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Girder distribution factors for steel bridges subjected to permit truck or super load

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Abstract. There are constraints on truck weight, axle configurations and size imposed by departments of transportation around the globe due to structural capacity limitations of highway pavements and bridges. In spite of that, freight movers demand some vehicles that surpass the maximum size and legal weight limits to use the transportation network. Oversized trucks serve the purpose of spreading the load on the bridge; thus, reducing the load effect on the superstructure. For such vehicles, often a quick structural analysis of the existing bridges along the traveled route is needed to ensure that the structural capacity is not exceeded. For a wide vehicle having wheel gage larger than the standard 1830 mm, the girder distribution factors in the design specifications cannot be directly used to estimate the live load in the supporting girders. In this study, a simple approach that is based on finite element analysis is developed by modifying the AASHTO LRFD's girder distribution factors for slab-on-steel-girder bridges to overcome this problem. The proposed factors allow for determining the oversized vehicle bending moment and shear force effect in the individual girders as a function of the gage width characteristics. Findings of the study showed that the relationship between the girder distribution factor and gage width is more nonlinear in shear than in flexure. The proposed factors yield reasonable results compared with the finite element analysis with adequate level of conservatism.

Keywords: bridges; girder distribution factor; finite element; oversized vehicle; permit truck; super load

1. Introduction

Structural design of new bridges nowadays is based on design specifications and codes that consider notional live load models whose structural effects resemble what is produced by the maximum legal heavy vehicles within the highway networks. Over time, marketplace demands around the world have increased the pressure for larger and heavier vehicles, thus raising concerns about the safety of highway structures. Regulating truck dimensions and weights is a difficult job because it involves different groups with opposing interests. On one hand, freight movers are interested in improving the efficiency of their operations, while on the other, public transportation agencies are mainly concerned about highway safety and infrastructure preservation.

Legal dimensions and weight limits of trucks permitted to travel over major highways vary

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from one country to another. However, most regulations address maximum weight on any single axle, the maximum weight on any group of axles, maximum weight of the entire vehicle, maximum length/width/height, and maximum number of trailers. Some countries regulate other dimensions as well, and some impose separate limits for different classes of roads. Also, various types of special permits, exemptions, and grandfather rights allow some trucks to operate at dimensions exceeding the normal limits.

In the United States, federal regulations (Committee 2002) are based on a maximum weight of 89 kN on any single axle and 151 kN on any tandem axle for vehicles on Interstate highways. There is also a maximum weight limit on any group of axles of a vehicle as a function of the span of the axle group and the number of axles, referred to as the bridge formula. The maximum weight of the entire vehicle cannot exceed 356 kN. Furthermore, Federal law requires states to allow vehicles up to 2.59 m wide on the network, requires the states to allow single trailers at least 14.6 m long and tractors pulling two 8.5 m trailers on the travel on the National Network.

Heavy truck weight and dimension limits for interprovincial operations in Canada are based on the Canadian national Memorandum of Understanding, M.o.U (Woodrooffe *et al*. 2010). The M.o.U defines 8 vehicle configurations: (1) tractor-semitrailers with 3-6 axles and length limit of 23 m, (2) A-train doubles with 5-8 axles and length limit of 25 m, (3) B-train doubles with 5-8 axles and length limit of 25 m, (4) C-train doubles with 5-8 axles and length limit of 25 m, (5) straight truck with 2-3 axles and length limit of 12.5 m, (6) truck-pony trailer with 3-6 axles and length limit of 23 m, (7) truck-full trailer with 4-7 axles and length limit of 23 m, and (8) intercity bus with 2-3 axles and length limit of 14 m. The steer axle of a tractor is allowed 54 kN and of a straight truck is allowed 71 kN. A tandem axle is allowed 167 kN, and a tridem axle is allowed 206 to 235 kN, depending on the spread, which varies from 2.4 to 3.7 m. The six eastern provinces allow 177 kN on a tandem axle, and 255 kN for a tridem axle with a spread from 3.6 to 3.7 m.

Permissible maximum dimensions of Lorries in European countries are published by the International Transport Forum (2015). In general, the maximum allowed lorry height is 4-4.65 m and width is 2.55-3.0 m, depending on the country. The maximum lorry or trailer length is 12 m for all countries except for Sweden where is 24 m and for Ukraine where it is 22 m. For road trains, the maximum length varies between 18.75 and 25.25 m. The length limit on articulated vehicles is 15.5-24 m.

Vehicle dimensions and weight limits for countries in Asia and the Pacific region are summarized by Nagl (2007). In some Asian countries, the maximum permissible axle weight is 88-100 kN and the gross vehicle weight is 353-446 kN. The maximum truck dimensions in the same countries are limited to lengths of 18-22.4 m, heights of 3.8-4.4 m, and widths of 2.5-2.7 m. In the study, the author also addresses the economic implications of permitting the use of longer combination vehicles in these countries.

Common trucks which satisfy the legal weight and size limits can travel freely on bridges. However, existing bridges are often subjected to truck configurations and weights much different than what they have been designed for. Examples of typical oversized/overweight trucks are mobile cranes, as well as carriers of mobile homes, structural steel members, precast concrete elements, and large pressure vessels. A vehicle which exceeds the legal limits usually requires a special permit in order for it to use the roadway network. Vehicles not within the weight and axle spacing limits for a routine issue permit are designated a super loads and require a special analysis. For such cases, the concerned agency specifies a route that the vehicle must follow at a given date and time. The bridges along the route that a nonstandard vehicle is supposed to use to reach its destination shall be checked to see if the imposed loading on them is acceptable from a structural capacity view point.

2. Problem statement

The high percentage of substandard bridges around the world and lack of financial resources for infrastructure repair and replacement require more efficient structural analysis approaches to be utilized for checking the adequacy of existing bridges subjected to permit trucks or super loads. The load effect of an oversized/overweight truck on the deck slab can be directly accounted for using the AASHTO's strip design method (AASHTO LRFD 2014). Although infrequently checked, the influence of a nonstandard truck on the substructure can be simply determined using the lever rule, in which the girder reactions due to live load on a pier or abutment can be obtained by assuming the deck slab to have internal hinges at the location of interior girders. To determine the load effect of a truck on the supporting girders in slab on girder bridges, truck configuration along the length of the vehicle can be considered in the evaluation of the shear and bending moment along the bridge length. However, the girder distribution factors included in the AASHTO specifications cannot be directly used to evaluate the maximum live load effect in the individual girders if the truck gage width is different from 1.83 m. Consideration of the actual gage width when evaluating the structural capacity of an existing bridge may help increase the allowable load on bridges subjected to oversized vehicles and reduce potentially longer routes taken by such vehicles if efficient methods of structural analysis are unavailable. Literature review on the subject has revealed that most of the recently published studies have narrowly focused on comparing results from an analytical method with field testing carried out on one or two actual bridges. Their objective was not to derive general formulations that are applicable to various bridges subjected to different oversized vehicles; instead, their goal was often to check if a particular overload can pass over a specific bridge without causing distress. In that respect, applications of their findings to other bridges and truck configurations were limited. This paper aims at filling the gap in research on the subject by proposing realistic girder distribution factors that can be used for steel girder bridges subjected to oversized trucks.

3. Objective

The objective of this research is to develop flexural and shear girder distribution factors for slab-on-steel-girder bridges subjected to permit and super loads having nonstandard gage widths. This study builds on the earlier work by Tabsh and Tabatabai (2001) in which the authors developed modification factors for girder distribution factors for permit trucks to account for the effect of wide single-lane trailers. It expands the previous work to include super loads in the form of dual-lane trailers. Unlike the previous work, the current study proposes girder distribution factors that are in-line with the format of the AASSHTO's LRFD bridge design specifications (2014), rather than modification factors to the code-specified factors. This approach reduces the high-level of conservatism that is often associated with the design of new structures.

4. Literature review

A literature review on load distribution in bridges subjected to oversized trucks showed limited studies and most of the published work addresses bridges exposed to standard trucks. Presented below is a summary of relevant research on the subject, particularly for girder bridges subjected to trucks having wide gages.

In an early study by Keating *et al*. (1995), the authors addressed the necessary procedures for issuing permits for overweight vehicles crossing major and secondary bridges in Texas. Bridge formulas were developed for the purpose determining the maximum truck weight which may be safely carried by a given axle configuration over a bridge by converting it to an equivalent truck having the same configuration as the design truck. Turer and Akjtan (1999) used finite element analysis and experimental tests to predict critical stresses in three steel stringer bridges in Ohio subjected to super load and compared their results with the measured response of the bridges. The study showed that it is possible to reliably predict bridge behavior under super loads by using a combination of diagnostic tests and finite element analysis. Culmo *et al*. (2004) considered actual super load vehicle configurations to determine their effect on steel bridges. Simplified methods of structural analysis on live load distribution, impact, and trailer layout were considered. Accuracy of the simple methods were compared to field measurements conducted on a three-span composite steel bridge in Connecticut subjected to 4500 kN-vehicle. The results confirmed the conservatism of the simple methods when compared with the strain-monitoring findings. A procedure involving diagnostic testing was utilized by Phares *et al*. (2005) for rating a bridge subjected to super load. The bridge was instrumented with strain transducers and tested with known loads. Finite element models of the bridge were developed and calibrated on the basis of the field-measurements. Results from the calibrated model were used to rate the bridge through the super load geometry and axle loadings. Finding of the rating showed that the bridge can accommodate the super load without damage. Grimson *et al*. (2008) used finite element modeling prior to field evaluation of three super loads that crossed a bridge in Louisiana, USA. Focus was placed on the comparisons between the calculated and measured response due to rotational restraint at the bearings, live load distribution within the superstructure, and the stiffening effect of bridge parapets. Bae and Oliva (2012) derived distribution factors for both composite steel and precast pretressed concrete girder bridges subjected to unusual vehicle configuration based on finite element analysis. They considered a single-lane trailer with a fixed 2.44 m-gage width and dual-lane trailer with 3.05-5.49 m-gage width. The developed distribution factors consisted of product of variables raised to powers. The study considered the skew angle, number of spans, and presence of end diaphragms. On average the developed equations predicted the load effect by 15% higher than the corresponding finite element results. Hammada (2012) compared analytical and field strain measurements for 12 super load crossings over two bridges in Ohio. Finite element models of the bridges were developed and calibrated against field strain measurements for five diagnostic dump truck tests. The measured and calculated strains were reasonably close for the super load crossing. The finite element model allowed for rating of the existing bridges against the super loads. Recently, Seo *et al*. (2013) and Seo and Hu (2015) investigated the lateral live load distribution characteristics of girder bridges loaded with agricultural vehicles consisting of axles having oversized gage widths. Results of the studies showed that the analytical and field observed distribution factors were in most cases smaller than the code-specified values, although in some cases they exceeded the code values. The variability in agricultural vehicles layout had a significant effect on the girder distribution factors.

5. Methodology

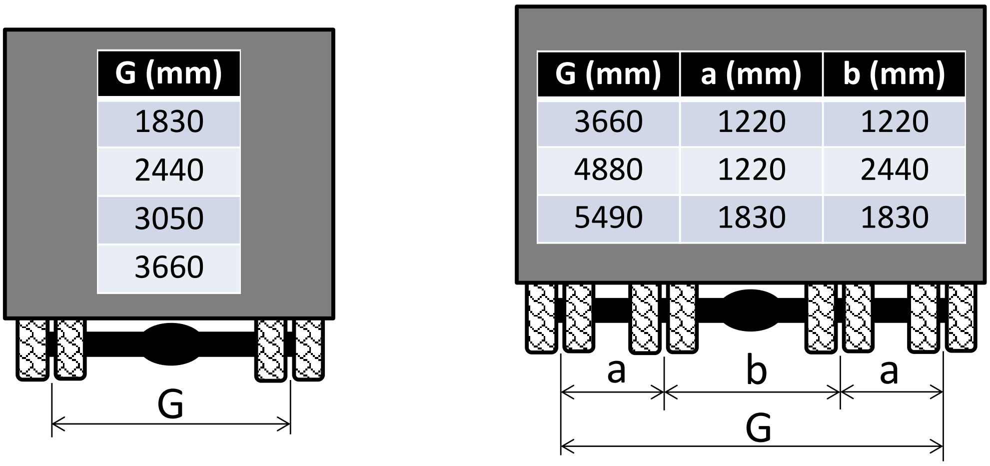
The finite element (FE) method is used to compute the effect of the truck gage width on the live

Table 1 Geometric properties of the considered bridges

Span Length (mm)	Girder Spacing (mm)	Slab Thickness (mm)	Steel Girder Section Dimensions (mm)			
			Flanges		Web	
			Thickness	Width	Thickness	Depth
14640	1220	150	22	292	15	497
	2440	200	22	292	15	797
	3660	250	22	292	15	1097
29280	1220	150	43	423	24	548
	2440	200	43	423	24	848
	3660	250	43	423	24	1148
43920	1220	150	45	405	26	728
	2440	200	45	405	26	1028
	3660	250	45	405	26	1328

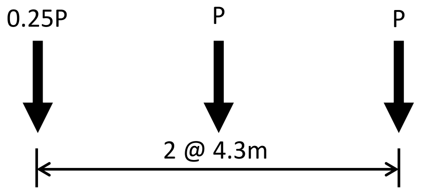
load distribution characteristics of slab-on-steel-girder bridges. Several composite steel bridges with different span lengths, girder spacings, and girder sizes are considered. One superstructure is composed of a 150 mm thick slab on 7 steel beams spaced at 1.22 m, another consisted of a 200 mm thick slab on 5 steel beams spaced at 2.44 m, and a third included a 250 mm thick slab on 4 steel beams spaced at 3.66 m. For each bridge layout, 3 different simple span lengths were chosen, including 14.6, 29.3, and 43.9 m. For the 2.44 m girder spacing, the rolled steel beam cross section is W840×193 when the span is 14.6 m, W920x446 when the span is 29.3 m, and W1120x498 when the span is 43.9 m. For each span length of the considered bridges, the web depth of the rolled steel beam used with the 2.44 m girder spacing is decreased by 300 mm for the 1.22 m girder spacing, and increased by 300 mm for the 3.66 m girder spacing. The deck slab overhang is taken equal to one-half the girder spacing. Steel railings with negligible width were used on all bridges. Table 1 summarizes the important geometrical properties of the considered bridges.

On each bridge, a single permit truck in the form of a single lane trailer is applied with four different gage widths (1.83, 2.44, 3.05 and 3.66 m) or super load in the form of dual lane trailer with three different gage widths (3.66, 4.88 and 5.49 m), as shown in Fig. 1. The FE results are then used to develop distribution factors that can predict the live load live in slab-on-steel-girder bridges subjected to wide vehicles. Four truck configurations were examined, including the AASHTO’s HS20-44 design truck, PennDOT’s P-82 permit truck, OHBDC's level-3 truck, and the HTL-57 notional truck, shown in Fig. 2. The four trucks differ from each other in the number of axles, axle spacing, gross weight, and weight distribution to the axles. In an earlier study (Tabsh and Tabatabai 2001), it was found that the AASHTO's HS20-44 design truck caused the most critical flexural and shear effects in the supporting girders within the considered bridges, as shown in Fig. 3. This finding, which was true for all the considered truck gage widths, is not surprising since the HS20-44 truck has the shortest overall length and least number of axles among the considered trucks. Based on this finding, the HS20-44 longitudinal truck configuration with a 4.30 m distance between the middle and rear axles will be considered with different gage widths between the wheels in the transverse direction. The truck will be incrementally displaced in the transverse direction on the selected bridges while the intermediate axle is positioned at midspan, and the critical girder distribution factor for the interior girders will be recorded. The procedure is repeated for each of the chosen bridges and gage widths, and the results of the structural analysis are used to develop girder distribution factors that are functions of the gage width.

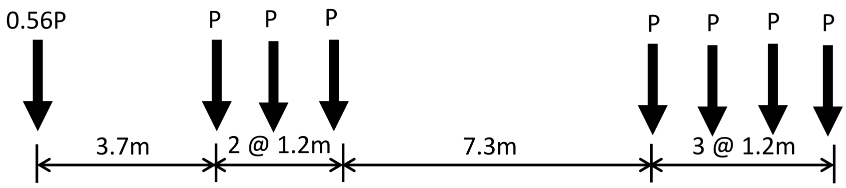


(a) Single lane trailer (b) Dual lane trailer

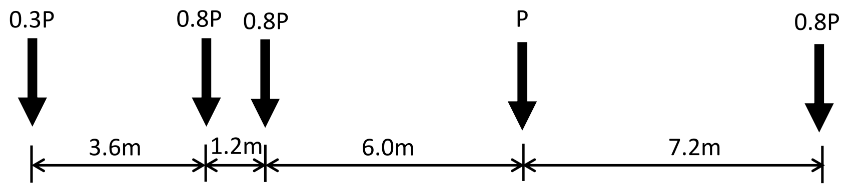
Fig. 1 Considered transverse wheel gage configurations and widths



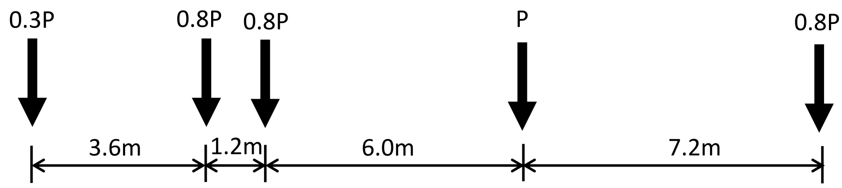
(a) HS20-44 truck



(b) PennDOT P-82 permit truck

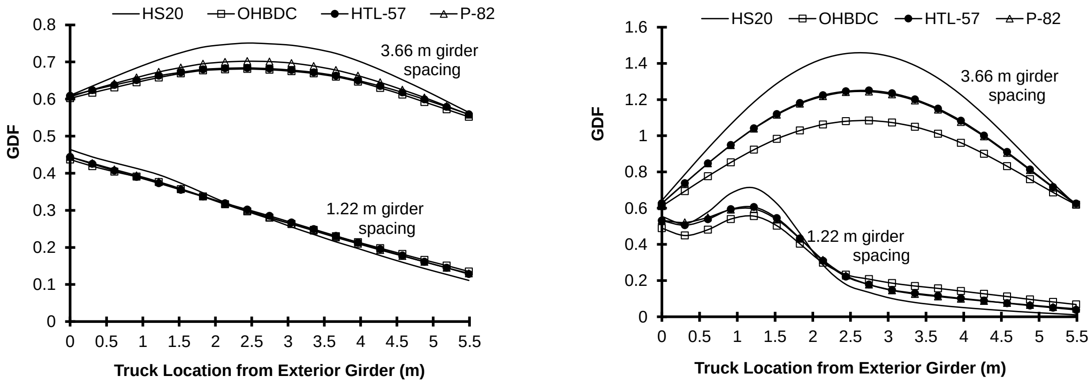


(c) OHBDC truck



(d) HTL-57 turck

Fig. 2 Mesh grid of topographic model



(a) Flexure at midspan (b) Shear at support

Fig. 3 Truck configuration effect on GDF for the 29.3 m long bridge and 1.83 m gage width

The finite element analysis of the considered bridges revealed that the first interior girder consistently received the most load effects among all the interior girders. The load effect in the exterior girders is excluded from the study because it is highly dependent on the overhang width and can only govern over interior girders when the truck is positioned very close to the parapet. Nevertheless, the girder distribution factors in such cases can be simply calculated using the lever rule (AASHTO LRFD 2014). The transverse position of the oversized vehicle can also be controlled during bridge crossing to minimize the effect on exterior girders (Bae and Oliva 2012).

6. Background

In the design and evaluation of slab-on-girder bridges, simple formulas that represent the critical fraction of the live load effect carried by the girders, referred to as girder distribution factors (GDF), are usually adopted. Such an approach greatly simplifies the analysis by replacing unnecessary 3-dimensional modeling with 1-dimensional beam representation. In the AASHTO LRFD Specifications (2014), the truck load girder distribution factor for the case of flexure in an interior girder in a slab-on-girder bridge subjected to one loaded lane, $(GDF)_M$, is given by

$$(GDF)_M = 0.06 + \left(\frac{S}{4300}\right)^{0.4} \left(\frac{S}{L}\right)^{0.3} \left(\frac{K_g}{Lt_s^3}\right)^{0.1} \tag{1}$$

where S is the girder spacing (mm), L is the span length (mm), t_s is the slab thickness (mm), and K_g (mm^4) is a girder stiffness parameter computed from

$$K_g = n(I + Ae_g^2) \tag{2}$$

in which n is the modular ratio between the girder and slab, I is the moment of inertia of the girder (mm^4), A is the cross-sectional area of the girder (mm^2), and e_g is the distance from the geometric center of the bare girder and the mid-depth of the deck slab (mm). Note that the above expression includes an embedded multiple presence factor equal to 1.2 for the case of one loaded lane. If the multiple presence factor is filtered out from Eq. (1), the girder distribution factor expression becomes

$$(GDF)_M = 0.05 + \left(\frac{S}{6800}\right)^{0.4} \left(\frac{S}{L}\right)^{0.3} \left(\frac{K_g}{Lt_s^3}\right)^{0.1} \tag{3}$$

The corresponding AASHTO's LRFD live load girder distribution factor for shear in the interior girder due to a single loaded lane without the multiple presence factor, $(GDF)_V$, is given by

$$(GDF)_V = 0.30 + \frac{S}{9120} \tag{4}$$

7. Finite element modeling

The finite element method was employed to analyze the three considered slab-on-steel-girder bridge superstructures subject to the oversized trucks. All bridges were analyzed in the linearly-elastic range using the finite element software ALGOR (1998) based on a model first suggested and verified on an actual bridge by Bishara *et al*. (1993). Three elements were used to model the geometry of each steel girder. The top and bottom steel flanges were modelled using 2-node beam elements in which the geometric and stiffness properties of the elements were lumped at the centroid of the flanges. The steel web of the girders and concrete deck slab were modelled by 4-node rectangular shell elements with consideration of both membrane and bending stiffness, and in-plane and out-of-plane bending. Bracing of the girders was done through the use of cross frames made from angles modelled by 3-dimensional beam elements. Rigid 3-dimensional beam elements were used to connect the centroids of the top flange steel beam elements to the centroids of the deck slab elements directly above them. These elements were utilized in order to satisfy composite action between the top flange of the girders and the concrete slab. The finite element model of a 29.3 m long bridge consisting of a reinforced concrete deck slab supported on 5 girders that are spaced at 2.44 m is shown in Fig. 4.

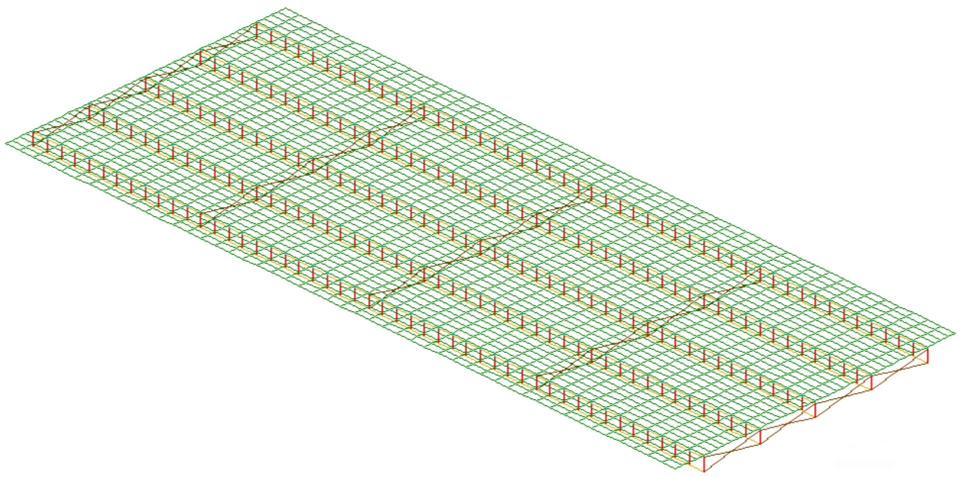


Fig. 4 Finite element model of a 29.3 m long bridge with 5 girders at 2.44 m spacing

The girder distribution factor for flexure in a simply supported bridge can be obtained by longitudinally positioning one truck on the bridge so that the bending moment in the structure is maximized at midspan. The transverse position of the truck can be obtained by checking the maximum flexural stress in the bottom flange of the critical girder due to consideration of a number of transverse truck positions. Once the correct transverse truck position is determined, the GDF for flexure, GDF_M, can be computed from

$$GDF_M = \frac{f_j}{\sum_{i=1}^{N} f_i} \tag{5}$$

where f_j is extreme bottom flange stress of the critical interior girder, f_i is extreme bottom flange stress of beam *i*, and *N* is number of girders within the superstructure. Note that the multiple presence factor is not included in the above equation.

The corresponding girder distribution factor for shear due to a single truck positioned on a simple span bridge to maximum shear in the interior girders, GDF_V, can be computed based on the support reactions of the individual girders at the loaded end of the bridge and is given by

$$GDF_V = \frac{R_j}{\sum_{i=1}^{N} R_i} \tag{6}$$

where R_j is the support reaction of the critical interior girder, R_i is the support reaction of girder *i*, and *N* is number of girders within the superstructure.

8. Results

The nine simply supported bridges with simple spans of 14.6, 29.3, and 43.9 m and girder spacing of 1.22, 2.44, and 3.66 m are analyzed for the HS-20 truck longitudinal configuration with various gage widths representing single-lane and dual-lane trailers. A summary of the finite element analysis for all the considered bridges subjected to the considered loads are presented in Figs. 5 and 6, respectively, showing the GDF versus the girder spacing for a specific gage width. In each figure, the results are displayed for the critical interior girder in flexure and also in shear due to a single truck on the bridge with consideration of various gage widths.

Findings of the finite element analysis confirm that girder distribution factors for shear are larger than those for flexure, especially for bridges with wide girder spacing. This is because shear is checked at the support where little distribution of load occurs due to smaller relative deflection between the girders, when compared with flexure at midspan where the girders have more freedom to displace and distribute the load effect among them. The results also indicate that the shear GDF is to a large extent independent of the bridge length and superstructure stiffness, as suggested by the GDF expression in the AASHTO LRFD specifications (2014). Further, the effect of the span length on the girder distribution factor for the case of flexure is more profound when the girder spacing is large than when it is small. The results demonstrate that the relationship between the GDF and girder spacing or gage width is more nonlinear in shear than in flexure.

The finite element results reveal that as the gage width increases, the critical live load carried by a single interior girder reduces due to the distribution of the wheel loads over larger distances in

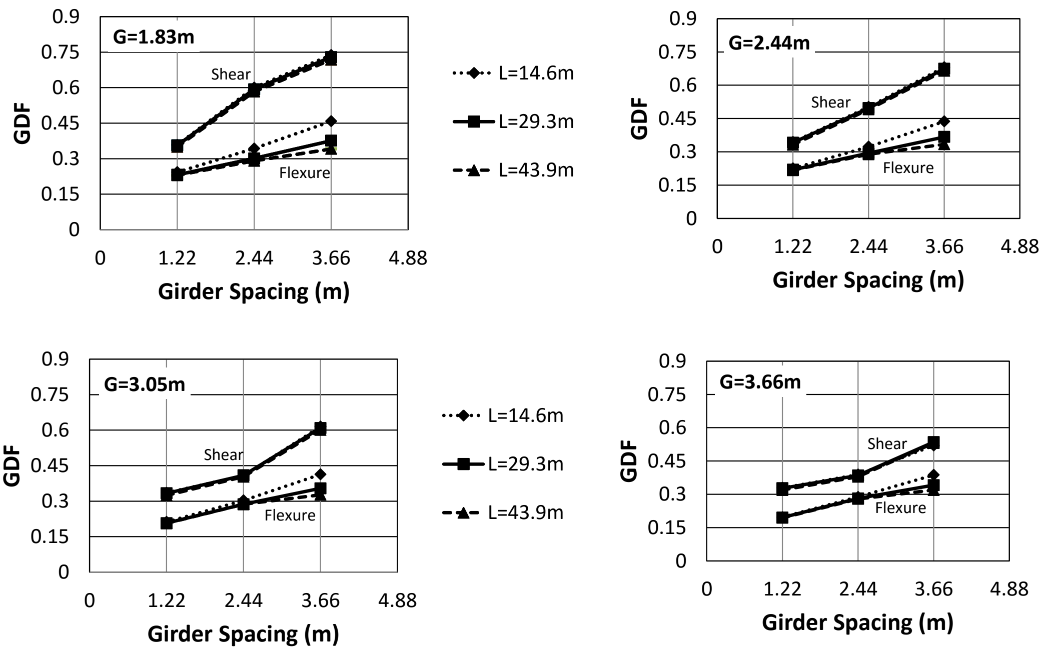


Fig. 5 Finite-element GDF versus girder spacing for the single lane trailer

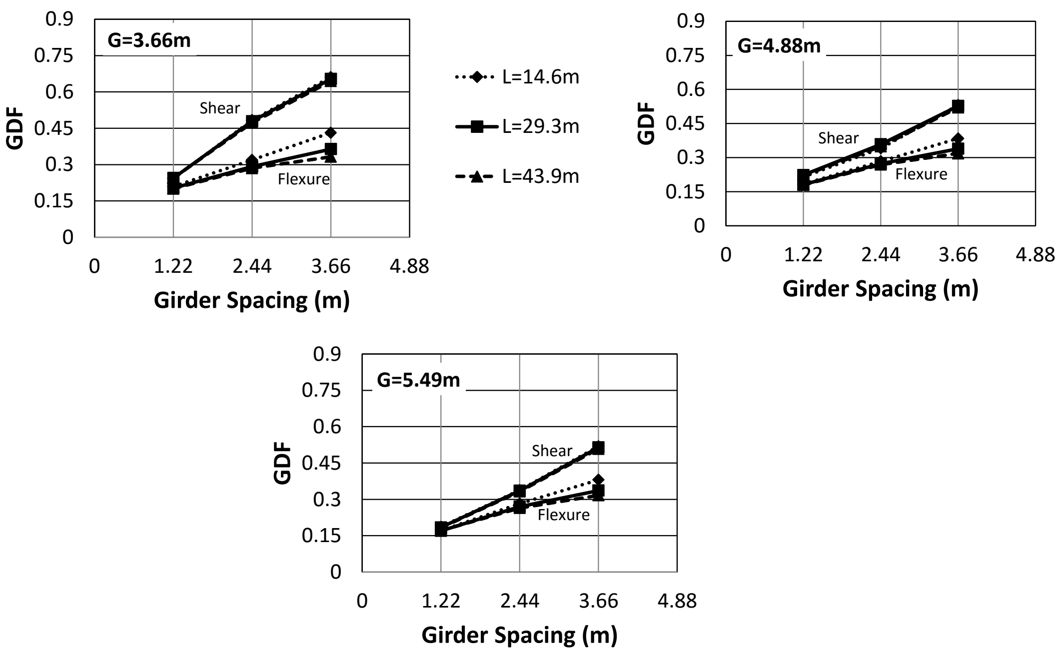


Fig. 6 Finite-element GDF versus girder spacing for the dual lane trailer

the transverse direction. The decrease in the GDF is much more significant for shear than for flexure due to the inhibited differential deflection among the girders near the supports where shear is determined, compared to midspan where flexure is considered. For bridges subjected to single-lane or dual-lane trailers, a close look at the results shows that as the girder spacing increases the effect of an increase in the gage width on the flexural GDF is always reduced. This trend is not observed for the bridges and trucks when considering GDF for shear. In the latter case, the results showed that as the girder spacing increases the effect of an increase in the gage width on the shear GDF increases for single-lane trailers, but stays more or less constant for dual-lane trailers.

Based on the results of the finite element analyses in Figs. 5 and 6, simple formulas for the GDF in shear and flexure for single-lane and dual-lane trailers are developed with consideration of the gage width, G. The proposed girder distribution factors follow a similar format to that of the AASHTO LRFD Specifications (2014). For slab-on-steel-girder bridges subjected to permit trucks in the form of single-lane trailers, the GDF for interior girders in flexure and shear are

$$(GDF_M)_{single-lane} = 0.05 + \left(\frac{S}{4G}\right)^{0.4} \left(\frac{S}{L}\right)^{0.25} \left(\frac{K_g}{Lt_s^3}\right)^{0.3} \tag{7}$$

$$(GDF_V)_{single-lane} = 0.20 + \left(\frac{S}{31.7}\right)\left(\frac{1}{G}\right)^{0.7} \tag{8}$$

where all the parameters in the above expressions have been defined earlier. The corresponding GDF for bridges subjected to super loads in the form of dual-lane trailers are

$$(GDF_M)_{dual-lane} = 0.05 + \left(\frac{S}{4(G-a)}\right)^{0.4} \left(\frac{S}{L}\right)^{0.25} \left(\frac{K_g}{Lt_s^3}\right)^{0.3} \tag{9}$$

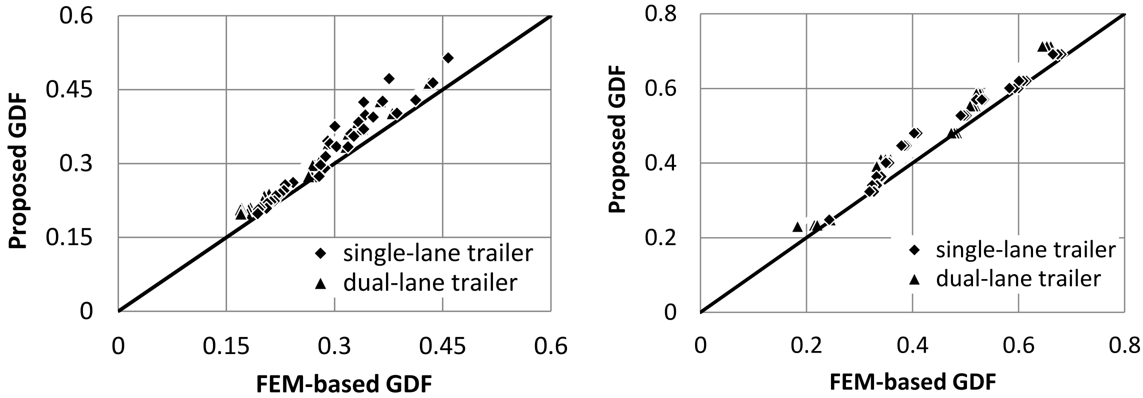
$$(GDF_V)_{dual-lane} = 0.19 + \left(\frac{S-915}{8.75}\right)\left(\frac{1}{a}\right)^{0.5} \left(\frac{1}{G-2a}\right)^{0.4} \tag{10}$$

where a is the distance between the exterior and interior wheels (mm), as shown in Fig. 1(b).

The above four equations were tested on steel girder bridges with the following ranges of variables: 1220 mm$\leq S \leq$3660, 14640 mm$\leq L \leq$43920 mm, 152 mm$\leq t_s \leq$254mm, and 2.5×10^9 mm$^4 \leq K_g \leq 5.5\times10^{11}$mm^4. The overhang width from the center of the exterior girder to the edge of the railing for all the considered bridges was taken one-half the girder spacing.

The finite element results are compared in Table 2 with the corresponding GDF values obtained from using the AASHTO LRFD specification (2014) and proposed expressions for the case of single-lane trailers with standard gage width of 1830mm. There is a good agreement among the three approaches, with the proposed GDF being closer to the finite element results than the AASHTO values. The findings also indicate that the AASHTO equation overestimates the shear in the interior girder for the bridges with small girder spacing and underestimates it for the large girder spacing. This deficiency has been rectified with the proposed GDF expression for shear.

The accuracy of the developed factors is shown in Fig. 7 for the 126 considered cases involving flexure and shear. The figure shows the finite element based GDF values versus the corresponding ones obtained from the proposed equations. On average, the proposed equations for flexure due to single and dual lane trailers provide, respectively, 9.4% and 11.3% higher GDF than the corresponding FE results. Likewise, the proposed equations for shear due to single and dual lane trailers provide on average 7.2% and 10.7%, respectively, higher GDF than the corresponding FE results. Overall, the developed GDF expressions for flexure and shear provide, respectively, about



(a) Flexure (b) Shear

Fig. 7 Accuracy of the proposed GDF equations for flexure and shear

10.2% and 8.7% higher values than the corresponding findings obtained from the finite element analysis, with coefficients of variation of 5.5% and 6.4%, respectively. This level of conservatism is reasonable when used on existing bridges subjected to oversized vehicles, and can eliminate the time-consuming 3-dimensional finite element analysis. Note that the force effects resulting from heavy vehicles in one lane with routine traffic in adjacent lanes can be accounted for by using the proposed GDF in this study together with the procedure outlined in section 4.6.2.2.5 (Special Loads with Other Traffic) of the AASHTO LRFD (2014) specifications.

9. Conclusions

Findings of this study lead to the following conclusions that are relevant for slab-on-steel-girder bridges and subjected to oversized vehicles in the form of either single-lane or dual-lane trailers:

1. The finite element analysis of the considered bridges subjected to single-lane trailer vehicles having 1830 mm gage width showed that the AASHTO's girder distribution factors for interior girders provide reasonable estimate of the flexural load effect. However, they overestimate the shear in the interior girder for the bridges with small girder spacing and underestimate it for the large girder spacing.
2. Girder distribution factors for shear due to single-lane or dual-lane trailers are always larger than those for flexure, especially for bridges with wide girder spacing, and to a large extent they are independent of the bridge length and superstructure stiffness. The relationship between the GDF and girder spacing or gage width is more nonlinear in shear than in flexure.
3. As the gage width for the considered trailers increases, the critical live load carried by a single interior girder reduces, and this is more significant for shear than for flexure. As the girder spacing increases the effect of an increase in the gage width on the flexural GDF is always reduced. This trend is not observed for the bridges and trucks when considering the GDF for shear.
4. The accuracy of the proposed GDF factors for bridges subjected to single-lane and dual-lane trailers is reasonable. When used on existing bridges subjected to oversized vehicles, the

proposed factors can eliminate much of the time and effort spent on 3-dimensional finite element analysis and the high costs associated with field testing.

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