Evaluation of carbon grid reinforced asphalt overlays with accelerated pavement testing

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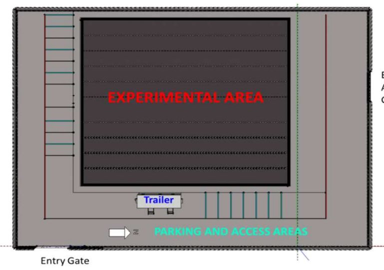
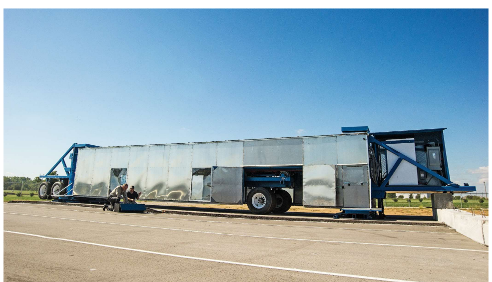
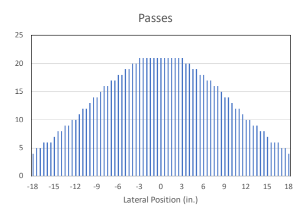
APT Facility Layout



PTM – In Testing Mode



Lateral Wander Mechanism



Wheel Load Calibration

PTM Capabilities

- Loading two sections at a time
- Axle load = up to 16.3kN (36 kips)
- Loading speed = 6km/h (4mph) Test length at uniform speed = 6m (20ft)
- Passes = 100,000 / week
- Maximum Lateral Wander = ± 0.6m (24 in.)
- Lateral Wander Pattern – user defined
- Temperature Control of the Air above the Pavements = ± 4°F
- Can be easily towed to a remote location – electric power needed there
- Power needed:
  - 480V/3Ph – 100A for operation without heating/cooling
  - 480V/3Ph – 200A for operation with heating/cooling

APT Loading

- Target temperature:
  - “Fatigue cracking” and “reflection cracking” = 20°C (68°F),
  - “Rutting” sections = 40°C (104°F)
- Loading Conditions:
  - Bi-directional trafficking for “fatigue cracking” and “rutting” pavements sections
  - Uni-directional trafficking for “reflection cracking” pavement sections.
  - Single axle load = 81.6 kN (18,000 lb)
  - Tire inflation pressure = 690 kPa (100 psi)
  - Lateral Wander: Max Lateral Position = 38cm (15 inch), SD = 25cm (10 inch)
- Accelerated loading is applied until:
  - 19 mm (0.75 in.) Permanent Deformation at the pavement surface;
  - 25% of each lane area is cracked (equivalent to 50% of the trafficked area cracked).

Artificial Accelerated Ageing : Two heating boxes

Seven infrared lamps in each box
Heating controlled at 203°F (95°C) on each lamp


Artificial Accelerated Ageing


Binder - 2013 Section	G*/sin δ @64C (kPa)	Aging ratio
Virgin binder in 2013	2.387	
Binder extracted in 2020 core	23.57	9.9
Binder - 2020 Section	G*/sin δ @70C (kPa)	Aging ratio
Extracted virgin binder	1.747	
After 3 weeks of ageing @ 95°C	5.114	2.9
After 4 weeks of ageing @ 95°C	7.396	4.2
After 5 weeks of ageing @ 95°C	25.813	14.8

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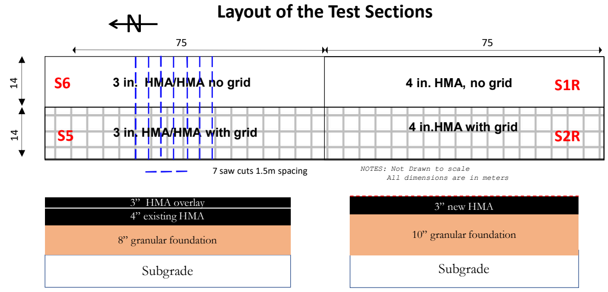
Geogrid Reinforcement of HMA layers Experiment

The purpose of this work is to conduct a full scale APT on the performance of geogrid reinforced HMA layers on distressed flexible pavement structures.

Layout of the Test Sections



Subgrade Layer Construction

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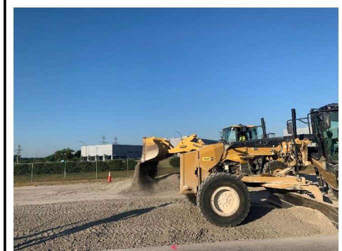
Flex Base Placement



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Sealing of the Flex Base with Prime Coat

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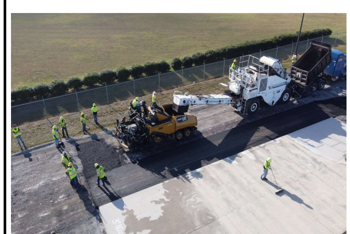
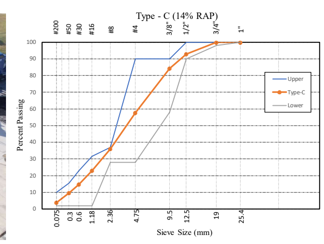
HMA Layers





All HMA layers are TxDOT Type SP-C mix (12.5mm NMAS) with 14% RAP

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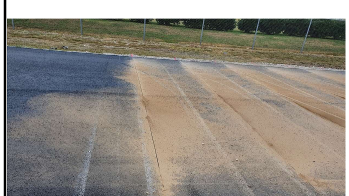
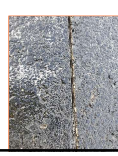
Saw Cutting in the Bottom HMA Layer





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Installation of the Geogrid

Carbophalt G200/200

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Geogrid Reinforcement

	Carbophalt G200/200	
	Longitudinal	**Transverse**
Material	Carbon fiber	Carbon fiber
Mechanical Properties		
Modulus of Elasticity	≥34,800 ksi (≥240,000 N/mm^2)	≥34,800 ksi (≥265,000 N/mm^2)
Tensile Strength	13.7 kip/ft. (200 kN/m)	13.7 kip/ft. (200 kN/m)
Elongation at break	1.5 ± 0.2%	1.5 ± 0.2%
Fiber Cross Section	0.022 $in.^2/ft.$ (46 mm^2/m)	0.022 $in.^2/ft.$ (46 mm^2/m)
Fiber Strands per Length	15.5 strands per ft. 51 strands per m	15.9 strands per ft. 52 strands per m

Bitumen-saturated carbon fiber grid coated with silica sand attached to a clear parting film.

Mesh Opening 0.59" (15 mm) x 0.59" (15 mm).

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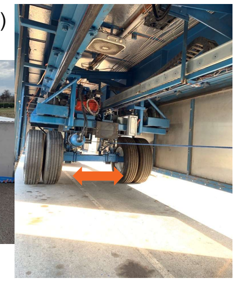
Accelerated Testing

Heating of test areas for 5 weeks @ 203°F (95°C)

APT testing

- Bi-directional loading
- 18,000lb and up (81kN) single axle load
- Speed = 3mph (5 km/h)
- Target Air Temp. = 77°F (25°C)
- Wheel wander with a truncated normal distribution with SD = 10in and maximum lateral position ± 15in (380 mm)



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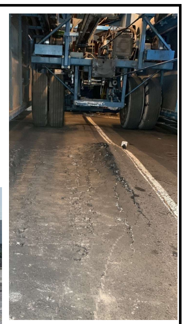
APT Testing - Measurements

- Permanent Deformation in 5 transverse profiles
- Crack Mapping
- Temperature at the surface and mid-depth of the AC surface layer.
- L-FWD (Lightweight – Falling Weight Deflectometer)



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Permanent Deformation / Rutting Measurements

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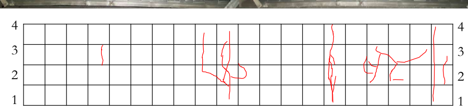
Crack mapping – Example



Number of squares with cracks =_24/80
% Cracked Area =__30%

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Failure criteria selection

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consequences of a project exceeding a particular performance criterion could likely be requiring maintenance or rehabilitation activities earlier than programmed. Table 7-1 provides the performance values for considerations by highway agencies, realizing that these values may vary among agencies based on their specific conditions.

Table 7-1. Design Criteria or Threshold Values Recommended for Use in Judging the Acceptability of a Trial Design

Pavement Type	Performance Criteria	Threshold Value at End of Design Life
AC pavement and overlays	Alligator cracking (AC bottom-up cracking)	Interstate: 10% lane area Primary: 20% lane area Secondary: 35% lane area
	Total rut depth (permanent deformation in wheel paths)	Interstate: 0.40 in. Primary: 0.50 in. Others (<45 mph): 0.65 in.
	Transverse cracking length (thermal cracks)	Interstate: 500 ft/mi Primary: 700 ft/mi Secondary: 700 ft/mi
	IRI (smoothness)	Interstate: 160 in./mi Primary: 200 in./mi Secondary: 200 in./m

<70 km/h: 16.5 mm

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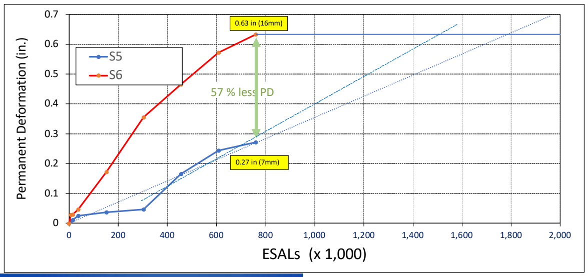
HMA Overlay - Rutting Performance Comparison



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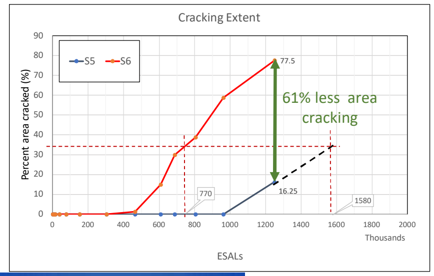
HMA Overlay - Cracking Development



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HMA Overlay - Cracking Pattern

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The geogrid reinforced section had **61% less** cracking at the end of testing.

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HMA Overlay - Performance Comparison

Comparison of rutting lives for S5 and S6

Section	Failure Criteria for Permanent Deformation at the Pavement Surface (mm)							
	6.35 mm ¼ in.	9.5 mm 3/8 in.	10 mm	12.5 mm ½ in.	15 mm	19 mm ¾ in.	20 mm	25.4 mm 1.0 in.
S5	518.0	990.5	1,085.0	1,582.3	2,079.7	2,885.5	3,074.5	4,148.8
S6	232.5	402.2	440.0	570.9	816.1	1,290.1	1,401.3	2,033.2
Life ratio S5/S6	2.228	2.463	2.466	2.772	2.548	2.237	2.194	2.041

Comparison of fatigue cracking lives for S5 and S6

Section	Failure Criteria (% of trafficked area)					
	50%	60%	70%	75%	80%	100%
S5 (ESALs)	2,217.4	2,468.4	2,719.4	2,844.9	2,970.4	3,472.4
S6 (ESALs)	1,032.9	1,141.7	1,250.4	1,304.8	1,359.2	1,576.6
Life ratio S5 / S6	2.147	2.162	2.175	2.180	2.185	2.202

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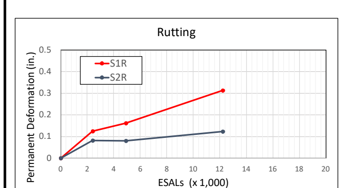
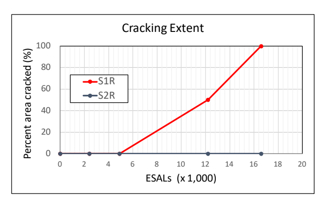
New HMA - Distress Development





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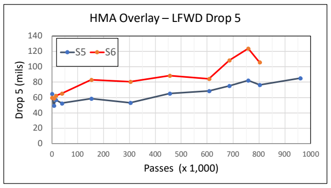
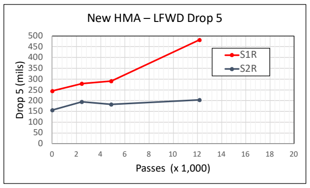
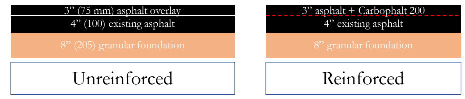
LFWD- Central Deflection





The vertical stresses at the top of the subgrade layer and transverse vertical strains at the bottom of the HMA layer are smaller in section S2R than those measured at the same time in section S1R. This indicates that the paving grid reinforces the asphalt surface layer.

Conclusions from the APT Testing – HMA Overlay



- Test stopped once the control section reached 0.63in. (16 mm) rut depth, at 1.25mil. ESALs
- The geogrid reinforced section withstood **61%** less cracking and **57%** less rutting.
- It took **4 times as long** for the first crack to appear on the geogrid reinforced section.
- The geogrid reinforced section had the cracking and rutting lives **at least double** of those of the unreinforced section. Therefore, the reinforcement of HMA overlays with geogrids brings significant benefits to the performance of pavement sections.

Evaluation of RAP/RAS Dallas pavement sections with accelerated pavement testing

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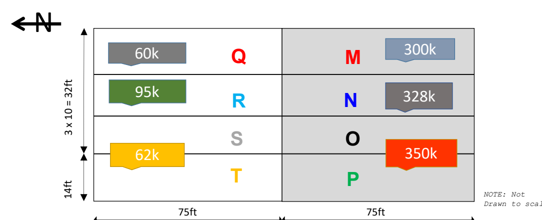
PAVEMENT TEST SECTIONS



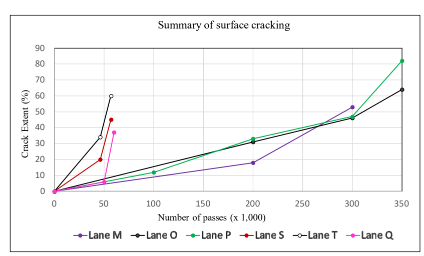
HMA Mixes

Test Section	Superpave-C HMA, SAC B 3.0 in. thick	Base Material 10.0 in. thick
M, Q	PG 64-22 (15%RAP +2%RAS) = Reference Mix	Type A Gr 1&2 Flex Base
O	PG 70-22 (15%RAP)	
N	PG 70-22 (no RAP or RAS)	
P	PG 64-28 (15% RAP + BMD)	
R	PG 64-22 (25% RAP + BMD)	
S	PG 64-22(15% RAP+2%RAS + BMD)	
T	PG 64-22 (15% RAP+2%RAS + BMD + Rejuvenator)	

LABORATORY TESTING
- Dynamic modulus
- Ideal RT
- HWRT
- SCB
- Ideal CT
- 4-Point Fatigue Bending

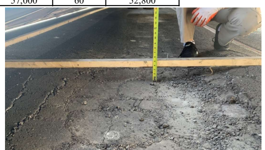
APT Testing: Crack mapping - Performed when first crack were observed

- Grid panel with 6-inch openings
- % of area cracked

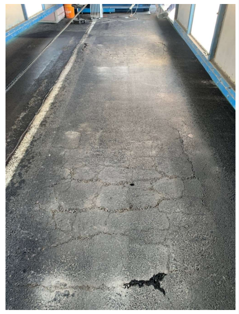


APT Testing: Summary of results

Section	No of passes	% area cracked	No of passes @failure
M	300,000	53	291,400
N	328,000	51	314,600
O	350,000	64	311,100
P	350,000	57	307,100
Q	60,000	37	63,400
R	95,000	60	91,200
S	62,000	53	59,200
T	57,000	60	52,800



Lane Q after 60,000 passes



Lane M after 300,000 passes

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Conclusions – Cracking

- Mixes that contain RAS performed worse than mixes with the same binder grade but no RAS.
- The BMD mixes had a reasonable good performance in comparison to the conventional mixes.
- Using a higher grade binder, PG70-22 instead of PG64-22, did not decrease the crackling performance of the mix but in improved it slightly.
- Mix T, with the binder containing the rejuvenator had the shortest life in the APT test, even though the IDEAL CT test predicted a better resistance for this mix, because ageing affected the binder with the rejuvenator more than it affected the other binders.
- The OT showed high variability with no correlation to the field performance.
- The SCB test has the potential to better estimate the cracking resistance. However, the variations of the results obtained were relatively high.
- The CT Index was linearly proportional to the SCB - FI index.
- There was minimal or no correlations between the cracking tests and the performance recorded by the APT, possible due to the limited number of mixes tested.

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Conclusions - Rutting

- Rutting is not a problem for Dallas recycled mixes
- Aging increased the stiffness of the asphalt mixtures by about 50 %
- BMD mixes perform better than Superpave mixes
- Section Q experienced large rates of deformations caused by the soft sublayers
- The HWT test correlated the best with the field performance.
- Dynamic Modulus showed a good correlation to the HWT results.

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Recommendations

- The higher grade binder (PG70-22) should be used instead of PG64-22 without expecting a reduction in cracking performance of the mix.
- Rejuvenators should be used with caution because they may increase the ageing potential of the binder and decrease the cracking resistance of the mix. Further laboratory testing must be performed on aged and unaged mixes to evaluate how each rejuvenator affects the ageing potential and the cracking resistance.

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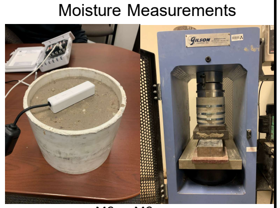
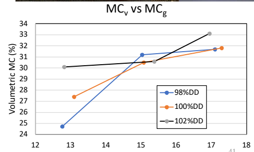
NOT MUCH SUCCESS WITH

Strain Gauges on Geogrids

Moisture Measurements



MC_v vs MC_g



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