# 16

# Site-specific and Component-specific Bridge Load Models

Jeffrey A. Laman[1] and Andrzej S. Nowak[2]

[1] Research Assistant, Department of Civil and Environmental Engineering, University of Michigan, Ann Arbor, Michigan, 48109.

[2] Professor of Civil Engineering, University of Michigan, Ann Arbor, Michigan, 48109.

Bridge reliability analysis is based on load and resistance models. In particular, load spectra vary depending on site and component. The objective of this paper is to present the results of measurements of truck loads on girder bridges. The study included several structures located on interstate highways and surface streets.

The study confirms that truck loads are strongly site specific. There is a negative correlation between law enforcement effort and occurrence of overloaded trucks. Illegally loaded trucks are observed on roads not controlled by truck weigh stations. A comparison of the truck citation data and weigh-in-motion (WIM) measurements obtained in this study confirms this observation.

Load spectra are measured for various components, including each girder. The results indicate that the stress spectra are component specific. Girders located directly under the traffic lanes support the largest portion of the load. This observation is important for fatigue analysis considerations. Measured loads are presented in terms of strains and gross vehicle weight (GVW). Cumulative distribution functions (CDF's) of the data are plotted for enhanced interpretation.

## 1. INTRODUCTION

Presented are measurement results of truck GVW's and strain loads on girder bridges. A study of four bridge structures was performed at locations of different average daily truck traffic (ADTT) and proximity to stationary weigh stations. Measurements were conducted using a bridge weighing system and a data acquisition system. Approximately 22,000 truck files are included in the data base of WIM. In addition, 1985 citation data from the Michigan State Police Motor Carrier Division was processed. The recorded truck data was processed to develop cumulative distribution functions (CDF's) of GVW for each of four sites. Stress histories are collected at mid span of each girder bottom flange for one week periods and processed using the rainflow algorithm. This data is then converted to an equivalent (root mean cube) stress as a convenient method of comparison between components. Load spectra, particularly fatigue loads, differ depending on ADTT, proximity of industrial facilities, and position of the girder. The results indicate that live load is strongly site specific and component specific.

Bridge live load is a dynamic load which may be considered as a sum of static and dynamic forces. This study is concerned with the both the static portion of the load and the resulting dynamic response. Actual truck axle weights and spacing, GVW, ADTT, and the load effects of the trucks such as moments, shears, and stresses are important parameters used in the effective evaluation of a bridge. Truck data is available from highway weigh station logs, citation data, and also through the use of WIM technology. The stationary weigh scales at weigh stations are biased and will not reflect accurately the distribution of truck axle weights, spacing, and gross vehicle weights due to avoidance of scales by illegally loaded trucks. WIM measurements of trucks and strain measurements can be taken discretely, resulting in unbiased data for a statistically accurate sample of truck traffic crossing a particular bridge. Strain measurements can be collected at various locations on the bridge to sample the stress effects of

R. Rackwitz et al. (eds.), *Reliability and Optimization of Structural Systems*

the measured truck traffic. Presented in this study are WIM gross vehicle weight (GVW) for the bridge site and strains in the main girders.

## 2. SELECTED BRIDGES

During 1991, 1992, and 1993 WIM and strain measurements were conducted at seven bridge sites. These sites are located in southeast Michigan on US, Interstate, Michigan, and city roadways. The location and description of the bridges are as follows:

1. The bridge on US-23 over the Huron River (US-23/Huron Rr.) east of Ann Arbor, Michigan is constructed as a two lane, five simple span, 6 steel composite girder structure and carries northbound (NB) traffic. (See figure 1)

2. The bridge on US-23 over the Saline River (US-23/Saline Rr.) south of Milan, Michigan is constructed as a two lane, three simple span, 10 steel composite girder structure and carries southbound (SB) traffic between the metropolitan Detroit area and Toledo Ohio. There is no weigh station on the route. (See figure 2)

3. The bridge on I-94 over Pierce Road (I-94/Pierce Rd.) west of Ann Arbor, Michigan and east of Jackson, Michigan is constructed as a three simple span, composite steel, ten girder bridge and carries eastbound (EB) traffic between Detroit and Chicago. The site is 4 miles east of a weigh station. (See figure 3)

4. The bridge on US-23/M-14 over the New York City Railroad (M14/New York RR) north of Ann Arbor, Michigan is constructed as a two lane, three simple span, 8 steel composite girder structure and carries eastbound (EB) traffic. (See figure 4)

## 3. TRUCK WEIGHT MEASUREMENTS

Statistical data is presented in the form of cumulative distribution functions (CDF's). CDF's are used to present and compare the critical extreme values of the data and are plotted on normal probability paper.

Most states allow a maximum GVW of 356 kN (80 kips), however in Michigan the legal limit for an eleven axle truck is over 712 kN (160 kips), depending on axle configuration. From the tables and graphs it can be seen that there were a number of illegally loaded trucks measured during data collection at several of the sites.

GVW results are plotted in figure 5. Measurements of GVW taken at US-23/Huron Rr NB indicate the upper tail is dominated by 11 axle vehicles. This bridge is not on a route near or between major industrial areas and the data reflects this as there are almost entirely legally loaded vehicles, despite the absence of a weigh station in the vicinity. The US-23/Saline Rr SB bridge site is along a north-south route between the major industrial areas of metropolitan Detroit and Toledo, Ohio with no weigh station along the route. It can be expected, as the GVW data reveals, that heavily and illegally loaded trucks will be motivated to travel this route. The heaviest vehicle weighed was a 1100 kN (248 kip) 11 axle truck. Several vehicles weighed over 900 kN (200 kips) and many exceeded legal limits.

Measurements taken at I-94/Pierce Rd. in 1993 were conducted when the nearby stationary weigh station was closed for repairs. As a comparison, WIM data was collected in 1991 with the stationary weigh station in operation . It is suspected that illegally loaded trucks avoid stationary weigh scales causing the data to be biased. The data presented supports this notion. The 1993 maximum GVW of 800 kN (181.5 kips) is considerably larger than the 1991 maximum GVW of 590 kN (133.3 kips). GVW measurements collected at M-14/New York RR EB indicate very heavy vehicles with the upper tail dominated by the 11 axle vehicles. This bridge, while not in an industrial area, may be a route used between northern Detroit suburbs and the metropolitan Chicago area

## 4. STRAIN MEASUREMENTS

All strain measurements were taken in the bridge girder bottom flange at mid span. The strain data was collected using the rainflow algorithm enabling one week of continuous data collection at each bridge site. Equivalent stress (root mean cube) results of the strain data collection are presented in figure 10a through 10d. For orientation, girder 1 is located at the extreme right of the right lane of the bridge.

## 5. CONCLUSIONS

From the presented data of GVW and lane moments, load spectra is highly site-specific and is dependent upon a number of factors. These factors include proximity to stationary weigh stations, weigh station hours of operation, proximity to industrial areas, and desirability of the route for traffic between major metropolitan areas. The distribution of moments caused by the truck traffic is related to the same factors as GVW as well. In some locations the level of the lane moments may be exceedingly high. Michigan State Police Citation data confirms that very heavy trucks should be expected when data is collected without observation, which is possible with WIM equipment.

Strain spectra is component dependent and varies greatly from girder to girder. The tests consistently indicated that girders located nearest the right lane left wheel track experienced the highest stains, typically girder 3 to 5. Girders supporting the left lane experienced moderate strains, and outer girders low levels of strain.

## ACKNOWLEDGMENTS

The research presented in this paper has been sponsored by the Michigan Department of Transportation and the Great Lakes Center for Truck Transportation Research, (GLCTTR), which is gratefully acknowledged.

## REFERENCES

Nowak, A.S. and Laman, J.A., *Effect of Truck Loads on Bridges*, Research Report UMCE 94-22, Department of Civil and Environmental Engineering, The University of Michigan, Ann Arbor, Michigan, September 1994.

## FIGURES

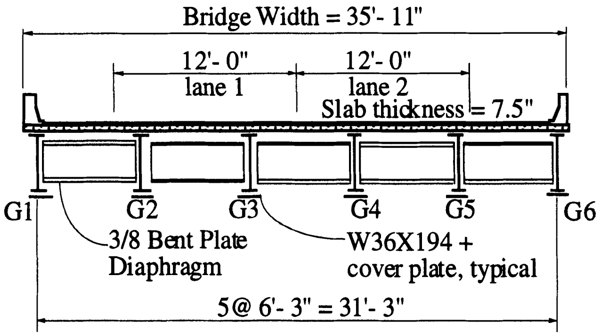



Fig. 1, US23/Huron River Northbound Section Looking South.

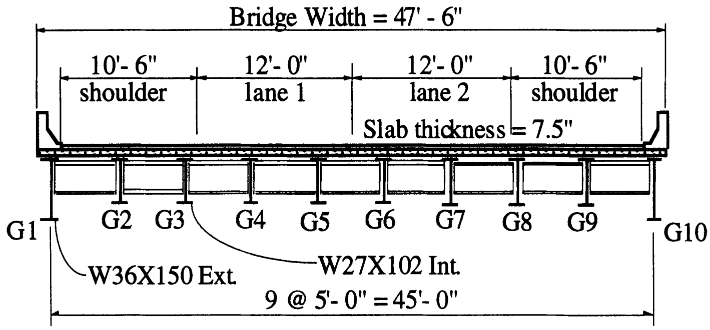



Fig. 2, US23/Saline River Southbound Section Looking North.

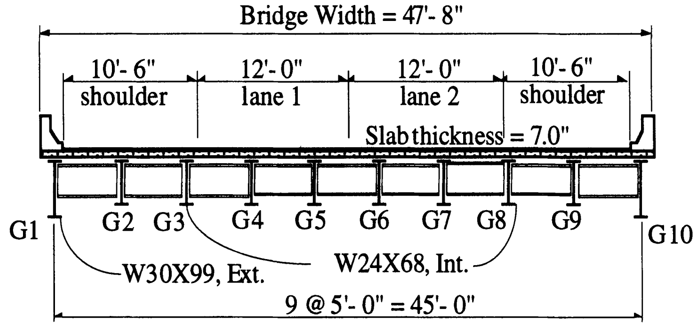



Fig. 3, I-94/Pierce Road Eastbound Section Looking West.

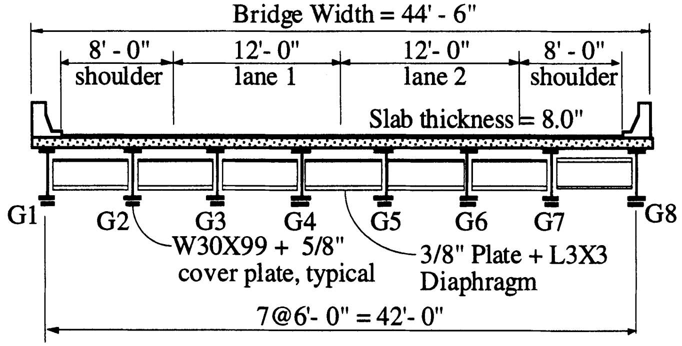



Fig. 4, M14/NYC Railroad Section Looking West.

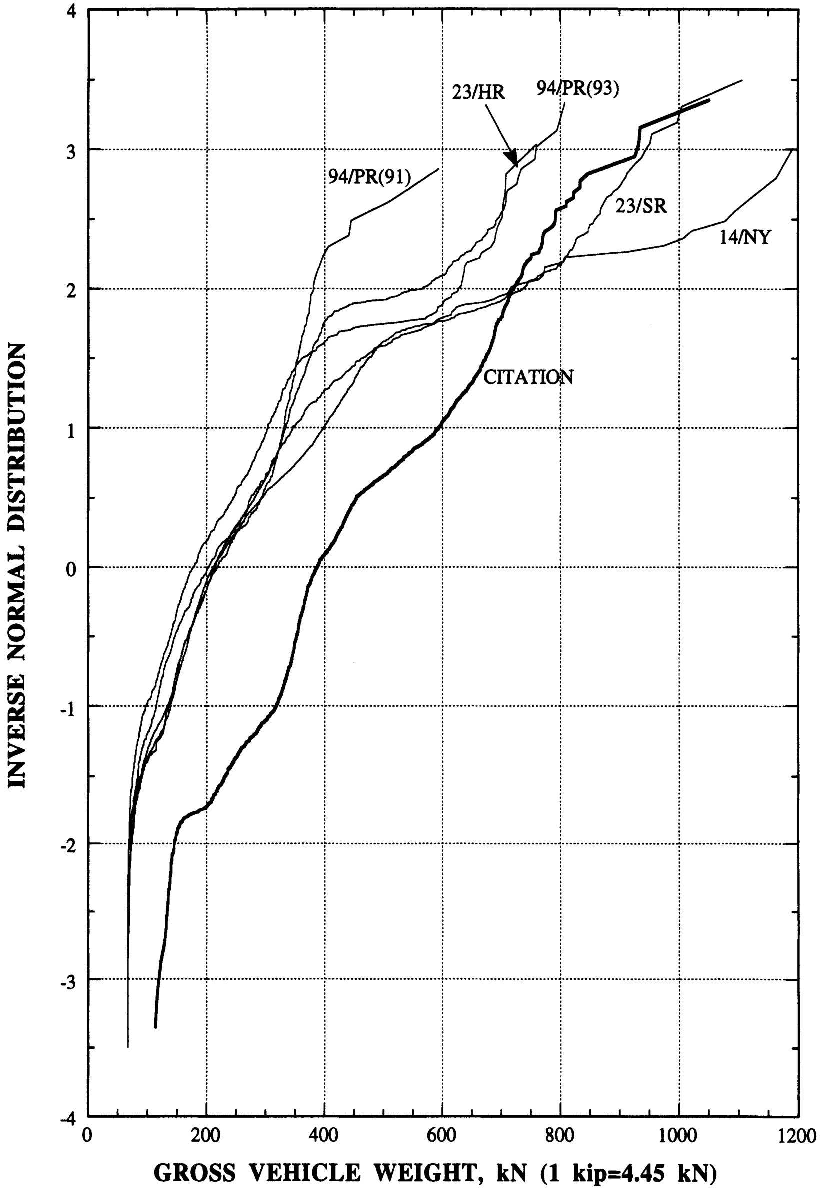



Fig. 5, Gross Vehicle Weight CDF's of All Trucks > 65 kN with Citation Data.

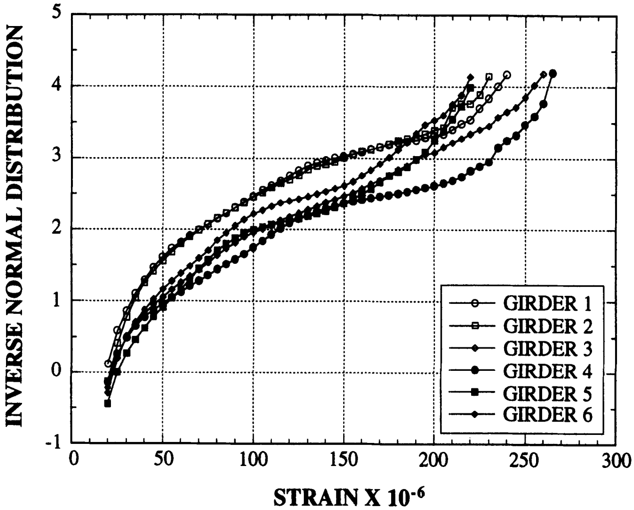



Fig. 6, US23/Huron Rr NB Rainflow Strain CDF's for G1-G6.

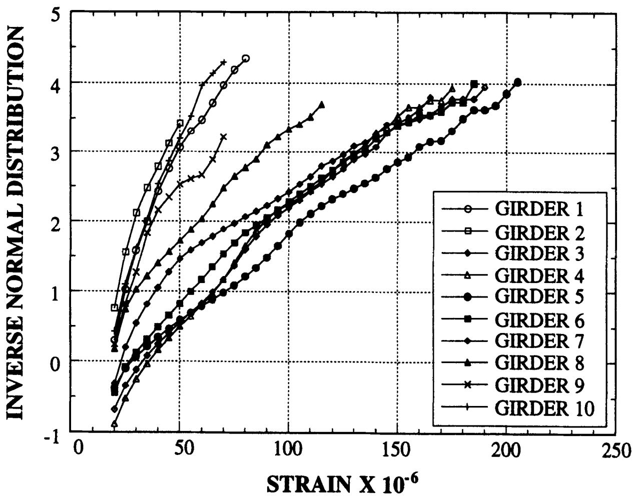



Fig. 7, US-23/Saline Rr SB, Rainflow Strain CDF's for G1-G10.

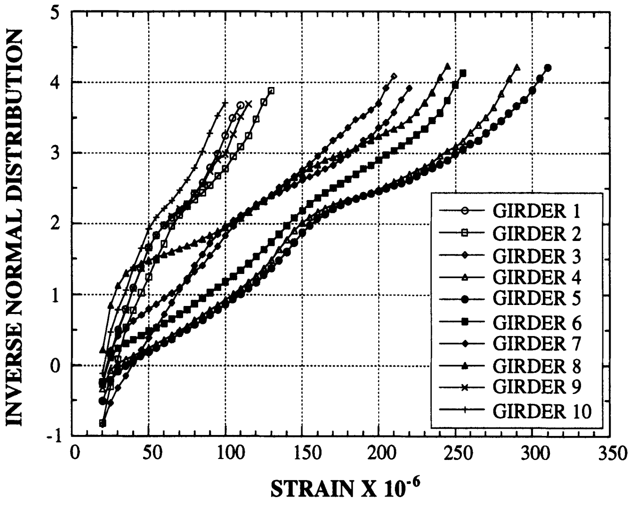



Fig. 8, I-94/Pierce Rd EB Rainflow Strain CDF's for G1-G10.

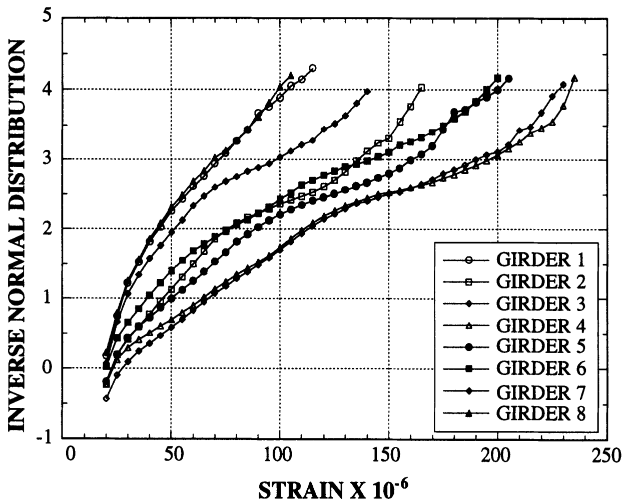
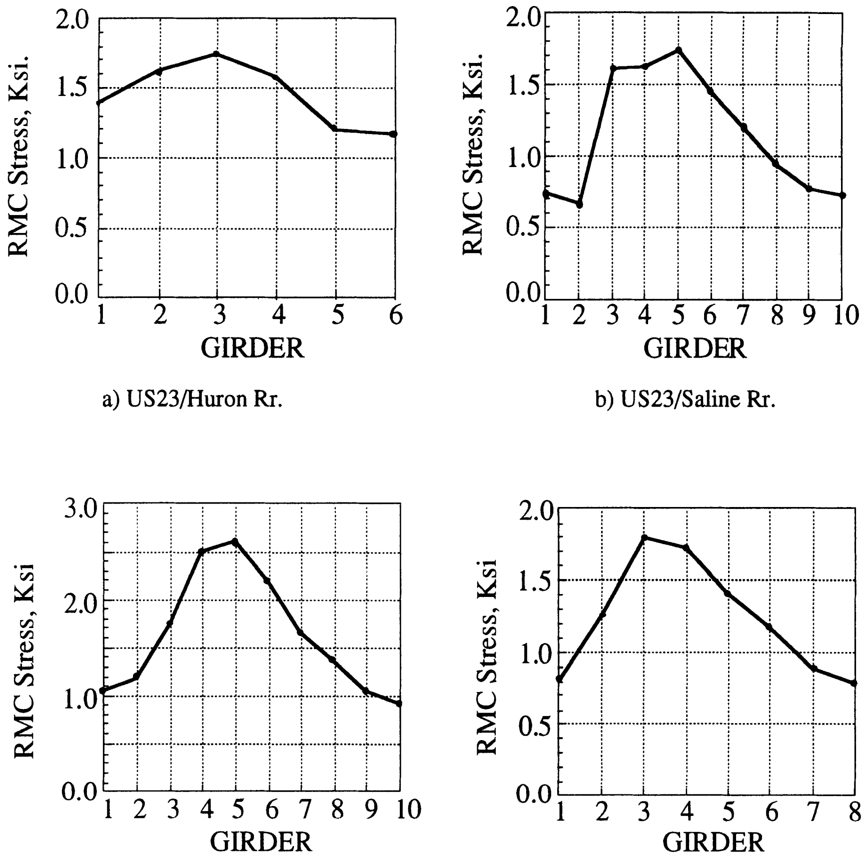



Fig. 9, M-14/New York City RR EB, Rainflow Strain CDF's for G1-G8.




a) US23/Huron Rr.

b) US23/Saline Rr.

c) I94/Pierce Rd.

d) M14/NYC RR.

Fig. 10, Equivalent (Root Mean Cube) stress for each Girder of the Selected Bridges.
(1 ksi = 6.9 MPa)