CALIBRATION OF ALBERTA FATIGUE TRUCK

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Paper prepared for presentation
at the Structures Session
of the Conference of the
Transportation Association of Canada
St. John’s, NL

Acknowledgements

The work presented in this paper was sponsored by the Technical Standards Branch of Alberta Transportation.

ABSTRACT

The Province of Alberta uses one of the heaviest design trucks in Canada for the design of its highway bridges. Despite the use of a CL-800 design truck, most of the fatigue damage is caused by the more frequent trucks rather than the heaviest trucks used for design at the ultimate limit states level. The Canadian Highway Bridge Design Code, CSA-S6-14, uses a fatigue design truck with a GVW of 52% of the design truck and a further reduction of 27% is applied when the volume of heavy trucks not more than the greater of 200 trucks per day or 5% of the ADTT. In order to verify whether these fatigue truck factors are still valid for traffic on Alberta highways, a re-calibration of the fatigue truck was conducted using an extensive database of weigh-in-motion data collected from six sites from September 2004 to July 2013. The data collection sites include Highway 2 at Leduc and at Red Deer, Highway 2A at Leduc, Highway 3 at Fort MacLeod, Highway 16 at Edson, and Highway 44 at Villeneuve.

The data processing consisted of filtering the data to eliminate data that were found to be unreliable either because of excessive vehicle speed, unrealistic axle spacing or weights, and light trucks that would not have any impact on the fatigue damage of bridges. Filtering of the raw data resulted in the elimination of about 90% of the collected data at each site. However, approximately 30 million trucks were retained for the calibration of a fatigue truck for Alberta highways.

The calibration of a CL-800 truck was conducted for the double slope fatigue curves defined in CSA-S6-14 using four different influence lines, namely, the midspan moment of a simply supported span and the moments at midspan of the end span, at the midspan of an interior span and at an interior support of a four span continuous beam. Span lengths from 2 m to 70 m were investigated. The calibration for all six WIM sites indicated that the calibration factor varies with span length, but is essentially constant for span lengths longer than 12 m and decreases significantly for shorter span lengths. Although the results for most WIM sites were similar, the Edson site showed slightly heavier trucks than at the other sites. The trucks at Highway 2A at Leduc (having the lowest traffic volume of all sites) were found to be significantly lighter than at the other sites, resulting in smaller calibration factors for all span lengths.

The calibration of the fatigue truck was conducted for the number of equivalent stress cycles specified in CSA-S6-14. The calibration process supported a fatigue truck factor of 0.52 for bridges with span lengths greater than or equal to 12 m. A linearly variable fatigue truck factor is proposed for spans shorter than 12 m. It was found that the factor C_L as presented in CSA-S6-14 is adequate for low traffic roads, although this could be verified at only one location in Alberta.

1. INTRODUCTION

With the aging of the Canadian Highway bridges, more effort is devoted to assess existing bridges for their remaining fatigue life than ever before. This information is crucial for the management of existing bridges within the constraint of limited budgets and optimal use of available resources. The quality of the remaining life prediction greatly depends on the quality of the truck used to conduct the fatigue assessment. It is important that the fatigue truck used for bridge evaluation be representative of the local traffic that impacts the fatigue response of the bridge being evaluated. Although Alberta Transportation collects traffic volumes on provincial highways at many site around the province, the data do not provide specific information about axle weights and spacing. However, knowledge of axle weights and spacing is critical in assessing the fatigue damage on bridge components.

To better understand the nature of the traffic on Alberta Highways, in 2004 Alberta Transportation installed weigh-in-motion (WIM) systems at six different sites in and data were collected over the period September 2004 to July 2013. WIM is the process by which the static vehicle tire loads or axle loads are estimated from measurements of the dynamic forces of moving vehicles. WIM data provide a representation of the axle or wheel load distribution from moving vehicles on the highway, which can be different from static measurements. The database of WIM data collected in Alberta contains the axle loads and spacing for over 254 million vehicles and was collected at six different sites located in the south and central regions of Alberta. Although data was collected mainly for pavement studies, its value for the re-calibration of the Alberta fatigue truck was recognized by the Technical Standards Branch of Alberta Transportation and AECOM was mandated to review the available datasets and calibrate a fatigue truck representative of highways in Alberta. The main objective of this re-calibration was to obtain a truck weight distribution that can be more representative of the current highway traffic to improve the accuracy of fatigue life predictions.

The following describes the calibration process, which includes data filtering used to improve the reliability of the database, the truck calibration results, and recommendations for the number of design stress cycles experienced by a bridge for each passage of the design truck. More details of this Alberta Transportation sponsored project can be found in reference 1.

1.1 Current Practice

The fatigue truck used in CSA-S6-14 consists of a CL-W truck configuration shown in Figure 1, with two calibration factors to account for the fact that the truck used for design at the ultimate limit state and at the serviceability is heavier than the most common trucks on Canadian highways that cause the fatigue damage to bridges. The aggregate factor consists of 0.52 C_L where C_L is a modification factor used when the design truck for a province is heavier than the CL-625 truck. This factor is used for low volume roads where the daily truck traffic is less than 200 per day and represents no more than 5% of the ADTT on the highway. The expression for this factor is $C_L = 0.20 + 500/W$ where *W* is the design truck weight. For the Alberta CL-800 design truck this factor is 0.825. The factor 0.52 is the calibration factor for the CL-625 truck and other CL-W trucks on the higher volume roads. Both factors were verified as part of the re-calibration presented in this paper.

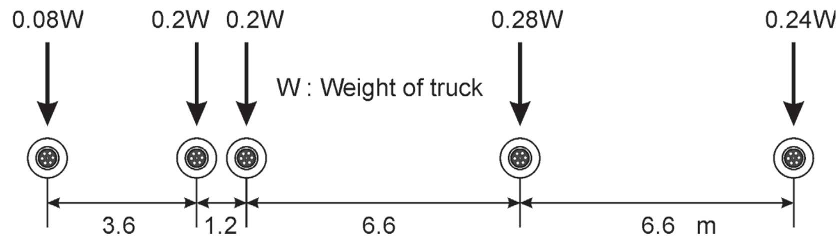


Figure 1 – CSA-S6-14 CL-W truck axle configuration

A factor that affects calibration significantly is the fatigue curve used for the calibration. The North American fatigue curves are expressed as a linear relationship between the log of the stress range and the log of the fatigue life, expressed in cycles of loading. This relationship takes the form of the commonly known S-N curves (stress range versus fatigue life). This is illustrated in Figure 2 for fatigue categories A to E1, which represents different levels of stress concentration in the fatigue details each curve represents. The 2014 edition of CSA-S6 adopted double slope curves, with a shallower slope below the constant amplitude fatigue limit to reflect the effect of variable amplitude loading at low stress ranges. Further discussion of the fatigue curves presented in Figure 2 is presented later in this paper.

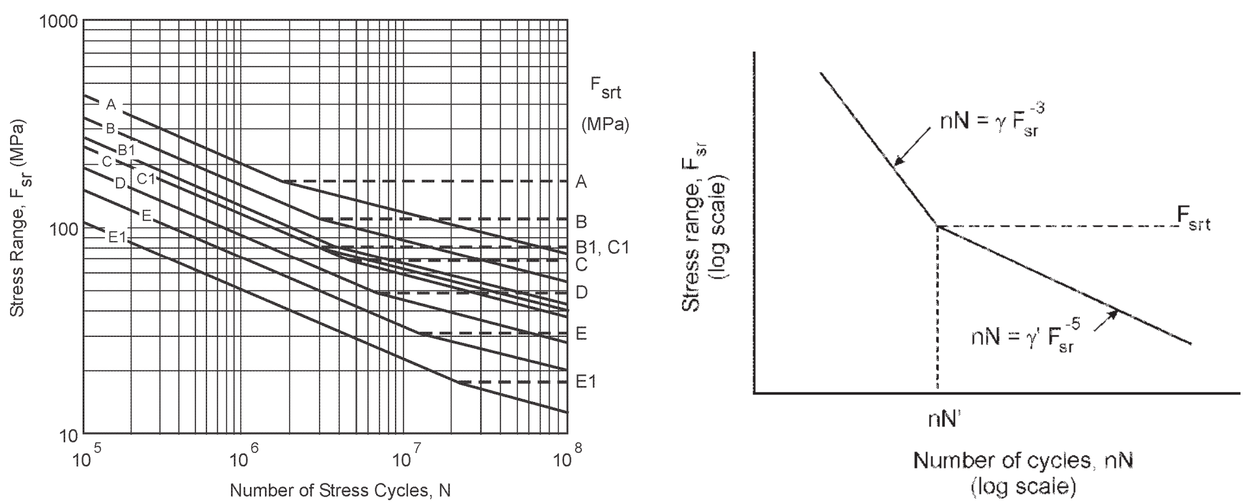


Figure 2 – CSA-S6-14 Fatigue Curves

2. FATIGUE TRUCK CALIBRATION PROCESS

Calibration of a fatigue truck involves three main components: collection and filtering of WIM data, derivation of a truck load factor (currently set at 0.52 for the CL-625 truck in CSA-S6-14), and the derivation of an equivalent number of stress cycles per passage of a design truck. The overall weight of the current Canadian fatigue truck is 0.52 x 625 = 325 kN for a CL-625 design truck and 416 kN for a CL-800 design truck. When the fatigue truck is calibrated for a CL-800 truck, the current factor is reduced to 0.43 for low truck traffic volume roads, which results in a fatigue truck weight of 0.43 x 800 = 344 kN. Low truck traffic volume is defined in CSA-S6-14 as a volume of heavy trucks not more than the greater of 200 trucks per day or 5% of the ADTT.

The calibration process involves:

1. Screening of database – The screening of the data files is critical to ensure that the data is reliable.

2. Running each truck from the screened database influence lines representing the force effects at various locations along bridges of various configurations and span lengths to obtain the stress history at various locations. The calibration of the CHBDC made use of single, double span and five span bridges with equal spans varying from 2 m to 70 m. Similar configurations can be used for the calibration of the Alberta truck.
3. For each stress history at various locations along the sample bridges, a rainflow analysis is conducted to determine the stress range spectrum for each detail of interest.
4. Using a Miner's fatigue damage assumption, the fatigue damage caused by the real trucks is calculated for each point of interest and each bridge configuration.
5. Steps 2 to 4 are repeated for the CSA-S6-14 design truck. The fatigue truck factor is obtained by equating the damage from the entire database of trucks to the damage caused by the CHBDC truck driven across the bridge the same number of times as the number of trucks in the database.
6. A fatigue truck factor or multiple fatigue truck factors representative of Alberta truck traffic are then selected for the various truck configurations investigated.
7. Design and evaluation of fatigue damage in highway bridges is based on the maximum stress range created by the passage of the design truck on the bridge, although the passage of a single truck can create multiple stress ranges of different magnitudes. Therefore, the second aspect of the calibration process involves the determination of the equivalent number of stress cycles per design truck passage. This calculation is based on the truck factor selected in step 6 and the fatigue damage calculated in step 4.

3. SCREENING OF WIM DATA

WIM truck data represent a valuable source of information about the actual truck configurations and weights on the roads. However, this information is only as good as the quality of the data. In order to control the data quality, ASTM E1318 sets clear guidelines that must be followed during data collection to minimize data error. In addition, it is critical that the data be screened before use to eliminate obvious errors and to eliminate very light vehicles that do not cause fatigue damage but would increase the truck count if they were kept in the database.

The filters adopted for the screening process apply to all the characteristics recorded by the WIM equipment, namely, truck speed, truck vehicle weight, axle weights, and axle spacing. The filters adopted for this work are as follows:

1. Remove any truck with speed higher than 130 km/h. For type II WIM systems used in this program, ASTM E1318 states that the data-collection system shall be capable of accommodating vehicle speeds up to 130 km/h. Therefore, when the recorded vehicle speed is significantly higher than 130 km/h the recorded values may be unreliable. Other research programs in the U.S., which are based on the same standard, have used a limit of 160 km/h for screening. However, based on a dataset of almost 2 million trucks in Manitoba, it was found that less than 5% of trucks are driving at a speed greater than 110 km/h (MacAngus *et al*., 2012). Therefore, the proposed 130 km/hr should capture most, if not all, valid trucks from the database.

2. Remove trucks with speed less than 15 km/h. Slow moving traffic can create difficulty in separating vehicles, causing multiple vehicles being combined as a single vehicle. Since the data are collected at a site other than the bridge site, the collected data would not be representative of the vehicle's configuration on a bridge.
3. Remove trucks with a gross vehicle weight (GVW) less than 53 kN. This limit is proposed to keep the truck count to a level that is high enough to cause fatigue damage. A value of 53 kN has been used by other researchers (Sivakumar *et al*. 2008).
4. Remove trucks with lengths greater than 45 m. The truck length regulation limit in TAC (1991) is set at 25.0 m. However this limit can easily be exceeded in the case of special permit trucks. Therefore, an allowance for permit trucks that exceed the standard limit is made in the screening. However, to avoid the combination of several vehicles (e.g. a five axle truck with a passenger car) a limit is set on the total length of a truck. A sensitivity analysis was conducted for truck lengths from 40 m to 70 m for trucks from the Leduc and Red Deer stations on Highway 2 and it was found that there are very few trucks that are longer than 40 m and only 3 trucks out of about 100 million trucks were found to be longer than 60 m. It was found that for a 40 m length as the cut-off, slightly more than 4000 trucks (less than 0.1 % of the total number of trucks) would have been eliminated from the Red Deer site and even fewer trucks from the Leduc site database. At a 45 m truck length, although up to 374 trucks are eliminated if the filter is applied on the total database, it is found that these trucks get eliminated by the first three filters described above, thus making the 45 m length limit inconsequential for the data files used for this sensitivity study.
5. Remove trucks with steering axle weight greater than 95 kN since the Alberta limit is set at 90 kN and carry out a sensitivity analysis. Sivakumar *et al*. (2008) observed that the average steer axle weight is fairly constant and significant deviation of steer axle weights is a sign of scale operational problems. Therefore, a limit is placed above the TAC (1991) limit for the steer axle weight of 70 kN.
6. Remove trucks with a total number of axles ≤ 2. This allows school buses or ambulances, which can be fairly heavy, to be retained in the database. Passenger vehicles and light weight pick-up trucks do not cause fatigue damage and are removed through the minimum GVW filter.
7. Remove trucks with any individual axle weight (except steer axle) < 9 kN or > 200 kN. The effect of the light axle removal was found to be small for the database for Highway 2 since less than 1% of the trucks were eliminated from this filter once all the previous filters were applied. Although a maximum axle weight of 310 kN was proposed by Sivakumar *et al.* (2008), this value was found to be too large and was reduced to 200 kN. It was found that none of the trucks were eliminated by the maximum individual axle weight filter.
8. Remove trucks with any axle spacing less than 1.0 m.

Although filtering reduces random error in the data, it does not eliminate the systematic error that would result from incorrect calibration of the equipment. This is why ASTM E1318 has performance requirements that are aimed at keeping this source of error under control.

A summary of the filtering process results is presented in Table 1 where the number of trucks remaining after filtering varies from 3.3% for Highway 2A in Leduc to 21.3% for Edson. The Highway 2A site in Leduc is a secondary road and, although it sees a lot of traffic, the truck traffic is at a much lower frequency than at all the other sites measured. When all the sites are pooled together it is found that

11.4% of the vehicles in the WIM database are trucks, which represents a data set for the calibration of 28.9 million trucks. This provides a statistically significant data set of trucks to conduct the calibration. Furthermore, with the smallest subset of data including 740 550 trucks, the subsets are sufficiently large to perform the analysis on each WIM site separately to enable a comparison of the different sites. It is also noted that the smallest subset of 737 306 trucks represents a daily truck traffic of just slightly over 200 (i.e. it is 226). Therefore, this set will be used to verify the fatigue factor C_L used for low volume traffic roads.

Table 1 – Results of Data Filtering

	No. trucks before filtering	No. of trucks after filtering	Percentage of trucks in database (%)
Edson Site	21 438 630	4 654 450	21.3
Highway 3 at Fort MacLeod	21 336 752	2 144 207	10.1
Villeneuve	20 517 709	4 191 405	20.4
Highway 2 at Red Deer	98 771 096	9 707 352	9.8
Highway 2 at Leduc VIS	69 192 449	7 511 565	10.9
Leduc 2A	22 440 898	737 306	3.3
SUM	253 697 534	28 866 520	11.4

4. CALIBRATION PROCEDURE

The filtered data consist of trucks defined by axle weight and axle spacing. This database of trucks was used for the calibration process, which consists of the following steps, illustrated in Figure 3.

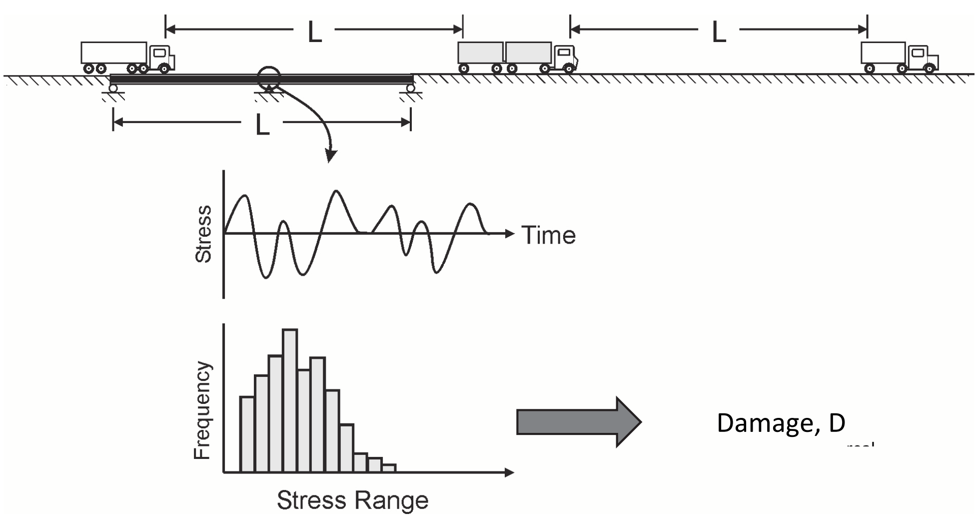
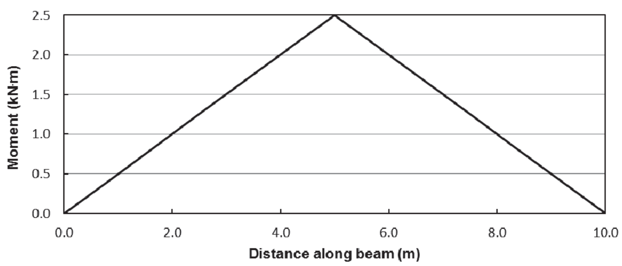


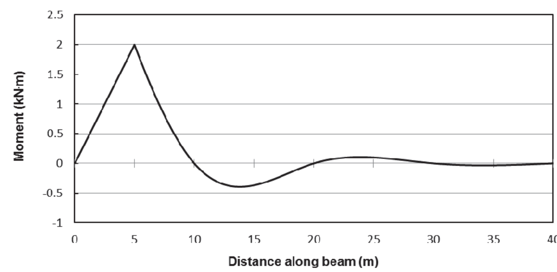
Figure 3 – Schematic of the calibration process

1. A moment versus time history for the database of trucks is generated for each site. This consists of moving each truck on the influence line corresponding to the load effect in

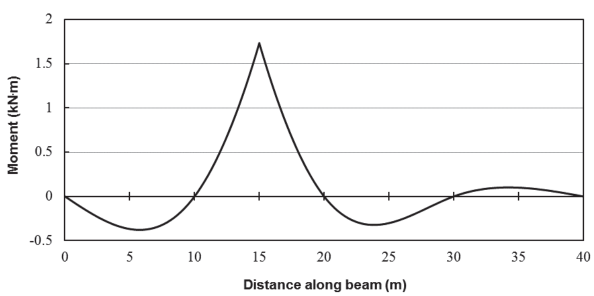
increments of L/20 where L is the span length. The calibration was conducted using four different influence lines, illustrated in Figure 4 for a span length of 10 m. The influence lines used are: midspan moment of a simple span; midspan moment for the end span of a four span continuous beam; the midspan moment for an interior span of a four span continuous beam; and the moment at an interior support. Coughlin and Walbridge (2010) have shown that shear does not govern the calibration of fatigue trucks. Therefore, only moment influence lines were used for the calibration of the Alberta fatigue truck.



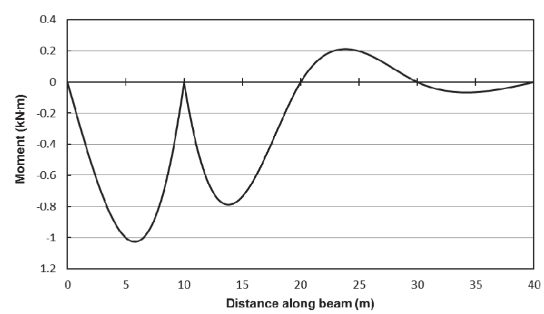
(a) Simply Supported Span Moment



(b) End Span Positive Moment – 4-span continuous



(c) Interior Span Positive Moment – 4-span continuous



(d) Interior Support Moment – 4-span continuous

Figure 4 – Moment influence lines for 10 m span length

2. As each truck from the database crosses an influence line, maximum and minimum moments are stored for further processing. Each influence line is loaded with each truck from the screened database. It is assumed that there is only one truck at a time on the bridge and each truck is moved along the moment influence lines in steps of L/20 where L is the span length.

3. The moment history is converted to a moment range spectrum using the rainflow method to count the moment ranges. The rainflow counting method is one of the most widely used cycle counting methods and is recommended in ASTM E1049-85 (2011). The moment range spectrum is converted into a stress range spectrum by dividing the moment range by a constant, equivalent to the elastic section modulus of the girder. This constant is obtained by dividing the maximum moment range by a stress range of about 150 MPa for the maximum moment obtained from the single span moment influence line. Although the same constant is used for all the influence lines of a given span length, different values are used for different span lengths. A reference stress range of 150 MPa was arbitrarily selected to convert the moment range to a stress range since the calibration factor is not affected by

the reference stress range as long as the same constant is used for the actual trucks and the design truck stress ranges.

4. Fatigue damage caused by the trucks from the screened database (D_{real}) is computed using Miner's cumulative damage summation rule and the stress range spectrum. Similarly, the fatigue damage caused by the design truck (D_{code}) is obtained. Both D_{real} and D_{code} were obtained for all fatigue categories for the single slope (2006 edition of CSA-S6) and the double slope (2014 edition of CSA-S6) fatigue design curves. The double slope fatigue curves illustrated in Figure 2 are represented by Equations [1] and [2] where the exponent, m, is equal to -3 above the constant amplitude fatigue limit (CAFL) and equal to -5 below the CAFL.

$$N_c = \gamma' \times (\Delta\sigma)^{-5} \qquad \text{if } \Delta\sigma < \text{CAFL} \qquad [1]$$

$$N_c = \gamma \times (\Delta\sigma)^{-3} \qquad \text{if } \Delta\sigma \geq \text{CAFL} \qquad [2]$$

where γ and γ' are fatigue life constants depending on the fatigue category. Using Miner's rule, the fatigue damage is obtained from:

$$D_{real,3} = \sum_{i=1}^{N} \frac{n_i}{\gamma \times (\Delta\sigma_i)^{-3}} \qquad \text{for fatigue evaluation with m=3} \qquad [3]$$

where n_i is the number of stress cycles of magnitude $\Delta\sigma_i$ and *N* is the number of stress range values in the stress range spectrum, which was taken as 50 for this work. The calculations for a fatigue curve with a slope m=5 uses the same equation, except that equation [1] is used in the denominator of equation [3]. Because the design truck is driven on the influence lines only once, the fatigue damage D_{code} is obtained by multiplying the damage from one truck by the number of trucks in the filtered database, N_{truck} :

$$D_{code,3} = N_{truck} \sum_{i=1}^{n} \frac{1}{\gamma \times (\Delta\sigma_i)^{-3}} \qquad \text{for fatigue evaluation with m=3} \qquad [4]$$

where n is the number of stress cycles with the passage of a single CL truck on the influence line. The calculations for a fatigue curve with a slope m=5 uses the same equation, except that equation [1] is used in the denominator on the right hand side of equation [4].

5. The objective of the calibration being to make the damage from the design trucks to equal the damage from the real trucks, the fatigue truck factor is calculated as the mth root of the ratio of the damage caused by the trucks from the truck database, D_{real} , to the damage D_{code}. For a single slope fatigue curve with m = 3, this is expressed as:

$$\text{Fatigue truck factor} = \left(\frac{D_{real,3}}{D_{code,3}} \right)^{(1/3)} \qquad [5]$$

For a single slope fatigue curve with m = 5 (equation [1]), the fatigue truck damage is obtained from:

$$\text{Fatigue truck factor (FTF)} = \left(\frac{D_{real,5}}{D_{code,5}}\right)^{(1/5)} \qquad [6]$$

For double slope fatigue curves defined by equations [1] and [2] the fatigue truck factor will lie between the values obtained from equations [5] and [6]. In this case, the magnitude of the fatigue truck factor depends on the stress range level, which depends on the girder size and level of conservatism used in the design. In order to simplify the calibration process, calibration factors will be obtained from equations [5] and [6]; the design calibration factor will be based on the larger of the two. It should be noted that since D_{real} and D_{code} are both determined using the same fatigue curve, the fatigue constant γ, which reflects the fatigue category, cancels out in the formulation, which makes the fatigue truck factor, FTF, independent of the fatigue category when the calibration is performed for a single slope fatigue curve.

6. The last step in the calibration process consists of determining the number of stress cycles per single crossing of the design truck. Since the fatigue design process is based on the maximum stress range experienced at a detail of interest as the design fatigue truck crosses the bridge, an equivalent number of cycles that results in the same amount of damage as the real trucks is required. Figure 5 shows a typical stress variation at the middle of the end span of a 4-span continuous bridge with 4 m long spans as a CL-625 truck crosses the bridge. A rainflow analysis of this stress history indicates four major stress ranges, namely, 113 MPa, 104.4 MPa, 98.2 MPa and 23.9 MPa. The fatigue truck factor calculated in Step 4 is based on the fatigue damage resulting from these four stress ranges, calculated using a Minor's summation. Since fatigue design is based on the maximum stress range only, an equivalent number of cycles at the maximum stress range magnitude that will cause the same amount of fatigue damage as the fatigue damage caused by the variable amplitude fatigue loading is required. However, since the design fatigue truck factor might be selected as a different value from the calculated fatigue truck factor for this particular span length, another adjustment to the number of equivalent stress cycles is required to account for the discrepancy between the design factor and the calculated factor from Step 5. The procedure used to make these adjustments is based on the basis that the fatigue damage caused by the design truck, crossing the bridge as many times as there are trucks in the database used to calculate the real fatigue damage, is equal to the fatigue damage caused by the real trucks, D_{real}. This can be expressed as:

$$D_{real,3} = N_{truck} \times n \times \frac{1}{\gamma \times \left(FTF \times \Delta\sigma_{max,CL625}\right)^{-3}} \qquad [7]$$

where N_{truck} is the number of trucks in the database used to calculate D_{real}, n is the equivalent number of stress cycles at the maximum stress range $FTF \times \Delta\sigma_{max,CL625}$, which is the maximum stress range caused by the fatigue design truck, and FTF is the design fatigue truck factor. Equation [7] is based on calibration with a fatigue curve with slope m=3. For a calibration based on m=5, the exponent 3 is replaced by 5 and γ is replaced by γ'. The reader is reminded that since $D_{real,3}$ was calculated using the same fatigue detail category as for the design fatigue truck, the fatigue curve constant γ is found on both sides of equation [7] and it will effectively cancel out, which makes the calibration independent of the fatigue category. It is not, however, independent of the slope m of the fatigue curves. Equation [7] can be solved for the equivalent number of stress cycles per truck crossing, n, or for the fatigue truck factor, FTF, if the number of stress cycles is fixed is arbitrarily selected. For the Alberta fatigue truck calibration, the number of stress cycles per truck crossing was taken as the values presented in Table 10.5 of CSA-S6-14.

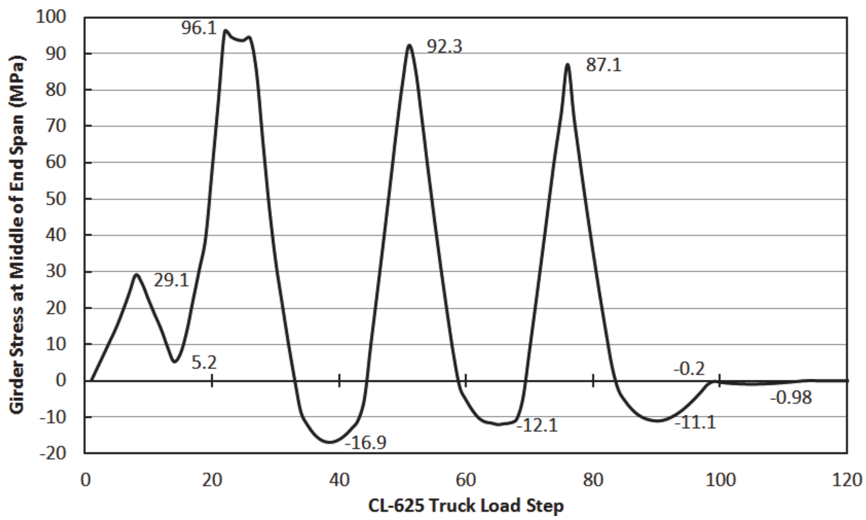


Figure 5 – Typical Stress History in Exterior Span of Four-Span Girder (Span Length = 4 m)

5. RESULTS OF CALIBRATION

Since the fatigue truck factors are independent of the fatigue category but dependent on the slope of the fatigue curves, calibration was carried out for two slopes, defined by m=3 and 5, separately. The correct calibration factor should lie between the two values and depends on the stress level in the members, i.e. the bridge cross-section, which is in turn a function of the designer of the bridge. Figure 6 presents sample calibration factors obtained with the truck data from the Red Deer WIM site. It should be noted that although calibration factors have been derived for short spans with multispan bridge configurations, the short span bridges are typically single spans and the calibration curves for the multispan bridges are just for illustration purposes in the short span range. Figure 6 shows that the calibration factors are higher for a fatigue curve slope, m, of 5. Although the calibration was carried out for m = 3 and m = 5, only the results for the more conservative slope, m = 5, are presented below.

The calibration factors presented in Figure 6 have not been processed through step 6 in the calibration procedure presented in the previous section. Although the last step of the calibration process affects the design fatigue truck factor, the effect of the difference between the two fatigue curve slopes will remain essentially the same.

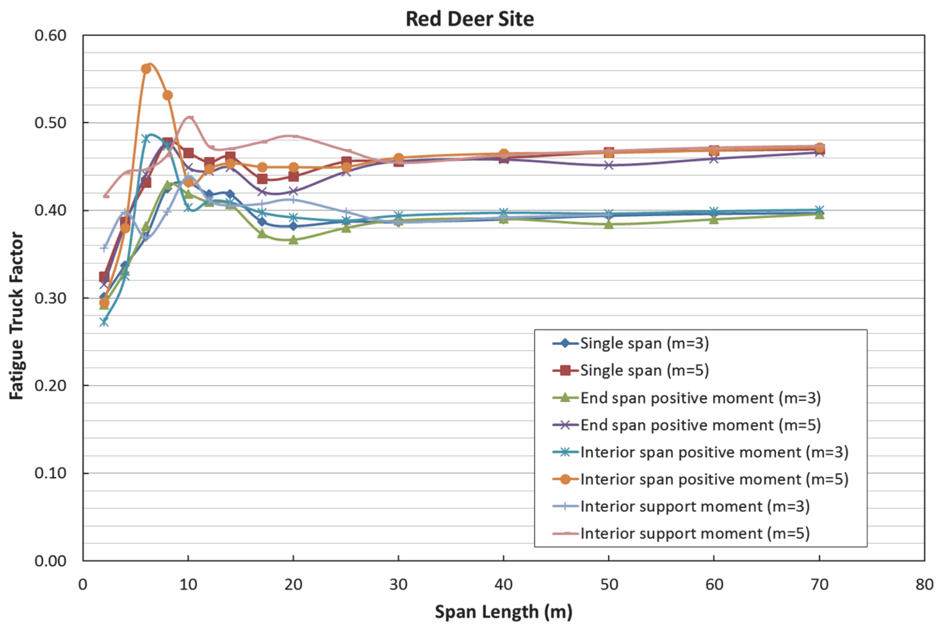


Figure 6 – Calibration factors for Red Deer Site (CL-800 truck)

Since the design truck in Alberta is the CL-800, the results of the calibration procedure for the six Alberta WIM sites are presented only for the CL-800 truck. Detailed fatigue truck factors for a CL-625 truck are presented in reference 1. Although Figure 6 calibration factors did not account for the number of stress cycles per truck crossing, the following results account for this factor using equation [7] and the number of stress cycles per truck crossing proposed in Table 10.5 of CSA-S6-14. Table 2 presents some of the number of cycles from Table 10.5 of CSA-S6 that were used for the calibration results presented in the following. Figures 7 to 12 show that the fatigue truck factor for bridge spans greater than about 20 m has reached a plateau. For span lengths shorter than about 12 m, the calibration factor significantly drops with decreasing span length. Note that for spans shorter than 12 m the fatigue truck factor is not presented for the multispan bridges since such short spans would not be used for multispan bridges. For span lengths between 12 m and 20 m the fatigue truck factor peaks to a value that can be over 15% higher than the value obtained for the span lengths greater than 20 m.

Table 2 – Number of stress cycles per truck crossing (from Table 10.5 of CAN/CSA-S6-14)

Condition	Span length, L, ≥ 12 m	Span length, *L,* < 12 m
Simple span girders	1.0	2.0
Continuous girders next to interior supports	1.5	2.0
Continuous girders all other locations	1.0	2.0

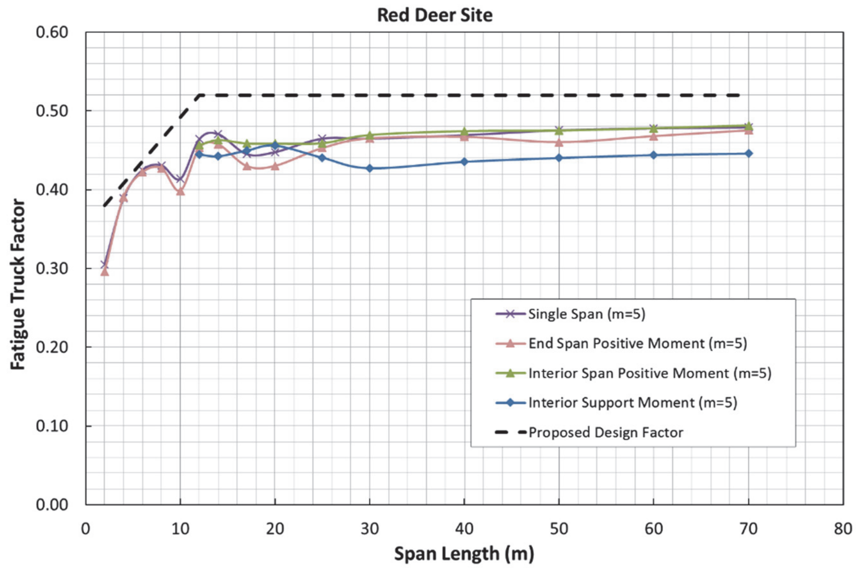


Figure 7 – Adjusted fatigue truck factors for Red Deer Site (CL-800 truck)

A comparison of the different WIM sites indicates that the fatigue truck factor for the Edson site (Figure 11) is slightly higher than for the other sites, although all sites show similar trends. The fatigue truck factors for the Fort MacLeod site provide almost identical results to those obtained from the Red Deer site data for all span lengths. The fatigue truck factor for Highway 2A at the Leduc site is consistently lower than for the other five sites, indicating that the trucks on Highway 2A are lighter than at the five other locations. Since Highway 2A is a local road, this trend was expected. Furthermore, the truck traffic volume at this site is relatively low, so the results will be used to verify the value of C_L .

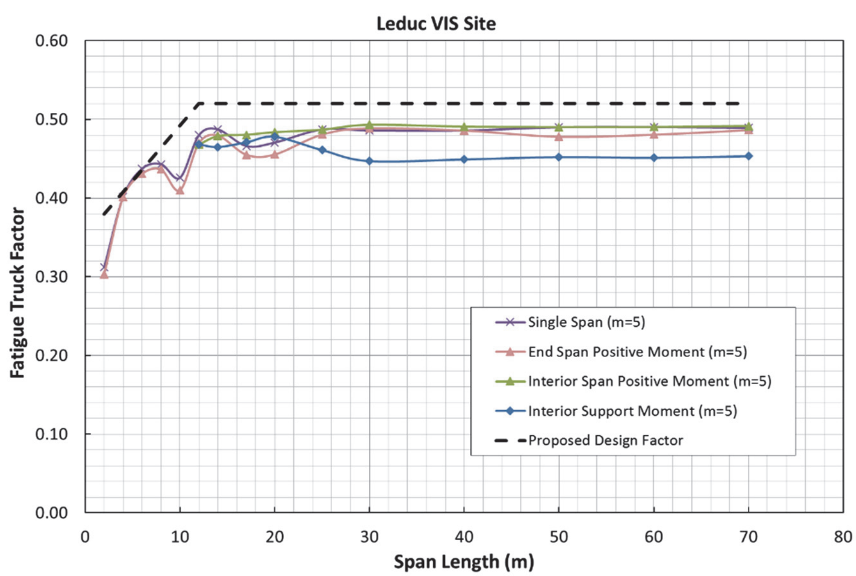


Figure 8 – Adjusted fatigue truck factors for Leduc Hwy 2 Site (CL-800 truck)

Since the data presented in Figures 7 to 12 indicate that the fatigue truck factor varies with span length, this variation should be accounted for in the design process. The approach used in CSA-S6 consists of selecting a single value of fatigue truck factor for all span lengths. The variation of fatigue truck factor with span length can then be accommodated by selecting the number of equivalent stress cycles per truck crossing for the selected value of fatigue truck factor so the fatigue damage caused by the design truck is the same as from the real trucks (i.e. adjusting the values in Table 10.5 of CSA-S6-14). An alternative approach is to select different fatigue truck factors for different span lengths and derive the number of equivalent stress cycles for the variable fatigue truck factors. Since it was decided to maintain the values of Table 10.5 unchanged, a variation of fatigue truck factor with span length was the approach selected.

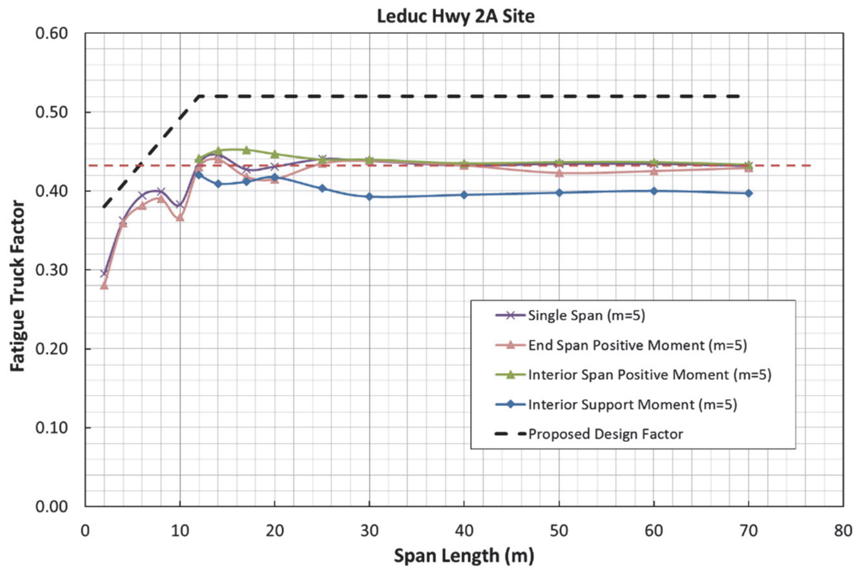


Figure 9 – Adjusted fatigue truck factors for Leduc Hwy 2A Site (CL-800 truck)

The black dotted line in Figures 7 to 12 represent the suggested calibration factor. For span lengths longer than 12 m, the recommended calibration is 0.52, i.e. the same value that is currently used in the Code. A reduced factor, which is linearly variable with span length, is recommended for spans shorter than 12 m. This is expressed as:

For $L < 12$ m, $FTF = 0.014\ L + 0.352$ [8a]

For $L \geq 12$ m, $FTF = 0.52$ [8b]

where L is the span length in metres. Equation [8a] is also applicable to transverse members with a spacing less than 6 m and Equation [8b] for transverse members with a spacing greater than or equal to 6 m.

The daily truck traffic for the Leduc 2A site is about 226 trucks per day, which brings it close to the limit of application of the C_L reduction factor of 0.824 proposed in CSA-S6-14 for the fatigue truck. The reduced fatigue truck factor, 0.52 C_L, is shown as a red dotted line in Figure 9 and seems to be a good fit for the Leduc Hwy 2A site. Therefore, based on this one site, the value of C_L in CSA-S6-14 seems justified.

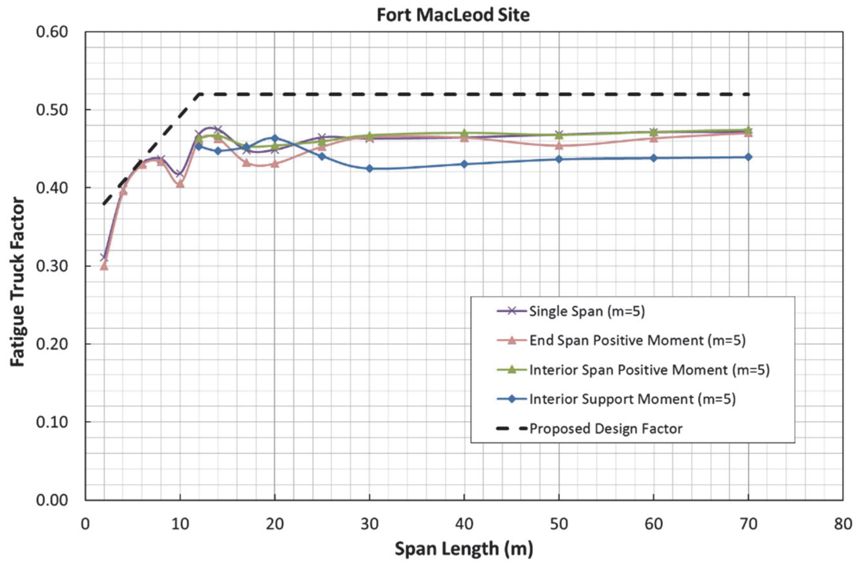


Figure 10 – Adjusted fatigue truck factors for Fort MacLeod Site

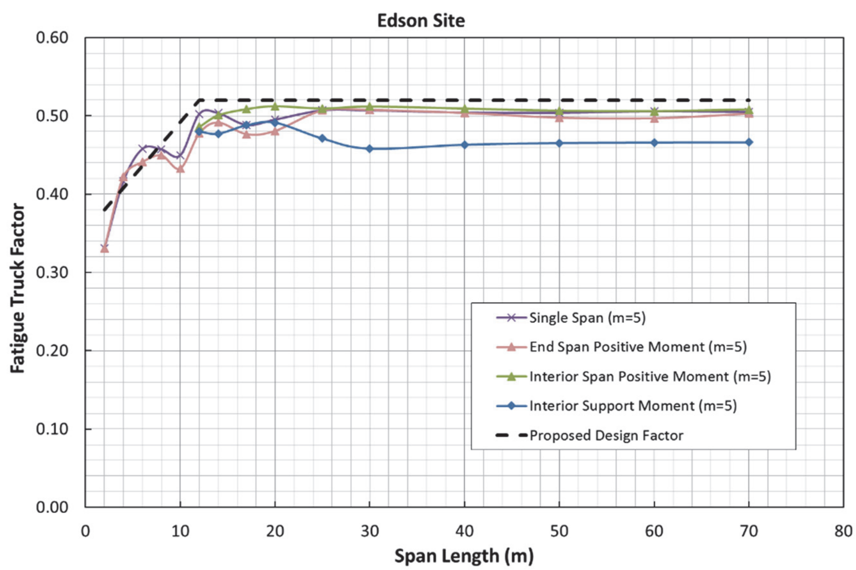


Figure 11 – Adjusted fatigue truck factors for Edson Site

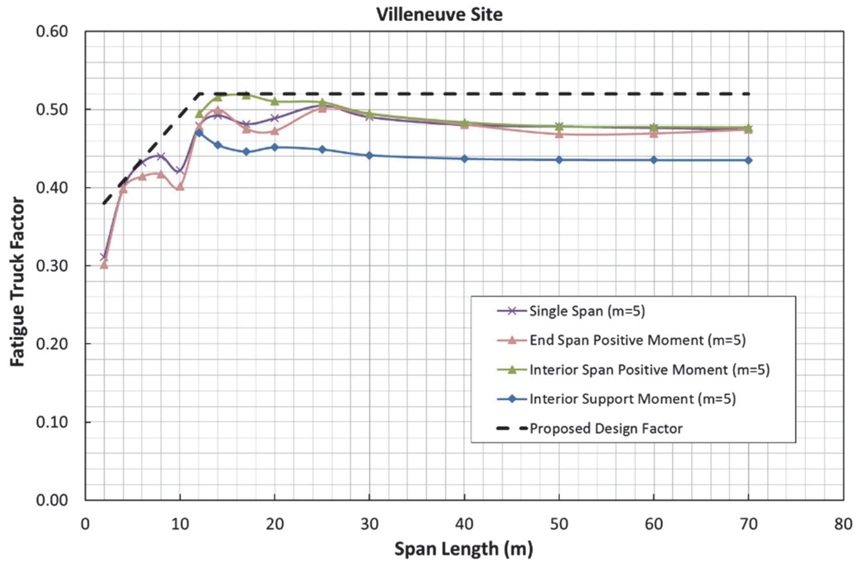


Figure 12 – Adjusted fatigue truck factors for Edson Site

6. SUMMARY AND CONCLUSIONS

Weigh-in-motion data collected from six sites in Alberta over a period spanning from September 2005 to July 2013 were used to calibrate a fatigue truck for the design of Alberta bridges. A screening process was developed that eliminated approximately 90% of the trucks. This resulted in a data set of about 28.9 million trucks distributed between the six WIM sites over the central and southern regions of Alberta.

The calibration was conducted for the double slope fatigue curves defined in CSA-S6-14 and the number of stress cycles per truck passage specified in Table 10.5. It was found that the fatigue load reduction factor, C_L, should be taken as 1.0 for a CL-800 design truck and a fatigue truck factor of 0.52 used for bridges with span lengths greater than or equal to 12 m. It was also found that the factor C_L as presented in CSA-S6-14 is adequate for low traffic roads, although this could be verified at only one location in Alberta. A linearly variable fatigue truck factor is proposed for short span bridges.

The data presented in this report support the current fatigue truck factor used in CSA-S6-14 along with the bi-linear fatigue curves, although the value of 0.52 is conservative for spans shorter than 12 m. A reduced fatigue truck factor is recommended to provide a more realistic prediction of remaining life for existing short span bridges.

7. REFERENCES

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