



Asphalt Millings Rejuvenator

InvigoySoy CIP

Introducing InvigoSoy CIP



Cold-in-place recycling enabled by soy



Millings: Good, Bad, and Ugly

- Asphalt millings (recycled asphalt pavement that has been milled) are abundant and can cost as little as \$55/ton
- A well designed pavement built using asphalt millings can have high compressive strength as well as particle adhesion.
- Asphalt millings (AM), if not properly designed show subpar performance including cracking, rutting and other material failure issues. Worse yet, these millings can erode and cause tracking issues. This is both a cosmetics issue as well as an environmental problem.

Why an Asphalt Emulsion Enhanced by Modified Soybean Oil?

- Asphalt emulsions act as a quick binding agent, allowing the AMs to rapidly adhere
- Asphalt emulsions are a commercially available substance and are efficient carriers for the modified soybean oil
- Modified soybean oil chemically reacts with the asphalt to reverse aging process as well as cure the entire asphalt matrix. This provides strength, waterproofing, and prevents aggregate from being disrupted.



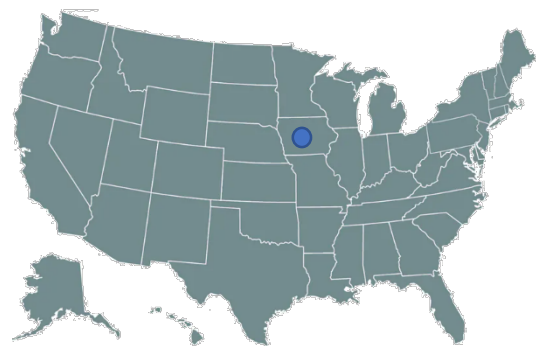


Trial Section before application of product.



Trial Section after application of product.

Field Trials in Postville, IA



Two distinct application methodologies:

1. Darker color sections have been pre-compacted and then re-compacted after application of additive.
2. Lighter sections additive is applied and incorporated into the millings through raking.

Field Trials in Postville, IA



After material cures:

1. The surface becomes hard.
2. The aggregate is fused together.
3. Tracking does not occur.
4. Chipping does not occur when struck with a pointed edge such as a shovel or pick.



Next Steps for InvigoSoy CIP

- Laboratory Testing:
 - Specimen will be made in the labs to test compressive strength, fracture energy, and other tests associated with asphalt mix design.
 - Properties as a function of cure time & temperature will be determined.
 - Formulation will be tweaked based off the results from these tests.



Modified Soybean Oil is the Key

- The previous slides show initial field trial results using a modified soybean oil/asphalt emulsion mixture
- The next slides discuss this same modified soybean oil as an additive for hot-mix asphalt
- The soybean/asphalt emulsion technology is newer; however, the technology our company has access to through ISU licenses has been studied for over 12 years and has been proven to work in asphalt.
- This modified soybean oil is the key to taking old asphalt and converting it to good-as-new pavements.
- The modified soybean oil in Invigorate CIP is the same technology that powers Invigorate by Colorbiotics (<https://invigorateasphalt.com>)





Paving Results

Invigorate

Mason City, IA Demonstration Binder Results

Code	Mix	PG	RAP%	ΔT_c	MSCR 64.0 C
Lab	58-28S	(60.1-28.8)	-	0.4	0.0%
Lab	58-28S + RAP	(67.7-24.9)	30.0%	-2.9	3.19%
Lab	58-28S + RAP	(-)	40.0%		
Lab	58-28S + RAP	(69.3-25.1)	45.0%	-2.1	4.67%
Lab	58-28S + 2.76% Invigorate (bnb)	(64.4-28.2)	30%	-0.8	1.18%
Lab	58-28S + 4.71% Invigorate (bnb)	(62.7-30.5)	30%	0.5	0.40%
Lab	58-28S + 5.61% Invigorate (bnb)	(62.8-29.5)	40%	-0.4	0.69%
Lab	58-28S + 7.12% Invigorate (bnb)	(61.7-30.3)	45%	-0.5	0.81%
Lab	58-28S + 11.06% Invigorate (bnb)	(54.5-34.3)	45%	0.7	0.00%

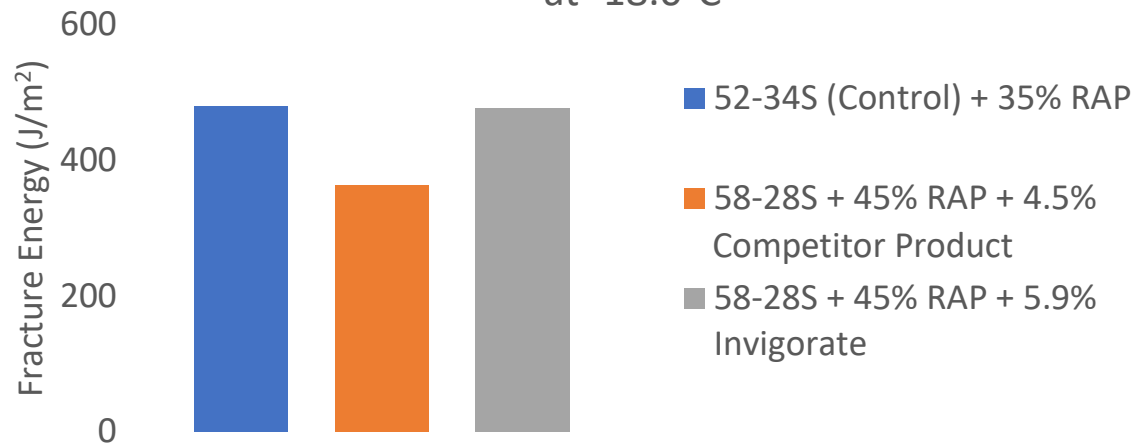
Mason City, IA Demonstration Results

Binder/ Mix ID	Demo #	Location	Extracted Binder Testing				Mix Testing	
			PG	RAP%	ΔT_c	MSCR 64.0 °C	Average CT index	Average DCT Energy (J/m ²) -18.0 °C
52-34S (Control)	Demo 1	Rock Falls	(63.4-30.8)	34%	-0.5	0.72%	104.22	480.33
58-28S + 3.0% Competitor Product	Demo 1	Rock Falls	(64.8-29.7)	34%	-0.1	1.38%	106.96	396.33
58-28S + 2.0% Invigorate	Demo 3	Charles City		34%			96.4	410.33
58-28S + 4.5% Competitor Product	Demo 1	Rock Falls	(67.4-30.8)	45%	-0.1	2.21%	101.54	363.00
58-28S + 5% Invigorate	Demo 2	Mason City	(64.0 -31.1)	45%	-1.4	1.10%	119.4	490.67

Mason City, IA Demonstration Results

Binder/ Mix ID	Extracted Binder Testing				Mix Testing	
	PG	RAP%	ΔT_c	MSCR 64.0 °C	Average CT index	Average DCT Energy (J/m ²)
52-34S (Control) + 35% RAP	(63.4-30.8)	34%	-0.5	0.72%	104.22	480.33
58-28S + 45% RAP + 4.5% Competitor Product	(67.4-30.8)	45%	-0.1	2.21%	101.54	363
58-28S + 45% RAP + 5% Invigorate	(64.0 -31.1)	45%	-1.4	1.10%	119.4	490.67

Charles City , IA Project Average DCT Energy at -18.0°C



Indiana Demonstration Binder Results

Code	Mix	PG	RAP%	ΔT_c	MSCR 64.0 C
Lab	64-22S	(65.4-25.1)	-	-0.6	
Lab	64-22S + 4.5% Invigorate (bnb)	(58.9-29.7)	-	0.0	
Lab	64-22S + 6.5% Invigorate (bnb)	(56.2-31.3)	-	0.7	
Lab	RAP	(85.40-)	100%		
Lab	64-22S + 4.5% Invigorate (bnb)	(73.9-21.2)	45%	-2.9	
Lab	64-22S + 6.5% Invigorate (bnb)	(71.7-23)	45%	-2.5	
Field	64-22S + 5.7% Invigorate (bnb)	(55.6-32.96)	-	-0.18	0.00%
Field	70-22S	(73.1-22.0)	-	-5.18	31.85%
Field Extracted	64-22S (Control)	(74-22.8)	25%	-3.6	3.39%
Field Extracted	64-22S + 5.7% Invigorate (bnb)	(65.8-29.7)	40%	0.2	0.00%

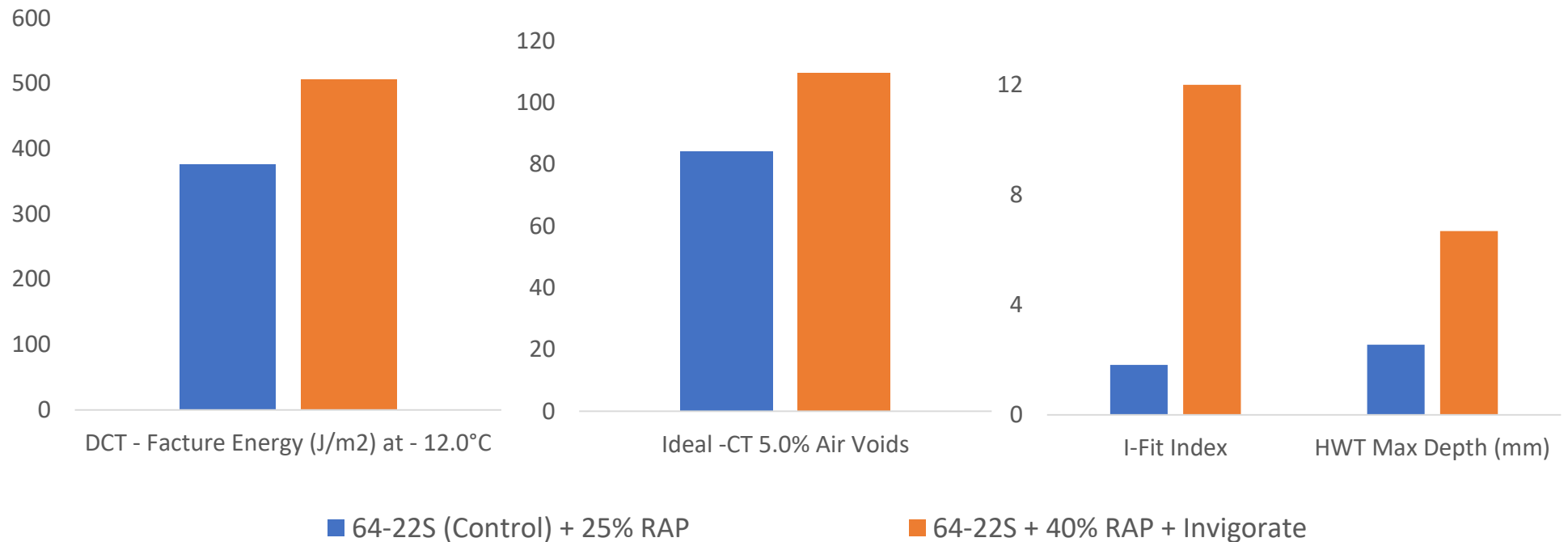
Indiana Demonstration Results



Indiana Demonstration Results

- DCT failure is fracture energy below 400
- According to MDOT CT index failure is below 80
- Failure for I-Fit index is 8.0
- HWT maximum allowable rut depth is 12.5 mm

Indiana Demonstration Project Results



Indiana Demonstration Results

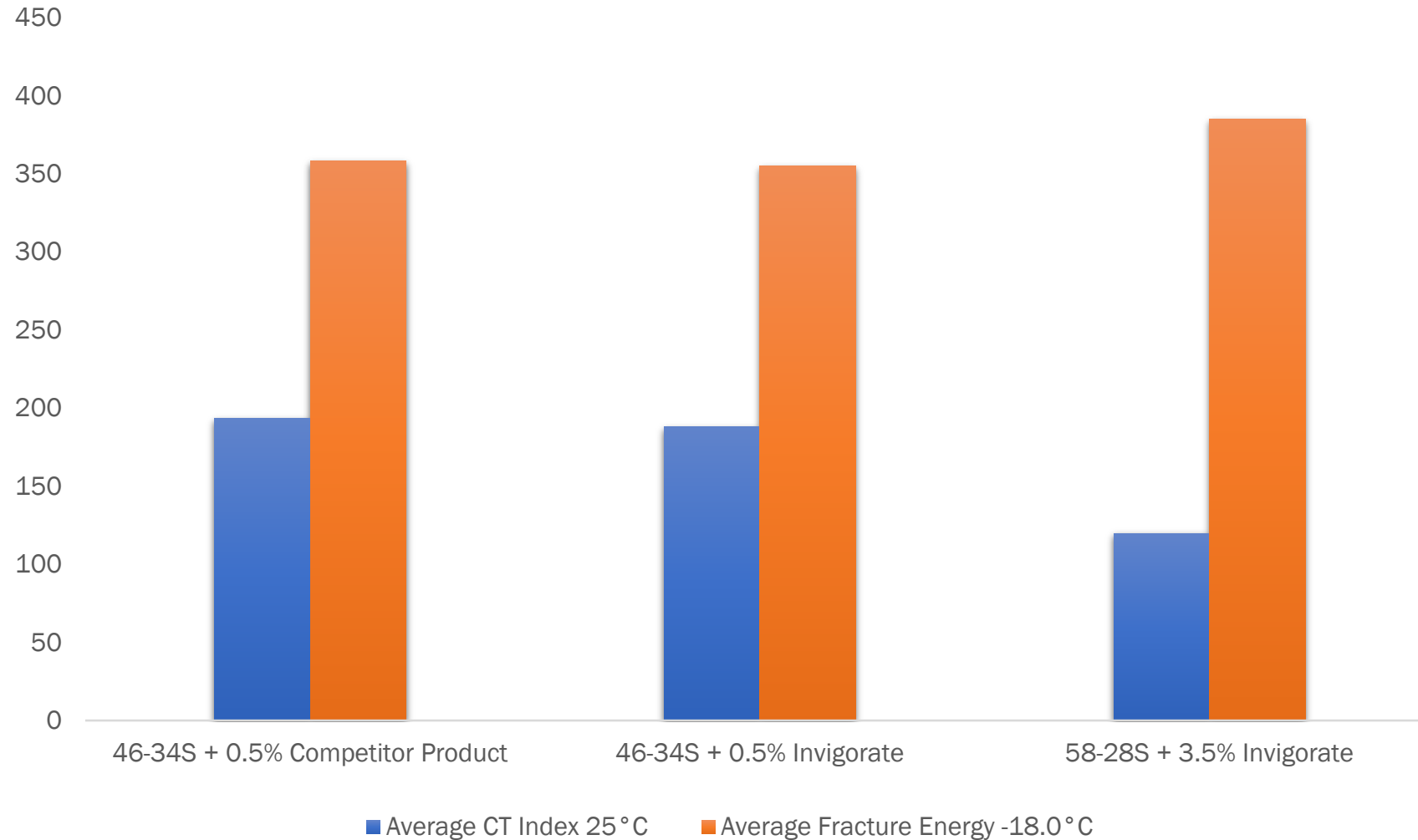
Binder/ Mix ID	Extracted Binder Testing				Mix Testing				
	PG	RAP %	ΔT_c	MSCR 64.0 °C	Average CT index 7.0%	5.0%	Average DCT Energy (J/m ²)	IFIT	HWT at 20,000 passes
64-22S (Control)	(74-22.8)	25%	-3.6	3.39%	139.0	84.3	375.7	1.82	2.549
64-22S + Invigorate	(65.8-29.7)	40%	0.2	0.00%	142.4	109.6	506.7	12.6	6.681

Wisconsin Demonstration Results

Binder/ Mix ID	Extracted Binder Testing									Mix Testing		
	RAP %	RAS %	High PG	Low PG	Overall PG range	PG Range	ΔT_c	MSCR 58.0 °C	$J_{nr 3.2}$	Average CT index 25.0 °C	Average DCT Energy (J/m ²) - 18.0 °C	HWT at 20,000 passes
52-34S – Base Binder	-	-	53.4	-34.7	88.1	52-34	1.5	0.0%	8.655			
58-28S – Base Binder	-	-	60.4	-30.2	90.6	58-28	0.6	0.0%	3.348			
52-34S + 0.5% Competitor Product	35.0	5.0	79.7	-22.3	102.0	76-22	-8.4	40.94%	0.124	193.5	358	
52-34S + 0.5% Invigorate	35.0	5.0	77.5	-21.7	99.2	76-16	-8.1	31.99%	0.187	188.2	355	
58-28S + 3.5% Invigorate	35.0	5.0	76.7	-23.9	100.6	76-22	-6.3	24.79%	0.248	119.8	385	

Wisconsin Demonstration Results

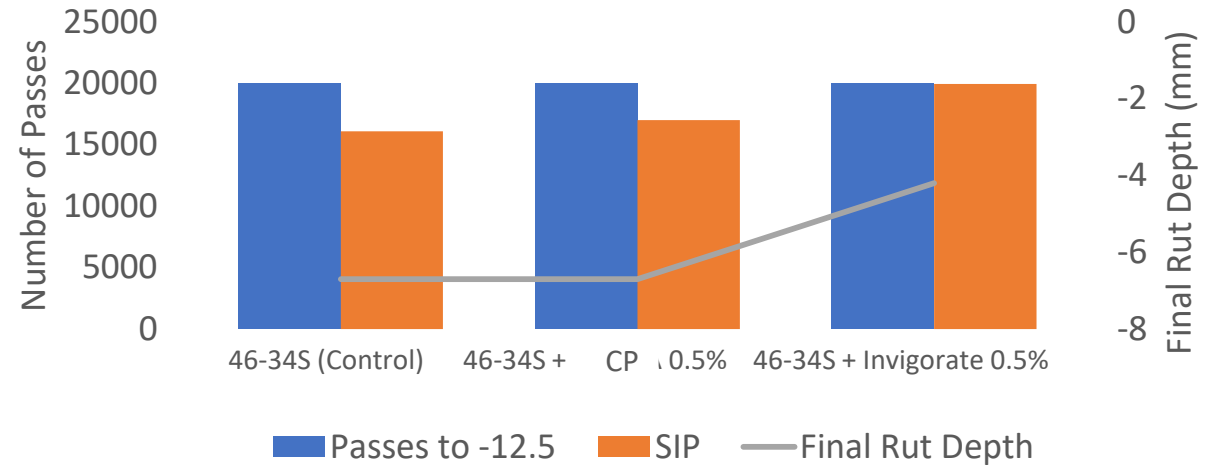
Ideal CT and DCT Results



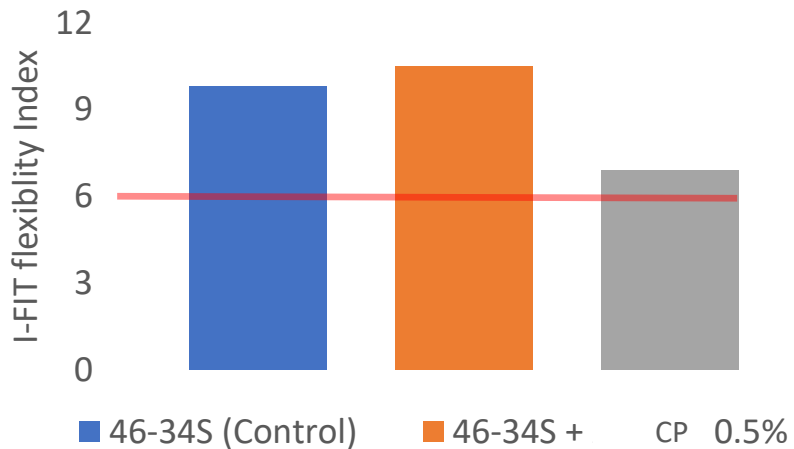
Wisconsin Lab LT Mix Results

Binder/ Mix ID	Mix Testing	
	IFIT	Average DCT Energy (J/m ²)
46-34S (Control)	9.8	356.7
46-34S + Competitor Product 0.5%	10.5	403.3
46-34S + Invigorate 0.5%	6.9	410.7

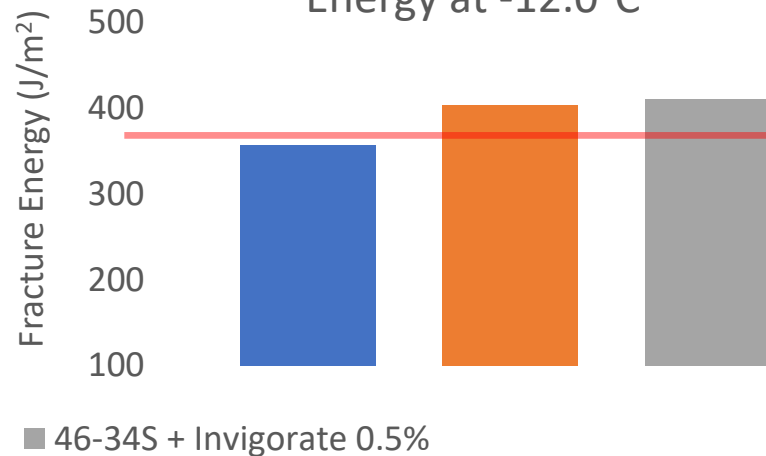
Wisconsin Project HWT study



Wisconsin Project I-FIT testing 25.0°C



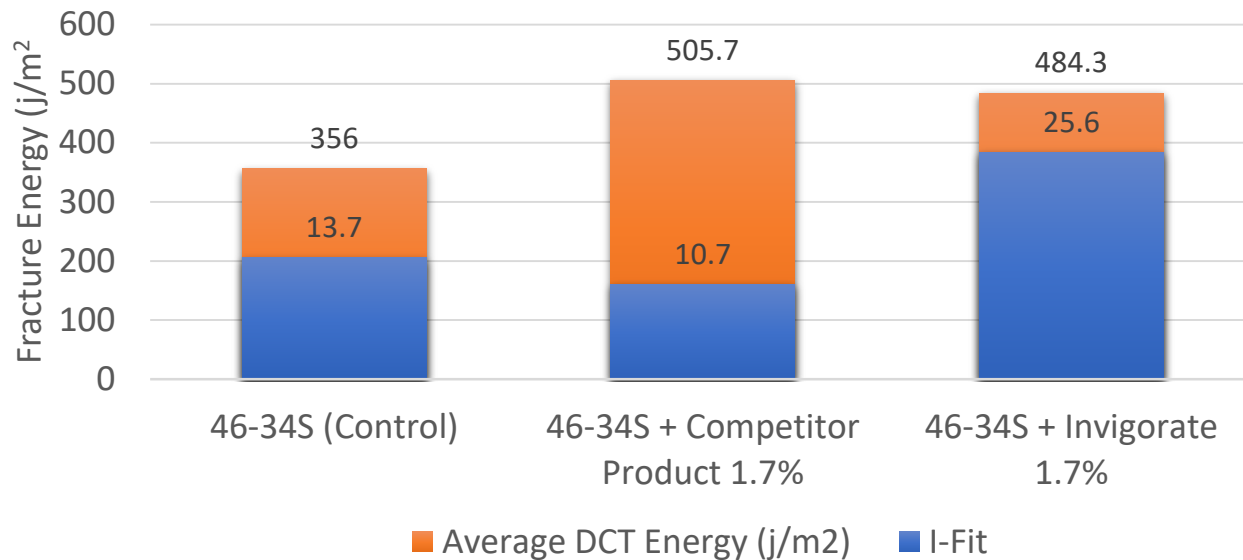
Wisconsin Project Average DCT Energy at -12.0°C



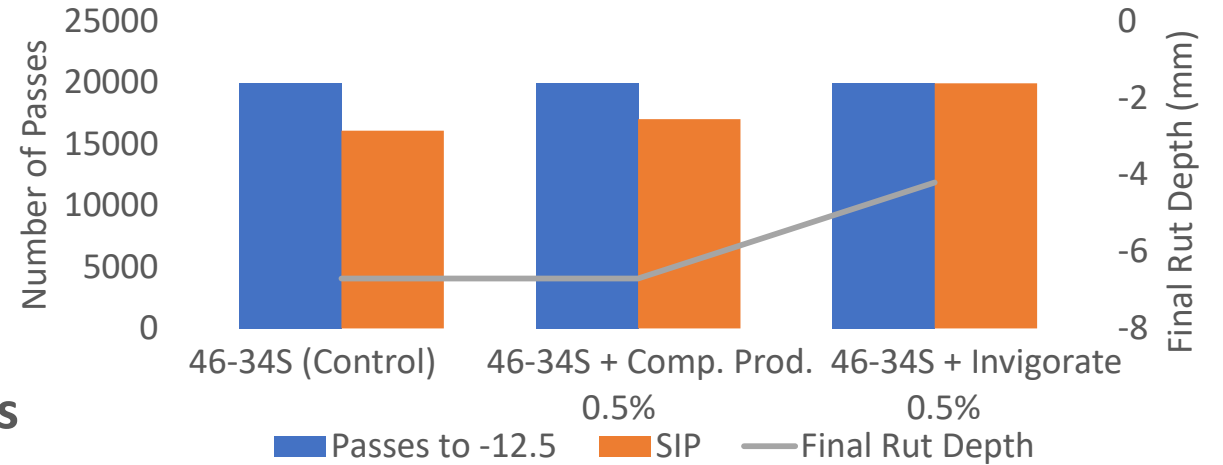
Wisconsin Lab MT - Mix Results

Binder/ Mix ID	Mix Testing	
	IFIT	Average DCT Energy (J/m ²)
46-34S (Control)	13.7	356.0
46-34S + Competitor Product 1.7%	10.7	505.7
46-34S + Invigorate 1.7%	25.6	484.3

DCT and I-Fit results for MT mix results



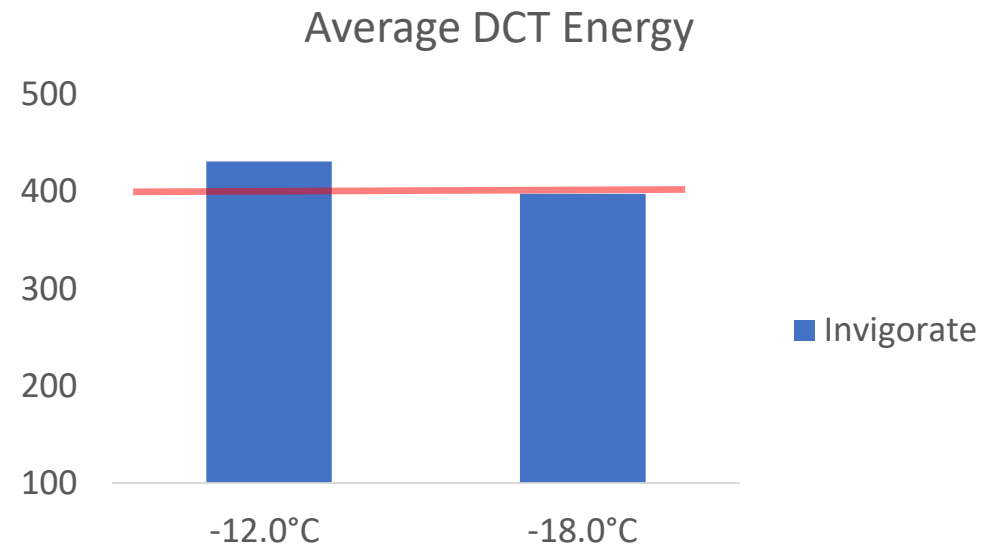
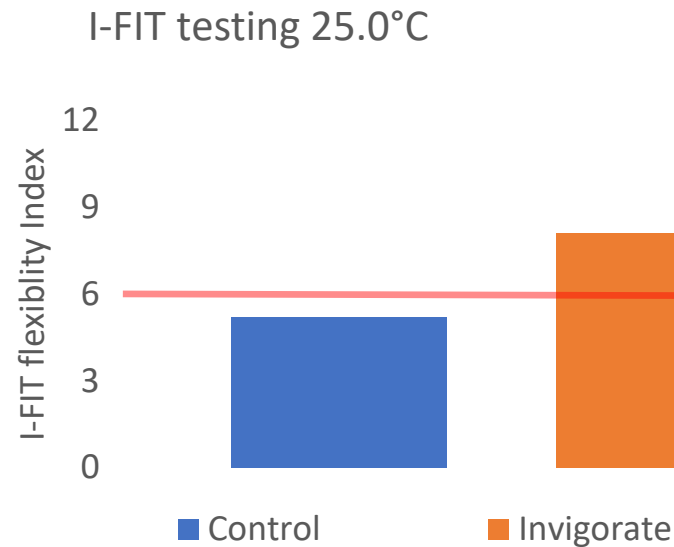
Wisconsin Project HWT study



Legend: Passes to -12.5 (Blue), SIP (Orange), Final Rut Depth (Grey Line)

Illinois Demonstration Results

Binder/ Mix ID	Mix Testing						
	IFIT		DCT Energy (J/m ²)		# of Passes to -12.5	SIP	Final Rut Depth
	Short Term	Long Term	-12.0°C	-18.0°C			
Control	5.2	-	0	-	20000	14425	-5.4
Invigorate	8.1	2.4	431	398	20000	15775	-3.34



Emily, MN Demonstration Results

Binder/ Mix ID	Extracted Binder Testing				Mix Testing	
	PG	RAP%	ΔT_c	MSCR 64.0 °C	Average CT index	Average DCT Energy (J/m ²)
58-28S (Control) + 25% RAP	(-)	40%	-0.5	0.72%	104.22	402.6
58-28S + 40% RAP + 4.0% Invigorate	(67.4-30.8)	40%	-0.7	- %	-	423.0