Site-Specific Truck Load Study

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ABSTRACT

The objective of this research was to determine the actual truck loads on selected bridges in the Detroit Area. Seven representative bridges were selected in cooperation with the Michigan DOT staff. The measurements were taken using a weigh-in-motion system manufactured by Bridge Weighing Systems (BWS) Inc. The equipment is calibrated using a truck with known gross vehicle weight (GVW) and axle weights. The accuracy of GVW measurements is estimated at (+/-) 5 percent for most types of trucks. The accuracy of axle weights is estimated at (+/-) 20 percent. Selected bridges were instrumented and measurements were taken for two or three consecutive days.

In general, truck loads on bridges are strongly site-specific. There is a considerable variation in traffic volume and weight of trucks. The estimated average daily truck traffic (ADTT) varies from 500 to 1,500 in one direction. The maximum observed GVW's vary from 80 kips to 250 kips. The maximum observed axle weights vary from 20 kips to almost 50 kips. The percentage of trucks exceeding the estimated Michigan legal limits varies depending on the road. The heaviest GVW and axle weights were observed on interstate highways. On surface roads with lower volume of traffic, the weight of trucks is mostly within the legal limits. The percentage of overloaded trucks varies from 0 to almost 90 percent, depending on the number of axles. The largest percentage of overloaded trucks was observed for 11 axle vehicles.

INTRODUCTION

Throughout the United States, bridges are evaluated for their capacity using standard design loads and truck configurations [1, 2]. However, the bridge location will determine the actual loads, load frequencies, and truck configurations that an existing bridge will experience. More realistic evaluations of bridges may be possible by using site-specific truck loads.

In 1993 and 1994, the study has been carried out to measure truck weights using Weigh-in-Motion (WIM) equipment. The WIM system operates on a bridge which serves as a scale. The structure is instrumented, strains are measured, and from the strain data, truck axle loads and gross vehicle weight (GVW) are calculated. The process is repeated for all vehicles passing on the bridge. The WIM system provides unbiased truck data because the instrumentation is invisible to the truck drivers and therefore they cannot make any effort to avoid the scales.

The measurements were taken on a total of seven bridge sites. The observed truck traffic is summarized in tables with number of trucks and corresponding number of axles, parameters of the gross vehicle weight (GVW) and axle weight. The histograms and cumulative distribution functions (CDF) of GVW and axle weight are shown in figures.

TESTING EQUIPMENT

Truck data such as static axle loads, gross vehicle weights (GVW), axle spacings, and vehicle speeds were collected using a weigh-in-motion (WIM) data acquisition system from the Bridge Weighing Systems, Inc. (BWS). The WIM equipment provides several advantages over other technologies and is therefore utilized for this study. It is portable, accurate, and the data can be collected without the knowledge of the traffic using the bridge. The accuracy of GVW measurements is estimated at (+/-) 5 percent for most types of trucks. The accuracy of axle weights is estimated at (+/-) 20 percent [3]. The testing equipment was provided by the Michigan DOT and University of Michigan. The BWS system is based on the method that was developed at the Case Western Reserve University [4]. The equipment was calibrated using a truck with known gross vehicle weight (GVW), axle weights, and axle spacings. Traffic control and calibration trucks were provided by MDOT. The axle configuration of the Michigan DOT calibration truck is shown in Figure 1.

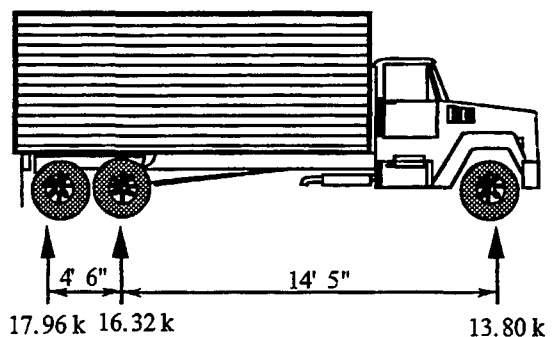17.96 k 16.32 k   13.80 k

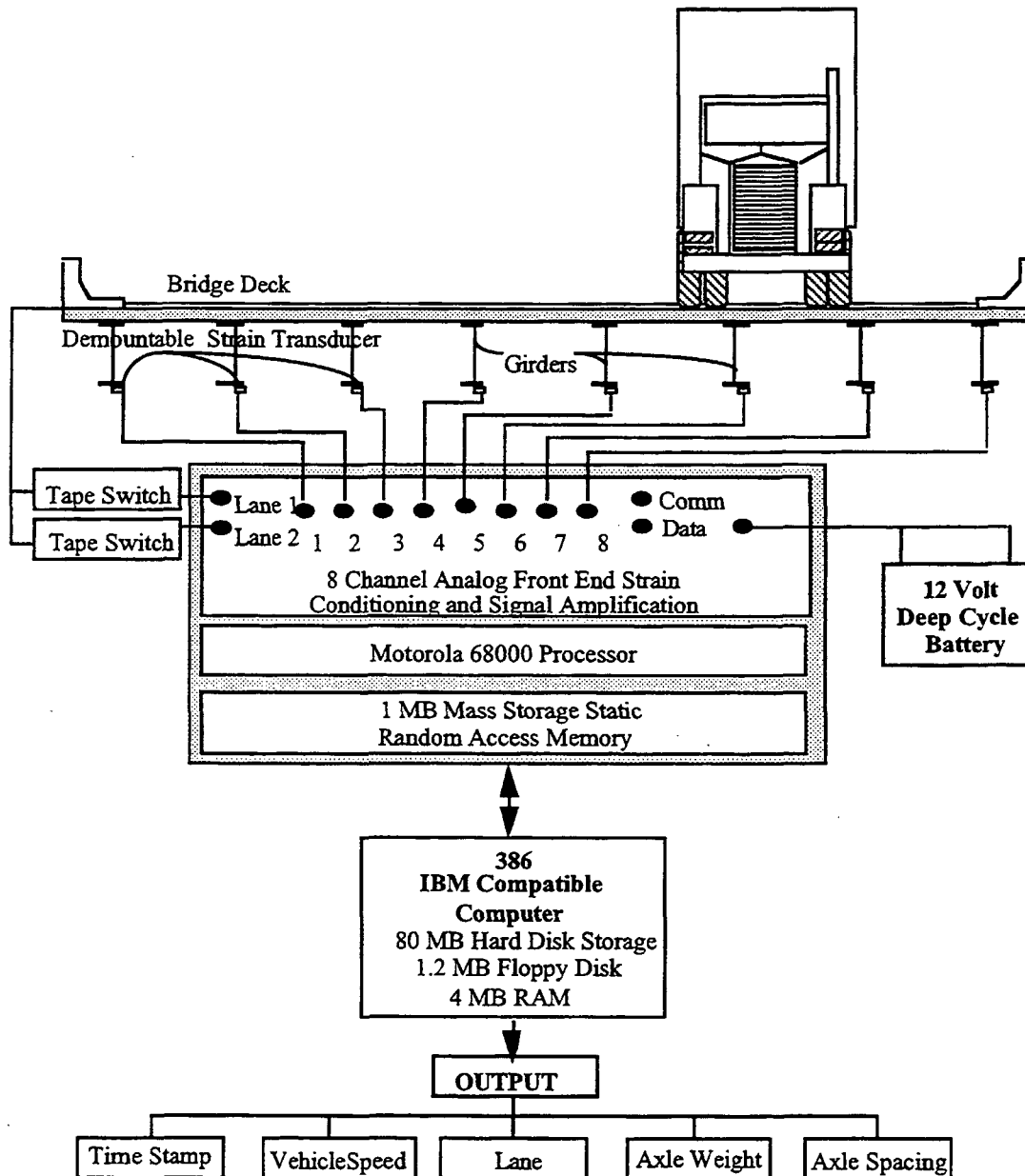Figure 1. Michigan DOT three axle calibration truck

Figure 2. Primary Component of the BWS system

The system consists of the main processing unit, strain transducers, portable computer, cables, battery, and lane sensors. The unit is capable of handling up to eight channels through the analog front end (AFE) and two channels for lane sensors. The main component configuration of BWS system is shown in Figure 2.

The main processing unit is constructed with three circuit boards which collect, process, and store all data received from the strain transducers and the roadway sensors. The central processing unit is a Motorola MC68000 processor and is connected to the Analog Front End (AFE) board via a parallel data port. The AFE acts as a signal conditioner and amplifier with a capacity of eight input channels.

Before data acquisition, the AFE resets the strain signals at zero. The auto-balancing of the strain transducers is started when the first axle of the vehicle crosses the first lane sensors. As the truck crosses the two lane sensors, the speed and axle spacings are determined. When the vehicle reaches

the bridge, the strain sampling is activated. When the last axle of the vehicle exits the instrumented bridge span, the strain sampling is turned off. Data received from strain transducers is processed using influence lines to determine GVW and axle weight. These data do not include dynamic loads. The total weighing process takes from 1.7 to 3.0 seconds, depending on the instrumented span length, vehicle length, number of axles, and vehicle speed.

The BWS WIM equipment operates on 12V DC. All files are stored in static random access memory (SRAM) which is capable of holding up to 20,000 truck records. Captured strain files may also be stored in SRAM with a maximum of 175 records.

The strain transducer used for the system is demountable and clamped to the upper or lower surface of the bottom flange of the steel girders. All transducers are placed on the girders at the same distance from the abutment, in the middle third of a simple span.

Two types of lane sensors were used depending on the

site conditions: tape switches, and infrared sensors. Tape switches consist of two metallic strips that are held out of contact in the normal condition. As a vehicle wheel passes over the tape it forces the metallic strips into contact and grounds a switch. If a voltage is impressed across the switch, a signal is obtained at the instant the vehicle crosses the tape. This signal is fed to a computer whereby the speed, axle spacing and number of axles are determined. The tape switches are placed perpendicular to the traffic flow and used to trigger the strain data collection.

In slow traffic area, infrared sensors were used. They consist of a source of infrared light beam and a reflector. Source of light is installed on the side of the road and reflector in the center of the traffic lane. The infrared system is more difficult to install and truck can easily move the reflector and interrupt the operation.

SELECTION OF BRIDGES

Bridges in the Detroit Area were selected in cooperation with the Michigan DOT staff [5]. Important factors considered in the selection process included accessibility for the equipment, low dynamic effects, the location of bridges, average daily truck traffic (ADTT) and placement of tapeswitches or infrared sensors. Seven bridges were selected as listed in Table 1. For brevity, each bridge is denoted by a special code symbol (abbreviation of the road number or name).

Table 1. Selected bridges

Symbol	Location
WY/I94	Wyoming Road over I-94 in Detroit, Wayne County, Michigan
I94/M10	I-94 Eastbound to M-10 Northbound, Detroit, Wayne County, Michigan
US12/I94	US-12 Eastbound to I-94 Eastbound, Dearborn, Wayne County, Michigan
DA/M10	Davison Ave. Eastbound over M-10, Detroit, Wayne County, Michigan
M39/M10	M-39 Southbound to M-10 Southbound, Southfield, Oakland County, Michigan
I94/I75	I-94 Westbound to I-75 Southbound, Detroit, Wayne County, Michigan
M153/M39	M-153 Westbound over M-39 Detroit, Wayne County

TRUCK LOAD MEASUREMENTS

The summary of the measured truck traffic mix is presented in Table 2. This data includes vehicles with a gross vehicle weight (GVW) greater than 10 kips for 2 axle vehicles, or greater than 15 kips for three and more axle vehicles. For the considered bridges, the number of trucks is given for various numbers of axles. The largest number of vehicles is in the two axle category followed by five axle trucks. A large proportion of 11 axle vehicles was observed in I94/M10. Most of vehicles consist of 2, 3, 5, and 11 axle vehicles, and only small numbers of 7, 8, 9, 10 axle vehicles were observed for the seven bridge sites.

The summary of the gross vehicle weight (GVW) parameters are given in Table 3, along with the estimated average daily truck traffic (ADTT) in one direction. The ADTT was estimated on the basis of truck measurements performed for this study. The ADTT varies from 500 to

Table 2. Number of trucks weighed

Bridge location	Gross vehicle weight > 10 kips for 2 axle vehicles, Gross vehicle weight > 15 kips for 3 or more axle vehicles.										
	Truck type (number of axles)										
	2	3	4	5	6	7	8	9	10	11	all
WY/I94	82	26	18	107	16	9	14	2	3	20	297
I94/M10	385	95	40	147	70	28	13	8	3	133	924
US12/I94	56	28	18	43	6	6	5	1	3	4	170
DA/M10	125	45	10	34	26	10	6	7	3	6	273
M39/M10	350	59	43	118	11	10	2	2	1	2	598
I94/I75	93	19	27	148	9	7	2	0	0	8	313
M153/M39	94	28	21	18	2	1	0	2	0	1	167

Table 3. ADTT, Gross vehicle weight, and axle weight

Bridge location	Estimated ADTT (in one direction)	GVW (kips)		Axle weight (kips)	
		Max.	Mean	Max.	Mean
WY/I94	750	177	40	32	9
I94/M10	1,500	263	64	49	14
US12/I94	500	154	34	41	9
DA/M10	750	126	31	29	8
M39/M10	1,500	109	28	44	8
I94/I75	1,500	178	41	50	10
M153/M39	500	78	21	21	7

1,500 in one direction. The maximum GVW's vary from 80 to over 250 kips, with the average from 20 to over 60 kips. The cumulative distribution functions (CDF) of GVW are shown in Figure 3. The results are plotted on normal probability paper. Clearly, traffic on I-94 over M-10 is heavier than on other bridges considered in this study. For five axle trucks and 11 axle trucks, the percentage of vehicles with GVW larger than estimated legal limits is shown in Table 4. The percentage of overloaded trucks varies from 0 to almost 90 percent, depending on the number of axles.
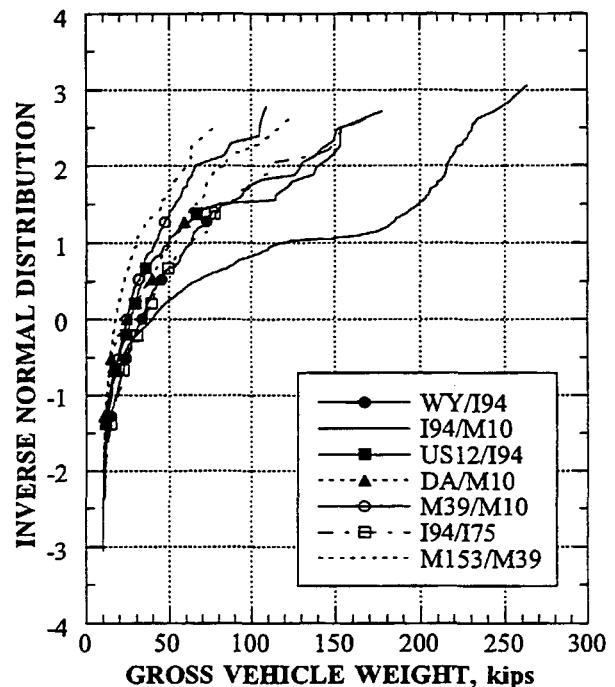

Figure 3. Gross vehicle weight distributions

Table 4. Percentage of overloaded vehicles and axles

GVW limit = 80 kips for 5 axle vehicles = 164 kips for 11 axle vehicles Axle weight limit = 18 kips for all vehicles			
Bridge location	Vehicle type	Overloaded vehicles (%)	Overloaded axles (%)
WY/I94	5 axles	4	4
	11 axles	5	1
I94/M10	5 axles	21	19
	11 axles	88	40
US12/I94	5 axles	0	1
	11 axles	0	0
DA/M10	5 axles	0	1
	11 axles	0	4
M39/M10	5 axles	1	2
	11 axles	0	5
I94/I75	5 axles	15	10
	11 axles	0	0
M153/M39	5 axles	0	1
	11 axles	0	0

The axle weights are also summarized in Table 3. The maximum axle weights vary from 21 to 50 kips, and average values from 7 to 14 kips. The CDF's are plotted on normal probability paper in Figure 4. The heaviest value was observed on I-94. For five axle trucks and 11 axle trucks, the percentage of vehicles with axle weight larger than estimated legal limits is also shown in Table 4. The results of measurements indicate that a considerable number of axle weights exceed the legal limits.

The front and all axle weight CDF's of Figures 4 and 5 indicate a significant difference in both variation and magnitude. Front axles have much smaller variation and maximum axle weight. Front axles have much smaller variation and maximum axle weight. The standard deviation of front axle weight varies, from 2 kips to 5 kips, with
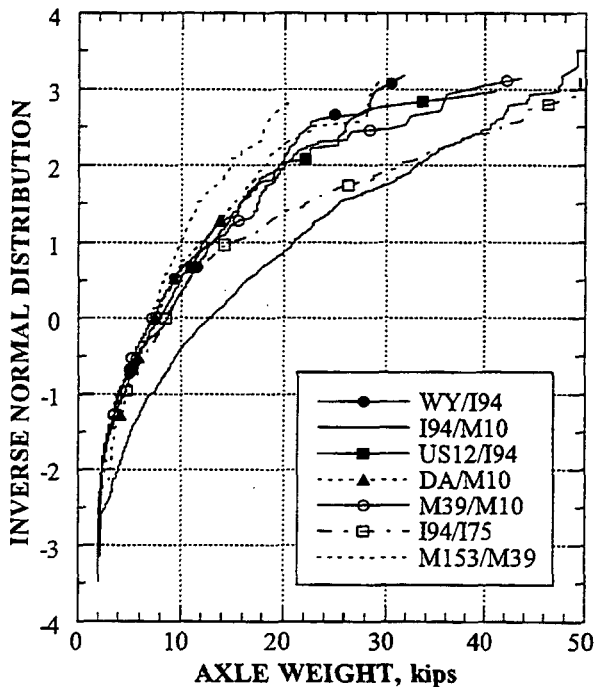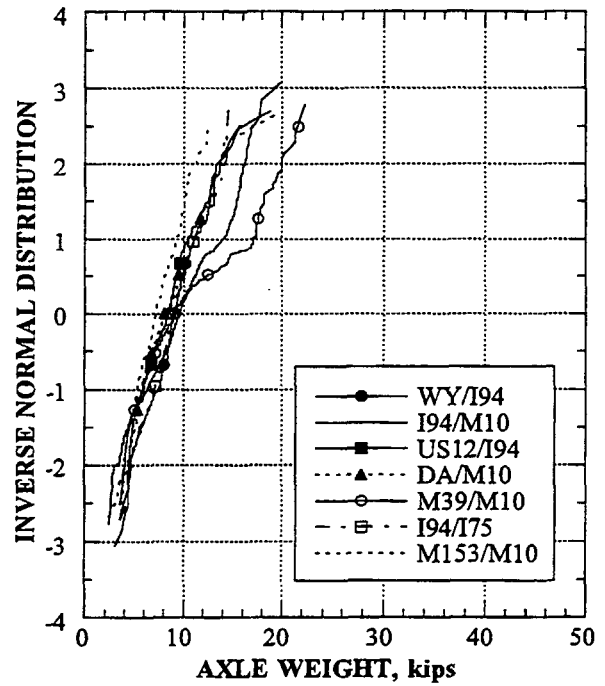

Figure 5. Front axle weight distributions.

the maximum of 13 kips to 22 kips. On the contrary, the standard deviation of all axle weight varies, from 3 kips to 8 kips, with the maximum of 21 kips to 50 kips.

Figure 6 presents GVW histograms of 2, 5, and 11 axle vehicles on bridge I94/M10. There is distinct difference in
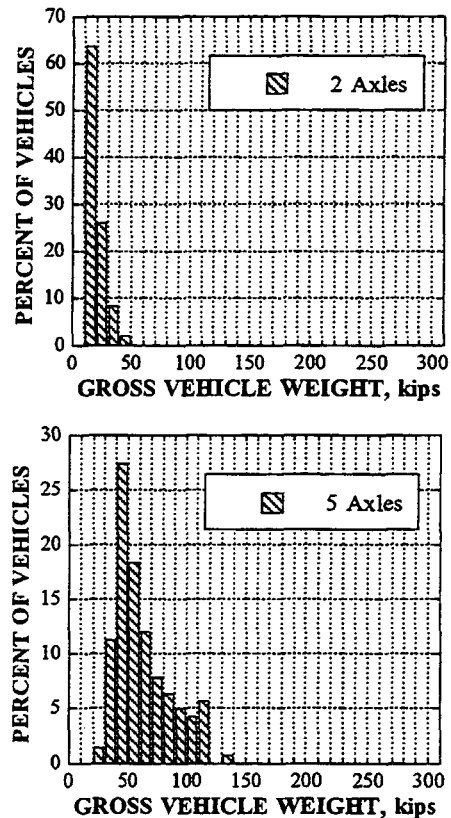

Figure 6. I94/M10, GVW histograms for 2, 5, and 11 axle vehicles (continued)
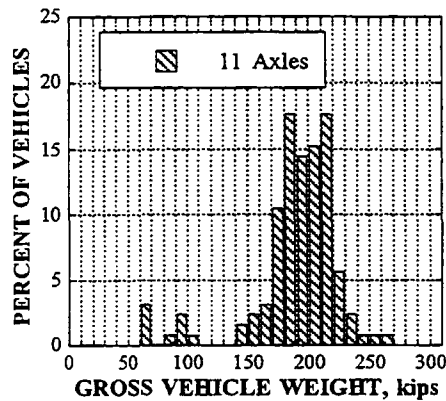

Figure 4. Axle weight distributions

Figure 6. I94/M10, GVW histograms
for 2, 5, and 11 axle vehicles

GVW for each axle group. The histograms indicate that the heaviest are 11 axle trucks and the lightest are 2 axle trucks. Most vehicles with less than 5 axles had GVW less than 120 kips.

CONCLUSION

The tests were carried out on bridges located on various types of roads in the Detroit Area. Some of these bridges carry surface street traffic while others carry highway loads. Truck loads on bridges are strongly site-specific. There is a considerable variation in traffic volume and weight of trucks. The estimated average daily truck traffic (ADTT) varies from 500 to 1,500 in one direction. The observed truck weights are often heavier than legal limits, especially the axle weight limit. The maximum GVW's vary from 80 kips to 250 kips. The maximum axle weights vary from 20 kips to almost 50 kips. Axle weights show much smaller variation than gross vehicle weights, from site to site, for each vehicle type. Front axles have much smaller variation and maximum axle weight than other axles. Most vehicles with fewer than 5 axles had GVW less than 120 kips. Eleven axle trucks had the heaviest GVW.

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