MnDOT's EXPERIENCE

Micro Milling with Surface Treatments

Introduction

The Minnesota Department of Transportation (MnDOT) began investigating the performance of micro milling of pavements combined with the application of thin bituminous pavement surface treatments in 2013. Micro milling is defined as:

> *A similar process to traditional pavement milling which uses a milling drum having about three times as many teeth as a typical milling drum. The additional teeth provide a tighter lacing pattern and smoother surface, providing a better surface than traditional milling for application of thin pavement surface treatments.*

Finished micro mill texture of TH 89

US 59 Micro Milled Pavement

Figure 1

The goal of this investigation is to use data gathered by MnDOT personnel to determine the effectiveness of micro milling with surface treatments at improving ride quality. For the purposes of this investigation, the ride quality data is an average of the left and right wheel paths known as the Mean Roughness Index (MRI). This is to keep the data concise between multiple projects being investigated for each treatment type. The MRIs were collected with an inertial profiler using a line laser setup.

The surface treatments placed in conjunction with micro milling include chip seal, micro surface, and Ultra-Thin Bonded Wear Course (UTBWC). Several projects were developed to incorporate micro milling with the different surface treatments. This investigation will also examine the performance of the different treatments when combined with micro milling. On average, micro milling costs about $1.25 per square yard or $8,800 per lane mile. The project locations can be found at the end of this document in the Appendix.

Treatment #1: Micro Mill with Chip Seal

Two chip seal projects with micro milling on Minnesota TH 9 and TH 89 were constructed in 2014 for this investigation. Ride quality data has been collected annually on these two projects and is outlined in the table and chart below. In summary the data shows there was immediate improvement of about 20 to 30 percent in measured MRI with micro milling and application of the chip seal. The TH 9 project returned to pretreatment ride by the third year after construction while TH 89 took an additional year, returning to pretreatment ride by year four. This means that for a relatively small cost, the ride quality of a pavement can be improved for several years by micro-milling when chip sealing.

Figure 2 - TH 89 after placement of chip seal

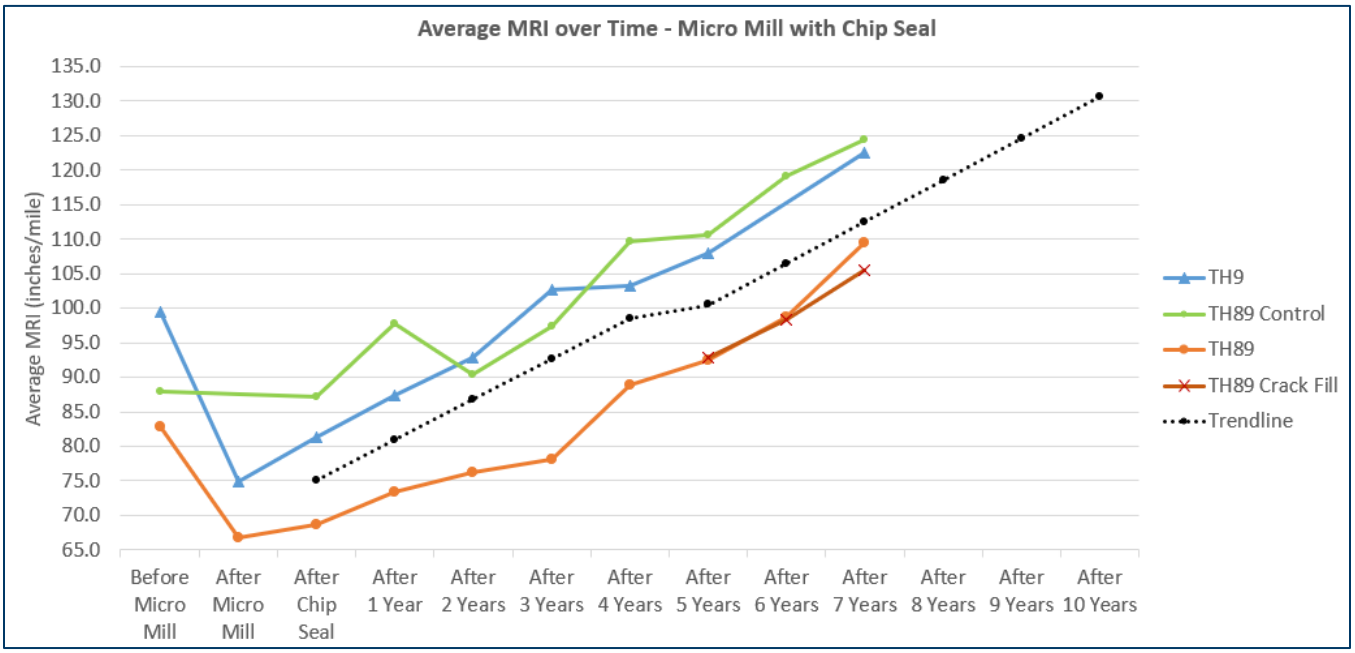

Figure 3 – Micro mill with chip seal performance chart

The data shown in Figure 3 can be found in the tables below. In all tables in this report, the "% Change" columns refer to the percent difference in MRI for a given year compared to the pre-treatment value. It should be noted that a section of TH 89 was crack sealed in 2018. This section has slightly different performance than the rest of the project and is shown in the tables below.

Performance of Micro Milling with Chip Seal																		
Highway (Construction Year)	Before Micro Mill	After Micro Mill		After Chip Seal		After 1 Year		After 2 Years		After 3 Years		After 4 Years		After 5 Years		After 6 Years		After 7 Years	
	Avg. MRI (in/mi)	Avg. MRI (in/mi)	% Change	Avg. MRI (in/mi)	% Change	Avg. MRI (in/mi)	% Change	Avg. MRI (in/mi)	% Change	Avg. MRI (in/mi)	% Change	Avg. MRI (in/mi)	% Change	Avg. MRI (in/mi)	% Change	Avg. MRI (in/mi)	% Change	Avg. MRI (in/mi)	% Change
TH 89 NB (2013)	80.7	64.3	20%	67.3	17%	75.0	7%	71.7	11%	76.1	6%	86.8	-8%	89.6	-11%	97.9	-21%	108.4	-34%
TH 89 SB (2013)	85.0	69.1	19%	69.9	18%	71.6	16%	80.7	5%	80.2	6%	90.9	-7%	95.4	-12%	99.7	-17%	110.7	-30%
Average	82.9	66.7	20%	68.6	17%	73.3	11%	76.2	8%	78.2	6%	88.9	-7%	92.5	-12%	98.8	-19%	109.6	-32%
TH 89 NB Crack Seal (2018)	-	-	-	-	-	-	-	-	-	-	-	-	-	85.7	-6%	90.6	-12%	98.6	-22%
TH 89 SB Crack Seal (2018)	-	-	-	-	-	-	-	-	-	-	-	-	-	99.9	-18%	105.9	-25%	112.3	-32%
Average														92.8	-12%	98.3	-18%	105.5	-27%
TH 9 NB (2014)	91.7	72.3	21%	78.5	14%	81.6	11%	85.9	6%	93.7	-2%	93.8	-2%	101.7	-11%		-	110.3	-20%
TH 9 SB (2014)	107.1	77.4	28%	84.3	21%	93.0	13%	99.7	7%	111.5	-4%	112.8	-5%	114.3	-7%		-	134.9	-26%
Averages	99.4	74.9	24%	81.4	18%	87.3	12%	92.8	7%	102.6	-3%	103.3	-4%	108.0	-9%			122.6	-23%

Table 1: Performance of micro milling with chip seal and crack seal

It is also worth noting that TH 89 included a control section, which was chip sealed without micro-milling. Without the smoothing benefits of micro-milling, this section shows - continued degradation in ride quality over time.

Performance of TH89 Chip Seal Without Micro Mill																	
Highway (Construction Year)	Before Chip Seal	After Chip Seal		After 1 Year		After 2 Years		After 3 Years		After 4 Years		After 5 Years		After 6 Years		After 7 Years	
	Avg. MRI (in/mi)	Avg. MRI (in/mi)	% Change	Avg. MRI (in/mi)	% Change	Avg. MRI (in/mi)	% Change	Avg. MRI (in/mi)	% Change	Avg. MRI (in/mi)	% Change	Avg. MRI (in/mi)	% Change	Avg. MRI (in/mi)	% Change	Avg. MRI (in/mi)	% Change
TH89 NB (2013)	95.7	95.9	0%	110	-15%	101.2	-6%	104.7	-9%	115.3	-20%	118.2	-24%	127.5	-33%	134.54	-41%
TH89 SB (2013)	80.1	78.3	2%	85.5	-7%	79.7	0%	89.9	-12%	104.2	-30%	103.0	-29%	110.7	-38%	114.3	-43%
Averages	87.9	87.1	1%	97.8	-11%	90.5	-3%	97.3	-11%	109.75	-25%	110.6	-26%	119.1	-36%	124.42	-42%

Table 2: Performance of chip seal control section

As noted in the table, a section of the TH 89 project was crack sealed in 2018, 5 years after the initial micro mill/chip seal treatment was placed. Preliminary results show slowed loss of ride through lower measured MRI numbers when compared to the non-crack sealed segment. Therefore, it appears including crack sealing along with this treatment option may provide added benefit. The trendline in Figure 3 shows a slight deflection as a result of this observation.

In summary, it is estimated to cost about $21,300 ($8,800 micro mill, $12,500 chip seal), to micro mill and chip seal a lane mile of bituminous pavement. Using this treatment, the ride quality of a bituminous pavement can be improved and the pavements serviceable life extended. Based on the data collected to date the expected ride improvement and life extension of a pavement would be four years. This would translate into an annual cost of $0.76 per square yard per year or $5,500 per lane mile per year.

Treatment #2: Micro Milling with Micro Surfacing

Three projects where micro milled prior to micro surfacing. The respective MRI data from these roadways has been analyzed for this investigation. The data shows there was significant improvement to ride quality on two of the three projects. More data will need to be collected to determine the longevity of the improvements in ride quality as two of the three projects have not yet reached their pretreatment ride values. Based on the MRI data collected to date from the TH 64 and US 10 projects, the trendline is interpreted to show that pavements receiving this treatment would reach pre-treatment MRI levels in about year 10. It should be noted the section on US 12 was performed on a bituminous overlay over a concrete pavement and had a much lower ride improvement level from the treatment. The pavement ride improvement on this project lasted only four years before returning to its pre-treatment MRI values.

After 1 Year (2015) Year 6 (2020)

Figure 4 - TH 64 Photos

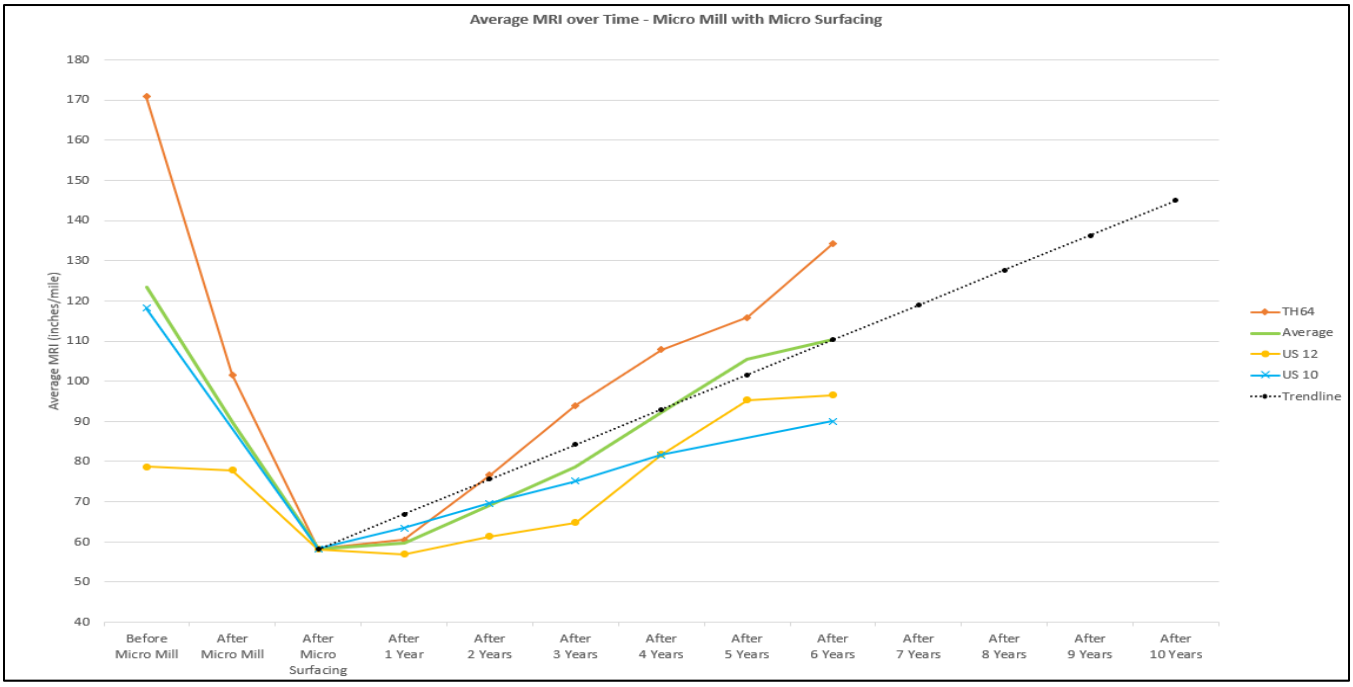

Figure 5 – Micro Mill with Micro Surfacing Performance Chart

The data shown in Figure 5 is tabulated below in Table 3: Performance of Micro Mill with Micro Surfacing.

Performance of Micro Milling with Micro Surfacing																	
Highway (Construction Year)	Before Micro Mill	After Micro Mill		After Micro Surfacing		After 1 Year		After 2 Years		After 3 Years		After 4 Years		After 5 Years		After 6 Years	
	Avg. MRI (in/mi)	Avg. MRI (in/mi)	% Change	Avg. MRI (in/mi)	% Change	Avg. MRI (in/mi)	% Change	Avg. MRI (in/mi)	% Change	Avg. MRI (in/mi)	% Change	Avg. MRI (in/mi)	% Change	Avg. MRI (in/mi)	% Change	Avg. MRI (in/mi)	% Change
TH 64 NB (2014)	166.3	99.6	40%	*58.3	65%	61.4	63%	77.3	54%	92.5	44%	104.5	37%	114.8	31%	132.2	20%
TH 64 SB (2014)	175.4	103.5	41%	*58.3	67%	59.6	66%	75.8	57%	95.5	46%	111.1	37%	116.9	33%	136.2	22%
US 12 EB (2014)	77.7	76.2	2%	58.2	25%	57.2	26%	62.9	19%	65.6	16%	85.3	-10%	101.9	-31%	107.6	-38%
US 12 WB (2014)	79.7	79.5	0%	58.2	27%	56.6	29%	59.7	25%	63.9	20%	78.3	2%	88.6	-11%	85.5	-7%
US 10 EB Driving Lane (2015)	118.2	-	-	58.3	51%	63.4	46%	69.6	41%	75.1	36%	81.6	31%	-	-	90.0	24%
Averages	123.5	89.7	21%	58.2	47%	59.6	46%	69.1	39%	78.5	32%	92.2	19%	105.6	6%	110.3	4%

Note: * This number was estimated as no MRI was recorded.

Table 3: Performance of Micro Mill with Micro Surfacing

The cost per lane mile to micro mill and micro surface is approximately $43,800 ($8,800 micro mill and $35,000 micro surfacing). This treatment is effective in improving ride quality of a bituminous pavement and extending the pavements serviceable life. The trendline in Figure 5 suggests a 10-year ride improvement and pavement serviceable life extension could be expected based on the MRI data collected. This would translate into an annual cost of $0.62 per square yard per year or $4,380 per lane mile per year for this 10-year period.

Treatment #3: Micro Mill with UTBWC

This investigation analyzed the ride data on two different micro mill projects with UTBWC projects. The data shows that ride quality can be significantly improved with this treatment as well. After 5 years, there is an average improvement of 34% on US 10 compared to the pre-treatment MRI. It is also worth noting that the micro mill and UTBWC placed on I-394 improved the ride quality to a level above its original construction. As an interesting hypothetical exercise, if one were to apply MnDOT smoothness equation HMA-C (single lift overlay) to any of the average MRI's on I-394 today, they would still be in the incentive range, four years after construction of the treatment.

As with micro surfacing, more ride data will need to be collected in subsequent years since the pavement sections in this report have not yet returned to their pre-treatment MRI values. Additional ride quality data will provide further insight into the effectiveness of micro milling with UTBWC at improving ride and preserving pavement condition.

Figure 6 – US 10 After 1 Year

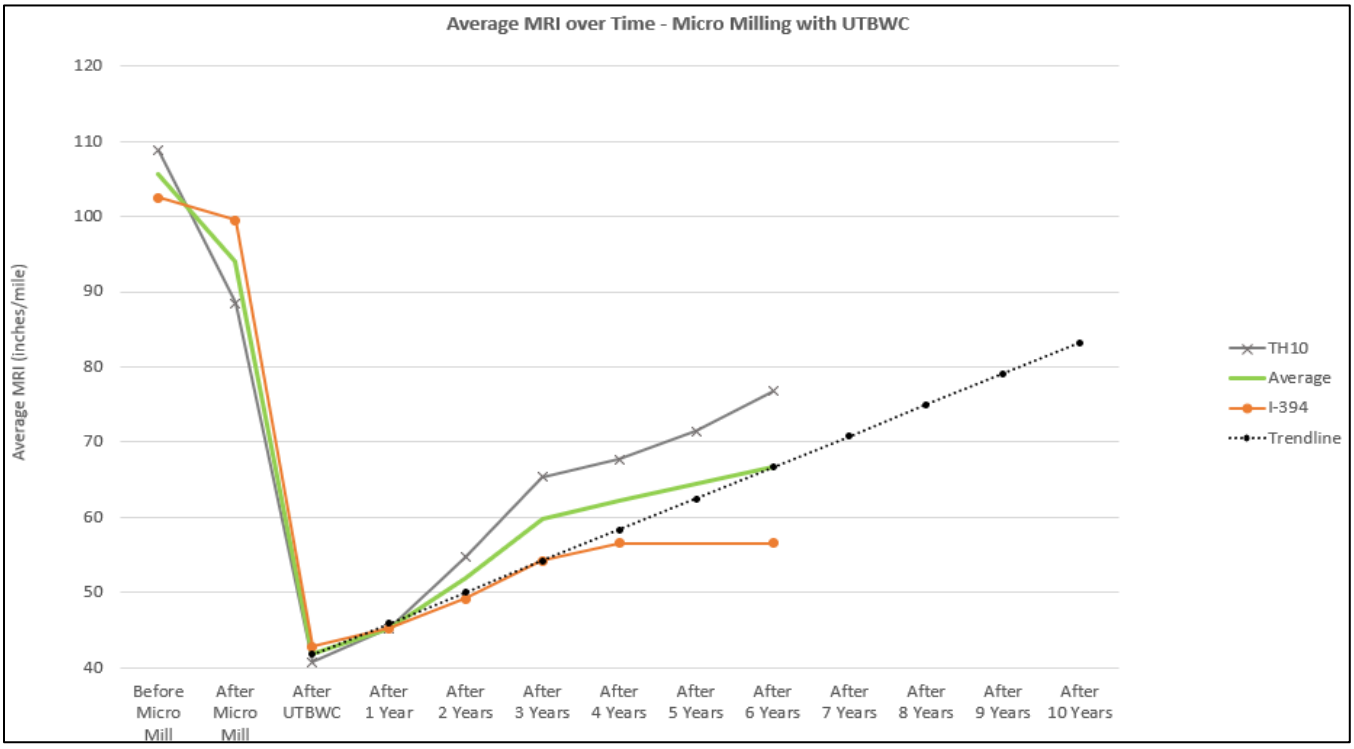

Figure 7 – Micro Mill with UTBWC Performance Chart

The data shown in Figure 7 is tabulated below.

Performance of Micro Milling with UTBWC																	
Highway (Construction Year)	Before Micro Mill	After Micro Mill		After UTBWC		After 1 Year		After 2 Years		After 3 Years		After 4 Years		After 5 Years		After 6 Years	
	Avg. MRI (in/mi)	Avg. MRI (in/mi)	% Change	Avg. MRI (in/mi)	% Change	Avg. MRI (in/mi)	% Change	Avg. MRI (in/mi)	% Change	Avg. MRI (in/mi)	% Change	Avg. MRI (in/mi)	% Change	Avg. MRI (in/mi)	% Change	Avg. MRI (in/mi)	% Change
TH10 EB Driving Lane (2014)	105.9	-	-	42.0	60%	46.2	56%	57.6	46%	67.1	37%	70.0	34%	71.3	33%	79.15	25%
TH10 EB Passing Lane (2014)	109.0	90.4	17%	41.2	62%	45.1	59%	54.1	50%	64.0	41%	64.4	41%	69.7	36%	72.9	33%
TH10 WB Driving Lane (2014)	109.4	-	-	39.4	64%	44.0	60%	54.8	50%	64.9	41%	67.6	38%	70.3	36%	75.7	31%
TH10 WB Passing Lane (2014)	110.8	86.5	22%	40.2	64%	45.6	59%	52.2	53%	65.6	41%	68.9	38%	74.3	33%	79.2	28%
Average	108.8	88.5	19%	40.7	63%	45.2	58%	54.7	50%	65.4	40%	67.7	38%	71.4	34%	76.7	29%
I-394 EB Driving Lane (2016)	93.1	-	-	43.9	53%	46.2	50%	48.2	48%	54.0	42%	54.5	41%		-	54.5	41%
I-394 EB Passing Lane (2016)	105.8	-	-	41.5	61%	44.6	58%	48.7	54%	52.9	50%	56.4	47%		-	56.4	47%
I-394 WB Driving Lane (2016)	97.9	99.5	-2%	42.8	56%	45.3	54%	49.0	50%	55.4	43%	55.8	43%		-	55.8	43%
I-394 WB Passing Lane (2016)	113.3	-	-	43.1	62%	44.9	60%	50.9	55%	54.5	52%	59.7	47%		-	59.7	47%
Average	102.5	99.5		42.8	58%	45.3	56%	49.2	52%	54.2	47%	56.6	45%			56.6	45%
Overall Average	105.7	94.0	19%	41.8	60%	45.2	57%	51.9	51%	59.8	43%	62.2	41%			66.7	37%

Table 4: Performance of micro milling with UTBWC

At approximately $47,550 per lane mile ($8,800 micro mill, $38,750 UTBWC) micro milling with UTBWC has shown the best results at improving ride quality and extending serviceable pavement life within the scope of this investigation. While it has the highest initial cost of the three treatments detailed herein, it may be the most cost effective at improving ride quality long-term. This treatment has an estimated ride improvement and pavement life extension of more than 10 years as noted by the trendline in Figure 7. Based on a 10-year period, the annual cost would be about $0.68 per square yard per year or $4,755 per lane mile per year.

Conclusions

As discussed above, since the MRI of most of the micro surfacing and UTBWC sections have not yet returned to the original values, additional ride data will need to be collected in subsequent years to provide a true comparison of cost/benefit ratio and longevity of the different treatments. Based on the available data, micro milling in combination with bituminous pavement surface treatments has the potential to significantly improve ride quality of a bituminous pavement. Higher initial cost treatments using microsurfacing and UTBWC delivered measurably better performance. The cost per year of these are slightly lower. Micro mill with chip seal provided four years of improvement and continued to outperform the segment of chip seal alone. It also has a lower initial cost than the other two options of micro surfacing and UTBWC. Budget and needs could show that the lower initial cost of a micro mill and chip seal treatment is a valuable option to your network.

Please see the MnDOT Pavement Preservation Manual for more information on bituminous pavement preventive maintenance surface treatments.

For more information on Micro Milling with bituminous pavement surface treatments, please contact:

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References

"Micro-Milling - The Finer Side of Milling." Pavement Interactive
www.pavementinteractive.org/micro-milling-the-finer-side-of-milling/

MnDOT Standard Specification – 2232 Mil Pavement Surface

LCCA Worksheets - MnDOT Pavement Design

MnDOT Pavement Preservation Manual

DEPARTMENT OF TRANSPORTATION

Appendix

The following table lists the approximate reference post numbers corresponding to each project location:

Micro Mill Project Limits		
Chip Seal Projects	**Reference Post Limits**	**Length (mi)**
TH 89 Control Section	59.0 - 60.0	1.0
TH 89 Micro Mill Section	60.0 - 71.3	11.3
TH 89 Micro Mill with Crack Seal Section	71.3 - 74.0	2.7
TH 9	119.8 - 132.8	13.0
Micro Surfacing Projects	**Reference Post Limits**	**Length (mi)**
US 10 (eastbound only)	78.6 - 86.8	8.2
US 12	67.4 - 72.9	5.5
TH 64	0 - 18.7	18.7
UTBWC Projects	**Reference Post Limits**	**Length (mi)**
I-394	0 - 6.3	6.3
US 10	116.2 - 131.6	15.4

Table 5: Micro Mill Project Reference Post Limits