# Pavement Surface Evaluation beyond Cracking with Deep Learning

**Kelvin C.P. Wang**

**Oklahoma State University & WayLink Systems Corp**

**2019 RPUG & Pavement Evaluation Conference**

**Hotel Roanoke and Convention Center**

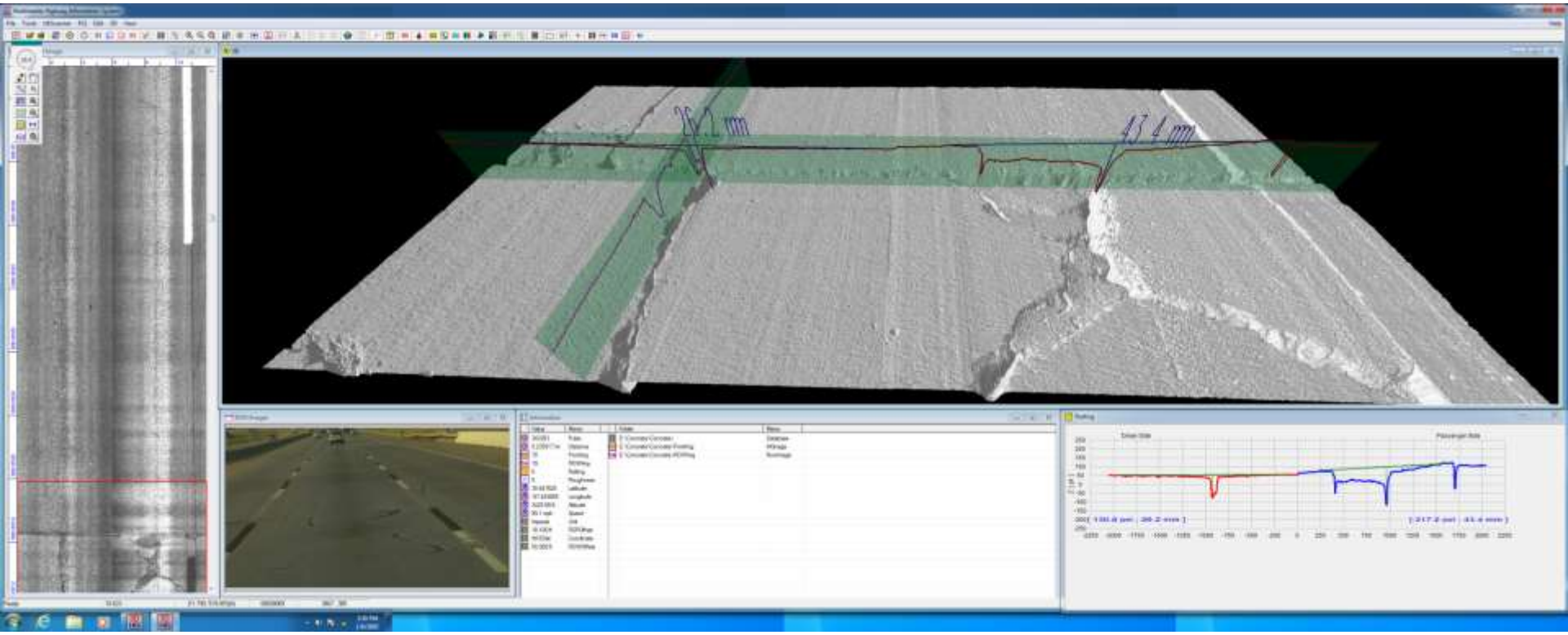
**Sept 19 2019**

# Four Parts

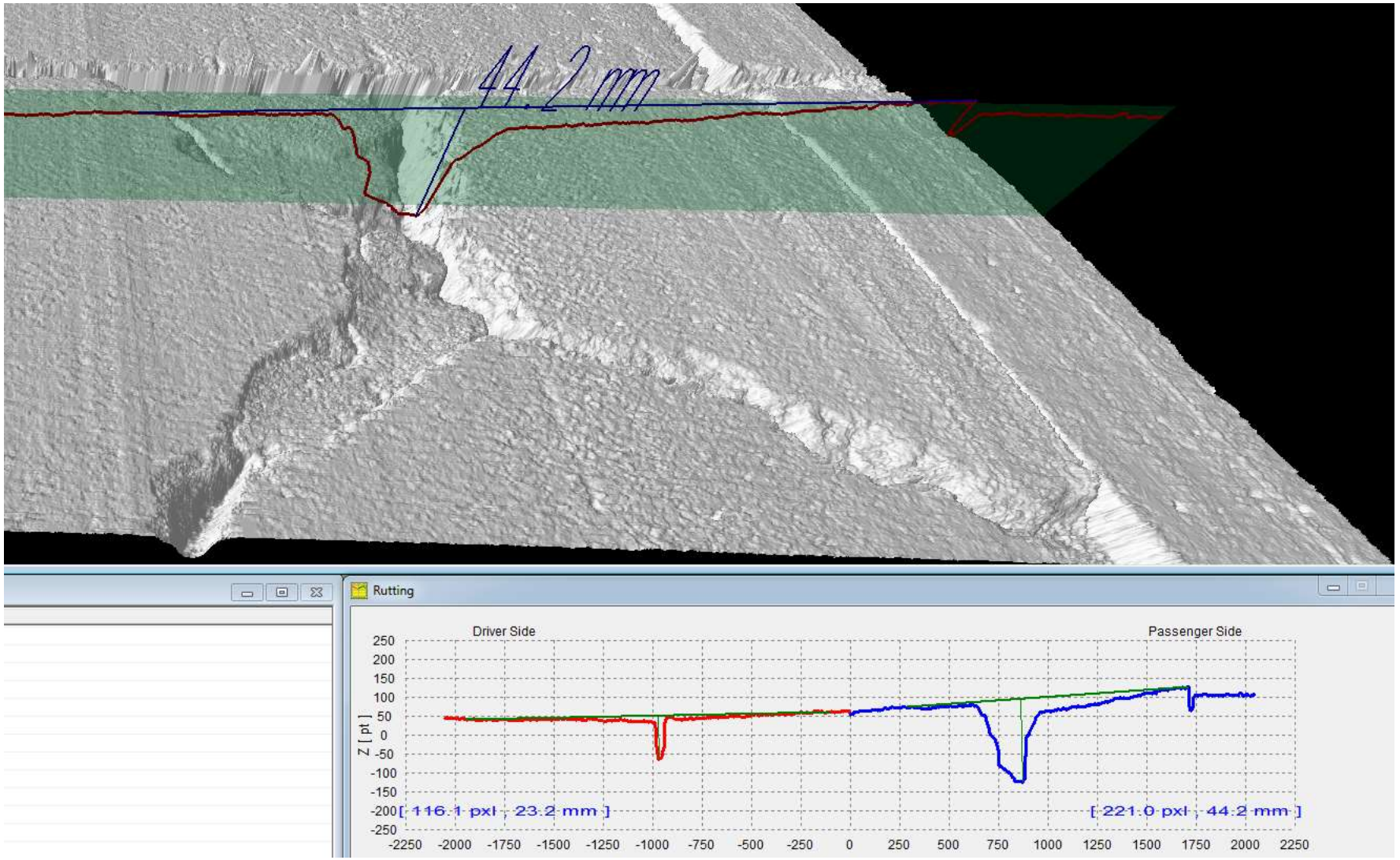
- 1 : From 1mm 3D to 0.5mm 3D
  - Pave3D 8K
- 2 : Deep-Learning based AI System for Automated Cracking Analysis
- 3 : Non-Cracking Analysis with Deep-Learning
- 4 : 0.1mm 3D for Safety Analysis

# Part 1: Current Applications of 3D Laser Imaging

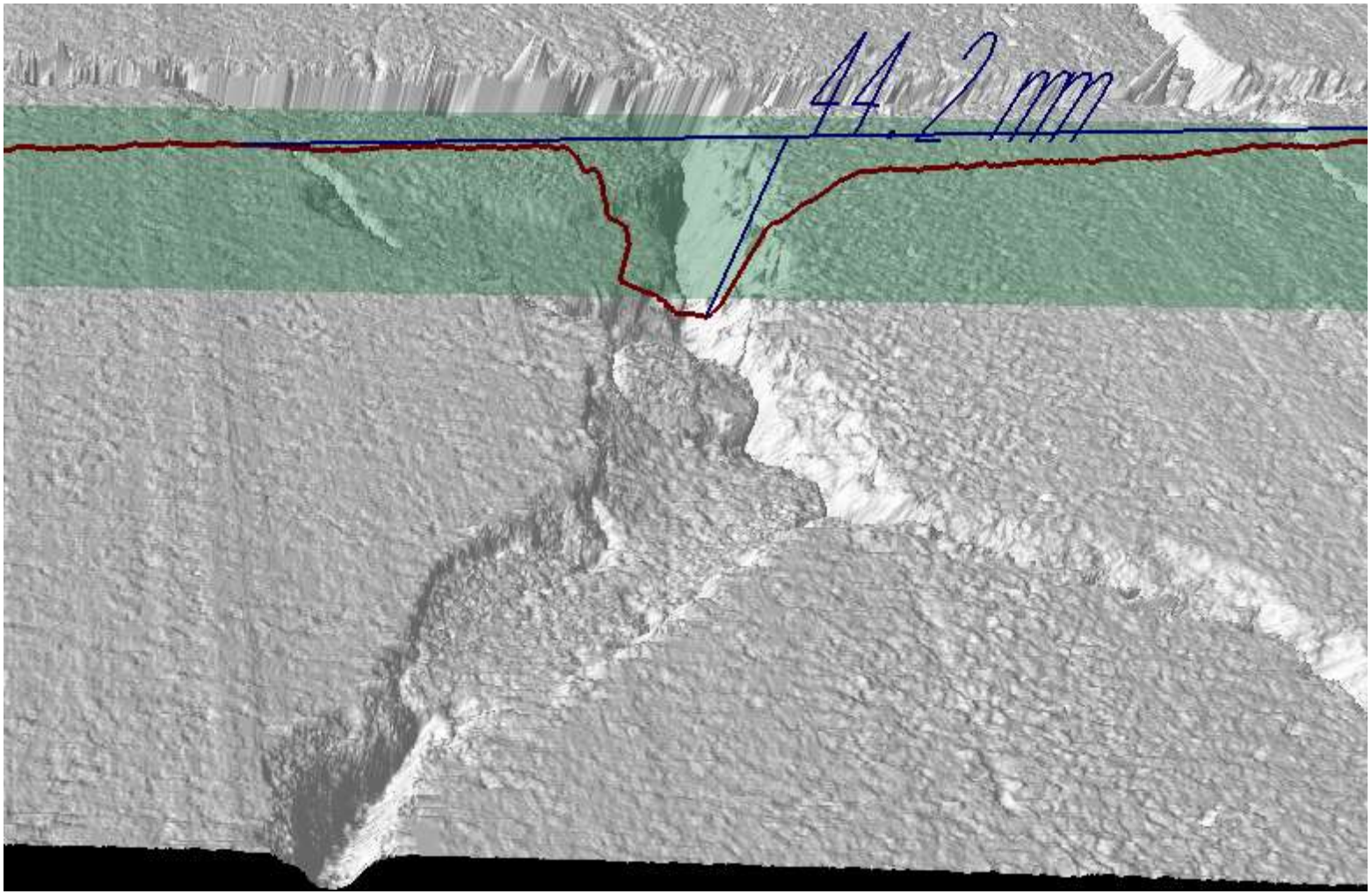
# Sample 3D Data at 1mm Resolution Collected at 60MPH 10 Years Ago



# Sample 3D Data at 1mm Resolution Collected at 60MPH 10 Years Ago



# Sample 3D Data at 1mm Resolution Collected at 60MPH 10 Years Ago



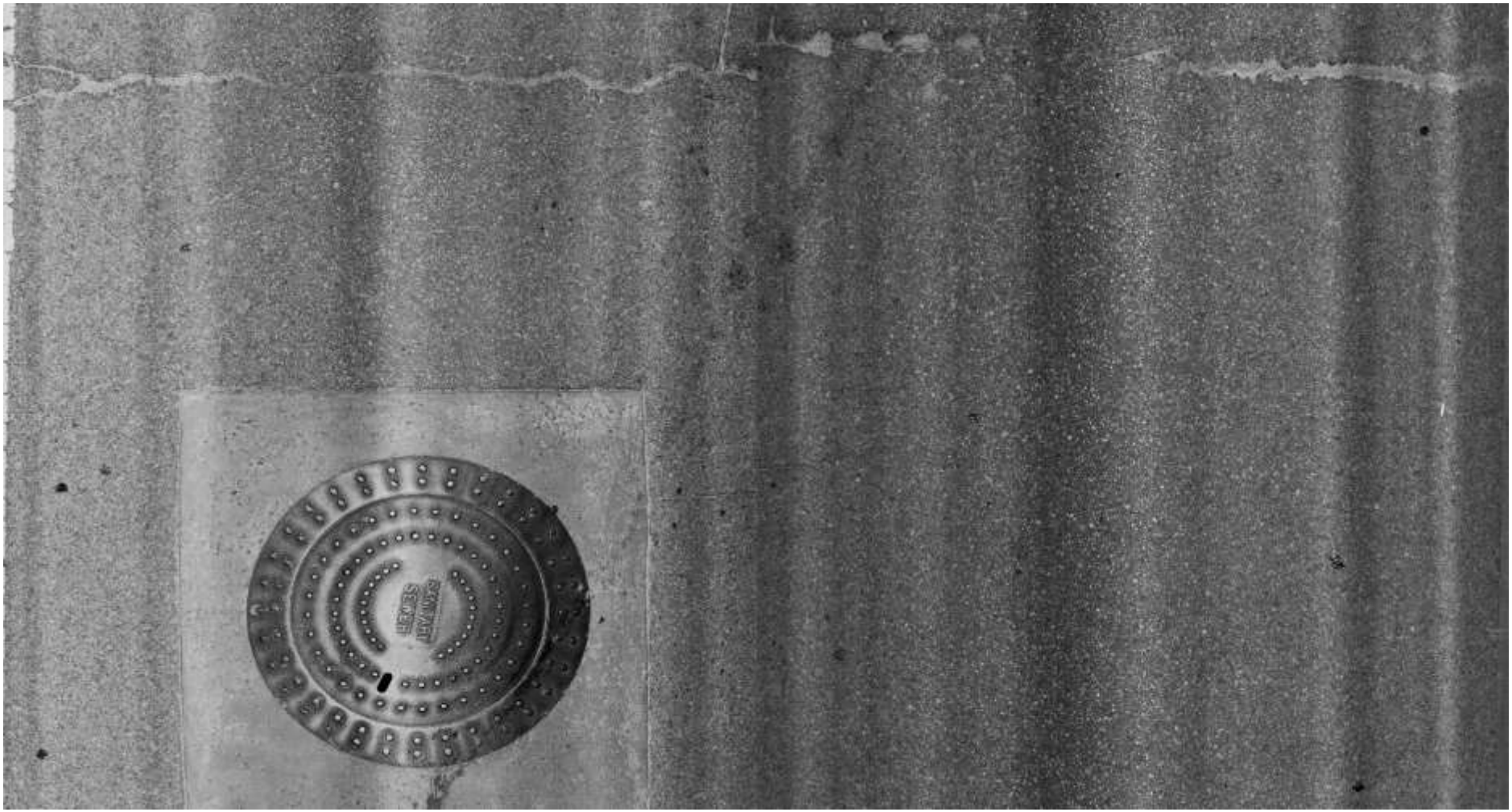
# Pave3D 8K: the Next-Generation

- More than 8,000 Pixels in 2D & 3D in the Transverse Direction, Covering Full-Lane
- 30KHz Line Rate in the Longitudinal Direction: 1mm longitudinal resolution at 60MPH
- Compatible with Current Deep-Learning Solutions
- Built-In Inertial Sensor for Longitudinal Profiling
- Cracking/Rutting/Patching/Pothole/Sealed Cracking, et al, and IRI

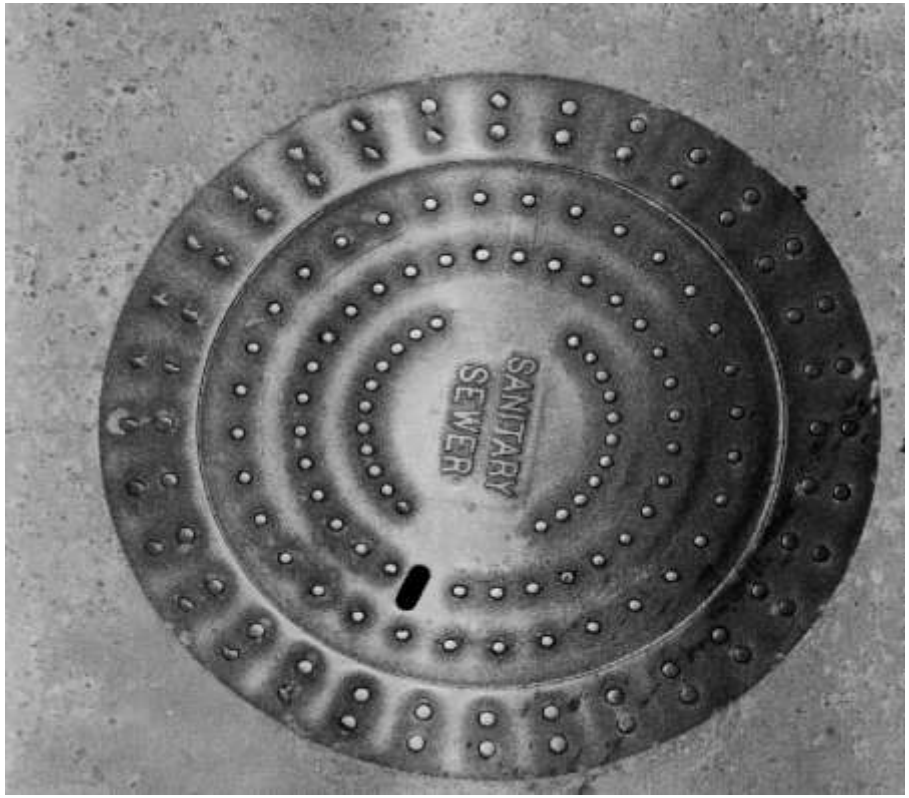
# Pave3D 8K in Truck Mount

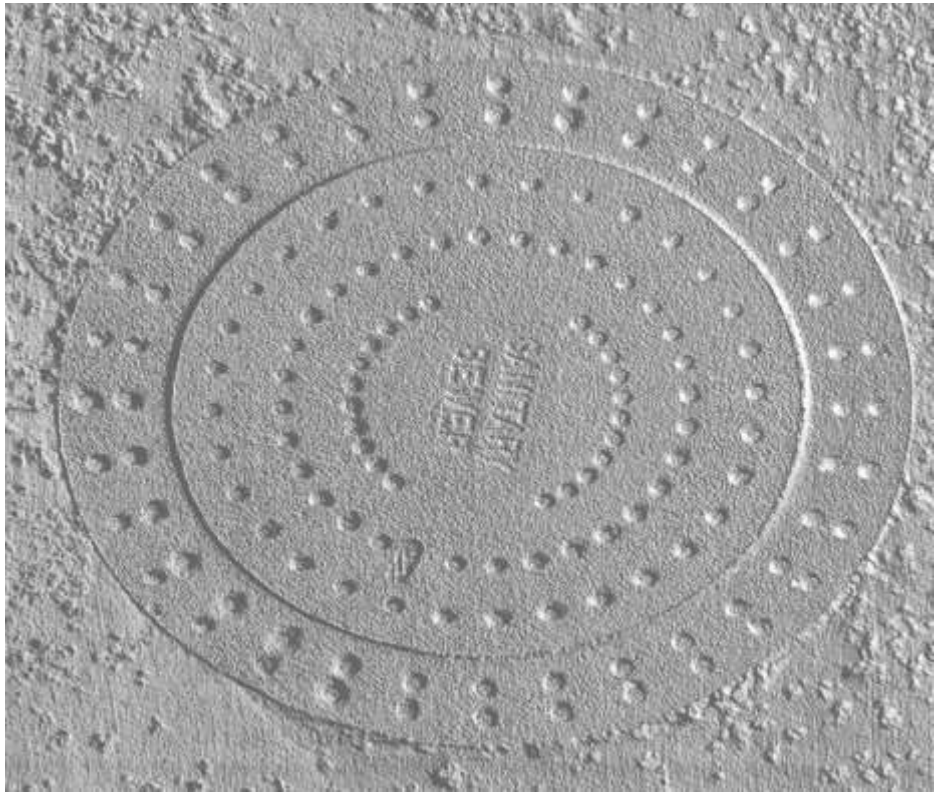
# New Sensor Design

# Sample Data of Manhole, Full-Lane 2D

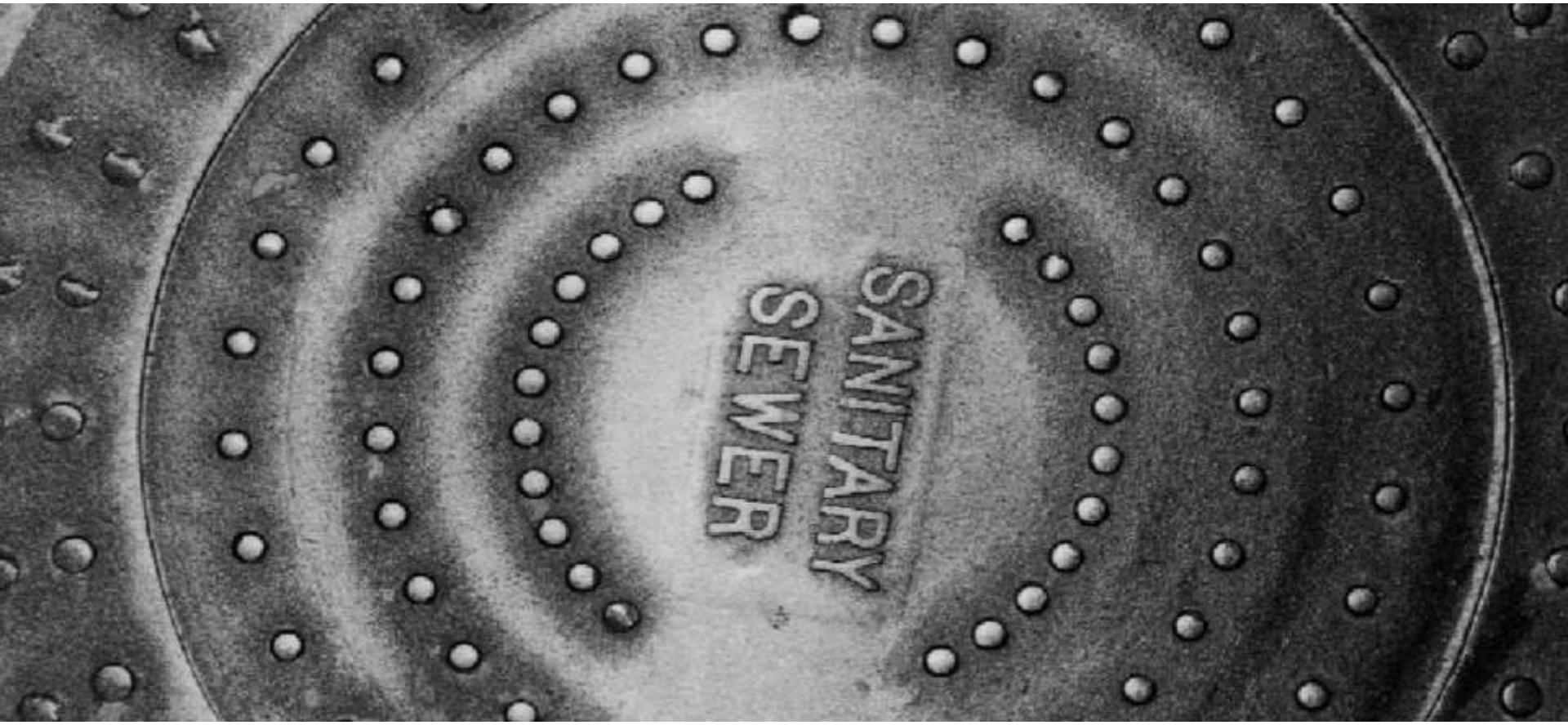


# Sample Data of Manhole, 2D & 3D

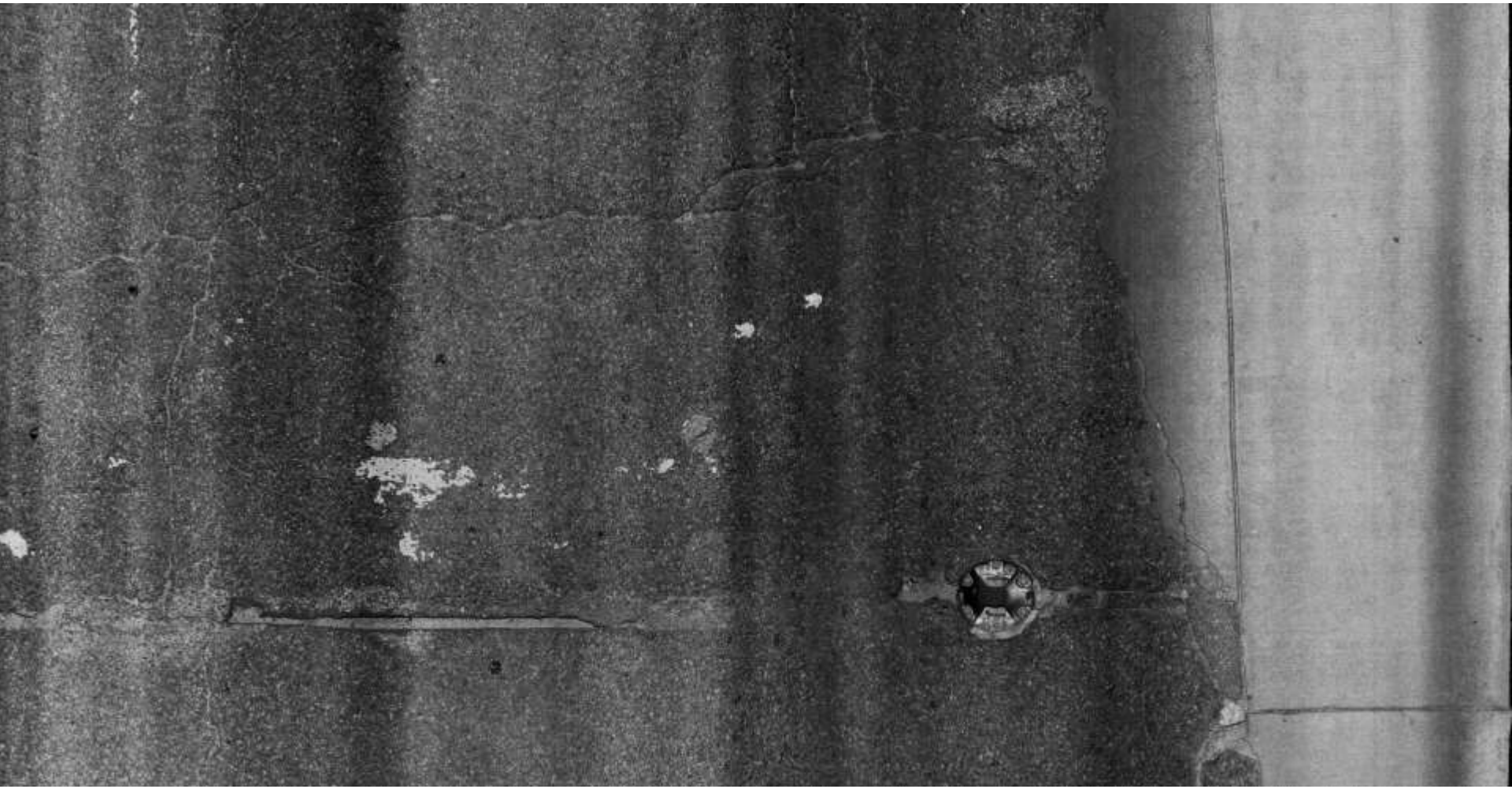


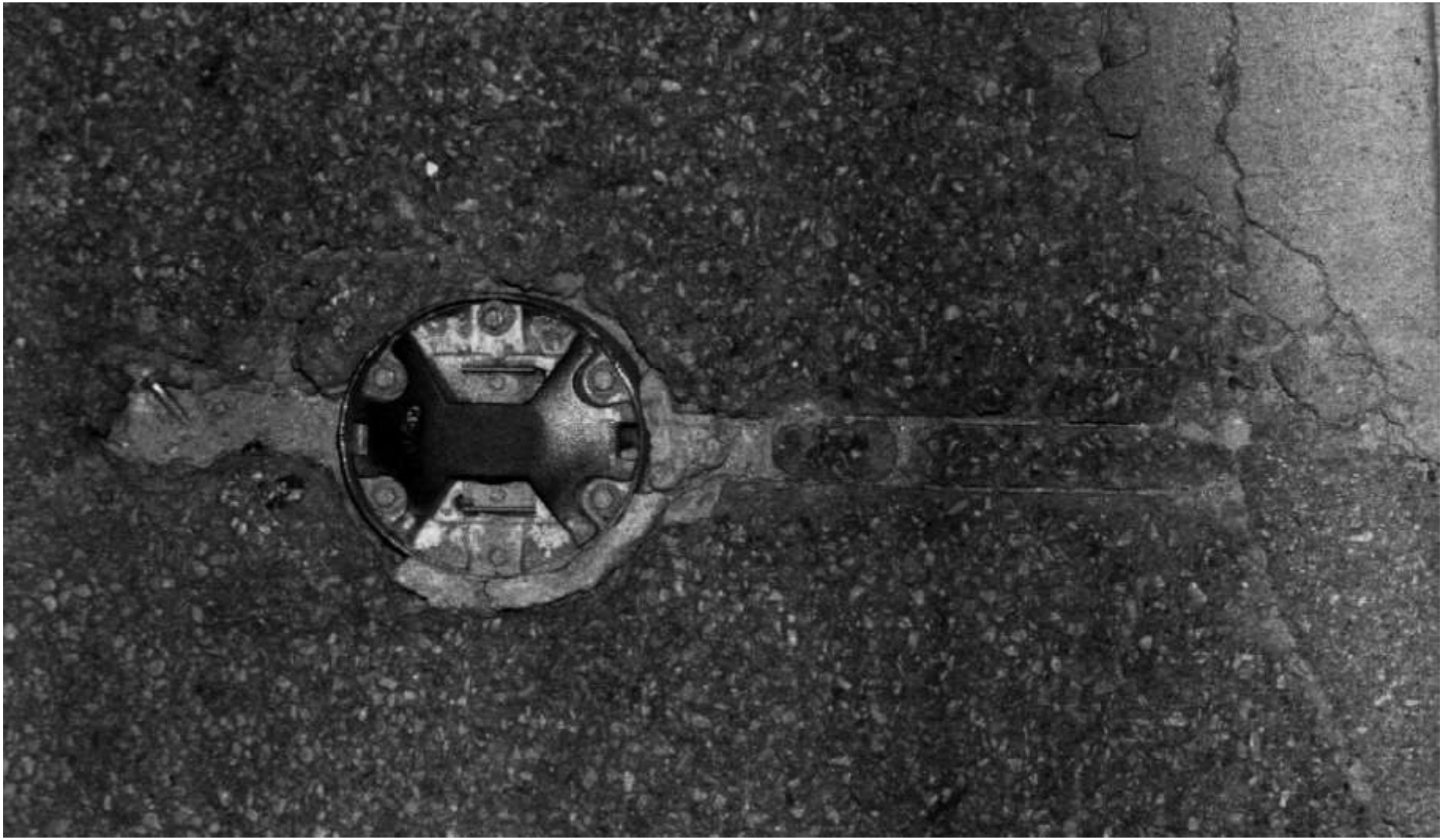
# Sample Data of Manhole, Zoomed-In 2D



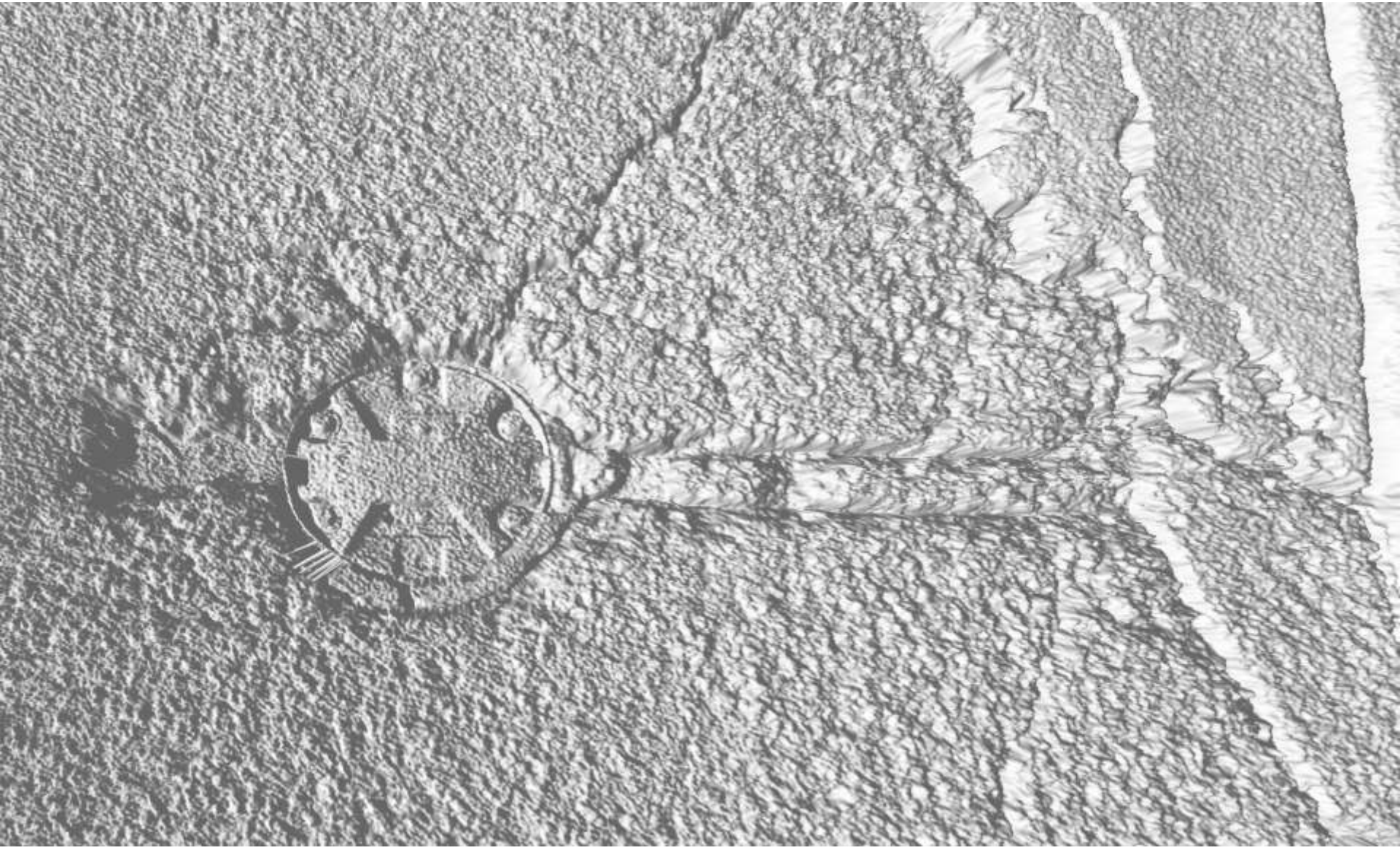
# Light Reflector, Full-Lane Width



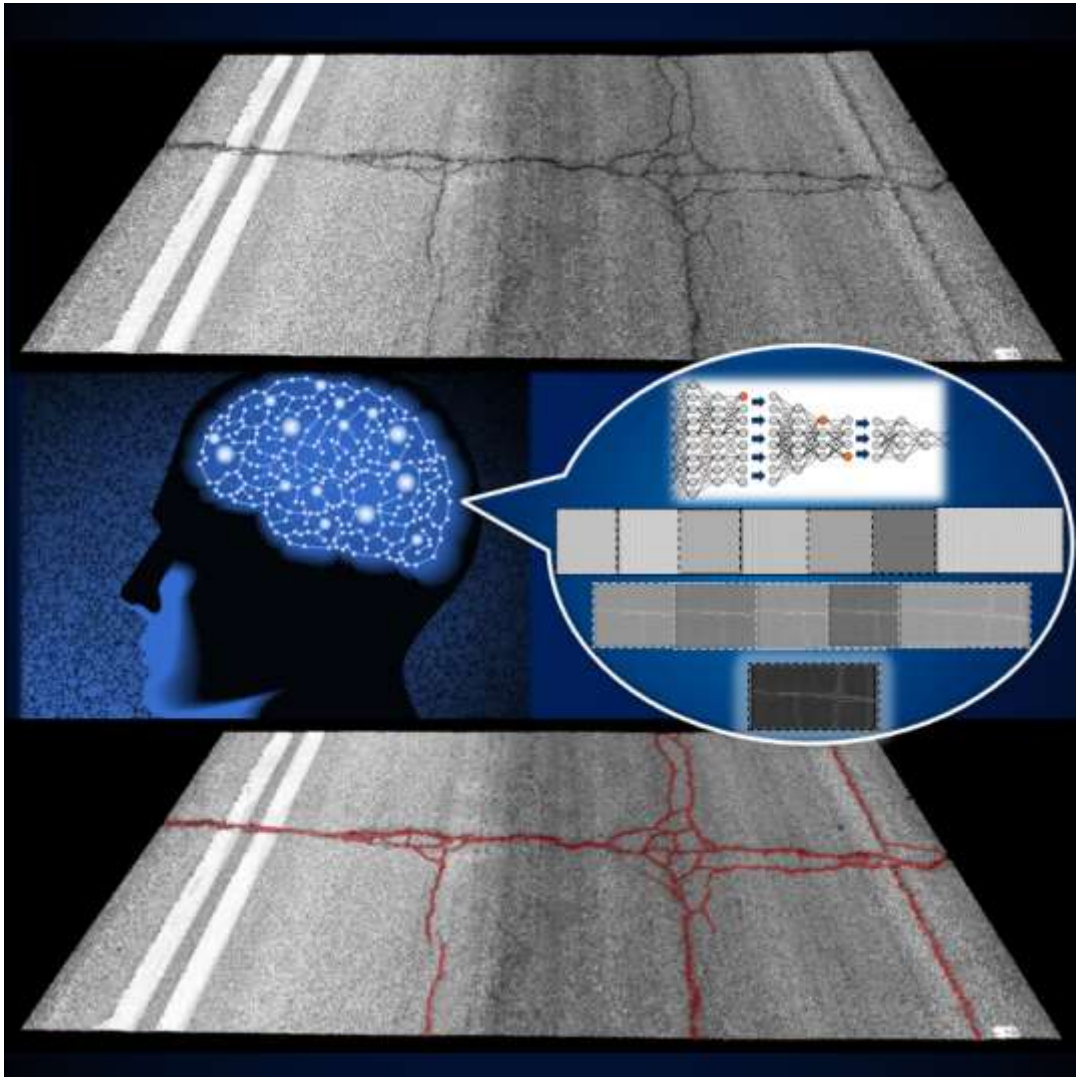
# Light Reflector, Zoomed-In 2D



# Light Reflector, Zoomed-In 3D

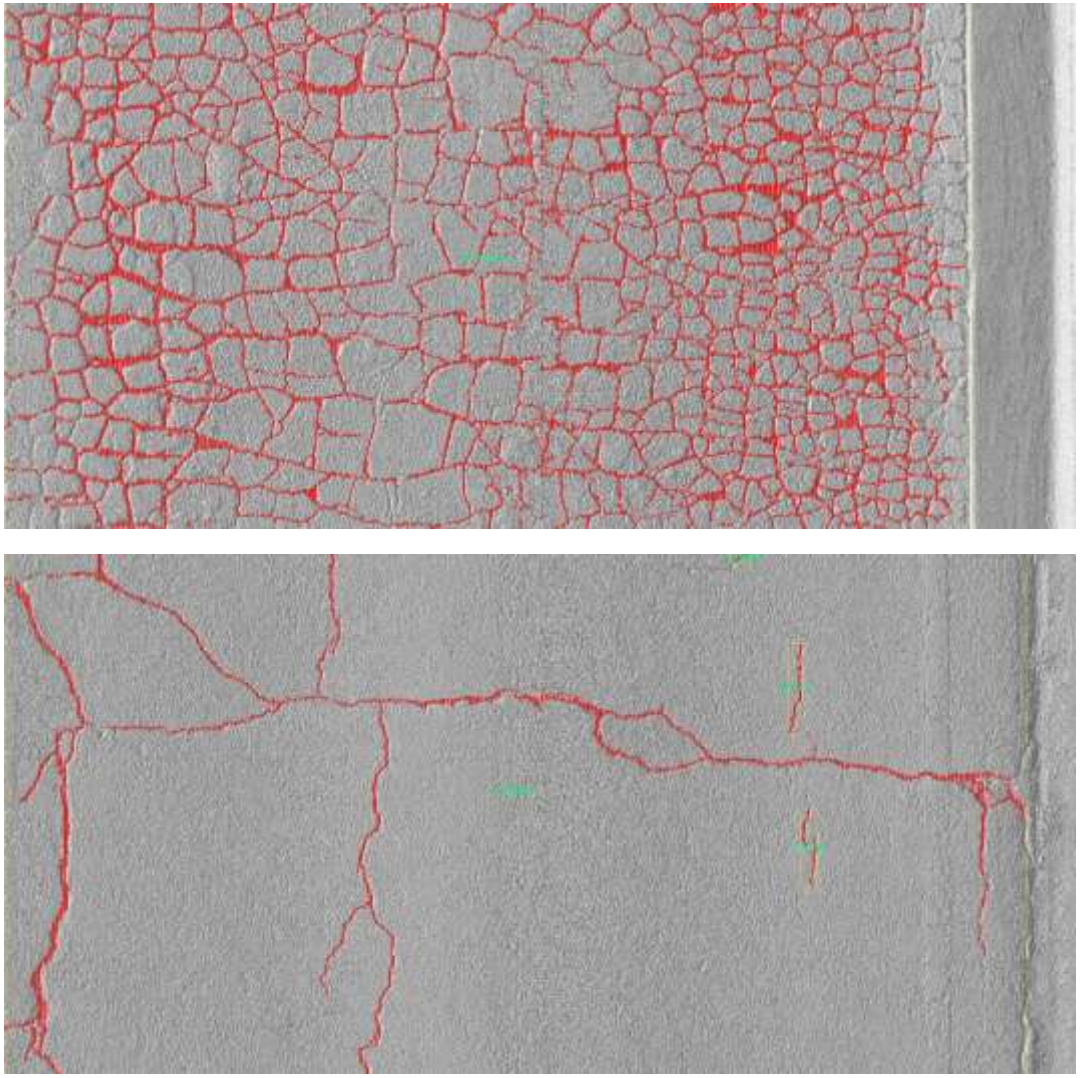


# AI Analysis based on Deep-Learning

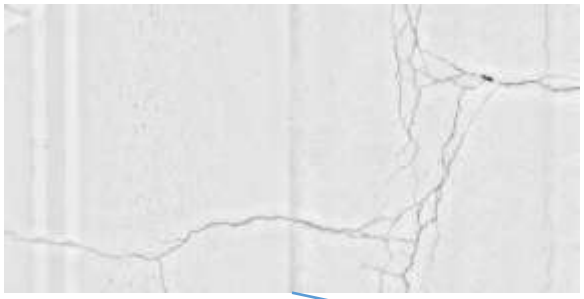


- Pixel Level Recognition
- Deep-Learning based Neural Network
- Big-Data with Parallel Processing
- Stability, Consistency, High-Speed, and Accuracy

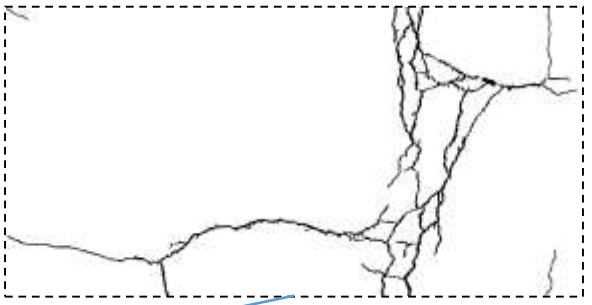
# Learning Database ： Critical for Successful Learning



# CrackNet: from Training to Operation

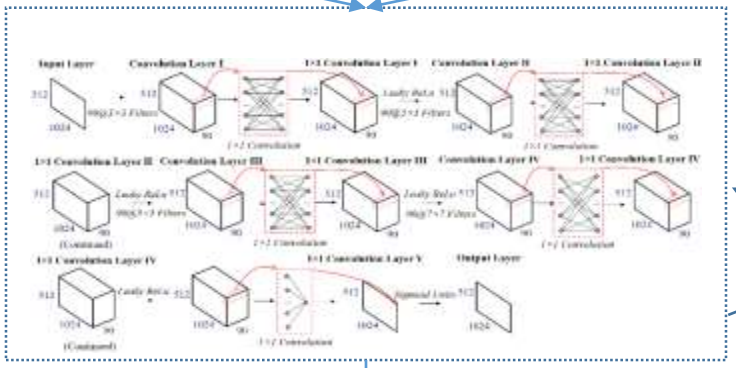


Input Image

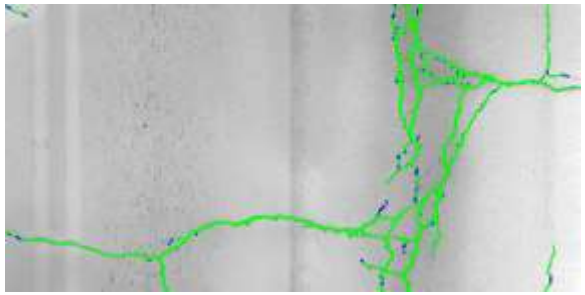


Ground Truth with Pixel-Perfect Accuracy

DL Network

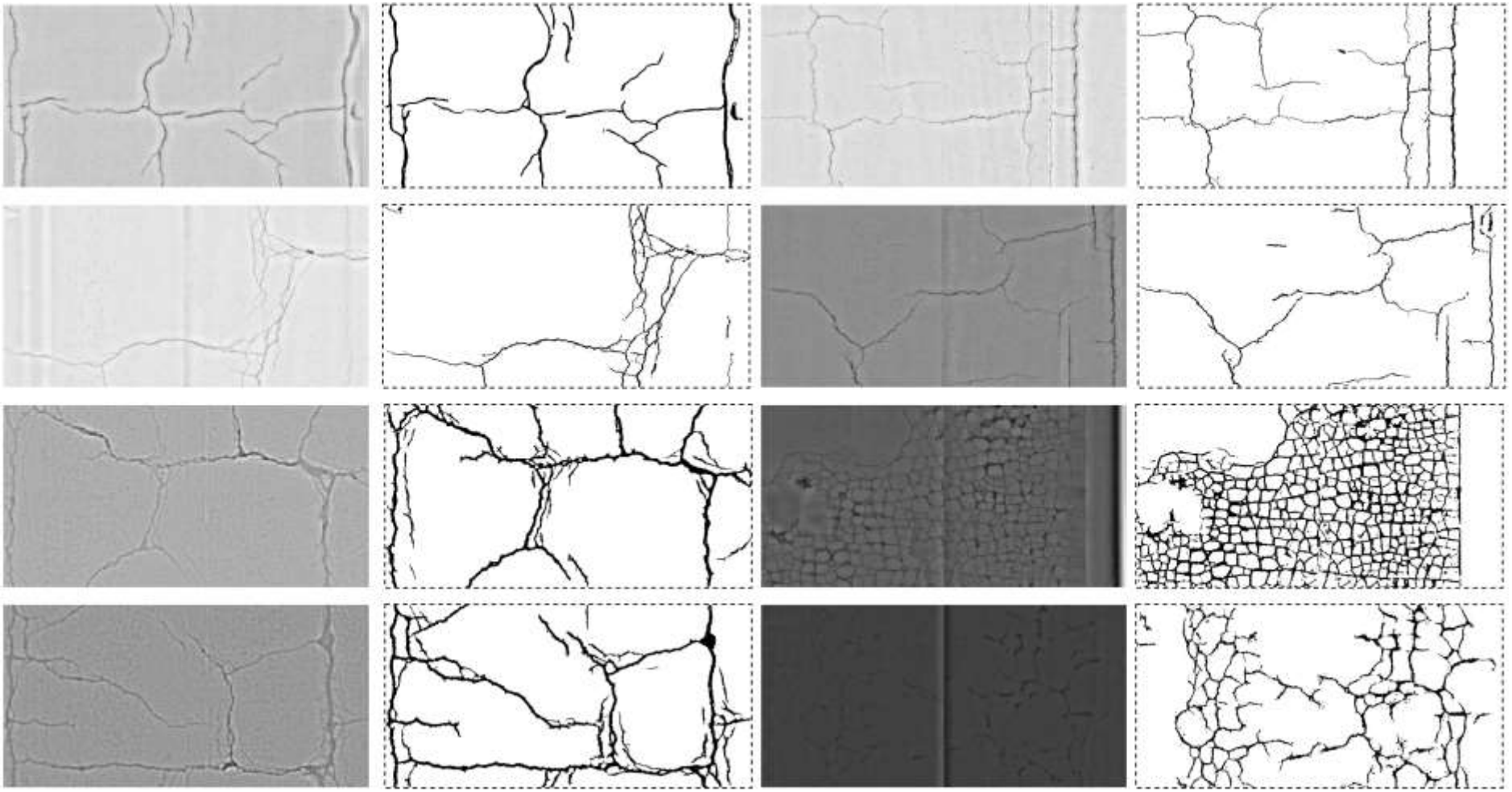


Recursive Training



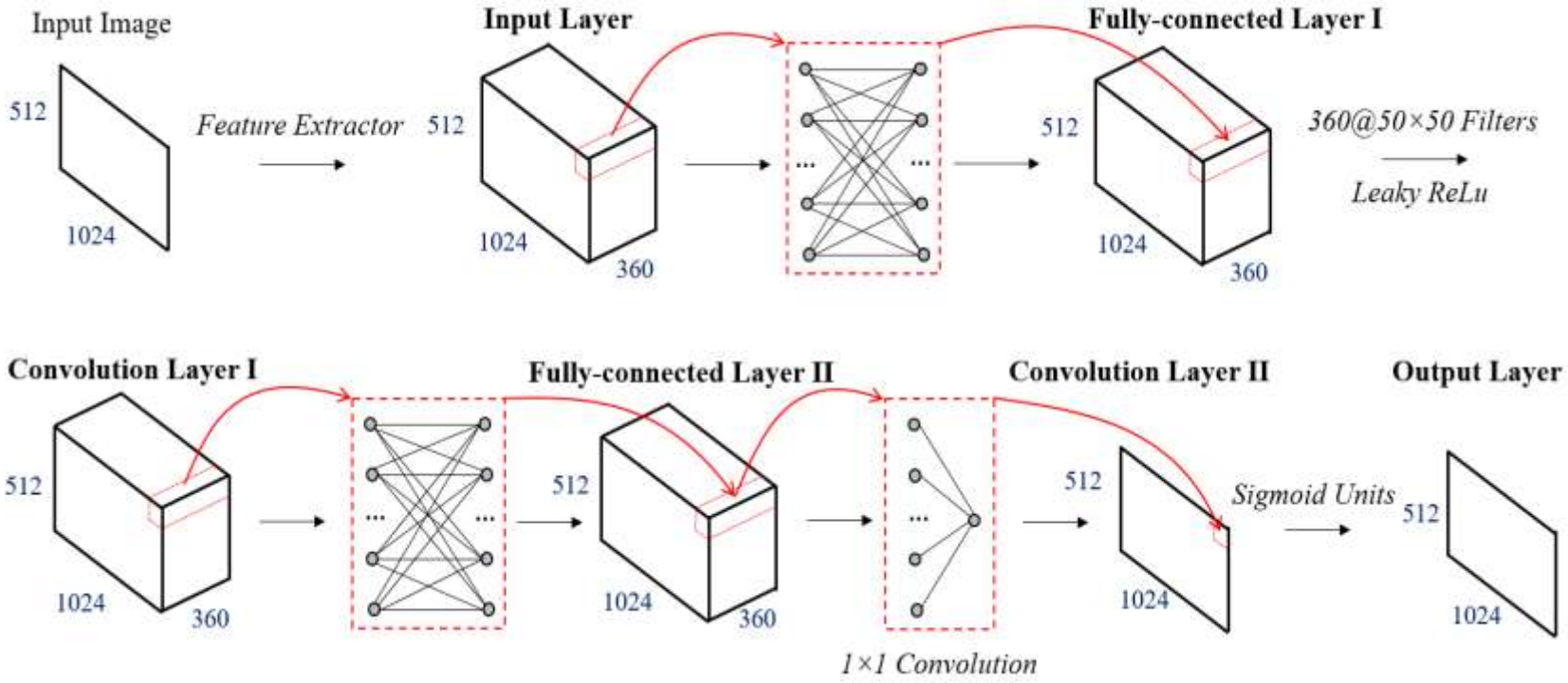
Detection Output with Pixel-Level Accuracy

# Pixel Level Intelligence



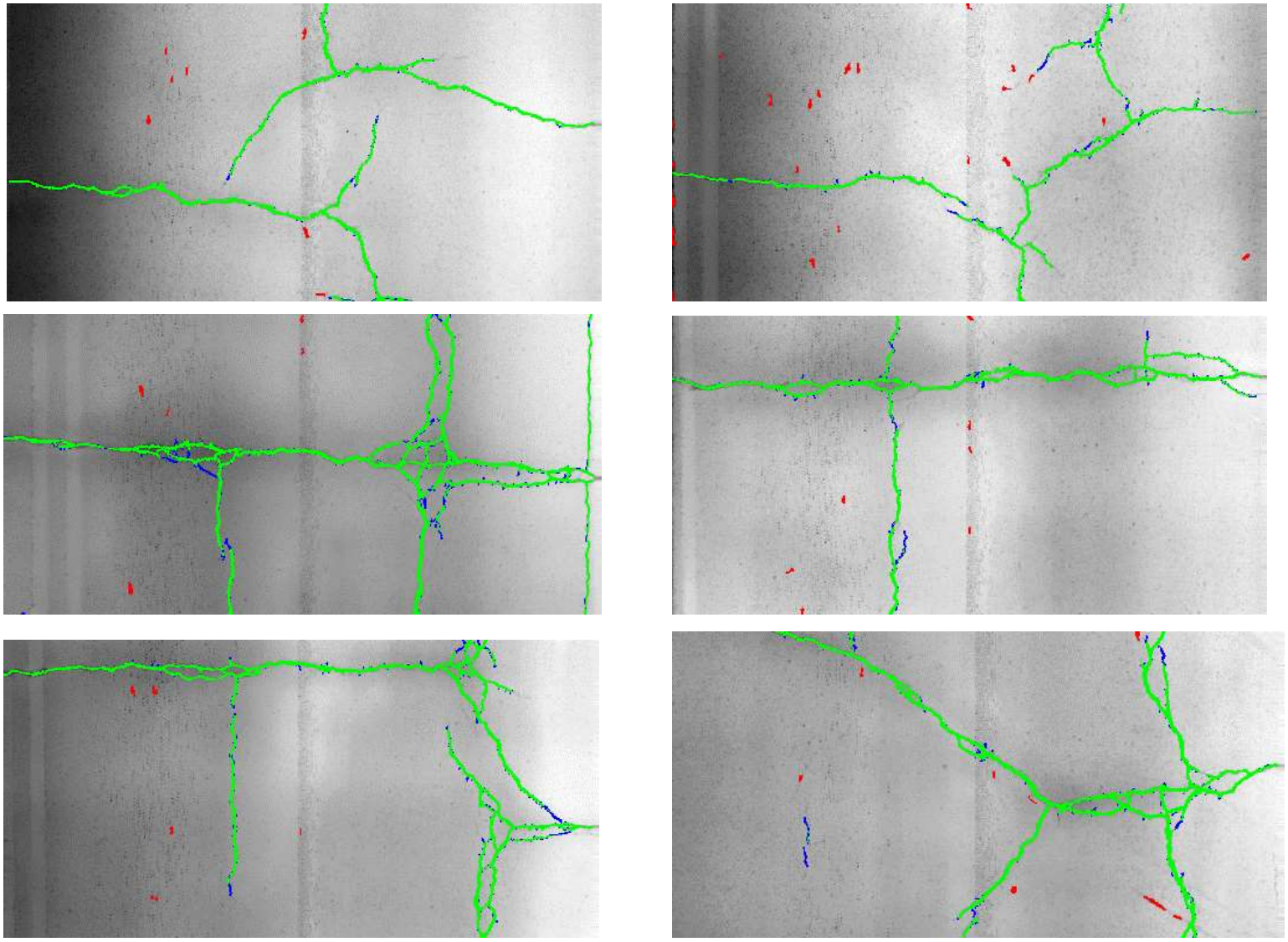
Automated Pixel-level Pavement Crack Detection on 3D Asphalt Surfaces with a Recurrent Neural Network [J], *Computer-Aided Civil and Infrastructure Engineering*, https://doi.org/10.1111/mice.12409.

# First-Gen CrackNet

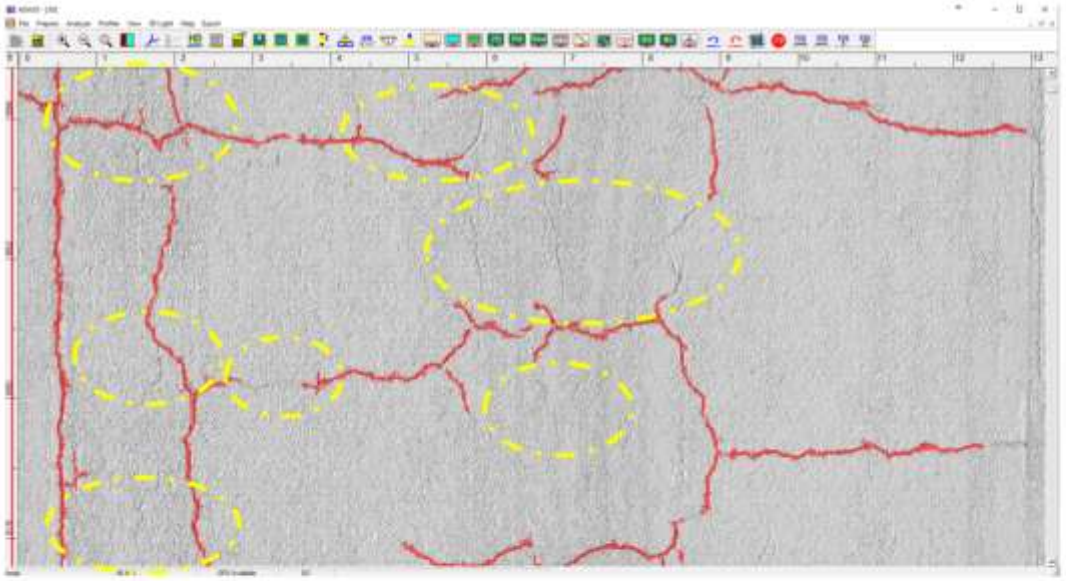



- 7 Layers
- 1,159,561 Parameters

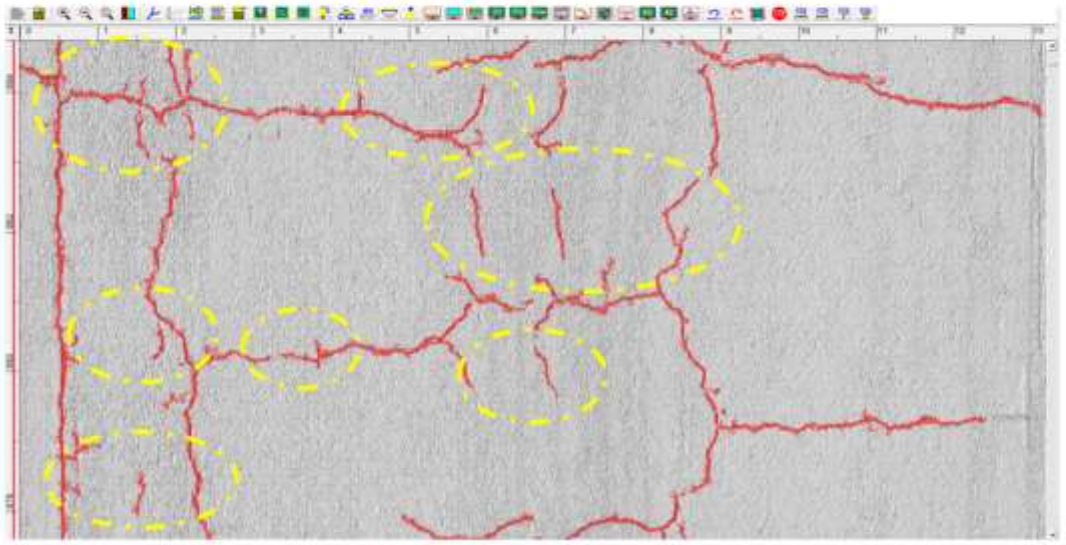
# Sample Results of 1st Gen CrackNet



# Samples of 2nd Gen CrackNet

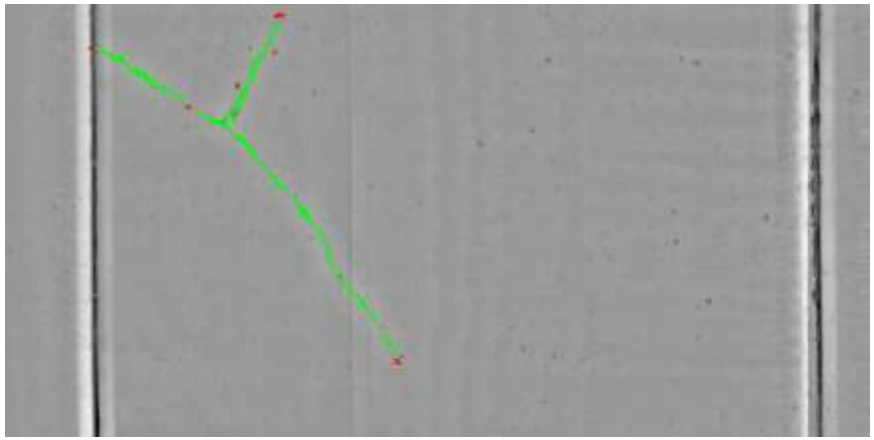


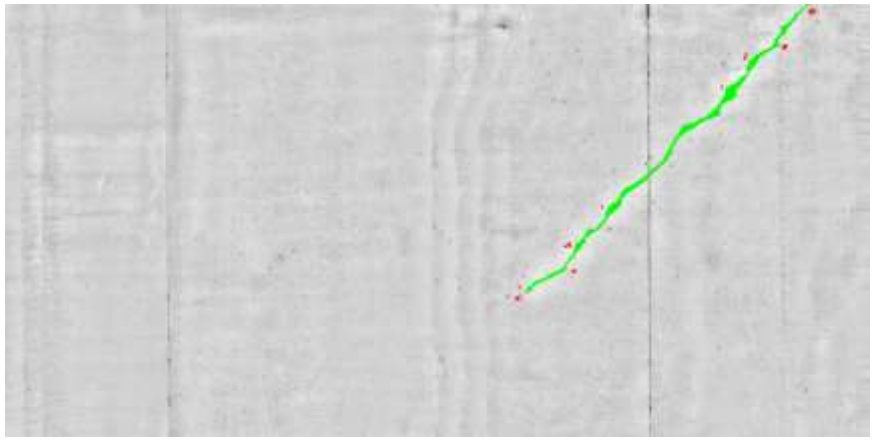
Best CrackNet



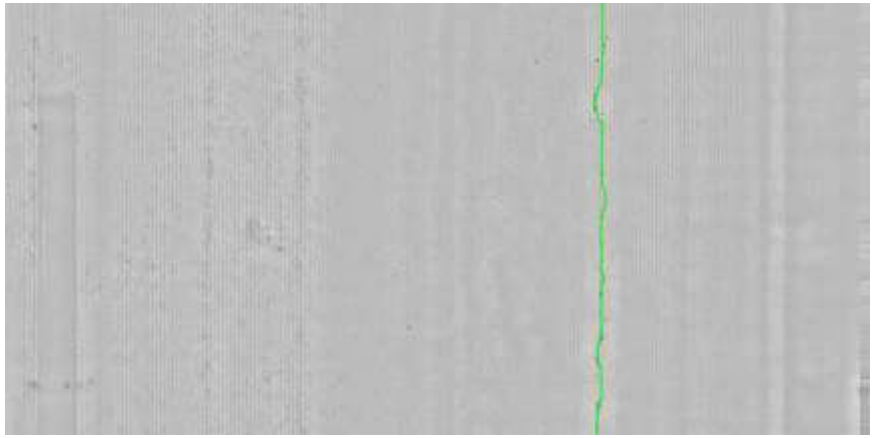
Best CrackNet + RNN

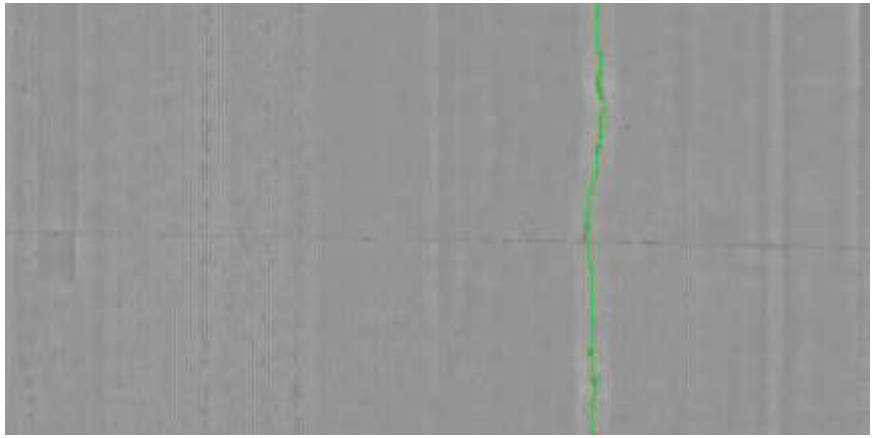
# CrackNet on Concrete Pavements





普通水泥路面



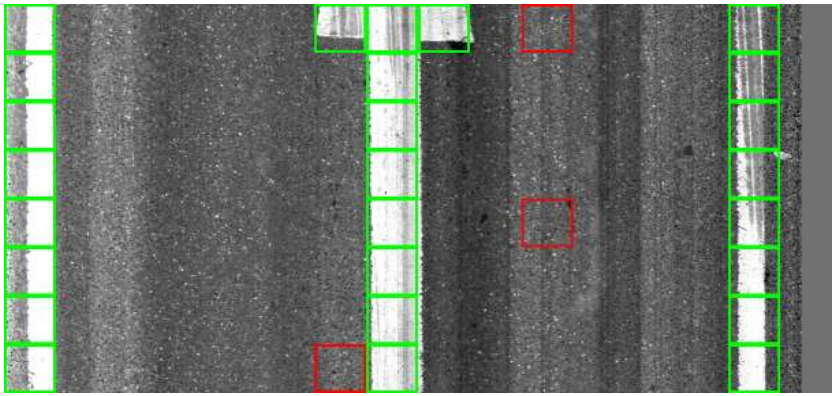


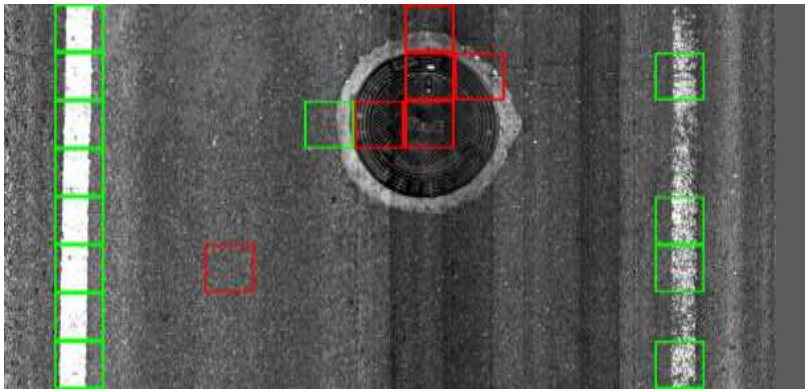
含路面刻槽(Groove)的水泥路面

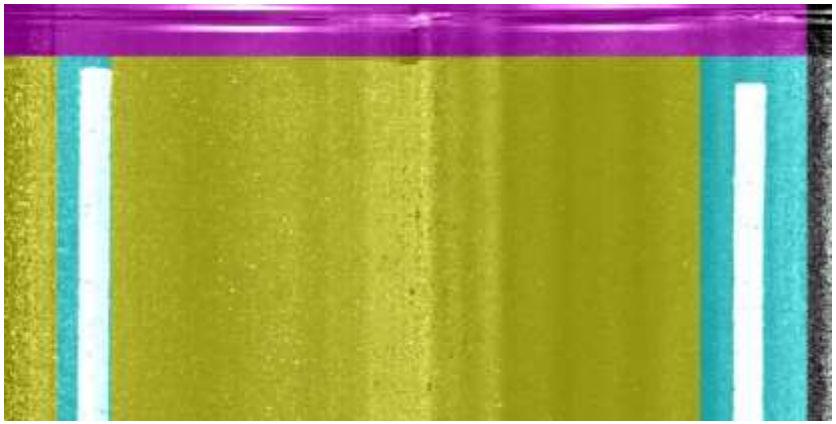
# Key Advantages of CrackNet

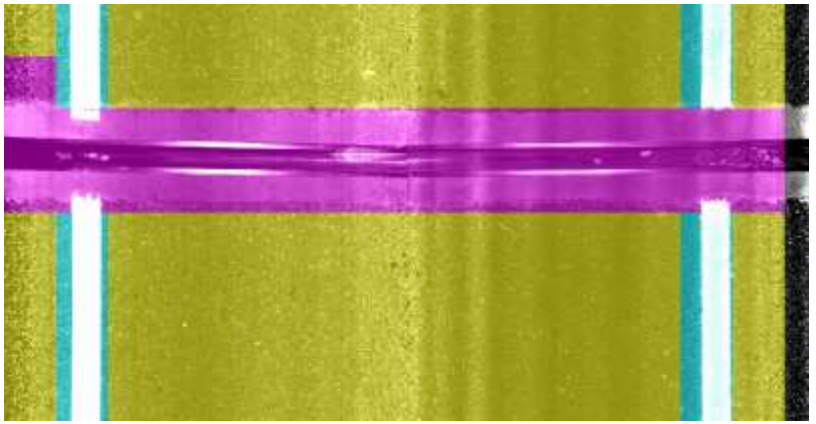
- Stability of Recognition
- >90% P & R
- Accumulated Learning
- NOT Based on Analytical Modeling

# Other Non-Cracking Features： Markings, Man-Hole, Bridge Expansion Joint

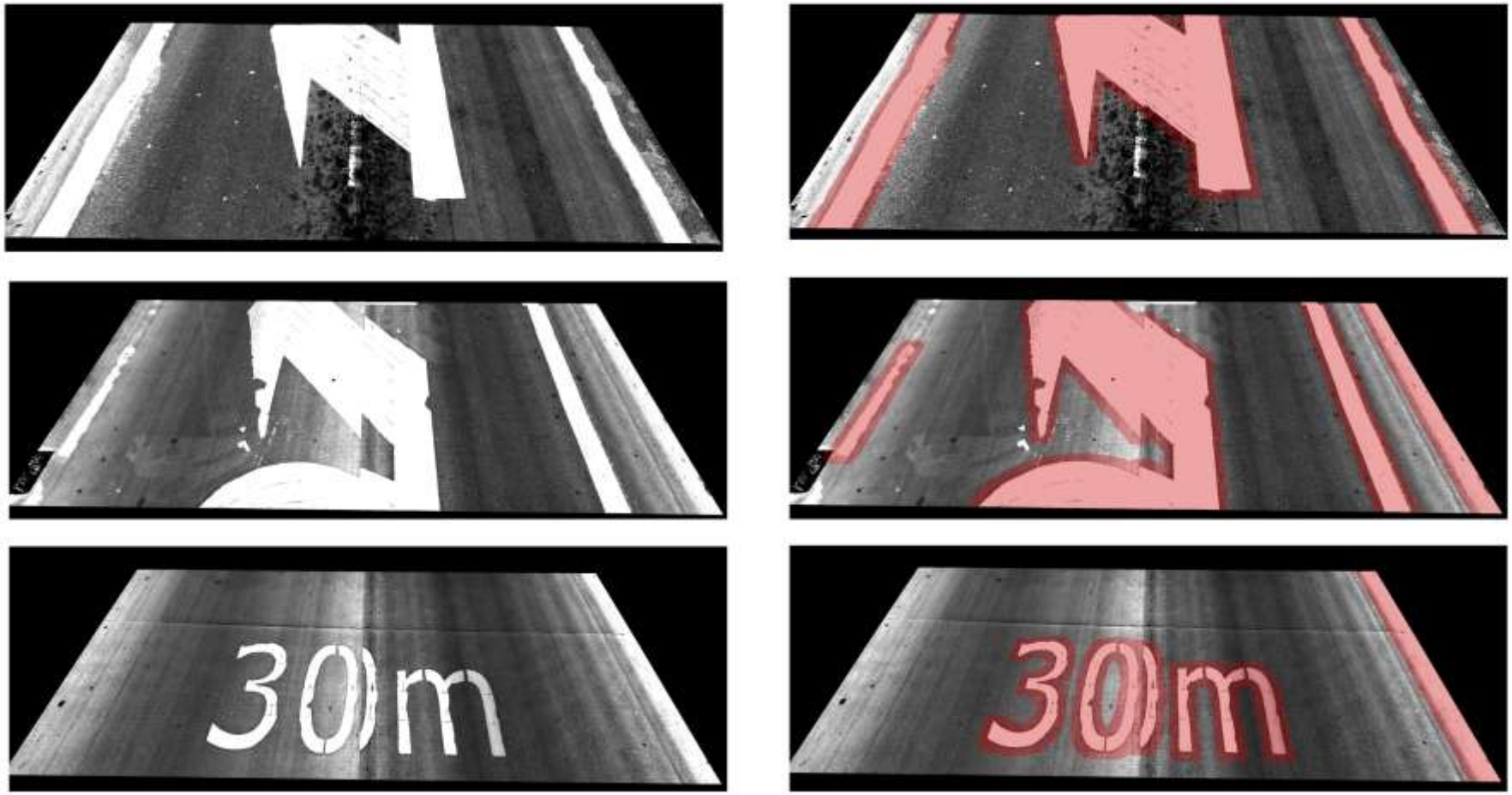




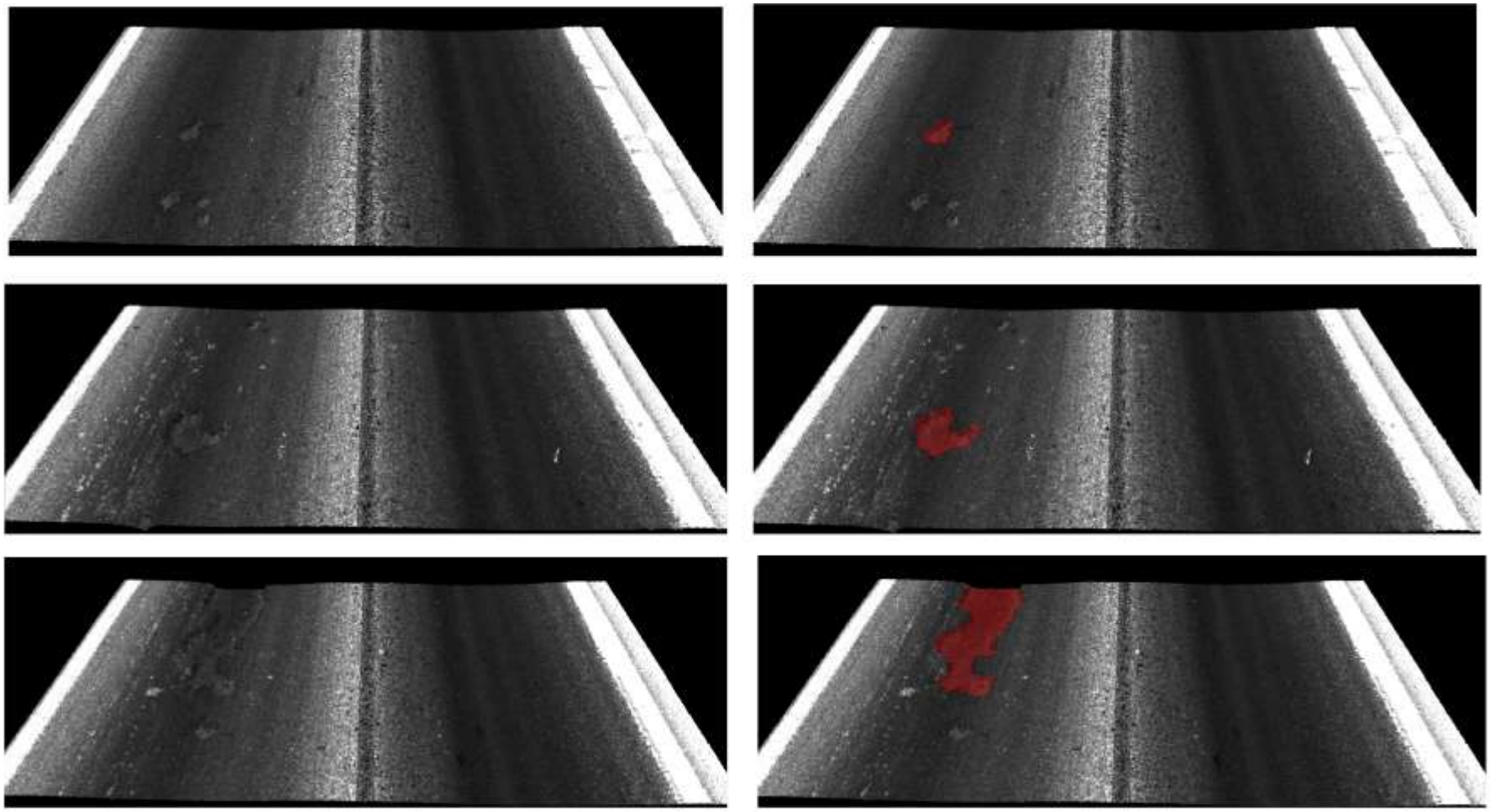




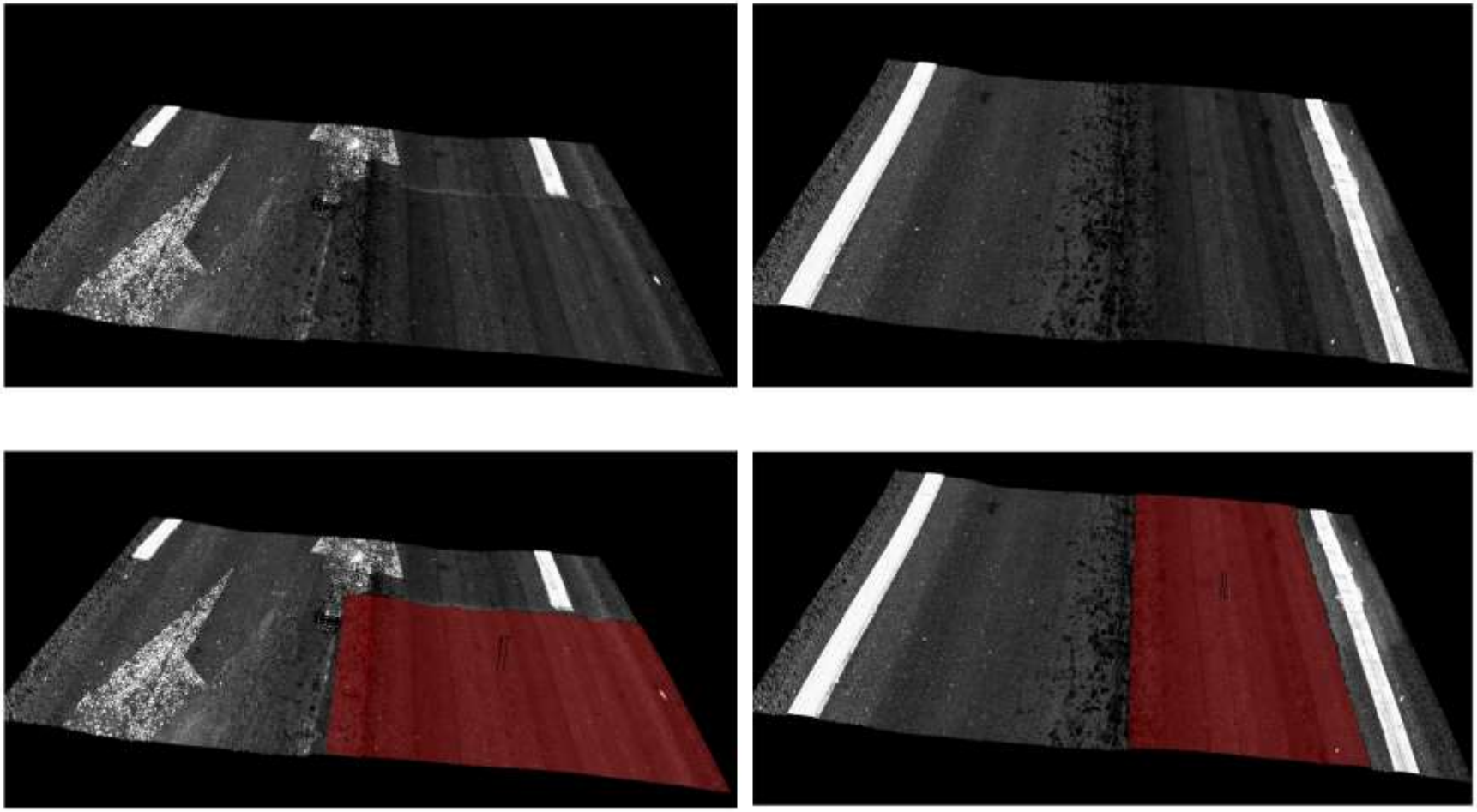
# DL based Marking Identification



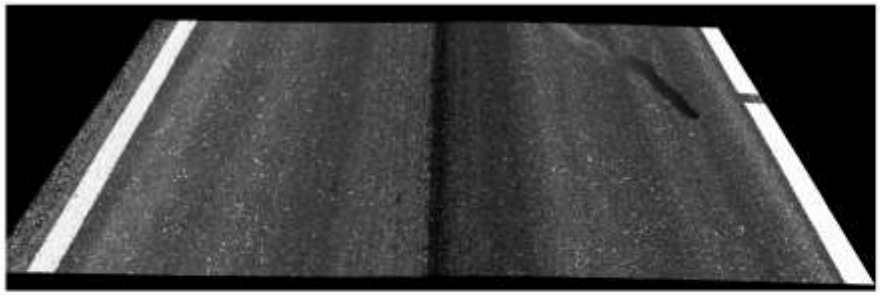
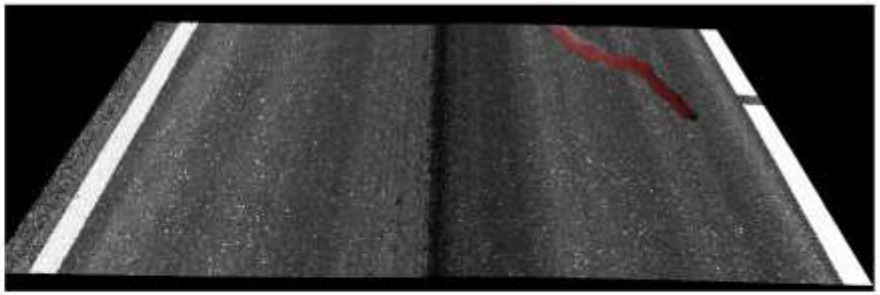
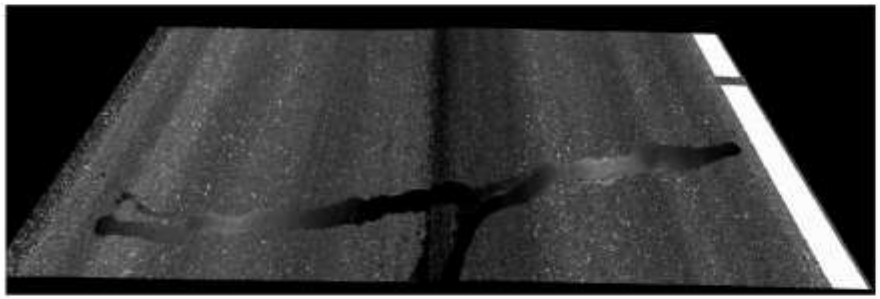
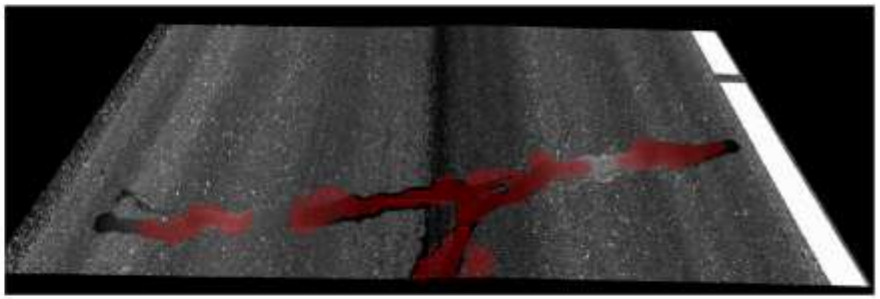
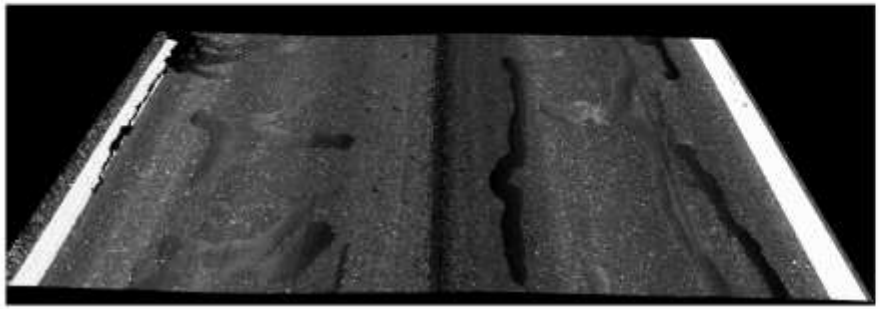
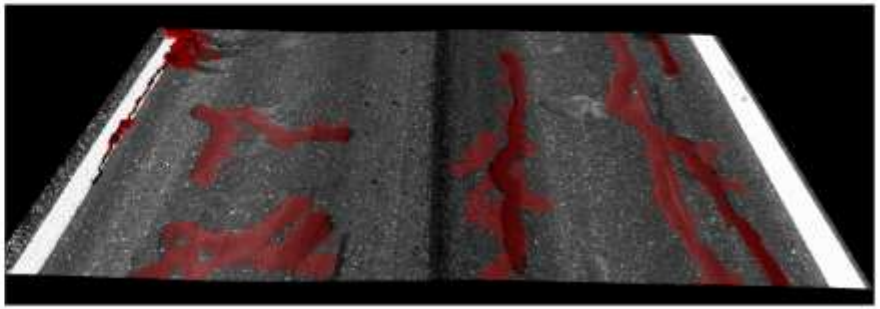
# Pothole Identification



# Patching Identification



# Sealed-Cracking Identification

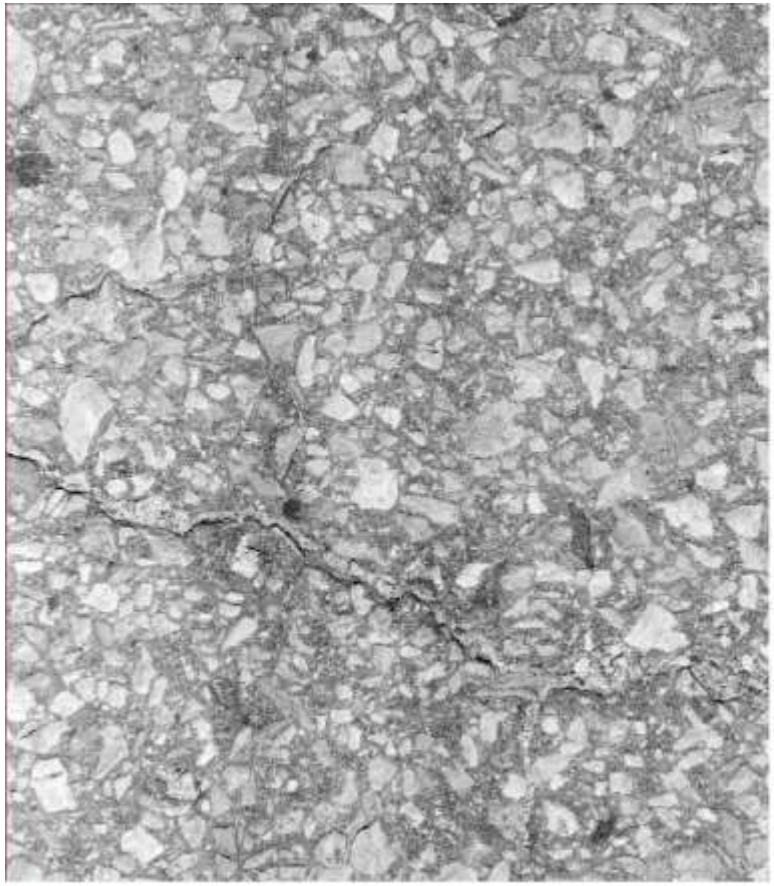







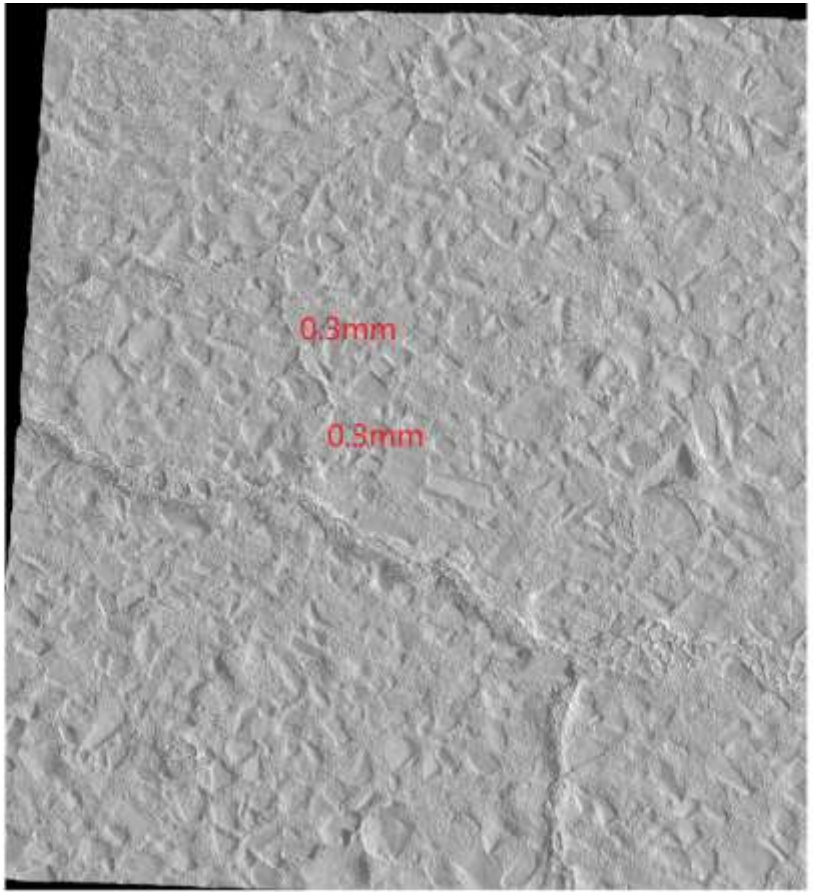
# 0.1mm 3D Laser Imaging for Safety

# Non-Contact 0.1mm 3D Imaging for Continuous Safety Evaluation

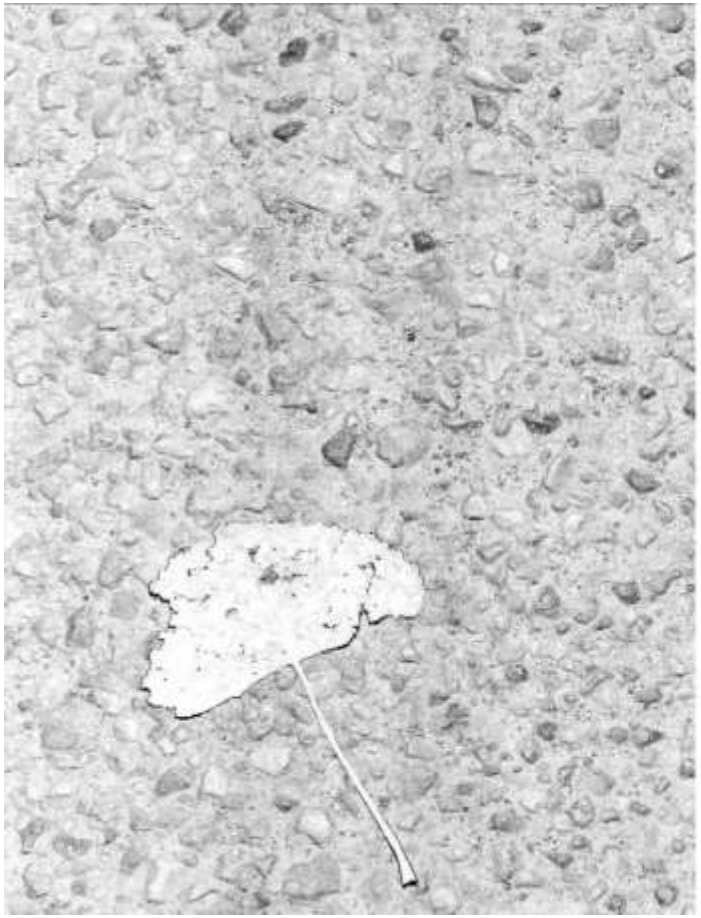
- Pavement Safety
  - Micro/Macro Texture, Friction
- Current Contact-Based Friction Testers
  - Decades old std, Contact/Water, Tire Wear
  - Large Variations in Consistency, Repeatability
- 0.1mm non-Contact Approach, Possible
- Critical
  - Data Quality, Processing Methods

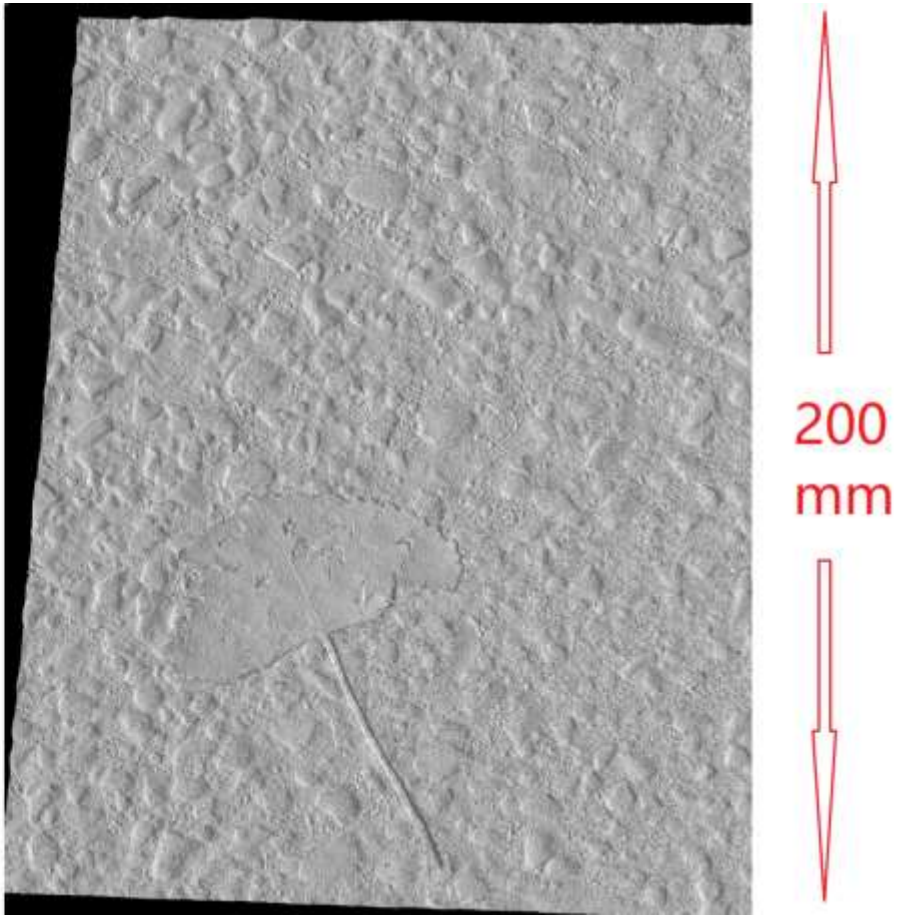
# Samples of 0.1mm 3D Pavement Surface





# Samples of 0.1mm 3D Pavement Surface





# Conclusions

- Sub-mm (0.1mm to 0.5mm) 3D Data & Processing Tech
  - Next-Gen & Next 10 Years
- Comprehensive: Condition, Function, Safety
- 5G/BIM/Cloud/VR/Exascale Computing: many available platforms
- Most Critical: Solutions to Users