Cargill – Hardrives partnership for Rejuvenator Research at MnROAD

(Updated – April 6, 2021)

In this unique partnership between Cargill and the Minnesota Department of Transportation (MnDOT), four bituminous pavement test sections were built in 2018 to investigate the effective use of an asphalt rejuvenator to increase the amount of recycled material in high traffic pavements, the effective role of performance-based design methods in utilizing such technologies in practice.

Although millions of tons of high performing rejuvenated high-recycled Hot Mix Asphalt are produced every year in the united states for commercial and private markets, the utility of such technology has been more limited in public projects, generally due to limited experience with such technology and the necessity to modify existing specification to allow such designs.

The test sections in this study were designed by augmenting the existing Minnesota volumetric design process with Disc Compact Tension (DCT) and Hamburg Wheeltracking test results, to establish the equivalence of the higher RAP material to the standard mix in terms of lab-measured cracking and rutting resistance.

Currently (April 2021), after over two and half years since construction all the sections are performing well in the field, indicating that the Cargill's Anova® rejuvenator was able to provide equivalent early life performance to the control while almost doubling the recycled content of the mix.

Overall, the Cargill test sections appear to show good performance similar to the control sections.

TEST SECTION LOCATION & CONSTRUCTION

The sections were built on Interstate 94 at the Minnesota Road Research Facility (MnROAD) in Monticello, MN. Sections were built at either end of MnROAD, as shown below. At each end, a control mix and the "Anova® mix" were used. The Anova® mix utilized Cargill's Anova® asphalt rejuvenator to offset the impacts of increasing the reclaimed asphalt pavement (RAP) content. The control mix met MnDOT requirements for the location and traffic volume demands (SPWEB540B). The RAP content was increased from 25% in the control mix to 45% for the Anova® mix.

(a) (b)

Figure 1 - 2018 Cargill Partnership test sections at MnROAD a) east transition b) west transition

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Partnership agreement 10300927 was developed between MnDOT and Cargill Incorporated and Minnesota Paving and Materials (formerly Hardrives, Inc.) for a research study on the effective use of asphalt mix rejuvenators at MnROAD for the National Road Research Alliance signed July 2018. This agreement allowed MnROAD to work directly with Cargill and Hardrives to repave the transitions in and out of MnROAD on I-94 utilizing State construction dollar funding. The agreement stated that MnDOT provided reconstruction plans, collect and share material samples, perform material testing, long term monitoring, report development on the results, and payment to Hardrives for the work being performed. Hardrives would furnish all materials, mix designs, equipment, traffic control to construct the transitions according to state guidelines and standard practices. Cargill would provide, the Anova rejuvenator, technical support, and conduct laboratory testing on the mixes. This partnership allowed MnDOT to work with Cargill to better understand asphalt mix rejuvenators and their long-term benefits and allowed MnDOT to repave the MnROAD transitions at a 40% reduction of cost over what was initially budgeted engineering estimate.

The location of these cells is referred to as “MnROAD transition areas” as they tie in the MnROAD Mainline with I-94 westbound. The thickness of the existing asphalt to the east and west averaged just under 13” of asphalt mix and the west end of the original westbound lane consisted of a 2.5” to 4.3” overlay of the existing PCC pavement. Milling consisted of 2” to 5” depending on the extent of the local distress. A single lift of HMA was paved on the small, 2” portion and two lifts were used on the majority of the job when the HMA thicknesses were greater than 2”.

To reduce the impact on I-94 traffic, the project was constructed using overnight work. Construction was completed on October 13, 2018 after 3 nights of work. The weather was cold, between 30-40° F and snowflakes were observed at times during the construction. Despite the cold temperatures and 45 minute haul distance, satisfactory density (averaged 94% in-place density) and ride was achieved. It can be seen in Figure 2 that a material transfer device was used to improve construction quality on this project.

Approximately 3,000 tons of asphalt concrete were placed with 1,500 tons of the control and 1,500 tons of the Anova® mix.

Figure 2 – Night Construction of 2018 Cargill Partnership test sections on I-94 at MnROAD

LABORATORY PERFORMANCE TESTING/BALANCED MIX DESIGN TESTING

Material samples were collected throughout all stages of the project. This consisted of the following:

- Samples of project RAP for laboratory extraction, recovery, and grading (performed at Cargill lab). The results were used to determine the proper rejuvenator dosage.
- Laboratory produced mixes from the volumetric mix design process were sent to an external lab (AET) for mixture performance testing to confirm equivalence of the experimental mix design to the control section.
- During construction, plant produced loose mix samples were collected for QC and QA purposes, and further performance testing. QA testing using the DCT was performed by MNDOT. Further performance testing was performed by the National Center for Asphalt Technology (NCAT) at Auburn.

Although some of the testing and analysis of results continues, the tables 1 and 2 and Figure 3 summarizes the majority of the binder and mixture performance results obtained to date. The following main conclusions and observations can be made so far:

- In terms of both binder and mixture performance indices, a general equivalence can be seen between the lower RAP control and the high RAP rejuvenated mix. This observation meets the general objective of the design, which was to establish the ability to equalize the performance of lower RAP pavement by use of the Anova® rejuvenator with high RAP content.

- The mixture performance results are statistically similar in all cases except potentially for the overlay tester and the Hamburg wheel-tracking results, for both which the rejuvenated mix seems to outperform the control. By all measures, the performance of both mixes is satisfactory.
- Although the results from these two mixes are not sufficient to establish a correlation between various binder and mixture performance parameters, the results will be integrated into a larger dataset including similar performance test measures from the NCAT test track and analyzed to this purpose.

Table 1. Extracted binder testing and analysis. Performance grading and advanced rheological measures were derived through the use of mastercurves generated using 4-mm spindles in a Dynamic Shear Rheometer with cryogenic capabilities.

			Extracted from Production Loose Mix	
Test Name	**Condition**	**Unit**	**25% RAP Control**	**45% RAP + RA**
Solvent AC (%)		%	5.19%	4.51%
As estracted HT Grad	As extracted	°C	74.5	74.5
IT PG	Aged	°C	21.5	19.0
S Grade	10 rad/s	°C	-26.9	-29.4
m Grade	10 rad/s	°C	-25.0	-26.0
ΔTc	10 rad/s	°C	-1.9	-3.4
G-R Parameter	0.005 rad/s	kPa	166.2	108.6
Log G (G-R)	0.005 rad/s	Log kPa	2.8	2.6
δ (G-R)	0.005 rad/s	°	60.7	61.2
Tδ=45 (1.59Hz)	10 rad/s	°C	19.7	18.8
Tδ=30 (1.59Hz)	10 rad/s	°C	2.4	1.1
Tδ=45 (0.005 rad/s)	0.005 rad/s	°C	-0.7	-1.4
Tδ=30 (0.005 rad/s)	0.005 rad/s	°C	-15.0	-15.3

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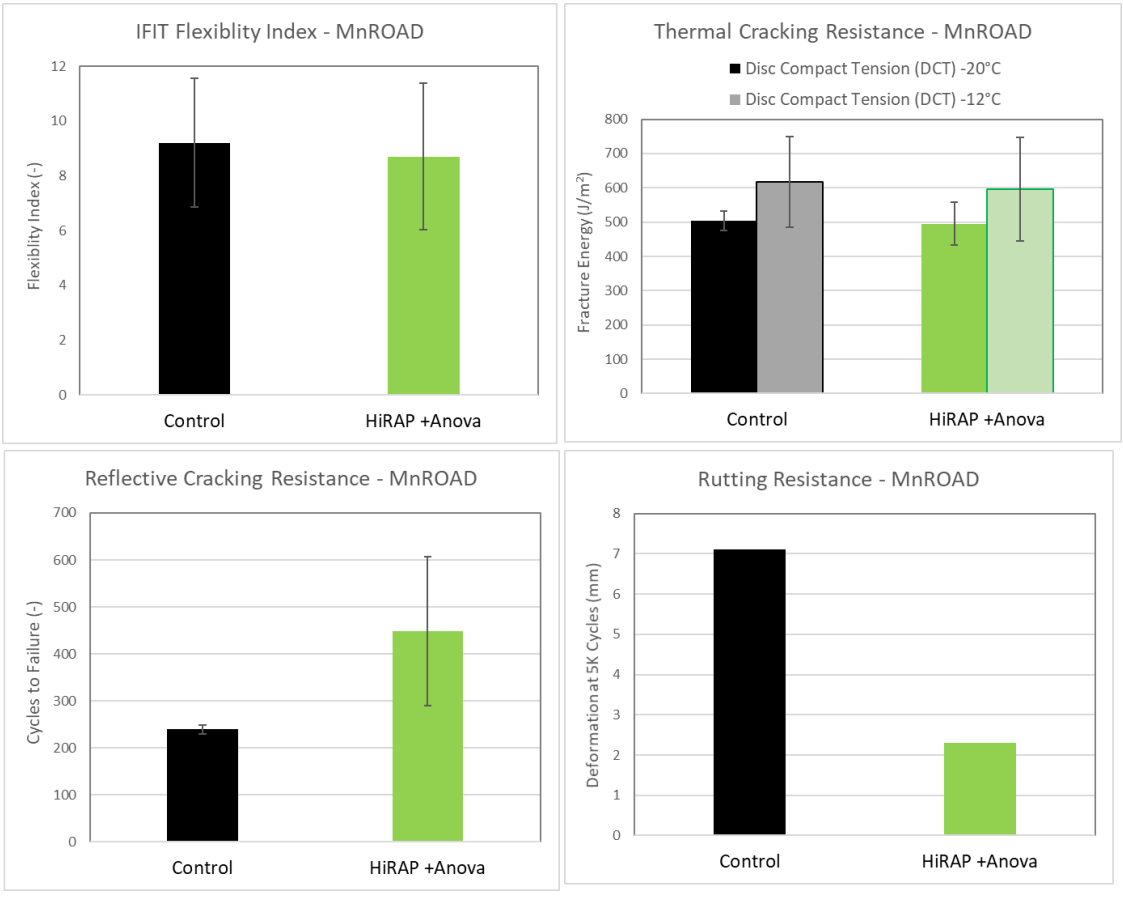
Table 2- Mixture performance testing results. Displayed results are the mean value, with the standard deviation presented in parenthesis. Outliers were defined as datapoints that were outside of 2.0 standard deviations from the mean, and were removed from the analysis.

			LPLC from Mix Design		PPLC from Production		Test
Test Name	**Temperature**	**Unit**	**25% RAP Control**	**45% RAP + RA**	**25% RAP Control**	**45% RAP + RA**	Perfomed By:
Disc Compact Tensior	-20°C	J/m^2	503	495	468	458	MNDOT
Standard Deviation			(83.7)	(18.5)	(28.2)	(62)	
Hamburg Wheeltrack	50°C	mm at 5K	7.1	2.3	N/A	N/A	AET
Standard Deviation		Cycles					
CT_{Index}	25°C	(-)	N/A	N/A	55.5	66.9	NCAT
Standard Deviation					(4.5)	(12.6)	
Overlay Tester	25°C	Cycles	N/A	N/A	239	449	NCAT
Standard Deviation					(9.7)	(158.4)	
Disc Compact Tensior	-12°C	J/m^2	N/A	N/A	618	595	NCAT
Standard Deviation					(132.6)	(150.9)	
IFIT Flexiblity Index	25°C	(-)	N/A	N/A	9.2	8.7	NCAT
Standard Deviation					(2.35)	(2.67)	

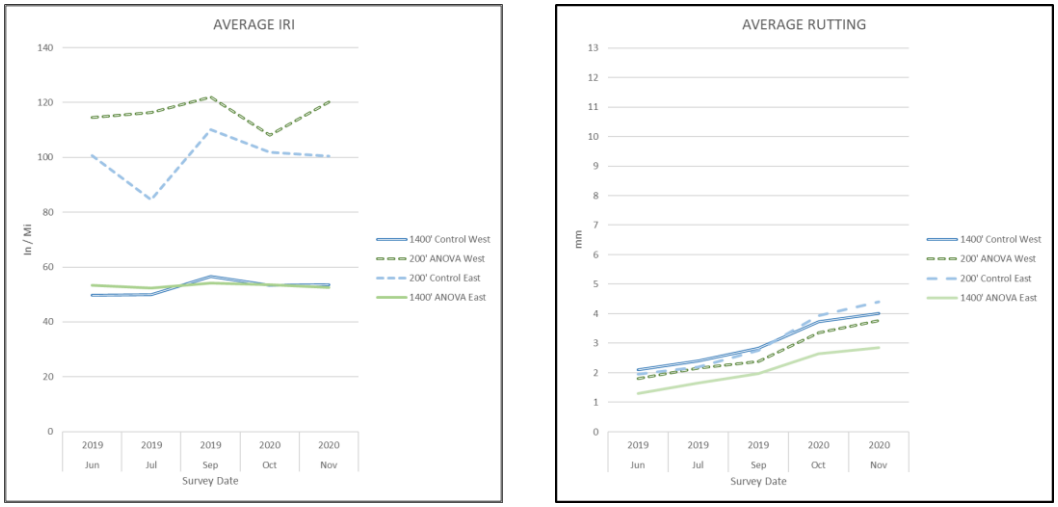


Figures 3 – Performance Test results performed on plant produced and lab compacted samples

FIELD PERFORMANCE

Traffic

A portion of each section that had comparable structural thickness and traffic pattern was identified for long-term field performance monitoring. Due to the location in the MnROAD transition area, all performance data needed to be collected under live traffic, which eliminates many of the MnROAD field performance monitoring tools. MnDOT regularly collected data over the entire project length sections using a Pathways Services Inc. high-speed, digital inspection vehicle. The average International Roughness Index (IRI) and the average rut depth were measured in both left and right wheelpaths; the data reported in this document were averaged for both wheelpaths in both lanes.



Figures 4a and 4b – Roughness Index and Rutting Data Collected by Pathways Pavement Management Van

Figure 4a shows the average IRI for each test section. There is a significant difference between the longer sections that extend into Old Westbound (Control West and Anova® East) and the sections the are entirely on the Mainline (Anova® West and Control East) that can be explained by differences in the underlying structure. The roughness index has shown no significant increase for any of the test sections.

Figure 4b shows the average rutting measurements for each test section. Each test sections shows similar trends of minimal increases in rutting over the collection period.

As expected with asphalt mill and inlay projects in Minnesota, reflective cracking has been observed in the sections. Reflective cracking was apparent at the project extents where only a single 2” lift of asphalt was placed over concrete pavement. It is important to point out that no difference in cracking has been observed in the Anova® sections and that the mill and inlay sections were expected to develop reflective cracking. The MnROAD research team is currently working to quantify the percentage of cracking for each section.

Overall, the Cargill test sections appear to show good performance similar to the control sections.

National Road Research Alliance

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CONCLUSIONS & RECOMMENDATIONS

In 2018 Cargill and MNDOT partnered to build four bituminous pavement test sections at either end of the MnROAD test facility on Interstate 94 in Monticello, MN. The objective of the study was to investigate the effective use of performance based design and the Cargill Anova® rejuvenator for incorporation of increased amount of recycled material in high traffic pavements, especially in colder climates.

A general equivalence In terms of both binder and mixture performance indices was observed between the lower RAP control and the high RAP rejuvenated mix, meeting the design target for this project. In terms of field performance, after over two and half years since construction all the sections are performing well, indicating that the Cargill's Anova® rejuvenator was able to provide equivalent early life performance to the control while almost doubling the recycled content of the mix.

The results so far support the ability to equalize the performance of lower RAP pavement by use of the Anova® rejuvenator with high RAP content at the lab and field scale, while also demonstrating the ability to use performance-based design methods (in this case volumetric design augmented with DCT and Hamburg wheeltracking performance) to effectively incorporate such designs in practice in Minnesota and other regions with similar conditions.

It is recommended that the findings and design methodology of this study be used to support future larger projects using rejuvenated higher recycled content designs in order to further establish the necessary experience for regular implementation of such technologies that can enable sustainable and economical construction of high performing pavements.