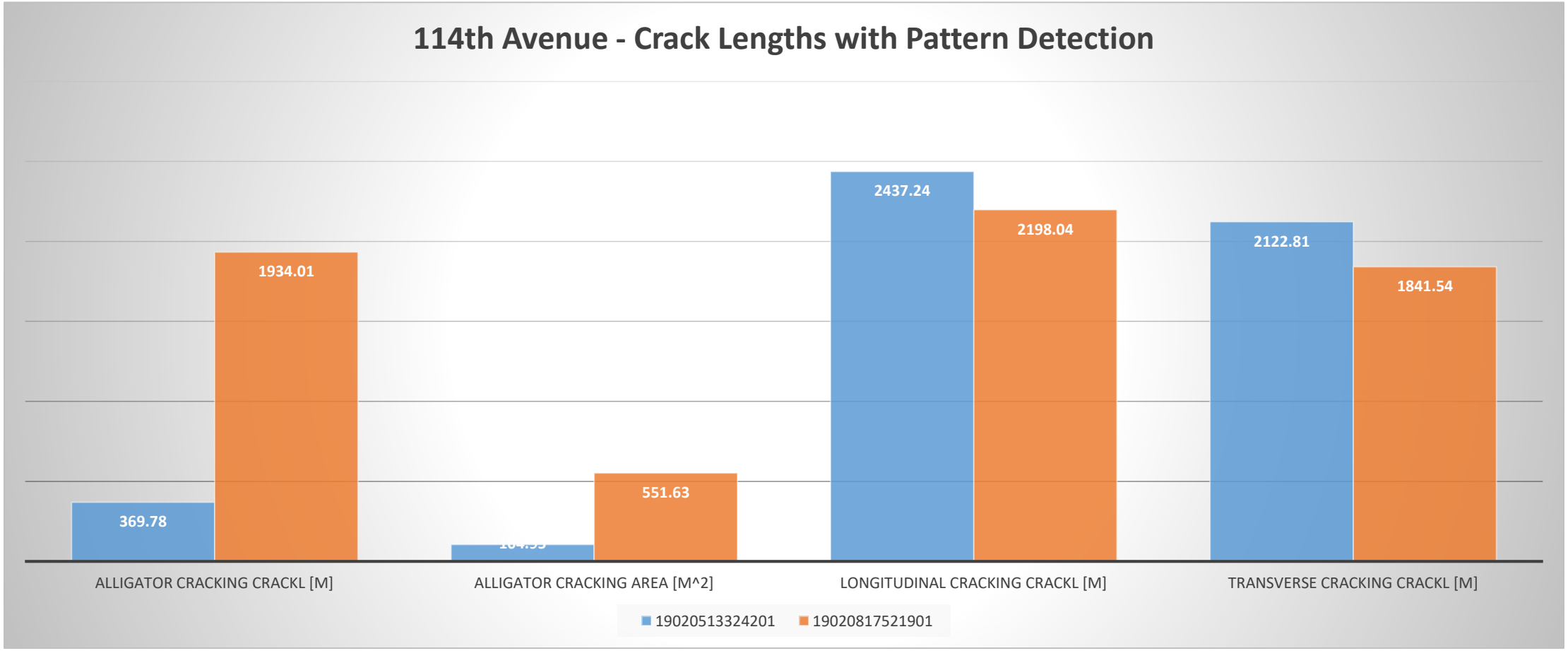
Test Results

Bad



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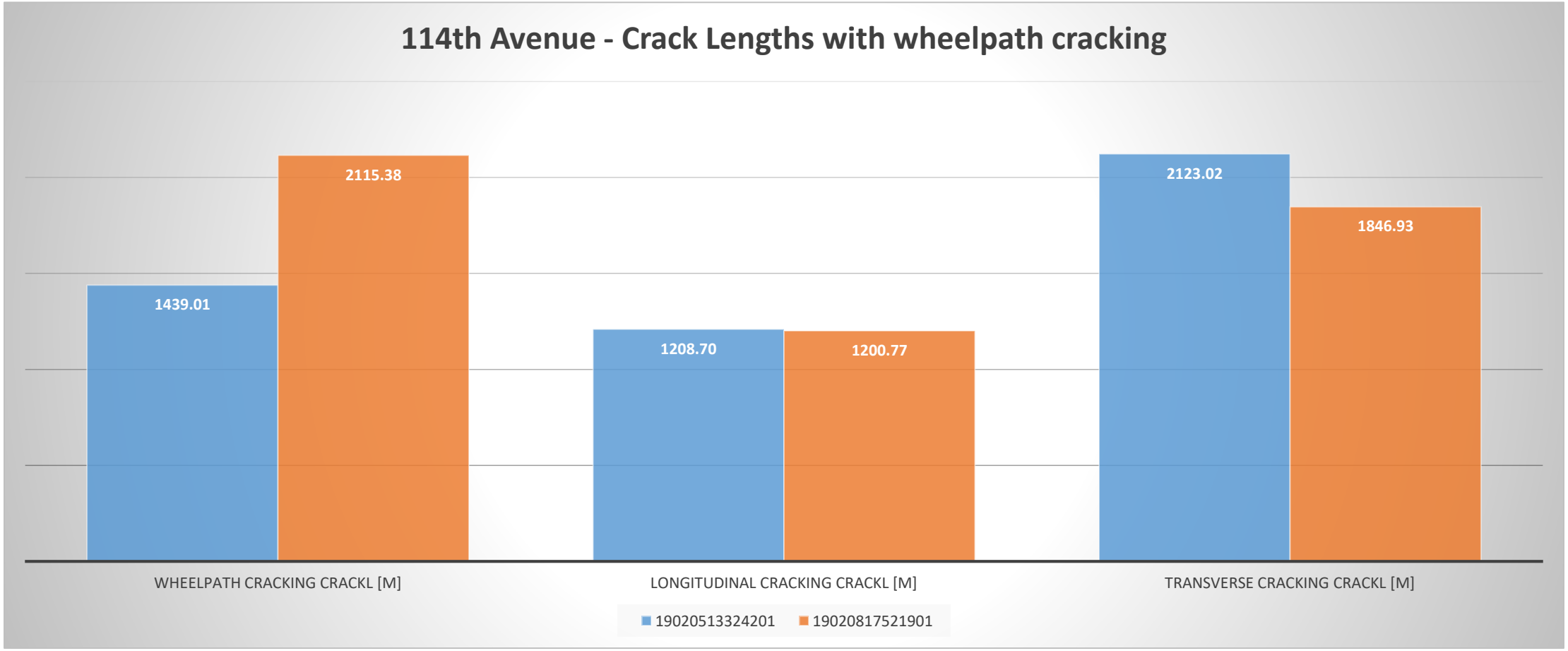
Test Results

Better



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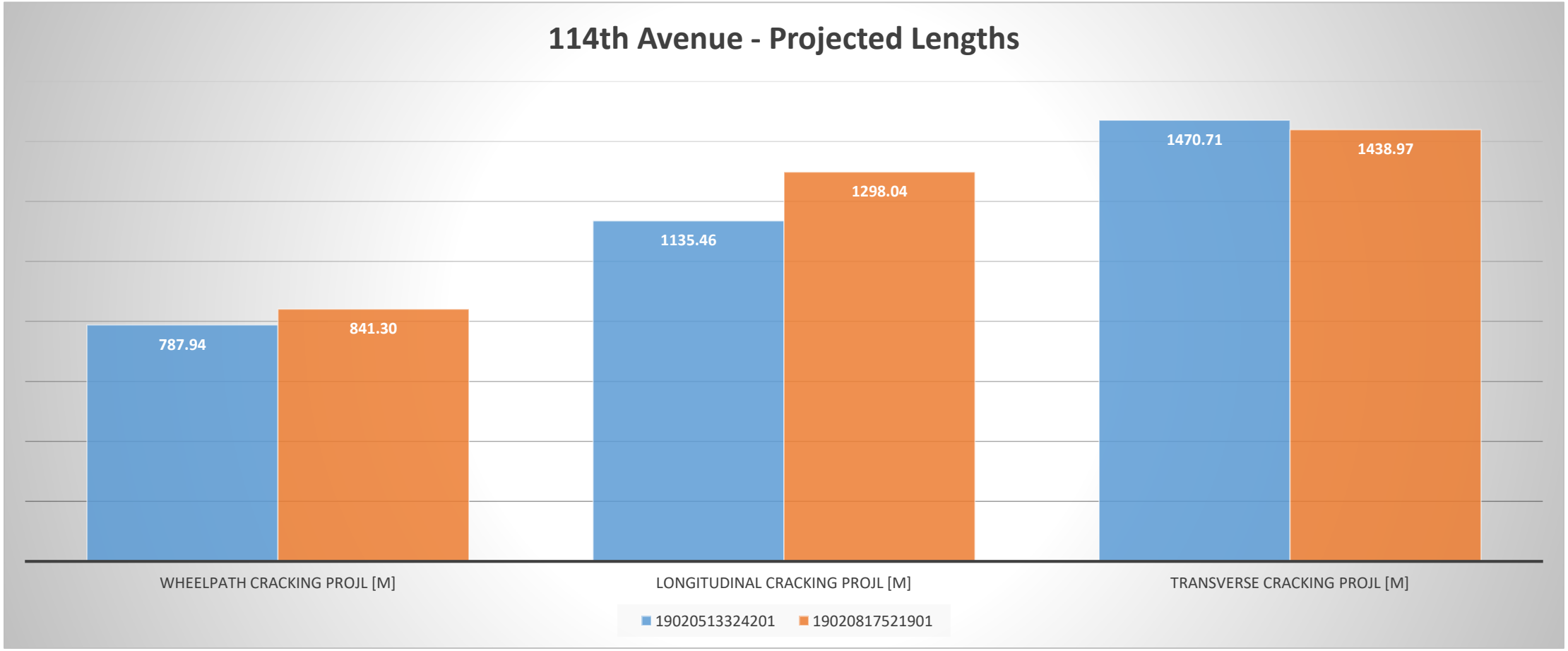
Test Results

Best



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Conclusions

- To improve repeatability of distress condition measurement:
  - Keep your existing sensor! (Maybe.)
  - Switch to metrics that are less sensitive to small changes in the input data, like projected lengths and length of road affected
  - Move to continuous severity measurement and eliminate multiple deduct curves

- Thank you!
- Michael Nieminen, mnieminen@internationalcybernetics.com