

排水沥青路面在大中修罩面工程中的应用 及其养护技术

Application of porous asphalt overlay on expressway pavement and its maintenance

江苏高速公路工程养护技术有限公司
茅荃

Jiangsu Expressway Engineering Maintenance Technology Co.,Ltd
Quan Mao



江苏高速公路工程养护技术有限公司
JIANGSU EXPRESSWAY ENGINEERING MAINTENANCE TECHNOLOGY CO.LTD

江苏排水沥青路面应用背景

Backgrounds of the application of porous asphalt in Jiangsu

2005

盐通高速新建排水沥青路面
new construction
in Yan-Tong
Expressway
(16.8KM)

2008

宁杭高速新建排水沥青路面
new construction
in Ning-Hang
Expressway
(40KM)

2014

江苏高速养护工程使用排水沥青路面
used as Maintenance
measure in
Expressways in Jiangsu



江苏排水沥青路面应用背景

Backgrounds of the application of porous asphalt in Jiangsu

2015年

排水沥青路面在盐通高速使用10年，性能良好
used in Yan-tong for 10 years with good performance

通车里程累计4539公里，规划里程约5200公里，2035年新规划里程6600公里
milage of expressway 4539km in jiangsu, with planned milage 6666 in 2035

通车15年以上高速占24%，通车10年以上高速占64%
24% of expressway open to traffic for 15 years
64% of expressway for 10 years

排水沥青路面值得推广
worth promotion

排水路面在新建高速应用规模受限
limited use in new construction

排水沥青路面在养护大中修工程中应用前景广泛
potential in middle-large maintenance projecy

交通运输部企业创新项目《江苏省排水沥青路面成套技术研究及应用》
enterprize innovation project "research and application of porous asphalt in jiangsu as a systematic technology



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排水沥青路面应用背景/Backgrounds of the application of porous asphalt in Jiangsu

江苏省排水沥青路面发展历程及主要工程概况（2005~2017）
Statistics of the application of porous asphalt in Jiangsu(2005-2017)

年份/year	项目名称/project name	项目类型/type	里程/amount
2005年	沿海高速公路（盐通段）排水沥青路面工程	新建/new	17 km
2008年	宁杭高速公路二期排水沥青路面工程	新建/new	40 km
2010年	南京南站至禄口机场高速公路排水沥青路面工程	新建/new	2.5 km
2014年	盐靖高速公路2014年度旧路改造应用排水沥青路面工程	养护/overlay	12 km
2015年	盐靖高速公路2015年度旧路改造应用排水沥青路面工程	养护/overlay	10 km
2015年	宁宿徐高速公路2015年度旧路改造应用排水沥青路面工程	养护/overlay	12 km
2015年	沿海高速公路（盐通段）排水沥青路面预防性养护工程	养护/overlay	17 lane km
2016年	盐靖高速公路2016年度旧路改造应用排水沥青路面工程	养护/overlay	4.5 km
2016年	宁宿徐高速公路2016年度旧路改造应用排水沥青路面工程	养护/overlay	17 km
2017年	宁宿徐、盐靖、沿海等高速公路	养护/overlay	68km
累计/total			195km





汇报大纲/Outline

1

排水沥青路面在大中修罩面工程中的应用
Application of porous asphalt as Expressway
pavement overlay

2

排水沥青路面的养护技术
Techniques of porous asphalt maintenance



汇报大纲/Outline

一、排水沥青路面在大中修罩面工程中的应用 Application of porous asphalt as Expressway pavement overlay

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➤ 旧路面性能多维度评价
multi-dimensional evaluation of existing pavement

2

➤ 防水粘结层优化设计
optimization of waterproofing layer design

3

➤ 排水系统改造设计
retrofit of existing pavement drainage system

4

➤ 分车道施工冷接缝技术
cold joint technology between lanes

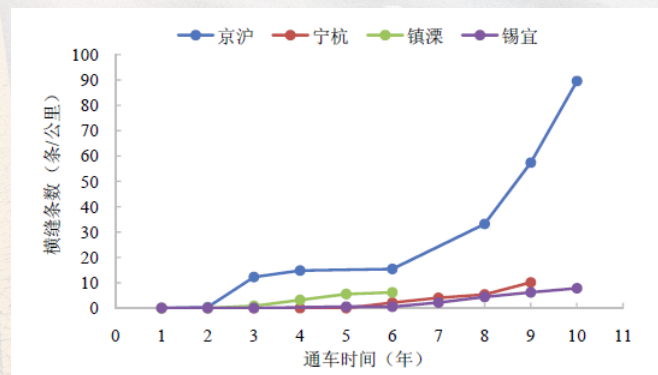
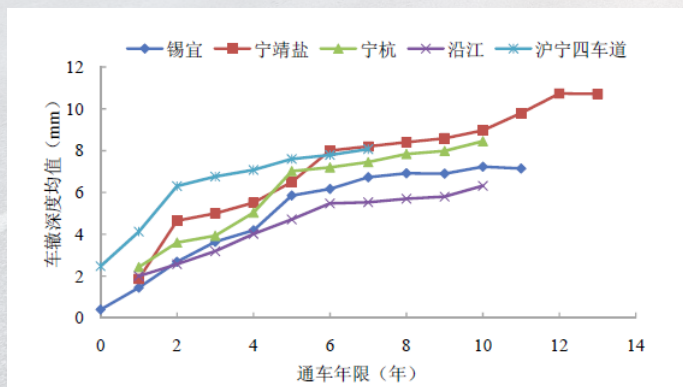
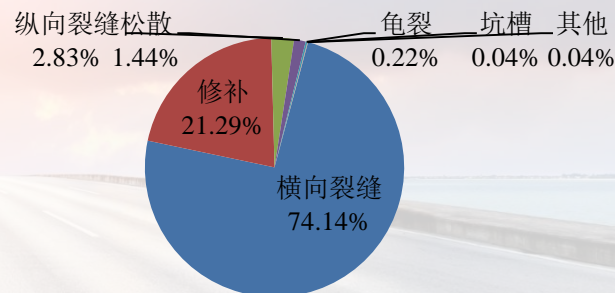
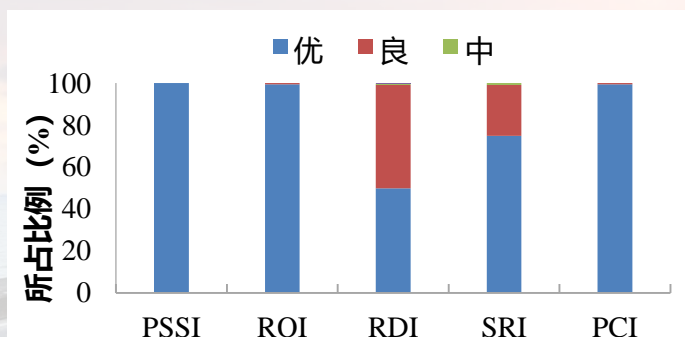
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➤ 质量控制新技术
new quality control technology



旧路面性能多维度评价/multi-dimensional evaluation of existing pavement

- 路表使用性能主要问题为车辙增长和抗滑性能衰减；路面破损主要为横向裂缝和修补/the primary surface issues related to performance: rutting and friction loss; the primary pavement distress issues: transverse cracking and patches;
- 江苏高速公路典型病害：车辙与裂缝。/in Jiangsu the main expressway distress: rutting and cracking



旧路面性能多维度评价/multi-dimensional evaluation of existing pavement

病害类型 /distress	评价方法/Evaluation method	评价指标/index	评价性能/performances
车辙/rutting	MMLS3加速加载试验/MMLS3 APT	车辙深度、变形率 /Rutting depth, permanent deformation rate	评价 高温稳定性 / (high temperature performance)
	全厚式车辙试验/ Full depth rutting test	车辙深度、变形率/ Rutting depth, permanent deformation rate	
	横断面车辙深度检测/ Rutting profiler	车辙类型（磨损型、压 密型、失稳型）/ Rutting type(wearing, densification, plastic flow)	辅助判定车辙类型/ rutting types(auxiliary test method)
裂缝/cracking	劈裂试验/ IDT	劈裂强度/ IDT	评价 常温抗裂性 cracking resistance
	裂缝拓展深度检测 （取芯或3D探地雷达检测） cracking extension measurement(coring or 3D GPR)	裂缝类型（温缩型、疲 劳型、反射型）/ cracking types(thermal, fatigue, reflection)	辅助判定裂缝类型 (auxiliary test for cracking types evaluation)
材料老化、疲劳 损伤等/aging and fatigue	回收沥青三大指标试验/ Property measurements on extracted asphalt	针入度、软化点、延度 /penetration, softening pint, Ductility	评价面层材料的 老化 、 疲劳损伤 等状况，辅助 分析典型病害成因/ aging, fatigue (auxiliary test for distress diagnostic)
	旧沥青混合料抽提筛分试验 /Quantitative Extraction of Asphalt Binder	油石比、矿料级配 Bitumen-Aggregate Ratio, aggregate gradation	

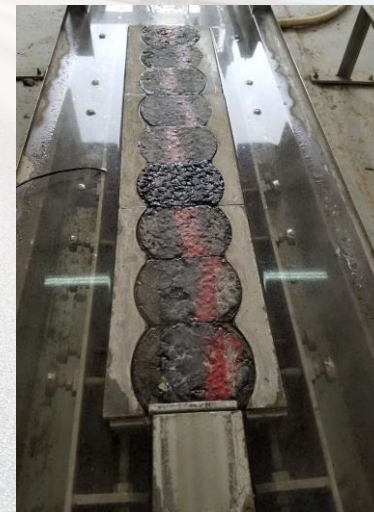
旧路面性能多维度评价/multi-dimensional evaluation of existing pavement

■ MMLS3加速加载试验/ MMLS3 APT

- 路面芯样直径为 $\phi 150\text{mm}$ ，厚度一般为上中面层总厚度。 /

the diameter of the cored sample $\phi 150\text{mm}$, core depth usually equivalent to the depth of top surface and middle surface layer combined

- 测试加载20万次时路面芯样的车辙深度，并计算变形率，最终评价不同路面的**抗高温变形能力**。 / measure the rutting depth and the deformation rate with 200,000 wheel passes to evaluate the high temp. performance



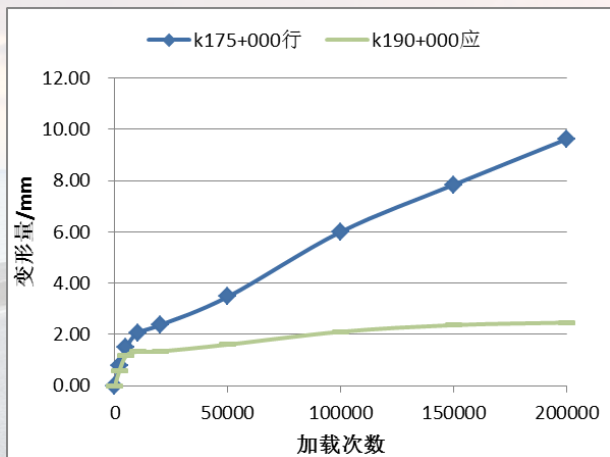
旧路面性能多维度评价/multi-dimensional evaluation of existing pavement

■ MMLS3加速加载试验/ MMLS3 APT

■ 试验温度65°C水浴, 加载速率7200次/h, 加载轮接地压强0.7MPa。 /
sample conditioning(65°C water), loading rate 7200 passes/h, tire pressure 0.7MPa

■ 取典型断面芯样, 深车辙、浅车辙; 行车道、应急车道等。

core location: deep rutting site, light rutting site, driving lane, emergency lane, etc.



行车道与应急车道芯样
Deformation for driving and emergency lane
after different loading passes

高温性能不良芯样
cores with poor high temperature
performances

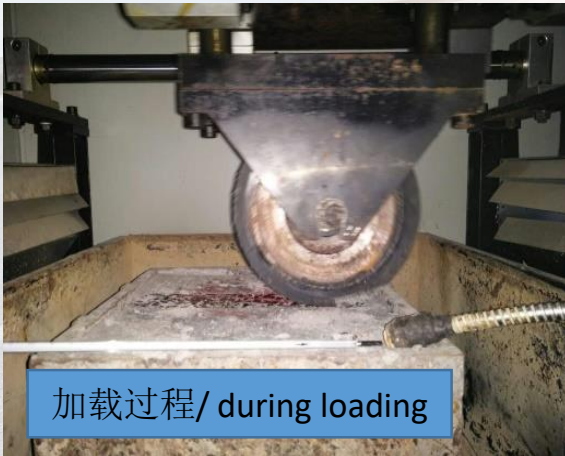
旧路面性能多维度评价/multi-dimensional evaluation of existing pavement

■ 全厚式车辙试验/full depth rutting test

- 路面芯样直径为 $\phi 300\text{mm}$ ，厚度一般为上中下面层总厚度。

the diameter of the cored sample $\phi 300\text{mm}$, core depth usually equivalent to the depth of the top surface, middle and bottom surface layer combined

- 加载至路面芯样发生破坏或者车辙变形趋于稳定，一般车辙变形趋于稳定需要连续加载72h以上。loading till the failure of the sample or when the rutting becomes stable, usually it takes more than 73-h continuous loading



加载过程/ during loading



加载后芯样/cores after loading



旧路面性能多维度评价/multi-dimensional evaluation of existing pavement

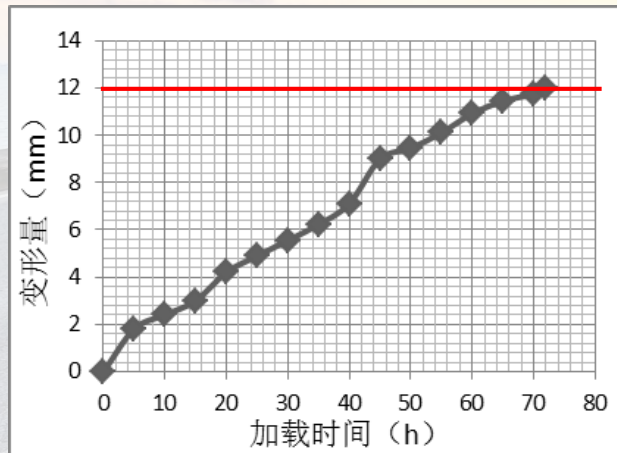
■ 全厚式车辙试验/full depth rutting test

- 试验温度65°C，加载速率2520次/h，加载轮接地压强0.7MPa。

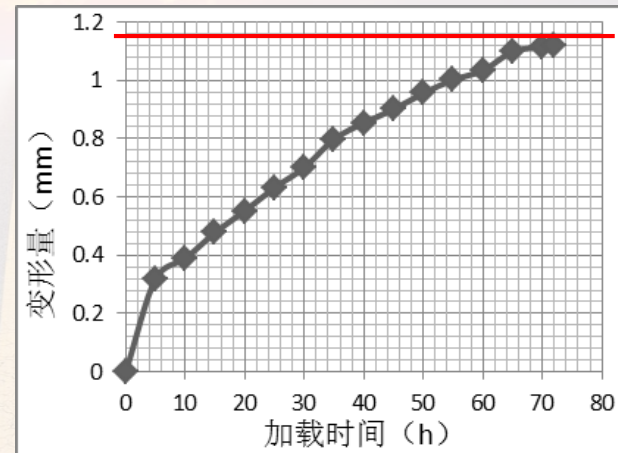
sample conditioning(65°C water), loading rate 2520 passes/h, tire pressure 0.7MPa

- 取典型断面芯样，深车辙、浅车辙；行车道、应急车道等。

core location: deep rutting site, light rutting site, driving lane, emergency lane, etc.



行车道芯样



应急车道芯样

Deformation for driving and emergency lanes after different loading time



旧路面性能多维度评价/multi-dimensional evaluation of existing pavement

■ 横断面车辙深度测定/transverse rutting profiling

- 按照JTG E60-2008中T 0973-2008采用路面横断面仪或横断面尺进行测量。

using transverse rutting profiling device or a straightedge based on T 0973-2008 in the Chinese standard JTG E60-2008

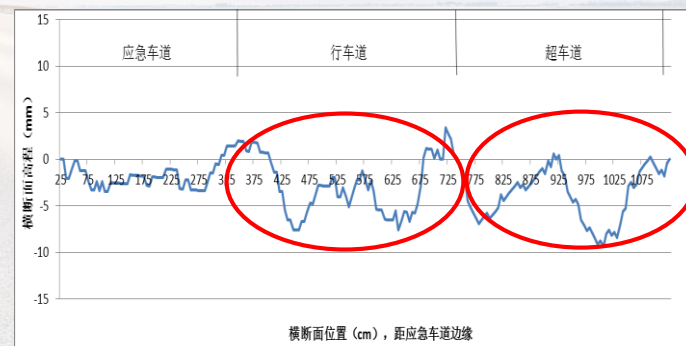
- 或者人工采用激光笔和钢尺测量。



路面横断面尺
pavement straightedge



人工测量/
manual measurement



横断面车辙深度测试结果
results of a transverse rutting
profiling



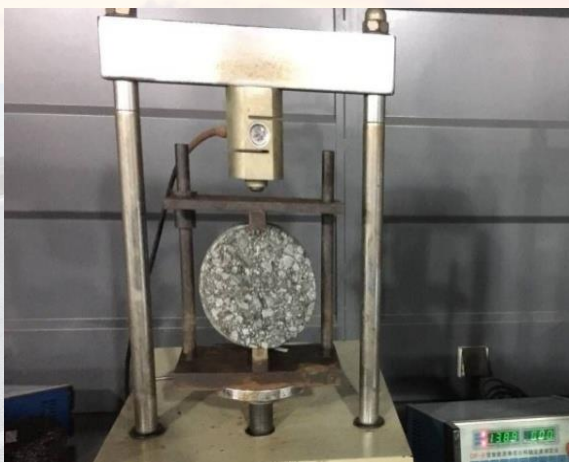
旧路面性能多维度评价/multi-dimensional evaluation of existing pavement

■ 劈裂试验/IDT

- 路面芯样直径为 $\phi 100\text{mm}$ ，厚度为上、中、下面层的面层厚度。

the diameter of the cored sample $\phi 100\text{mm}$, core depth usually equivalent to the depth of THE top surface, middle and bottom surface layer combined

- 试验温度 15°C ，加载速率 $50\text{mm}/\text{min}$ 。 /test temperature 15°C , loading rate $50\text{mm}/\text{min}$



劈裂试验过程
during test



劈裂后芯样
after test



旧路面性能多维度评价/multi-dimensional evaluation of existing pavement

■ 裂缝病害现场调查/field survey for cracking distress

- 路面现场人工调查，统计裂缝桩号、类型、长度等信息，并计算裂缝间距、裂缝贯穿度。

Walking surveys for the mileposts where cracking is located, cracking types, length, spacing, crack penetration depth, etc.

取芯或开挖，观察裂缝拓展情况。/take cores or excavate to observe the cracking penetration



现场调查裂缝
field survey



取芯观察裂缝
cracking in the cored sample



开挖观察裂缝
excavation for crack
inspection



旧路面性能多维度评价/multi-dimensional evaluation of existing pavement

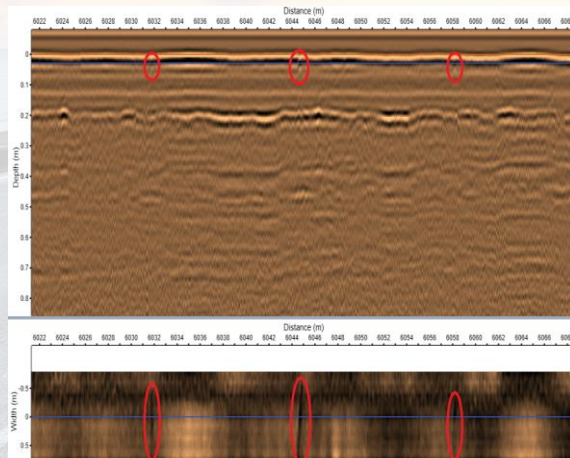
■ 三维探地雷达检测/3D GPR

- 用三维雷达对路面结构进行扫描，以了解裂缝病害范围及深度。

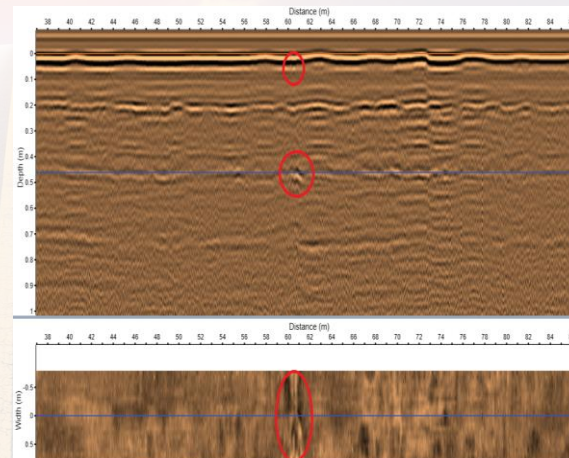
3D GPR scan for the scope and depth of cracking

- 根据裂缝发育机理，可将裂缝分为疲劳裂缝、温缩裂缝和反射裂缝三大类。

Based on the mechanism of initiation, cracking classified as fatigue, thermal and reflection cracking



面层开裂
surface cracking



基层开裂
base cracking



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optimization of waterproofing layer design

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cold joint technology between lanes

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质量控制新技术
new quality control technology



防水粘结层优化设计/optimization of waterproofing layer design

- 旧路加铺排水沥青路面防水粘结层/waterproofing layer for porous asphalt overlay
- 改性沥青碎石封层，如SBS改性沥青碎石封层、橡胶沥青碎石封层等。
chip seal using modified asphalt, eg. SBS, Rubber asphalt
- 改性乳化沥青，如SBS改性乳化沥青等。 Polymer-Modified Asphalt Emulsions. eg. SBS

	防水粘结层类型/waterproofing layer type		
	SBS 改性乳化沥青 SBS modified asphalt emulsion	SBS 改性沥青碎石封层 SBS modified bitumen chip seals	橡胶沥青碎石封层 Rubber modified bitumen chip seals
	沥青用量0.4kg/m ² asphalt usage 0.4kg/m ²	沥青用量1.2kg/m ² asphalt usage 1.2kg/m ² 碎石粒径5-10mm agg. size 5-10mm 碎石撒布面积60% chip spray area 60%	沥青用量1.5kg/m ² asphalt usage 1.5kg/m ² 碎石粒径5-10mm agg. size 5-10mm 碎石撒布面积60% chip spray area 60%
层间抗剪强度 (MPa) Shear bond strength	0.454	0.600	0.654
层间抗拉强度 (MPa) Tensile bond strength	0.252	0.339	0.442



防水粘结层优化设计/optimization of waterproofing layer design

- 旧路加铺排水沥青路面防水粘结层/waterproofing layer for porous asphalt overlay
- 改性沥青碎石封层，如SBS改性沥青碎石封层、橡胶沥青碎石封层等。
chip seal using modified asphalt, eg. SBS, Rubber asphalt
- 改性乳化沥青，如SBS改性乳化沥青等。 Polymer-Modified Asphalt Emulsions. eg. SBS



橡胶沥青碎石封层
Rubber modified bitumen chip seal



改性乳化沥青粘层
Polymer modified asphalt emulsions bond layer



防水粘结层优化设计/optimization of waterproofing layer design

- 双层水沥青路面粘结层/bonding layer for double-layer porous asphalt
- 改性乳化沥青，如SBS改性乳化沥青等。/Polymer-Modified Asphalt Emulsions. eg. SBS
- 既保证竖向的渗透功能，又提供良好的层间粘结。/adequate bonding and vertical permeability



改性乳化沥青洒布前
Before bonding layer laying



改性乳化沥青洒布后
after bonding layer laying



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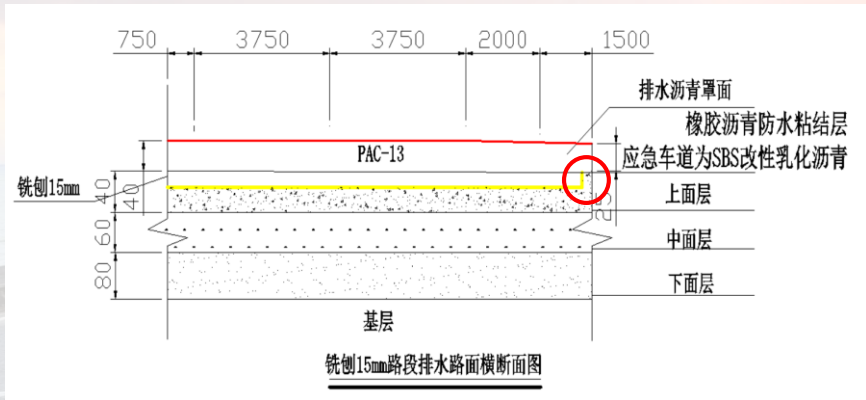
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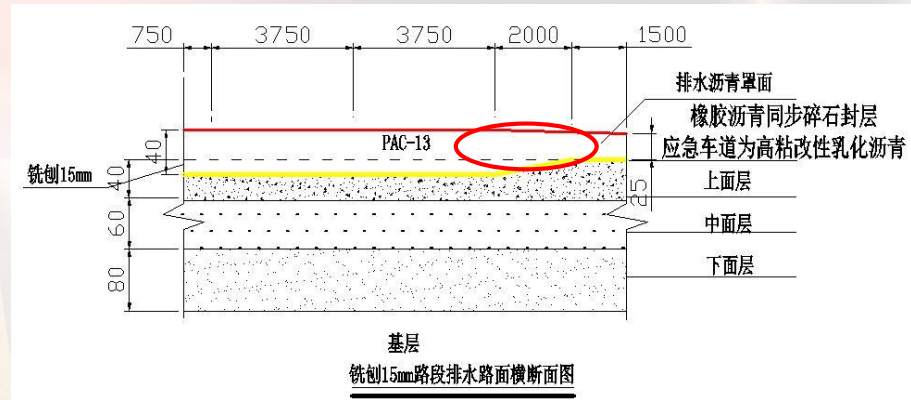


排水系统改造设计/retrofit of existing pavement drainage system

- 应急车道横向阻水改造/modification for the transverse drainage of the emergency lane
- 铣刨机受护栏影响，无法铣刨到边，通过渐变深度铣刨，实现铣刨界面的高程过渡，改善应急车道阻水问题。 Variable milling along the width of the emergency lane



固定深度铣刨造成边缘阻水
constant milling-poor drainage



渐变深度铣刨
variable milling-good drainage



排水系统改造设计/retrofit of existing pavement drainage system

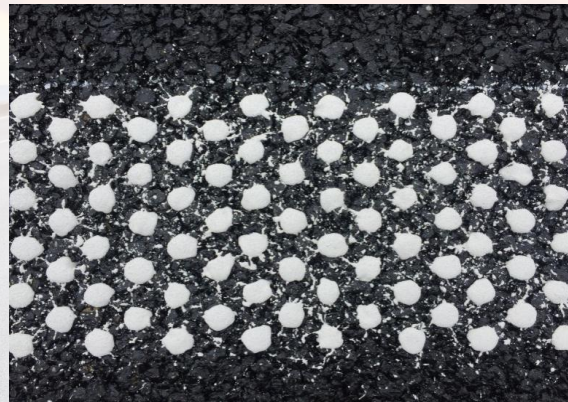
■ 透水标线技术/ Permmark Technology

- 普通热熔标线存在阻水现象，点状或絮状透水标线改善标线位置排水效果。

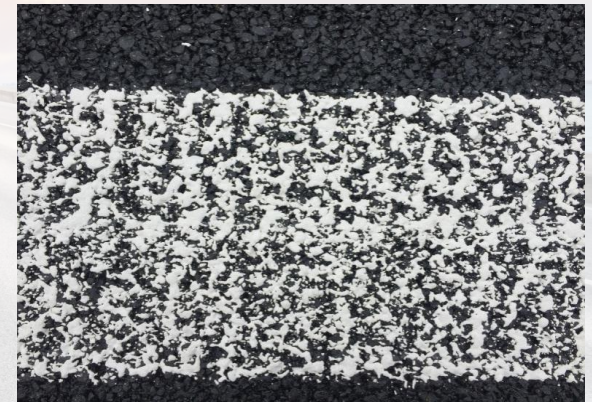
conventional marking can reduce the permeability of pavement while dotted or floccus marking can keep the permeability



热熔标线雨天阻水
conventional



点状透水标线
dotted



絮状透水标线
floccus



排水系统改造设计/retrofit of existing pavement drainage system

- 桥面排水系统改造/retrofit of bridge deck drainage system
- (1) 利用原桥面的横向或竖向泄水孔。/use the transverse and vertical inlet of the existing deck



横向泄水孔
transverse inlet



竖向泄水孔
vertical inlet



排水系统改造设计/retrofit of existing pavement drainage system

- 桥面排水系统改造/retrofit of bridge deck drainage system
- (2) 桥头伸缩缝位置打孔/boring at the location of the bridge joint



伸缩缝位置打孔
boring

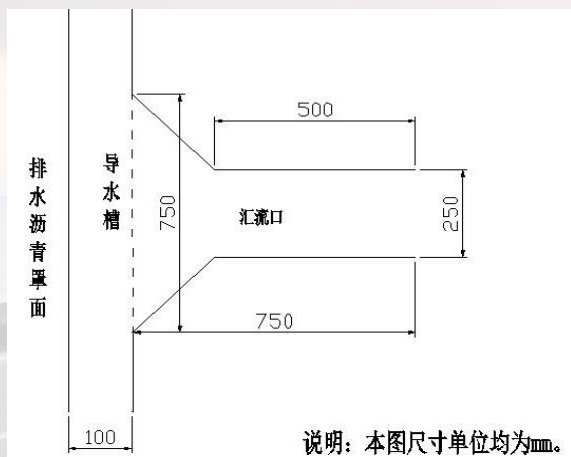


PVC管构成横向排水通道
PVC Pipe for the transverse drainage



排水系统改造设计/retrofit of existing pavement drainage system

- 顺坡段排水系统改造/retrofit of slope drainage system
- 通过路侧设置纵向导水槽与横向泄水口，实现顺坡段排水。
- longitudinal gutter + transverse discharge



顺坡段排水设施
slope drainage



纵向导水槽
longitudinal gutter



横向泄水口
transverse discharge



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分车道施工冷接缝技术/cold joint technology between lanes

- 正常路段施工，建议采用多台摊铺机联合摊铺；收费站、服务区等加宽段施工，建议增加1台摊铺机。 2 pavers for regular road section construction, 3 for special sections, eg. toll gate, service area;
- 建议采用热接缝形式施工排水沥青路面。 hot joint construction suggested



正常路段2台摊铺机
2 pavers for the regular section



加宽段3台摊铺机
3 pavers for the regular section



分车道施工冷接缝技术/cold joint technology between lanes

- 对于占道施工，或加宽段分车道施工，导致纵向冷接缝；
- 建议采用**渗透性树脂**，保证接缝界面通畅的前提下，增强界面粘结。

For constructions with unavoidable cold joint diffusible resin is suggested as the joint bonding material



分车道摊铺
paving by lanes



铣刨形成接缝
joint via milling



接缝界面
joint interface

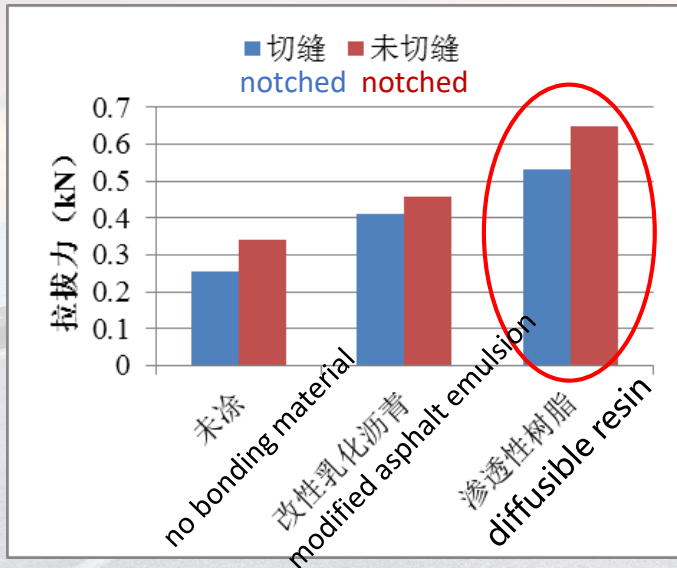


渗透性树脂涂抹
diffusible resin
application

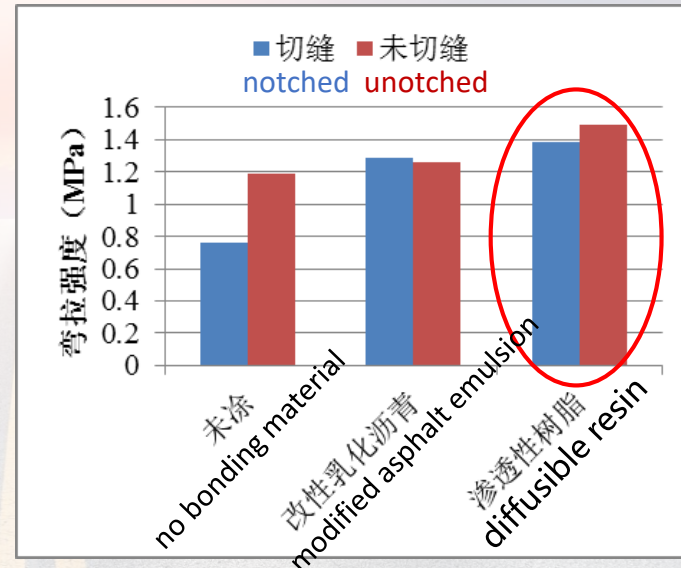


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渗透性树脂抗拉性能
tensile strength of diffusible resin



渗透性树脂抗弯拉性能
bending strength diffusible resin



汇报大纲/Outline

一、排水沥青路面在大中修罩面工程中的应用 Application of porous asphalt as Expressway pavement overlay

1

旧路面性能多维度评价
multi-dimensional evaluation of existing pavement

2

防水粘结层优化设计
optimization of waterproofing layer design

3

排水系统改造设计
retrofit of existing pavement drainage system

4

分车道施工冷接缝技术
cold joint technology between lanes

5

质量控制新技术
new quality control technology



质量控制新技术/new quality control technology

- 高粘度添加剂HVA投放工艺/High viscosity admixture(HVA) dropping approach
- (1) 人工投放(manual dropping); (2) 机械投放(mechanical dropping); (3) 专用罐投放(storage bin dropping)
- HVA投放实现自动化, 精度高。(high precision, automatic dropping of HVA)



人工投放
manual dropping



机械投放
mechanical dropping



专用罐投放
storage bin dropping



质量控制新技术/new quality control technology

- 钢轮+胶轮组合碾压工艺(Steel Wheels+Rubber Tires)
- 通过胶轮揉搓改善粗集料颗粒之间的点点接触状态；排水路面表面集料接触紧密；提高抗飞散能力及耐久性。 kneading effect to increase the point-point contact for coarse agg. and increase the resistance of raveling and durability



钢轮碾压
steel wheels compaction



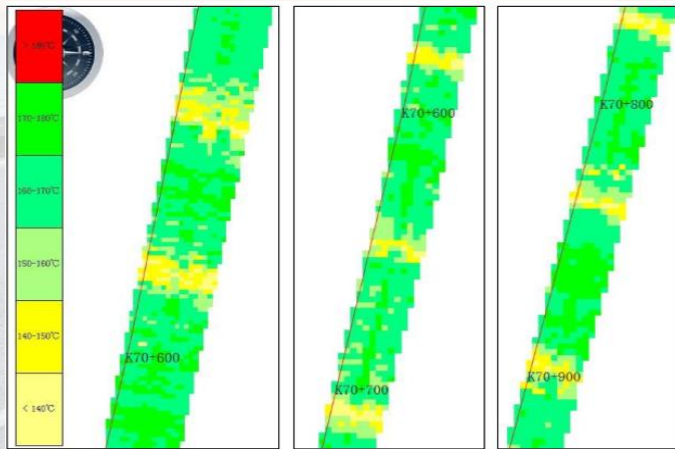
胶轮碾压
rubber tire compaction



质量控制新技术/new quality control technology

■ 摊铺碾压智能监控技术/Intelligent compaction

- 智能摊铺：通过温度传感器，动态采集摊铺温度。(temperature sensor to collect the compaction temperature automatically)
- 智能碾压：通过温度和位移传感器，动态采集碾压温度和碾压遍数。(via temperature and displacement sensors to monitor the compaction temperatures and compaction passes)



摊铺温度/compaction temperature



碾压遍数/compaction passes



质量控制新技术/new quality control technology

■ 排水沥青路面检测新技术/new testing techniques for porous asphalt

■ (1) 真空塑封仪/Vacuum packing machine

与体积法相比，可以减少试件表面开口孔隙对真实空隙率的影响，更接近实际情况。

Compared with the volumetric method, vacuum plastic wrapped sample can reduce the effect of open voids on the true air content.



真空塑封仪
Vacuum packing machine



封装试件
sealed sample



质量控制新技术/new quality control technology

■ 排水沥青路面检测新技术/new testing techniques for porous asphalt

■ (2) 电子渗水仪/electronic permeability instrument

排水沥青路面渗透400ml水需要4s左右，普通渗水仪受人为影响大；电子渗水仪自动记录渗水时间，结果更加准确。 / 4s for 400ml water permeated, conventional instrument is more dependent on operators;



电子渗水仪
Electronic permeability
instrument



操作界面
software Interface



汇报大纲/Outline

二、排水沥青路面养护技术 Techniques of porous asphalt maintenance

1

排水沥青路面清孔
vacuuming porous asphalt

2

雾封层
fog seals

3

大空隙超薄磨耗层
porous ultra thin bonded wearing course

4

厂拌热再生
hot central plant recycling



排水沥青路面清孔/vacuuming porous asphalt

■ 排水沥青路面专用清孔车/porous asphalt cleaning vehicle

- 通过喷射高压水，清理并回收路面内部的灰尘、泥沙等杂物

High-pressure water jetting, cleaning and collecting the dust, sand and debris inside the pavement



专用清孔车
porous asphalt cleaning vehicle



清孔
dust and debris cleaning





汇报大纲/Outline

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雾封层/fog seal

■ 还原-粘结型雾封层/rejuvenate-bonding type fog seal

- 还原-粘结型雾封层 (RJ+CEM):RJ成分主要功能为还原老化沥青; 沥青基材料CEM可起到增补沥青膜厚度, 增强粘结的功能。

reduction-bonding type fog seal (RJ+CEM): RJ component for rejuvenate asphalt and CEM for increase the asphalt film thickness



还原-粘结型雾封层材料
rejuvenate-bonding fog seal



雾封层洒布
fog seal laying



雾封层/fog seal

■ 还原-粘结型雾封层/rejuvenate-bonding type fog seal

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reduction-bonding type fog seal (RJ+CEM): RJ component for rejuvenate asphalt and CEM for increase the asphalt film thickness and bonding



雾封层洒布前
before fog seal



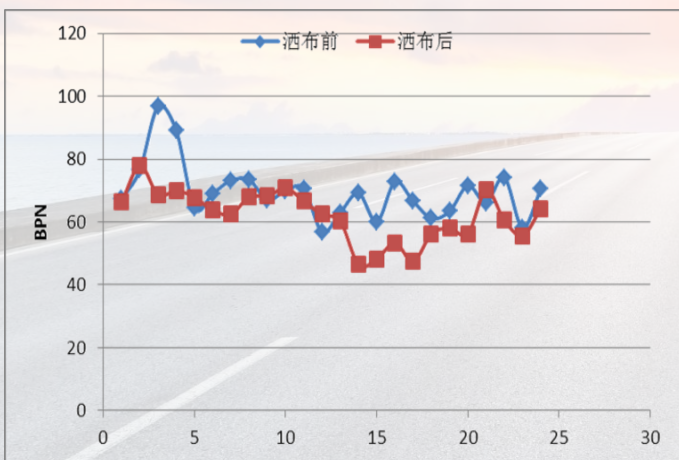
雾封层洒布后
after fog seal



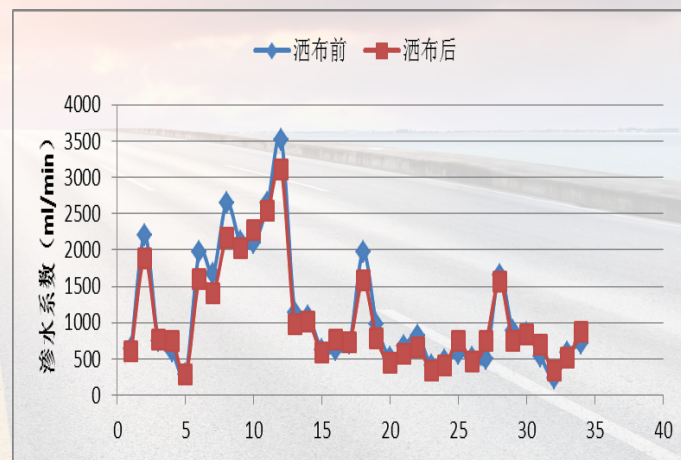
雾封层/fog seal

■ 还原-粘结型雾封层/rejuvenate-bonding type fog seal

养护材料的洒布对原路面的抗滑能力和渗水能力影响不大(摩擦系数降低率 $\leq 25\%$, 渗水系数降低率 $\leq 20\%$)。limited effect of fog seal on skid resistance and permeability, decrease of skid resistance $\leq 25\%$, permeability coefficient $\leq 20\%$)



洒布前后抗滑指标
skid resistance before and after
applying fog seal



洒布前后渗水指标
permeability before and after
applying fog seal



雾封层/fog seal

■ 表面强化型雾封层/surface strengthening fog seal

将渗透性树脂喷洒于排水路面表面，起到超前养护的目的，主要用于陡坡、急转弯等路段。

diffusible resin on porous asphalt pavement surface, mainly used on steep slope and curved road section.



表面强化型雾封层材料洒布
Surface strengthening fog seal
application



洒布效果
Effect



汇报大纲/Outline

二、排水沥青路面养护技术 Techniques of porous asphalt maintenance

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vacuuming porous asphalt

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大空隙超薄磨耗层
porous ultra thin bonded wearing course

4

厂拌热再生
hot central plant recycling



大空隙超薄磨耗层/porous ultra thin bonded wearing course

■ 技术背景/background

- “老、中、青” 排水路面均存在，缺少预防性养护和大中修养护之间的过渡性养护技术。

Porous asphalt in Jiangsu are at different ages, lacking a transitional maintenance technique besides preventive maintenance and rehabilitation.

- 江苏省高速公路进入养护高峰期，加铺与排水路面特性相同的功能层，达到排水、抗滑、降噪等效果，后期只需对该功能层铣刨重铺或再生利用，延长旧路面使用年限，减少全寿命周期养护成本。porous ultra thin bonded wearing course can keep the existing pavement permeable , skid-resistance and noise reducing and for later maintenance the thin layer can be milled and recycled



PUC-10



大空隙超薄磨耗层/porous ultra thin bonded wearing course

■ 结构形式及用途/structure arrangement and function

- 采用专用机械设备将设计空隙率大于14%的间断开级配热拌沥青混合料与黏层同步或异步铺装在下承层上，厚度为10mm~25mm的薄层沥青路面结构。

10-25mm thin layer (> 14% air content) bonded wearing course over existing pavement.

- 大空隙超薄磨耗层的英文为Porous Ultra-thin wearing Course，简称PUC：
 - PUC-I型（最大公称粒径4.75mm，设计厚度10mm~15mm），主要用于密级配路面浅车辙路段雨天抗滑性能改善；
PUC-I type (NMAS4.75mm, design thickness10mm~15mm) , used on dense graded light rutting pavement ;
 - PUC-II型（最大公称粒径7.5mm，设计厚度15mm~20mm），主要用于排水路面单车道维修；
PUC-II type (NMAS4.75mm, design thickness15mm~20mm) , used on lane repair of porous asphalt ;
 - PUC-III型（最大公称粒径9.5mm，设计厚度20mm~25mm），主要用于密级配路面或排水路面半幅加铺，用于服务功能提升。
PUC-IIItype (NMAS9.5mm, design thickness20mm~25mm) , used on Half width pavement repair of porous asphalt or dense graded pavement ;



汇报大纲/Outline

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hot central plant recycling



厂拌热再生/hot central plant recycling

- 使用排水路面铣刨料 (RAP) , 经破碎筛分后, 与新料共同拌和, 生产厂拌热再生排水沥青混合料。

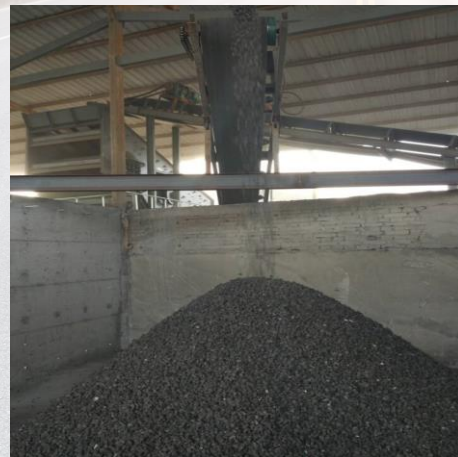
Use RAP from milled porous asphalt, crushing and mixed with new materials to produce porous asphalt material.

- RAP掺量为30%, 经室内试验和实体工程验证, 厂拌热再生排水沥青混合料的各项技术指标均能满足相关规范的技术要求。

With the addition of 30% RAP, recycled mixture can meet the requirement of the related specification.



排水路面铣刨料破碎
crushing of milled porous
asphalt



破碎后粗集料
coarse agg after
crushing



厂拌热再生混合料摊铺
paving of hot central plant recycled
material



江苏高速公路工程养护技术有限公司
JIANGSU EXPRESSWAY ENGINEERING MAINTENANCE TECHNOLOGY CO.,LTD

谢谢

Thank you



江苏高速公路工程养护技术有限公司
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