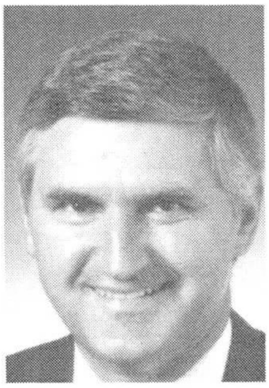
Zeitschrift: IABSE reports = Rapports AIPC = IVBH Berichte
Band: 73/1/73/2 (1995)

Artikel: Monitoring bridge load spectra
Autor: Nowak, Andrzej S. / Laman, Jeffrey A.
DOI: https://doi.org/10.5169/seals-55187

Monitoring Bridge Load Spectra
Mesure des charges sur les ponts
Messungen von Brückenlasten

Andrzej S. NOWAK
Professor
University of Michigan
Ann Arbor, MI, USA



Andrzej S. Nowak received his Ph.D. from Warsaw Univ. of Technology, Poland, and has been at University of Michigan since 1979. He has been involved in reliability-based development of the LRFD bridge design codes in the United States and Canada.

Jeffrey A. LAMAN
Research Associate
University of Michigan
Ann Arbor, MI, USA

Jeffrey Laman recently completed his Ph.D. at the University of Michigan. His dissertation focused on fatigue load models for girder bridges. For the past four years he has been conducting tests on steel highway bridges. He also has ten years of professional engineering experience.

SUMMARY
The objective of the study is to determine actual live loads for highway bridges located within a large metropolitan area. Truck weights were measured using weight-in-motion technology. The parameters obtained include gross vehicle weight, axle weights and axle spacing. Seven bridges were selected to represent the total population. The statistical data is presented as cumulative distribution functions. The results are shown for the different parameters. Live load varies considerably from site to site.

RÉSUMÉ
L'objectif de cette étude est de déterminer les charges réelles sur les ponts. Les paramètres considérés sont le poids et la dimension des camions. Sept ponts sont étudiés. Les résultats sont présentés sous forme de fonctions statistiques.

ZUSAMMENFASSUNG
Das Ziel dieses Projekts ist die Bestimmung von Brückenlasten. Die untersuchten Parameter sind Gewichte und Dimensionen von Lastwagen. Insgesamt wurden sieben Brükken ausgesucht. Die Ergebnisse werden anhand von statistischen Funktionen dargestellt.

1. INTRODUCTION

The two major questions facing bridge owners are: what is the actual strength of the structure and what is the remaining life? Structural performance depends on bridge resistance and actual loads. It has been observed that truck loads are strongly site-specific. There is considerable variation in traffic volume and truck weights, even within a given geographic area. Therefore, the objective of this paper is to present actual truck loads on selected bridges in a major metropolitan area.

Seven bridges were selected to represent a wide cross section of traffic in the greater Detroit area. The selection criteria included location, accessibility for testing equipment, span length, truck traffic volume and presence of traffic control. The basic parameters of the selected bridges are summarized in Table. 1. The parameters include span length, number of girders, girder spacing, number of traffic lanes and average daily truck traffic (ADTT).

Table 1. Parameters of Selected Bridges.

No.	Symbol	Span (m)	Number of girders	Girder spacing (m)	Number of lanes	ADTT (one direction)
1	WY/I94	10	9	1.55	2	750
2	I94/M10	33	5	2.70	2	1,500
3	US12/I94	12	9	1.65	2	500
4	DA/M10	13	8	1.60	2	750
5	M39/M10	10	8	1.85	3	1,500
6	I94/I75	13.5	8	1.40	2	1,500
7	M153/M39	9.5	12	1.75	3	500

Measurements were taken using a weigh-in-motion (WIM) system. The truck weights and axle weights are calculated from strains measured in bridge girders. Sensors were installed in each lane at the bridge entrance to determine the vehicle speed, number of axles and axle spacing. The equipment is calibrated using a truck with known axle weights. Measurement accuracy of gross vehicle weight (GVW) is about 5 percent for most types of trucks and the measurement accuracy of axle weights is about 20 percent. Selected bridges were instrumented and measurements were taken for two or three consecutive days.

2. TRUCK TRAFFIC

The number of axles on trucks varies. Analysis of the WIM data indicates that a majority of the trucks are two axle vehicles. Many two axle vehicles are of low GVW and do not affect the bridge life. An important vehicle type is the five axle truck, which is the majority of the heavier vehicles (greater than 70 kN). The heaviest vehicles in the Detroit Metropolitan Area are 11 axle trucks, which constitute up to five percent of truck traffic with GVW greater than 70 kN.

The general observation that live load on bridges is strongly site-specific can be made from the WIM data. There is a considerable variation in traffic volume and weight of trucks from sit to site. The estimated average daily truck traffic (ADTT) (in one direction) varies from 500 to 1,500. The maximum observed truck weight varies from 350 kN to 1,100 kN. The maximum observed axle weights vary from 90 kN to nearly 220 kN. The largest GVW and axle weights were observed on interstate highway I-94 and Michigan highway M-39. These roads also have the largest observed traffic volume with an estimated ADTT of 1,500 in each direction. The weight of trucks on surface roads with lower volume of traffic is mostly within the legal limits.

3. TRUCK WEIGHTS AND AXLE WEIGHTS

Results of field truck measurements are shown on normal probability paper. The vertical axis is the inverse of the standard normal probability function, corresponding to the probability exceedance. For example, 0 corresponds to probability 0.5 and 2 corresponds to 0.02 (the probability of exceeding given value of truck weight is 0.02).

The CDFs of GVW are plotted in Fig. 1. The observed extreme GVW varies depending on the route. Most overloaded trucks were observed on I-94 and M-39, which are high volume highways. For these two bridges, the maximum GVWs are approximately 1,000 kN. For other bridges, the maximum values of GVW are approximately 700 kN.

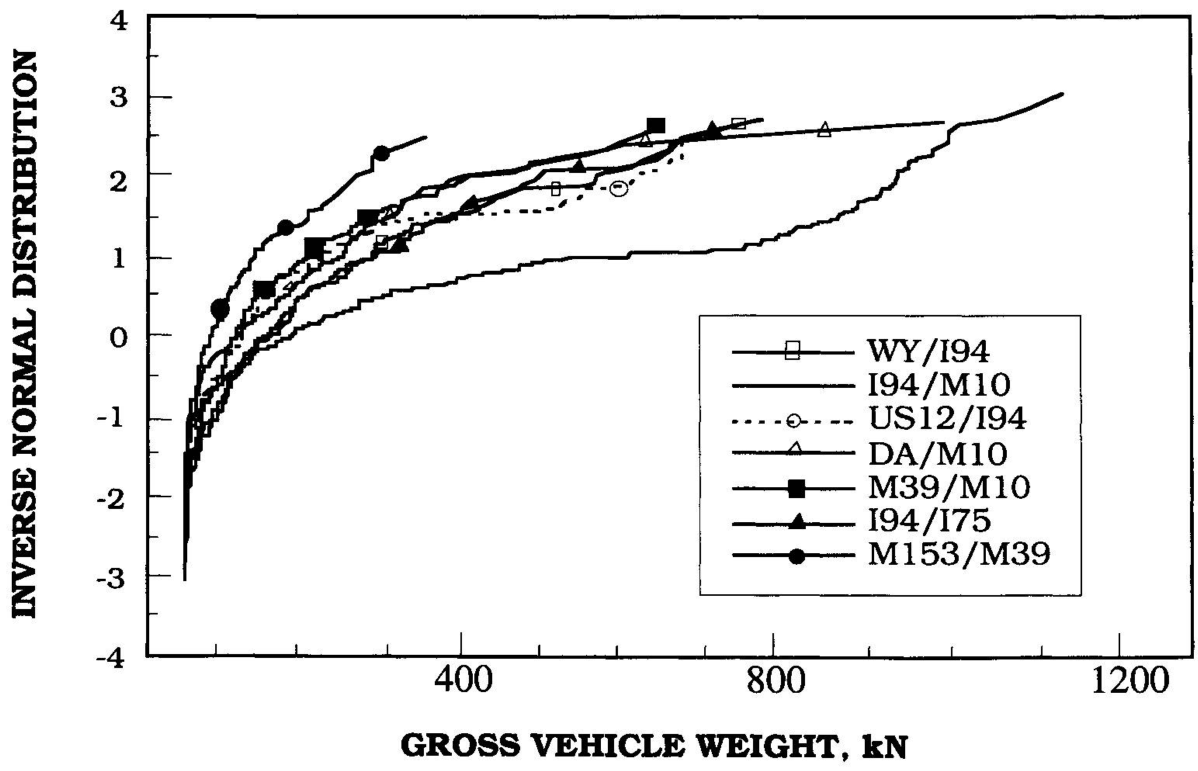


Fig. 1. Distribution Functions of Gross Vehicle Weight.

Truck axle weight is also an important parameter. The CDFs of axle weight are shown in Fig. 2 for the considered bridges. Similar to the GVW, the extreme values are associated with bridges carrying I-94 and M-39. The largest values of axle weight exceed 200 kN.

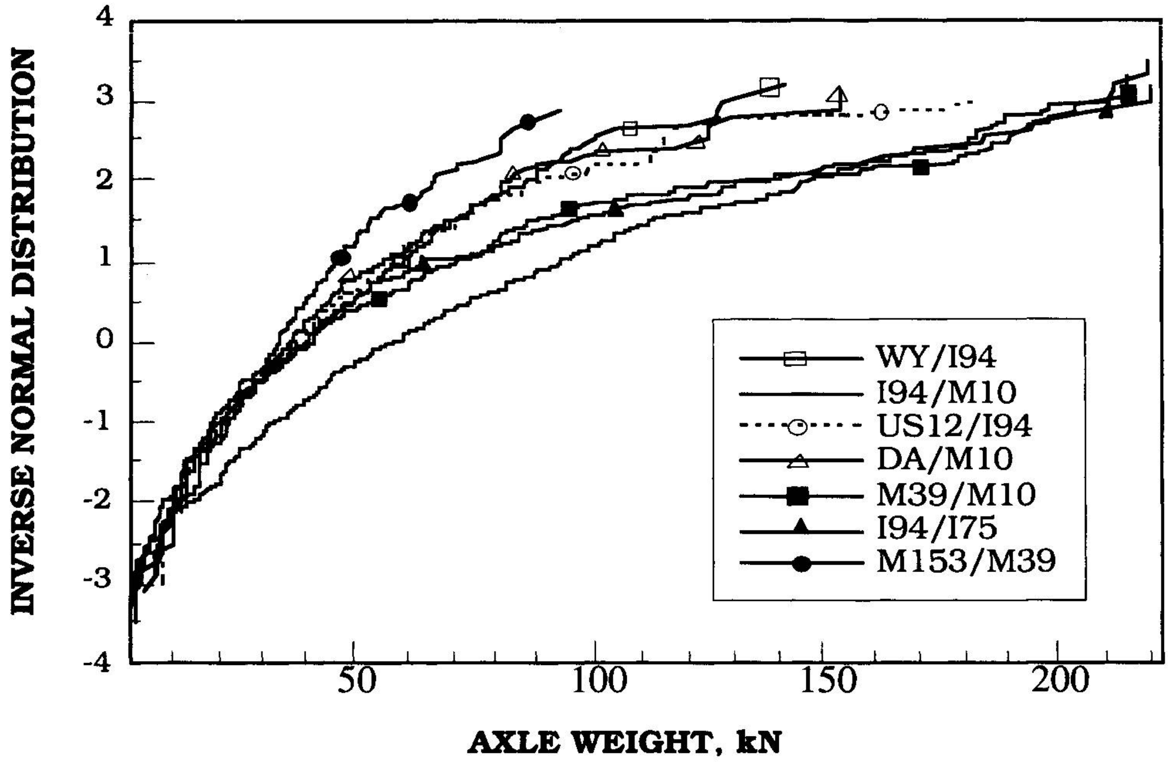


Fig. 2. Distribution Functions of Axle Weight.

4. EFFECT OF BRIDGE LIVE LOAD

Bridge damage is caused by load effect rather than the load itself. The effect of truck loads on bridges can be evaluated by consideration of lane moments. The calculations were carried out using influence lines. The maximum simple span moment was determined for each truck in the data base. The results are shown in Fig. 3 on normal probability paper. For an easier comparison, the moments are divided by corresponding HS-20 moments, calculated according to the AASHTO Specifications (1992).

The variation of maximum moments is similar to that of gross vehicle weights. For I-94 and M-39, the extreme values exceed 2.5 HS-20 moments. For other bridges, the maximum moments are about 1.5 design live load.

To determine the actual load taken by each girder, stress spectra were determined using the rainflow method. It was observed that even though a large number of trucks exceed the legal weight limits, the actual stress range due to live load is within acceptable limits. However, the number of axle weights exceeding the legal limits seems to be too high. Multiple passages of heavy axles contribute to the deterioration of the bridge deck slabs and road pavement. More law enforcement may be needed for the highways with a high percentage of overloads.

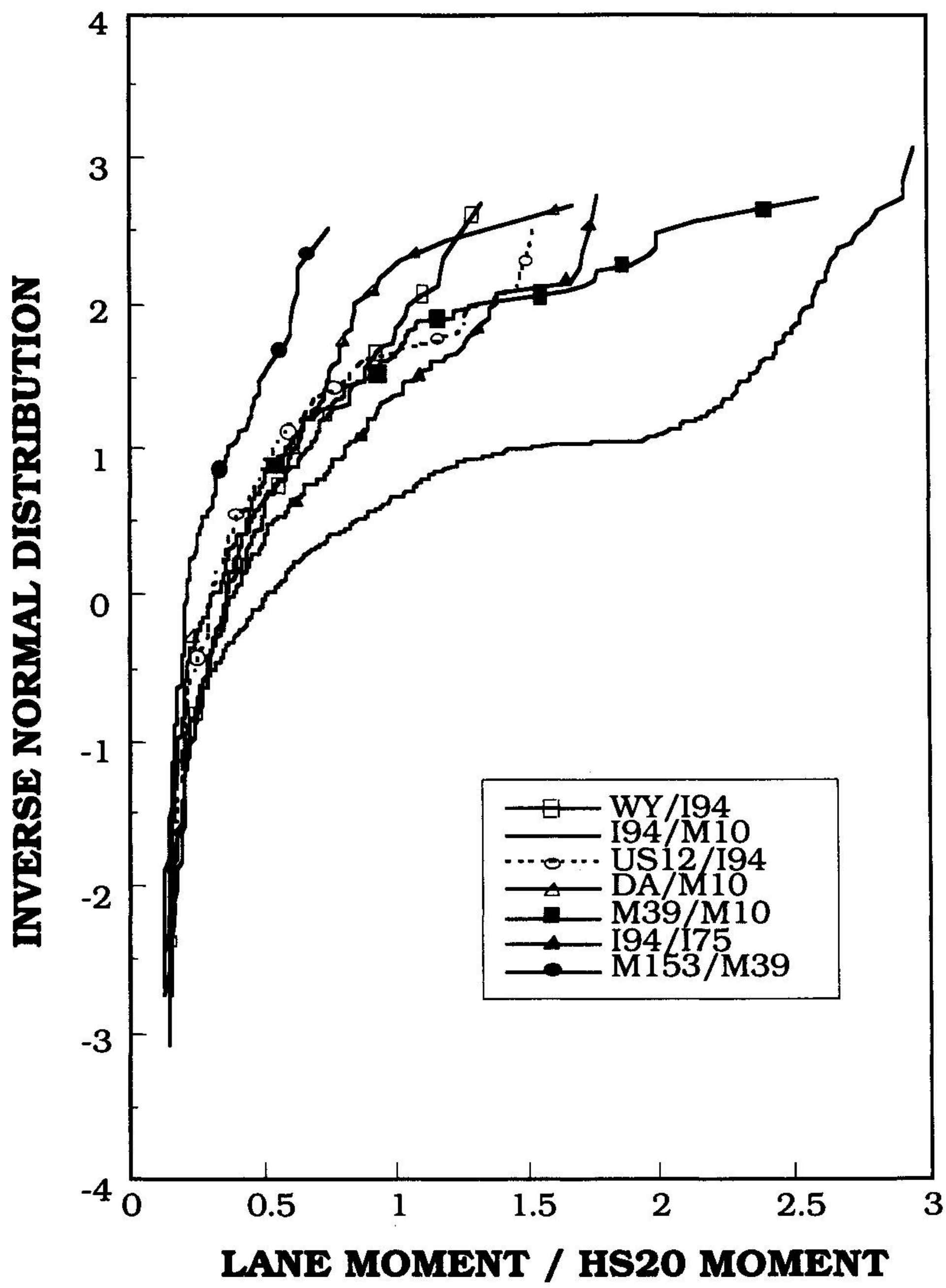


Fig. 3. Distribution Functions of Midspan Moments.

6. CONCLUSIONS

The tests were carried out on bridges located on various types of roads in the Metropolitan Detroit Area. Some of these bridges carry surface street traffic while others carry highway loads. The results of measurements indicate that traffic is strongly site-specific. This applies to number of trucks, gross vehicle weight, axle weight and midspan moment.

ACKNOWLEDGEMENTS

The presented study was sponsored by the Michigan Department of Transportation and Great Lakes Center for Truck Transportation Research (GLCTTR) at the University of Michigan Transportation Research Institute which is gratefully acknowledged. Thanks are due to Sangjin Kim for his help in calculations.

REFERENCES

Laman, J.A., "Fatigue Load Models for Girder Bridges", Doctoral Dissertation, University of Michigan, Ann Arbor, Michigan, January 1995.

Laman, J.A., "Load Spectra for Girder Bridges", Fourth International Bridge Engineering Conference in San Francisco, CA, TRB, Washington. D.C., August 1995, to appear.

Laman, J.A. and Nowak, A.S., "Verification of Truck Loads for Girder Bridges", ASCE, Structures Congress, Boston, MA, April 1995, to appear.

Nowak, A.S., Kim, S., Laman, J.A., Saraf, V. and Sokolik, A. F., "Truck Loads on Selected Bridges in the Detroit Area", Research Report UMCE 94-34, Department of Civil and Environmental Engineering, University of Michigan, Ann Arbor, Michigan, December 1994.

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