3D Sidewalk inspection

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Vision Systems for the Automated Inspection of Transporation Infrastructures

Sidewalk Market

- New York City has 12,750 miles of sidewalks compared to 6,000 line miles of roads. They replace 2 million sq feet of sidewalk annually
  - http://www.nyc.gov/html/dot/html/infrastructure/sidewalkintro.shtml
  - http://www.nyc.gov/html/dot/downloads/pdf/2013-dot-sustainable-streets-5-infrastructure.pdf
- Seattle has 2,200 miles of sidewalks and 3,952 miles of road
  - https://www.seattle.gov/Documents/Departments/SDOT/MaintenanceProgram/PavementManagementSeattlePavementTypesCondition.pdf
  - http://sdotblog.seattle.gov/2014/06/24/seattle-has-how-many-miles-of-sidewalk/
- Los Angeles has 10,750 miles of sidewalks, compared to 6,500 centerline miles of road
  - https://la.curbed.com/2016/12/1/13813474/sidewalk-crack-broken-los-angeles-fix-repair
  - http://bss.lacity.org/state_streets/stateofthestreets.htm

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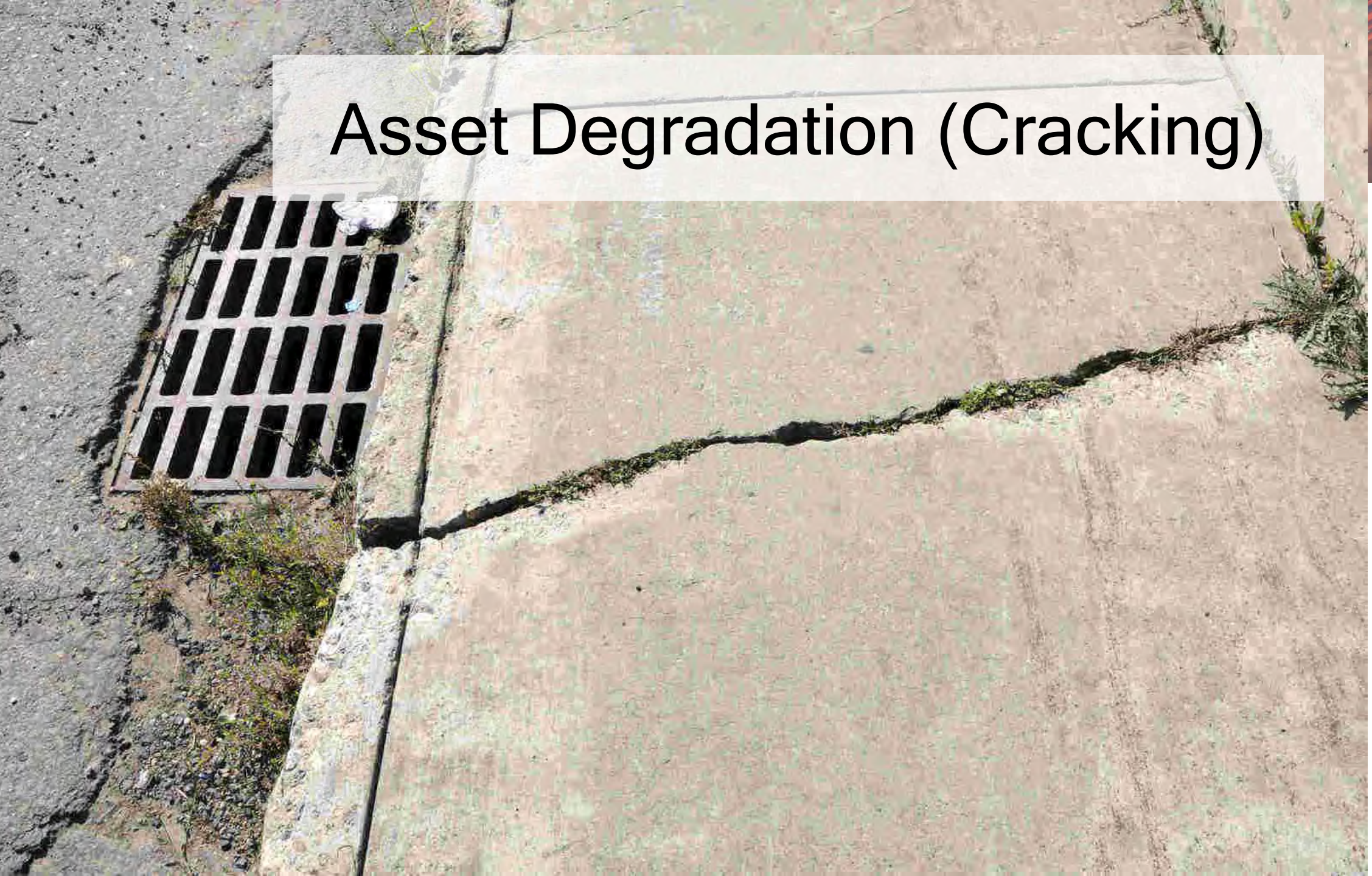
Key Sidewalk Issues

- Problems to Address:
  - Asset Condition Measurement for Maintenance Planning
  - Trip and Fall Hazards
  - Poor Accessibility

Measurement Requirements

- Length and Width of Sidewalk
- Type (Concrete, Asphalt, Interlocking Brick)
- Cracking and spalling
- Faulting (positive and negative)
- Cross-fall, slope
- Change in surface texture
- Raised features (sewer drain plugs, covers, etc.)
- Drop-off at side/edge

Asset Degradation (Cracking)



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Sidewalk Asset Degradation

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Asset Degradation (Holes/Chips)

Trip and Fall (Faulting)

Trip and Fall (Raised Valves)

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Trip and Fall (Edge Drop Off)

Sidewalk Asset Degradation (Holes)

Asset Degradation (Pop-outs, Raveling)

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Sidewalk Market

- Legal Requirement: In some States and Provinces municipalities are required by law to inspect sidewalks. For example, in Ontario, municipalities are required to inspect sidewalks every year and fix any vertical bump over 2cm.

- However, even if a municipality does not have a legal requirement to perform an inspection on some frequency; they are all exposed to legal risk if someone has an accident:

  - 2014 case in NYC where a woman was awarded $2.25 million after a fall on defective sidewalk. This was just part of a total of $60 million dollars the city spent over a 22 month period for sidewalk related claims (885 payments in total). https://nypost.com/2014/11/30/nyc-forks-over-706m-in-under-2-years-to-settle-legal-claims/
  - 2015 court case in Hamilton, ON awarded an 89 year old woman $192,000 after tripping on a 23.8mm bump in the sidewalk. City had failed to inspect that portion of the sidewalk.
  - Sidewalk lawsuits 2001-2010: Kitchener–221 trip and fall claims. Total payout $2.05 million.

Effect of lawsuits…on sidewalk conditions

Effect of lawsuits…on sidewalk conditions

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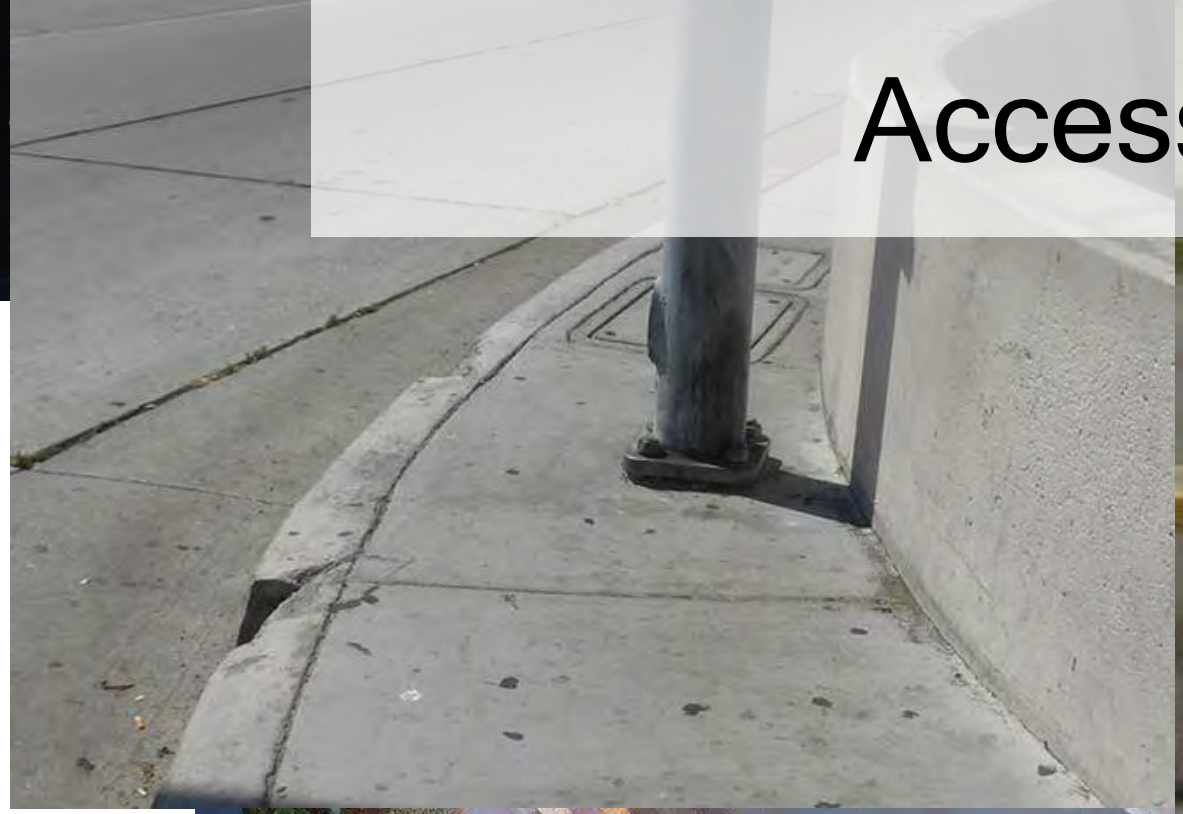
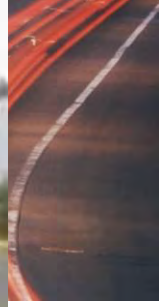
Accessability

Accessibility





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Accessibility

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Project description

- 9 sites were scanned as a first test for la Ville de Québec
  - Boul. René-Lévesque Est
  - Rue de Claire-Fontaine
  - Rue Saint-Jean
  - Rue Arago Ouest
  - Rue de Jumonville
  - Rue Saint-Joseph
  - Rue Boisclerc
  - Ave. Saint-Sacrement
  - Boul. de l'Entente
- Total length: 1386 mètres

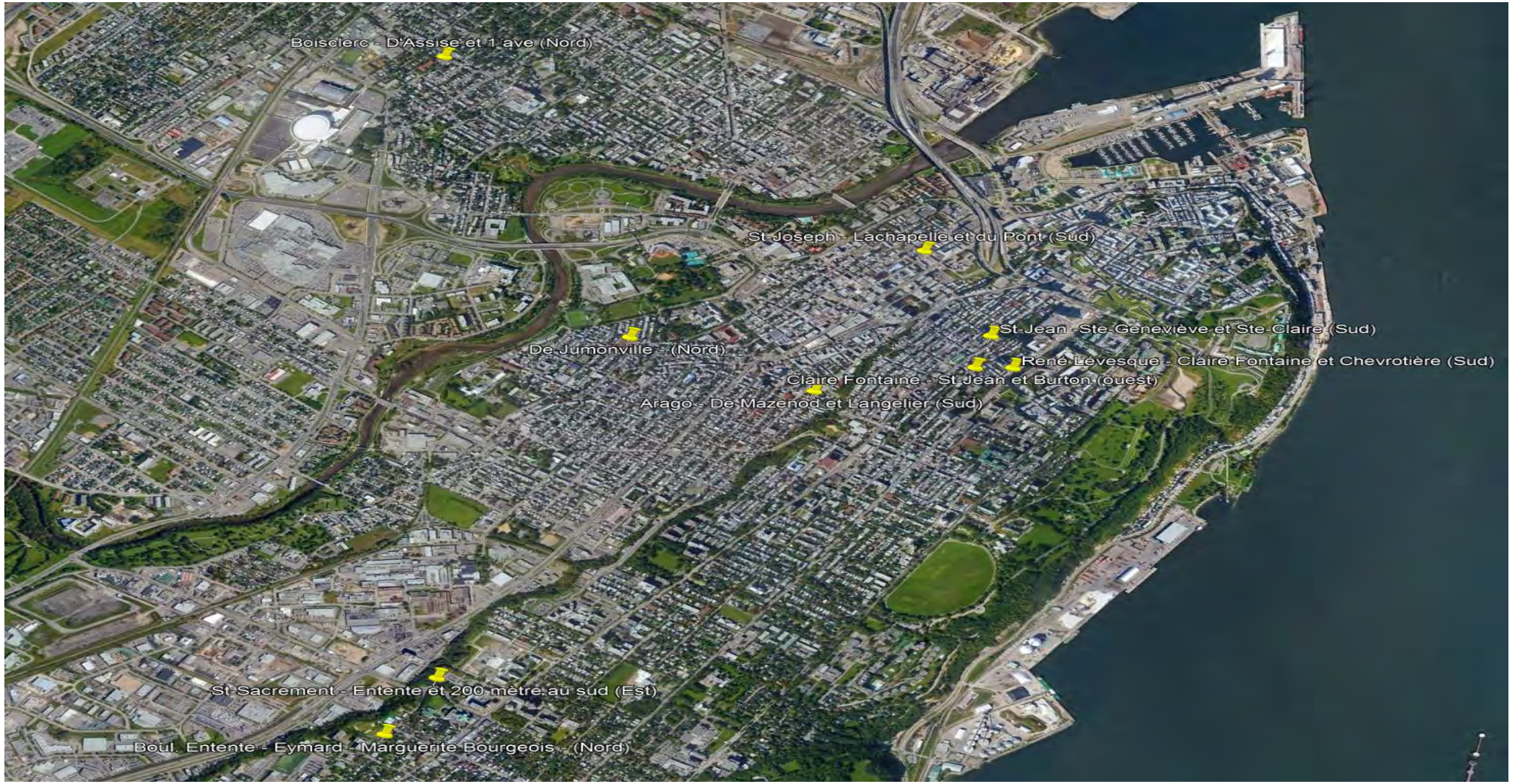
Description du projet

- Diverse types of surfaces
  - Concrete sidewalks
  - With or without curbs
  - Interblock sidewalks
  - Different widths
  - Presence of obstacles
  - Etc.

Defect list – Quebec city requirements

					Niveau de sévérité			
Type de défauts	**Code**	**units**	**type**	**What to measure**	**Low**	**Medium**	**High**	Urgent
Cracking	FISS	m	Longueur	Opening crack (mm)	0 à 5	> 5 à 15	>15	Dangerous
Fractured slabs	BF	m^2	Surface	Opening crack (mm)	0 à 5	> 5 à 15	>15	Dangerous
Pop outs	ECA	m^2	Surface	Depth (mm)	0 à 10	> 10 à 25	>25	Dangerous
Ravelleing	ARR	m^2	Surface	Depth (mm)	0 à 10	> 10 à 25	>25	Dangerous
Faulting	DV	m	Longueur	Height (mm)	0 à 10	> 10 à 25	>25	Dangerous
Spalling	EP	m	Longueur	Width (mm)	0 à 25	> 25 à 50	>50	Dangerous
Opening joint trans.	OJTT	m	Longueur	Opening (mm)	5 à 15	> 15 à 30	>30	Dangerous
Opening joint long.	OJL	m	Longueur	Opening (mm)	5 à 15	> 15 à 30	>30	Dangerous
Inversed x-slope	PEN	m	Longueur	%	0%	> 0 à 1 %	> 1%	Dangerous
Repairs	RP	m^2	Surface	Image	Good	Cracked	Degraded	Dangerous
Inserts	IGRA	m	Longueur	Image	Good	Open joints	missing	Dangerous
Spalling edge	EPB	m	Longueur	Width (mm)	0 à 25	> 25 à 50	>50	Dangereux
Granit curb cant	DEC	m	Longueur	Angle degrees	0 à 15°	> 15 à 30°	>30°	Dangerous
Opening joint trans. curb	OJTB	m	Longueur	Opening (mm)	5 à 15	> 15 à 30	>30	Dangerous
Opening joint long. curb	OJLB	m	Longueur	Opening (mm)	5 à 15	> 15 à 30	>30	Dangerous

The sites


Boisclerc - D'Assise et 1 ave (Nord)
St-Joseph - Lachapelle et du Pont (Sud)
St-Jean - Ste-Geneviève et Ste-Claire (Sud)
De Jumonville - (Nord)
René Lévesque - Claire-Fontaine et Chevrotière (Sud)
Claire Fontaine - St-Jean et Burton (ouest)
Arago - De Mazenod et Langelier (Sud)
St-Sacrement - Entente et 200 mètre au sud (Est)
Boul. Entente - Eymard - Marguerite Bourgeois - (Nord)

LCMS – Sidewalks, bike paths

Prototype vehicle tests for
the
Ville de Québec

Components

1. LCMS-2

- 2 3D laser sensors
- Optical encoder(DMI)
- Résolution: 1 x 1 mm
- Vertical accuracy: 0.25 mm

2. Applanix POS-LV 420

- accéléromètres / gyroscopes (IMU)
- GNSS (2 antennes/récepteurs)

Vehicle Calibration

1. Scan of validation object
2. Stop and Go and figure 8 type scans
3. Encoder calibration
4. Physical distance measurements (IMUs, sensors, encoder, wheel axels)

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System calibration

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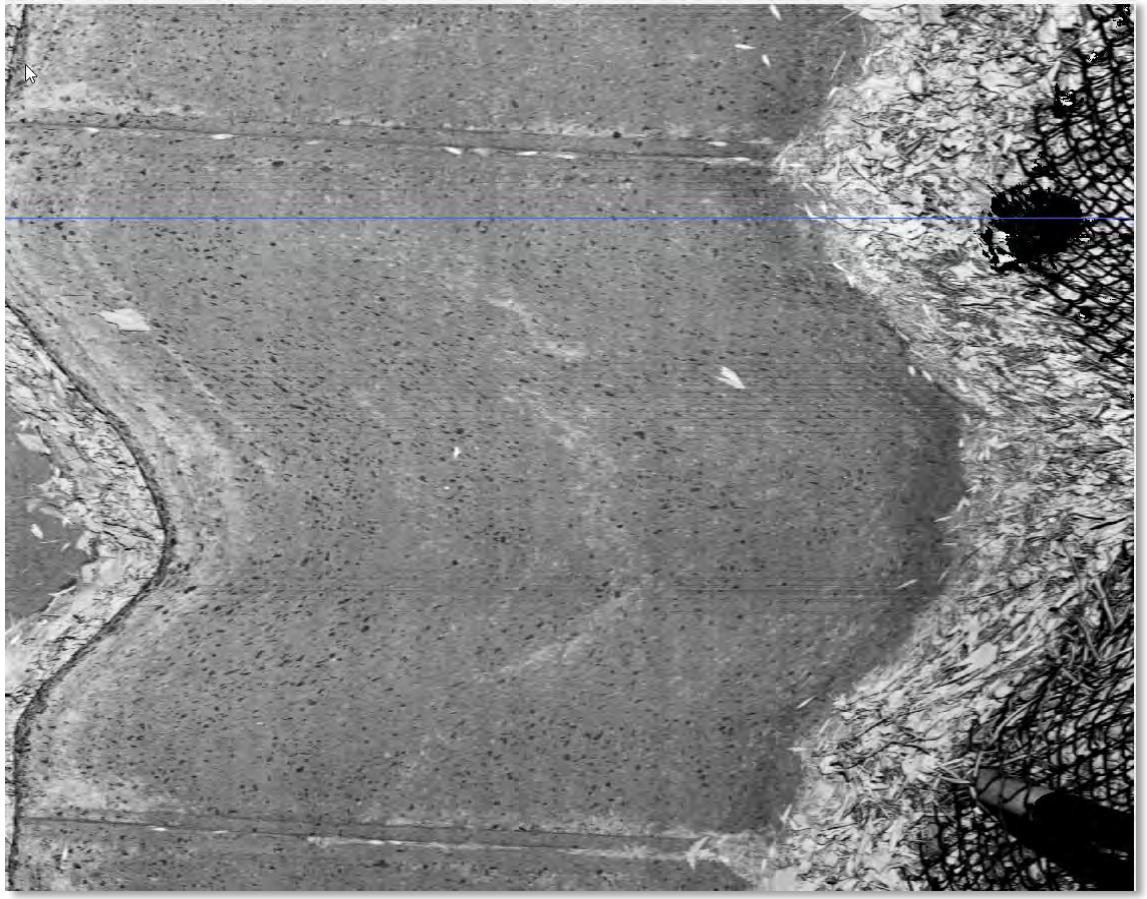
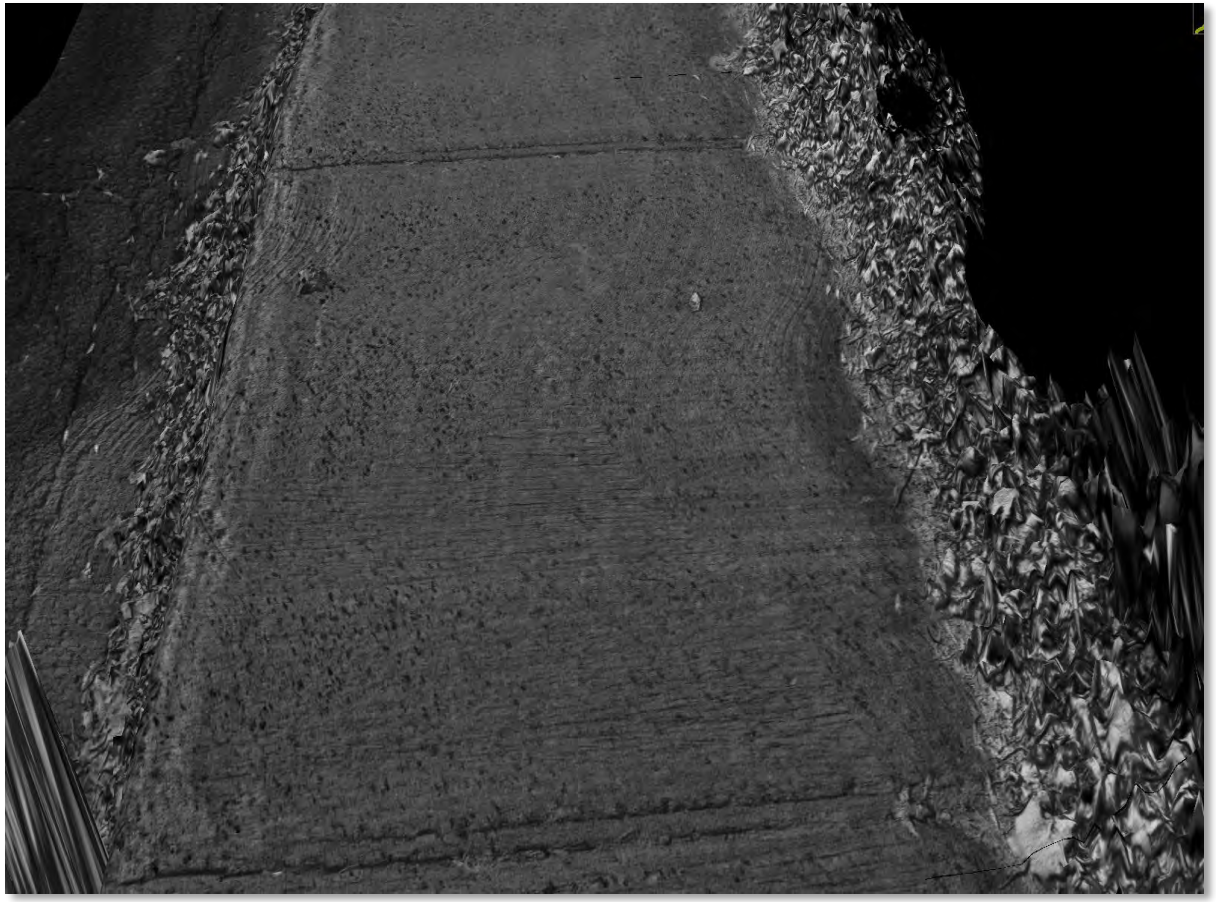
Motion compensation (X,Y,Z)



Without motion compensation



With motion compensation

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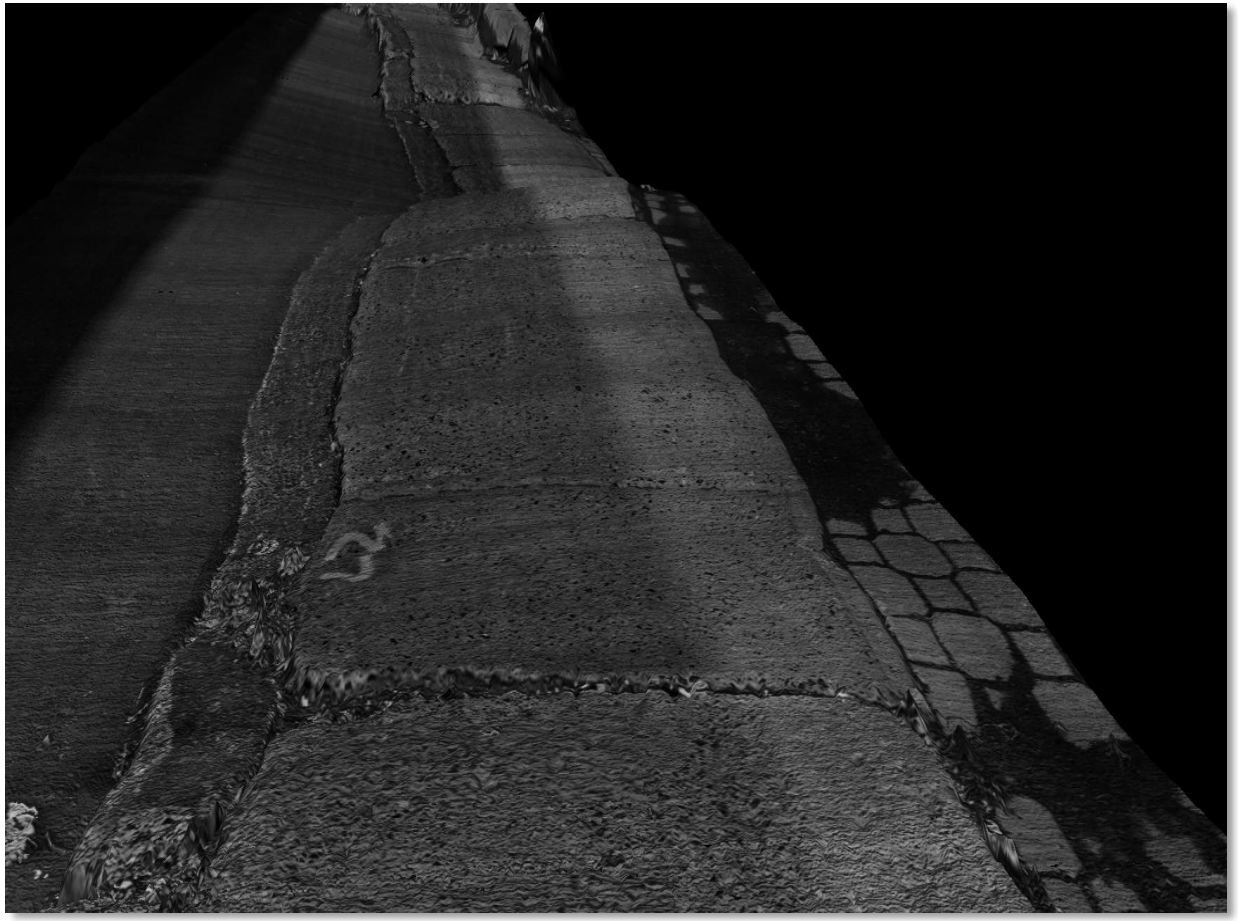
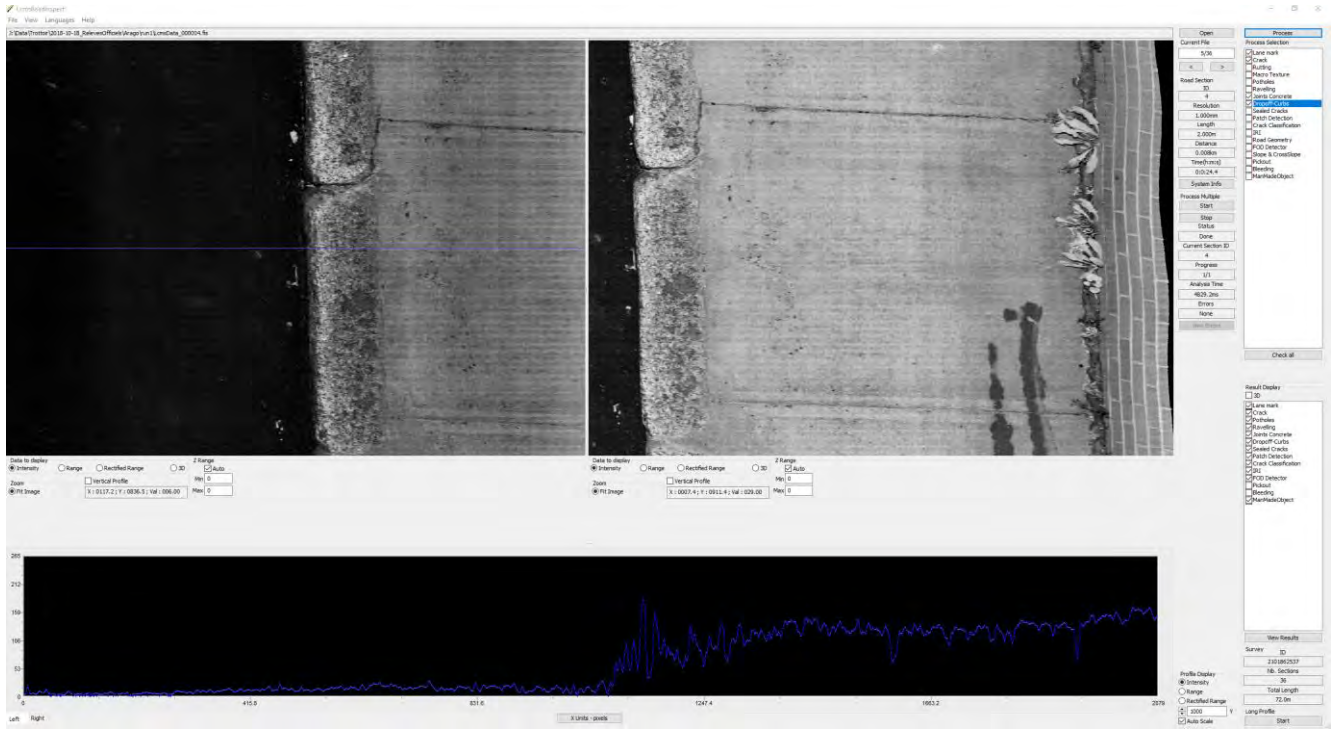
Motion compensation (X,Y,Z)

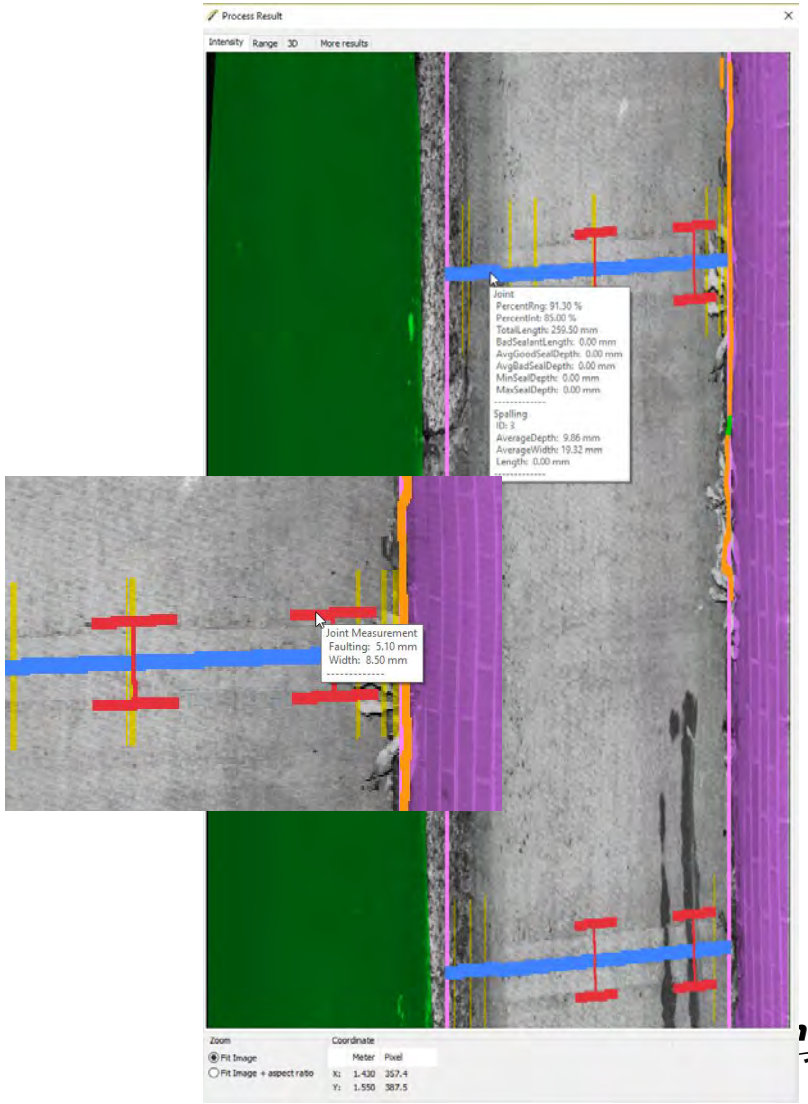


Without motion compensation

With motion compensation

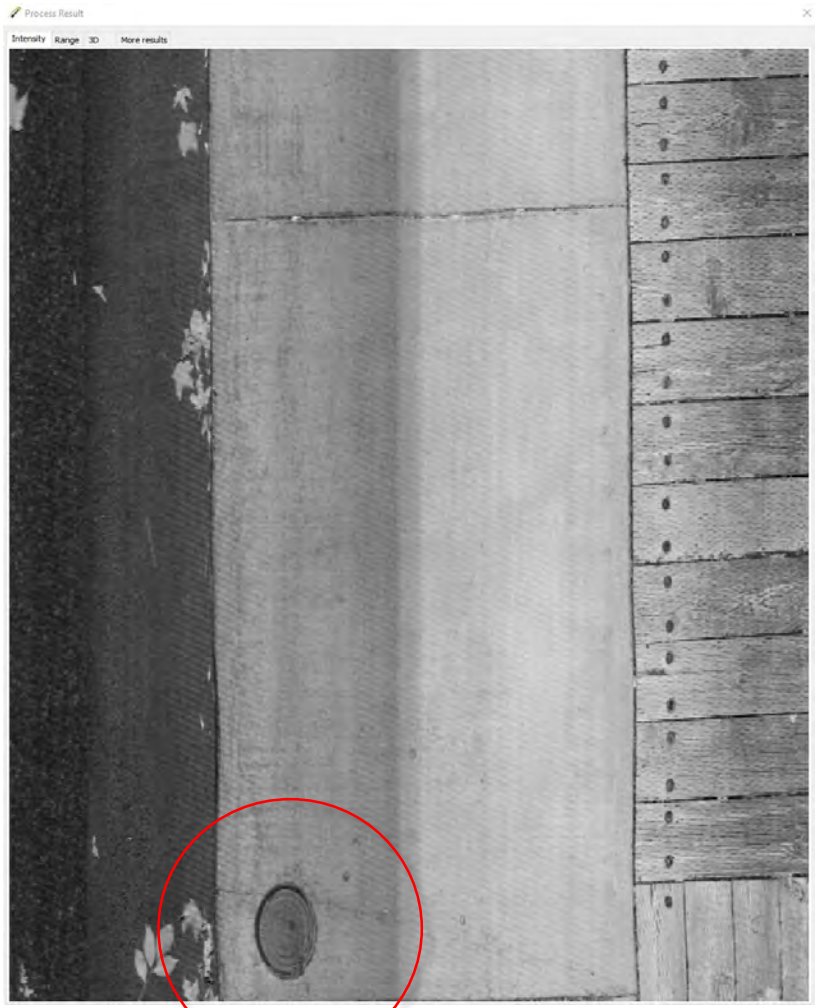
Cement sidewalks



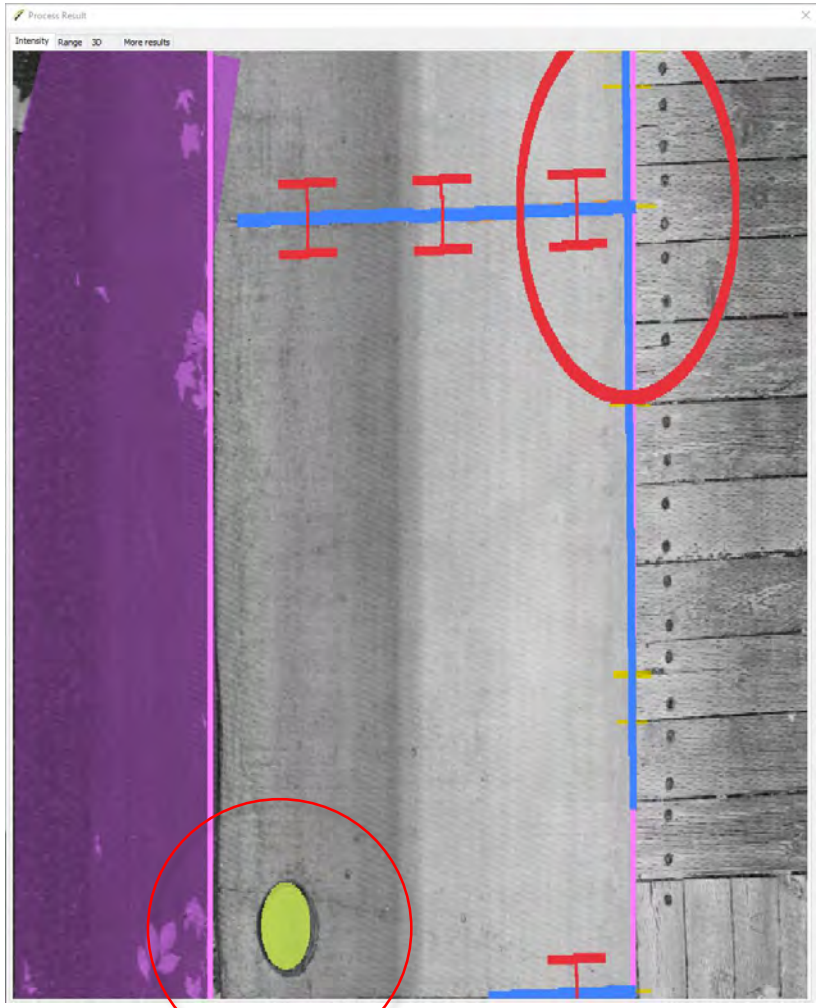


- Transverse joints well detected
- Granit curbs needed work…

Man made objects



- Man made object detection (circles) is used for covers



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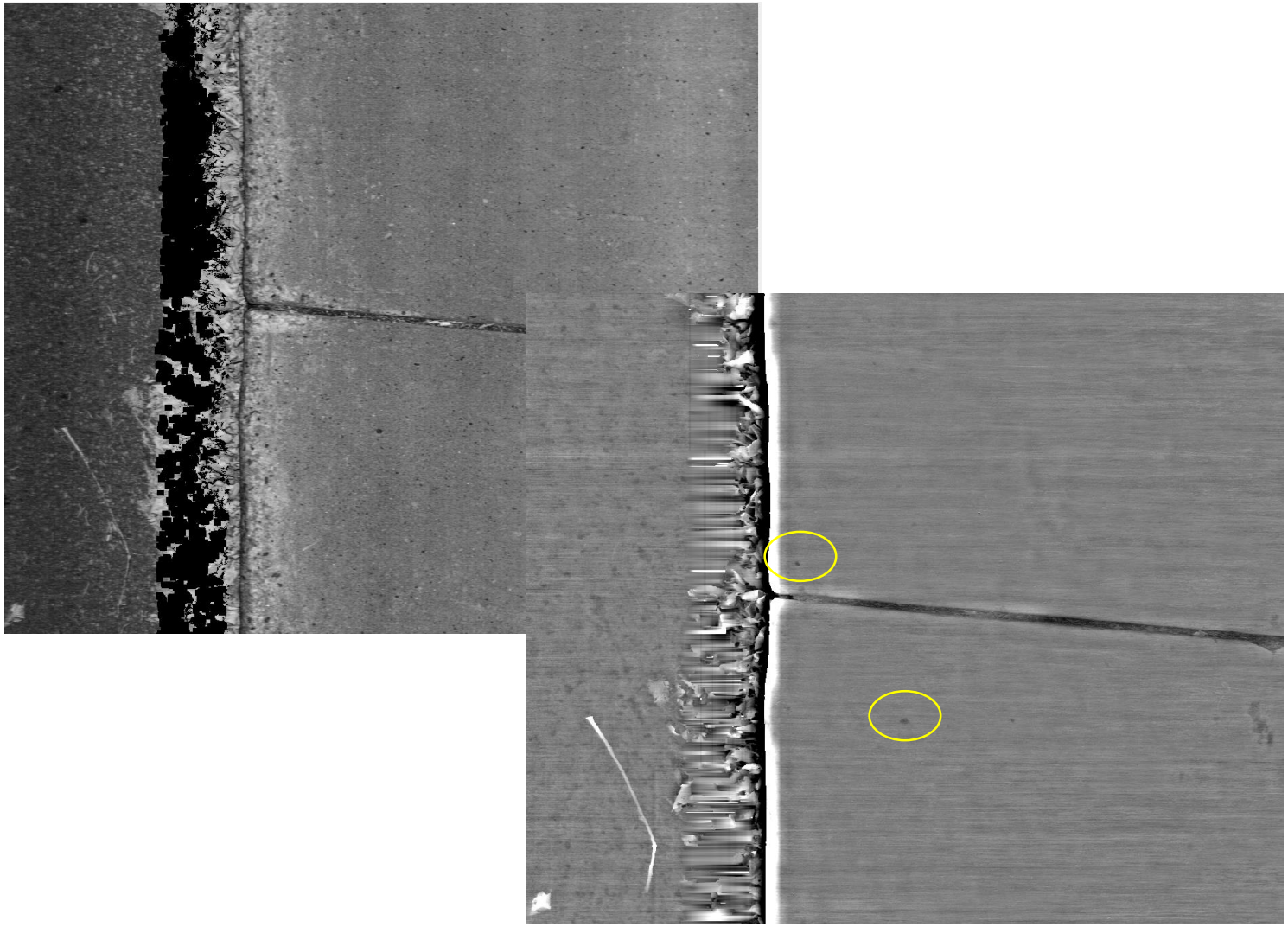
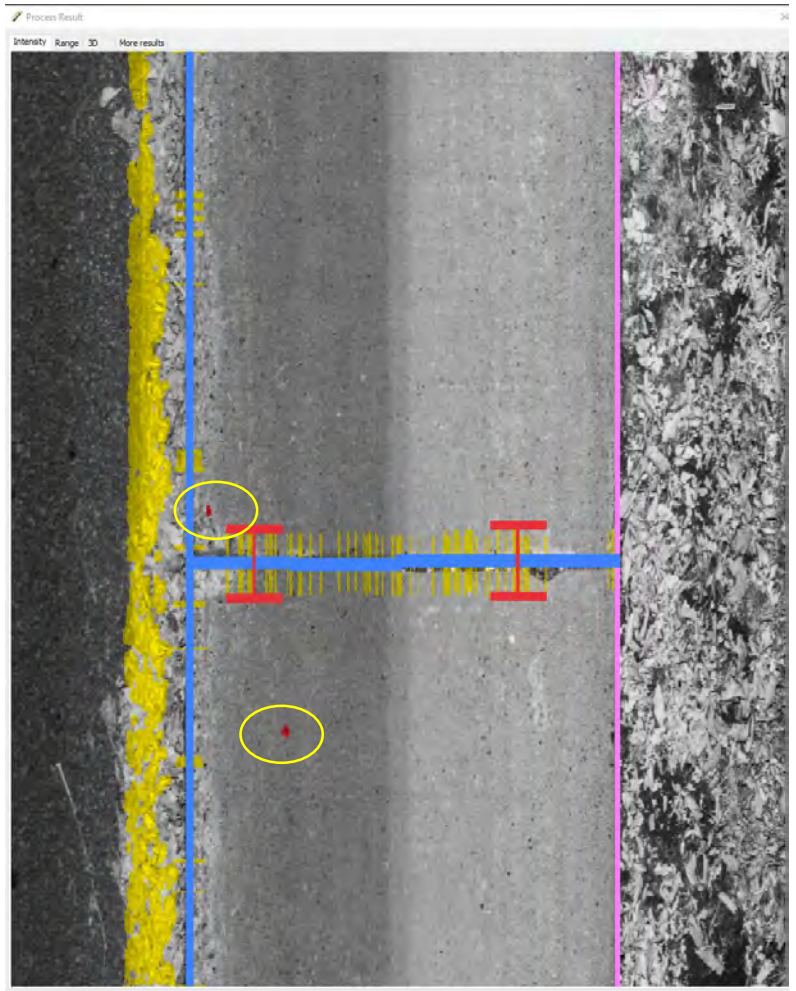
Pop outs





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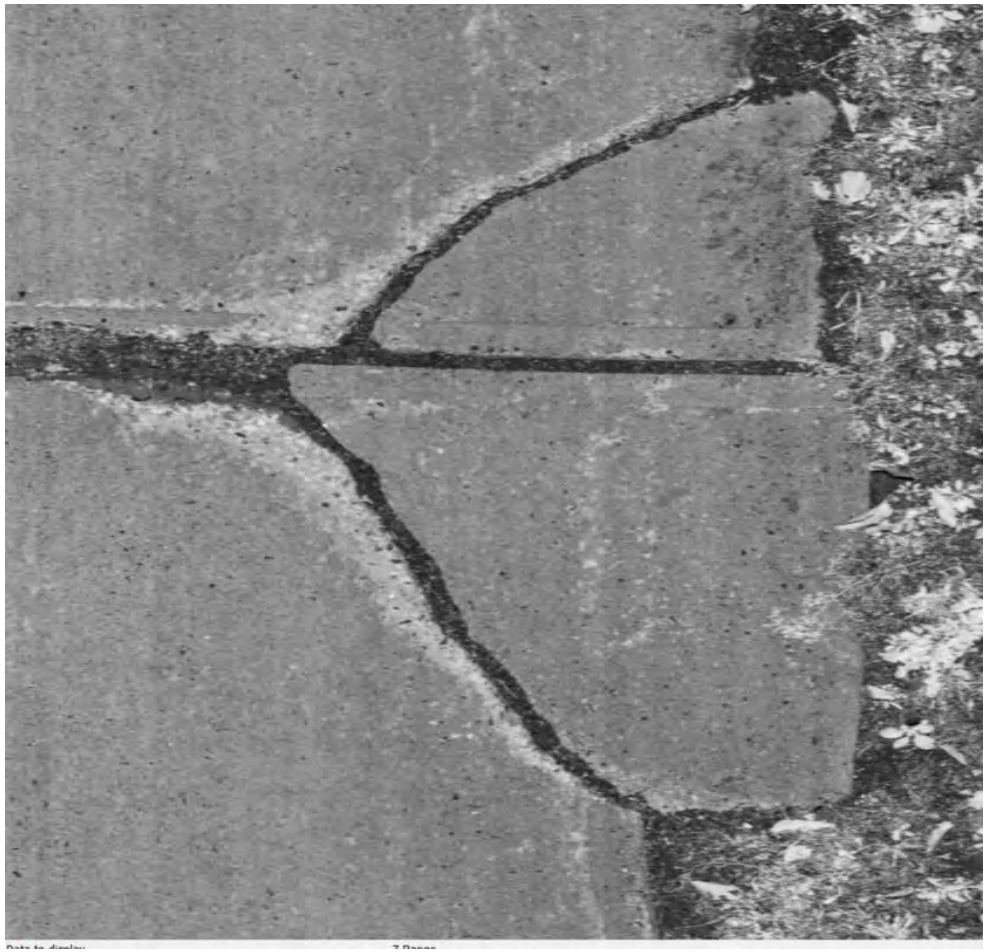
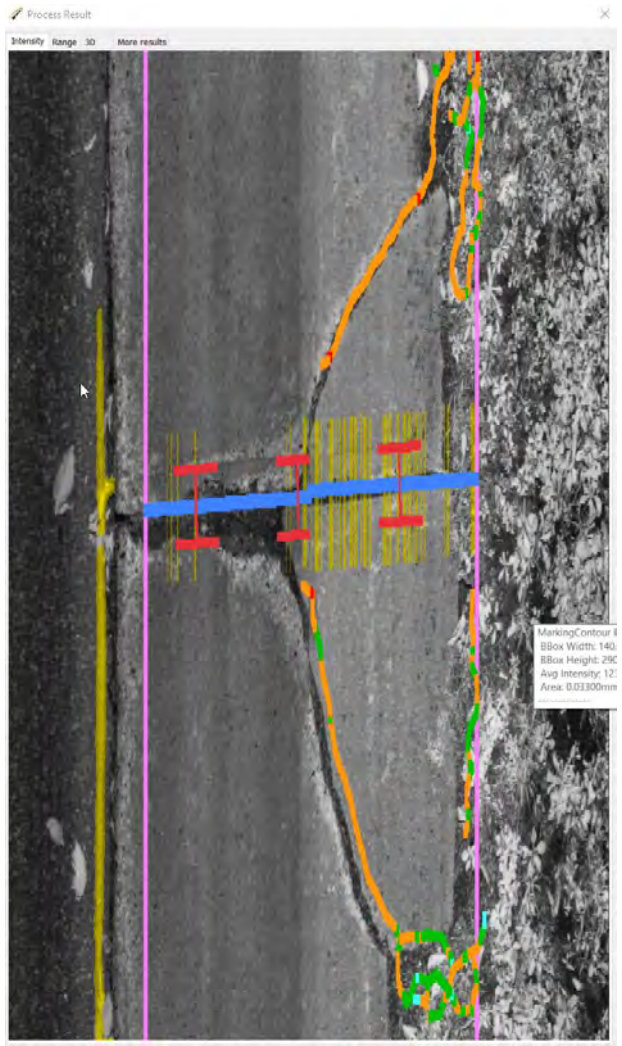
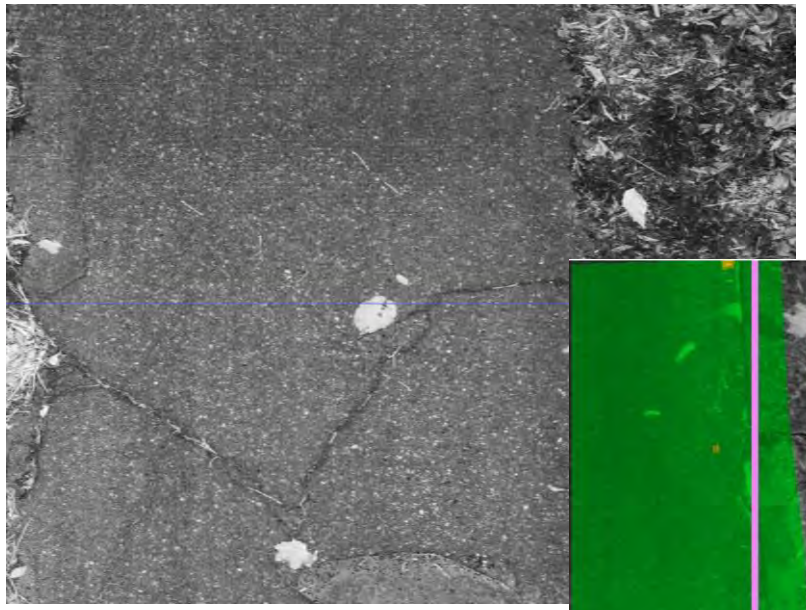
Broken slabs



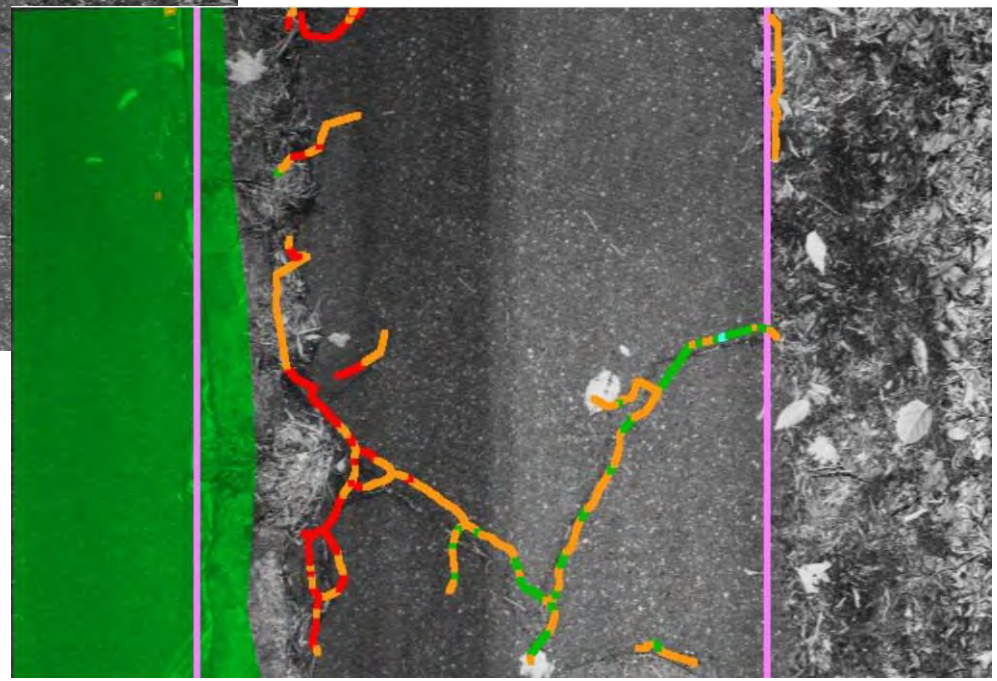
- Joint detection
- Crack detection
- Spalling detection



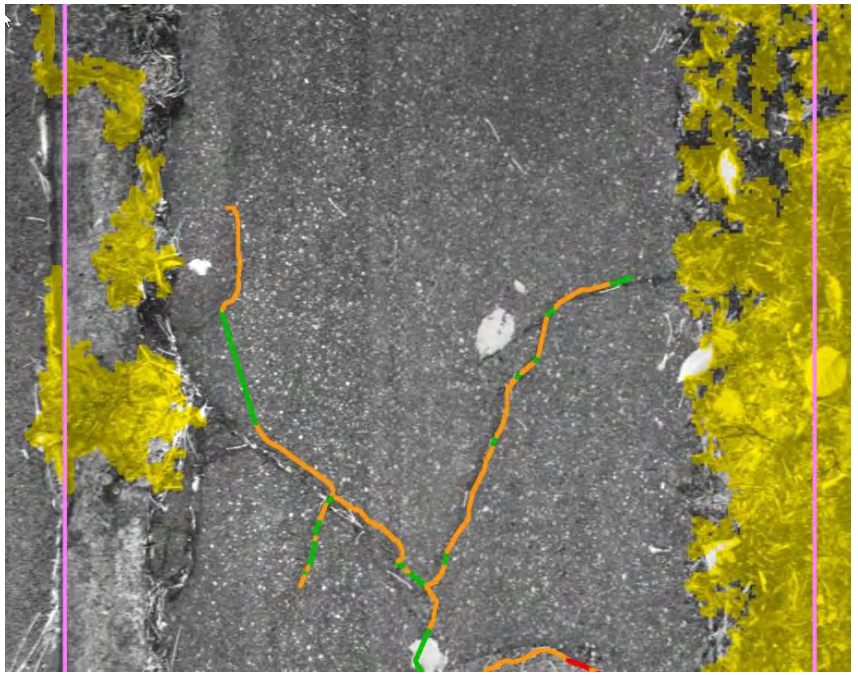
Grass detection needed !



- Crack detection algorithms work well but
- A lot of work needed for properly detecting edges and grass that would cause false detections



Without grass detection



With grass detection

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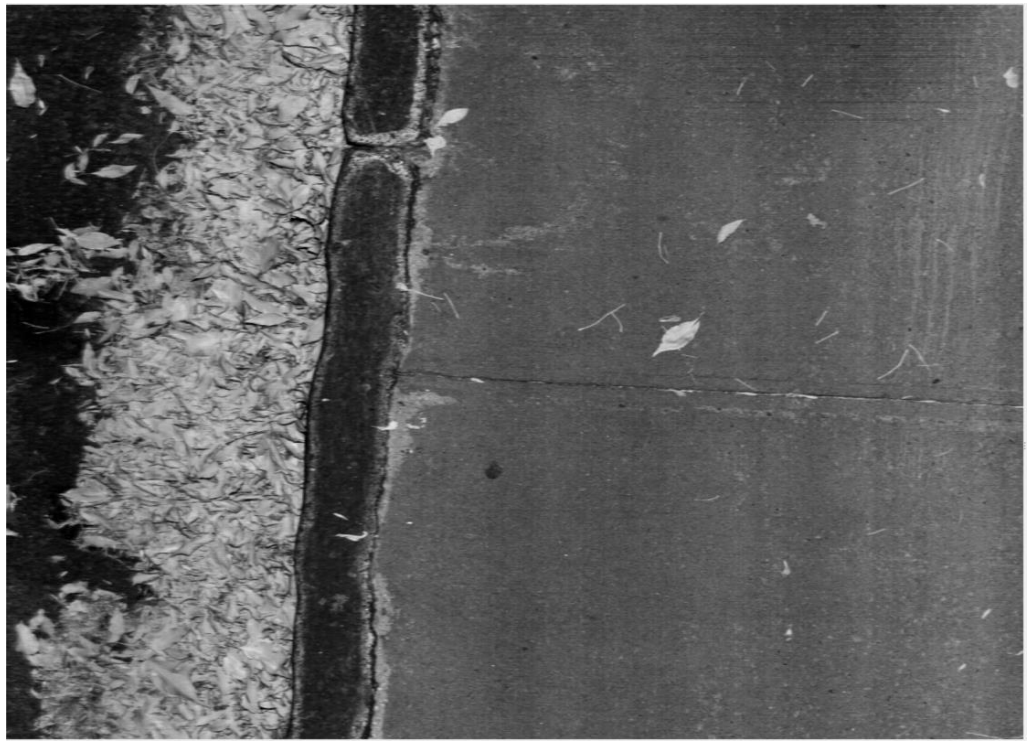
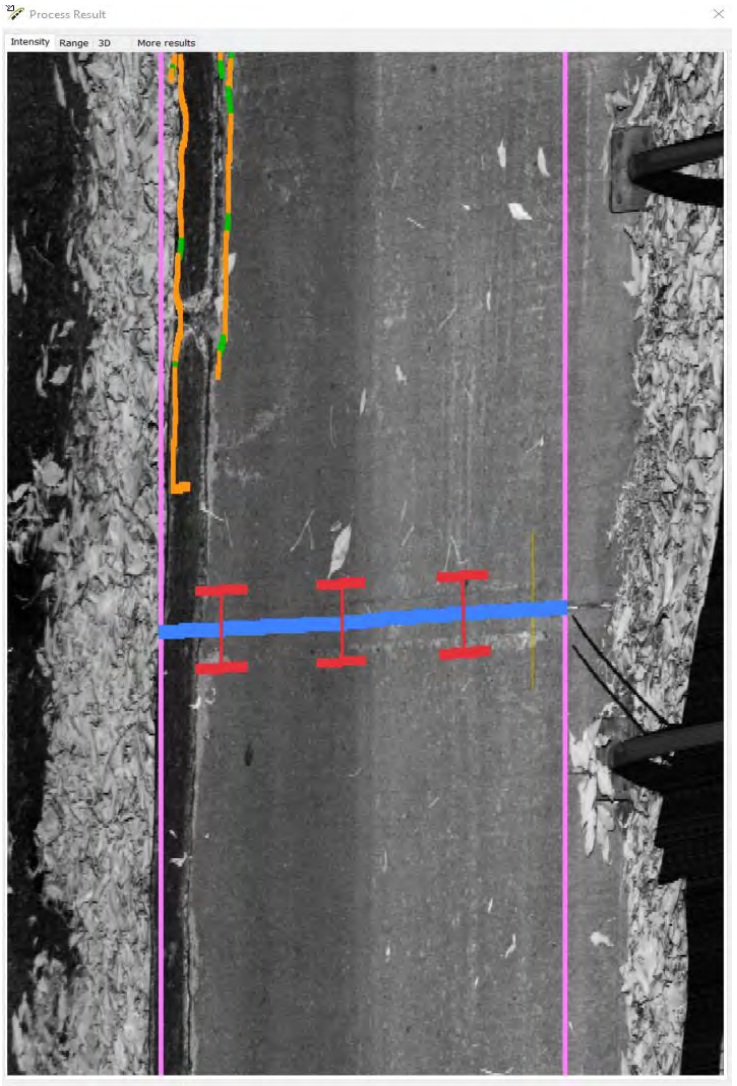
Longitudinal joints vs curbs



- Longitudinal joint detection needed improving
- Often was detected as cracks
- Curb/Edge detection needed improving (lots of leaves…)



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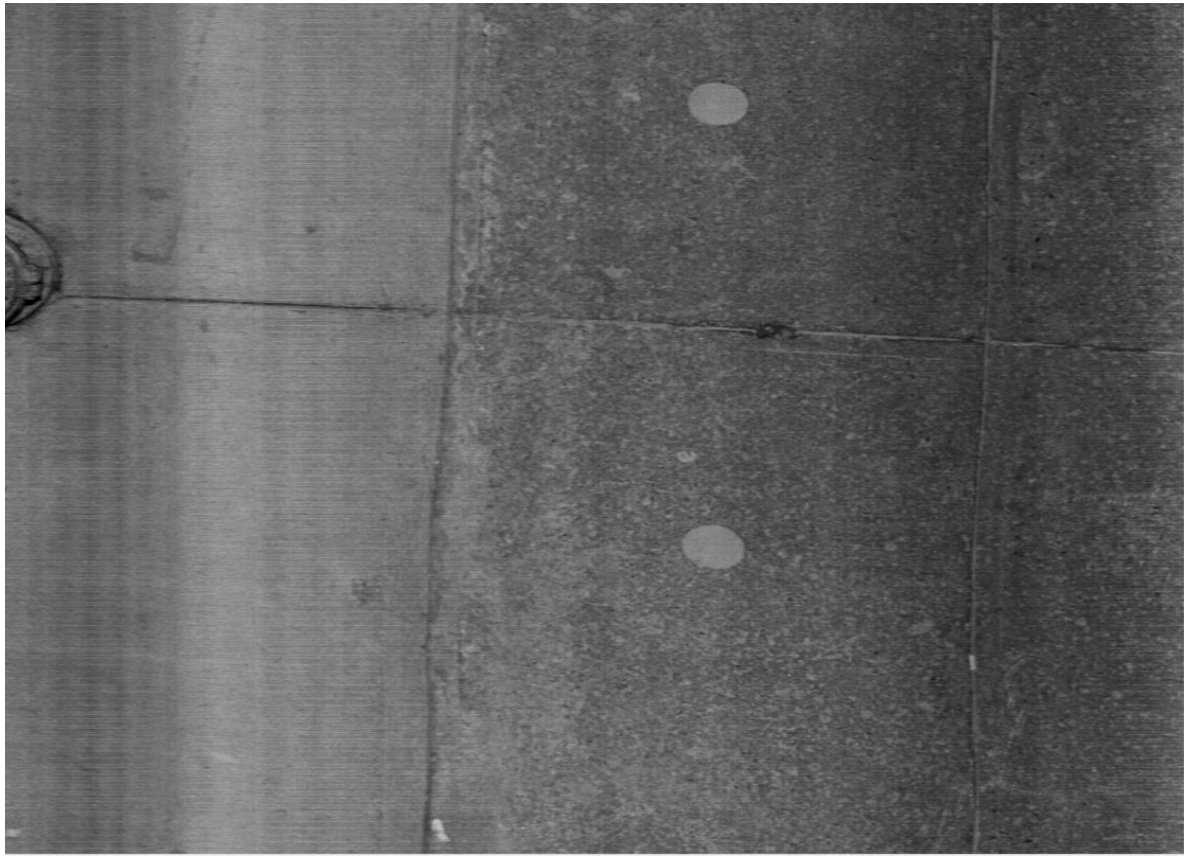
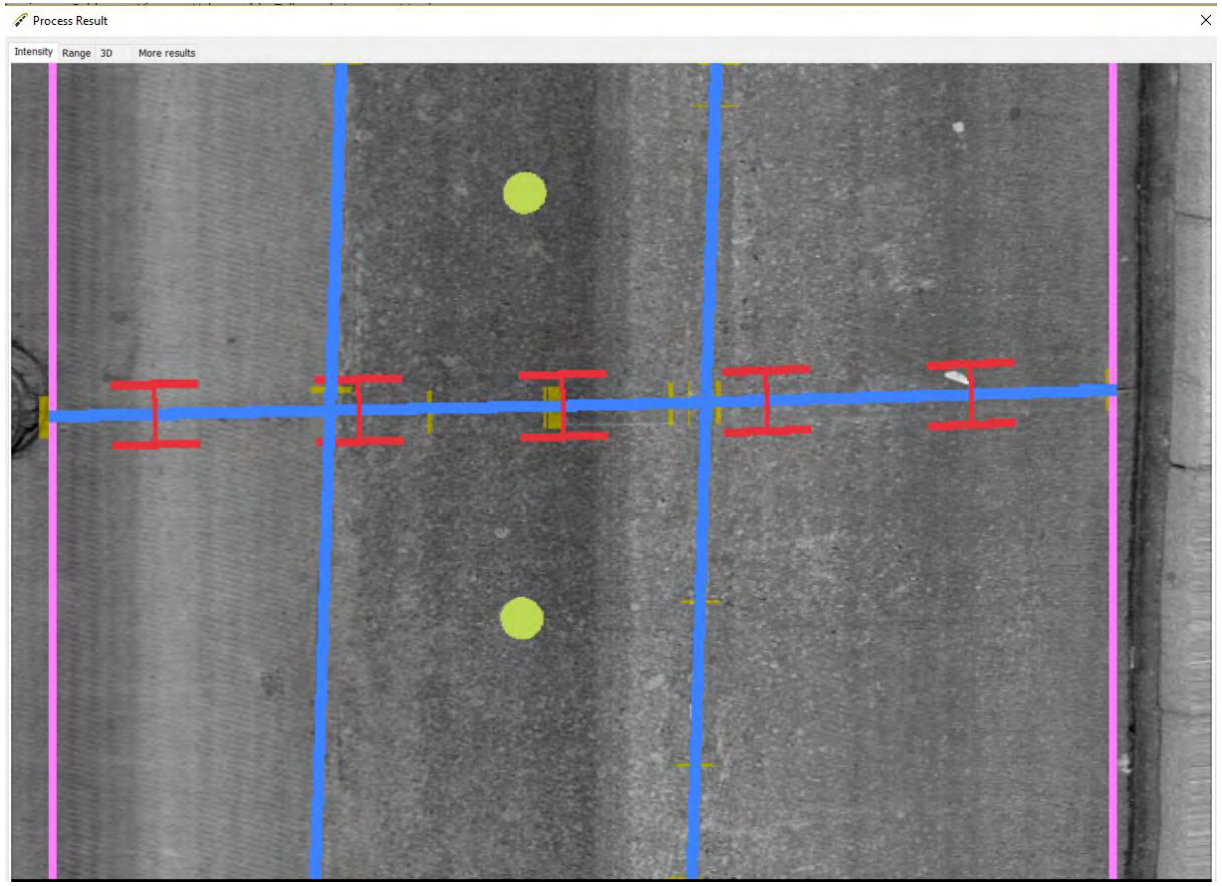
Joints and covers





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Sidewalk inspection trailer option

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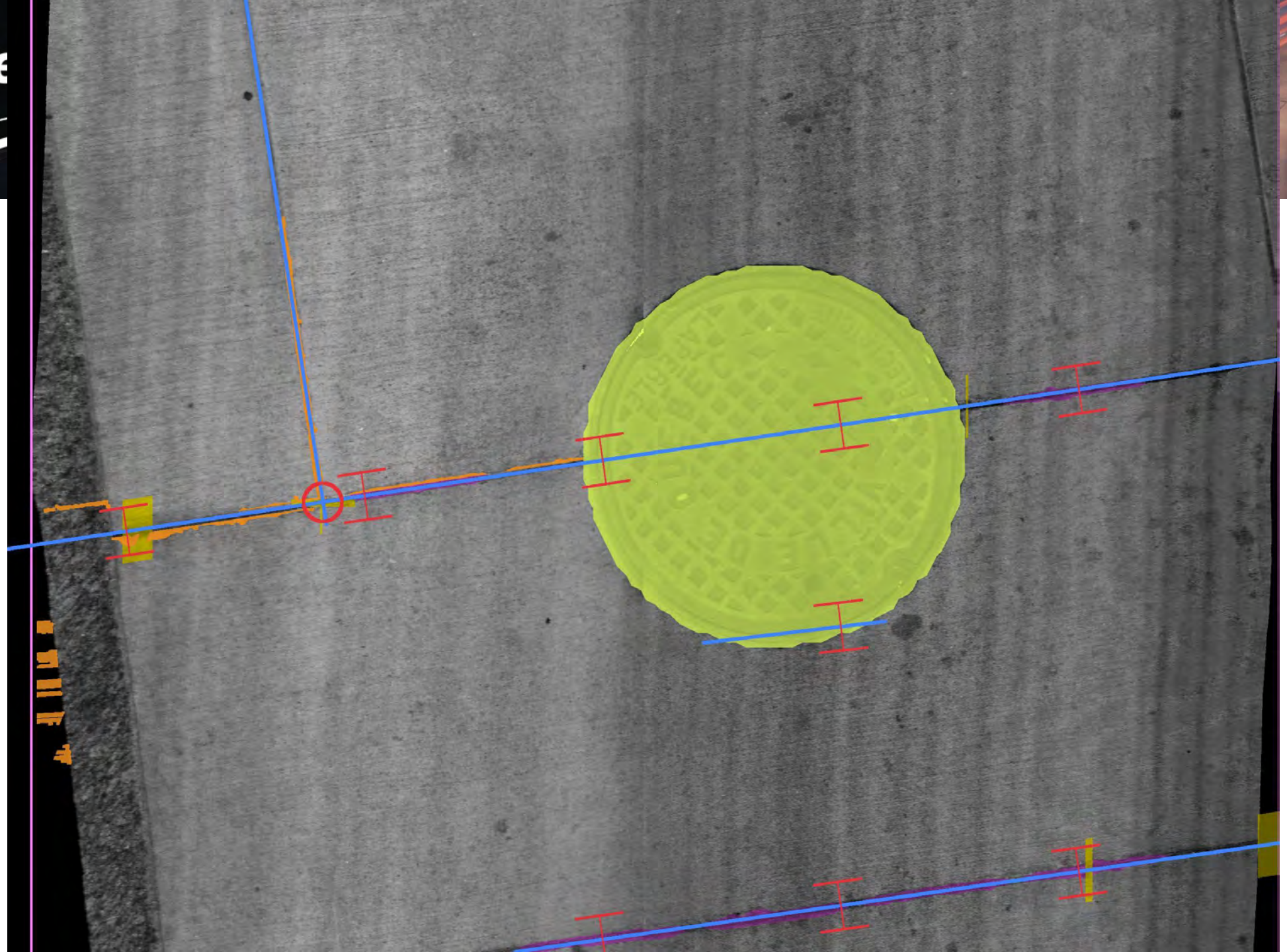

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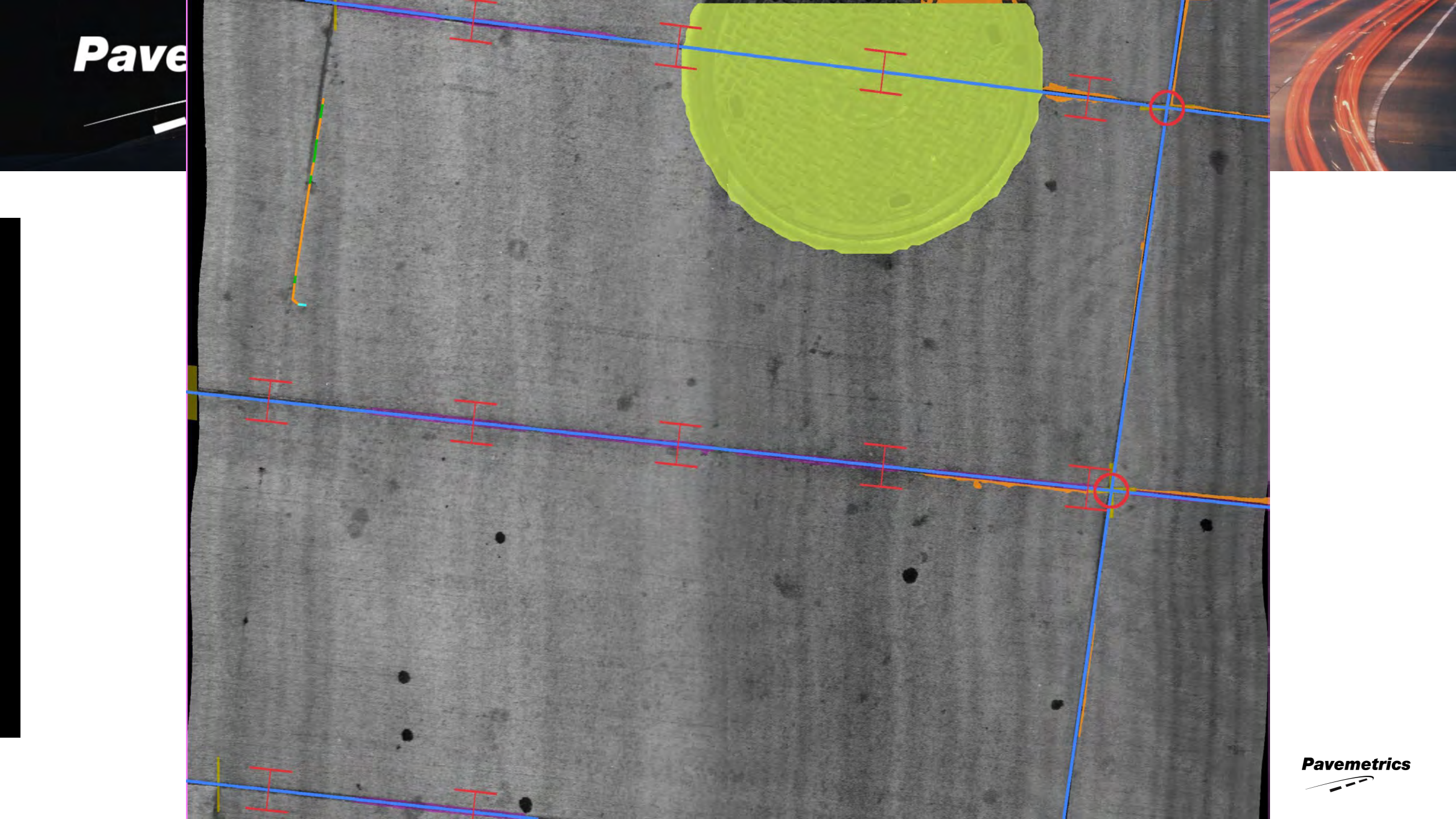
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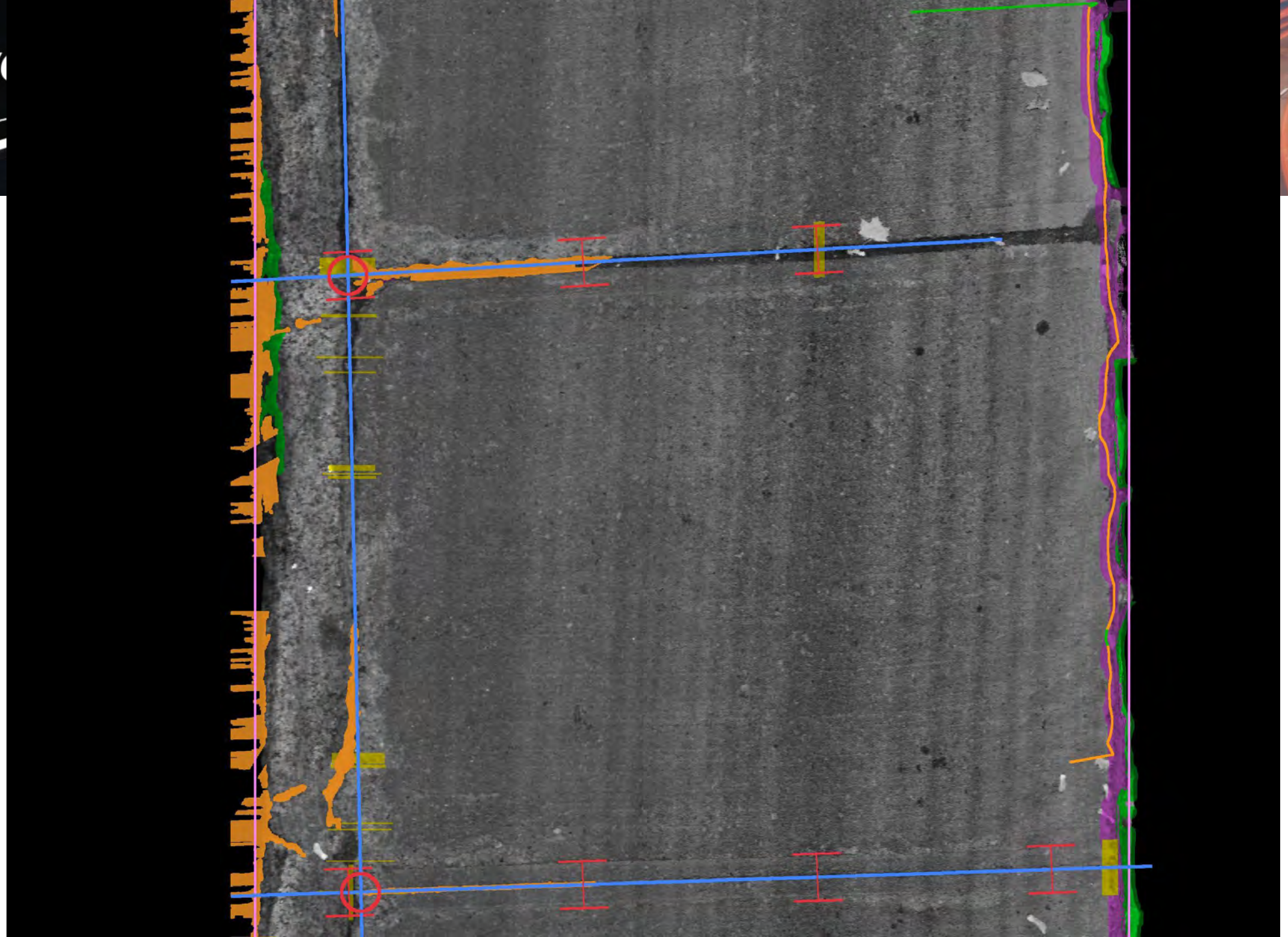

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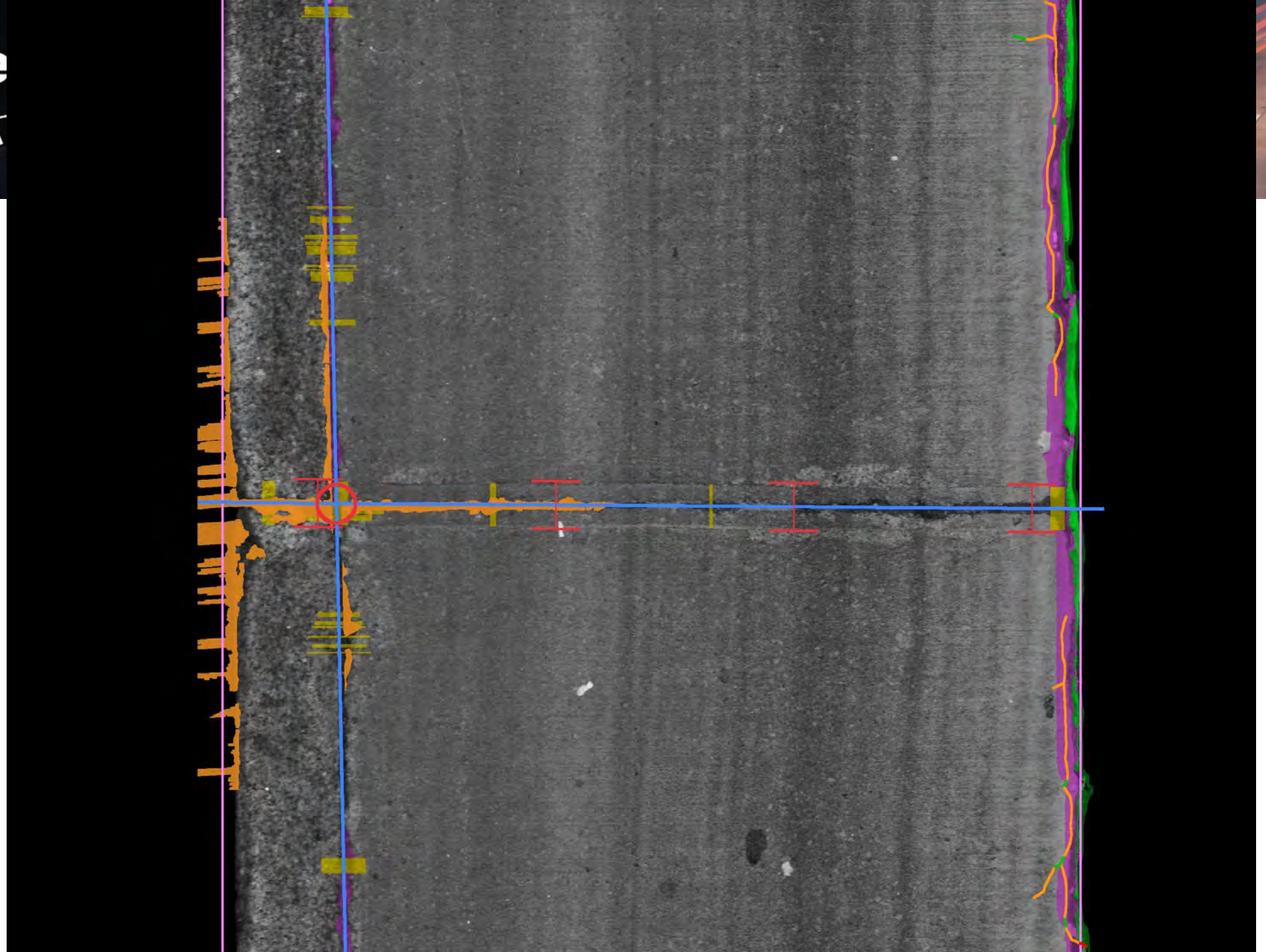

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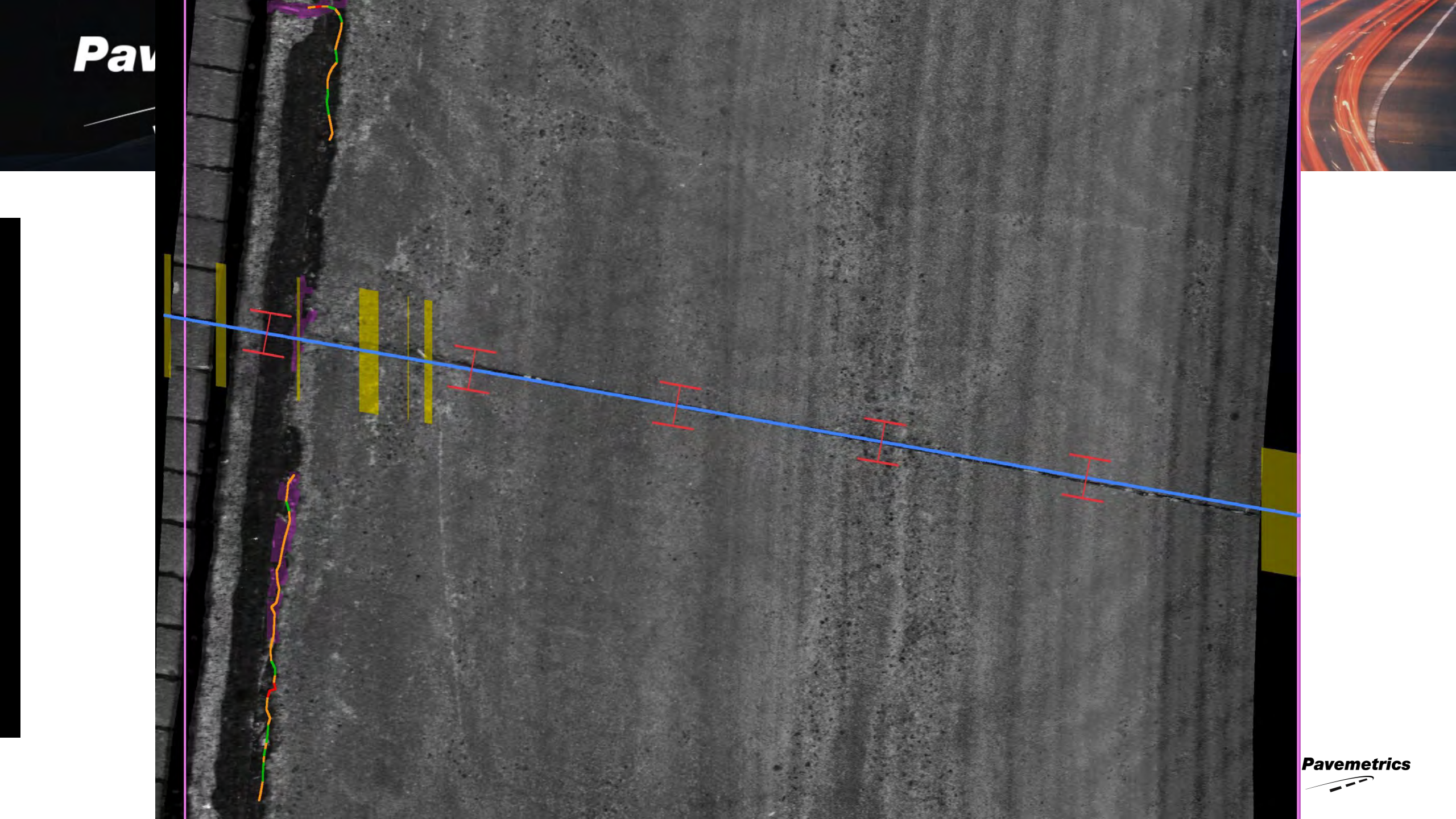
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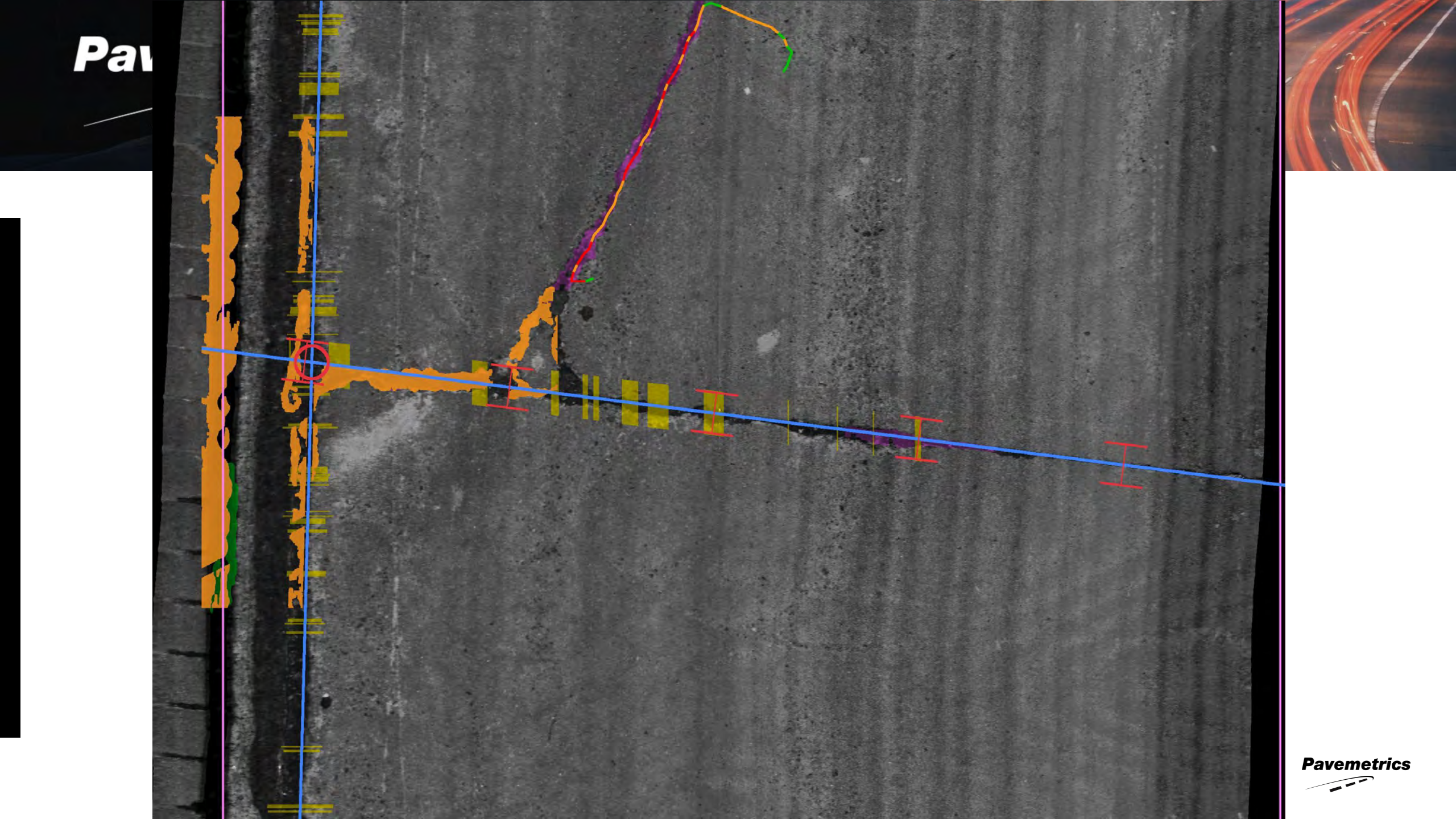
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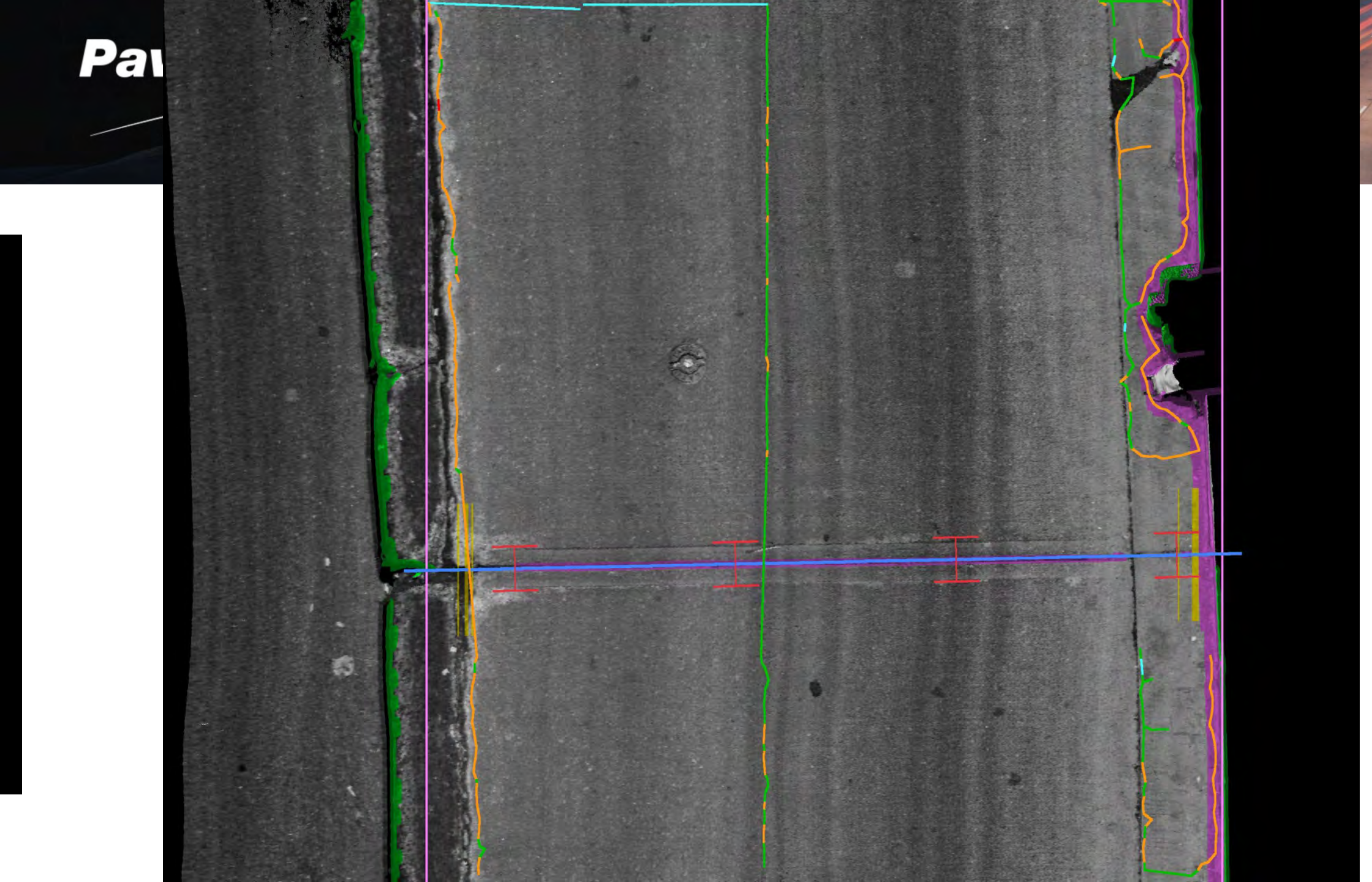

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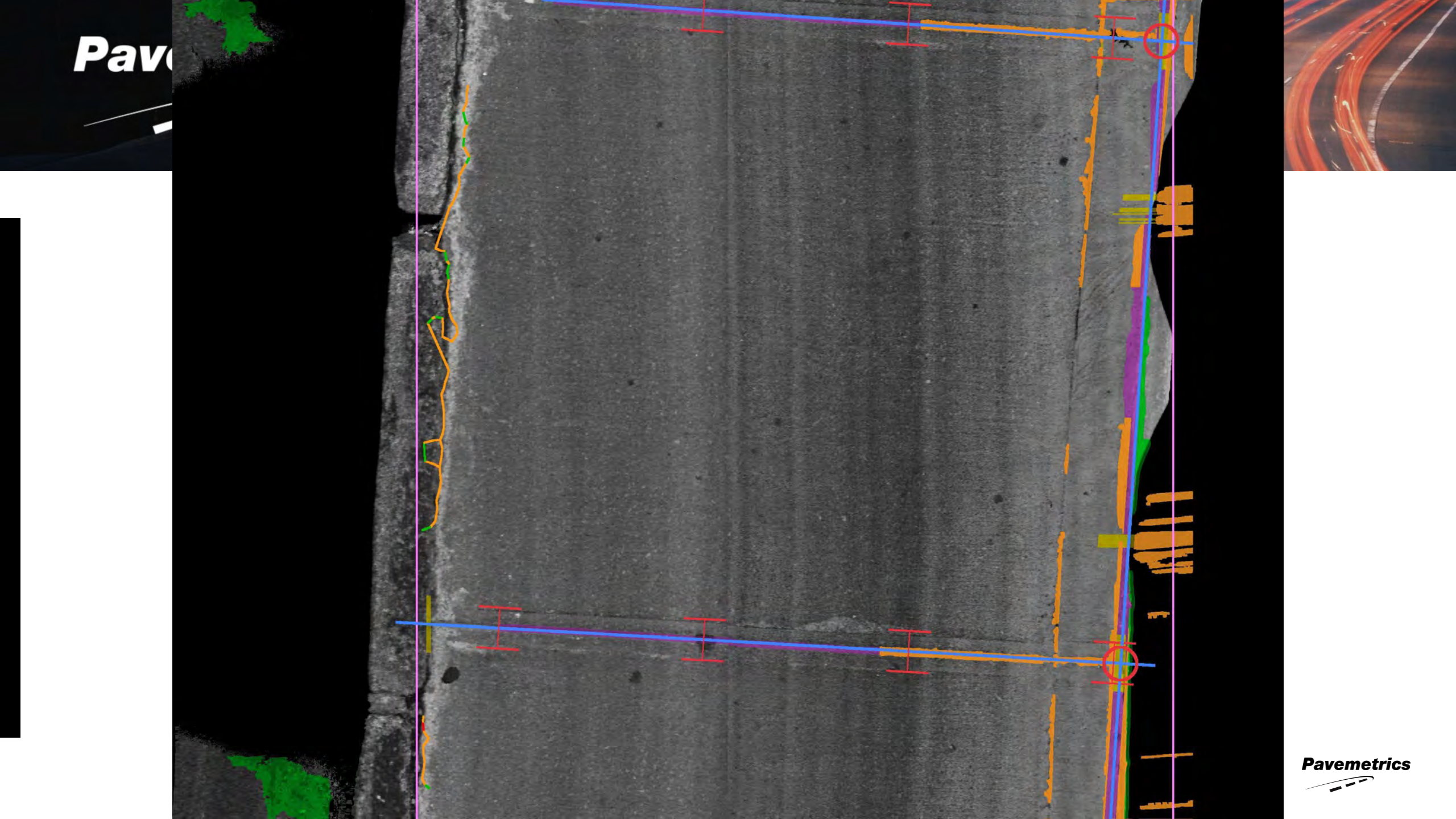
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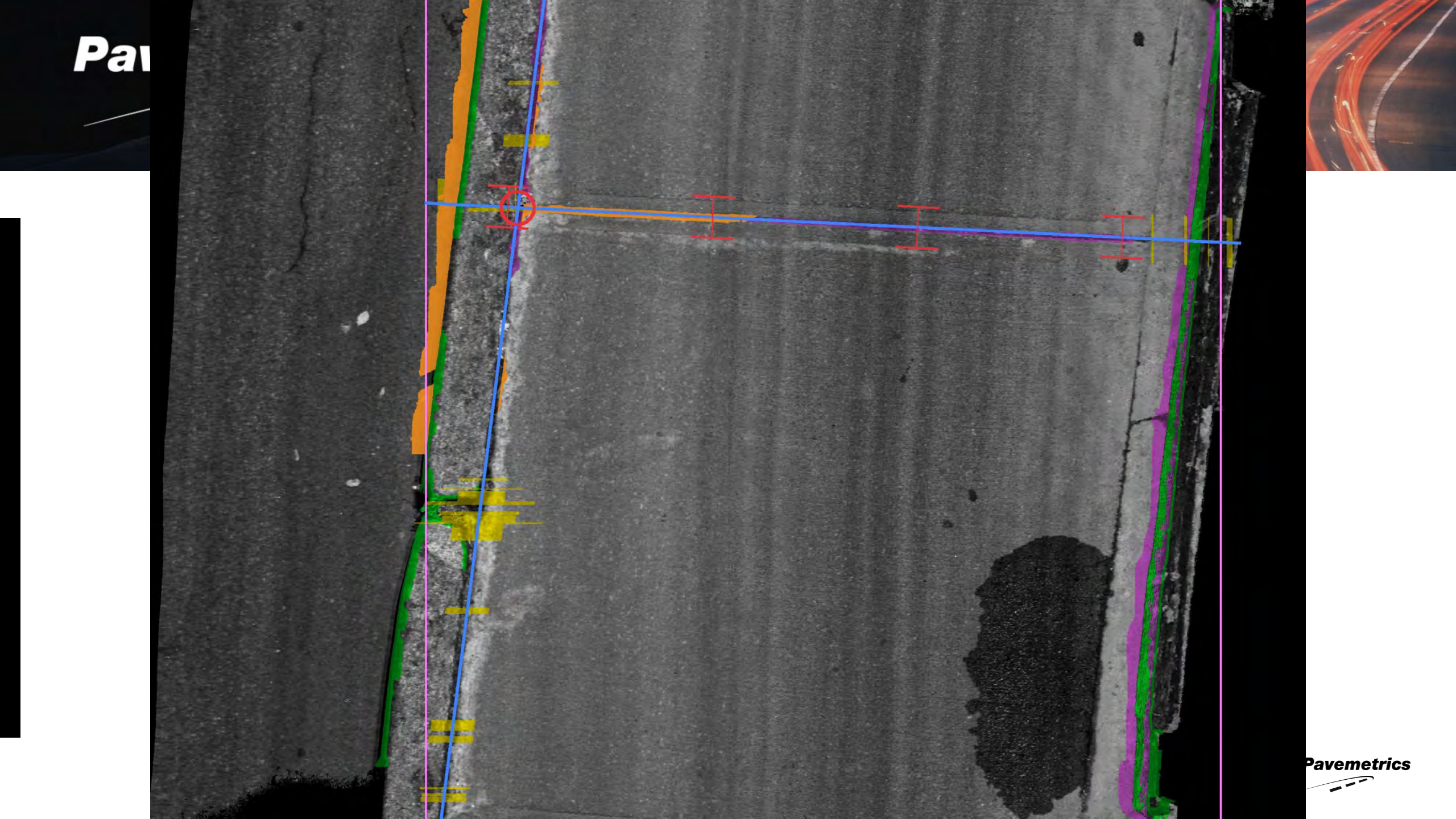
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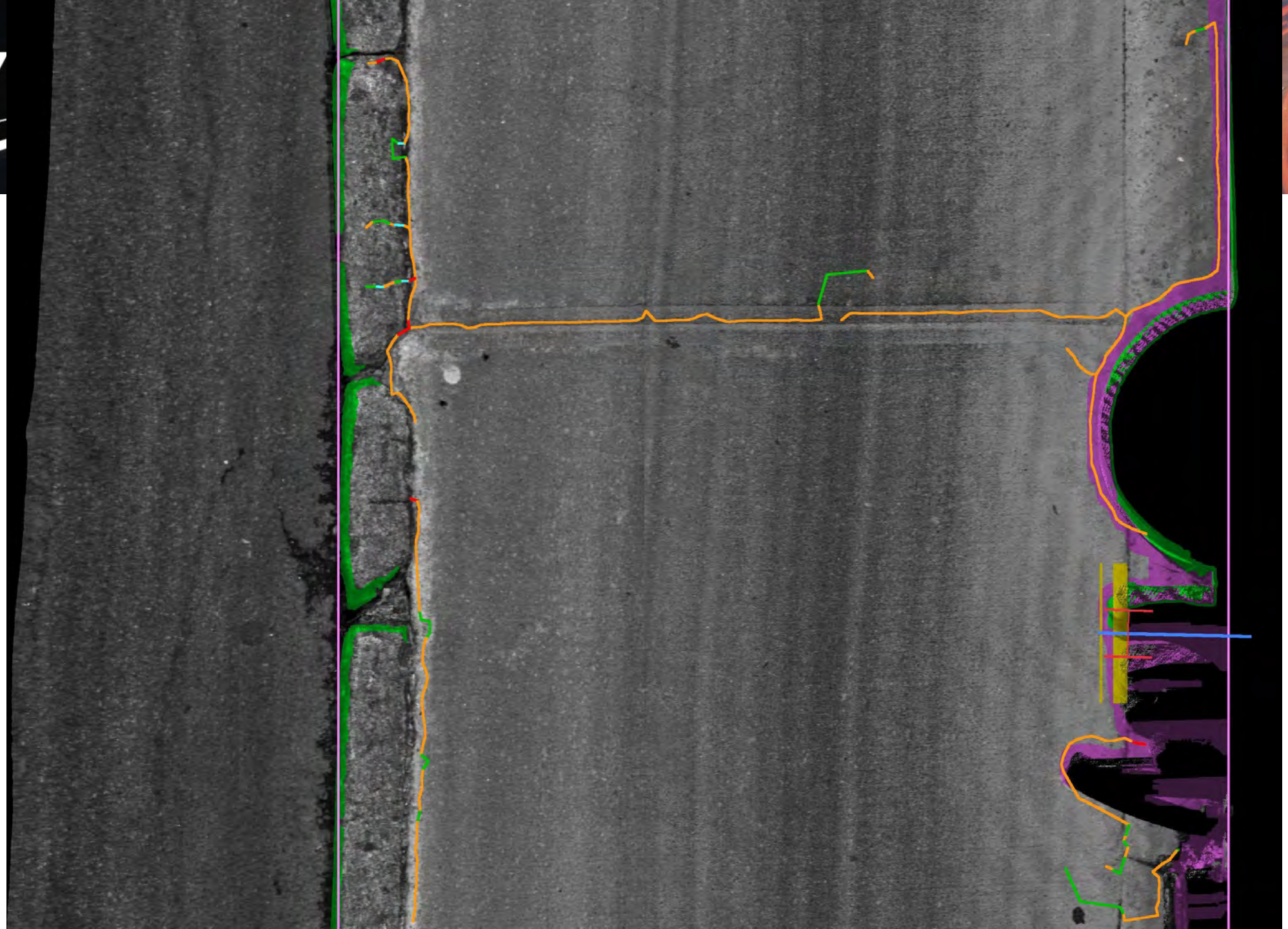

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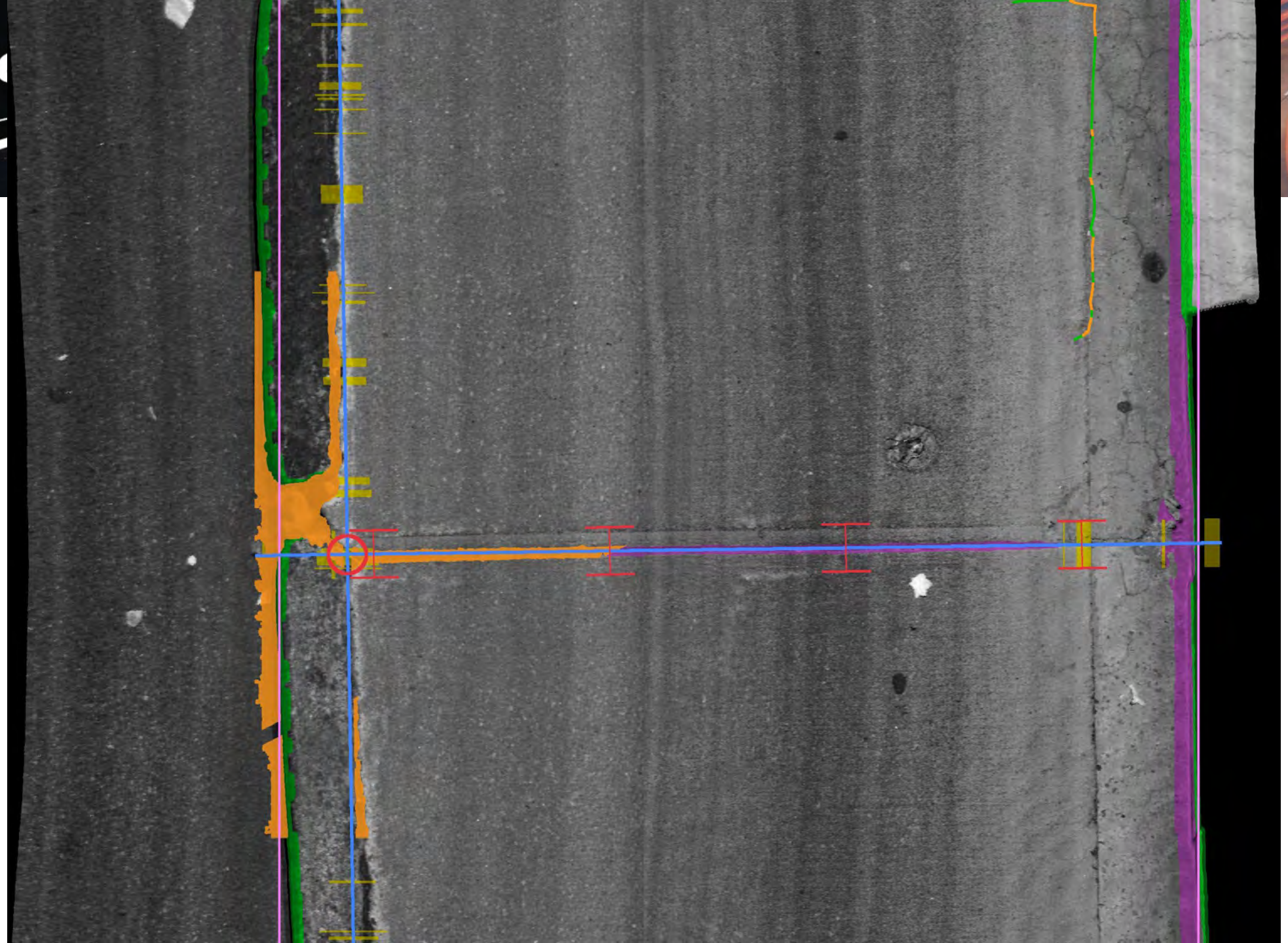

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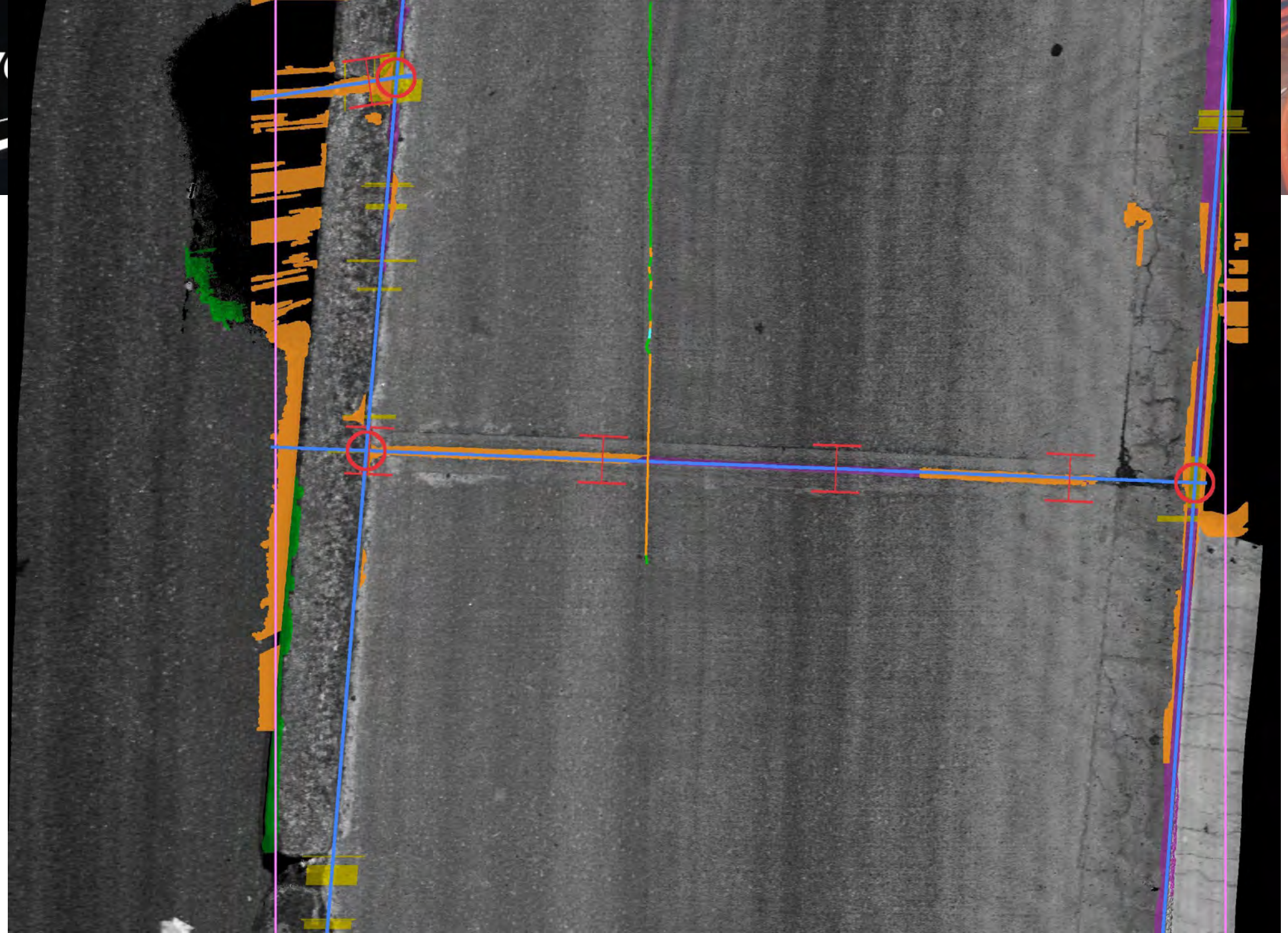

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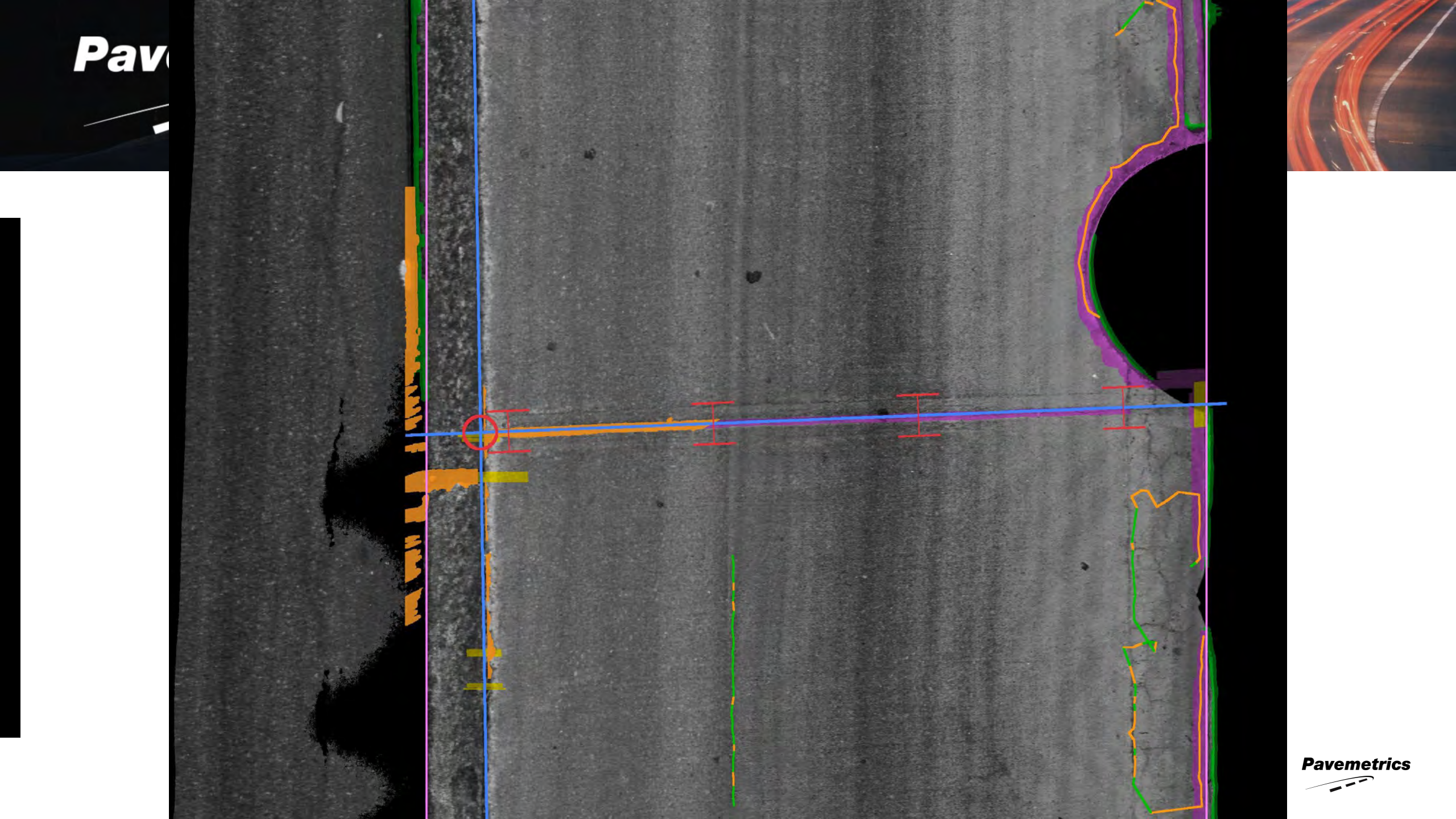
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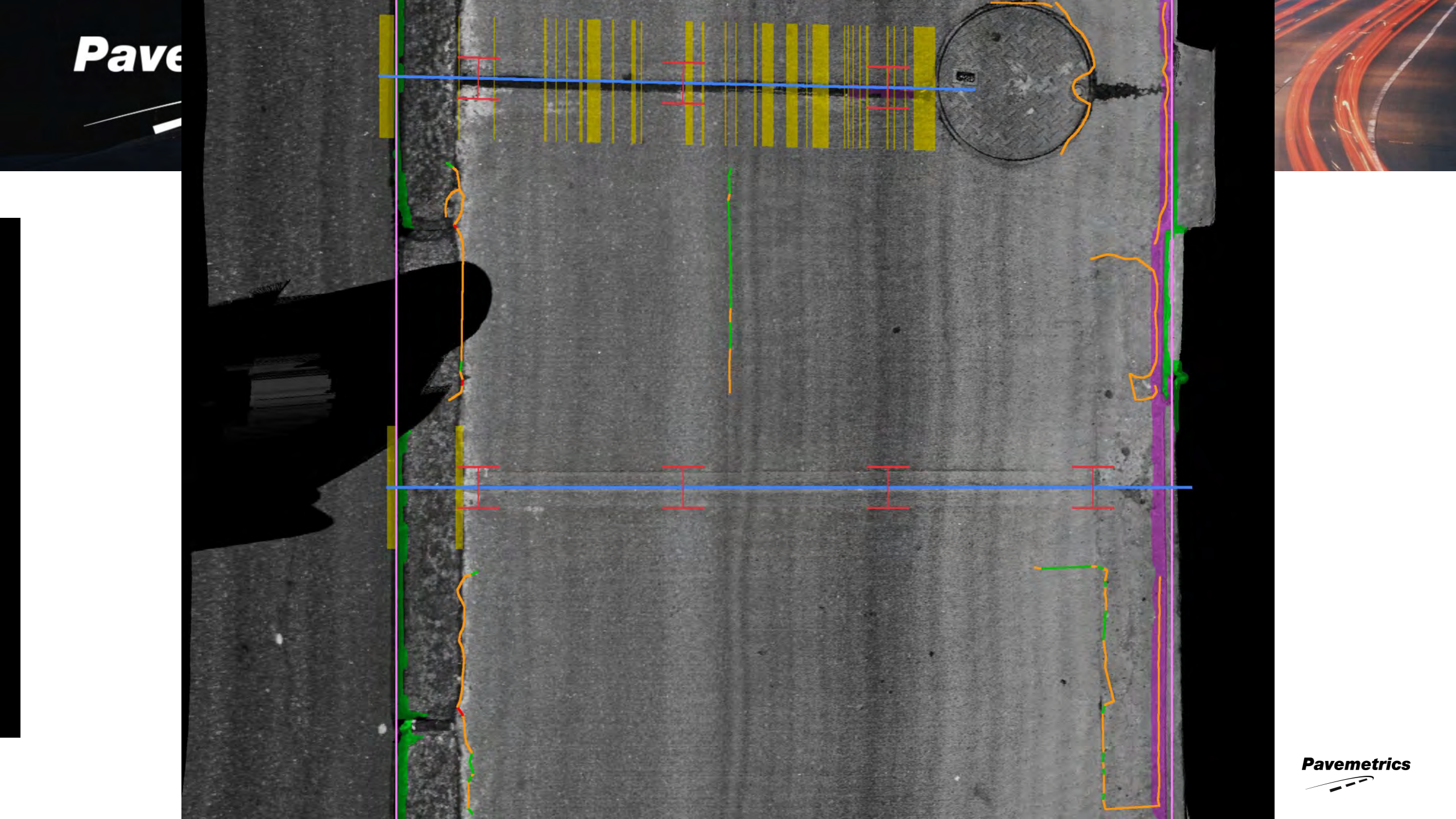
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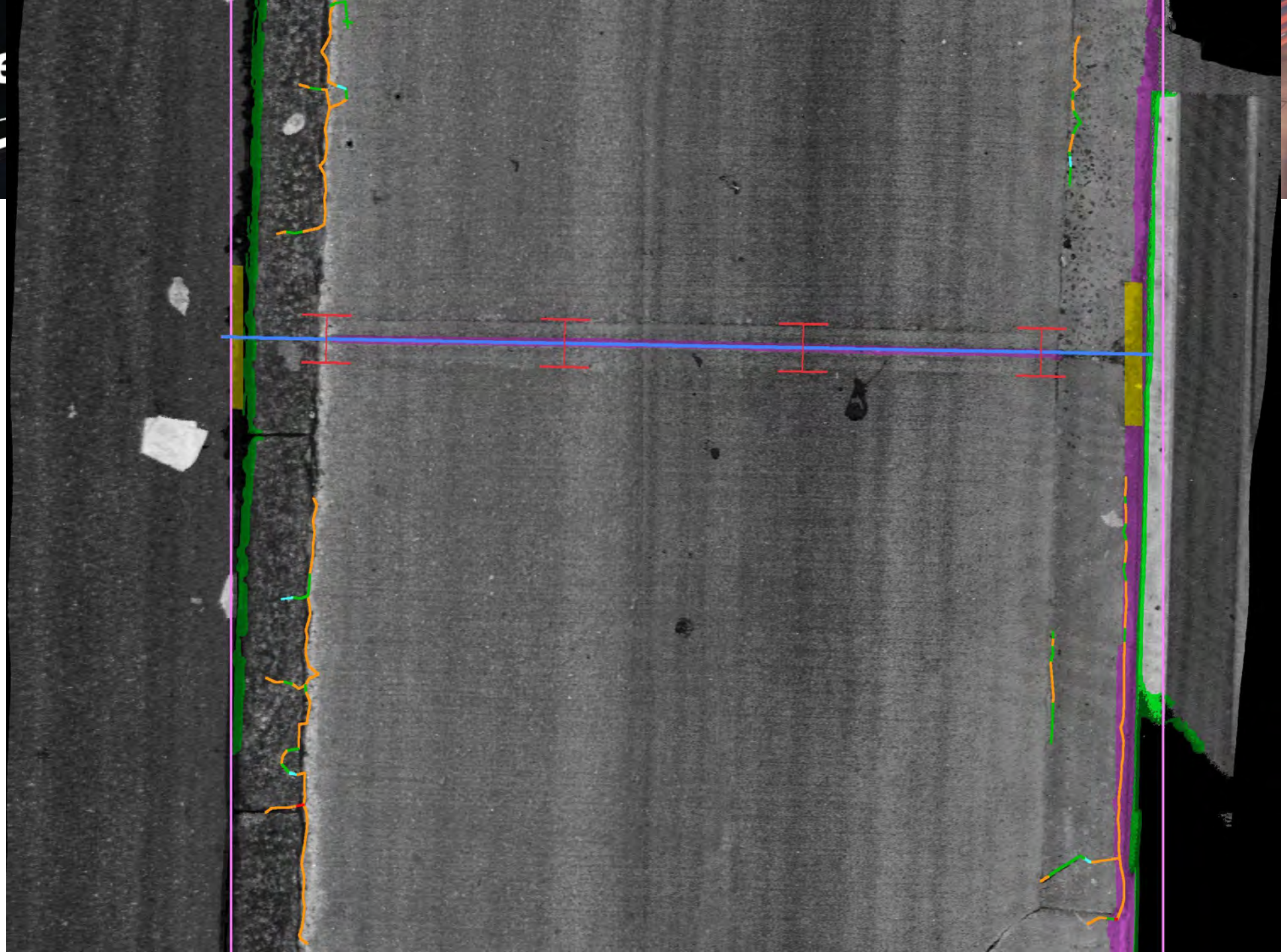

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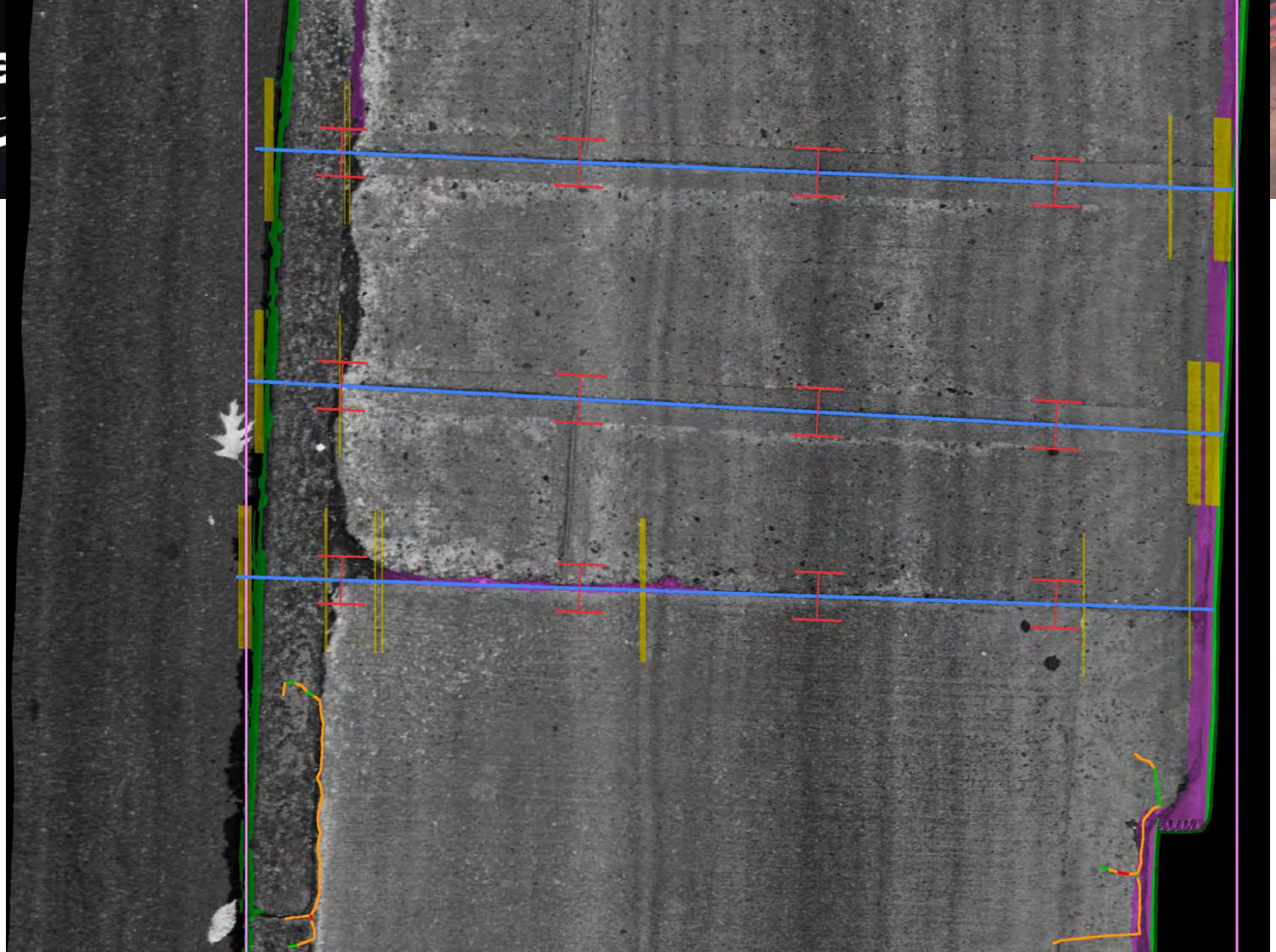

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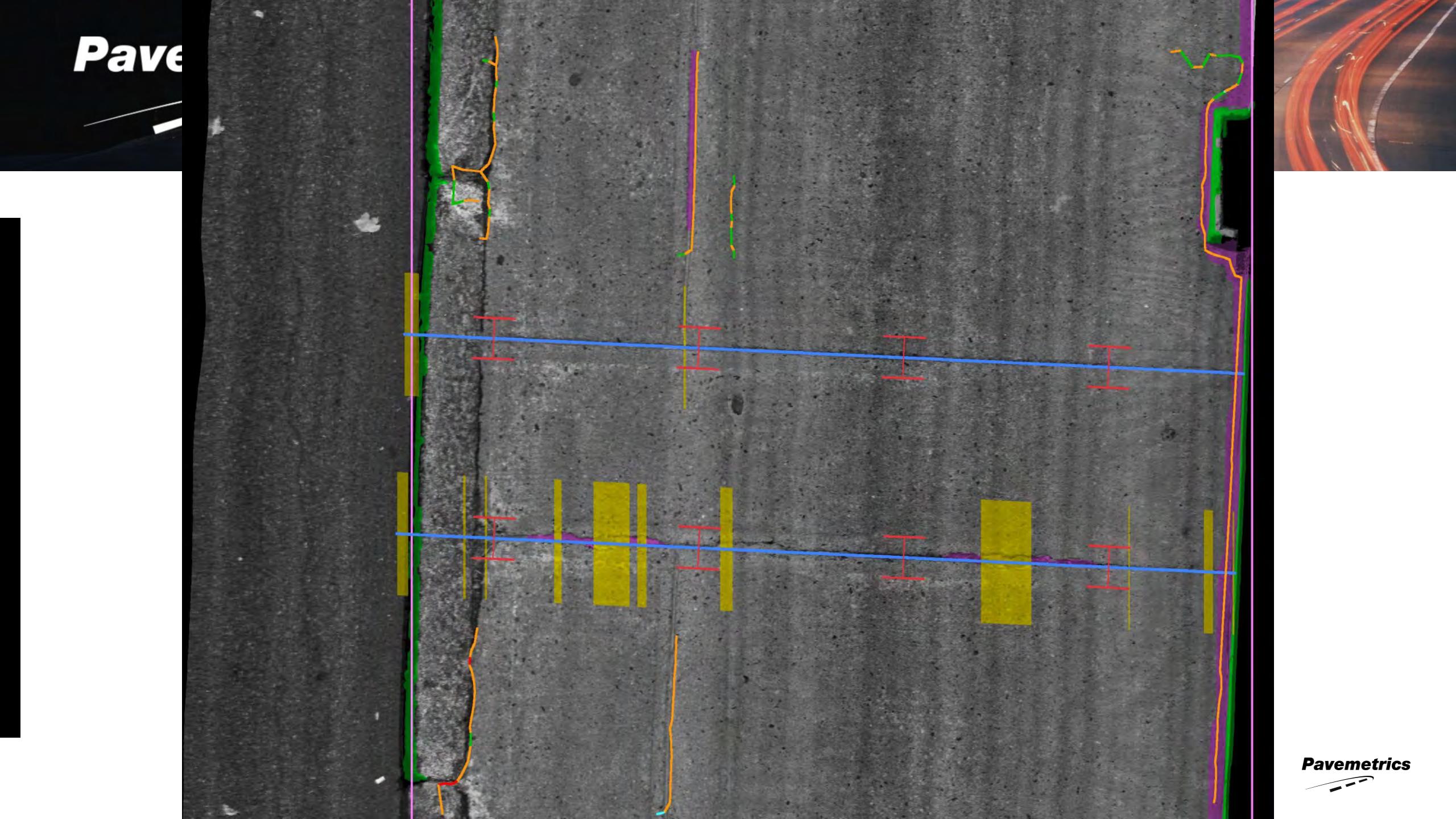
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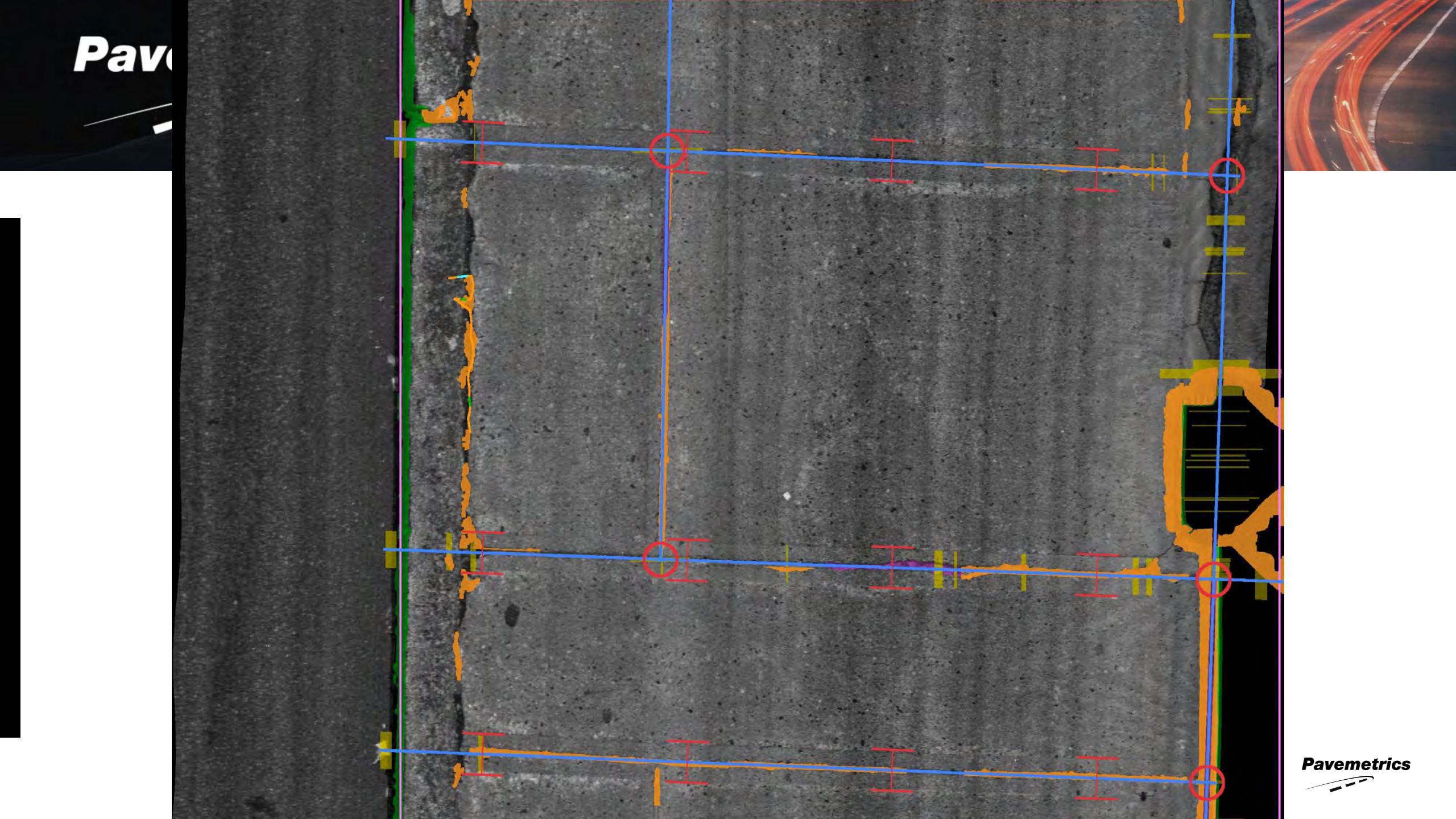

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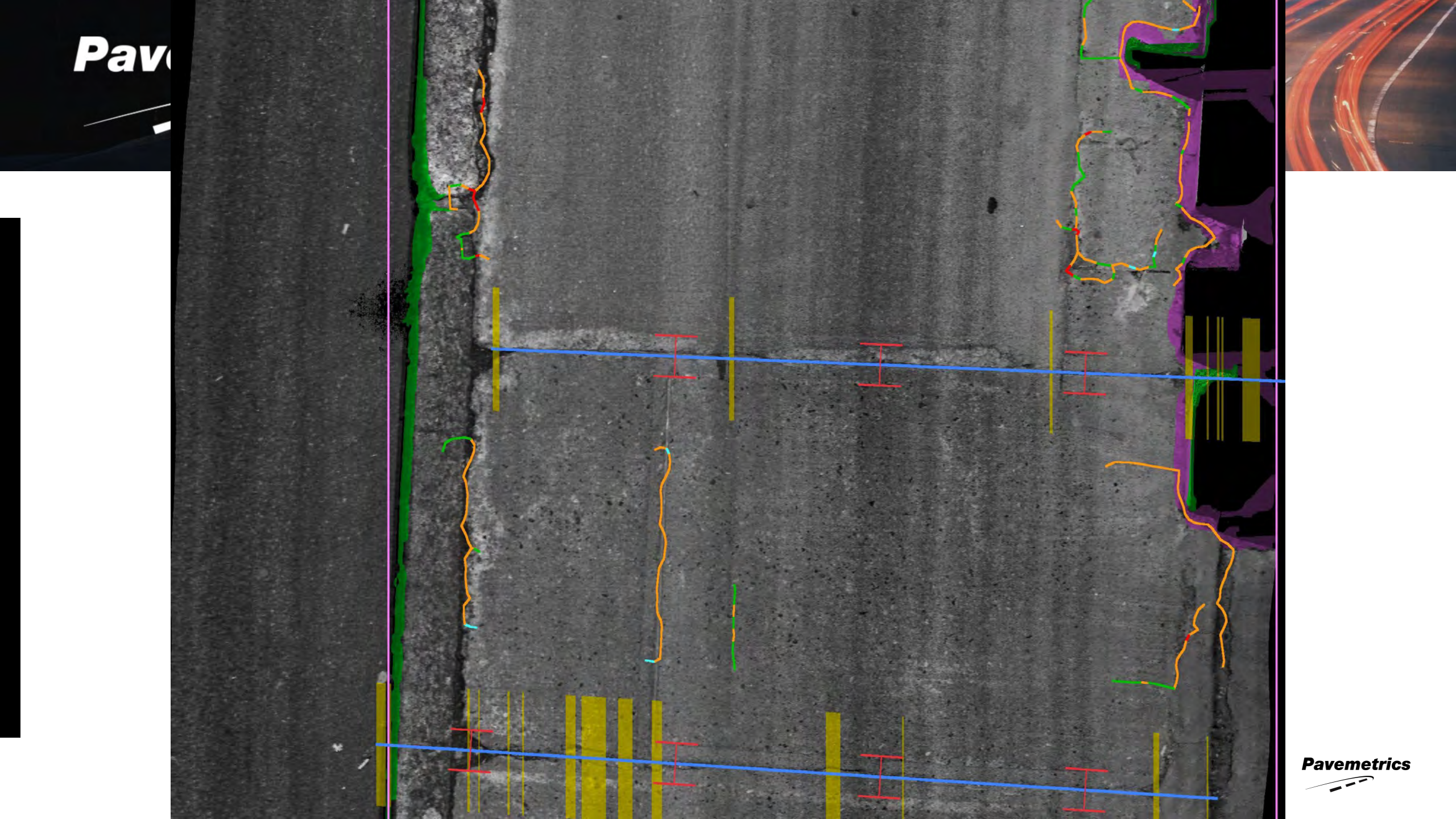

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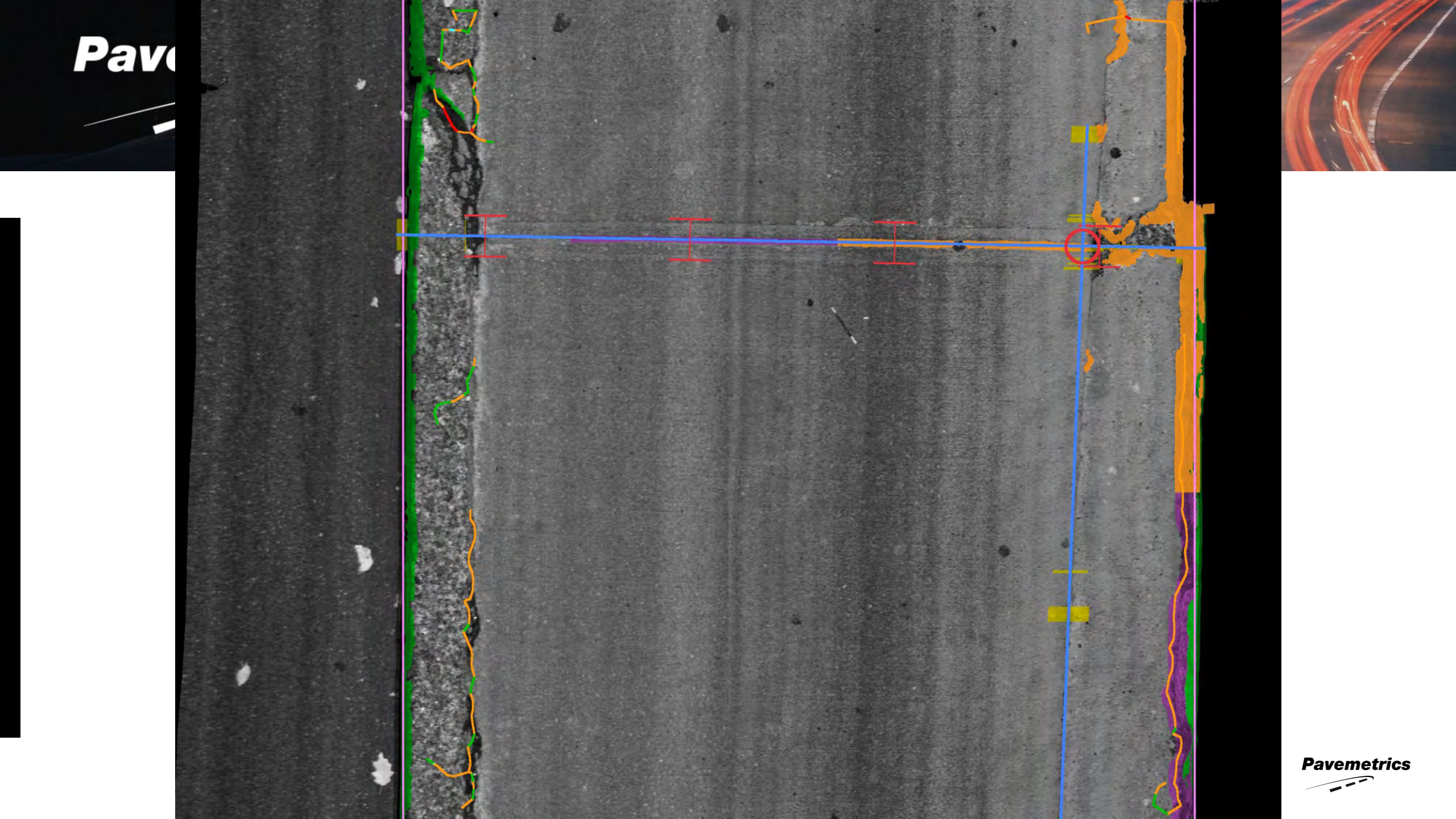

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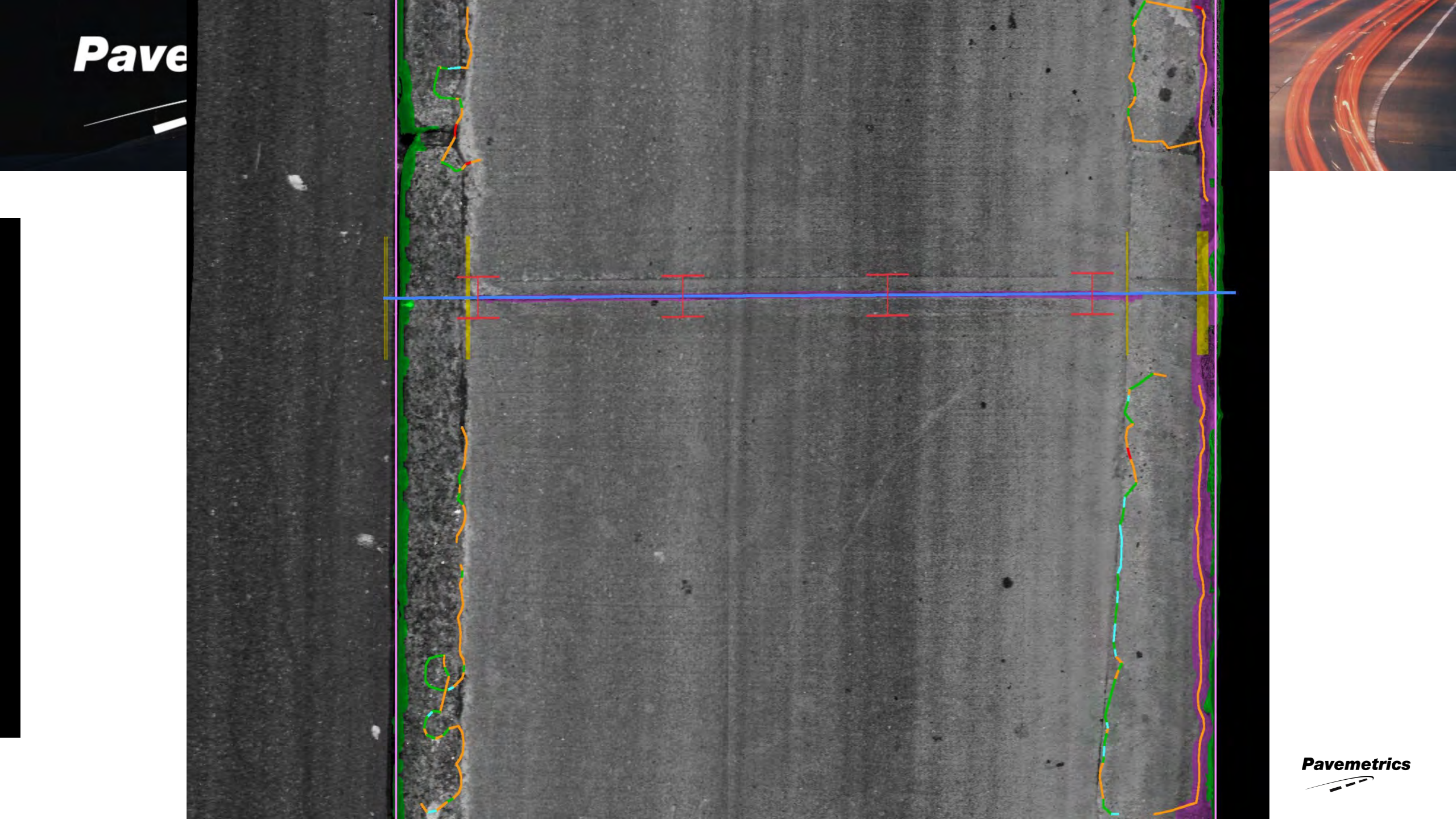
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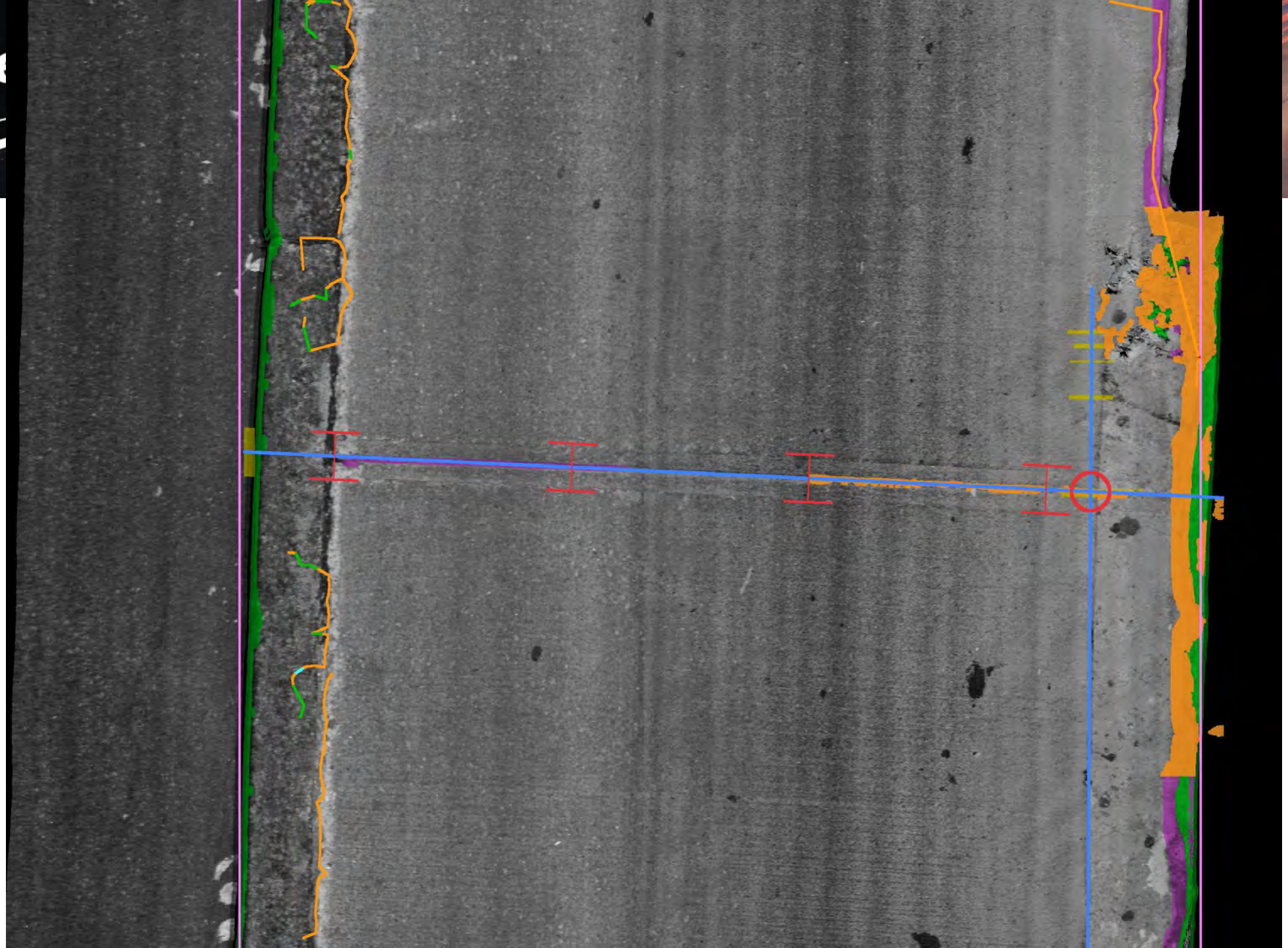

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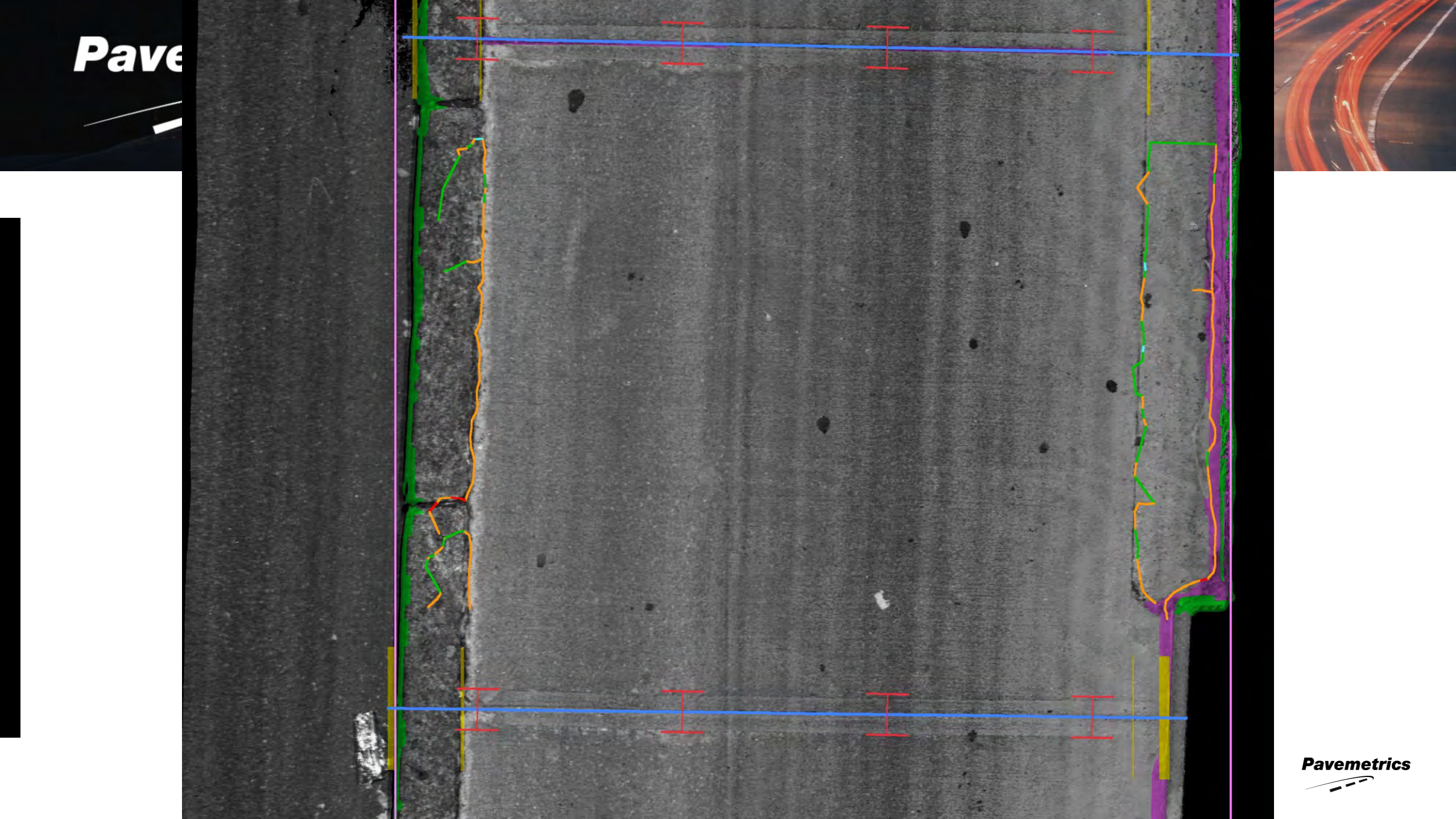

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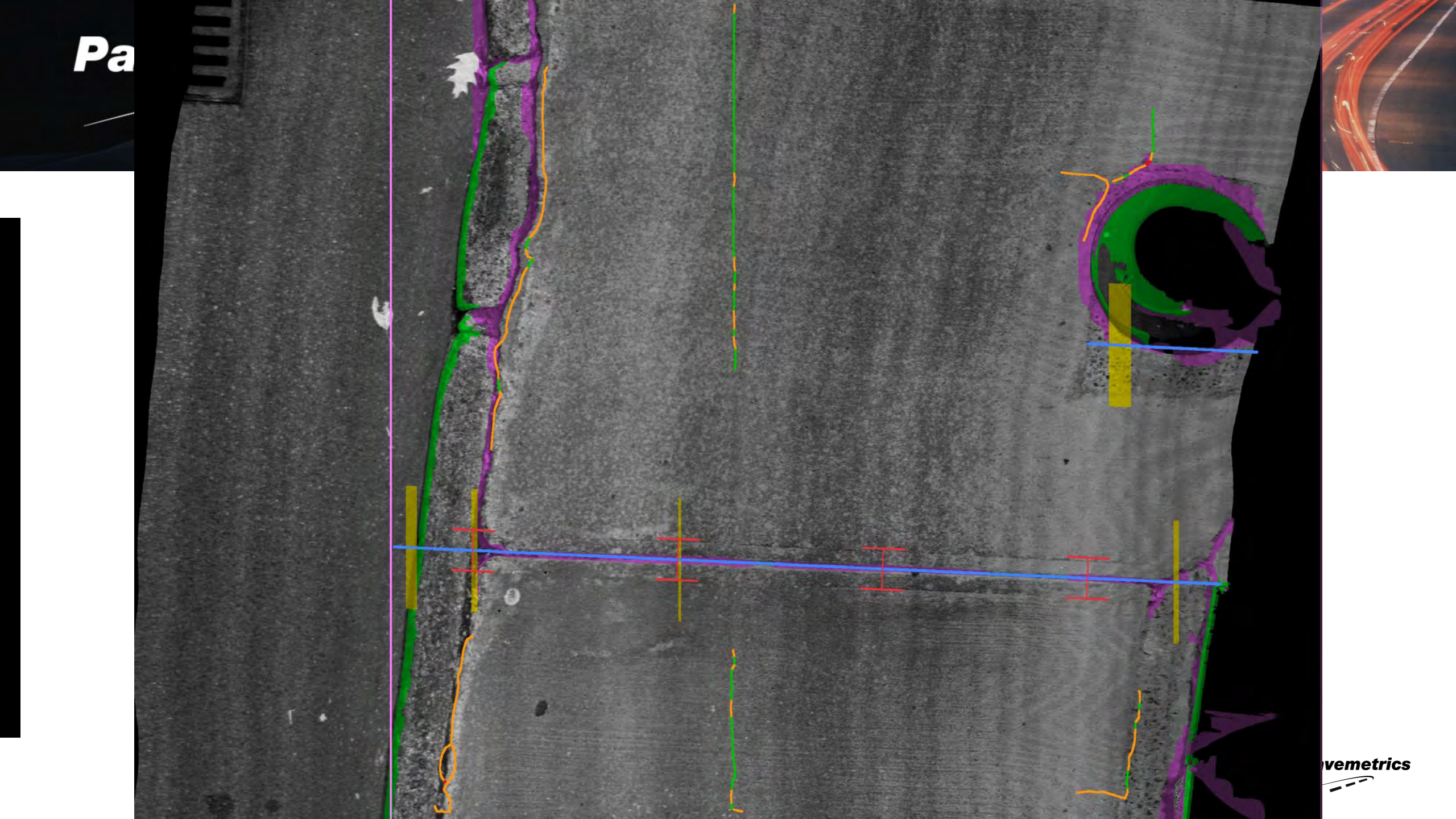

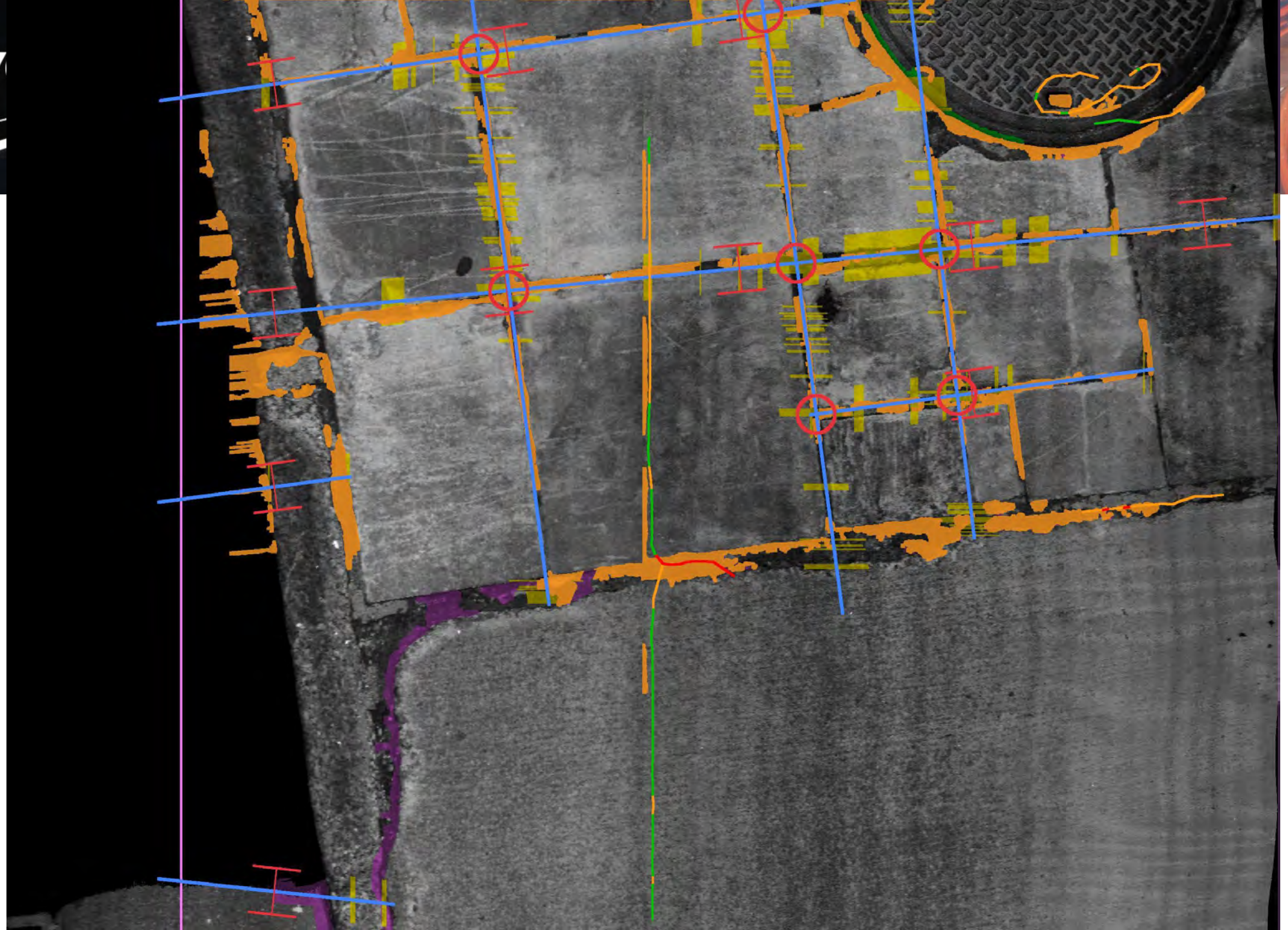

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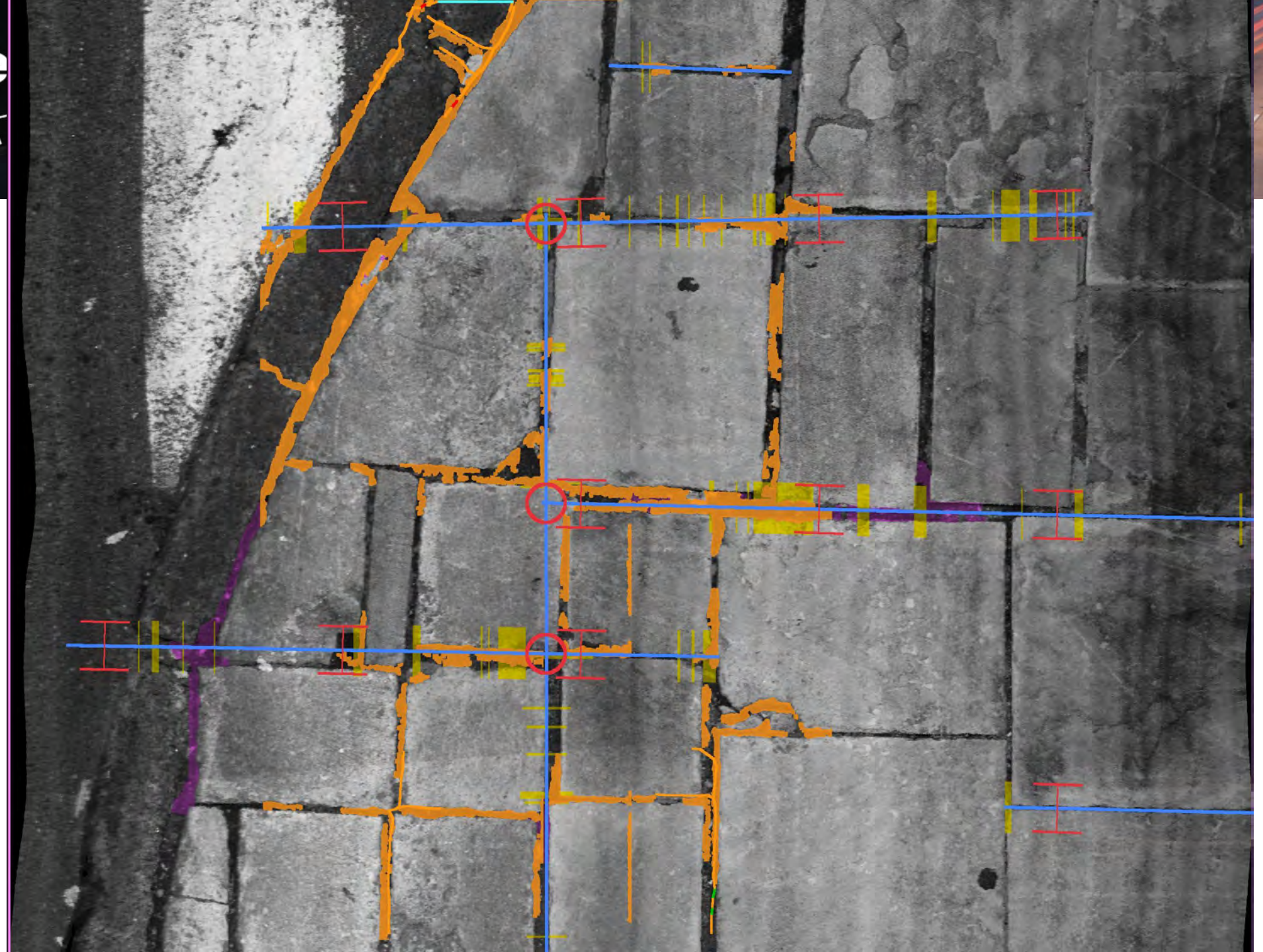

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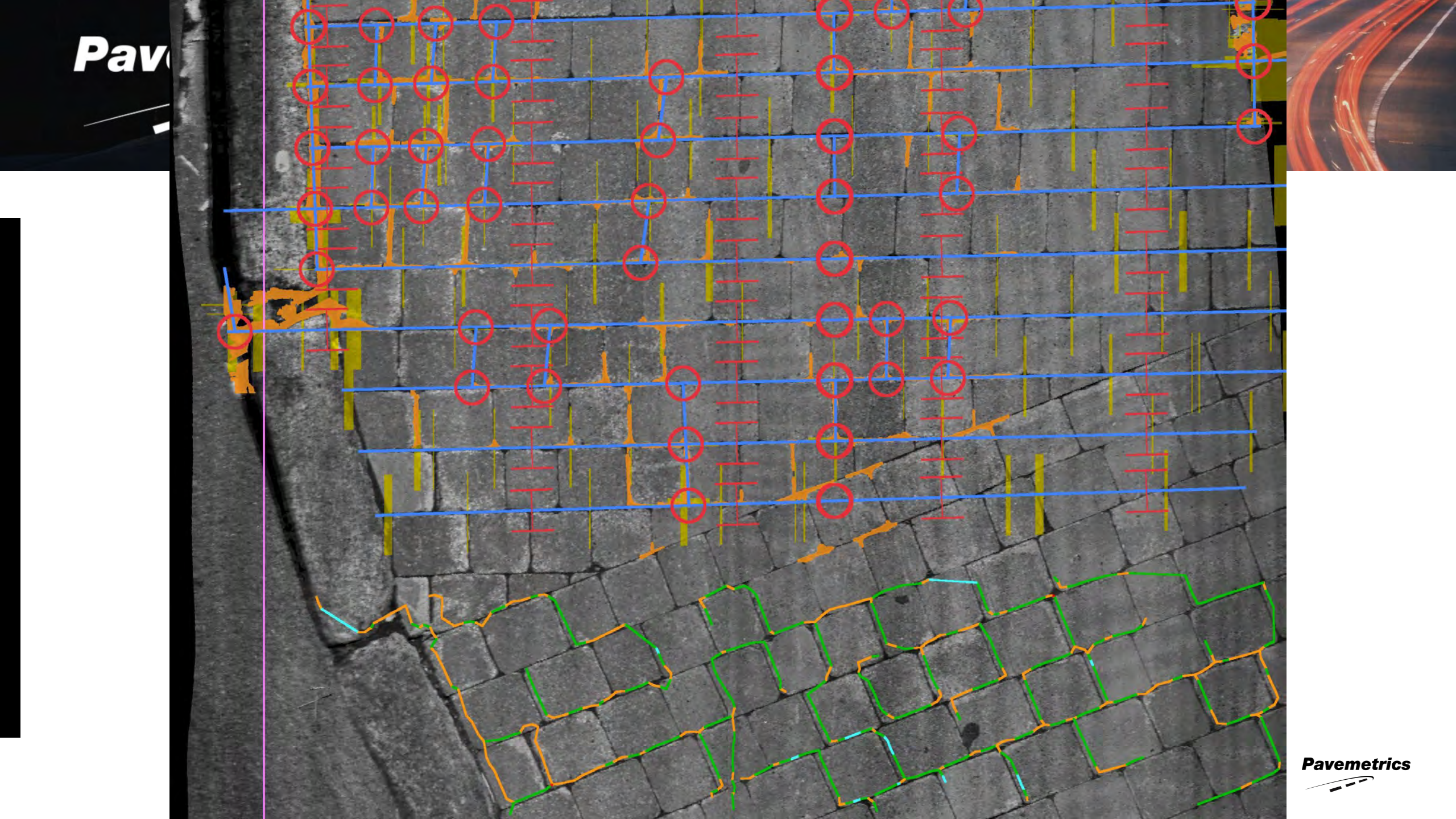
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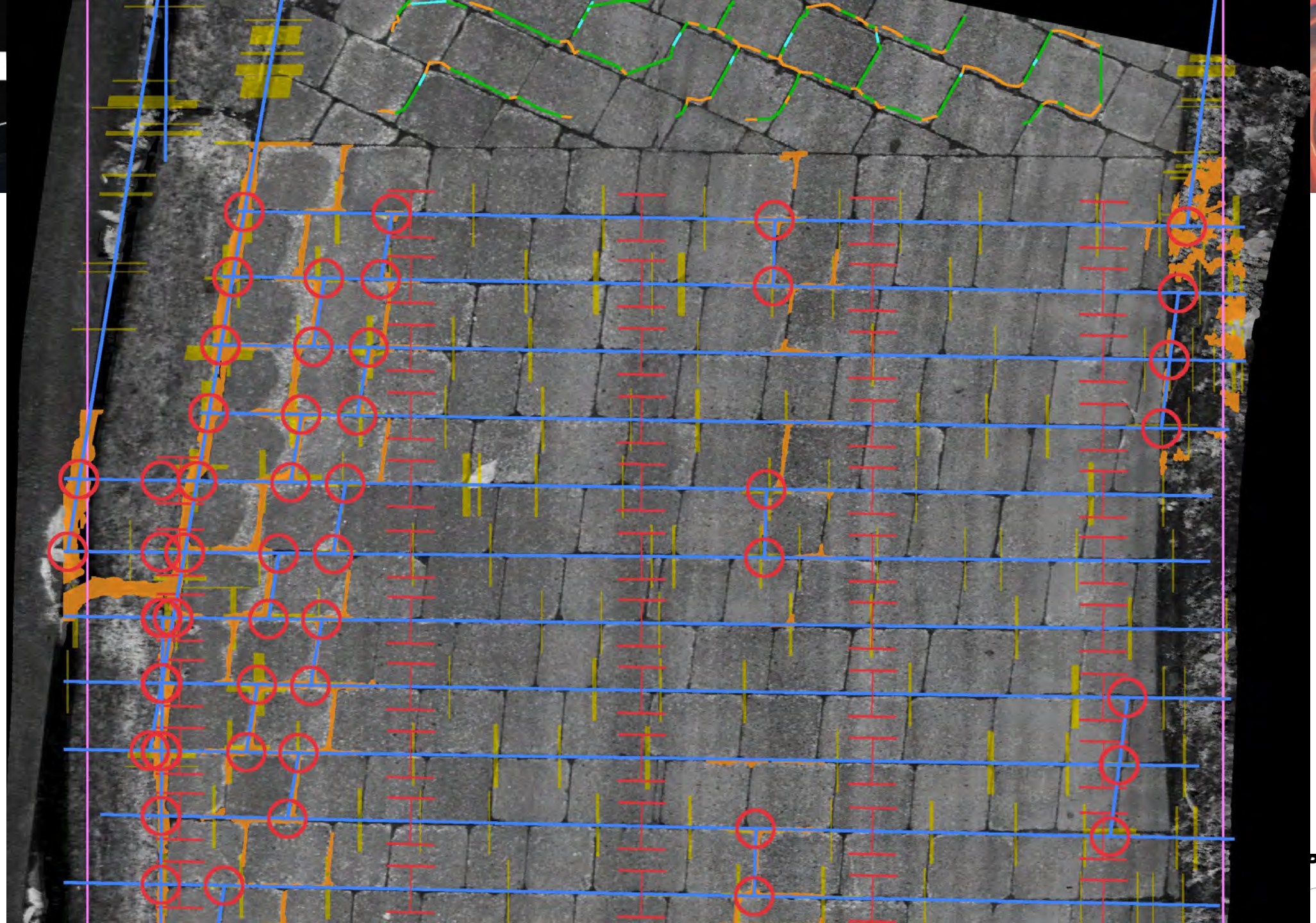

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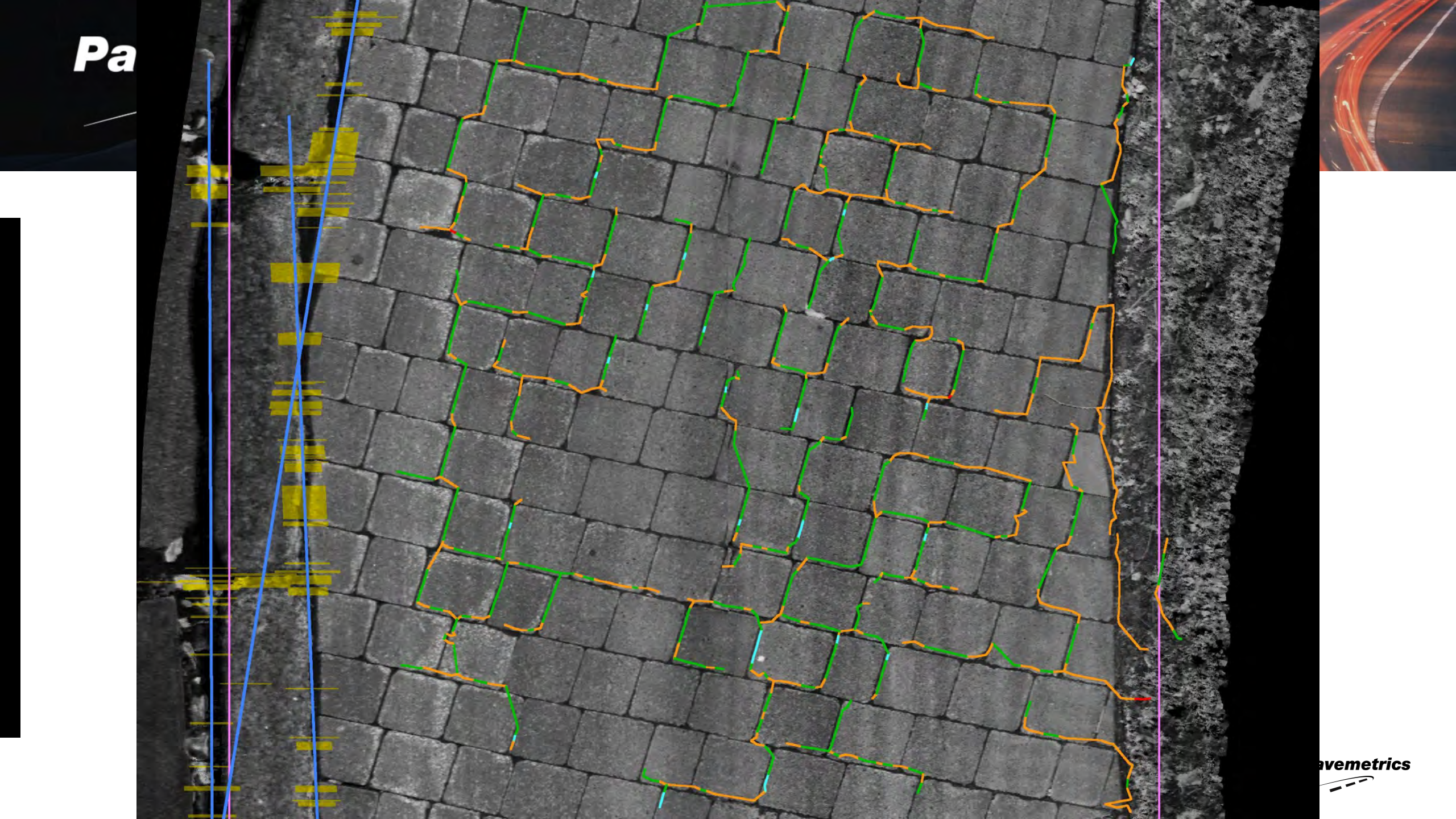

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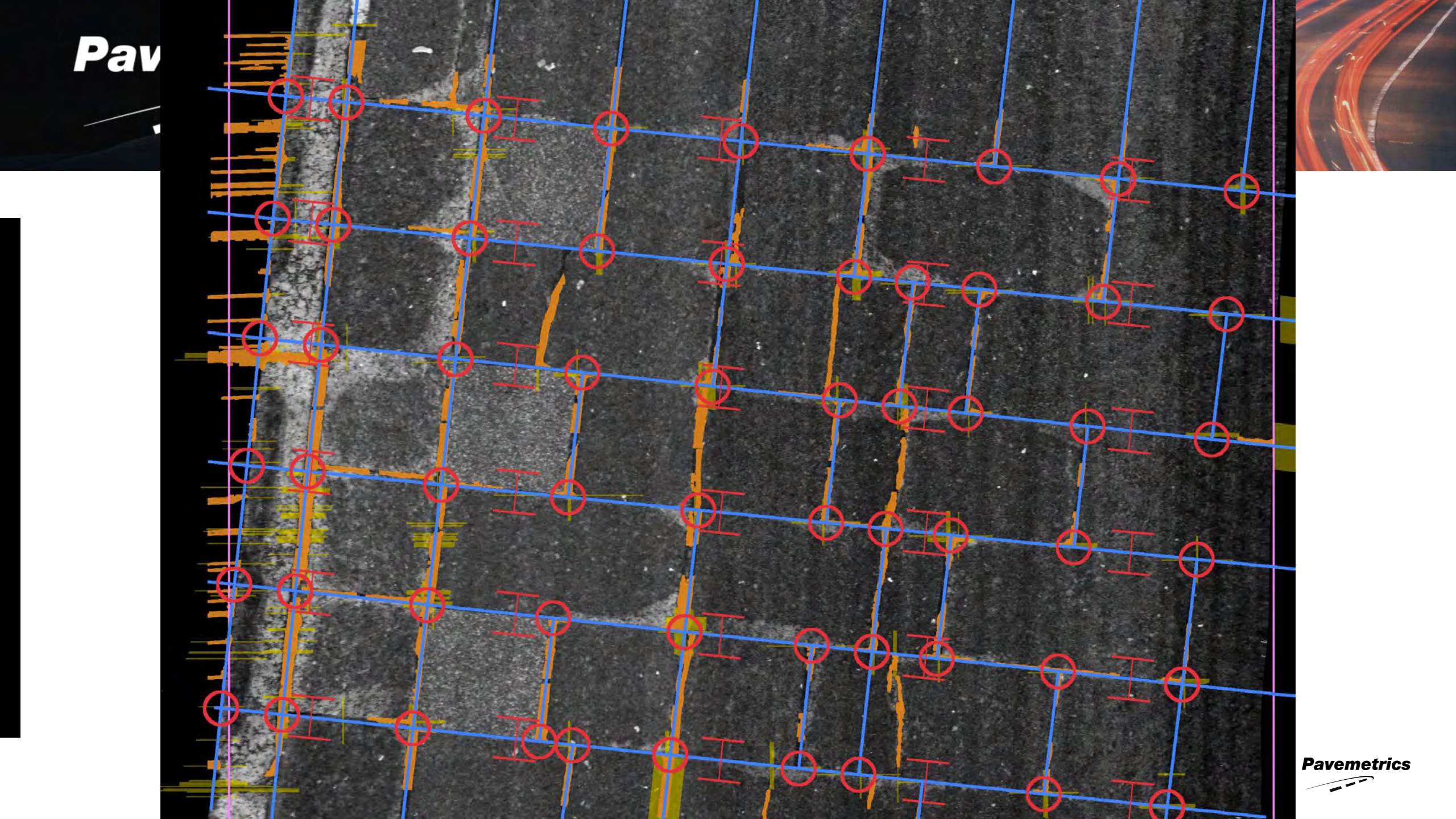
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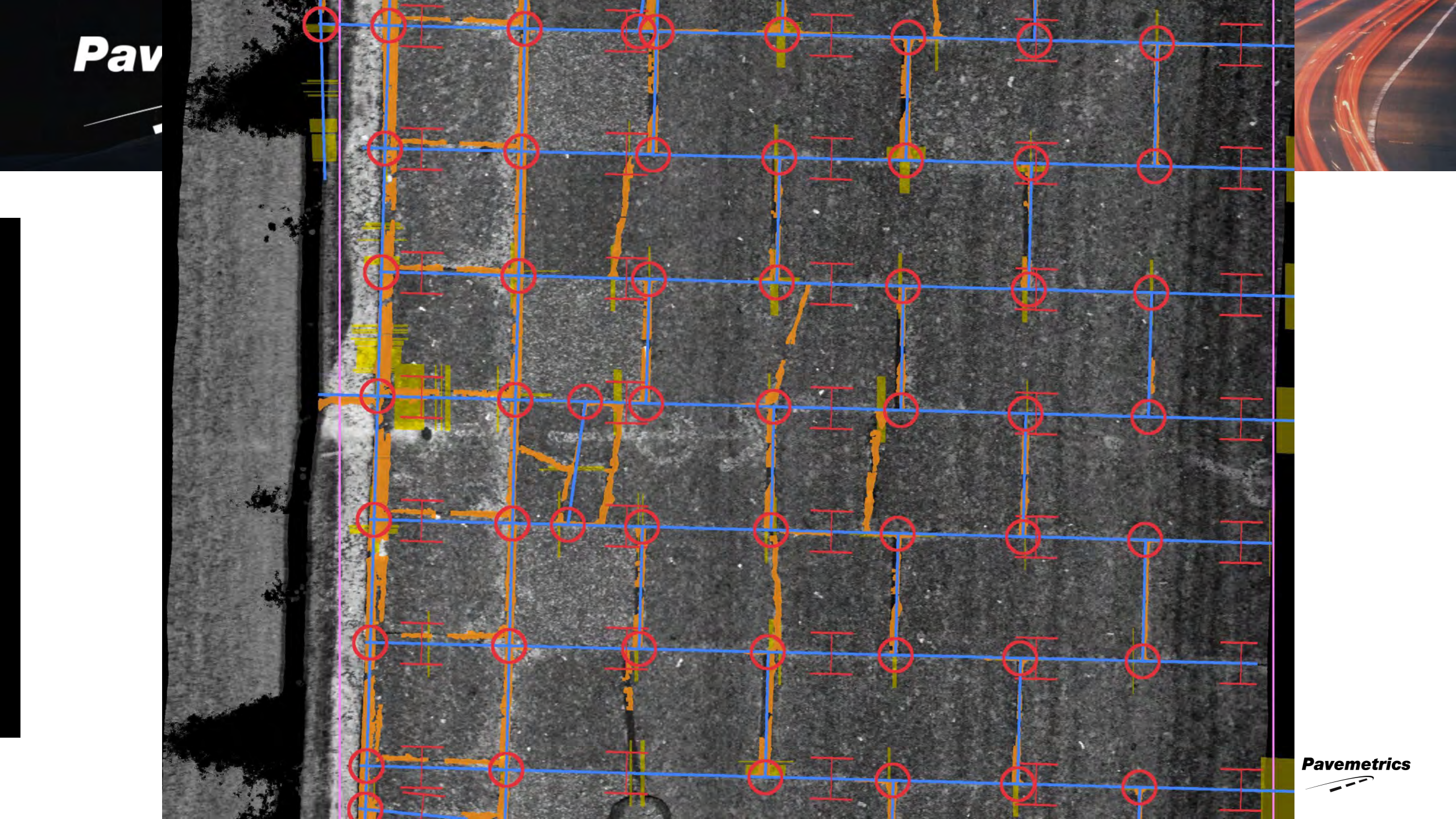
Pavemetrics

LCMS Sidewalk Measurement Capabilities

Requirement	LCMS Capability
Length and Width	Yes
Surface Type	Yes
Cracking and Spalling	Yes
Faulting	Yes
Slope and Cross-fall and Longitudinal Profile	Yes
Texture	Yes
Raised Features	Yes
Edge Drop Off	Yes