Development of a Structural Asset Management System for Urban Pavements

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ABSTRACT

The City of Saskatoon's current pavement management system relies solely on surface condition data from manual and automated ratings to assign treatment without incorporating structural capacity or load spectra directly into the management decision making process. The current system employs generic performance models for various classes of roads, not taking into account road usage or specific field state conditions on a segment by segment basis. Overlooking road segment structural condition and applied load spectra has been identified as a primary limitation to accurately estimating the service life of urban road segments, especially under current field state conditions of significant growth in commercial truck traffic experienced in Saskatoon. The potential danger of this management process is invariably applying treatments far too late for their benefits to be optimized, particularly to preserve structural integrity of the road assets.

The objective of this research was to investigate non-destructive ground penetrating radar and falling weight deflection measurements to assess the structural asset value of various road classes within the City of Saskatoon road network. This research demonstrates that structural asset measurements can be incorporated into the asset management system employed by the City of Saskatoon to accurately assess pavement structural condition across the city's diverse road network. This research also demonstrates that the incorporation of structural measures can improve the accuracy of the empirical based performance prediction models currently used.

Key Words: structural asset management, ground penetrating radar, falling weight deflection

INTRODUCTION

Historically, the City of Saskatoon has relied on roughness and surface distress measurements such as rutting and aggregate popouts to characterize the condition of their road assets. Although this may be appropriate at the network level for preservation budget prioritization approximation, more detailed engineering information is most often required at the semi-network and project levels for asset management preservation treatment decision optimization. In addition, more detailed structural information is usually required to ensure the specific causes of road performance problems are properly remedied by the treatments selected.

The conventional asset management system employed by the City of Saskatoon does not currently quantify the structural performance and asset value of the road network. Structural surveys performed on the City of Saskatoon network has shown that severe structural weakening can exist without the presence of surface distresses being identified through automated surveys. As a result, structural condition assessment that is based on roughness and surface distress measures alone often results in distress treatment diagnosis that is too late, generating reactive as opposed to preventative preservation treatment programs. Conventional asset management can also be a particularly dangerous approach to managing roads because by the time structural deterioration has advanced to the point of being detected by automated surface condition data collection methods, the structural deterioration of the road has typically reached such a severe condition state that cost effective preventative surface treatments are no longer a viable option. Reactive based preservation strategies can therefore be significantly higher in cost once structural deterioration has occurred. In addition, surface condition based asset valuation can result in inaccurate asset value and depreciation assessment of roads.

As a result, the City of Saskatoon investigated the use of non-destructive structural and surface condition measurements based on integrated falling weight deflection and ground penetrating radar measurement profiling. The road structural condition data collection techniques employed in this study are an attempt to develop more reliable measures of pavement structural condition, as well as surface performance, and therefore optimized pavement preservation treatments.

PROJECT OBJECTIVE

The objective of this study was to demonstrate the use of ground penetrating radar (GPR) surface condition assessment and falling weight deflection (FWD) load spectra analysis to compliment and integrate with the conventional asset management systems and procedures currently employed within the City of Saskatoon.

NON-DESTRUCTIVE PAVEMENT SURFACE AND STRUCTURAL ANALYSIS

This project employed integrated non-destructive falling weight deflection and ground penetrating radar assessment technologies to characterize the surface condition as well as the structural condition of the roads surveyed. This chapter provides a summary of the non-destructive assessment techniques employed.

Falling weight deflectometer measures provide structural integrity of the road structure across the spectrum of commercial truck loadings typically experienced in the field. Primary deflection response profiles were measured under dynamic loadings ranging from secondary legal load limits to primary legal load limits plus 50 percent. Based on the falling weight deflection load spectra analysis, the peak surface deflection, and PSIPave structural index were calculated. The structural value in terms of peak surface deflection, as well as PSIPave structural index for each road segment is presented to cross compare each road segment surveyed.

Ground penetrating radar technology has been used in road structural surveys for over two decades. Ground penetrating radar operates on the principal of measuring changes in material dielectric permittivity and has traditionally been used to provide layer thickness and dielectric permittivity profiles of road structure layers. For purposes of this study, ground penetrating radar was investigated to measure road surface dielectric permittivity profiles and surface deterioration index. The ground penetrating radar data for this study was collected using a one GHz air coupled truck mounted pulse radar system.

The ground penetrating radar evaluation included surface dielectric permittivity profiles and PSIPave surface deterioration index analysis. The average values of each road segment surveyed is presented to illustrate the differences and to cross compare the results obtained from each road segment. For purposes of this study, layer thickness and substructure dielectric permittivity profiles were not included in the scope of the study as they are considered project level analysis information. However, it should be noted that layer thickness and substructure dielectric permittivity profiles were collected and can be processed at any time.

NON-DESTRUCTIVE CHARACTERIZATION OF EXPRESSWAY

Deflection profiles were collected on specified expressway segments by lane and by direction. The expressway considered within the scope of this study included Circle Drive from North River Crossing Bridge abutment to Avenue C. Figure 1 illustrates the peak surface deflection results at primary plus 50 percent loading. As seen in Figure 1, the peak surface deflection of the expressway segments under primary legal load limits plus 50 percent resulted in dynamic deflection ranging from 0.29 mm to 1.38 mm.

The peak surface deflection profiles obtained across each expressway segment were categorized into good, fair, and poor structural performance based on thresholds as summarized below.

Good: <0.75 mm
Fair: 0.75 mm to 1.25 mm
Poor: >1.25 mm

Figure 2 illustrates the mean PSIPave structural index values of each Circle Drive road segment surveyed. As seen in Figure 2, the PSIPave structural index of the expressway surveyed ranged from 74 to 263 for the flexible pavement structures. It should be noted that the relatively high PSIPave structural index of Circle Drive eastbound from Idylwyld Drive to Avenue C is because this road segment is constructed of jointed plain concrete pavement.

As also presented in Figure 2, the PSIPave structural index of the expressway surveyed was used to rank the selected roads into good, fair, and poor condition states. The thresholds used to categorize the PSIPave structural index of the expressway surveyed are summarized below.

Good: >150
Fair: 100 to 150
Poor: <100

It can be seen in Figure 2, that the PSIPave structural values of Circle Drive from the Idylwyld Bridge to Avenue C in the eastbound direction are extremely high because they are constructed of jointed plain concrete pavement. However, it should also be noted that the structural condition index of the curb lane jointed plain concrete pavement in the curb lane was considerably lower than the other two concrete lanes, which may indicate structural deterioration of this lane.

Ground penetrating radar profiles were collected on the expressway segments by lane and by direction. The expressway considered within the scope of this study included Circle Drive from North River Crossing Bridge abutment to Avenue C.

Based on the surface dielectric permittivity profiles, Figure 3 illustrates the average PSIPave surface deterioration index results for the expressway surveyed by segment, by direction, and by lane. As seen in Figure 3, the surface deterioration index was found to range from 4.6 to 16.8.
As also seen in Figure 3, the surface deterioration was used to rank the selected roads into good, fair, and poor condition states. The thresholds used to categorize the surface deterioration of the expressway surveyed are summarized below.

Good: <10.0
Fair: 10.0 to 20.0
Poor: >20.0

Based on the structural condition assessment performed on Circle Drive from the river crossing abutment to Avenue C, Figure 4 illustrates the PSIPave structural index spatially. As seen in Figure 4, the PSIPave structural index of Circle Drive from the river crossing bridge abutment to the median gore point, and near Millar Avenue rated as poor. It can also be seen that the PSIPave structural index near the Warman Road overpass rated as good due to a substructure drainage system installed.

Based on the surface deterioration assessment performed on Circle Drive from the east river crossing abutment to Avenue C, Figure 5 illustrates the surface deterioration index spatially. As seen in Figure 5, Circle Drive westbound curb lane from the median gore point to Millar Avenue is exhibiting poor surface condition.

Table 1 cross compares the non-destructive structural and surface condition assessment results of the expressway surveyed. The peak surface deflection at primary plus 50 percent loading, PSIPave structural index, and PSIPave surface deterioration index of the surveyed expressway are summarized in Table 1 with green indicating good, yellow as fair, and red as poor behaviour. As seen in Table 1, the center eastbound lane of Circle Drive from Faithfull Avenue to the Idylwyld Bridge abutment rated as poor structurally across all structural measures, but rated as having a good surface condition. Conversely, all three lanes of the jointed plain concrete pavement from Avenue C to the Idylwyld Bridge abutment rated very good structurally, but fair with regards to surface condition.

NON-DESTRUCTIVE CHARACTERIZATION OF ARTERIALS

Deflection profiles were collected on specified arterial segments by lane and by direction. The arterials considered within the scope of this study included 8th Street from Boychuk Drive to McKercher Drive; Attridge Drive from McOrmond Drive to Central Avenue; Avenue C from Circle Drive to 47th Street, and; Preston Avenue from 8th Street to 14th Street. Figure 6 illustrates the peak surface deflection results at primary plus 50 percent loading. As seen in Figure 6, the peak surface deflection of the arterial segments under primary legal load limits plus 50 percent resulted in dynamic deflection ranging from 0.87 mm to 1.67 mm.

The peak surface deflection profiles obtained across each arterial segment were categorized into good, fair, and poor structural performance based on thresholds as summarized below.

Good: <1.15 mm
Fair: 1.15 mm to 1.30 mm
Poor: >1.30 mm

Figure 7 illustrates the mean PSIPave structural index values of each arterial road segment surveyed. As seen in Figure 7, the PSIPave structural index of the arterials surveyed ranged from 49 to 156.

As also presented in Figure 7, the PSIPave structural index was used to rank the selected roads into good, fair, and poor condition state. The thresholds used to categorize the PSIPave structural index of the arterials surveyed are summarized below.

Good: >100
Fair: 70 to 100
Poor: <70

Ground penetrating radar profiles were collected on the arterial segments by lane and by direction. The arterials considered within the scope of this study included 8th Street from Boychuk Drive to McKercher Drive; Attridge Drive from McOrmond Drive to Central Avenue; Avenue C from Circle Drive to 47th Street, and; Preston Avenue from 8th Street to 14th Street.

Based on the surface dielectric permittivity profiles, Figure 8 illustrates the average PSIPave surface deterioration index results for the arterials surveyed by segment, by direction, and by lane. As seen in Figure 8, the surface deterioration index of the arterials was found to range from 7.1 to 41.2.

As also seen in Figure 8, the surface deterioration was used to rank the selected roads into good, fair, and poor condition states. The thresholds used to categorize the surface deterioration of the arterials surveyed are summarized below.

Good: <10.0
Fair: 10.0 to 20.0
Poor: >20.0

Based on the structural condition assessment performed on 8th Street, Attridge Drive, Avenue C, and Preston Avenue, Figure 9 illustrates the PSIPave structural index spatially. As seen in Figure 9, the PSIPave structural index behaviour of the arterials surveyed rated from fair to poor for the majority of the segments surveyed. As seen in Figure 9, the PSIPave structural index of Attridge Drive from Kenderdine Road to Berini Drive rated as poor, with the reminder of Attridge Drive rated as fair.

Based on the surface deterioration assessment performed on 8th Street, Attridge Drive, Avenue C, and Preston Avenue, Figure 10 illustrates the surface deterioration index spatially for each road segment, respectively. As illustrated in Figure 10, Attridge Drive from Kenderdine Road to Berini Drive, the southern half of the northbound lanes of Avenue C from Circle Drive to 47th Street, and most of Preston Avenue from 8th Street to 14th Street, are exhibiting poor surface condition. The remainder of the arterials surveyed exhibited a good surface condition state.

Table 2 cross compares the non-destructive structural and surface condition assessment results of the arterials surveyed. The peak surface deflection at primary plus 50 percent loading, the PSIPave structural index, and the PSIPave surface deterioration index of the surveyed arterials are summarized in Table 2 with green indicating good, yellow as fair, and red as poor behaviour. As seen in Table 2, Attridge Drive from Berini Drive to Central Avenue rated as good across all measures with the exception of PSIPave structural index which rated as fair. The remaining segments rated as a combination of good, fair and poor across all remaining road segments.

NON-DESTRUCTIVE CHARACTERIZATION OF LOCALS

Deflection profiles were collected on specified local segments by lane and by direction. The locals considered within the scope of this study included 31st Street from Avenue R to Avenue W; Adelaide Street from Lansdowne Avenue to Cumberland Avenue; Emmeline Road from Swan Crescent to Nemeiben Road; Hilliard Street from Lansdowne Avenue to Cumberland Avenue; Isabella Street from Lansdowne Avenue to Cumberland Avenue, and; Rylston Road from Whitney Avenue to Avenue X. Figure 11 illustrates the peak surface deflection results at primary plus 50 percent loading. As seen in Figure 11, the peak surface deflection of the local segments under primary legal load limits plus 50 percent resulted in dynamic deflection ranging from 1.26 mm to 3.26 mm.

The peak surface deflection profiles obtained across each local segment were categorized into good, fair, and poor structural performance based on thresholds as summarized below.

Good: <1.00 mm
Fair: 1.00 mm to 2.00 mm
Poor: >2.00 mm

Figure 12 illustrates the mean PSIPave structural index values of each local road segment surveyed. As seen in Figure 12, the PSIPave structural index of the locals surveyed ranged from 15 to 50.

As also presented in Figure 12, the PSIPave structural index was used to rank the selected local roads into good, fair, and poor condition states. The thresholds used to categorize the PSIPave structural index of the local streets surveyed are summarized below.

Good: >30
Fair: 20 to 30
Poor: <20

It can be seen in Figure 12, that the segment of Emmeline Road from Swan Crescent to Nemeiben Road is in poor structural condition and Adelaide Street from McKinnon Avenue to Haultain Avenue rated as fair PSIPave structural index condition. 31st Street from Avenue R to Avenue W and Rylston Road from Whitney Avenue to Avenue X rated as good.

Ground penetrating radar profiles were collected on the local segments by lane and by direction. The locals considered within the scope of this study included 31st Street from Avenue R to Avenue W; Adelaide Street from McKinnon Avenue to Haultain Avenue; Emmeline Road from Swan Crescent to Nemeiben Road, and; Rylston Road from Whitney Avenue to Avenue X.

Based on the surface dielectric permittivity profiles, Figure 13 illustrates the average PSIPave surface deterioration index results for the locals surveyed by segment, by direction, and by lane. As seen in Figure 13, the surface deterioration index of the local streets surveyed was found to range from 7.0 to 17.6.

As also seen in Figure 13, the surface deterioration was used to rank the selected roads into good, fair, and poor condition states. The thresholds used to categorize the surface deterioration of the local streets surveyed are summarized below.

Good: <10.0
Fair: 10.0 to 20.0
Poor: >20.0

Based on the structural condition assessment performed on 31st Street, Adelaide Street, Emmeline Road, and Rylston Road, Figure 14, Figure 15, and Figure 16 illustrate the PSIPave structural index spatially. As seen in Figure 14, the structural condition of most of 31st Street from Avenue R to Avenue W is in good structural condition state, having previously been strengthened. Figure 15 illustrates poor structural condition state of Emmeline Road from Swan Crescent to Nemeiben Road, an unstrengthened length of the local road. Figure 16 indicates poor structural condition of Hilliard Street from kilometer 0.000 to 0.700 where the road has not previously been strengthened and good structural condition between kilometers 0.700 and 1.000 where the road has previously been strengthened.

Table 3 cross compares the non-destructive structural and surface condition assessment results of the local streets surveyed. The peak surface deflection at primary plus 50 percent loading, the PSIPave structural index, and the PSIPave surface deterioration index of the surveyed local streets are summarized in Table 3 with green indicating good, yellow as fair, and red as poor behaviour. As seen in Table 3, Emmeline Road from Swan Crescent to Nemeiben Road exhibited poor structural condition across all structural measures, but yielded a fair surface condition. The remainder of the structural and surface condition measures across the local segments surveyed rated as fair and good.

NON-DESTRUCTIVE CHARACTERIZATION OF LOCAL-INDUSTRIALS

Deflection profiles were collected on specified local-industrial segments by lane and by direction. The local-industrials considered within the scope of this study included Idylwyld Drive N Service Road from 51st Street to 71st Street; Edson Street from Jasper Avenue to Portage Avenue; Jasper Avenue from Melville Street to Circle Drive, and; Portage Avenue from Melville Street to Edson Street. Figure 17 illustrates the peak surface deflection results at primary plus 50 percent loading. As seen in Figure 17, the peak surface deflection of the local-industrial segments under primary legal load limits plus 50 percent resulted in dynamic deflection ranging from 0.46 mm to 2.16 mm.

The peak surface deflection profiles obtained across each local-industrial segment were categorized into good, fair, and poor structural performance based on thresholds of as summarized below.

Good: <0.75 mm
Fair: 0.75 mm to 1.25 mm
Poor: >1.25 mm

Figure 18 illustrates the mean PSIPave structural index values of local-industrial road segments surveyed. As seen in Figure 18, the PSIPave structural index of the local-industrials surveyed ranged from 69 to 462.

As also presented in Figure 18, the PSIPave structural index was used to rank the selected local-industrial roads into good, fair, and poor condition state. The thresholds used to categorize the PSIPave structural index performance are summarized below.

Good: >150
Fair: 100 to 150
Poor: <100

Ground penetrating radar profiles were collected on the local-industrial segments by lane and by direction. The local-industrials considered within the scope of this study included Idylwyld Drive N Service Road from 51st Street to 71st Street; Edson Street from Jasper Avenue to Portage Avenue; Jasper Avenue from Melville Street to Circle Drive, and; Portage Avenue from Melville Street to Edson Street.

Based on the surface dielectric permittivity profiles, Figure 19 illustrates the average PSIPave surface deterioration index results for the local-industrials surveyed by segment, by direction, and by lane. As seen in Figure 19, the surface deterioration was used to rank the selected roads into good, fair, and poor condition states. The thresholds used to categorize the surface deterioration of the local-industrials surveyed are summarized below.

Good: <10.0
Fair: 10.0 to 20.0
Poor: >20.0

Based on the structural condition assessment performed on Idylwyld Drive North Service Road, Edson Street, Jasper Avenue, and Portage Avenue, Figure 20 illustrates the PSIPave structural index spatially. As seen in Figure 20, the segment of Idylwyld Drive North Service Road from 51st Street to 60th Street is in poor structural condition. The remaining segment of Idylwyld Drive from 60th Street to 71st Street is exhibiting good structural condition.

Based on the surface deterioration assessment performed on Idylwyld Drive North Service Road, Edson Street, Jasper Avenue, and Portage Avenue, Figure 21 illustrates the surface deterioration index spatially. As illustrated in Figure 21, the surface deterioration index of the Idylwyld Service Road is exhibiting poor surface condition.

Table 4 cross compares the integrated non-destructive structural and surface condition assessment results of the local-industrials surveyed. The peak surface deflection at primary plus 50 percent loading, the PSIPave structural index, and the PSIPave surface deterioration index of the surveyed local-industrials are summarized in Table 4 with green indicating good, yellow as fair, and red as poor behaviour.

SUMMARY AND CONCLUSIONS

Historically, the City of Saskatoon asset management system has relied on roughness and surface distresses to evaluate pavement condition state. Unfortunately, surface based performance measures can be misleading for quantifying the current condition state as well as predicting performance of road assets because of the lack of structural information. This is particularly the case for Saskatoon arterials and expressways that experience significant truck loadings, and therefore potential rapid structural deterioration once structural deterioration of the road assets has occurred.

This study piloted the use of integrated ground penetrating radar and falling weight deflection profiling to characterize the surface condition as well as structural condition state of various City of Saskatoon streets across all road classes. Based on the ground penetrating radar and falling weight deflection analysis results obtained from this study, the following conclusions were observed.

1) Ground penetrating radar surface dielectric permittivity profiles accurately characterized the general surface condition of various classes of roads as validated through visual inspection.
2) Falling weight deflection measures accurately quantified structural variability spatially across various road classes, as expected.
3) Falling weight deflection profiles across load spectra can be used to calculate non-linear primary responses of pavement structures, which is known to be related to structural performance of roads.
4) PSIPave non-linear based pavement structural index more accurately characterized the depreciation rate of pavement structures surveyed relative to peak surface deflection measures.

5) Integrated ground penetrating radar and falling weight deflection surveys provide spatially continuous pavement condition information for approximately the same unit cost of conventional semi-automated surface condition surveys. However, integrated GPR and FWD surveys provide the added benefit of performing structural assessment of roads in addition to surface condition evaluation of roads.

In summary, the pilot GPR-FWD survey conducted in this study provide both surface condition evaluation as well as structural condition of various classes of urban roads. The data evaluation technique illustrated herein also provides continuous road condition information which enables road managers to conveniently illustrate road conditions spatially.

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Table 1 Non-Destructive Survey Summary of Expressway

Road Name and Limits	Direction & Lane		Peak Surface Deflection at Primary + 50% Loading (mm)	PSIPave Structural Index	PSIPave Surface Deterioration Index
Circle Dr N Bridge Abutment to Median Gore Point	EB	Curb	0.75	111	5.8
		Median	0.70	113	5.5
	WB	Median	0.94	74	5.6
		Curb	0.98	115	9.0
Circle Dr Median Gore Point to Millar Ave	EB	Curb	0.74	180	7.3
		Median	0.66	115	7.0
	WB	Median	0.83	110	7.2
		Curb	0.99	103	14.3
Circle Dr Millar Ave to 1st Ave N	EB	Curb	0.57	157	6.6
		Centre	0.71	139	5.6
		Median	0.58	152	5.1
	WB	Median	0.51	209	9.5
		Centre	0.46	169	5.6
		Curb	0.54	130	5.3
Circle Dr 1st Ave N to Faithfull Ave	EB	Curb	0.76	85	5.1
		Centre	0.69	127	5.1
		Median	0.43	215	4.6
	WB	Median	0.65	189	9.3
		Centre	0.66	165	5.7
		Curb	0.64	149	7.7
Circle Dr Faithfull Ave to Idylwyld Bridge Abutment	EB	Curb	0.77	127	9.6
		Centre	1.38	86	7.6
		Median	0.65	204	7.8
	WB	Median	0.62	153	12.2
		Centre	0.62	162	9.7
		Curb	0.62	230	11.9
Circle Dr Idylwyld Bridge Abutment to Avenue C	EB	Curb (JPCC)	0.49	371	13.2
		Centre (JPCC)	0.29	1218	13.5
		Median (JPCC)	0.39	1049	16.8
	WB	Median	0.46	263	8.7
		Centre	0.41	157	9.3
		Curb	0.57	220	15.1

Table 2 Non-Destructive Survey Summary of Arterials

Road Name and Limits	Direction & Lane		Peak Surface Deflection at Primary + 50% Loading (mm)	PSIPave Structural Index	PSIPave Surface Deterioration Index
8th St Boychuk Dr to McKercher Dr	EB	Curb	1.25	93	9.3
		Centre	1.13	156	7.1
		Median	1.15	98	8.1
	WB	Median	1.21	97	9.8
		Centre	1.25	98	9.4
		Curb	1.49	71	9.5
Attridge Dr McOrmond Dr to Kenderdine Rd	EB	Curb	1.16	80	11.2
		Median	1.14	75	15.4
	WB	Median	1.13	71	12.6
		Curb	1.20	86	10.8
Attridge Dr Kenderdine Rd to Berini Dr	EB	Curb	1.41	58	23.3
		Median	1.43	49	31.4
	WB	Median	1.32	69	25.2
		Curb	1.67	49	24.1
Attridge Dr Berini Dr to Central Ave	EB	Curb	1.11	84	9.2
		Median	1.10	79	9.9
	WB	Median	1.10	72	9.8
		Curb	1.12	92	15.3
Avenue C Circle Dr to 47th St	SB	Curb	1.26	77	10.1
		Median	0.91	95	8.7
	NB	Median	0.87	128	15.5
		Curb	1.20	74	13.0
Preston Ave 8th St to Main St	SB	Curb	1.05	68	22.9
	NB	Curb	0.89	95	14.9
Preston Ave Main St to 14th St	SB	Curb	1.32	61	24.4
	NB	Curb	1.17	78	41.2

Table 3 Non-Destructive Survey Summary of Locals

Road Name and Limits	Direction & Lane		Srengthened/ Unstrengthened	Peak Surface Deflection at Primary + 50% Loading (mm)	PSIPave Structural Index	PSIPave Surface Deterioration Index
31st St Avenue R to Avenue W	EB/WB	Curb	Strengthened	1.26	50	7.0
Adelaide St Cumberland Ave to Lansdowne Ave	EB/WB	Curb	Unstrengthened	2.15	84	12.3
			Strengthened	1.99	97	10.6
Emmeline Rd Swan Cres to Nemeiben Rd	EB/WB	Curb	Unstrengthened	3.26	15	17.6
Hilliard St Cumberland Ave to Lansdowne Ave	EB/WB	Curb	Unstrengthened	2.97	17	15.1
			Strengthened	1.15	47	8.8
Rylston Rd Whitney Ave to Avenue X	EB/WB	Curb	Strengthened	1.69	43	11.6

Table 4 Non-Destructive Survey Summary of Local-Industrials

Road Name and Limits	Direction & Lane		Peak Surface Deflection at Primary + 50% Loading (mm)	PSIPave Structural Index	PSIPave Surface Deterioration Index
Idylwyld Dr N Service Rd 51st St to 60th St	SB/NB	Curb	2.16	69	27.5
Idylwyld Dr N Service Rd 60th St to 71st St	SB/NB	Curb	0.94	264	21.1
Edson St Jasper Ave to Portage Ave	EB/WB	Curb	0.74	134	11.0
Jasper Ave Melville St to Edson St	SB/NB	Curb	0.85	146	18.8
Jasper Ave Edson St to Circle Dr	SB/NB	Curb	0.46	462	13.2
Portage Ave Melville St to Edson St	SB/NB	Curb	0.95	117	14.3

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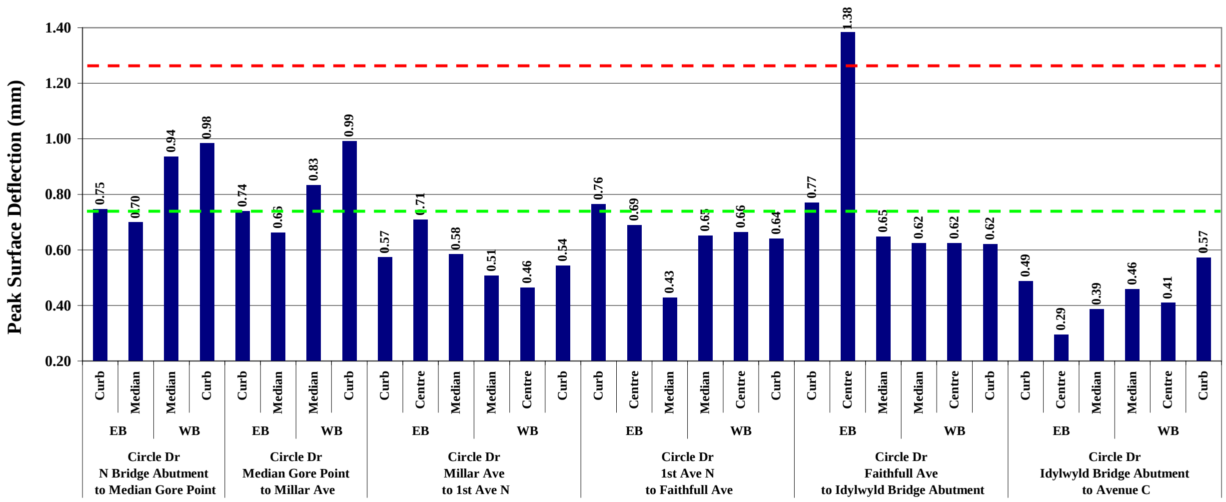

Figure 1 Peak Surface Deflection at Primary + 50% Loading of Expressway

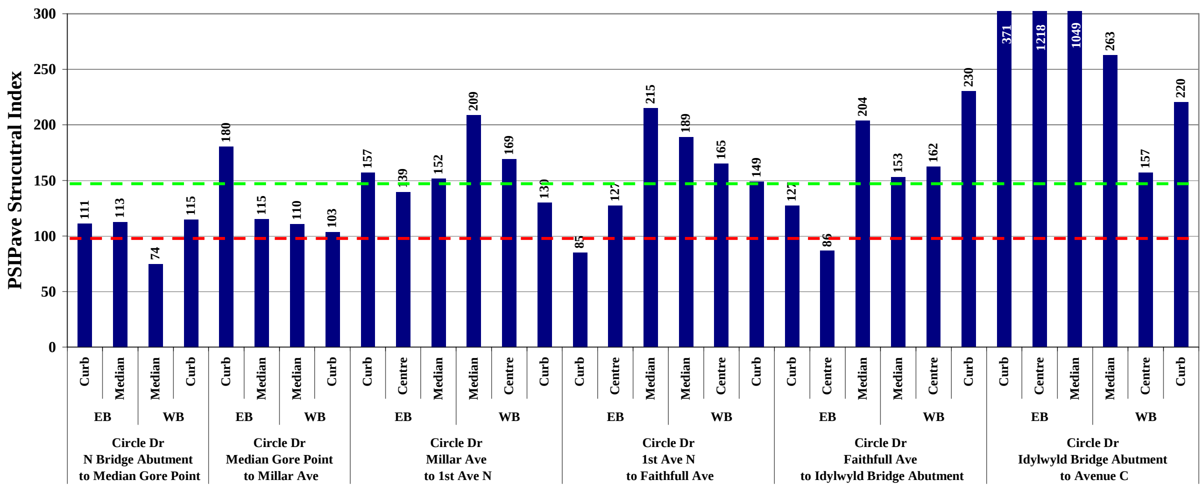

Figure 2 PSIPave Structural Index for Expressway

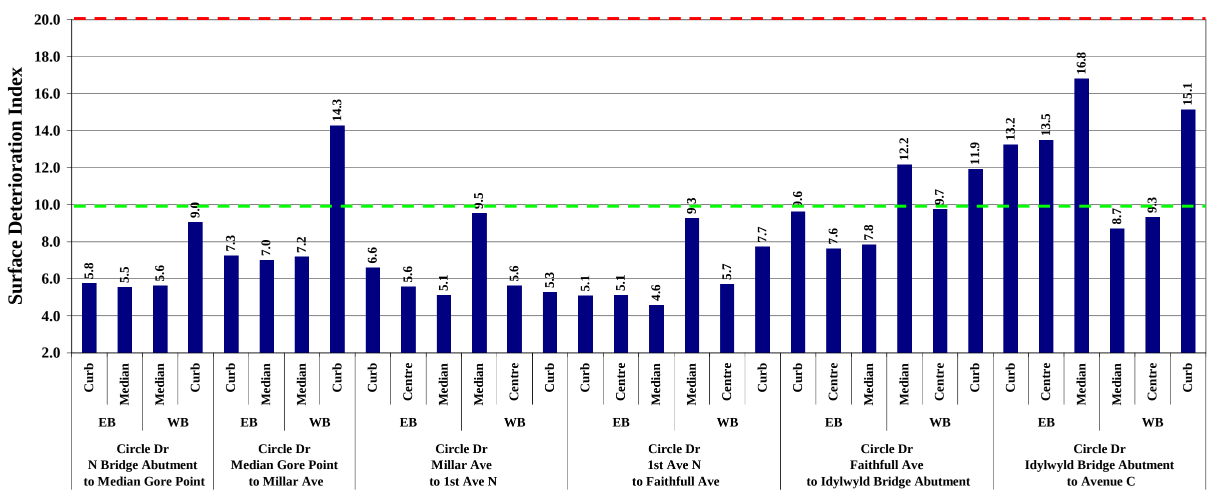

Figure 3 Mean PSIPave Surface Deterioration Index of Expressway

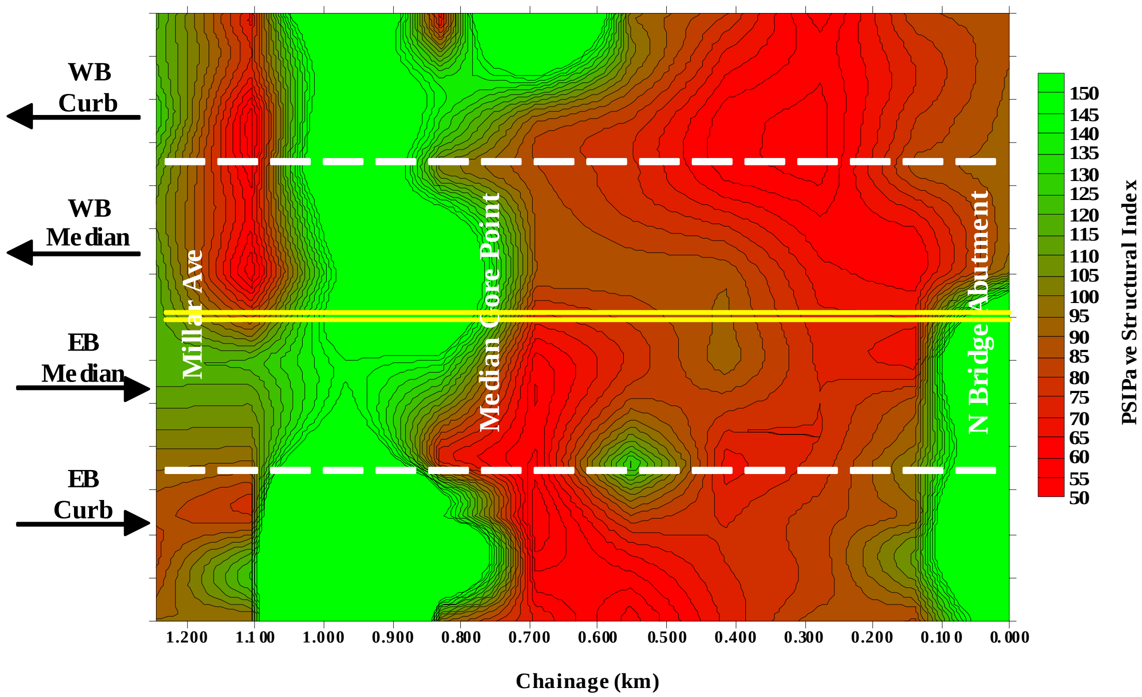

Figure 4 PSIPave Structural Index – Circle Dr (River Crossing to Millar Ave)

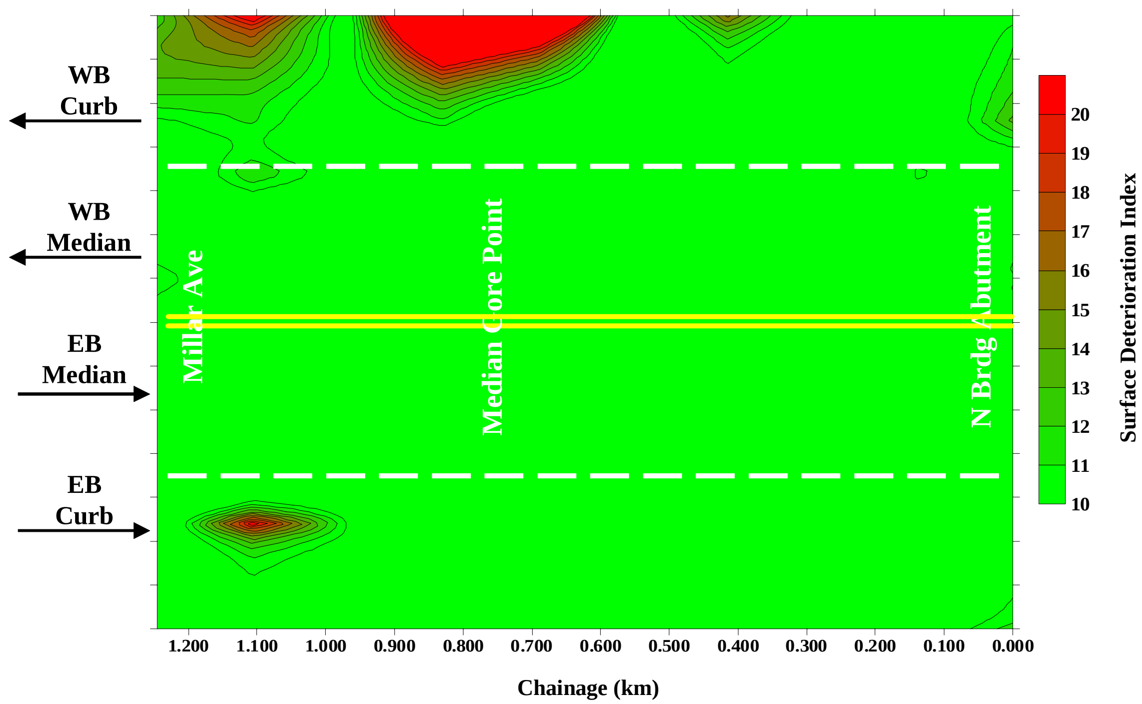

Figure 5 Surface Deterioration Index Contour – Circle Dr (River Crossing to Millar Ave)

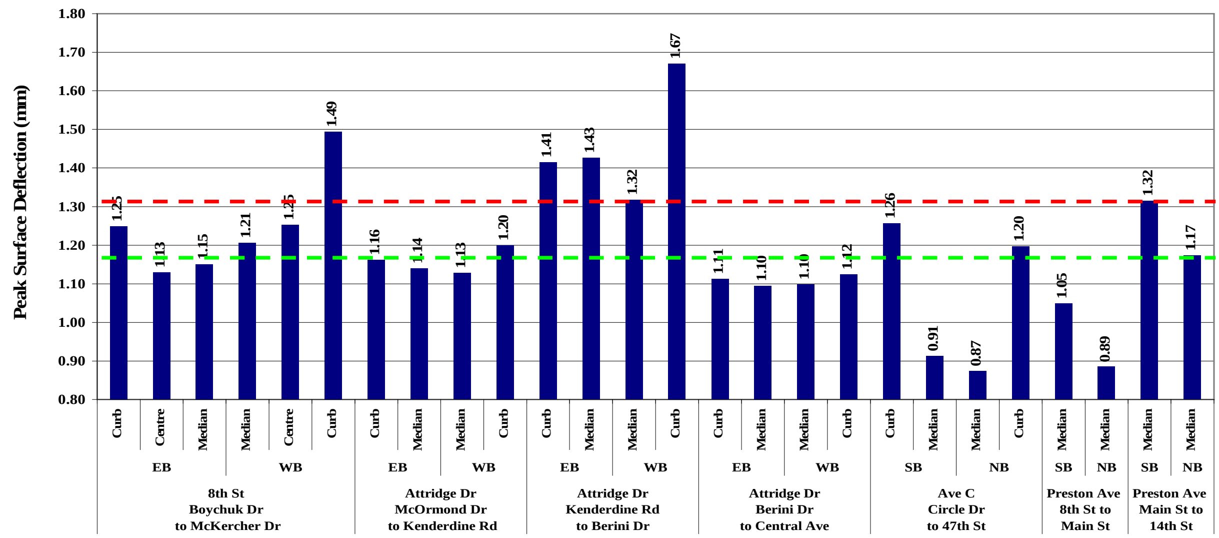

Figure 6 Peak Surface Deflection at Primary + 50% Loading of Arterials

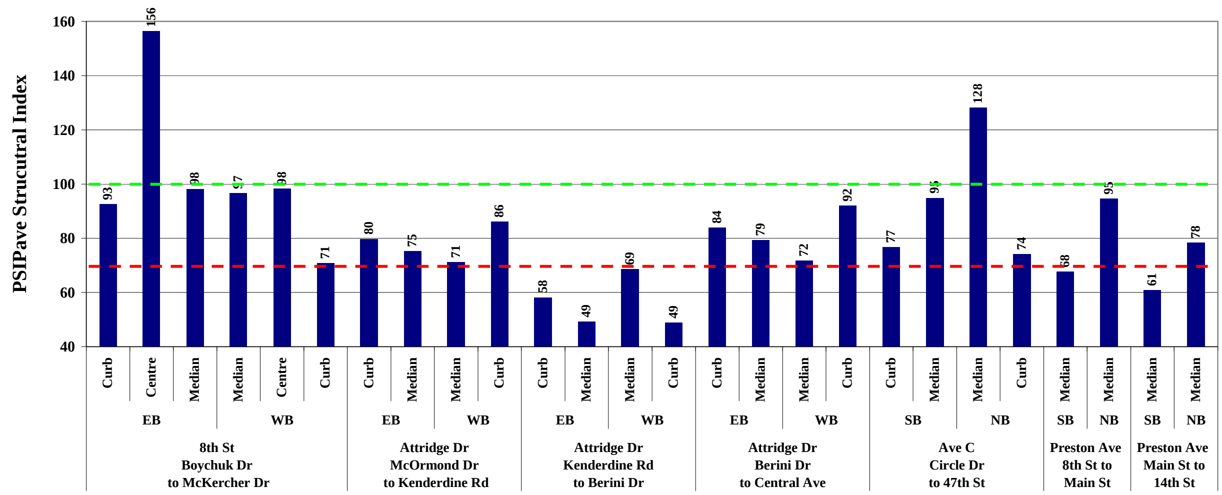

Figure 7 PSIPave Structural Index for Arterials

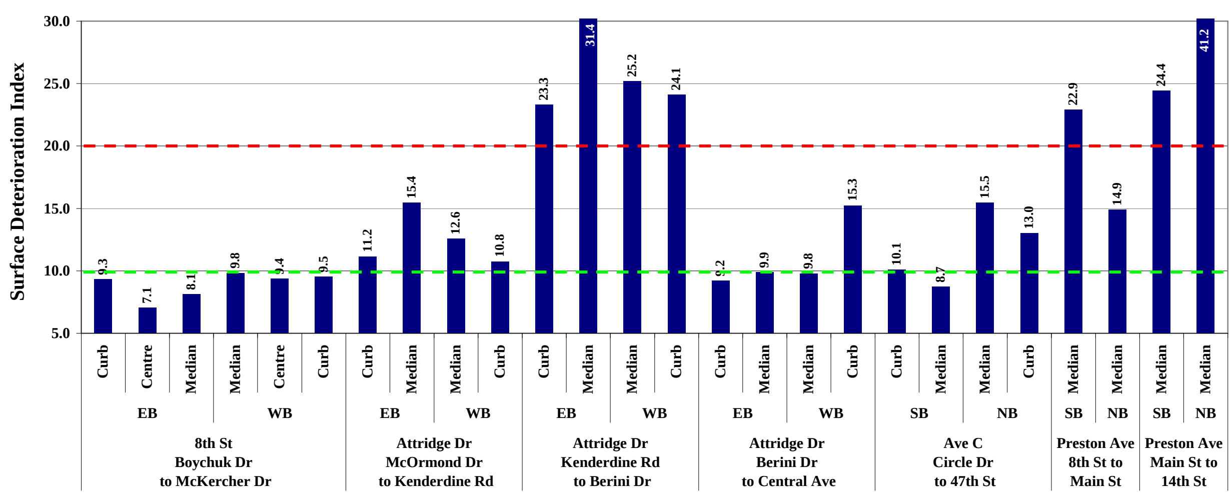

Figure 8 Mean PSIPave Surface Deterioration Index of Arterials

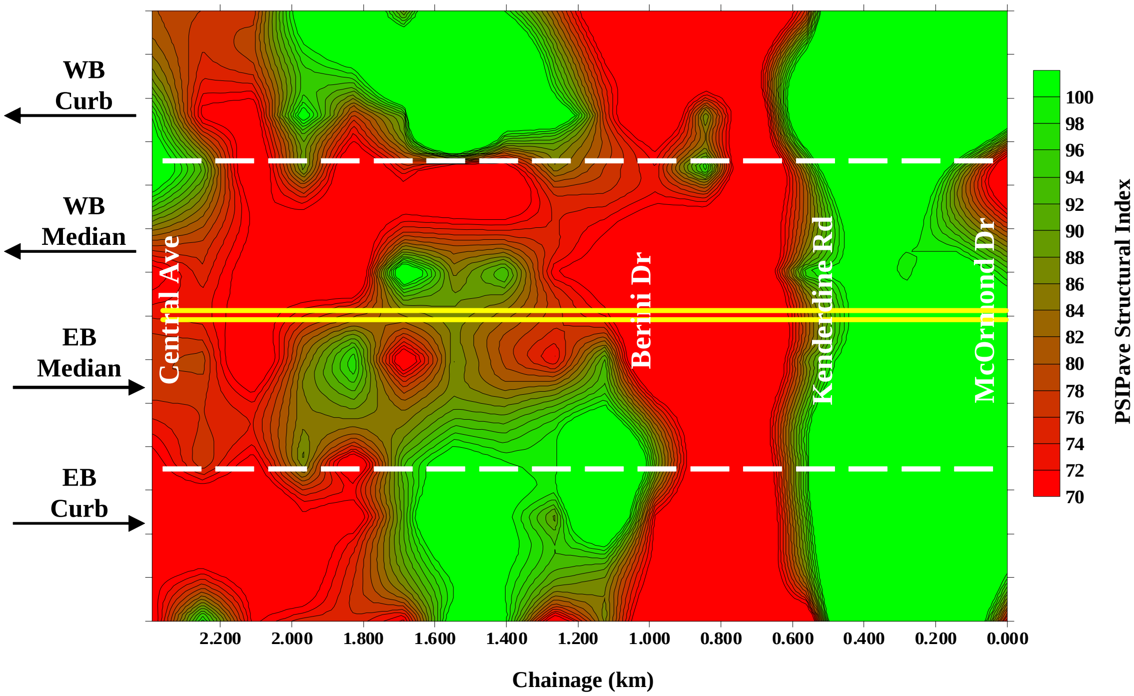

Figure 9 PSIPave Structural Index – Attridge Drive (McOrmond Dr to Central Ave)

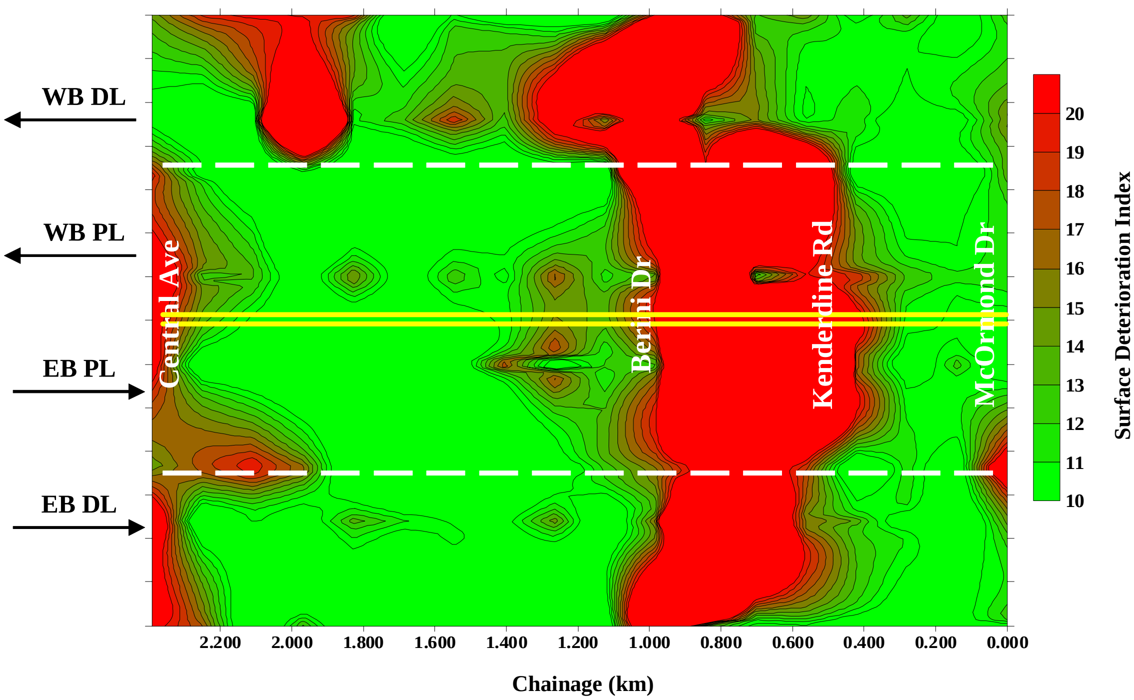

Figure 10 Surface Deterioration Index – Attridge Dr (McOrmond Dr to Central Ave)

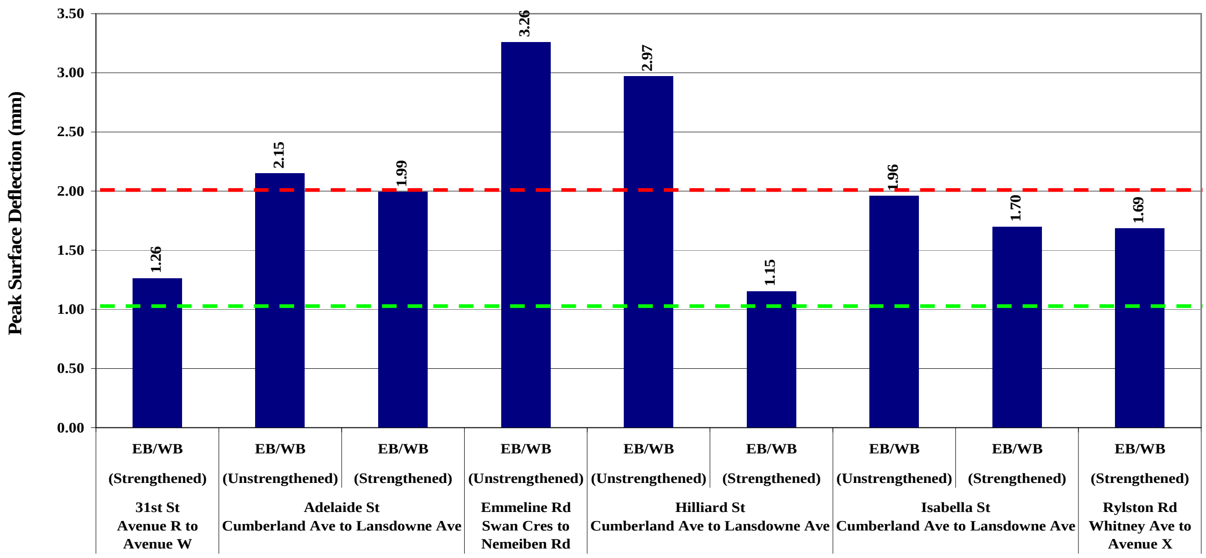

Figure 11 Peak Surface Deflection at Primary + 50% Loading of Locals

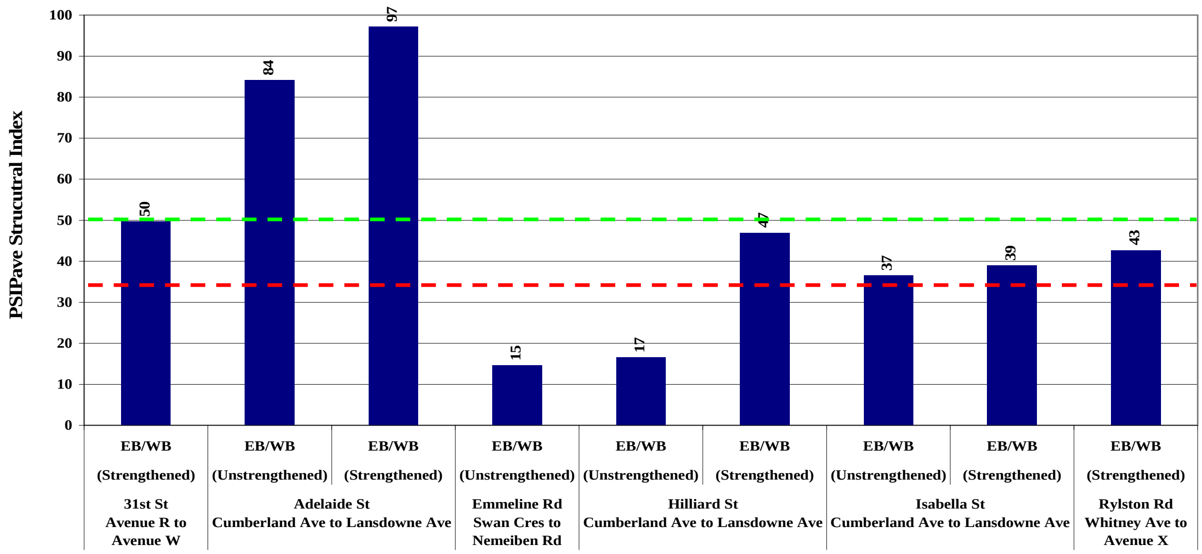

Figure 12 PSIPave Structural Index for Locals

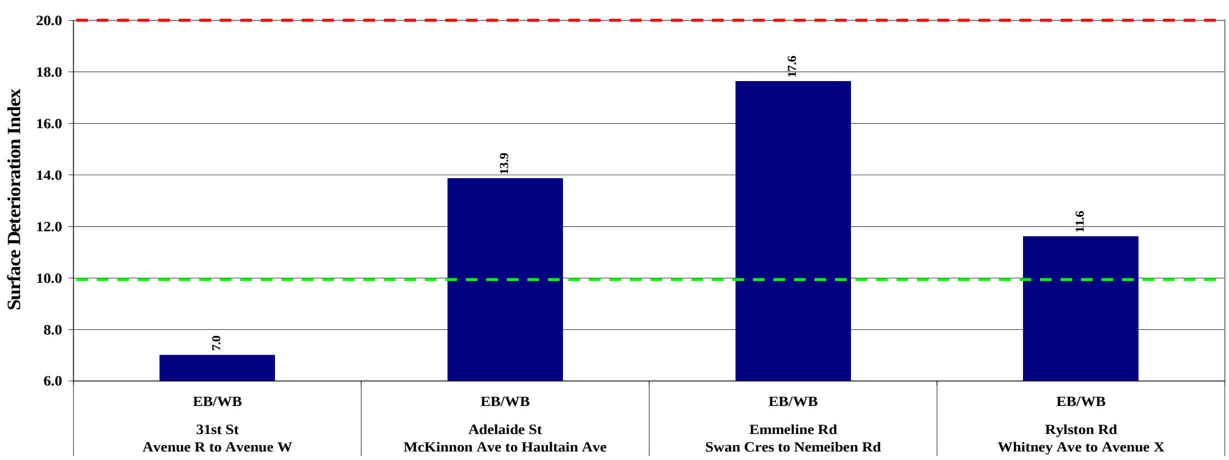

Figure 13 PSIPave Surface Condition Index of Locals

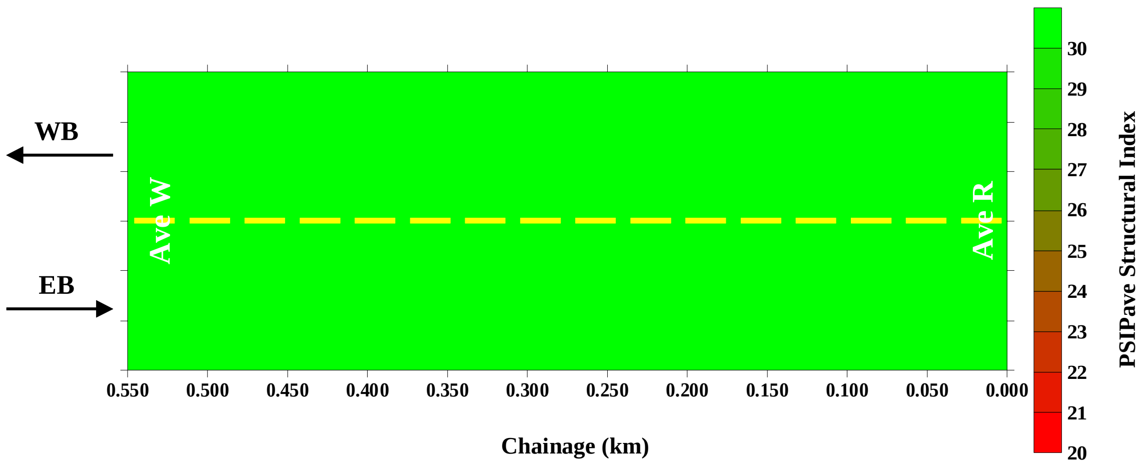

Figure 14 PSIPave Structural Index – 31st Street (Avenue R to Avenue W)

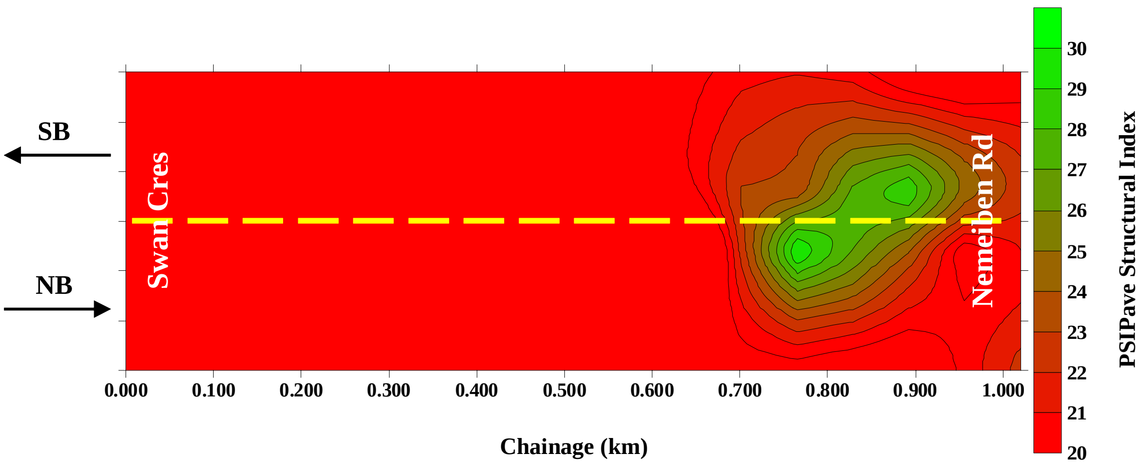

Figure 15 PSIPave Structural Index – Emmeline Road (Swan Cres to Nemeiben Rd)

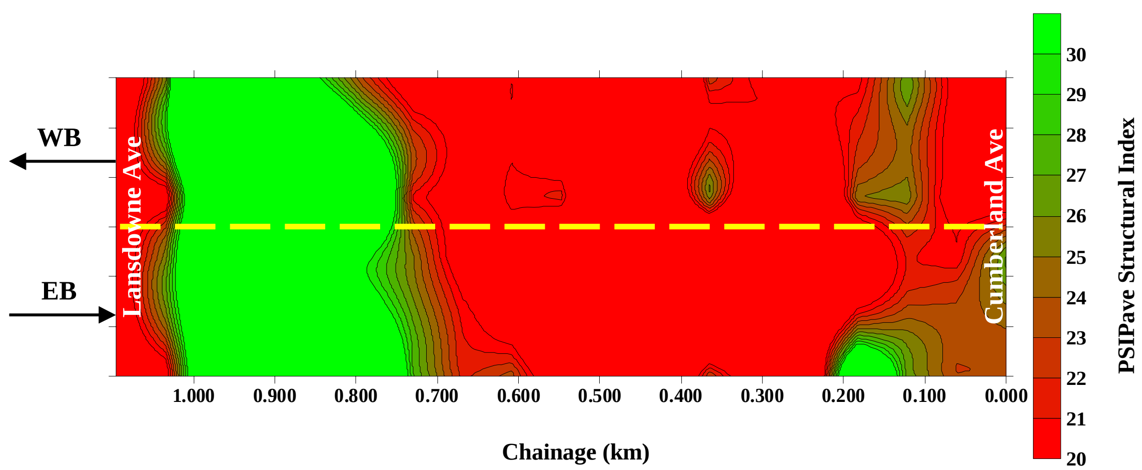

Figure 16 PSIPave Structural Index – Hilliard Street (Cumberland Ave to Lansdowne Ave)

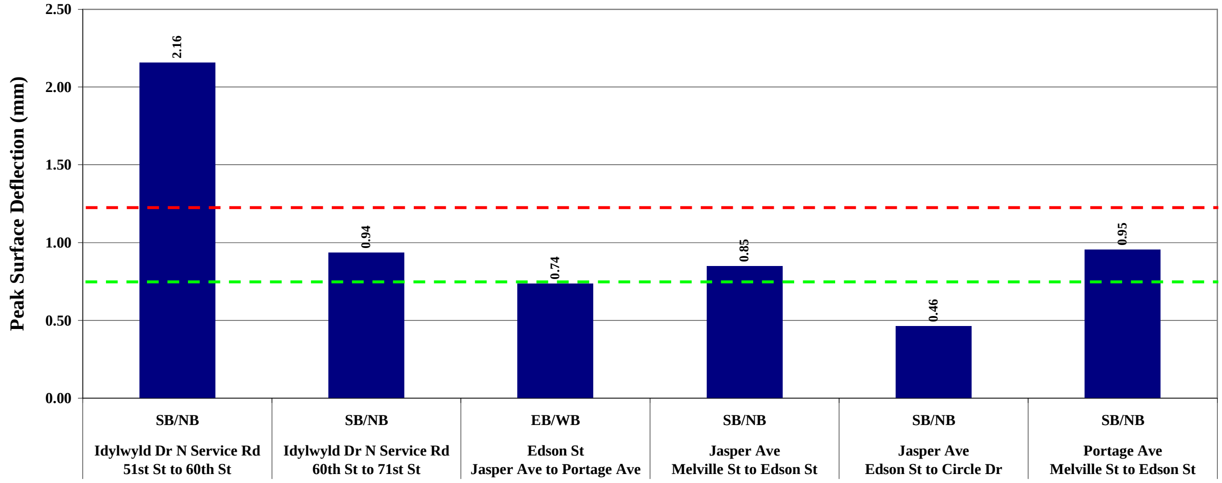

Figure 17 Peak Surface Deflection at Primary + 50% Loading of Local-Industrials

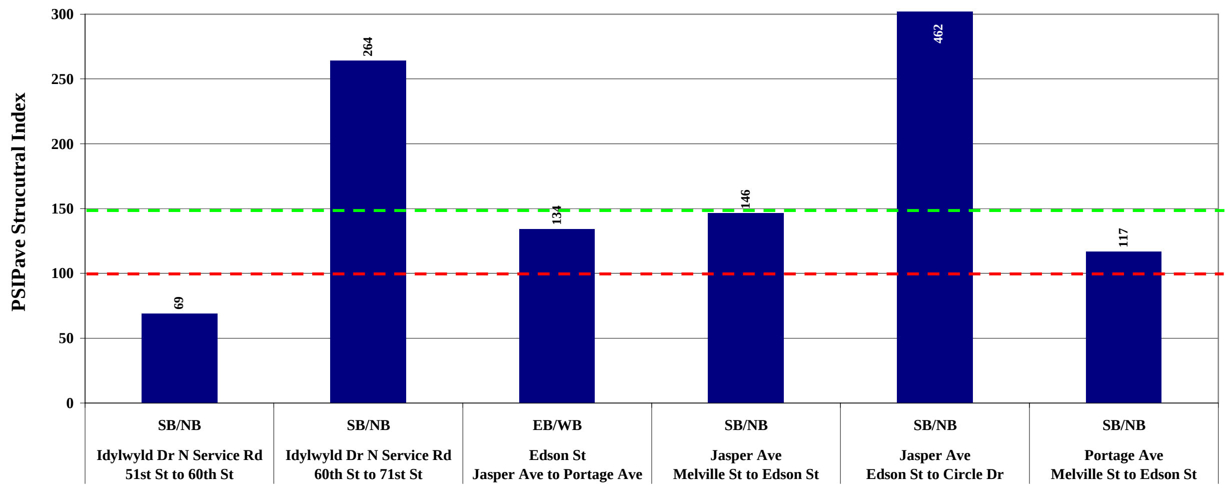

Figure 18 PSIPave Structural Index for Local-Industrials

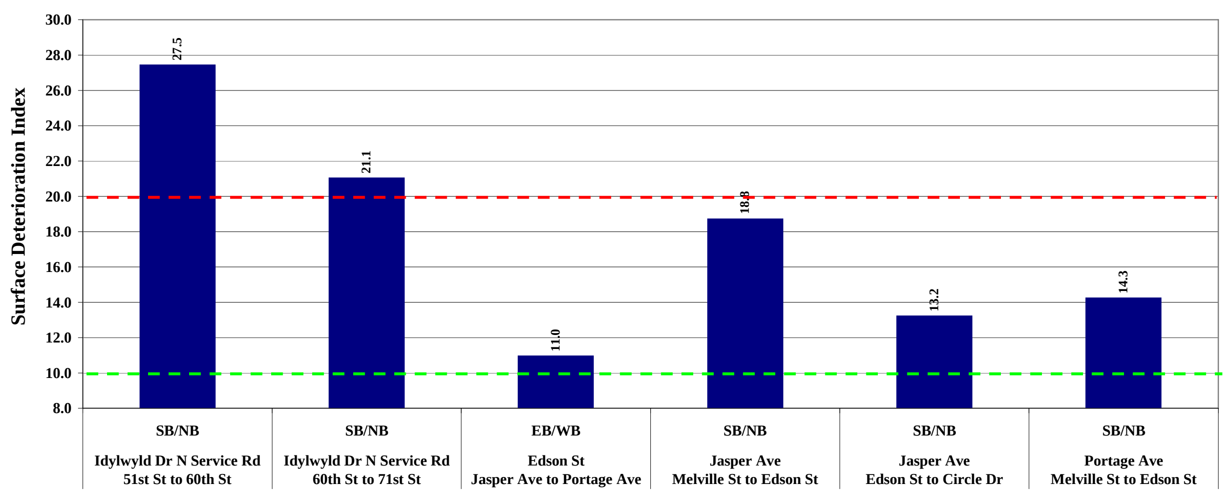

Figure 19 PSIPave Surface Deterioration Index of Local-Industrials

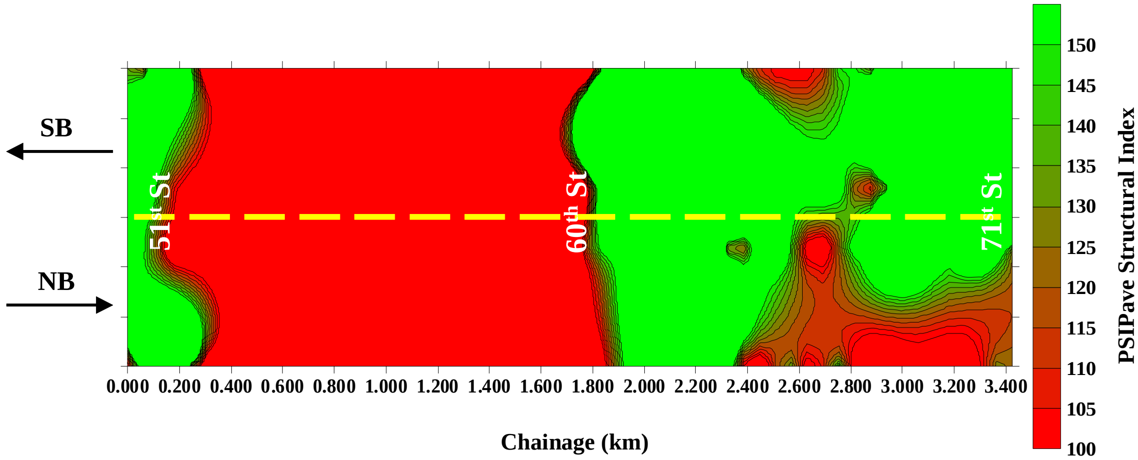

Figure 20 PSIPave Structural Index – Idylwyld Dr N Service Road (51st St to 71st St)

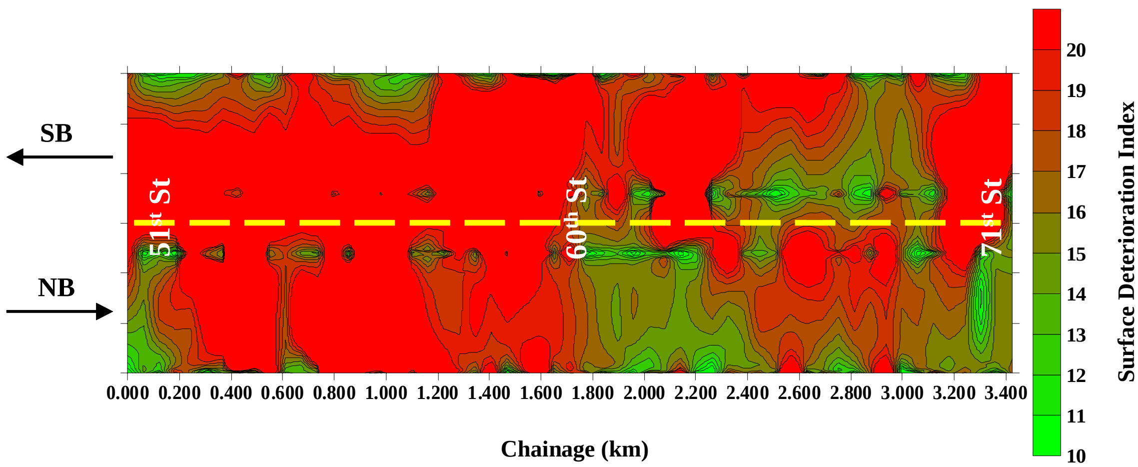

Figure 21 Surface Deterioration Index – Idylwyld Dr N Service Rd (51st St to 71st St)