PPRA

Better roads today. Stronger networks tomorrow.

2021 AEMA-ARRA-ISSA Annual Meeting

February 15-18

Using a Polyurethane Binder with Recycled Plastic in Cold Recycling of Roadways

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Pavement Recycling Systems, Inc.

Agenda

- The binder: What it is & how it works
- Industry potential
- How we developed comfort with the technology
  - Lab
  - Field
- What's next?

Modification of a Cold Recycle Process

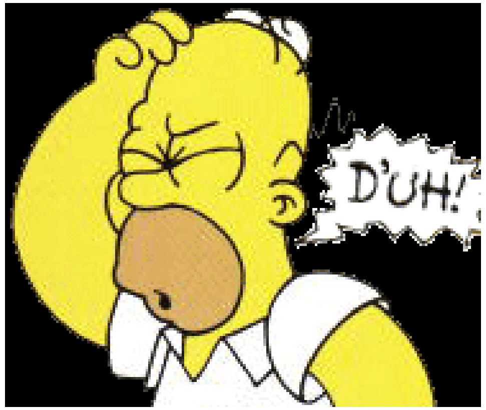
- Employs a Cold Recycling train or Cold Central Plant with minor modifications
- Complete substitution of a bituminous binder for a polyurethane binder with recycled plastic
- Conducted at ambient temperatures
- Has the potential to be used as a wearing course

First - Polyurethane vs Plastic

The METS Chemistry lab performed tests on the G5 and Polyol obtained from the field activities. Fourier-Transform Infrared (FTIR) results indicated:

- The G5 had an 82% match with Spenkel M-65. Spenkel M-65 is an isocyanate monomer. When an isocyanate monomer reacts with polyols, it produces polyurethanes.
- Polyol had an 86% match with Polyester, terephthalic acid. Terepthalic acid is an organic compound that is used principally as a precursor to the polyester PET, used to make clothing and plastic bottles.
- The G5/Polyol was mixed and allowed to cure hard and had an 81% match with polyether urethane.

What Does This Mean?



G5 is a Polyurethane Binder From Technisoil (New Binder Name is Neo)

Polyol is Made from Recycled Plastic

- Post Consumer
- Post Industrial

They Can Be Added as Two Separate Streams

Or Combined Together By the Manufacturer

Industry Potential

Performance & Sustainability

What piqued our interest?

- Solve two problems at once:
  - **Failing infrastructure:** Road conditions in North America
  - **Plastic epidemic:** First downstream application of plastic big enough to make a dent in the plastics problem
- With a completely new category of pavement: plastic (synthetic composite)

Sustainability Topline

- Potential to utilize 150,000 plastic bottles per lane mile (divert from single-use, post-consumer waste into long-term use solution)
- 90% reduction in greenhouse gas emissions.
- In-place recycling + ability to serve as wearing course
- Can be recycled into itself

How We Got Comfortable

Lab & Field

Performance Evaluation of a 100% Recycled Asphalt Pavement Mixture using a Polymer Binder: A Pilot Study

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ABSTRACT: Recently, a significant increase in the use of recycled asphalt pavement (RAP) in the United States (US) has been observed. In 2014, more than 70 million tons of RAP material was used in new pavements making RAP one of, if not the largest, recycled materials in the US. Old and aged RAP material is known to have an asphalt binder that is stiffer and more brittle than virgin asphalt binders typically used in asphalt mixtures. While the use of RAP in an asphalt mixture is expected to improve the mixture's resistance to rutting, it has a great tendency to reduce the mixture's resistance to cracking especially at the significantly high amount of RAP (more than 30%). In this pilot study, a new polymer binder called TechniSoil G5® was evaluated for use with a 100% RAP material. An extensive laboratory evaluation of the mechanical and mechanistic performance of the stabilized 100% RAP mixture was conducted. The designed mixture was evaluated in terms of its dynamic modulus property, resistance to rutting, and resistance to fatigue and thermal cracking. A mechanistic analysis was also conducted to determine the fatigue life of the stabilized 100% RAP mixture when used in a typical pavement structure at two different vehicle speeds using the 3D-Move Analysis software. The data showed that the stabilized 100% RAP with TechniSoil G5® has excellent resistance to the evaluated and critical asphalt pavement distresses. A significant increase in the fatigue life was also observed when compared to a typical dense-graded asphalt mixture. Based on the promising laboratory results, a field demonstration project was constructed in 2016 at the Al Wakar water station in Doha, Qatar. Initial field inspection six months after construction showed that the pavement with G5®-stabilized RAP mixture is performing very well under the hot desert environment.

(1) Dynamic Modulus (AASHTO TP79 and PP61)

(2) Rutting Resistance (AASHTO TP79)

(3) Fatigue Cracking Resistance (AASHTO T321)

(4) Thermal Cracking Resistance (Draft AASHTO)

(5) Mechanistic-Empirical Analysis of Pavement Structure

Conclusions from UNR

Conclusion of Lab Test Results

- lab test results show that G5®-stabilized mixture (100% RAP)
  - Is stable with a high stiffness.
  - Has high resistance to rutting at 60°C; hence, offering significantly more resistance to rutting at higher pavement temperatures.
  - has a high resistance to fatigue cracking at 21°C while maintaining a high flexural stiffness.
  - Has a cold fracture temperature of -34°C indicating that the mixture will perform well in designated cold environment.

Getting it in the field

2015 Trial
St. George Utah

Lessons Learned:

- Pumping system redesign
- Refine crushing system to hit optimal gradations
- Limit introduction of water to minimum

Trial Road 5 years Later

2015 – 2018: Continued R&D

- G5 Binder with addition of recycled plastic
- RAP gradations
- Testing and retrofit equipment for in-place processing unit
- In 2018 Department of Energy identified the product as a possible solution to a broader strategic initiative to address plastic waste. Goals include:
  - Utilize single-use plastics in long-term use applications
  - High value contribution to circular economy
  - Applications of large scale
- This peaked the City of Los Angeles's interest

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How We Got Comfortable

Domestic Resources

Anticipated Research: NCHRP Project NCHRP 09-66: Mechanical Properties of Laboratory Produced Recycled Plastic Modified (RPM) Asphalt Binders and Mixtures.

"On the Road to Solving Our Plastic Problem," Jade Grifin, News Post, University of California San Diego, October 2018.

"Building Roads From Plastic Recyclables," News Release, University of Texas at Arlington, April 2020.

Manufacturers and Vendors

Dow Completes Roads Improved With Recycled Plastic, Dow, 2020.

G5 100% Road Recycle System, TechniSoil Industrial LLC, 2019.

Evaluation of TechniSoil G5 Stabilizer With 100% Recycled Asphalt Pavement (RAP), TechniSoil Industrial LLC, undated.

"A Major Chemical Company is Building Roads Made of Recycled Plastic. They've Already Stopped 220,000 Pounds of Waste from Ending Up In Landfills," Aria Bendix, *Business Insider*, March 2019.

International Resources

Australia

Public Procurement of Road Building Materials—Research into Recycled Content, Victoria Bond, Australian Council of Recycling, October 2019.

Viability of Using Recycled Plastics in Asphalt and Sprayed Sealing Applications, Christina Chin and Peter Damen, Austroads Ltd., October 2019.

"Waste Plastic as Additive in Asphalt Pavement Reinforcement: A Review," Nuha S. Mashaan, Ali Rezagholilou and Hamid Nikraz, *18th AAPA International Flexible Pavements Conference,* 2019

"Recycled Waste Plastic for Extending and Modifying Asphalt Binders," Greg White and Gordon Reid, *8th Symposium on Pavement Surface Characteristics: SURF 2018—Vehicle to Road Connectivity*, 2018.

"Stiffness Properties of Recycled Concrete Aggregate With Polyethylene Plastic Granules in Unbound Pavement Applications," Ehsan Yaghoubi, Arul Arulrajah, Yat Choy Wong and Suksun Horpibulsuk, *Journal of Materials in Civil Engineering*, Vol. 29, Issue 4, 2017.

China

"Effects of Waste Polyethylene on the Rheological Properties of Asphalt Binder," Qunshan Ye, Serji Amirkhanian, Jin Li and Zixuan Chen, *Journal of Testing and Evaluation*, Vol. 48, Issue 3, pages 1893-1904, May 2020.

"Impact Performance of Recycled Plastic-Based Concrete," Feng Liu, Yong Yan, Lijuan Li, Cheng Lan and Gongfa Chen, *Journal of Materials in Civil Engineering*, Vol. 27, Issue 2, February 2015.

International Resources

India

"Study on Indirect Tensile Strength of Plastic Waste Bituminous Concrete for Road Construction," Anurag V. Tiwari and Y. R. M. Rao, *Romanian Journal of Transport Infrastructure,* Vol. 7, Issue 1, pages 93-106, July 2018.

"Plastic Roads: Use of Waste Plastic in Road Construction," Ahmed Trimbakwala, *International Journal of Scientific and Research Publications*, Vol. 7, Issue 4, pages 137-139, April 2017.

"Plastic Roads: A Recent Advancement in Waste Management," Huda Shafiq and Anzar Hamid, *International Journal of Engineering Research and Technology*, Vol. 5, Issue 9, pages 684-688, September 2016.

"Effect of Waste Plastics Utilization on Indirect Tensile Strength Properties of Semi Dense Bituminous Concrete Mixes," M. R. Archana, H. S. Sathish, M. Ashwin and Hanamant Hunashikatti, *Indian Highways*, Vol. 42, Issue 2, pages 69-78, 2014.

Spain

"Use of Plastic Wastes From Greenhouse in Asphalt Mixes Manufactured by Dry Process," J. E. Martin-Alfonso, A.A. Cuadri, J. Torres, M.E. Hidalgo and P. Partal, *Road Materials and Pavement Design*, Vol. 20, Supplement 1, pages S265-S281, 2019.

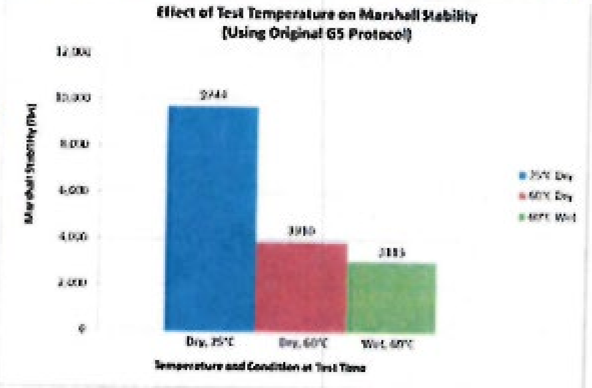
TECHNISOIL G5

Standards Division Research
City of Los Angeles
February 2019

Test results for G5 and 100% RAP (Using 4.0% G5 and Original Testing Protocol. 150 blows/face. Cured in compaction mold for 1 hour + a static load of 1,000 lbf. for 60±5 sec). Extracted and Cured for 24 hours at 25°C. Tested: 1) @ 25°C Ambient, 2) @ 60°C 2 Hours in Oven, 3) @ 60°C Immersed in Water for 30 min.

[illegible]	1	2	3
[illegible]	25°C Dry	60°C Dry	60°C Wet
[illegible]	132	132	132
[illegible]	9744	3910	3113
[illegible]	85.7	30.8	33.1

Using CIR Binder Content Criteria



Initial Testing in PRS Facility in Colton, CA

What We Learned

The G5 Binder is Much Different than the Bituminous Cold Recycling Products and Techniques We Were Used to In the Past

The Behavior and Viscosity is Different. Our Two Key Take Aways:

- We Had to Adapt our Pumping Equipment
- Need to Focus on Warmer Temperatures for the Binder

City of Los Angeles

Goal – High Profile Project in Front of Walt Disney Concert Hall. Announced by The Mayor

But we did Not Take a Ready, Fire Aim Approach

- First Project in a City Maintenance Yard
- Then a Project on a Less Profile City Street

City of LA Maintenance Yard

- **Small CCPR Project**
- **12.5 feet by 250 feet**
- **4 inches Deep**
- **¾" Gradation**

- Considered the "proof-of-concept" for using Technisoil material with PRS equipment

What We Learned

The G5 Binder is Much Different than the Bituminous Cold Recycling Products and Techniques We Were Used to In the Past

Our Two Key Take Aways:

- Water is Bad!
- You Can Over Roll It!

Think Gorilla Glue

Wentworth Road

- **Small CIR Project on Public Road**
- **12.5 feet by 1,000 feet**
- **4 inches Deep**
- **¾" Gradation**

Sample #1, taken at near the starting edge of the test strip, has a lab density=132 lbs/ft^3, Marshall Stability= 9,961 lbs, and ITS= 108 lbs/in^2.

Sample #2, taken at the halfway point of the test strip, has a lab density=128 lbs/ft^3, Marshall Stability= 8,151 lbs, and ITS= 107 lbs/in^2.

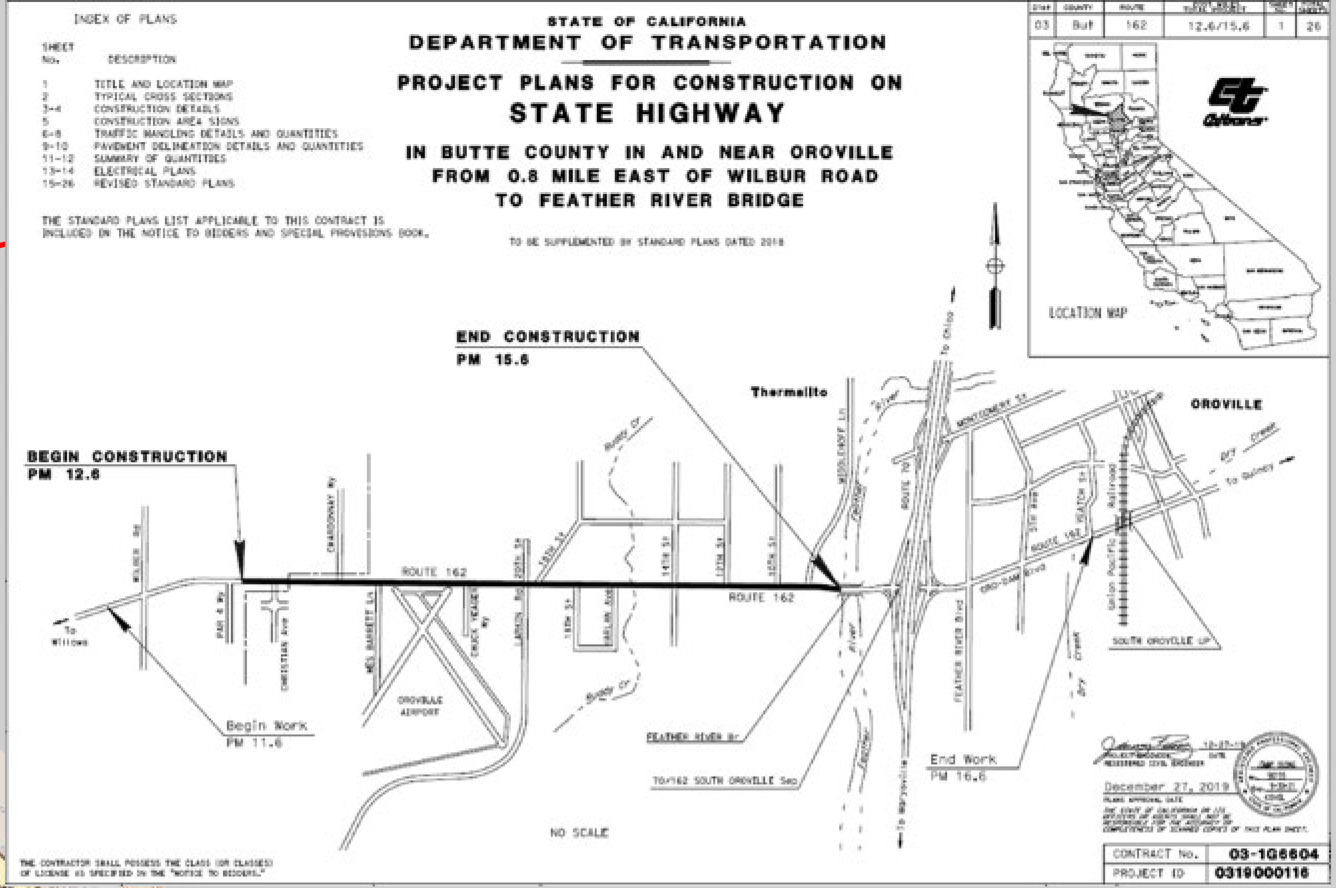
What We Learned

The G5 Binder is Much Different than the Bituminous Cold Recycling Products and Techniques We Were Used to In the Past

Our Two Key Take Aways:

- Smaller Gradation?
- We Can Make This Work

Happy Dance



Caltrans State Route 162
Plastic Pilot Project
Orville, California

State Route 162 Pilot

Caltrans Goals

- Recycling
- Future Uses
- Building a Spec
  QC and QA

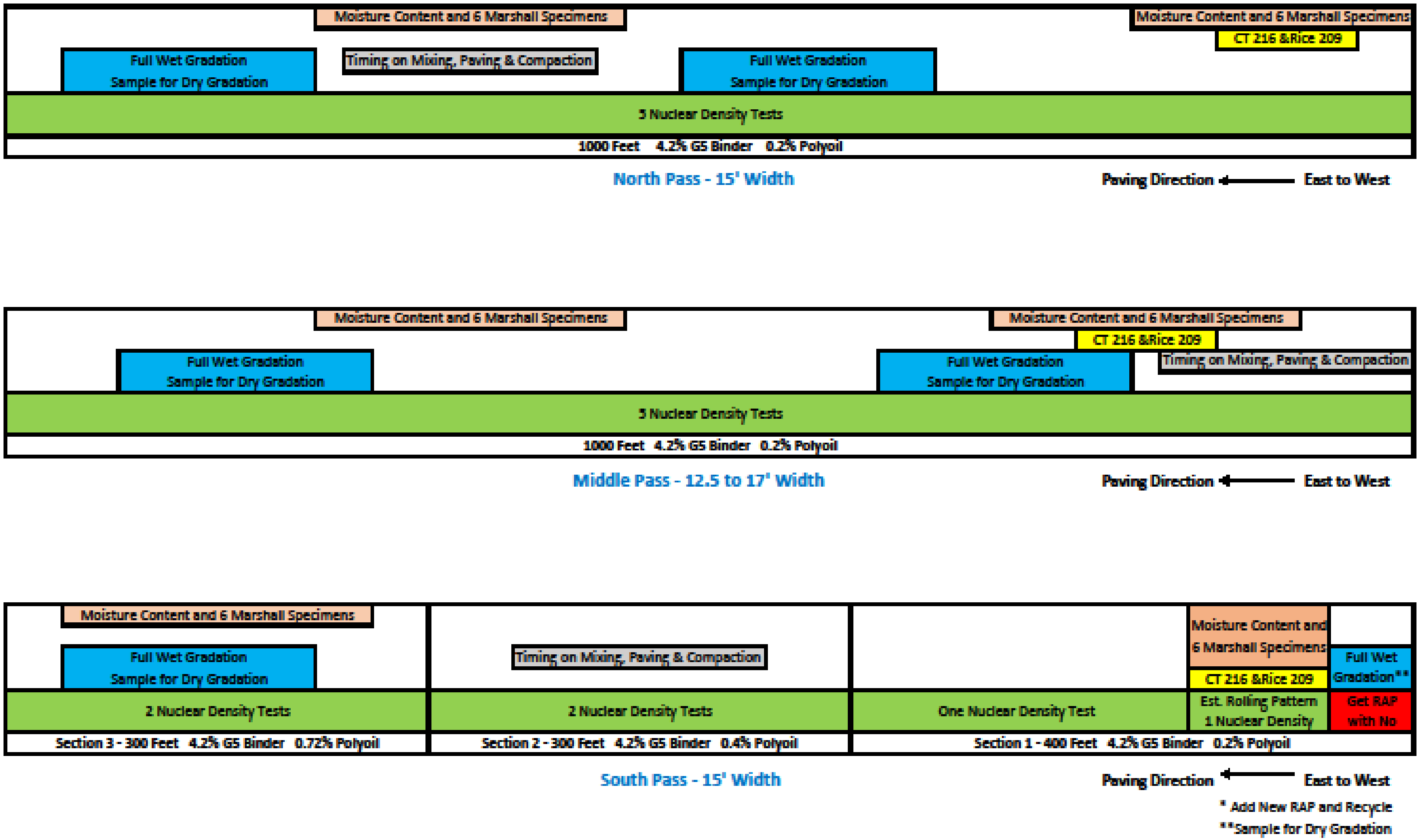
Project Information

- Original Project - Approximately 6 lane-miles of 3” CIR 3” using Foamed Asphalt with 1 ½” Maximum Gradation
- Switched Final 1000-ft of 3 Lanes to Technisoil Pilot

Specific Focus (Using Lessons Learned)

- ½” Maximum Gradation
- Minimal Water
- Hot Temperatures for Best Pumping of the Binder
- Varying % of Recycled Plastic (Polyol) Used

SR 162 - Plastic Binder Cold In-Place Recycling Pilot Project



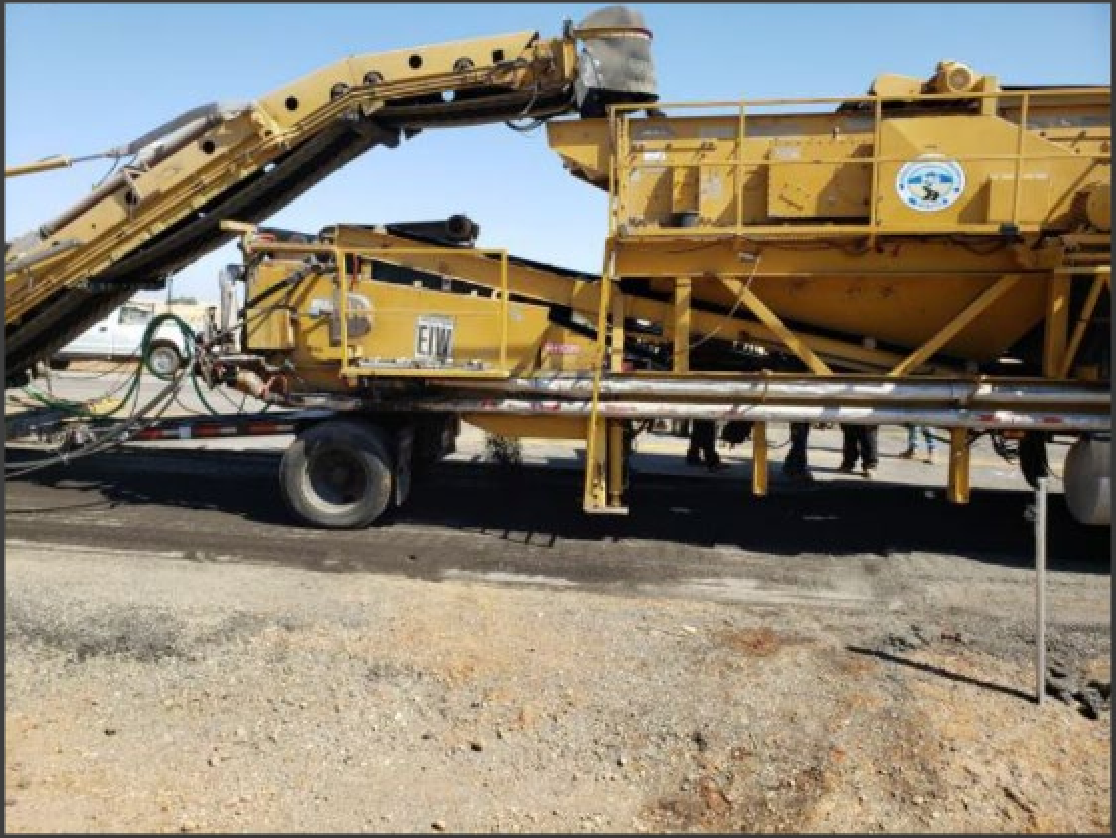
State Route 162

Cold Planing

Extra Width Mill

Full Width Mill

Sizing and Mixing



Screen, Crusher and Pugmill

Full Train

Binder Additive in Two Streams

G5 Binder

Polyol Tote

Placement

Pickup and Paving

Rolling and Compaction

Challenge During Construction

Locked Up Paver Twice

Hot Ambient Temperatures and Slow Processing Speed Due to Max. Gradation (Had to Avoid Overrunning Crusher)

Challenge During Construction

Broadcasting (handwork) behind paver

Shoveling material behind paver

The Unfortunate Email with the Word “Unsafe”

Some Distress After Construction

Isolated Raveling

Led to Complete Removal

Even Though Distresses were Isolated and the Slabs Taken Were the Best I Have Ever Seen on a Fresh Cold Recycling Project

To Caltrans Credit

Forensic Testing Plan of Failed Plastic Pavement
and
Laboratory Testing to Inform 2nd Plastic Pavement Trial Project

Final Draft 8-24-2020

Task	Goal
1a	Investigate the pavement failure by evaluating the impact of moisture, temperature, and time between mixing and compaction. This will use RAP and binder sampled from the BUT-162 project.
1b	Investigate the pavement failure by assessing material properties (and changes in those properties) along BUT-162 test section. This will use pavement slabs sampled from the roadway.
1c	(Optional) Investigate the pavement failure using supplemental testing.
1d	UCPRC Testing (work plan will be provided by UCPRC; involves facets of 1a, 1b, 1c, and 2 and beyond)
2	Identify thresholds (moisture, temperature, time between mixing and compaction) that can help the upcoming test section to succeed. This will use RAP sampled from the BUT-162 project and representative binder supplied by the manufacturer.

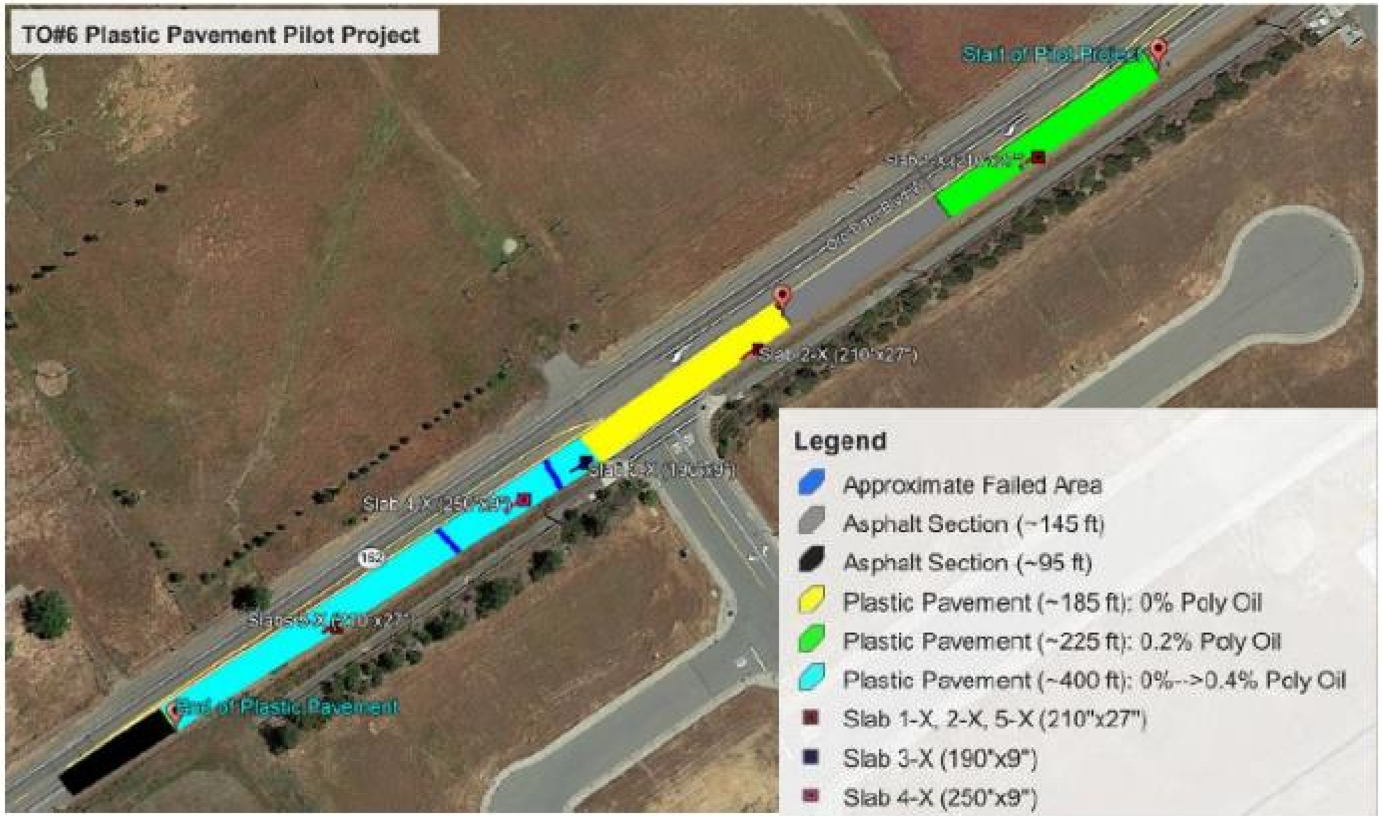
Timing:
-Task 1a will begin first and Task 2 will start once the necessary information is obtained from Task 1a.
-Task 1b and 1d can start concurrently with Task 1a.
-Task 1c will start after completion of Task 1b.

Notes:
-Testing in any task is subject to adjustment based on ongoing findings.
-Use material in a fume hood in the lab
-Be sure to check with manufacturer regarding the safety of the material in the lab at the proposed handling and testing temperatures.

SAMPLE PREPERATION AND TESTING

Prior to removal of the plastic road, ingot (slab) samples were obtained by UCPRC. Samples were removed from 5 different areas consisting of:

- Slab 1 – 0.2% Polyol
- Slab 2 – 0% Polyol
- Slab 3 – Area of Significant distress
- Slab 4 – Area of Significant distress
- Slab 5 – 0.4% Polyol



What Happened?

Crosslinking

Unlike Asphalt It is a One-Way Street. Once the Chemical Reaction Occurs It gets Hard and will not Stick to Each Other

Due to the High Ambient Heat the Chemical Reaction Occurred Really Fast

Repairs Did Not Always Stick

Lessons Learned

The G5 Binder is Much Different than the Bituminous Cold Recycling Products and Techniques We Were Used to In the Past

Make Sure You Build It Right The First Time - Then Let it Crosslink To Give The Strong Performance How Intended

Need to Focus on

Environmental Conditions

Construction Processes

Can See it In the Test Results

	Lab	Lab	Construction QC	Lab	Construction QC	Post Construction
Test	UNR	PRS(G5-P)	Aragon(G5-P)	LA CITY(G5)	Wentworth(G5)	METS(G5-P)
Density (lbs/ft^3)	NA	NA	120.8-129.4	130+	132-128	120-129
Air Voids (%)	11.8		NA	NA	NA	NA
Marshal Stability (lbs)	NA	5,813-3,880 (W)	NA	12,220-11,561(D) 5,050-4,372(W)	9,961- 8,151 (D)	NA
Indirect Tensile Strength (psi)	NA	94.1-49.2	52.0-21.9	196-191(D) 73-60(W)	108-107	89-40
Compressive Strength (psi)	NA	NA	NA	NA	NA	610-410
Hamburg	NA	7.5mm[1]	NA	NA	NA	4-11[2]
Beam stiffness (ksi)	1011	NA	NA	NA	NA	NA
Flow Number	No Flow @					

My Conclusions

Shows Some Real Promise as an In-place Recycled Finish Course

Needs Some Additional Research (Questions Answered)

1) Is Gradation as Important as Speed of Recycling?
2) How Much Construction Water can Exist Before Lowers Performance?
3) Can the Binder Be Modified to Allow More Workability During Hotter Environmental Conditions

Darren Will Address Some of These and Talk About Next Steps

St. George Post Caltrans Demo

1) Section w/ fines
2) Regular CIR
3) Natural Base

St. George 2020

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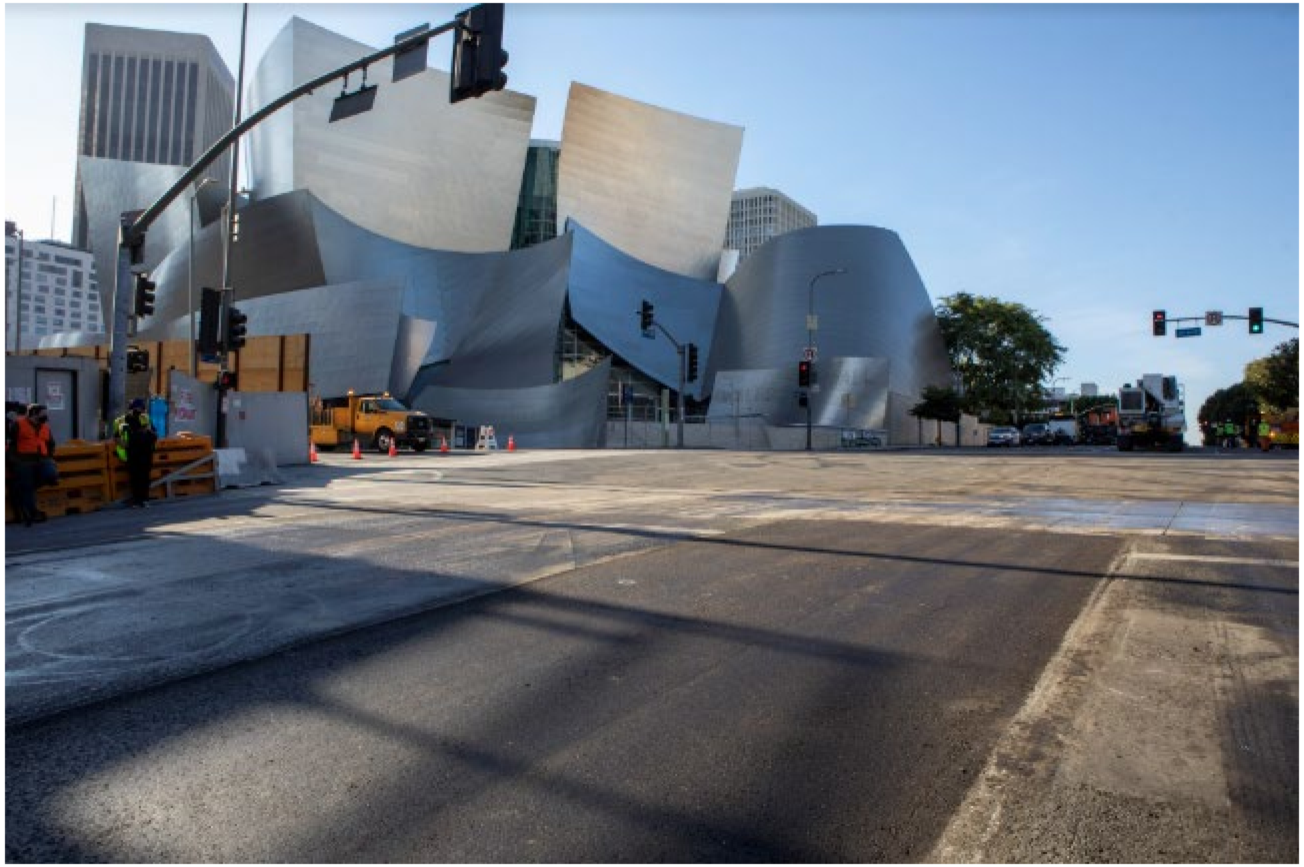
LA City Demo at First & Grand



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LA City Demo at First & Grand

AEMA ARRA ISSA

What’s Next?

Continued evolution and adoption

Making the field match the lab

- Advancements in the binder:
  - Pursuing an increase in workability time
  - Pursuing use of HDPE
- Advancements in equipment
  - Working on different gradations
  - Optimizing pumping of polymer binder
- Continued adoption, driven by both performance & green infrastructure

Questions?

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