Assessment of Load Bans for the City of Calgary using the TAC Guide to Load Management for Weak Pavement Structures

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Abstract

Tetra Tech was retained by the City of Calgary (The City) to complete pavement data collection and analysis of the roadway segments subjected to spring load bans and year-round load bans imposed by The City. The load ban assessment effort comprised of pavement structure determination (using Ground Penetrating Road Radar testing and asphalt pavement coring), pavement strength testing using a Falling Weight Deflectometer (FWD), and analysis of the collected data to determine required load bans and structural adequacy of the existing pavement structures. A total of 49 roadway segments were included in this study. FWD data was collected in three rounds to evaluate seasonal variations in subgrade strength. Mean Benkelman Beam Deflections (MBD) were estimated from the FWD data, and the Maximum Tolerable Deflections (MTD) were calculated for the calculated design traffic. The proposed load bans or weight restrictions (spring and year-round) were determined based on the relationship between the MBD and MTD using the Transportation Association of Canada Guide to Load Management for Weak Pavement Structures.

Structural asphalt overlay required to convert the roads subjected to load bans to all season roads (roads with no load ban restrictions) were also determined using Asphalt Institute (AI) and American Association of State Highway and Transportation Officials (AASHTO) design standards. This paper provides a summary of the load ban estimation and structural overlay determination effort.

1.0 Introduction

Pavement structures generally become weak during the spring thaw period after the winter season due to warming of the temperatures. Defrosting of the ice lenses present in the granular pavement layers and subgrade layers from the previous winter leads to soil saturation and eventual weakening of the pavement structure until excess moisture fully dissipates. The term Weak Pavement Structure (WPS) can be used to define pavements that display relatively high deflections during this wet transition state when tested with an FWD equipment. The Transportation Association of Canada Guide to Load Management for Weak Pavement Structures, TAC (2016 edition) (TAC Guide) describes these structures as those susceptible to damage in the short-term due to lack of drainage and/or insufficient pavement structure to mitigate a wet or freeze-thaw event. The coupling effect of existing traffic on WPS leads to accelerated pavement damage and shortened service life with ruts and/or fatigues cracks appearing on the surface earlier than usual.

The City of Calgary has a number of roadway segments (49 segments) that are subjected to load bans. The City retained Tetra Tech to complete testing and analysis to evaluate the spring load bans and year-round load bans currently in-effect. The City also asked to determine the amount of asphalt overlay required to convert the roadway segments with load restrictions to all season roads with no load restrictions.

1.1 Roadway Segments included in Study

The roadway segments subjected to load bans within The City's jurisdiction as of June 2020 are shown in Figure 1:

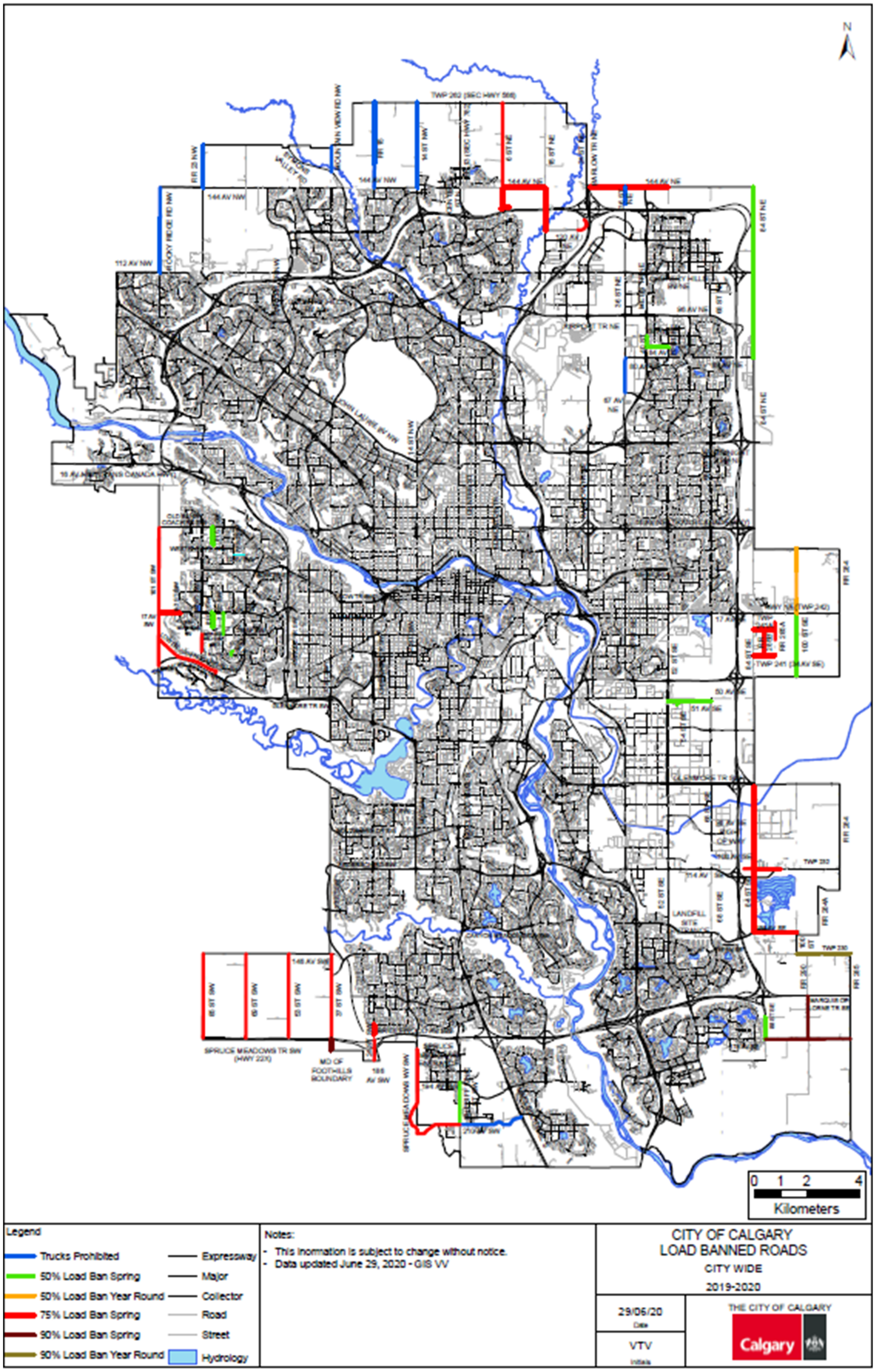

Figure 1: Roadway Segments included in Study

The pavement structure is weakest during the spring season due to thawing of the subgrade. Traffic loads traversing these weak pavement structures cause additional distresses on the pavement structure resulting in premature failure of the pavement structures and reduced service life. Most of the owner agencies manage the potential additional distresses in the spring season by restricting the loads of the vehicles traversing the roadway segments. This practice of managing imposed traffic loads can be referred to as Load Management and it is achieved by imposing weight restrictions or load bans during the spring period and/or year-round if necessary. The magnitude of these restrictions is determined from analysis of pavement deflections when the pavement is the weakest (spring season) and when it is the strongest (during summer season). Two types of load bans are described below:

Spring Load Bans

The spring load ban is the recommended weight restriction imposed to reduce the rate of pavement deterioration or damage when underlying pavement layers thaw following winter in spring season.

Year-Round Load Bans

Year-round road bans are imposed for the roadway segments which are considered structurally inadequate to support the traffic loads even during the summer months when the subgrade is the strongest.

2.0 Load Ban Evaluation Methodology

The methodology for the load ban evaluation comprised of the following:

- Data collection (pavement strength testing using a Falling Weight Deflectometer (FWD);
- Road Radar testing (to determine the thickness of the pavement layers) and asphalt pavement coring (to determine the thickness of the asphalt pavement layers and calibrate the Road Radar data); and
- Analysis of collected data (FWD data and Road Radar data), data obtained from the City (traffic data), and analysis to determine the required load bans.

The pavement layer thicknesses of the roadway sections were determined from analysis of the Ground Penetrating Radar (GPR) collected data and the determined thickness values were used in the overlay design. The FWD data was collected in May 2021, June 2021 and August 2021.

The existing load bans imposed by the City were 50%, 75% and 90% spring bans or year-round bans. The proposed spring load bans for 2022 were determined from the FWD collected in the Spring season (May 2021), and proposed year-round load bans from the analysis of the data collected in summer months (June and August 2021).

Alberta’s Ministry of Transportation and Economic Corridors (the government agency in charge of provincial transportation) typically impose spring restrictions based on thaw depth readings across the province. The spring weight restrictions typically come into effect around the first week of April and extend till around mid-June. However, the thaw line of the Frost and Thaw map published by Alberta Transportation in 2022 indicate that thawing started around mid-March in Southern Alberta Region, where the City of Calgary is located. This was about 3 weeks prior to the official spring restrictions declared by Alberta Transportation. Municipalities generally refer to the provincial published dates as a primary source of thawing information and then adjust the start and end date for spring weight restrictions also considering other local socio-economic activities.

The load bans are expressed in form of relative percentage of Maximum Tolerable Deflection (MTD) to Mean Benkelman Beam Deflection (MBD) according to the Transportation Association of Canada's Guide to Load Management for Weak Pavement Structures, (2016 edition) (TAC Guide).

To eliminate the need for load bans, FWD data was analyzed to assess the structural adequacy of the existing pavement structures and asphalt overlay required to convert the roads subjected to load bans to all season roads with no load bans. The paved and unpaved roadway segments were designed using the AASHTO methodology and Asphalt Institute design method respectively.

3.0 Data Collection and Processing

3.1 FWD Testing

The FWD testing was completed in three (3) rounds on the roadway segments included in the study:

- Round 1 (May 2021);
- Round 2 (June 2021); and
- Round 3 (August 2021).

A total of 10 FWD tests were collected for each roadway segment for a 1000 m segment length at a spacing of 100 m between the tests or the spacing was adjusted to allow for at least 10 tests (in case of shorter roadway segments to allow for enough data for statistical analysis). Deflection measurements during the three rounds were used to assess the impact of the seasonal conditions on moisture susceptibility and moisture retention in the underlying and subgrade layers.

The FWD field data was collected in accordance with American Society for Testing and Materials (ASTM) D4694 and ASTM D4695 standards. The collected FWD data was converted into Benkelman Beam equivalent deflections using established Alberta Transportation's procedure to complete the analysis. Tetra Tech worked with Alberta Transportation from 1998 through 2002 to develop FWD to Benkelman Beam Road Ban conversion application for Alberta Transportation. The application which was calibrated to Alberta pavement conditions factored the influence of base layer material types and have coefficients iterated for the pavement structures comprising of soil-cement base, granular base and full-depth asphalt pavement. The application used for conversion follow two defined procedures discussed below:

- Normalization of each deflection reading to 40 KN based on FWD plate size. Paved surfaces were tested using a plate size of 300 mm diameter, and unpaved/gravel surfaces with a plate size of 450 mm diameter.
- Calculation of equivalent Benkelman Beam deflection (BBD) from normalized deflection values of the sensor 1 geophone using the calibration coefficients for different base types. Deflection units were reported as thousandth of an inch and were converted to BBD's in mm.

3.2 Asphalt Pavement Coring

Asphalt pavement coring was completed for the roadway segments to determine the thickness of the asphalt concrete pavement (ACP) layer. One or two 50 mm diameter cores were extracted for each roadway segment included in the project scope.

The measured ACP thicknesses were used to calibrate the Road Radar data.

3.3 Road Radar Testing

The Road Radar™ System is a patented ground penetrating radar (GPR) solution developed by Tetra Tech. Road Radar testing was completed for the roadway segments included in the project scope. Road Radar collects continuous pavement layer thickness data at programmed distance interval (0.2 to 0.8 m typical), at posted roadway speeds. For this project, data was collected and reported for 20 m segments. Road Radar testing was carried out in three (3) lines for each travelled lane. The testing was completed in the inner wheelpath, center of lane, and outer wheelpath for each continuous lane and the testing was completed in the center of the lane for short turning lanes.

The Road Radar System used a distance measuring instrument (DMI) connected to the transmission of the vehicle to trigger the collection of a radar data sample based on a pre-programmed longitudinal sampling interval of 0.62 to 0.63 m. In this way, radar samples were collected at precisely known intervals and the system is not survey speed dependent. Therefore, precise horizontal control was achieved by setting up start positions relative to a distinct benchmark or intersection and logging the location of physical landmarks observed at the time of survey.

Road Radar testing was completed as part of Round 1 of data collection to estimate pavement layer thicknesses, for the roadway segments. The Asphalt Concrete Pavement (ACP) layer and Granular Base Course (GBC) layer thicknesses were determined. The Road Radar provides an accuracy of ±5% for the ACP layer and ±10% for granular base layers.

The data was analyzed and reported in the form of tabular and graphical format as shown in Figure 2.

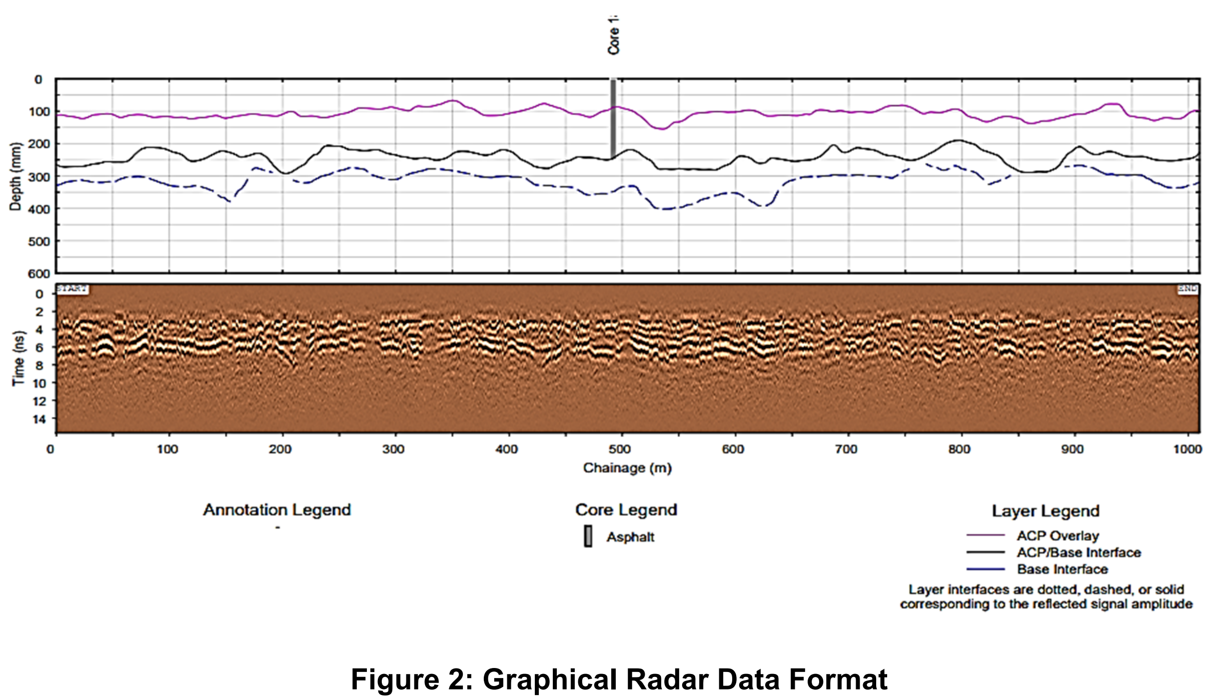

Figure 2: Graphical Radar Data Format

4.0 Data Analysis

Collected data (FWD and pavement structure) and data received from the City (Traffic data) was analyzed to determine the load bans required for various roadway segments. The completed analysis and the input parameters used in the analysis are discussed in the sections below.

4.1 Traffic Data

Actual traffic data was not available for most of the roadway segments included in the study. Based on discussions with the City, average annual daily traffic (AADT) of 1000 vehicles and average annual daily truck traffic (AADTT) of 50 vehicles (5% of AADT) was used for all the roadway segments except for 84th Street SE.

Considering some ongoing and proposed project developments in the vicinity of 84th Street SE, AADT of 2,000 and AADTT of 170 (8.5% of AADT) were suggested to be used by The City. Load equivalency factors of 0.0004 for Passenger Vehicles, 1.0 for Single Unit Trucks (SUT), and 2.0 for Tractor Trailer Combination (TTC) as specified in The City's specifications were used for the calculation of design traffic. A truck traffic split of 50/50 was assumed between SUT and TTC for the calculation of design Equivalent Single Axle Loads (ESALs) for the project.

Table 1. Design Traffic

Roads	AADT	AAD Truck Traffic	Trucks per Day in Design Lane	Percentage Truck (%)	SUT (%)	TTC (%)	ESALs/day/ direction
All Roadway Segments (except 84th St SE)	1,000	50	25	5.0	2.5	2.5	38
84th Street SE	2,000	170	85	8.5	4.3	4.3	255

Design ESALs were calculated for an analysis period of 20 years considering a growth rate of 3 % as outlined in The City's Road Construction Specifications. Table 2 shows calculated ESAL values for 20 years.

Table 2. Design ESALs

Street	AADT	ESALs/day/direction (Year 2021)	Percent ESALs	20-yr Design ESALs
All Roadway Segments (Except 84th St SE)	1000	38	100%	3.73E+05
84th Street SE	2000	255	100%	2.50E+06

There could be potential conservativeness in the proposed load bans considering that the AADTT of 50 included in the analysis could be higher for some of the roadway segments. However, this is considered reasonable as estimated ESALs empirically reflect the range of traffic common to these roadway segments based on the City's experience.

4.2 Measured Beam Deflection and Maximum Tolerable Deflection

The TAC Guide provides guidelines on using trucks per day in the design lane and mean Benkelman Beam Rebound Deflection (Measured Beam Deflections (MBD) (measured and corrected) to design load restrictions at a fundamental level.

Figure 3 presents the chart for the load restriction design. This empirical chart has been found to correlate with agency practices in Manitoba and British Columbia, providing a quick load ban estimation based on measured mean deflection. As per the TAC criteria, pavement deflections must be measured when the pavement is at the weakest time of the year, which is generally during the spring thaw period to accurately predict applicable load restriction using this chart. The chart assumes that the pavement segment has relatively homogeneous segment strength and traffic. A representative traffic was chosen for the full length of the roads under study and measured deflections aggregated into an average value. The use of these two variables (trucks per day in design lane and MBD) maintains consistency with the Asphalt Institute (AI) based flexible pavement design methodology provided in Chapter 7 of the TAC Guide.

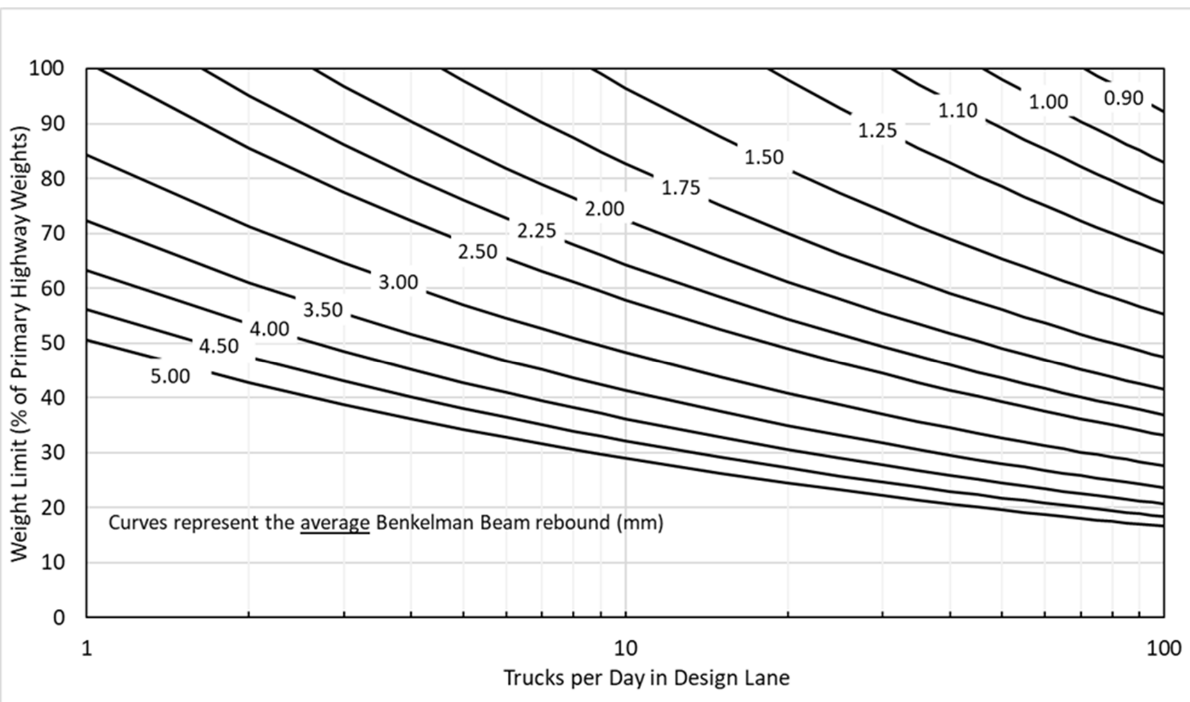

Figure 3: Deflection/Loading versus Weight Limit (TAC Guide, 2016)

The collected FWD data was converted into mean Benkelman Beam deflections. The number of trucks per day in design lane were then traced to the respective road segment mean deflection and the point it coincides with the weight limit axis is the required load ban value for that segment. The equations used for the development of this chart are presented below:

$$MTD\ (mm) = 2.5279 * TDL^{-0.242}$$

$$WL\ (\%) = \frac{MTD}{MBD} * 100$$

$$\text{Where: MTD } = Maximum\ Tolerable\ Deflection\ (mm)$$

$$TDL = Trucks\ per\ day\ in\ design\ lane$$

$$MBD = Mean\ Benkelmen\ Beam\ Deflection\ (mm)$$

$$WL = Weight\ Limit\ or\ Load\ Ban\ (\%)$$

The roads included in the study were mostly classified as residential and residential collector streets with a maximum specified deflection of 50 mils (1.27 mm) and 35 mils (0.889 mm), respectively (per section 308.04.00 of City of Calgary's Road Construction Specifications, 2015 edition). MTD of 1.160 mm and 0.863 mm were calculated using the TAC equations for all roadway segments (with the exception of 84th St SE) and 84th St SE respectively. Truck traffic of 25 and 85 trucks per lane per day was used as per the direction received from The City for all roadway segments (except 84th St SE) and 84th St SE respectively.

The weakest periods observed from measured data were primarily in Round 1 (as expected) and some in Round 2. The highest deflection values measured on various roadway segments amongst all rounds of FWD testing were selected as MBD's. These values represent the pavement's critical (weakest) state and load bans and overlay calculations were determined based on these values. Representative Rebound Deflection (RRD) values are used in the overlay requirement calculations and are estimated using MBDs and their standard deviation values.

5.0 Conversion to All Season Roads

The ACP overlay thicknesses required to convert roadway segments with load bans to all season roads (without any load restrictions) were determined using the Asphalt Institute (AI) methodology for the unpaved/gravel roads and AASHTO '93 design method for the paved roadways. Unpaved/gravel surface pavement subgrade modulus were unrealistically low and did not reasonably represent the condition of the site when back-calculated using established AASHTO '93 procedure. Therefore, the AI methodology was used for the gravel roads. These design methodologies are discussed in the sections below.

5.1 Gravel Surface Roads - Asphalt Institute Overlay Design Method

For overlay designs using the AI method, the RRD is typically calculated by adding MBD to two standard deviations and used in estimating the overlay thickness. This addition accounts for variability in measured deflection values to represent a deflection level that would be exceeded in only 2% of the length of the pavement segment (AI 1969). RRD equation is shown below:

$$RRD\ (mm) = MBD + \ 2\, xSD$$

$$RRD = \ Representative\ Rebound\ Benkelmen\ Beam\ Deflection\ (mm)$$

$$SD = Standard\ Deviation\ (mm)$$

The RRD represents the most critical state of the pavement and allows for evaluation of temperature and seasonal effects on subgrade soils. A structural ACP overlay is not required when the existing pavement is structurally adequate to support the traffic loadings year-round (i.e., RRD is less than MTD). As expected, calculated RRD values for the unpaved / gravel roads were higher than MTD due to lower surface stiffness, resulting in a need for ACP overlays. The placement of ACP overlay thicknesses determined by AI methodology on the gravel roads would remove the need for load restrictions on those roadways.

The overlay thickness requirement is established using the chart presented in Figure 4 based on RRD and design ESAL values. The minimum deflection value at which no overlay is needed depends on the number of ESALs estimated for the design period.

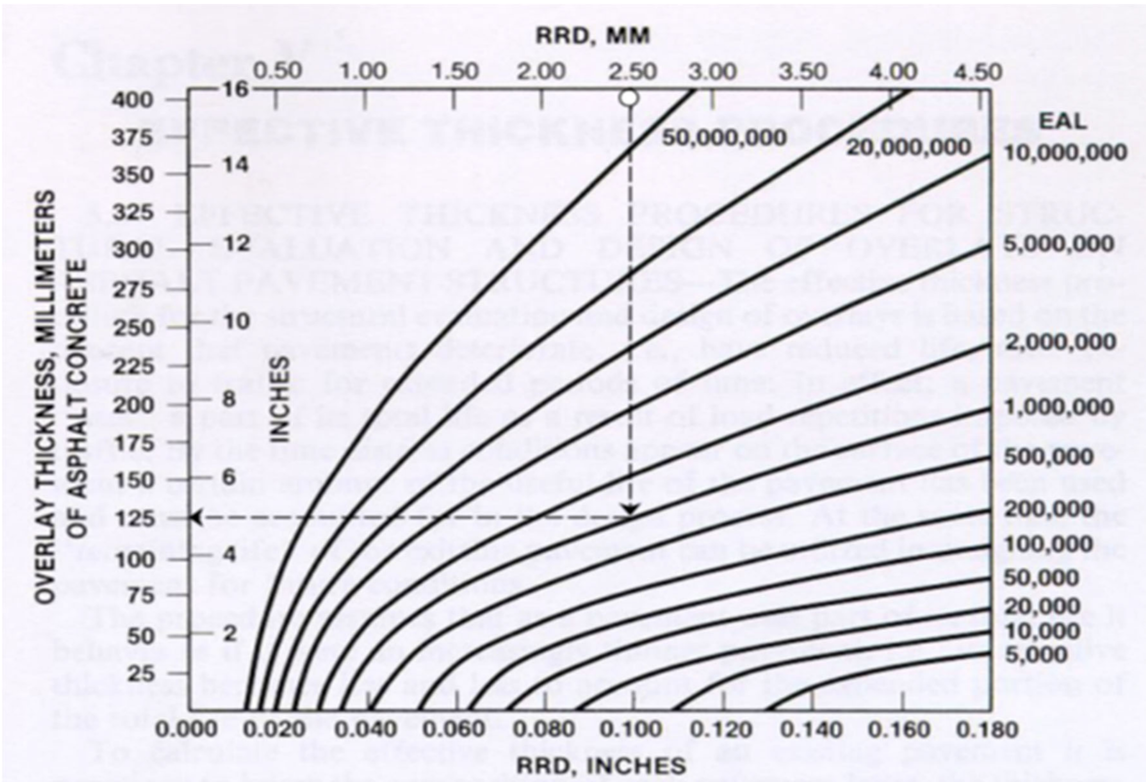

Figure 4: Asphalt Institute Overlay Design Chart

5.2 Paved Roadway Segments - AASHTO '93 Overlay Design Method

The AASHTO '93 method was used for the determination of the strengthening requirements for the paved/ACP surfaced roadways included in the scope. Therefore, measured FWD deflection data was analyzed as per the AASHTO '93 design methodology to determine overlay thicknesses for the 20-year design traffic. Following discussions with the City, a 70% design reliability was used during the analysis. It should be noted here that the recommended overlays were determined for the 20-year design as calculated in Table 2.

The design input values required by the AASHTO methodology and as outlined in "The City of Calgary Road Construction Specifications" are presented below:

FWD Deflection Data	– All sensors were made available for the analysis using an AASHTO based design program.
Design ESALs	– Design period of 20 years.

– A 3% growth rate compounded annually was used for calculating Design ESALs of:

	20-yr Design ESALs (× 10^6)
All Roadway Segments (except 84th St SE)	0.37
84th Street SE	2.50

Reliability	70%
Serviceability	Initial Serviceability = 4.2
	Terminal Serviceability = 2.5
	Serviceability Loss = 1.7
Overall Standard Deviation	S_o = 0.45
Resilient Modulus Correction Factor	0.36

5.3 Roadways with Overlay Strengthening and No-load Bans

The 2016 TAC Guide indicate that the use of MBD plus two standard deviations result in a more conservative weight restriction policies than current agency practices, and therefore recommends use of MBD in load ban calculations.

The required load ban is a percentage ratio of the MTD to the measured MBD. One of the following three (3) scenarios could exist for the MBD:

Scenario 1: MBD is greater than MTD – Load bans will be required. ACP overlay will be required to convert the roadway segment to a structurally adequate all-season road with no load bans.

Scenario 2: MBD is lower than MTD (relatively closer) - Load bans will not be required, but ACP overlay may be required to convert the roadway segment to a structurally adequate road. In this instance, RRD values (calculated by adding two standard deviations to MBD) get higher than MTD, resulting in a need for ACP overlay.

For some of the roadway segments where the MBD is lower than MTD one of the 2 approaches discussed below could be adopted:

- Maintain current load bans until the City decides to place recommended ACP overlay.
- Remove load ban in the short term and monitor the condition of the road. This should be followed by FWD testing and analysis of data collected and placement of the ACP overlay. However, it is recommended that the placement of the required ACP Overlay should not be delayed by more than three years following the removal of the load bans so as not to cause permanent damage to the pavement structure and the subgrade. This is in consideration of the 5 years validity period of measured FWD deflections.

Scenario 3: MBD is lower than MTD **–** No load bans will be required. If the MBD is much lower than MTD, estimated RRD value would stay below MTD and no overlay would be required. No load bans will be required.

6.0 Sensitivity Analysis

For sensitivity check, the AI method was used to estimate overlay thicknesses for paved roads. Required overlay thickness values at 50% reliability and the 70% reliability (recommended by The City using the AASHTO method) were calculated and compared with overlay thicknesses determined using the AI method. Overlay requirement values at 50 % reliability were comparable to the values obtained using the AI method. At 70 % reliability however, an additional average of 20 mm overlay was estimated.

The load bans determined from this analysis were compared with the load bans currently required by The City and recommendations have been made (where required) to adjust the road bans.

7.0 Summary of Load Bans and Overlay Recommendations

Detailed summary of the reviewed data, completed analysis, calculated load ban requirements and load ban recommendations are summarized in Table 3 to Table 6.

Table 3. Roadway Segments with 50% Load Bans - Summary of Required Load Bans and ACP Overlay Thicknesses

Street	Measured Mean Benkelman Deflection MBD (mm)	Current Load Ban (%)	Calculated Allowable Load Limit (%)	Proposed Load Bans (%)		Required ACP Overlay[1] (mm)
				Spring	Year Round	
Sheriff King Street SW (194 Avenue S.W. to 210 Avenue S.W south city limits)	1.9050	50	61	50	50	115
88 Street S.E. (End of pavement 700 m South of Marquis of Lorne Trail SE to 178 Avenue S.E.)	0.8636	50	100	-	-	150[3]
51 Avenue S.E. (68 Street SE to 52 Street SE)	1.7272	50*	67	50	50	105
54 Street S.E. (51 Avenue SE to 52 Avenue SE)	1.7272	50*	67	50	-	115
81 Street SW (17 Avenue SW to Spring Willow Mews SW)	1.5240	50	76	75	-	155
77 Street S.W. (26 Avenue SW to 17 Avenue SW)	1.0668	50	100	-	-	110[3]
Elmont Drive S.W. (Elkton Drive SW to 53 Elmont Drive SW)	1.3208	50	76	75	-	100
81 Street S.W. (Old Banff Coach Road SW to Westpark Place SW)	2.2098	50	52	50	50	200
144 Avenue N.W. (Evanston Hill NW To 620 m East of Evanston Hill NW)	0.8128	50*	100	-	-	0
144 Avenue N.W.[2] (620 m East of Evanston Hill NW To Center Street North)	0.8128	50*	100	-	-	75[3]

* Current load ban is Year-Round

1 – ACP overlay required to convert to All Season Road

2 – Lower pavement thickness observed in this segment of 144 Avenue NW.

3 – Roadways requiring no-load ban but need overlay strengthening

Table 4. Roadway Segments with 75% Load Bans - Summary of Proposed Load Bans and ACP Overlay Thicknesses

Street	Measured Mean Benkelman Deflection MBD (mm)	Current Load Ban (%)	Calculated Allowable Load Limit (%)	Proposed Load Bans (%)		Required ACP Overlay[1] (mm)
				Spring	Year Round	
101 Street S.W. (Glenmore Trail S.W. (Hwy. 8) to Old Banff Coach Road S.W.)	0.7112	75	100	-	-	0
85 Street S.W. (Timberline Gate S.W. to 160m North of Timberline Gate S.W.)	1.1938	75	97	90	-	0
85 Street S.W.[A] (160m North of Timberline Gate S.W. to Mystic Ridge Gate S.W. (26 Ave S.W.))	1.1938	75	97	90	-	70
17 Avenue S.W.[B] (101 Street S.W. to 240m East of 101 Street S.W.)	0.9906	75	100	-	-	100[2]
17 Avenue S.W. (240m East of 101 Street S.W. to 93 Street S.W.)	0.9906	75	100	-	-	45[2]
Lower Springbank Road S.W. (Glenmore Trail S.W. (Hwy. 8) to 101 Street S.W.)	0.7874	75	100	-	-	40[2]
Garden Heights/23 Avenue S.E. (Twp Road 241A) (84 Street S.E. to 92 Street S.E. (RR 258A))	2.3876	75	49	50	50	100
34 Avenue S.E. (Twp Road 241) (84 Street S.E. to Dead End East)	1.8288	75	63	50	50	85
92 Street S.E. (Range Road 285A) (Dead End North to Dead End South)	2.4892	75	47	50	50	110
88 Street S.E. (Range Road 285B) (23 Avenue S.E. (Twp 241A) to 34 Avenue S.E. (Twp 241))	2.2860	75	51	50	50	115
84 Street S.E.	1.4478	75	60	50	50	120

Table 4. Roadway Segments with 75% Load Bans - Summary of Proposed Load Bans and ACP Overlay Thicknesses

Street	Measured Mean Benkelman Deflection MBD (mm)	Current Load Ban (%)	Calculated Allowable Load Limit (%)	Proposed Load Bans (%)		Required ACP Overlay[1] (mm)
				Spring	Year Round	
(114 Avenue S.E. to Dead End North)						
114 Avenue S.E. (Twp 232) (84 Street S.E. to Railroad tracks east of Shepard Industrial Park)	1.0160	75	100	-	-	75[2]
84 Street S.E. (138 Avenue S.E to720m North of 138 Avenue S.E)	1.3970	75	62	50	50	110
84 Street S.E. (720 m North of 138 Avenue S.E to 114 Avenue S.E)	0.7874	75	93	90	-	40
138 Avenue S.E. (Twn Road 230A) (84 Street S.E. to 100 Street S.E.)	2.0066	75	58	50	75	110
Spruce Meadows Way S.W. (Spruce Meadows Entrance to 620 m South of Spruce Meadows Entrance)	2.4130	75	48	50	50	210
Spruce Meadows Way S.W. (620 m south of Spruce Meadows Entrance to 210 Avenue S.W. (south city limits))	1.3208	75	88	75	-	35
210 Avenue S.W. (Spruce Meadows Way S.W. to Sheriff King Street S.W.)	1.4732	75	79	75	75	75
24 Street S.W. (Bridlewood Avenue S.W. to 186 Avenue S.W. (South city limits))	1.7526	75	66	50	-	295
114 Avenue S.E. (Twp 232) (84 Street S.E. to Cul-de-sac West)	0.9906	75	100	-	-	105[2]
37 Street S.W. (146 Avenue S.W. to Spruce Meadows Trail S.W.)	0.7366	75	100	-	-	15

Table 4. Roadway Segments with 75% Load Bans - Summary of Proposed Load Bans and ACP Overlay Thicknesses

Street	Measured Mean Benkelman Deflection MBD (mm)	Current Load Ban (%)	Calculated Allowable Load Limit (%)	Proposed Load Bans (%)		Required ACP Overlay[1] (mm)
				Spring	Year Round	
69 Street S.W. (Spruce Meadows Trail S.W. (Hwy 22X). to 146 Avenue S.W.)	2.2352	75	52	50	50	110
85 Street S.W. (Spruce Meadows Trail S.W. (Hwy 22X). to 420 m North of Spruce Meadows Trail S.W. (Hwy 22X)	2.3368	75	50	50	50	125
85 Street S.W. (420 m North of Spruce Meadows Trail S.W. (Hwy 22X) to Cul-de-sac North)	2.3368	75	50	50	50	125
53 Street S.W. (Spruce Meadows Trail S.W. to 146 Avenue S.W.)	2.5146	75	46	50	50	115
15 Street N.E. (144 Avenue N.E. to 128 Avenue N.E.)	1.6002	75	72	75	75	110
6 Street N.E. (RR 12) (176 Avenue N.E. (Hwy 566) to 144 Avenue N.E.)	2.6162	75	44	Trucks Prohibited	50	120
6 Street N.E. (144 Avenue N.E. to Cul-de-sac South)	2.4384	75	48	50	50	110
144 Avenue N.E. (6 Street N.E. to 15 Street N.E.)	2.4130	75	48	50	50	115
144 Avenue N.E. (Metis Trail N.E. to 52 Street N.E.)	2.4130	75	48	50	-	125
100 Street S.E./ Garden Road (Range Road 285) (17 Ave S.E. / Hwy 1A to Pegigan Trail S.E.)	2.1336	75	54	50	50	115
100 Street S.E./ Garden Road (Range Road 285) (17 Ave S.E. / Hwy 1A to 8 Ave N.E.)	0.8382	75	100	-	-	0
146 Avenue S.W. (37 Street S.W. to Fish Creek Boulevard S.W.)	1.0668	75	100	-	-	85[2]

[A] – Lower pavement thickness observed in this segment of 85 Street S.W.
[B] – Lower pavement thickness observed in this segment of 17 Avenue S.W.
[1] – ACP overlay required to convert to All Season Road
[2] – Roadways requiring no-load ban but need overlay strengthening

Table 5. Roadway Segments with 90% Load Bans - Summary of Proposed Load Bans and ACP Overlay Thicknesses

Street	Measured Mean Benkelman Deflection MBD (mm)	Current Load Ban (%)	Calculated Allowable Load Limit (%)	Proposed Load Bans (%)		Required ACP Overlay[1] (mm)
				Spring	Year Round	
146 Avenue S.E. (Twp Road 230) (120 Street S.E. (RR 285) to 360 m West of 120 Street S.E. (RR 285))	1.3462	90*	86	75	-	130
146 Avenue S.E. (Twp Road 230) [A] (360 m West of 120 Street S.E. (RR 285) to 100 Street S.E. (RR 290))	1.3462	90*	86	75	-	170
178 Avenue S.E. (TWP 224) (88 Street S.E. to Range Road 285 S.E.)	2.1082	90	55	50	50	105
104 Street (Marquis of Lorne Trail to 178 Avenue)	2.2606	90	51	50	50	100
37 Street S.W. (Spruce Meadows Trail S.W. (Hwy 22X) to South city limits (approx. 430 m south of Spruce Meadows Trail))	1.0922	90	100	-	-	110[3]

[1] ACP overlay required to convert to All Season Road
[2] Current Load Ban is Year-Round
[3] Roadways requiring no-load ban but need overlay strengthening
[A] Lower pavement thickness observed in this segment of 146 Avenue S.E. (Twp Road 230).

Table 6. Summary of Proposed Load Bans & Overlay Thicknesses to No-load Bans (Truck Prohibited Roadways)

Street	Measured Mean Benkelman Deflection MBD, (mm)	Current Status - Load Ban (%)	Calculated Allowable Load Limit (%)	Proposed Load Bans (%)		Required ACP Overlay[1] (mm)
				Spring	Year Round	
85 Street N.W. (RR 23) (144 Avenue N.W.to City limit 800 m South of Township Road 261A)	1.2446	Trucks Prohibited	93	90	-	125
Rocky Ridge Road N.W. (Country Hills Boulevard N.W.to 144 Avenue N.W.)	0.7366	Trucks Prohibited	100	-	-	25[2]
Panorama Road N.W. (RR 15) (144 Avenue N.W.to 176 Avenue N.W. (Hwy 566))	2.5654	Trucks Prohibited	45	Trucks Prohibited	Trucks Prohibited	130
Mountain View Road N.W. (RR 20) (Symons Valley Road N.W.to City Limits, 980 m North of Symons Valley Road N.W.)	1.143	Trucks Prohibited	100	-	-	120[2]
14 Street N.W. (RR 14) (144 Avenue N.W.to 176 Avenue N.W. (Hwy 566))	2.7686	Trucks Prohibited	42	Trucks Prohibited	Trucks Prohibited	120
36 Street N.E. (Airport Trail N.E.to 67 Avenue N.E.)	0.9398	Trucks Prohibited	100	-	-	50[2]
36 Street N.E. (144 Avenue N.E.to Cul-de-sac South (S of 144 Ave))	2.1844	Trucks Prohibited	53	50	50	115
210 Avenue S.W. (Sheriff King Street S.W.to Macleod Trail South)	0.7366	Trucks Prohibited	100	-	-	0

[1] ACP overlay required to convert to All Season Road
[2] Roadways requiring no-load ban but need overlay strengthening

8.0 Conclusion

This paper presents a summary of the results of the load ban assessment and analysis results for the roadway segments subjected to load restrictions in the City of Calgary.

The City currently have weight restrictions on 49 roadway sections within its road network. The restrictions are enforced during the spring season for some roadway sections and year-round for some others. Existing load bans range from - Trucks Prohibited; 50% load bans (spring and year-round); 75% spring load ban; and 90% load ban (spring and year-round) on various road segments. The City retained Tetra Tech to evaluate the adequacy of the current load bans. Analysis was also completed to determine the structural strengthening required for conversion of these roadway segments into all season roadways with no load bans.

Established guidelines in the 2016 Transportation Association of Canada (TAC) Guide to Load Management for Weak Pavement Structures were followed to determine weight limits or load bans based on the relationship between MBD and design MTD allowed on the various roadway segments. To determine strengthening requirements, the unpaved and paved road structures were designed using Asphalt Institute (AI) and AASHTO '93 design methodology for a 20-year design period respectively. In the AI method, measured FWD data was first converted into equivalent Benkelman Beam (BB) deflections, Representative Rebound Deflections (RRD) were calculated from the BB data, and overlay thickness were determined based on the 20-year design traffic. In the AASHTO '93 method, the collected FWD data was analyzed to determine required overlay thicknesses. The recommended overlay thicknesses were calculated to convert the roadway segments with load restrictions to all season roads with no load bans.

The roadway sections with recommended load bans and required overlay thicknesses are included in this paper. During the analysis, it was observed that some roadways do not require load bans, but they need overlay to be classified as all season roads with no load restrictions. Two approaches are proposed to resolve these cases:

- Maintain current load bans until the City decides to place recommended ACP overlay; or
- Remove load ban in the short term and monitor the condition of the road. This should be followed by FWD testing and analysis of data collected and placement of the ACP overlay. However, it is recommended that the placement of the required ACP Overlay should not be delayed by more than three years following the removal of the load bans so as not to cause permanent damage to the pavement structure and the subgrade.

9.0 Future Work

FWD testing (3 rounds) is scheduled for this year. The data will be analyzed to determine the deterioration (if any) and revise the load ban requirements for the various roadway segments. This data will be analyzed and included in the presentation at the fall conference.

10.0 References

1. Kingham Ian, Asphalt Institute Asphalt Overlay Design. 1969. Transportation Research Board 48th Annual Meeting https://onlinepubs.trb.org/Onlinepubs/hrr/1969/300/300-007.pdf.

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3. City of Calgary Roads Construction Standard Specifications. 2015. https://www.calgary.ca/content/dam/www/transportation/roads/documents/contractors-and-consultants/roads-construction-2015-standard-specifications.pdf