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Extending the Life of Paint and Reflective Markers by Using Partial Rubber Plow Blades

Dwayne Harris

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16. Abstract

Winter roadway maintenance in Indiana typically involves the removal of snow and ice from the roadway with metal plow blades. The interaction of the wearable metal portion of the plow and the roadway causes damage to raised pavement markers (RPMs) and painted line markings. Partial rubber snow plow blades (PRPBs) are currently available as an alternative to full metal blades. The purpose of this project was to conduct a limited study to evaluate the decrease in damage to the RPMs and pavement markings, and rate the snow removal performance of the PRPB verses the traditional steel carbide blade. Overall there was no solid evidence supporting the premise that the PRPB equipped with rubber wingtips damaged RPMs and striping less than the traditional plow equipped with a steel cutting edge. Overall the PRPB did not perform nearly as well as the steel blade based on the opinions of INDOT plow operators.

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EXECUTIVE SUMMARY

EXTENDING THE LIFE OF PAINT AND REFLECTIVE MARKERS BY USING PARTIAL RUBBER PLOW BLADES

Introduction

Winter roadway maintenance in Indiana typically involves the removal of snow and ice from the roadway with metal plow blades. The interaction of the wearable metal portion of the plow and the roadway causes damage to raised pavement markers (RPMs) and painted line markings. Partial rubber snow plow blades (PRPBs) are currently available as an alternative to full metal blades.

INDOT maintenance would like to evaluate the effectiveness of PRPBs.

The hypothesis of this study is that the PRPB will cause less damage to the pavement markings and the raised pavement markers, but provide somewhat less effective snow removal than the steel carbide blade. The purpose of this project was to conduct a limited study to evaluate the decrease in damage to the RPMs and pavement markings, and rate the snow removal performance of the PRPB versus the traditional steel carbide blade.

Findings

Overall, there was no solid evidence supporting the premise that the PRPB equipped with rubber wingtips removes less RPMs than a traditional plow with all steel cutting edges. Consequently, the results of the study do not support the hypothesis that plowing roads with PRPBs is significantly less damaging to RMPS than plowing roads with plows equipped with only steel cutting edges.

The analysis of the retroreflectivity data was inconclusive in supporting the premise that plowing roads with the traditional steel blade damages the paint striping more than plowing with a PRPB. There were instances where the changes (after snow—before snow) in population means, medians, variances, and interquartile ranges suggested that there was more damage caused by the steel blade; however, this was inconsistent.

Overall, the PRPB did not perform nearly as well as the steel blade, based on the opinions of INDOT plow operators. The results of the survey conducted as part of this study showed that the performance of the PRPB was significantly to severely diminished when compared with the performance of a steel blade. Furthermore, many of the operators stated that the PRPB does not cut through the snow down to the pavement. There were also issues with slush coming over the plow, interfering with plow operation and driver vision. Utilizing the PRPB also introduced increased motion in the plow, which decreased the overall effectiveness of the plow, especially at Interstate plowing velocities.

Implementation

The sample size was too small, and length evaluation was too short to provide a solid evaluation of the decrease in damage to RMPS or pavement striping by utilization of PRPBS. A solid evaluation would require many more testing sections with a much longer evaluation period. The possibility of extending this study, including studying a larger sample size for a longer period of time, was introduced at an SAC meeting. However, the SAC declined further study based on the lack of performance of the PRPB, and the increase plow motion introduced by the PRPB, especially at Interstate plowing velocities.

The consensus of the SAC members was that PRPB could be utilized on routes plowed at speeds less than 20 mph, but not on Interstate routes.

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1. INTRODUCTION

Winter roadway maintenance in Indiana typically involves the removal of snow and ice from the roadway with metal plow blades. The interaction of the wearable metal portion of the plow and the roadway causes damage to raised pavement markers (RPMs) and painted line markings. Partial rubber snow plow blades (PRPBs) are currently available as an alternative to full metal blades.

INDOT maintenance would like to evaluate the effectiveness of PRPBs.

The hypothesis of this study is that the PRPB will cause less damage to the pavement markings and the raised pavement markers, but provide somewhat less effective snow removal than the steel carbide blade (Roosevelt, 1995). The purpose of this project was to conduct a limited study to evaluate the decrease in damage to the RPMs and pavement markings, and rate the snow removal performance of the PRPB verses the traditional steel carbide blade.

1.1 Scope

This study was initiated by INDOT Maintenance and the Greenfield District/Centerville sub-district. The Cambridge City Maintenance Unit (Unit) obtained a number of pieces of rubber and altered a several plows to evaluate the PRPB performance. The PRPBs were to be utilized on two of Cambridge City Maintenance Units' plow routes. One of the routes was located on I-70 and the other route was located on US-40 (see Figure 1.1 and Figure 1.2).

Furthermore, the Cambridge City Unit was plowing a route on US-27 through Richmond, Indiana utilizing a full rubber blade. At least part of this section of US-27 consisted of thermoplastic striping instead of traditional paint; consequently, this section was selected to evaluate thermoplastic tape.

This study was very limited in scope. The sample size was small with the evaluation of the PRPBs limited to just two routes, with an additional route plowed utilizing a full rubber blade.

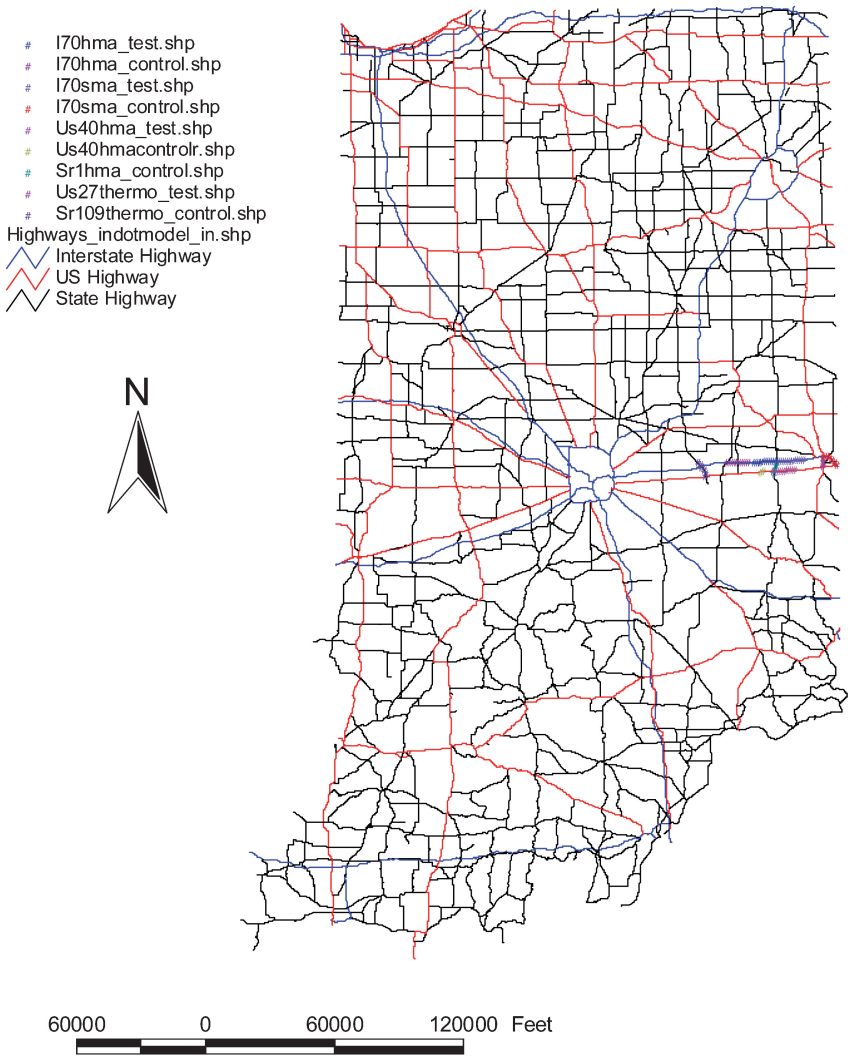

Figure 1.1 Map showing test and control areas for PRPB study.

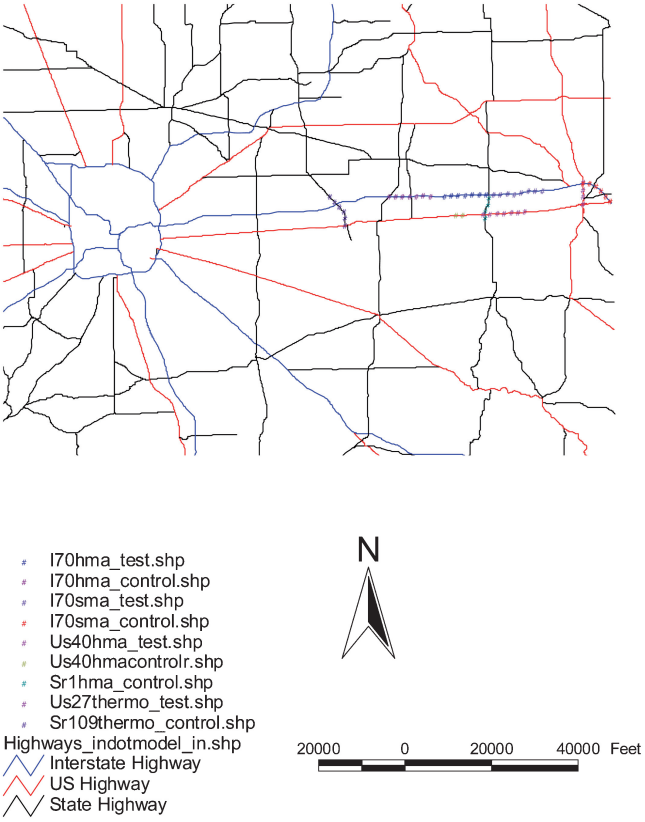

Figure 1.2 Map (zoomed) showing test and control areas for PRPB study.

This report will cover the following:

- Description of the partial rubber plow blade
- Evaluation of the damage of RPM's
- Evaluation of damage of painted line markings
- Evaluation of the snow removal performance

2. PARTIAL RUBBER PLOW BLADE

The PRPB is an altered snow plow blade where the steel carbide cutting surface (cutting edge) of part of the blade is replaced with pieces of rubber (see Figure 2.1). For this study the wing tips (18″ from both edges) of the plow blade were replaced with rubber (see Figure 2.1, Figure 2.2, and Figure 2.3). Figure 2.4 is an image of plow with a full rubber cutting edge (see Figure 2.4).

The steel/carbide cutting edge was replaced with rubber on the wing tips because this is the part of the plow that rides on the RPM's and pavement markings for a majority of the snow removal process. The hypothesis is that the rubber will damage RPMs or striping less than a steel cutting edge.

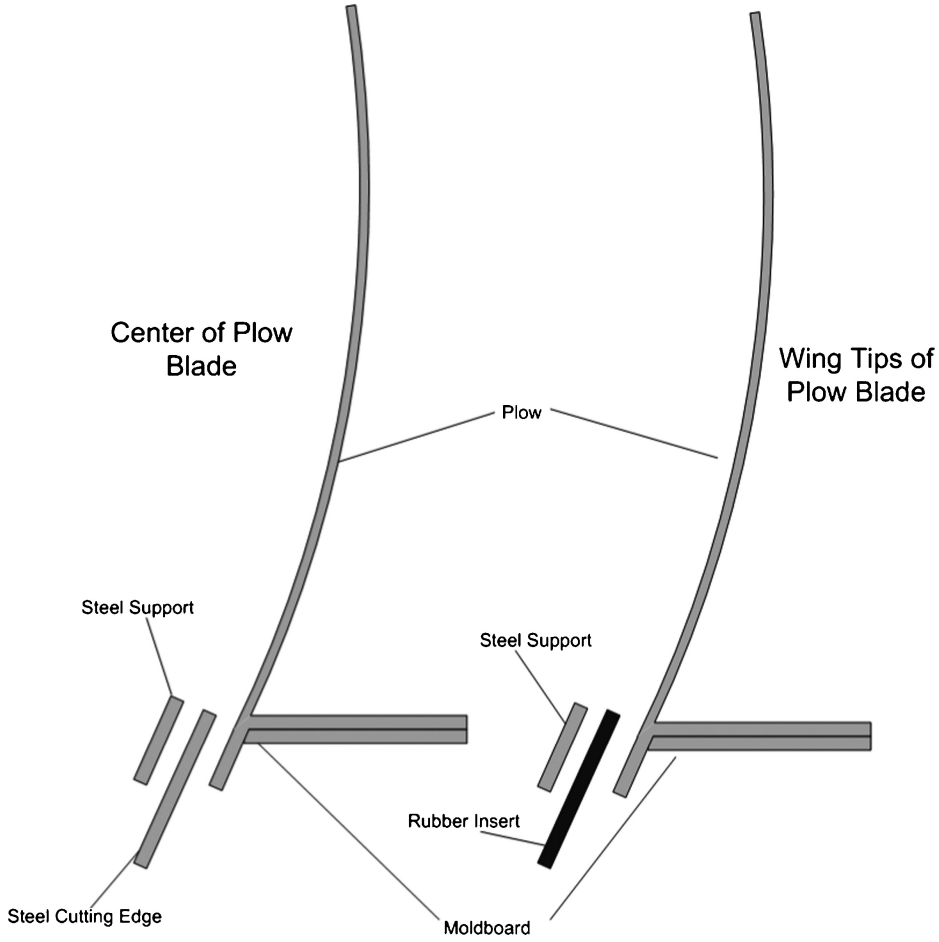

Figure 2.1 Cross section of plow in center and on wing tips (edges).

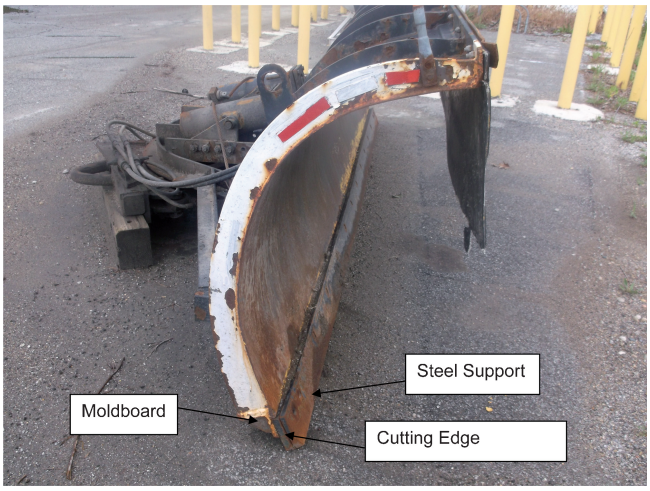

Figure 2.2 Image of INDOT plow.

Figure 2.3 Image of INDOT plow showing location of rubber inserts.

Figure 2.4 Image of full rubber cutting edge (Resolute Rubber, 2013).

3. DAMAGE EVALUATION

The damage evaluation of the PRPBs' was conducted by comparing the change in number of missing RPMS and the paint striping retro reflectivity of the test areas (routes plowed by using PRPB or full rubber blade) and the number of missing RPMs and paint striping retro reflectivity of control sections (routes plowed using traditional steel carbide cutting edges) collected before the snow season and collected after the snow season.

The test sections included pavement surfaces composed of HMA and SMA. These test sections included both traditional paint striping and thermoplastic tape. The snow removal for thermoplastic tape test section was done using a full rubber blade.

3.1 RPM Damage Evaluation

The RPM damage evaluation consisted of selecting control and test sections, counting the RPMs in these sections prior to the snow season and counting the RPMs at the completion of the snow season.

Damage to and removal of the RPMs during the snow removal process is caused by the impact of the snow plows' cutting edge on the RPMs. The impact force of the steel cutting edge on the RPM is larger than the impact force of the rubber on the RPM, because steel is a more rigid harder material. Therefore, the probability of removal of the RPM by plowing is greater for roads plowed with steel cutting edges as opposed to those plowed with a PRPB. This increased probability of damage/removal may be reflected as an increased number in missing RPMs for pavement sections plowed with the steel cutting edge (control sections) as opposed to those sections plowed with the PRPB (test sections) at the end of the snow season.

RPM counts were made for two HMA test sections and control sections. One of the test sections and one of the control sections was located on I-70 (see Figure 1.2). The other HMA test section was located on US-40, and the second HMA control section was on located on SR-1 (see Figure 1.2). The SMA test and control sections were located on I-70 (see Figure 1.2). The thermoplastic tape test section is located on US-27 and the thermoplastic control section is located on SR-109 (see Figure 1.2). The number of missing RPMs was counted for all of the sections after the snow season and for some of the sections before the snow season. The results of the RPM counts are included in Table 3.1 (see Table 3.1).

There were blunders identified in the RPM count data at the conclusion of making the counts in June of 2013. There should not be more RPMs in the counts taken after the snow season. This is the case for the I-70 West HMA section, the I-70 SMA control sections, the I-70 East SMA test section, and the SR-109 tape control section (see Table 3.1). Furthermore, there were sections with significantly difference in the counts such as the US-40 test center; SR-1 control, I-70 West SMA control, I-70 East test, and SR-109 control (see Table 3.1). There are a number of potential sources for these blunders. These possible sources include the following:

1. Human errors in counting the RPMs
2. Errors in locating the start and end points of the count

There were no apparent blunders in the counts of missing RPMs. The count of missing RPMs after the snow season is always greater than or equal to the number of missing RPMS counted before the snow season for all sections where there were both before and after counts are available.

There were no missing RPMs in the counts for the US-27 HMA Tape test section and the SR-109 HMA Tape control section for both before and after the snow season (see Table 3.1). Consequently, traditional plow with the steel cutting edge did not remove any more RPMs than the plow equipped with the rubber cutting edge.

The numbers of missing RPMs were the same in the counts for before and after the snow season for the US-40 HMA Test section and for the SR-1 HMA Control Section (see Table 3.1). Consequently, the traditional plow with a steel cutting edge did not remove any more RPMs than the PRPB equipped with rubber cutting edges on the wingtips.

The numbers of missing RPMs were similar in the counts for the I-70 HMA Control Section and the I-70 HMA Test Section made after the snow season (see Table 3.1). Consequently, there is no solid evidence supporting the premise that the traditional plow with steel cutting edge removes significantly more RPM's than the PRPB with rubber cutting edges on the wingtips.

The count of missing RPMs increased at least 25 for the I-70 SMA Test Sections between the count made after the snow season as opposed the count prior to the snow season, and the count of missing RPMs made after the snow season for the I-70 SMA Control Sections is a maximum 6 (see Table 3.1). Consequently, there is no evidence supporting the premise that the

TABLE 3.1
RPM Counts

	Start RP	End RP	Count Oct 2012	Count 1 June 2013	Count 2 June 2013	Missing Count Oct 2012	Missing Count June 2013
HMA							
I-70 Cont East	123	129	389	386	386	na	5–11
I-70 Cont West	129	123	391	388	388	na	6
SR-1 Cont	61	59	299	268	na	0	0
I-70 Test East	132	137	325	319	321	na	6
I-70 Test West	137	132	315	318	318	na	6
US-40 Test Center	134	139	689	659	653	na	4
US-40 Test East	134	139	323	323		2	2
US-40 Test West	139	134	340	329		0	0
SMA							
I-70 Cont East	151	156	307	326	326	na	6
I-70 Cont West	156	151	303	333	na	na	5
I-70 Test East	137	145	452	472	475	18	43–45
I-70 Test West	145	137	484	477	475	11	41
HMA Tape							
SR-109 Cont	1	3	384	198–329	na	0	0
SR-109 Cont	3	10	466	560	na	0	0
US-27 Test Center			166	167	na	0	0
US-27 Test North			88	88	na	0	0
US-27 Test South			91	91	na	0	0

traditional plow with steel cutting edge removes significantly more RPM's than the PRPB with rubber cutting edges on the wingtips. The opposite can be inferred because the data supports the conclusion that the PRPB removes more RPMs than the traditional plow.

Overall there was no solid evidence supporting the premise that the PRPB equipped with rubber wingtips removes less RPMs than a traditional plow with all steel cutting edges. Consequently, the results of the study do not support the hypothesis that plowing roads with PRPBs is significantly less damaging to RPMs than plowing roads with plows equipped with only steel cutting edges.

Removal of the RPMs by the plowing process is heavily dependent on the quality of the RPM installation was an idea proposed by SAC members.

The length of PRPB evaluation based on RPM removal would have to be significantly longer than one year to show any meaningful results.

3.2 Paint Striping Damage Evaluation

The measurement of the paint retroreflectivity is a standard method of evaluating the visibility (amount of light reflected off of the markings) of pavement striping at night. In ASTM E1710-11 retroreflecivity (coefficient of retroreflected luminance) is defined as the ratio of the luminance, of a projected surface to the normal illuminance at the surface on a plane normal to the incident light, expressed in millicandelas per square meter per lux ($mcd.m^{-2}.lx^{-1}$) (ASTM International, 2011). The retroreflectivity of the pavement striping is dependent on the amount of intact glass beads present in the striping. Removal or damage to the glass beads by the snow removal process decreases the retroreflectivity of the striping. Consequently, the magnitude of a decrease in the retroreflectivity of the pavement marking is an indicator of an increase in damage to the striping.

The paint striping evaluation consisted of making retroreflectivity readings on the control and test sections prior to the snow season and after the snow season (INDOT, 2013; 2014). For each of the test and control sections a 1 mile section was selected for retrorelfectivity testing (see Figure 3.1). Twenty retroreflectivity readings were made in each of the 1 mile sections. Descriptive statistics were determined for the retroreflectivity measurement populations for each of the sections. Damage to the paint striping should be reflected as changes in the descriptive statistics of the before verses after snow season measurement populations. The population means of the measurements taken after the snow season should be smaller than before the snow season due to paint wear and damage. The difference in the populations mean retrorelectivities should be greater for striping where greater damage was incurred by the plowing process. Furthermore, the differences in the populations' variances should be greater where greater damage was incurred by the plowing process.

There were three control HMA sections and two HMA test sections tested for two comparisons. One of

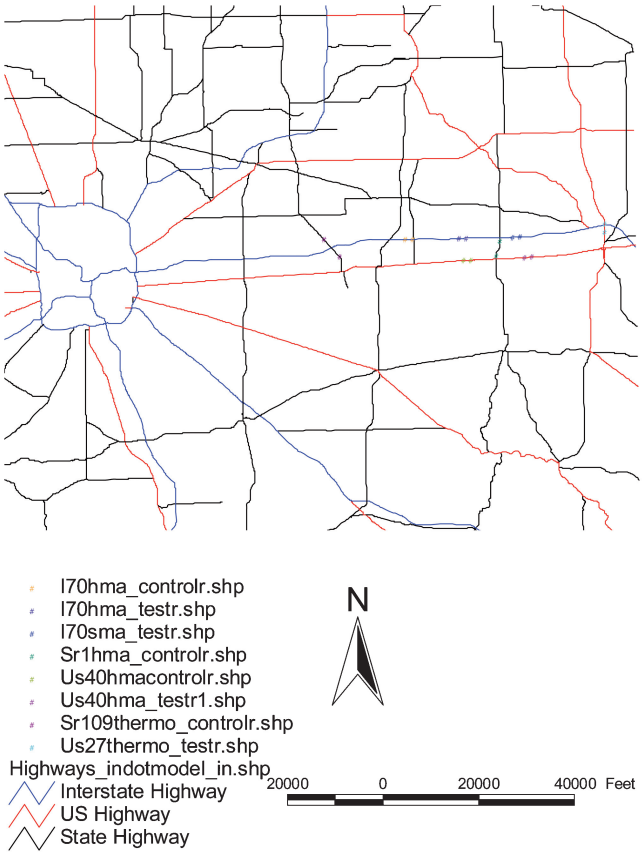

Figure 3.1 Location of the paint retroreflectivity tests; data collected between points.

the comparisons used a section of US-40 and SR-1 for control sections and a section of US-40 for the test section. For this comparison the difference in the means for the white edge is larger for the test section, −74.55 (PRPB), than for the control section, −53.5 (steel) (see Table 3.2). The mean of the white skip actually increased with after the snow season. The change in variance is much larger for the control sections (1,236 and 1,702) than for the test section (110) (see Table 3.2). For the white paint, the change in means do not support more paint damage in the control section; however, the variance would suggest more damage in the control section as opposed to the test section. The yellow center paint results show very similar changes in the means (35.2 verses 32.5) and variances (505 verses 515) for both the control and the test areas (see Table 3.3).

A box whisker plot of the results of the US-40/SR-1 retroreflectivity shows the differences between the before season and after snow season retroreflectivity measurements (see Figure 3.2). There is little change in the white skip measurements columns 1 and 2 in the top Figure (see Figure 3.2). The there is little change in the median values (red lines), or interquartile ranges (IQR) (height of the boxes) (see Figure 3.2). However, there are outliers present in the readings taken after the snow season (column 2 red points). These outliers inflated the variance of the after population which led to an increase in the change of variance (see Table 3.2). This is obvious when comparing the white skip and the white edge results. For the white skip, the change of variance (1702) when compared to the change in interquartile range (0.5) is much larger than for the white edge (110 and 105). Consequently, for the white skip data, the large change in variance in the before verse

TABLE 3.2
US-40/SR-1 White Paint Retroreflectivity Results

	RP 127 Control US-40 White Skip Before	RP 127 Control US-40 White Skip After	Control SR-1 White Edge Before	Control SR-1 White Edge After	RP 135 Test US-40 White Edge After	RP 135 Test US-40 White Edge After	Difference After – Before SR-1 White Edge	RP 135 Difference After – Before US-40 White Edge	RP 127 Difference After – Before US-40 White Skip
# of Samples	20	20	20	20	20	20			
Minimum	255	221	153	81	157	80			
Maximum	348	472	290	269	214	153			
Mean	310.35	320.90	233.60	180.10	188.40	113.85	−53.50	−74.55	10.55
Variance	731.08	2433.25	1191.31	2427.25	355.52	465.19	1235.95	109.67	1702.17
STD	27.04	49.33	34.52	49.27	18.86	21.57	14.75	2.71	22.29
CV	8.71%	15.37%	14.78%	27.36%	10.01%	18.94%	12.58%	8.94%	6.66%
Median	316.5	317.5	238.5	180.5	186.5	111.5	−58	−75	1
Percentile 25%	290.5	299	211	145.5	175.5	98	−65.5	−77.5	8.5
Percentile 75%	334	343	257.5	228.5	207	131	−29	−76	9
IQR	43.5	44	46.5	83	31.5	33	36.5	1.5	0.5
Skewness	−0.52	1.00	−0.65	−0.09	−0.21	0.32			
Kurtosis	2.18	6.06	2.96	2.35	1.84	2.03			

TABLE 3.3
US-40/SR-1 Yellow Paint Retroreflectivity Results

	RP 127 Control US-40 Yellow Edge Before	RP 127 Control US-40 Yellow Edge After	Control SR-1 Yellow Center Before	Control SR-1 Yellow Center After	RP 135 Test US-40 Yellow Center After	RP 135 Test US-40 Yellow Center After	Difference After – Before SR-1 Yellow Center	RP 135 Difference After – Before US-40 Yellow Center	RP 127 Difference After – Before US-40 Yellow Edge
# of Samples	20	20	20	20	20	20			
Minimum	203	96	119	67	180	126			
Maximum	272	224	164	147	250	239			
Mean	236.40	165.00	147.45	112.25	214.25	181.75	−35.20	−32.50	−71.40
Variance	246.15	1446.32	88.89	594.30	687.67	1203.04	505.41	515.37	1200.17
STD	15.69	38.03	9.43	24.38	26.22	34.68	14.95	8.46	22.34
CV	6.64%	23.05%	6.39%	21.72%	12.24%	19.08%	15.32%	6.84%	16.41%
Median	236.5	171	148.5	110.5	216.5	174.5	−38	−42	−65.5
Percentile 25%	229.5	133.5	143	100	187.5	159	−43	−28.5	−96
Percentile 75%	240	193	152	135	237	210.5	−17	−26.5	−47
IQR	10.5	59.5	9	35	49.5	51.5	26	2	49
Skewness	0.25	−0.24	−0.99	−0.19	0.00	0.05			
Kurtosis	3.60	2.15	5.56	2.21	1.28	1.99			

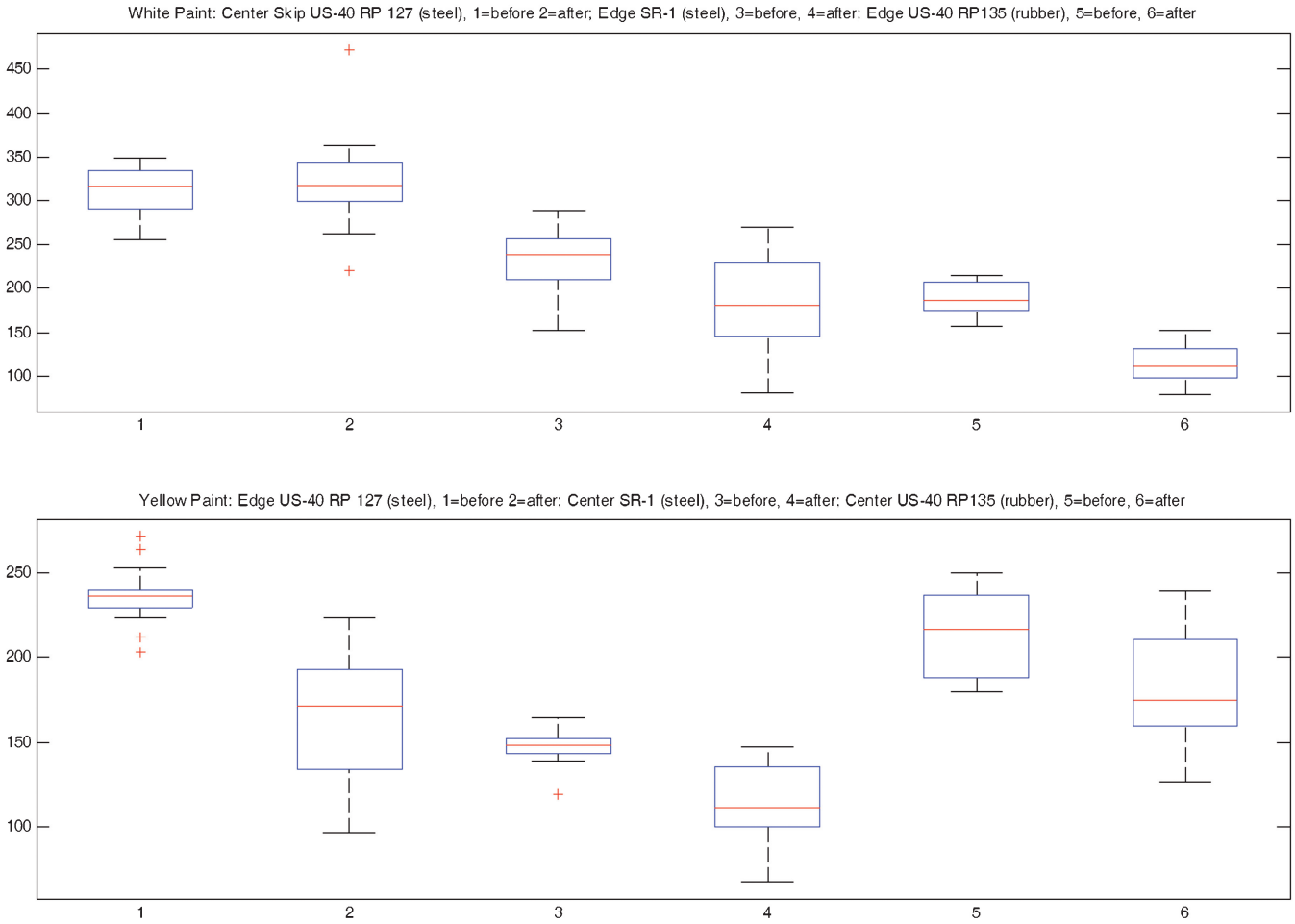

Figure 3.2 Box whisker plot of US-40/SR-1 paint retroreflectivity data.

after snow season results is in large part to the presence of outliers in the data and not increased plow damage. The changes in the interquartile ranges (IQR) are a more robust representation of changes in population variances with when outliers are present in the data.

Figure 3.2, top white paint results, shows little difference the in median change (distance between red lines) before snow season verses after for the control (columns 3 and 4) verses test (columns 5 and 6) (see Figure 3.2); however the change in the interquartile range for the control (change in lengths of the boxes column 3 and 4 top) is much larger than the test area (change in lengths of the boxes columns 5 and 6) (see Figure 3.2). The larger change in interquartile for the control section suggests greater damage incurred in the control section verses the test section.

Figure 3.2, bottom yellow paint results, shows little difference the in median change (distance between red lines) before snow season verses after for the control (columns 3 and 4) verses test (columns 5 and 6) (see Figure 3.2); however, the change in the interquartile range for the control (change in lengths of the boxes column 3 and 4 bottom) is much larger than the test area (change in lengths of the boxes columns 5 and 6 bottom) (see Figure 3.2). The larger change in interquartile for the control section suggests greater damage incurred in the control section verses the test section. This change in interquartile range is not reflected in a significant change in variances due to the presence of an outlier (red dot) in the before snow control population (column 3 bottom) (see Figure 3.2).

For the retroreflectivity data collected on both the yellow center and white edge stripe on SR-1 and US-40, the changes in the interquartile ranges of the populations of data collected prior to snow season verses after the snow season suggest more damage was done by the traditional snow plow (control section) as opposed to the PRPB (test section).

Retroreflectivity data was collected on both the white skip and the yellow edge for a HMA control section (RP 125), a HMA test section (RP 132), and a SMA test section (RP 139) (see Figure 3.1).

For the white skip data, the change in means and medians (distance between red lines) for the populations before verses after snow season is greater for the control HMA control section (columns 1 and 2 top) versus the HMA test section (columns 3 and 4) and the SMA test section (columns 5 and 6) (see Table 3.4) (see Figure 3.3). The changes in the HMA population variances and interquartile ranges (length of boxes) for before verses after snow season show more change in variability for the control HMA section (columns 1 and 2 top) than for the test section (columns 3 and 4) or for the SMA test section (columns 5 and 6) (see Table 3.4) (see Figure 3.3). These findings suggests more damage incurred by steel blade as opposed to the PRPB for both the HMA and SMA test sections; however, according to the measurements, the retroreflectivity of the paint striping was better (higher mean with lower variance and interquartile range) after plowing than before for section of HMA pavement plowed by the PRPB.

For the retroreflectivity measurements for the yellow edge stripe, the changes in means, medians (difference distance between red lines) variances, and interquartile ranges (length of boxes) for before snow season population verses after the snow seasons the for the HMA control (columns 1 and 2 bottom) are smaller than for the HMA test section (columns 3 and 4 bottom); furthermore, the changes in variances and interquartile

TABLE 3.4
I-70 White Paint Retroreflectivity Results

	RP 125 Control I-70 HMA White Skip Before	RP 125 Control I-70 HMA White Skip After	RP 132 Test I-70 HMA White Skip Before	RP 132 Test I-70 HMA White Skip After	RP 139 Test I-70 SMA White Skip Before	RP 139 Test I-70 SMA White Skip After	RP 125 Difference After - Before I-70 Cont White Skip	RP 132 Difference After – Before I-70 HMA White Skip	RP 139 Difference After – Before I-70 SMA White Skip
# of Samples									
Minimum	322	215	331	293	80	60			
Maximum	486	424	504	482	227	198			
Mean	418.45	302.55	432.90	438.35	152.85	103.65	−115.90	5.45	−49.20
Variance	2737.84	3552.37	2525.36	1972.56	1759.08	1470.66	814.53	−552.80	−288.42
STD	52.32	59.60	50.25	44.41	41.94	38.35	7.28	−5.84	−3.59
CV	12.50%	19.70%	11.61%	10.13%	27.44%	37.00%	7.20%	−1.48%	9.56%
Median	429.5	308.5	437	442	143	95	−121	5	−48
Percentile 25%	370.5	244.5	401	419	130	78	−126	18	−52
Percentile 75%	462	346	475.5	472.5	177	125	−116	−3	−52
IQR	91.5	101.5	74.5	53.5	47	47	10	−21	0
Skewness	−0.40	0.20	−0.49	−1.76	0.38	0.95			
Kurtosis	1.75	2.05	2.16	6.69	2.39	3.00			

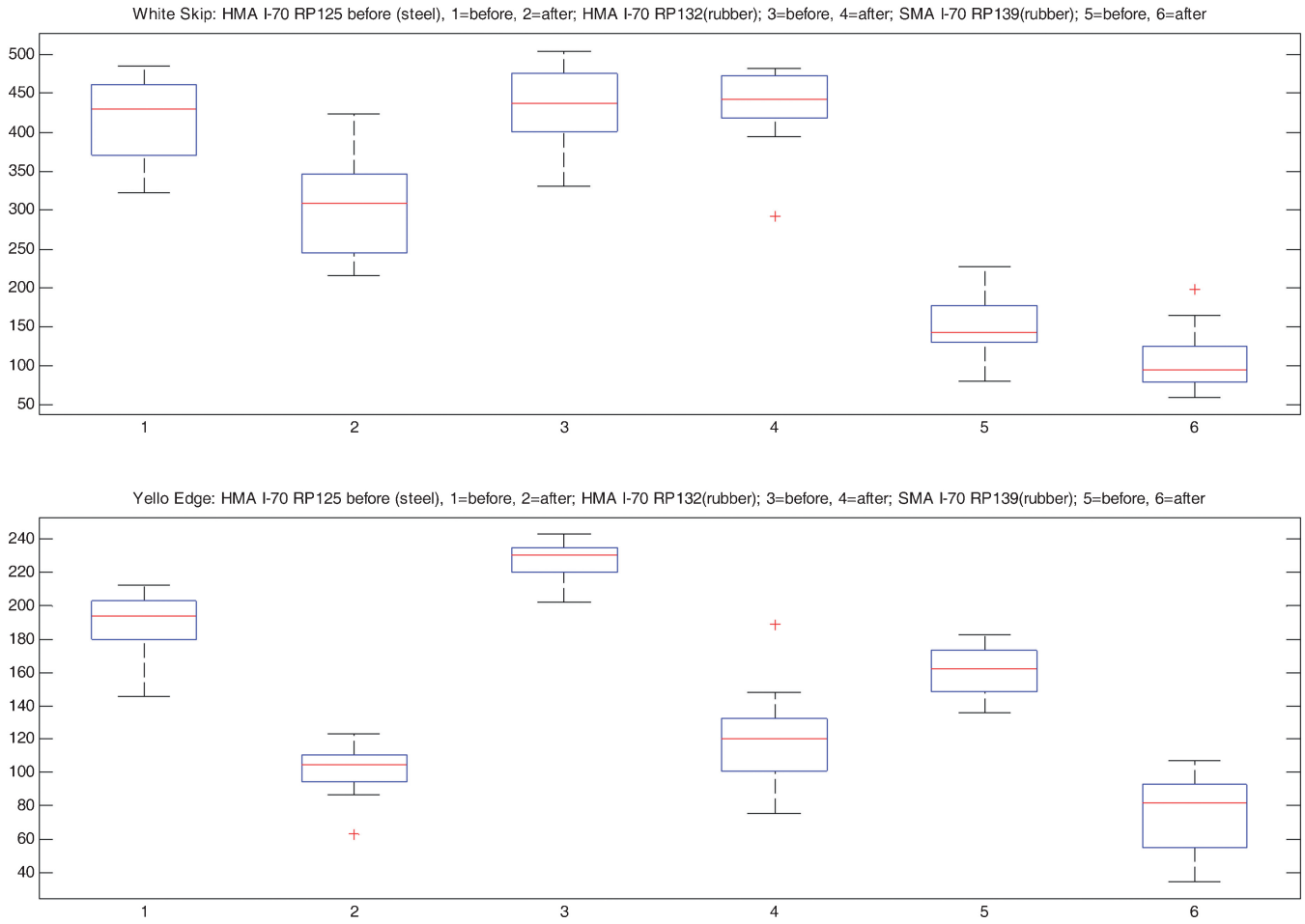

Figure 3.3 Box whisker plot of I-70 retroreflectivity data.

TABLE 3.5
I-70 Yellow Paint Retroreflectivity Results

	RP 125 Control I-70 HMA Yellow Edge Before	RP 125 Control I-70 HMA Yellow Edge After	RP 132 Test I-70 HMA Yellow Edge Before	RP 132 Test I-70 HMA Yellow Edge After	RP 139 Test I-70 SMA Yellow Edge Before	RP 139 Test I-70 SMA Yellow Edge After	RP 125 Difference After – Before I-70 Cont Yellow Edge	RP 132 Difference After – Before I-70 HMA Yellow Edge	RP 139 Difference After – Before I-70 SMA Yellow Edge
# of Samples									
Minimum	146	63	202	76	136	35			
Maximum	213	123	243	189	183	107			
Mean	189.25	102.55	227.40	119.45	160.55	77.15	−86.70	−107.95	−83.40
Variance	348.72	191.42	142.15	634.05	205.52	503.71	−157.31	491.90	298.19
STD	18.67	13.84	11.92	25.18	14.34	22.44	−4.84	13.26	8.11
CV	9.87%	13.49%	5.24%	21.08%	8.93%	29.09%	3.62%	15.84%	20.16%
Median	194.5	104.5	230.5	120.5	162	81.5	−90	−110	−80.5
Percentile 25%	180	94.5	220	101	149	55	−85.5	−119	−94
Percentile 75%	203	110.5	235	132.5	173	93	−92.5	−102.5	−80
IQR	23	16	15	31.5	24	38	−7	16.5	14
Skewness	−0.85	−0.97	−0.78	0.69	−0.09	−0.26			
Kurtosis	2.82	4.45	2.58	4.20	1.96	1.90			

ranges show less change when comparing the HMA control and the SMA test sections (columns 5 and 6 bottom) (see Table 3.4) (see Figure 3.3). Consequently, the analysis of retroreflectivity populations show less or about the same level of damage on the pavement sections plowed with the steel blade as opposed to the PRPB.

Retroreflectivity data was collected on both the white edge and the yellow skip for HMA thermoplastic tape control sections on SR-109 (RP 4 North and RP 2 south), a HMA thermoplastic test section US-27 (see Figure 3.1).

For the retroreflectivity measurements for the white edge stripe SR-109 control verses the white skip of test area, the changes in means (after-before snow), medians (difference distance between red lines) were significantly greater for the SR-109 South (columns 3 and 4 top); however, there was little difference between the SR-109 north control (columns 1 and 2 top) and the US-27 test section (columns 5 and 6 top)(see Table 3.6) (Figure 3.4). The changes in the variances, and interquartile ranges (length of boxes) for before snow season population verses after the snow seasons the for the North control (columns 1 and 2 top) are greater than for the test section (columns 5 and 6 top), but changes are smaller for the south control section (columns 3 and 4 top) (see Table 3.6) (Figure 3.4). The SR-109 south after snow population variance and interquartile range is smaller than that of the before snow populations for both the white edge and the yellow skip indicating less damage to the stripe after the plow season. A comparison of the changes in the means and medians (distance between red lines) (after snow—before snow) for the yellow skip of the SR-109 north (columns 1 and 2 bottom) and the US-27 test (columns 5 and 6 bottom) shows little difference between the control and the test (see Table 3.1, Table 3.6, and Figure 3.4). The analysis of the retroreflectivity data from white thermoplastic tape does not show a significant increase in damage to sections plowed with a traditional plow verses the PRPB.

The analysis of the retroreflectivity data was inconclusive in supporting the premise that plowing roads with the traditional steel blade damages the paint striping more than plowing with a PRPB. There were instances where the changes (after snow – before snow) in population means, medians, variances, and interquartile ranges suggested that there was more damage caused by the steel blade; however, this was inconsistent.

TABLE 3.6
Descriptive Statistics White Retroreflectivity measurements tape

	RP 4 Control SR-109 N White Edge Before	RP4 Control SR-109 N White Edge After	RP 2 Control SR-109 S White Edge Before	RP 2 Control SR-109 White Edge After	Test US-27 White Skip Before	Test US-27 White Skip After	RP 4 Difference After – Before SR-109 N White Edge	RP 2 Difference After – Before SR-109 S White Edge	Difference After – Before US-27 White Skip
# of Samples									
Minimum	373	253	611	190	258	155			
Maximum	530	442	815	340	517	380			
Mean	481.60	357.15	712.80	282.90	391.00	266.90	−124.45	−429.90	−124.10
Variance	1421.94	3574.45	3323.75	1474.62	4468.74	5411.25	2152.51	−1849.13	942.52
STD	37.71	59.79	57.65	38.40	66.85	73.56	22.08	−19.25	6.71
CV	7.83%	16.74%	8.09%	13.57%	17.10%	27.56%	8.91%	5.49%	10.46%
Median	488.5	371	712	281	392.5	240.5	−117.5	−431	−152
Percentile 25%	473.5	310.5	667.5	255.5	345.5	211.5	−163	−412	−134
Percentile 75%	502.5	413.5	756	314	426.5	341.5	−89	−442	−85
IQR	29	103	88.5	58.5	81	130	74	−30	49
Skewness	−1.48	−0.31	−0.16	−0.48	−0.01	0.29			
Kurtosis	5.16	1.87	2.19	2.87	2.54	1.67			

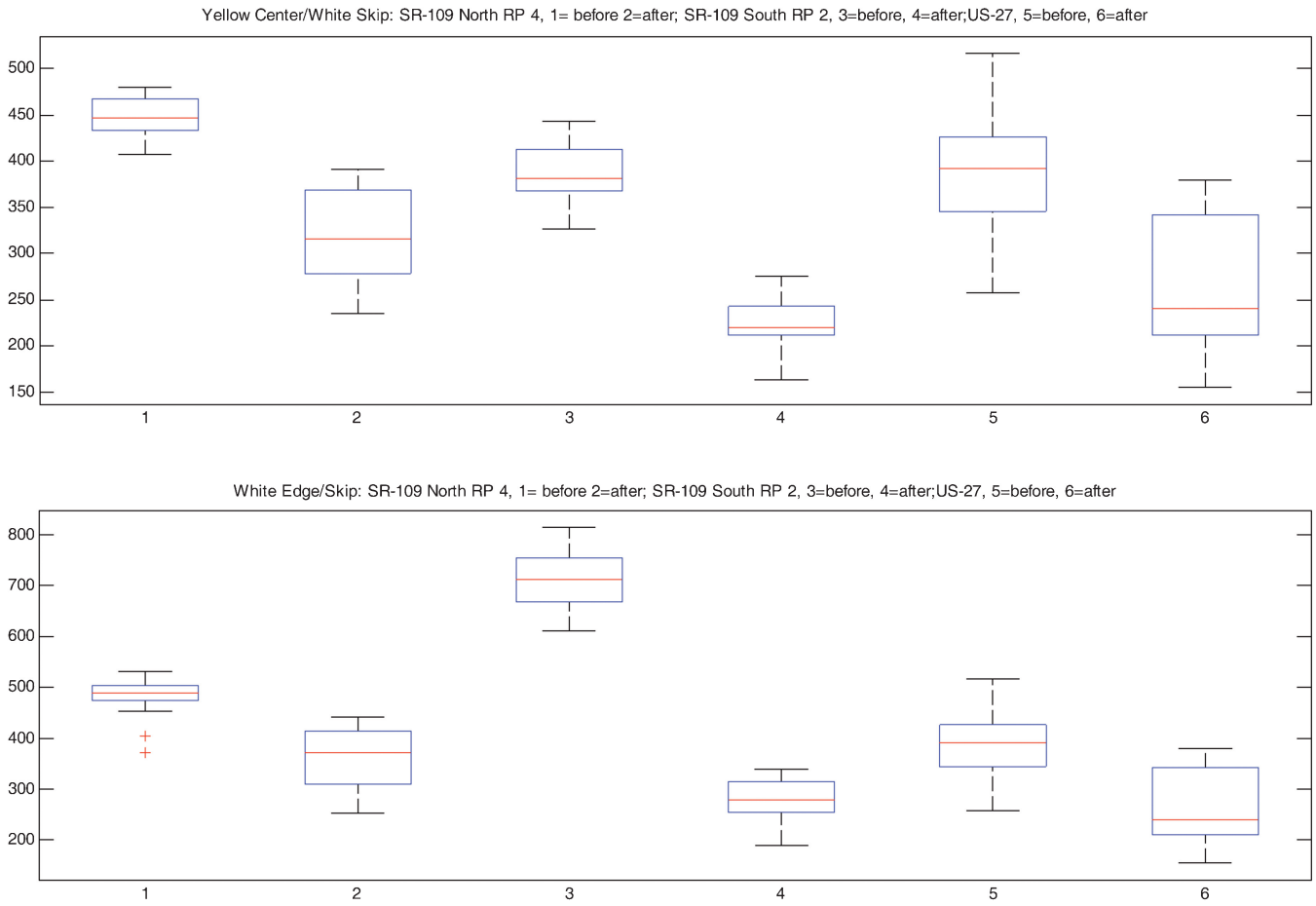

Figure 3.4 Box whisker plot of SR-109/US-27 retroreflectivity data.

TABLE 3.7
Descriptive Statistics Yellow Retroreflectivity measurements tape

	RP 4 Control SR-109 N Yellow Center Before	RP 4 Control SR-109 N Yellow Center After	RP 2 Control SR-109 S Yellow Center Before	RP 2 Control SR-109 Yellow Center After	RP 4 Difference After – Before SR-109 N Yellow Center	RP 4 Difference After – Before SR-109 S Yellow Center
# of Samples						
Minimum	407	235	327	164		
Maximum	480	391	443	276		
Mean	447.70	319.60	387.15	226.30	−128.10	−160.85
Variance	507.48	2404.88	997.40	683.48	1897.40	−313.91
STD	22.53	49.04	31.58	26.14	26.51	−5.44
CV	5.03%	15.34%	8.16%	11.55%	10.31%	3.40%
Median	447	316	380.5	220	−131	−160.5
Percentile 25%	433	279	367	211.5	−154	−155.5
Percentile 75%	468	368.5	412.5	243.5	−99.5	−169
IQR	35	89.5	45.5	32	54.5	−13.5
Skewness	−0.23	−0.06	−0.01	0.06		
Kurtosis	1.97	1.68	2.15	3.34		

4. PARTIAL RUBBER PLOW BLADE PERFORMANCE

Another goal of this research study was to evaluate performance characteristics of the PRPB. A subjective study was conducted to evaluate the performance of the PRPB based on opinions of INDOT snow plow operators and their supervisors. A survey was designed and circulated to the unit foreman (see Figure 4.1). The survey was to be filled out by the snow plow operator and his supervisor after every snow event and returned. The comments and input of the maintenance operators and supervisors that were included on the study advisory committee were also taken into account.

A total of nine surveys were returned. The surveys cover just two snow events one in the winter of 2011 and one in the winter of 2012. Two of the returned surveys were filled out by personnel operating a snow plow blade with polymer wings instead of rubber. The snow event in 2011 did not including significant snowfall. A compilation of the tabulated information located on the left hand side of the survey is included in Table 4.1 (see Table 4.1). One of the surveys completed in 2011 stated there was not enough snowfall to make a judgment on the ability of the PRPB to cut the snow; therefore, the compilation includes the results of the other 8 surveys (see Table 4.1). One half of the completed PRPB (rubber) surveys (3 of 6) stated the ability of the PRPB ability to cut snow was severely diminished in comparison to the steel blade (see Table 4.1). One of PRPB surveys stated that the PRPB ability to cut snow was significantly diminished in comparison to the steel blade and one survey stated that the PRPB performed similar to the steel blade (see Table 4.1). However, there was not significant snowfall involved in the latter case (performance similar). This was the same event where the other operator filling out a form stated that there was not enough snowfall to judge the performance of the PRPB. Overall the results of the survey showed that the performance PRPB was significantly to severely diminished when compared with the performance of a steel blade. The surveys are included in Appendix A.

The comments provided by the snowplow operators as part of the survey provided insight into the performance of the PRPB. Both of the surveys filled on after the 2011 event stated that the snow/slush came up over the plow making it difficult to see, and one of surveys from the 2012 event stated that the hazard of slush coming back on the windshield outweighed any benefits of the poly blade. Four of the eight PRPB surveys (4 of the 6 from the event with significant snowfall) state the PRPB does not cut down to the pavement surface, and one other survey states that the PRPB does not work on snow pack and ice (see Table 4.1). Furthermore, one of the surveys stated that the PRPB left two strips of snow that turned into snow pack/ice. Comments from three of the surveys state that the interstate is not the place to be testing or using PRPBs.

Opinions were also freely expressed during the study advisory committee meetings held for this project. Concerns regarding problems with the performance of the partial rubber blade were also discussed. These concerns include a significant decrease in snow pack cutting performance when the partial rubber blades are utilized. The possibility of utilizing the partial rubber plows specifically on the interstates was discussed. Concerns regarding the performance and behavior of the partial rubber blade at the interstate plow speeds were discussed. The high rate of speed increased the wear rate of the partial rubber pieces. This increased wear rate would increase the down time (maintenance) of any plow fitted with the partial rubber blade. The high rate of speed also caused increased snow plow blade movement issues. The increased movement was initiated by frequent friction changes of the materials on which rubber plow rested. The materials include snow, ice, dry pavement, and wet pavement, etc.

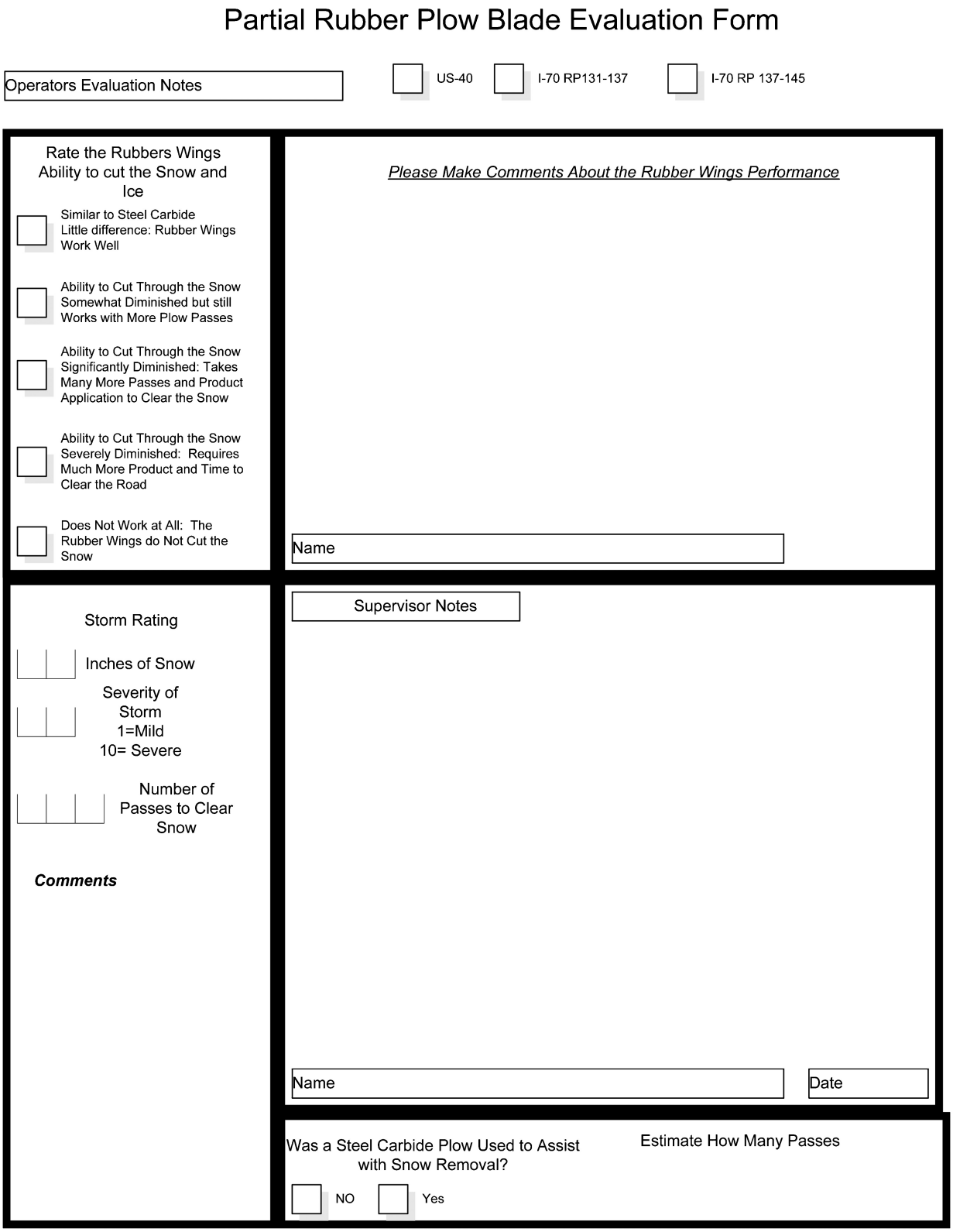

Figure 4.1 Snow plow performance evaluation form.

TABLE 4.1
Survey Results Compilation

Date	Snowfall inches	Storm Severity	# of Passes	Road	Ability to Cut Snow and Ice	Material
11/29/2011	4	5	12	US-40	Similar to steel	Rubber
12/26/2012	7	7	9	I-70	Significantly diminished	Rubber
12/26/2012	7	7	10	US-40	Significantly diminished	Poly
12/26/2012	7	7	7	I-70	Severely diminished	Rubber
12/26/2012	7	7	na	US-40	Somewhat diminished	Poly
12/26/2012	7	7	9	I-70	Severely diminished	Rubber
12/26/2012	7	7	8	US-40	Severely diminished	Rubber
12/26/2012	7	7	9	I-70	Significantly less	Rubber

5. CONCLUSIONS AND RECOMMENDATIONS

The purpose of this project was to conduct a limited study to evaluate the decrease in damage to the RPMs and pavement markings with utilization of a PRPB, and rate the snow removal performance of the PRPB verses the traditional steel carbide blade. This study was very limited in sample size; consequently, any inferences made from the results of this study should be scrutinized.

Overall there was no solid evidence supporting the premise that the PRPB equipped with rubber wingtips removes less RPMs than a traditional plow with all steel cutting edges. Consequently, the results of the study do not support the hypothesis that plowing roads with PRPBs is significantly less damaging to RMPS than plowing roads with plows equipped with only steel cutting edges.

The analysis of the retroreflectivity data was inconclusive in supporting the premise that plowing roads with the traditional steel blade damages the paint striping more than plowing with a PRPB. There were instances where the changes (after snow – before snow) in population means, medians, variances, and interquartile ranges suggested that there was more damage caused by the steel blade; however, this was inconsistent.

Overall the PRPB does not perform nearly as well as the steel blade based on the opinions of INDOT plow operators. The results of the survey conducted as part of this study showed that the performance PRPB was significantly to severely diminished when compared with the performance of a steel blade. Furthermore, many of the operators stated that the PRPB does not cut through the snow down to the pavement. There were also issues with slush coming over the plow interfering with plow operation and driver vision. Utilizing the PRPB also introduced increased motion in the plow which decreased the overall effectiveness of the plow especially at interstate plowing velocities.

The sample size was too small, and length evaluation was too short to provide a solid evaluation of the decrease in damage to RMPS or pavement stripping by utilization of PRPBS. A solid evaluation would require many more testing sections with a much longer evaluation period. The possibility of extending this study including studying a larger sample size for a longer period of time was introduced at SAC meeting. However, the SAC declined further study based on the lack of performance of the PRPB, and the increase plow motion introduced by the PRPB especially at interstate plowing velocities.

The consensus of the SAC members was that PRPB could be utilized on routes plowed at speeds less than 20 MPH, but not on interstate routes.

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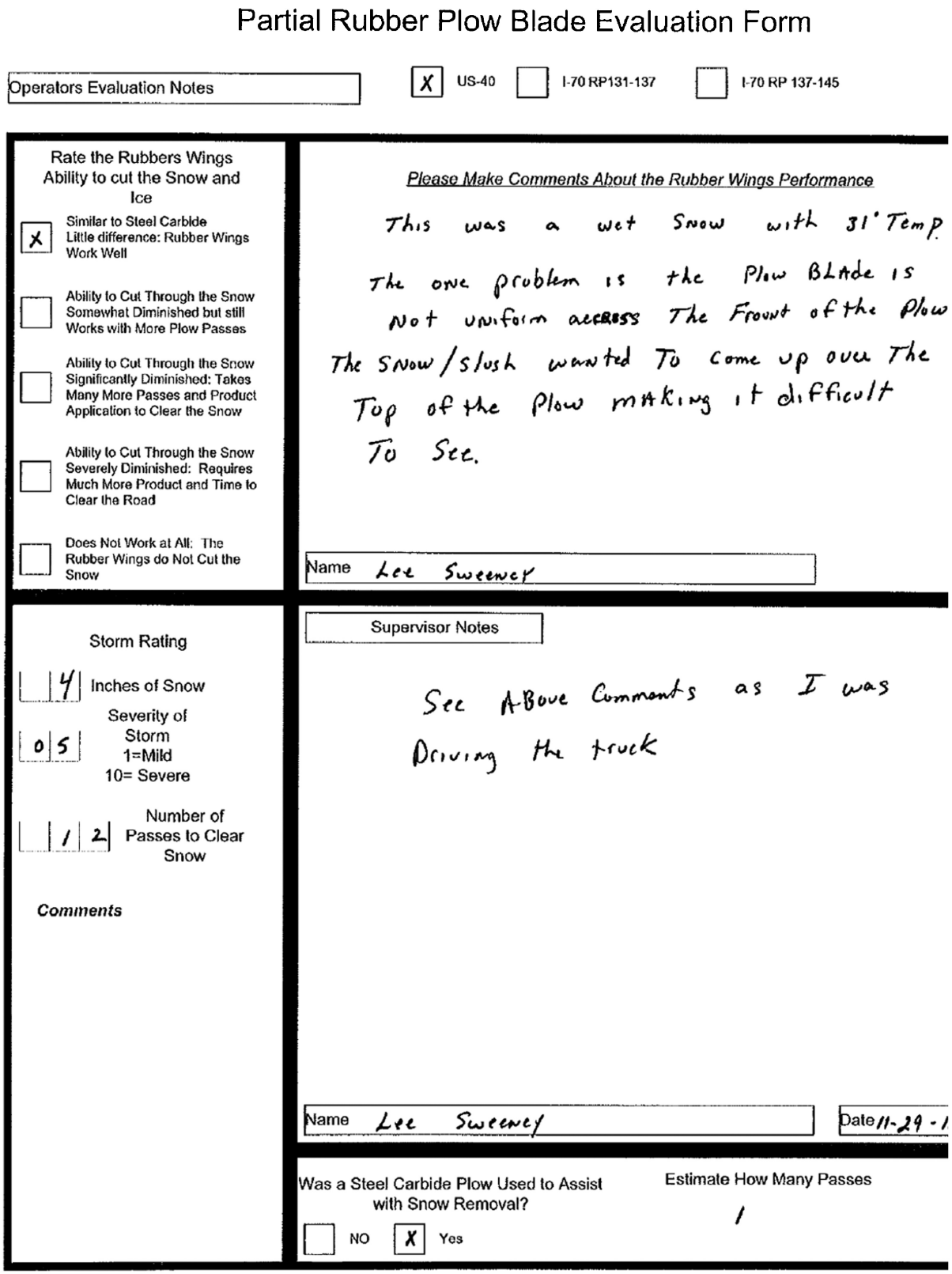


Partial Rubber Plow Blade Evaluation Form

Operators Evaluation Notes

[X] US-40 [ ] I-70 RP131-137 [ ] I-70 RP 137-145

Rate the Rubbers Wings Ability to cut the Snow and Ice

[X] Similar to Steel Carbide Little difference: Rubber Wings Work Well

[ ] Ability to Cut Through the Snow Somewhat Diminished but still Works with More Plow Passes

[ ] Ability to Cut Through the Snow Significantly Diminished: Takes Many More Passes and Product Application to Clear the Snow

[ ] Ability to Cut Through the Snow Severely Diminished: Requires Much More Product and Time to Clear the Road

[ ] Does Not Work at All: The Rubber Wings do Not Cut the Snow

Please Make Comments About the Rubber Wings Performance

This was a wet Snow with 31° Temp
The one problem is the Plow BLade is
Not uniform accross The Fromt of the Plow
The Snow/slush wanted To come up over The
Top of the Plow making it difficult
To See.

Name Lee Sweeney

Storm Rating

4 Inches of Snow

0 5 Severity of Storm 1=Mild 10= Severe

1 2 Number of Passes to Clear Snow

Comments

Supervisor Notes

See ABove Comments as I was
Driving the truck

Name Lee Sweeney Date 11-29-1

Was a Steel Carbide Plow Used to Assist with Snow Removal?

[ ] NO [X] Yes

Estimate How Many Passes

1

Figure A.1 Survey response 1.

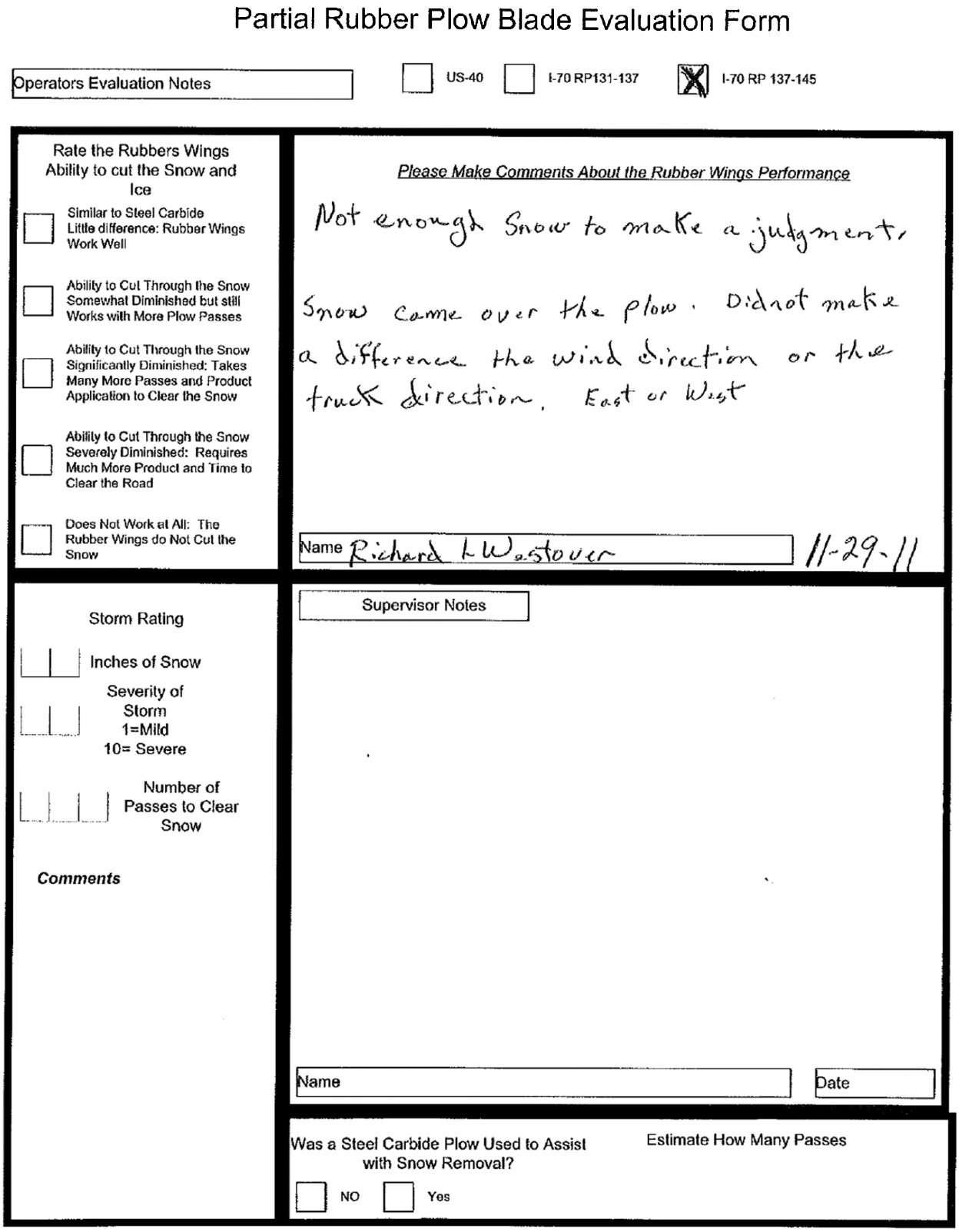
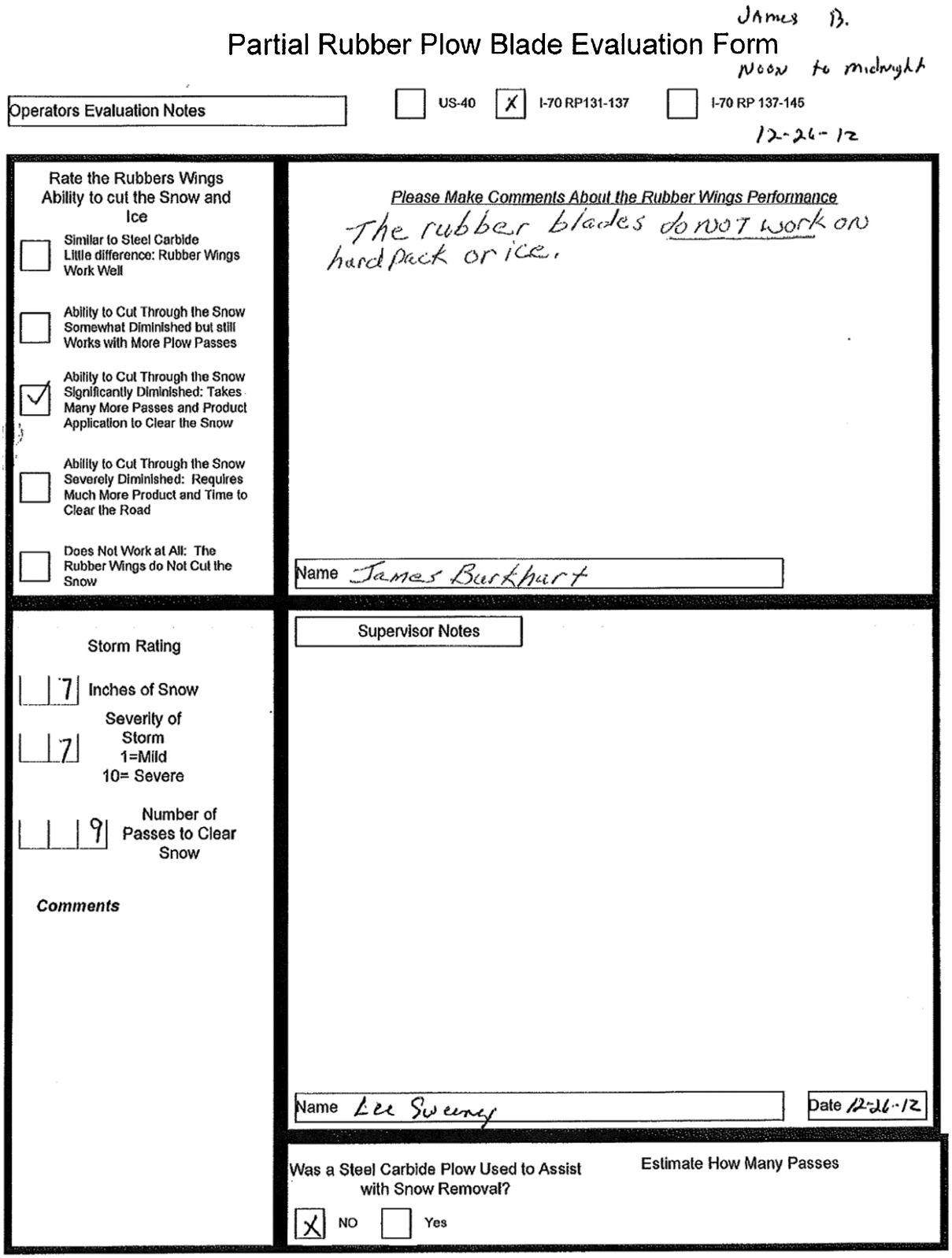


Figure A.2 Survey response 2.


James B.

Partial Rubber Plow Blade Evaluation Form

Noon to midnight

Operators Evaluation Notes

☐ US-40 ☒ I-70 RP131-137 ☐ I-70 RP 137-145

12-26-12

Rate the Rubbers Wings Ability to cut the Snow and Ice

☐ Similar to Steel Carbide Little difference: Rubber Wings Work Well

☐ Ability to Cut Through the Snow Somewhat Diminished but still Works with More Plow Passes

☑ Ability to Cut Through the Snow Significantly Diminished: Takes Many More Passes and Product Application to Clear the Snow

☐ Ability to Cut Through the Snow Severely Diminished: Requires Much More Product and Time to Clear the Road

☐ Does Not Work at All: The Rubber Wings do Not Cut the Snow

Please Make Comments About the Rubber Wings Performance

The rubber blades do not work on hard pack or ice.

Name James Burkhart

Storm Rating

7 Inches of Snow

7 Severity of Storm 1=Mild 10= Severe

9 Number of Passes to Clear Snow

Comments

Supervisor Notes

Name Lee Sweeney

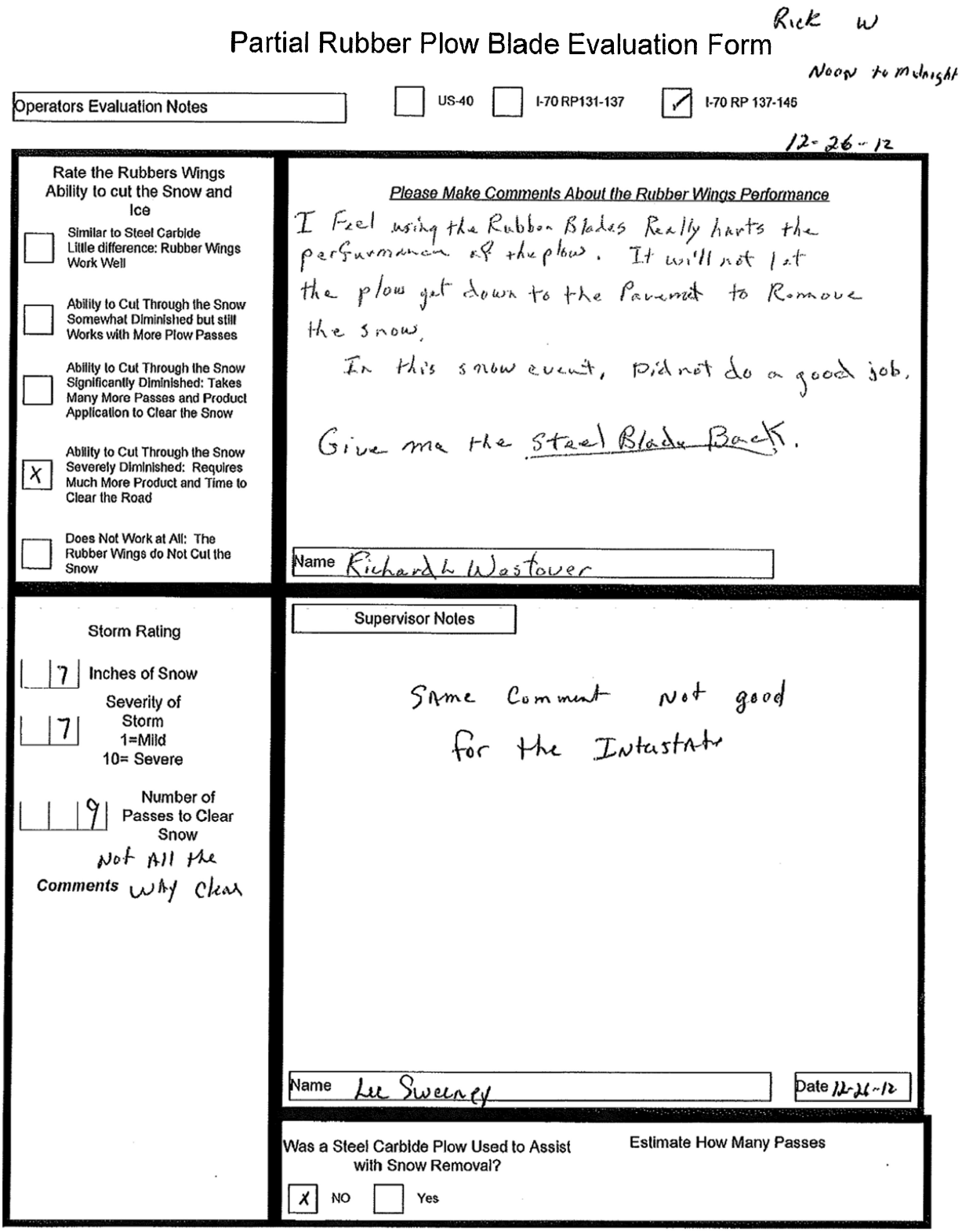
Date 12-26-12

Was a Steel Carbide Plow Used to Assist with Snow Removal?

☒ NO ☐ Yes

Estimate How Many Passes

Figure A.3 Survey response 3.



Partial Rubber Plow Blade Evaluation Form

Rick W

Noon to midnight

Operators Evaluation Notes

☐ US-40 ☐ I-70 RP131-137 ☑ I-70 RP 137-145

12-26-12

Rate the Rubbers Wings Ability to cut the Snow and Ice

☐ Similar to Steel Carbide Little difference: Rubber Wings Work Well

☐ Ability to Cut Through the Snow Somewhat Diminished but still Works with More Plow Passes

☐ Ability to Cut Through the Snow Significantly Diminished: Takes Many More Passes and Product Application to Clear the Snow

☒ Ability to Cut Through the Snow Severely Diminished: Requires Much More Product and Time to Clear the Road

☐ Does Not Work at All: The Rubber Wings do Not Cut the Snow

Please Make Comments About the Rubber Wings Performance

I Feel using the Rubber Blades Really hurts the performance of the plow. It will not let the plow get down to the Pavement to Remove the snow.

In this snow event, did not do a good job.

Give me the Steel Blade Back.

Name Richard L Westover

Storm Rating

7 Inches of Snow

7 Severity of Storm 1=Mild 10= Severe

9 Number of Passes to Clear Snow

Not All the

Comments Why Clear

Supervisor Notes

Same Comment not good for the Intastate

Name Lee Sweeney

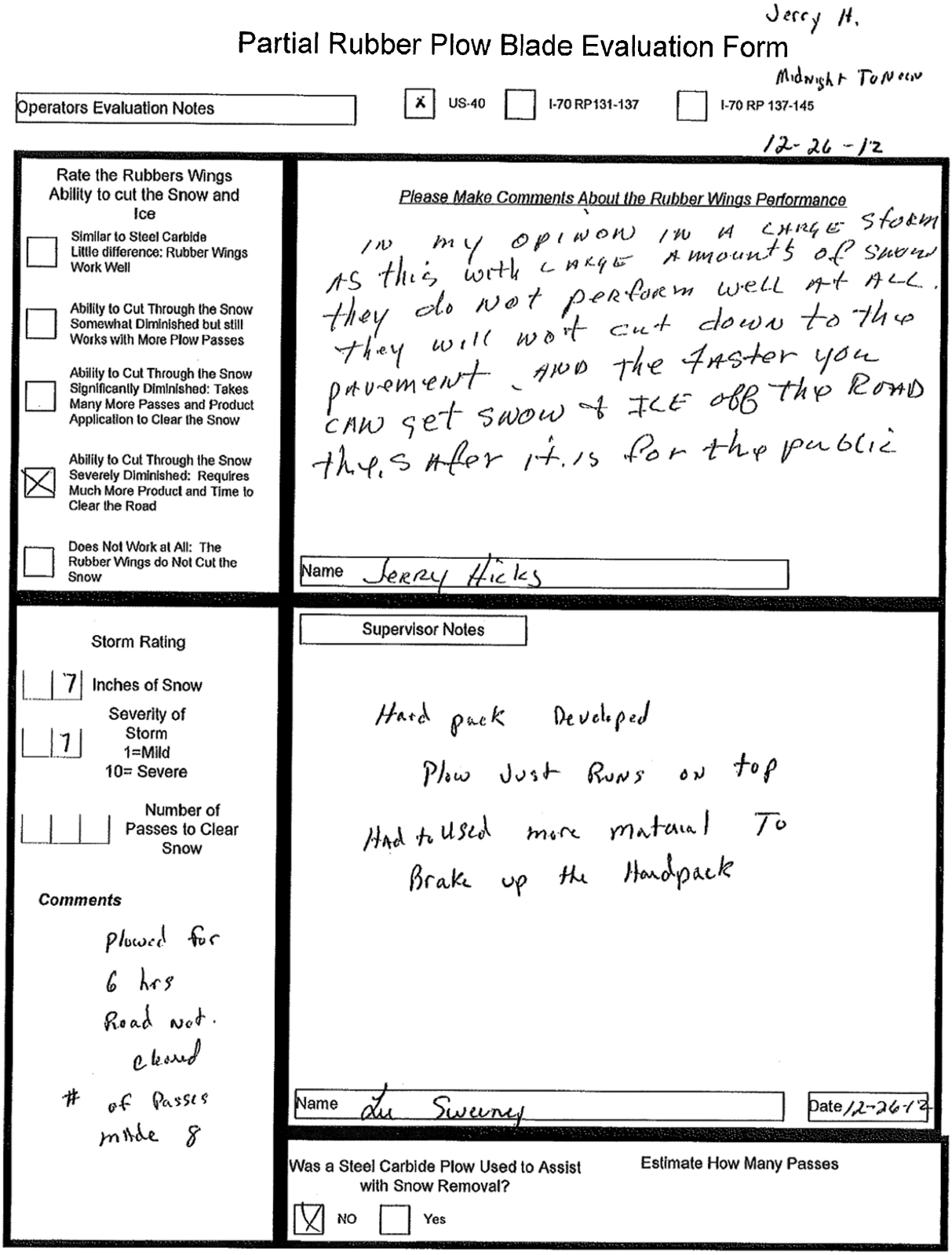
Date 12-26-12

Was a Steel Carbide Plow Used to Assist with Snow Removal?

☒ NO ☐ Yes

Estimate How Many Passes

Figure A.4 Survey response 4.



Jerry H.

Partial Rubber Plow Blade Evaluation Form

Midnight To Noon

Operators Evaluation Notes

[X] US-40 [ ] I-70 RP131-137 [ ] I-70 RP 137-145

12-26-12

Rate the Rubbers Wings Ability to cut the Snow and Ice

- [ ] Similar to Steel Carbide Little difference: Rubber Wings Work Well
- [ ] Ability to Cut Through the Snow Somewhat Diminished but still Works with More Plow Passes
- [ ] Ability to Cut Through the Snow Significantly Diminished: Takes Many More Passes and Product Application to Clear the Snow
- [X] Ability to Cut Through the Snow Severely Diminished: Requires Much More Product and Time to Clear the Road
- [ ] Does Not Work at All: The Rubber Wings do Not Cut the Snow

Please Make Comments About the Rubber Wings Performance

In my opinion in a large storm as this with large amounts of snow they do not perform well at all. they will not cut down to the pavement. And the faster you can get snow & ice off the road this after it is for the public

Name Jerry Hicks

Storm Rating

7 Inches of Snow

7 Severity of Storm 1=Mild 10= Severe

___ Number of Passes to Clear Snow

Comments

Plowed for 6 hrs Road not cleared # of Passes made 8

Supervisor Notes

Hard pack Developed

Plow Just Runs on top

Had to used more material To Brake up the Hardpack

Name Lee Sweeney Date 12-26-12

Was a Steel Carbide Plow Used to Assist with Snow Removal?

[X] NO [ ] Yes

Estimate How Many Passes

Figure A.5 Survey response 5.

DALE S.

Partial Rubber Plow Blade Evaluation Form

midnight to noon

Operators Evaluation Notes

☐ US-40 ☐ I-70 RP131-137 ☑ I-70 RP 137-145

12-26-12

Rate the Rubbers Wings Ability to cut the Snow and Ice

- ☐ Similar to Steel Carbide Little difference: Rubber Wings Work Well
- ☐ Ability to Cut Through the Snow Somewhat Diminished but still Works with More Plow Passes
- ☑ Ability to Cut Through the Snow Significantly Diminished: Takes Many More Passes and Product Application to Clear the Snow
- ☐ Ability to Cut Through the Snow Severely Diminished: Requires Much More Product and Time to Clear the Road
- ☐ Does Not Work at All: The Rubber Wings do Not Cut the Snow

Please Make Comments About the Rubber Wings Performance

THE INTERSTATE IS NO PLACE TO USE THE RUBBER WINGS, IN TOWN MAYBE ALRIGHT WITH DRAINS AND MAN HOLE COVERS. THEY LEFT TWO STRIPS IN EACH LANE WITCH FORMED HARD PACKED ICE. THEY DO NOT SCRAPE THE PAVEMENT LIKE METAL BLADES, I THINK THEY FLOAT ON THE SNOW. WHAT MONEY IT SAVES ON RESTRIPING WITH PAINT DOES NOT OUT WEIGH THE COST OF EXTRA MATERIAL AND LABOR TO CLEAR THE INTERSTATE.

Name DALE STOCKTON

Storm Rating

7 Inches of Snow

7 Severity of Storm 1=Mild 10= Severe

Number of Passes to Clear Snow

Comments

Plowed For 6 hrs Road Not Cleared

Plowed 9 passes

Supervisor Notes

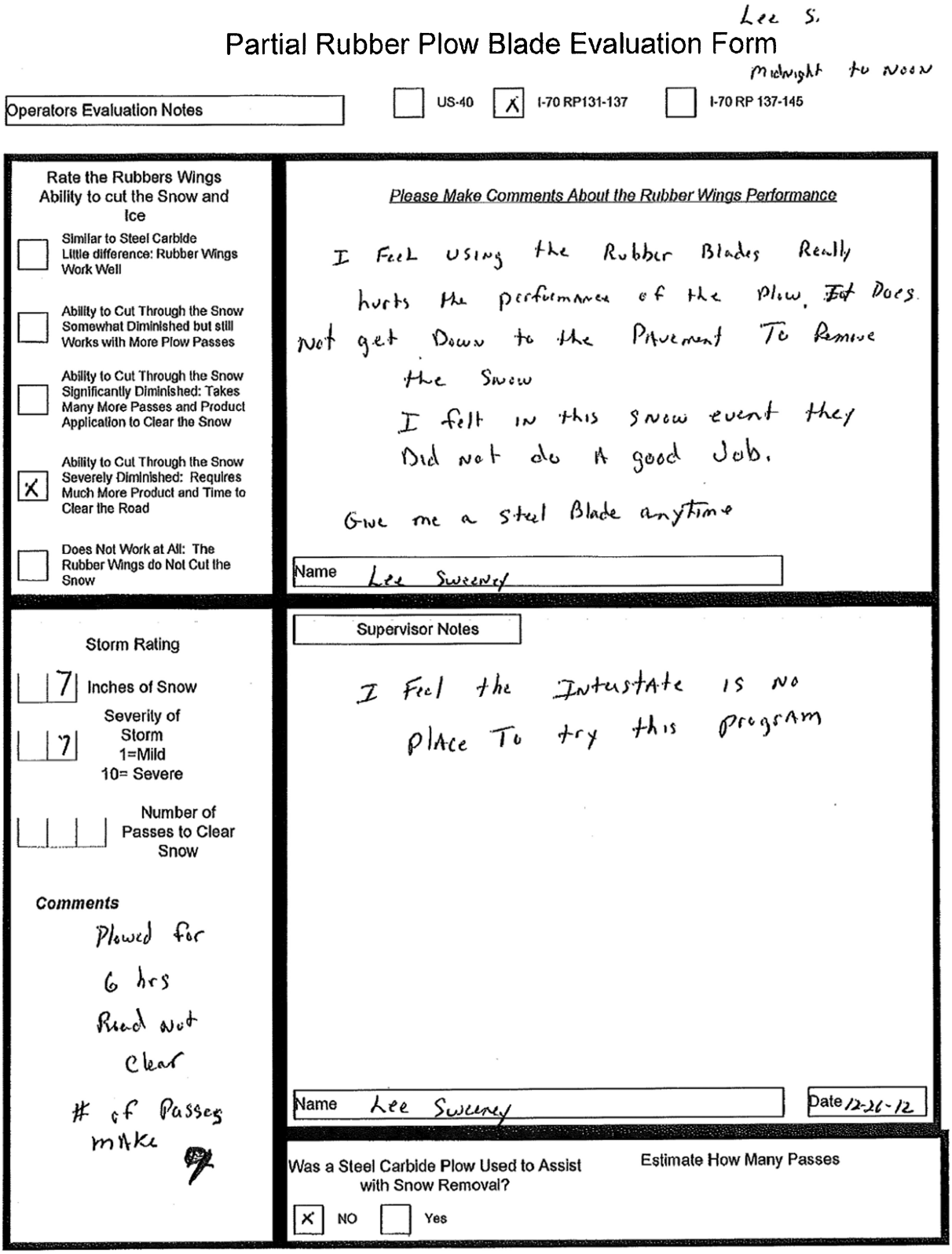
Name Lee Sweeney Date 12-26-12

Was a Steel Carbide Plow Used to Assist with Snow Removal?

☒ NO ☐ Yes

Estimate How Many Passes

Figure A.6 Survey response 6.


Lee S.

Partial Rubber Plow Blade Evaluation Form

midnight to noon

Operators Evaluation Notes

[ ] US-40 [X] I-70 RP131-137 [ ] I-70 RP 137-145

Rate the Rubbers Wings Ability to cut the Snow and Ice

[ ] Similar to Steel Carbide Little difference: Rubber Wings Work Well

[ ] Ability to Cut Through the Snow Somewhat Diminished but still Works with More Plow Passes

[ ] Ability to Cut Through the Snow Significantly Diminished: Takes Many More Passes and Product Application to Clear the Snow

[X] Ability to Cut Through the Snow Severely Diminished: Requires Much More Product and Time to Clear the Road

[ ] Does Not Work at All: The Rubber Wings do Not Cut the Snow

Please Make Comments About the Rubber Wings Performance

I Feel using the Rubber Blades Really hurts the performance of the Plow. ~~It~~ Does Not get Down to the Pavement To Remove the Snow

I felt in this Snow event they Did not do A good Job.

Give me a steel Blade anytime

Name Lee Sweeney

Storm Rating

[7] Inches of Snow

[7] Severity of Storm 1=Mild 10= Severe

[ ] Number of Passes to Clear Snow

Comments

Plowed for 6 hrs Road not Clear

# of Passes make 7

Supervisor Notes

I Feel the Interstate is no place To try this program

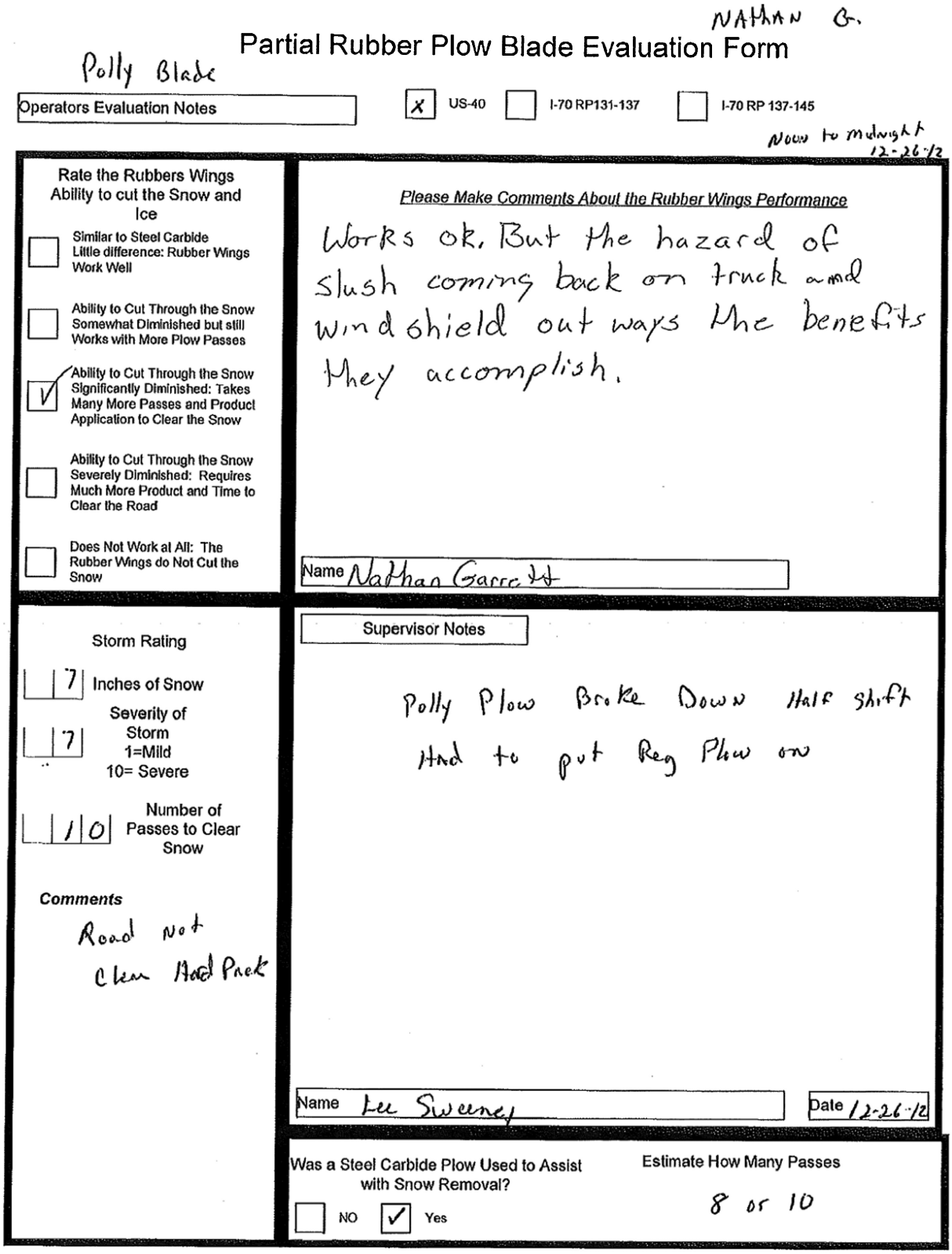
Name Lee Sweeney Date 12-26-12

Was a Steel Carbide Plow Used to Assist with Snow Removal?

[X] NO [ ] Yes

Estimate How Many Passes

Figure A.7 Survey response 7.


NATHAN G.

Partial Rubber Plow Blade Evaluation Form

Polly Blade

Operators Evaluation Notes

[X] US-40 [ ] I-70 RP131-137 [ ] I-70 RP 137-145

Noon to midnight 12-26-12

Rate the Rubbers Wings Ability to cut the Snow and Ice

[ ] Similar to Steel Carbide Little difference: Rubber Wings Work Well

[ ] Ability to Cut Through the Snow Somewhat Diminished but still Works with More Plow Passes

[V] Ability to Cut Through the Snow Significantly Diminished: Takes Many More Passes and Product Application to Clear the Snow

[ ] Ability to Cut Through the Snow Severely Diminished: Requires Much More Product and Time to Clear the Road

[ ] Does Not Work at All: The Rubber Wings do Not Cut the Snow

Please Make Comments About the Rubber Wings Performance

Works ok. But the hazard of slush coming back on truck and windshield out ways the benefits they accomplish.

Name Nathan Garrett

Storm Rating

7 Inches of Snow

7 Severity of Storm 1=Mild 10= Severe

10 Number of Passes to Clear Snow

Comments

Road not clear had Prek

Supervisor Notes

Polly Plow Broke Down Half shift had to put Reg Plow on

Name Lee Sweeney

Date 12-26-12

Was a Steel Carbide Plow Used to Assist with Snow Removal?

[ ] NO [✓] Yes

Estimate How Many Passes

8 or 10

Figure A.8 Survey response 8.

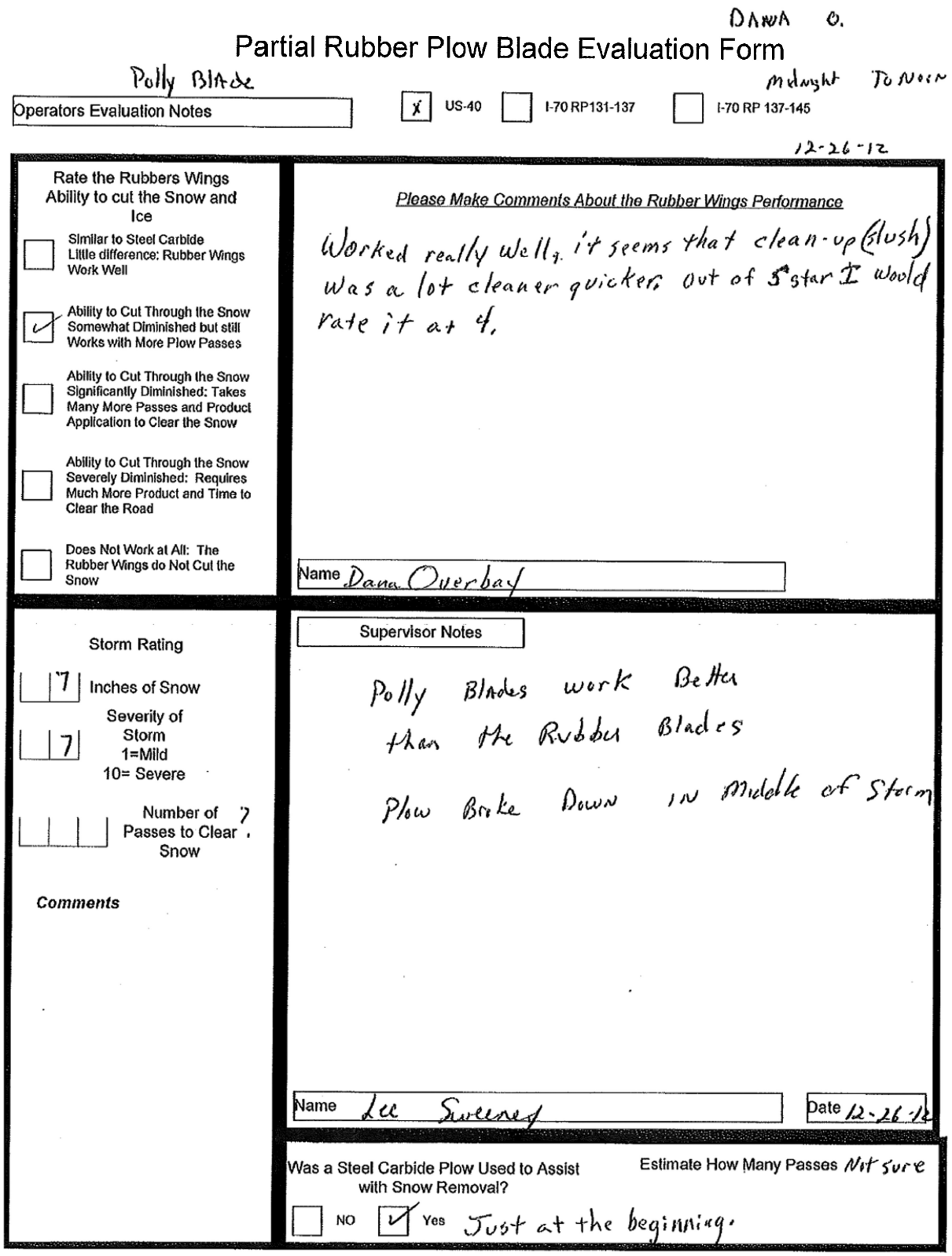


Figure A.9 Survey response 9.

About the Joint Transportation Research Program (JTRP)

On March 11, 1937, the Indiana Legislature passed an act which authorized the Indiana State Highway Commission to cooperate with and assist Purdue University in developing the best methods of improving and maintaining the highways of the state and the respective counties thereof. That collaborative effort was called the Joint Highway Research Project (JHRP). In 1997 the collaborative venture was renamed as the Joint Transportation Research Program (JTRP) to reflect the state and national efforts to integrate the management and operation of various transportation modes.

The first studies of JHRP were concerned with Test Road No. 1—evaluation of the weathering characteristics of stabilized materials. After World War II, the JHRP program grew substantially and was regularly producing technical reports. Over 1,500 technical reports are now available, published as part of the JHRP and subsequently JTRP collaborative venture between Purdue University and what is now the Indiana Department of Transportation.

Free online access to all reports is provided through a unique collaboration between JTRP and Purdue Libraries. These are available at: http://docs.lib.purdue.edu/jtrp

Further information about JTRP and its current research program is available at: http://www.purdue.edu/jtrp

About This Report

An open access version of this publication is available online. This can be most easily located using the Digital Object Identifier (doi) listed below. Pre-2011 publications that include color illustrations are available online in color but are printed only in grayscale.

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