LOAD EFFECT ADJUSTMENTS IN THE
AASHTO LRFD SPECIFICATION BASED ON ADTT

Eric Steinberg, Ph.D., P.E.
and
Jibril Shehu
Department of Civil Engineering
Ohio University
Athens, OH

ABSTRACT

Several load factors in the AASHTO LRFD Bridge Design Specification are based on ADTT. The multiple presence factors for live load, as discussed in section 3.6.1.1.2 of the AASHTO LRFD Specification, are based on an assumed ADTT of 5000 in one direction. The approximate load distribution factors of section 4.6.2.2 and 4.6.2.3 already account for the multiple presence factors. Modifications to the force effects can be made if the ADTT is less than 1000. In addition, the frequency of the fatigue load is based on the ADTT. The ADTT can be estimated as a portion of the ADT per Table C3.6.4.2-1. Based on the ADTT from the 2003 NBI, the design of numerous bridges in the US should be taking advantage of the reductions to force effects. The percentages of the ADTT in the ADT are relatively accurate based on the 2003 NBI data.

Keywords: LRFD, Truck Live Load, Multiple Presence Factors, ADTT, Fatigue, and Bridge Design.

INTRODUCTION

Live Load:

The notional truck live load established for the AASHTO LRFD Design Specification[1] was developed utilizing a database of about 10,000 trucks from the Ontario Ministry of Transportation. This data was developed from a survey in 1975 at which time the Ontario truck population was assumed to be representative of trucks in the U.S. The truck data was then used to analyze numerous simple and two span bridges of varying length to determine the maximum moments and shears[2]. These results were relatively accurately assumed to be normally distributed. The truck survey occurred over a 2 week period and therefore it was assumed that nearly 20,000,000 trucks would occur over a 75 year design life (10,000 x 26 x 75). The moments and shear results were then extrapolated along the normal cumulative distribution function to arrive at various design truck lives[2], i.e. 75 year truck, 5 year truck, etc.

Analyses for single lane loading were then performed to account for one truck as well as two trucks in the lane separated by a headway distance. The single truck was the 75 year truck and the two truck analyses consisted of the following three combinations as shown in Table 1 below[2].

Table 1: Multiple Truck Analyses

Two-Truck Case	Truck	Truck Year	Correlation Coefficient, ρ
1	T1	1 year	0
	T2	Average	
2	T1	6 month	0.5
	T2	1 day	
3	T1	1 month	1.0
	T2	1 month	

The correlation coefficient, ρ, defines the correlation between the two trucks, T1 and T2. If the two trucks are independent of one another, $\rho = 0$. A high correlation means the trucks are directly related to one another. Though data did not exist to determine actual levels of correlation between two trucks, the assumption that a heavily loaded truck would more likely be followed by an average truck and two directly related trucks would more likely be of lesser magnitude seems reasonable.

The analyses also investigated the effect of loads in two lanes. This required assessment of the transverse distribution of the loads which is commonly done via load distribution factors. Two general types of loading were analyzed: one lane fully loaded with the other unloaded and both lanes loaded with varying levels of correlation of the truck loads between the lanes. The case of both lanes loaded by two fully correlated 2 month trucks controlled for interior girders[2]. The ratio of the response (shear or moment) from the 2 month truck compared to the 75 year truck was consistently about 0.85 for all spans. To account for differences in multiple lane loadings, a multilane live load factor was developed. The factor was taken as 1.00 for two lanes loaded with an ADTT of 1000 in each direction. Other multiple lane factors are shown in Table 2 below[2].

Table 2: Multiple Lane Loading Factor

ADTT (one direction)	Number of Lanes			
	1	2	3	4 or more
100	1.15	0.95	0.65	0.55
1,000	1.20	1.00	0.85	0.60
5,000	1.25	1.05	0.90	0.65

The AASHTO LRFD Specification shows similar factors known as Multiple Presence Factors, m[1]. These factors are provided in Table 3.6.1.1.2-1 of the LRFD Specification and provided below in Table 3.

Table 3: AASHTO Multiple Presence Factors

Number of Lanes	Multiple Presence Factor, m
1	1.20
2	1.00
3	0.85
> 3	0.65

The commentary of the LRFD Specification in Article 3.6.1.1.2 notes that the multiple presence factors were developed based on an ADTT of 5,000 in one direction and that the factors may be reduced for lower ADTT traffic. The reductions are 95% for ADTT between 100 and 1,000 and 90% for ADTT less than 100. The Multiple Presence Factors are also included in the distribution factors of Articles 4.6.2.2 and 4.6.2.3 in the LRFD Specification. Though it is not directly stated, it would seem to be implicit that the 95% and 90% reductions also then apply if ADTT is lower than 1,000 and the approximate distribution factor procedures are used. The question then arises, how many bridges have ADTT less than 1,000 or less than 100? In addition, how many bridges actually have an ADTT greater than 5,000.

Fatigue:

The other loading issue that incorporates ADTT in the LRFD Specification is fatigue loading. If the ADTT is not known, ADTT can be estimated as a portion of the ADT per Table C3.6.4.2-1 reproduced as Table 4 below.

Table 4: Fraction of Trucks in Traffic

Class of Highway	Fraction of Trucks in Traffic
Rural Interstate	0.20
Urban Interstate	0.15
Other Rural	0.15
Other Urban	0.10

NATIONAL BRIDGE INVENTORY

The 2003 National Bridge Inventory (NBI) was utilized to determine the number of bridges with ADTT values of 5,000 or more, less than 1,000 and less than 100. The results are summarized in Table 5 through 7. As shown in Table 5, California (CA) has the largest percentage of bridges with an ADTT ≥ 5,000 at about 15%. All but three states have a percentage less than 10%. Of all the bridges in the U.S., only about 4% have an ADTT greater than 5,000. Therefore, it would seem reasonable that the majority of bridges should be designed utilizing reduced loads

Table 5: Bridges with ADTT ≥ 5,000

State	% of Bridges w/ ADTT ≥ 5,000	State	% of Bridges w/ ADTT ≥ 5,000	State	% of Bridges w/ ADTT ≥ 5,000
CA	15%	GA	5%	MS	1%
DC	10%	AL	5%	AR	1%
RI	10%	SC	4%	NH	1%
DE	9%	NM	4%	AZ	0%
FL	8%	KY	4%	WY	0%
WV	8%	TX	4%	KS	0%
MI	8%	PA	4%	MA	0%
UT	7%	MO	4%	AK	0%
OH	7%	NY	4%	CO	0%
WA	7%	OR	3%	CT	0%
IL	6%	WI	3%	HI	0%
MD	6%	OK	2%	ME	0%
TN	6%	VA	2%	MT	0%
LA	5%	IN	1%	ND	0%
NV	5%	ID	1%	NE	0%
NJ	5%	MN	1%	SD	0%

NC	5%	IA	1%	VT	0%
Nation ≈ 4%					

Table 6 shows the percentage of bridges in each state with an ADTT less than 1,000 as reported in the 2003 NBI. As noted in the LRFD specification, bridges with an ADTT < 1,000 can reduce multiple presence factors through a 0.95 factor. This is also implied if the approximate distribution factor procedures of sections 4.6.2.2 and 4.6.2.3 are used. As shown in Table 6, six states showed that all of their bridges had ADTT < 1,000 and all but five states and the District of Columbia (DC) had more than 70% of their bridges with an ADTT < 1,000. Almost 85% of all the bridges in the nation have an ADTT < 1,000.

Table 6: Bridges with ADTT < 1,000

State	% of Bridges w/ ADTT < 1,000	State	% of Bridges w/ ADTT < 1,000	State	% of Bridges w/ ADTT < 1,000
CO	100%	WI	87%	WV	81%
CT	100%	NH	87%	OH	81%
MT	100%	WY	87%	NJ	81%
ND	100%	IN	86%	LA	80%
NE	100%	SC	86%	TX	80%
HI	100%	ME	86%	WA	77%
AK	98%	VA	86%	NM	77%
AR	98%	PA	86%	MI	76%
MA	97%	ID	85%	AZ	75%
IA	95%	AL	85%	MD	72%
SD	95%	TN	85%	UT	71%
VT	93%	NY	85%	CA	66%
MN	92%	GA	84%	NV	66%
KS	92%	IL	84%	FL	64%
MS	92%	OR	83%	DE	60%
KY	91%	NC	82%	DC	52%
OK	89%	MO	82%	RI	45%
Nation ≈ 85%					

Table 7 shows the results from the NBI on the percentage of bridges with an ADTT < 100 for each state and the overall nation. As shown, almost 63% of the bridges in the nation have an ADTT < 100. This would imply the usage of the 0.90 on the multiple presence factors and the results from the approximate distribution factor procedures. All but 12 states and DC had over 50% of their bridges with ADTT < 100.

Table 7: Bridges with ADTT < 100

State	% of Bridges w/ ADTT < 100	State	% of Bridges w/ ADTT < 100	State	% of Bridges w/ ADTT < 100
CO	100%	IL	66%	NH	55%
CT	100%	MS	64%	VA	54%
ND	100%	ID	63%	TX	53%
NE	96%	MO	63%	MI	51%
HI	95%	IN	62%	GA	48%
AR	89%	PA	62%	WA	48%
MT	86%	OH	61%	WY	47%
IA	80%	VT	59%	MD	45%
MN	79%	SC	59%	UT	42%
OK	79%	AL	59%	ME	39%
KS	77%	TN	57%	NV	37%
SD	77%	NY	57%	CA	36%
MA	72%	NC	57%	NM	35%
AK	71%	LA	57%	FL	32%
KY	71%	OR	57%	DE	28%
WI	68%	WV	56%	RI	11%
AZ	68%	NJ	56%	DC	11%
Nation ≈ 63%					

To review the validity of AASHTO Table C3.6.4.2-1 (Table 4 above) for the portion of trucks in traffic, the NBI from 2003 was utilized. Tables 8 and 9 provide the results of the average percentage of trucks in ADT for each state and D.C. Table 8 is for the bridges that are maintained by the state agency and Table 9 reports the results for bridges maintained by the counties. It is assumed that the states will more likely be maintaining the interstates and the counties are more likely maintaining the other rural and urban bridges. As can be seen from Table 8, the percentage of trucks in ADT varies from 22% to 1%. The upper end of the results is near the range of 20% to 15% as given in AASHTO Table C3.6.4.2-1 for Rural and Urban Interstates, respectively. Therefore, the values in AASHTO Table C3.6.4.2-1 are very reasonable and slightly conservative.

Table 8: Average Percentage of Trucks for Bridges Maintained by State

State	% of Trucks	State	% of Trucks	State	% of Trucks
WY	22%	MO	12%	ME	8%
NM	19%	FL	12%	NC	8%
AZ	18%	GA	11%	MD	8%
KS	18%	CA	11%	DE	7%
NV	17%	WV	11%	NH	7%
TX	17%	TN	11%	SC	7%
UT	16%	MN	10%	HI	6%
ID	15%	PA	10%	NJ	6%
LA	15%	KY	10%	VA	5%
IL	15%	RI	10%	DC	3%
AL	15%	AK	9%	AR	3%
OK	14%	MS	9%	MT	2%
IA	14%	IN	9%	ND	2%
OR	14%	WI	9%	CO	1%
SD	13%	VT	9%	CT	1%
OH	13%	MI	9%	MA	1%
WA	13%	NY	8%	NE	1%

Table 9 provides the percentage of trucks in ADT for bridges maintained by the counties. These values vary from a high of 47% to 0%. With the exception of WV, the upper end of the results is near the range of 15% to 10% as given in AASHTO Table C3.6.4.2-1 for Other Rural and Urban highways, respectively. Therefore, the values in AASHTO Table C3.6.4.2-1 are very reasonable and again slightly conservative.

Table 9: Average Percentage of Trucks for Bridges Maintained by County

State	% of Trucks	State	% of Trucks	State	% of Trucks
WV	47%	OH	7%	HI	3%
IA	15%	MD	6%	SD	2%
LA	14%	PA	6%	NH	2%
ID	12%	MI	6%	AR	1%
WY	12%	IL	5%	NM	1%
WA	12%	FL	5%	AK	1%
OR	10%	NV	5%	NE	1%
MO	10%	OK	5%	CO	0%
AZ	10%	GA	5%	ND	0%
KY	10%	IN	5%	CT	N/A
KS	10%	TN	5%	DC	N/A
WI	9%	SC	4%	DE	N/A
MS	8%	UT	4%	MA	N/A
MN	8%	TX	4%	ME	N/A
AL	8%	NJ	3%	NC	N/A

NY	7%	MT	3%	RI	N/A
CA	7%	VA	3%	VT	N/A

CONCLUSIONS

Though the original development of the LRFD specification scaled multiple presence factors for a more reasonable ADTT of 1,000, the LRFD Bridge Design Specification uses a conservative 5,000 ADTT for the scaling and then mentions additional factors for lower ADTT in the commentary. Based on the results of this study and the data from the 2003 NBI, it seems reasonable that the bridge engineering community should be informed of the additional factors that apply when the ADTT is less than 1,000 as well as an ADTT less than 100, due the significant number of bridges that have these levels of ADTT. It is true that the ADTT can increase over the design life of the bridge, but the fact that a large percentage of bridges have an ADTT less than 100 and to design these bridges based on an ADTT of 5,000 seems overly conservative. This is especially true when one considers the magnitude of the design truck with its accompanying load factor.

The percentage of trucks that can be assumed in ADT as provided in Table C3.6.4.2-1 of the Specification does not provide any reference for data supporting these values. However based on this limited study utilizing the 2003 NBI, the percentages are reasonable.

It should be noted that the efforts are under way to update and improve the live load models for use in bridge design. One study, NCHRP ???, will investigate the development of procedures for the use of data from the numerous weigh-in-motion (WIM) systems on the roadways today.

REFERENCES

1. AASHTO LRFD Bridge Design Specifications, 2004, Third Edition with 2005 Interim Revisions, American Association of State and Highway Officials, Washington, D.C.
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