LRRB

Local Operational Research Assistance Program (OPERA) for Local Transportation Groups Field Report

Date: January 25, 2011

Project Title: Rehabilitating / Upgrading Low Volume Roads With Waste Shingles

Project Number: QCPS # 0000363153; Contractor # 0000020664

Agency: Blue Earth County Highway Department

Person Completing Report: Alan Forsberg, Blue Earth County Engineer and Dan Wegman, Road Science LLC.

Project Leader: Alan Forsberg, P.E.

Phone Number: 507-304-4025

Problem: The Blue Earth County Highway system includes over 300 miles of aggregate surfaced farm to market roads. These roads provide all weather access to our rural, productive agricultural areas. However, they are dusty, bumpy and prone to severe damages during the spring thawing period. They are also costly to maintain, requiring regular blading to smooth bumps and replacement of gravel surfacing.

Grading to modern geometric standards and then paving these roads is not affordable. The County has been searching for alternatives for providing a hard, smooth driving surface, including bituminous stabilized gravel. This was effective but became more costly in recent years as asphalt prices increased.

Solution: Demonstrate a bituminous stabilized gravel road using waste shingles, RAS, and recycled asphalt product, RAP, to reduce the amount of asphalt emulsion needed.

Procedure: In partnership, Blue Earth County, Waste Management Inc. and Road Science, LLC, developed a roadway surfacing design using RAP, RAS and a relatively small amount of asphalt emulsion. These materials are combined in the proper proportion, mixed, smoothed and compacted to form a hard, smooth driving surface.

A demonstration project was constructed in the fall of 2010. CSAH 48 from TH 14 to CSAH 7, a segment about 1 mile long located 8 miles east of Mankato was chosen for the demonstration project. It is a low traffic volume aggregate surfaced farm to market roadway. The south end was reconstructed by MnDot several years ago with the TH 14 Expressway project. The north segment was reshaped by County forces and additional gravel added at that time. Although low traffic volume, as is typical with agricultural farm to market roads, it carries heavy loads to serve adjacent fields and pork producers.

Waste Management and Road Science developed the trial mix. The target compressive strength property was 120 pounds per square inch, psi; the trial mix resulted in 125 psi. The target minimum retained compressive strength (wet strength/dry strength X 100) was 60%; the trial mix resulted in 98%.

The County provided the RAP from a substantial stockpile available from earlier road reconstruction projects. Waste Management furnished the RAS at no cost. Road Science provided a 10% discount on the asphalt emulsion. County forces and equipment supplemented by rental equipment did the construction. County forces and equipment also placed a final seal coat wearing surface to complete the project.

The design section consisted of the original gravel surfacing and 5 inches of shingle mix. The mix design by weight was 85% RAP, 15%, RAS and 2 % asphalt emulsion. Without RAS and based on earlier bituminous stabilized gravel road projects, about 6% asphalt emulsion would have been required.

The County hauled and placed 5 inches of RAP to begin the project. Rental trucks hauled the RAS from a metro area Waste Management facility and County forces spread it. A rental reclaimer machine added the asphalt emulsion and mixed the ingredients. Two rented hot in place, HIP, heaters were used in tandem. Initially the two HIP heaters were used to heat the mix in two 3" lifts. However, this proved slow and of limited effectiveness. The HIP heaters were then used only on the final lift and were effective in reducing surface voids and sealing the surface. Compaction was by heavy rubber tire rental roller and steel finish rollers. The rolling pattern was established by a density meter to provide the maximum density. County forces then placed a seal coat to further protect the driving surface from raveling. The final thickness of the shingle mix was approximately 6".

The total cost of the 1 mile long project was $119,945. This cost was somewhat higher then a longer project would be where the equipment mobilization costs could be spread over a larger project. On a larger project, at current costs, costs may be about $100,000 per mile.

Attached is 1) location map, 2) summary of costs, 3) calculation of quantities and thicknesses for RAP and RAS, 4) material spread sheets for these two materials, 5) construction photos and 6) mix design and field test data.

Results: The design developed and provided by Waste Management and Road Science worked well. The plan to use the HIP heaters for two 3" lifts was modified to use them only to seal the surface. In order to ensure sufficient time for the seal coat to cure, future projects should be done in the first half of the summer. To date, the surfacing is performing well with no significant raveling or rutting observed.

Implementation: The County plans to observe the performance of the shingle mix for one to two years. Assuming it performs well, and it has to date, the economics remains favorable and funds are available, additional projects would be done. The HIP heaters were costly and not effective in placing the mix, perhaps because the milled materials did not conduct heat as well as an in place hot mix pavement. They did appear to contribute to a more tightly sealed top surface. It would be useful to demonstrate a section without use of the HIP heaters.

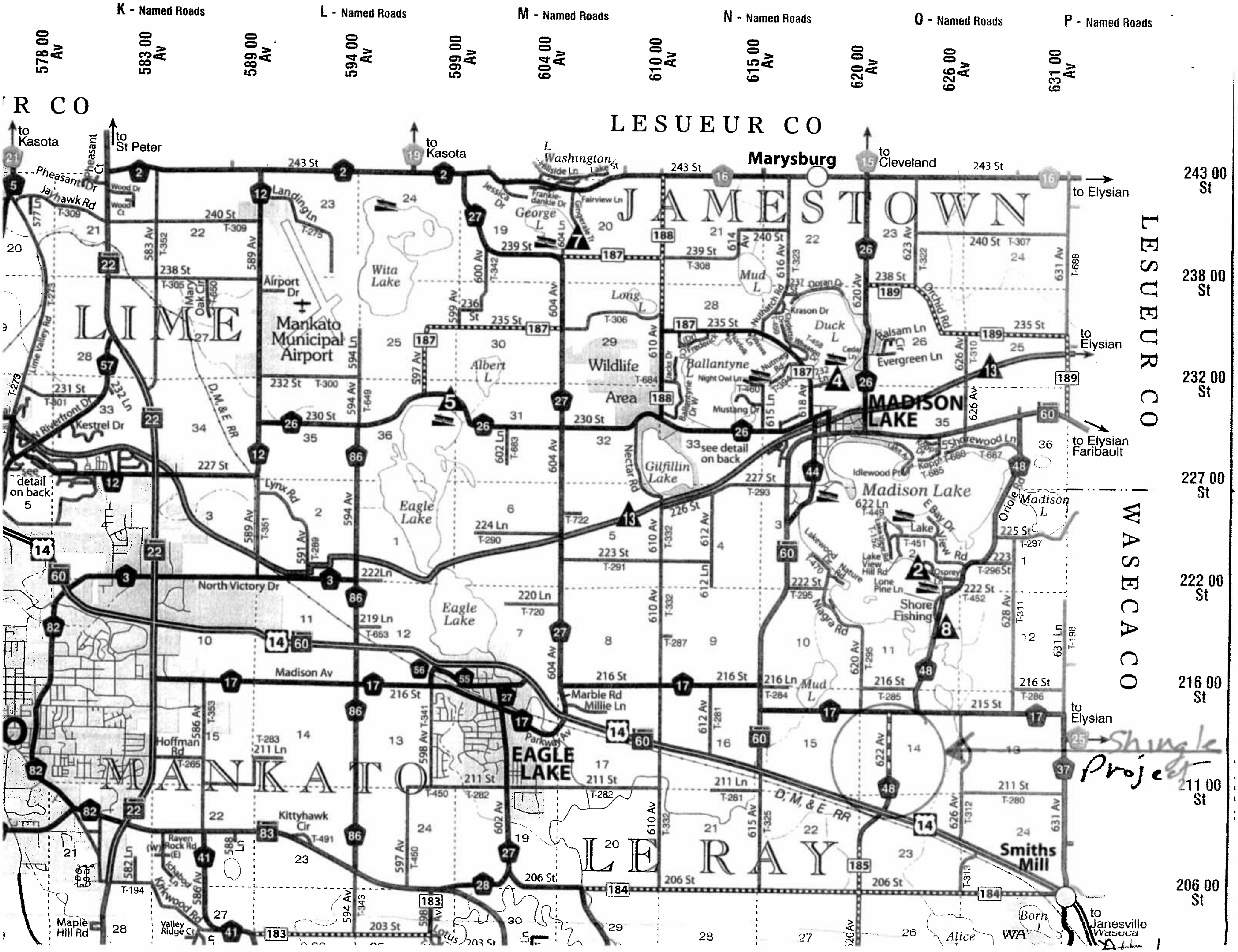
Status: The project is complete except for monitoring for future performance.

Total Duration of Project: Approximately six months to develop the plan and 1 week to construct.

Project End Date: November 01, 2011, except for future monitoring.

Approximate Cost of Entire Project: $120,000 (not including County furnished RAP, WMI furnished waste shingles and 10% Road Science discount on asphalt emulsion).

Total OPERA Funds used for project: $10,000.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LESUEUR CO
WASECA CO
JAMESTOWN
LIME
MANKATO
LE RAY
Marysburg
MADISON LAKE
EAGLE LAKE
Smiths Mill
Mankato Municipal Airport
Wildlife Area
Madison Lake
Eagle Lake
Wita Lake
Gilfillin Lake
Duck L
Mud L
Long L
Albert L
George L
L Washington
Shore Fishing
to Kasota
to St Peter
to Cleveland
to Elysian
to Elysian Faribault
to Janesville
see detail on back
Shingle Project

CR 48
Shingle Project

		Sub Total
Midstate		
Reclaimer	$11,060.00	
(2) Roller	$ 5,130.00	$ 16,190.00
Dustrol		
(2) Heaters-2 days	$26,000.00	$ 26,000.00
Fortress Oil		
17,623 gallons Oil	$37,173.00	
Wayne Transport	$ 2,127.57	$ 39,300.51
R & E Enterprises		
Haul Recycle Shingles	$ 2,411.03	
	$ 5,623.68	$ 8,089.68
Jebro		
Seal Coat Oil	$14,149.61	$ 14,149.61
Blue Earth County		
Labor & Equipment	$12,339.97	
Patch Materials & Recycle	$ 3,875.07	$ 16,215.04
	TOTAL	$119,944.84

H:/WORD/JOE/LISTS/CR 48 Shingle Project

AH 2

BLUE EARTH COUNTY
CSAH 48 SHINGLE DEMO

8/30/2010

MATERIAL	% by Weight	Density lb / Cu.Ft.	Weight 100 lbs of mix	Volume in 100 lbs. of mix Cu. Ft.
RAP	65	105	65	0.62 *
RAS	15	53.3	15	0.28
GRAVEL	18	140	18	0.13
FORTRESS	2	66	2	0.03
			100 lbs	**1.06 Cu. Ft.**

* Note #1: (65 lbs) / $\frac{\text{Cu. Ft.}}{105 \text{ lbs}}$ = 0.62 Cu. Ft.

Mix Density $\frac{100 \text{ lbs}}{1.06 \text{ Cu. Ft.}}$ = 94.34 lbs. / Cu. Ft.

Mix Volume Total (4900 ft) x (26 ft) x (0.5 ft) = 63,700 Cu. Ft.

OR

$\frac{(63{,}700 \text{ Cu. Ft.}) \times (94.34 \text{ lbs. / Cu. Ft.})}{2000 \text{ lbs. / ton}}$ = 3005 ton

	Percent	Ton	Inches
RAP	0.65	1953.25	3.5 **
RAS	0.15	450.75	1.6
GRAVEL	0.18	540.90	0.7
FORTRESS	0.02	60.10	0.2
	TOTAL	**3005**	**6.0**

** Note #2: 1953 ton / $\frac{\text{Cu. Ft.}}{105 \text{ lbs}}$ x $\frac{2000 \text{ lbs}}{1 \text{ Ton}}$ / $\frac{1}{4900 \text{ Ft.}}$ / $\frac{1}{26 \text{ Ft.}}$ = 0.29 Ft x 12" = **3.5"**

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Att 3

08/30/10

BLUE EARTH COUNTY HIGHWAY DEPARTMENT
MATERIAL PLACEMENT SPREADSHEET

JOB NO. CSAH 48
LIFT NO. 1 BOTTOM WIDTH: 26.00 DENSITY: 105
SLOPE: 3 : 1 AVERAGE WIDTH: 25.63
LIFT THICKNESS: 1.5 INCHES TOP OF LIFT WIDTH: 25.25

Tons	Spread in Feet	Tons	Spread in Feet	Tons	Spread in Feet	Tons	Spread in Feet	Tons	Spread in Feet	Tons	Spread in Feet	Tons	Spread in Feet	Tons	Spread in Feet	Tons	Spread in Feet
4.0	23.8	7.6	45.2	11.2	66.6	14.8	88.0	18.4	109.4	22.0	130.8	25.6	152.2	29.2	173.6	32.8	195.0
4.1	24.4	7.7	45.8	11.3	67.2	14.9	88.6	18.5	110.0	22.1	131.4	25.7	152.8	29.3	174.2	32.9	195.6
4.2	25.0	7.8	46.4	11.4	67.8	15.0	89.2	18.6	110.6	22.2	132.0	25.8	153.4	29.4	174.8	33.0	196.2
4.3	25.6	7.9	47.0	11.5	68.4	15.1	89.8	18.7	111.2	22.3	132.6	25.9	154.0	29.5	175.4	33.1	196.8
4.4	26.2	8.0	47.6	11.6	69.0	15.2	90.4	18.8	111.8	22.4	133.2	26.0	154.6	29.6	176.0	33.2	197.4
4.5	26.8	8.1	48.2	11.7	69.6	15.3	91.0	18.9	112.4	22.5	133.8	26.1	155.2	29.7	176.6	33.3	198.0
4.6	27.4	8.2	48.8	11.8	70.2	15.4	91.6	19.0	113.0	22.6	134.4	26.2	155.8	29.8	177.2	33.4	198.6
4.7	27.9	8.3	49.4	11.9	70.8	15.5	92.2	19.1	113.6	22.7	135.0	26.3	156.4	29.9	177.8	33.5	199.2
4.8	28.5	8.4	50.0	12.0	71.4	15.6	92.8	19.2	114.2	22.8	135.6	26.4	157.0	30.0	178.4	33.6	199.8
4.9	29.1	8.5	50.5	12.1	72.0	15.7	93.4	19.3	114.8	22.9	136.2	26.5	157.6	30.1	179.0	33.7	200.4
5.0	29.7	8.6	51.1	12.2	72.5	15.8	94.0	19.4	115.4	23.0	136.8	26.6	158.2	30.2	179.6	33.8	201.0
5.1	30.3	8.7	51.7	12.3	73.1	15.9	94.6	19.5	116.0	23.1	137.4	26.7	158.8	30.3	180.2	33.9	201.6
5.2	30.9	8.8	52.3	12.4	73.7	16.0	95.1	19.6	116.6	23.2	138.0	26.8	159.4	30.4	180.8	34.0	202.2
5.3	31.5	8.9	52.9	12.5	74.3	16.1	95.7	19.7	117.1	23.3	138.6	26.9	160.0	30.5	181.4	34.1	202.8
5.4	32.1	9.0	53.5	12.6	74.9	16.2	96.3	19.8	117.7	23.4	139.1	27.0	160.6	30.6	182.0	34.2	203.4
5.5	32.7	9.1	54.1	12.7	75.5	16.3	96.9	19.9	118.3	23.5	139.7	27.1	161.2	30.7	182.6	34.3	204.0
5.6	33.3	9.2	54.7	12.8	76.1	16.4	97.5	20.0	118.9	23.6	140.3	27.2	161.7	30.8	183.2	34.4	204.6
5.7	33.9	9.3	55.3	12.9	76.7	16.5	98.1	20.1	119.5	23.7	140.9	27.3	162.3	30.9	183.7	34.5	205.2
5.8	34.5	9.4	55.9	13.0	77.3	16.6	98.7	20.2	120.1	23.8	141.5	27.4	162.9	31.0	184.3	34.6	205.8
5.9	35.1	9.5	56.5	13.1	77.9	16.7	99.3	20.3	120.7	23.9	142.1	27.5	163.5	31.1	184.9	34.7	206.3
6.0	35.7	9.6	57.1	13.2	78.5	16.8	99.9	20.4	121.3	24.0	142.7	27.6	164.1	31.2	185.5	34.8	206.9
6.1	36.3	9.7	57.7	13.3	79.1	16.9	100.5	20.5	121.9	24.1	143.3	27.7	164.7	31.3	186.1	34.9	207.5
6.2	36.9	9.8	58.3	13.4	79.7	17.0	101.1	20.6	122.5	24.2	143.9	27.8	165.3	31.4	186.7	35.0	208.1
6.3	37.5	9.9	58.9	13.5	80.3	17.1	101.7	20.7	123.1	24.3	144.5	27.9	165.9	31.5	187.3	35.1	208.7
6.4	38.1	10.0	59.5	13.6	80.9	17.2	102.3	20.8	123.7	24.4	145.1	28.0	166.5	31.6	187.9	35.2	209.3
6.5	38.7	10.1	60.1	13.7	81.5	17.3	102.9	20.9	124.3	24.5	145.7	28.1	167.1	31.7	188.5	35.3	209.9
6.6	39.2	10.2	60.7	13.8	82.1	17.4	103.5	21.0	124.9	24.6	146.3	28.2	167.7	31.8	189.1	35.4	210.5
6.7	39.8	10.3	61.2	13.9	82.7	17.5	104.1	21.1	125.5	24.7	146.9	28.3	168.3	31.9	189.7	35.5	211.1
6.8	40.4	10.4	61.8	14.0	83.3	17.6	104.7	21.2	126.1	24.8	147.5	28.4	168.9	32.0	190.3	35.6	211.7
6.9	41.0	10.5	62.4	14.1	83.8	17.7	105.3	21.3	126.7	24.9	148.1	28.5	169.5	32.1	190.9	35.7	212.3
7.0	41.6	10.6	63.0	14.2	84.4	17.8	105.8	21.4	127.3	25.0	148.7	28.6	170.1	32.2	191.5	35.8	212.9
7.1	42.2	10.7	63.6	14.3	85.0	17.9	106.4	21.5	127.9	25.1	149.3	28.7	170.7	32.3	192.1	35.9	213.5
7.2	42.8	10.8	64.2	14.4	85.6	18.0	107.0	21.6	128.4	25.2	149.9	28.8	171.3	32.4	192.7	36.0	214.1
7.3	43.4	10.9	64.8	14.5	86.2	18.1	107.6	21.7	129.0	25.3	150.4	28.9	171.9	32.5	193.3	36.1	214.7
7.4	44.0	11.0	65.4	14.6	86.8	18.2	108.2	21.8	129.6	25.4	151.0	29.0	172.5	32.6	193.9	36.2	215.3
7.5	44.6	11.1	66.0	14.7	87.4	18.3	108.8	21.9	130.2	25.5	151.6	29.1	173.0	32.7	194.5	36.3	215.9

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08/30/10

BLUE EARTH COUNTY HIGHWAY DEPARTMENT
MATERIAL PLACEMENT SPREADSHEET

JOB NO. CSAH 48
LIFT NO. 1
SLOPE: 3 : 1
LIFT THICKNESS: 1.6 INCHES

BOTTOM WIDTH: 26.00
AVERAGE WIDTH: 25.60
TOP OF LIFT WIDTH: 25.20

DENSITY: 53.3

Tons	Spread in Feet	Tons	Spread in Feet	Tons	Spread in Feet	Tons	Spread in Feet	Tons	Spread in Feet	Tons	Spread in Feet	Tons	Spread in Feet	Tons	Spread in Feet	Tons	Spread in Feet
4.0	44.0	7.6	83.5	11.2	123.1	14.8	162.7	18.4	202.3	22.0	241.9	25.6	281.4	29.2	321.0	32.8	360.6
4.1	45.1	7.7	84.6	11.3	124.2	14.9	163.8	18.5	203.4	22.1	242.9	25.7	282.5	29.3	322.1	32.9	361.7
4.2	46.2	7.8	85.7	11.4	125.3	15.0	164.9	18.6	204.5	22.2	244.0	25.8	283.6	29.4	323.2	33.0	362.8
4.3	47.3	7.9	86.8	11.5	126.4	15.1	166.0	18.7	205.6	22.3	245.1	25.9	284.7	29.5	324.3	33.1	363.9
4.4	48.4	8.0	87.9	11.6	127.5	15.2	167.1	18.8	206.7	22.4	246.2	26.0	285.8	29.6	325.4	33.2	365.0
4.5	49.5	8.1	89.0	11.7	128.6	15.3	168.2	18.9	207.8	22.5	247.3	26.1	286.9	29.7	326.5	33.3	366.1
4.6	50.6	8.2	90.1	11.8	129.7	15.4	169.3	19.0	208.9	22.6	248.4	26.2	288.0	29.8	327.6	33.4	367.2
4.7	51.7	8.3	91.2	11.9	130.8	15.5	170.4	19.1	210.0	22.7	249.5	26.3	289.1	29.9	328.7	33.5	368.3
4.8	52.8	8.4	92.3	12.0	131.9	15.6	171.5	19.2	211.1	22.8	250.6	26.4	290.2	30.0	329.8	33.6	369.4
4.9	53.9	8.5	93.4	12.1	133.0	15.7	172.6	19.3	212.2	22.9	251.7	26.5	291.3	30.1	330.9	33.7	370.5
5.0	55.0	8.6	94.5	12.2	134.1	15.8	173.7	19.4	213.3	23.0	252.8	26.6	292.4	30.2	332.0	33.8	371.6
5.1	56.1	8.7	95.6	12.3	135.2	15.9	174.8	19.5	214.4	23.1	253.9	26.7	293.5	30.3	333.1	33.9	372.7
5.2	57.2	8.8	96.7	12.4	136.3	16.0	175.9	19.6	215.5	23.2	255.0	26.8	294.6	30.4	334.2	34.0	373.8
5.3	58.3	8.9	97.8	12.5	137.4	16.1	177.0	19.7	216.6	23.3	256.1	26.9	295.7	30.5	335.3	34.1	374.9
5.4	59.4	9.0	98.9	12.6	138.5	16.2	178.1	19.8	217.7	23.4	257.2	27.0	296.8	30.6	336.4	34.2	376.0
5.5	60.5	9.1	100.0	12.7	139.6	16.3	179.2	19.9	218.8	23.5	258.3	27.1	297.9	30.7	337.5	34.3	377.1
5.6	61.6	9.2	101.1	12.8	140.7	16.4	180.3	20.0	219.9	23.6	259.4	27.2	299.0	30.8	338.6	34.4	378.2
5.7	62.7	9.3	102.2	12.9	141.8	16.5	181.4	20.1	221.0	23.7	260.5	27.3	300.1	30.9	339.7	34.5	379.3
5.8	63.8	9.4	103.3	13.0	142.9	16.6	182.5	20.2	222.1	23.8	261.6	27.4	301.2	31.0	340.8	34.6	380.4
5.9	64.9	9.5	104.4	13.1	144.0	16.7	183.6	20.3	223.2	23.9	262.7	27.5	302.3	31.1	341.9	34.7	381.5
6.0	66.0	9.6	105.5	13.2	145.1	16.8	184.7	20.4	224.3	24.0	263.8	27.6	303.4	31.2	343.0	34.8	382.6
6.1	67.1	9.7	106.6	13.3	146.2	16.9	185.8	20.5	225.4	24.1	264.9	27.7	304.5	31.3	344.1	34.9	383.7
6.2	68.2	9.8	107.7	13.4	147.3	17.0	186.9	20.6	226.5	24.2	266.0	27.8	305.6	31.4	345.2	35.0	384.8
6.3	69.3	9.9	108.8	13.5	148.4	17.1	188.0	20.7	227.6	24.3	267.1	27.9	306.7	31.5	346.3	35.1	385.9
6.4	70.4	10.0	109.9	13.6	149.5	17.2	189.1	20.8	228.7	24.4	268.2	28.0	307.8	31.6	347.4	35.2	387.0
6.5	71.5	10.1	111.0	13.7	150.6	17.3	190.2	20.9	229.8	24.5	269.3	28.1	308.9	31.7	348.5	35.3	388.1
6.6	72.6	10.2	112.1	13.8	151.7	17.4	191.3	21.0	230.9	24.6	270.4	28.2	310.0	31.8	349.6	35.4	389.2
6.7	73.7	10.3	113.2	13.9	152.8	17.5	192.4	21.1	232.0	24.7	271.5	28.3	311.1	31.9	350.7	35.5	390.3
6.8	74.8	10.4	114.3	14.0	153.9	17.6	193.5	21.2	233.1	24.8	272.6	28.4	312.2	32.0	351.8	35.6	391.4
6.9	75.9	10.5	115.4	14.1	155.0	17.7	194.6	21.3	234.2	24.9	273.7	28.5	313.3	32.1	352.9	35.7	392.5
7.0	77.0	10.6	116.5	14.2	156.1	17.8	195.7	21.4	235.3	25.0	274.8	28.6	314.4	32.2	354.0	35.8	393.6
7.1	78.1	10.7	117.6	14.3	157.2	17.9	196.8	21.5	236.4	25.1	275.9	28.7	315.5	32.3	355.1	35.9	394.7
7.2	79.2	10.8	118.7	14.4	158.3	18.0	197.9	21.6	237.5	25.2	277.0	28.8	316.6	32.4	356.2	36.0	395.8
7.3	80.3	10.9	119.8	14.5	159.4	18.1	199.0	21.7	238.6	25.3	278.1	28.9	317.7	32.5	357.3	36.1	396.9
7.4	81.3	11.0	120.9	14.6	160.5	18.2	200.1	21.8	239.7	25.4	279.2	29.0	318.8	32.6	358.4	36.2	398.0
7.5	82.4	11.1	122.0	14.7	161.6	18.3	201.2	21.9	240.8	25.5	280.3	29.1	319.9	32.7	359.5	36.3	399.1

Rehabilitating/Upgrading low volume road with waste shingles

OPERA PROJECT PROFILE

General Project Information

Many local Governments have networks with significant miles of low volume roads. Maintenance costs for these roads continue to increase because gravel is lost to grading and traffic; dust control is a problem and smoothness is difficult to maintain. Gravel road stabilization can address these problems by locking up the gravel and providing a smooth surface while maintaining a rural road aesthetic. Stabilization becomes less attractive for low volume roads when additives are required at application rates that become cost prohibitive. Waste shingles offer a viable means to offset additives required in the stabilization process since significant asphalt is present in the shingles. Preliminary design analysis has shown that emulsion content can be reduced by up to 5% saving significant costs from the stabilization process. Blue Earth County conducted a demonstration project using waste shingles to address a low volume road need. This green process makes a waste product a valuable resource in a road rehabilitation process. Should this rehab alternative become a viable low volume road solution it will address a significant need amoung local Governments.

Construction Information

Contractors:	Midstate Reclamation, Lakeville, MN Blue Earth County Maintenance Crew
Construction:	September 2010, Daytime, Road open to local traffic
Stabilization:	5" depth – 80% RAP/15% Recycled Shingle/2% Eng. Emulsion
Surfacing:	MC Cutback Chip seal by BE County Maintenace Crew
Material Supply:	Waste Management supplied shingles at no cost Road Science supplied EE at 10% discount
Surface Heating:	HIP Heaters used to heat surface

Photos
CSAH 48

Placing RAS/RAP Blend
with Blade

Placing RAS/RAP Blend
with Blade

Mixing EE with RAS/RAP Blend

Heating and Compacting Surface

Design and Performance Result

Significant design work was conducted for this project by Waste Management. Economics are also available as part of the Opera submittal. Constructability was a major component of this research. Based on results, the process is viable for future use by local governments. Performance will be evaluated following the spring thaw and a follow-up report will be written at that time.

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Cold Mix Test Results

% RAS-C	% Fortress	%RAP	Temperature	Dry Compressive Strength	Wet Compressive Strength	Retained Ratio	Equivalent AC content
10	1	0	200	88	59	67%	3.16
	1	50	175	127	88	69%	5.16
	1	50	150	135	92	68%	5.16
	1	***50***	***125***	***123***	***90***	***73%***	***5.16***
	2	0	200	90	70	78%	3.82
15	2	0	Ambient	75	-	N/A	5.07
	2	0	200	95	90	95%	5.07
	2	***50***	***200***	***141***	***121***	***86%***	***7.07***
25	2	0	200	95	90	95%	7.57

Att 6

Blue Earth County
CSAH 48
Dynamic Cone Penetration

Road Science used the DCP to evaluate the strength of the pavement during the different stages of the construction process on CSAH 48. The process of building the road presented an opportunity to evaluate the change in strength of the pavement at the different stages. The testing evaluated the material in a pre-injected state before the reclaimer (Sections 1 & 3), post compaction pre-heat, and post compaction post-heat at depths of 6", 8", and 12".

Section 1

	Pre-Injection 9-27-2010	**Pre-Heat 9-27-2010**	**Post-Heat 9-27-2010**	**Post-Heat 9-28-2010**	**Post-Heat 9-29-2010**
6"	19 Blows	14 Blows	16 Blows	28 Blows	30 Blows
8"	27 Blows	24 Blows	24 Blows	40 Blows	40 Blows
12"	37 Blows	40 Blows	32 Blows	62 Blows	62 Blows

Average number of blows to reach the desired depth from start to finish increased - 36%

Section 2

	Pre-Heat 9-28-2010	**Post-Heat 9-28-2010**	**Post-Heat 9-29-2010**
6"	17 Blows	24 Blows	29 Blows
8"	20 Blows	33 Blows	45 Blows
12"	30 Blows	54 Blows	59 Blows

Average number of blows to reach the desired depth from start to finish increased - 49%

Section 3

	Pre-Injection 9-28-2010	**Pre-Heat 9-28-2010**	**Post-Heat 9-28-2010**	**Post-Heat 9-29-2010**
6"	10 Blows	19 Blows	15 Blows	26 Blows
8"	14 Blows	21 Blows	17 Blows	31 Blows
12"	30 Blows	34 Blows	22 Blows	38 Blows

Average number of blows to reach the desired depth form start to finish increased - 46%

Based on the data that was recorded during the construction process through the use of the DCP, CSAH 48 gained strength at the three depths in all three sections.