2024 THNS TRANSFORMING TRANSPORT

Transport à Haut Niveau Service

Subject : Mesoscale Image Acquisition Method for Asphalt Mixtures Using Microscopy

主题 : 沥青混合料介观尺度图像微距采集方法

Presenter : Ying Wang

演讲人 : 王 莹

I Study on Imaging of Asphalt Mixtures
沥青混合料图像研究

I. Study on Imaging of Asphalt Mixtures
沥青混合料图像研究

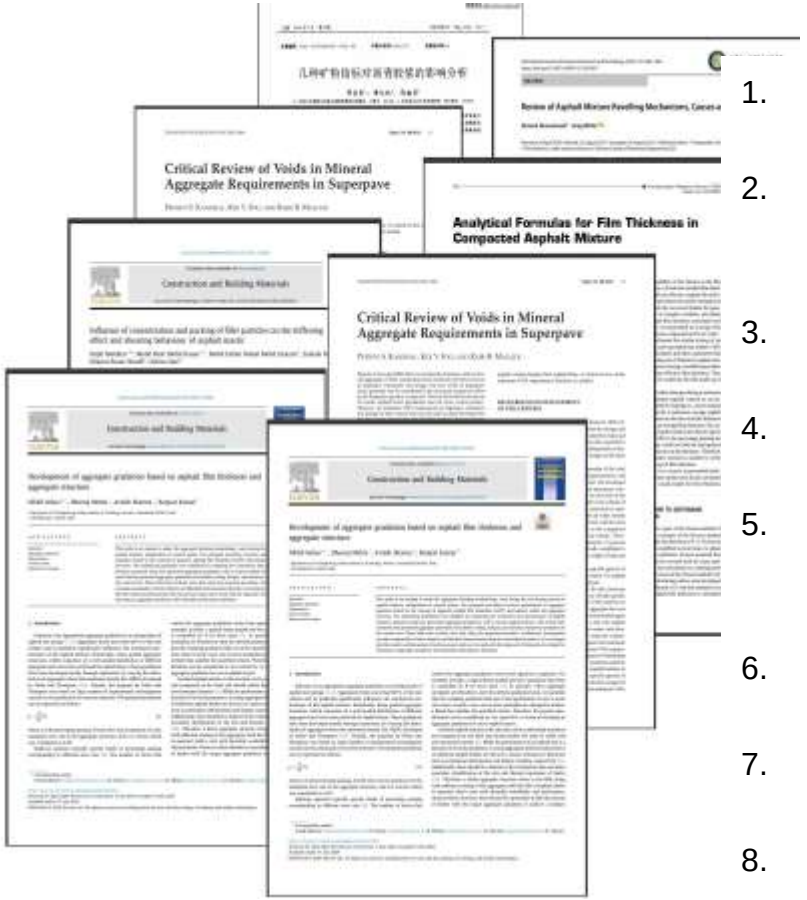
Research on the Influence of Mineral Filler Gradation on Asphalt Mixture Performance
矿粉级配对沥青混合料性能影响的相关研究

1. 邵显智,谭忆秋,邵敏华.几种矿粉指标对沥青胶浆的影响分析[J].公路,2004,(5):122-124.
2. 徐光宪.物质结构的层次和尺度[J].科技导报,2002,(1): 3-6.
3. 莫石秀,孔令云,王娜.矿粉粒径对沥青胶浆性能影响的试验研究[J].广西大学学报(自然科学版),2011,(4): 616-621.
4. 李科瑶,郑传峰,田海波.矿粉填料细观特征对沥青胶浆低温黏结强度的影响分析[J].公路,2015,60(1): 144-148.
5. 刘瑞.沥青胶浆抗车辙性能定量评价方法研究[D].海南.海南大学,2022.
6. Buttlar W.G., Bozkurt D., Al-Khateeb G.G., Waldhoff A.S.. Understanding Asphalt Mastic Behavior Through Micromechanics[J].Transportation Research Record,1999,Vol.1681(1):157-169.

Study on the Influence of Asphalt Film Structural Features on Asphalt Mixture Performance
沥青膜结构特征对沥青混合料性能影响的相关研究

1. Prithvi S. Kandhal;Kee Y. Foo;Rajib B. Mallick.Critical Review of Voids in Mineral Aggregate Requirements in Superpave[J].Transportation Research Record,1998,Vol.1609(1): 21-27.
2. Mukhtar, Najib ;Mohd Hasan, Mohd Rosli ;Mohd Ghazali, Mohd Fahmi Haikal ;Mohd Zin, Zainiah ;Shariff, Khairul Anuar ;Sani, Ashiru .Influence of concentration and packing of filler particles on the stiffening effect and shearing behaviour of asphalt mastic.[J].Construction & Building Materials,2021,Vol.295: 123660.

I. Study on Imaging of Asphalt Mixtures
沥青混合料图像研究



Study on Asphalt Film Thickness
沥青膜厚度的相关研究

1. Campen W H, Smith J R, Erickson L G, and Mertz L R. The relationships between voids, surface area, film thickness and stability in bituminous paving mixtures[J]. Asphalt Paving Technology, 1959,28:149–178.
2. Schram S, Abdelrahman M. Effects of Asphalt Film Thickness on Field Performance[C]// Transportation Research Board. Transportation Research Board 90th Annual Meeting. Washington, United States,2011:4236-4253.
3. Abouelsaad A, White G. Review of Asphalt Mixture Ravelling Mechanisms, Causes and Testing[J]. International Journal of Pavement Research and Technology,2022, 15(6):1448-1462.
4. Radovskiy B. Analytical Formulas for Film Thickness in Compacted Asphalt Mixture[J].Transportation Research Record,2003, 1829(1): 26-32.
5. Heitzman M. New approaches for computing film thickness[C]// Association of Asphalt Paving Technologists. 2006 Journal of the Association of Asphalt Paving Technologists. Minnesota, USA: Association of Asphalt Paving Technologists, 2006: 1120-1168.
6. Nikhil Saboo;Dheeraj Mehta;Avnish Sharma;Ranjeet Kumar.Development of aggregate gradation based on asphalt film thickness and aggregate structure[J].Construction and Building Materials,2024,Vol.440: 137424.
7. Lan Wang;Zhihua Xue;Yingying Guo;Hui Wu;Minda Ren, Ph.D..Effect of Asphalt Film Thickness on Asphalt–Aggregate Adhesion under Aging[J].Journal of Materials in Civil Engineering,2024,Vol.36(4): 04024005.
8. Zhang, Yao1;Chen, Hu1;Xiao, Peng1;Deng, Yong2;Kang, Ai-Hong1.Investigation of average asphalt film thickness of dense graded asphalt mixtures with compaction effects.[J].Construction & Building Materials,2022,Vol.326: 126696.

Ⅰ. Study on Imaging of Asphalt Mixtures
沥青混合料图像研究

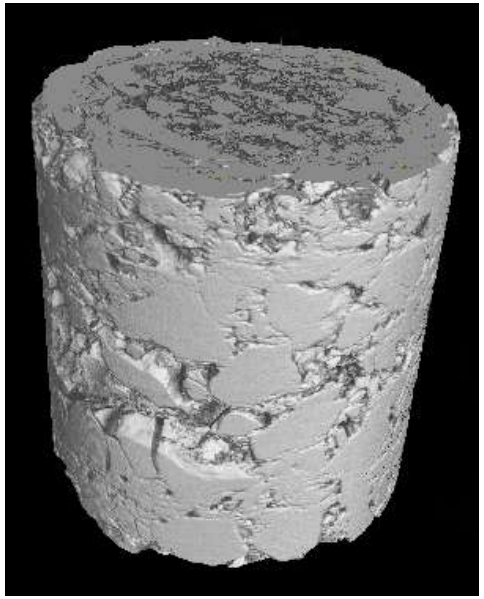
Precision of Asphalt Mixture Image Research
沥青混合料图像研究精度

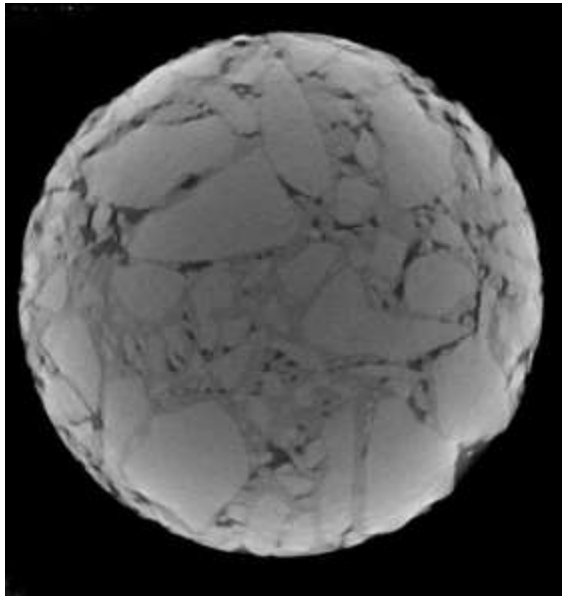
Title 题名	Author 作者	Precision 精度	Imaging System 图像采集设备
Aggregate orientation and segregation in laboratory compacted asphalt samples	Hunter A. ,Airey G. , Collop A.	0.7mm	数码相机 Digital Camera
一种基于数字图像处理技术的沥青混合料均匀性研究新方法	彭勇，孙立军，杨宇亮，董瑞琨	0.3mm	CDD电荷域传感器 Charge Domain Device
基于数字图像处理技术和熵权法分析沥青路面均匀度的方法	梁乃兴,杜镇宇,徐建平,等	9.5mm	数码相机 Digital Camera
基于数字图像技术的摊铺路面最佳采集高度研究	岳鹏	9.5mm	数码相机 Digital Camera
一种基于图像的沥青混合料矿料级配检测方法	沙爱民,王超凡,孙朝云	0.075mm	数码相机 Digital Camera
Comprehensive Evaluation of AIMS Texture, Angularity and Dimension Measurements	Mahmoud E, Gates L, Masad E, et al.	4.75mm	CT扫描 CT Scanning

Ⅱ Asphalt Mixture Image Capture Technique
沥青混合料图像采集方法

Ⅱ. Asphalt Mixture Image Capture Technique
沥青混合料图像采集方法

CT



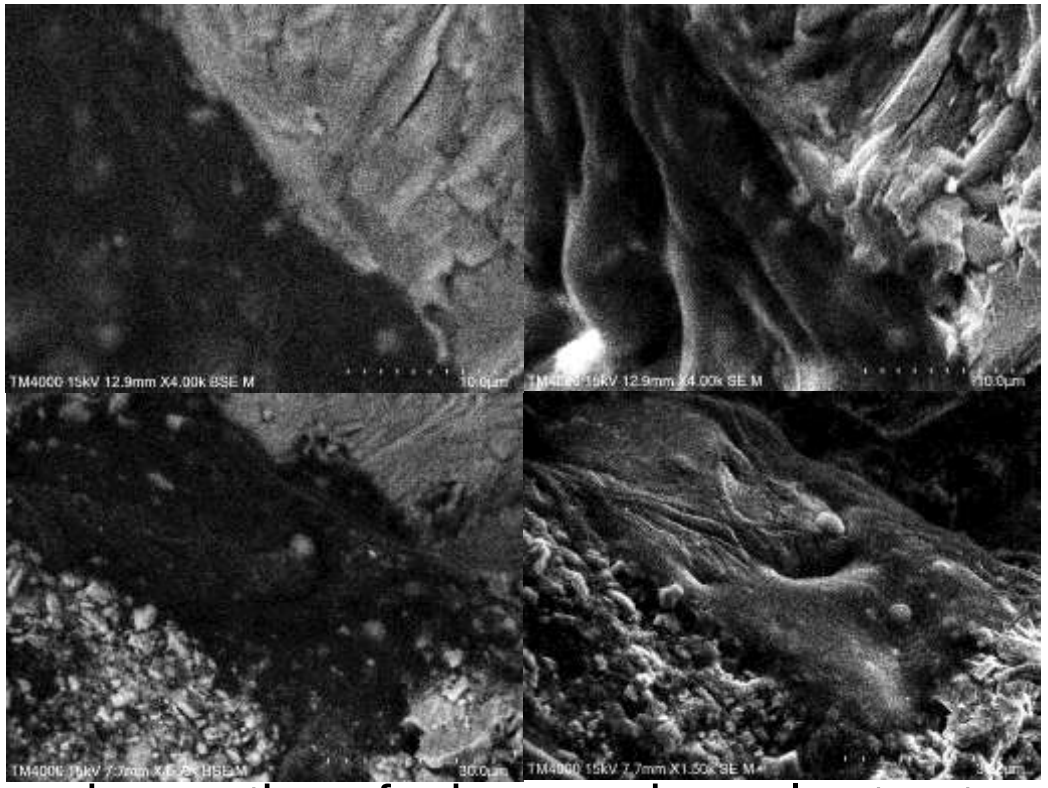


Pors: Enables observation of the internal structure without disrupting the integrity of the sample.
优点：不需要破坏试样结构就可以观测内部情况。

Cons: The image exhibits uneven brightness distribution and low accuracy.
缺点： 图像亮度分布不匀，精度低。

Ⅱ. Asphalt Mixture Image Capture Technique
沥青混合料图像采集方法

SEM

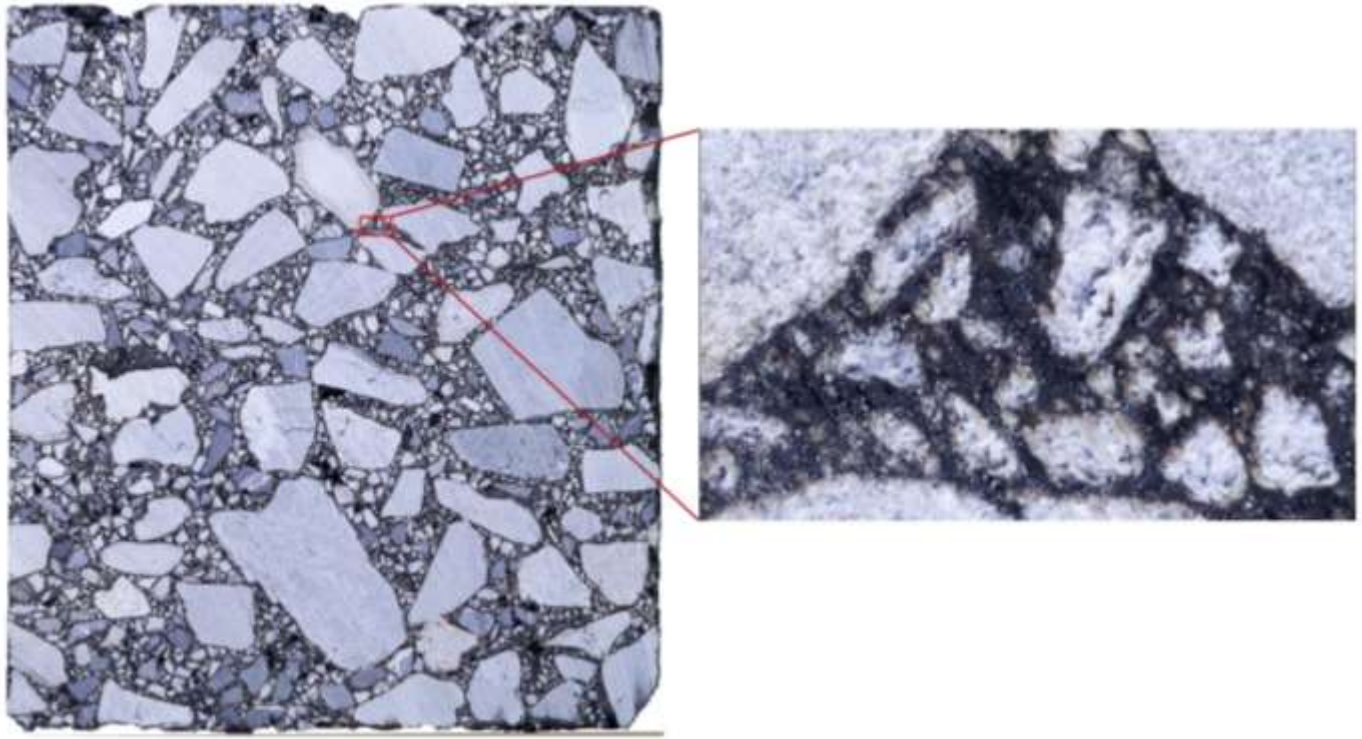


Pors: The image has high resolution, allowing for observation of microscopic-scale structures.
优点：图像精度高，可以观察到微观尺度结构。

Cons: In secondary electron images, the aggregate particles used for identification are sometimes not located on the same plane, which may lead to misinterpretation.
缺点：二次电子图像(SE)中用于识别的集料颗粒，有时并不在同一平面上，易产生误判。

Ⅱ. Asphalt Mixture Image Capture Technique
沥青混合料图像采集方法

DC



Pors: The image exhibits high resolution, allowing for observation of mesoscale structures; it is simple to operate and easy to obtain.
优点：图像精度较高，可以观察到介观尺度结构；操作简单，易获取。

Cons: There is no standardized procedure for image acquisition.
缺点：没有标准的图像采集操作流程。

Ⅲ Target of Asphalt Mixture Imaging
沥青混合料图像的应用目标

Ⅲ. Target of Asphalt Mixture Imaging
沥青混合料图像的应用目标

研究目的
Research Objective

Study on the Internal Structure of Asphalt Mixtures
研究沥青混合料内部结构

- Asphalt Film Structure
- 沥青膜结构
- Distribution Characteristics of Mineral Filler
- 矿粉分布特征

研究方法
Research Method

- CT扫描
  难以提供足够精度的图像
- CT Scanning
  Difficult to achieve images with adequate precision.
- 扫描电镜、CDD电荷域传感器
  难以采集到完整的试样截面
- SEM, CDD
  It is challenging to capture the complete cross-section of the specimen.

NO

- 数码相机
  没有规范的图像采集方法
- DC
  There is no standardized method for image acquisition.

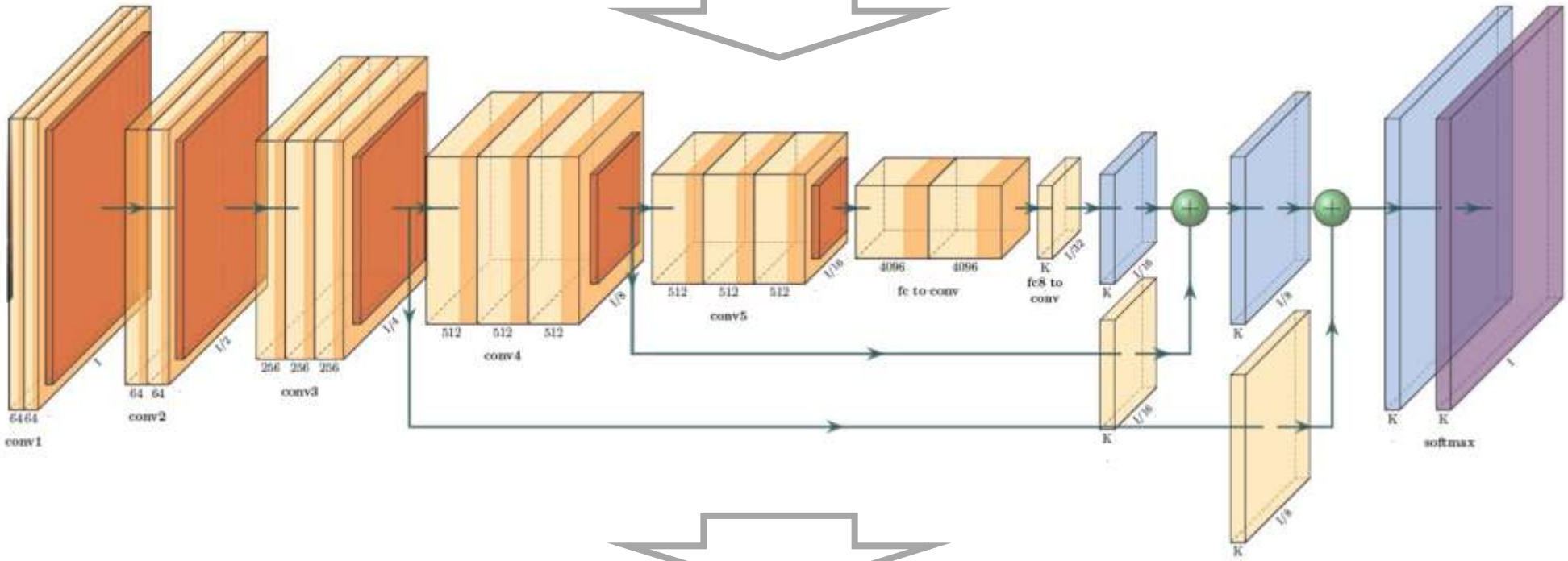
YES

目标成果
Expected Outcomes

高精度、信息完整、可以用于识别分割的沥青混合料截面图象
High-resolution, comprehensive cross-sectional images of asphalt mixtures that can be utilized for identification and segmentation

Ⅲ. Target of Asphalt Mixture Imaging
沥青混合料图像的应用目标

高精度、信息完整、可以用于识别分割的沥青混合料截面图象
High-resolution, comprehensive cross-sectional images of asphalt mixtures that can be utilized for identification and segmentation



带标签的特征图像
Labeled Feature Images

IV Mesoscale Image Acquisition Method for Asphalt Mixtures Using Microscopy
沥青混合料介观尺度图像微距采集方法

IV. Mesoscale Image Acquisition Method for Asphalt Mixtures Using Microscopy
沥青混合料介观尺度图像微距采集方法

1. 图像采集方法
   Image Acquisition Method

2. 图像拼接方法
   Image Stitching Technique

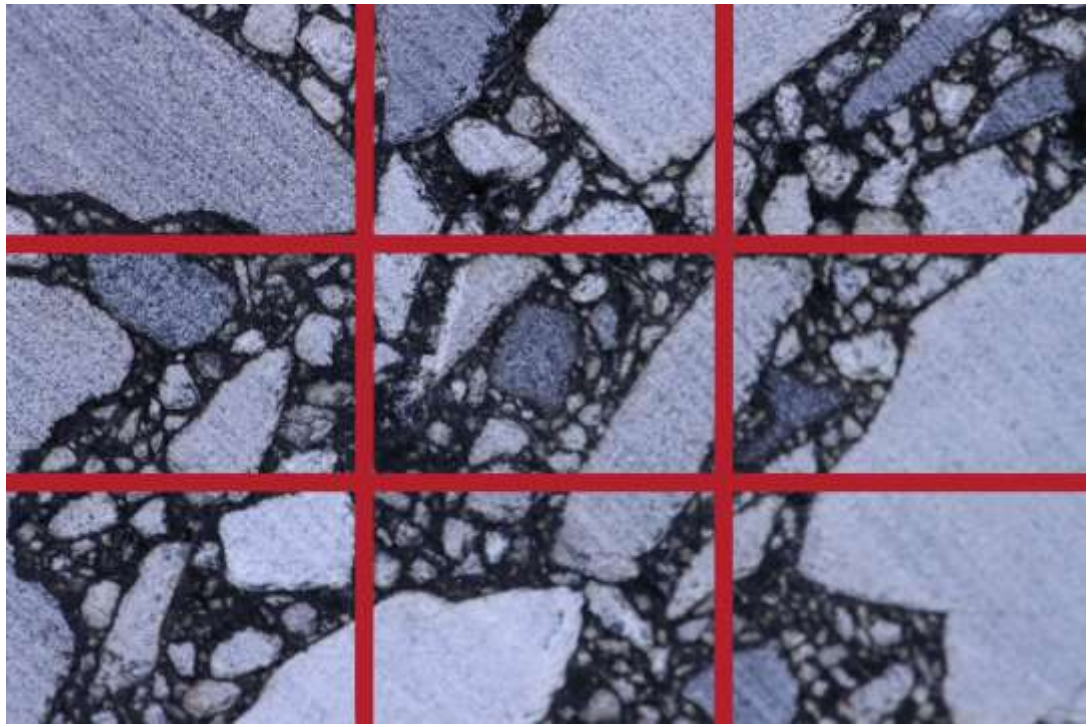
3. 图像预处理方法
   Image Preprocessing Method

在数码相机的监控器内，手动点选每个双向3等分参考线内（如图所示）的每一格，分别进行对焦拍摄。拍摄完一个视野范围后，保持沥青混合料试样的位置不变，调整数码相机的位置，使每个视野范围与移动之前相比都有一定程度的重复。

In the digital camera's monitor, each grid within the bi-directional trisected reference lines (as shown) is manually selected and focused for individual capture. After completing the imaging within a single field of view, the position of the asphalt mixture specimen remains fixed while the camera position is adjusted. When repositioning the digital camera, each field of view should contain a certain degree of overlap with the previous image.

4. 图像深度学习分割结果
   Deep Learning-Based Image Segmentation Results

IV. Mesoscale Image Acquisition Method for Asphalt Mixtures Using Microscopy
沥青混合料介观尺度图像微距采集方法



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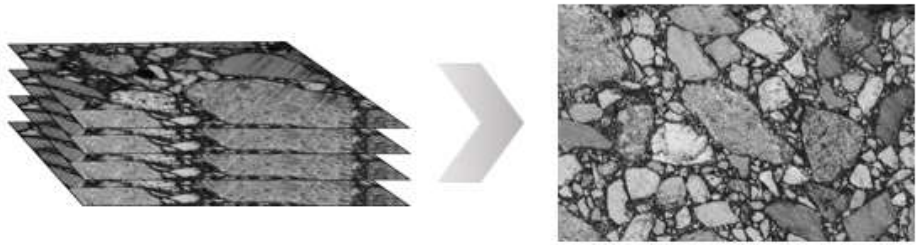
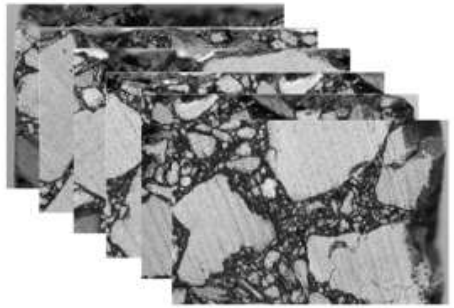
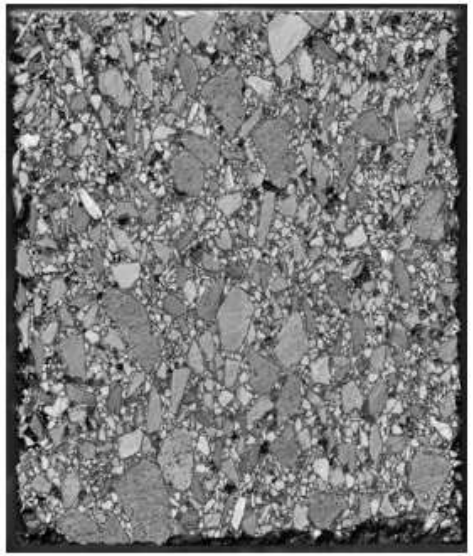
   Deep Learning-Based Image Segmentation Results

合并同一视野范围内不同对焦点图像
Merge images captured at varying focal points within the same field of view.

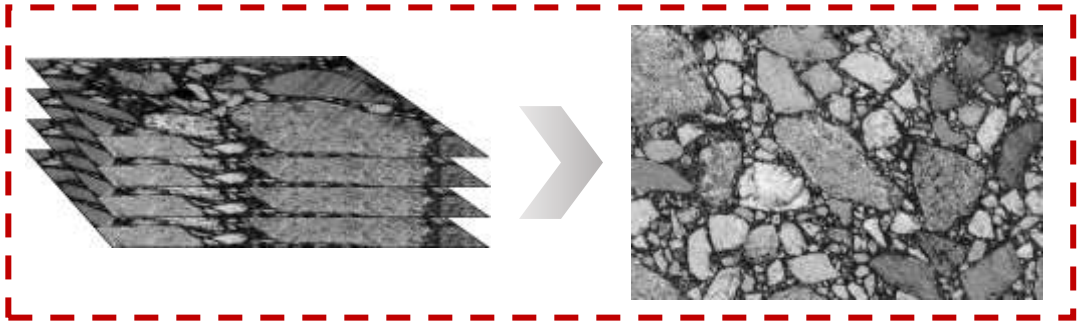






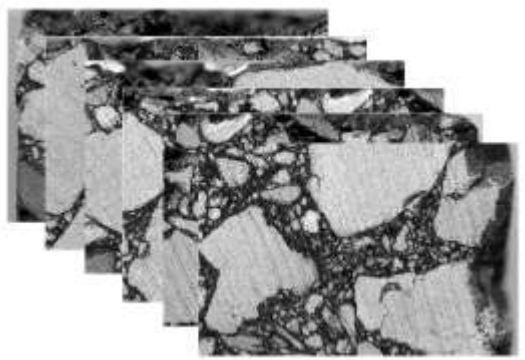
合并同一截面不同视野范围内图像
Merge images from various fields of view within the same cross-sectional area.

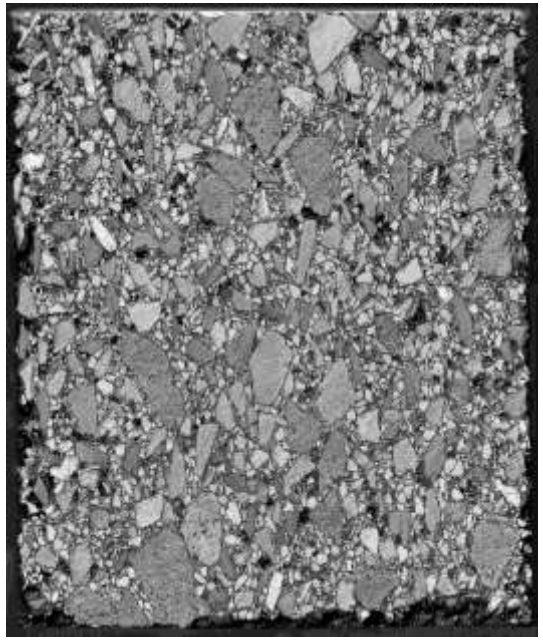
IV. Mesoscale Image Acquisition Method for Asphalt Mixtures Using Microscopy
沥青混合料介观尺度图像微距采集方法



2. 合并同一截面不同视野范围内图像
2. Merge images from various fields of view within the same cross-sectional area.

1. 合并同一视野范围内不同对焦点图像
1. Merge images captured at varying focal points within the same field of view.





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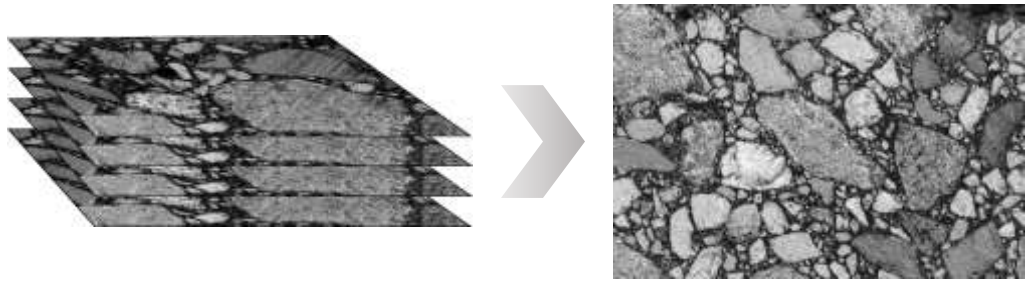

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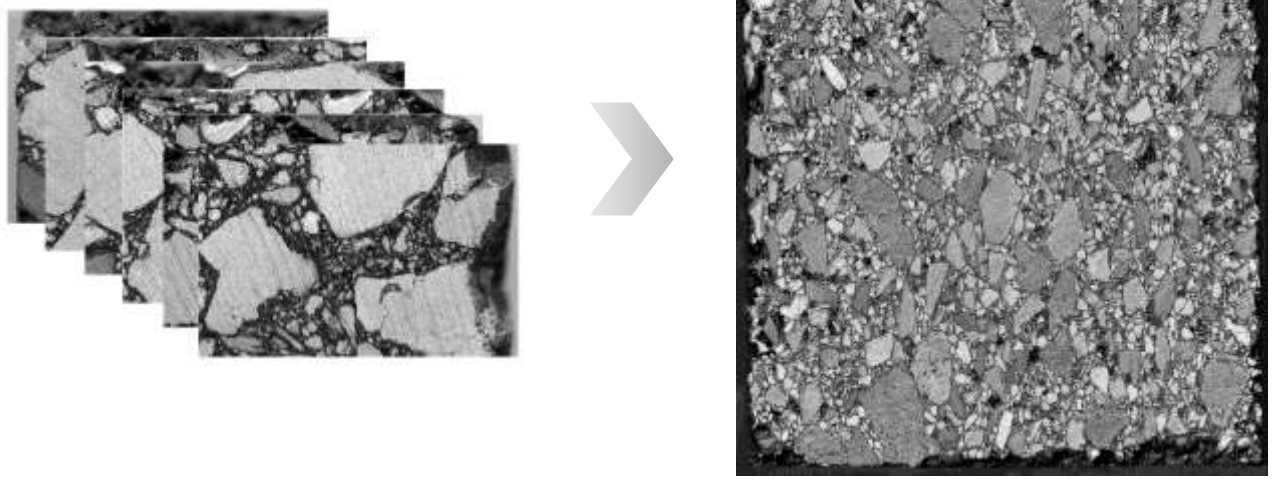

IV. Mesoscale Image Acquisition Method for Asphalt Mixtures Using Microscopy
沥青混合料介观尺度图像微距采集方法

1. 图像采集方法
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3. 图像预处理方法
   Image Preprocessing Method

去除合并后图像内，大集料颗粒内，沥青胶浆在集料表面污染留下的斑点、集料本身深浅不一的纹理。清除会造成学习训练误判的干扰因素。

Remove spots left by asphalt mastic contamination on aggregate surfaces and variations in aggregate texture within large aggregate particles in the merged image. Eliminating these factors helps prevent misleading artifacts that could interfere with training accuracy.

4. 图像深度学习分割结果
   Deep Learning-Based Image Segmentation Results

IV. Mesoscale Image Acquisition Method for Asphalt Mixtures Using Microscopy
沥青混合料介观尺度图像微距采集方法

去纹理是一种不常见的处理手段，只在数字图像保留了足够多的细节时，才需要进行这步操作。经过拼接合并的沥青混合料截面图像，在呈现了尽可能多的结构分布细节的同时，也保留了沥青混合料内部集料的纹理，和因为切割产热沾黏在集料切面上的沥青。这些集料本身的天然纹理、集料切面上残留的沥青胶浆，在后续针对集料的识别分割工作中都会造成误判，干扰分类算法的学习训练，因此必须在识别分割之前对其进行处理。

Texture removal is an unconventional preprocessing step, only necessary when digital images retain sufficient detail. Merged cross-sectional images of asphalt mixtures provide extensive structural distribution details, while also preserving natural aggregate textures and asphalt adhered to aggregate surfaces due to heat generated during sectioning. These inherent textures and residual asphalt mastic on aggregate surfaces can lead to misclassification and interfere with segmentation algorithms in subsequent aggregate identification tasks. Therefore, it is essential to address these artifacts prior to segmentation.

IV. Mesoscale Image Acquisition Method for Asphalt Mixtures Using Microscopy
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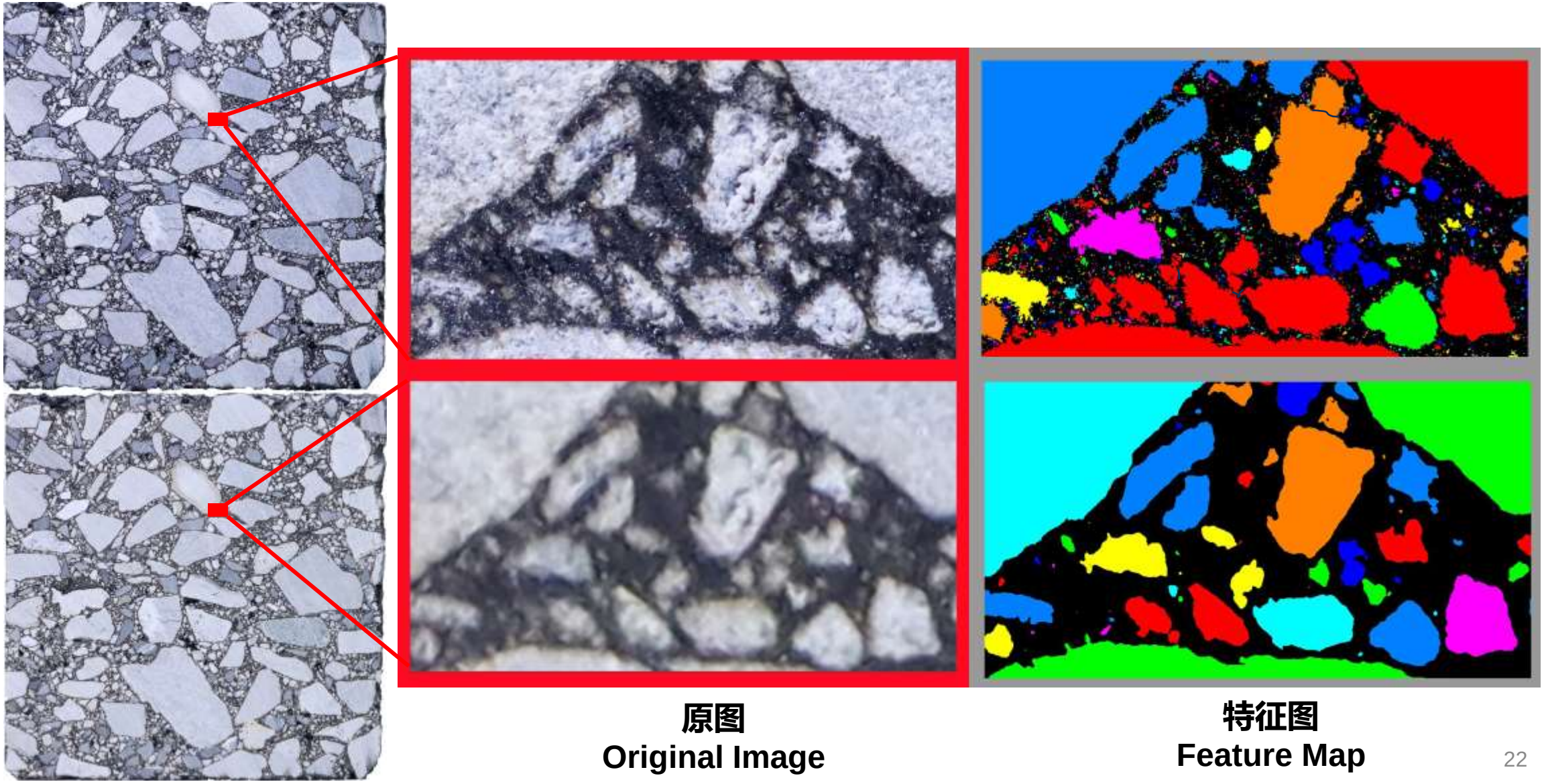
采用这一图像采集处理方法得到的高清数字图像，从主观视觉角度和客观分析角度，都与直拍图像之间存在明显不同。

The high-resolution digital images obtained through this image acquisition and processing method exhibit significant differences from directly captured images, both in terms of subjective visual perception and objective analytical metrics.

IV. Mesoscale Image Acquisition Method for Asphalt Mixtures Using Microscopy
沥青混合料介观尺度图像微距采集方法



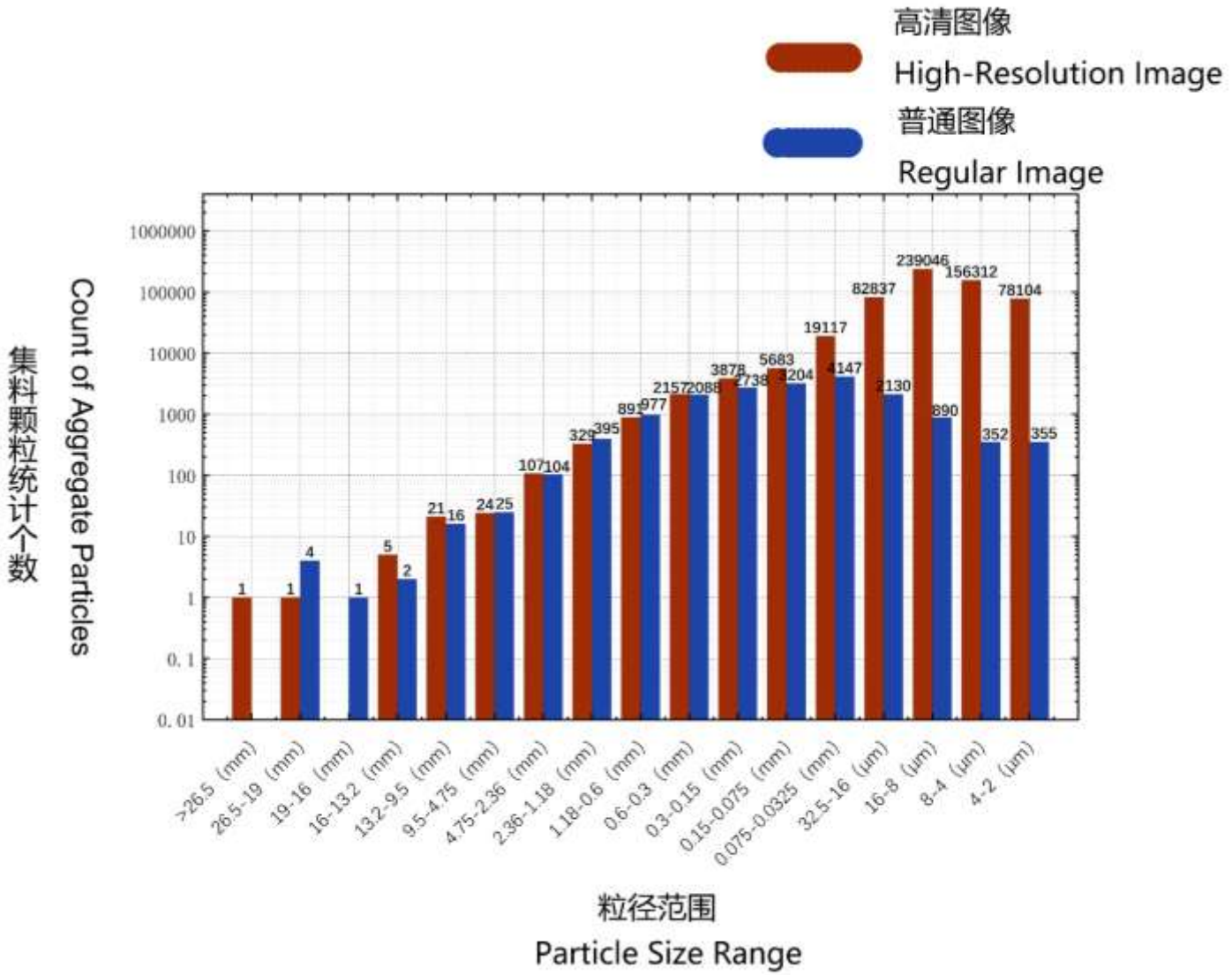
原图
Original Image

特征图
Feature Map

Ⅳ. Mesoscale Image Acquisition Method for Asphalt Mixtures Using Microscopy
沥青混合料介观尺度图像微距采集方法

集料颗粒的统计结果显示，高清图像像中，一共识别出588513个集料颗粒，是普通图像像中集料总个数（17428）的近34倍。粒径>0.075mm范围内的颗粒分布，在两个截面图像中都显示出相似的统计结果。

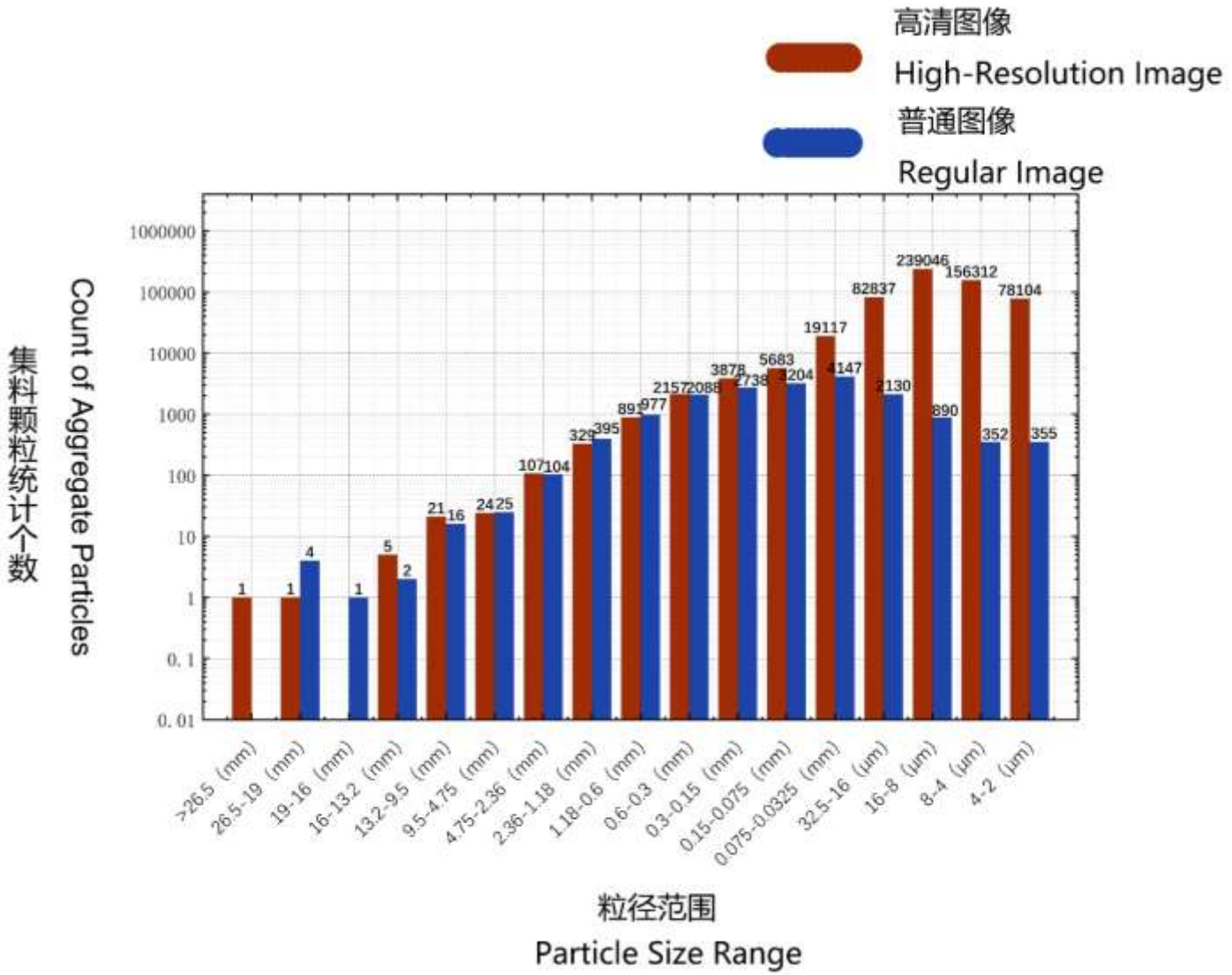
The statistical results of aggregate particles indicate that in the high-resolution image, a total of 588,513 aggregate particles were identified, nearly 34 times the total count in the standard image (17,428). The particle distribution within the size range >0.075 mm exhibits similar statistical outcomes across both cross-sectional images.



IV. Mesoscale Image Acquisition Method for Asphalt Mixtures Using Microscopy
沥青混合料介观尺度图像微距采集方法

两种图像的各档统计结果之间不存在数量级差距，但是个数不同，说明，数字图像分辨率和锐度的提高，保留了更详细的集料颗粒边界形状信息；粒径<0.075mm范围内的集料颗粒统计结果显示，高清图像像中的颗粒个数相对于普通图像的数量更大，存在数量级差。

The statistical results for each category across the two images show no order-of-magnitude differences but vary in particle counts, indicating that the increased resolution and sharpness of the digital image preserve more detailed information on aggregate particle boundary shapes. For particles within the size range <0.075 mm, the high-resolution image reveals a significantly larger particle count than the standard image, indicating an order-of-magnitude difference.



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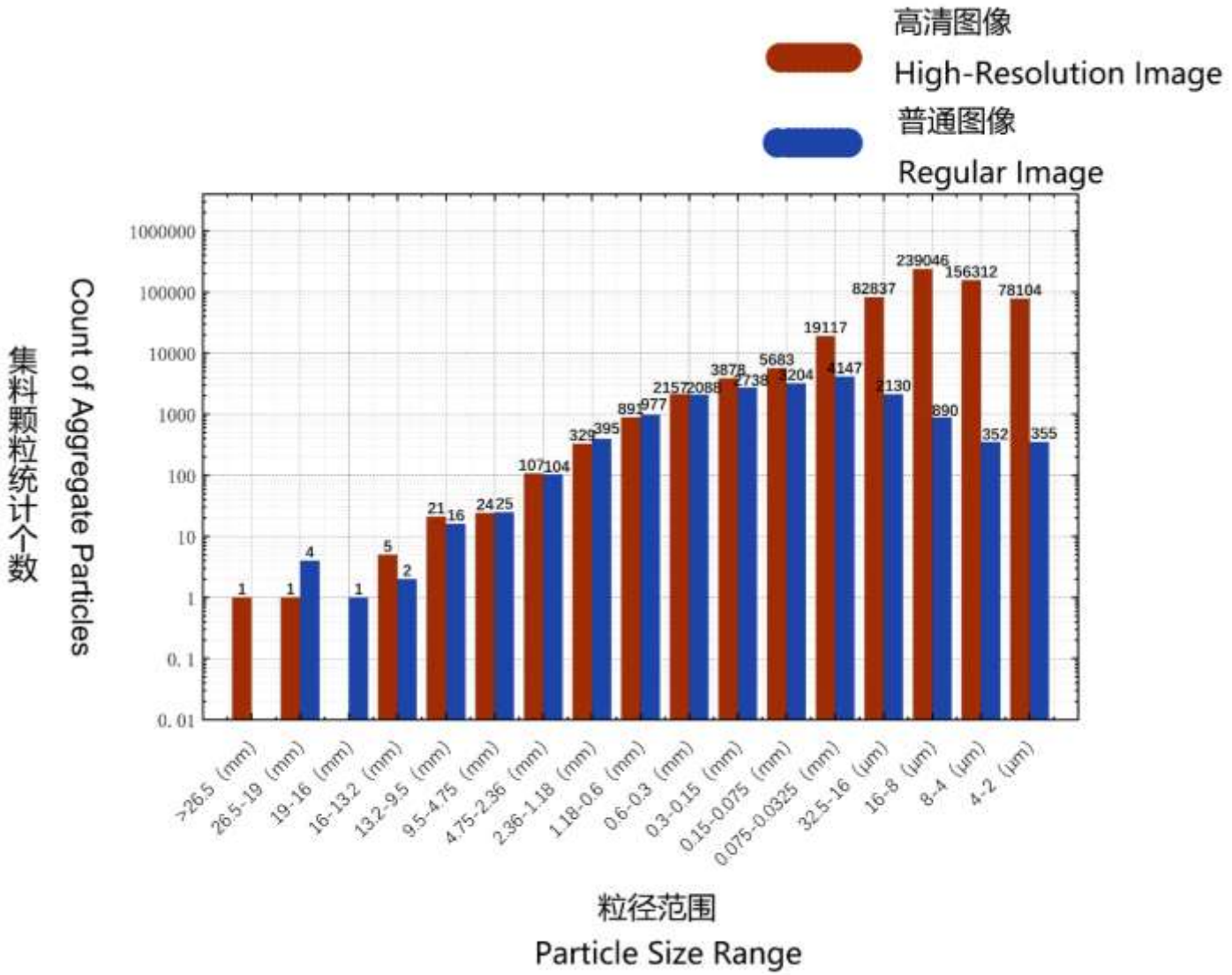
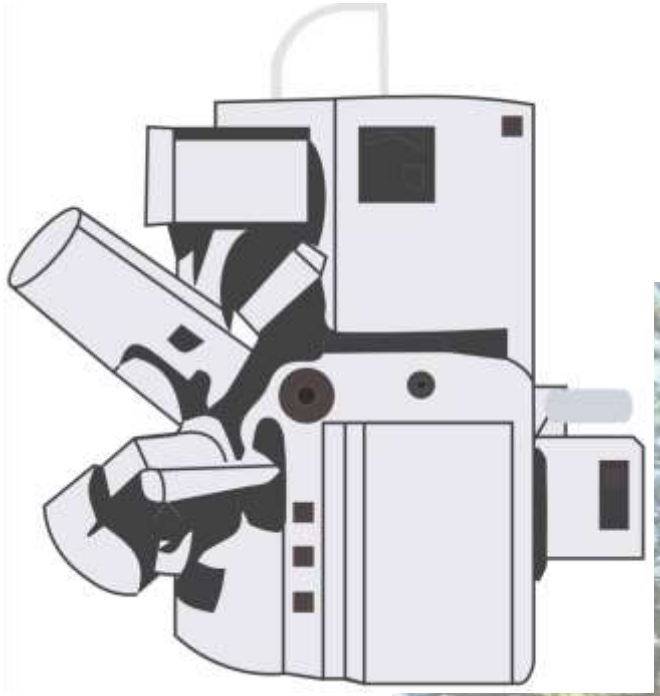
高清图像中，<0.075mm的集料颗粒占总颗粒数的占比，符合对沥青混合料内各粒径范围内集料颗粒个数分布的普遍认知，也侧面说明了高清图像在介观尺度结构信息上的还原度。

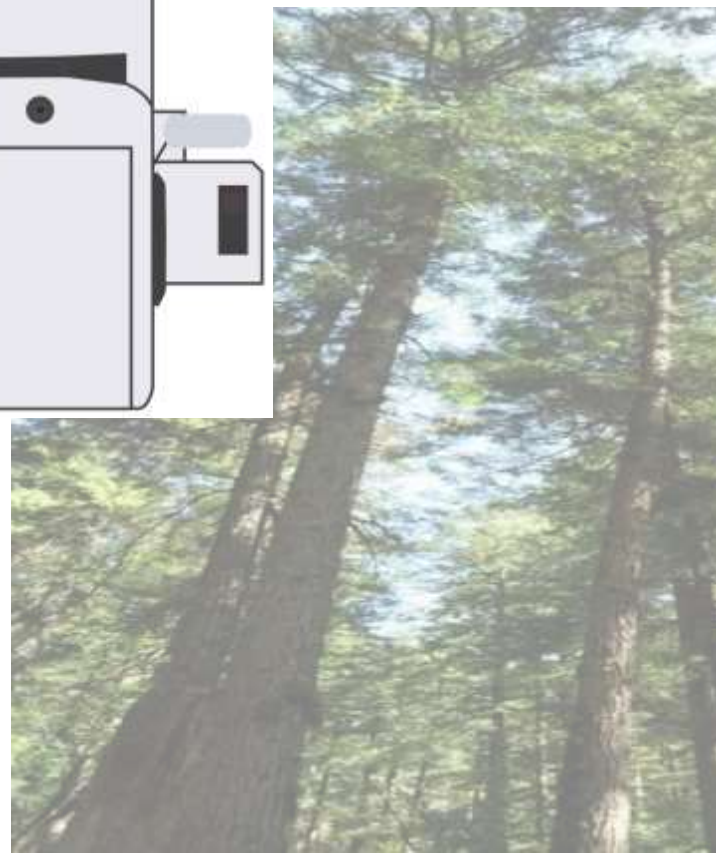
In the high-resolution image, the proportion of aggregate particles <0.075 mm relative to the total particle count aligns with the commonly accepted distribution of particle counts across size ranges in asphalt mixtures, indirectly indicating the high-resolution image's fidelity in capturing meso-scale structural information.



V This Method and Environment
本方法对环境的意义

V. Summary 总结





高精度的图像采集技术，可以更准确地分析沥青混合料的成分和结构，优化材料配比，提高其耐久性和性能。间接或直接的延长道路的使用寿命，减少因道路维修而造成的环境影响。
研究沥青混合料图像采集方法还有助于开发更加环保的材料和施工方法，推动可持续交通建设的发展，减少对自然资源的消耗。

High-precision imaging technology enables more accurate analysis of asphalt mixture composition and structure, optimizing material proportions to enhance durability and performance. This directly or indirectly extends road lifespan and minimizes environmental impacts associated with road maintenance. Furthermore, research on asphalt mixture image acquisition methods supports the development of more eco-friendly materials and construction techniques, advancing sustainable transportation infrastructure and reducing natural resource consumption.

感谢您的倾听！
Thank you for your attention！