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TRUCK LOADS ON SELECTED BRIDGES IN THE DETROIT AREA

Report submitted to
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EXECUTIVE SUMMARY

The objective of the project is to determine the actual truck loads on selected bridges in the Detroit Area. The study is focused on structures which showed signs of deck deterioration, in particular spalling concrete. Eight bridges were selected by the project team in cooperation with the Michigan DOT staff. The selection criteria included location, accessibility for testing equipment, span length, truck traffic volume and presence of stop lights. The results of measurements are available for seven bridges. The truck traffic on the eighth bridge was too slow for the equipment to operate properly.

The measurements were taken using a weigh-in-motion system manufactured by Bridge Weighing Systems (BWS) Inc.. The system consists of a main processing unit serving eight channels, strain transducers, cables, and a portable computer. Two tape switches are attached to the pavement in each lane at the bridge entrance. The front wheel of a truck depresses the tape switch and triggers the measurement cycle. Truck speed is determined by computing the time from one tape switch to another. Axle spacings are calculated using the measured time intervals between passages of consecutive axles. Strain gages are attached to the lower flanges of girders. The measured strain records are processed using influence lines to determine the axle loads and gross vehicle weight (GVW). For each measured truck, the record includes vehicle speed, axle spacings and axle loads. The equipment is calibrated using a truck with known 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. The test data include truck GVW and axle weights.

Trucks vary with regard to the number of axles. The analysis of the test data indicates that most of the trucks are two axle vehicles. However, many of these vehicles are rather light and they do not affect the performance of the bridge. An important group are five axle

trucks, with the percentage varying from site to site. The heaviest are 11-axle trucks, and they constitute up to about five percent of truck traffic. The test data is shown separately for various truck types (number of axles).

For each bridge, the results are shown for all truck types together, and then separately for each truck type (by number of axles). The presented data includes histograms, cumulative distribution functions (CDF) of the gross vehicle weight (GVW) as well as of axle weight

In general, live load on bridges is 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 truck weight varies from 80 kips to 250 kips. The maximum observed axle weights vary from 20 kips to almost 50 kips.

The largest GVW and axle weights were observed on I-94 and M-39. These roads also have the largest observed traffic volume with the estimated ADTT = 1,500 in one direction. The weight of trucks on surface roads with lower volume of traffic is mostly within the legal limits.

The observed truck weights are compared with estimated Michigan legal limits. It can be seen that the percentage of trucks exceeding the legal limits varies depending on the road. Most of the overloaded trucks were observed on high volume highways (I-94 and M-39). The actual percentage varies depending on the number of axles, from 0 to 40 percent. The largest percentage of overloaded trucks was observed for 11 axle vehicles.

Bridge damage is caused by load effect rather than load. Therefore, it is important to consider the moments, shear forces, and stress spectra. For bridge girders, the major consideration is the maximum value of stress. The stress is a function of the gross vehicle

weight (GVW). On the other hand, the performance of a concrete deck depends on the axle weights rather than GVW.

Stress spectra were measured on a number of Michigan bridges as a part of the first part of the project and the results are described in the Report on Effect Truck Loads on Bridges, submitted to MDOT (Nowak et al. 1994). The observed stress values are rather low, with the maximum stress due to live load being less than 10 ksi (10,000 lb/sq inch), and less than 6 ksi in most structures. This observation was made even on bridges with the heaviest trucks. Stress due to dead load is about 7 ksi. The allowable stress in steel is about 20 ksi for a yield stress of 36 ksi. Therefore, the total maximum stress due to dead load and live load is still within the specified safety reserve.

For the bridge girders, the conclusion is that even though a considerable number of trucks exceeds the legal weights, the actual stress range due to live load is within the 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.

It is recommended to continue the testing program to cover a larger number of structures and with a focus on the effect of excessive gross vehicle weight and axle weight on bridge components, in particular girders and concrete slab.

ACKNOWLEDGMENTS

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The Project Team received help from other researchers, current and former students and staff of the University of Michigan. In particular, thanks are due to Chan Hee Park and Kayleen Seaver. They were involved in field instrumentation and measurements.

Thanks are due to the Michigan State Police for their cooperation. Traffic control was provided by the Michigan DOT and Wayne County.

The realization of the research program would not be possible without in kind support of the Michigan DOT and the University of Michigan. Measurements were taken using a weigh-in-motion (WIM) system provided by the Michigan DOT and purchased from Bridge Weighing Systems, Inc. MDOT also provided trucks for calibration of the equipment. The University of Michigan provided support for other needed equipment, including a van and technician support.

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Note:

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1. INTRODUCTION

In the spring and early summer of 1993, there were some reports of concrete falling off bridges in the Detroit Area. In response, Michigan DOT carried out an inspection program aimed at assessing the extent of the problem. Bridges with deteriorated decks were identified. Immediate measures were taken to prevent spalling concrete from falling on the roadway below the bridge. Furthermore, structures in question were scheduled for repair, rehabilitation or replacement. An important part of bridge evaluation is knowledge of the actual loads. Therefore, the objective of this project is to determine the truck loads on selected bridges in question.

The study has been carried out by measurement of 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.

In this project, bridges were selected from the list of structures, some of them with deteriorated decks, prepared by the Michigan DOT. The selection criteria included:

- span length (30 to 80 ft),
- accessibility for the equipment (tail spans were preferred)
- traffic speed (equipment requires a minimum vehicle speed of about 25 mph, therefore, presence of stop lights may cause a problem).
- geommetry (maximum skewness is 40 degrees)

A total of eight bridges were selected. However, the truck weights were measured on seven structures. The traffic on the eighth bridge was too slow for the equipment to operate properly.

The measurements were taken by the project team from the University of Michigan. The equipment used was provided by the Michigan DOT and University of Michigan. Traffic control and calibration truck were provided by MDOT.

The Report is divided into 12 chapters.

Chapter 2 provides a description of the testing procedures. The equipment and its operation are only summarized. A more detailed description is given in the Report on Effect of Truck Loads on Bridges submitted to MDOT (Nowak et al. 1994).

The basic parameters of selected bridges are presented in Chapter 3. The location of the considered structures is shown on a map. For an easier reference, each tested bridge is assigned a code symbol.

The results of measurements are shown in Chapters 4 through 11. For each tested bridge, the provided data includes a description of geometrical parameters with elevation, cross section, information about skewness, and layout of girders. The observed truck traffic is summarized in tables with number of trucks and corresponding number of axles, number of trucks per lane, 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. The CDF's are presented on the normal probability paper. The normal probability scale allows for a better interpretation of results. In particular, this applies to the upper tails of the distribution of GVW and axle weight. The construction and use of the normal probability paper is summarized in the Report on Effect of Truck Loads on Bridges submitted to MDOT (Nowak et al. 1994).

The histograms and CDF's are shown for all trucks and separately for different number of axles. For comparison, the results are also presented for measurements taken on different days.

The summary and conclusions are presented in Chapter 12.

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2. TESTING PROCEDURE

The testing equipment used in this project was selected in order to collect data for the development of live load spectra on selected bridges in Detroit. Truck data such as static axle loads, gross vehicle weights (GVW), axle spacing, and vehicle speed were collected using a weigh-in-motion (WIM) data acquisition system from the Bridge Weighing Sytems, Inc. (BWS).

The BWS system is designed to collect axle weights and gross vehicle weights (GVW) of vehicles moving at highway speeds. The system uses instrumented bridge girders that offer several advantages over pavement scales. The measurements can be carried out in up to two traffic lanes. The WIM data acquisition system was calibrated using trucks provided by the Michigan Department of Transportation.

The system used in this project consists of the main processing unit, strain transducers, portable computer, cables, 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 the system is shown in Fig. 2-1.

The system 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 Motorolla 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 is determined. When the vehicle reaches the bridge, the strain sampling is activeted. 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.

Lane 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.

Infrared system, consists of a source of infrared light beam and a reflector, was tested. 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.

The comparison of the results of calibration of WIM system, performed on some bridges in previous projects, indicates that the accuracy of measurements is within 13 percent for 11-axle trucks. The accuracy for 5-axle trucks varries from0.23 to 6.76 and the

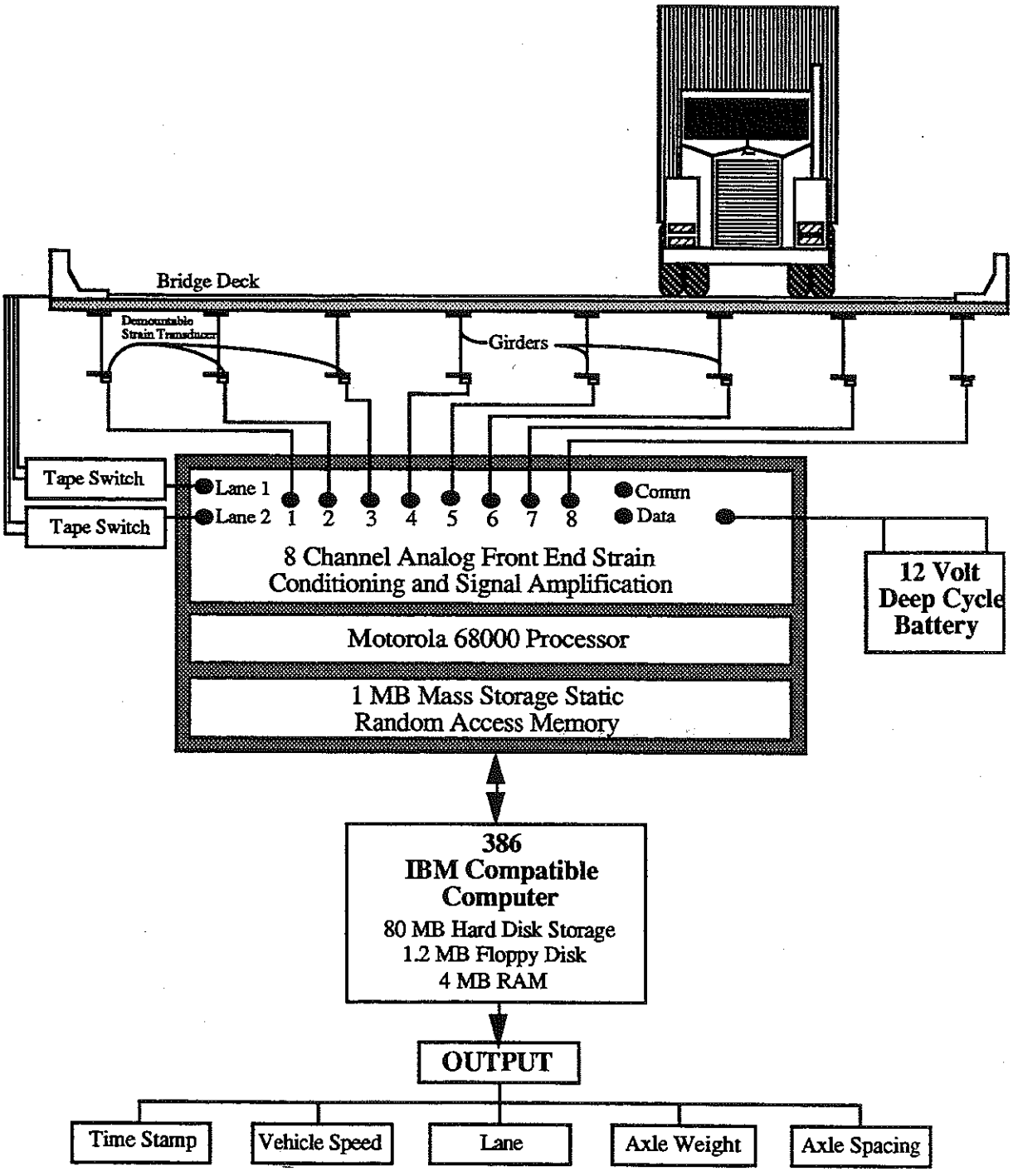


Fig. 2-1. Primary Components of the BWS Weigh-in-Motion System.

average is within 2.5 percent. However, the accuracy is higher for GVW than for axle loads.

For more information and additional details concerning testing equipment see Nowak, A.S., and Laaman, J.A., and Nassif,H.: *Effect of Truck Loading on Bridges,* Report 94-22, Department of Civil Engineering, University of Michigan, December 1994.

3. SELECTION OF BRIDGES

Bridges in the Detroit Area were selected by the Project Team in cooperation with the Michigan DOT staff. The selection criteria included:

- signs of deterioration of the deck (spalling concrete, cracks) if any
- accessibility for the equipment
- presence of stop lights (minimum truck speed is 25 mph)
- truck traffic (ADTT)
- geometry (maximum skew is 40°)
- span length (30 to 80 ft)

A list of bridges in the Detroit Area with deck problems requiring some repairs, rehabilitation or replacement was provided by MDOT. Most of the structures were inspected visually by the project team. The most promising bridges were recorded using a video camera for further consideration.

Eight structures were selected as are listed below together with data describing the traffic condition. There is 1993 annual average 24-hour traffic volumes (ADTT) and annual average 24-hour commercial traffic volumes (CADT). The data is for one direction of traffic, because the measurements were mostly done on connection ramps, and has been provided by MDOT-Transportation Planing Department.

In the report, each bridge is denoted by a special code symbol (abbreviation of the road number or name). Their locations are shown in Fig. 3-1.

1. WY/I94 - Wyoming Road over I-94, Detroit, Wayne County
   Michigan State Bridge ID: S36-82022
   ADTT: Unknown
   CADT: Unknown

2. I94/M10 - I-94 eastbound to M-10 northbound (Lodge Highway)
   Detroit, Wayne County
   Michigan State Bridge ID: S25-82023
   ADTT: 8,000
   CADT: 300 - 3.8 percent

3. US12/I94- US-12 eastbound ramp to I-94 eastbound. Detroit, Wayne County.
   Michigan State Bridge ID: S32-82022
   ADTT: 6,000
   CADT: 300 - 5.0 percent

4. DA/M10 - Davison Ave. eastbound over M-10 southbound (Lodge Highway), Detroit, Wayne County.
   Michigan State Bridge ID: S15-82112
   ADTT: 8,000
   CADT: 600 - 7.5 percent

5. M39/M10- M-39 southbound ramp over M-10 northbound (Lodge Highway), Southfield, Oakland County.
   Michigan State Bridge ID: S09-63801
   ADTT: 25,000
   CADT: 600 - 2.5 percent

6. I94/I75. - I-94 westbound over I-75 to I-75 Southbound, Detroit, Wayne County.
   Michigan State Bridge ID: S24-82251
   ADTT: 20,000
   CADT: 700 - 3.5 percent

7. M153/M39- M-153 westbound (Ford Road) over M-39 southbound (Southfield Freeway), Detroit, Wayne County.
   Michigan State Bridge ID: S01-82081
   ADTT: 26,000
   CADT: 700 - 2.7 percent

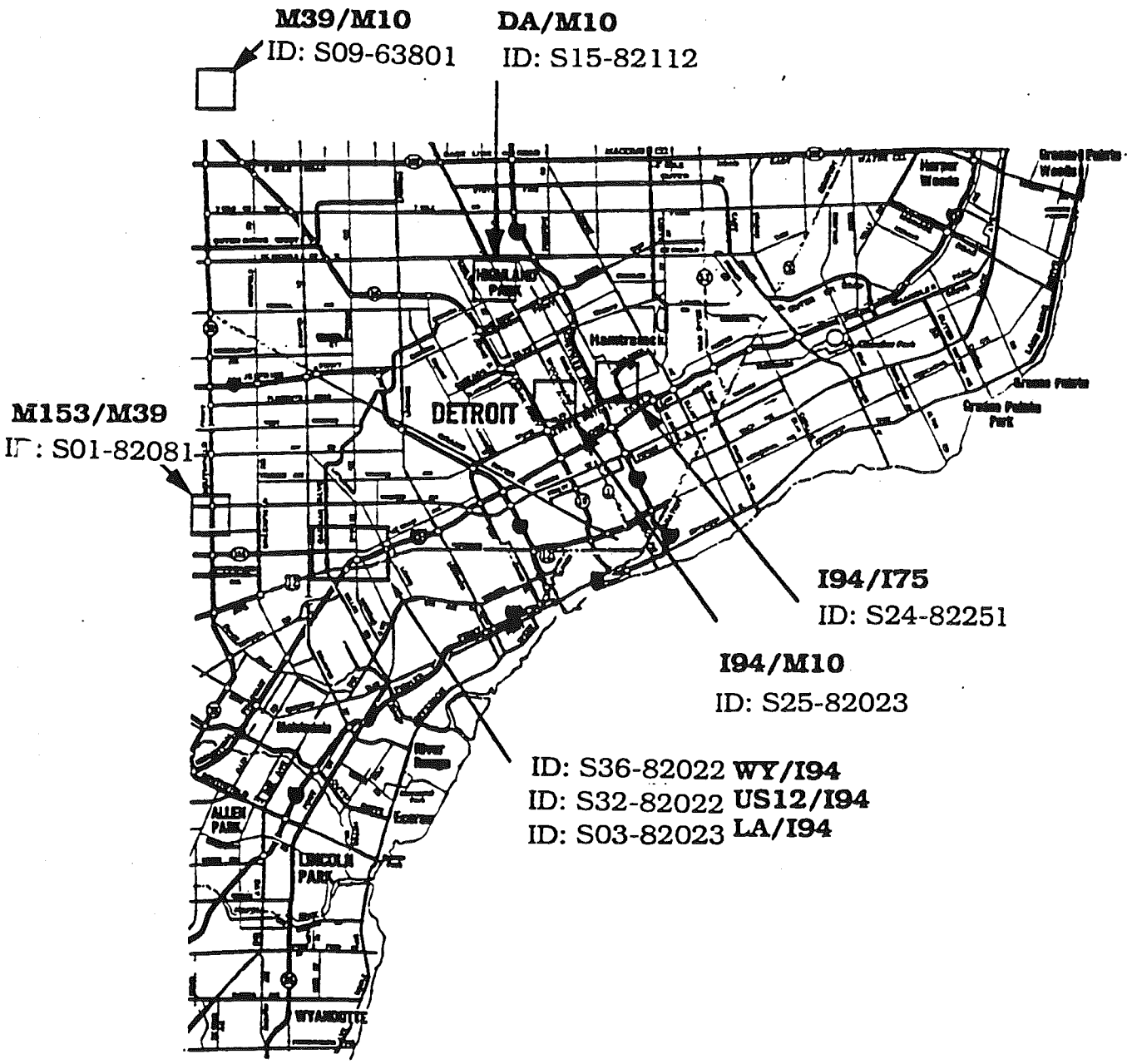


Fig. 3-1. Location of Selected Bridges in the Detroit Area.

8. LA/I94 - Lonyo Ave. southbound over I-94 Westbound, Detroit, Wayne County
   Michigan State Bridge ID: S03-82023
   ADTT: 8,500
   CADT: 200 - 2.4 percent

The parameters of the selected bridges are summarized in Table 3-1, including span length, number and spacing of girders, skew, number of traffic lanes. Further there is 1993 CADT in one direction (provided by MDOT) and estimated annual average 24-hour truck traffic (ECADT) based on the measurements in the field during the summer 1994.

Table 3-1. Parameters of Selected Bridges.

No.	Symbol	Span (ft)	Girders Nos.	Girders Spac.	Skew (dg.)	Nos. of lan.	CADTT (one direction)	ECADT
1	WY/I94	32.0	9	5.1'	18	2	NONE	750
2	I94/M10	76.1	5	8.8'	27	2	300	1,500
3	US12/I94	39.2	9	5.5'	9	2	300	500
4	DA/M10	42.8	8	5.3'	8	2	600	750
5	M39/M10	32.3	8	6.0'	6	3	600	1,500
6	I94/I75	44.4	8	4.6'	30	2	700	1,500
7	M153/M39	31.7	12	5.8'	0	3	700	500
8	LA/I94	31.7	12	5.4'	18	2	200	750

4. BRIDGE ON WYOMING ROAD OVER I-94 IN DETROIT (WY/I94)

4. 1 Description of the bridge

Bridge WY/I94 carries Southbound traffic on Wyoming Road over I-94 in Detroit. It is shown in Fig. 4-1. The elevation, cross section and other details are shown in Fig. 4-2 and 4-3. Measurements were taken in the entrance span (in the direction of traffic). The selected span is 32'-0 and the half bridge width is 43'-11" with a skewness of 18 degrees and consists of nine girders spaced at 5'-1 1/2".

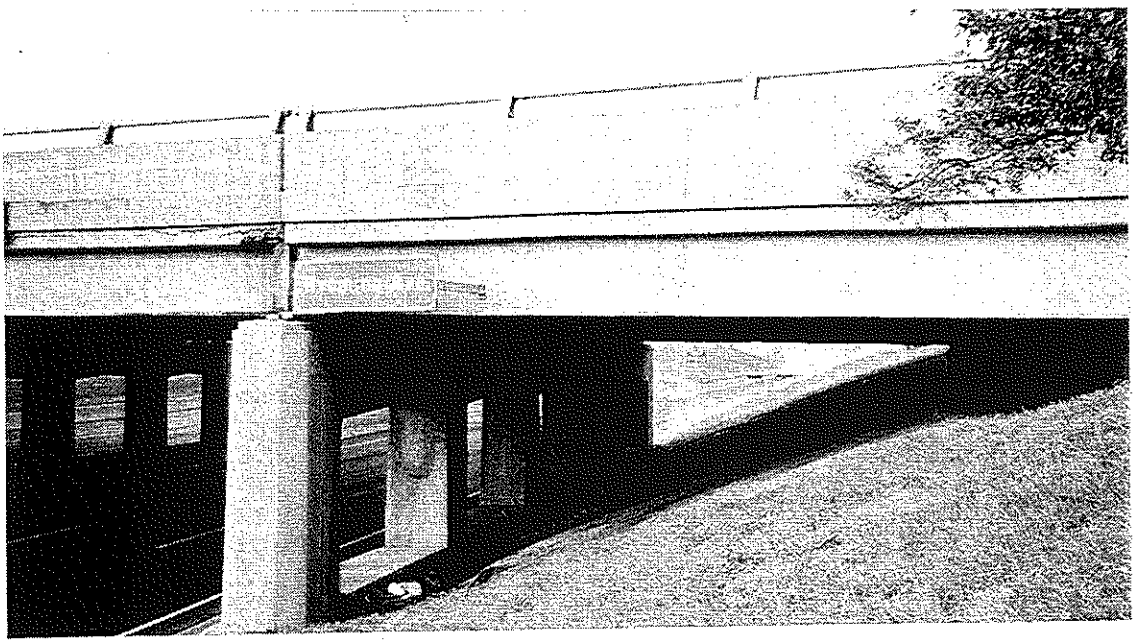


Fig. 4-1. Bridge WY/I94 on Wyoming Road over I-94 in Detroit.

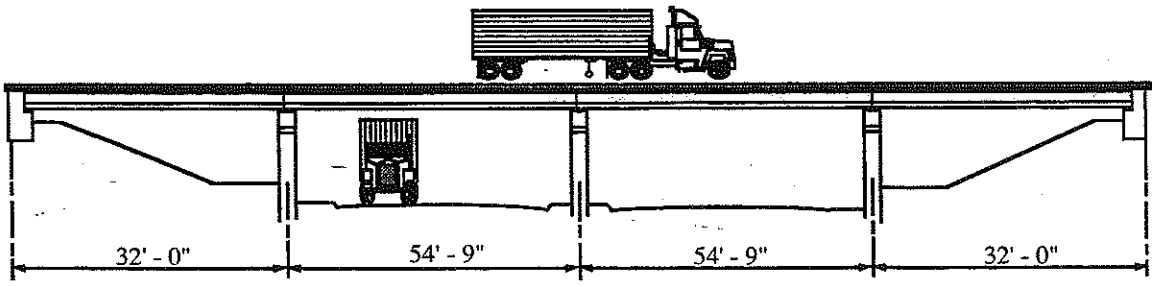


Fig. 4-2. Bridge WY/I94 on Wyoming Road over I-94. Side Elevation.

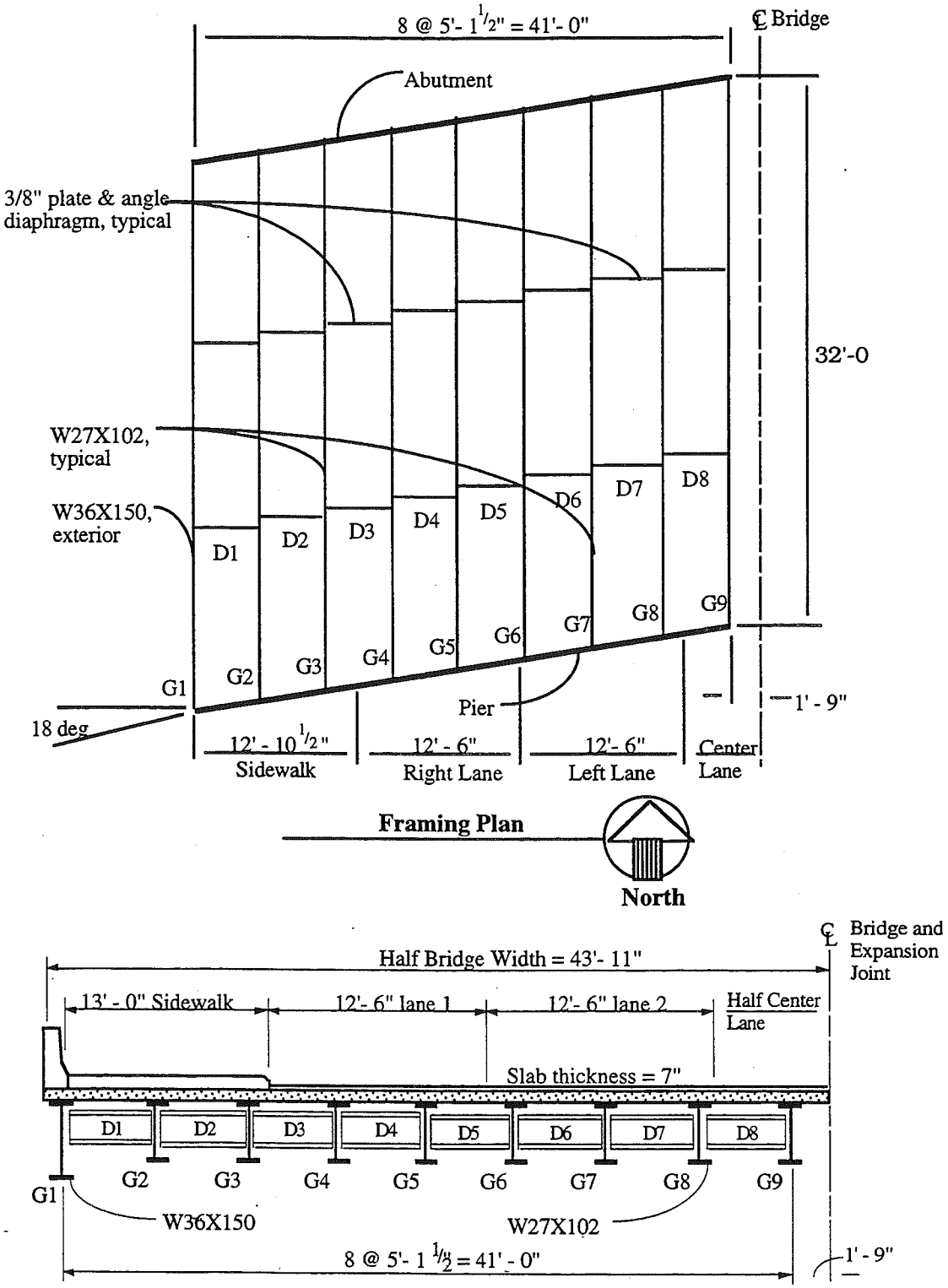


Fig.4-3. Bridge WY/I94 on Wyoming Road over I-94.
Plan View and Cross Section. Entrance Span.

4.2 Weigh-in-Motion Measurements

Weigh-in-motion (WIM) statistics are presented in Table 4-1 to Table 4-6 and in Fig. 4-4 to Fig. 4-67. This data includes all trucks with a gross vehicle weight (GVW) of 10 kips and greater for 2-axle vehicles, and of 15 kips and greater for three or more axle vehicles, regardless of axle weight. This filtered WIM data has been used for all analysis of GVW and axle weight. The data may also include permit loads. The data measured by WIM are recorded in the FHWA card seven 80-column format.

Table 4-1 summarizes an estimated average daily truck traffic (ADTT) in one direction, and the total number of vehicles weighed by date and by different number of axle vehicles. Fig. 4-4 is the frequency histogram of trucks corresponding to different number of axles. Fig. 4-5 shows the daily frequency histogram of trucks. Practically, there is no difference by the date of measurement. Table 4-2 presents Federal Highway Administration (FHWA) truck class frequency vs lane statistics. Federal Highway Administration (FHWA) axle configuration class is presented in the Appendix A. Note that the last digit from the FHWA axle class is not included in Table 4-2.

Table 4-3 is the GVW statistics of maximum, mean, median, standard deviation, and percentage of overloaded vehicles. The statistics are given for all vehicles and separately for different number of axle vehicles. The GVW limit in Table 4-3 might not be the legal limit. It is difficult to determine the GVW limit with only number of axles. It depends not only on number of axles, but axle spacings. Thus, it was decided to assign reasonably high GVW limits and to give some ideas about how heavy the vehicles were. Fig. 4-6 and Fig. 4-7 are the histograms of GVW and the corresponding cumulative distribution function (CDF) of GVW for all trucks observed and measured on WY/I94 respectively. In Fig. 4-7, each circle represents one truck in the data file. From the graph and from Table 4-3 the heaviest vehicle observed weighed 177 kips with a mean GVW of 40 kips. Vehicles

over the GVW limit were 4 percent. Results of the individual day measurements are shown in Fig. 4-8 and Fig. 4-9. The day to day CDF's demonstrate a similar trend and average GVW with the largest difference at the upper tail of the distribution. GVW histograms for different number of axle vehicles are presented in Fig. 4-10 to Fig. 4-17. The corresponding CDF's are shown in Fig. 4-18 to Fig. 4-20. Overloaded 5 and 11-axle vehicles were 4 percent and 5 percent respectively. For comparison of the daily distributions of 5 and 11 axle vehicles, the CDF's for both days are plotted in Fig. 4-21.

Table 4-4 is the axle weight statistics of maximum, mean, median, standard deviation, and percentage of overloaded vehicles. The statistics are given for all vehicles and separately different number of axle vehicles. In this table, axle weight limits were intended to give some ideas about how heavy the axles were. The statistics depend on axle spacings rather than number of axles. Fig. 4-22 and Fig. 4-23 are the histogram of axle weight for all vehicles and the corresponding CDF respectively. The maximum axle weight observed at WY/I94 was 32 kips with a mean of 9 kips. Axles with axle weight of 18 kips and greater were 4 percent. Fig. 4-24 and Fig. 4-25 show the daily axle weight histogram and CDF's. As in the case with GVW, there is little daily variation in the vehicle axle weights with some differences at the upper tail of the distribution. Axle weight histograms for different number of axle vehicles are presented in Fig. 4-26 to Fig. 4-33. The corresponding CDF's are shown in Fig. 4-34 to Fig. 4-36. Overloaded axles for 5 and 11 axle vehicles were 4 percent and 1 percent respectively. The daily CDF's of axle weight for 5 and 11 axle vehicles are plotted in Fig. 4-37 for comparison of the daily distribution.

Table 4-5 is the steering axle weight statistics of maximum, mean, median, and standard deviation of all vehicles and different number of axle vehicles. Fig. 4-38 and Fig. 4-39 are the steering axle weight histogram for all vehicles and the corresponding CDF respectively. The maximum observed steering axle weight was 19 kips with a mean of 9 kips. Fig. 4-40 and Fig. 4-41 show the daily steering axle weight histogram and CDF's. Steering axle weight

histograms for different number of axle vehicles are presented in Fig. 4-42 to Fig. 4-49. The corresponding CDF's are shown in Fig. 4-50 to Fig. 4-52.

Table 4-6 is the non-steering axle weight statistics of maximum, mean, median, and standard deviation of all vehicles and different number of axle vehicles. Fig. 4-53 and Fig. 4-54 are the non-steering axle weight histogram for all vehicles and the corresponding CDF. The maximum non-steering axle weight was 32 kips with a mean of 8 kips. Fig. 4-55 and Fig. 4-56 show the daily non-steering axle weight histogram and CDF's. Non-steering axle weight histograms for different number of axle vehicles are presented in Fig. 4-57 to Fig. 4-64. The corresponding CDF's are shown in Fig. 4-65 to Fig. 4-67.

The steering and non-steering axle weight CDF's of Fig. 4-39 and Fig. 4-54 indicate a significant difference in both variation and magnitudes. The standard deviation of steering axle weight was 2 kips with a maximum of 19 kips while the standard deviation of non-steering axle weight was 5 kips with a maximum of 32 kips.

Review of the results indicates that most of the truck weights are within legal limits. Overloaded 5 and 11 axle vehicles were 4 percent and 5 percent respectively. Vehicles over the GVW limit were 4 percent. Overloaded axles for 5 and 11 axle vehicles were 4 percent and 1 percent respectively. Axles with axle weight of 18 kips and greater were 4 percent.

Table 4-1. WY/I94, Number of Trucks Weighed and Estimated ADTT.

Number of Trucks Weighed Gross Vehicle Weight > 10 Kips for 2 Axle Vehicles, Gross Vehicle Weight > 15 Kips for 3 or more Axle Vehicles.				
Date	8/19/93	9/8/93	Total	Vehicles (%)
2 Axles	39	43	82	27.6
3 Axles	8	18	26	8.8
4 Axles	9	9	18	6.1
5 Axles	41	66	107	36.0
6 Axles	4	12	16	5.4
7 Axles	2	7	9	3.0
8 Axles	4	10	14	4.7
9 Axles	0	2	2	0.7
10 Axles	1	2	3	1.0
11 Axles	7	13	20	6.7
All Vehicles	115	182	297	100.0
Estimated ADTT = 750 Trucks (in one direction)				

Table 4-2. Bridge WY/I94, Truck Class vs Lane Statistics.

Truck Class (FHWA)	Right Lane (1) (%)	Left Lane (2) (%)	Total (%)
4	2.9	1.2	4.1
5	19.6	32.0	51.6
6	1.8	1.8	3.6
7	0.6	0	0.6
8	0.9	2.3	3.2
9	8.8	10.3	19.1
10	2.1	1.2	3.2
11	0.0	0.0	0.0
12	0.0	0.0	0.0
13	0.0	0.0	0.0
14	6.2	8.5	14.7
Total Lane %	42.8	57.2	100.0

Table 4-3. Bridge WY/I94, Gross Vehicle Weight Statistics.

Vehicle Type	Max. (Kips)	Mean (Kips)	Median (Kips)	Std.Dev. (Kips)	GVW Limit (Kips)	Percentage over the Limit
2 Axles	46	19	18	7	40	3
3 Axles	55	27	24	10	60	0
4 Axles	76	39	37	16	70	9
5 Axles	90	43	37	17	80	4
6 Axles	94	54	47	23	90	5
7 Axles	102	73	68	25	120	0
8 Axles	142	53	43	28	125	5
9 Axles	64	60	60	5	135	0
10 Axles	149	125	126	25	150	0
11 Axles	177	84	62	44	164	5
All Vehicles	177	40	34	27	varies	4

Table 4-4. Bridge WY/I94, Axle Weight Statistics.

Vehicle Type	Max. (Kips)	Mean (Kips)	Median (Kips)	Std.Dev. (Kips)	Axle Weight Limit (Kips)	Percentage over the Limit
2 Axles	32	9	8	4	18	4
3 Axles	20	9	8	4	18	3
4 Axles	28	10	9	5	18	6
5 Axles	22	9	9	4	18	4
6 Axles	21	9	9	5	18	3
7 Axles	23	10	11	5	18	6
8 Axles	27	7	5	5	18	5
9 Axles	11	7	6	2	18	0
10 Axles	17	13	13	3	18	0
11 Axles	20	8	7	5	18	1
All Vehicles	32	9	9	5	18	4

Table 4-5. Bridge WY/I94, Steering Axle Weight Statistics.

Vehicle Type	Max. (Kips)	Mean (Kips)	Median (Kips)	Std.Dev. (Kips)	Vehicles (%)
2 Axles	14	8	8	2	27.6
3 Axles	15	9	8	3	8.8
4 Axles	19	10	9	3	6.1
5 Axles	13	10	9	1	36.0
6 Axles	13	10	10	1	5.4
7 Axles	12	11	10	1	3.0
8 Axles	14	10	9	2	4.7
9 Axles	10	10	10	0	0.7
10 Axles	13	12	12	1	1.0
11 Axles	14	11	11	2	6.7
All Vehicles	19	9	9	2	100.0

Table 4-6. Bridge WY/I94, Non-Steering Axle Weight Statistics.

Vehicle Type	Max. (Kips)	Mean (Kips)	Median (Kips)	Std.Dev. (Kips)	Vehicles (%)
2 Axles	32	11	10	5	27.6
3 Axles	20	9	7	4	8.8
4 Axles	28	10	9	6	6.1
5 Axles	22	8	7	5	36.0
6 Axles	21	9	9	5	5.4
7 Axles	23	10	11	6	3.0
8 Axles	27	6	4	5	4.7
9 Axles	11	6	6	2	0.7
10 Axles	17	13	13	3	1.0
11 Axles	20	7	5	5	6.7
All Vehicles	32	8	7	5	100.0

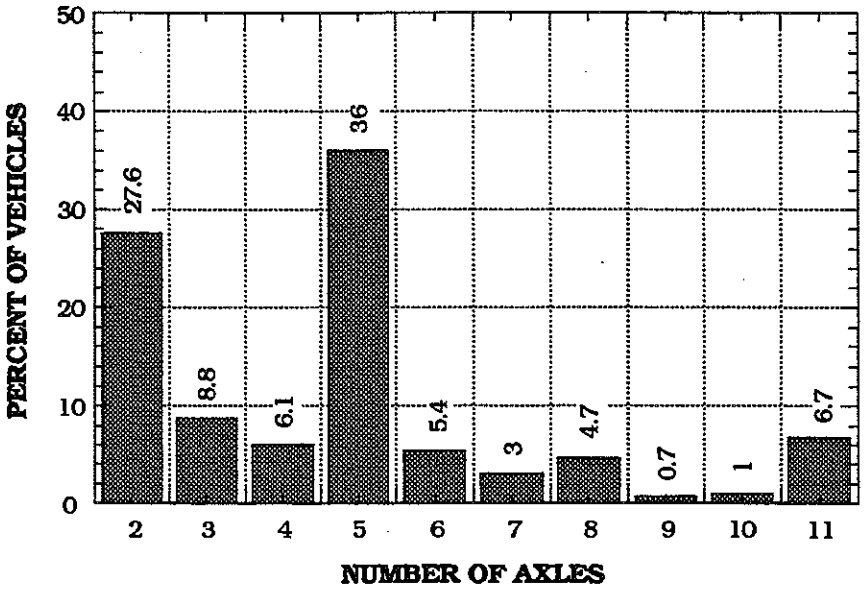


Fig. 4-4. WY/I94, Truck Type Histogram.

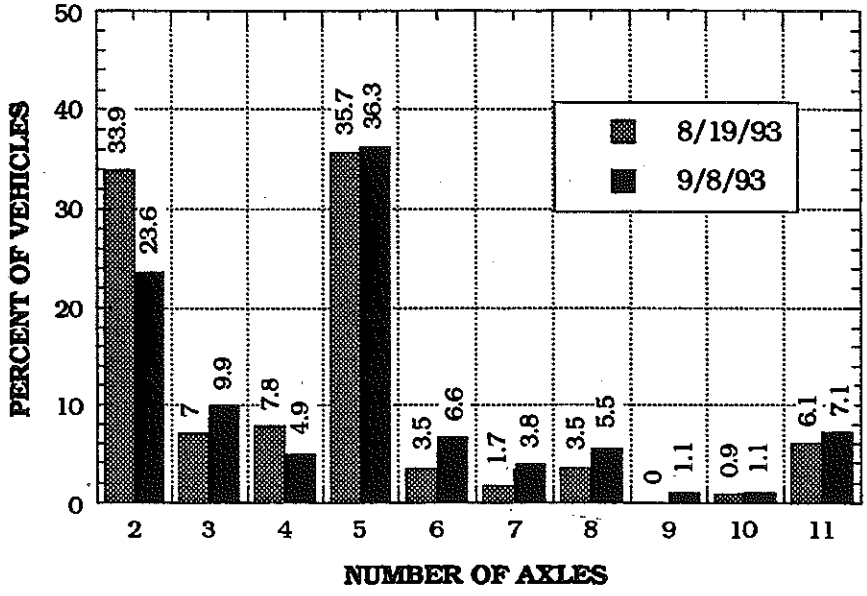


Fig. 4-5. WY/I94, Daily Truck Type Histogram.

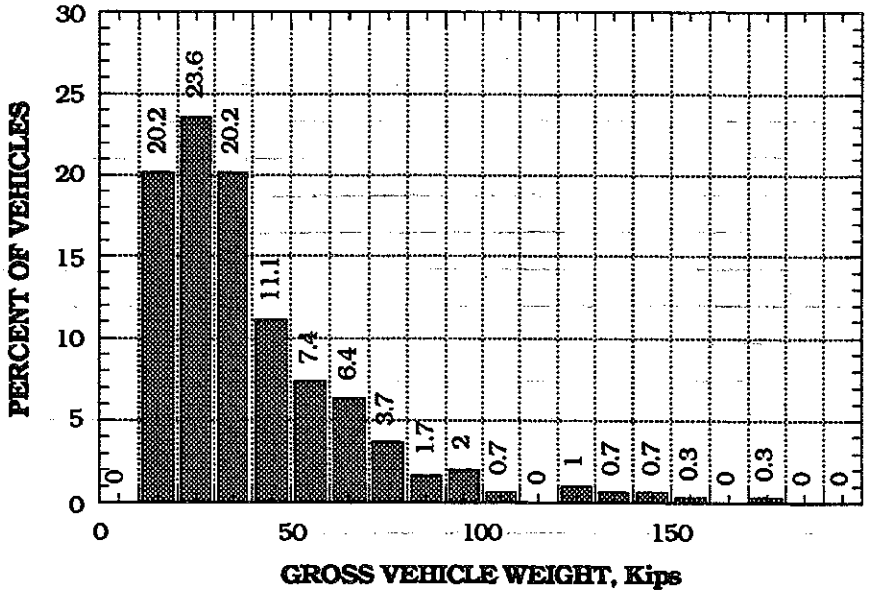


Fig. 4-6. WY/I94, GVW Histogram.

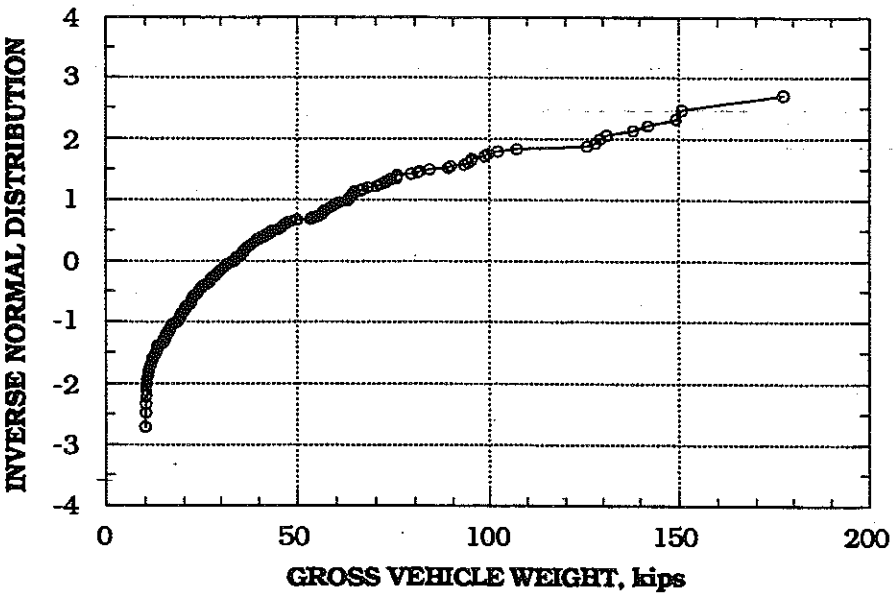


Fig. 4-7. WY/I94, GVW Distribution.

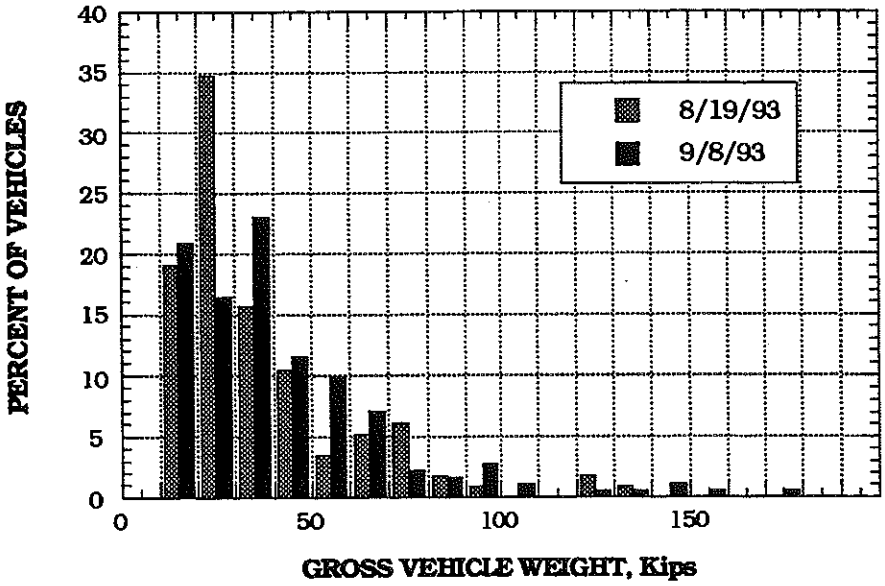


Fig. 4-8. WY/I94, Daily GVW Histogram.

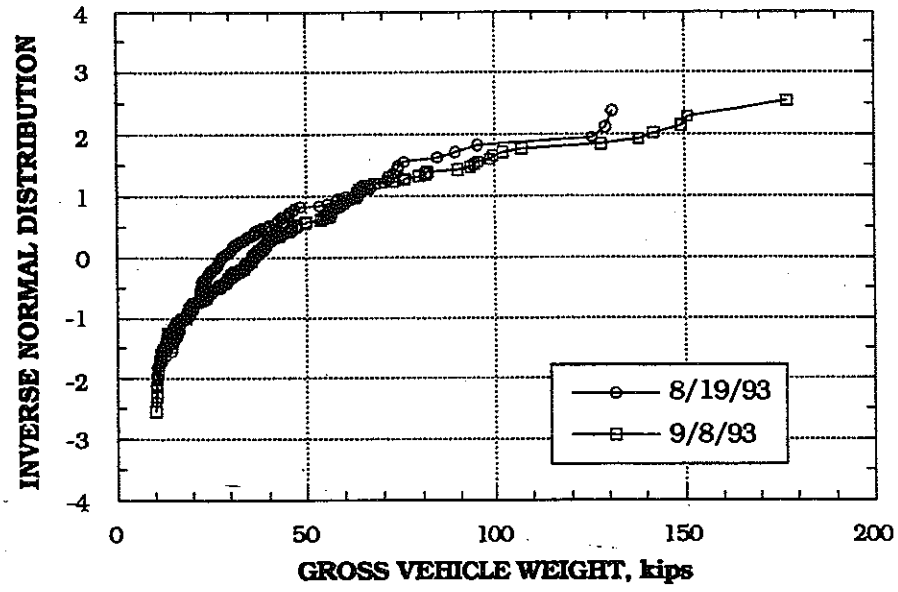


Fig. 4-9. WY/I94, Daily GVW Distributions.

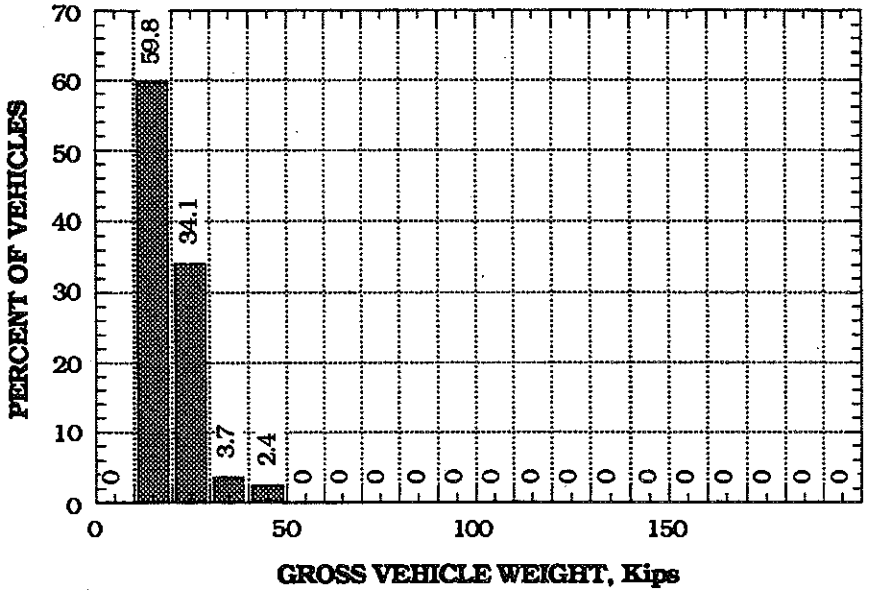


Fig. 4-10. WY/I94, 2 Axle GVW Histogram.

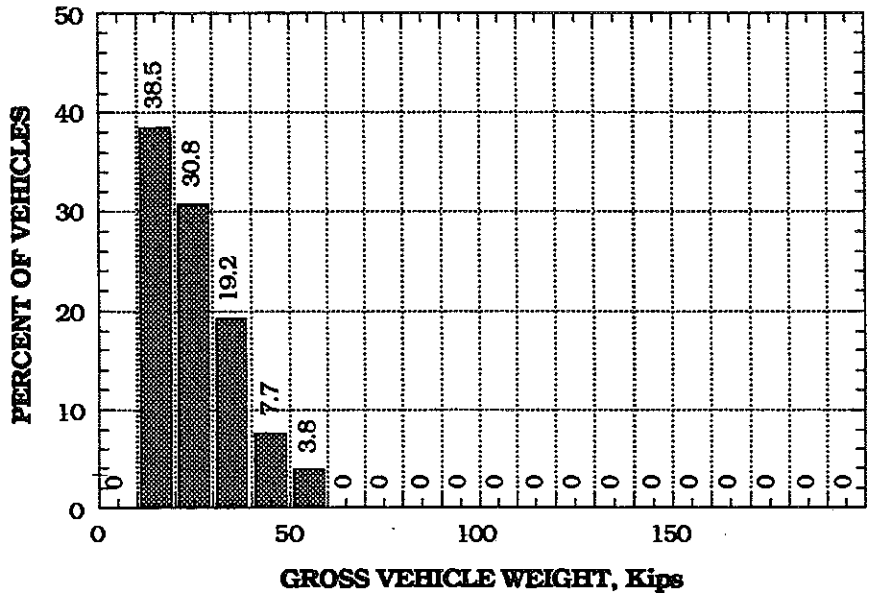


Fig. 4-11. WY/I94, 3 Axle GVW Histogram.

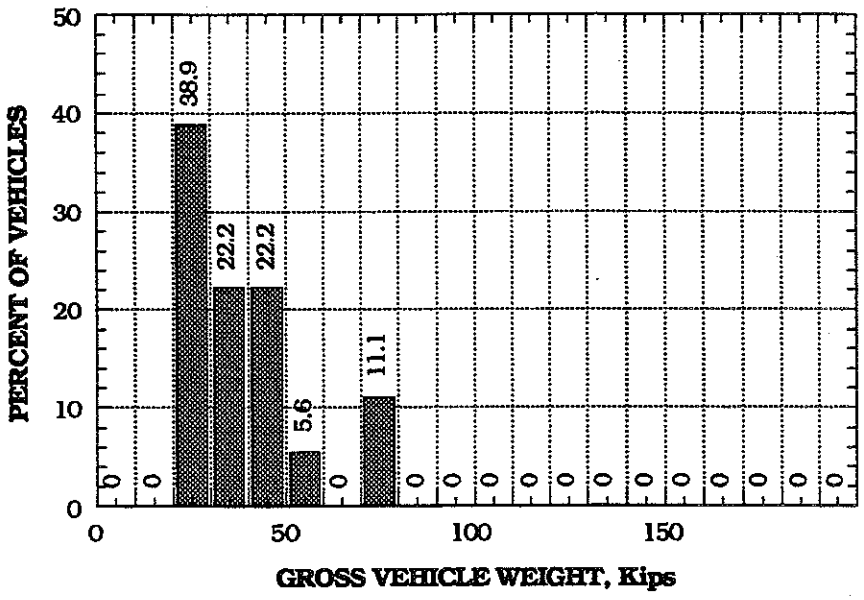


Fig. 4-12. WY/I94, 4 Axle GVW Histogram.

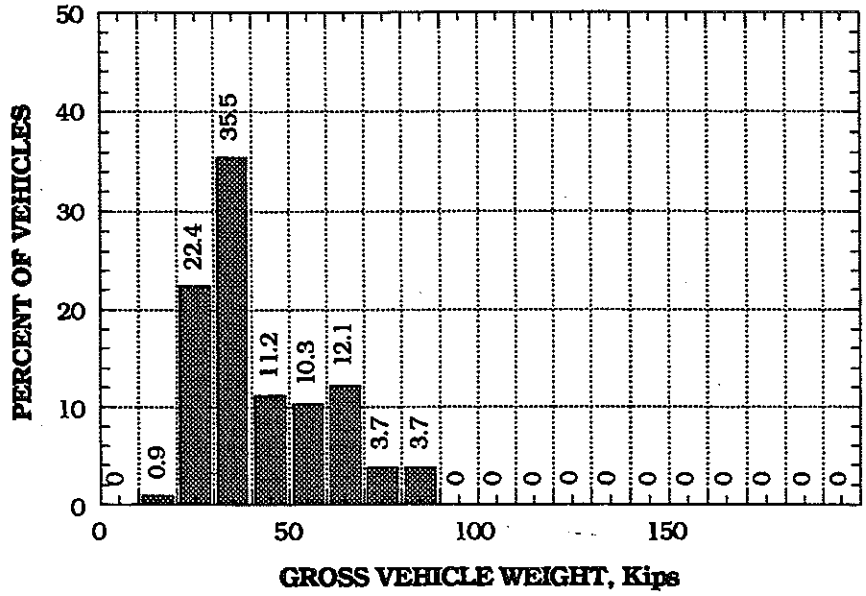


Fig. 4-13. WY/I94, 5 Axle GVW Histogram.

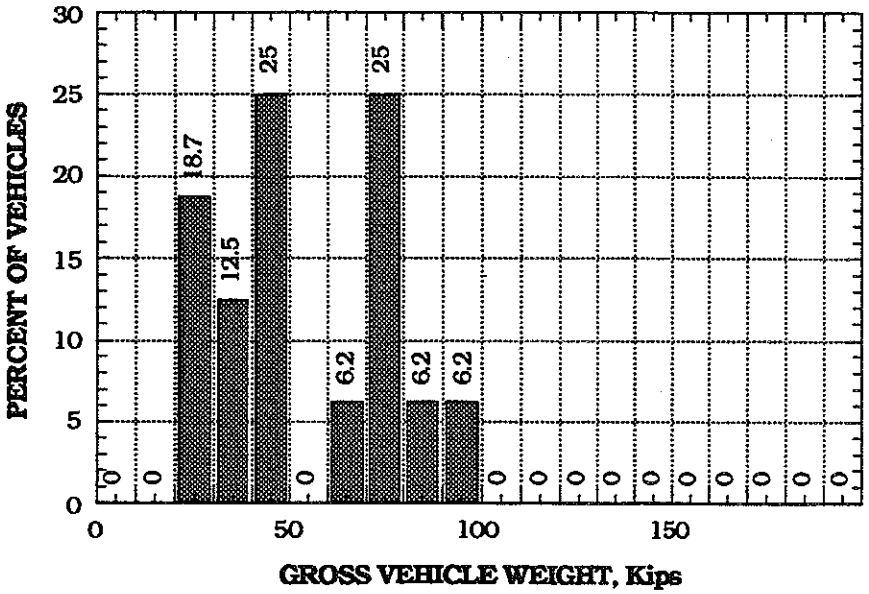


Fig. 4-14. WY/I94, 6 Axle GVW Histogram.

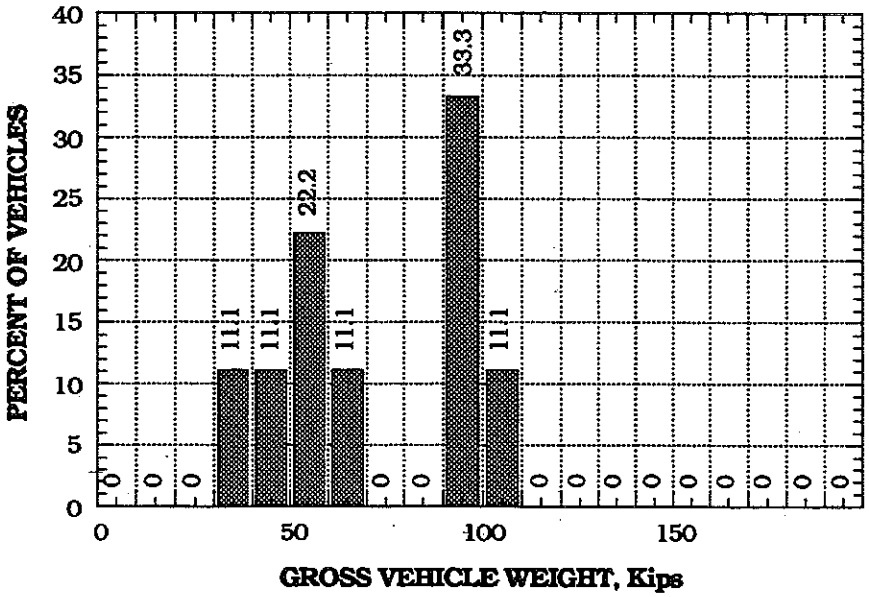


Fig. 4-15. WY/I94, 7 Axle GVW Histogram.

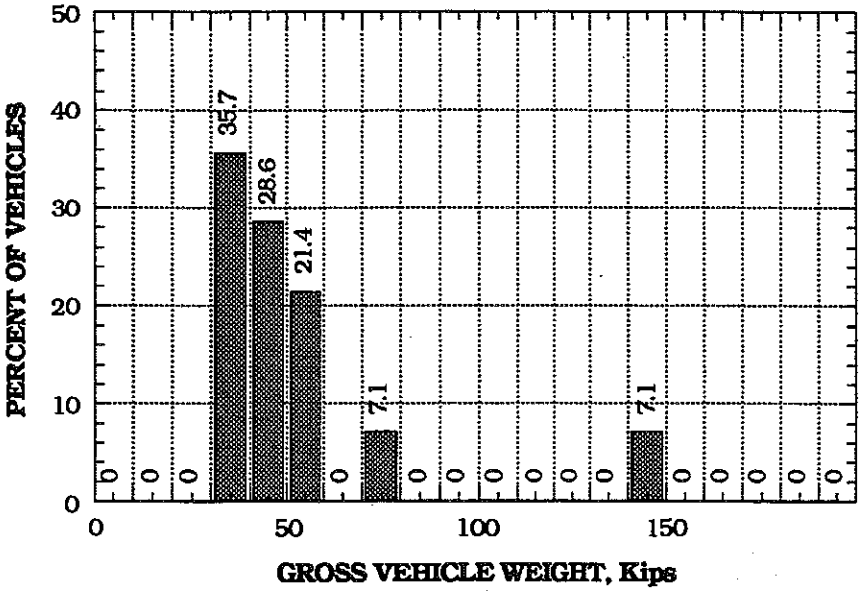


Fig. 4-16. WY/I94, 8 Axle GVW Histogram.

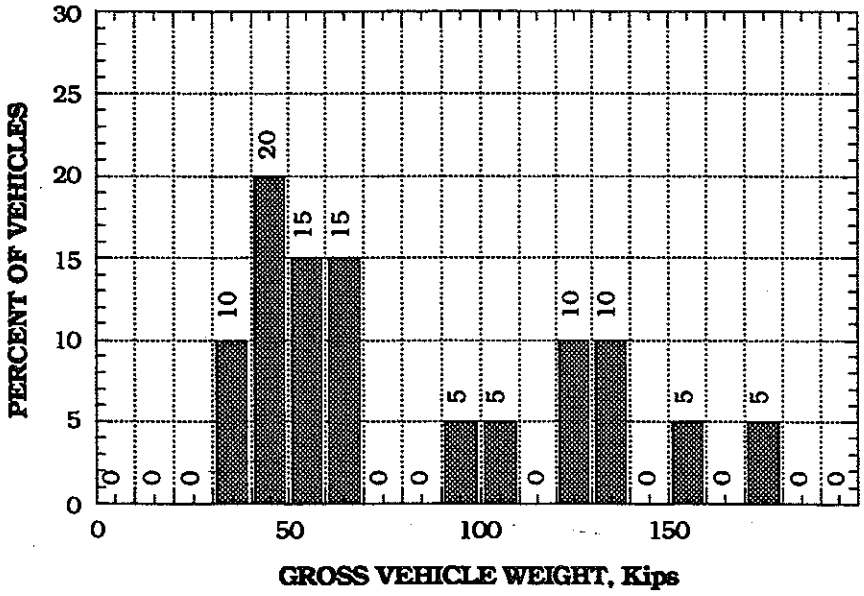


Fig. 4-17. WY/I94, 11 Axle GVW Histogram.

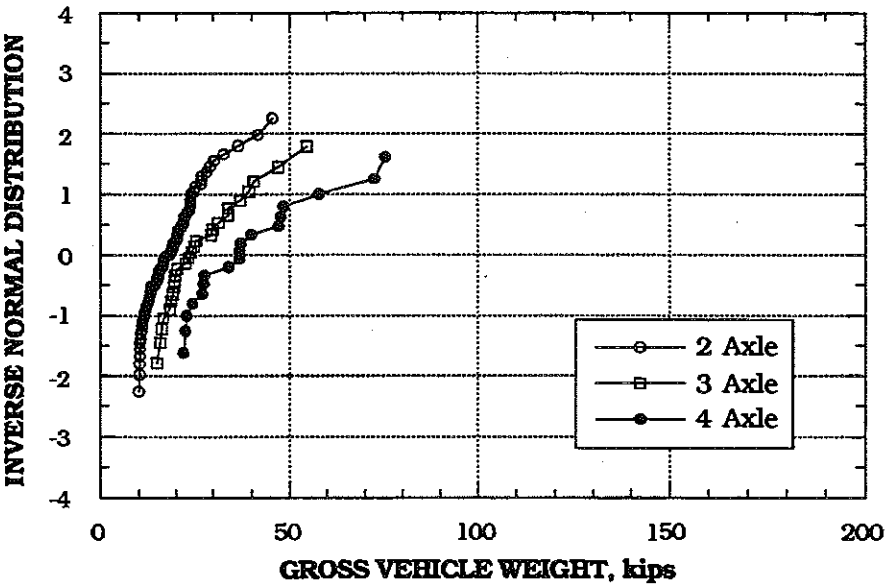


Fig. 4-18. WY/I94, 2, 3, and 4 Axle GVW Distributions.

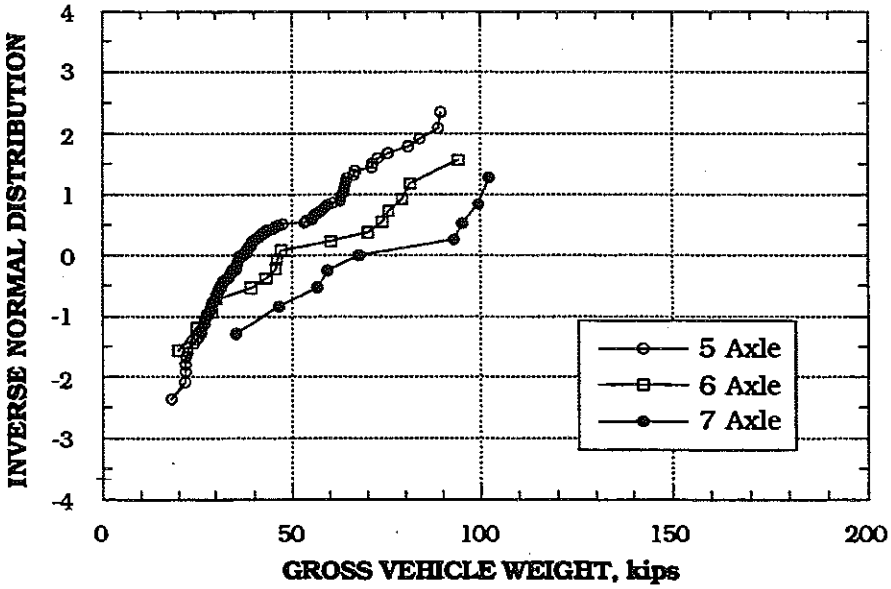


Fig. 4-19. WY/I94, 5, 6, and 7 Axle GVW Distributions.

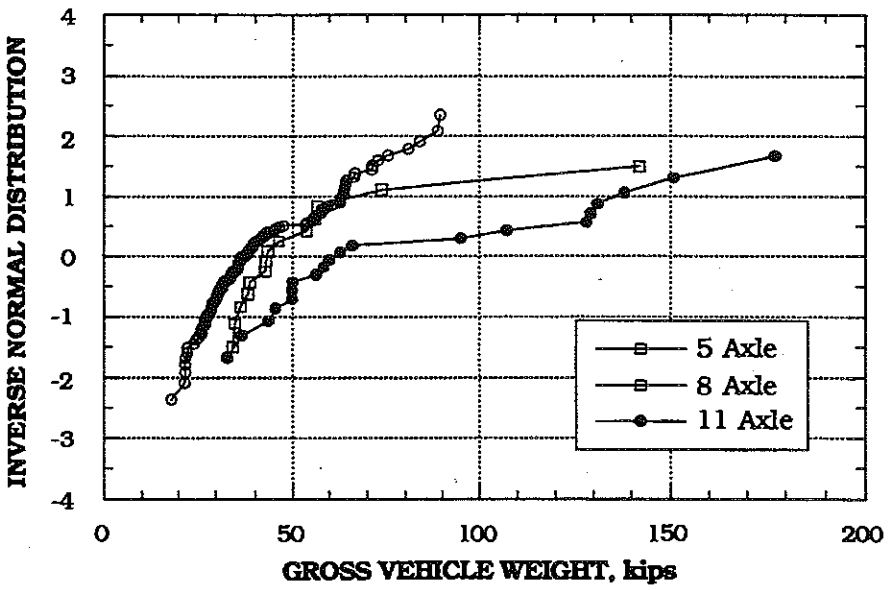


Fig. 4-20. WY/I94, 5, 8, and 11 Axle GVW Distributions.

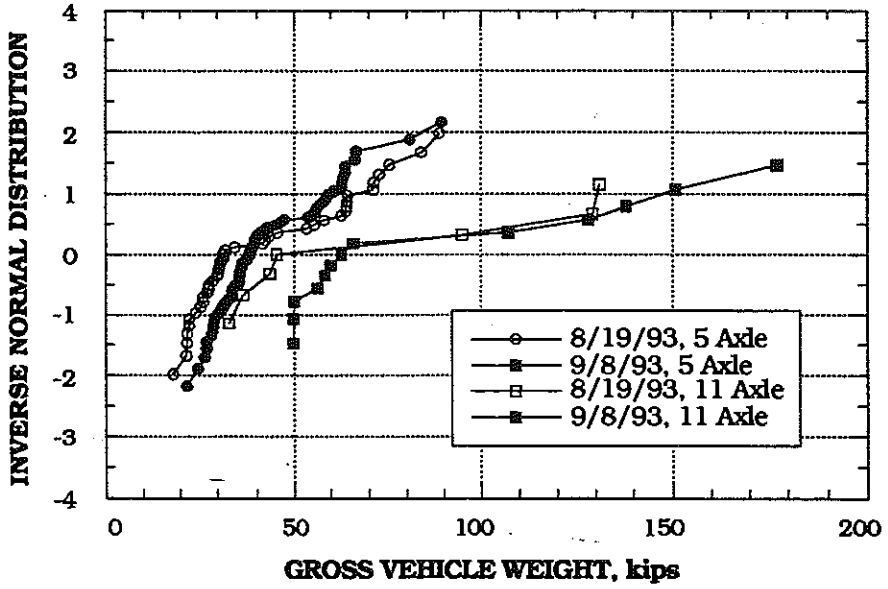


Fig. 4-21. WY/I94, Daily 5 and 11 Axle GVW Distributions.

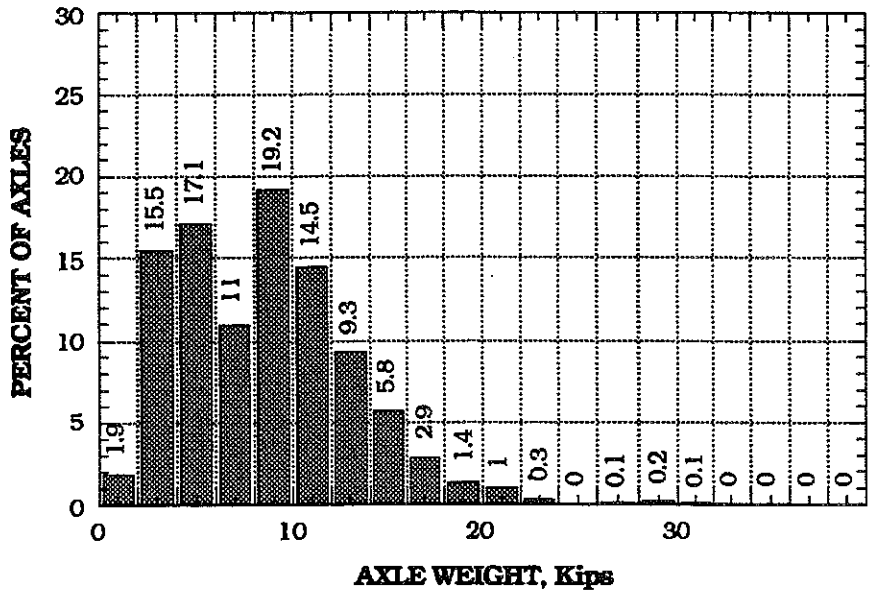


Fig. 4-22. WY/I94, Axle Weight Histogram.

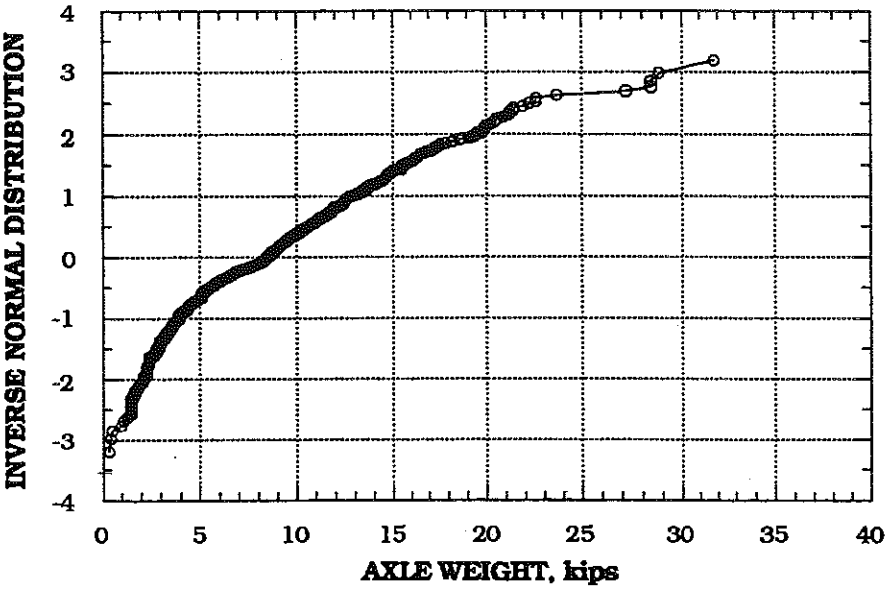


Fig. 4-23. WY/I94, Axle Weight Distribution.

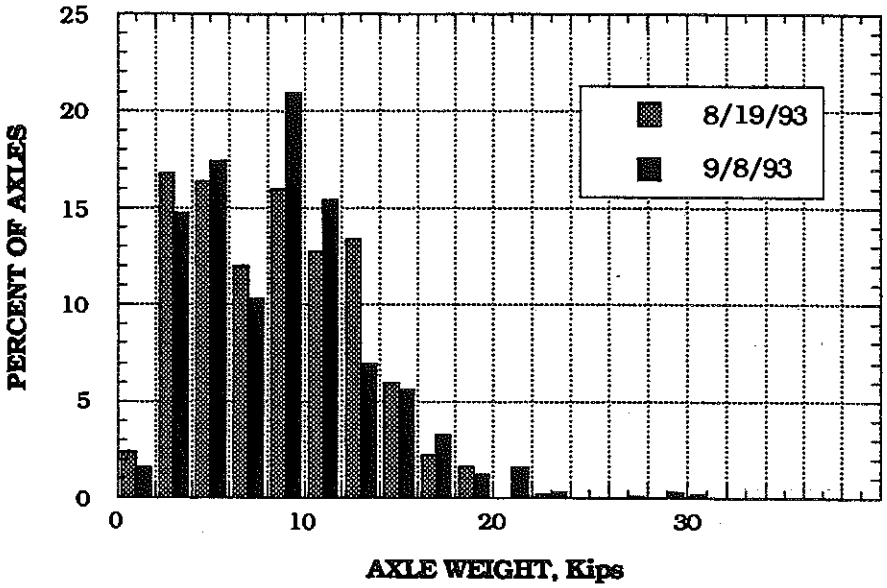


Fig. 4-24. WY/I94, Daily Axle Weight Histogram.

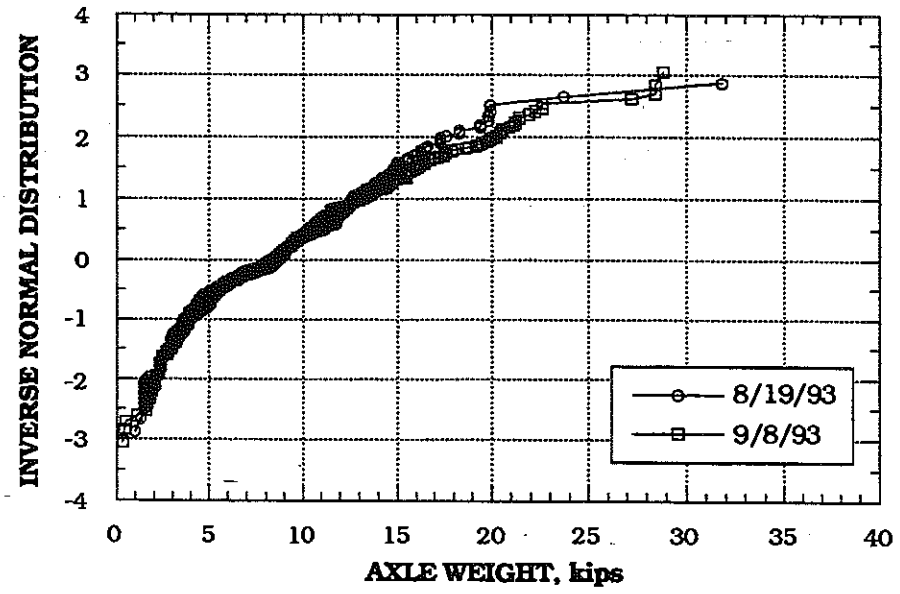


Fig. 4-25. WY/I94, Daily Axle Weight Distributions.

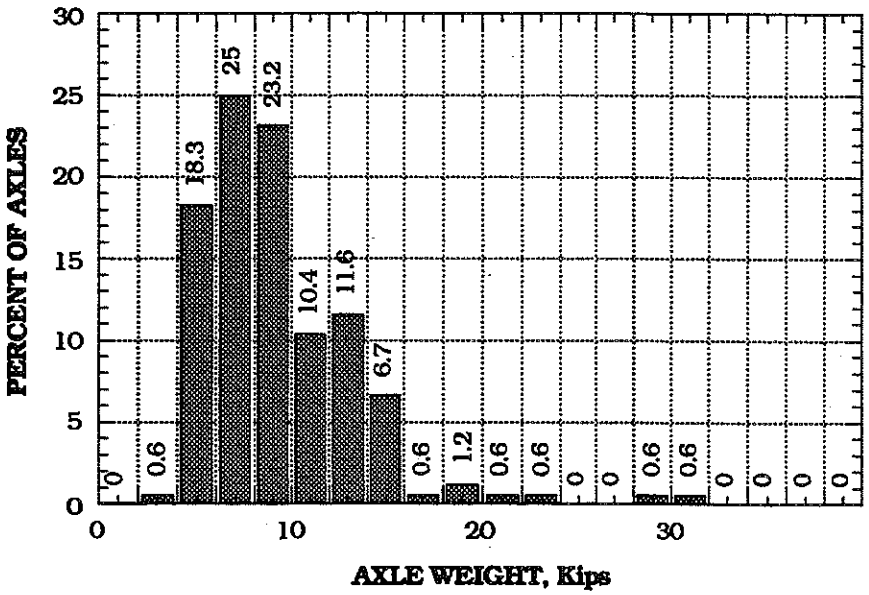


Fig. 4-26. WY/I94, Axle Weight Histogram of 2 Axle Vehicles.

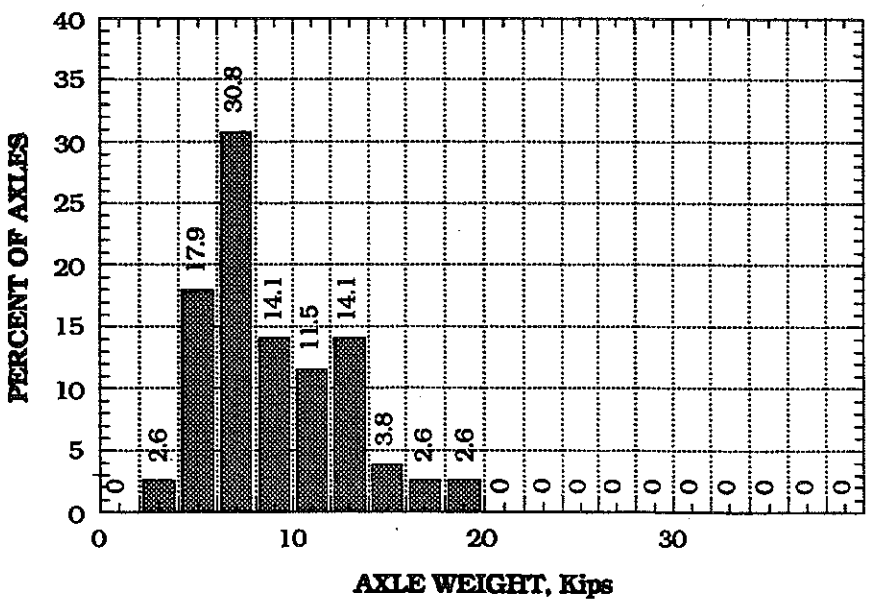


Fig. 4-27. WY/I94, Axle Weight Histogram of 3 Axle Vehicles.

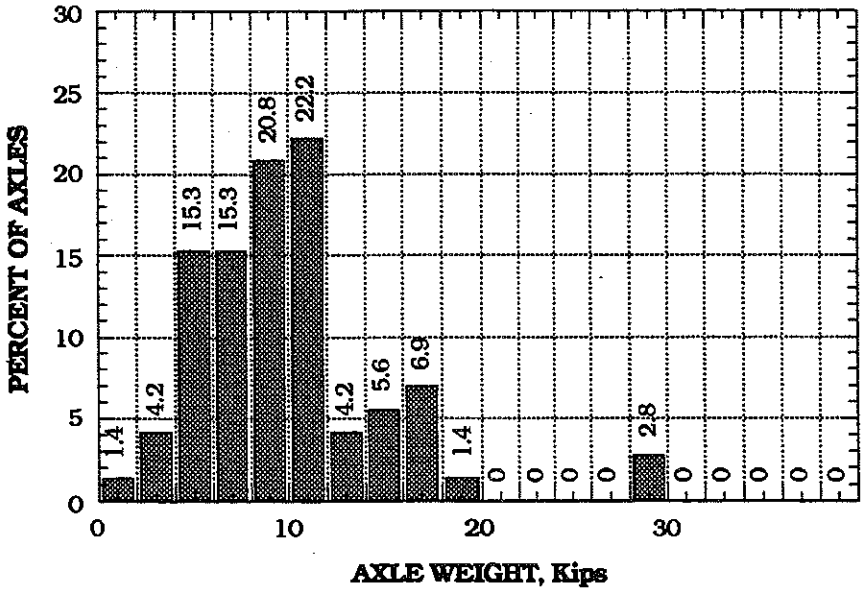


Fig. 4-28. WY/I94, Axle Weight Histogram of 4 Axle Vehicles.

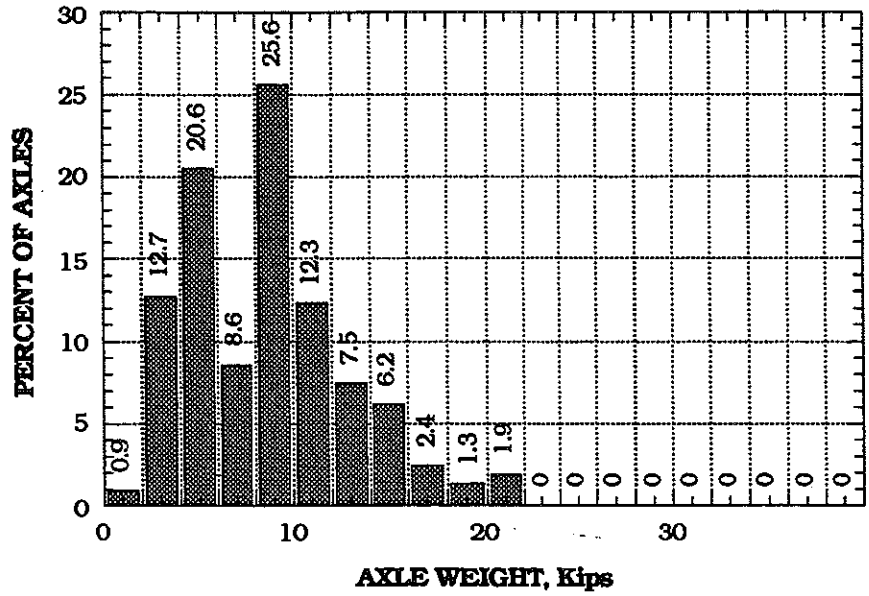


Fig. 4-29. WY/I94, Axle Weight Histogram of 5 Axle Vehicles.

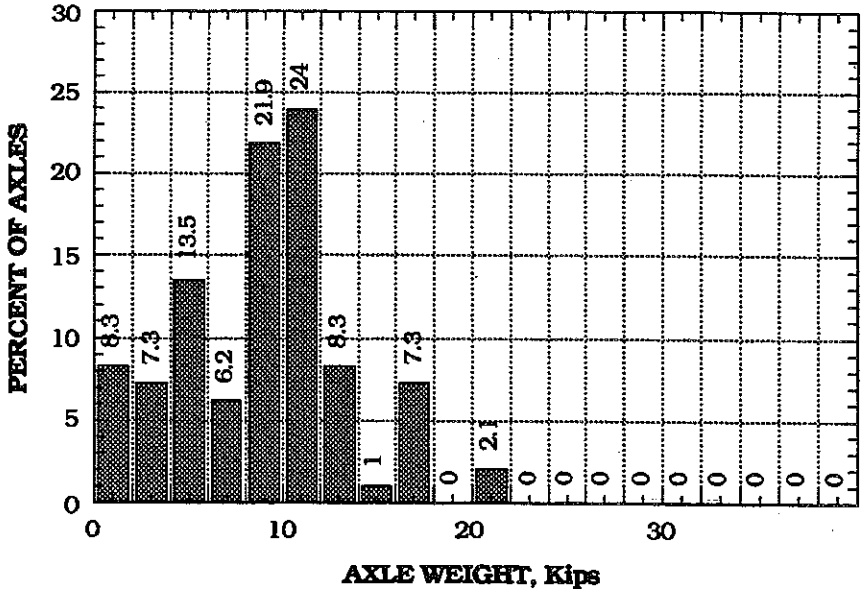


Fig. 4-30. WY/I94, Axle Weight Histogram of 6 Axle Vehicles.

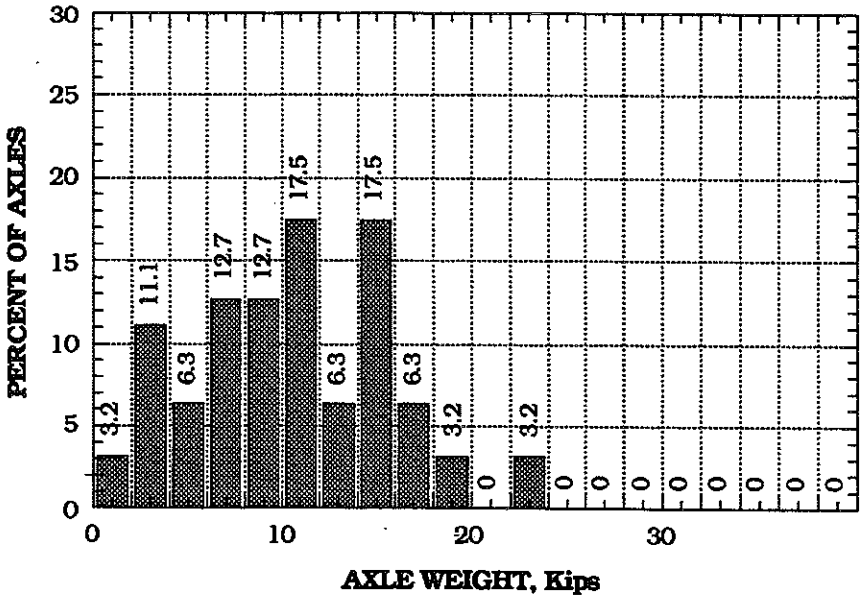


Fig. 4-31. WY/I94, Axle Weight Histogram of 7 Axle Vehicles.

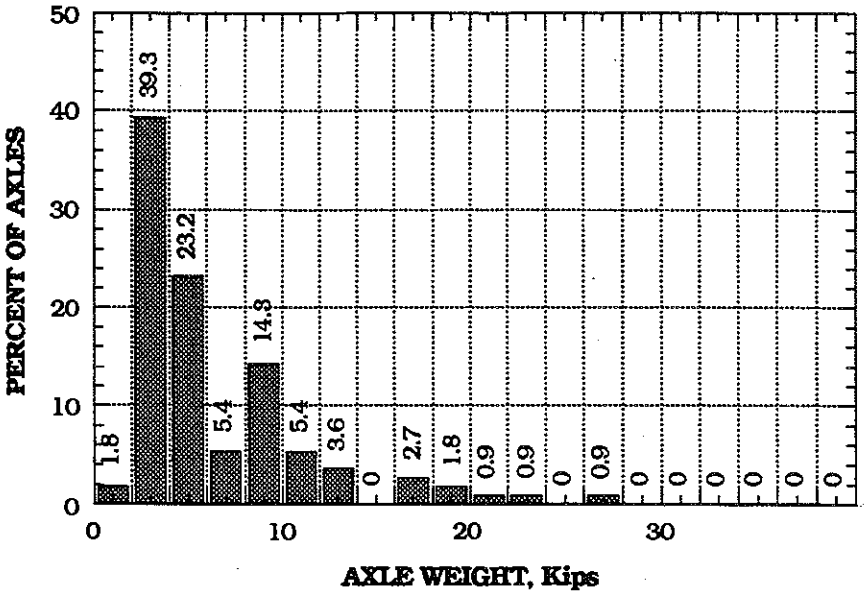


Fig. 4-32. WY/I94, Axle Weight Histogram of 8 Axle Vehicles.

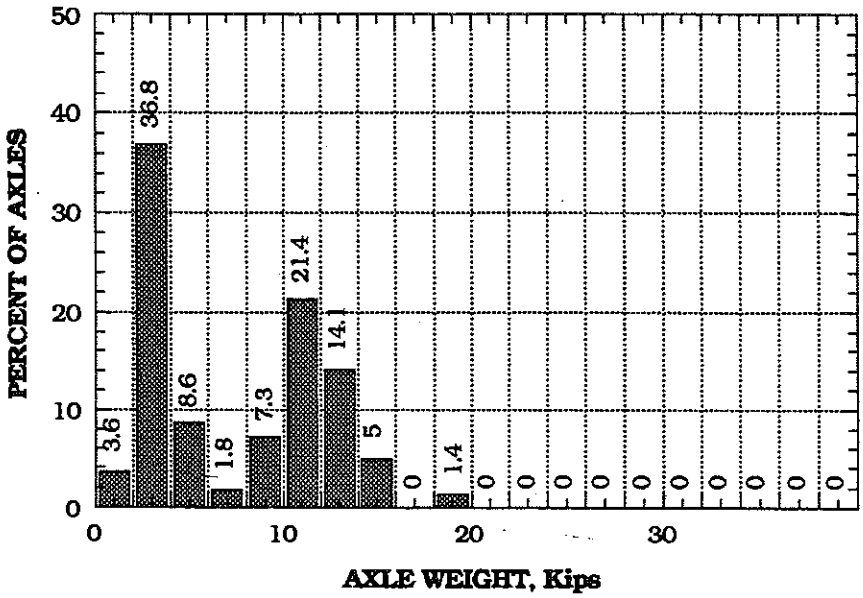


Fig. 4-33. WY/I94, Axle Weight Histogram of 11 Axle Vehicles.

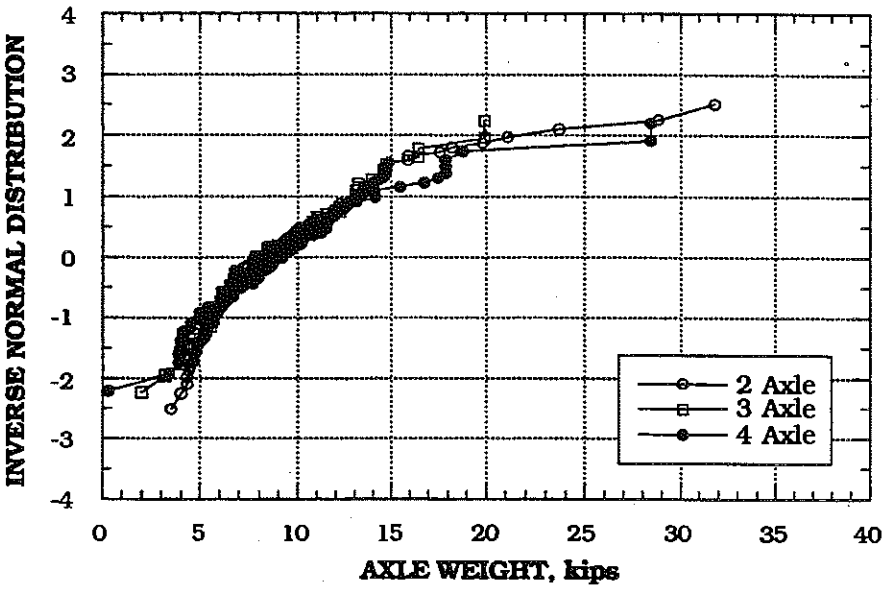


Fig. 4-34. WY/I94, Axle Weight Distributions of 2, 3, and 4 Axles.

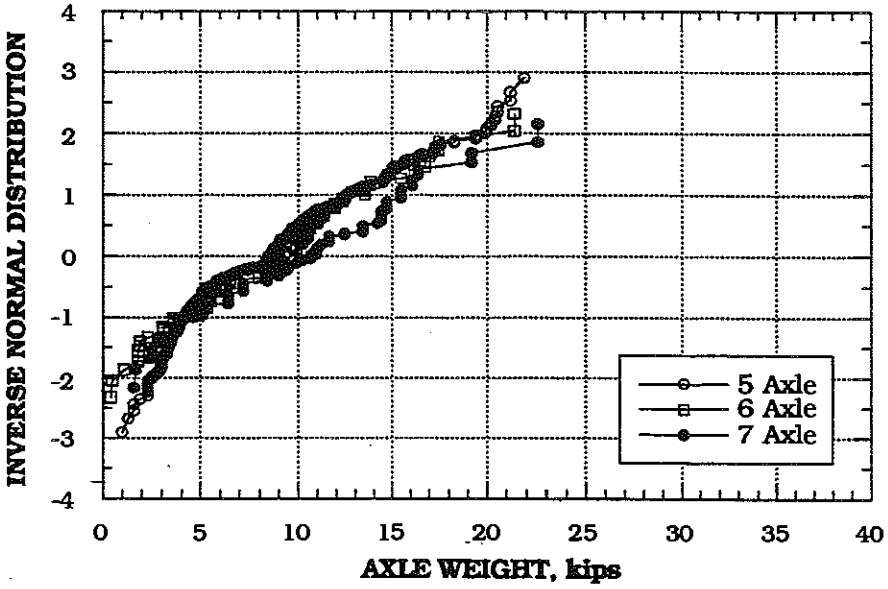


Fig. 4-35. WY/I94, Axle Weight Distributions of 5, 6, and 7 Axles.

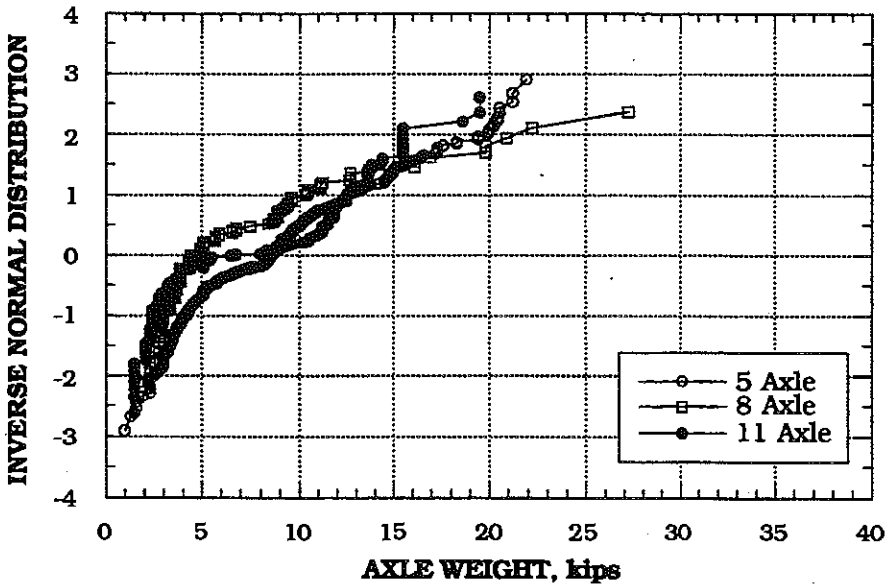


Fig. 4-36. WY/I94, Axle Weight Distributions of 5, 8, and 11 Axles.

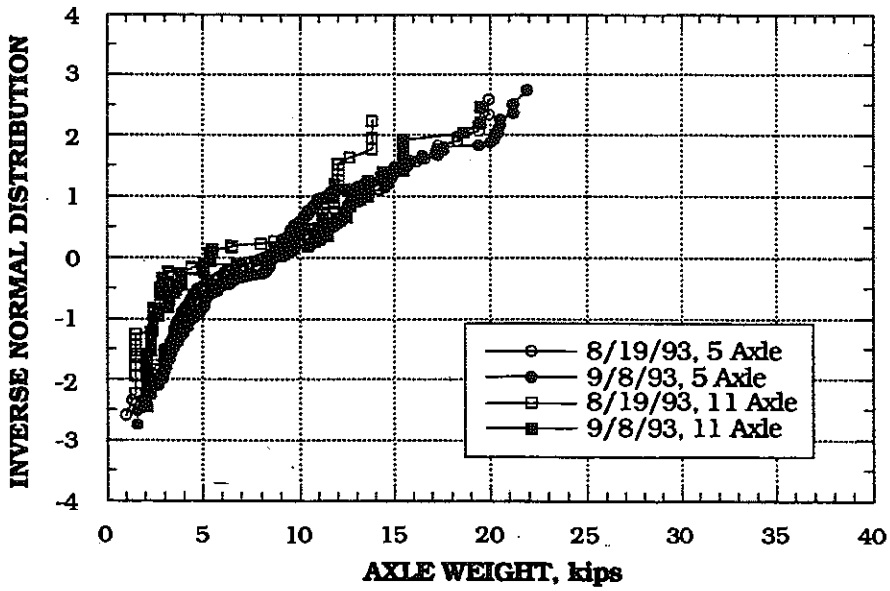


Fig. 4-37. WY/I94, Daily Axle Weight Distributions of 5 and 11 Axles.

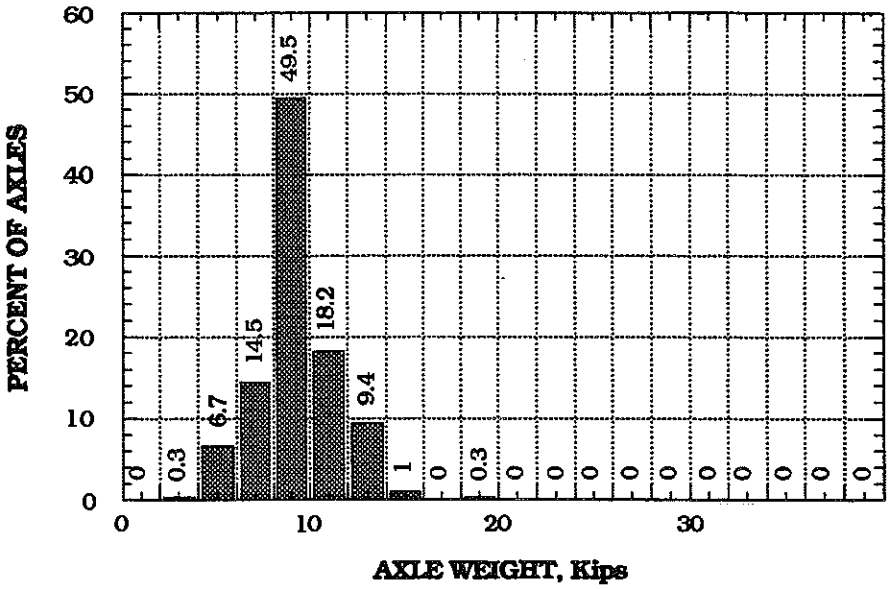


Fig. 4-38. WY/I94, Steering Axle Weight Histogram.

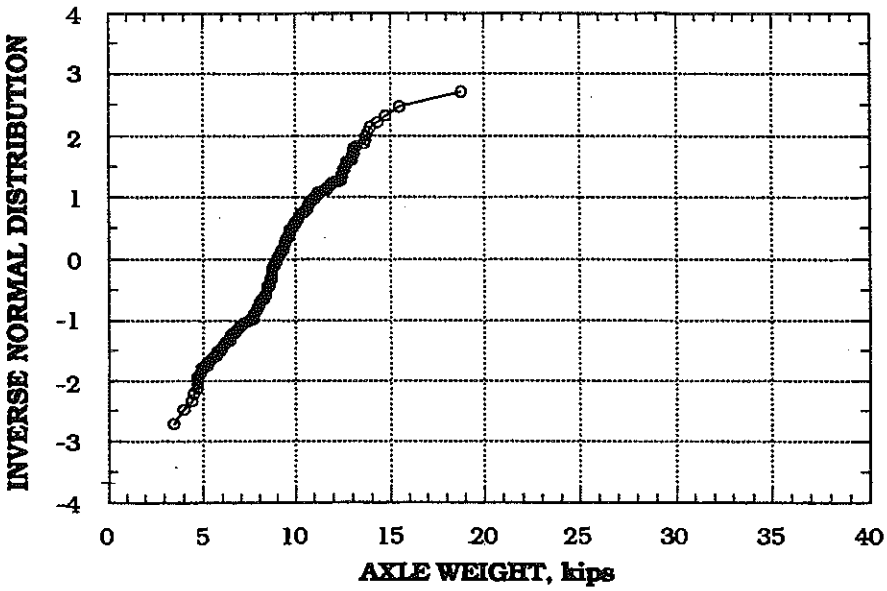


Fig. 4-39. WY/I94, Steering Axle Weight Distribution.

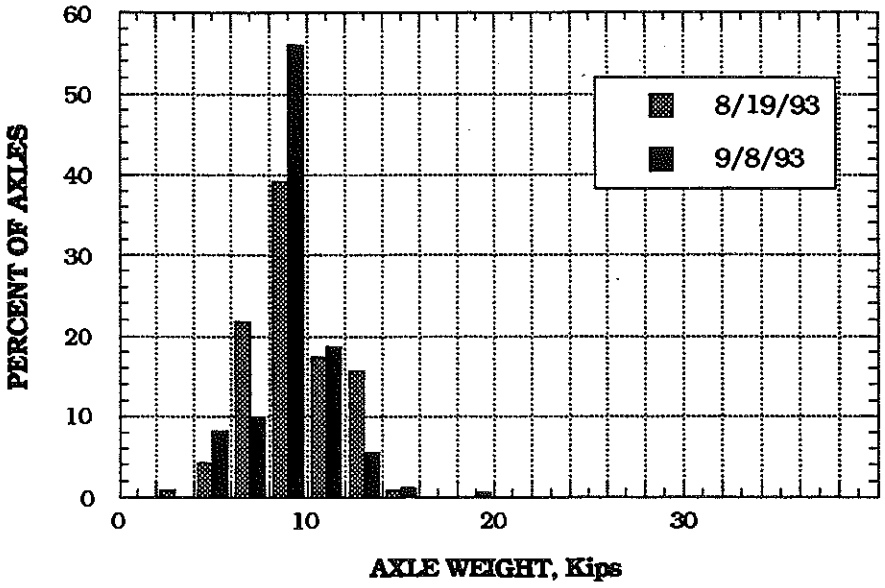


Fig. 4-40. WY/I94, Daily Steering Axle Weight Histogram.

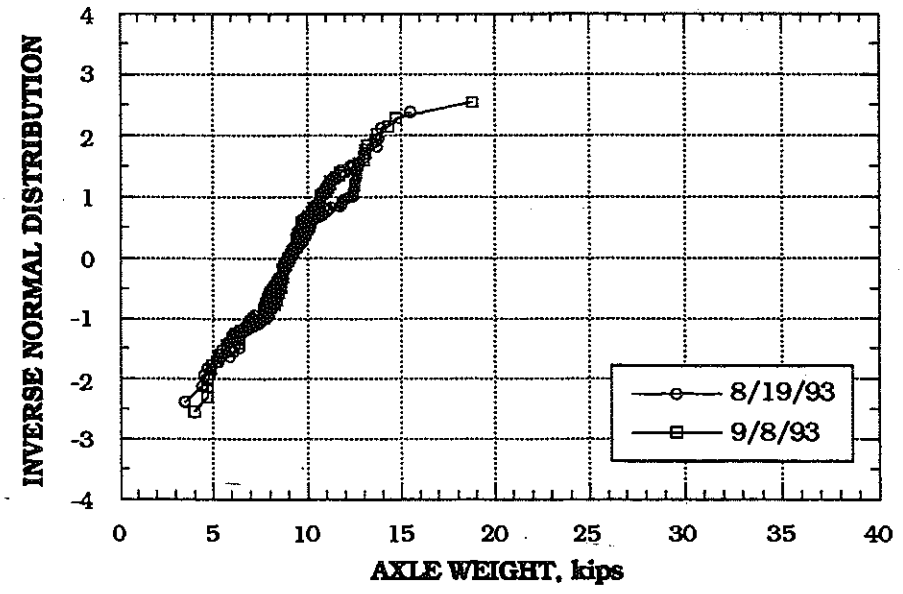


Fig. 4-41. WY/I94, Daily Steering Axle Weight Distributions.

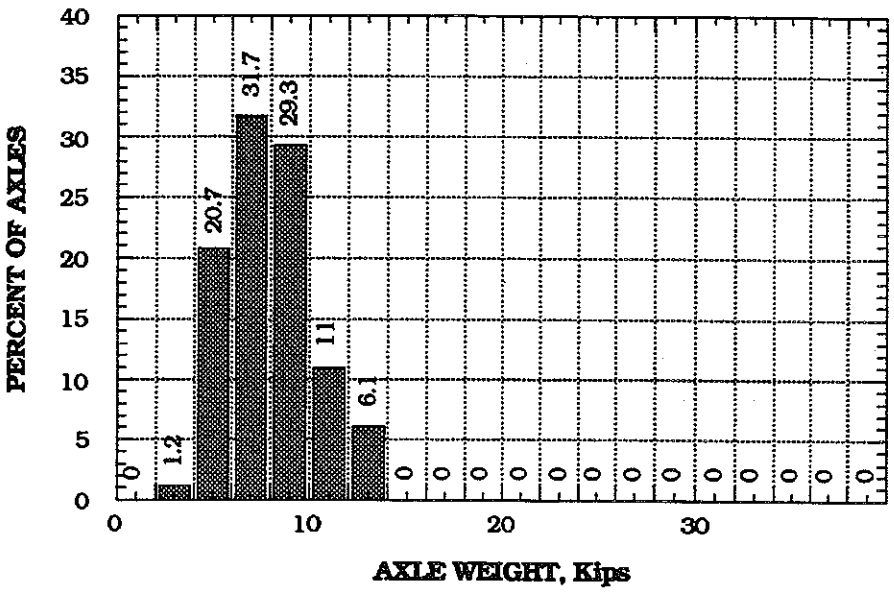


Fig. 4-42. WY/I94, Steering Axle Weight Histogram of 2 Axle Vehicles.

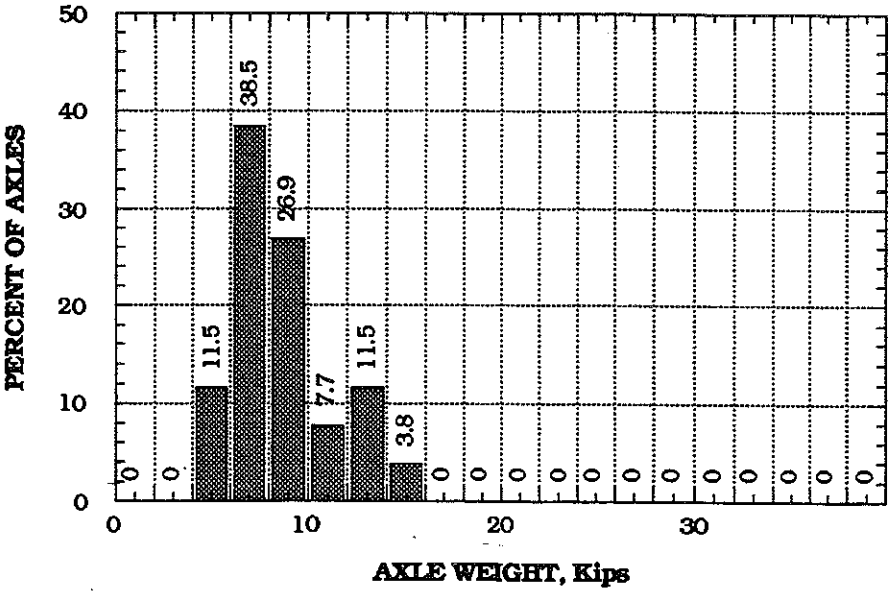


Fig. 4-43. WY/I94, Steering Axle Weight Histogram of 3 Axle Vehicles.

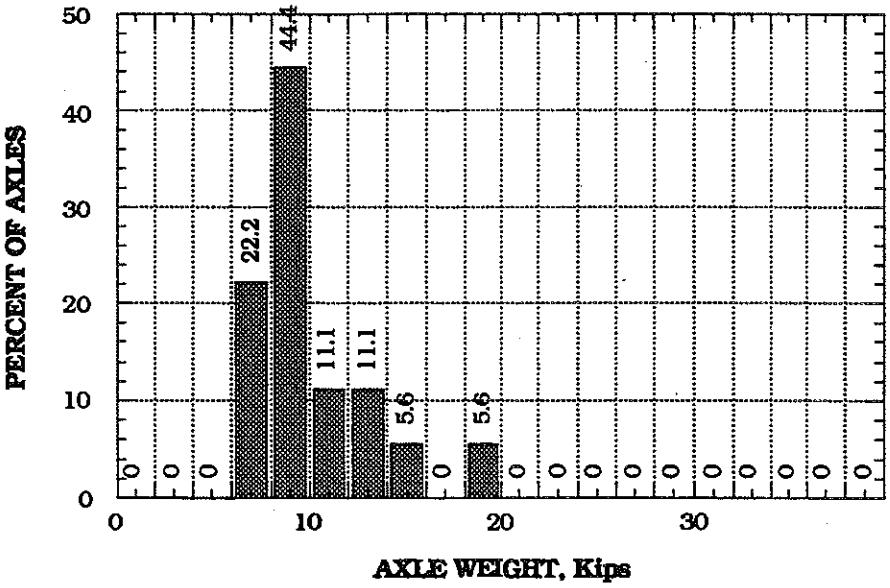


Fig. 4-44. WY/I94, Steering Axle Weight Histogram of 4 Axle Vehicles.

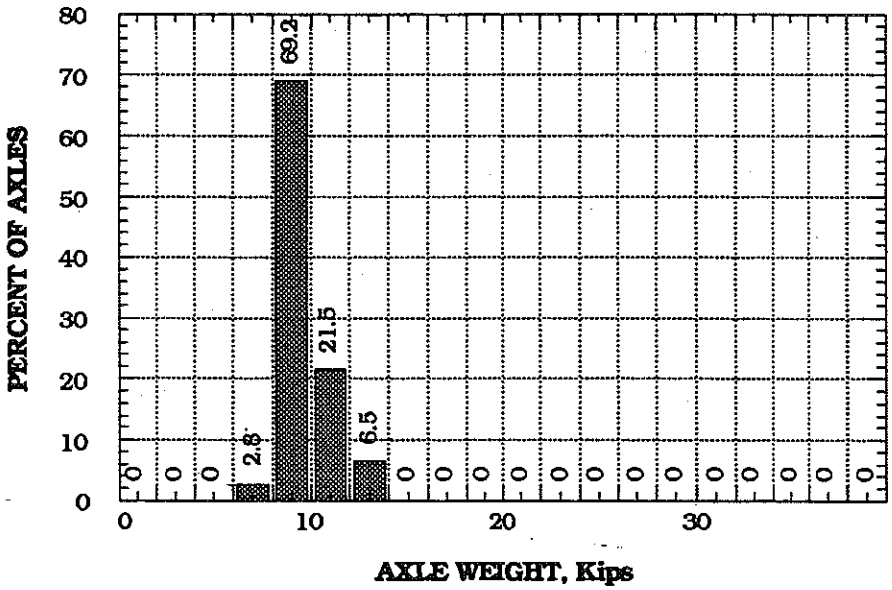


Fig. 4-45. WY/I94, Steering Axle Weight Histogram of 5 Axle Vehicles.

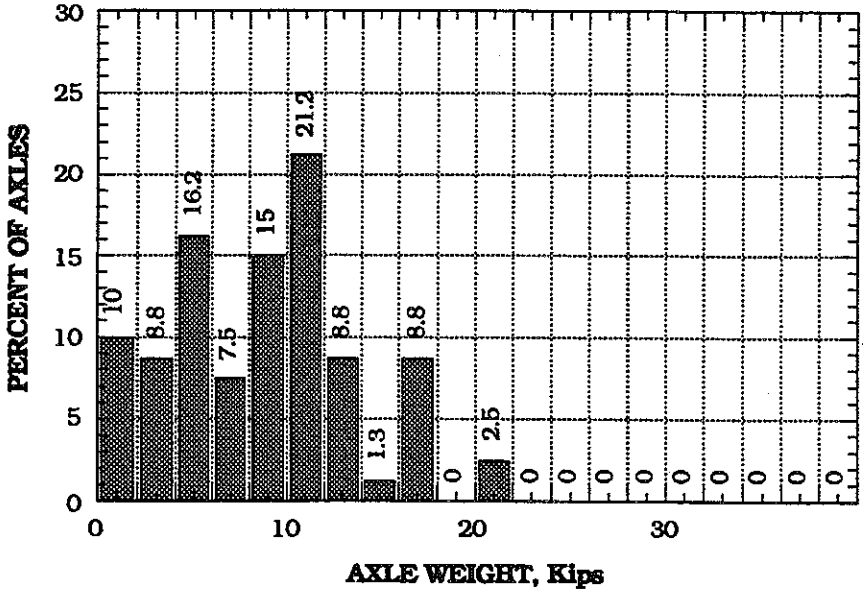


Fig. 4-46. WY/I94, Steering Axle Weight Histogram of 6 Axle Vehicles.

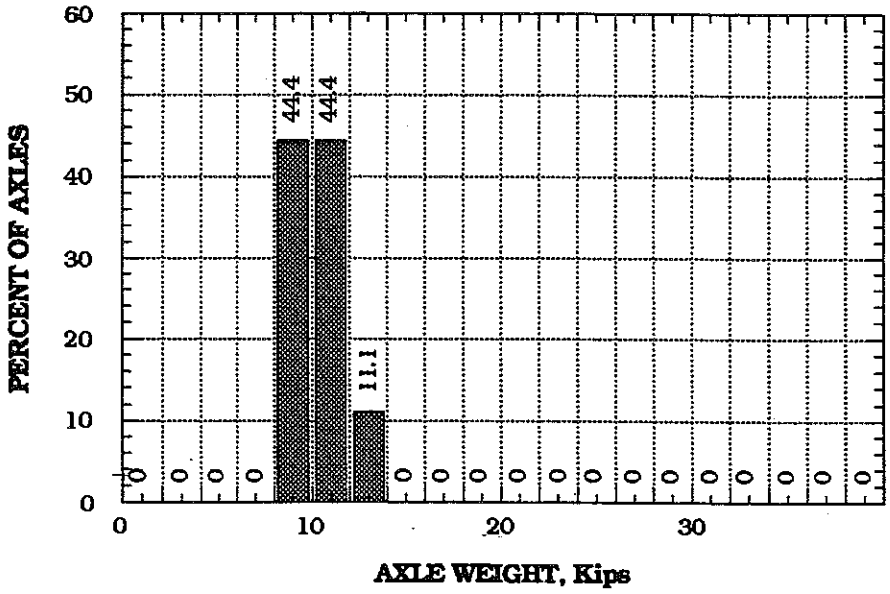


Fig. 4-47. WY/I94, Steering Axle Weight Histogram of 7 Axle Vehicles.

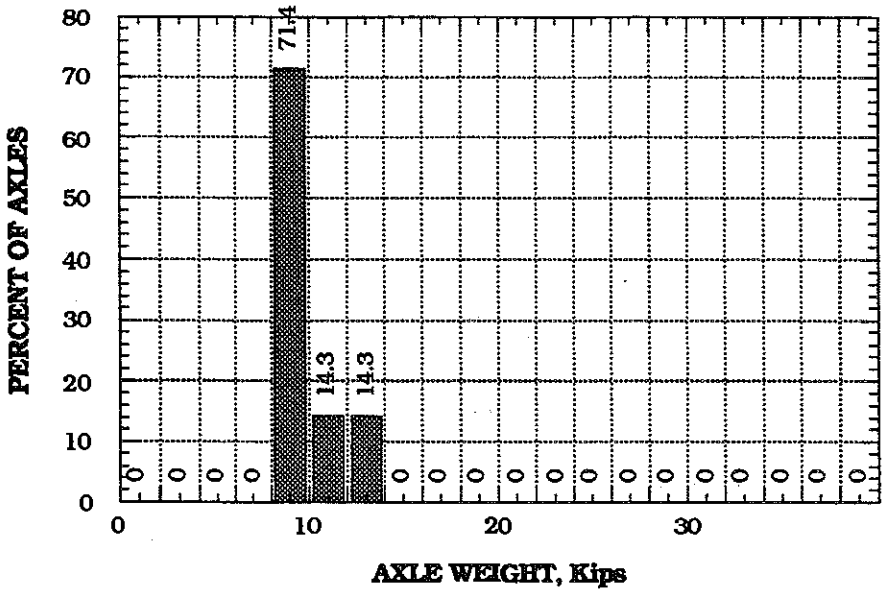


Fig. 4-48. WY/I94, Steering Axle Weight Histogram of 8 Axle Vehicles.

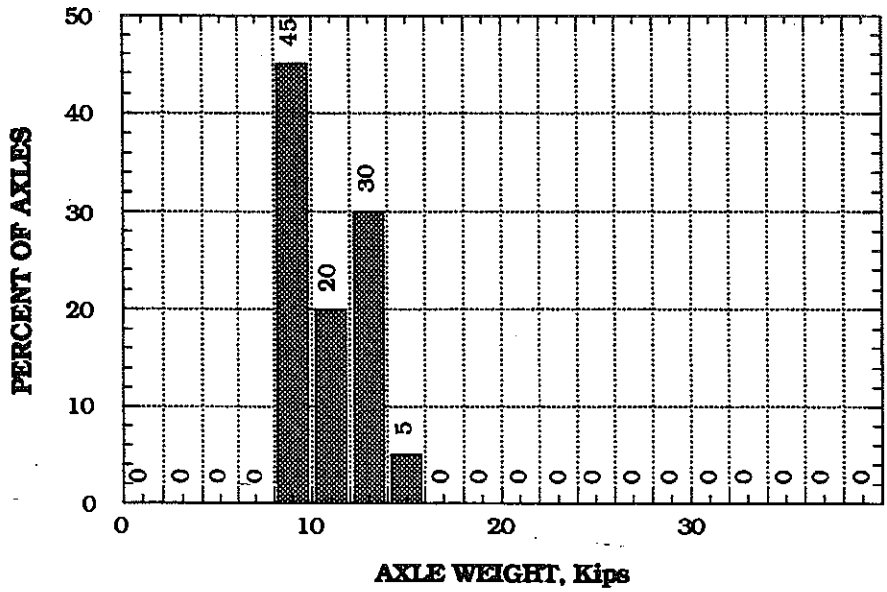


Fig. 4-49. WY/I94, Steering Axle Weight Histogram of 11 Axle Vehicles.

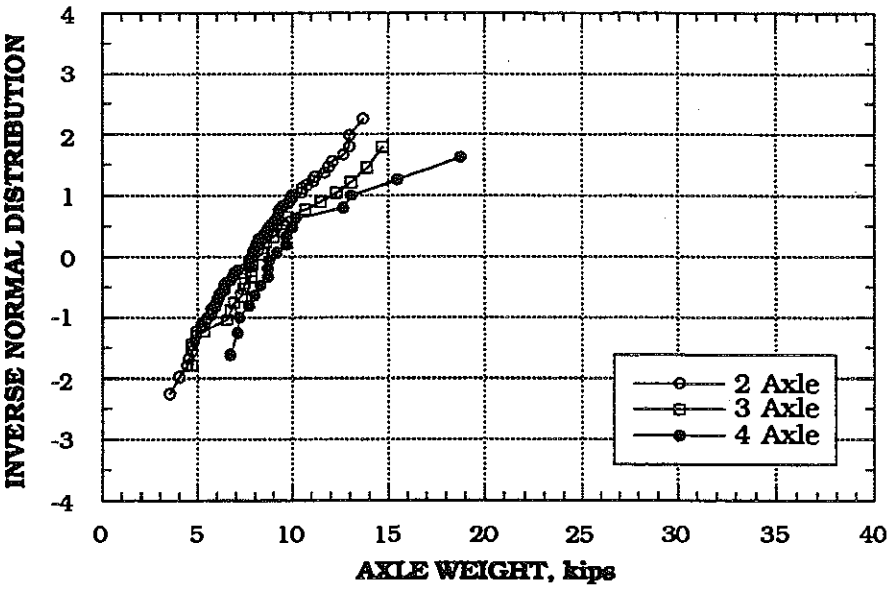


Fig. 4-50. WY/I94, Steering Axle Weight Distributions of 2, 3, and 4 Axle Vehicles.

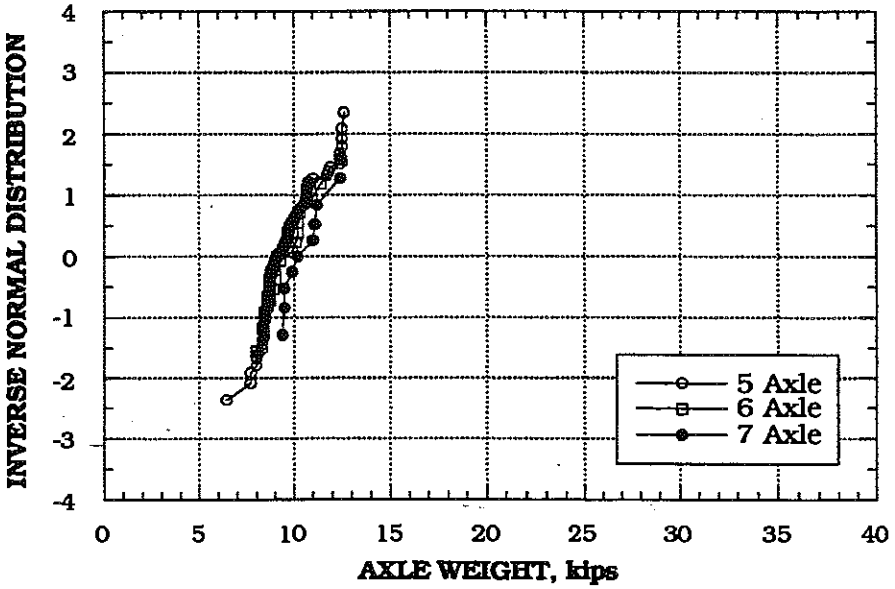


Fig. 4-51. WY/I94, Steering Axle Weight Distributions of 5, 6, and 7 Axle Vehicles.

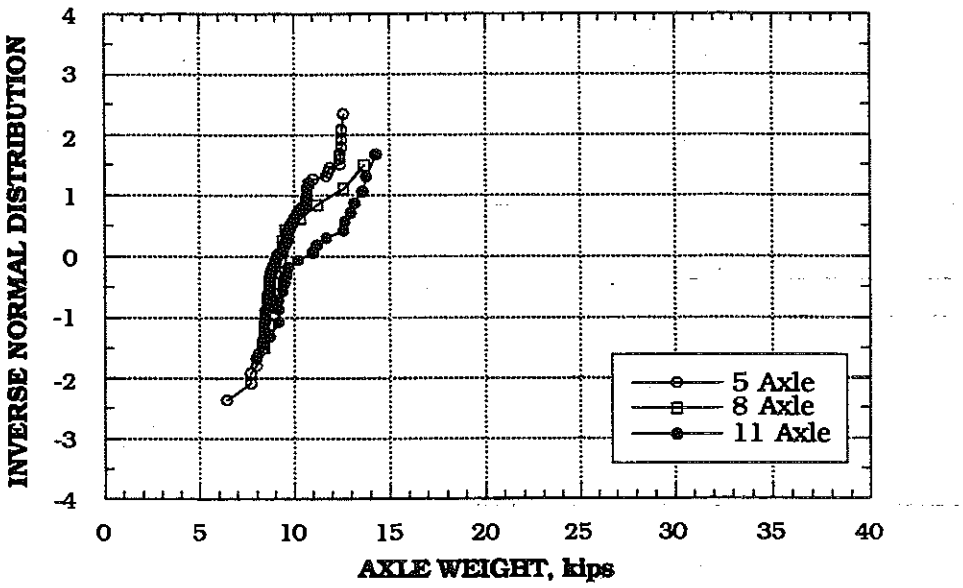


Fig. 4-52. WY/I94, Steering Axle Weight Distributions of 5, 8, and 11 Axle Vehicles.

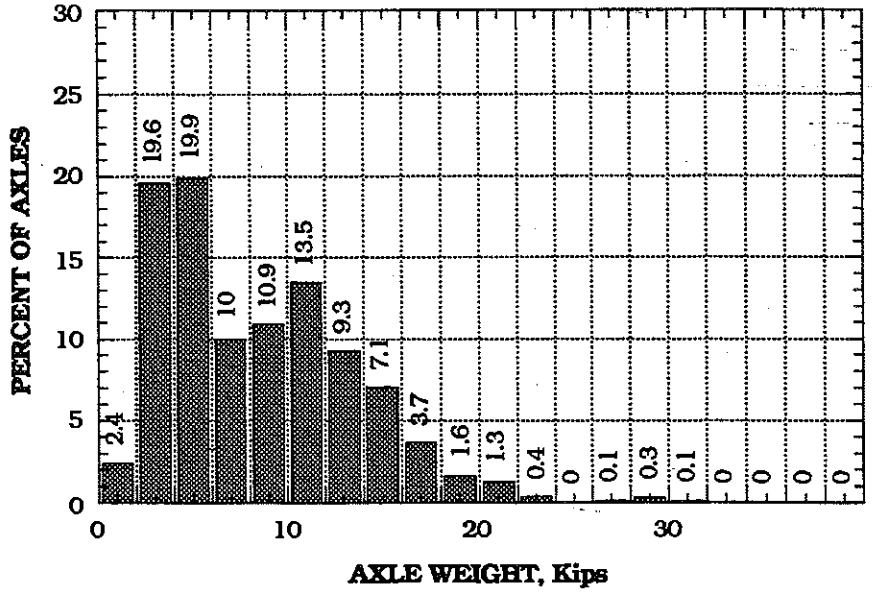


Fig. 4-53. WY/I94, Non-Steering Axle Weight Histogram.

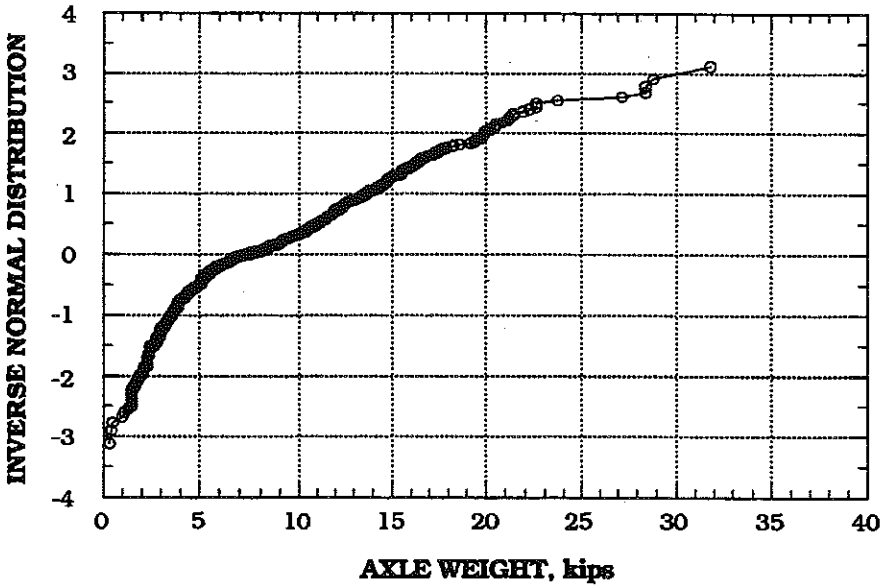


Fig. 4-54. WY/I94, Non-Steering Axle Weight Distributions.

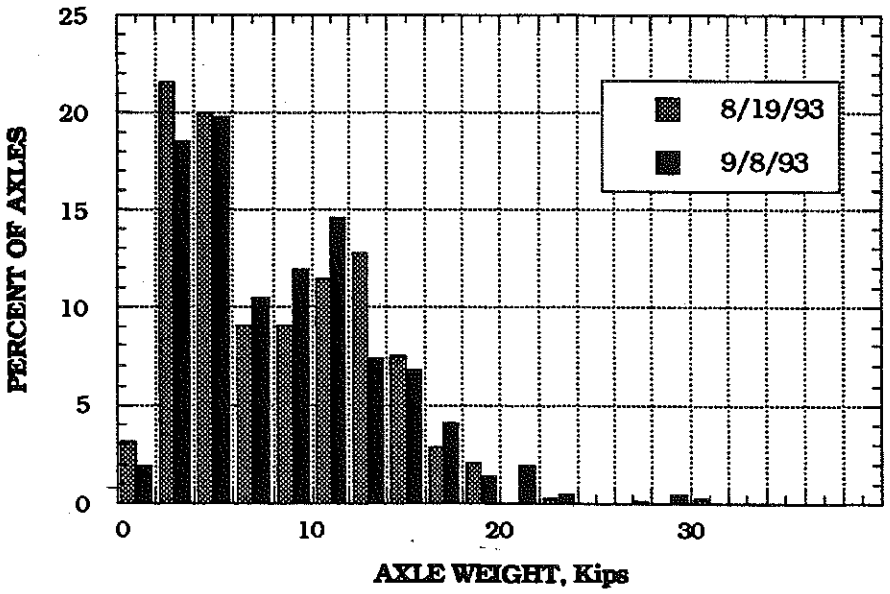


Fig. 4-55. WY/I94, Daily Non-Steering Axle Weight Histogram.

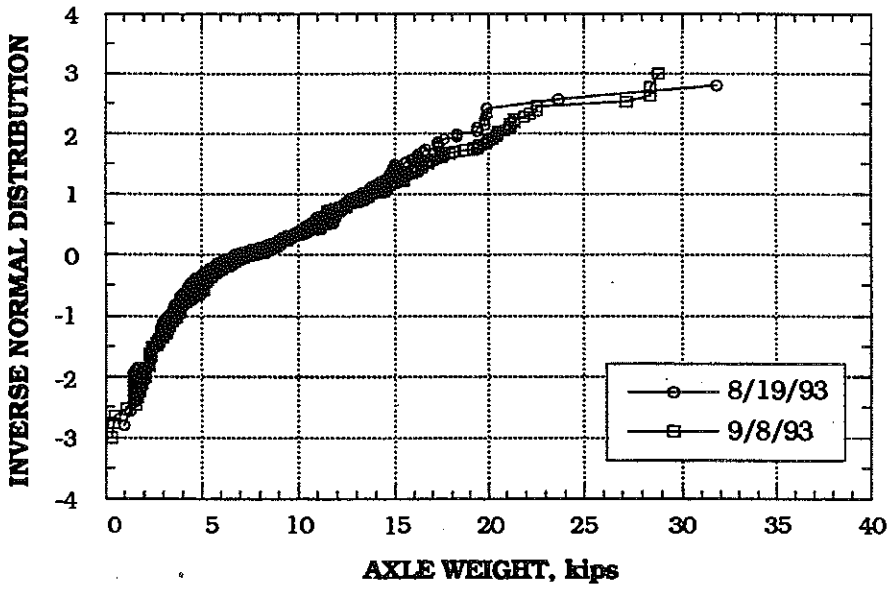


Fig. 4-56. WY/I94, Daily Non-Steering Axle Weight Distributions

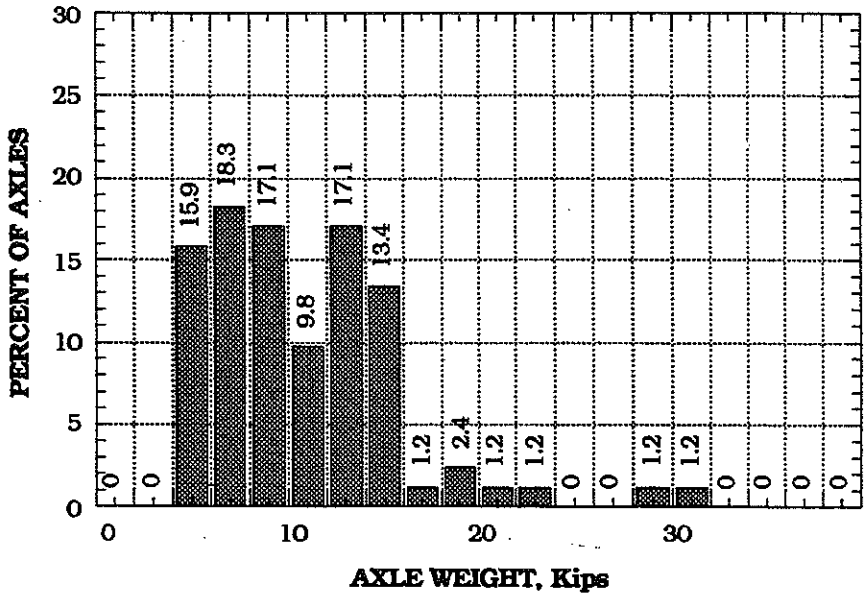


Fig. 4-57. WY/I94, Non-Steering Axle Weight Histogram of 2 Axles.

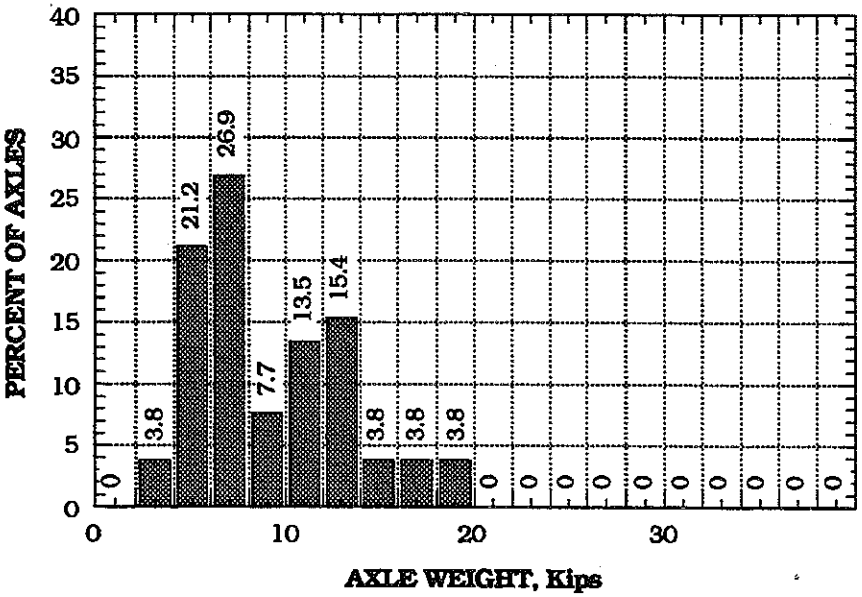


Fig. 4-58. WY/I94, Non-Steering Axle Weight Histogram of 3 Axles.

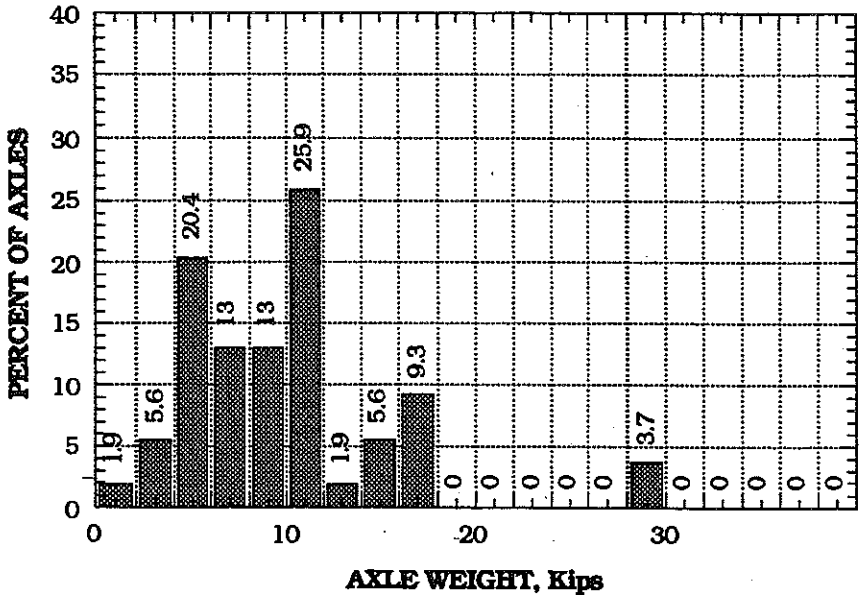


Fig. 4-59. WY/I94, Non-Steering Axle Weight Histogram of 4 Axles.

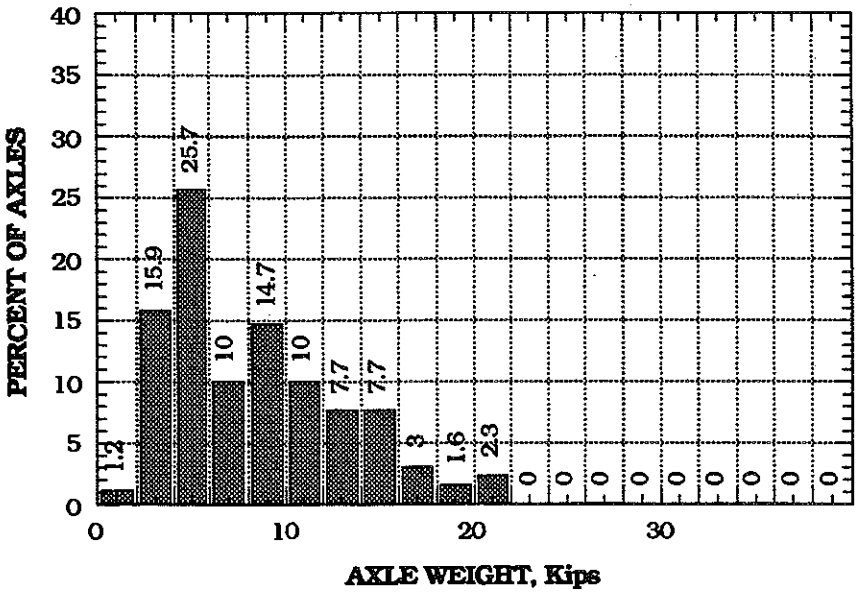


Fig. 4-60. WY/I94, Non-Steering Axle Weight Histogram of 5 Axles.

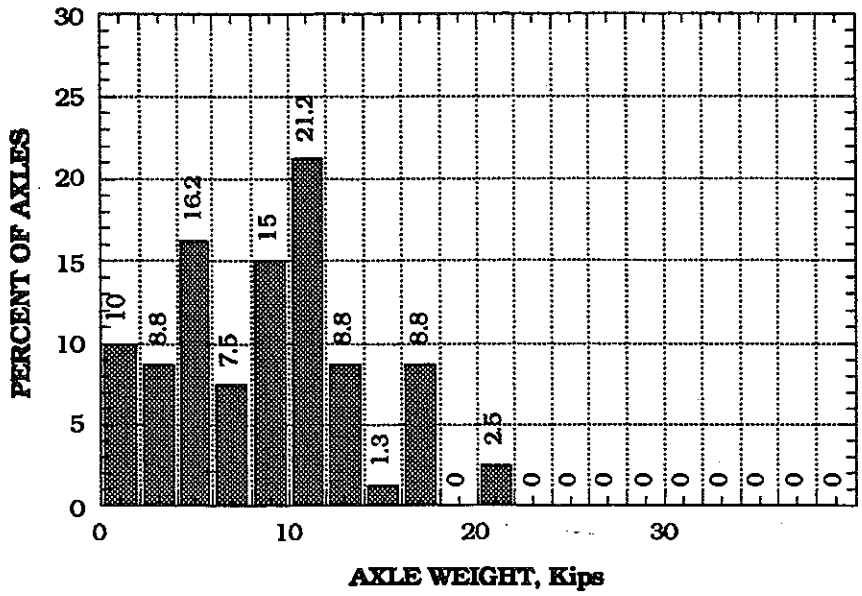


Fig. 4-61. WY/I94, Non-Steering Axle Weight Histogram of 6 Axles.

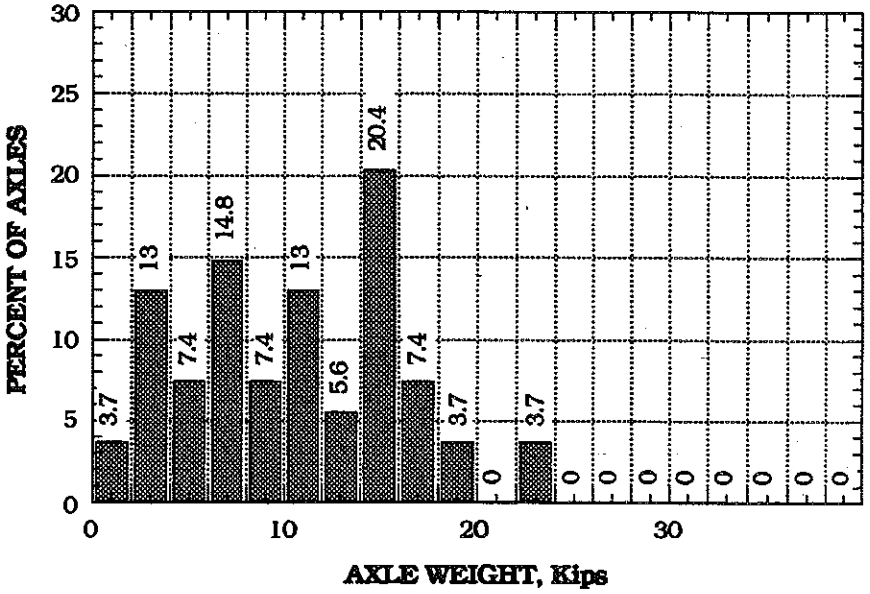


Fig. 4-62. WY/194, Non-Steering Axle Weight Histogram of 7 Axles.

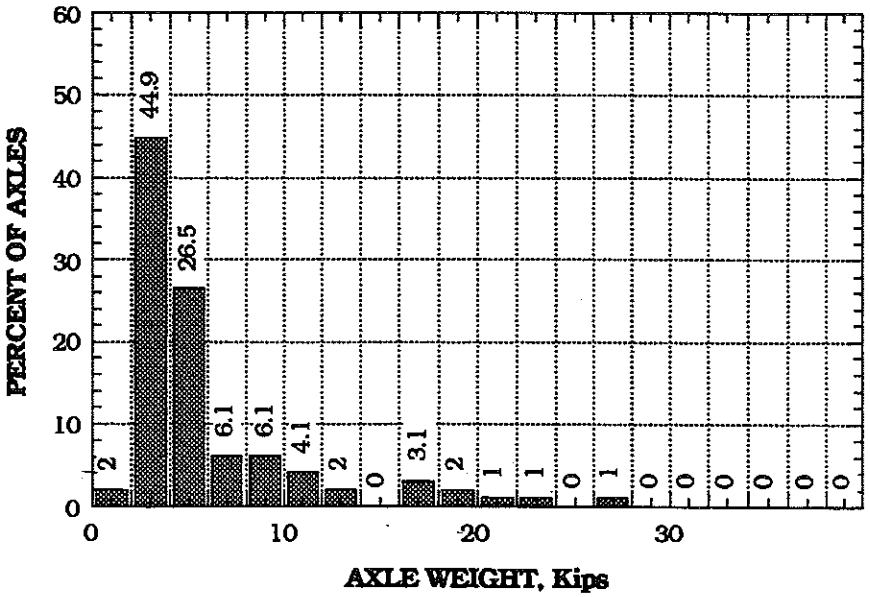


Fig. 4-63. WY/194, Non-Steering Axle Weight Histogram of 8 Axles.

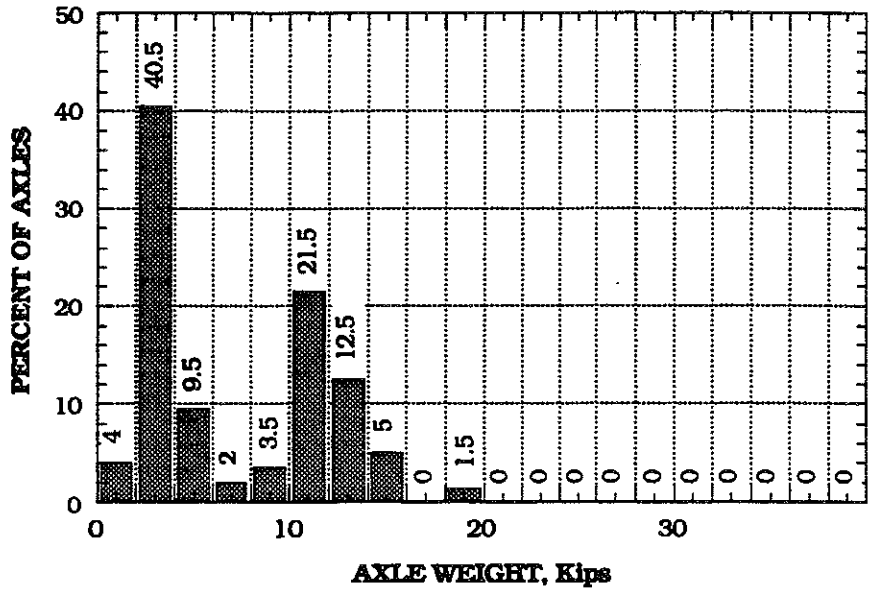


Fig. 4-64. WY/I94, Non-Steering Axle Weight Histogram of 11 Axles.

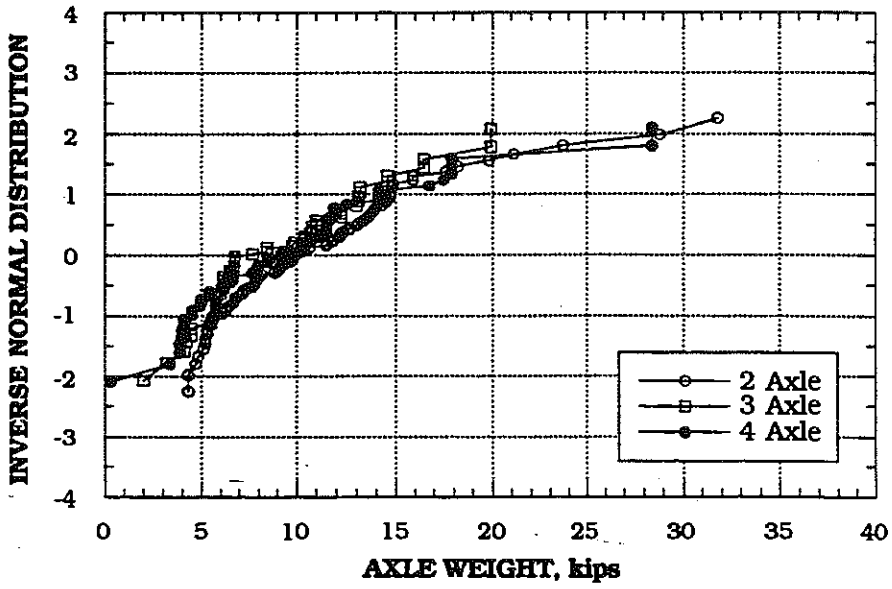


Fig. 4-65. WY/I94, Non-Steering Axle Weight Distributions of 2, 3, and 4 Axle Vehicles.

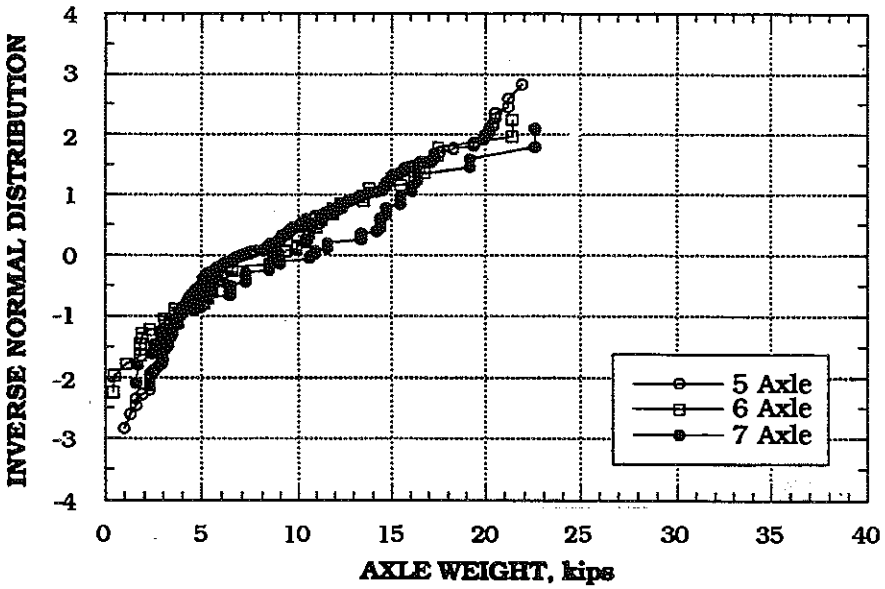


Fig. 4-66. WY/I94, Non-Steering Axle Weight Distributions of 5, 6, and 7 Axle Vehicles.

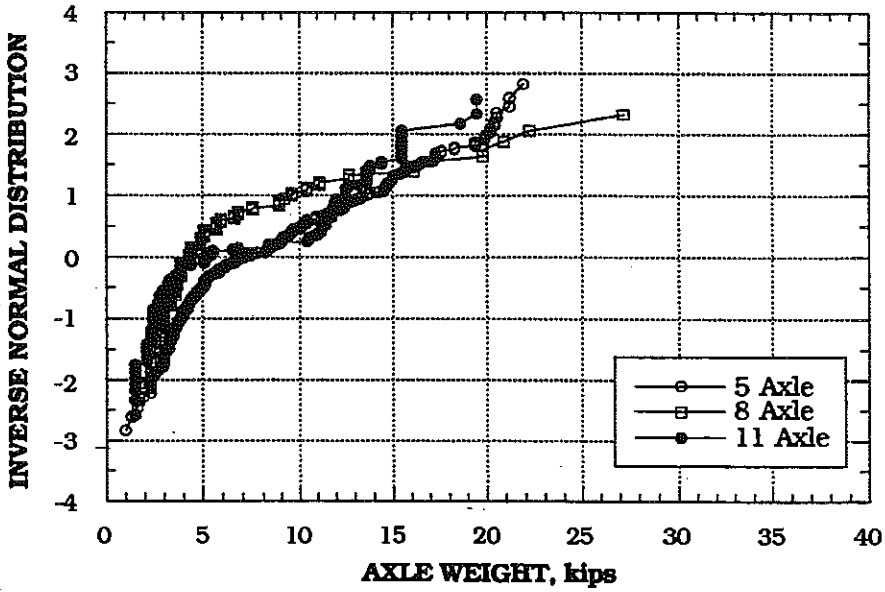


Fig. 4-67. WY/I94, Non-Steering Axle Weight Distributions of 5, 8, and 11 Axle Vehicles.

5. BRIDGE ON I-94 EASTBOUND TO M-10 NORTHBOUND-LODGE HIGHWAY IN DETROIT (I94/M10)

5. 1 Description of the bridge

Bridge I94/M10 is on the ramp which carries eastbound traffic from I-94 to northbound M-10 (Lodge Highway) over Edsel Ford Westbound and J.C. Lodge Southbound in Detroit as shown in Fig. 5-1. The plan view, cross section and other details are shown in Fig. 5-2. Measurements were taken in the span No.6 (in the direction of traffic). The investigated span is 76'-1 1/4" (59'-4" on the exterior side of the curve with radius 1058', and 95'-10 9/16" on the interior one) and the width of the bridge is 41'-8 1/2". The cross section consists of five girders spaced 8'-10 3/16".

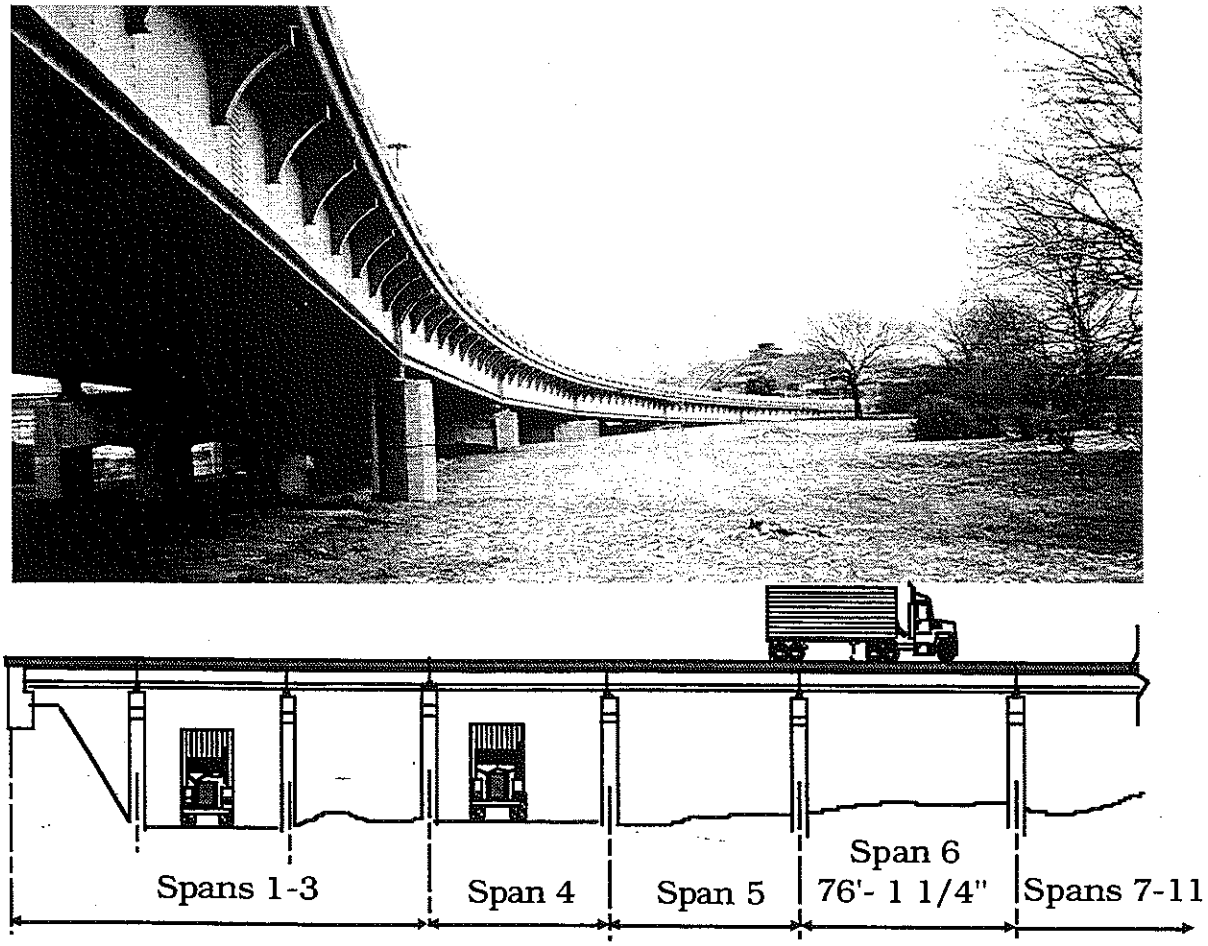


Fig. 5-1. Bridge I94/M10, I-94 Eastbound to M-10 Northbound. View and Side Elevation

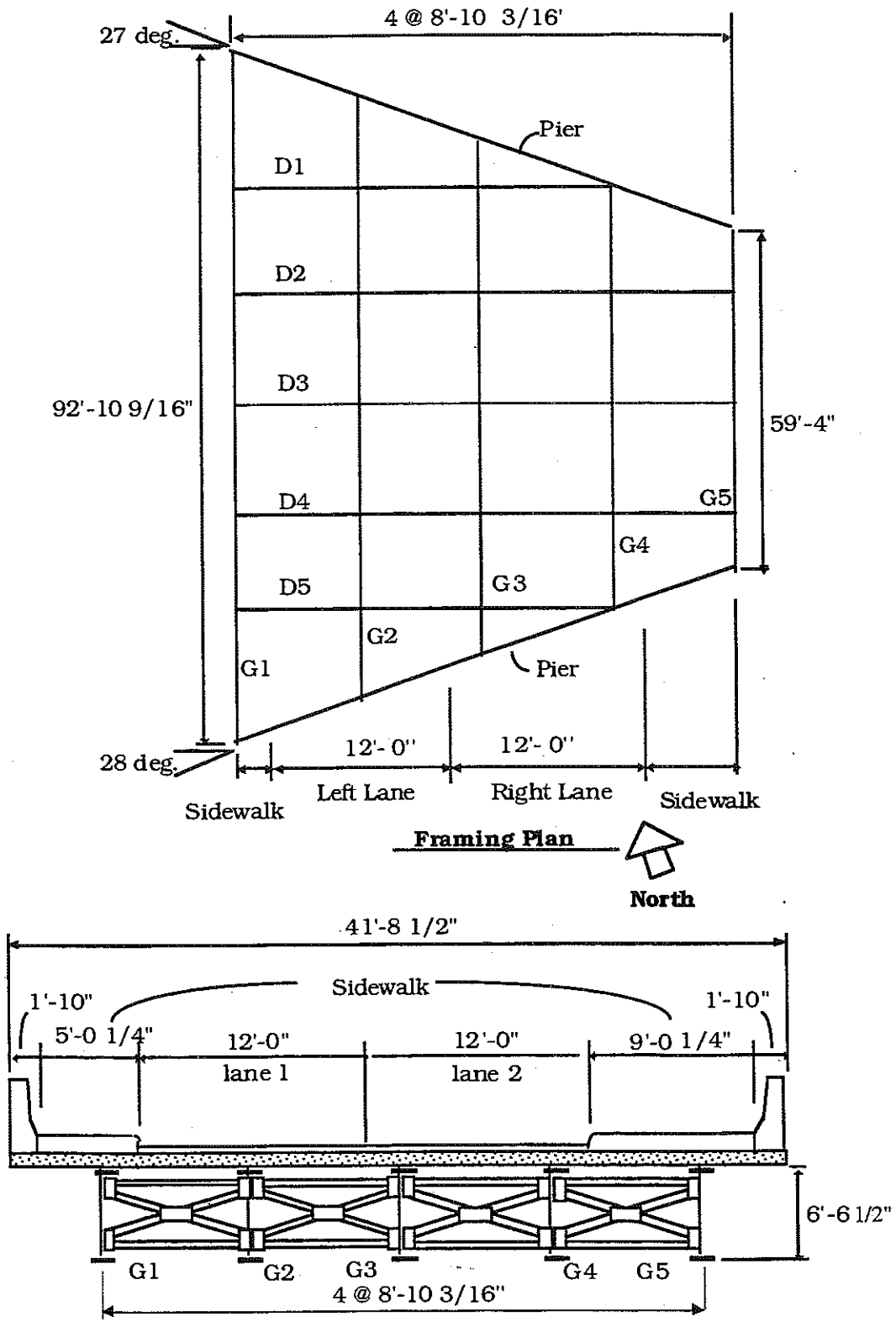


Fig. 5-2. Bridge I94/M10, I-94 Eastbound to M-10 Northbound. Plan View and Cross Section of Bridge Span No.6.

5.2 Weigh-in-Motion Measurements

Weigh-in-motion (WIM) statistics are presented in Table 5-1 to Table 5-6 and in Fig. 5-3 to Fig. 5-66. This data includes all trucks with a gross vehicle weight (GVW) of 10 kips and greater for two axle vehicles, and of 15 kips and greater for three or more axle vehicles, regardless of axle weight. This filtered WIM data has been used for all analysis of GVW and axle weight. At the time of measurement, there was construction work near the bridge. Many construction trucks and heavy trucks were observed. Sometimes there was a traffic jam on I-94 due to the construction work. The heaviest observed vehicles were 11 axle trucks carrying coils of steel or gravel. The data may also include permit loads. The data measured by WIM are recorded in the FHWA card seven 80-column format.

Table 5-1 summarizes an estimated average daily truck traffic (ADTT) in one direction, and the total number of vehicles weighed by date and by different number of axles. Fig. 5-3 is the frequency histogram of trucks corresponding to different number of axles. A large proportion of 11 axle vehicles was observed. Fig. 5-4 shows the daily frequency histogram of trucks. Practically, there is no difference by the date of measurement. Table 5-2 presents Federal Highway Administration (FHWA) truck class frequency statistics. Federal Highway Administration (FHWA) axle configuration class is presented in the Appendix A. Note that the last digit from the FHWA axle class is not included in Table 5-2.

Table 5-3 is the GVW statistics of maximum, mean, median, standard deviation, and percentage of overloaded vehicles. The statistics are given for all vehicles and separately different number of axle vehicles. The GVW limit in Table 5-3 might not be the legal limit. It is difficult to determine the GVW limit with only number of axles. It depends not only on number of axles, but axle spacings. Thus, it was decided to assign reasonably high GVW limits and to give some ideas about how heavy the vehicles were. Fig. 5-5 and Fig. 5-6 are the

histogram of GVW and the corresponding cumulative distribution function (CDF) of GVW for all trucks observed and measured on I94/M10 respectively. In Fig. 5-6, each circle represents one truck in the data file. From the graph and from Table 5-3 the heaviest vehicle observed weighed 263 kips with a mean GVW of 64 kips. Vehicles over the GVW limit were 25 %. Results of the individual day measurements are shown in Fig. 5-7 and Fig. 5-8. The day to day CDF's are very similar in shape and average GVW with the largest difference at the upper tail of the distribution. GVW histograms for different number of axle vehicles are presented in Fig. 5-9 to Fig. 5-16. The corresponding CDF's are shown in Fig. 5-17 to Fig. 5-19. There are distinct difference in GVW for each vehicle group. The histograms and CDF's for 5 and 11-axle vehicles clearly indicate that the much heavier vehicles are 11 axle trucks. Overloaded 5 and 11-axle vehicles were 21 % and 86 % respectively. For comparison of the daily distributions of 5 and 11 axle vehicles, the CDF's for three days are plotted in Fig. 5-21.

Table 5-4 is the axle weight statistics of maximum, mean, median, standard deviation, and percentage of overloaded axles. The statistics are given for all vehicles and separately different number of axle vehicles. In this table, axle weight limits were intended to give some ideas about how heavy the axles were. The statistics depend on axle spacings rather than number of axles. Fig. 5-21 and Fig. 5-22 are the histograms of axle weight for all vehicles and the corresponding CDF respectively. The maximum axle weight observed at I94/M10 was 49 kips with a mean of 14 kips. Axles with axle weight of 18 kips and greater were 26 %. Fig. 5-23 and Fig. 5-24 show the daily axle weight histogram and CDF's. As in the case with GVW, there is little daily variation in the vehicle axle weights with some differences at the upper tail of the distribution. Axle weight histograms for different number of axle vehicles are presented in Fig. 5-25 to Fig. 5-32. The corresponding CDF's are shown in Fig. 5-33 to Fig. 5-35. Overloaded axles for 5 and 11 axle vehicles were 18 percent and 40 percent respectively. The daily CDF's of axle weight for 5 and 11 axle vehicles are plotted in Fig. 5-36 for comparison of the daily distribution.

Table 5-5 is the steering axle weight statistics of maximum, mean, median, and standard deviation of all vehicles and different number of axle vehicles. Fig. 5-37 and Fig. 5-38 are the steering axle weight histogram for all vehicles and the corresponding CDF respectively. The maximum observed steering axle weight was 20 kips with a mean of 10 kips. Fig. 5-39 and Fig. 5-40 show the daily steering axle weight histogram and CDF's. Steering axle weight histograms for different number of axle vehicles are presented in Fig. 5-41 to Fig. 5-48. The corresponding CDF's are shown in Fig. 5-49 to Fig. 5-51.

Table 5-6 is the non-steering axle weight statistics of maximum, mean, median, and standard deviation of all vehicles and different number of axle vehicles. Fig. 5-52 and Fig. 5-53 are the non-steering axle weight histogram for all vehicles and the corresponding CDF. The maximum non-steering axle weight was 49 kips with a mean of 15 kips. Fig. 5-54 and Fig. 5-55 show the daily non-steering axle weight histogram and CDF's. Non-steering axle weight histograms for different number of axle vehicles are presented in Fig. 5-56 to Fig. 5-63. The corresponding CDF's are shown in Fig. 5-64 to Fig. 5-66.

The steering and non-steering axle weight CDF's of Fig. 5-38 and Fig. 5-53 indicate a significant difference in both variation and magnitudes. The standard deviation of steering axle weight was 3 kips with a maximum of 20 kips while the standard deviation of non-steering axle weight was 8 kips with a maximum of 49 kips.

Review of the results indicates that many truck weights are over legal limits. Overloaded 5 and 11 axle vehicles were 21 percent and 86 percent respectively. Vehicles over the GVW limit were 25 percent. Overloaded axles for 5 and 11 axle vehicles were 18 percent and 40 percent respectively. Axles with axle weight of 18 kips and greater were 26 percent. Some reasons for these heavy vehicles may be attributed to the construction work around the bridge.

Table 5-1. Bridge I94/M10, Number of Trucks Weighed and Estimated ADTT.

Number of Trucks Weighed Gross Vehicle Weight > 10 Kips for 2 Axle Vehicles, Gross Vehicle Weight > 15 Kips for 3 or more Axle Vehicles.					
Date	6/2/94	6/15/94	6/16/94	Total	Vehicles (%)
2 Axles	104	106	175	385	41.7
3 Axles	25	28	42	95	10.3
4 Axles	11	17	12	40	4.3
5 Axles	40	54	53	147	15.9
6 Axles	24	17	29	70	7.6
7 Axles	10	7	11	28	3.0
8 Axles	2	3	8	13	1.4
9 Axles	0	3	5	8	8.0
10 Axles	1	0	2	3	0.3
11 Axles	22	44	67	133	14.4
All Vehicles	239	281	404	924	100.0
Estimated ADTT = 1500 Trucks (in one direction)					

Table 5-2. Bridge I94/M10, Truck Class Statistics.

Truck Class (FHWA)	Vehicles (%)
4	0.0
5	71.5
6	3.0
7	0.6
8	2.3
9	7.3
10	4.4
11	0.0
12	0.0
13	0.1
14	10.9
Total Lane %	100.0

Table 5-3. Bridge I94/M10, Gross Vehicle Weight Statistics.

Vehicle Type	Max. (Kips)	Mean (Kips)	Median (Kips)	Std.Dev. (Kips)	GVW Limit (Kips)	Percentage over the Limit
2 Axles	46	19	17	8	40	3
3 Axles	77	42	41	14	60	12
4 Axles	81	45	43	14	70	4
5 Axles	138	61	54	24	80	21
6 Axles	160	89	92	25	90	55
7 Axles	185	97	89	33	120	25
8 Axles	221	133	151	56	125	62
9 Axles	200	119	106	51	135	28
10 Axles	205	195	193	10	150	100
11 Axles	263	185	193	41	164	86
All Vehicles	263	64	40	62	varies	25

Table 5-4. Bridge I94/M10, Axle Weight Statistics.

Vehicle Type	Max. (Kips)	Mean (Kips)	Median (Kips)	Std.Dev. (Kips)	Axle Weight Limit (Kips)	Percentage over the Limit
2 Axles	33	9	8	5	18	6
3 Axles	32	14	13	6	18	25
4 Axles	38	11	10	6	18	9
5 Axles	40	12	11	6	18	18
6 Axles	41	15	15	7	18	30
7 Axles	33	14	12	6	18	18
8 Axles	35	17	15	9	18	39
9 Axles	36	13	10	8	18	26
10 Axles	33	20	17	9	18	37
11 Axles	49	17	16	8	18	40
All Vehicles	49	14	13	8	18	26

Table 5-5. Bridge I94/M10, Steering Axle Weight Statistics.

Vehicle Type	Max. (Kips)	Mean (Kips)	Median (Kips)	Std.Dev. (Kips)	Vehicles (%)
2 Axles	15	8	7	3	41.7
3 Axles	20	11	10	3	10.3
4 Axles	17	10	10	3	4.3
5 Axles	13	10	9	1	15.9
6 Axles	14	11	11	1	7.6
7 Axles	15	11	11	1	3.0
8 Axles	16	13	13	2	1.4
9 Axles	15	12	12	2	8.0
10 Axles	15	15	15	0	0.3
11 Axles	18	15	15	2	14.4
All Vehicles	20	10	10	3	100.0

Table 5-6. Bridge I94/M10, Non-Steering Axle Weight Statistics.

Vehicle Type	Max. (Kips)	Mean (Kips)	Median (Kips)	Std.Dev. (Kips)	Vehicles (%)
2 Axles	33	11	10	6	41.7
3 Axles	32	15	15	6	10.3
4 Axles	38	12	10	6	4.3
5 Axles	40	13	12	7	15.9
6 Axles	41	16	16	7	7.6
7 Axles	33	14	13	7	3.0
8 Axles	35	17	16	9	1.4
9 Axles	36	13	10	8	8.0
10 Axles	33	20	17	10	0.3
11 Axles	49	17	16	9	14.4
All Vehicles	49	15	14	8	100.0

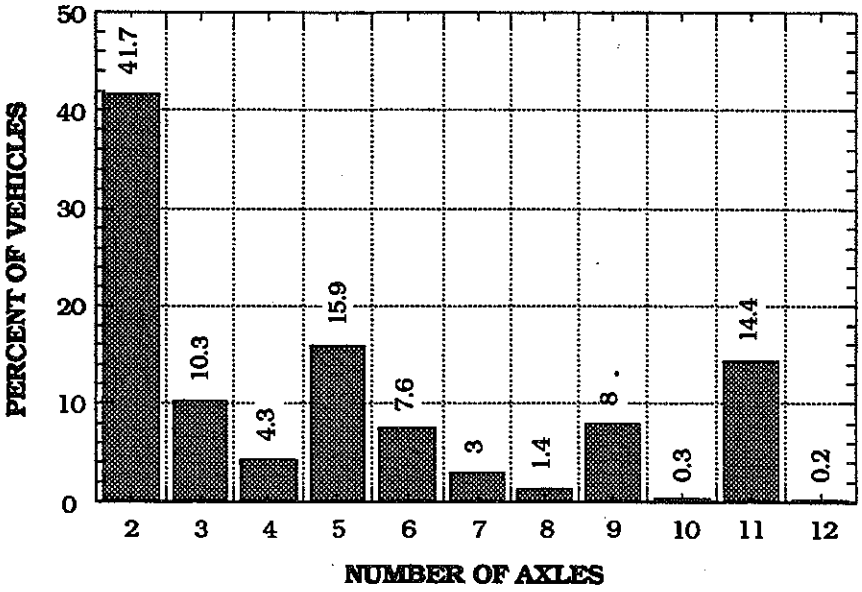


Fig. 5-3. I94/M10, Truck Type Histogram.

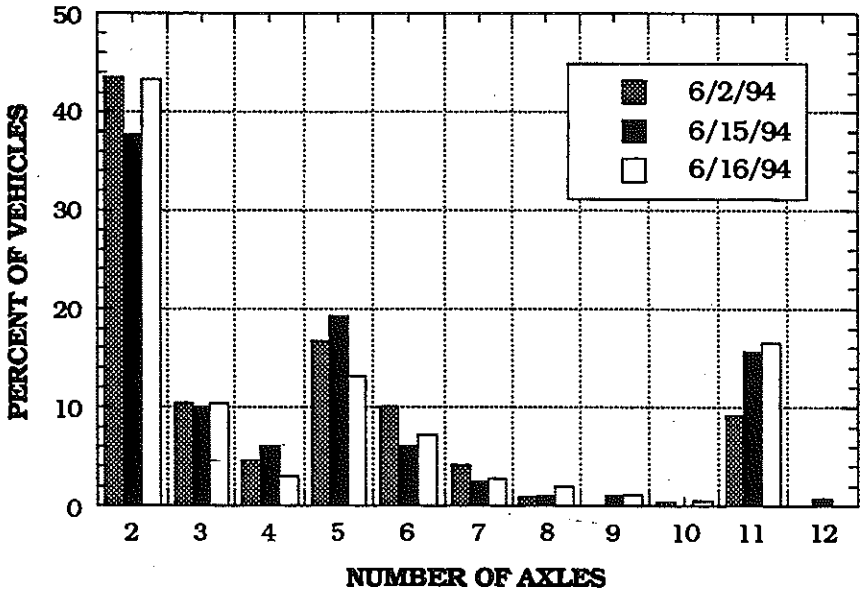


Fig. 5-4. I94/M10, Daily Truck Type Histogram.

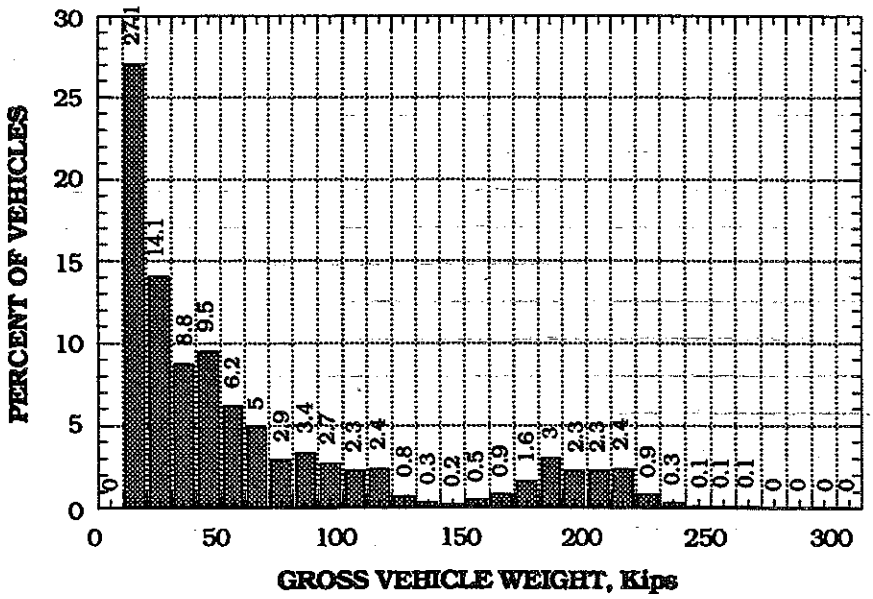


Fig. 5-5. I94/M10, GVW Histogram.

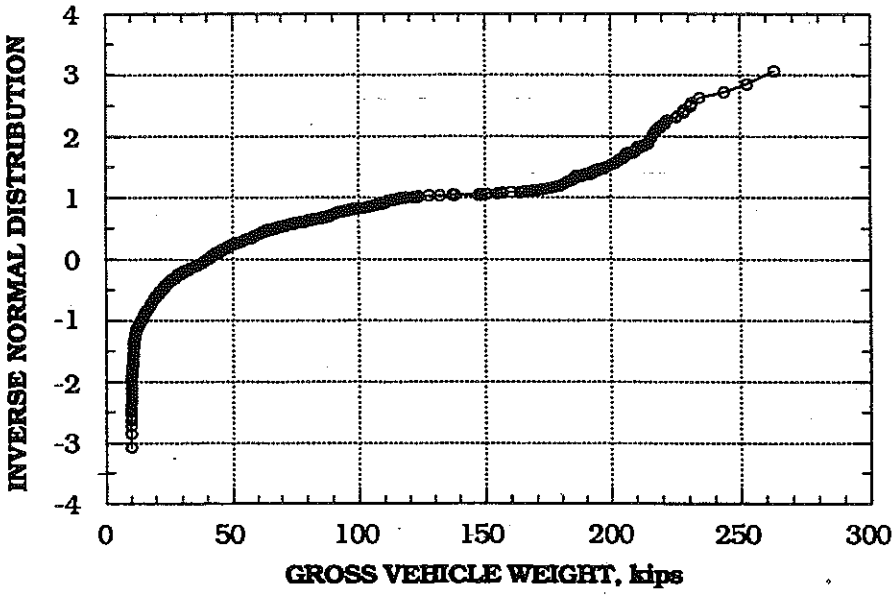


Fig. 5-6. I94/M10, GVW Distribution.

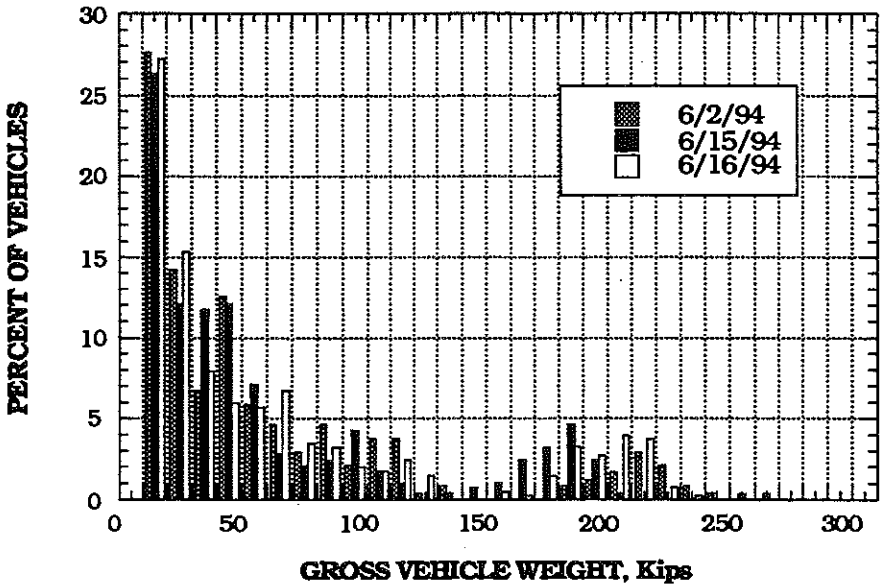


Fig. 5-7. I94/M10, Daily GVW Histogram.

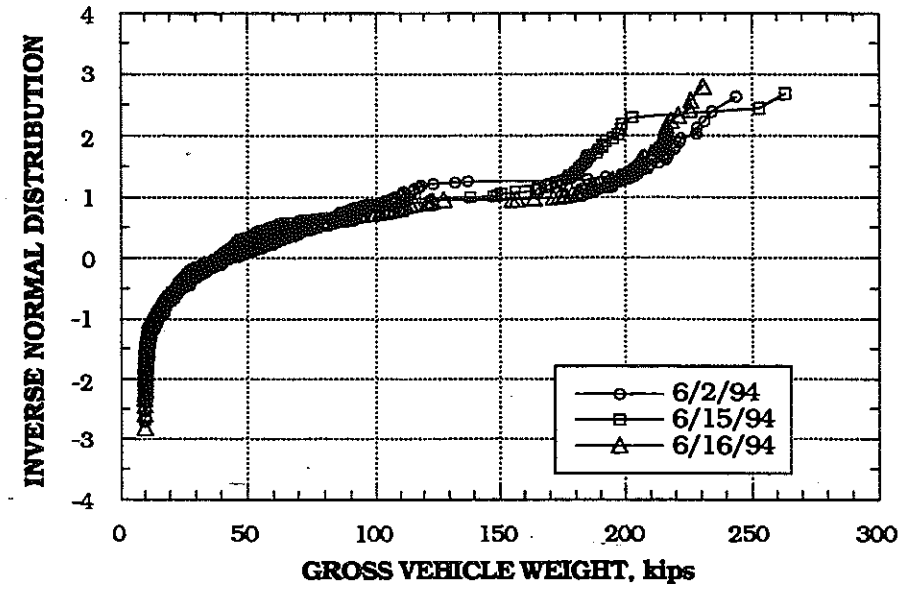


Fig. 5-8. I94/M10, Daily GVW Distributions.

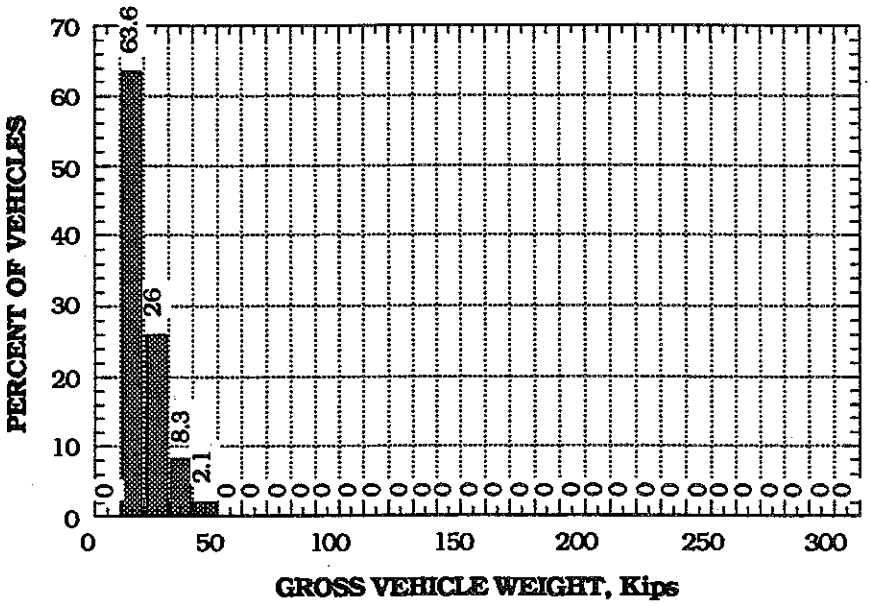


Fig. 5-9. I94/M10, 2 Axle GVW Histogram.

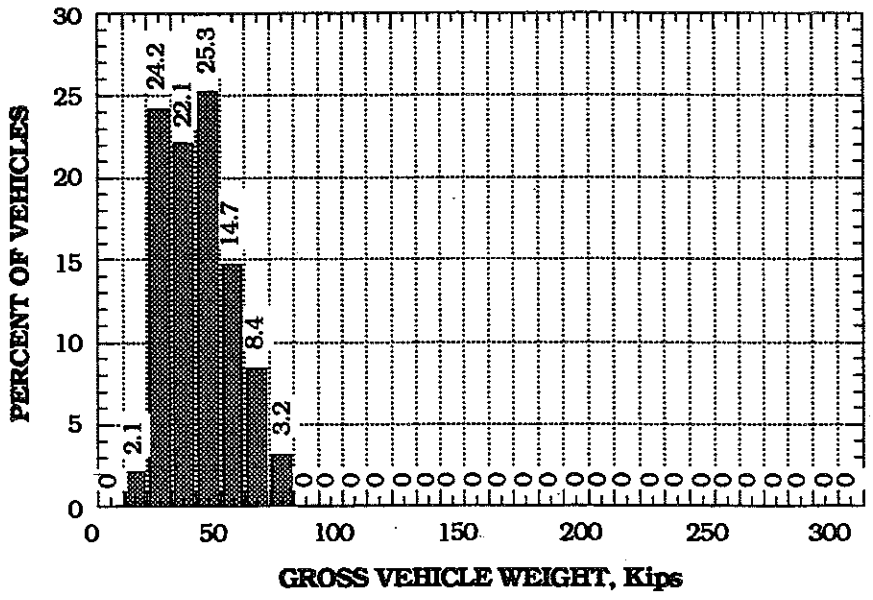


Fig. 5-10. I94/M10, 3 Axle GVW Histogram.

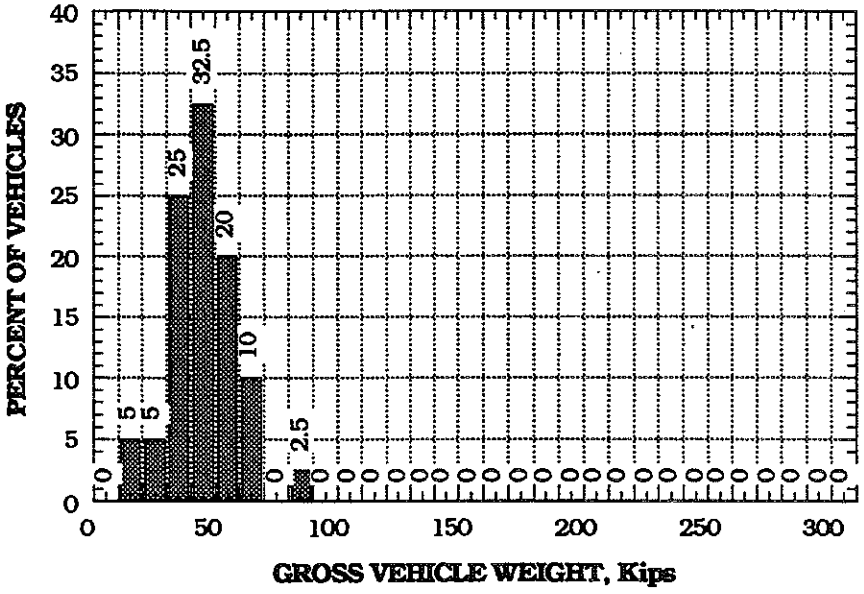


Fig. 5-11. I94/M10, 4 Axle GVW Histogram.

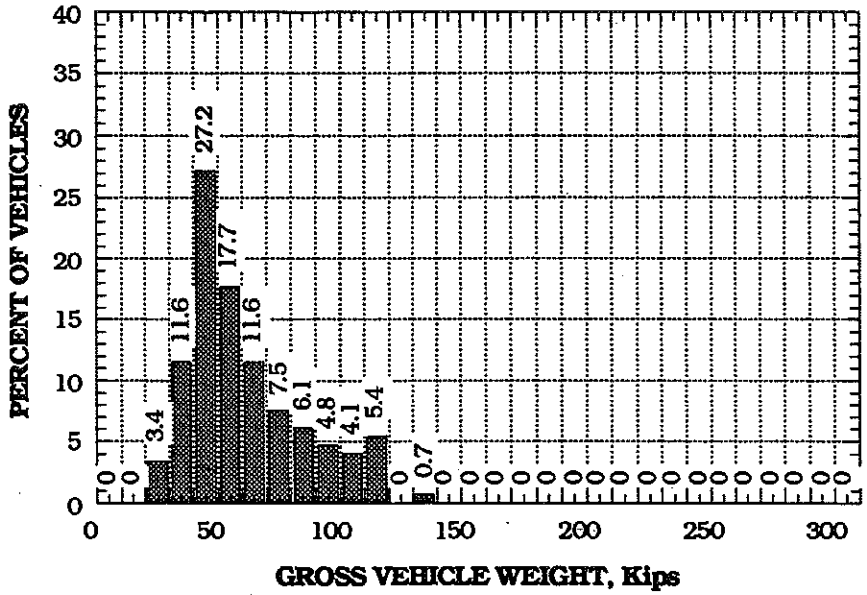


Fig. 5-12. I94/M10, 5 Axle GVW Histogram.

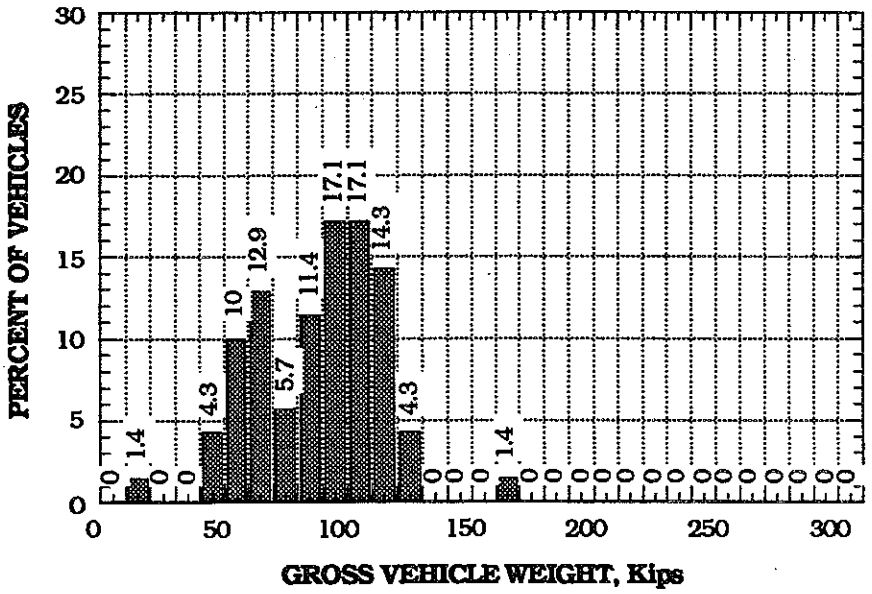


Fig. 5-13. I94/M10, 6 Axle GVW Histogram.

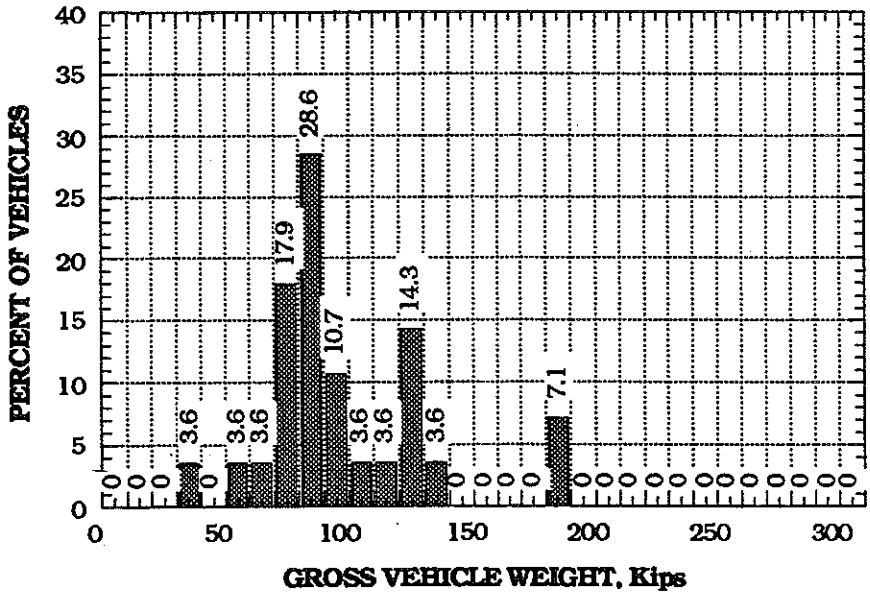


Fig. 5-14. I94/M10, 7 Axle GVW Histogram.

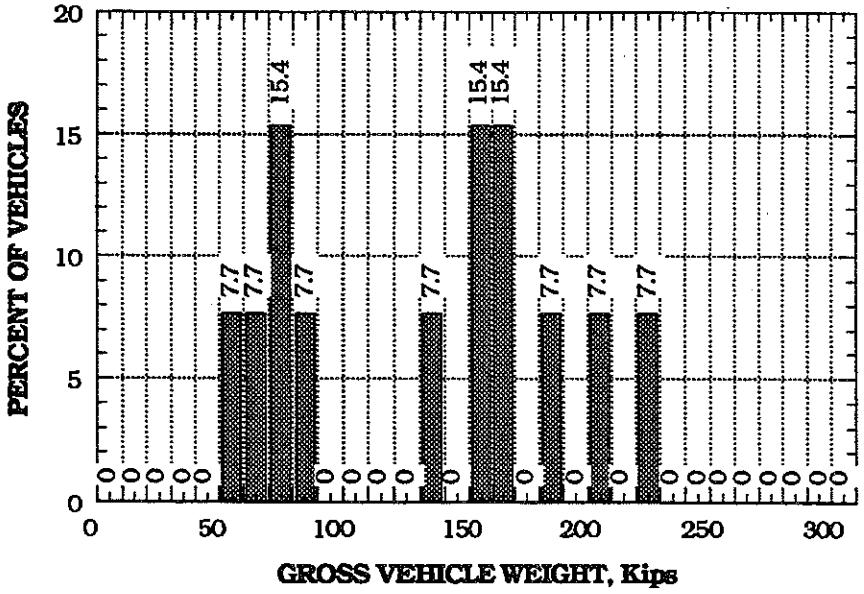


Fig. 5-15. I94/M10, 8 Axle GVW Histogram.

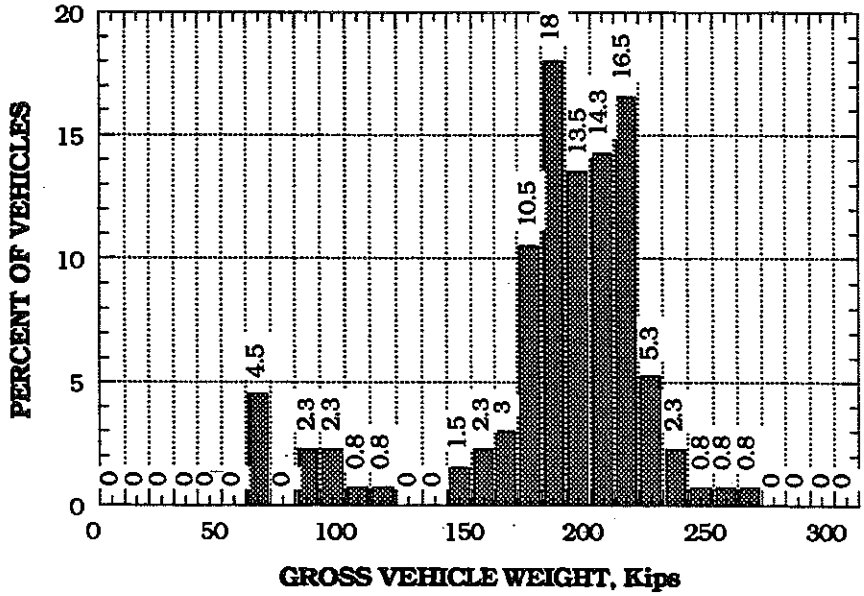


Fig. 5-16. I94/M10, 11 Axle GVW Histogram.

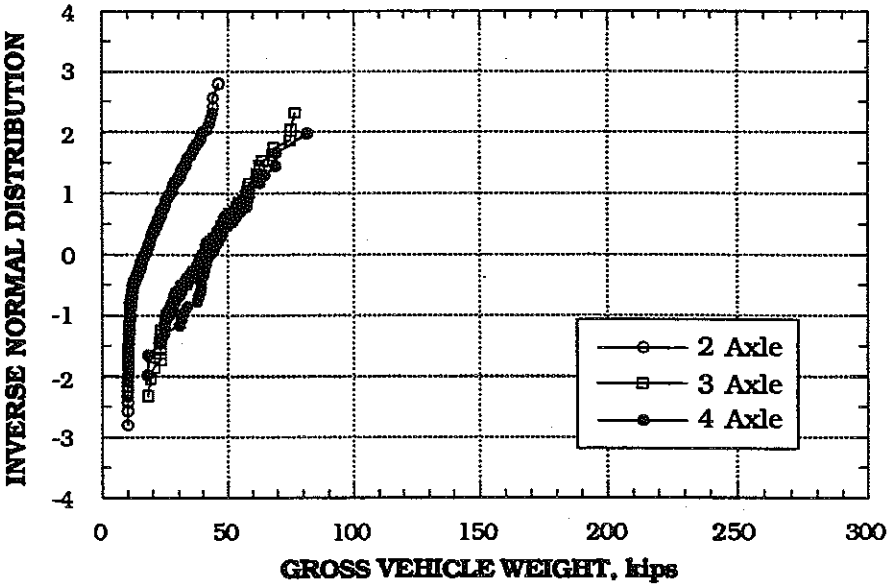


Fig. 5-17. I94/M10, 2, 3, and 4 Axle GVW Distributions.

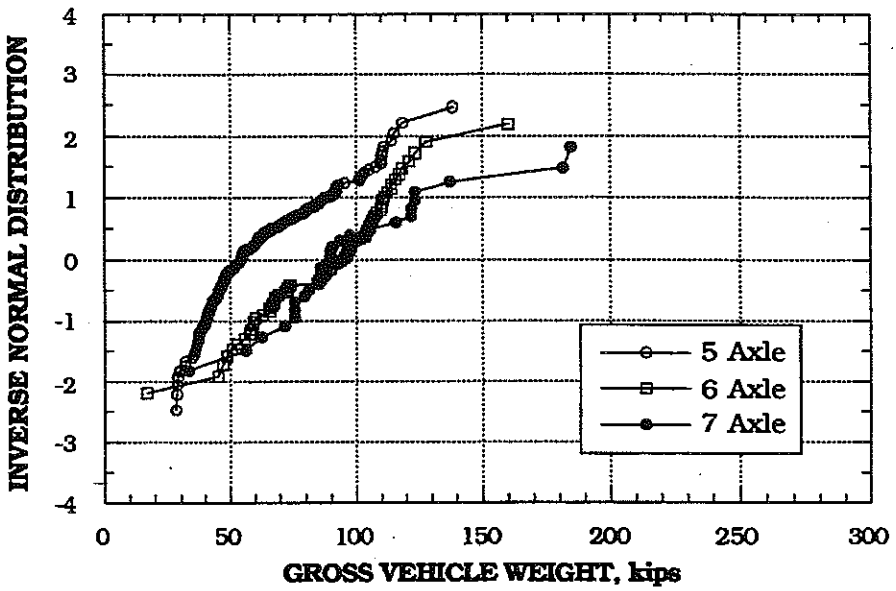


Fig. 5-18. I94/M10, 5, 6, and 7 Axle GVW Distributions.

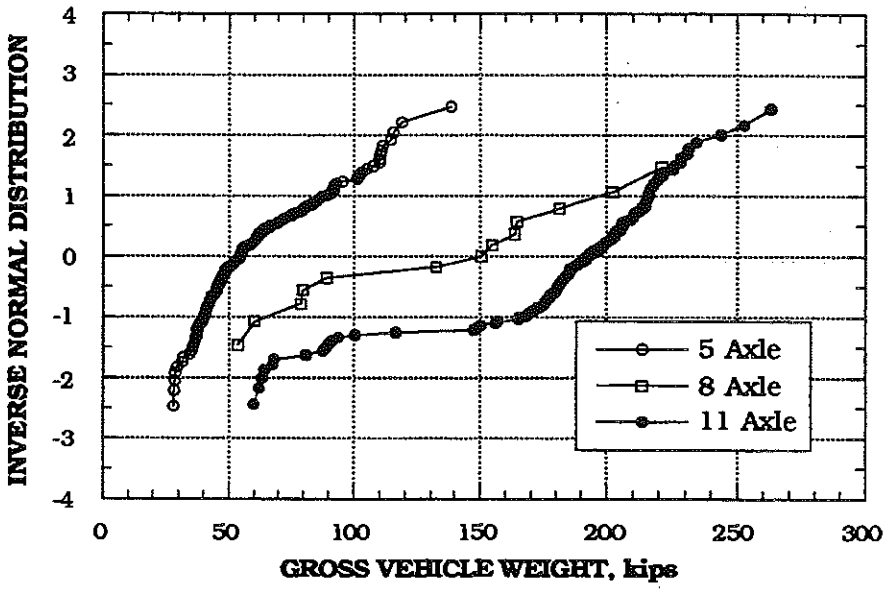


Fig. 5-19. I94/M10, 5, 8, and 11 Axle GVW Distributions.

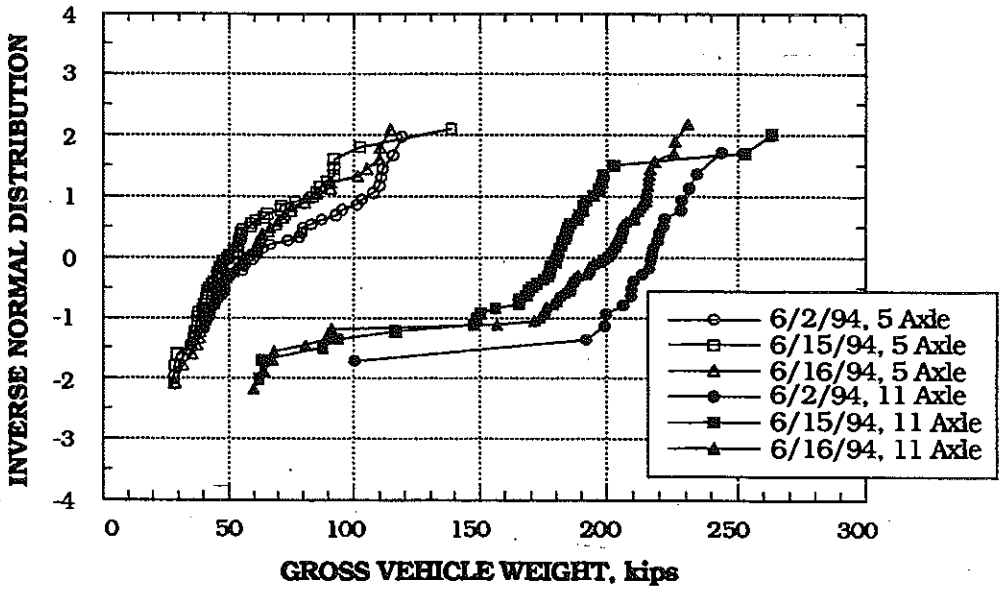


Fig. 5-20. I94/M10, Daily 5 and 11 Axle GVW Distributions.

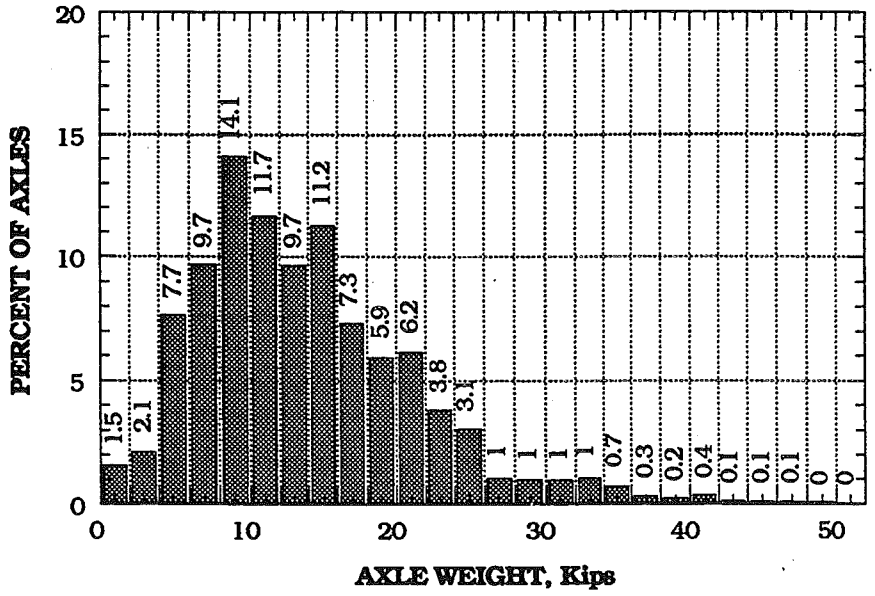


Fig. 5-21. I94/M10, Axle Weight Histogram.

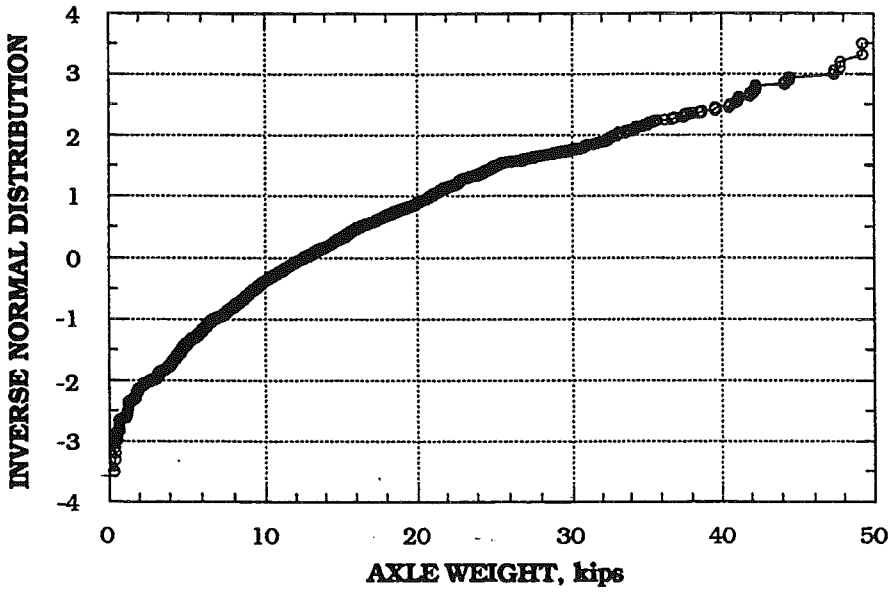


Fig. 5-22. I94/M10, Axle Weight Distribution.

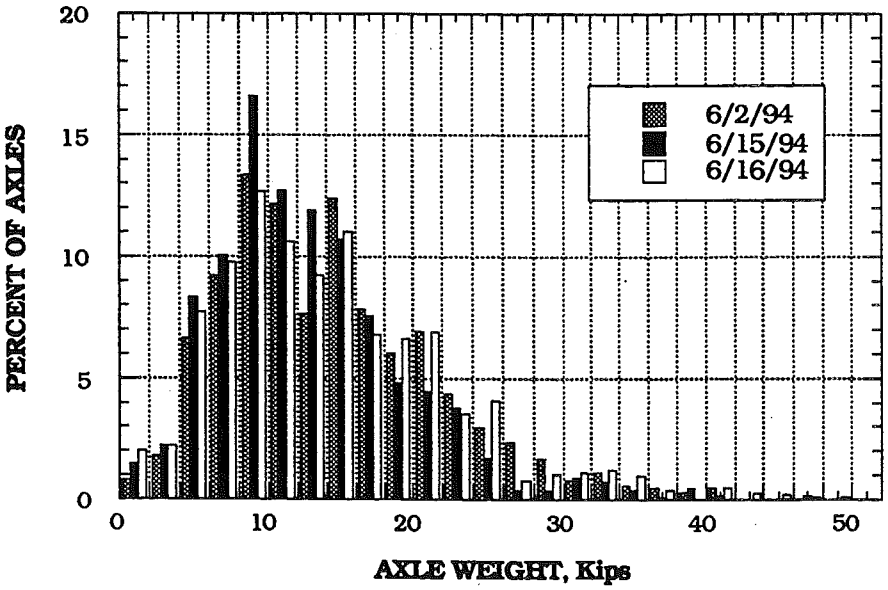


Fig. 5-23. I94/M10, Daily Axle Weight Histogram.

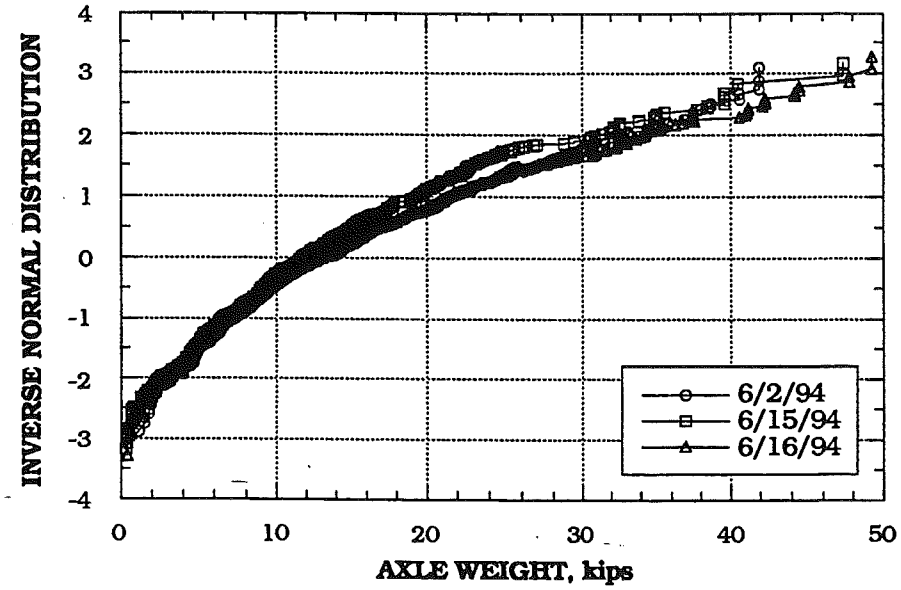


Fig. 5-24. I94/M10, Daily Axle Weight Distributions.

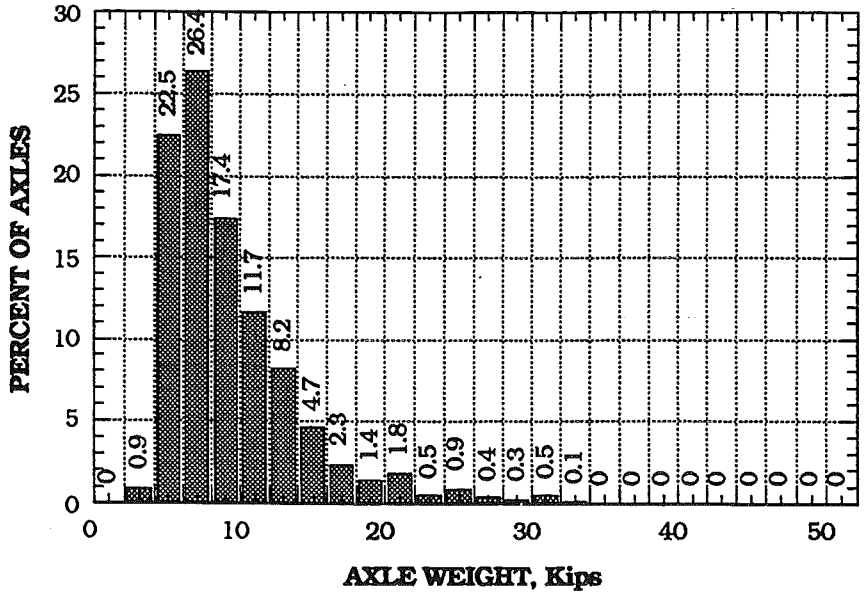


Fig. 5-25. I94/M10, Axle Weight Histogram of 2 Axle Vehicles.

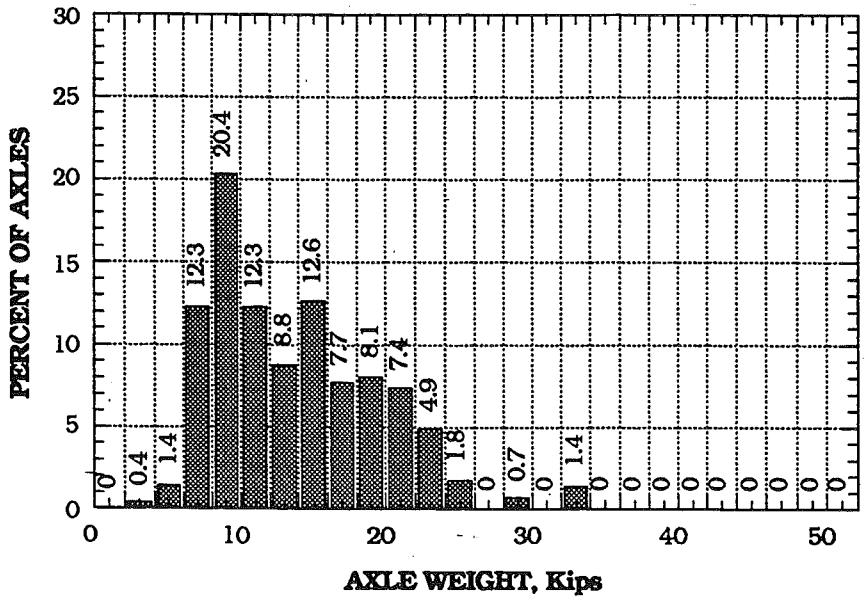


Fig. 5-26. I94/M10, Axle Weight Histogram of 3 Axle Vehicles.

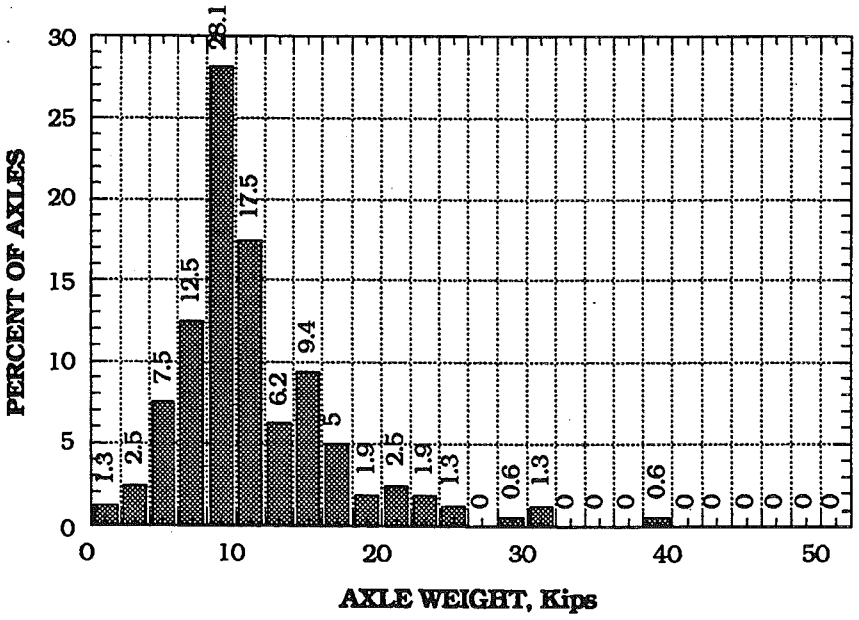


Fig. 5-27. I94/M10, Axle Weight Histogram of 4 Axle Vehicles.

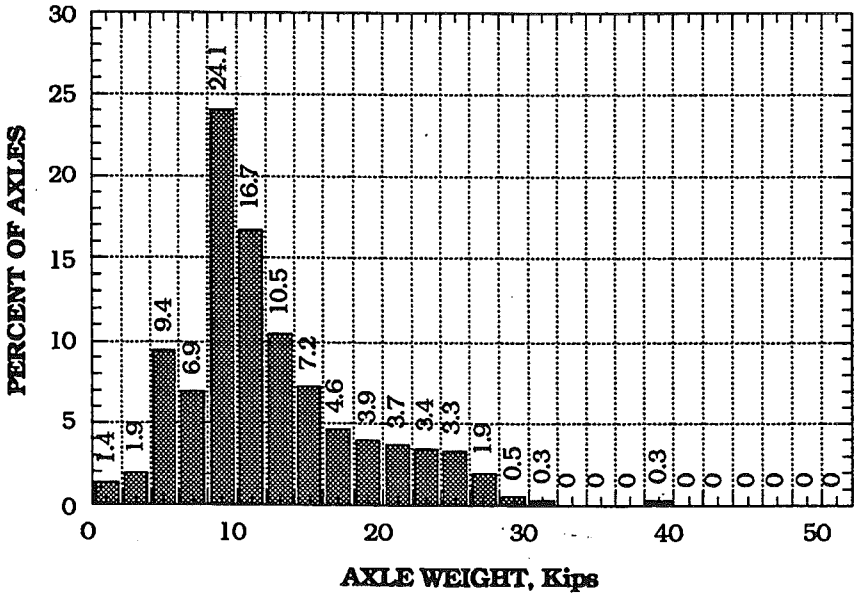


Fig. 5-28. I94/M10, Axle Weight Histogram of 5 Axle Vehicles.

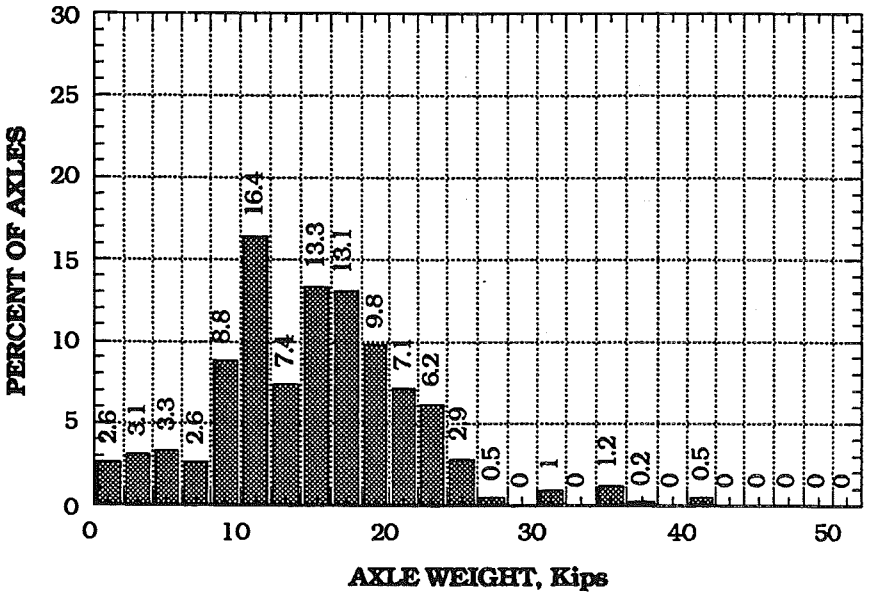


Fig. 5-29. I94/M10, Axle Weight Histogram of 6 Axle Vehicles.

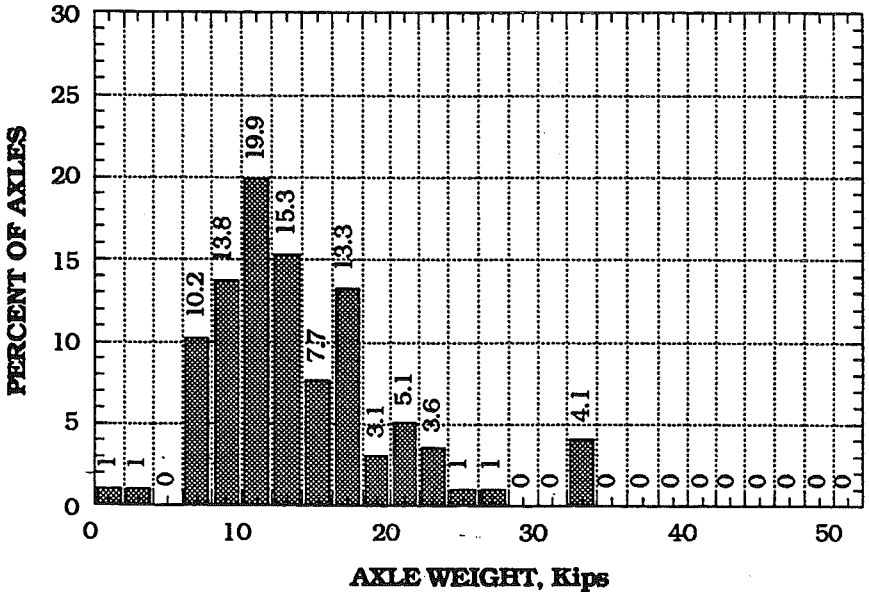


Fig. 5-30. I94/M10, Axle Weight Histogram of 7 Axle Vehicles.

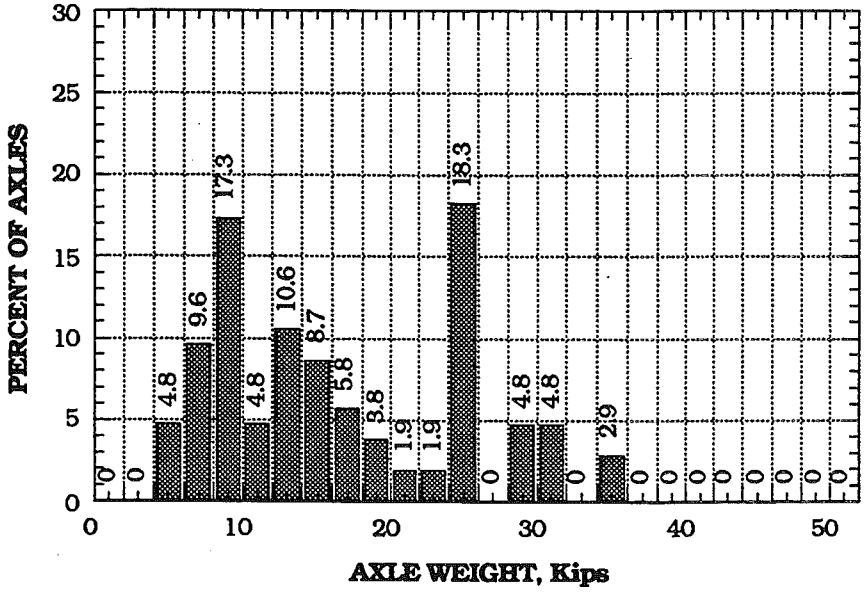


Fig. 5-31. I94/M10, Axle Weight Histogram of 8 Axle Vehicles.

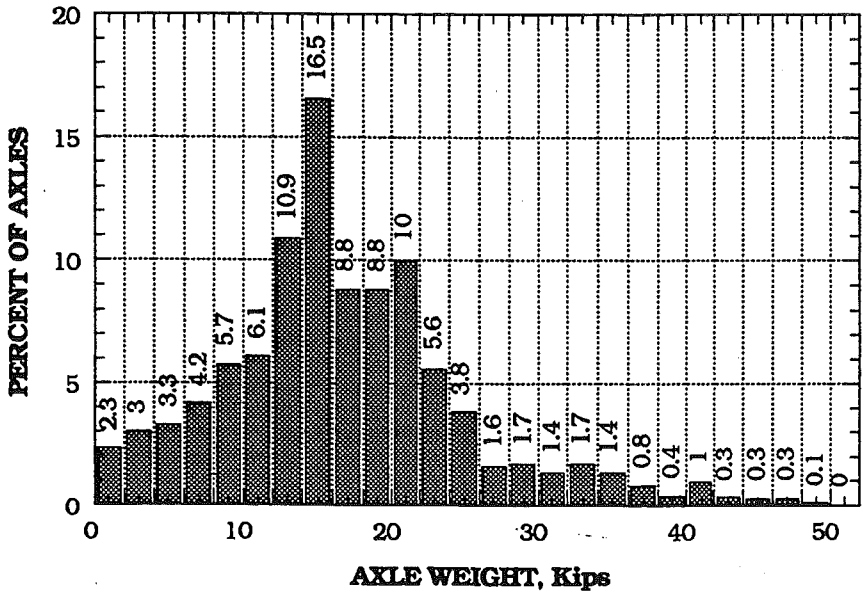


Fig. 5-32. I94/M10, Axle Weight Histogram of 11 Axle Vehicles.

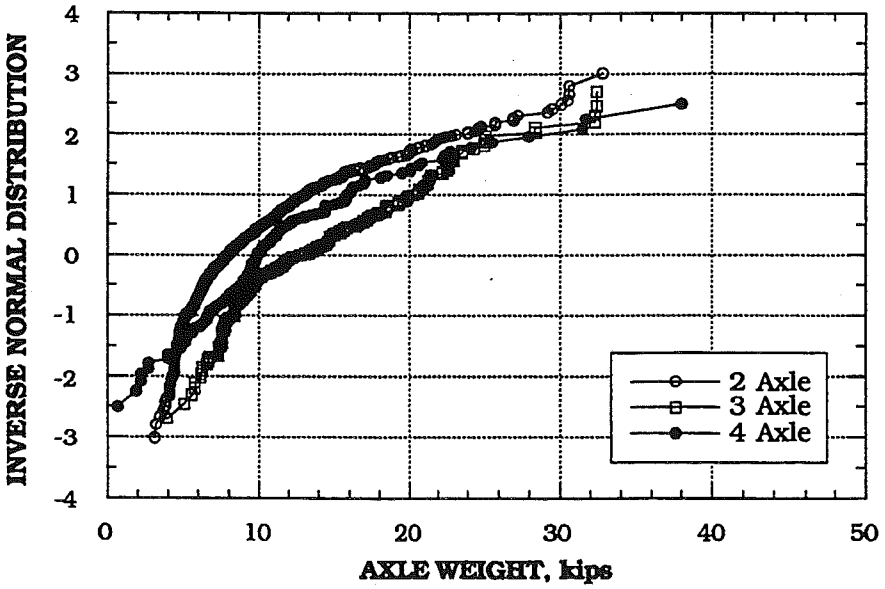


Fig. 5-33. I94/M10, Axle Weight Distributions of 2, 3, and 4 Axles.

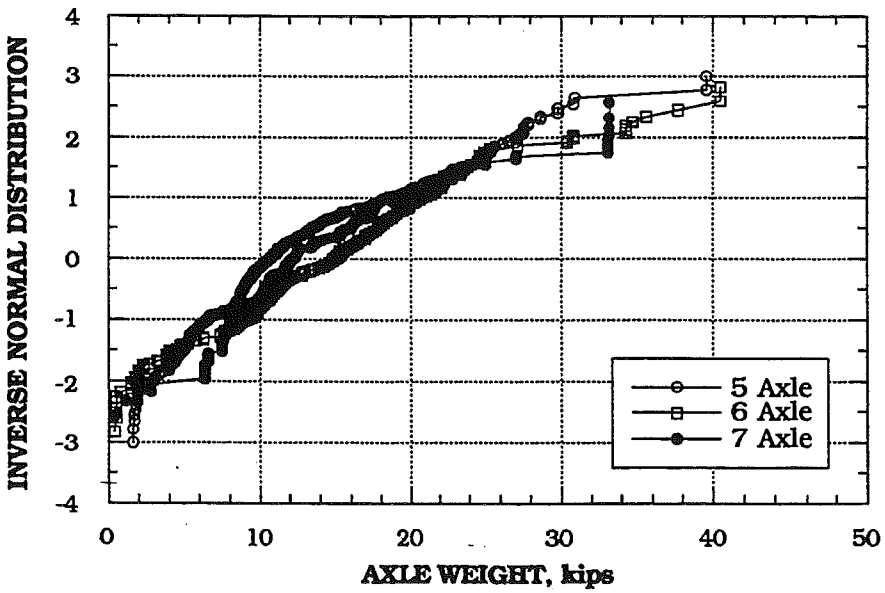


Fig. 5-34. I94/M10, Axle Weight Distributions of 5, 6, and 7 Axles.

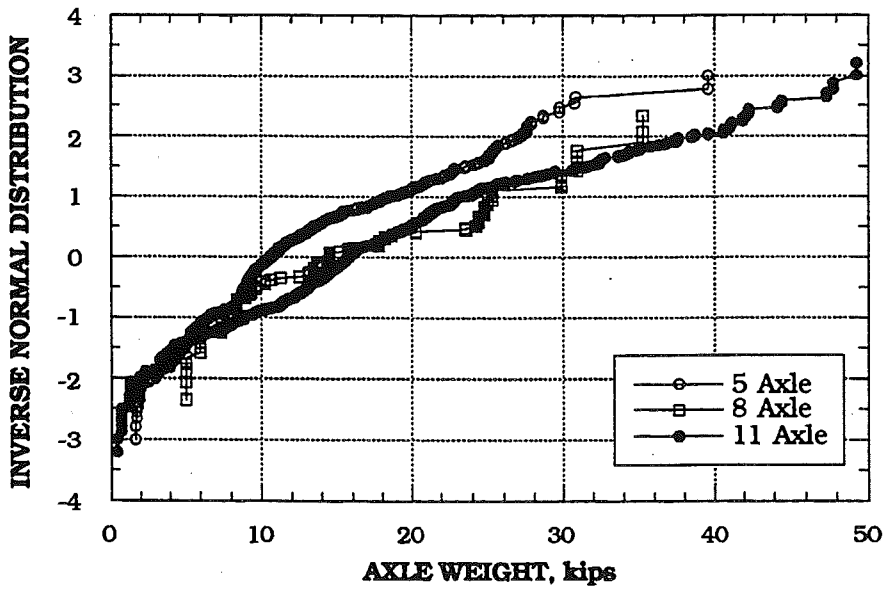


Fig. 5-35. I94/M10, Axle Weight Distributions of 5, 8, and 11 Axles.

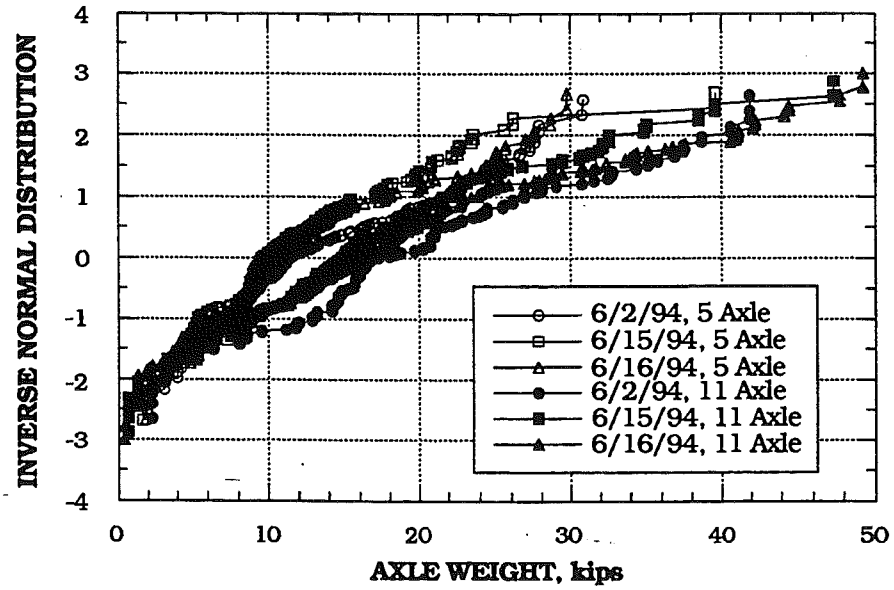


Fig. 5-36. I94/M10, Daily Axle Weight Distributions of 5 and 11 Axles.

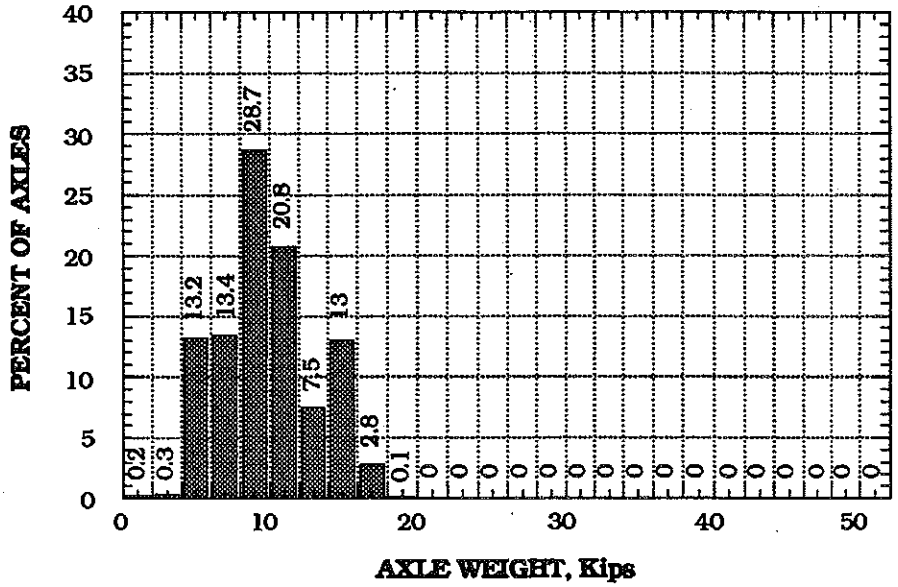


Fig. 5-37. I94/M10, Steering Axle Weight Histogram.

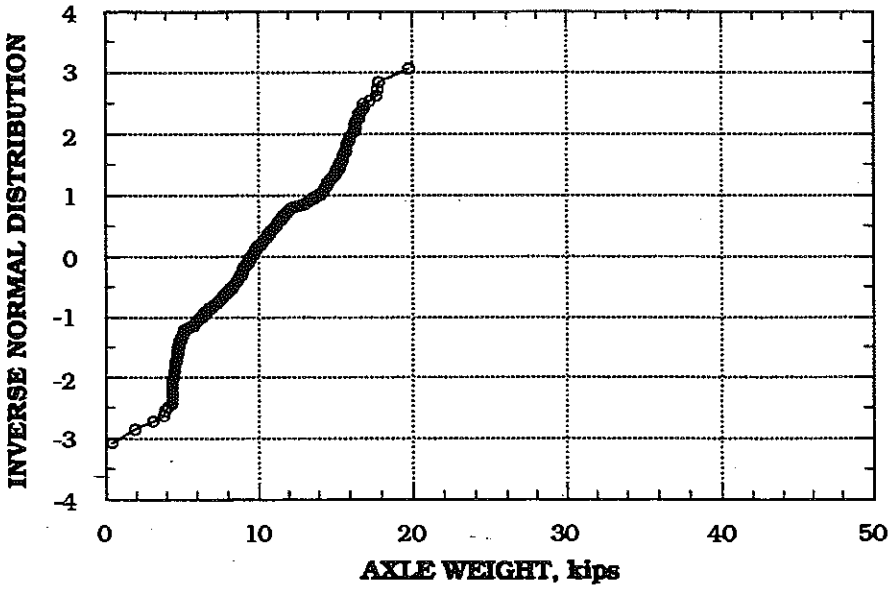


Fig. 5-38. I94/M10, Steering Axle Weight Distribution.

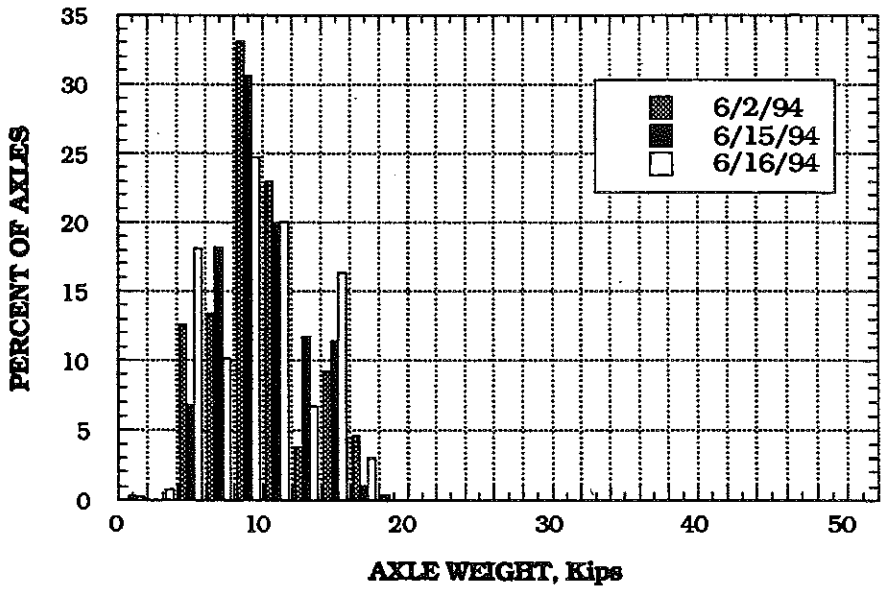


Fig. 5-39. I94/M10, Daily Steering Axle Weight Histogram.

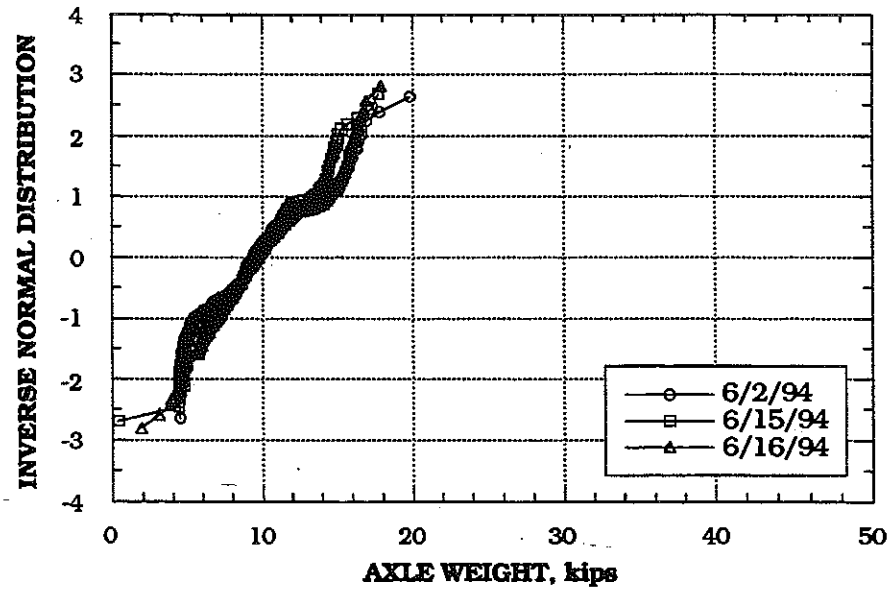


Fig. 5-40. I94/M10, Daily Steering Axle Weight Distributions.

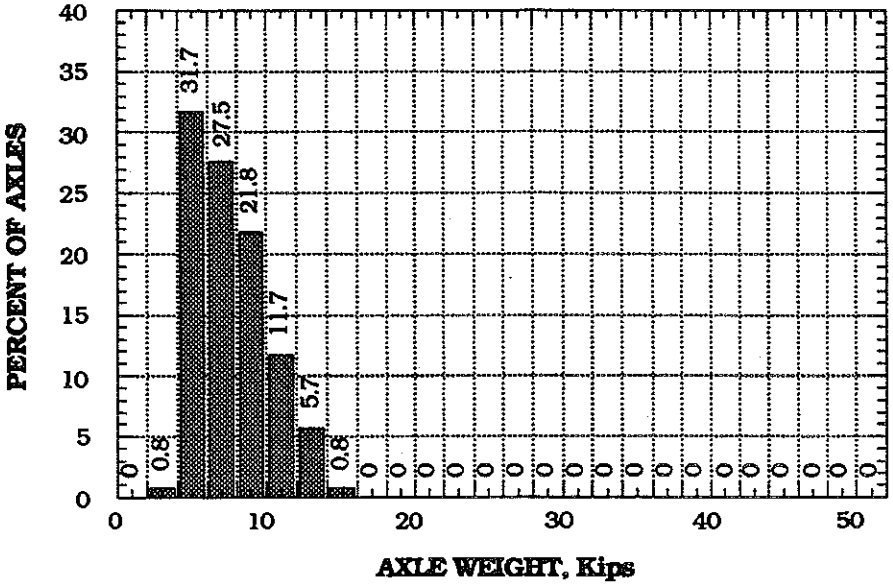


Fig. 5-41. I94/M10, Steering Axle Weight Histogram of 2 Axle Vehicles.

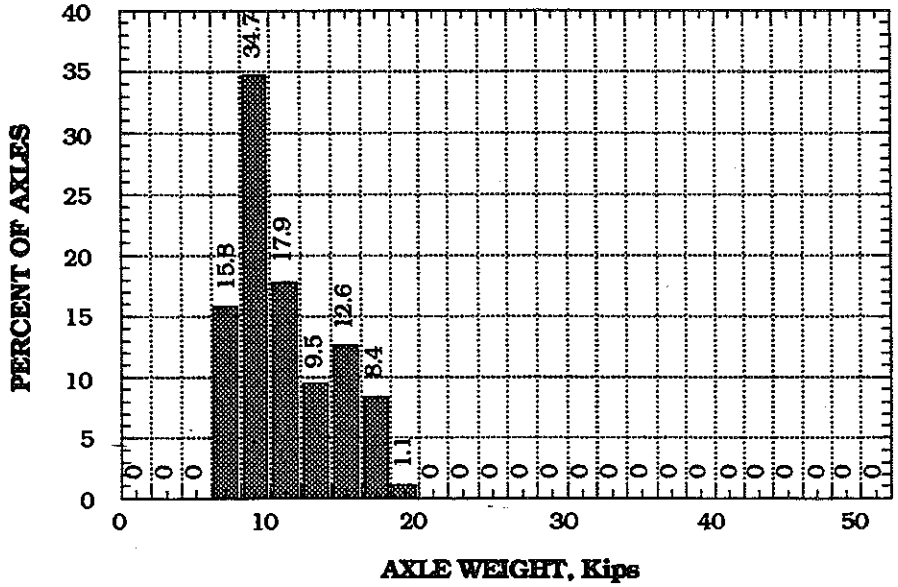


Fig. 5-42. I94/M10, Steering Axle Weight Histogram of 3 Axle Vehicles.

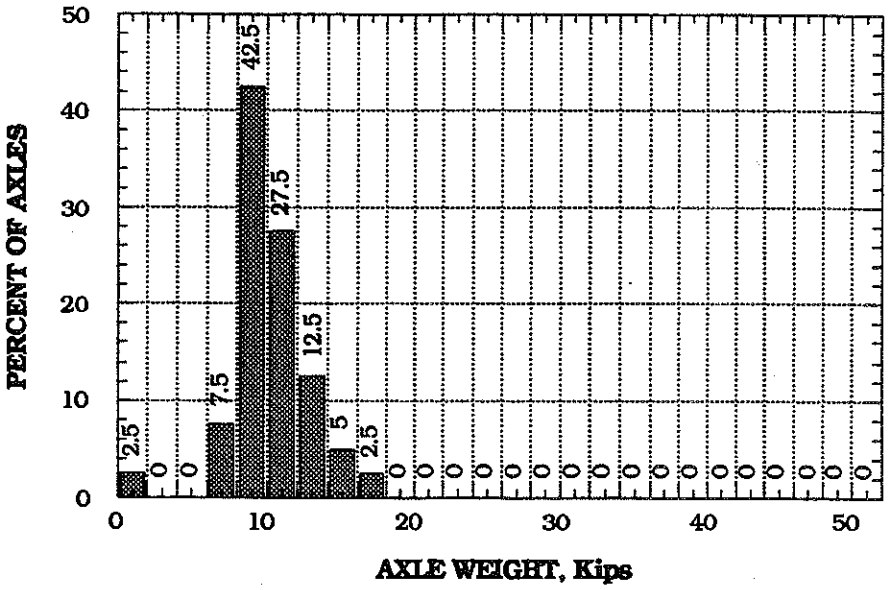


Fig. 5-43. I94/M10, Steering Axle Weight Histogram of 4 Axle Vehicles.

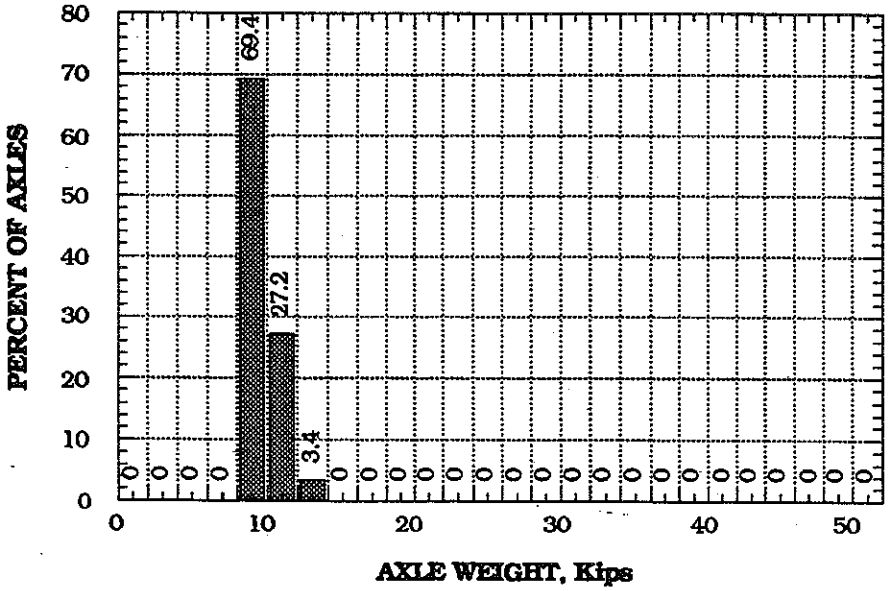


Fig. 5-44. I94/M10, Steering Axle Weight Histogram of 5 Axle Vehicles.

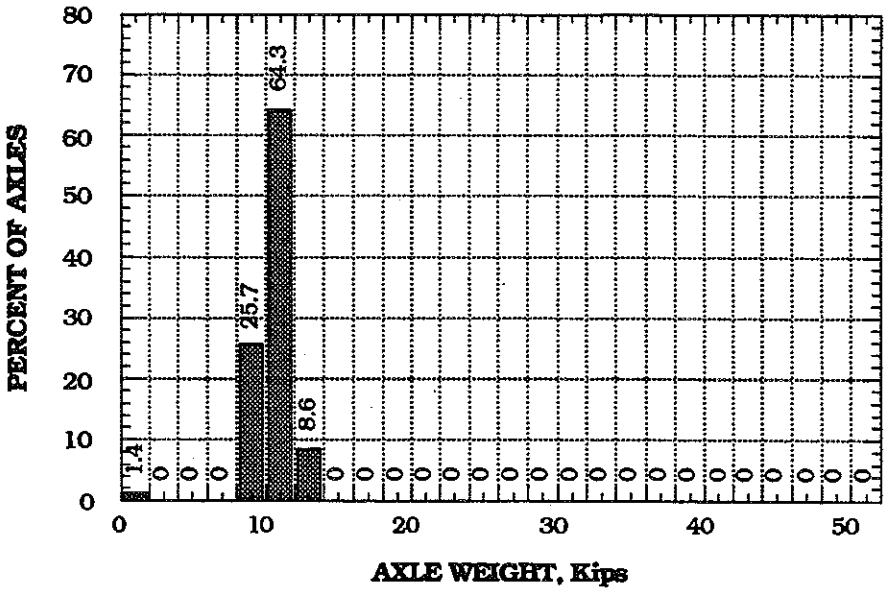


Fig. 5-45. I94/M10, Steering Axle Weight Histogram of 6 Axle Vehicles.

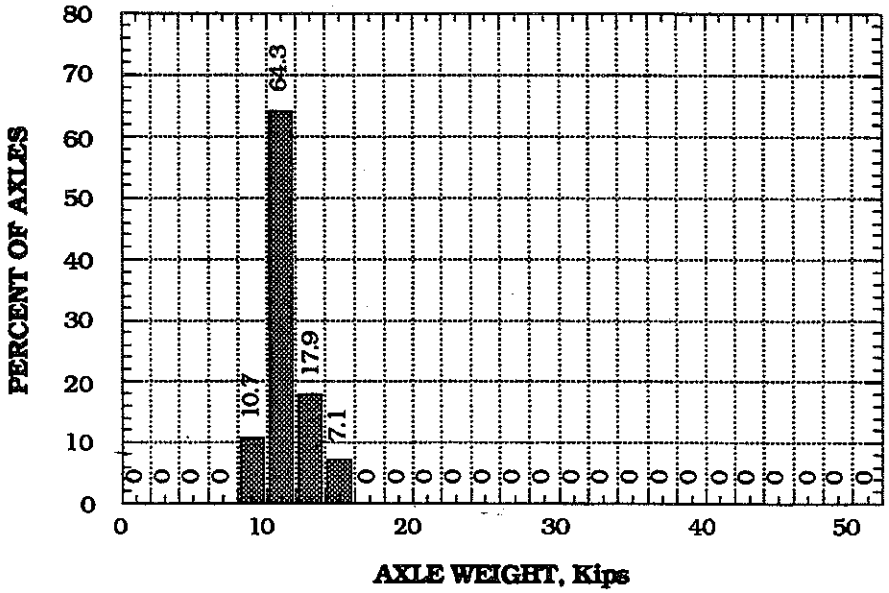


Fig. 5-46. I94/M10, Steering Axle Weight Histogram of 7 Axle Vehicles.

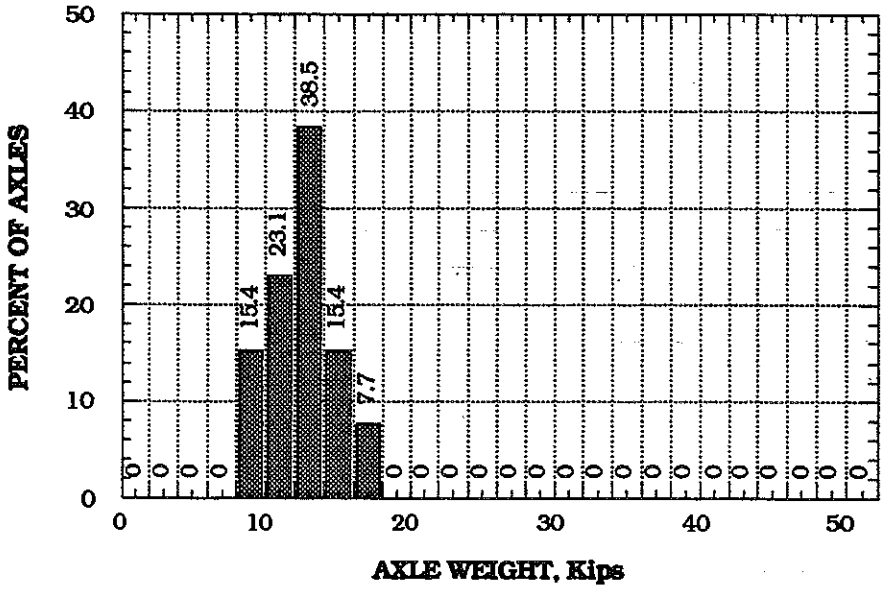


Fig. 5-47. I94/M10, Steering Axle Weight Histogram of 8 Axle Vehicles.

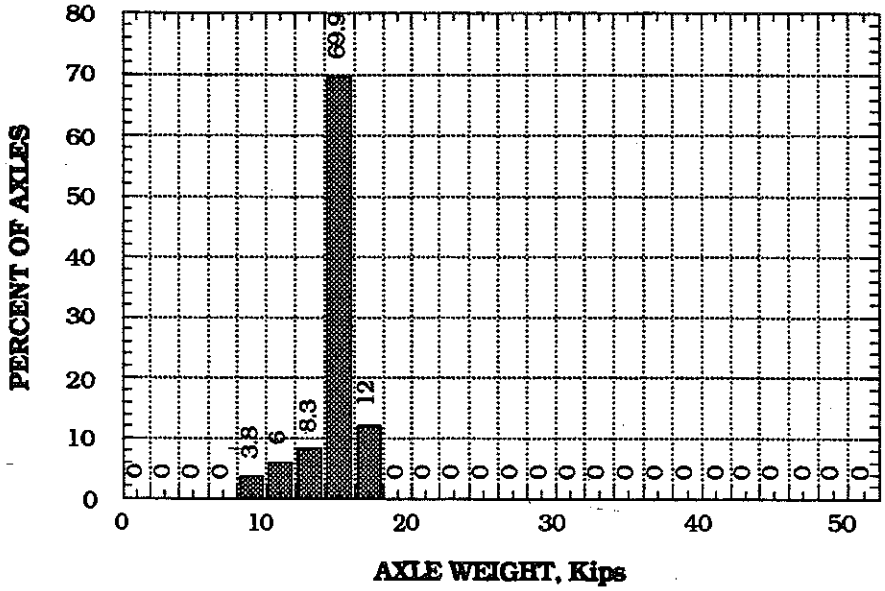


Fig. 5-48. I94/M10, Steering Axle Weight Histogram of 11 Axle Vehicles.

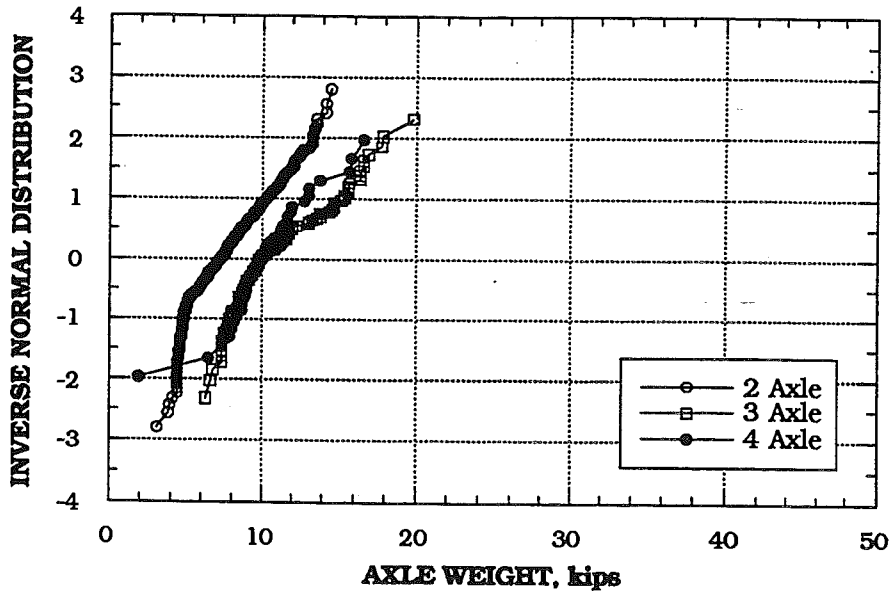


Fig. 5-49. I94/M10, Steering Axle Weight Distributions of 2, 3, and 4 Axle Vehicles.

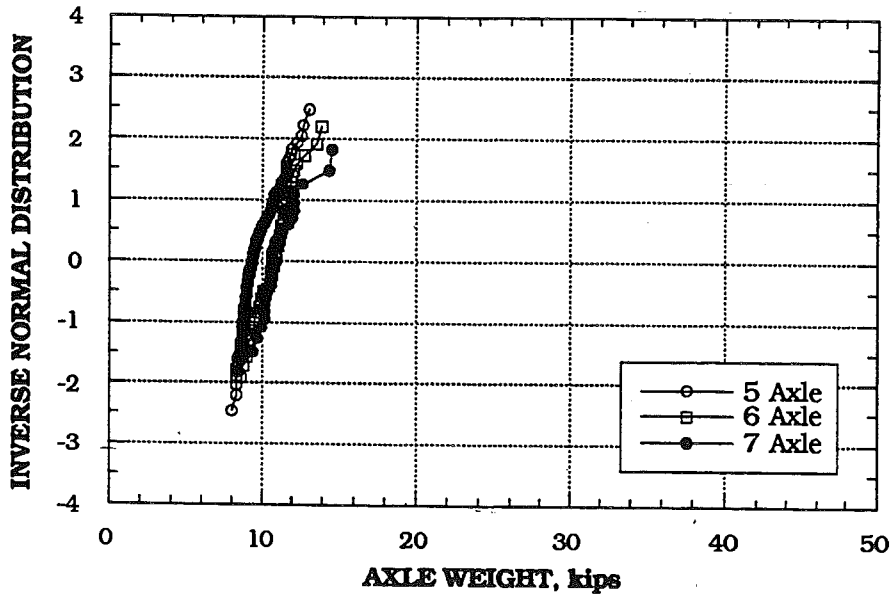


Fig. 5-50. I94/M10, Steering Axle Weight Distributions of 5, 6, and 7 Axle Vehicles.

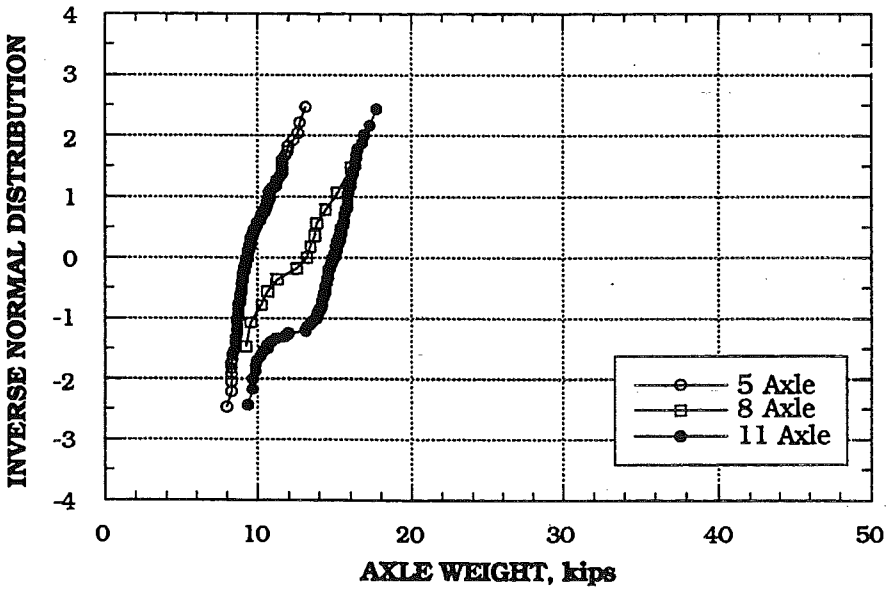


Fig. 5-51. I94/M10, Steering Axle Weight Distributions of 5, 8, and 11 Axle Vehicles.

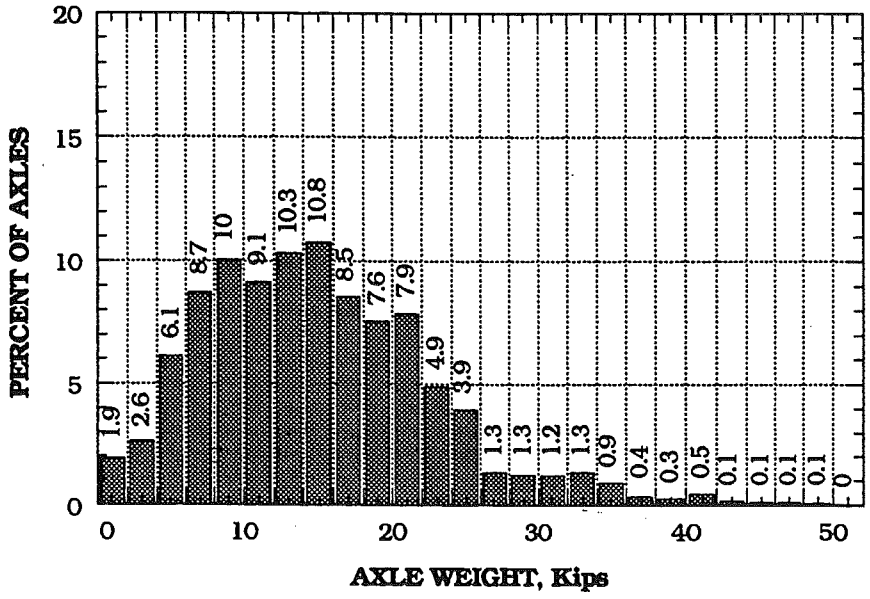


Fig. 5-52. I94/M10, Non-Steering Axle Weight Histogram.

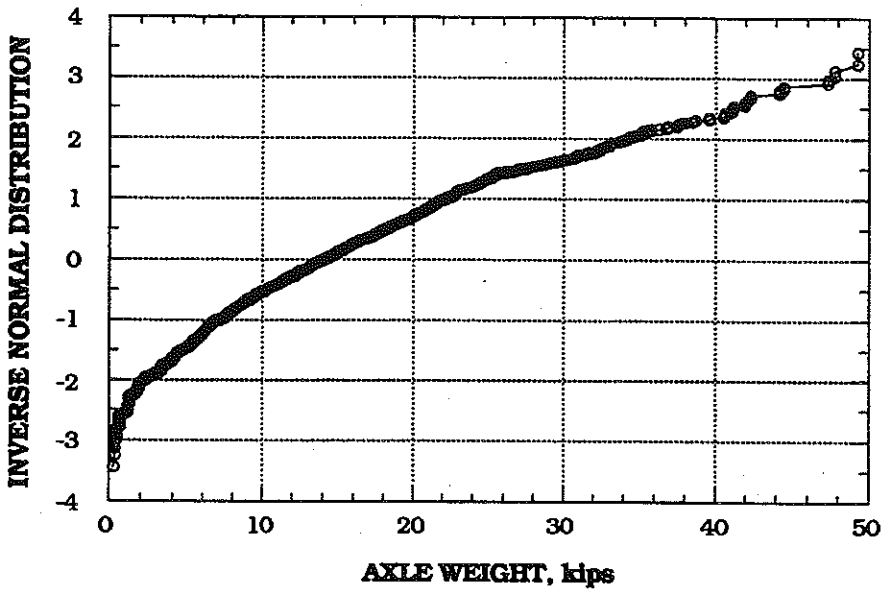


Fig. 5-53. I94/M10, Non-Steering Axle Weight Distributions.

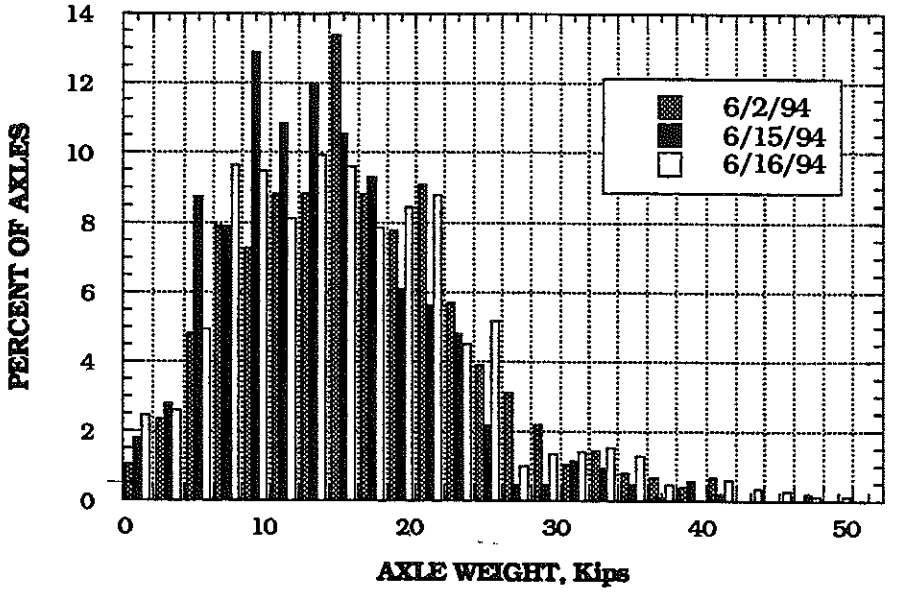


Fig. 5-54. I94/M10, Daily Non-Steering Axle Weight Histogram.

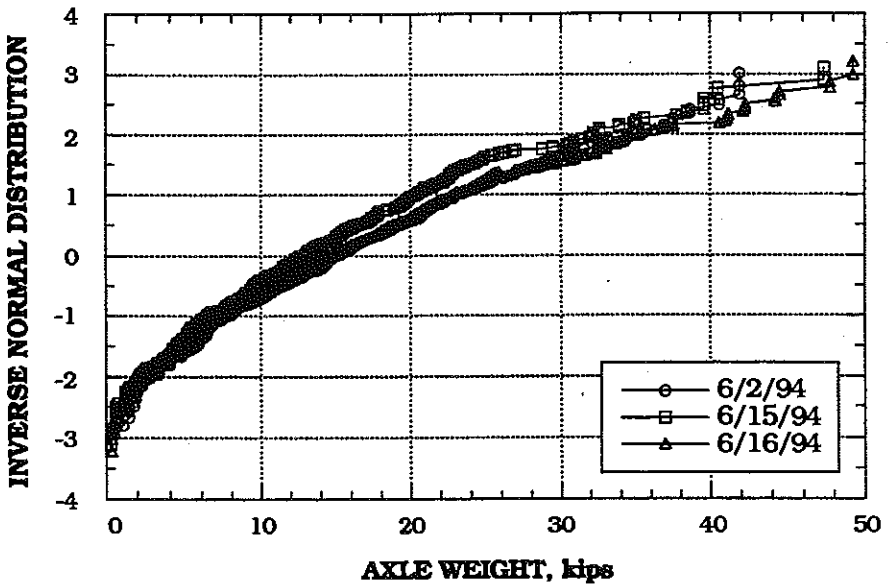


Fig. 5-55. I94/M10, Daily Non-Steering Axle Weight Distributions

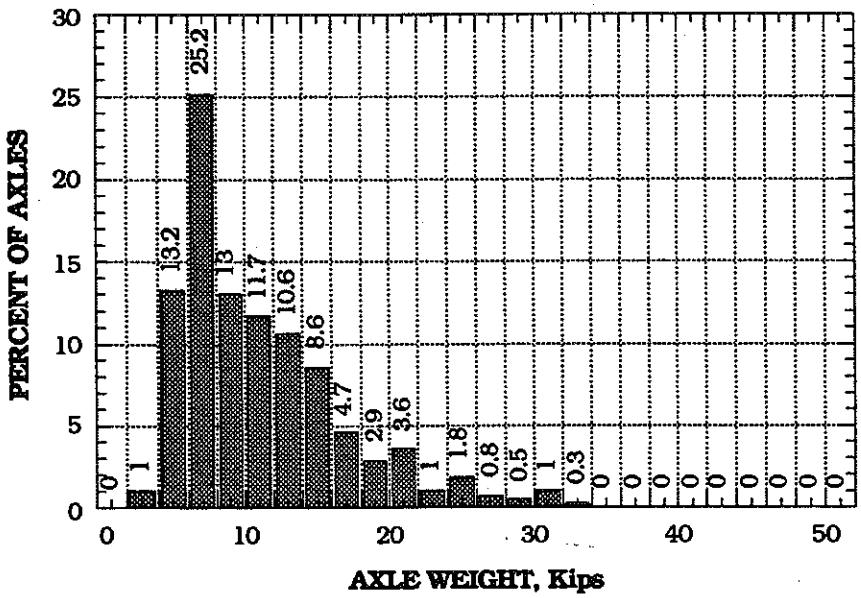


Fig. 5-56. I94/M10, Non-Steering Axle Weight Histogram of 2 Axles.

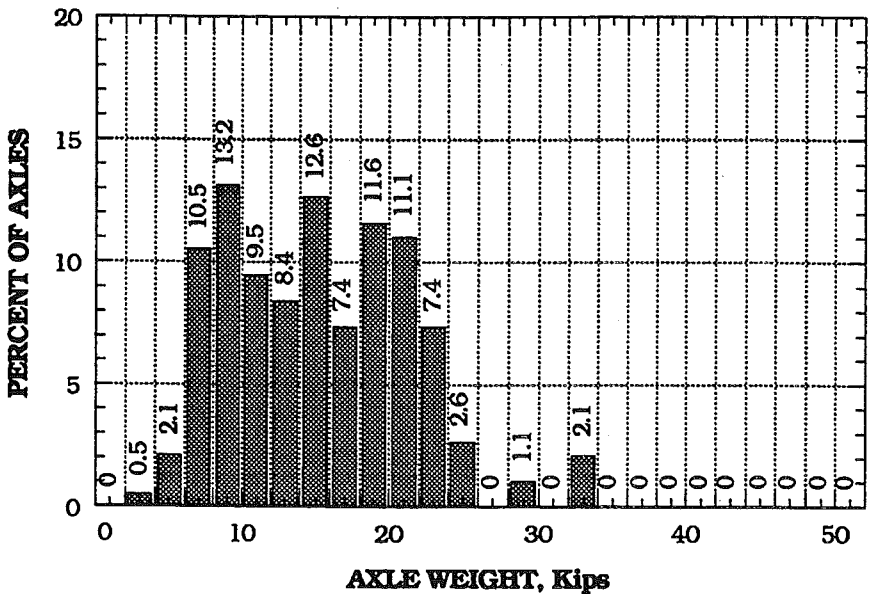


Fig. 5-57. I94/M10, Non-Steering Axle Weight Histogram of 3 Axles.

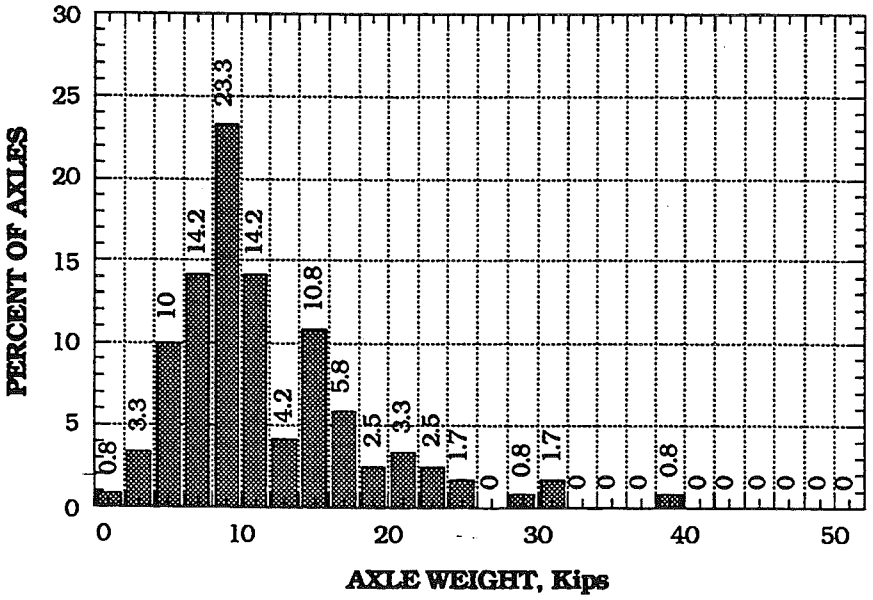


Fig. 5-58. I94/M10, Non-Steering Axle Weight Histogram of 4 Axles.

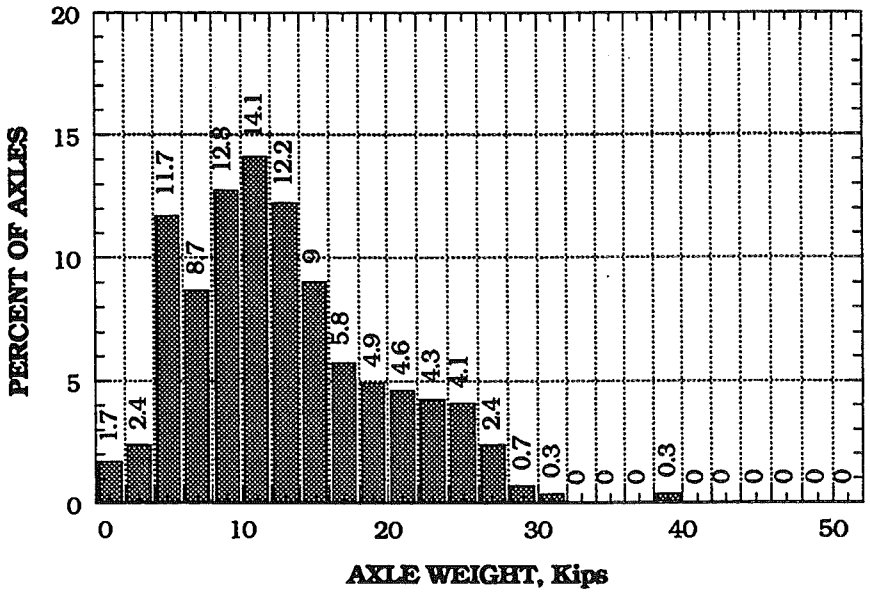


Fig. 5-59. I94/M10, Non-Steering Axle Weight Histogram of 5 Axles.

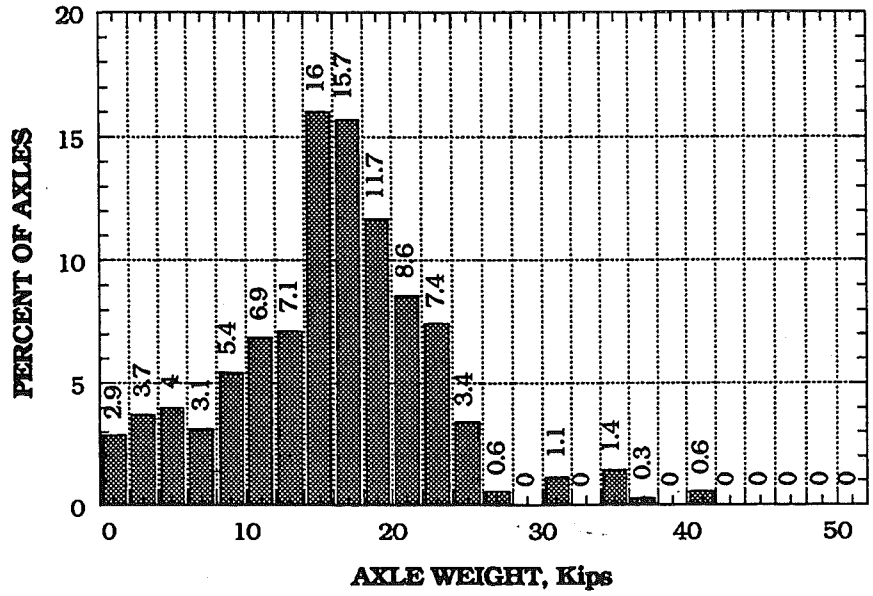


Fig. 5-60. I94/M10, Non-Steering Axle Weight Histogram of 6 Axles.

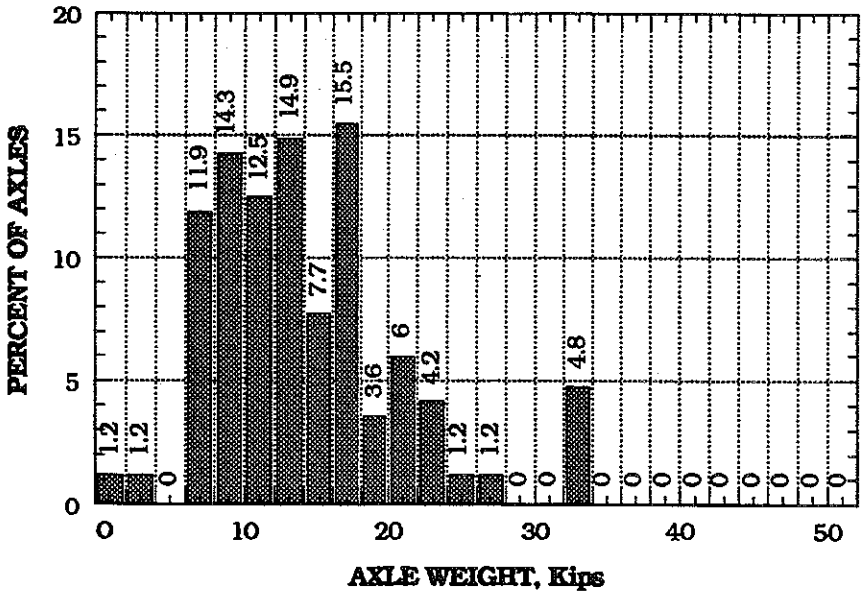


Fig. 5-61. I94/M10, Non-Steering Axle Weight Histogram of 7 Axles.

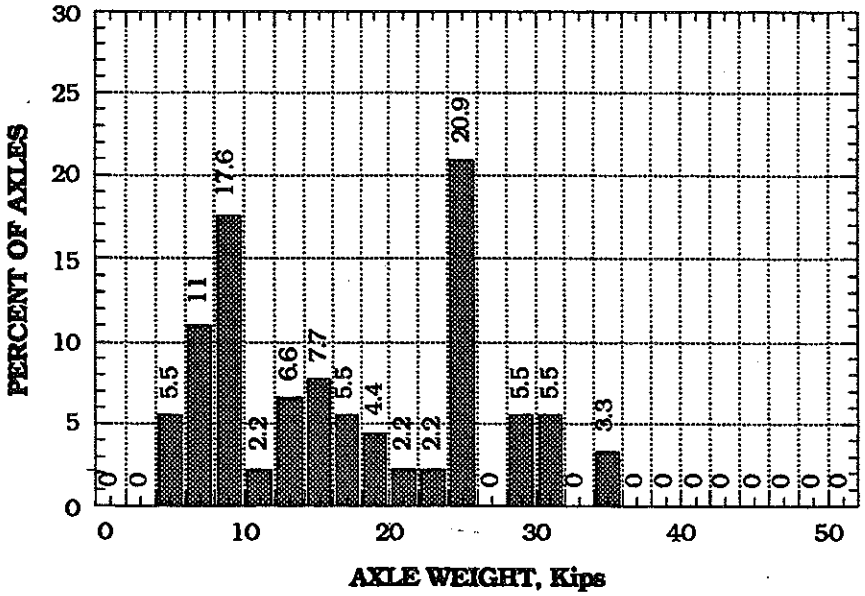


Fig. 5-62. I94/M10, Non-Steering Axle Weight Histogram of 8 Axles.

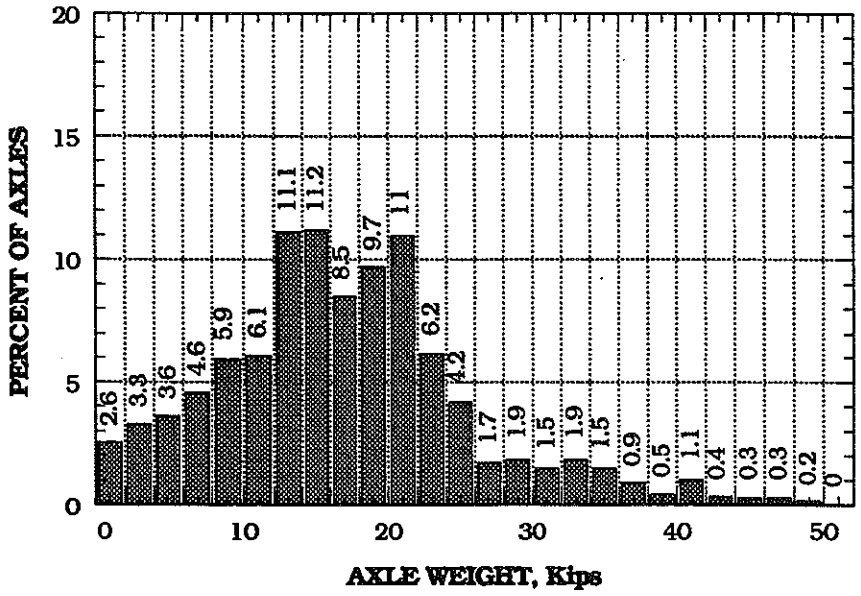


Fig. 5-63. I94/M10, Non-Steering Axle Weight Histogram of 11 Axles.

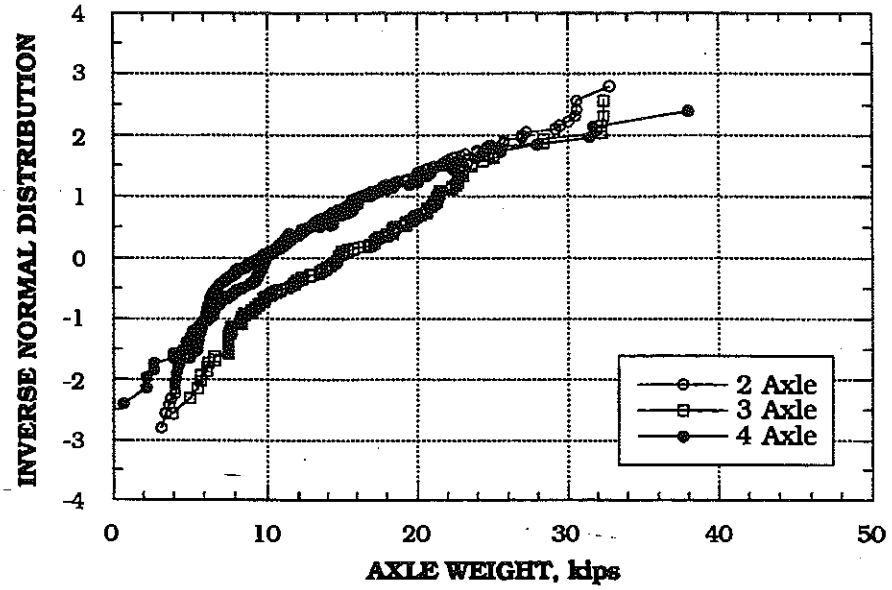


Fig. 5-64. I94/M10, Non-Steering Axle Weight Distributions of 2, 3, and 4 Axle Vehicles.

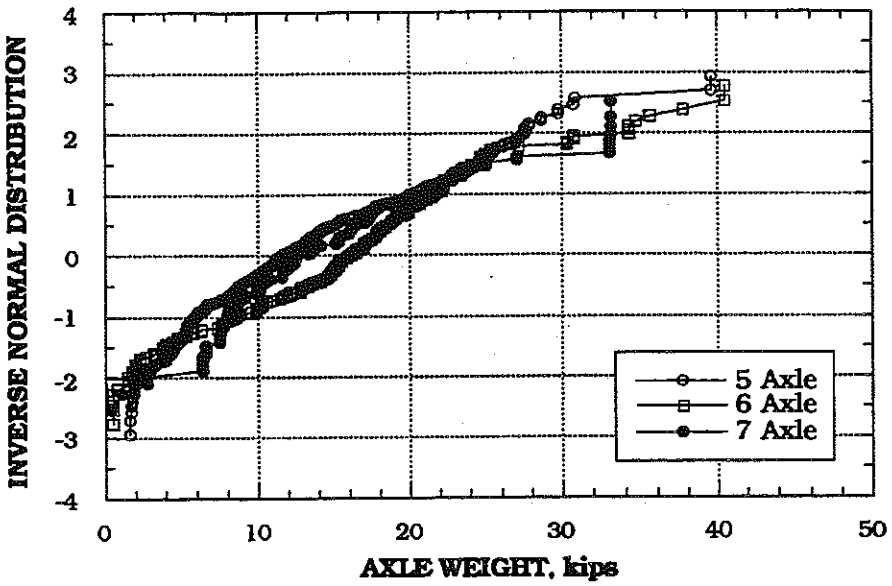


Fig. 5-65. I94/M10, Non-Steering Axle Weight Distributions of 5, 6, and 7 Axle Vehicles.

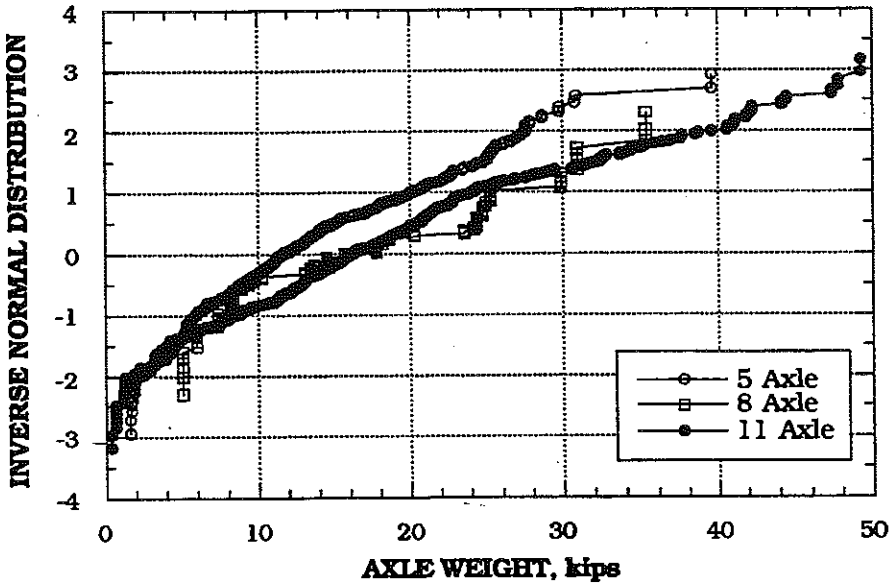
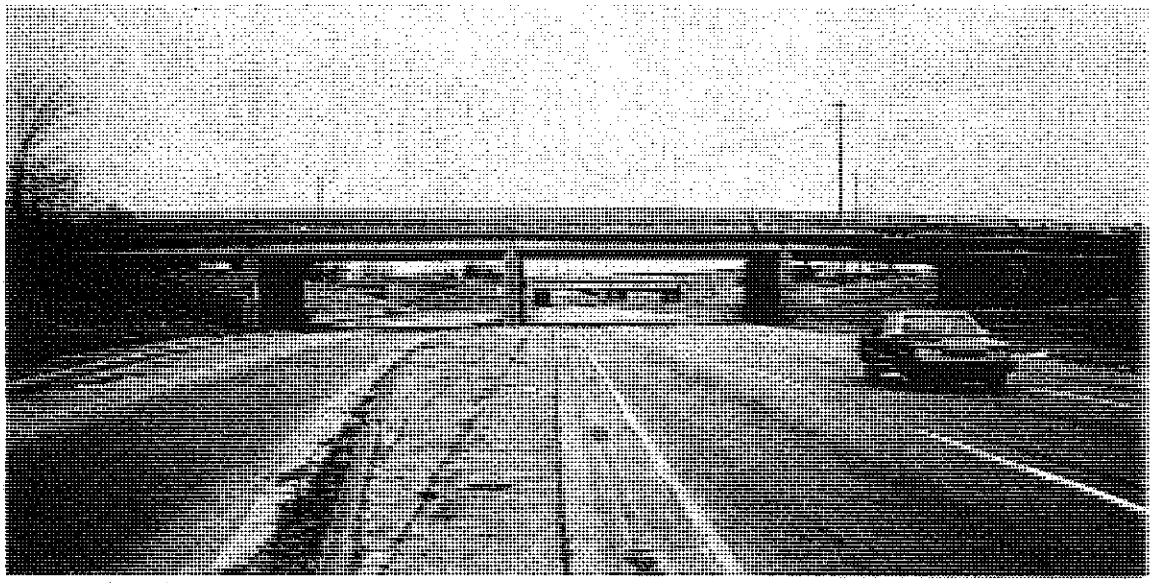


Fig. 5-66. I94/M10, Non-Steering Axle Weight Distributions of 5, 8, and 11 Axle Vehicles.

6. BRIDGE ON US - 12 EASTBOUND RAMP OVER I - 94 EASTBOUND IN DEARBORN (US12/I94)

6. 1 Description of the Bridge

Bridge US12/I94 is on the ramp which carries eastbound traffic from US-12 over I - 94 in Dearborn. The elevation, plan view, cross section and other details are shown in Fig. 6-1 and 6-2. Measurements were taken in the entrance span (in the direction of traffic). The investigated span is 39'-3" and the width of the bridge is 47'-8" with skewness of 80 degrees, 43 minutes. The cross section consists of nine girders spaced at 5'- 6".



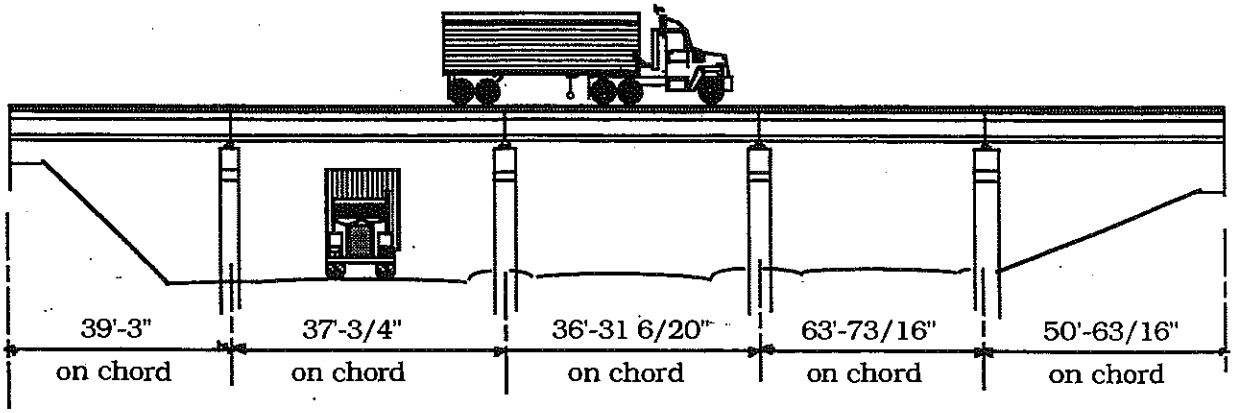


Fig. 6-1. Bridge US12/I94, US-12 Eastbound over I-94.
View and Side Elevation.

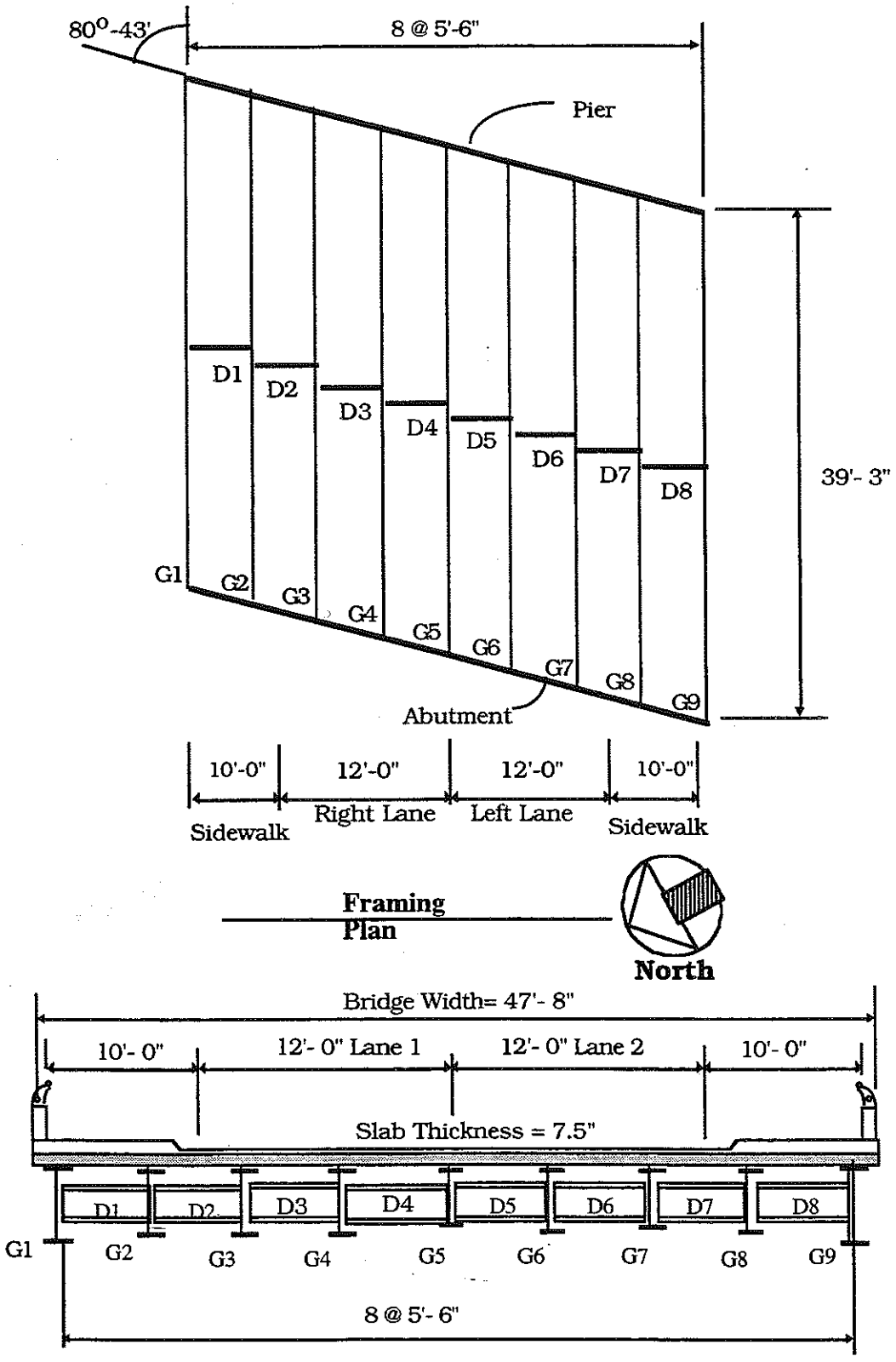


Fig. 6-2. Bridge US12/I94, US-12 Eastbound over I-94. Plan View and Cross section of Entrance Span.

6.2 Weigh-in-Motion Measurements

Weigh-in-motion (WIM) statistics are presented in Table 6-1 to Table 6-6 and in Fig. 6-3 to Fig. 6-42. This data includes all trucks with a gross vehicle weight (GVW) of 10 kips and greater for 2-axle vehicles, and of 15 kips and greater for three or more axle vehicles, regardless of axle weight. This filtered WIM data has been used for all analysis of GVW and axle weight. The data may also include permit loads. The data measured by WIM are recorded in the in the FHWA card seven 80-column format.

Table 6-1 summarizes an estimated average daily truck traffic (ADTT) in one direction, and the total number of vehicles weighed by date and by different number of axle vehicles. Fig. 6-3 is the frequency histogram of trucks corresponding to different number of axles. Only a few 11-axle trucks were observed. Fig. 6-4 shows the daily frequency histogram of trucks. Practically, there is no difference by the date of measurement. Table 6-2 presents Federal Highway Administration (FHWA) truck class frequency vs lane statistics. Federal Highway Administration (FHWA) axle configuration class is presented in the Appendix A. Note that the last digit from the FHWA axle class is not included in Table 6-2.

Table 6-3 is the GVW statistics of maximum, mean, median, standard deviation, and percentage of overloaded vehicles. The statistics are given for all vehicles and separately different number of axle vehicles. The GVW limit in Table 6-3 might not be the legal limit. It is difficult to determine the GVW limit with only number of axles. It depends not only on number of axles, but axle spacings. Thus, it was decided to assign reasonably high GVW limits and to give some ideas about how heavy the vehicles were. Fig. 6-5 and Fig. 6-6 are the histogram of GVW and the corresponding cumulative distribution function (CDF) of GVW for all trucks observed and measured on US12/I94 respectively. In Fig. 6-6, each circle represents one truck in the data file. From the graph and from Table 6-3 the heaviest

vehicle observed weighed 154 kips with a mean GVW of 34 kips. Vehicles over the GVW limit were 3 %. Results of the individual day measurements are shown in Fig. 6-7 and Fig. 6-8. The day to day CDF's are practically the same in shape and average GVW. GVW histograms for different number of axle vehicles are presented in Fig. 6-9 to Fig. 6-12. The corresponding CDF's are shown in Fig. 6-13. There were no overloaded 5 and 11 axle vehicles. For comparison of the daily distributions of 5-axle vehicles, the CDF's for both days are plotted in Fig. 6-15.

Table 6-4 is the axle weight statistics of maximum, mean, median, standard deviation, and percentage of overloaded axles. The statistics are given for all vehicles and separately different number of axle vehicles. In this table, axle weight limits were intended to give some ideas about how heavy the axles were. The statistics depend on axle spacings rather than number of axles. Fig. 6-15 and Fig. 6-16 are the histogram of axle weight for all vehicles and the corresponding CDF respectively. The maximum axle weight observed at US12/I94 was 41 kips with a mean of 9 kips. Axles with axle weight of 18 kips and greater were 4 percent. Fig. 6-17 and Fig. 6-18 show the daily axle weight histogram and CDF's. As in the case with GVW, there is little daily variation in the vehicle axle weights with some differences at the upper tail of the distribution. Axle weight histograms for different number of axle vehicles are presented in Fig. 6-19 to Fig. 6-22. The corresponding CDF's are shown in Fig. 6-23. Overloaded axles for 5 and 11-axle vehicles were 1 percent and 0 percent respectively. The daily CDF's of axle weight for 5 vehicles are plotted in Fig. 6-24 for comparison of the daily distribution.

Table 6-5 is the steering axle weight statistics of maximum, mean, median, and standard deviation of all vehicles and different number of axle vehicles. Fig. 6-25 and Fig. 6-26 are the steering axle weight histogram for all vehicles and the corresponding CDF respectively. The maximum observed steering axle weight was 16 kips with a mean of 8 kips. Fig. 6-27 and Fig. 6-28 show the daily steering axle weight histogram and CDF's. Steering axle weight

histograms for different number of axle vehicles are presented in Fig. 6-29 to Fig. 6-32. The corresponding CDF's are shown in Fig. 6-33.

Table 6-6 is the non-steering axle weight statistics of maximum, mean, median, and standard deviation of all vehicles and different number of axle vehicles. Fig. 6-34 and Fig. 6-35 are the non-steering axle weight histogram for all vehicles and the corresponding CDF. The maximum non-steering axle weight was 41 kips with a mean of 9 kips. Fig. 6-36 and Fig. 6-37 show the daily non-steering axle weight histogram and CDF's. Non-steering axle weight histograms for different number of axle vehicles are presented in Fig. 6-38 to Fig. 6-41. The corresponding CDF's are shown in Fig. 6-42.

The steering and non-steering axle weight CDF's of Fig. 6-26 and Fig. 6-35 indicate a significant difference in both variation and magnitudes. The standard deviation of steering axle weight was 2 kips with a maximum of 16 kips while the standard deviation of non-steering axle weight was 5 kips with a maximum of 41 kips.

Review of the results indicates that most of the truck weights are within legal limits. There were no overloaded 5 and 11 axle vehicles. Vehicles over the GVW limit were 3 %. Overloaded axles for 5 and 11 axle vehicles were 1 percent and 0 percent respectively. Axles with axle weight of 18 kips and greater were 4 percent.

Table 6-1. US12/I94,Number of Trucks Weighed and Estimated ADTT.

Number of Trucks Weighed Gross Vehicle Weight > 10 Kips for 2 Axle Vehicles, Gross Vehicle Weight > 15 Kips for 3 or more Axle Vehicles.				
Date	7/18/94	7/19/94	Total	Vehicles (%)
2 Axles	22	34	56	32.9
3 Axles	12	16	28	16.5
4 Axles	8	10	18	10.6
5 Axles	21	22	43	25.3
6 Axles	1	5	6	3.5
7 Axles	5	1	6	3.5
8 Axles	3	2	5	2.9
9 Axles	1	0	1	0.6
10 Axles	0	3	3	1.8
11 Axles	3	1	4	2.5
All Vehicles	76	94	170	100.0
Estimated ADTT = 500 Trucks (in one direction)				

Table 6-2. Bridge US12/I94, Truck Class vs Lane Statistics.

Truck Class (FHWA)	Right Lane (1) (%)	Left Lane (2) (%)	Total (%)
4	0.0	0.0	0.0
5	43.6	10.5	54.1
6	7.7	0.3	7.9
7	0.6	0.0	0.6
8	5.7	0.3	6.0
9	11.3	0.9	12.2
10	2.3	0.3	2.6
11	0.0	0.0	0.0
12	0.0	0.0	0.0
13	0.0	0.0	0.0
14	14.4	2.3	16.7
Total Lane %	85.6	14.4	100.0

Table 6-3. Bridge US12/I94, Gross Vehicle Weight Statistics.

Vehicle Type	Max. (Kips)	Mean (Kips)	Median (Kips)	Std.Dev. (Kips)	GVW Limit (Kips)	Percentage over the Limit
2 Axles	39	15	14	5	40	0
3 Axles	55	30	31	9	60	0
4 Axles	46	26	27	7	70	0
5 Axles	76	35	33	12	80	0
6 Axles	125	67	48	42	90	33
7 Axles	153	77	65	39	120	17
8 Axles	139	81	50	46	125	29
9 Axles	138	138	138	-----	135	-----
10 Axles	154	121	147	51	150	33
11 Axles	118	90	90	30	164	0
All Vehicles	154	34	27	29	varies	3

Table 6-4. Bridge US12/I94, Axle Weight Statistics.

Vehicle Type	Max. (Kips)	Mean (Kips)	Median (Kips)	Std.Dev. (Kips)	Axle Weight Limit (Kips)	Percentage over the Limit
2 Axles	27	8	7	3	18	1
3 Axles	20	10	10	3	18	3
4 Axles	14	7	7	3	18	0
5 Axles	19	7	6	4	18	1
6 Axles	26	11	9	7	18	18
7 Axles	41	11	10	7	18	10
8 Axles	23	10	8	6	18	10
9 Axles	19	15	16	3	18	33
10 Axles	19	12	13	5	18	7
11 Axles	15	8	9	4	18	0
All Vehicles	41	9	8	5	18	4

Table 6-5. Bridge US12/I94, Steering Axle Weight Statistics.

Vehicle Type	Max. (Kips)	Mean (Kips)	Median (Kips)	Std.Dev. (Kips)	Vehicles (%)
2 Axles	13	6	6	2	32.9
3 Axles	15	9	9	2	16.5
4 Axles	12	8	8	1	10.6
5 Axles	11	9	9	1	25.3
6 Axles	13	10	10	2	3.5
7 Axles	16	11	10	3	3.5
8 Axles	13	11	11	2	2.9
9 Axles	13	13	13	----	0.6
10 Axles	13	12	13	2	1.8
11 Axles	14	11	11	2	2.5
All Vehicles	16	8	9	2	100.0

Table 6-6. Bridge US12/I94, Non-Steering Axle Weight Statistics.

Vehicle Type	Max. (Kips)	Mean (Kips)	Median (Kips)	Std.Dev. (Kips)	Vehicles (%)
2 Axles	27	9	9	3	32.9
3 Axles	20	10	11	4	16.5
4 Axles	14	6	5	4	10.6
5 Axles	19	7	6	4	25.3
6 Axles	26	11	8	8	3.5
7 Axles	41	11	10	8	3.5
8 Axles	23	10	7	6	2.9
9 Axles	19	16	16	3	0.6
10 Axles	19	12	12	5	1.8
11 Axles	15	8	9	4	2.5
All Vehicles	41	9	7	5	100.0

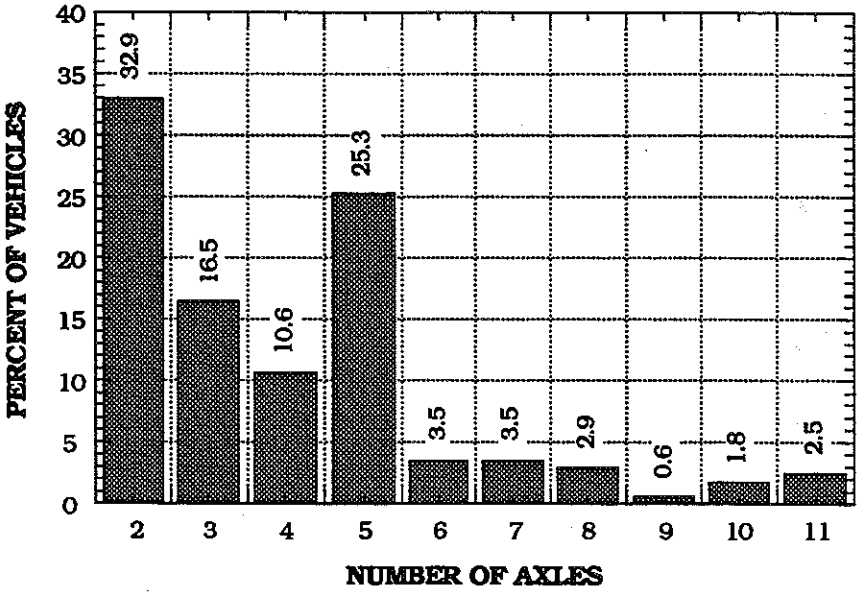


Fig. 6-3. US12/I94, Truck Type Histogram.

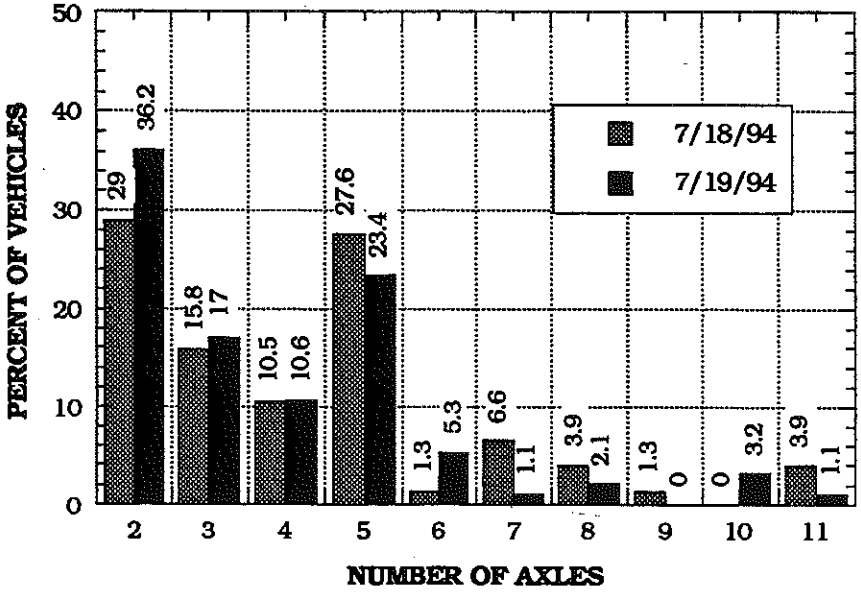


Fig. 6-4. US12/I94, Daily Truck Type Histogram.

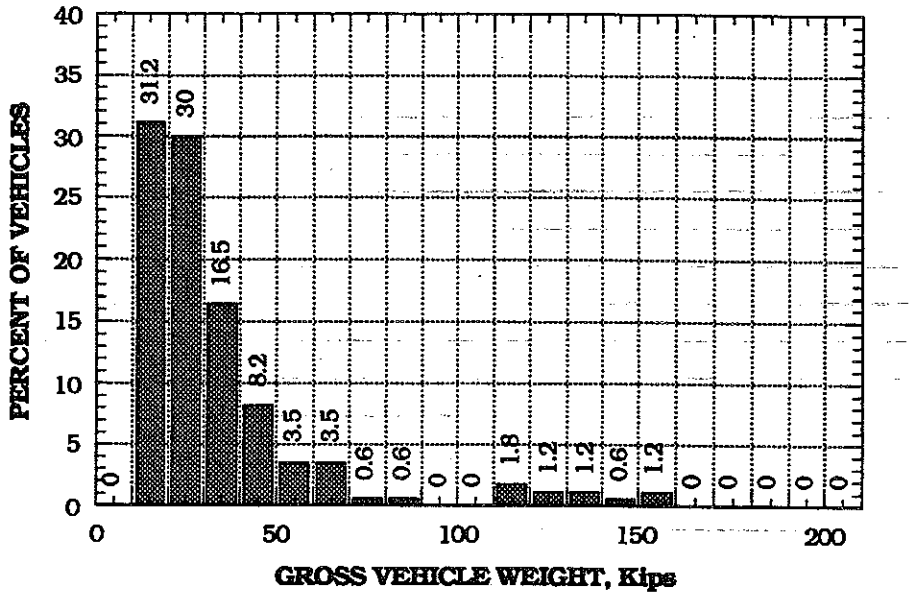


Fig. 6-5. US12/I94, GVW Histogram.

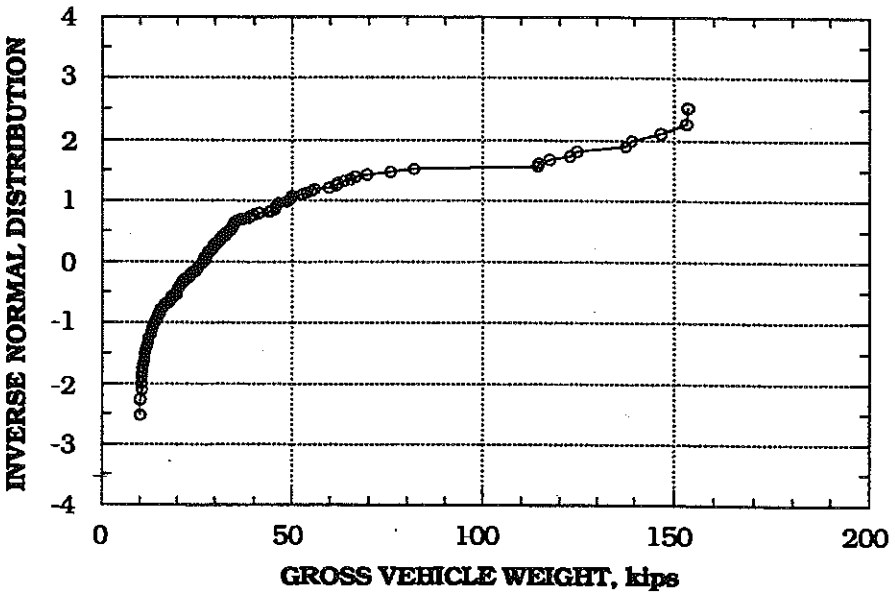


Fig. 6-6. US12/I94, GVW Distribution.

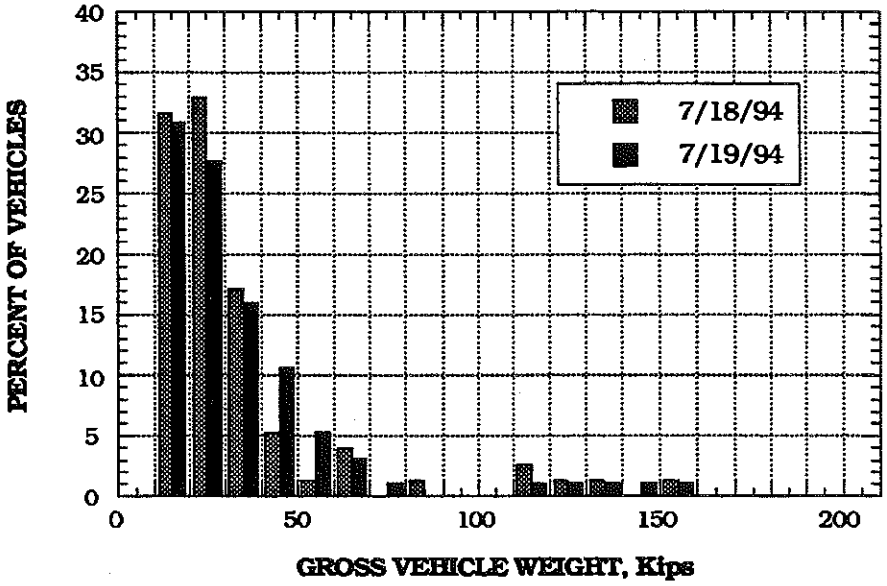


Fig. 6-7. US12/I94, Daily GVW Histogram.

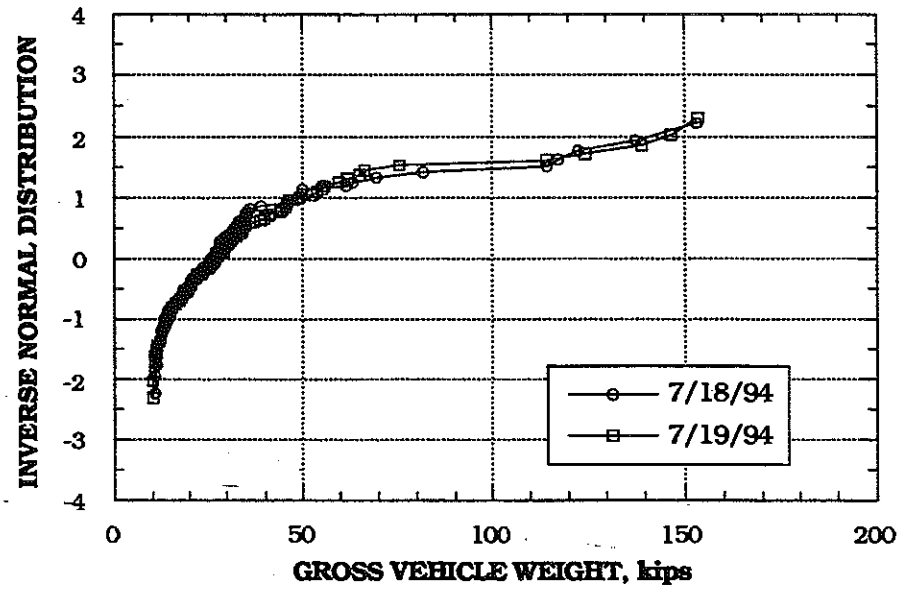


Fig. 6-8. US12/I94, Daily GVW Distributions.

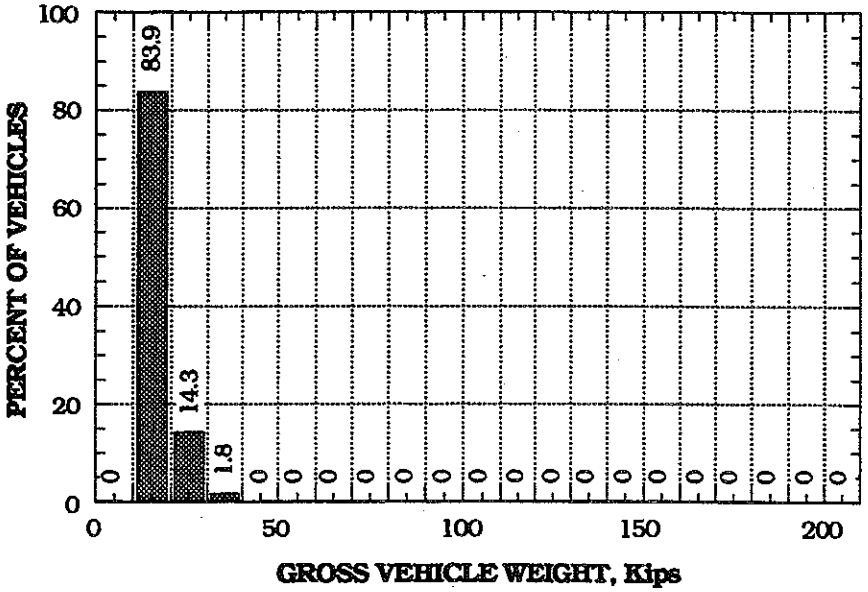


Fig. 6-9. US12/I94, 2 Axle GVW Histogram.

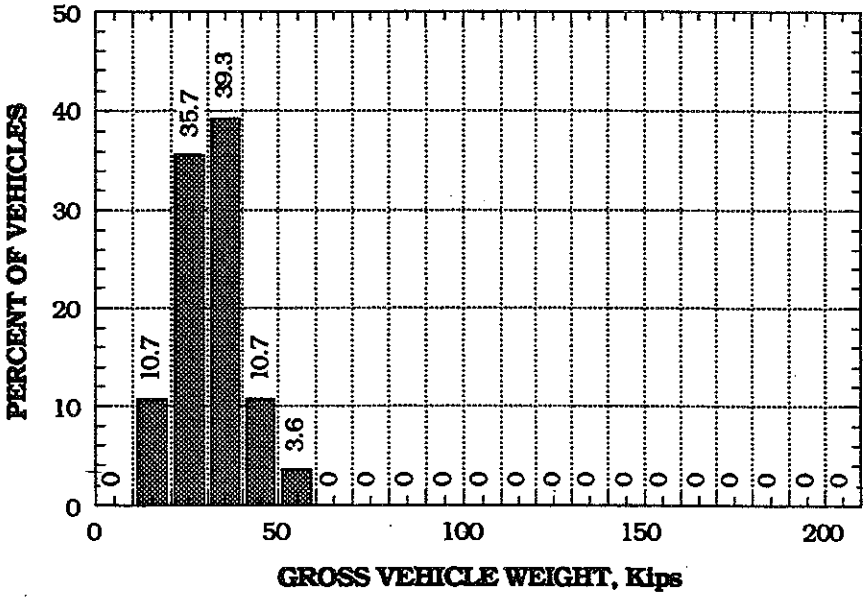


Fig. 6-10. US12/I94, 3 Axle GVW Histogram.

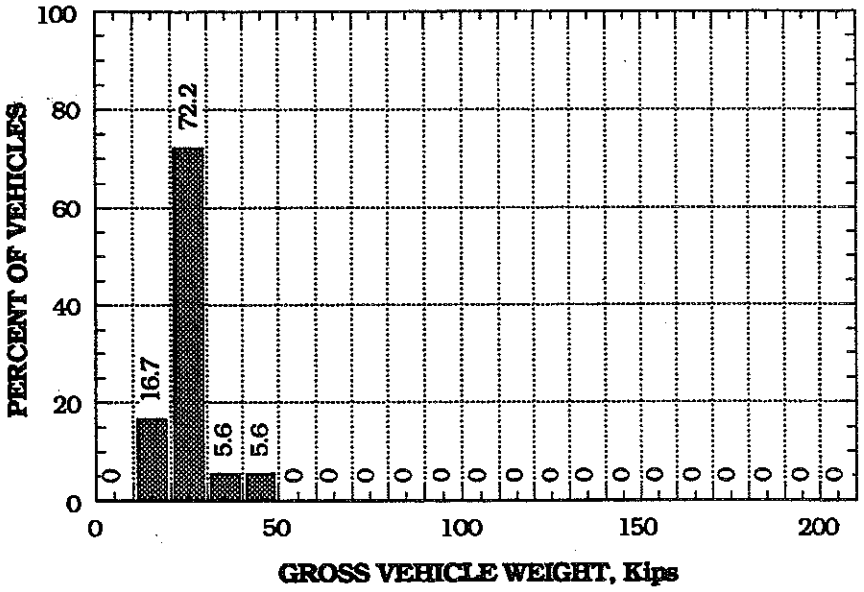


Fig. 6-11. US12/I94, 4 Axle GVW Histogram.

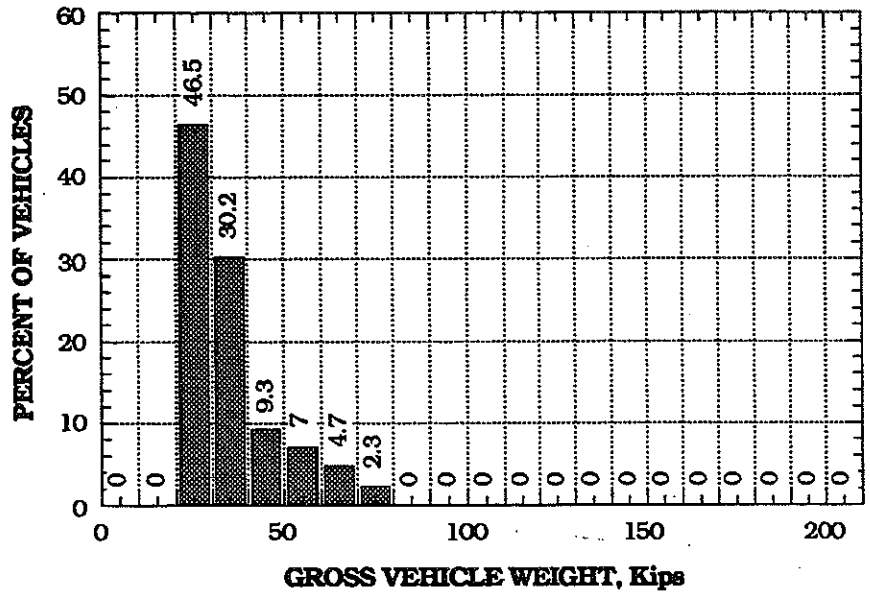


Fig. 6-12. US12/I94, 5 Axle GVW Histogram.

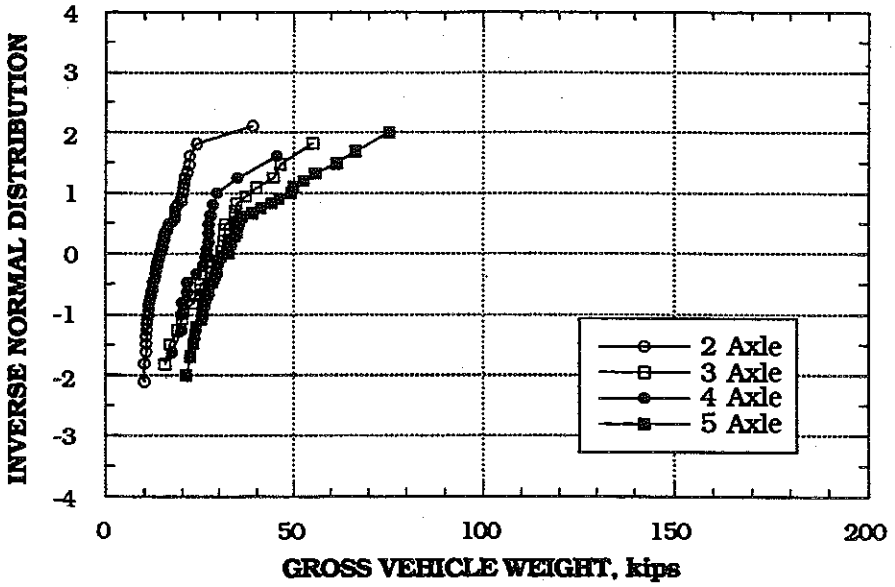


Fig. 6-13. US12/I94, 2, 3, 4 and 5 Axle GVW Distributions.

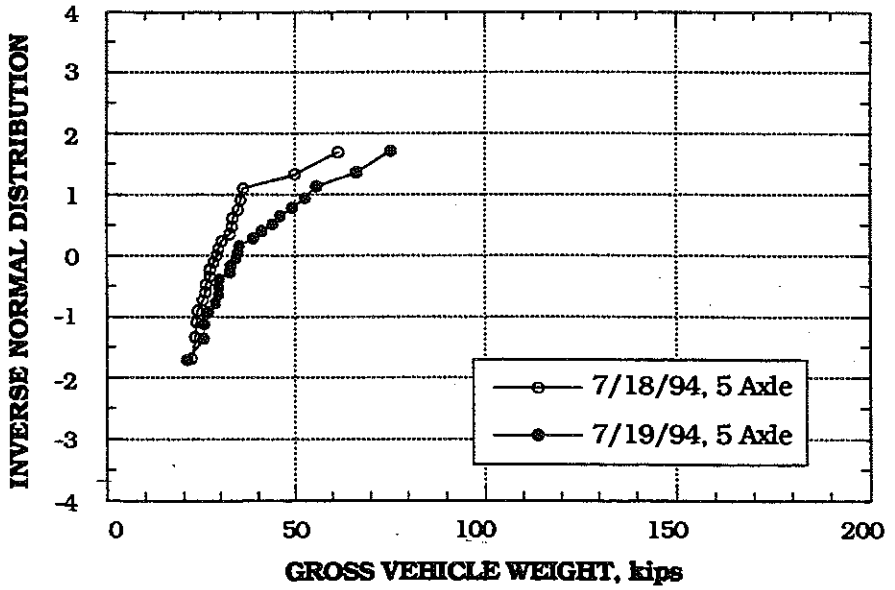


Fig. 6-14. US12/I94, Daily 5 Axle GVW Distributions.

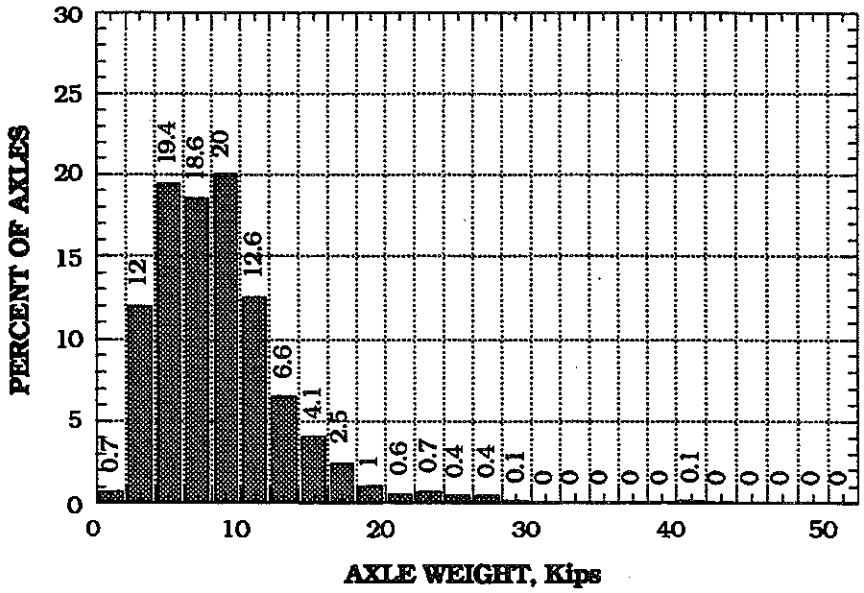


Fig. 6-15. US12/I94, Axle Weight Histogram.

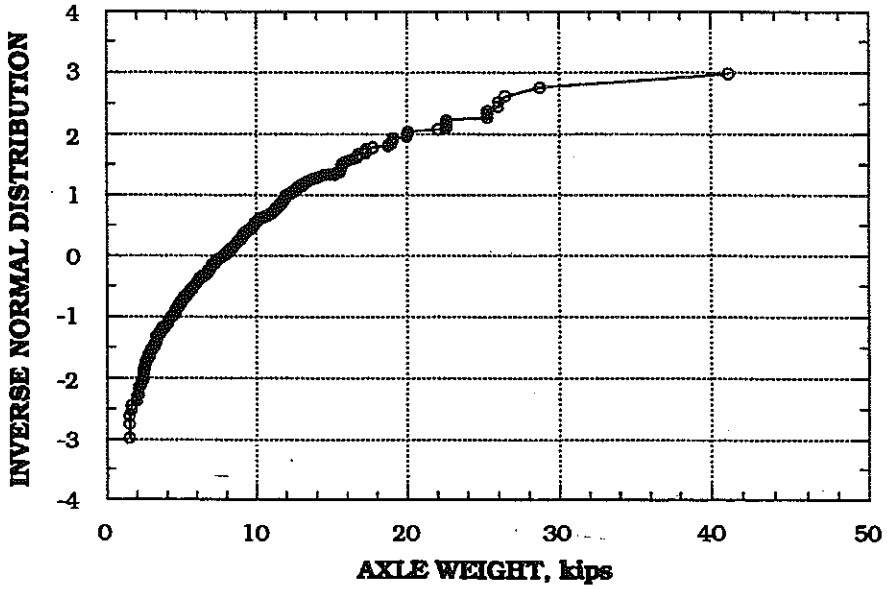


Fig. 6-16. US12/I94, Axle Weight Distribution.

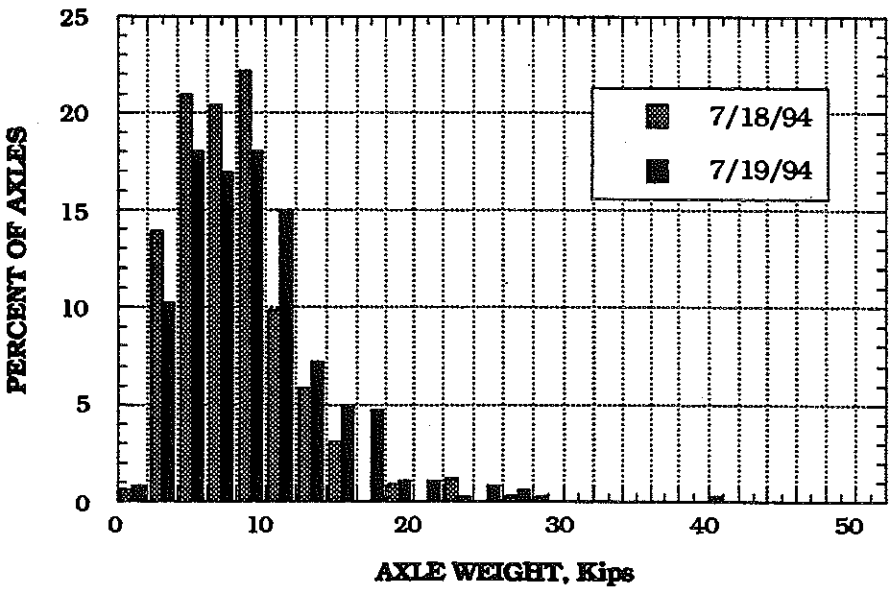


Fig. 6-17. US12/I94, Daily Axle Weight Histogram.

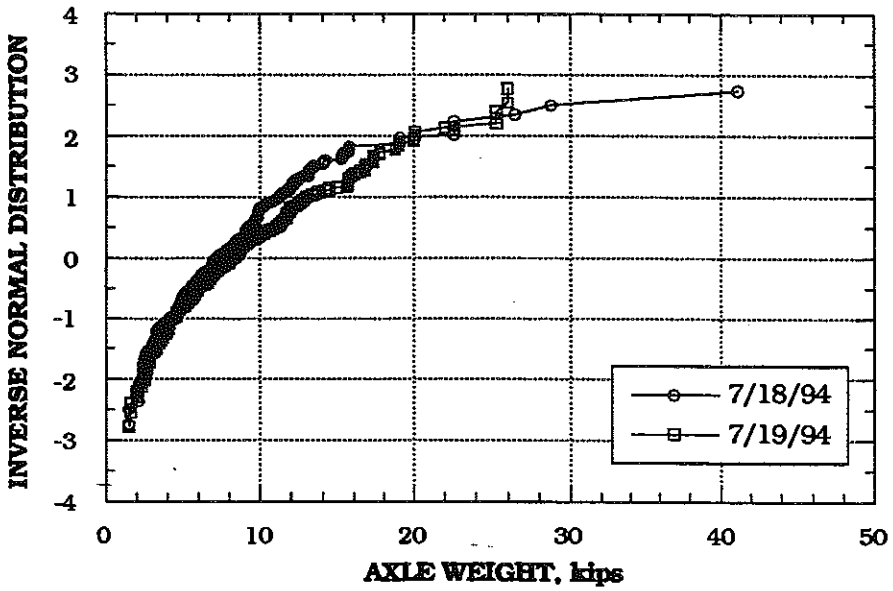


Fig. 6-18. US12/I94, Daily Axle Weight Distributions.

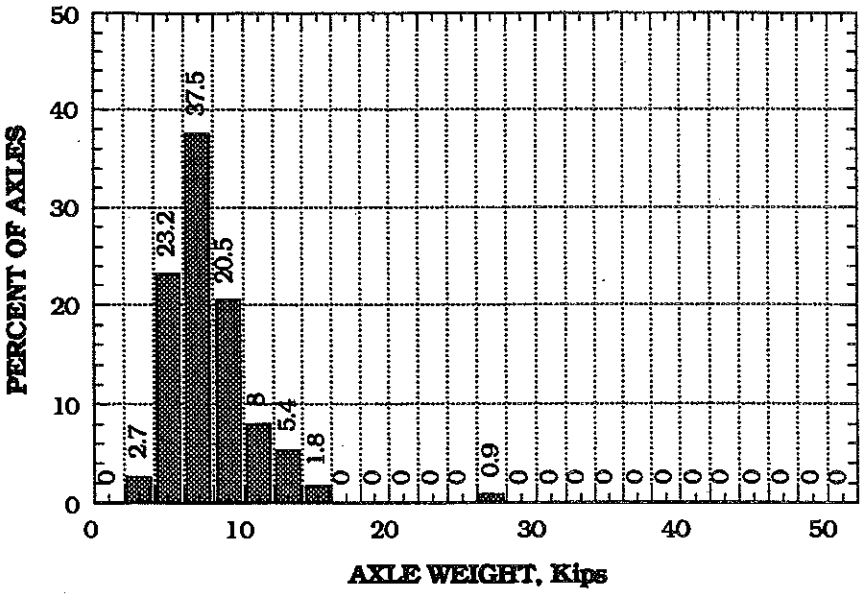


Fig. 6-19. US12/I94, Axle Weight Histogram of 2 Axle Vehicles.

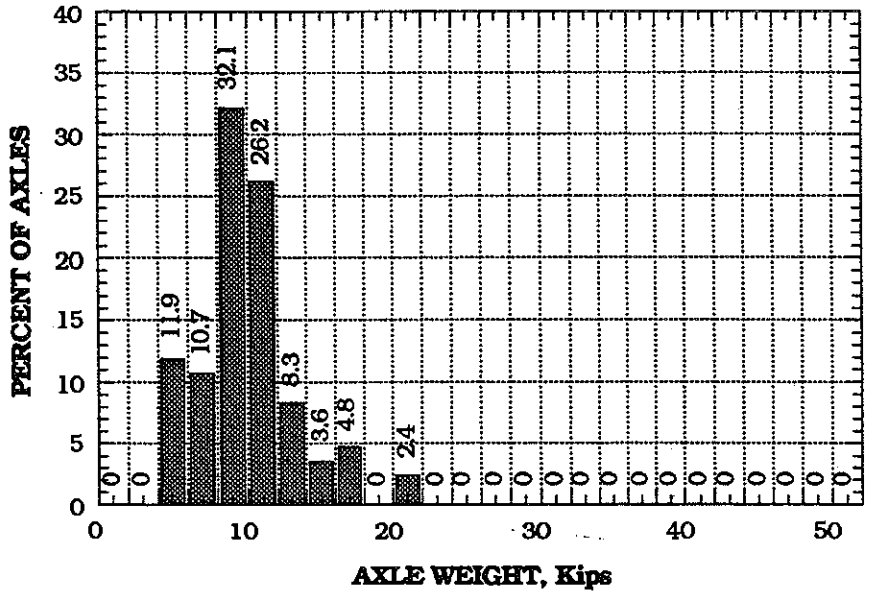


Fig. 6-20. US12/I94, Axle Weight Histogram of 3 Axle Vehicles.

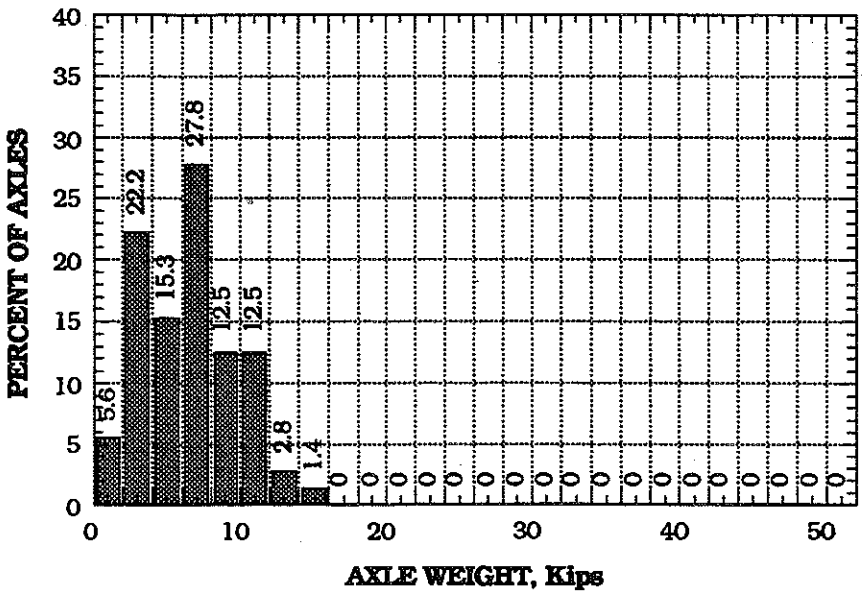


Fig. 6-21. US12/I94, Axle Weight Histogram of 4 Axle Vehicles.

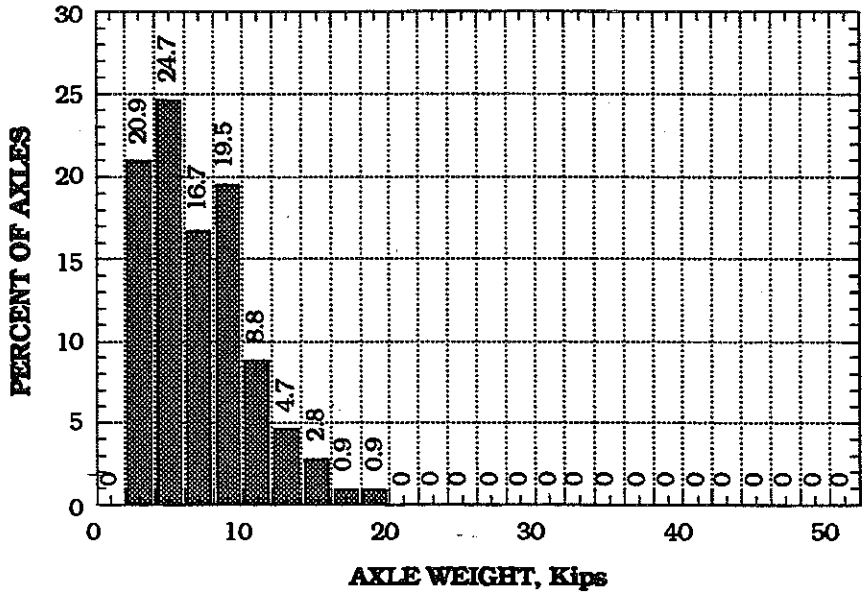


Fig. 6-22. US12/I94, Axle Weight Histogram of 5 Axle Vehicles.

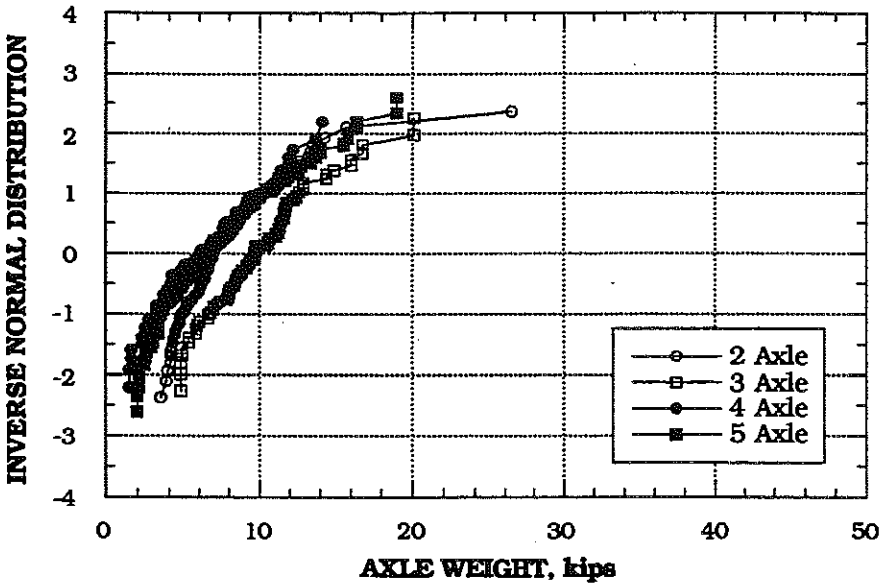


Fig. 6-23. US12/I94, Axle Weight Distributions of 2, 3, 4, and 5 Axles.

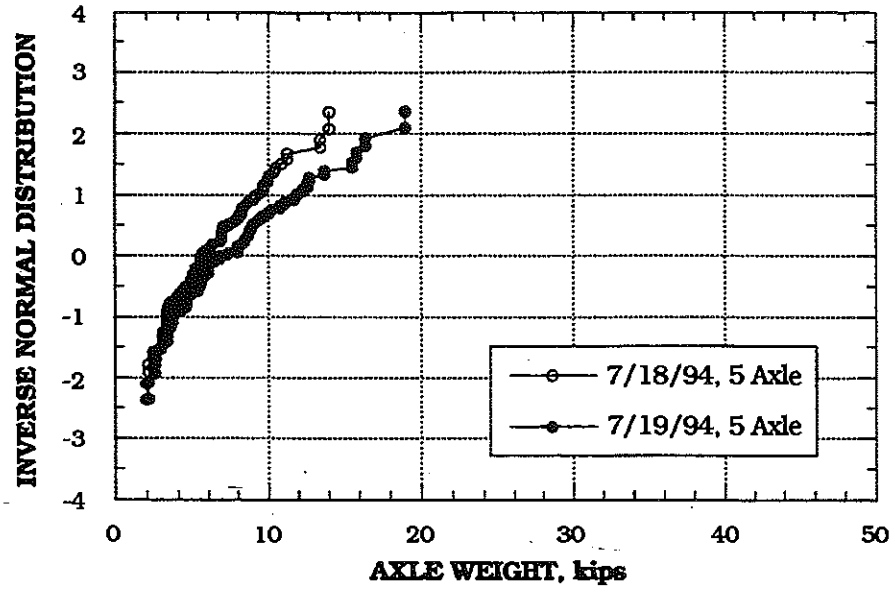


Fig. 6-24. US12/I94, Daily Axle Weight Distributions of 5 Axles.

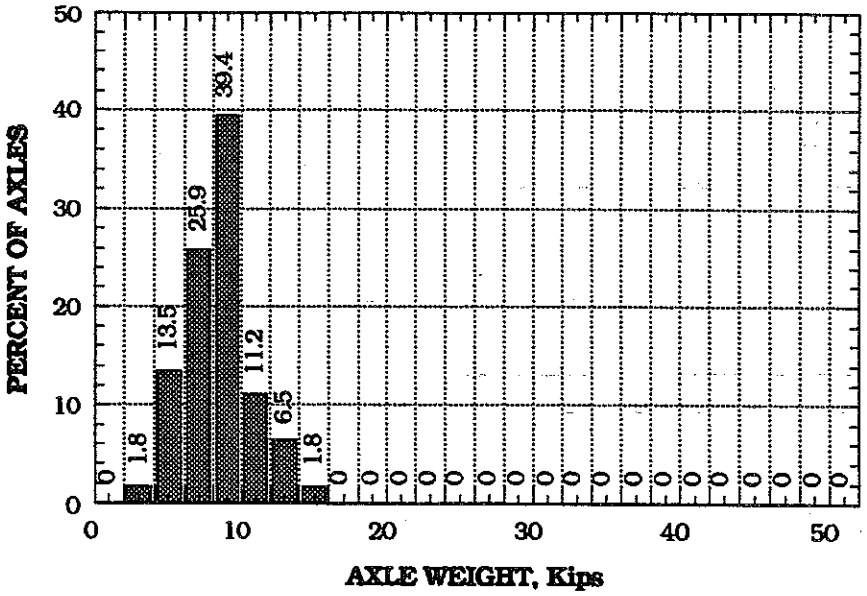


Fig. 6-25. US12/I94, Steering Axle Weight Histogram.

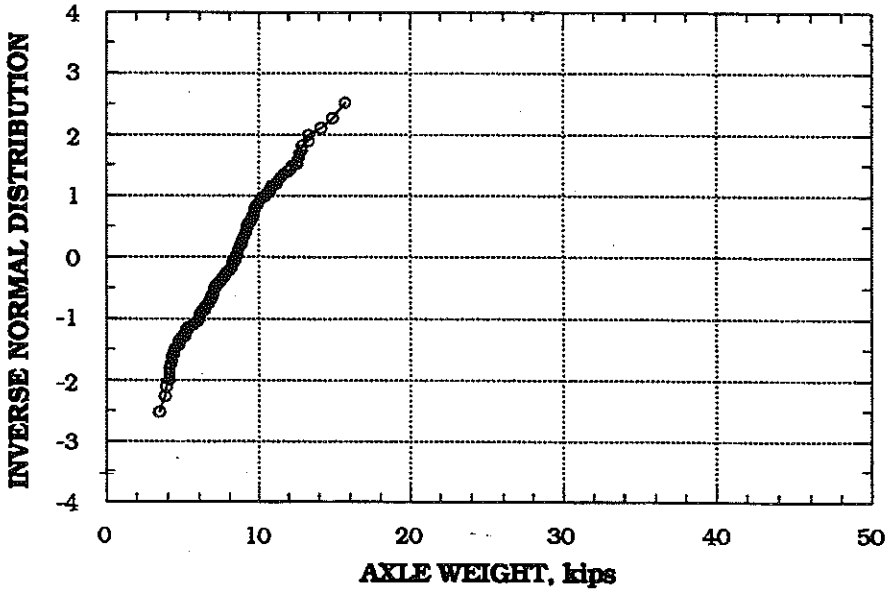


Fig. 6-26. US12/I94, Steering Axle Weight Distribution.

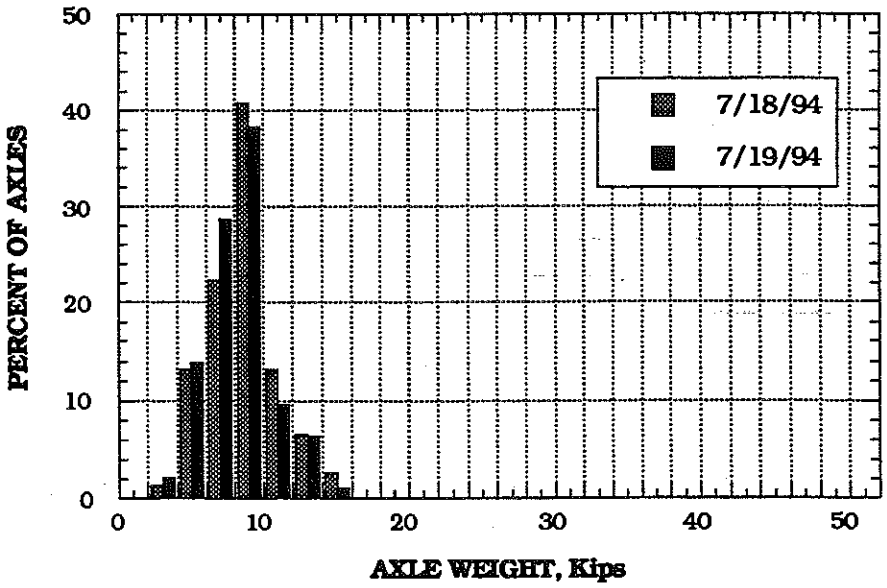


Fig. 6-27. US12/I94, Daily Steering Axle Weight Histogram.

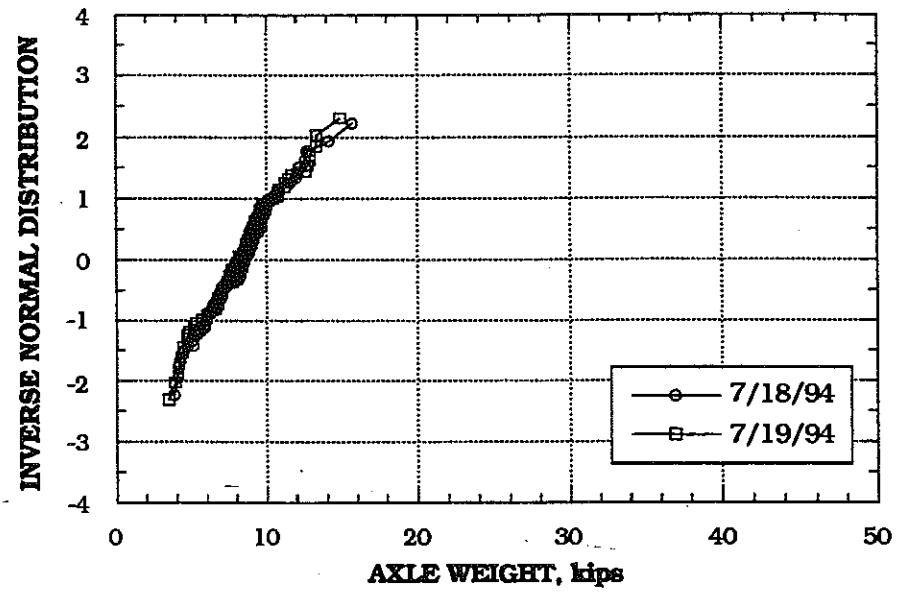


Fig. 6-28. US12/I94, Daily Steering Axle Weight Distributions.

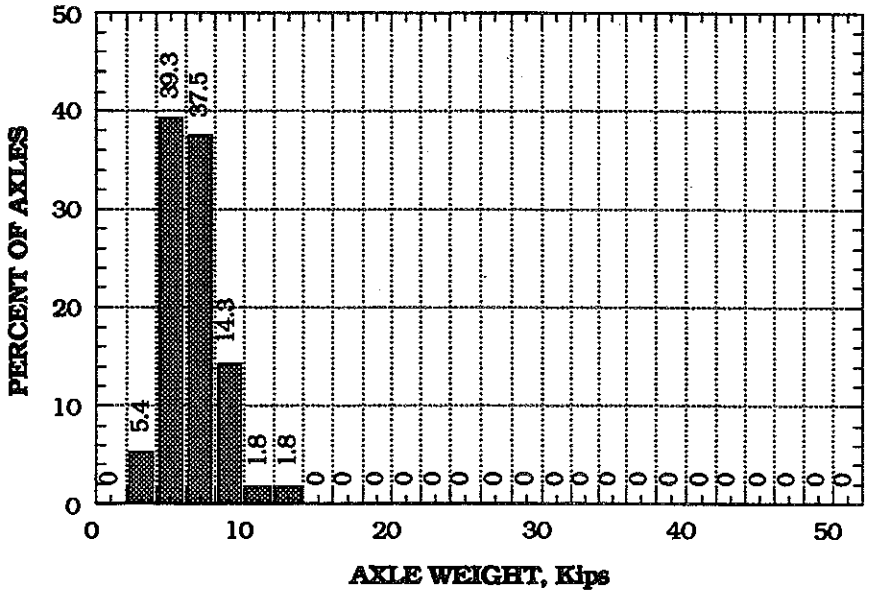


Fig. 6-29. US12/I94, Steering Axle Weight Histogram of 2 Axle Vehicles.

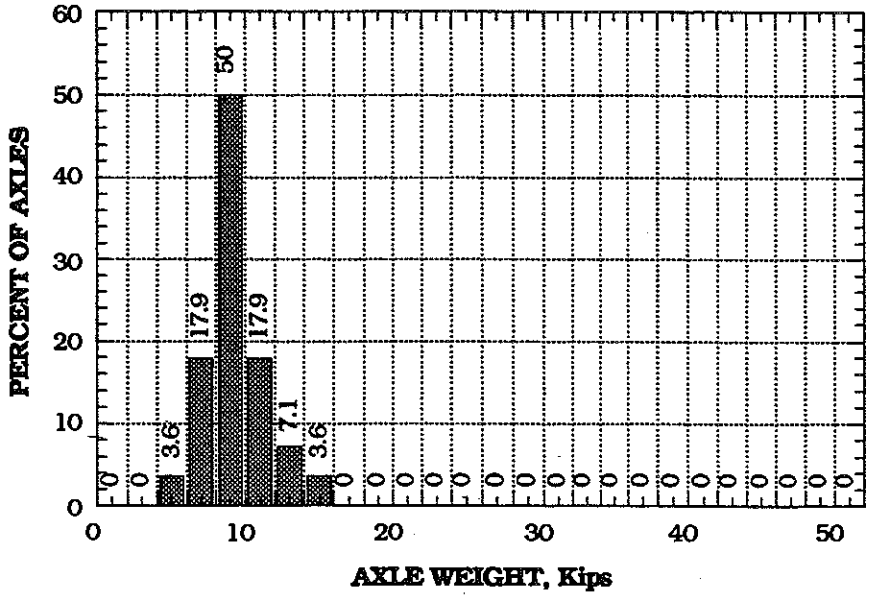


Fig. 6-30. US12/I94, Steering Axle Weight Histogram of 3 Axle Vehicles.

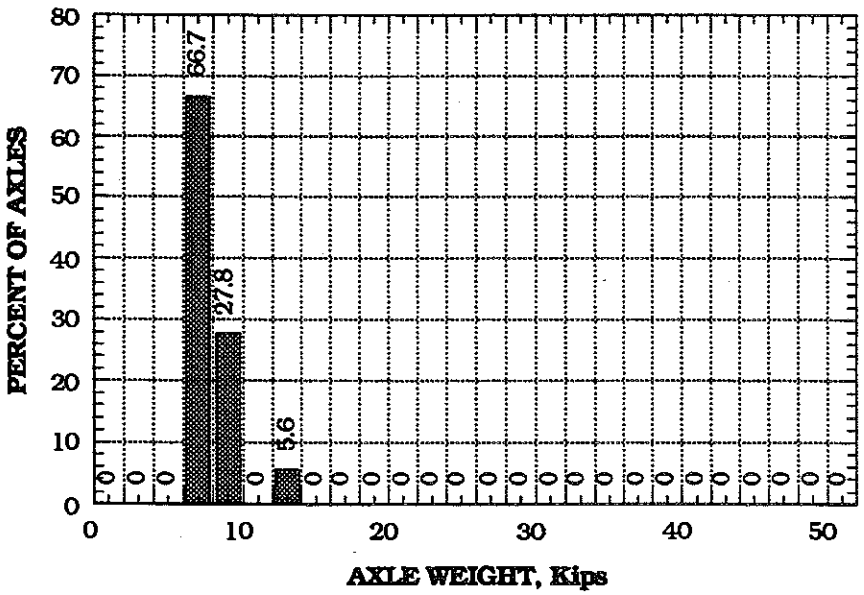


Fig. 6-31. US12/I94, Steering Axle Weight Histogram of 4 Axle Vehicles.

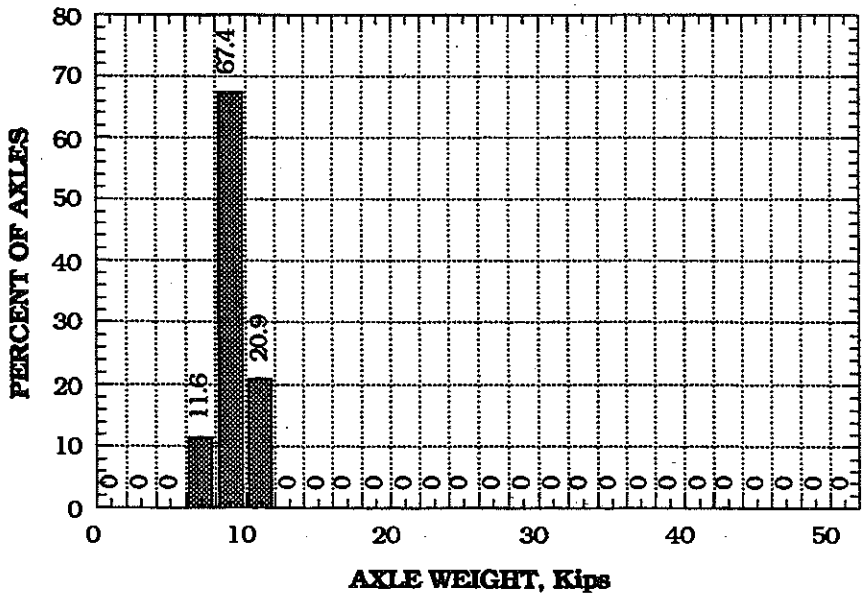


Fig. 6-32. US12/I94, Steering Axle Weight Histogram of 5 Axle Vehicles.

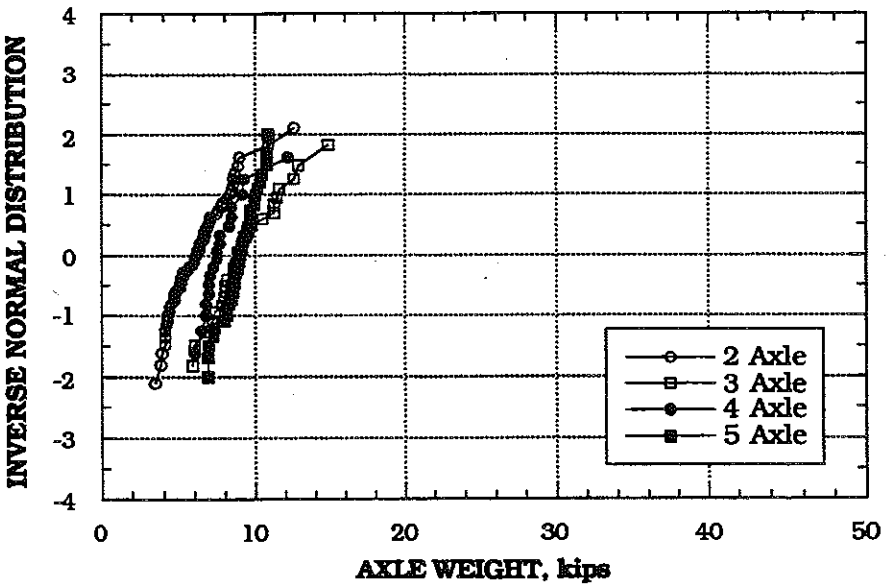


Fig. 6-33. US12/I94, Steering Axle Weight Distributions of 2, 3, 4, and 5 Axle Vehicles.

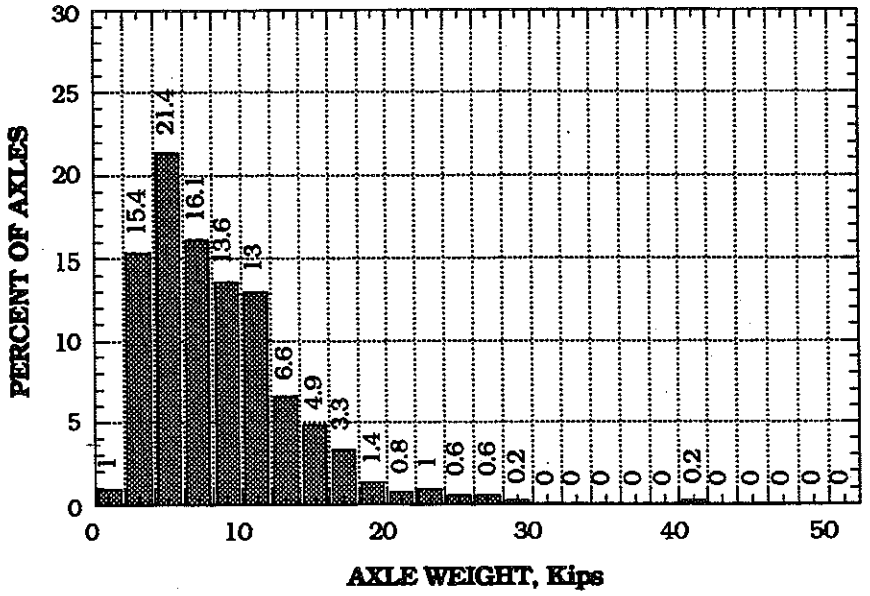


Fig. 6-34. US12/I94, Non-Steering Axle Weight Histogram.

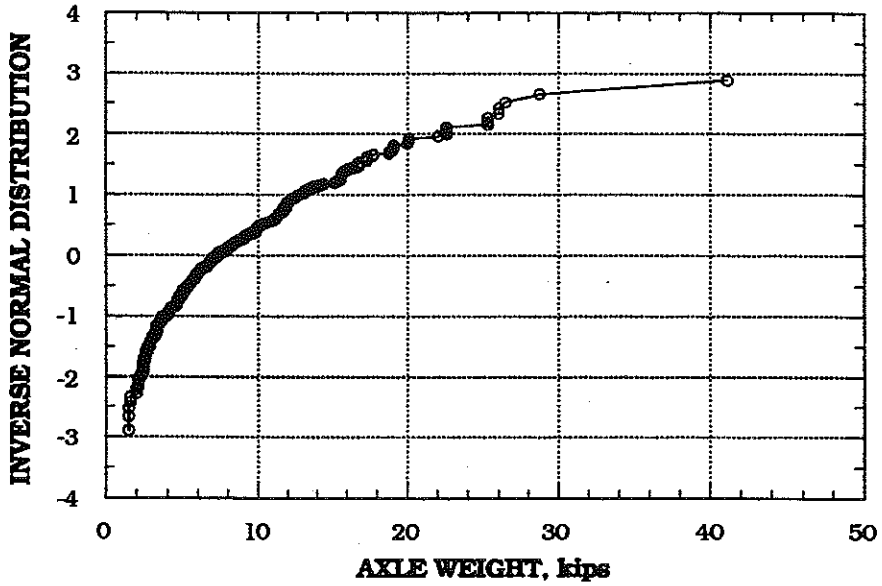


Fig. 6-35. US12/I94, Non-Steering Axle Weight Distribution.

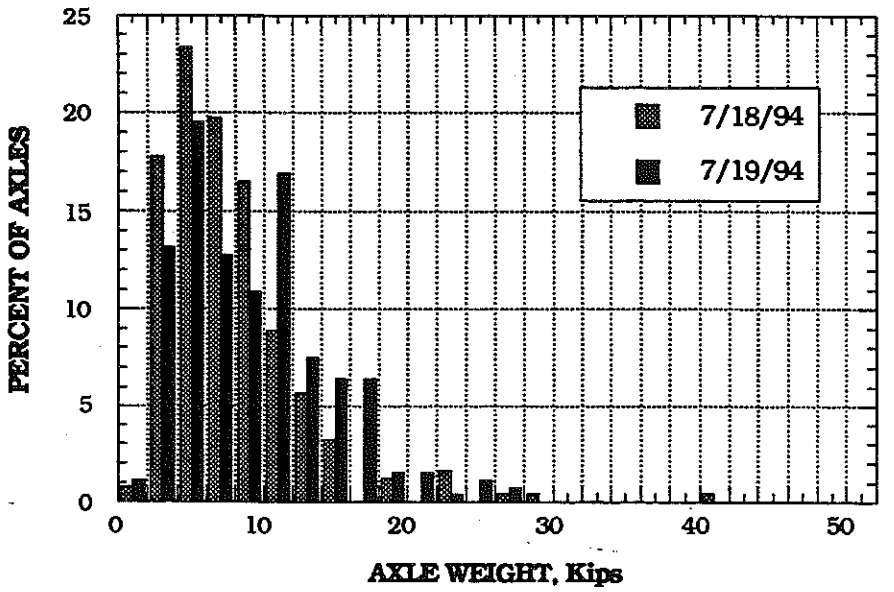


Fig. 6-36. US12/I94, Daily Non-Steering Axle Weight Histogram.

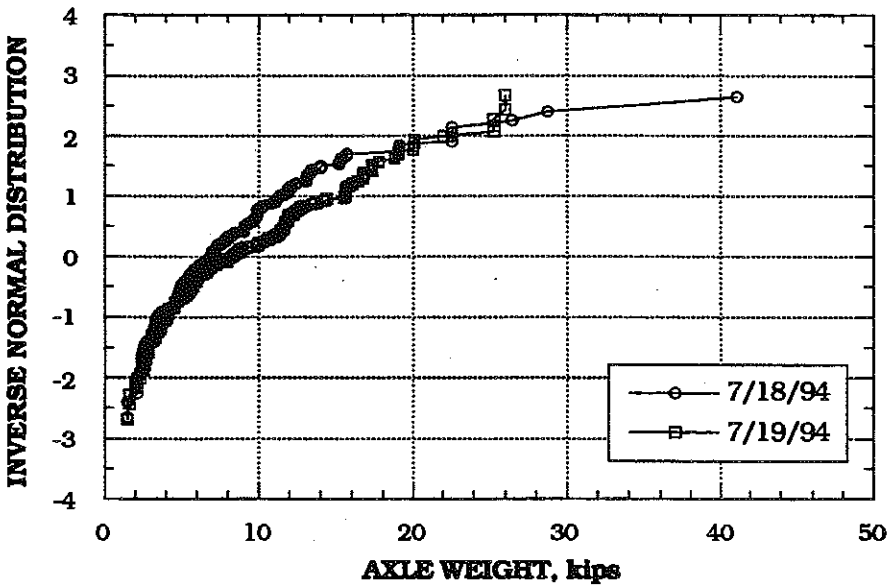


Fig. 6-37. US12/I94, Daily Non-Steering Axle Weight Distributions

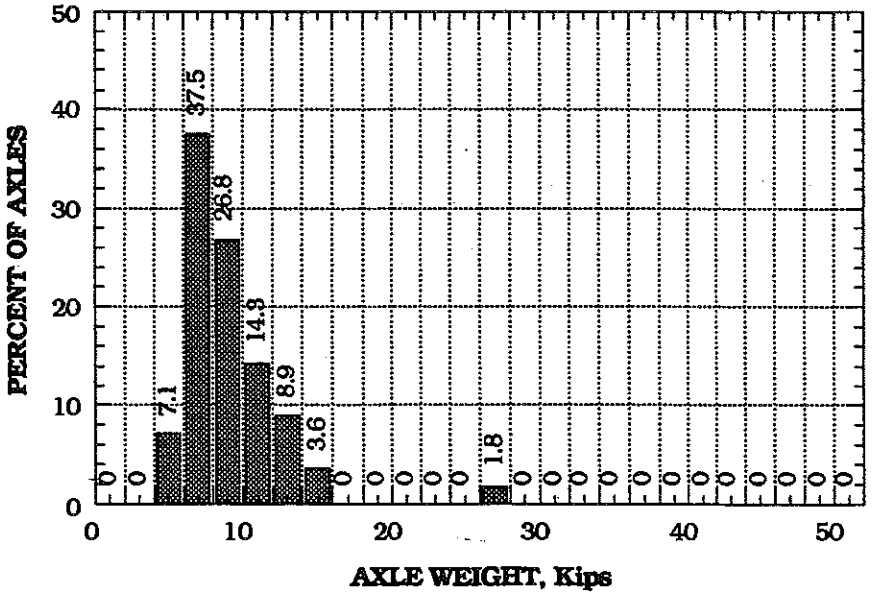


Fig. 6-38. US12/I94, Non-Steering Axle Weight Histogram of 2 Axles.

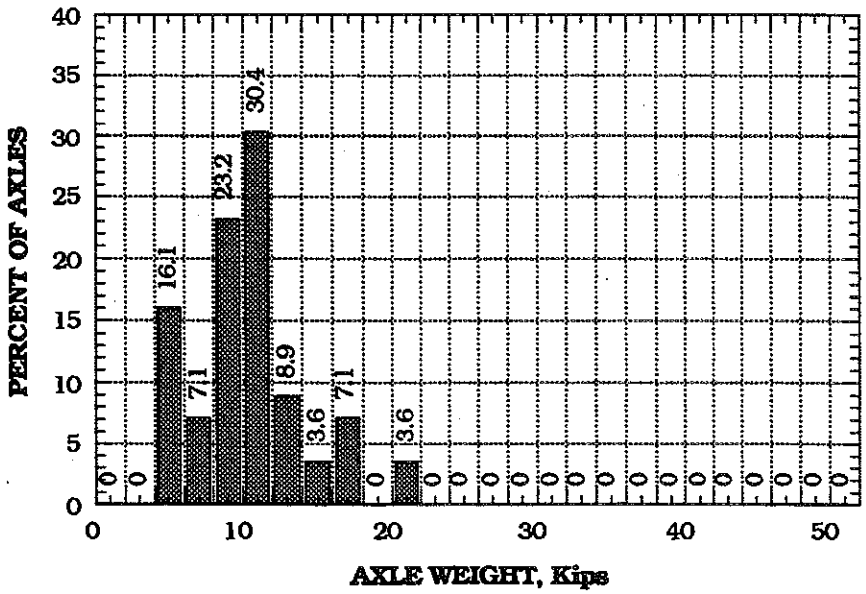


Fig. 6-39. US12/I94, Non-Steering Axle Weight Histogram of 3 Axles.

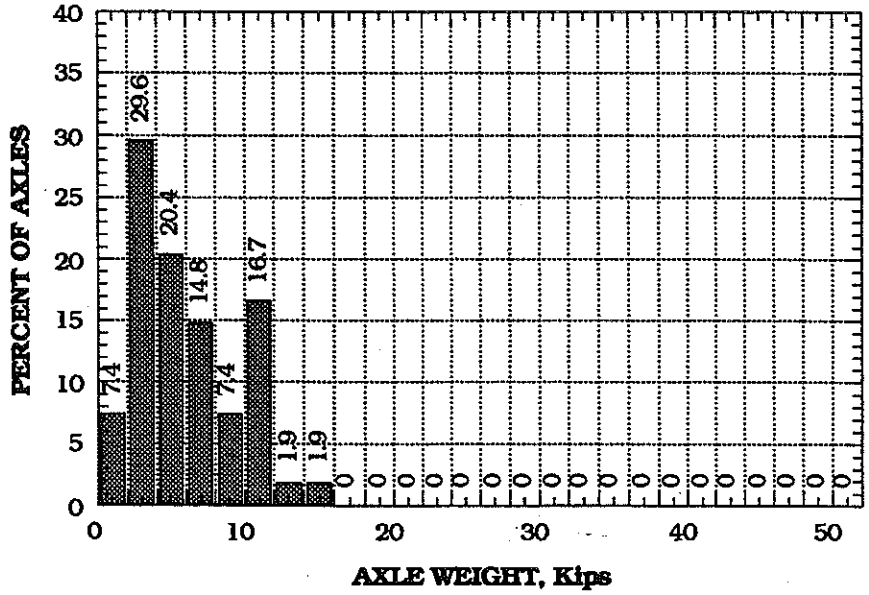


Fig. 6-40. US12/I94, Non-Steering Axle Weight Histogram of 4 Axles.

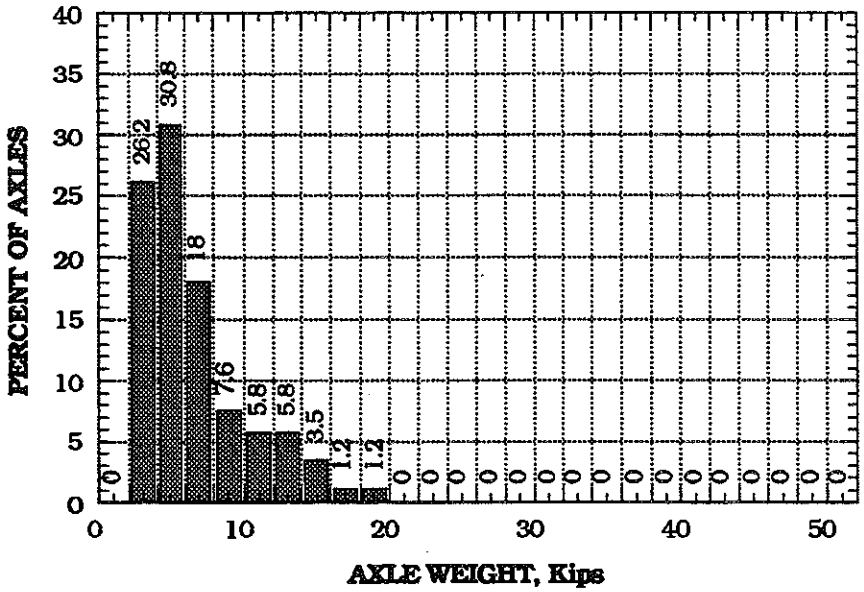


Fig. 6-41. US12/I94, Non-Steering Axle Weight Histogram of 5 Axles.

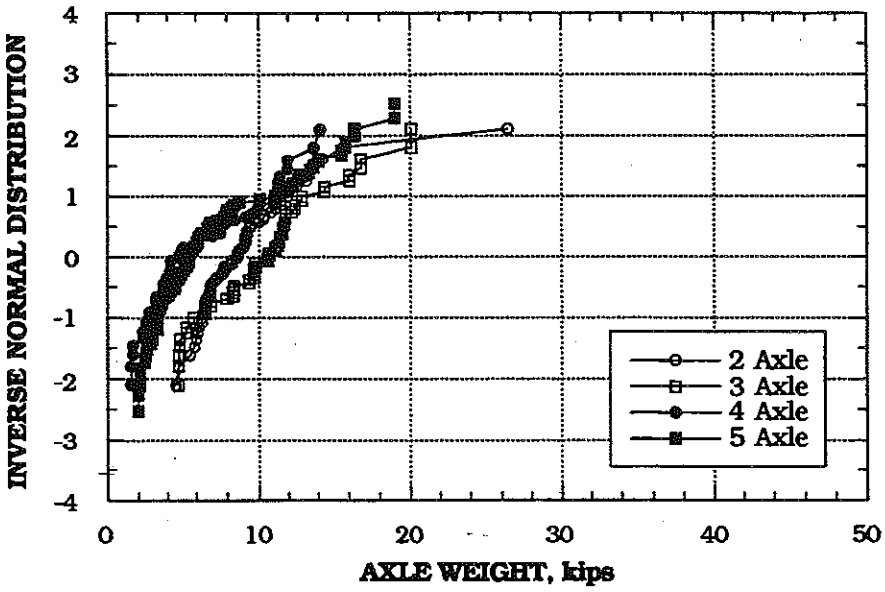


Fig. 6-42. US12/I94, Non-Steering Axle Weight Distributions of 2, 3, 4, and 5 Axle Vehicles.

7. BRIDGE ON DAVISON AVENUE EASTBOUND OVER M-10 SOUTHBOUND IN DETROIT (DA/M10)

7. 1 Description of the bridge

Bridge DA/M10 carries eastbound traffic on Davison Avenue over M-10 in Detroit. The elevation, framing plan and cross section and other details are shown in Fig. 7-1 and 7-2. Measurements were taken in the entrance span (in the direction of traffic). The selected span is 42'-10 1/4" and the width is 43' with a skew of 8 degree and consists of eight girders spaced at 5'-1 7/8" on the abutment and 5'-6" on the pier.

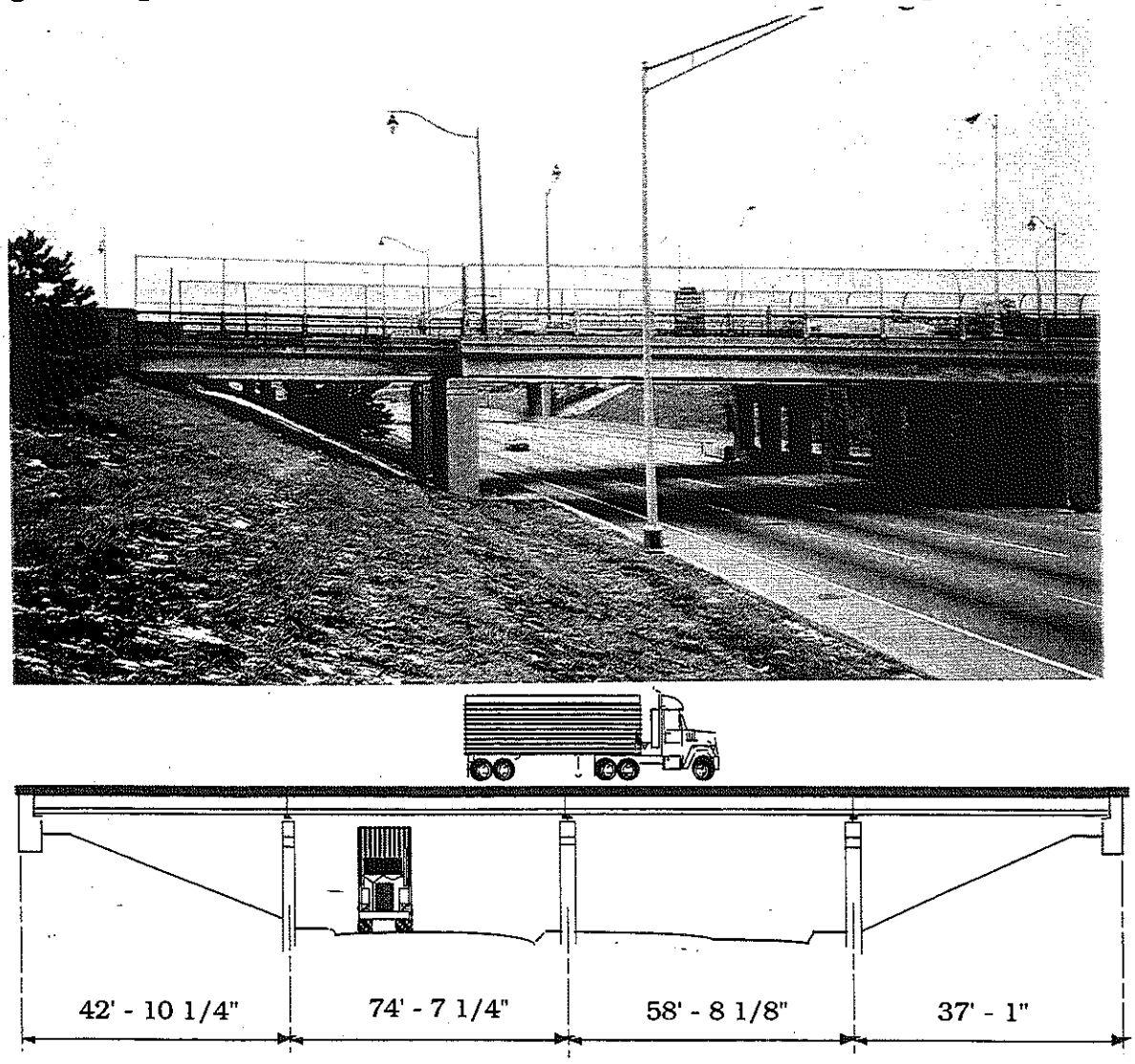
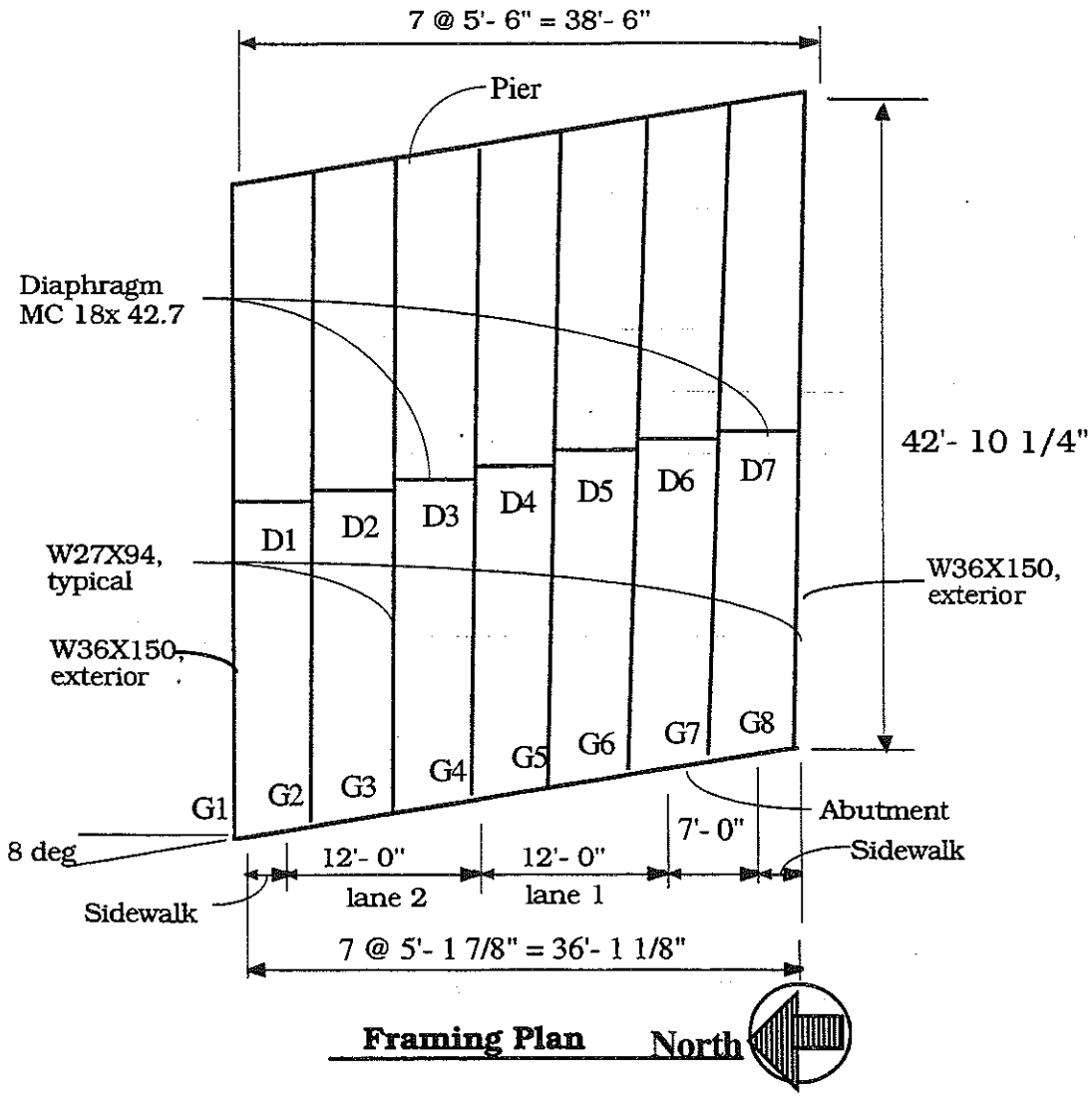


Fig. 7-1. Bridge DA/M10, Davison Avenue over M-10.
View and Side Elevation.



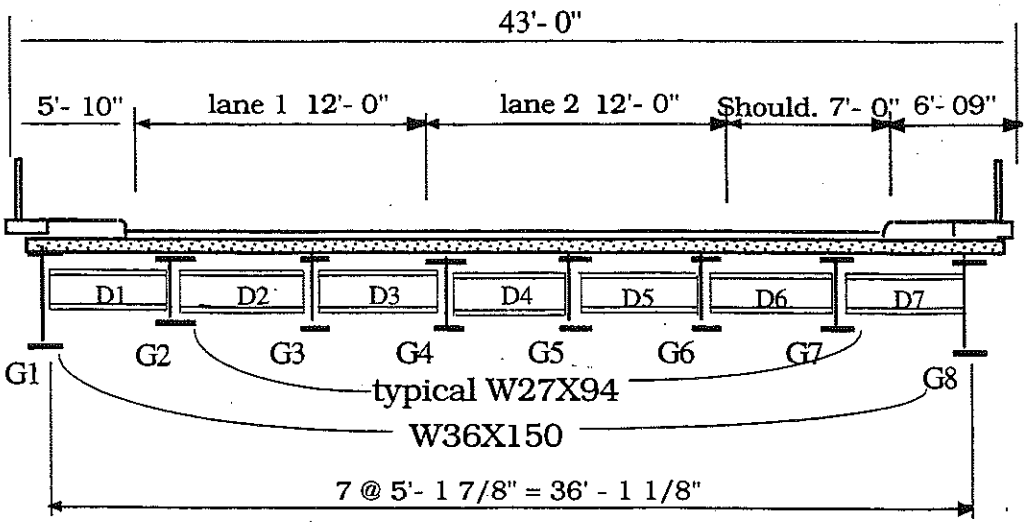


Fig. 7-2. Bridge DA/M10. Plan View and Cross Section of Entrance Span.

7.2 Weigh-in-Motion Measurements

Weigh-in-motion (WIM) statistics are presented in Table 7-1 to Table 7-6 and in Fig. 7-3 to Fig. 7-54. This data includes all trucks with a gross vehicle weight (GVW) of 10 kips and greater for 2-axle vehicles, and of 15 kips and greater for 3 or more axle vehicles, regardless of axle weight. This filtered WIM data has been used for all analysis of GVW and axle weight. The data may also include permit loads. The data measured by WIM are recorded in the FHWA card seven 80-column format.

Table 7-1 summarizes an estimated average daily truck traffic (ADTT) in one direction, and the total number of vehicles weighed by date and by different number of axle vehicles. Fig. 7-3 is the frequency histogram of trucks corresponding to different number of axles. Only a few 11 axle trucks were observed. Fig. 7-4 shows the daily frequency histogram of trucks. Practically, there is no difference by the date of measurement. Table 7-2 presents Federal Highway Administration (FHWA) truck class frequency vs lane statistics. Federal Highway Administration (FHWA) axle configuration class is presented in the Appendix A. Note that the last digit from the FHWA axle class is not included in Table 7-2.

Table 7-3 is the GVW statistics of maximum, mean, median, standard deviation, and percentage of overloaded vehicles. The statistics are given for all vehicles and separately different nmber of axle vehicles. The GVW limit in Table 7-3 might not be the legal limit. It is difficult to determine the GVW limit with only number of axles. It depends not only on number of axles, but axle spacings. Thus, it was decided to assign reasonably high GVW limits and to give some ideas about how heavy the vehicles were. Fig. 7-5 and Fig. 7-6 are the histogram of GVW and the corresponding cumulative distribution function (CDF) of GVW for all trucks observed and measured on DA/M10 respectively. In Fig. 7-6, each circle represents one truck in the data file. From the graph and from Table 7-3 the heaviest vehicle observed weighed 229 kips with a

mean GVW of 32 kips. Vehicles over the GVW limit were 2 %. Results of the individual day measurements are shown in Fig. 7-7 and Fig. 7-8. The day to day CDF's are similar in shape and average GVW with the largest difference at the upper tail of the distribution. GVW histograms for different number of axle vehicles are presented in Fig. 7-9 to Fig. 7-14. The corresponding CDF's are shown in Fig. 7-15 and Fig. 7-16. There were no overloaded 5-axle vehicles. The data base contains six passing 11-axle vehicles, which was not sufficient number to observe a general trend. One 11-axle vehicle has the heaviest GVW of 229 kips. For comparison of the daily distributions of 5-axle vehicles, the CDF's for both days are plotted in Fig. 7-17.

Table 7-4 is the axle weight statistics of maximum, mean, median, standard deviation, and percentage of overloaded axles. The statistics are given for all vehicles and separately different number of axle vehicles. In this table, axle weight limits were intended to give some ideas about how heavy the axles were. The statistics depend on axle spacings rather than number of axles. Fig. 7-18 and Fig. 7-19 are the histogram of axle weight for all vehicles and the corresponding CDF respectively. The maximum axle weight observed at DA/M10 was 35 kips with a mean of 8 kips. Axles with axle weight of 18 kips and greater were 3 percent. Fig. 7-20 and Fig. 7-21 show the daily axle weight histogram and CDF's. Differences between 8/2/94 and 8/3/94 data are more pronounced for axle weight, however a similar trend in the distributions is evident. Axle weight histograms for different number of axle vehicles are presented in Fig. 7-22 to Fig. 7-27. The corresponding CDF's are shown in Fig. 7-28 and Fig. 7-29. Overloaded axles for 5 and 11-axle vehicles were 1 percent and 8 percent respectively. The daily CDF's of axle weight for 5-axle vehicles are plotted in Fig. 7-30 for comparison of the daily distribution.

Table 7-5 is the steering axle weight statistics of maximum, mean, median, and standard deviation of all vehicles and different number of axle vehicles. Fig. 7-31 and Fig. 7-32 are the steering axle weight histogram for all vehicles and the corresponding CDF respectively. The maximum observed steering axle weight was 20 kips with a mean of 9

kips (Table 7-5). Fig. 7-33 and Fig. 7-34 show the daily steering axle weight histogram and CDF's. Steering axle weight histograms for different number of axle vehicles are presented in Fig. 7-35 to Fig. 7-40. The corresponding CDF's are shown in Fig. 7-41 and Fig. 7-42.

Table 7-6 is the non-steering axle weight statistics of maximum, mean, median, and standard deviation of all vehicles and different number of axle vehicles. Fig. 7-43 and Fig. 7-44 are the non-steering axle weight histogram for all vehicles and the corresponding CDF. The maximum non-steering axle weight was 35 kips with a mean of 8 kips (Table 7-6). Fig. 7-45 and Fig. 7-46 show the daily non-steering axle weight histogram and CDF's. Non-steering axle weight histograms for different number of axle vehicles are presented in Fig. 7-47 to Fig. 7-52. The corresponding CDF's are shown in Fig. 7-53 and Fig. 7-54.

The steering and non-steering axle weight CDF's of Fig. 7-32 and Fig. 7-44 indicate a significant difference in both variation and magnitudes. The standard deviation of steering axle weight was 3 kips with a maximum of 20 kips while the standard deviation of non-steering axle weight was 5 kips with a maximum of 35 kips.

Review of the results indicates that most of the truck weights are within legal limits. There were no overloaded 5 and 11 axle vehicles except one heavy 11 axle vehicle. Vehicles over the GVW limit were 3 percent. Overloaded axles for 5 and 11-axle vehicles were one percent and eight percent respectively. Axles with axle weight of 18 kips and greater were 3 percent.

Table 7-1. DA/M10, Number of Trucks Weighed and Estimated ADTT.

Number of Trucks Weighed Gross Vehicle Weight > 10 Kips for 2 Axle Vehicles, Gross Vehicle Weight > 15 Kips for 3 or more Axle Vehicles.				
Date	8/2/94	8/3/94	Total	Vehicles (%)
2 Axles	49	76	125	45.5
3 Axles	21	24	45	16.5
4 Axles	6	4	10	3.7
5 Axles	10	24	34	12.4
6 Axles	8	18	26	9.5
7 Axles	6	4	10	3.7
8 Axles	0	6	6	2.2
9 Axles	4	3	7	2.6
10 Axles	1	2	3	1.1
11 Axles	3	3	6	2.2
All Vehicles	109	164	273	100.0
Estimated ADTT = 750 Trucks (in one direction)				

Table 7-2. Bridge DA/M10, Truck Class vs Lane Statistics.

Truck Class (FHWA)	Right Lane (1) (%)	Left Lane (2) (%)	Total (%)
4	0.0	0.0	0.0
5	20.0	46.2	66.2
6	6.1	0.9	7.0
7	0.5	0.0	0.5
8	2.0	0.1	2.1
9	3.2	0.3	3.5
10	3.0	0.5	3.5
11	0.0	0.0	0.0
12	0.0	0.0	0.0
13	0.0	0.0	0.0
14	12.4	4.7	17.1
Total Lane %	47.3	52.7	100.0

Table 7-3. Bridge DA/M10, Gross Vehicle Weight Statistics.

Vehicle Type	Max. (Kips)	Mean (Kips)	Median (Kips)	Std.Dev. (Kips)	GVW Limit (Kips)	Percentage over the Limit
2 Axles	42	15	14	6	40	1
3 Axles	76	34	32	13	60	4
4 Axles	62	39	39	12	70	0
5 Axles	72	37	33	14	80	0
6 Axles	77	53	55	14	90	0
7 Axles	63	49	46	9	120	0
8 Axles	59	47	48	10	125	0
9 Axles	85	63	57	14	135	0
10 Axles	91	57	47	31	150	0
11 Axles	229	122	109	56	164	17
All Vehicles	229	32	25	25	varies	2

Table 7-4. Bridge DA/M10, Axle Weight Statistics.

Vehicle Type	Max. (Kips)	Mean (Kips)	Median (Kips)	Std.Dev. (Kips)	Axle Weight Limit (Kips)	Percentage over the Limit
2 Axles	28	8	7	4	18	3
3 Axles	28	11	10	5	18	4
4 Axles	29	10	9	4	18	3
5 Axles	21	7	7	4	18	1
6 Axles	20	9	8	4	18	6
7 Axles	14	7	7	2	18	0
8 Axles	14	6	5	3	18	0
9 Axles	14	7	6	3	18	0
10 Axles	15	6	5	4	18	0
11 Axles	35	11	10	7	18	8
All Vehicles	35	8	8	4	18	3

Table 7-5. Bridge DA/M10, Steering Axle Weight Statistics.

Vehicle Type	Max. (Kips)	Mean (Kips)	Median (Kips)	Std.Dev. (Kips)	Vehicles (%)
2 Axles	13	7	6	2	45.5
3 Axles	20	10	10	3	16.5
4 Axles	14	10	11	2	3.7
5 Axles	12	9	9	1	12.4
6 Axles	12	10	10	1	9.5
7 Axles	11	10	10	1	3.7
8 Axles	12	10	10	2	2.2
9 Axles	12	10	10	1	2.6
10 Axles	13	10	9	3	1.1
11 Axles	16	13	13	2	2.2
All Vehicles	20	9	8	3	100.0

Table 7-6. Bridge DA/M10, Non-Steering Axle Weight Statistics.

Vehicle Type	Max. (Kips)	Mean (Kips)	Median (Kips)	Std.Dev. (Kips)	Vehicles (%)
2 Axles	28	9	8	4	45.5
3 Axles	28	12	11	5	16.5
4 Axles	29	10	9	5	3.7
5 Axles	21	7	6	4	12.4
6 Axles	20	9	8	5	9.5
7 Axles	14	7	6	2	3.7
8 Axles	14	5	5	3	2.2
9 Axles	14	7	6	3	2.6
10 Axles	15	5	2	4	1.1
11 Axles	35	11	8	7	2.2
All Vehicles	35	8	7	5	100.0

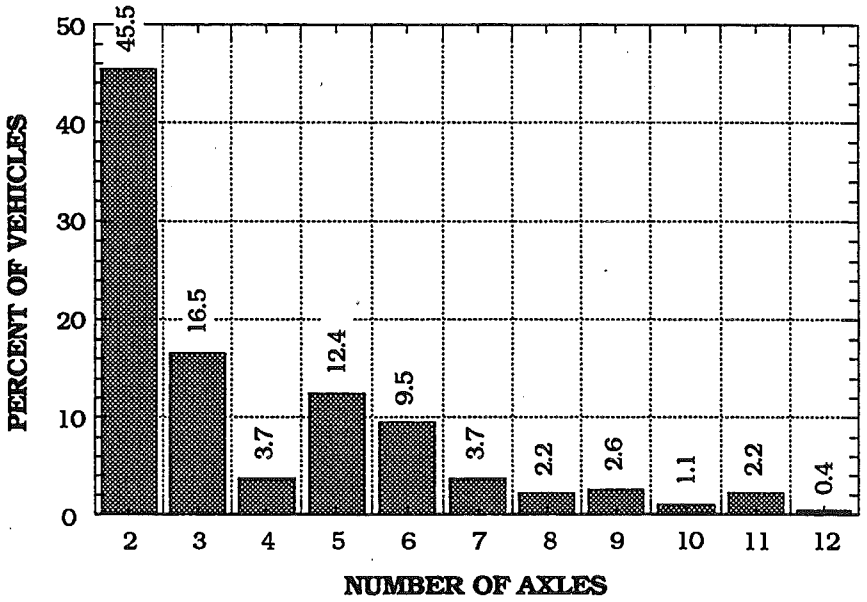


Fig. 7-3. DA/M10, Truck Type Histogram.

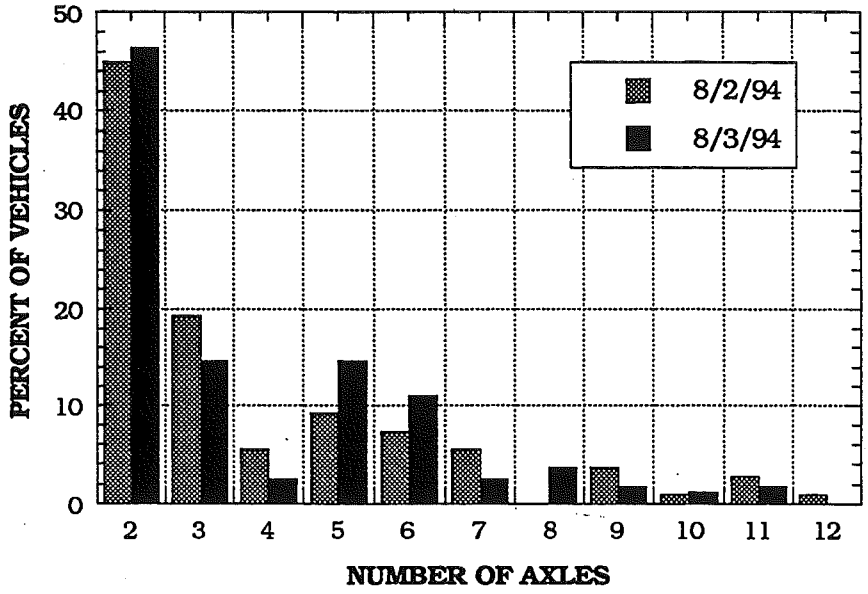


Fig. 7-4. DA/M10, Daily Truck Type Histogram.

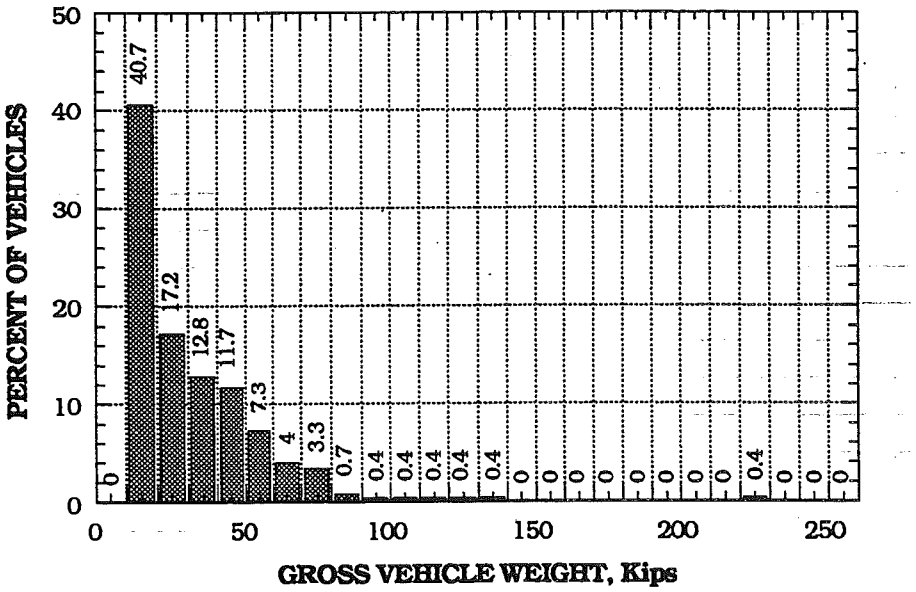


Fig. 7-5. DA/M10, GVW Histogram.

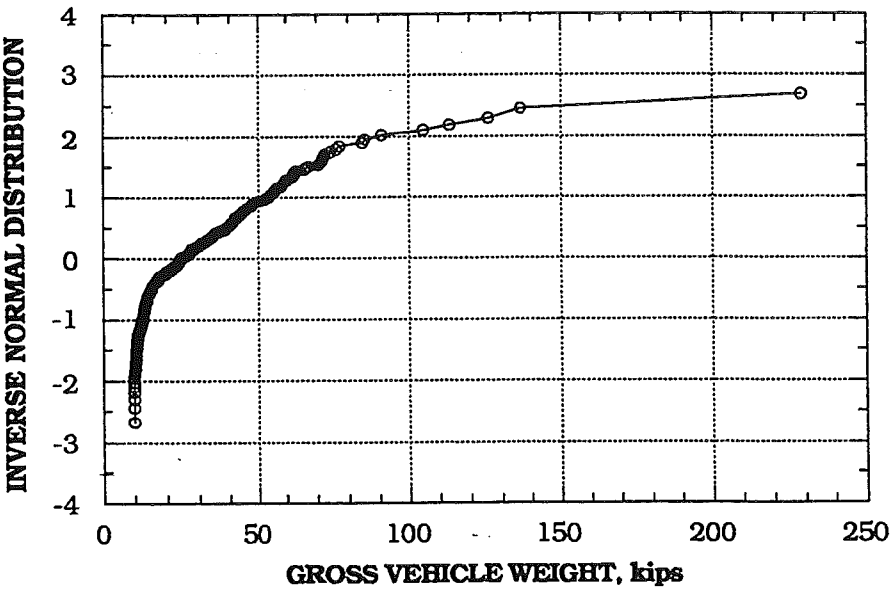


Fig. 7-6. DA/M10, GVW Distribution.

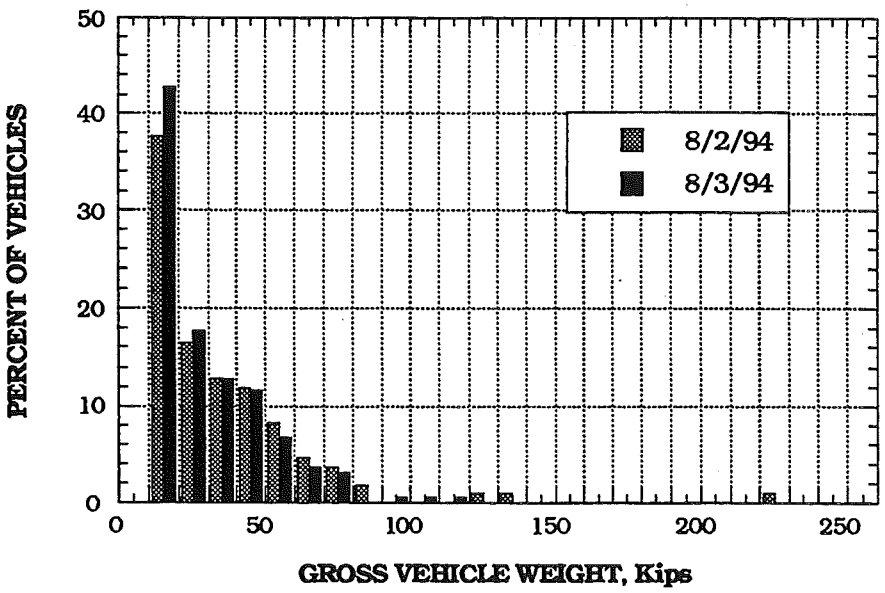


Fig. 7-7. DA/M10, Daily GVW Histogram.

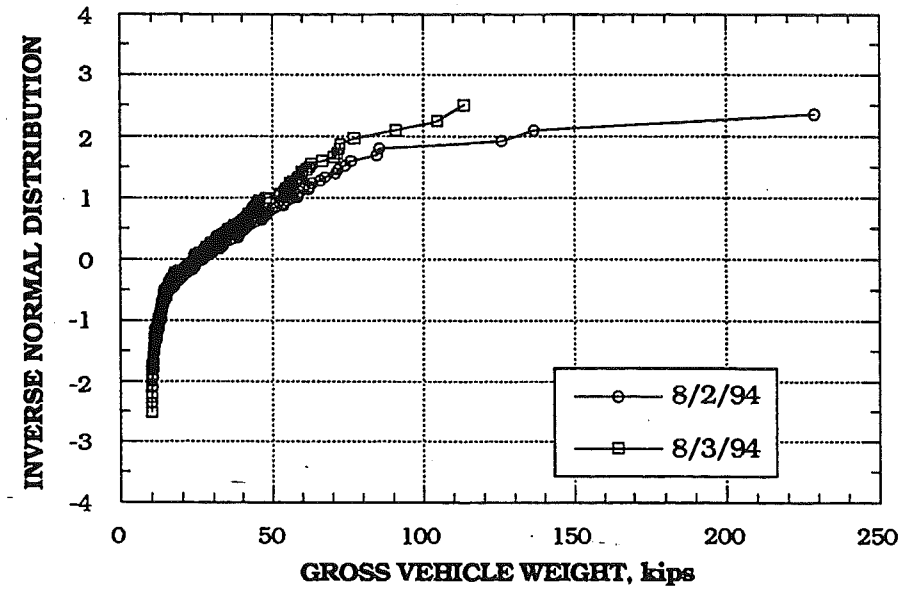


Fig. 7-8. DA/M10, Daily GVW Distributions.

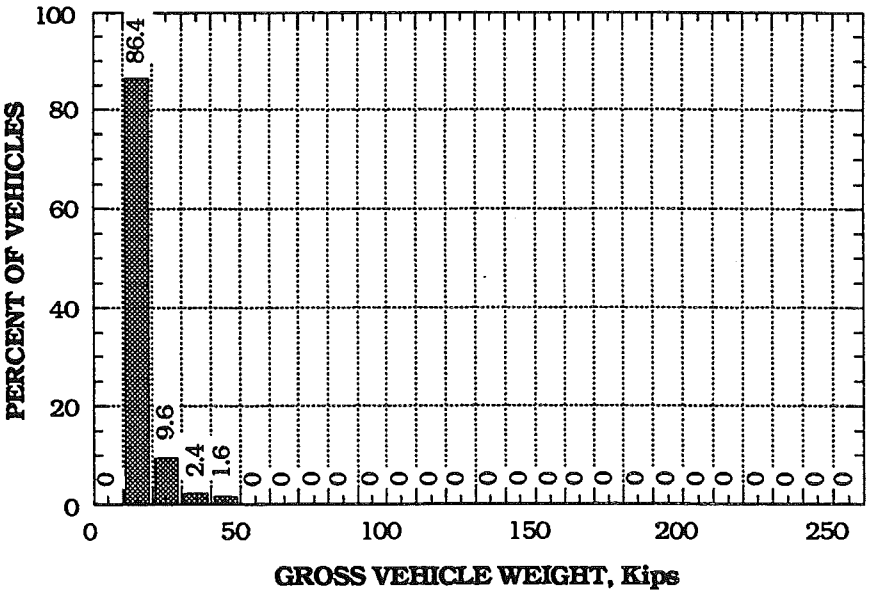


Fig. 7-9. DA/M10, 2 Axle GVW Histogram.

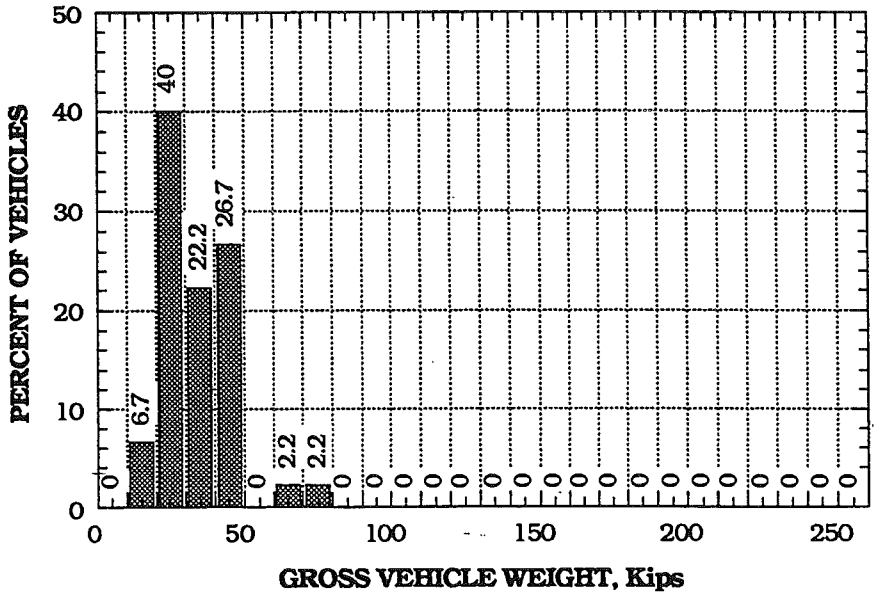


Fig. 7-10. DA/M10, 3 Axle GVW Histogram.

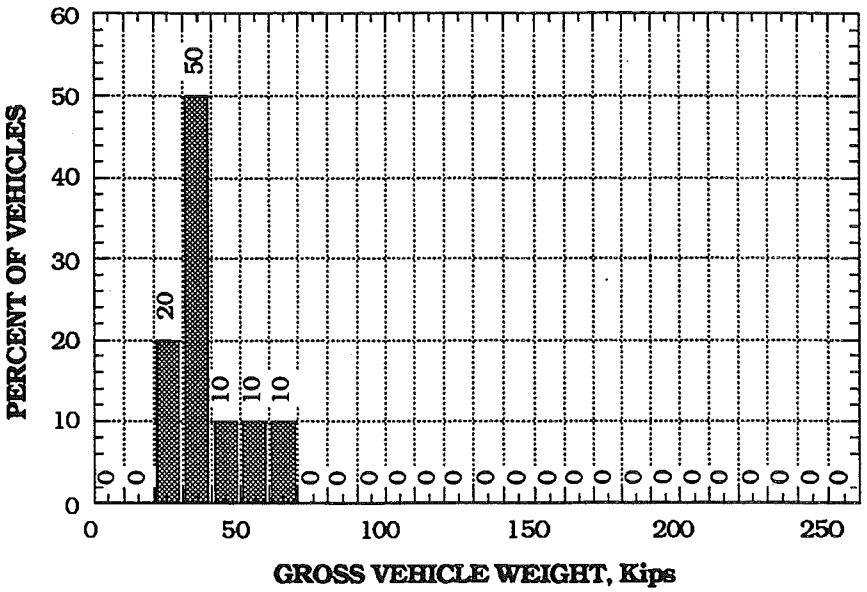


Fig. 7-11. DA/M10, 4 Axle GVW Histogram.

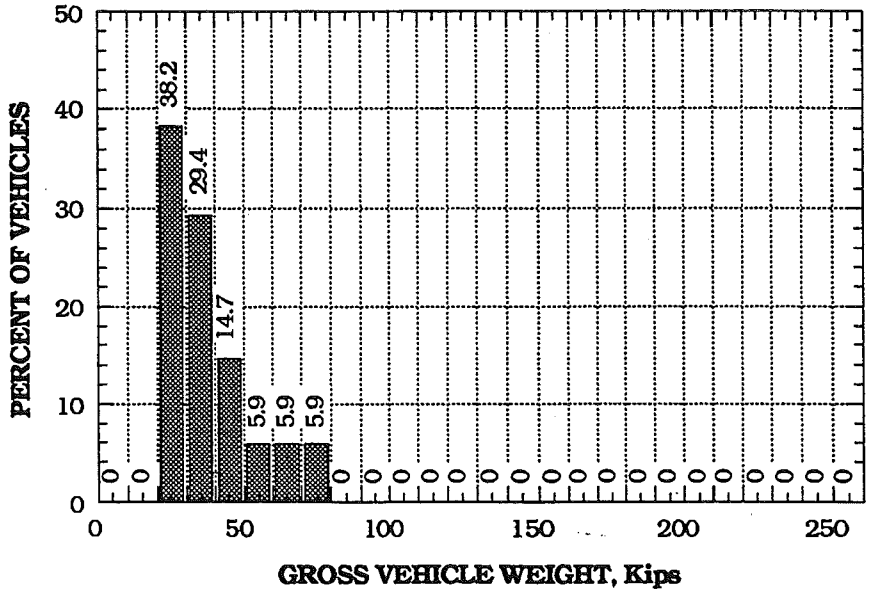


Fig. 7-12. DA/M10, 5 Axle GVW Histogram.

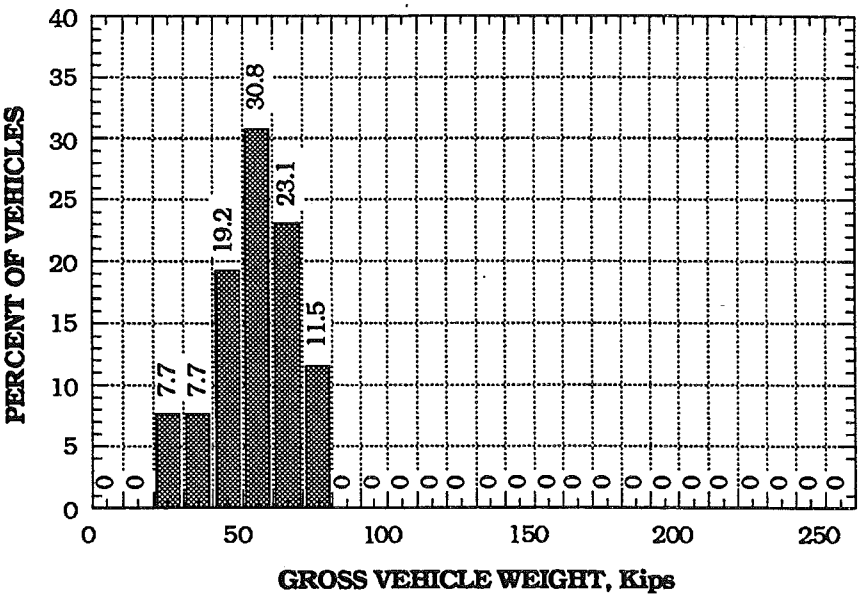


Fig. 7-13. DA/M10, 6 Axle GVW Histogram.

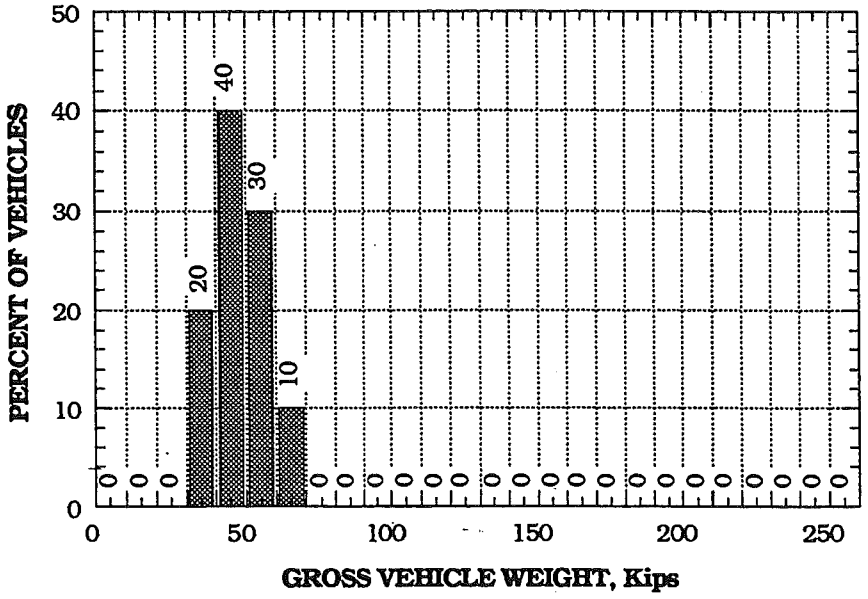


Fig. 7-14. DA/M10, 7 Axle GVW Histogram.

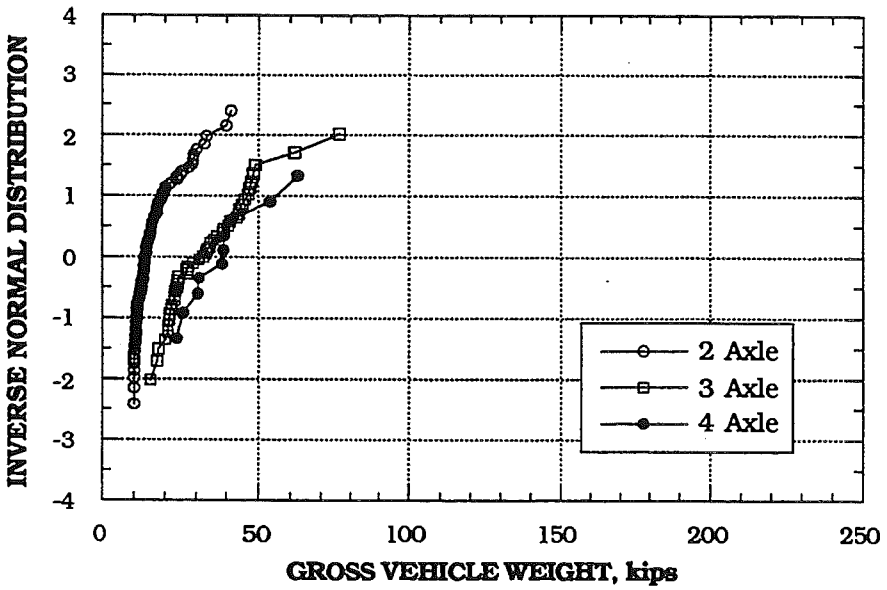


Fig. 7-15. DA/M10, 2, 3, and 4 Axle GVW Distributions.

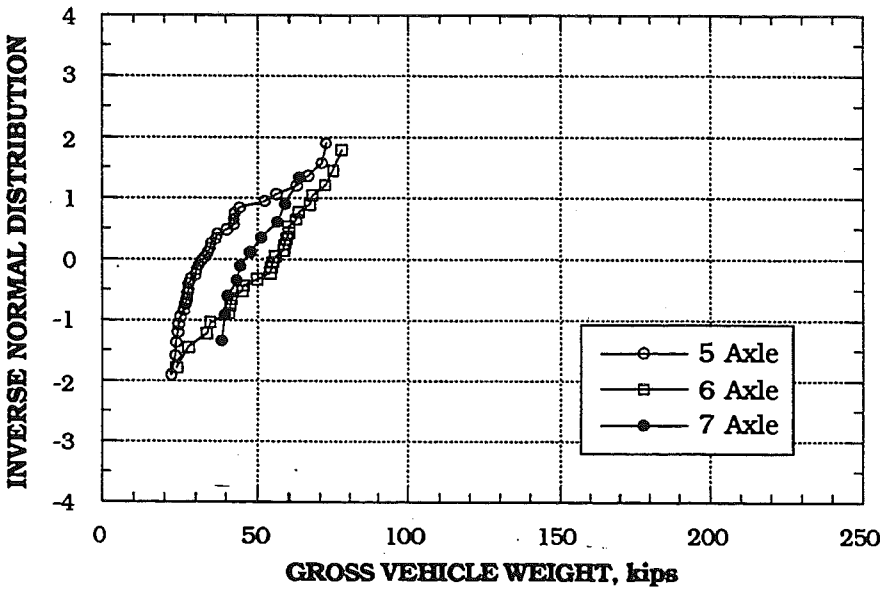


Fig. 7-16. DA/M10, 5, 6, and 7 Axle GVW Distributions.

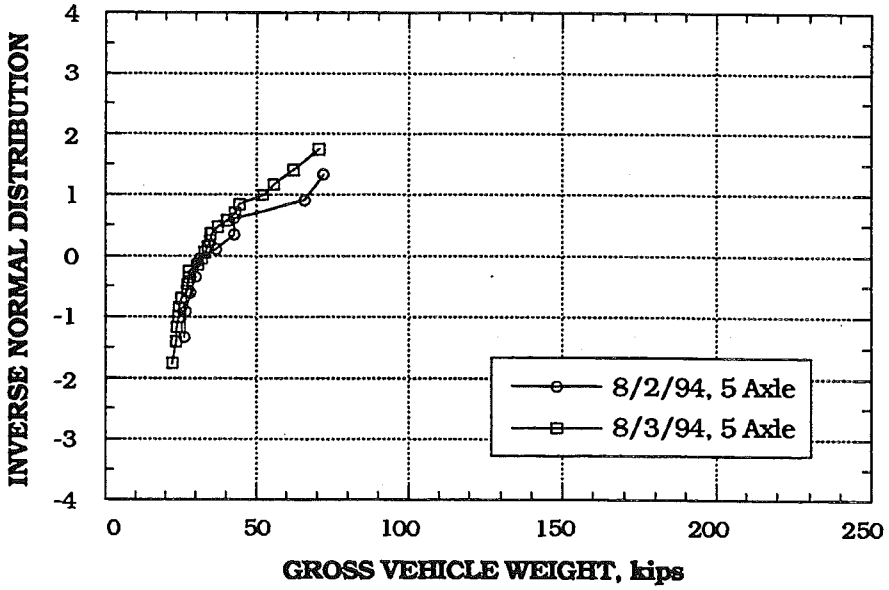


Fig. 7-17. DA/M10, Daily 5 Axle GVW Distributions.

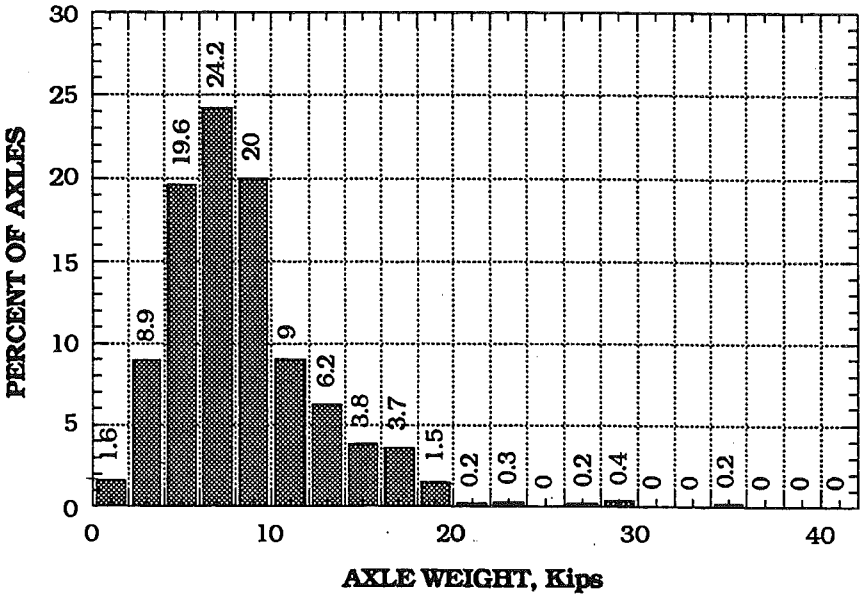


Fig. 7-18. DA/M10, Axle Weight Histogram.

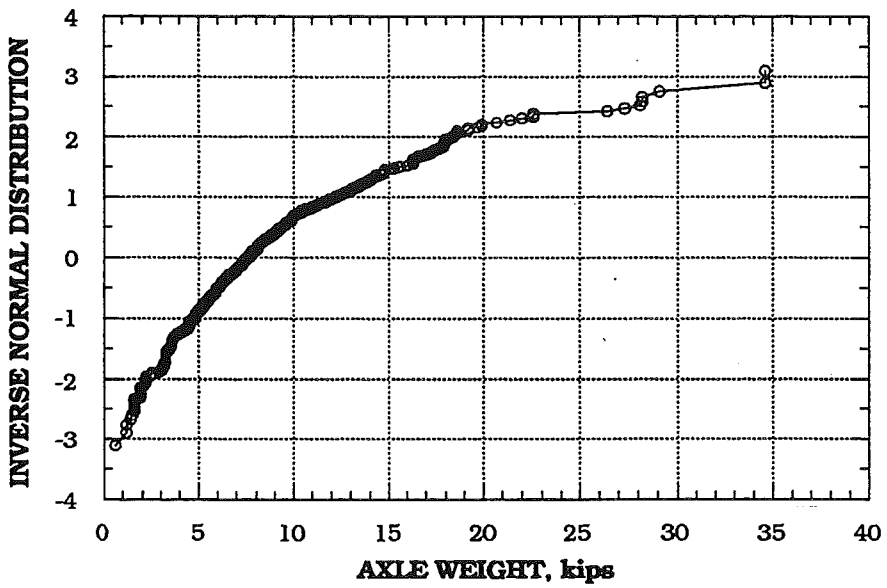


Fig. 7-19. DA/M10, Axle Weight Distribution.

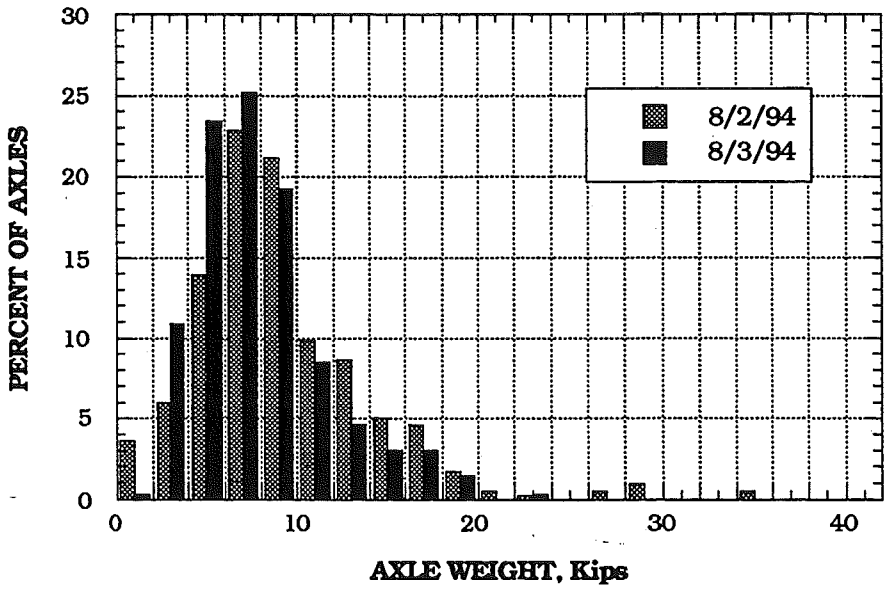


Fig. 7-20. DA/M10, Daily Axle Weight Histogram.

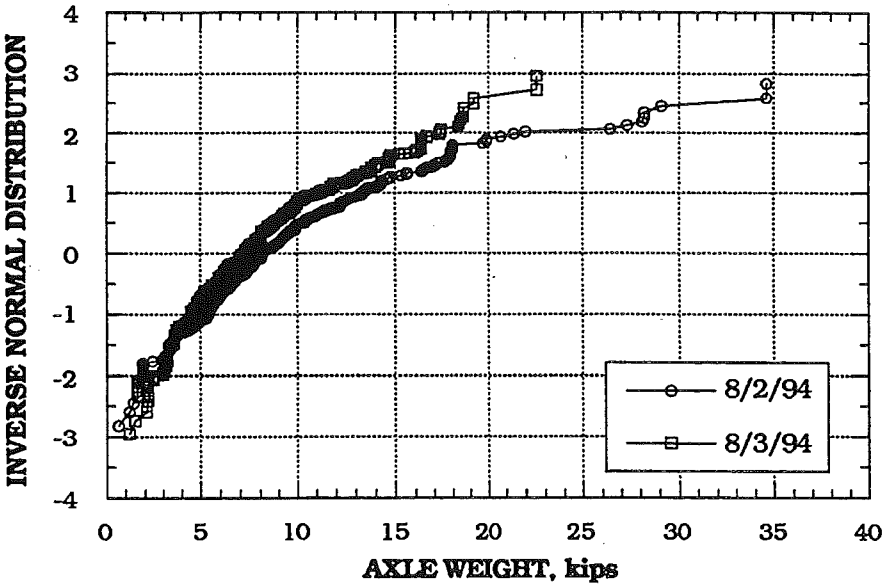


Fig. 7-21. DA/M10, Daily Axle Weight Distributions.

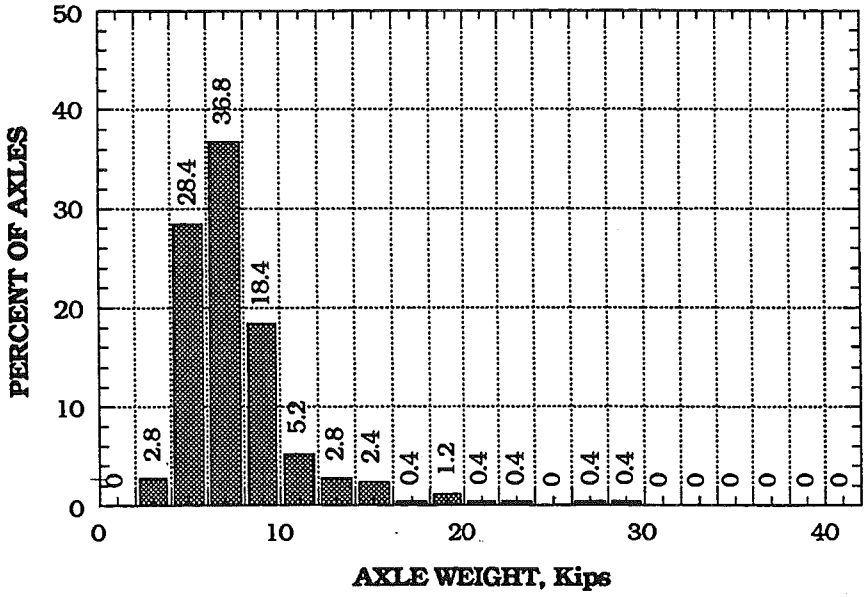


Fig. 7-22. DA/M10, Axle Weight Histogram of 2 Axle Vehicles.

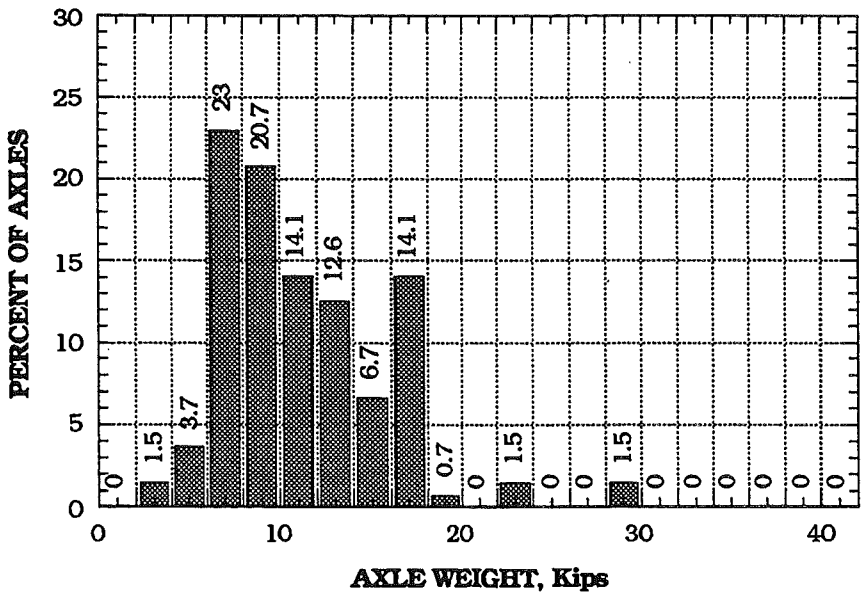


Fig. 7-23. DA/M10, Axle Weight Histogram of 3 Axle Vehicles.

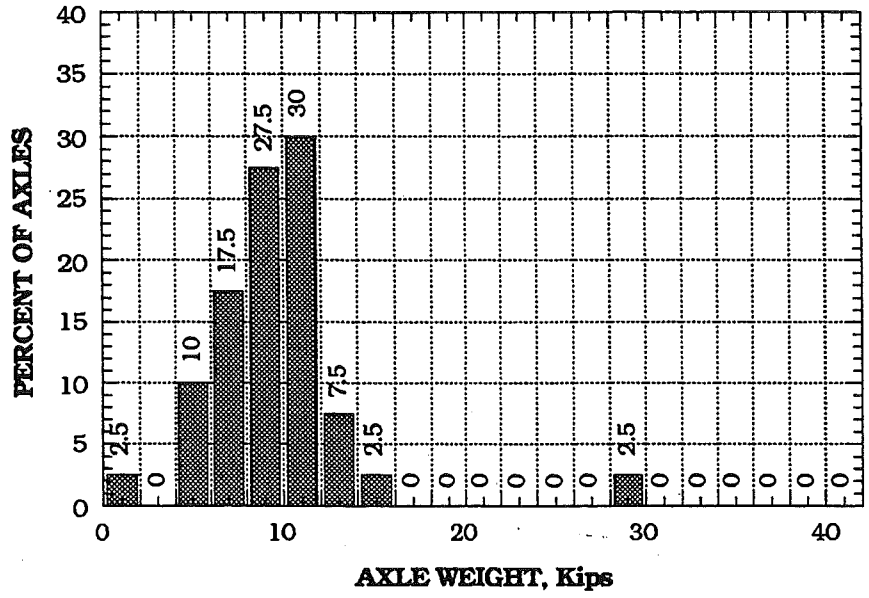


Fig. 7-24. DA/M10, Axle Weight Histogram of 4 Axle Vehicles.

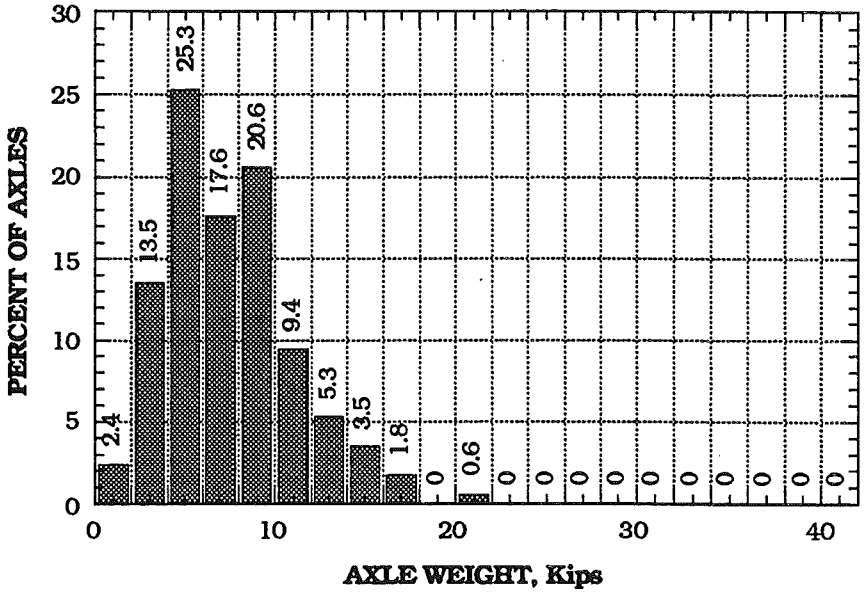


Fig. 7-25. DA/M10, Axle Weight Histogram of 5 Axle Vehicles.

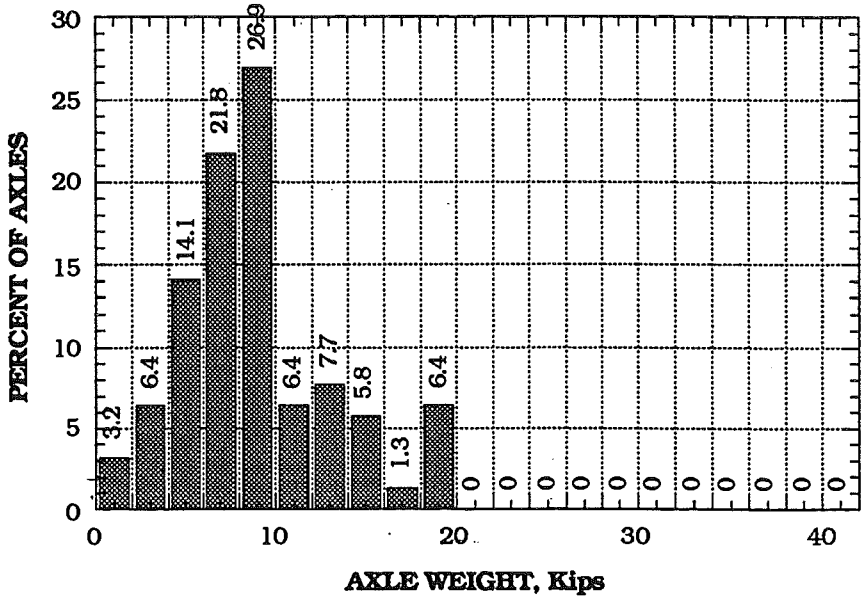


Fig. 7-26. DA/M10, Axle Weight Histogram of 6 Axle Vehicles.

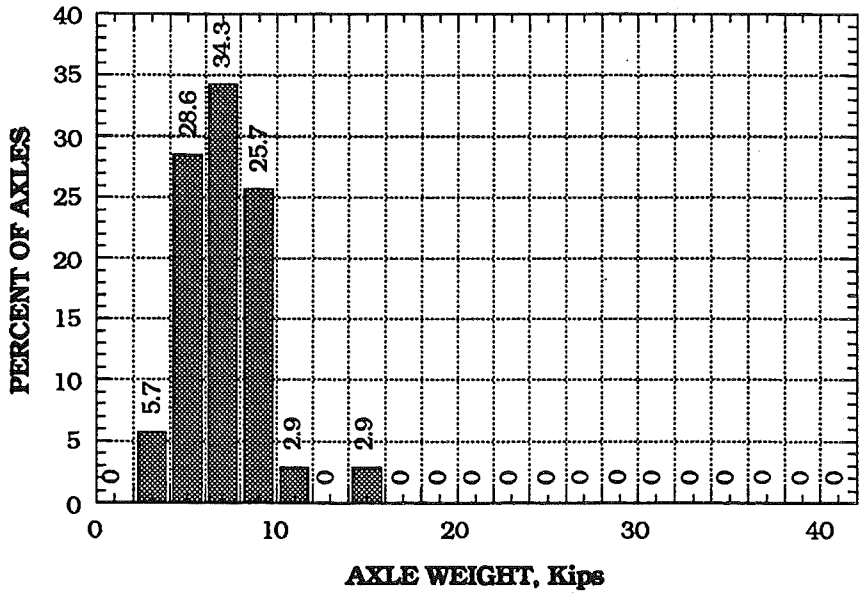


Fig. 7-27. DA/M10, Axle Weight Histogram of 7 Axle Vehicles.

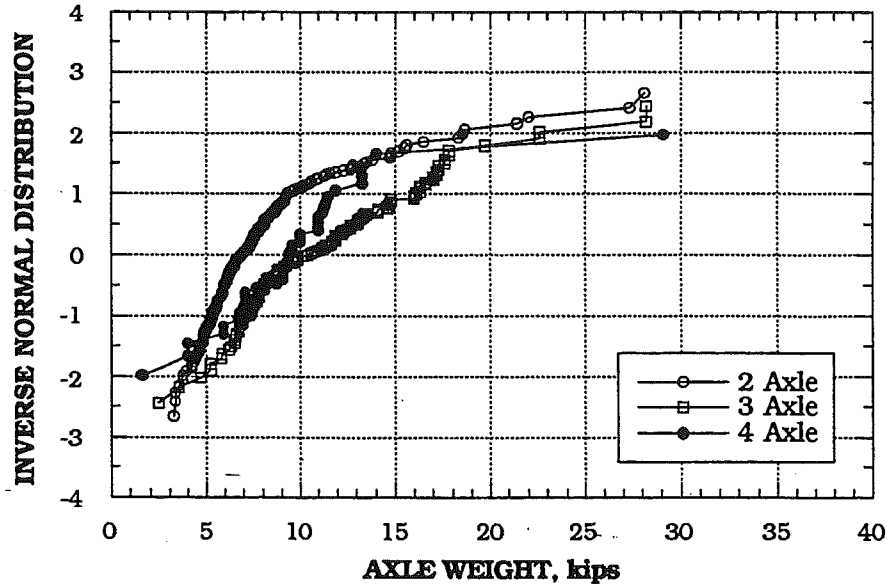


Fig. 7-28. DA/M10, Axle Weight Distributions of 2, 3, and 4 Axles.

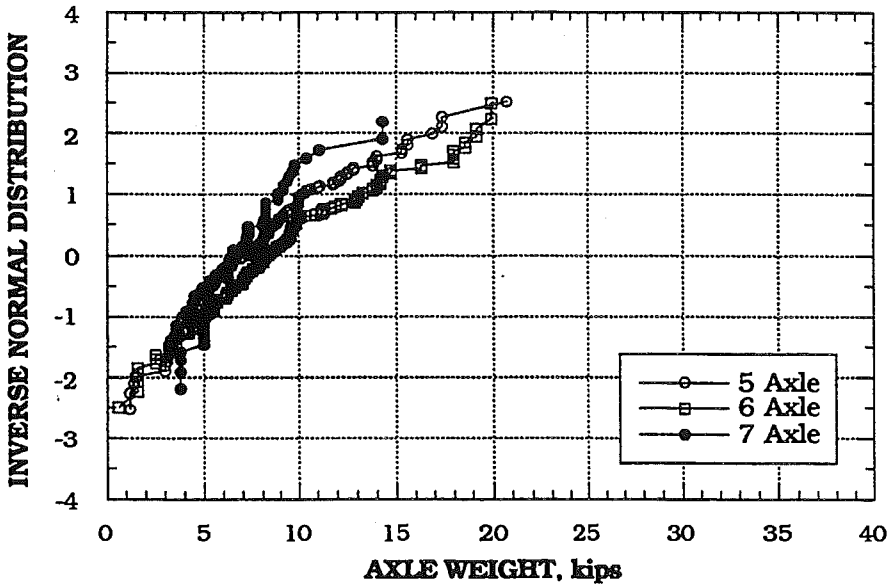


Fig. 7-29. DA/M10, Axle Weight Distributions of 5, 6, and 7 Axles.

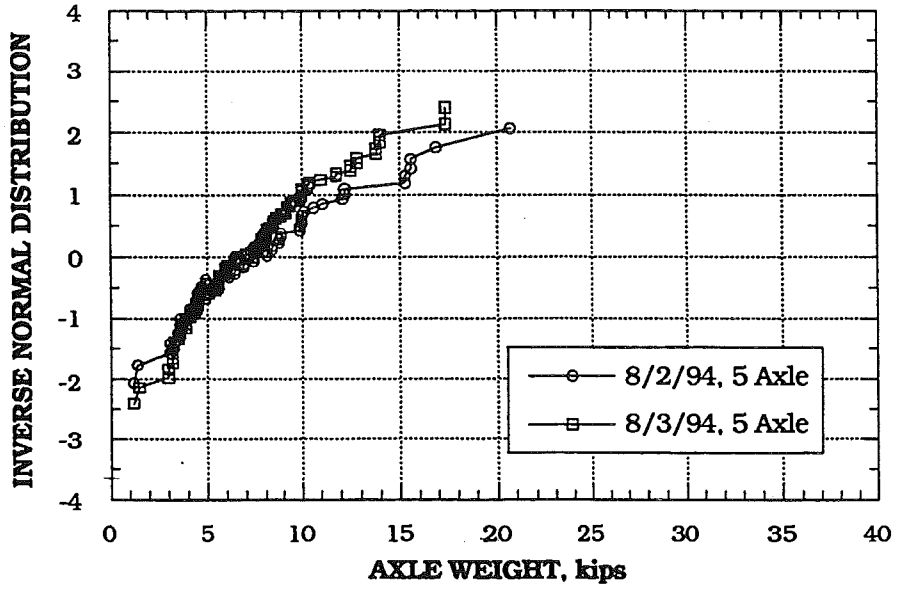


Fig. 7-30. DA/M10, Daily Axle Weight Distributions of 5 Axles.

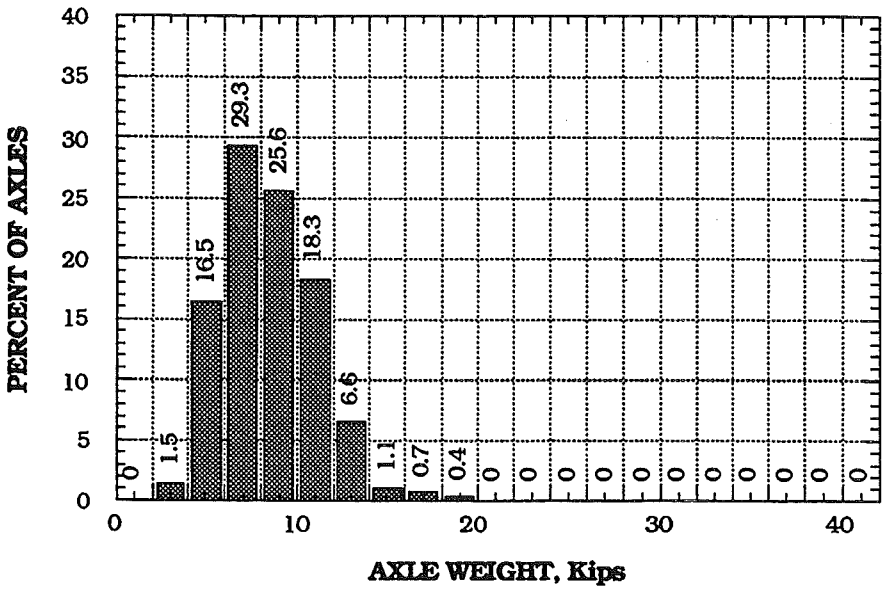


Fig. 7-31. DA/M10, Steering Axle Weight Histogram.

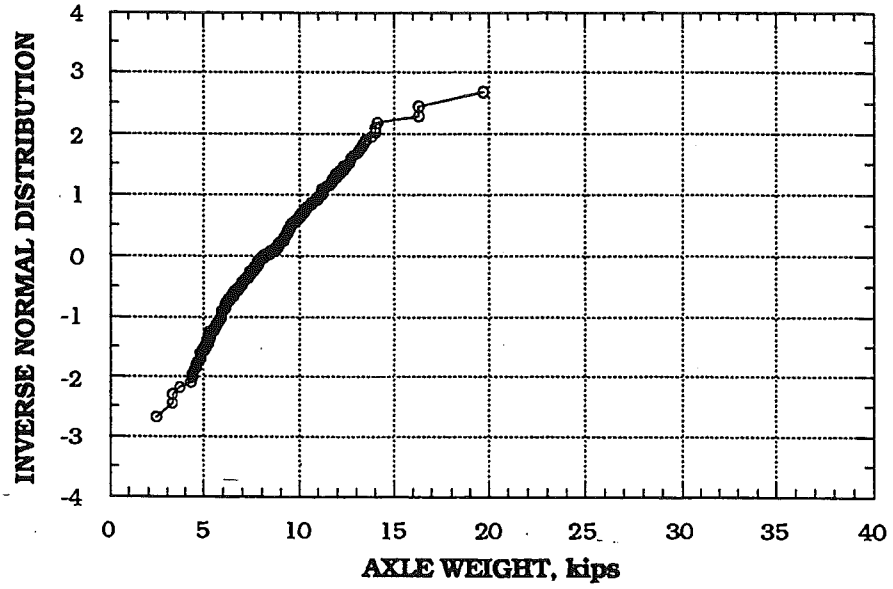


Fig. 7-32. DA/M10, Steering Axle Weight Distribution.

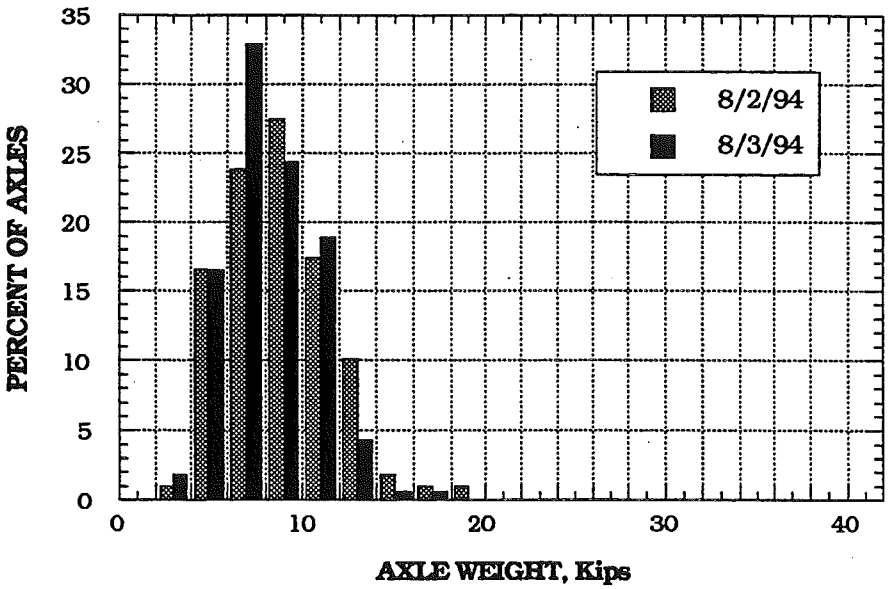


Fig. 7-33. DA/M10, Daily Steering Axle Weight Histogram.

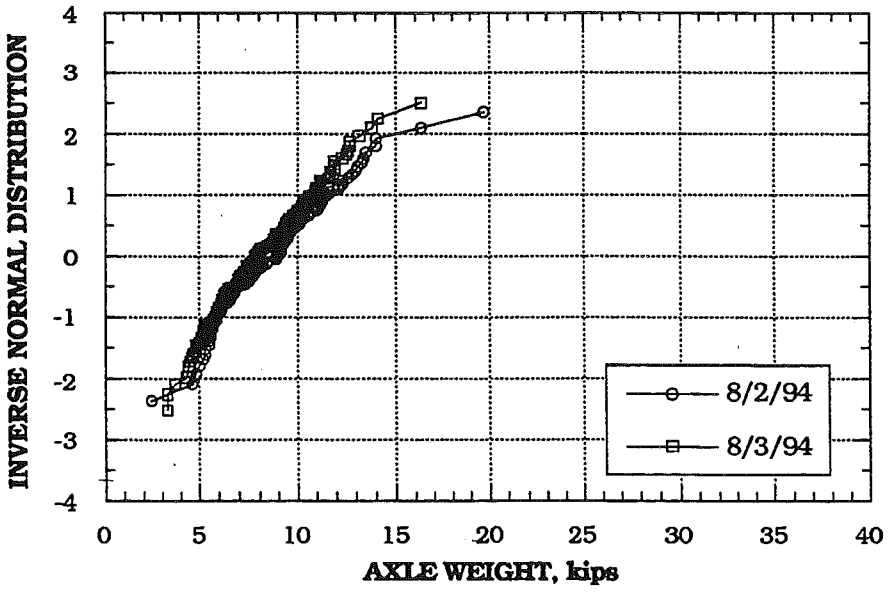


Fig. 7-34. DA/M10, Daily Steering Axle Weight Distributions.

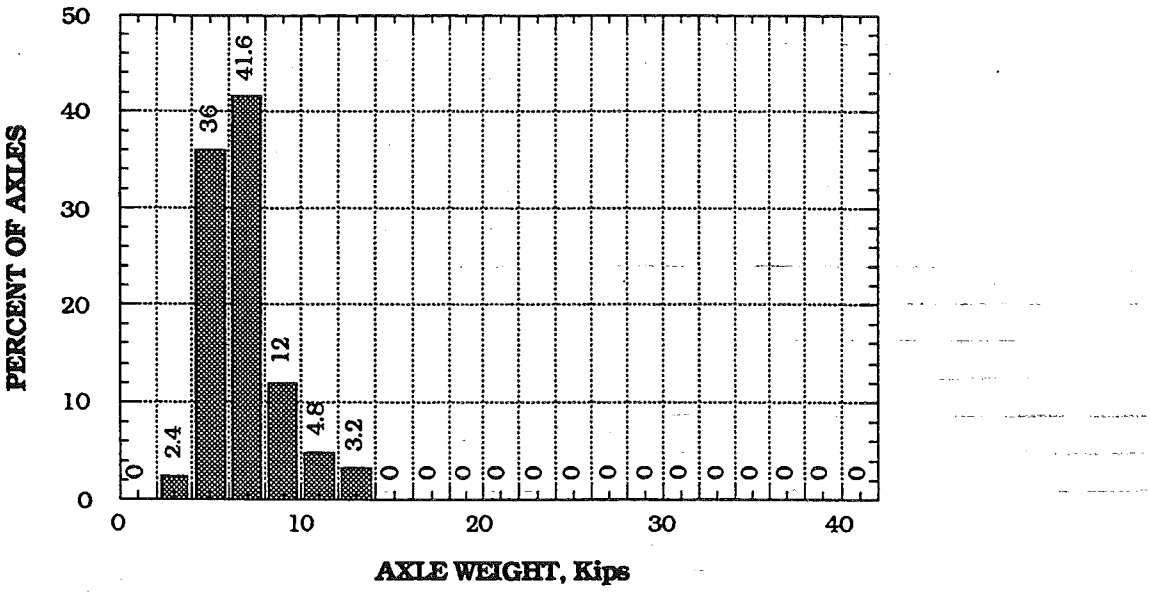


Fig. 7-35. DA/M10, Steering Axle Weight Histogram of 2 Axle Vehicles.

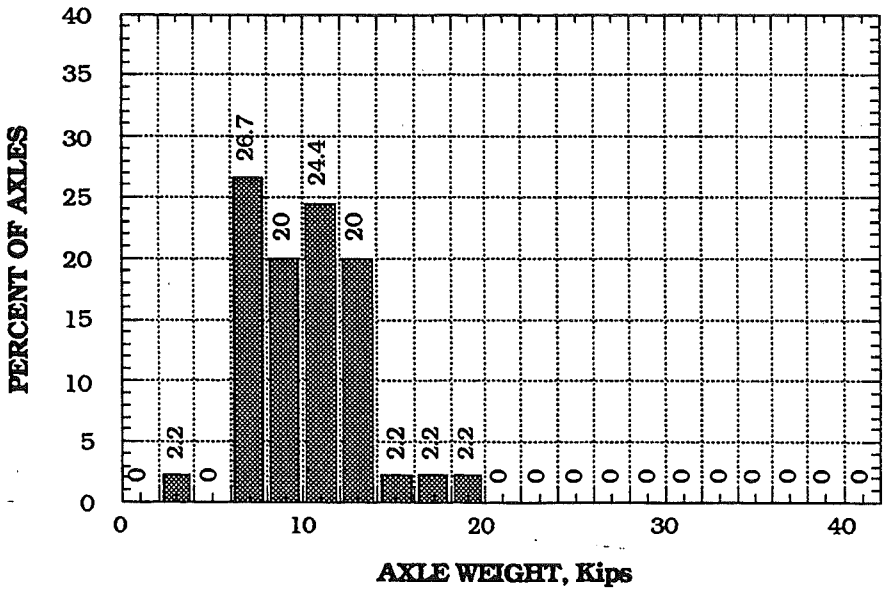


Fig. 7-36. DA/M10, Steering Axle Weight Histogram of 3 Axle Vehicles.

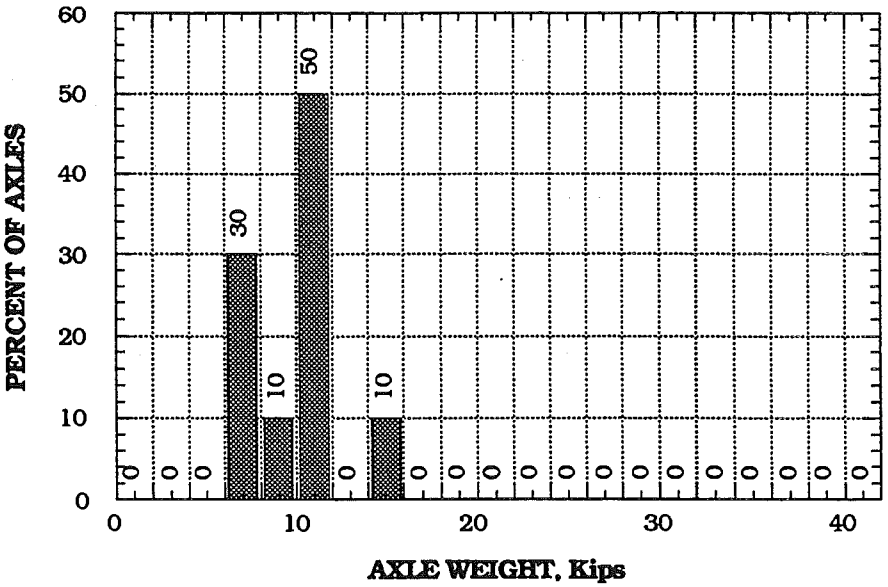


Fig. 7-37. DA/M10, Steering Axle Weight Histogram of 4 Axle Vehicles.

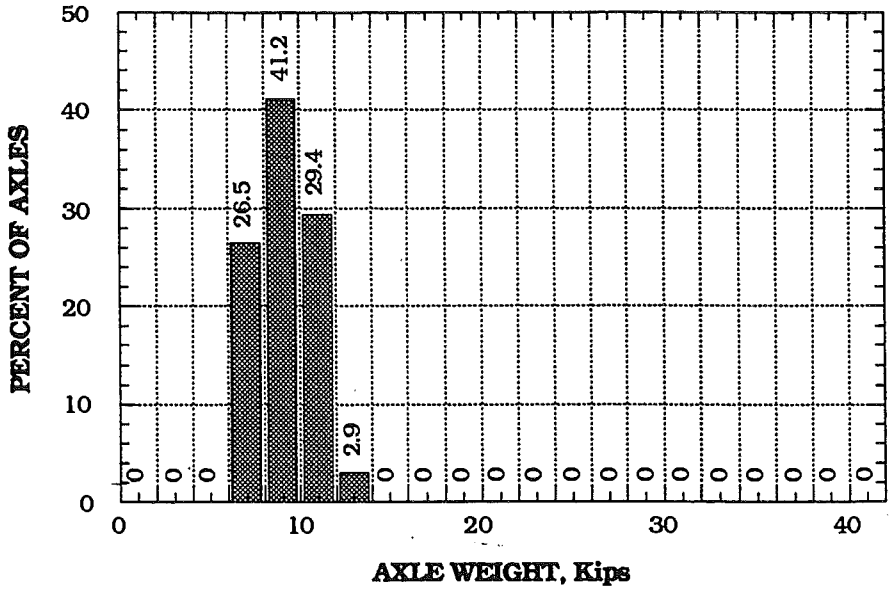


Fig. 7-38. DA/M10, Steering Axle Weight Histogram of 5 Axle Vehicles.

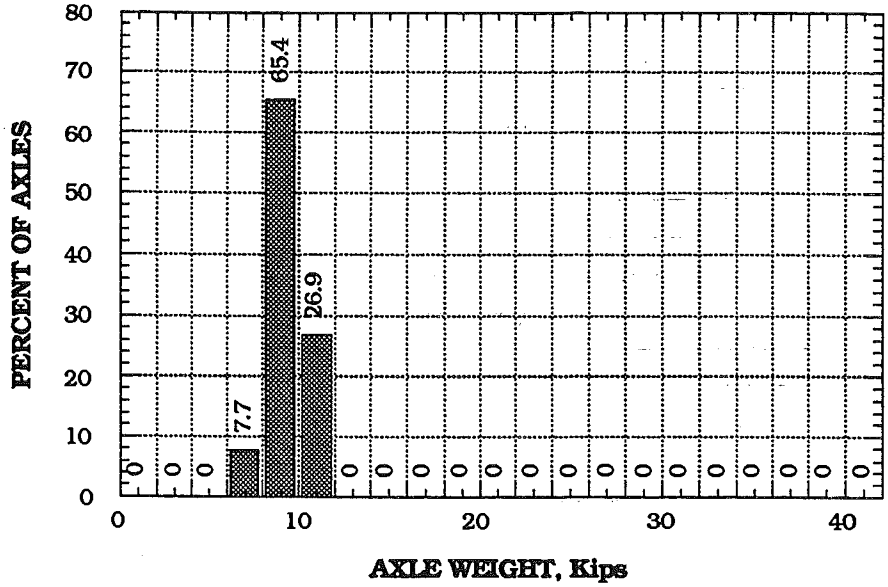


Fig. 7-39. DA/M10, Steering Axle Weight Histogram of 6 Axle Vehicles.

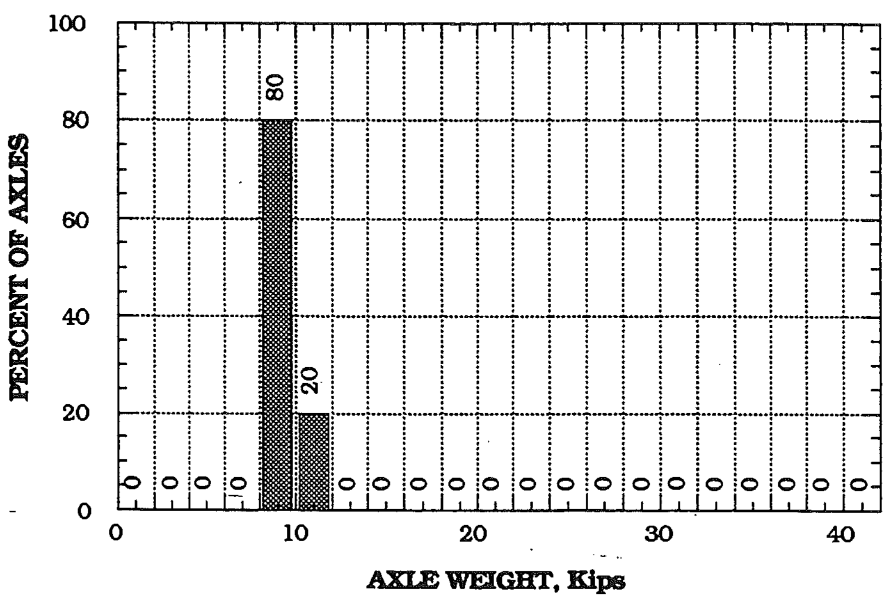


Fig. 7-40. DA/M10, Steering Axle Weight Histogram of 7 Axle Vehicles.

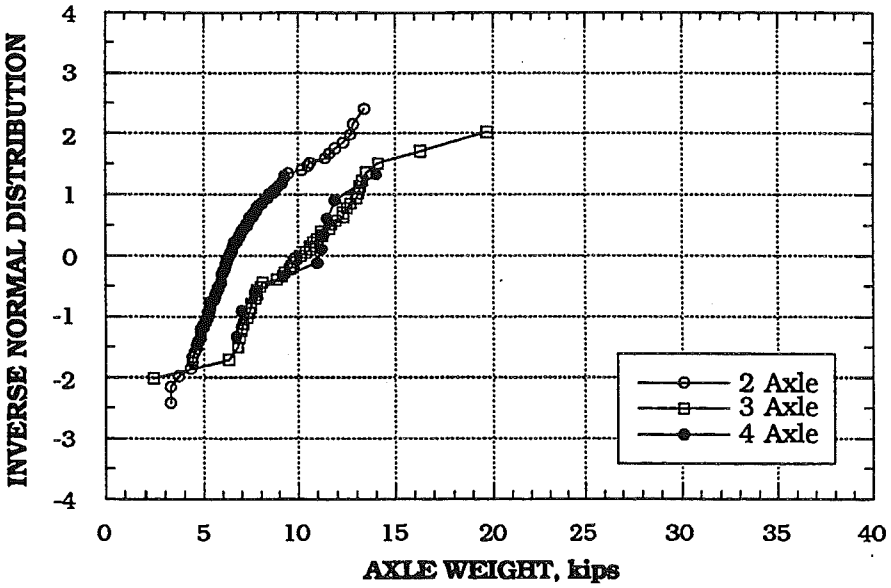


Fig. 7-41. DA/M10, Steering Axle Weight Distributions of 2, 3, and 4 Axle Vehicles.

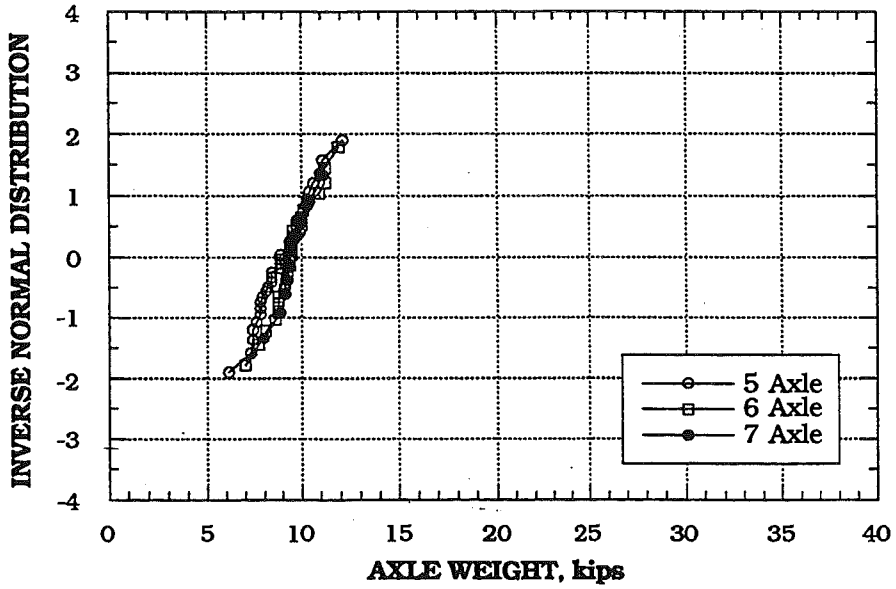


Fig. 7-42. DA/M10, Steering Axle Weight Distributions of 5, 6, and 7 Axle Vehicles.

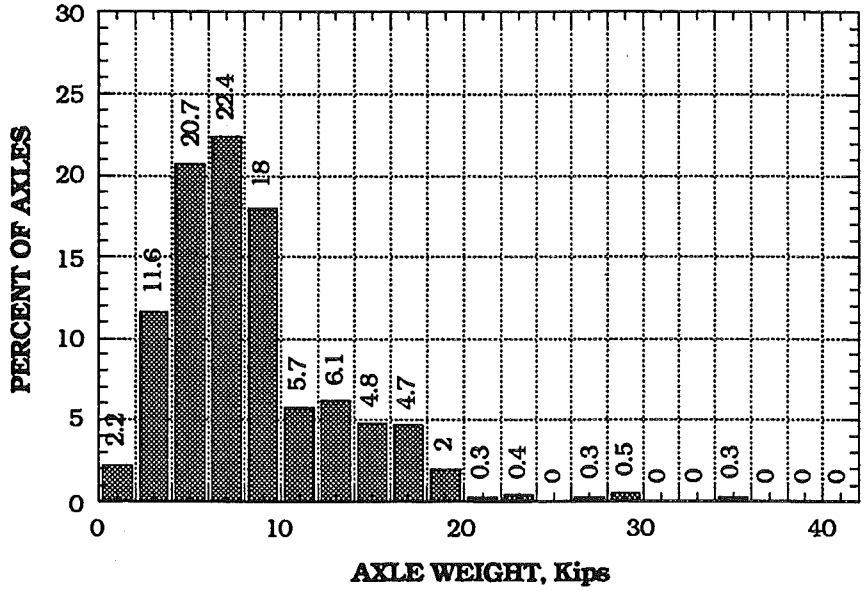


Fig. 7-43. DA/M10, Non-Steering Axle Weight Histogram.

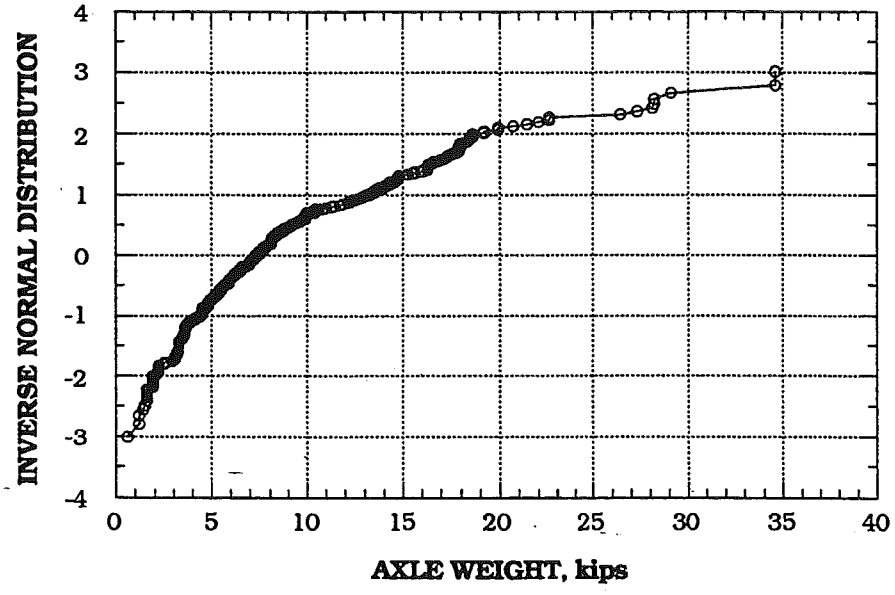


Fig. 7-44. DA/M10, Non-Steering Axle Weight Distributions.

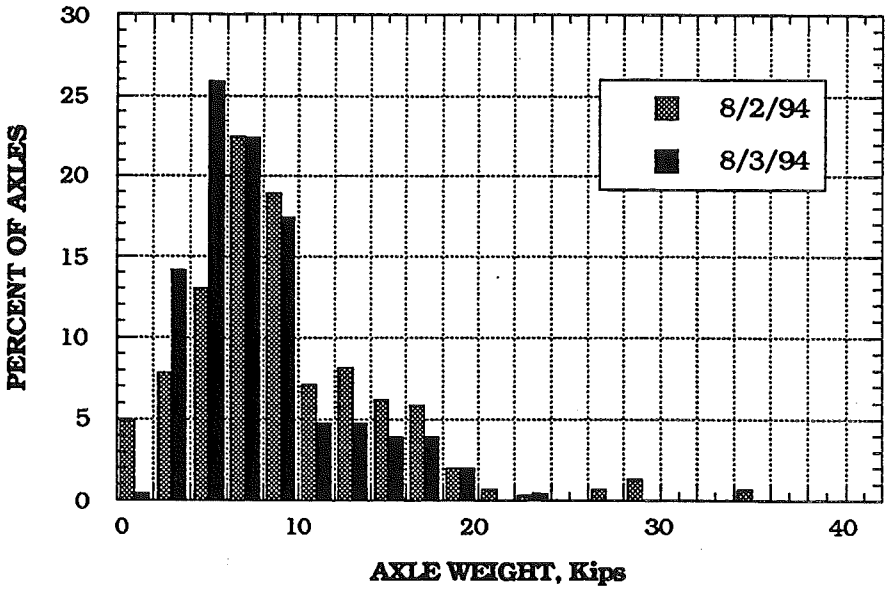


Fig. 7-45. DA/M10, Daily Non-Steering Axle Weight Histogram.

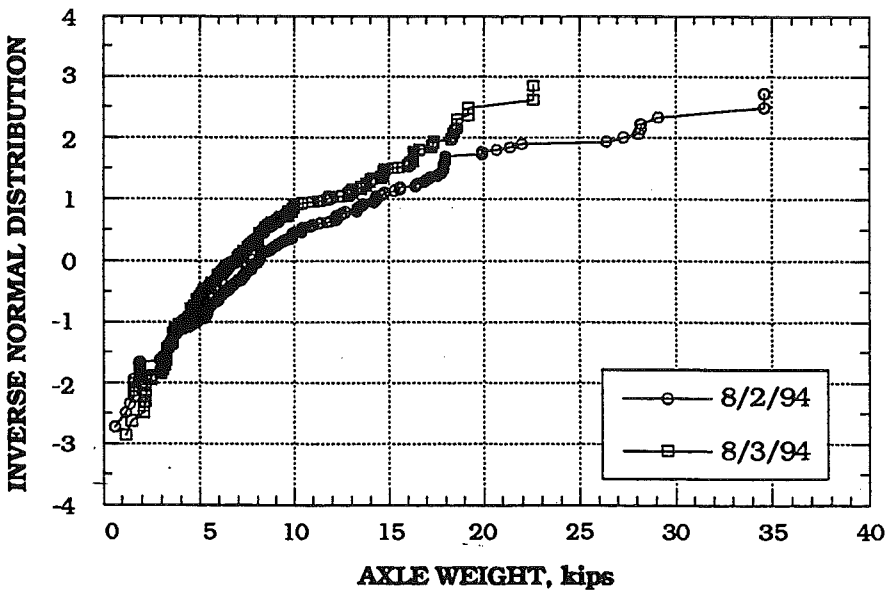


Fig. 7-46. DA/M10, Daily Non-Steering Axle Weight Distributions

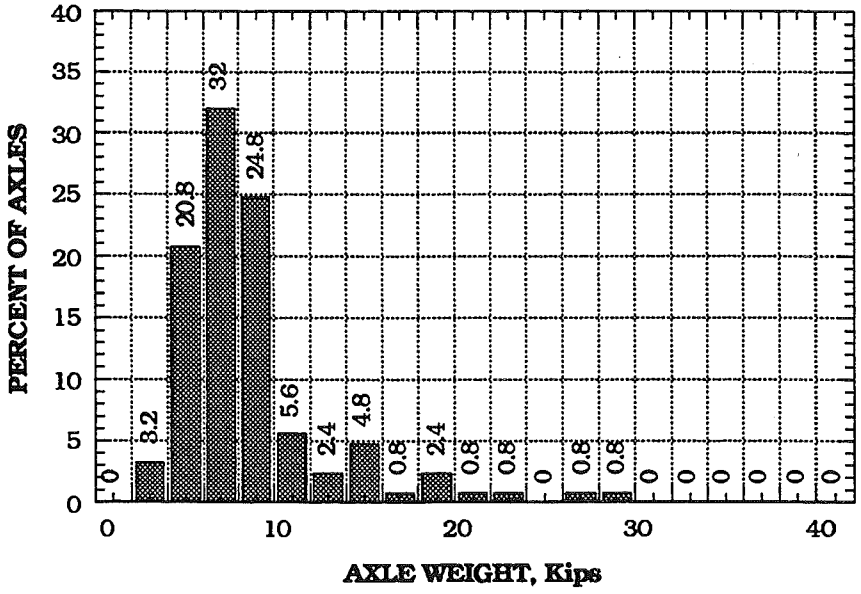


Fig. 7-47. DA/M10, Non-Steering Axle Weight Histogram of 2 Axles.

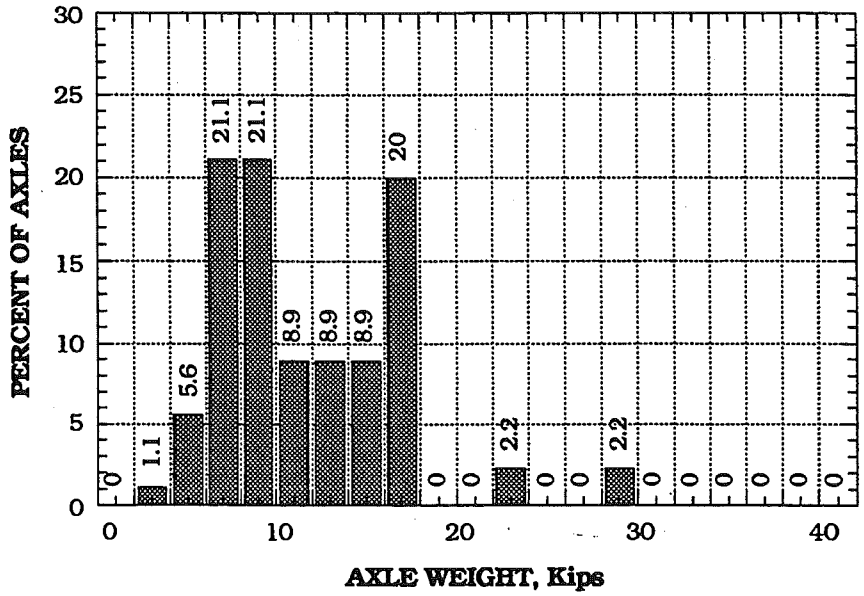


Fig. 7-48. DA/M10, Non-Steering Axle Weight Histogram of 3 Axles.

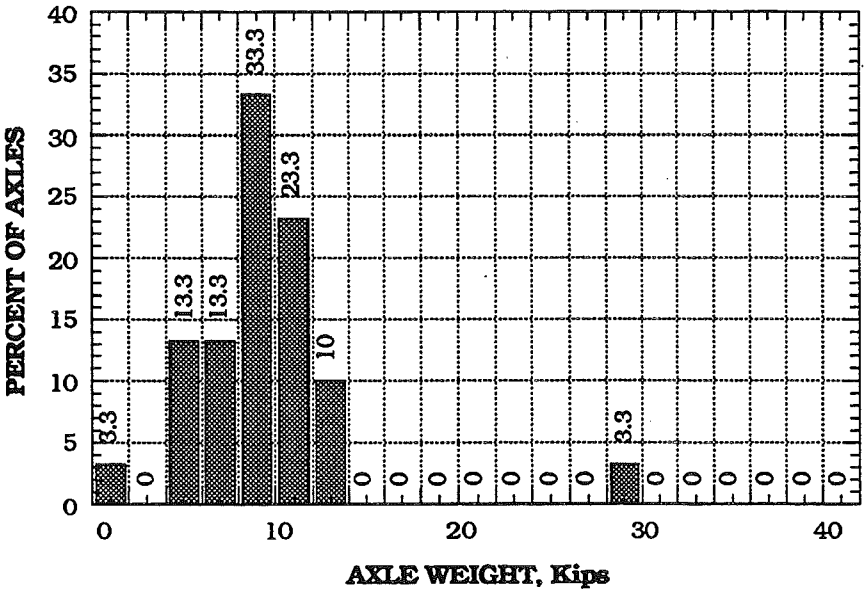


Fig. 7-49. DA/M10, Non-Steering Axle Weight Histogram of 4 Axles.

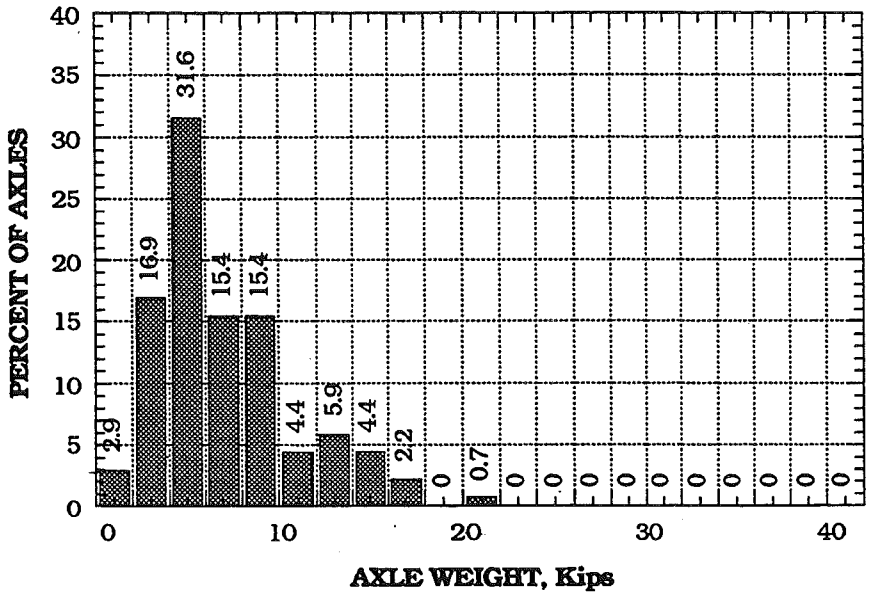


Fig. 7-50. DA/M10, Non-Steering Axle Weight Histogram of 5 Axles.

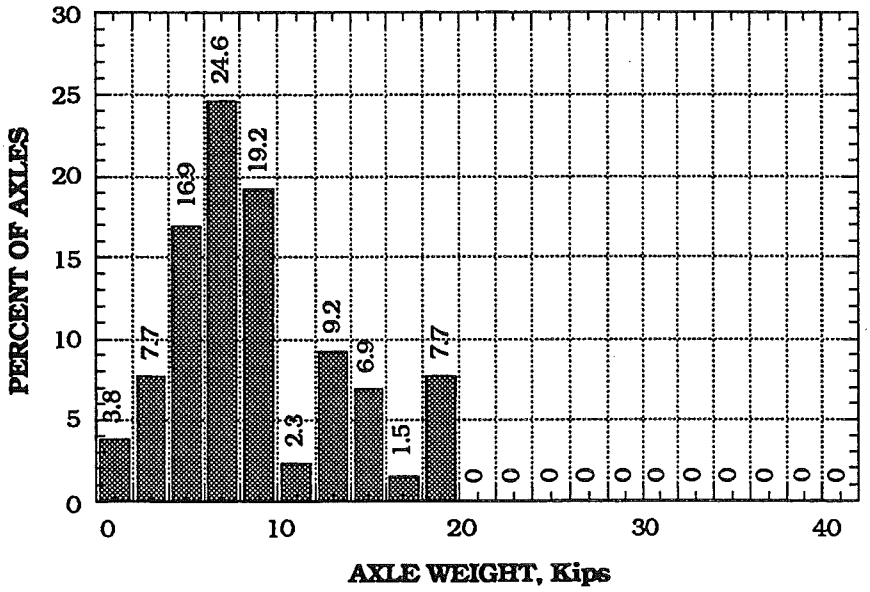


Fig. 7-51. DA/M10, Non-Steering Axle Weight Histogram of 6 Axles.

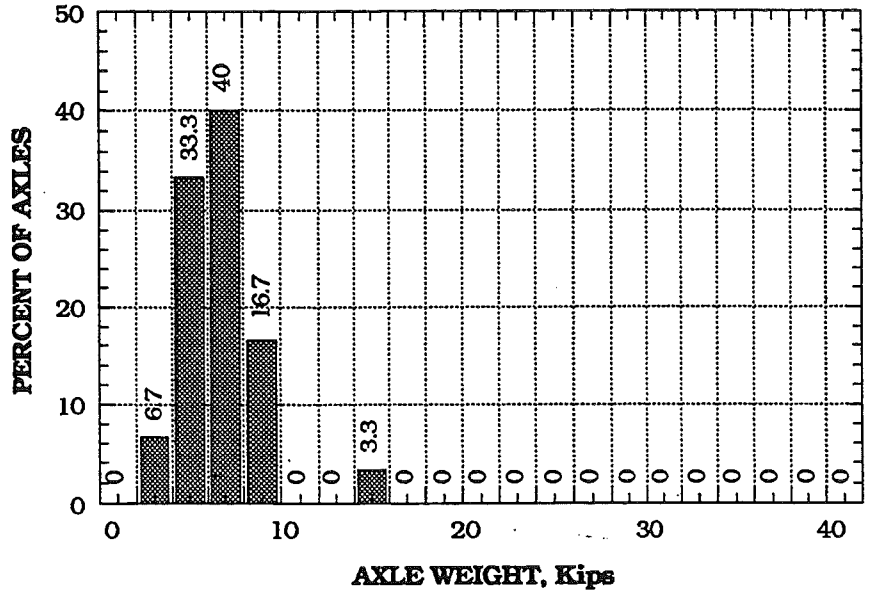


Fig. 7-52. DA/M10, Non-Steering Axle Weight Histogram of 7 Axles.

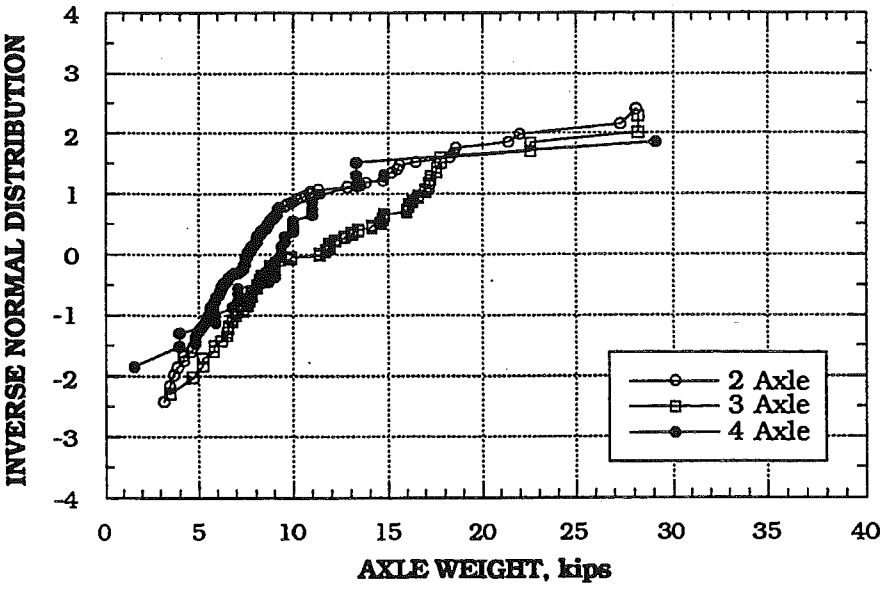


Fig. 7-53. DA/M10, Non-Steering Axle Weight Distributions of 2, 3, and 4 Axle Vehicles.

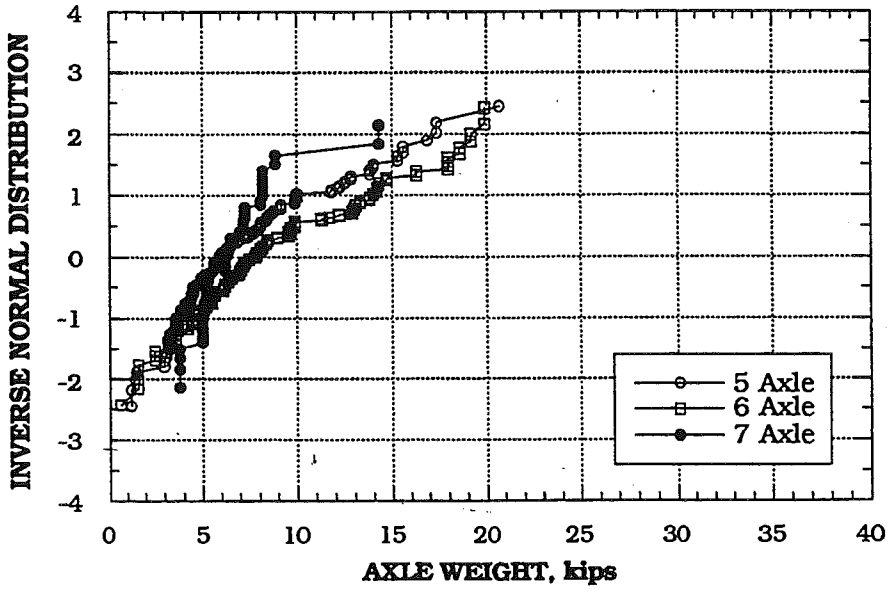
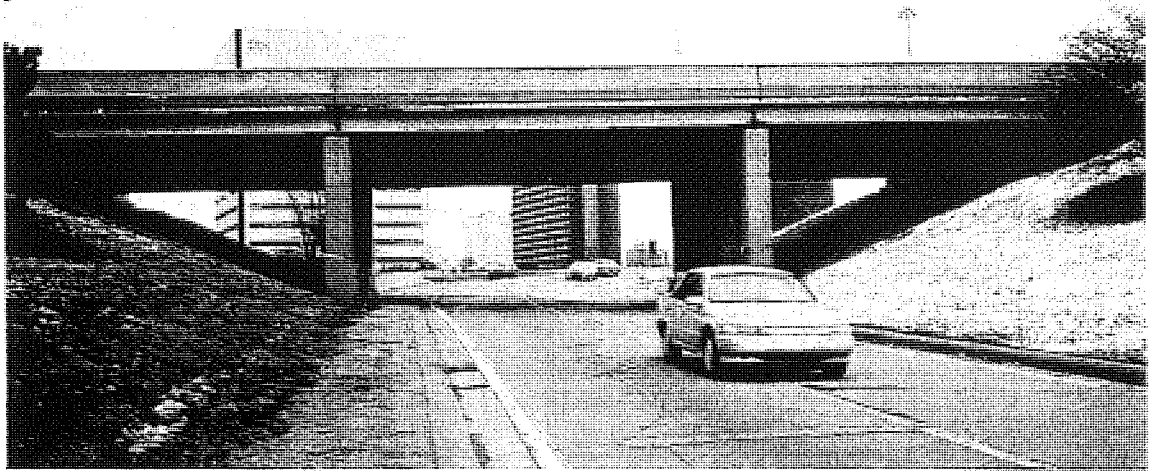


Fig. 7-54. DA/M10, Non-Steering Axle Weight Distributions of 5, 6, and 7 Axle Vehicles.

8. BRIDGE ON SOUTHBOUND M-39 RAMP (SOUTHFIELD ROAD) OVER M-10 NORTHBOUND (LODGE FREEWAY) IN SOUTHFIELD (M 39/ M10)

8. 1 Description of the Bridge

Bridge M39/M10 is on the ramp which carries southbound traffic from M - 39 over northbound M-10 to southbound M-10 (Lodge Freeway) in Southfield. The view, elevation, plan view, cross section and other details are shown in Fig. 8-1 and 8-2. Measurements were taken in the span No. 1 (in the direction traffic). The investigated span is 32'- 3 3/8" and the width of the bridge is 46'-11" (three one way traffic lanes) with a skewness of 6 degrees and consists of eight girders spaced at 6'- 0" which are composite with the concrete slab.



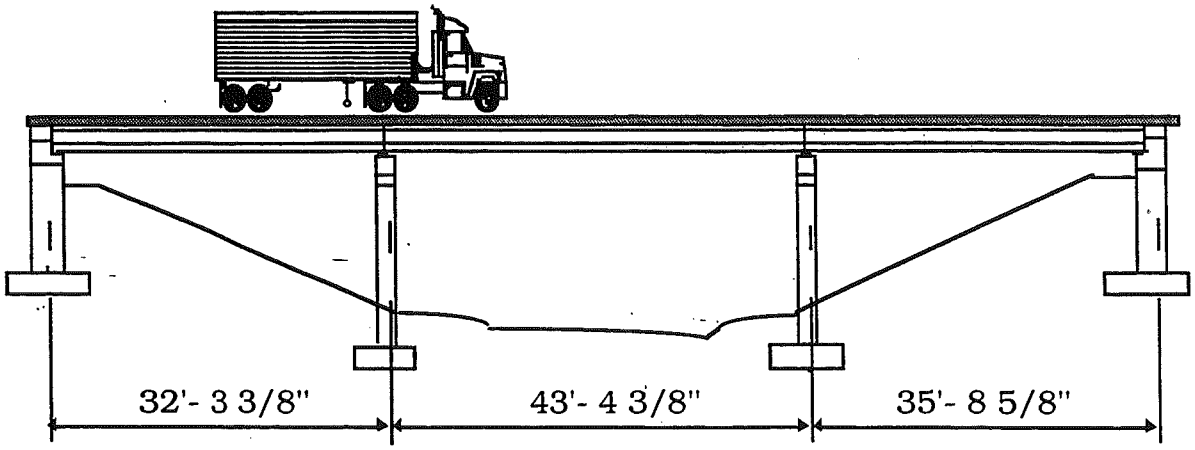


Fig. 8-1. Bridge M39/M10, M-39 (Southfield Road) over M-10 Northbound (Lodge Freeway) in Southfield. View and Side Elevation.

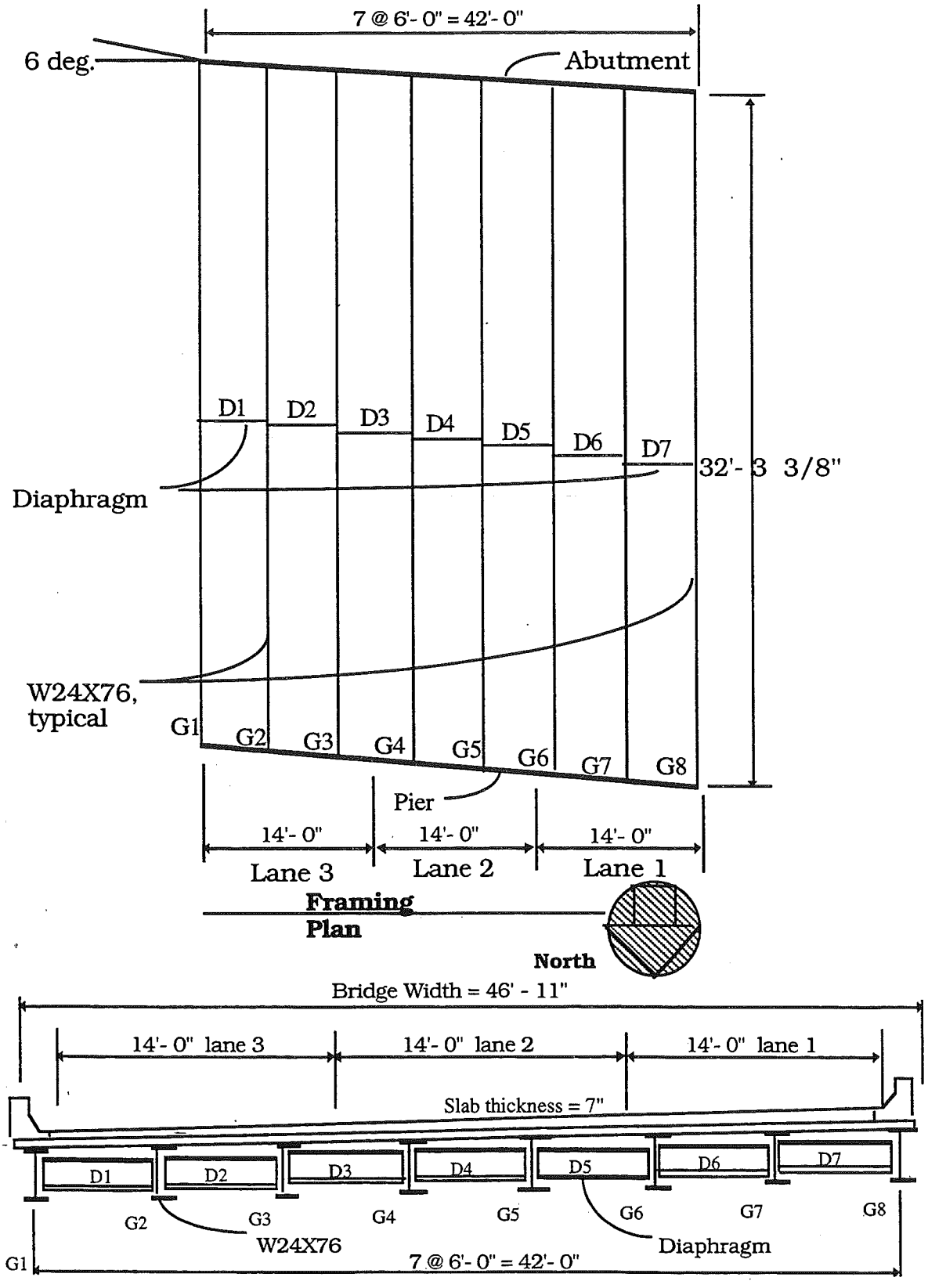


Fig. 8-2. Bridge M39/M10, M-39 Southbound over M-10 Northbound. Plan View and Cross Section of Entrance Span.

8.2 Weigh-in-Motion Measurements

Weigh-in-motion (WIM) statistics are presented in Table 8-1 to Table 8-6 and in Fig. 8-3 to Fig. 8-42. This data includes all trucks with a gross vehicle weight (GVW) of 10 kips and greater for 2-axle vehicles, and of 15 kips and greater for 3 or more axle vehicles, regardless of axle weight. This filtered WIM data has been used for all analysis of GVW and axle weight. The data may also include permit loads. The data measured by WIM are recorded in the FHWA card seven 80-column format.

Table 8-1 summarizes an estimated average daily truck traffic (ADTT) in one direction, and the total number of vehicles weighed by date and by different number of axle vehicles. Fig. 8-3 is the frequency histogram of trucks corresponding to different number of axles. Only a few 11 axle trucks were observed. Fig. 8-4 shows the daily frequency histogram of trucks. There is slight difference by the date of measurement. Table 8-2 presents Federal Highway Administration (FHWA) truck class frequency vs lane statistics. Federal Highway Administration (FHWA) axle configuration class is presented in the Appendix A. Note that the last digit from the FHWA axle class is not included in Table 8-2.

Table 8-3 is the GVW statistics of maximum, mean, median, standard deviation, and percentage of overloaded vehicles. The statistics are given for all vehicles and separately different number of axle vehicles. The GVW limit in Table 8-3 might not be the legal limit. It is difficult to determine the GVW limit with only number of axles. It depends not only on number of axles, but axle spacings. Thus, it was decided to assign reasonably high GVW limits and to give some ideas about how heavy the vehicles were. Fig. 8-5 and Fig. 8-6 are the histogram of GVW and the corresponding cumulative distribution function (CDF) of GVW for all trucks observed and measured on M39/M10 respectively. In Fig. 8-6, each circle represents one truck in the data file. From the graph and from Table 8-3 the heaviest

vehicle observed weighed 148 kips with a mean GVW of 31 kips. Vehicles over the GVW limit were 8 percent. Results of the individual day measurements are shown in Fig. 8-7 and Fig. 8-8. The day to day CDF's are different in shape and average GVW with the largest difference at the upper tail of the distribution. GVW histograms for different number of axle vehicles are presented in Fig. 8-9 to Fig. 8-12. The corresponding CDF's are shown in Fig. 8-13. Overloaded 5-axle vehicles were nine percent. The data base contains two passing 11-axle vehicles, which was not sufficient number to observe a general trend. For comparison of the daily distributions of 5-axle vehicles, the CDF's for both days are plotted in Fig. 8-14. Again, difference in the day to day distributions is apparent.

Table 8-4 is the axle weight statistics of maximum, mean, median, standard deviation, and percent of overloaded axles. The statistics are given for all vehicles and separately different number of axle vehicles. In this table, axle weight limits were intended to give some ideas about how heavy the axles were. The statistics depend on axle spacings rather than number of axles. Fig. 8-15 and Fig. 8-16 are the histogram of axle weight for all vehicles and the corresponding CDF respectively. The maximum axle weight observed at M39/M10 was 49 kips with a mean of 10 kips. Axles with axle weight of 18 kips and greater were 10 percent. Fig. 8-17 and Fig. 8-18 show the daily axle weight histogram and CDF's. There is slight difference in the axle weight distributions, however a similar trend in the distributions is evident. Axle weight histograms for different number of axle vehicles are presented in Fig. 8-19 to Fig. 8-22. The corresponding CDF's are shown in Fig. 8-23. Overloaded axles for 5 and 11-axle vehicles were eight percent and 31 percent respectively. The daily CDF's of axle weight for 5-axle vehicles are plotted in Fig. 8-24 for comparison of the daily distribution. Again, slight difference in the daily distributions can be observed. Measurement of extended period of time might reduce this difference.

Table 8-5 is the steering axle weight statistics of maximum, mean, median, and standard deviation of all vehicles and different

number of axle vehicles. Fig. 8-25 and Fig. 8-26 are the steering axle weight histogram for all vehicles and the corresponding CDF respectively. The maximum observed steering axle weight was 35 kips with a mean of 12 kips. Fig. 8-27 and Fig. 8-28 show the daily steering axle weight histogram and CDF's. Steering axle weight histograms for different number of axle vehicles are presented in Fig. 8-29 to Fig. 8-32. The corresponding CDF's are shown in Fig. 8-33.

Table 8-6 is the non-steering axle weight statistics of maximum, mean, median, and standard deviation of all vehicles and different number of axle vehicles. Fig. 8-34 and Fig. 8-35 are the non-steering axle weight histogram for all vehicles and the corresponding CDF. The maximum non-steering axle weight was 49 kips with a mean of nine kips. Fig. 8-36 and Fig. 8-37 show the daily non-steering axle weight histogram and CDF's. Non-steering axle weight histograms for different number of axle vehicles are presented in Fig. 8-38 to Fig. 8-41. The corresponding CDF's are shown in Fig. 8-42.

The steering and non-steering axle weight CDF's of Fig. 8-26 and Fig. 8-35 indicate a significant difference in both variation and magnitudes. The standard deviation of steering axle weight was five kips with a maximum of 35 kips while the standard deviation of non-steering axle weight was eight kips with a maximum of 49 kips.

Review of the results indicates that most of the truck weights are within legal limits. Overloaded 5-axle vehicles were nine percent. Vehicles over the GVW limit were 8 percent. Overloaded axles for 5-axle vehicles were eight percent. Axles with axle weight of 18 kips and greater were 10 percent. There were only two 11-axle vehicles, which was not sufficient number to observe a general trend. There was a difference in the day to day GVW distributions.

Table 8-1. M39/M10, Number of Trucks Weighed and Estimated ADTT.

Number of Trucks Weighed Gross Vehicle Weight > 10 Kips for 2 Axle Vehicles, Gross Vehicle Weight > 15 Kips for 3 or more Axle Vehicles.				
Date	8/24/94	8/25/94	Total	Vehicles (%)
2 Axles	239	111	350	58.5
3 Axles	37	22	59	9.9
4 Axles	23	20	43	7.2
5 Axles	61	57	118	19.7
6 Axles	6	5	11	1.8
7 Axles	5	5	10	1.7
8 Axles	1	1	2	0.3
9 Axles	0	2	2	0.3
10 Axles	1	0	1	0.2
11 Axles	2	0	2	0.3
All Vehicles	375	223	598	100.0
Estimated ADTT = 1500 Trucks (in one direction)				

Table 8-2. Bridge M39/M10, Truck Class vs Lane Statistics.

Truck Class (FHWA)	Right Lane (1) (%)	Center Lane (2) (%)	Total (%)
4	0.0	0.0	0.0
5	13.9	30.	43.9
6	4.1	1.5	5.6
7	0.7	0.1	0.8
8	3.1	2.6	5.7
9	9.6	3.6	13.2
10	1.0	0.2	1.2
11	0.1	0.0	0.1
12	0.0	0.0	0.0
13	0.0	0.0	0.0
14	4.2	25.3	29.5
Total Lane %	36.5	63.5	100.0

Table 8-3. Bridge M39/M10, Gross Vehicle Weight Statistics.

Vehicle Type	Max. (Kips)	Mean (Kips)	Median (Kips)	Std.Dev. (Kips)	GVW Limit (Kips)	Percentage over the Limit
2 Axles	70	23	21	11	40	8
3 Axles	132	41	31	27	60	15
4 Axles	65	31	28	11	70	0
5 Axles	148	42	32	26	80	9
6 Axles	56	41	42	14	90	0
7 Axles	88	67	67	15	120	0
8 Axles	44	44	44	1	125	0
9 Axles	46	45	45	1	135	0
10 Axles	109	109	109	----	150	0
11 Axles	146	126	126	28	164	0
All Vehicles	148	31	24	20	varies	8

Table 8-4. Bridge M39/M10, Axle Weight Statistics.

Vehicle Type	Max. (Kips)	Mean (Kips)	Median (Kips)	Std.Dev. (Kips)	Axle Weight Limit (Kips)	Percentage over the Limit
2 Axles	44	11	10	6	18	10
3 Axles	49	14	11	10	18	21
4 Axles	23	8	6	5	18	4
5 Axles	46	8	6	7	18	8
6 Axles	18	7	5	5	18	1
7 Axles	24	10	8	5	18	9
8 Axles	12	5	4	3	18	0
9 Axles	13	5	5	3	18	0
10 Axles	21	11	8	6	18	12
11 Axles	41	18	13	13	18	31
All Vehicles	49	10	8	7	18	10

Table 8-5. Bridge M39/M10, Steering Axle Weight Statistics.

Vehicle Type	Max. (Kips)	Mean (Kips)	Median (Kips)	Std.Dev. (Kips)	Vehicles (%)
2 Axles	27	11	10	5	58.5
3 Axles	35	14	13	6	9.9
4 Axles	21	12	14	5	7.2
5 Axles	22	13	11	6	19.7
6 Axles	18	14	17	6	1.8
7 Axles	24	18	19	3	1.7
8 Axles	12	12	12	1	0.3
9 Axles	13	12	12	1	0.3
10 Axles	21	21	21	----	0.2
11 Axles	28	24	24	5	0.3
All Vehicles	35	12	11	5	100.0

Table 8-6. Bridge M39/M10, Non-Steering Axle Weight Statistics.

Vehicle Type	Max. (Kips)	Mean (Kips)	Median (Kips)	Std.Dev. (Kips)	Vehicles (%)
2 Axles	44	12	10	7	58.5
3 Axles	49	14	10	11	9.9
4 Axles	23	6	5	4	7.2
5 Axles	46	7	6	6	19.7
6 Axles	17	5	4	3	1.8
7 Axles	18	8	8	3	1.7
8 Axles	8	5	4	2	0.3
9 Axles	6	4	5	2	0.3
10 Axles	18	10	7	5	0.2
11 Axles	41	18	12	14	0.3
All Vehicles	49	9	7	8	100.0

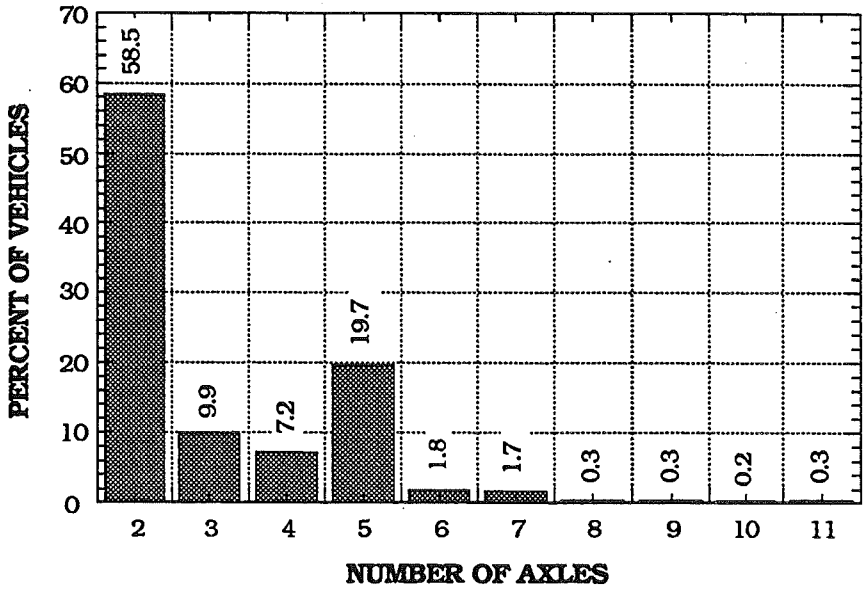


Fig. 8-3. M39/M10, Truck Type Histogram.

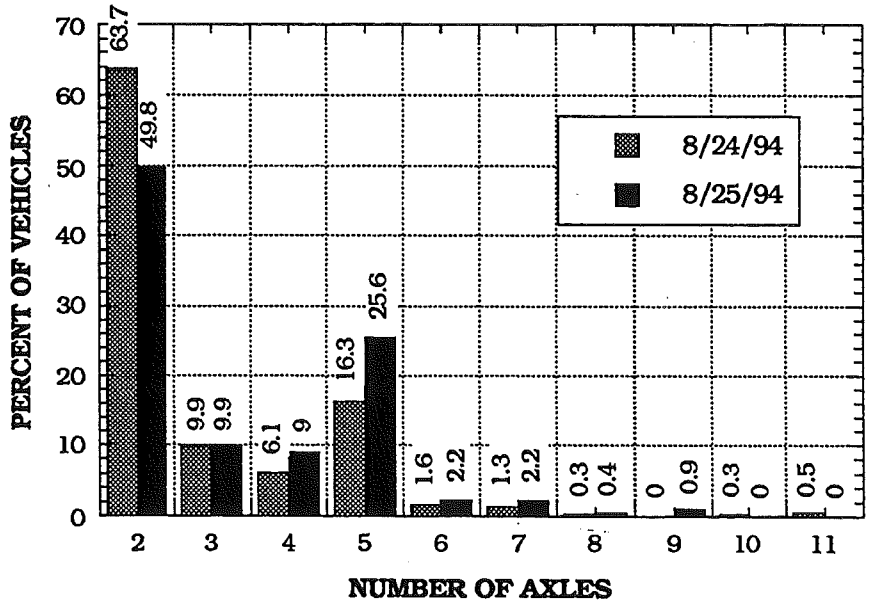


Fig. 8-4. M39/M10, Daily Truck Type Histogram.

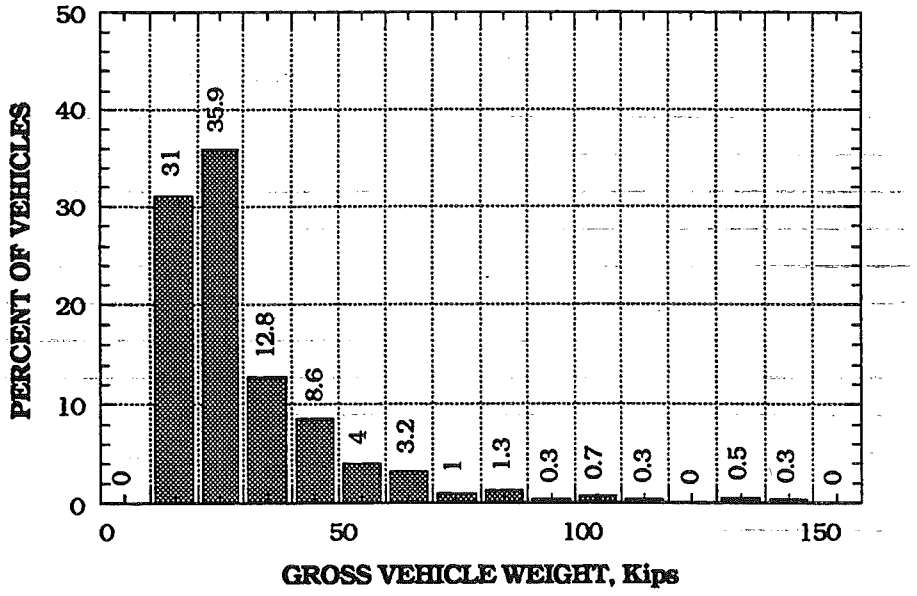


Fig. 8-5. M39/M10, GVW Histogram.

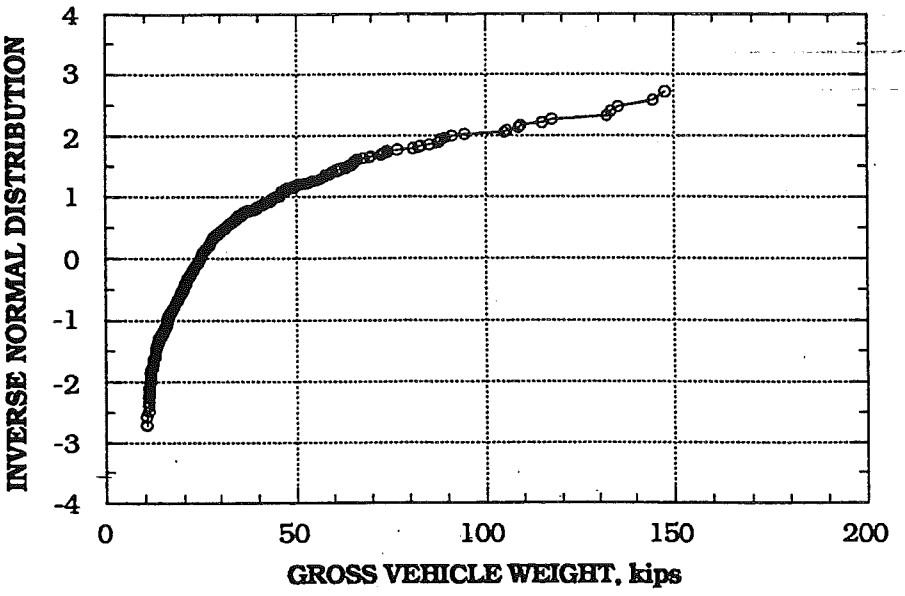


Fig. 8-6. M39/M10, GVW Distribution.

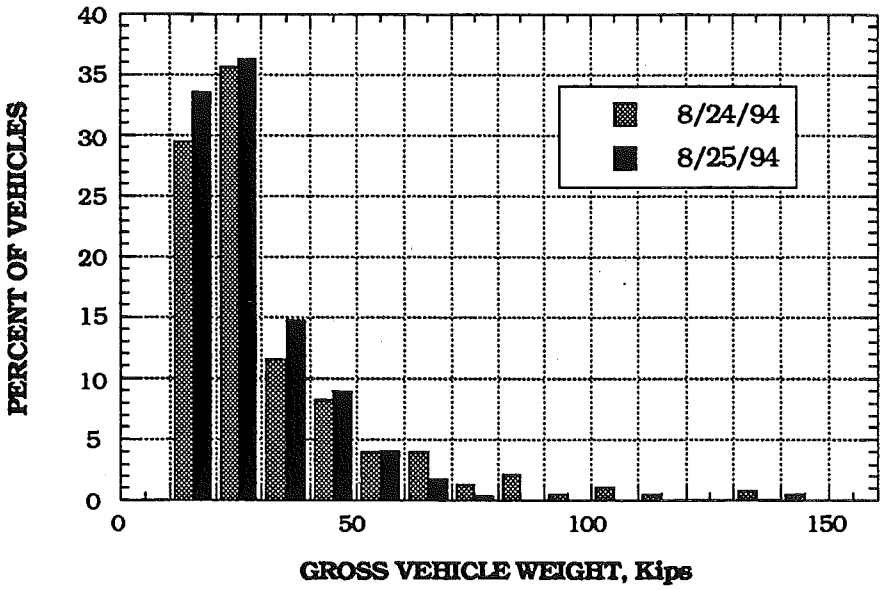


Fig. 8-7. M39/M10, Daily GVW Histogram.

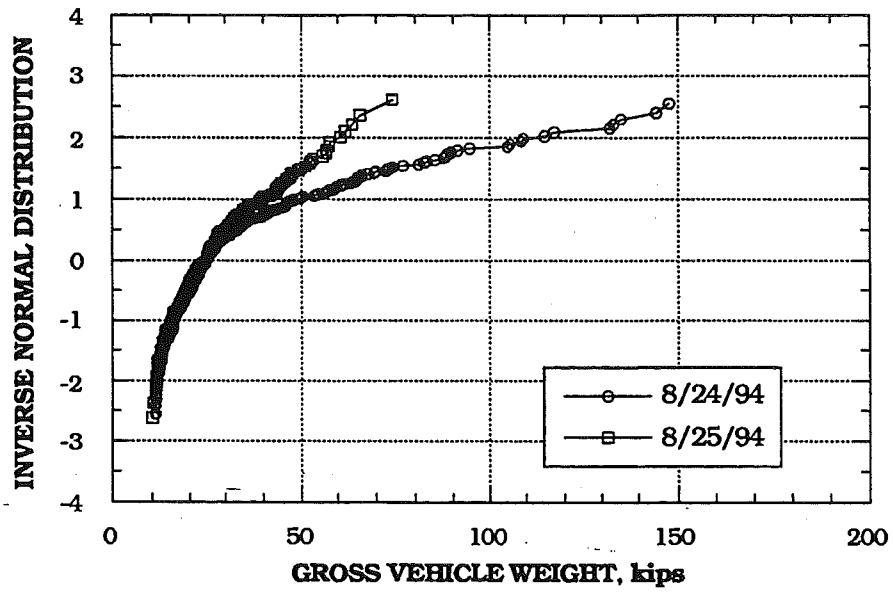


Fig. 8-8. M39/M10, Daily GVW Distributions.

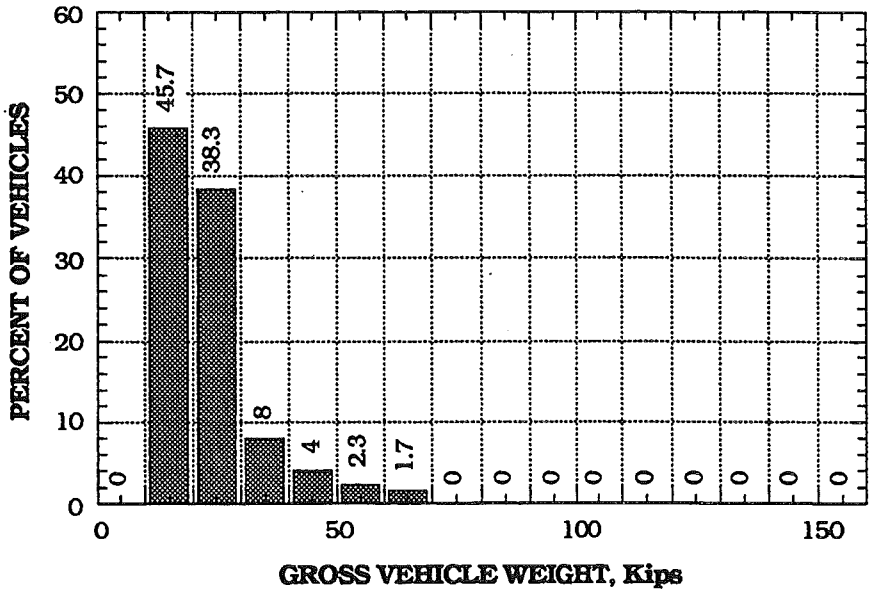


Fig. 8-9. M39/M10, 2 Axle GVW Histogram.

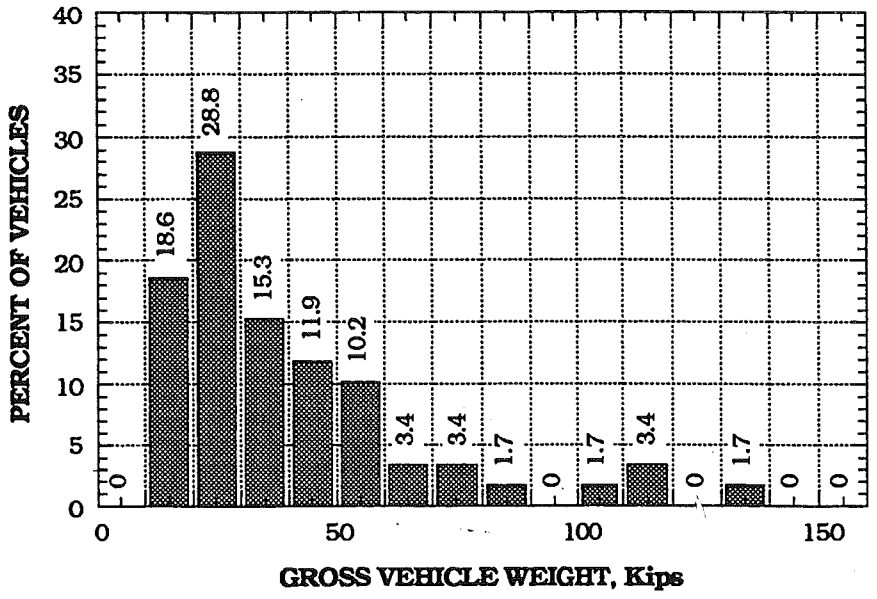


Fig. 8-10. M39/M10, 3 Axle GVW Histogram.

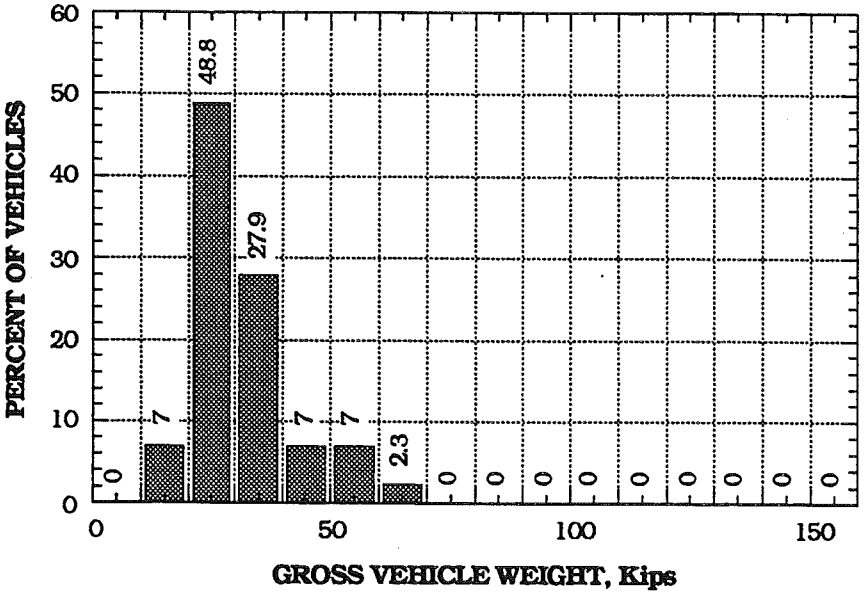


Fig. 8-11. M39/M10, 4 Axle GVW Histogram.

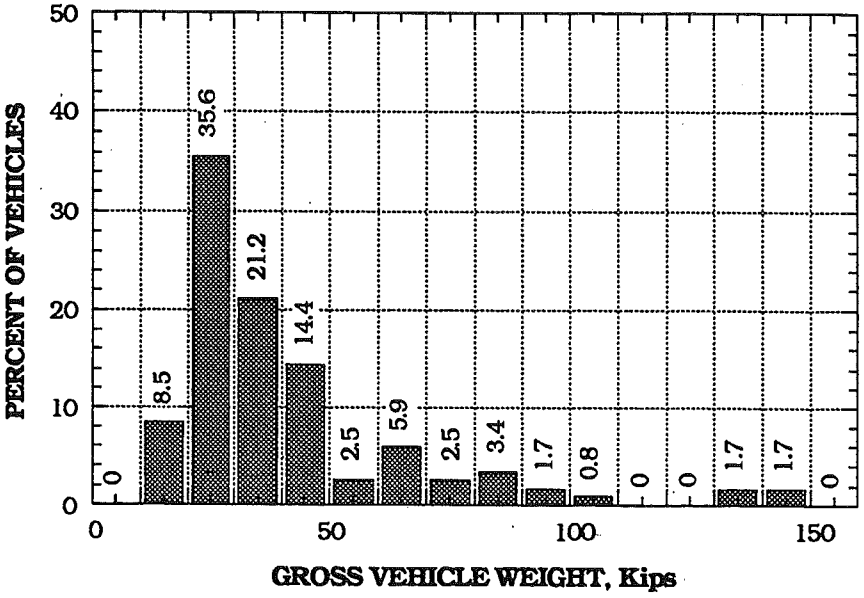


Fig. 8-12. M39/M10, 5 Axle GVW Histogram.

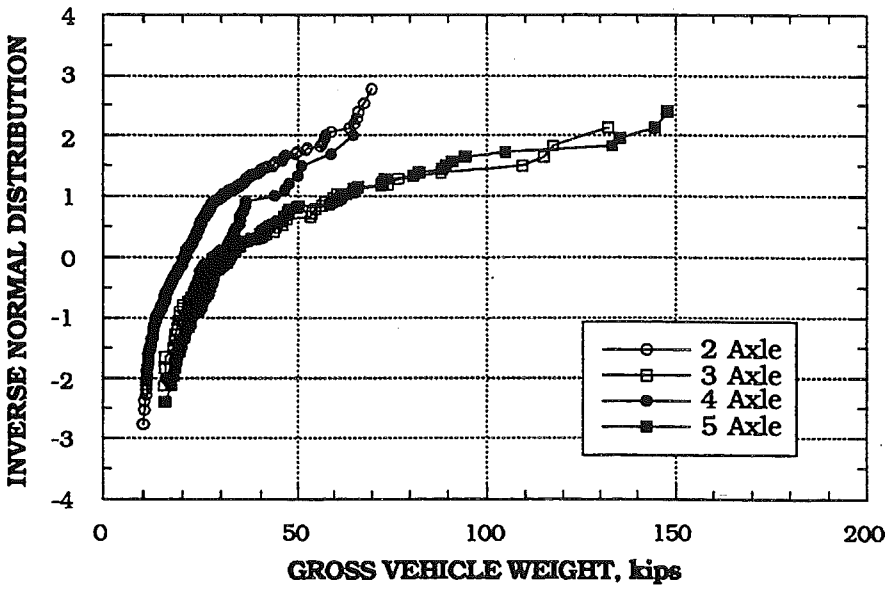


Fig. 8-13. M39/M10, 2, 3, 4, and 5 Axle GVW Distributions.

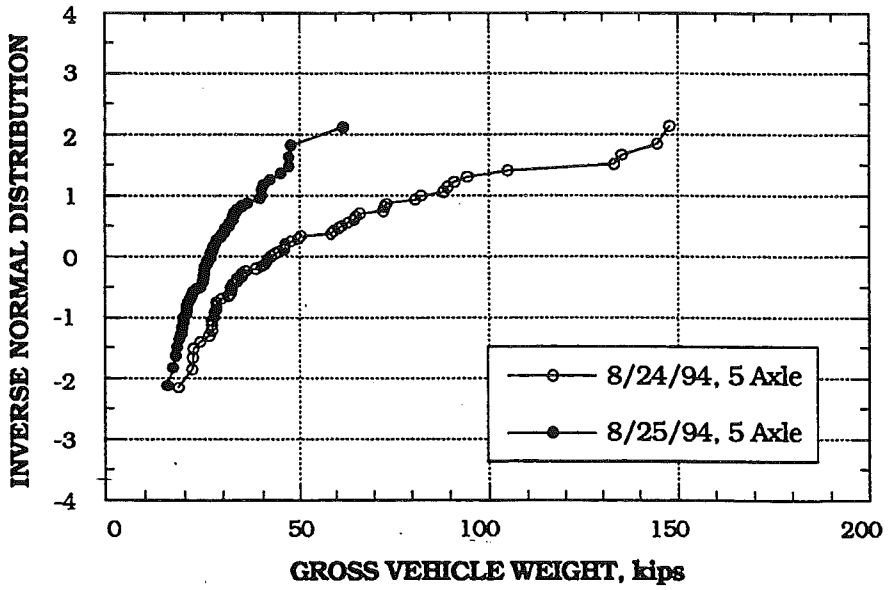


Fig. 8-14. M39/M10, Daily 5 Axle GVW Distributions.

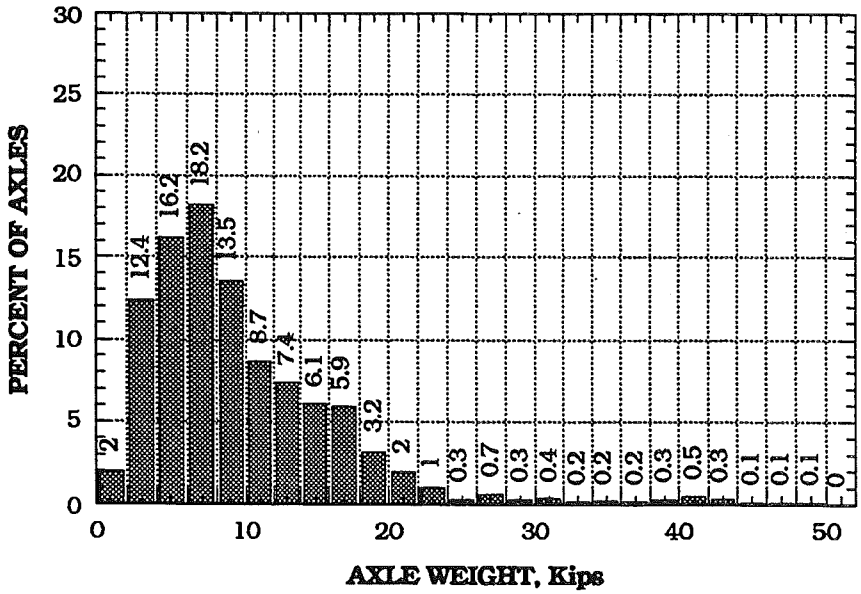


Fig. 8-15. M39/M10, Axle Weight Histogram.

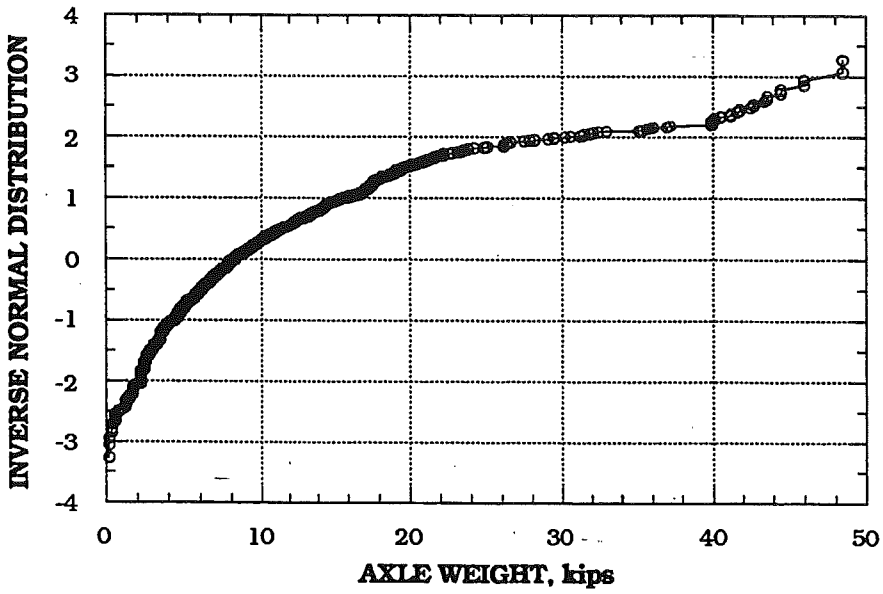


Fig. 8-16. M39/M10, Axle Weight Distribution.

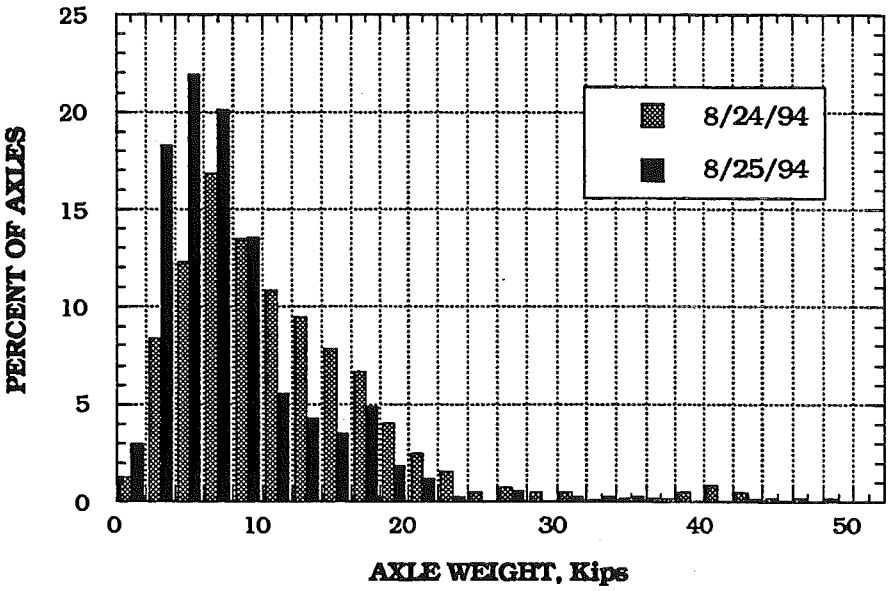


Fig. 8-17. M39/M10, Daily Axle Weight Histogram.

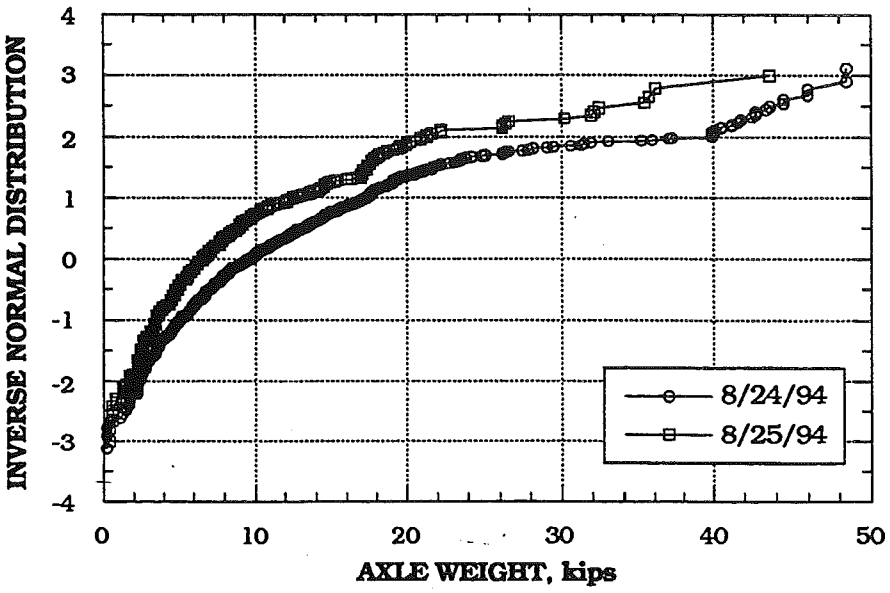


Fig. 8-18. M39/M10, Daily Axle Weight Distributions.

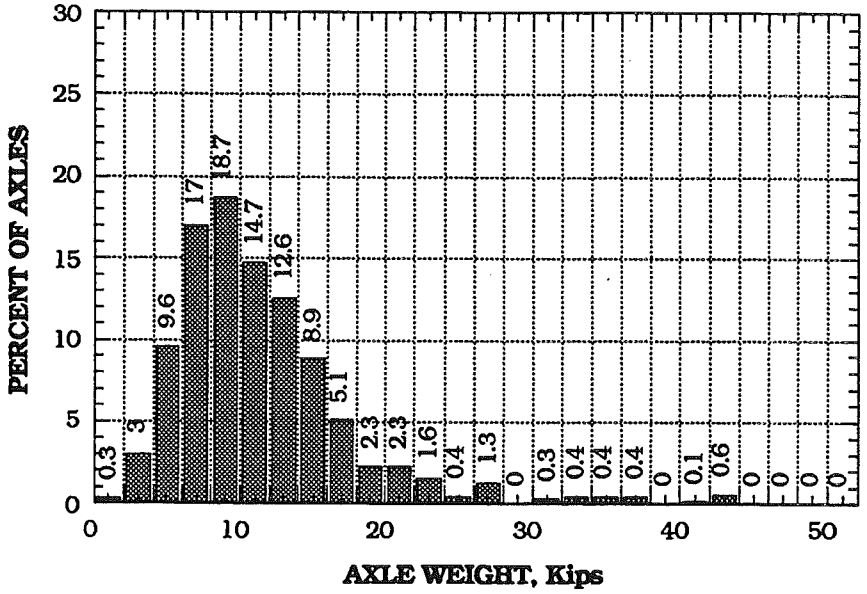


Fig. 8-19. M39/M10, Axle Weight Histogram of 2 Axle Vehicles.

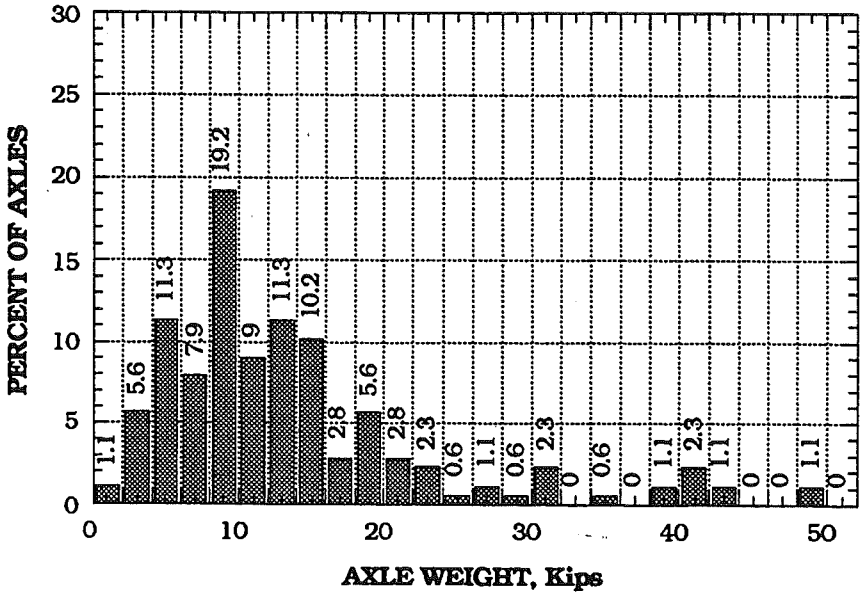


Fig. 8-20. M39/M10, Axle Weight Histogram of 3 Axle Vehicles.

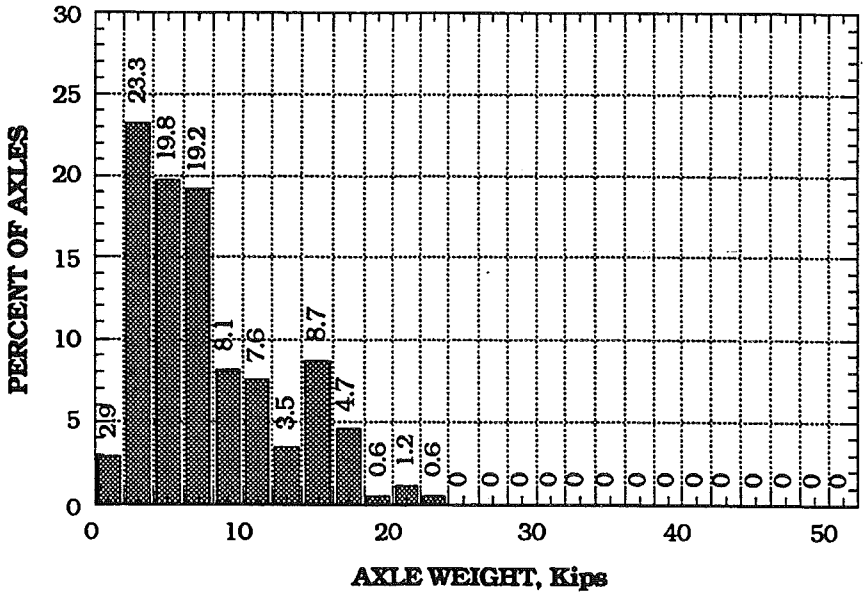


Fig. 8-21. M39/M10, Axle Weight Histogram of 4 Axle Vehicles.

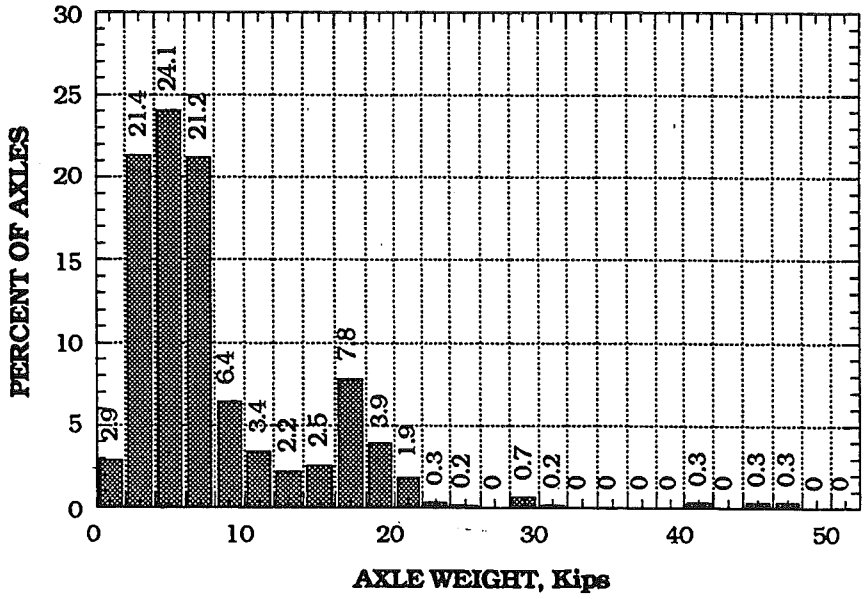


Fig. 8-22. M39/M10, Axle Weight Histogram of 5 Axle Vehicles.

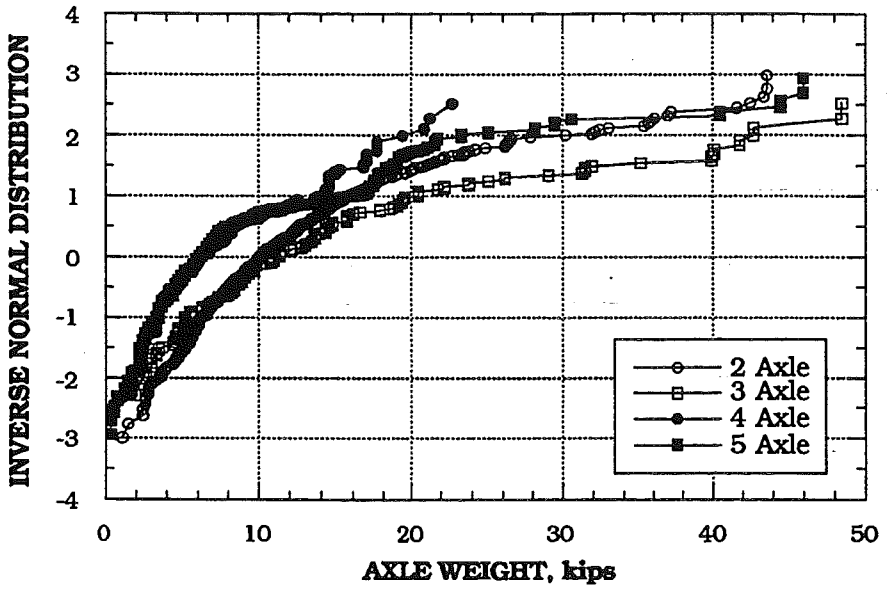


Fig. 8-23. M39/M10, Axle Weight Distributions of 2, 3, 4, and 5 Axles.

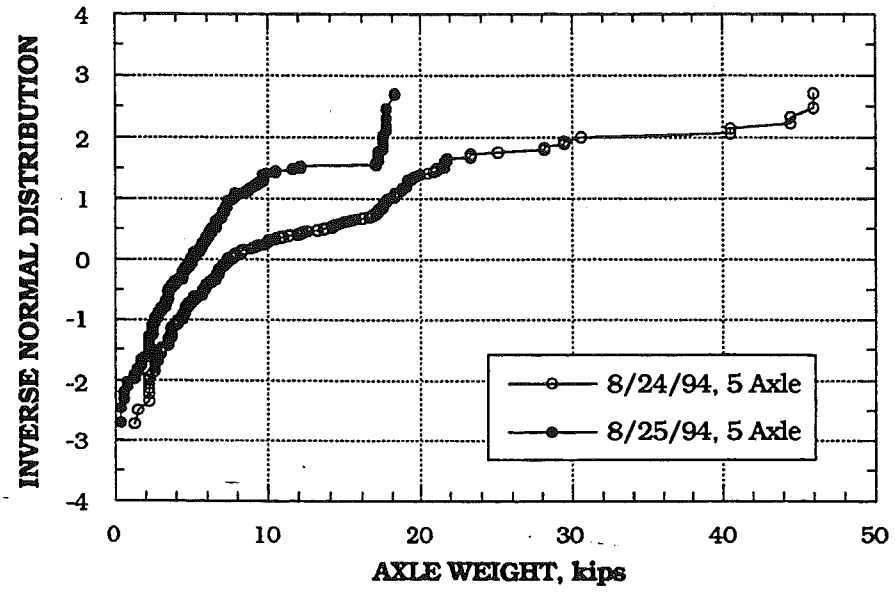


Fig. 8-24. M39/M10, Daily Axle Weight Distributions of 5 Axles.

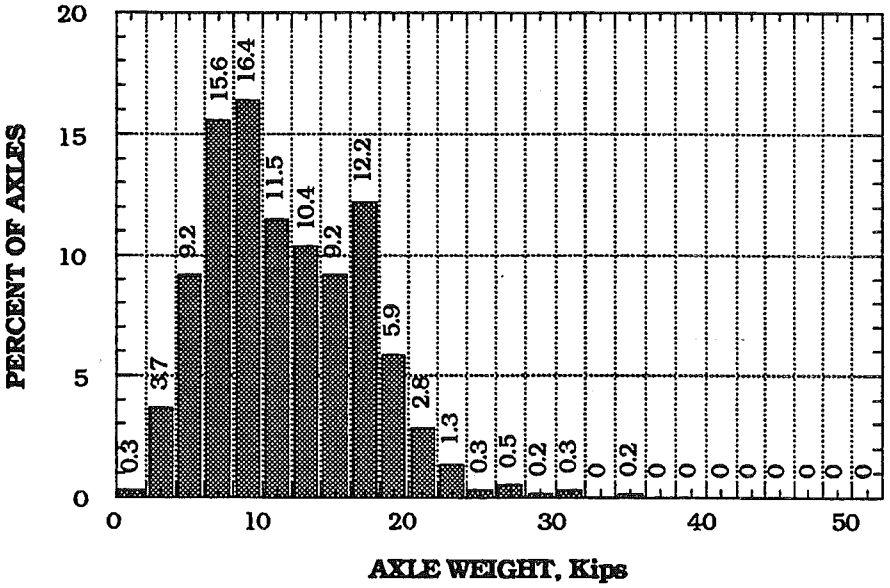


Fig. 8-25. M39/M10, Steering Axle Weight Histogram.

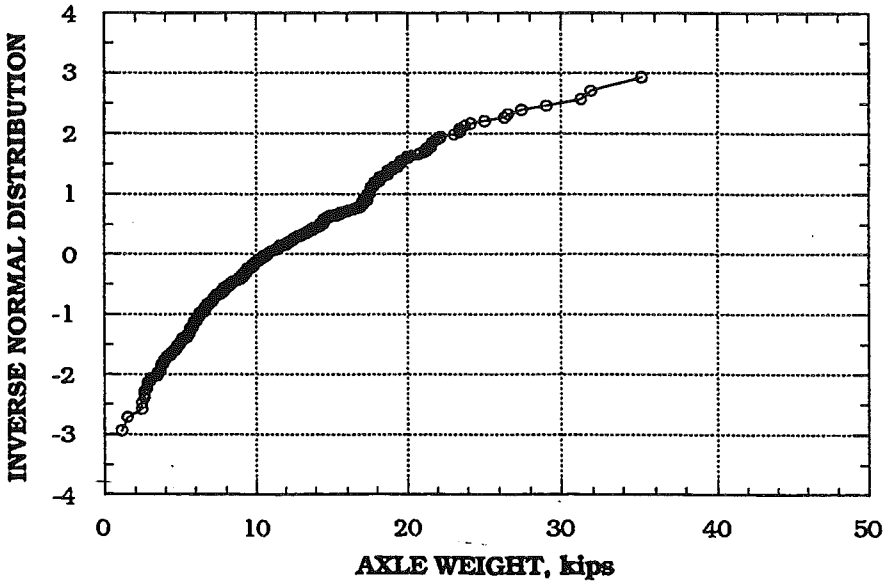


Fig. 8-26. M39/M10, Steering Axle Weight Distribution.

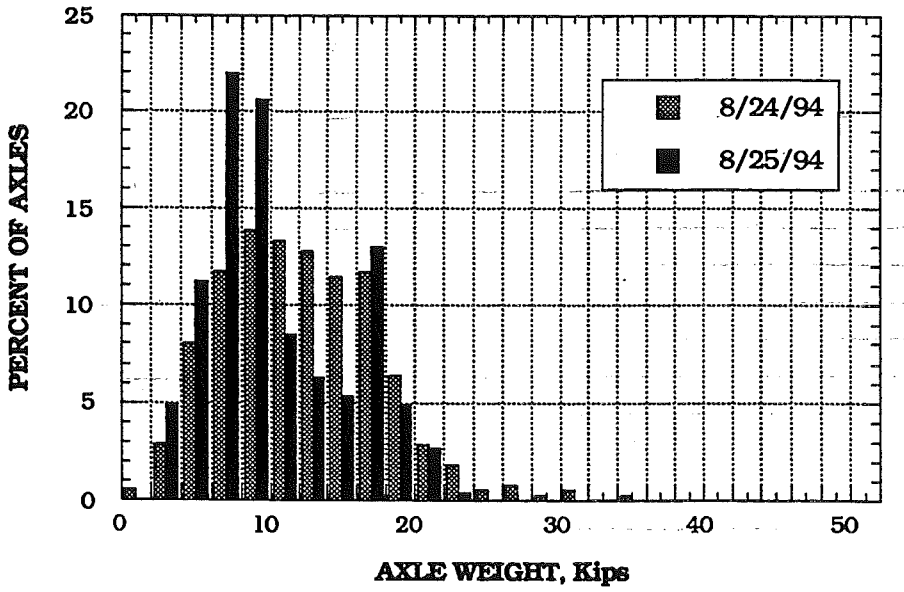


Fig. 8-27. M39/M10, Daily Steering Axle Weight Histogram.

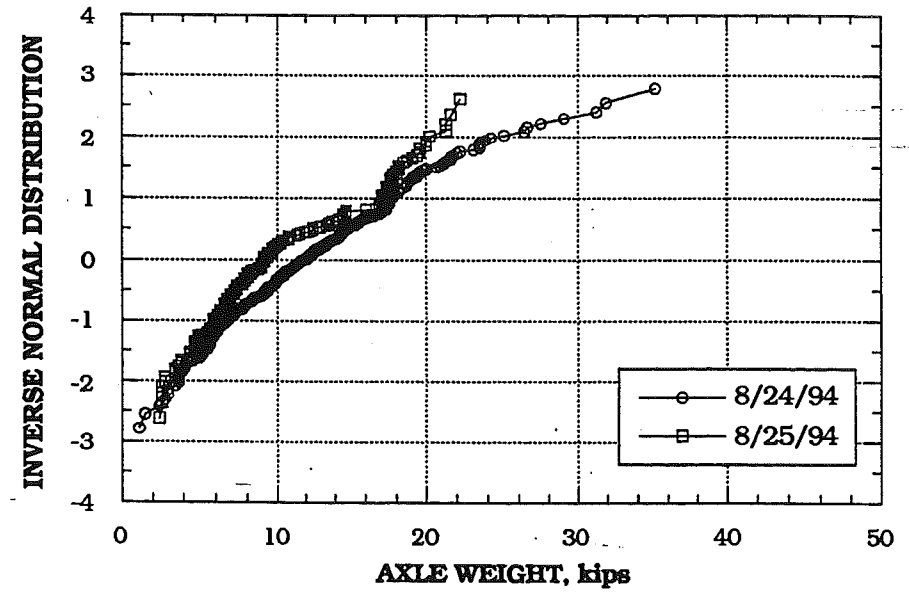


Fig. 8-28. M39/M10, Daily Steering Axle Weight Distributions.

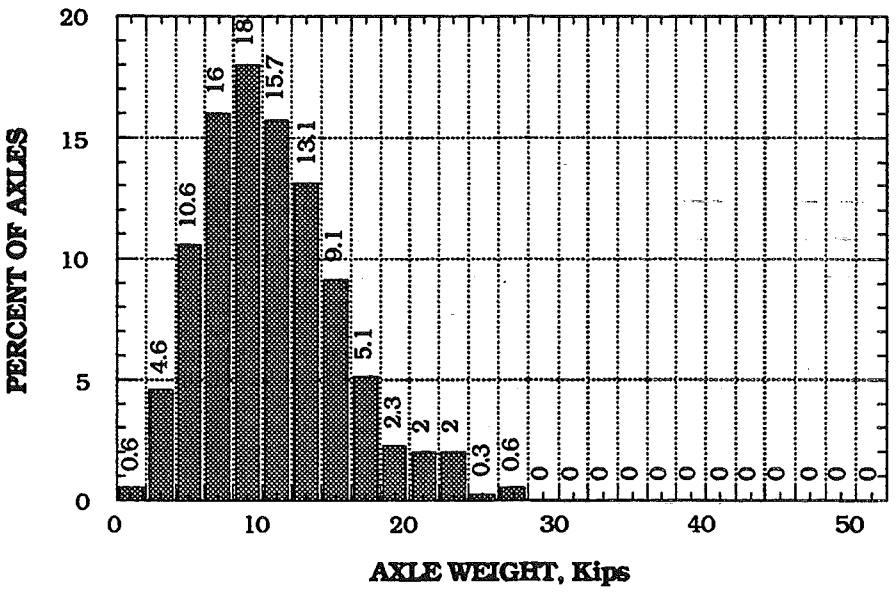


Fig. 8-29. M39/M10, Steering Axle Weight Histogram of 2 Axle Vehicles.

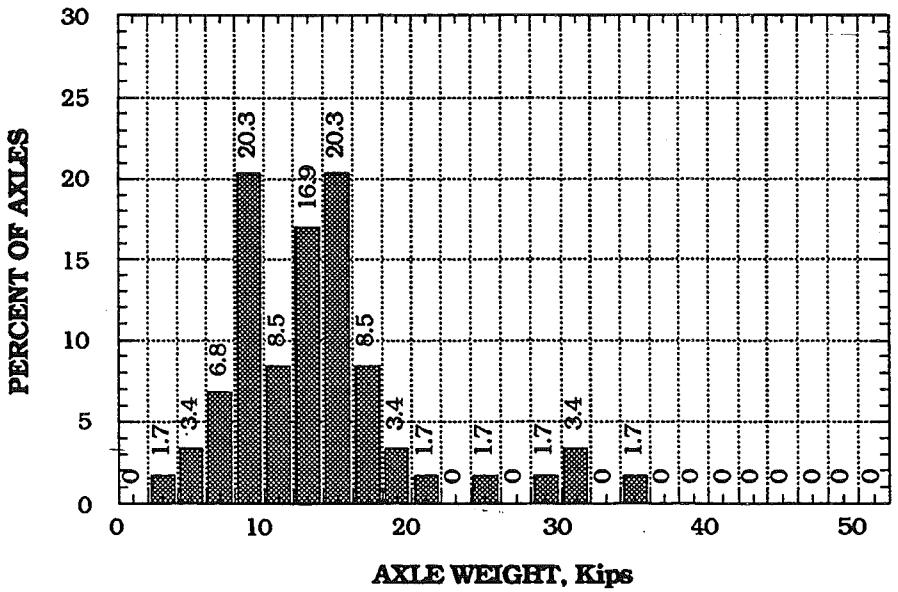


Fig. 8-30. M39/M10, Steering Axle Weight Histogram of 3 Axle Vehicles.

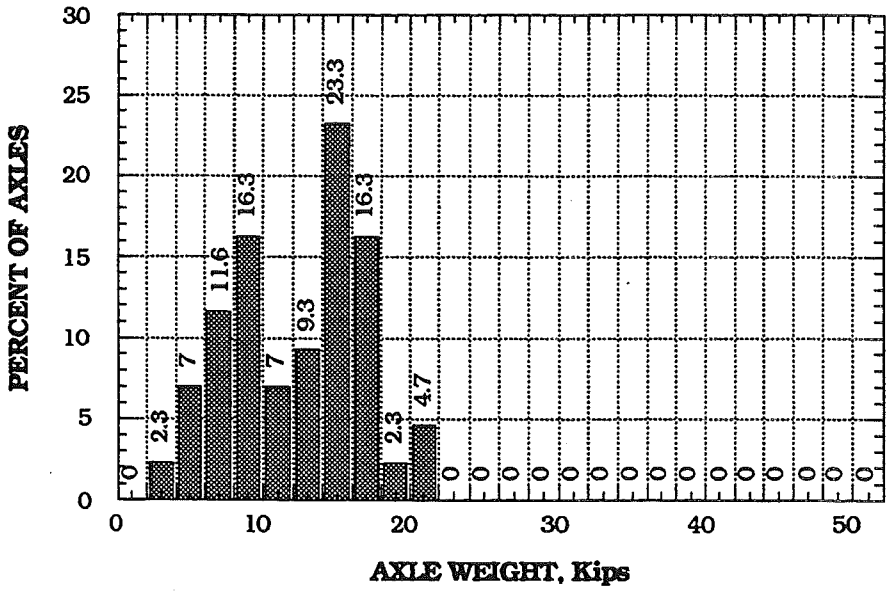


Fig. 8-31. M39/M10, Steering Axle Weight Histogram of 4 Axle Vehicles.

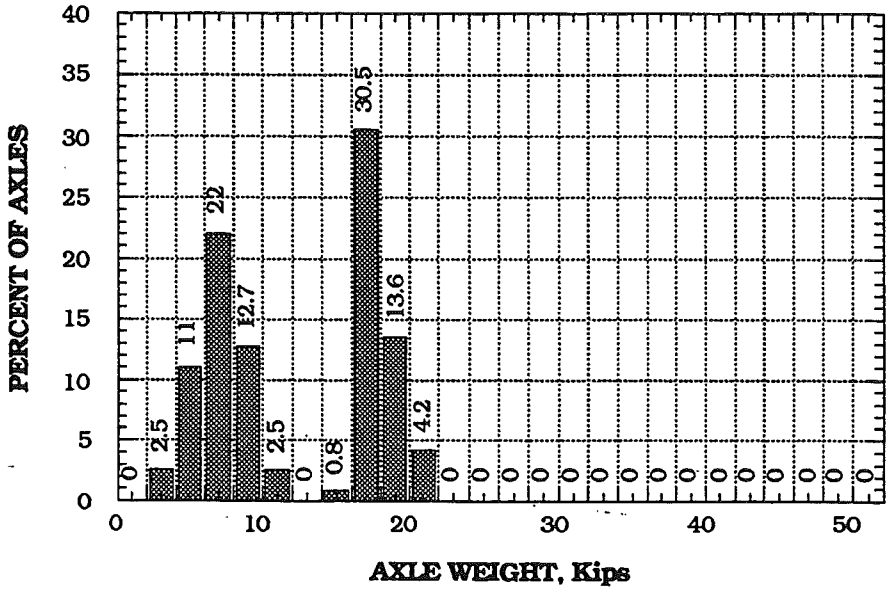


Fig. 8-32. M39/M10, Steering Axle Weight Histogram of 5 Axle Vehicles.

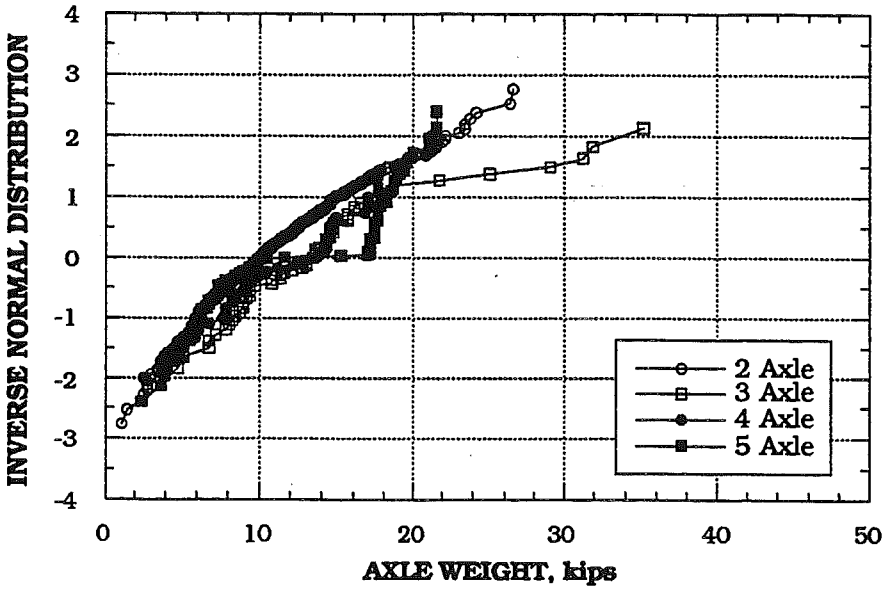


Fig. 8-33. M39/M10, Steering Axle Weight Distributions of 2, 3, 4, and 5 Axle Vehicles.

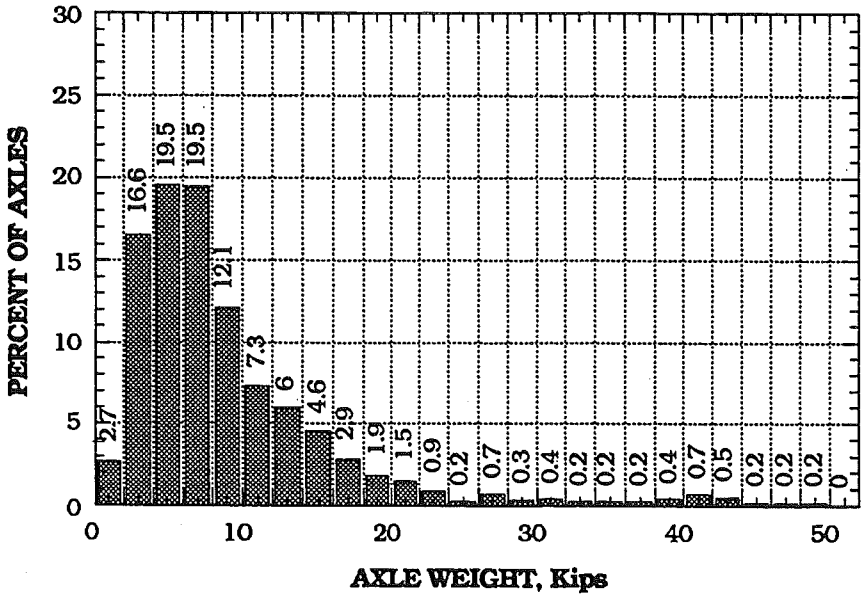


Fig. 8-34. M39/M10, Non-Steering Axle Weight Histogram.

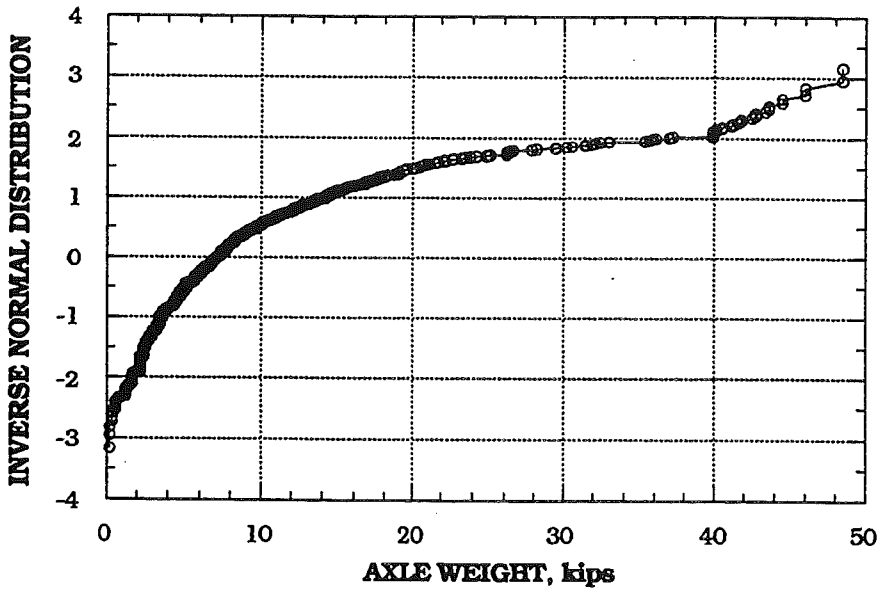


Fig. 8-35. M39/M10, Non-Steering Axle Weight Distributions.

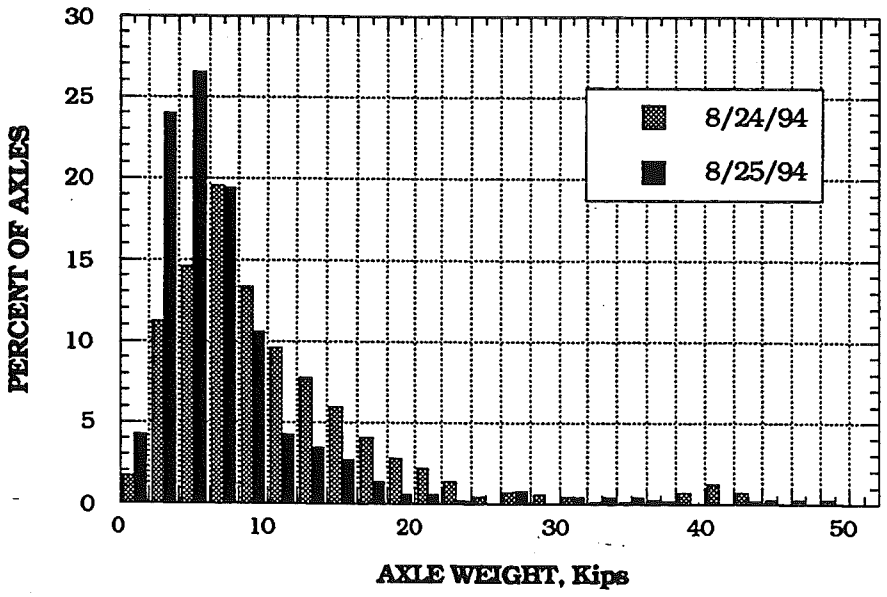


Fig. 8-36. M39/M10, Daily Non-Steering Axle Weight Histogram.

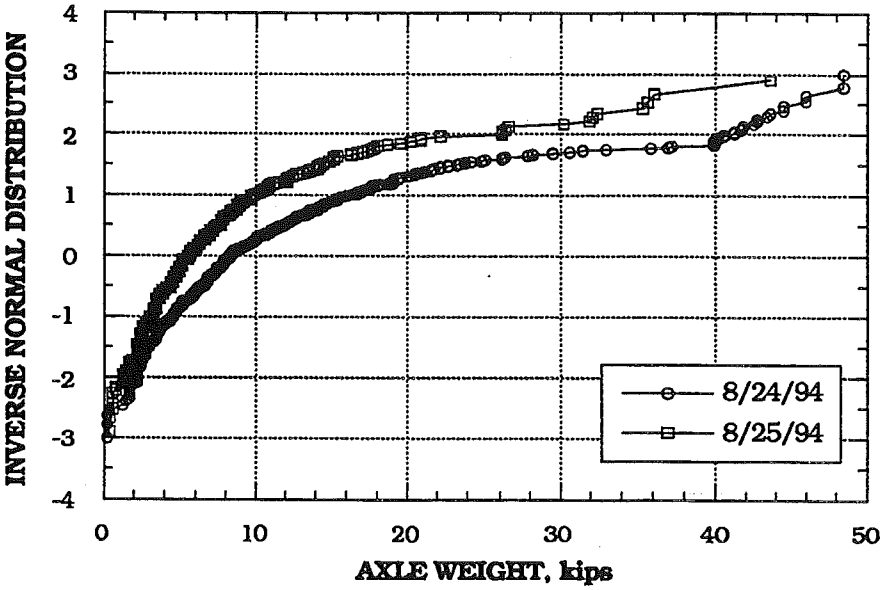


Fig. 8-37. M39/M10, Daily Non-Steering Axle Weight Distributions

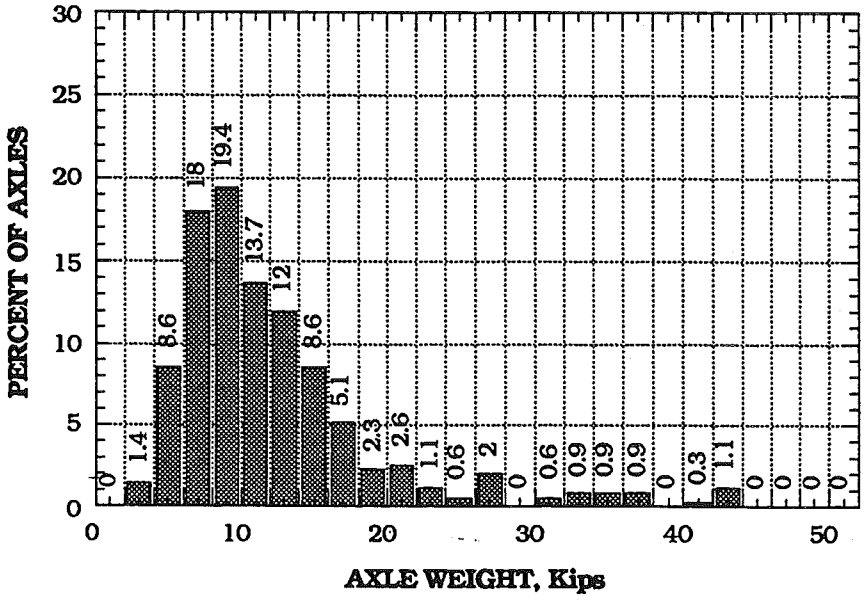


Fig. 8-38. M39/M10, Non-Steering Axle Weight Histogram of 2 Axles.

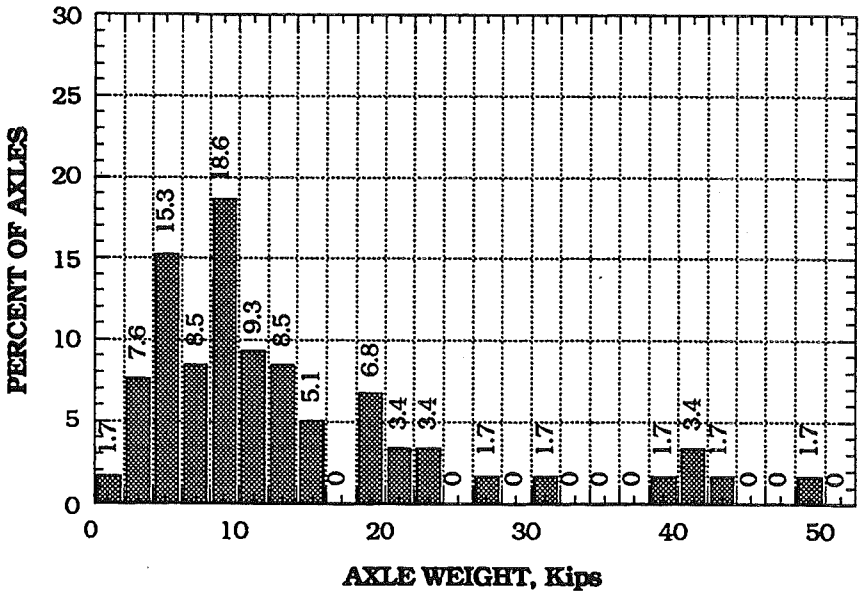


Fig. 8-39. M39/M10, Non-Steering Axle Weight Histogram of 3 Axles.

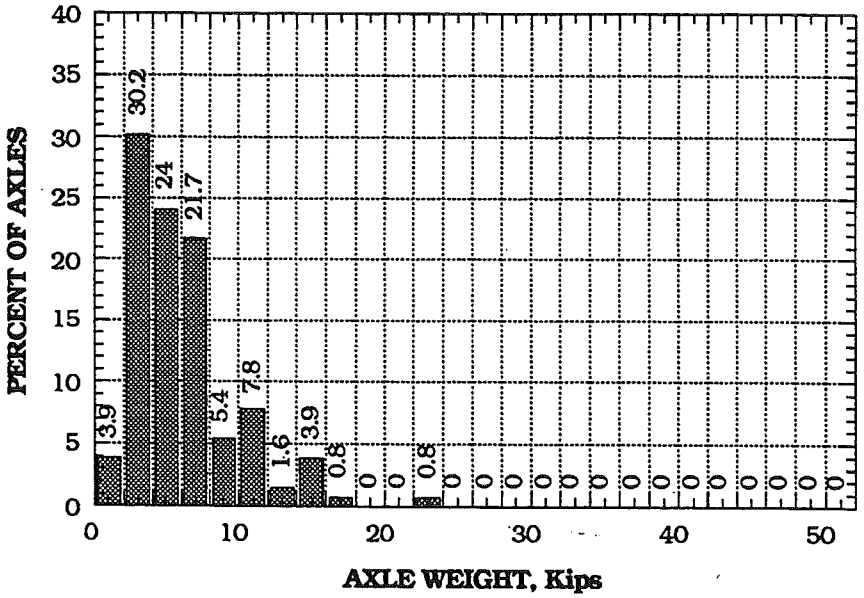


Fig. 8-40. M39/M10, Non-Steering Axle Weight Histogram of 4 Axles.

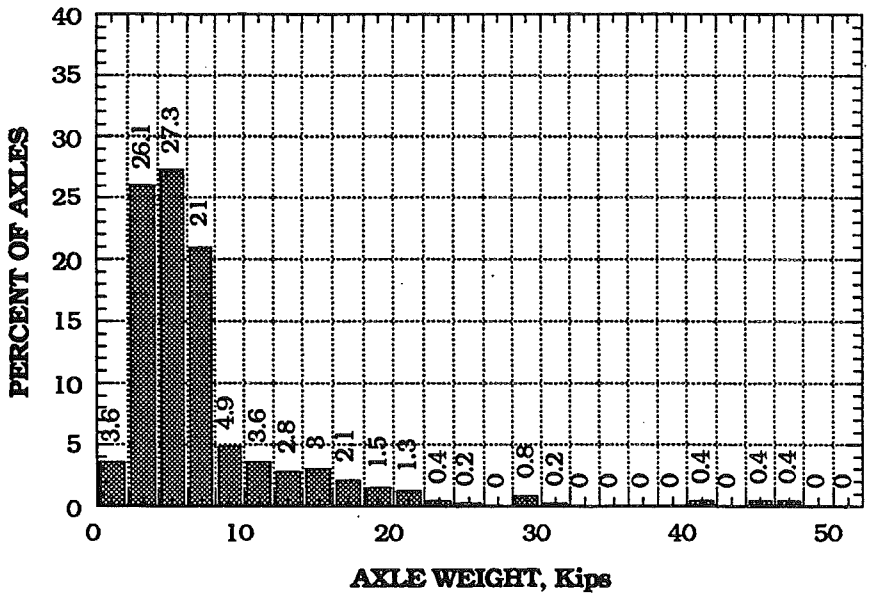


Fig. 8-41. M39/M10, Non-Steering Axle Weight Histogram of 5 Axles.

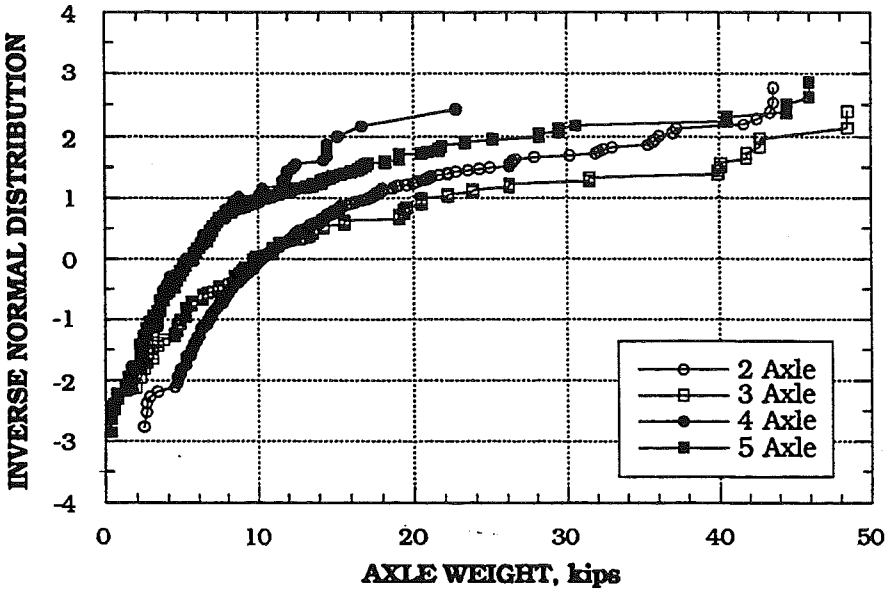


Fig. 8-42. M39/M10, Non-Steering Axle Weight Distributions of 2, 3, 4 and 5 Axle Vehicles.

9. BRIDGE ON I-94 WESTBOUND OVER SOUTHBOUND I-75 IN DETROIT (I94/I75)

9. 1 Description of the bridge

Bridge I94/I75 carries westbound traffic from I-94 over southbound I-75 in Detroit. It is shown in Fig. 9-1. The side elevation, plan view, cross section and other details are shown in Fig. 9-2 and 9-3. Measurements were taken in the span No. 4 (in the direction of traffic). The investigated span is 44'- 4 5/8', the width is 38'- 5" and the bridge is in the curve. The cross section consists of eight girders spaced 4'-7".

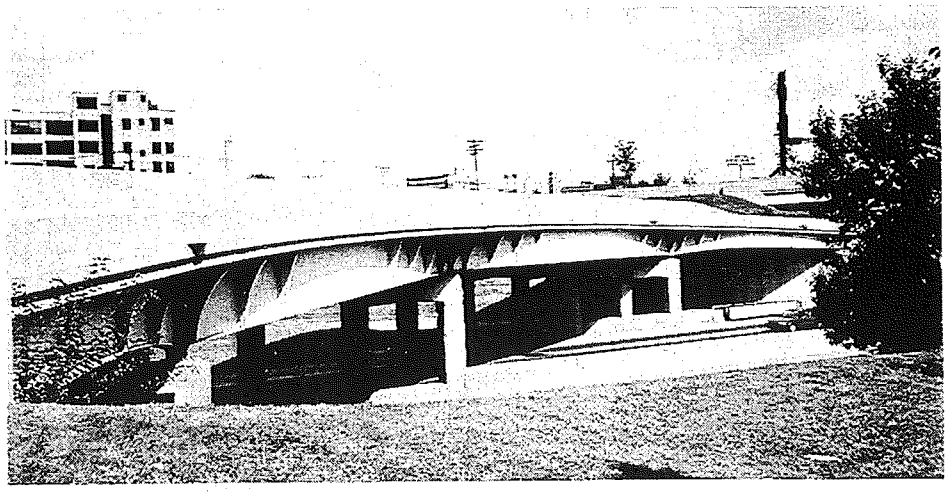


Fig. 9-1. View of Bridge I94/I75, I-94 Westbound over I-75.

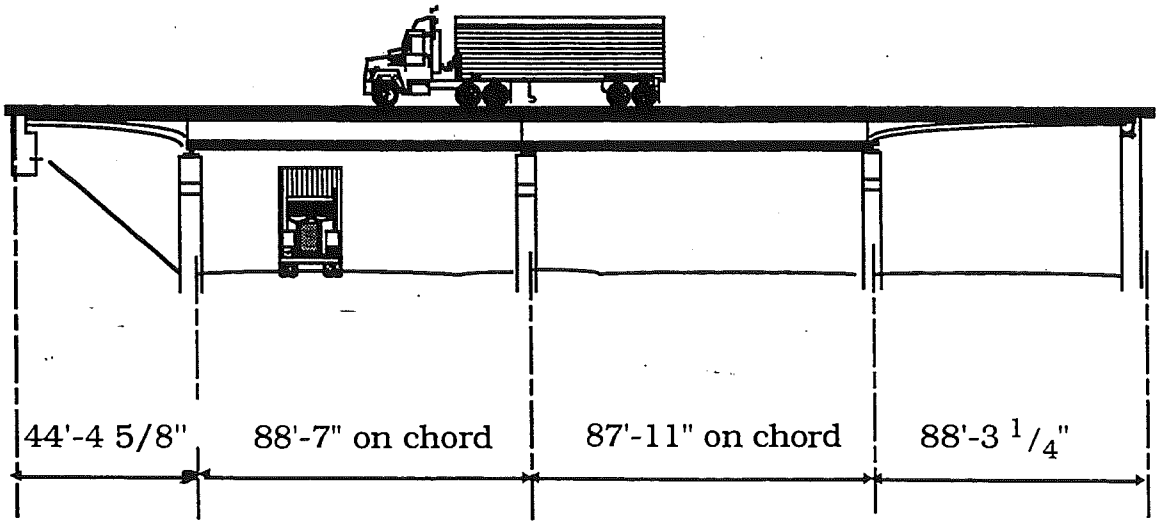


Fig. 9-2. Bridge I94/I75, I-94 Westbound over I-75. Side Elevation.

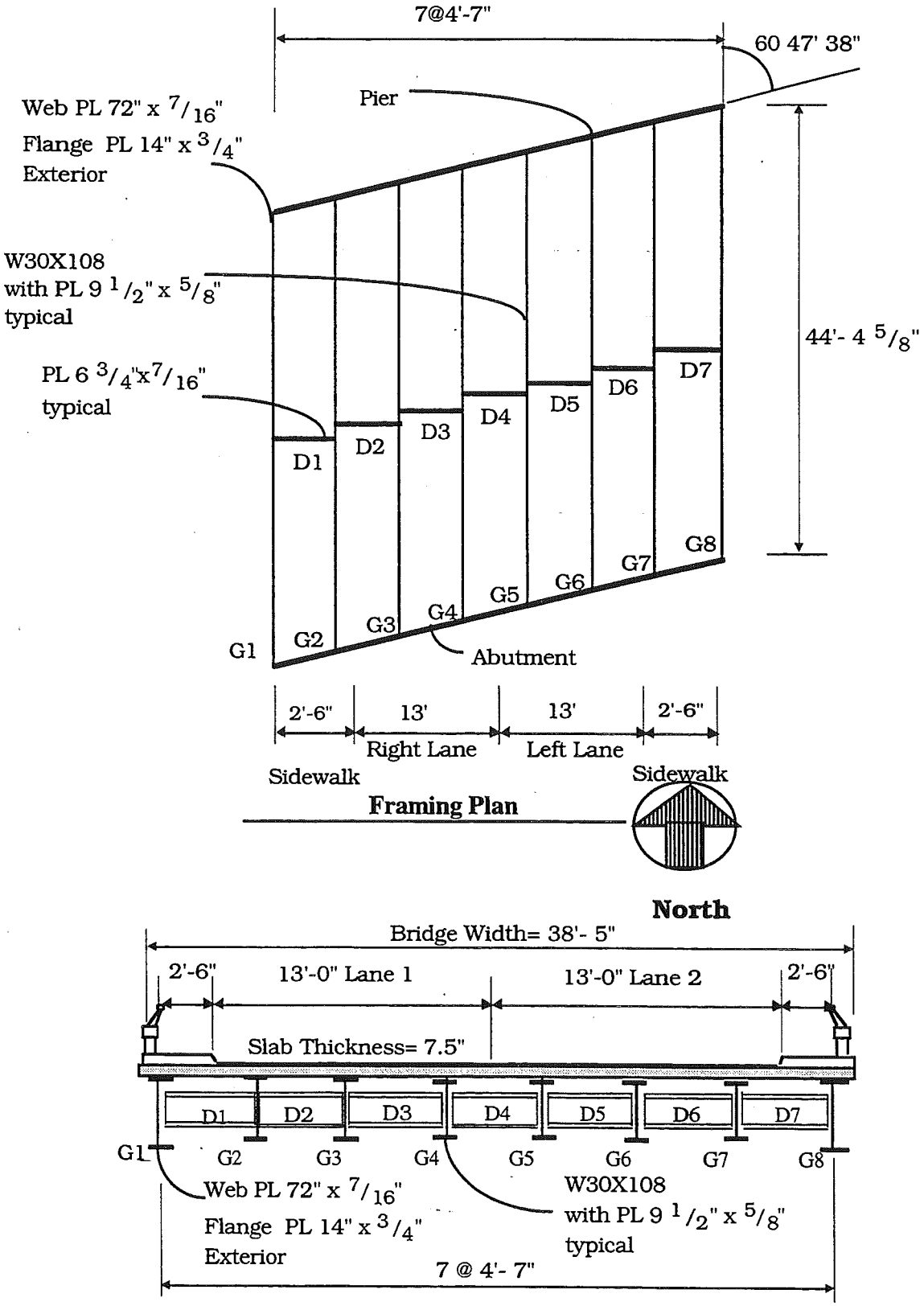


Fig. 9-3. Bridge I94/I75, I-94 Westbound over I-75. Plan View and Cross section of Span No. 4.

9.2 Weigh-in-Motion Measurements

Weigh-in-motion (WIM) statistics are presented in Table 9-1 to Table 9-6 and in Fig. 9-4 to Fig. 9-43. This data includes all trucks with a gross vehicle weight (GVW) of 10 kips and greater for 2-axle vehicles, and of 15 kips and greater for 3 or more axle vehicles, regardless of axle weight. This filtered WIM data has been used for all analysis of GVW and axle weight. The data may also include permit loads. The data measured by WIM are recorded in the FHWA card seven 80-column format.

Table 9-1 summarizes an estimated average daily truck traffic (ADTT) in one direction, and the total number of vehicles weighed by date and by different number of axle vehicles. Fig. 9-4 is the frequency histogram of trucks corresponding to different number of axles. Only a few 11-axle trucks were observed. Fig. 9-5 shows the daily frequency histogram of trucks. There is slight difference by the date of measurement. Table 9-2 presents Federal Highway Administration (FHWA) truck class frequency vs lane statistics. Federal Highway Administration (FHWA) axle configuration class is presented in the Appendix A. Note that the last digit from the FHWA axle class is not included in Table 9-2.

Table 9-3 is the GVW statistics of maximum, mean, median, standard deviation, and percent of overloaded vehicles. The statistics are given for all vehicles and separately different number of axle vehicles. The GVW limit in Table 9-3 might not be the legal limit. It is difficult to determine the GVW limit with only number of axles. It depends not only on number of axles, but axle spacings. Thus, it was decided to assign reasonably high GVW limits and to give some ideas about how heavy the vehicles were. Fig. 9-6 and Fig. 9-7 are the histogram of GVW and the corresponding cumulative distribution function (CDF) of GVW for all trucks observed and measured on I94/I75 respectively. In Fig. 9-7, each circle represents one truck in the data file. From the graph and from Table 9-3 the heaviest vehicle observed weighed 178 kips with a mean GVW of 41 kips. Vehicle over the GVW limit were 14 percent. Results of the individual day measurements are shown in Fig. 9-8 and Fig. 9-9. The day to day CDF's are slightly different in shape and average

GVW with the largest difference at the upper tail of the distribution. GVW histograms for different number of axle vehicles are presented in Fig. 9-10 to Fig. 9-13. The corresponding CDF's are shown in Fig. 9-14. Overloaded 5-axle vehicles were 15 percent. There were no overloaded 11-axle vehicles. For comparison of the daily distributions of 5 vehicles, the CDF's for both days are plotted in Fig. 9-15. Again, there is a slight difference in the day to day distributions.

Table 9-4 is the axle weight statistics of maximum, mean, median, standard deviation, and percentage of overloaded axles. The statistics are given for all vehicles and separately different number of axle vehicles. In this table, axle weight limits were intended to give some ideas about how heavy the axles were. The statistics depend on axle spacings rather than number of axles. Figures 9-16 and 9-17 are the histogram of axle weight for all vehicles and the corresponding CDF respectively. The maximum axle weight observed at I94/I75 was 50 kips with a mean of 10 kips. Axles with axle weight of 18 kips and greater were 10 percent. Fig. 9-18 and Fig. 9-19 show the daily axle weight histogram and CDF's. There is slight difference in the axle weight distributions, however a similar trend in the distributions is evident. Axle weight histograms for different number of axle vehicles are presented in Fig. 9-20 to Fig. 9-23. The corresponding CDF's are shown in Fig. 9-24. Overloaded axles for 5 and 11-axle vehicles were ten percent and four percent respectively. The daily CDF's of axle weight for 5-axle vehicles are plotted in Fig. 9-25 for comparison of the daily distribution. Again, slight difference in the daily distributions can be observed. Measurement of extended period of time might reduce this difference.

Table 9-5 is the steering axle weight statistics of maximum, mean, median, and standard deviation of all vehicles and different number of axle vehicles. Fig. 9-26 and Fig. 9-27 are the steering axle weight histograms for all vehicles and the corresponding CDF respectively. The maximum observed steering axle weight was 15 kips with a mean of nine kips (Table 9-5). Fig. 9-28 and Fig. 9-29 show the daily steering axle weight histogram and CDF's. Steering axle weight histograms for different number of axle vehicles are presented in Fig. 9-30 to Fig. 9-33. The corresponding CDF's are shown in Fig. 9-34.

Table 9-6 is the non-steering axle weight statistics of maximum, mean, median, and standard deviation of all vehicles and different number of axle vehicles. Fig. 9-35 and Fig. 9-36 are the non-steering axle weight histogram for all vehicles and the corresponding CDF. The maximum non-steering axle weight was 50 kips with a mean of 10 kips (Table 9-6). Fig. 9-37 and Fig. 9-38 show the daily non-steering axle weight histogram and CDF's. Non-steering axle weight histograms for different number of axle vehicles are presented in Fig. 9-39 to Fig. 9-42. The corresponding CDF's are shown in Fig. 9-43.

The steering and non-steering axle weight CDF's of Fig. 9-27 and Fig. 9-36 indicate a significant difference in both variation and magnitudes. The standard deviation of steering axle weight was two kips with a maximum of 15 kips while the standard deviation of non-steering axle weight was eight kips with a maximum of 50 kips.

Review of the results indicates that most of the truck weights are within legal limits. Overloaded 5 axle vehicles were 15 percent. Vehicles over the GVW limit were 14 percent. Overloaded axles for 5 and 11-axle vehicles were ten percent and four percent respectively. Axles with axle weight of 18 kips and greater were 10 percent. There were only eight passing 11-axle vehicles, which was not sufficient number to observe a general trend. There was a slight difference in the day to day GVW distributions.

Table 9-1. I94/I75, Number of Trucks Weighed and Estimated ADTT.

Number of Trucks Weighed Gross Vehicle Weight > 10 Kips for 2 Axle Vehicles, Gross Vehicle Weight > 15 Kips for 3 or more Axle Vehicles.				
Date	10/4/94	10/5/94	Total	Vehicles (%)
2 Axles	35	68	93	29.7
3 Axles	3	16	19	6.1
4 Axles	4	23	27	8.6
5 Axles	37	111	148	47.3
6 Axles	0	9	9	2.9
7 Axles	2	5	7	2.2
8 Axles	0	2	2	0.6
9 Axles	0	0	0	0.0
10 Axles	0	0	0	0.0
11 Axles	1	7	8	2.6
All Vehicles	72	241	313	100.0
Estimated ADTT = 1500 Trucks (in one direction)				

Table 9-2. Bridge I94/I75, Truck Class vs Lane Statistics.

Truck Class (FHWA)	Right Lane (1) (%)	Left Lane (2) (%)	Total (%)
4	0.0	0.0	0.0
5	7.9	36.0	43.9
6	1.1	1.3	2.4
7	0.0	0.4	0.4
8	2.6	2.9	5.5
9	16.7	15.4	32.1
10	0.7	2.0	2.6
11	0.0	0.0	0.0
12	0.0	0.0	0.0
13	0.0	0.0	0.0
14	3.7	9.2	13.0
Total Lane %	32.7	67.3	100.0

Table 9-3. Bridge I94/I75, Gross Vehicle Weight Statistics.

Vehicle Type	Max. (Kips)	Mean (Kips)	Median (Kips)	Std.Dev. (Kips)	GVW Limit (Kips)	Percentage over the Limit
2 Axles	64	25	22	13	40	18
3 Axles	64	29	28	13	60	4
4 Axles	111	41	36	22	70	10
5 Axles	178	50	41	29	80	15
6 Axles	79	47	34	23	90	0
7 Axles	78	48	45	21	120	0
8 Axles	154	98	98	78	125	35
9 Axles	----	----	----	----	135	----
10 Axles	----	----	----	----	150	----
11 Axles	93	54	44	24	164	0
All Vehicles	178	41	34	26	varies	14

Table 9-4. Bridge I94/I75, Axle Weight Statistics.

Vehicle Type	Max. (Kips)	Mean (Kips)	Median (Kips)	Std.Dev. (Kips)	Axle Weight Limit (Kips)	Percentage over the Limit
2 Axles	50	13	10	9	18	18
3 Axles	29	10	9	5	18	8
4 Axles	50	10	9	8	18	10
5 Axles	44	10	8	7	18	10
6 Axles	23	8	8	5	18	5
7 Axles	16	7	6	4	18	0
8 Axles	20	12	11	7	18	40
9 Axles	----	----	----	----	18	----
10 Axles	----	----	----	----	18	----
11 Axles	20	5	4	4	18	4
All Vehicles	50	10	8	7	18	10

Table 9-5. Bridge I94/I75, Steering Axle Weight Statistics.

Vehicle Type	Max. (Kips)	Mean (Kips)	Median (Kips)	Std.Dev. (Kips)	Vehicles (%)
2 Axles	14	9	9	3	29.7
3 Axles	15	9	8	2	6.1
4 Axles	12	9	9	2	8.6
5 Axles	14	9	9	1	47.3
6 Axles	10	9	9	1	2.9
7 Axles	10	9	8	1	2.2
8 Axles	13	11	11	3	0.6
9 Axles	----	----	----	----	0.0
10 Axles	----	----	----	----	0.0
11 Axles	11	10	9	1	2.6
All Vehicles	15	9	9	2	100.0

Table 9-6. Bridge I94/I75, Non-Steering Axle Weight Statistics.

Vehicle Type	Max. (Kips)	Mean (Kips)	Median (Kips)	Std.Dev. (Kips)	Vehicles (%)
2 Axles	50	16	13	10	29.7
3 Axles	29	10	9	6	6.1
4 Axles	50	11	8	9	8.6
5 Axles	44	10	8	8	47.3
6 Axles	23	8	5	5	2.9
7 Axles	16	7	6	4	2.2
8 Axles	20	12	13	8	0.6
9 Axles	----	----	----	----	0.0
10 Axles	----	----	----	----	0.0
11 Axles	20	4	4	4	2.6
All Vehicles	50	10	8	8	100.0

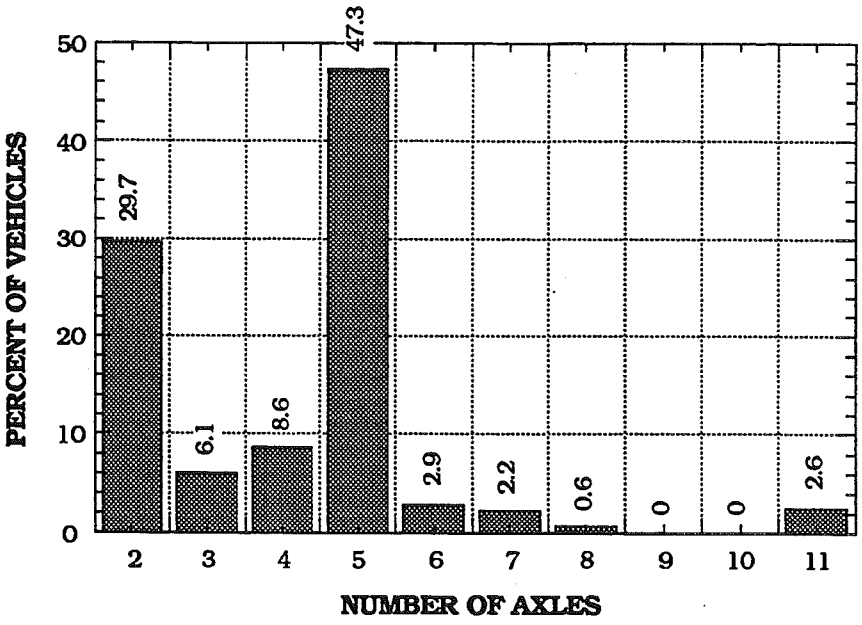


Fig. 9-4. I94/I75, Truck Type Histogram.

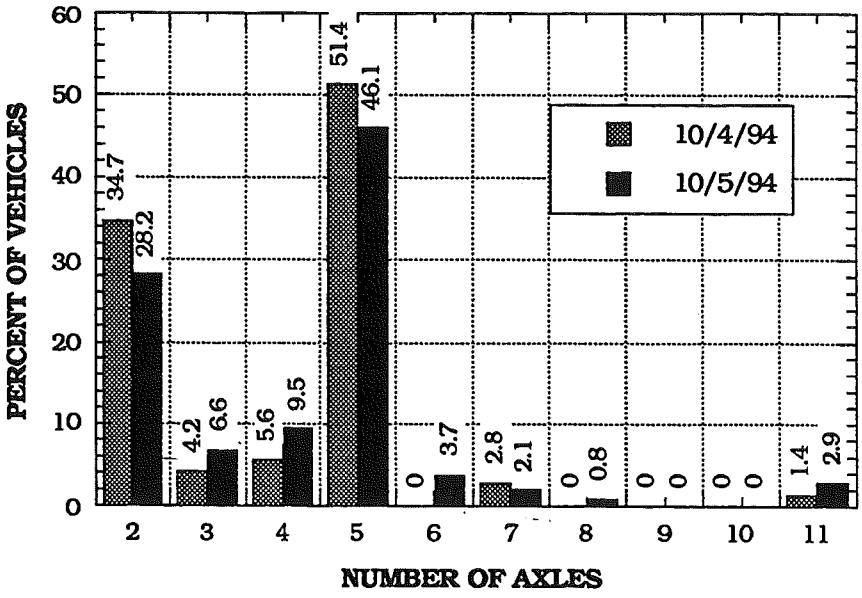


Fig. 9-5. I94/I75, Daily Truck Type Histogram.

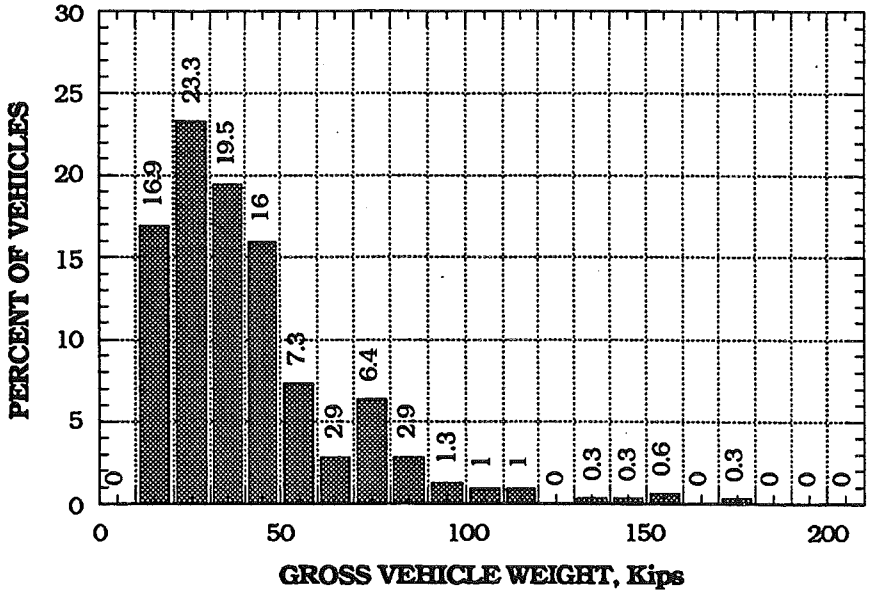


Fig. 9-6. I94/I75, GVW Histogram.

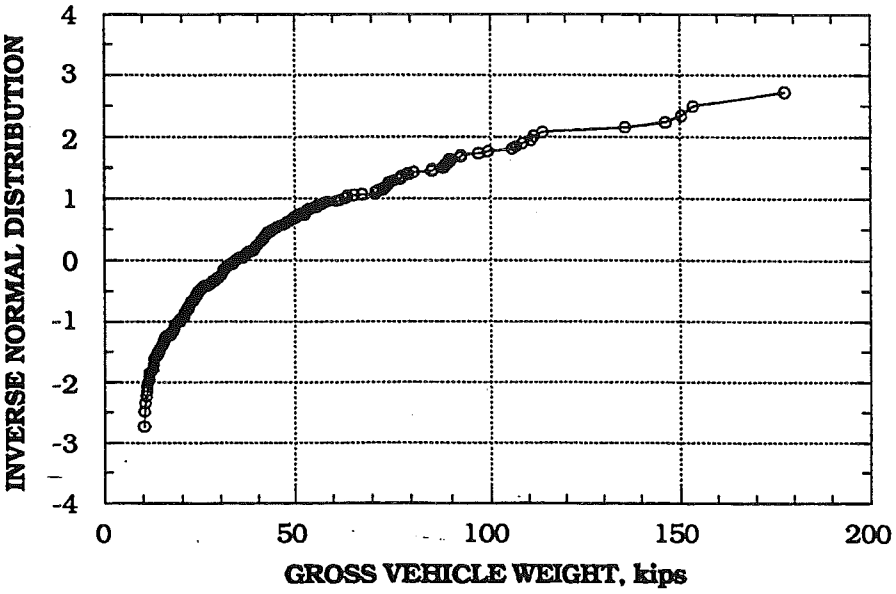


Fig. 9-7. I94/I75, GVW Distribution.

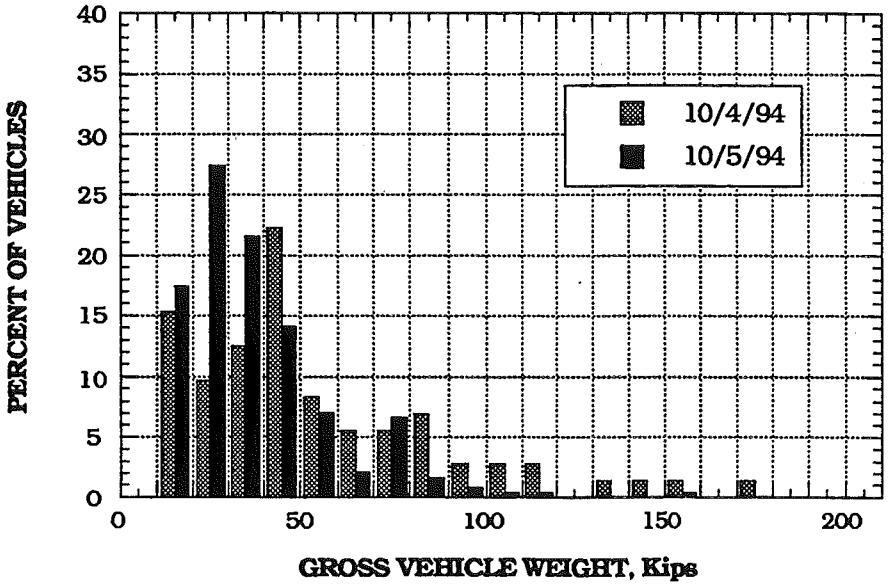


Fig. 9-8. I94/I75, Daily GVW Histogram.

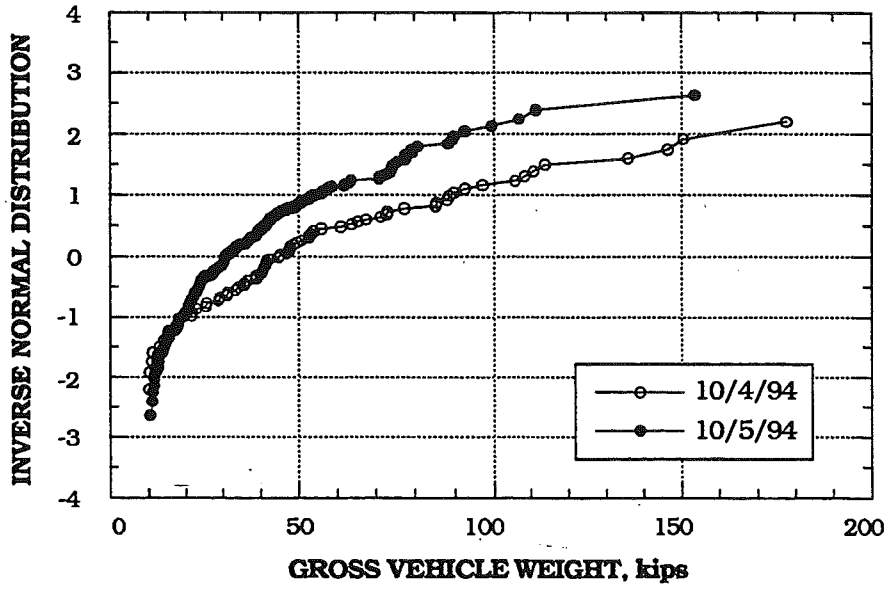


Fig. 9-9. I94/I75, Daily GVW Distributions.

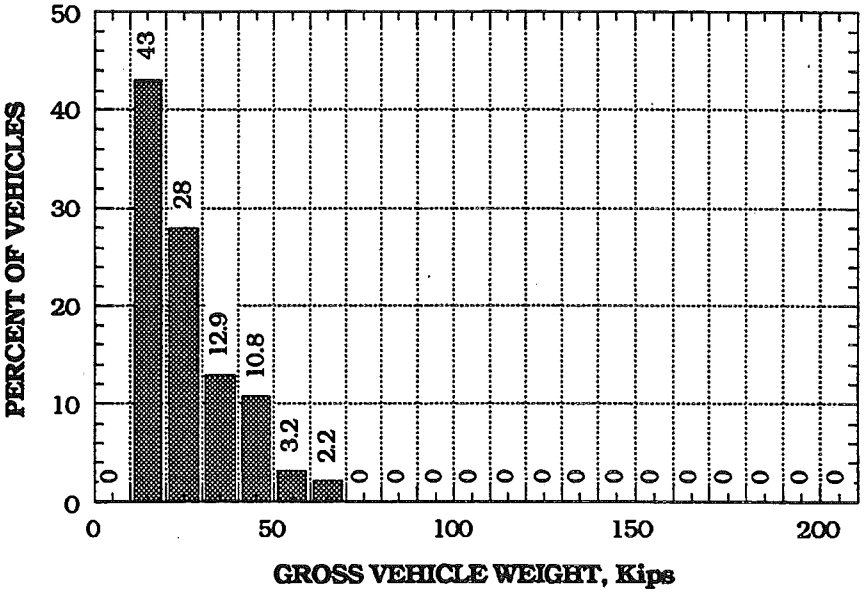


Fig. 9-10. I94/I75, 2 Axle GVW Histogram.

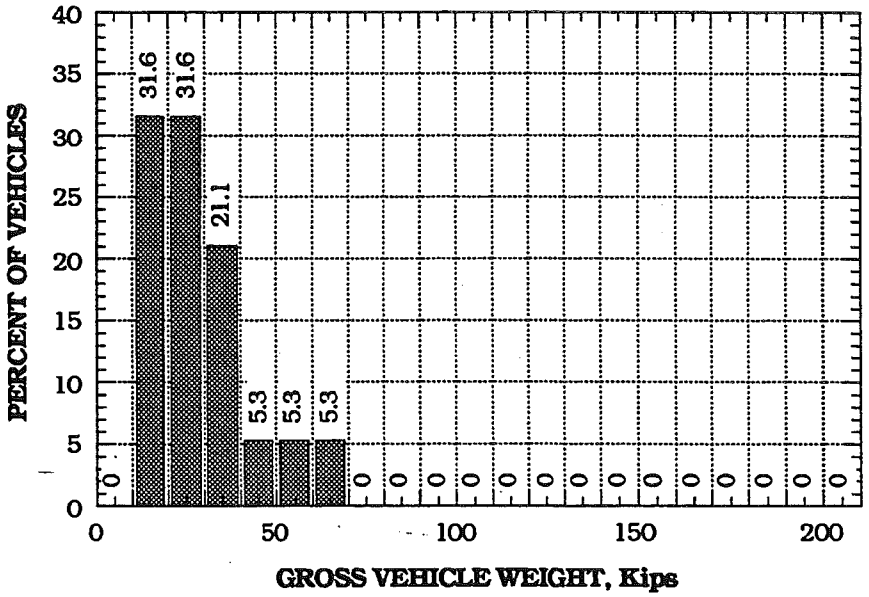


Fig. 9-11. I94/I75, 3 Axle GVW Histogram.

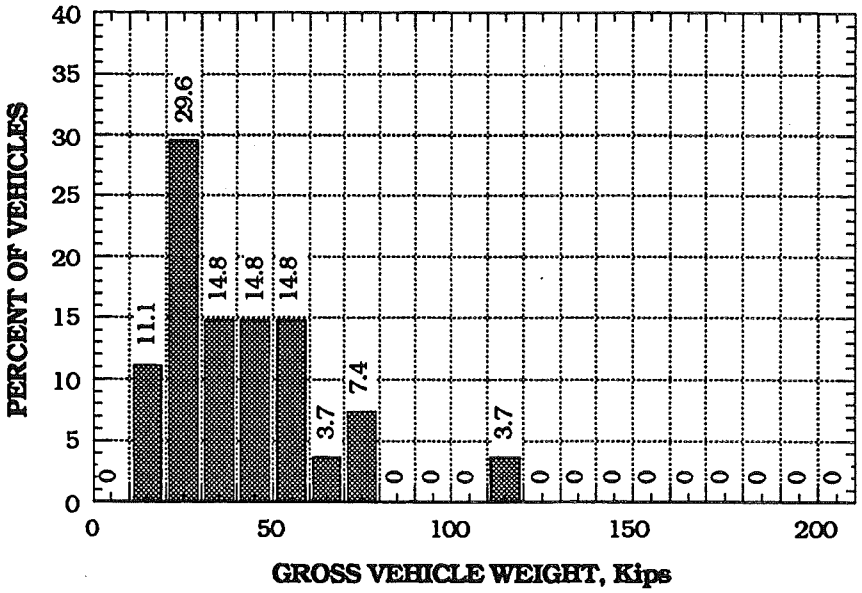


Fig. 9-12. I94/I75, 4 Axle GVW Histogram.

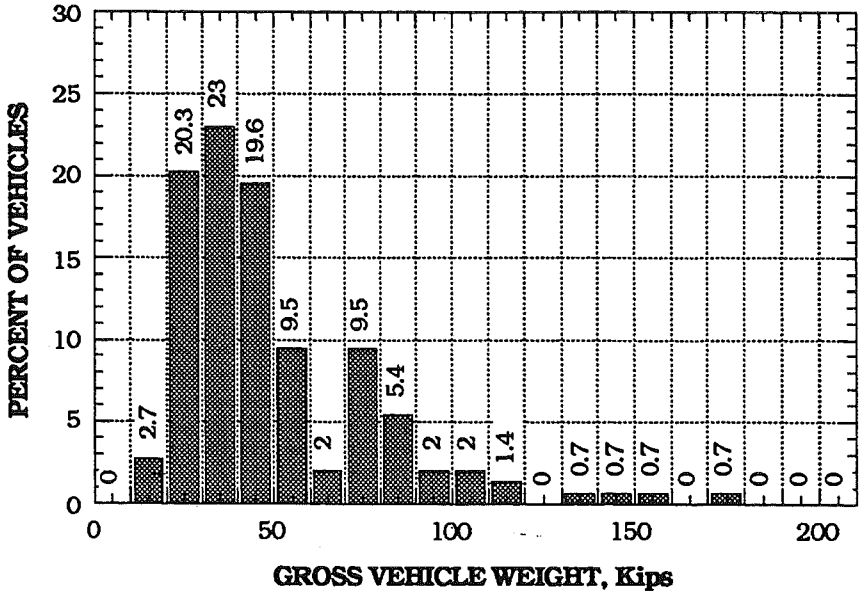


Fig. 9-13. I94/I75, 5 Axle GVW Histogram.

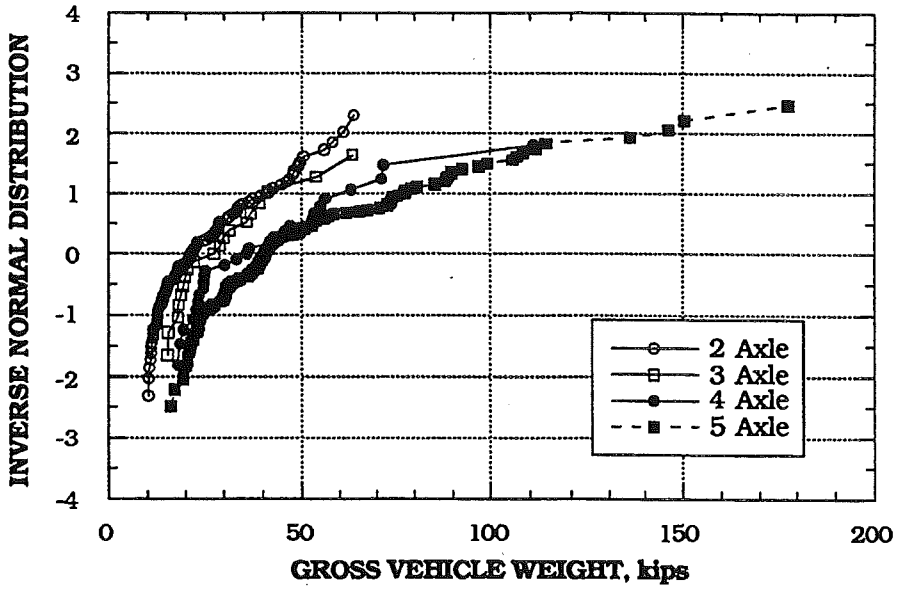


Fig. 9-14. I94/I75, 2, 3, 4, and 5 Axle GVW Distributions.

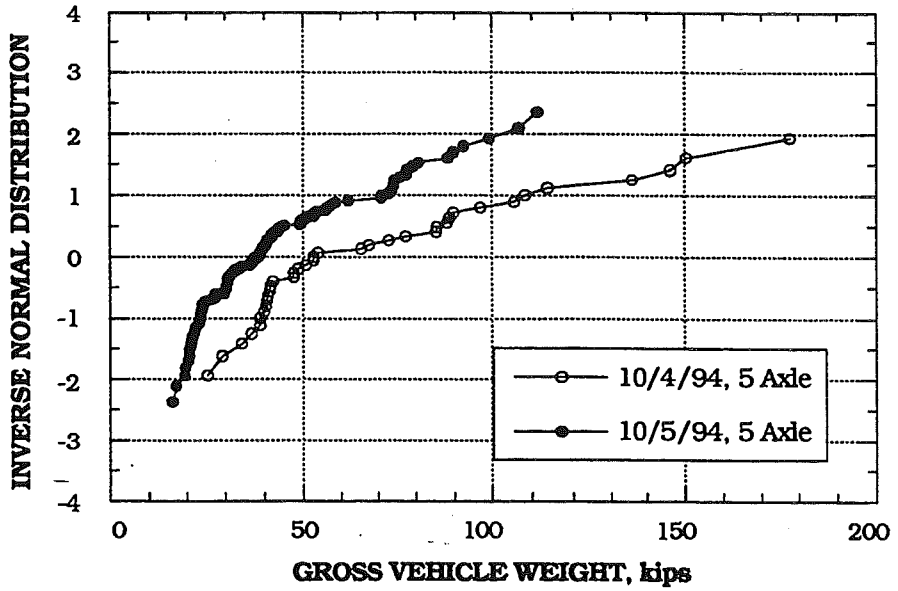


Fig. 9-15. I94/I75, Daily 5 Axle GVW Distributions.

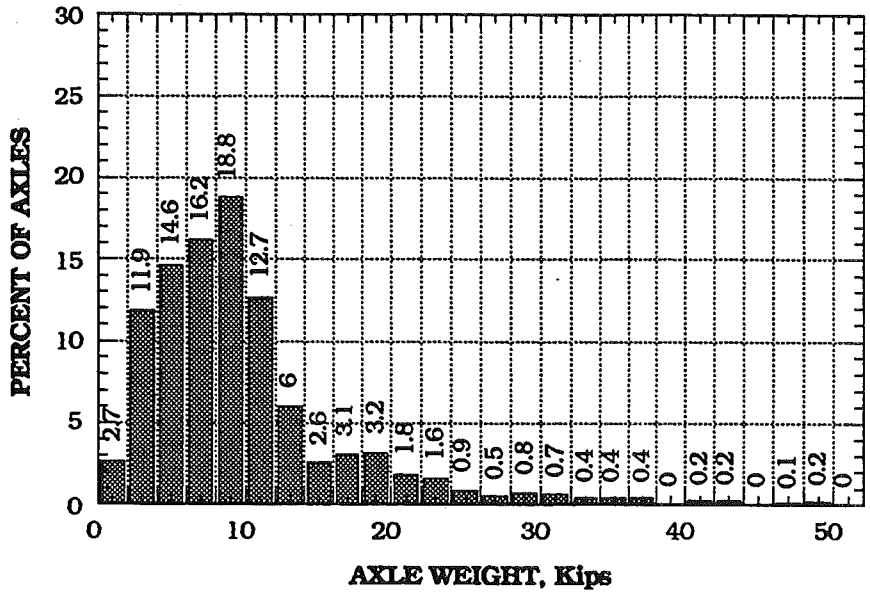


Fig. 9-16. I94/I75, Axle Weight Histogram.

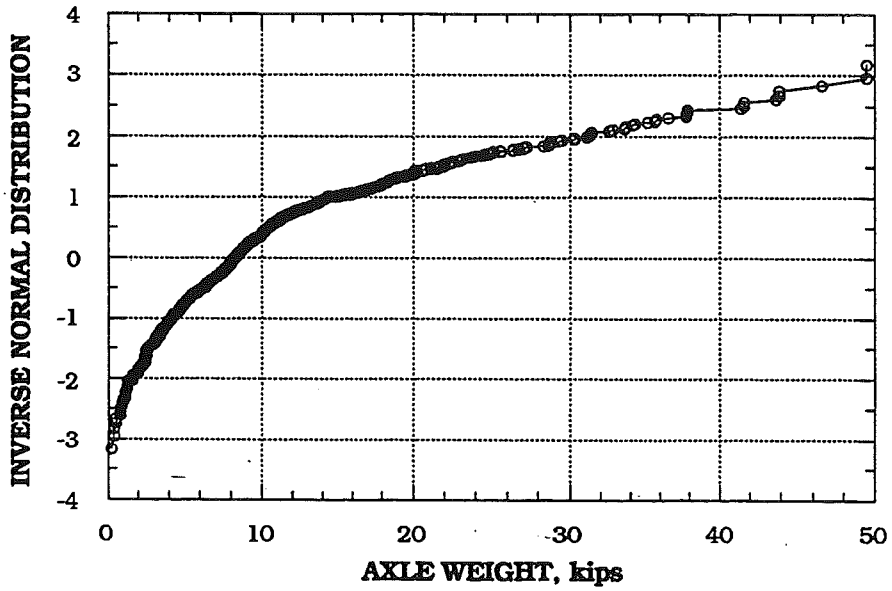


Fig. 9-17. I94/I75, Axle Weight Distribution.

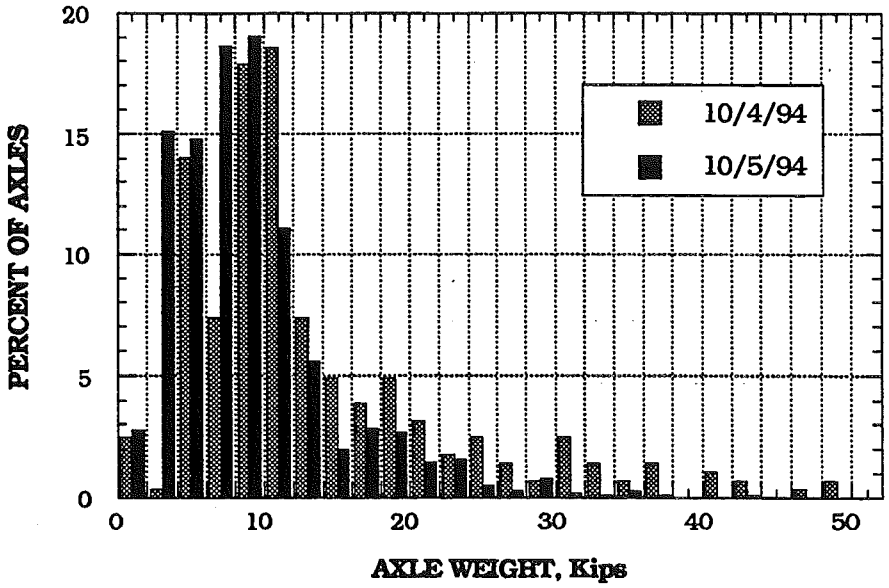


Fig. 9-18. I94/I75, Daily Axle Weight Histogram.

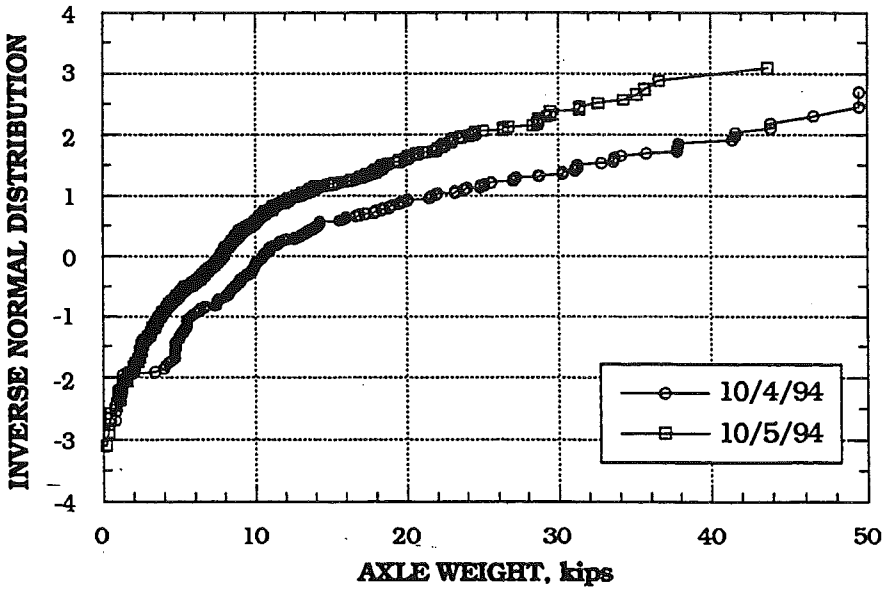


Fig. 9-19. I94/I75, Daily Axle Weight Distributions.

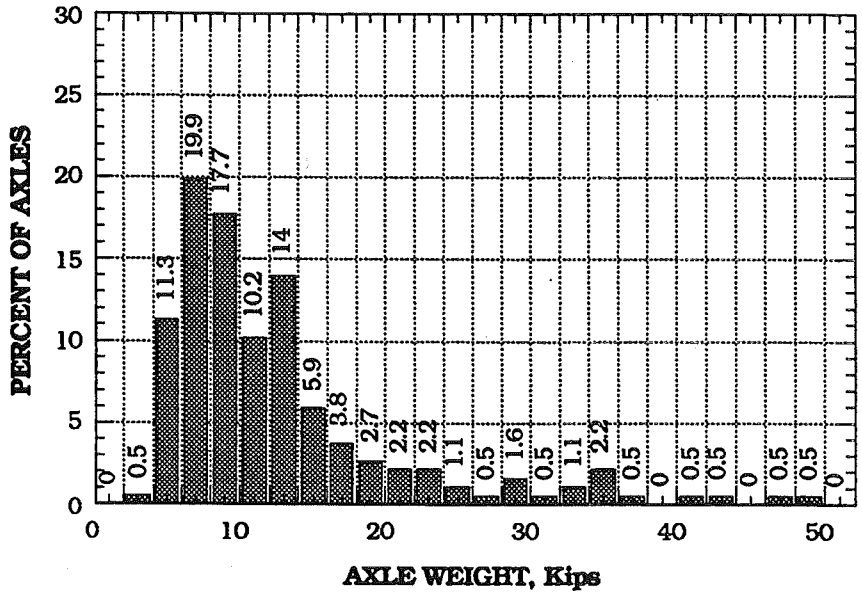


Fig. 9-20. I94/I75, Axle Weight Histogram of 2 Axle Vehicles.

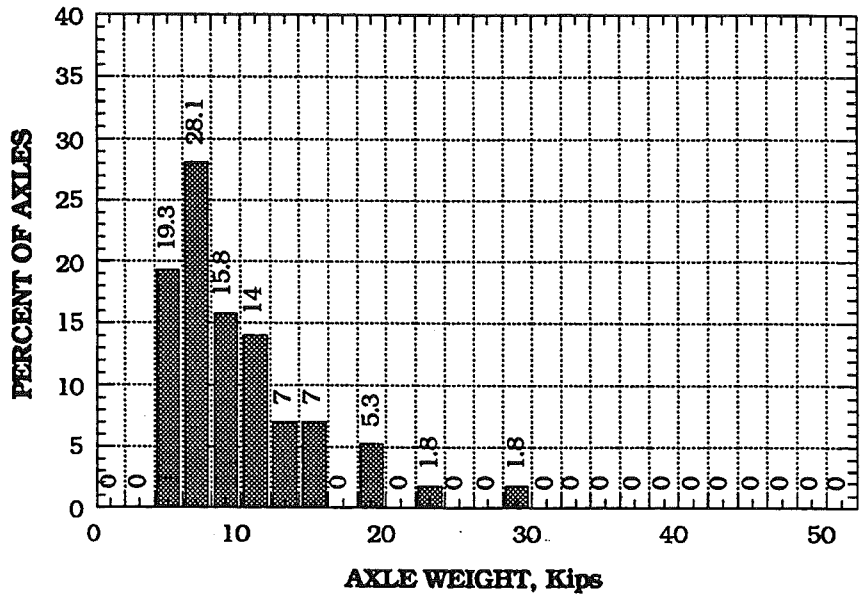


Fig. 9-21. I94/I75, Axle Weight Histogram of 3 Axle Vehicles.

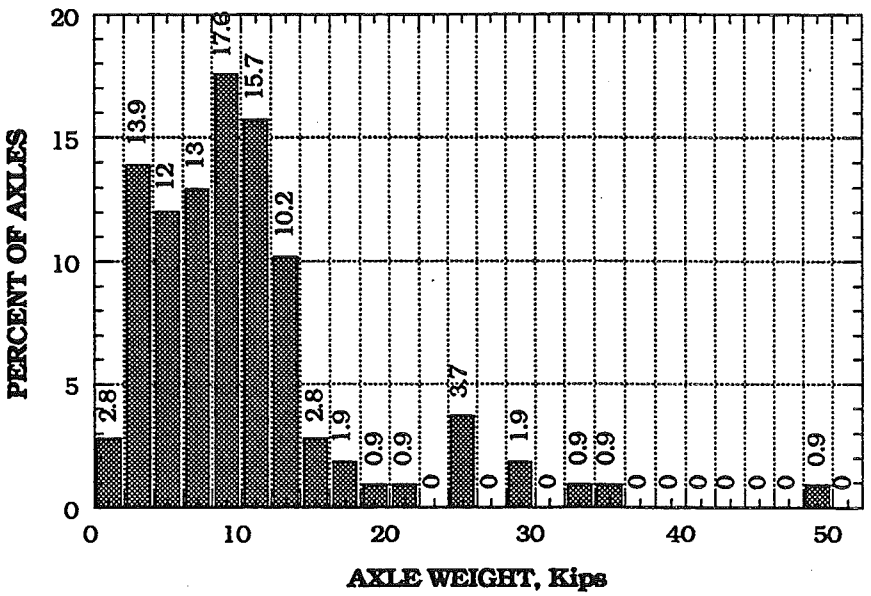


Fig. 9-22. I94/I75, Axle Weight Histogram of 4 Axle Vehicles.

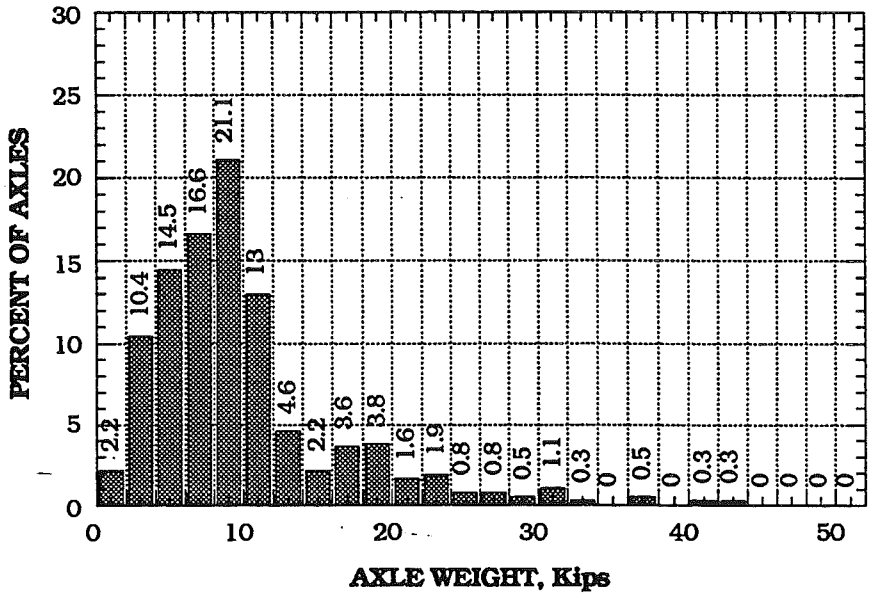


Fig. 9-23. I94/I75, Axle Weight Histogram of 5 Axle Vehicles.

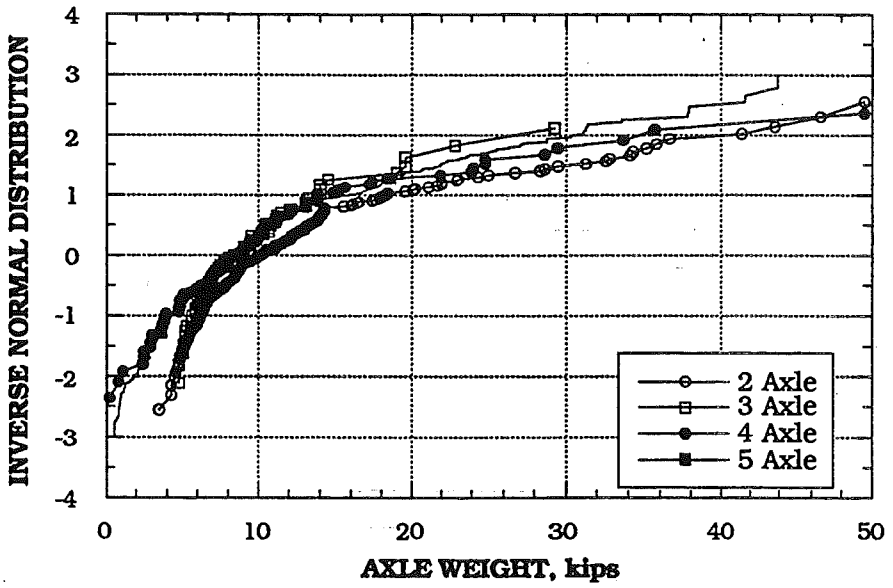


Fig. 9-24. I94/I75, Axle Weight Distributions of 2, 3, 4 and 5 Axles.

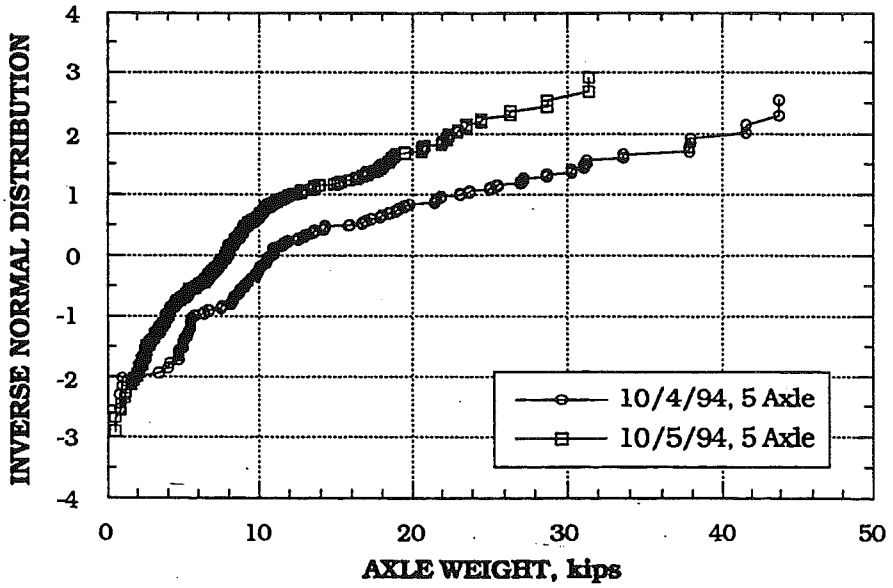


Fig. 9-25. I94/I75, Daily Axle Weight Distributions of 5 Axles.

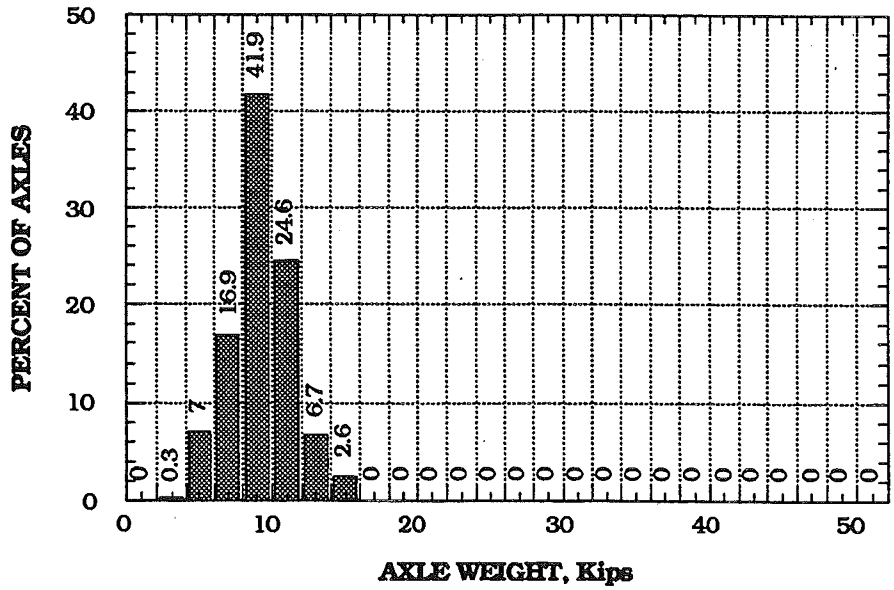


Fig. 9-26. I94/I75, Steering Axle Weight Histogram.

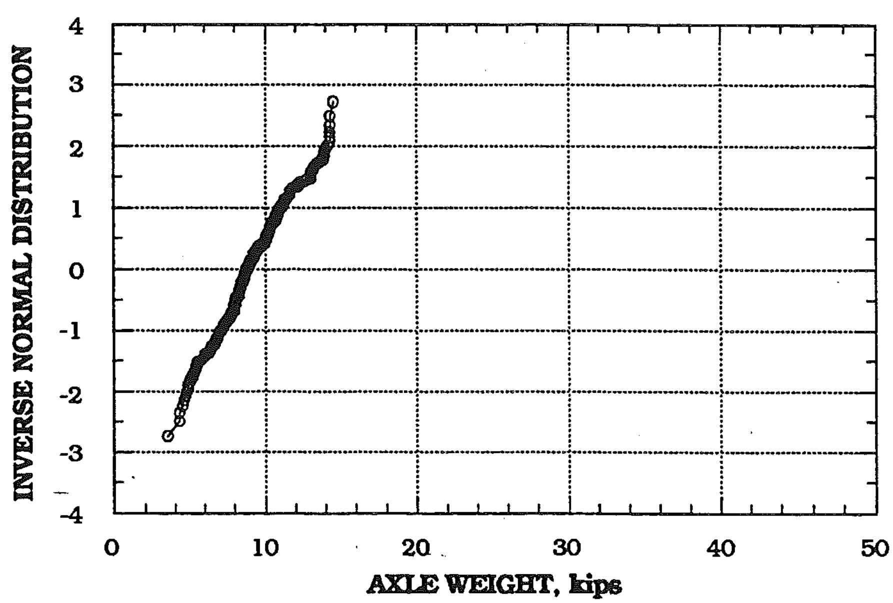


Fig. 9-27. I94/I75, Steering Axle Weight Distribution.

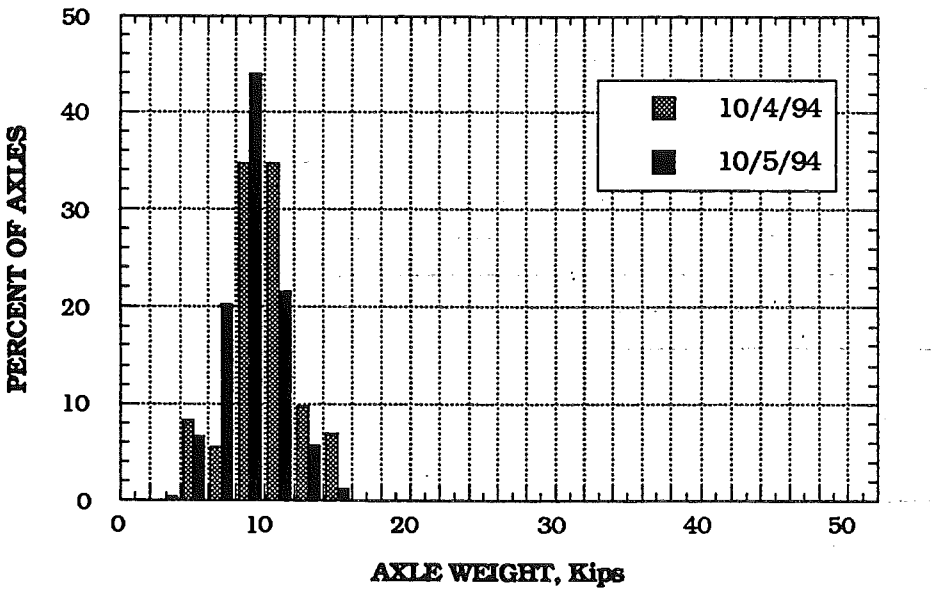


Fig. 9-28. I94/I75, Daily Steering Axle Weight Histogram.

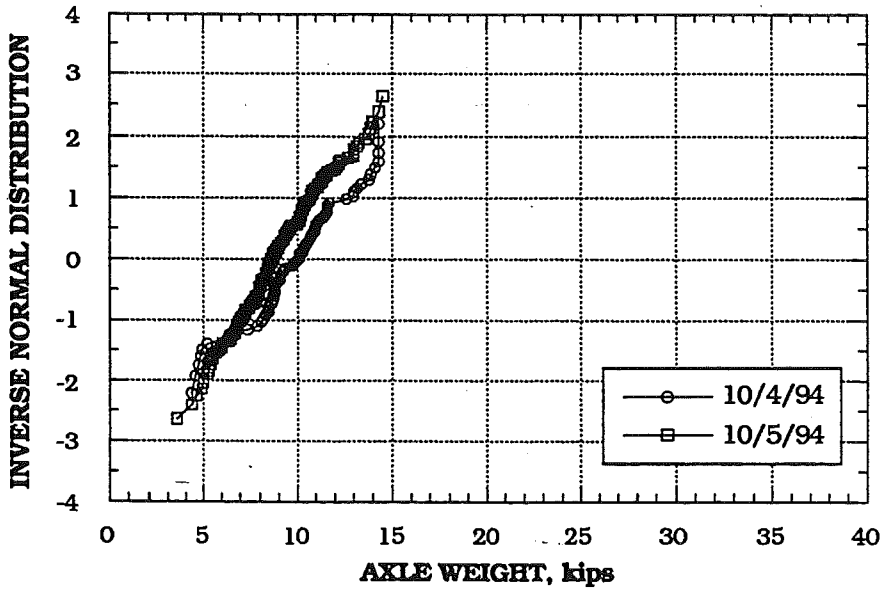


Fig. 9-29. I94/I75, Daily Steering Axle Weight Distributions.

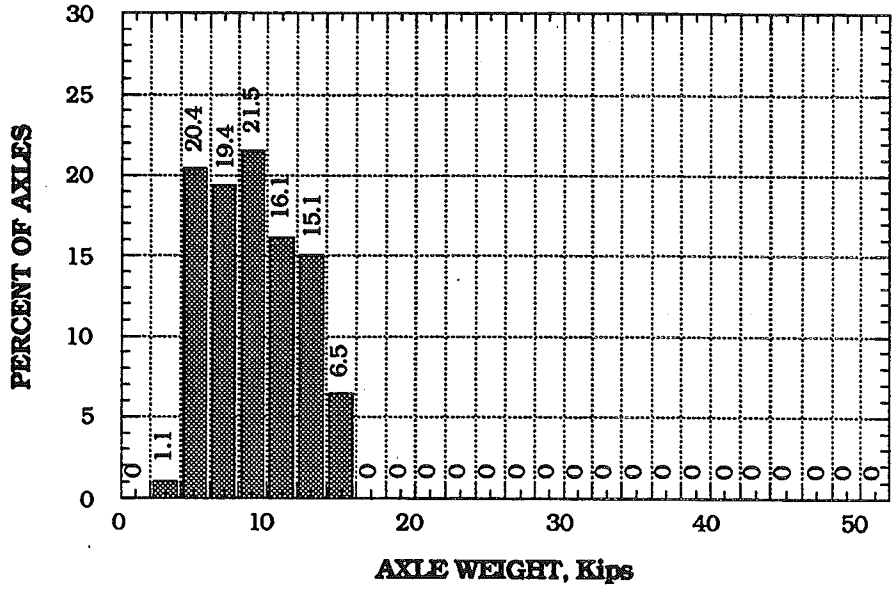


Fig. 9-30. I94/I75, Steering Axle Weight Histogram of 2 Axle Vehicles.

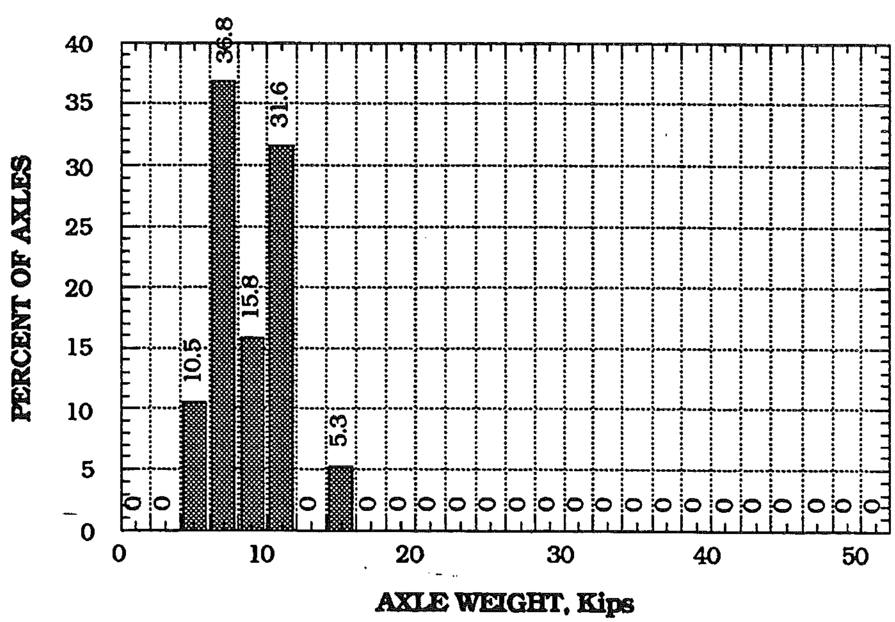


Fig. 9-31. I94/I75, Steering Axle Weight Histogram of 3 Axle Vehicles.

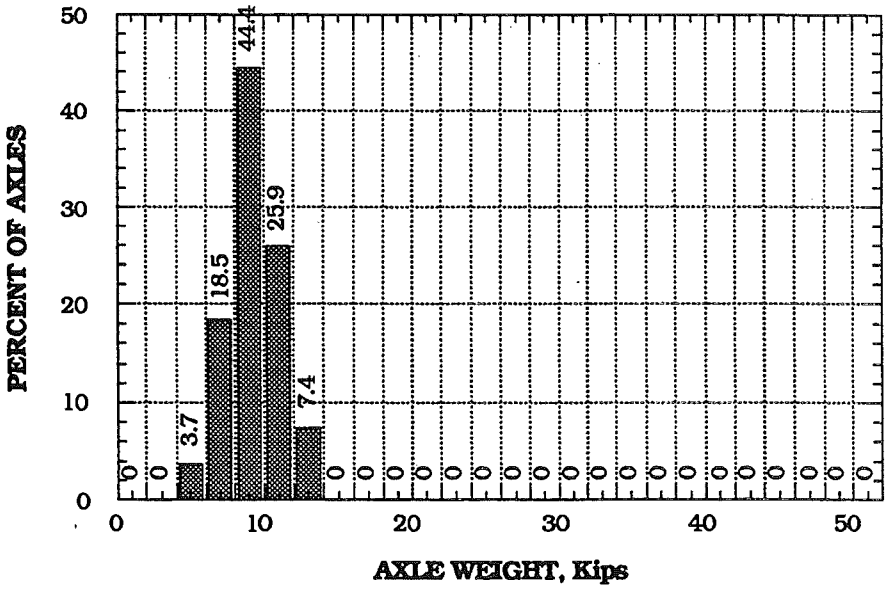


Fig. 9-32. I94/I75, Steering Axle Weight Histogram of 4 Axle Vehicles.

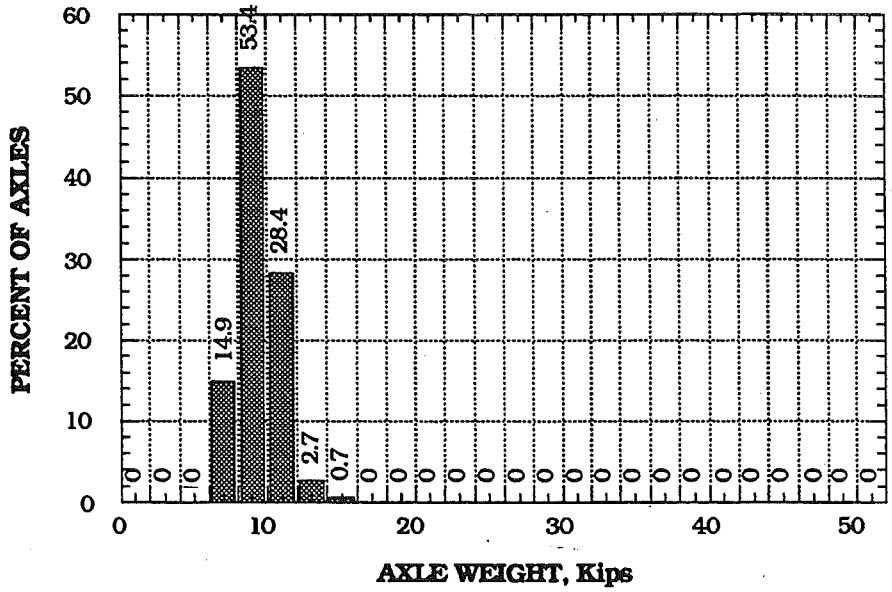


Fig. 9-33. I94/I75, Steering Axle Weight Histogram of 5 Axle Vehicles.

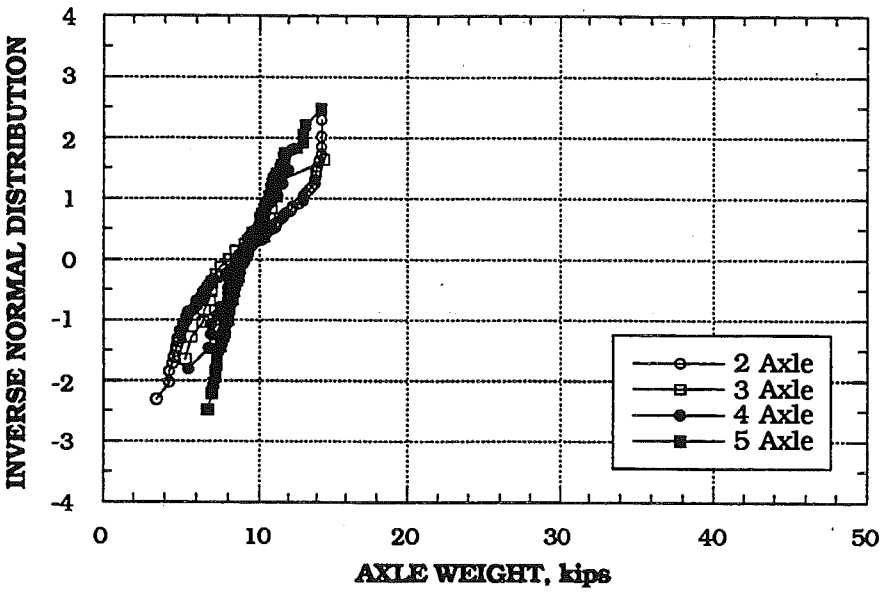


Fig. 9-34. I94/I75, Steering Axle Weight Distributions of 2, 3, 4 and 5 Axle Vehicles.

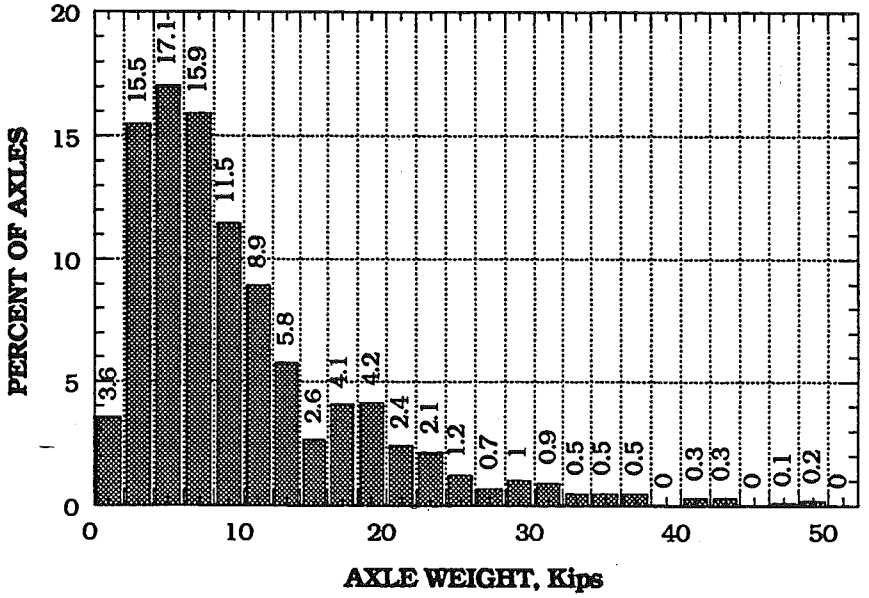


Fig. 9-35. I94/I75, Non-Steering Axle Weight Histogram.

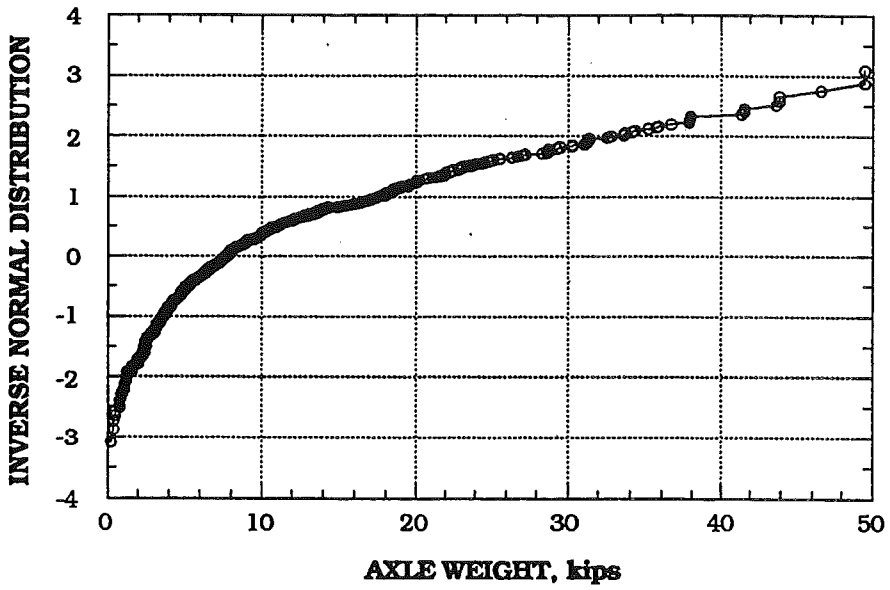


Fig. 9-36. I94/I75, Non-Steering Axle Weight Distribution.

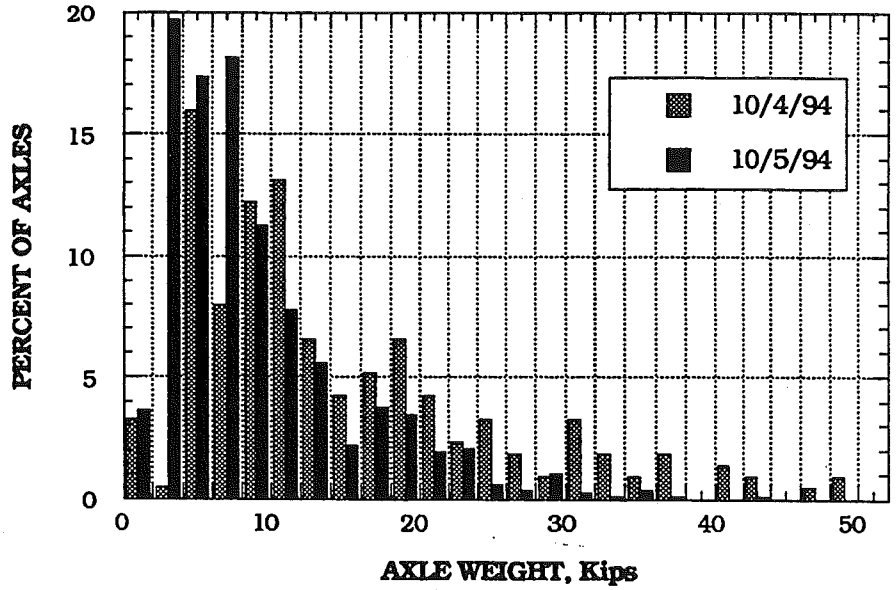


Fig. 9-37. I94/I75, Daily Non-Steering Axle Weight Histogram.

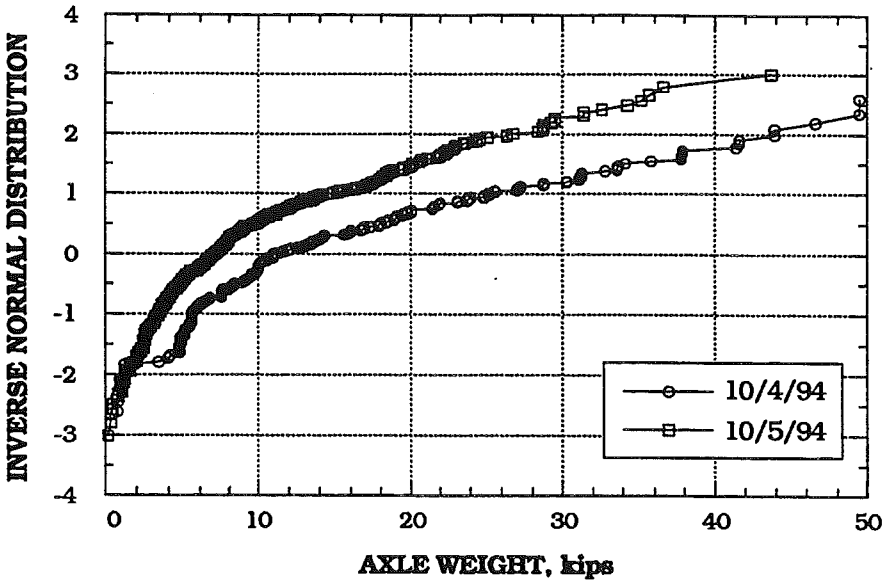


Fig. 9-38. I94/I75, Daily Non-Steering Axle Weight Distributions

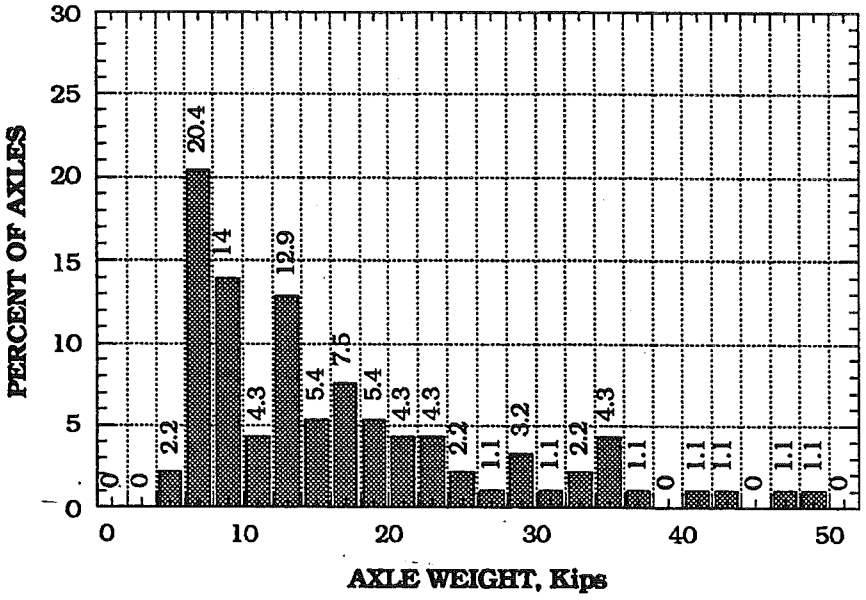


Fig. 9-39. I94/I75, Non-Steering Axle Weight Histogram of 2 Axles.

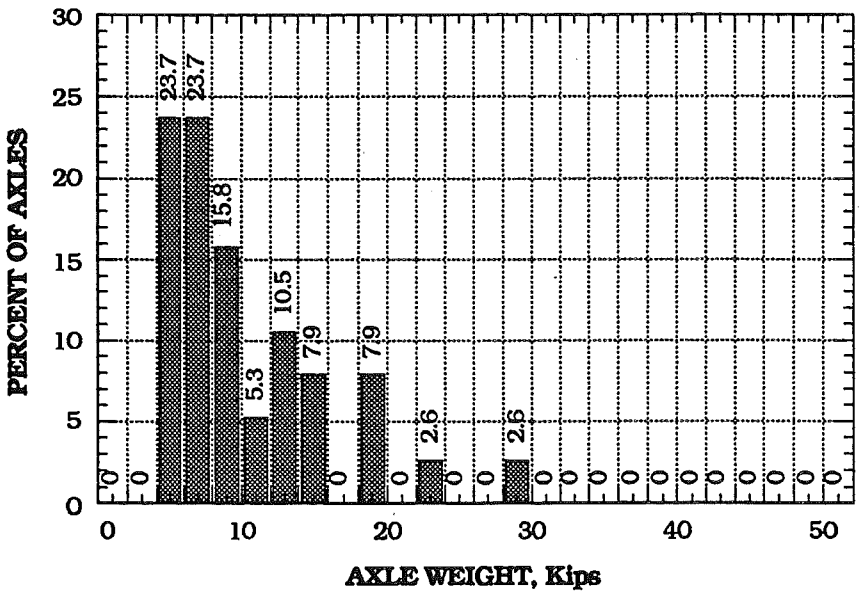


Fig. 9-40. I94/I75, Non-Steering Axle Weight Histogram of 3 Axles.

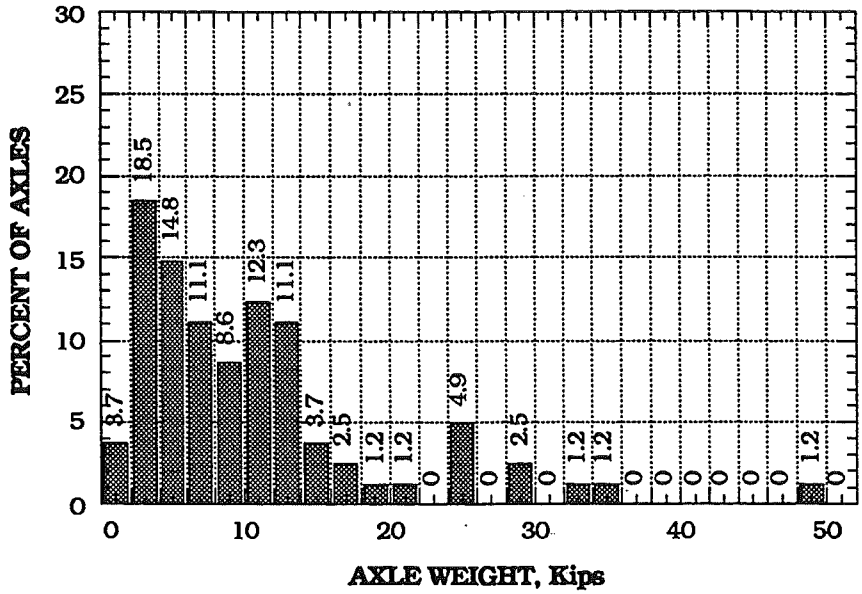


Fig. 9-41. I94/I75, Non-Steering Axle Weight Histogram of 4 Axles.

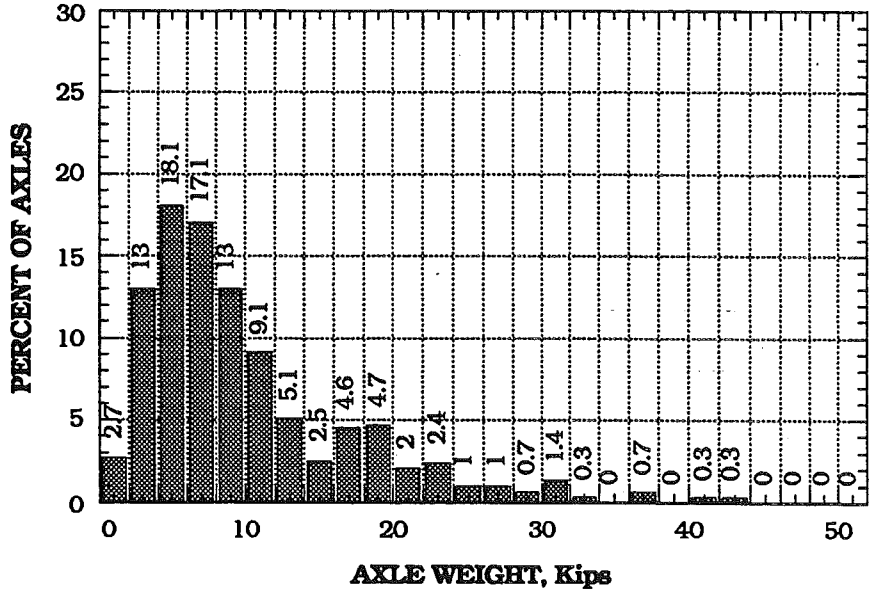


Fig. 9-42. I94/I75, Non-Steering Axle Weight Histogram of 5 Axles.

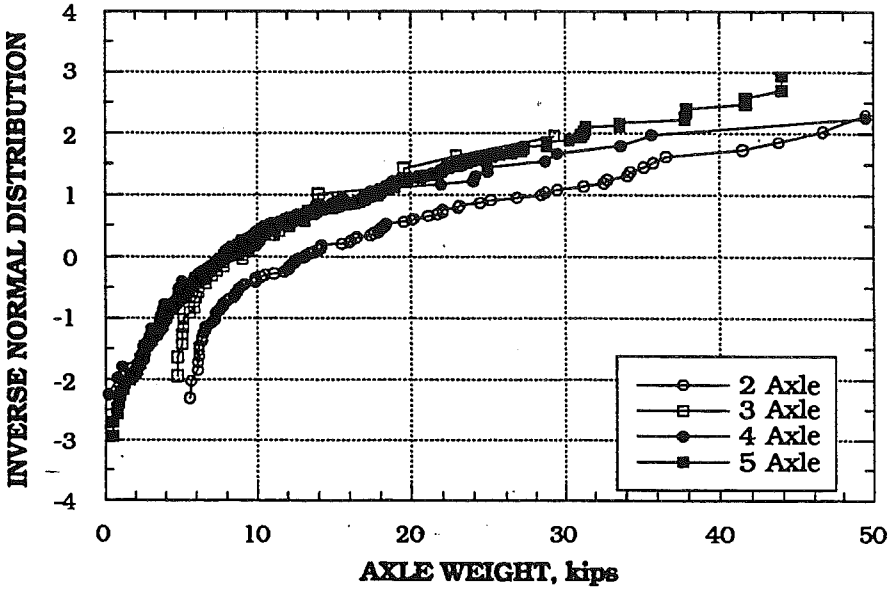


Fig. 9-43. I94/I75, Non-Steering Axle Weight Distributions of 2, 3, 4 and 5 Axle Vehicles.

10. BRIDGE ON M-153 WESTBOUND (FORD ROAD) OVER M39 SOUTHBOUND (SOUTHFIELD FREEWAY) IN DETROIT (M153/M39)

10. 1 Description of the bridge

Bridge M153/M39 carries westbound M-153 traffic on Ford Road over M-39 southbound (Southfield Freeway) in Detroit. It is shown in Fig. 10-1. The plan view, cross section and other details are shown in Fig. 10-2 and 10-3. Measurements were taken in the span No.6 (in the direction of traffic). The investigated span is 31'-9" and the width of the half bridge is 63'-11" with practically no skewness and consists of 12 girders spaced 4'-11 1/2" and 5'-10".

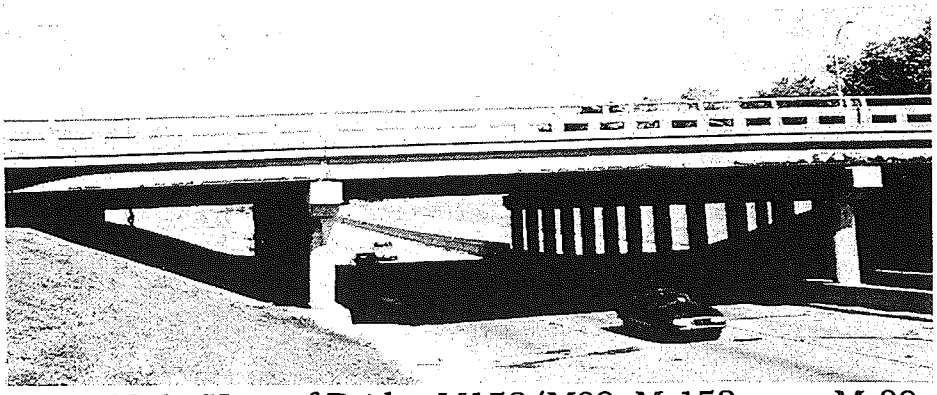


Fig. 10-1. View of Bridge M153/M39, M-153 over M-39.

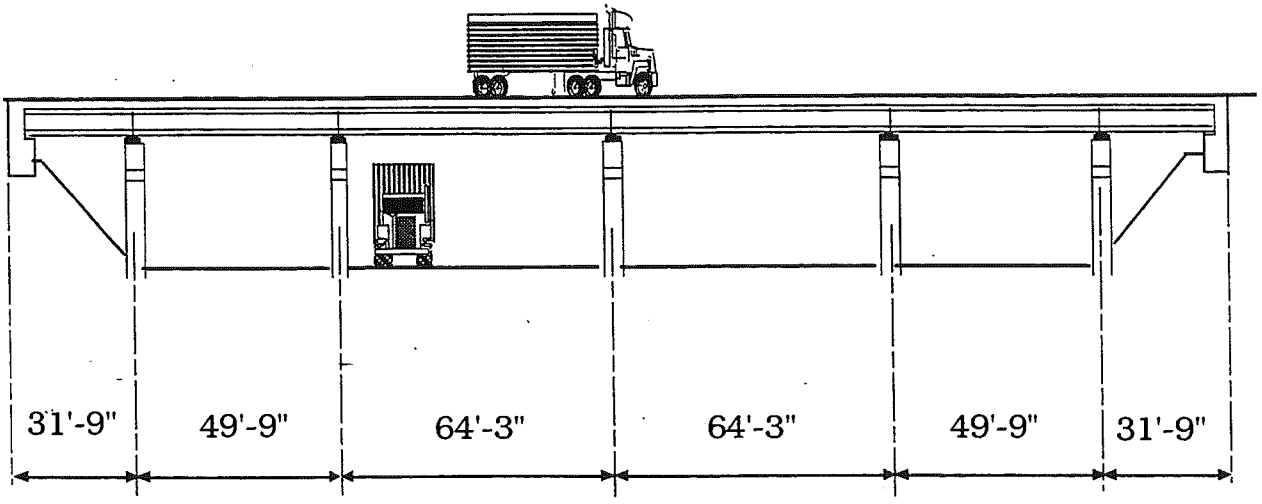


Fig. 10-2. Bridge M153/M39, M-153 Westbound over M-39 Southbound

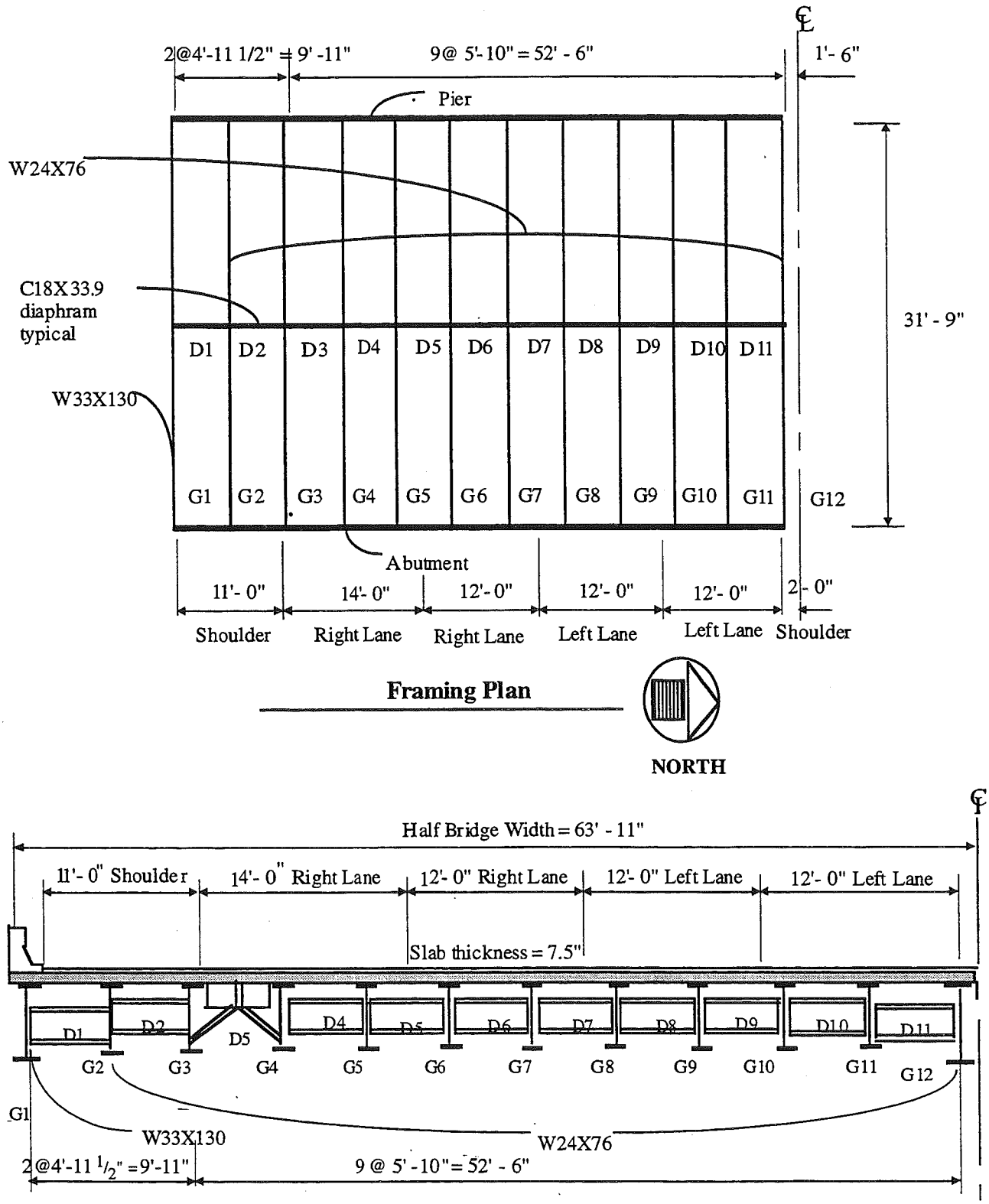


Fig. 10-3. Bridge M153/M39, M-153 Westbound over M-39 Southbound Plan View and Cross Section of Bridge Span No.6.

10.2 Weigh-in-Motion Measurements

Weigh-in-motion (WIM) statistics are presented in Table 10-1 to Table 10-6 and in Fig. 10-4 to Fig. 10-42. This data includes all trucks with a gross vehicle weight (GVW) of 10 kips and greater for 2-axle vehicles, and of 15 kips and greater for three or more axle vehicles, regardless of axle weight. This filtered WIM data has been used for all analysis of GVW and axle weight. The data may also include permit loads. The data measured by WIM are recorded in the FHWA card seven 80-column format.

Table 10-1 summarizes an estimated average daily truck traffic (ADTT) in one direction, and the total number of vehicles weighed by date and by different number of axle vehicles. Fig. 10-4 is the frequency histogram of trucks corresponding to different number of axles. Only a few 5 or 11-axle trucks were observed. Fig. 10-5 shows the daily frequency histogram of trucks. There is slight difference by the date of measurement. Table 10-2 presents Federal Highway Administration (FHWA) truck class frequency vs lane statistics. Federal Highway Administration (FHWA) axle configuration class is presented in the Appendix A. Note that the last digit from the FHWA axle class is not included in Table 10-2.

Table 10-3 is the GVW statistics of maximum, mean, median, standard deviation, and percentage of overloaded vehicles. The statistics are given for all vehicles and separately different number of axle vehicles. The GVW limit in Table 10-3 might not be the legal limit. It is difficult to determine the GVW limit with only number of axles. It depends not only on number of axles, but axle spacings. Thus, it was decided to assign reasonably high GVW limits and to give some ideas about how heavy the vehicles were. Fig. 10-6 and Fig. 10-7 are the histograms of GVW and the corresponding cumulative distribution function (CDF) of GVW for all trucks observed and measured on M153/M39 respectively. In Fig. 10-7, each circle represents one truck in the data file. From the graph and from Table 10-3 the heaviest vehicle observed weighed 78 kips with a

mean GVW of 22 kips. Results of the individual day measurements are shown in Fig. 10-8 and Fig. 10-9. The day to day CDF's are similar in shape and average GVW with the largest difference at the upper tail of the distribution. GVW histograms for different number of axle vehicles are presented in Fig. 10-10 to Fig. 10-13. The corresponding CDF's are shown in Fig. 10-14. There were no overloaded 5 or 11-axle vehicles.

Table 10-4 is the axle weight statistics of maximum, mean, median, standard deviation, and percentage of overloaded axles. The statistics are given for all vehicles and separately different number of axle vehicles. In this table, axle weight limits were intended to give some ideas about how heavy the axles were. The statistics depend on axle spacings rather than number of axles. Fig. 10-15 and Fig. 10-16 are the histograms of axle weight for all vehicles and the corresponding CDF respectively. The maximum axle weight observed at M153/M39 was 21 kips with a mean of seven kips. Fig. 10-17 and Fig. 10-18 show the daily axle weight histogram and CDF's. There is slight difference in the axle weight distributions, however a similar trend in the distributions is evident. Axle weight histograms for different number of axle vehicles are presented in Fig. 10-19 to Fig. 10-22. The corresponding CDF's are shown in Fig. 10-23. There were no overloaded axles for 5 and 11-axle vehicles. The daily CDF's of axle weight for five vehicles are plotted in Fig. 10-24 for comparison of the daily distribution. Again, slight difference in the daily distributions can be observed.

Table 10-5 is the steering axle weight statistics of maximum, mean, median, and standard deviation of all vehicles and different number of axle vehicles. Fig. 10-25 and Fig. 10-26 are the steering axle weight histogram for all vehicles and the corresponding CDF respectively. The maximum observed steering axle weight was 13 kips with a mean of 7 kips. Fig. 10-27 and Fig. 10-28 show the daily steering axle weight histogram and CDF's. Steering axle weight histograms for different number of axle vehicles are presented in Fig. 10-29 to Fig. 10-32. The corresponding CDF's are shown in Fig. 10-33.

Table 10-6 is the non-steering axle weight statistics of maximum, mean, median, and standard deviation of all vehicles and different number of axle vehicles. Fig. 10-34 and Fig. 10-35 are the non-steering axle weight histogram for all vehicles and the corresponding CDF. The maximum non-steering axle weight was 21 kips with a mean of eight kips. Fig. 10-36 and Fig. 10-37 show the daily non-steering axle weight histogram and CDF's. Non-steering axle weight histograms for different number of axle vehicles are presented in Fig. 10-38 to Fig. 10-41. The corresponding CDF's are shown in Fig. 10-42.

The steering and non-steering axle weight CDF's of Fig. 10-26 and Fig. 10-35 indicate a significant difference in both variation and magnitudes. The standard deviation of steering axle weight was two kips with a maximum of 13 kips while the standard deviation of non-steering axle weight was three kips with a maximum of 21 kips.

Review of the results indicates that virtually all truck weights are within legal limits. Only a few 2-axle vehicles had axle weight of 18 kips or greater.

Table 10-1. Bridge M153/M39, Number of Trucks Weighed and Estimated ADTT.

Number of Trucks Weighed Gross Vehicle Weight > 10 Kips for 2 Axle Vehicles, Gross Vehicle Weight > 15 Kips for 3 or more Axle Vehicles.				
Date	10/6/94	10/7/94	Total	Vehicles (%)
2 Axles	44	50	94	56.3
3 Axles	9	19	28	16.8
4 Axles	12	9	21	12.6
5 Axles	7	11	18	10.8
6 Axles	0	2	2	1.2
7 Axles	0	1	1	0.6
8 Axles	0	0	0	0.0
9 Axles	0	2	2	1.2
10 Axles	0	0	0	0.0
11 Axles	1	0	1	0.6
All Vehicles	73	94	167	100.0
Estimated ADTT = 500 Trucks (in one direction)				

Table 10-2. Bridge M153/M39, Truck Class vs Lane Statistics.

Truck Class (FHWA)	Right Lane (1) (%)	Left Lane (2) (%)	Total (%)
4	0.0	0.0	0.0
5	21.5	42.3	63.8
6	0.9	1.0	1.9
7	0.3	0.3	0.7
8	2.2	2.7	4.9
9	1.9	1.4	3.2
10	0.3	0.0	0.3
11	0.0	0.0	0.0
12	0.0	0.0	0.0
13	0.0	0.0	0.0
14	9.9	15.2	25.1
Total Lane %	37.0	63.0	100.0

Table 10-3. Bridge M153/M39, Gross Vehicle Weight Statistics.

Vehicle Type	Max. (Kips)	Mean (Kips)	Median (Kips)	Std.Dev. (Kips)	GVW Limit (Kips)	Percentage over the Limit
2 Axles	32	15	14	4	40	0
3 Axles	39	23	22	5	60	0
4 Axles	45	29	26	8	70	0
5 Axles	78	36	31	18	80	0
6 Axles	56	53	53	5	90	0
7 Axles	28	28	28	----	120	0
8 Axles	----	----	----	----	125	----
9 Axles	52	50	50	2	135	0
10 Axles	----	----	----	----	150	----
11 Axles	63	63	63	----	164	0
All Vehicles	78	22	18	12	varies	0

Table 10-4. Bridge M153/M39, Axle Weight Statistics.

Vehicle Type	Max. (Kips)	Mean (Kips)	Median (Kips)	Std.Dev. (Kips)	Axle Weight Limit (Kips)	Percentage over the Limit
2 Axles	21	7	7	3	18	1
3 Axles	15	8	7	2	18	0
4 Axles	15	7	7	3	18	0
5 Axles	18	7	7	4	18	0
6 Axles	10	9	9	1	18	0
7 Axles	8	4	4	2	18	0
8 Axles	----	----	----	----	18	----
9 Axles	12	6	3	4	18	0
10 Axles	----	----	----	----	18	----
11 Axles	10	6	7	3	18	0
All Vehicles	21	7	7	3	18	0

Table 10-5. Bridge M153/M39, Steering Axle Weight Statistics.

Vehicle Type	Max. (Kips)	Mean (Kips)	Median (Kips)	Std.Dev. (Kips)	Vehicles (%)
2 Axles	11	7	7	2	56.3
3 Axles	10	8	8	1	16.8
4 Axles	13	9	8	2	12.6
5 Axles	10	9	8	1	10.8
6 Axles	9	9	9	1	1.2
7 Axles	8	8	8	----	0.6
8 Axles	----	----	----	----	0.0
9 Axles	9	9	9	0	1.2
10 Axles	----	----	----	----	0.0
11 Axles	10	10	10	----	0.6
All Vehicles	13	7	7	2	100.0

Table 10-6. Bridge M153/M39, Non-Steering Axle Weight Statistics.

Vehicle Type	Max. (Kips)	Mean (Kips)	Median (Kips)	Std.Dev. (Kips)	Vehicles (%)
2 Axles	21	8	8	3	56.3
3 Axles	15	8	7	3	16.8
4 Axles	15	7	6	3	12.6
5 Axles	18	7	5	4	10.8
6 Axles	10	9	9	1	1.2
7 Axles	5	4	4	2	0.6
8 Axles	----	----	----	----	0.0
9 Axles	12	5	3	4	1.2
10 Axles	----	----	----	----	0.0
11 Axles	8	5	5	3	0.6
All Vehicles	21	8	7	3	100.0

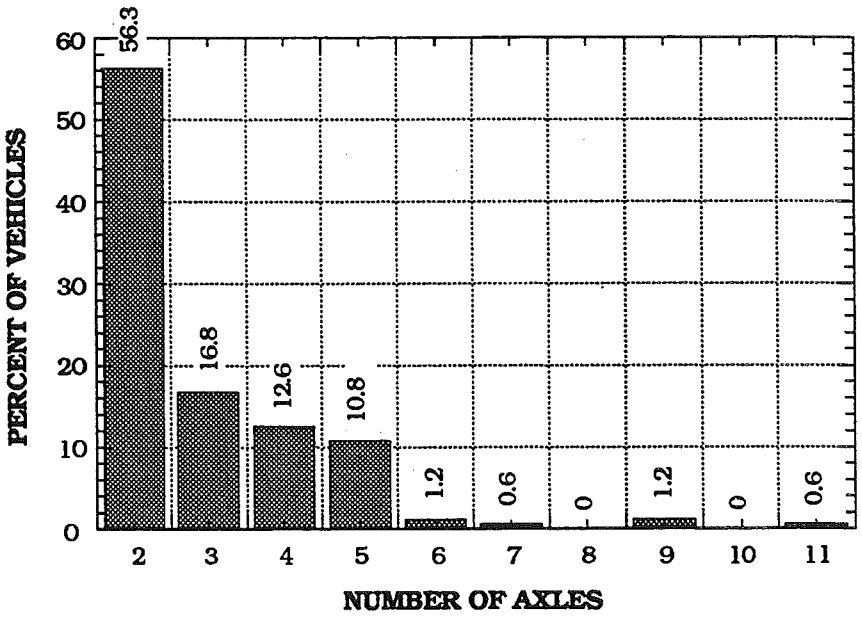


Fig. 10-4. M153/M39, Truck Type Histogram.

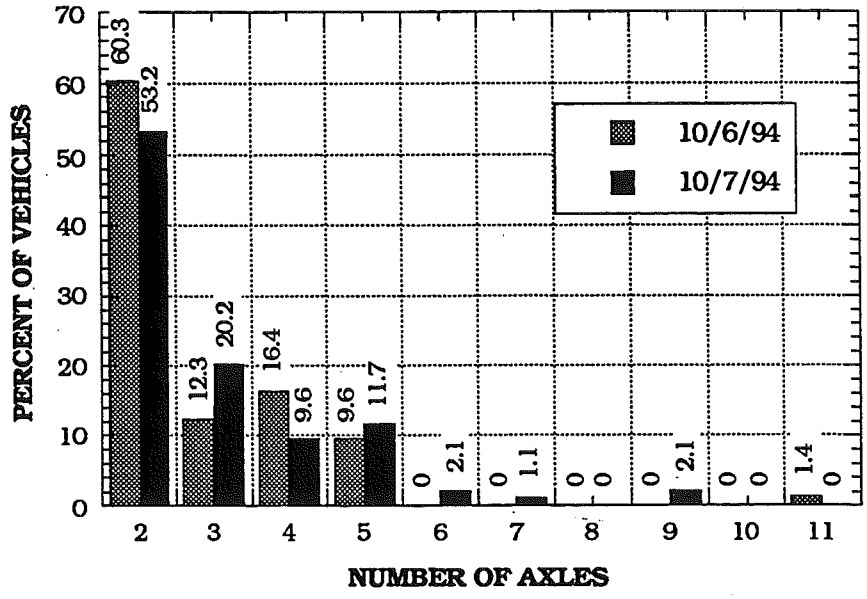


Fig. 10-5. M153/M39, Daily Truck Type Histogram.

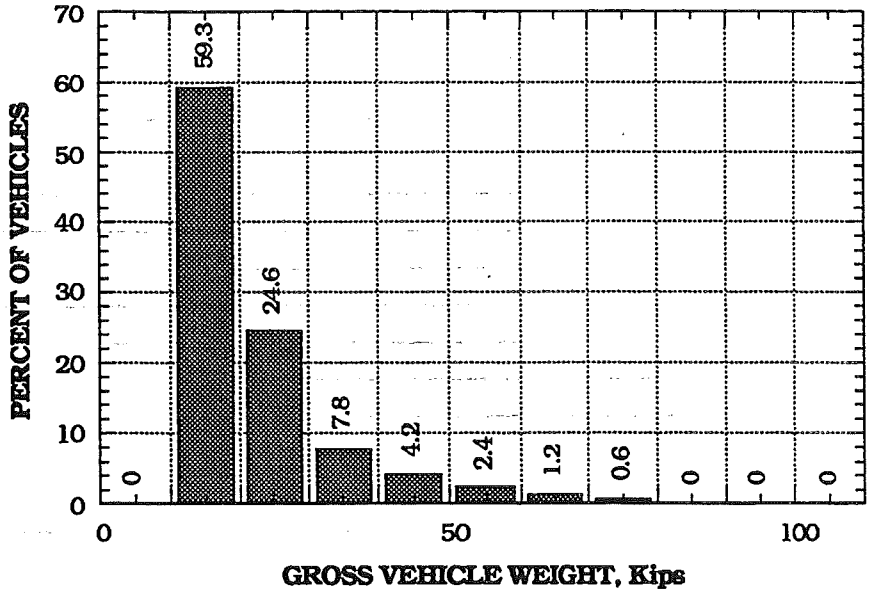


Fig. 10-6. M153/M39, GVW Histogram.

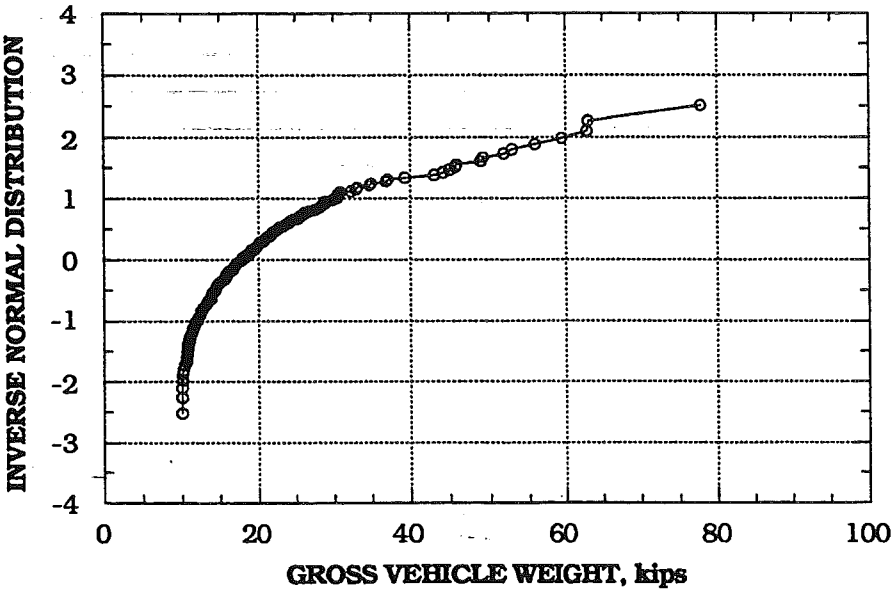


Fig. 10-7. M153/M39, GVW Distribution.

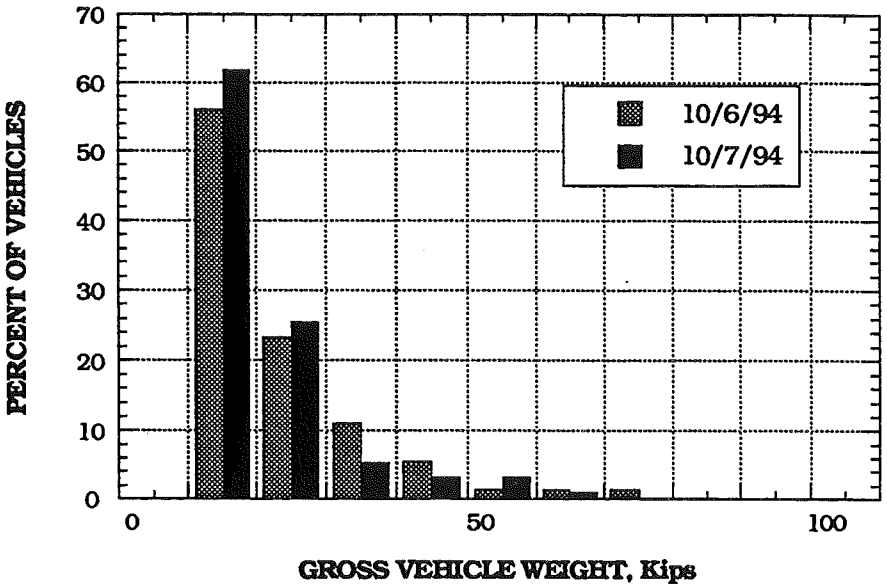


Fig. 10-8. M153/M39, Daily GVW Histogram.

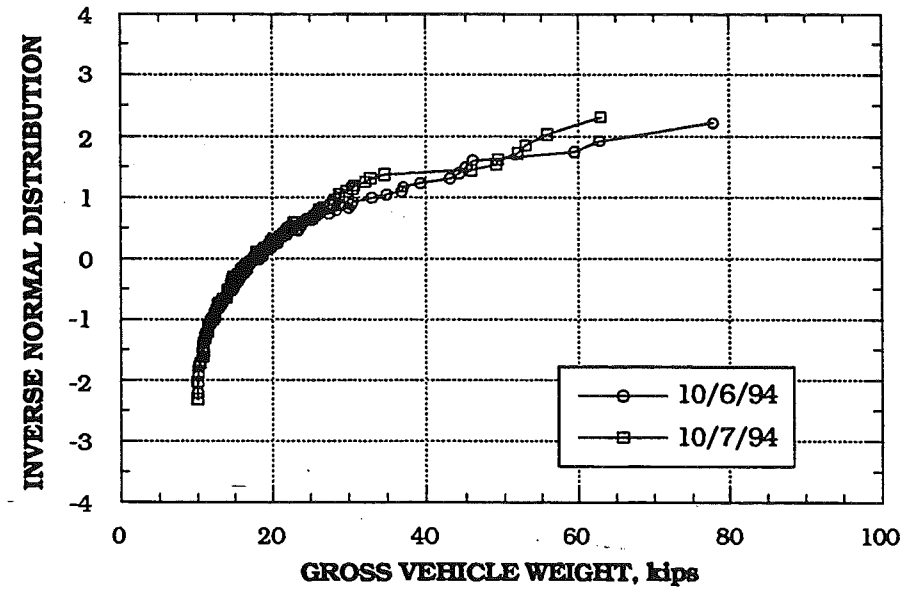


Fig. 10-9. M153/M39, Daily GVW Distributions.

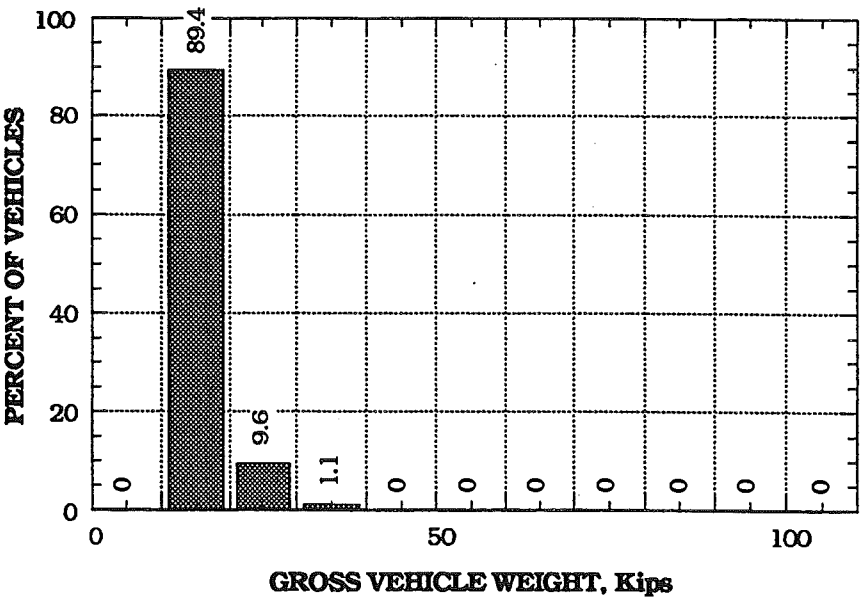


Fig. 10-10. M153/M39, 2 Axle GVW Histogram.

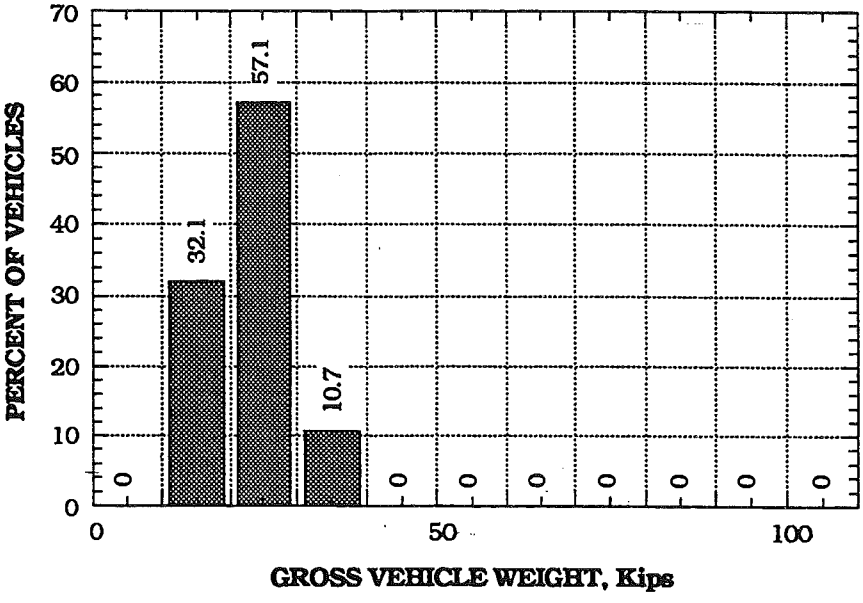


Fig. 10-11. M153/M39, 3 Axle GVW Histogram.

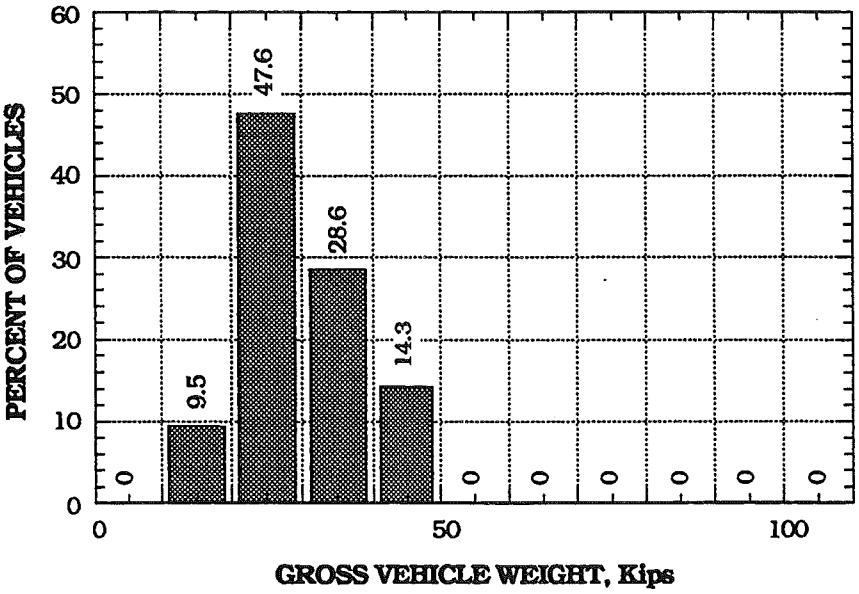


Fig. 10-12. M153/M39, 4 Axle GVW Histogram.

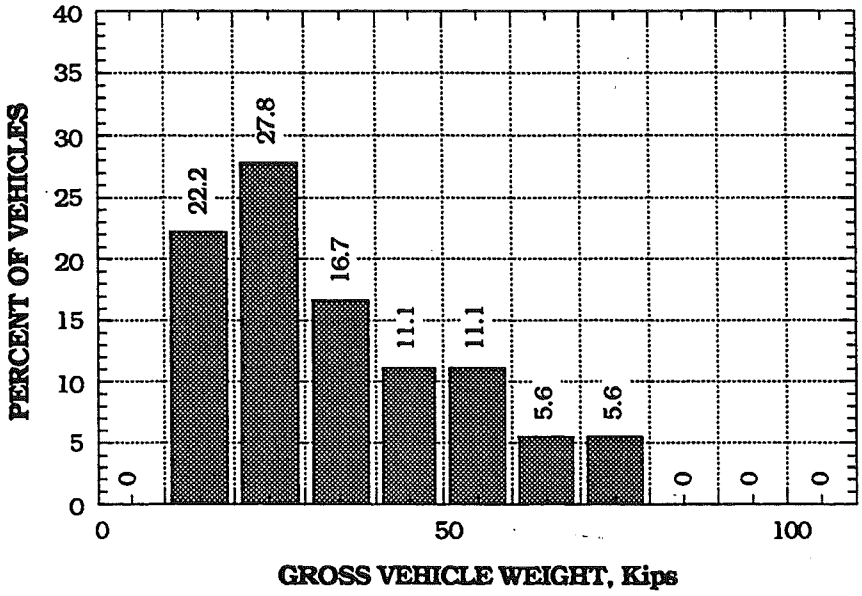


Fig. 10-13. M153/M39, 5 Axle GVW Histogram.

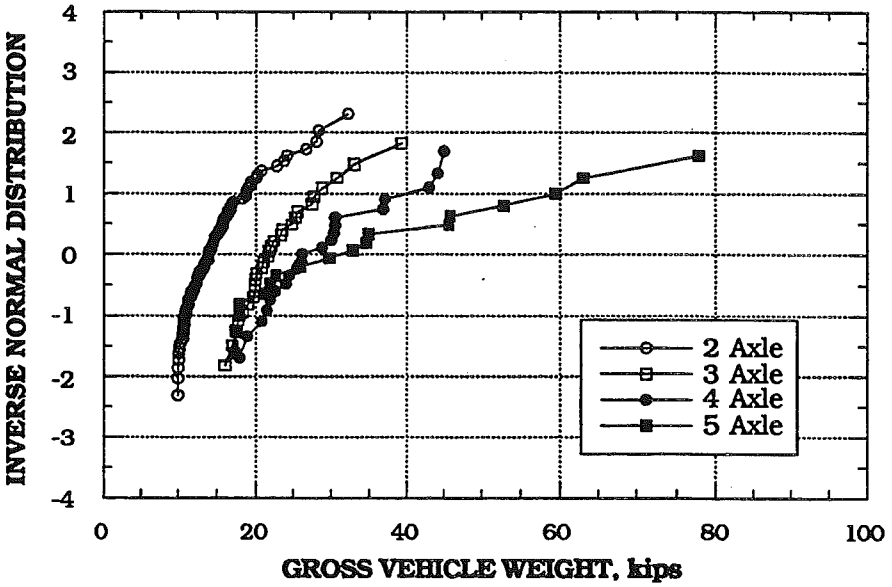


Fig. 10-14. M153/M39, 2, 3, 4 and 5 Axle GVW Distributions.

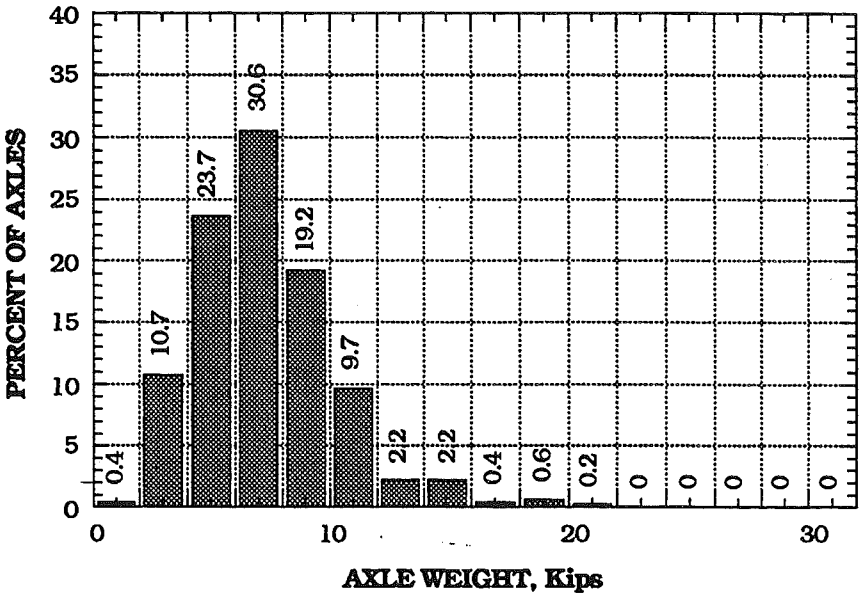


Fig. 10-15. M153/M39, Axle Weight Histogram.

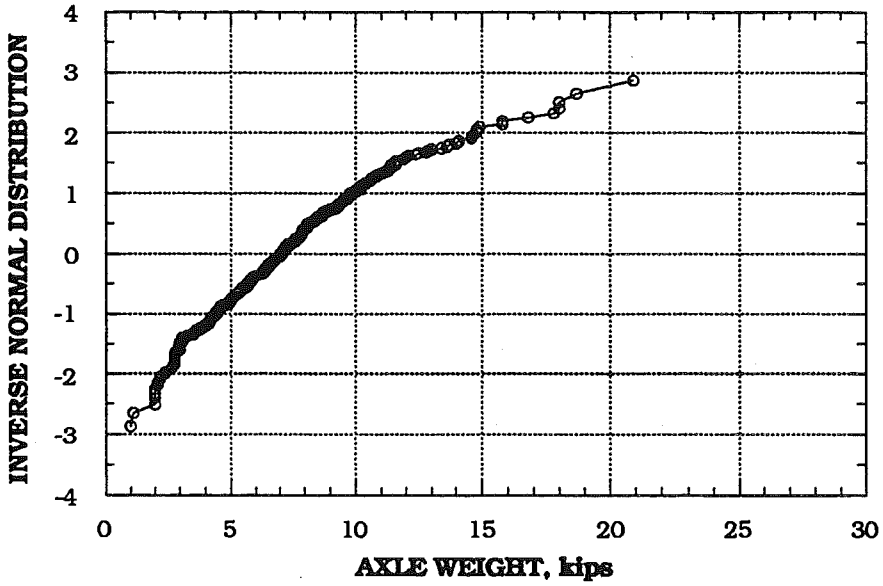


Fig. 10-16. M153/M39, Axle Weight Distribution.

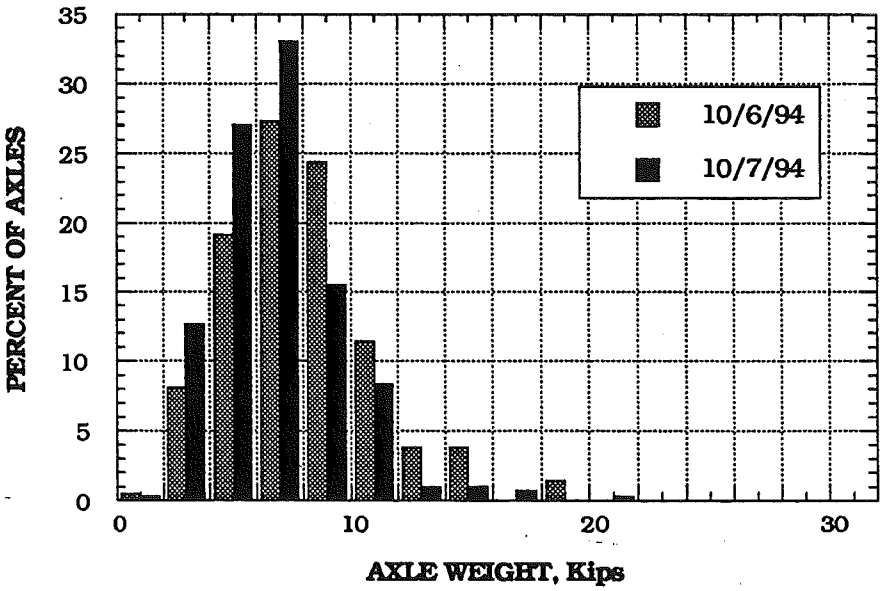


Fig. 10-17. M153/M39, Daily Axle Weight Histogram.

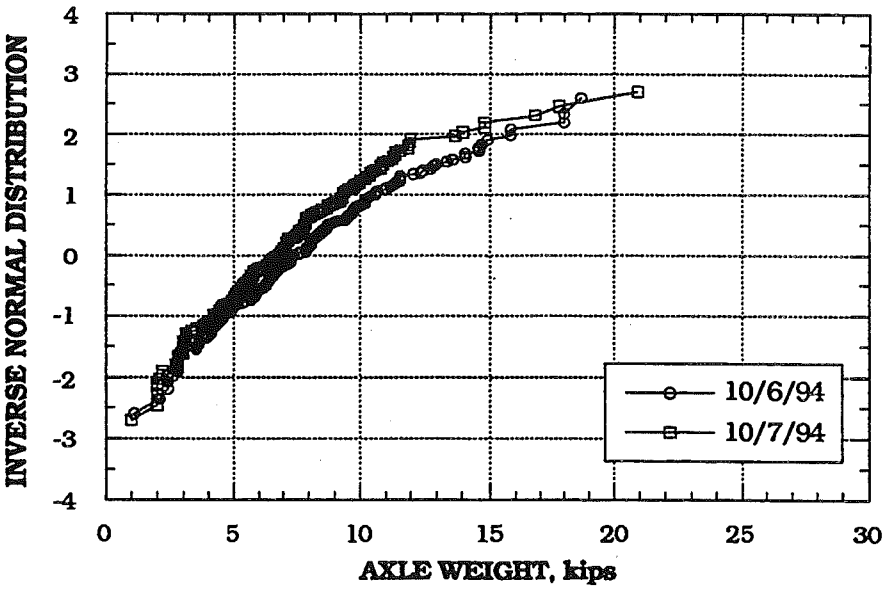


Fig. 10-18. M153/M39, Daily Axle Weight Distributions.

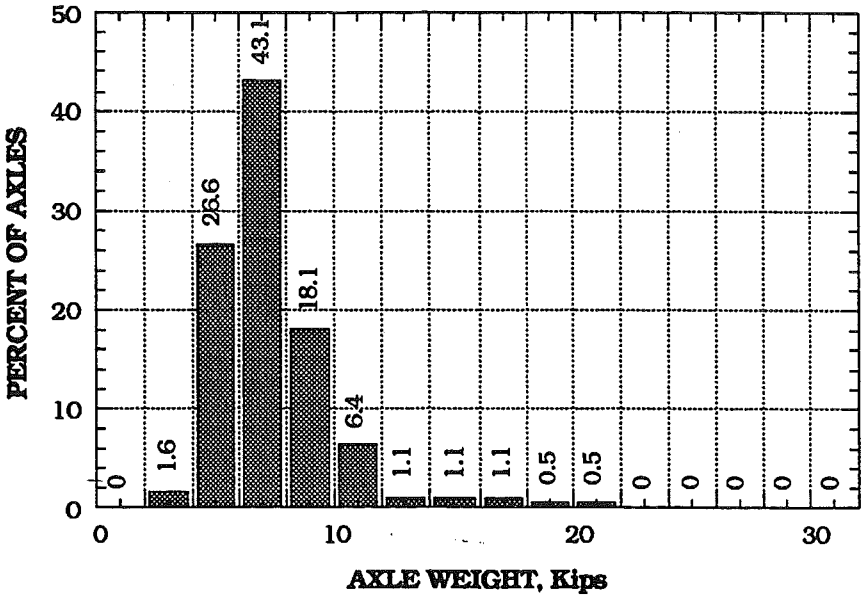


Fig. 10-19. M153/M39, Axle Weight Histogram of 2 Axle Vehicles.

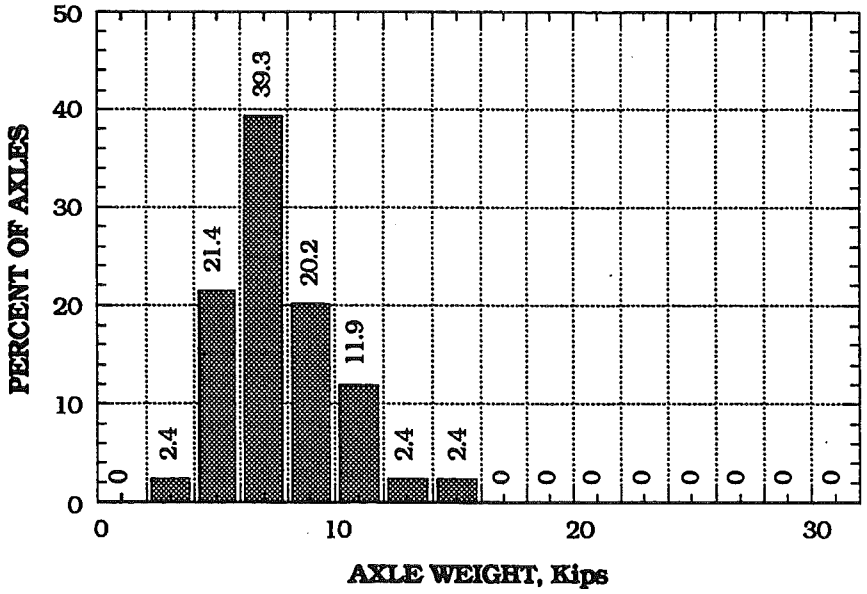


Fig. 10-20. M153/M39, Axle Weight Histogram of 3 Axle Vehicles.

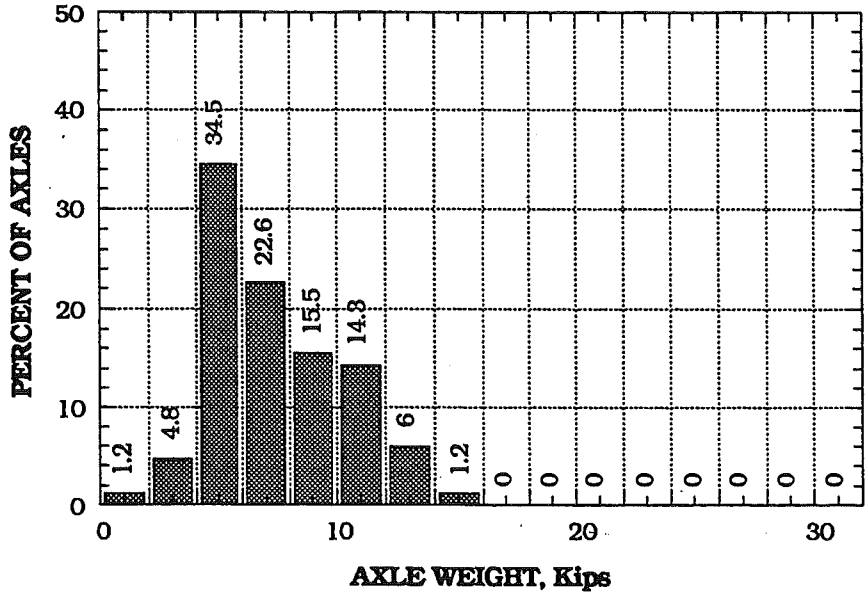


Fig. 10-21. M153/M39, Axle Weight Histogram of 4 Axle Vehicles.

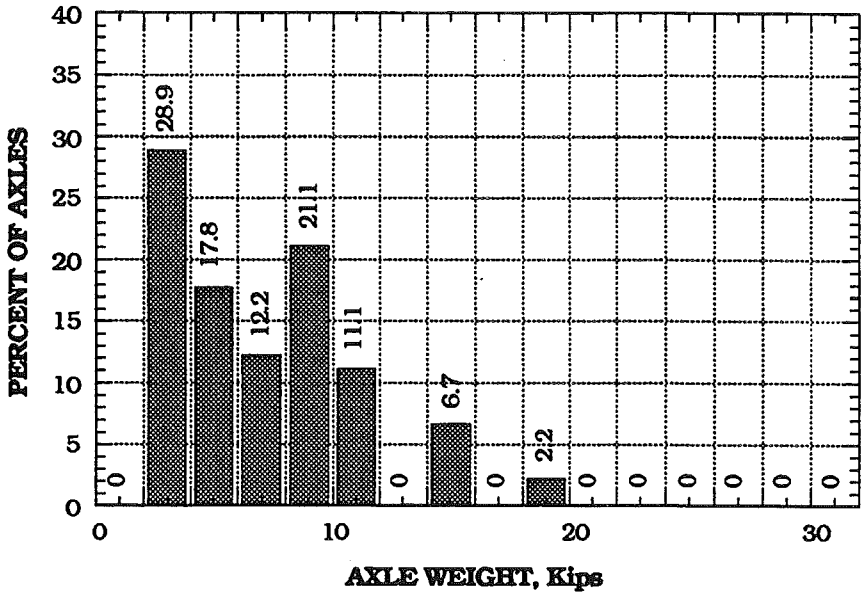


Fig. 10-22. M153/M39, Axle Weight Histogram of 5 Axle Vehicles.

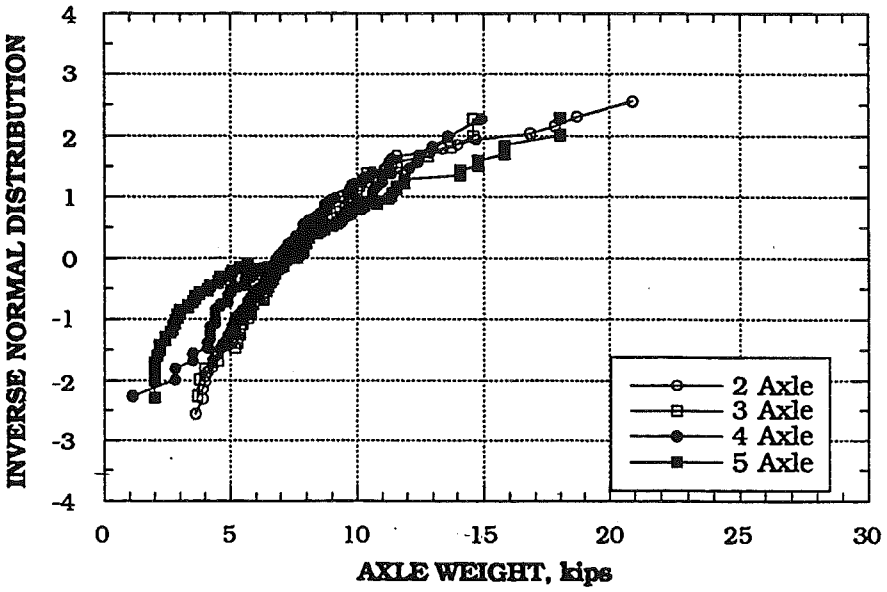


Fig. 10-23. M153/M39, Axle Weight Distributions of 2, 3, 4, and 5 Axle Vehicles.

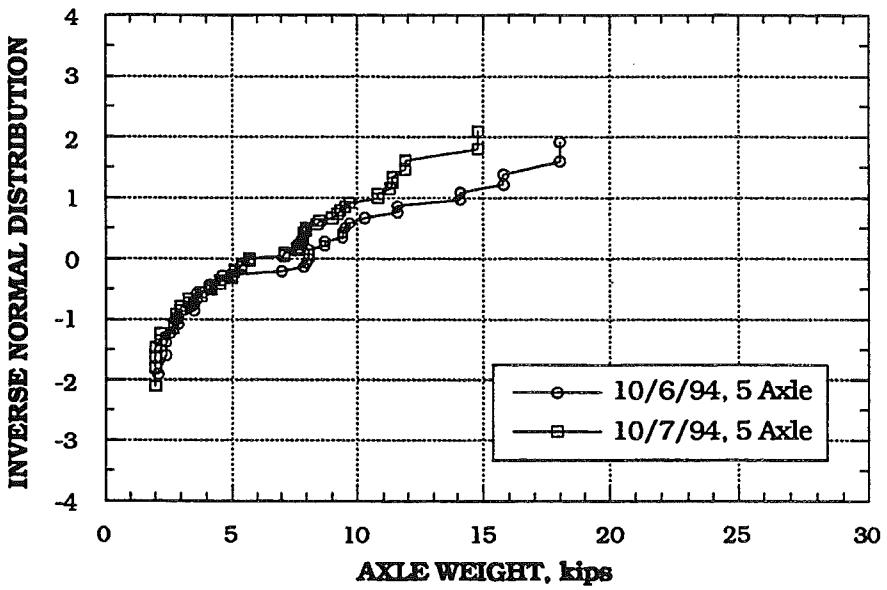


Fig. 10-24. M153/M39, Daily Axle Weight Distributions of 5 Axles.

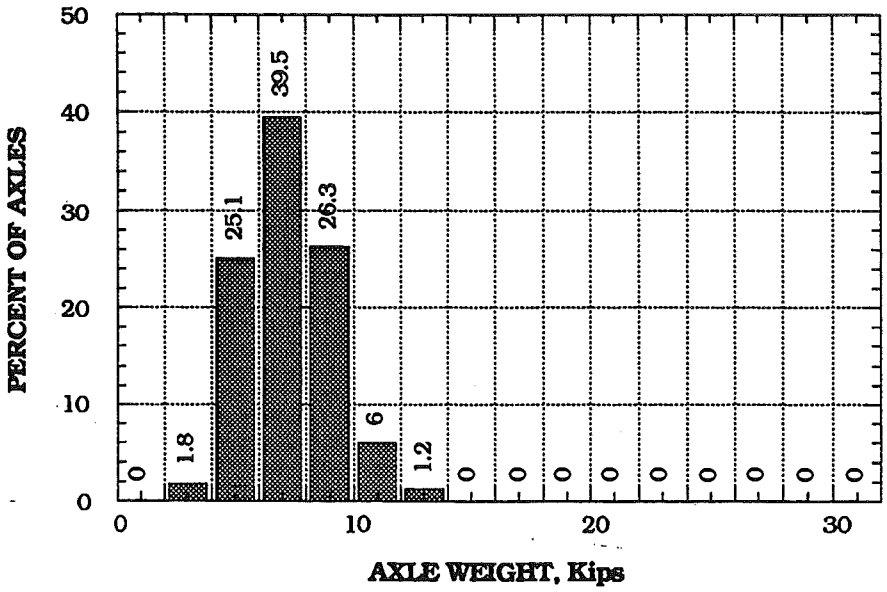


Fig. 10-25. M153/M39, Steering Axle Weight Histogram.

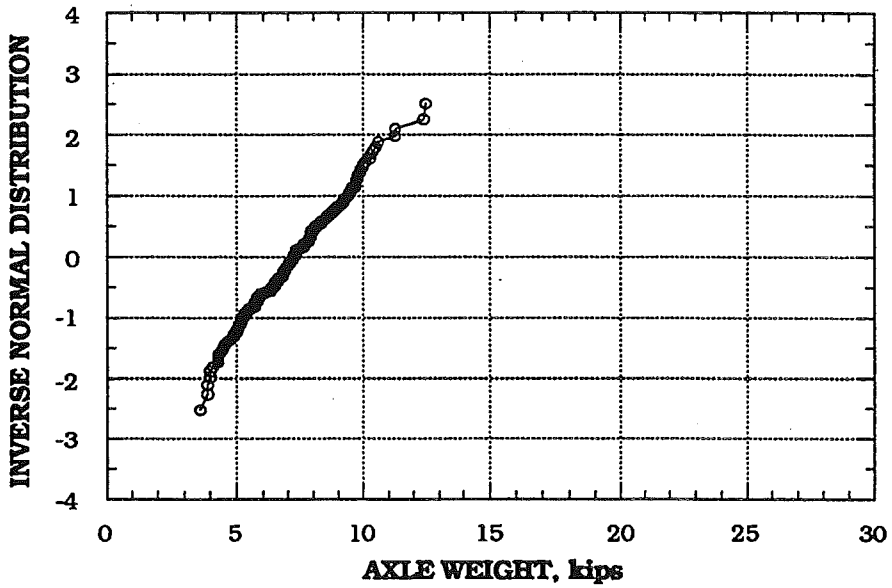


Fig. 10-26. M153/M39, Steering Axle Weight Distribution.

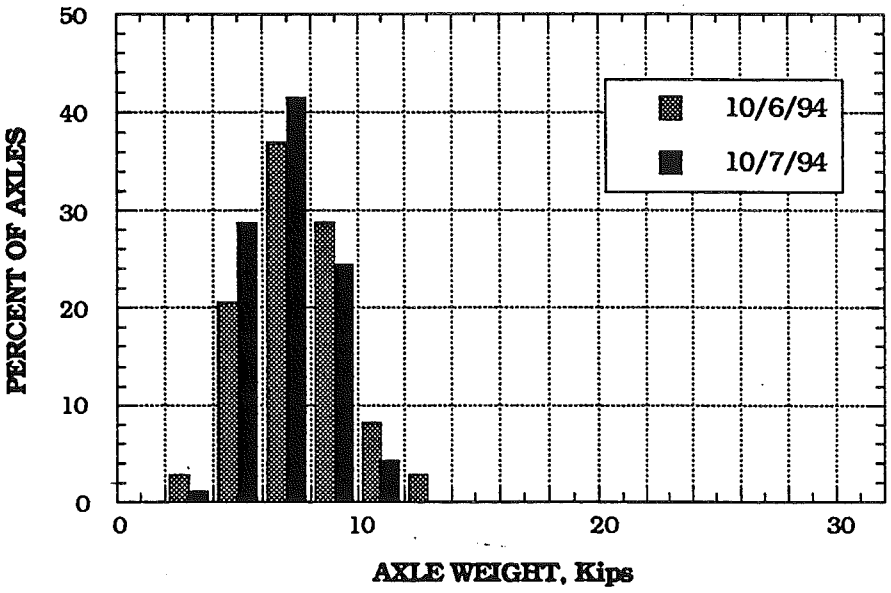


Fig. 10-27. M153/M39, Daily Steering Axle Weight Histogram.

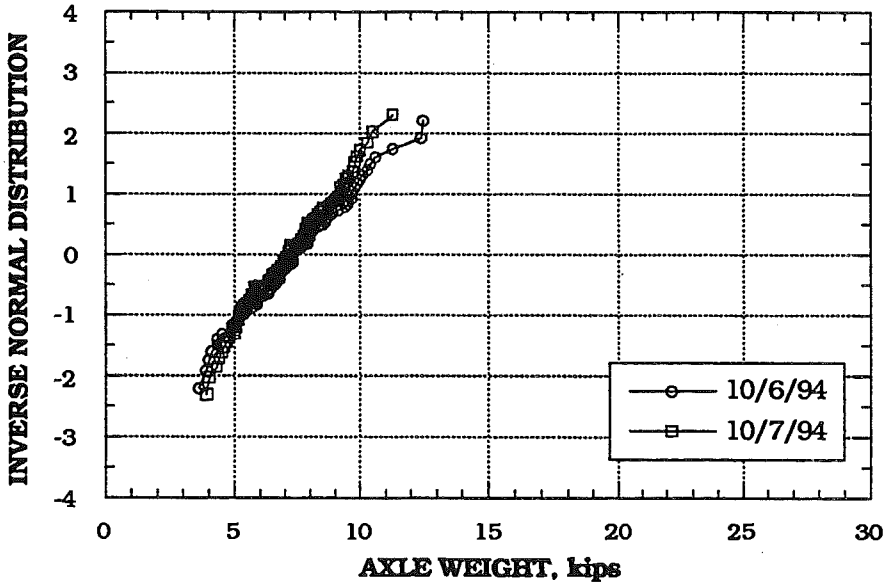


Fig. 10-28. M153/M39, Daily Steering Axle Weight Distributions.

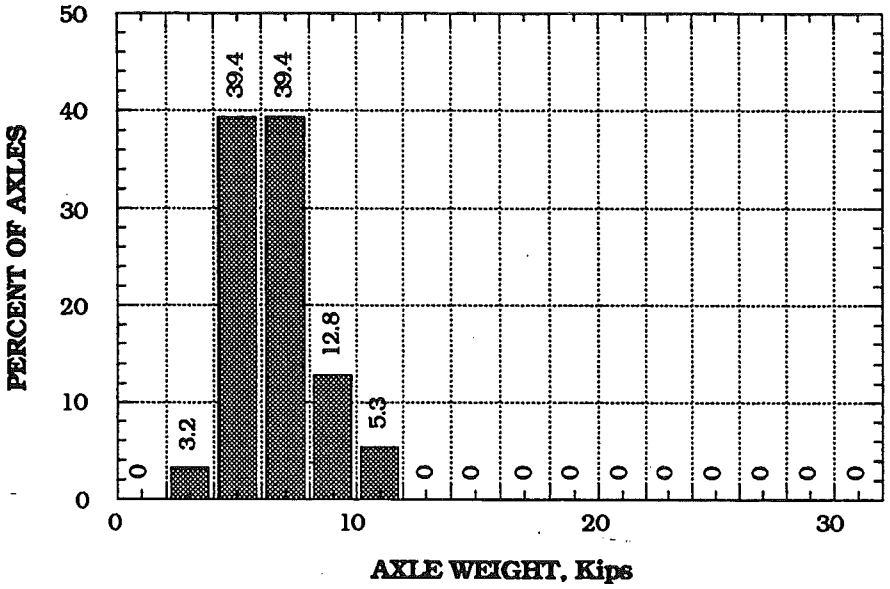


Fig. 10-29. M153/M39, Steering Axle Weight Histogram of 2 Axle Vehicles.

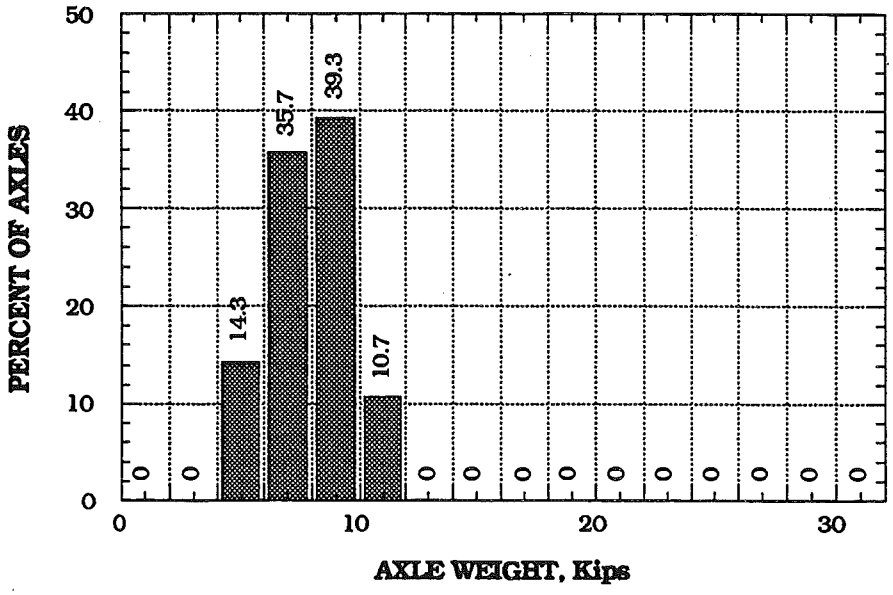


Fig. 10-30. M153/M39, Steering Axle Weight Histogram of 3 Axle Vehicles.

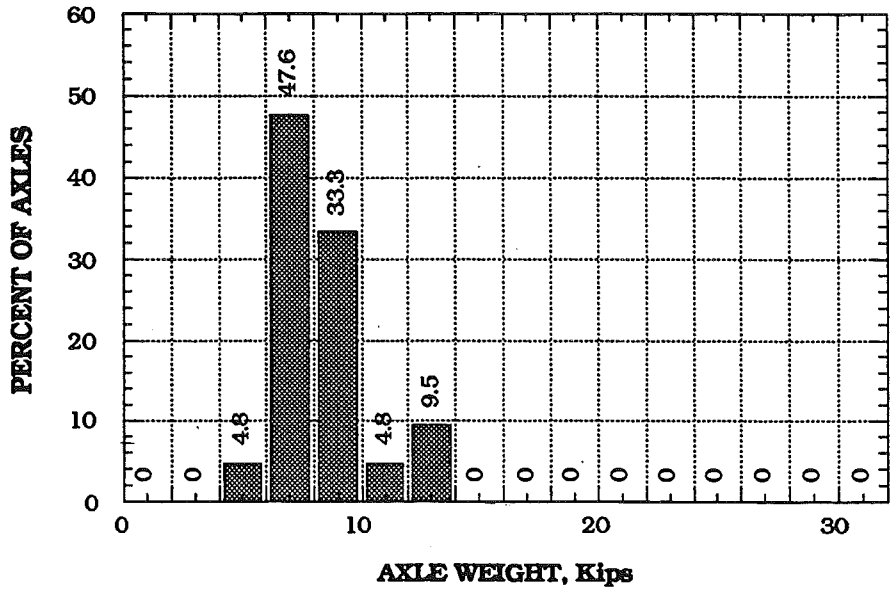


Fig. 10-31. M153/M39, Steering Axle Weight Histogram of 4 Axle Vehicles.

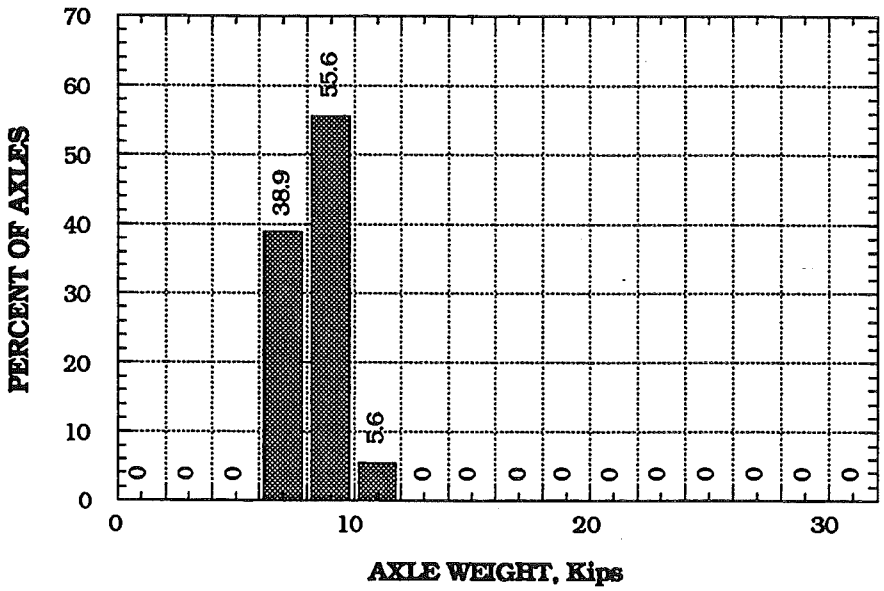


Fig. 10-32. M153/M39, Steering Axle Weight Histogram of 5 Axle Vehicles.

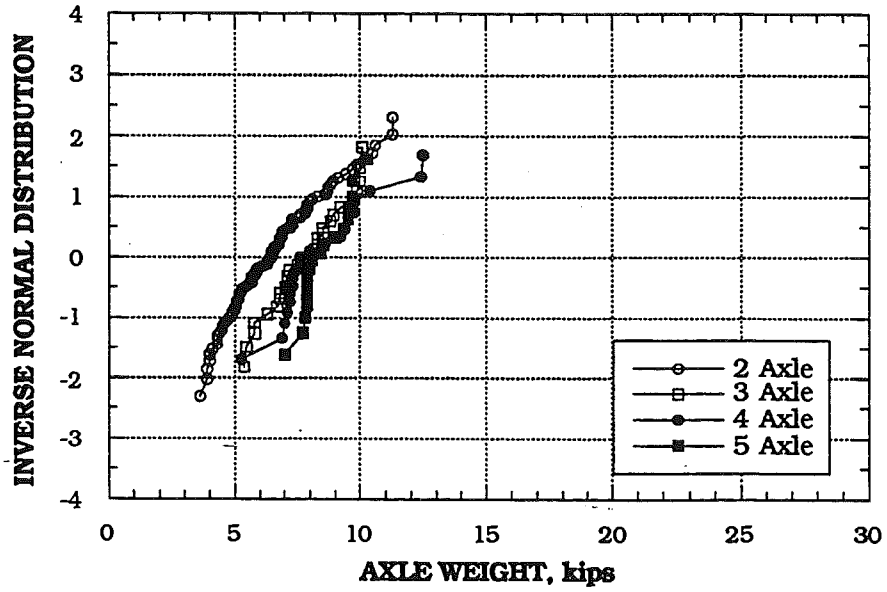


Fig. 10-33. M153/M39, Steering Axle Weight Distributions of 2, 3, 4, and 5 Axle Vehicles.

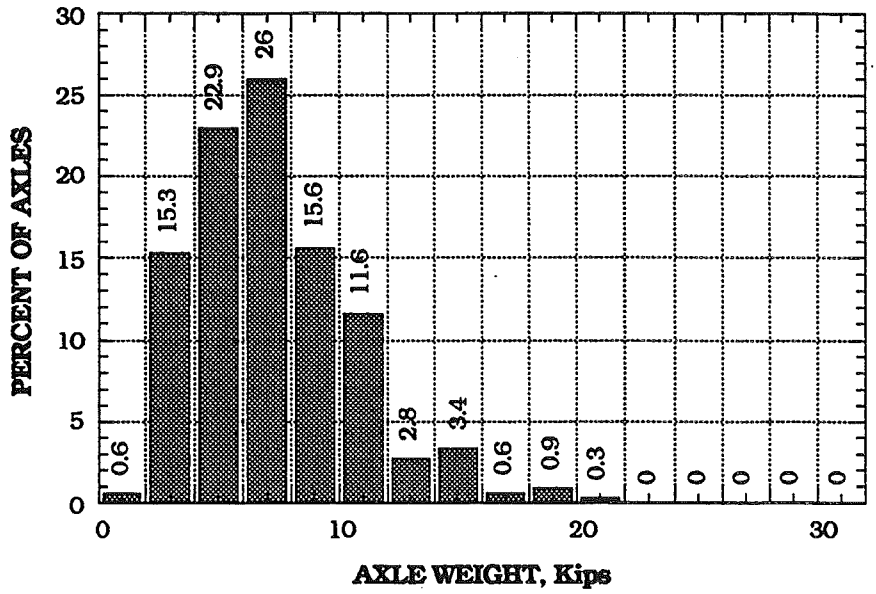


Fig. 10-34. M153/M39, Non-Steering Axle Weight Histogram.

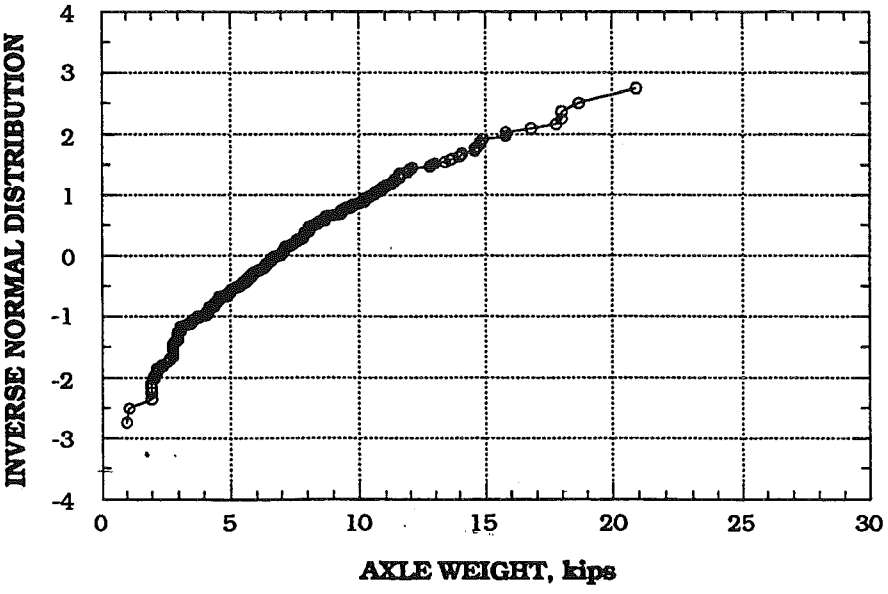


Fig. 10-35. M153/M39, Non-Steering Axle Weight Distributions.

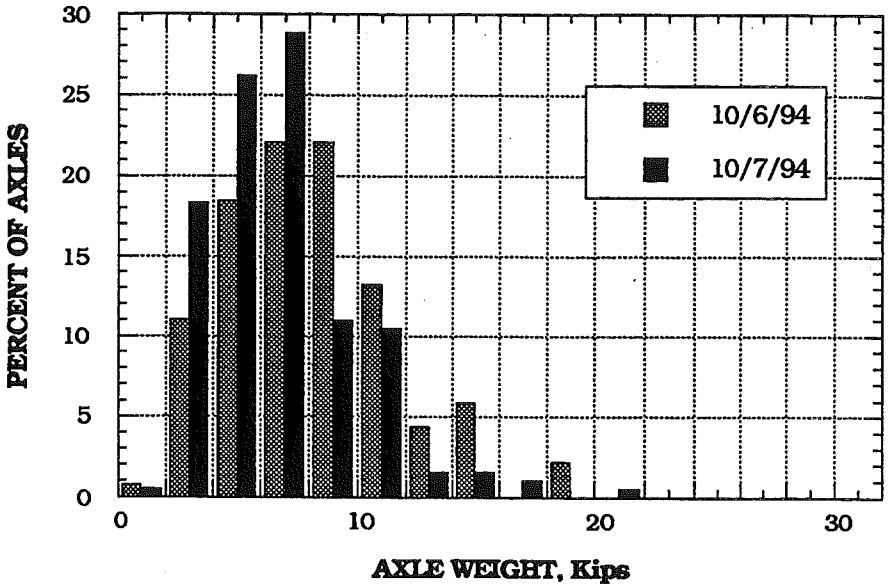


Fig. 10-36. M153/M39, Daily Non-Steering Axle Weight Histogram.

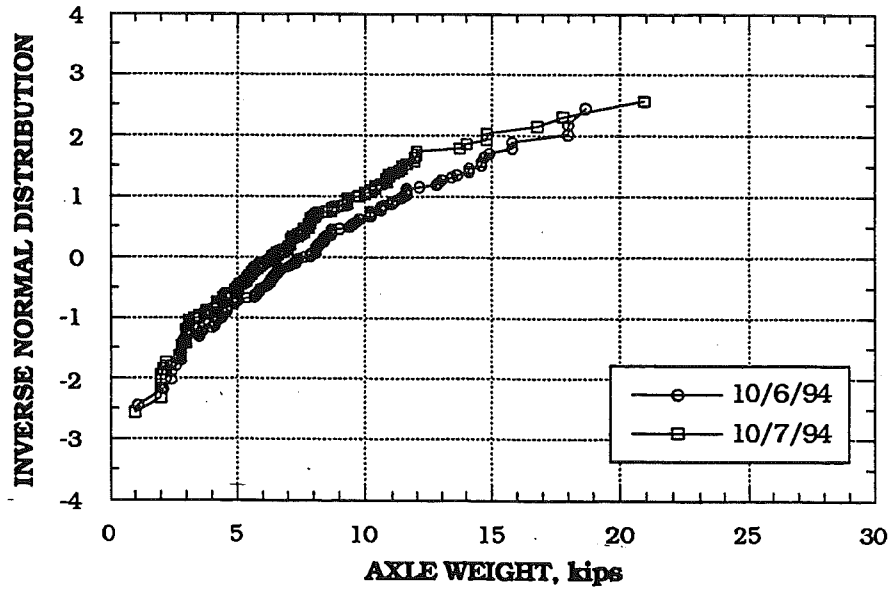


Fig. 10-37. M153/M39, Daily Non-Steering Axle Weight Distributions

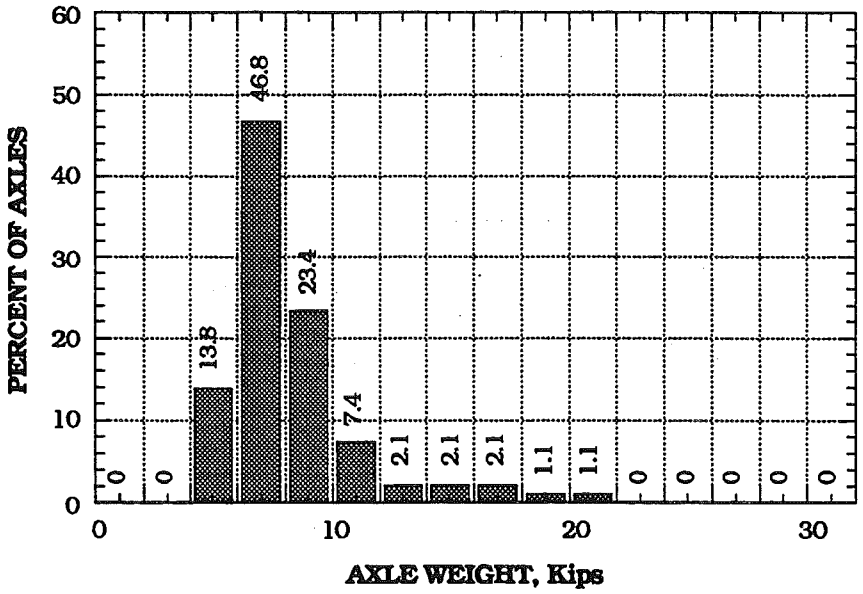


Fig. 10-38. M153/M39, Non-Steering Axle Weight Histogram of 2 Axles.

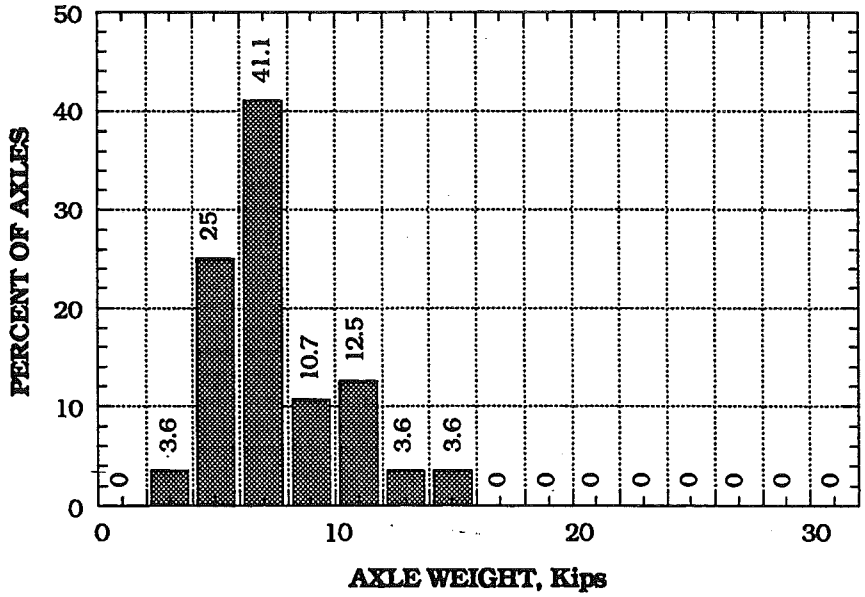


Fig. 10-39. M153/M39, Non-Steering Axle Weight Histogram of 3 Axles.

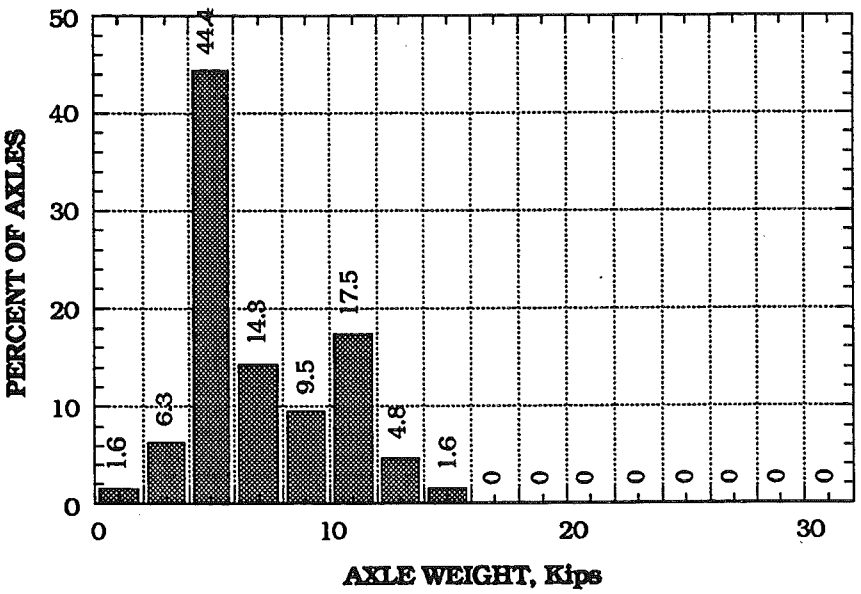


Fig. 10-40. M153/M39, Non-Steering Axle Weight Histogram of 4 Axles.

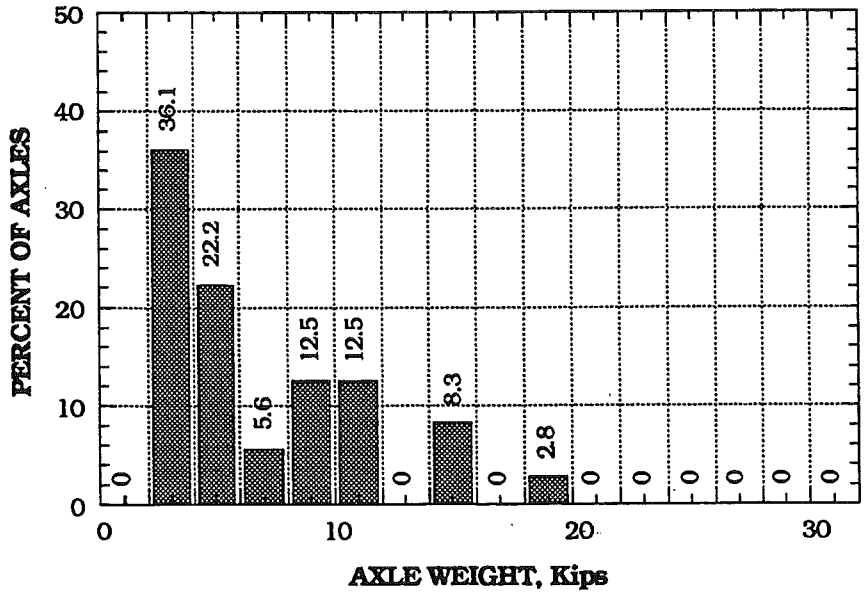


Fig. 10-41. M153/M39, Non-Steering Axle Weight Histogram of 5 Axles.

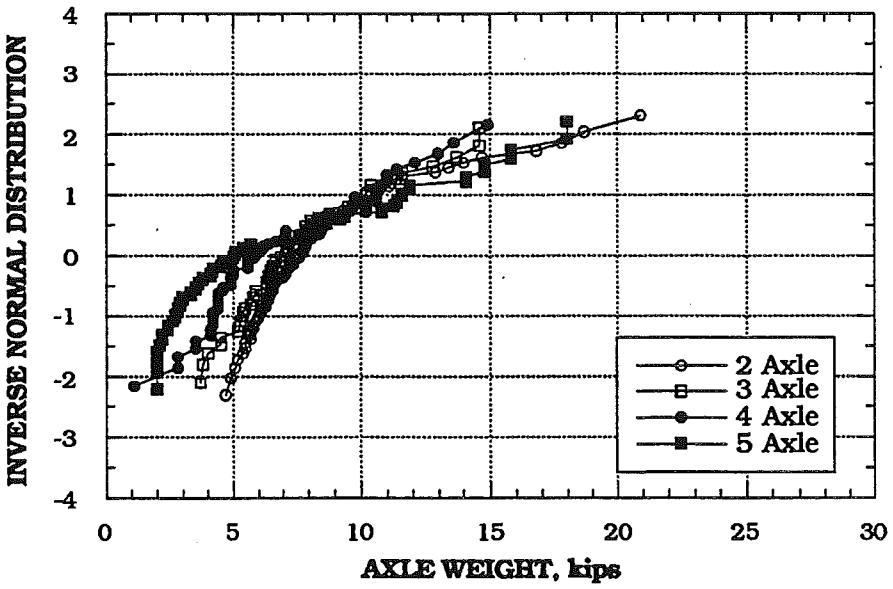


Fig. 10-42. M153/M39, Non-Steering Axle Weight Distributions of 2, 3, 4, and 5 Axle Vehicles.

11. BRIDGE ON LONYO AVENUE SOUTHBOUND OVER I-94 WESTBOUND IN DETROIT (LA/I 94)

11. 1 Description of the bridge

Bridge (LA/I94) carries southbound traffic on Lonyo Avenue over I - 94 in Detroit. The view, plan view, cross section and other details are shown in Fig. 8-1 and 8-2. The instruments were installed in the entrance span (in the direction of traffic). The investigated span is 31'-8 1/8" and the width is 61'-9" (half bridge is 30'-11") with skew of 18 degrees. The cross section consists of 12 girders spaced at 5'-9".

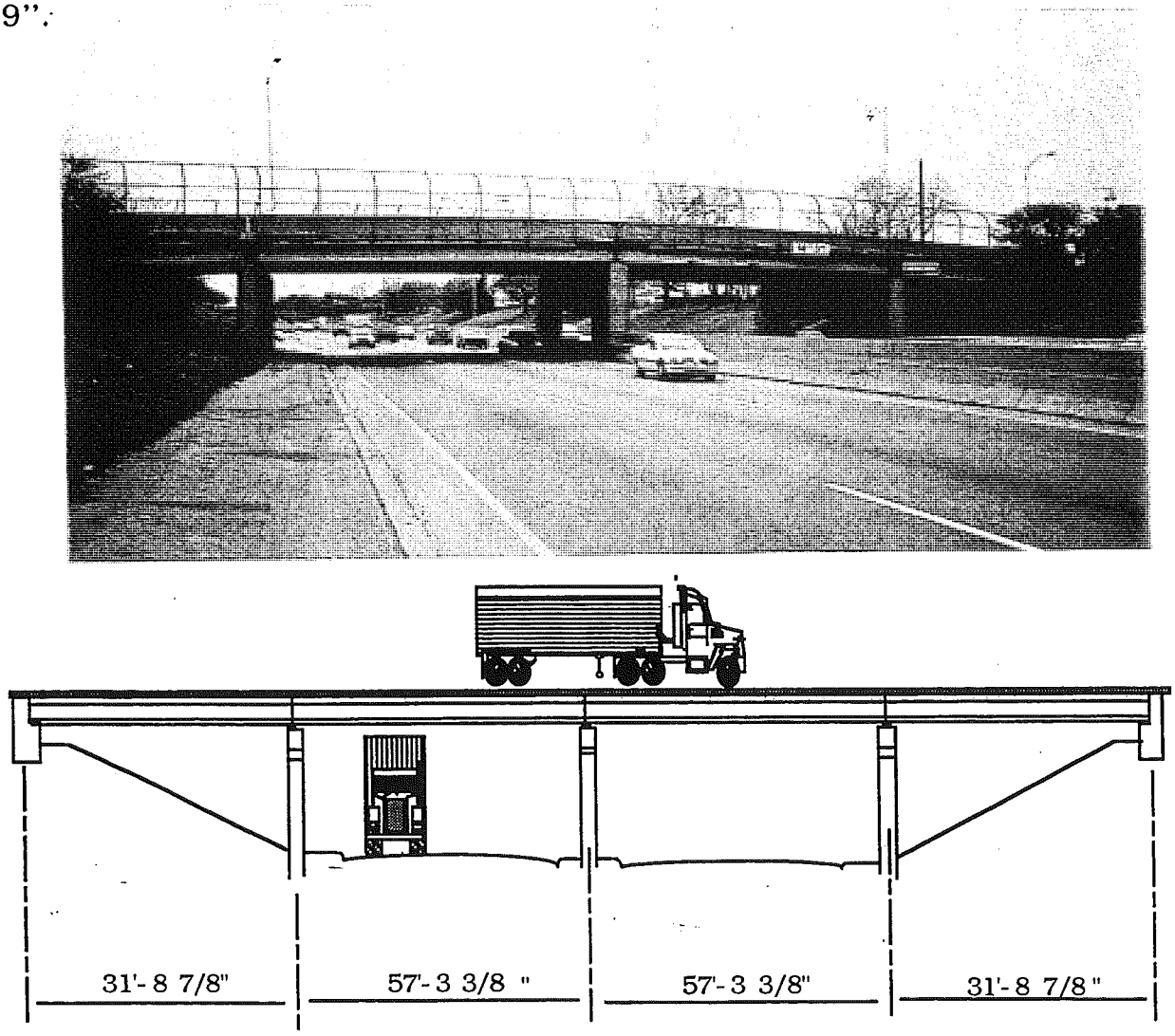
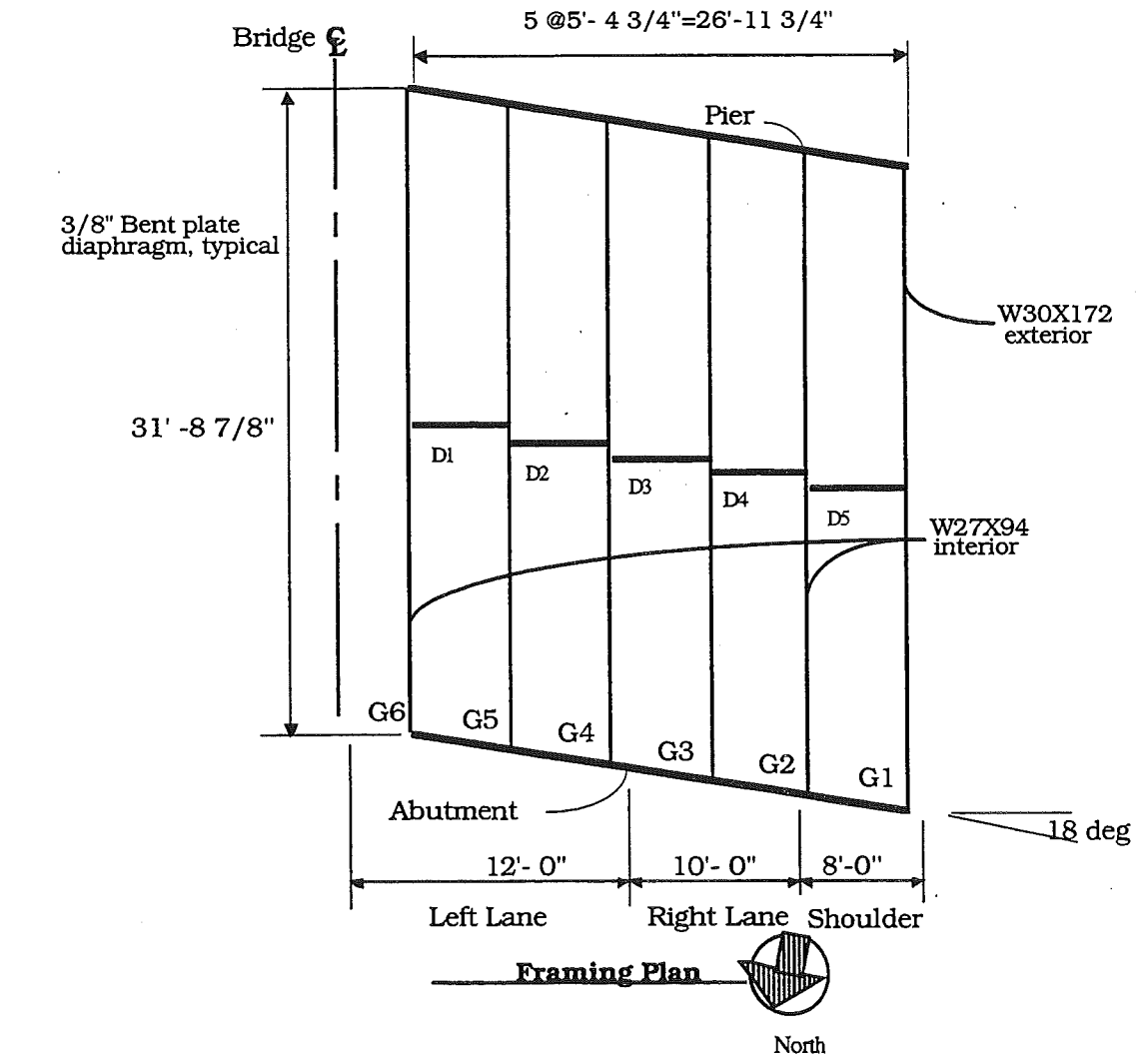


Fig. 11-1. Bridge LA/I94, Lonyo Avenue Southbound over I-94 Westbound in Detroit. View and Side Elevation.



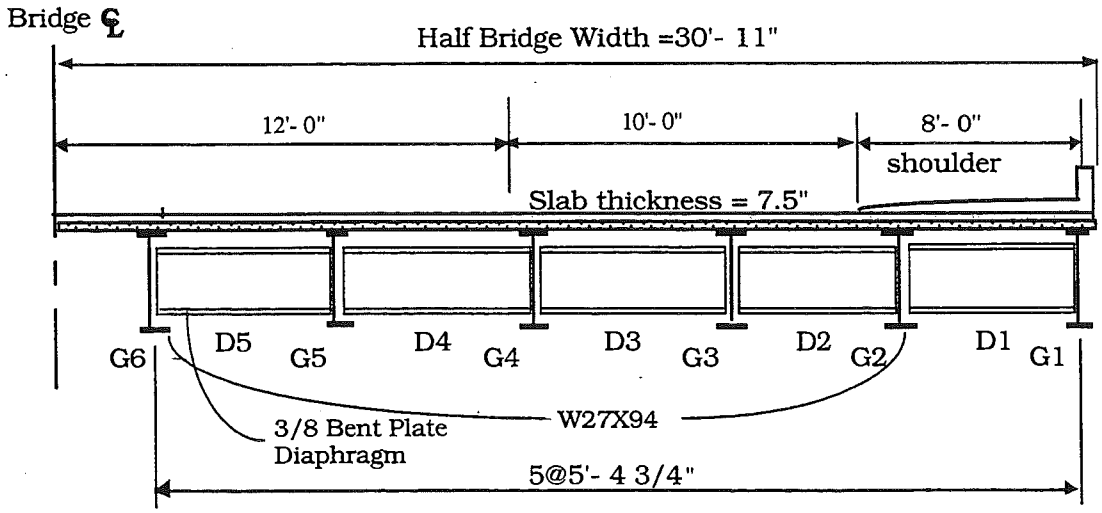


Fig. 11-2. Bridge LA/I94, Lonyo Avenue Sothbound over I94 Westbound in Detroit. Plan View and Cross Section of Entrance Span.

However, due to a low speed of trucks, no truck data could be recorded at the selected location. It turned out that traffic lights and stop signs did not allow any truck to gain a minimum speed required for the lane sensors to operate. Therefore, for this bridge, only a visual truck count was performed. The results are presented in Table 11-1.

Table 11-1. Visual Two Hour Truck Count on Bridge LA/I94.

Number of Axles	Southbound		Northbound		Total
	Right Lane	Left Lane	Right Lane	Left Lane	
2	10	9	3	1	23
3	4	3	2	0	9
4	8	1	0	0	9
5	15	13	0	1	29
6	1	1	0	0	2
7	2	1	1	0	4
8	3	0	0	0	3
9	6	1	0	0	7
10	2	0	0	0	2
11	10	4	0	0	14
Total	61	33	6	2	102

Because of the traffic pattern, most of the trucks use only the Southbound lanes. Northbound trucks turn directly onto I-94 and avoid the bridge. A relatively large percentage of 11 axle trucks was observed, and they appeared to be heavily loaded.

Note:
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12. SUMMARY AND CONCLUSIONS

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. The results of measurements indicate that traffic is strongly site-specific. This applies to number of trucks, gross vehicle weight and axle weight.

The summary of the measured truck traffic mix is presented in Table 12-1. For the considered bridges, the number of trucks is given for various number of axles. The largest number of vehicles is in the two axle category followed by five axle trucks. The heaviest group is 11 axle trucks, with the percentage varying from almost 0 to 15.

The summary of the gross vehicle weight (GVW) parameters are given in Table 12-2. The maximum GVW's vary from 80 to over 250 kips, with the average (mean value) from 20 to over 60 kips. The cumulative distribution functions (CDF) of GVW are shown in Fig. 12-1. 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 12-3.

The axle weights are also summarized in Table 12-2. 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 Fig. 12-2. The heaviest values are observed on I-94 and M-39. 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 12-3.

From the bridge safety point of view, it is more important to consider load effects rather than loads. The observed truck weights are often heavier than legal limits. The moments and shear forces resulting from passages of the actual vehicles are calculated in the

Report on Effect of Truck Loads on Bridges submitted to MDOT (Nowak et al. 1994). However, the measured maximum stress values in steel girders are rather low. In the tests carried out by the project team, the maximum live load stress was under 10 ksi (10,000 lb/sq inch), and less than 6 ksi in most cases.

The performance of a concrete deck is affected by axle load rather than gross vehicle weight. Recent studies indicate that deck slabs fail through punching shear. The results of measurements indicate that a considerable number of axle weights exceed the legal limits. In particular, this applies to traffic on I-94 and M-39, as shown in Fig. 12-2.

Table 12-1. Number of Trucks Weighed.

Number of Trucks Weighed Gross Vehicle Weight > 10 Kips for 2 Axle Vehicles, Gross Vehicle Weight > 15 Kips for 3 or more Axle Vehicles.											
Bridge Location	Truck Type (Number of Axles)										
	2	3	4	5	6	7	8	9	10	11	Total
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 12-2. Maximum Gross Vehicle and Axle Weight Statistic of All Trucks on Measured Bridges.

Bridge Location	Estimated ADTT	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	229	32	35	8
M39/M10	1,500	148	31	49	10
I94/I75	1,500	178	41	50	10
M153/M39	500	78	22	21	7

Table 12-3. 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	Number of Vehicles	Overloaded Vehicles (%)	Overloaded Axles (%)
WY/I94	5 Axles	107	4	4
	11 Axles	20	5	1
I94/M10	5 Axles	147	21	18
	11 Axles	133	86	40
US12/I94	5 Axles	43	0	1
	11 Axles	4	0	0
DA/M10	5 Axles	34	0	1
	11 Axles	6	17	8
M39/M10	5 Axles	118	9	8
	11 Axles	2	0	31
I94/I75	5 Axles	148	15	10
	11 Axles	8	0	4
M153/M39	5 Axles	18	0	0
	11 Axles	1	0	0

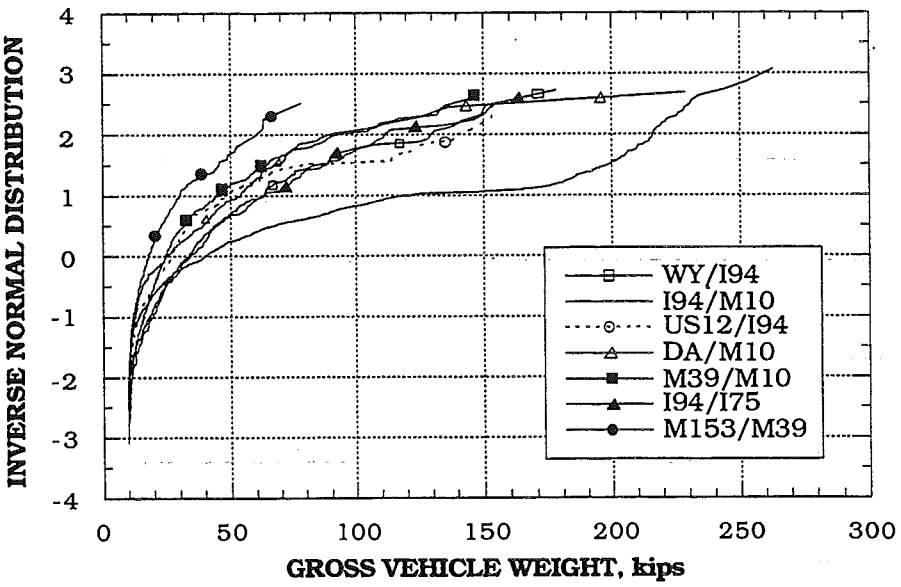

Fig. 12-1. Gross Vehicle Weight Distributions.

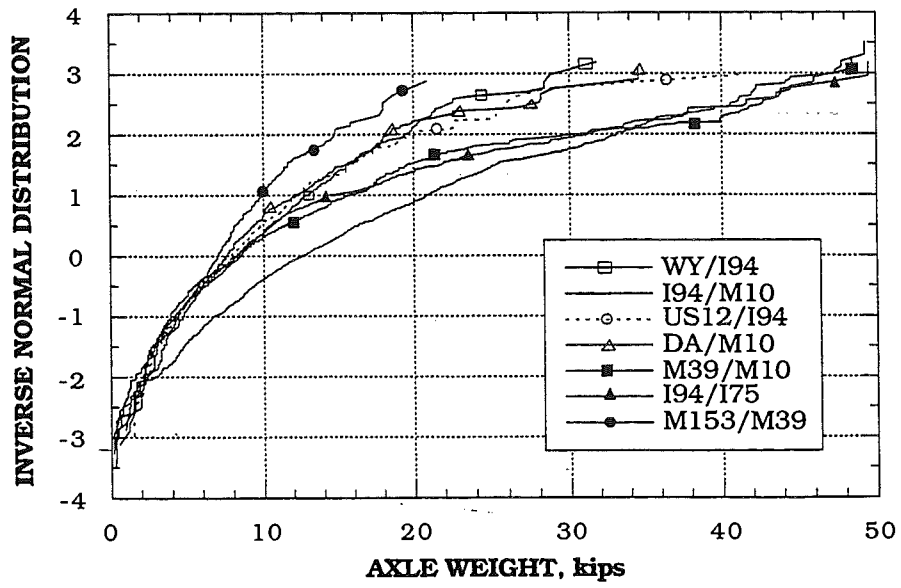

Fig. 12-2. Axle Weight Distributions.

APPENDIX A

FEDERAL HIGHWAY ADMINISTRATION (FHWA)
AXLE CONFIGURATION CLASS

DESCRIPTION	CLASS	SPACINGS (FT)	TOTAL LENGTH (FT)
2-axle vehicles:			
Motorcycle	10	0.0 - 6.7	6.7
Car	20	6.7 - 10.0	10.0
Pick-up/Van	30	10.0 - 13.3	13.3
Bus	40	20.0 - 40.0	40.0
2-axle/6-tire	50	13.3 - 20.0	20.0
3-axle vehicles:			
Car with 1-axle trailer	21	6.7 - 10.0 6.7 - 16.7	26.7
Pick-up/Van with 1-axle trailer	31	10.0 - 13.3 6.7 - 16.7	30.0
Bus	41	20.0 - 40.0 0.0 - 6.7	46.7
3-axle single unit	60	6.7 - 20.0 0.0 - 6.7	26.7
2S1	80	6.7 - 16.7 16.7 - 40.0	53.3

DESCRIPTION	CLASS	SPACINGS (FT)	TOTAL LENGTH (FT)
4-axle vehicles:			
Car with 2-axle trailer	22	6.7 - 10.0 6.7 - 13.3 0.0 - 6.7	30.0
Pick-up/Van with 2-axle trailer	32	10.0 - 13.3 6.7 - 16.7 0.0 - 3.0	33.0
4-axle single unit	70	6.7 - 20.0 0.0 - 6.7 0.0 - 6.7	33.3
3S1	81	6.7 - 20.0 0.0 - 6.7 10.0 - 40.0	66.7
2S2	82	7.6 - 16.7 13.3 - 40.0 0.0 - 6.7	66.7

DESCRIPTION	CLASS	SPACINGS (FT)	TOTAL LENGTH (FT)
5-axle vehicles:			
3S2	90	6.7 - 20.0	
		0.0 - 6.7	
		10.0 - 40.0	
		0.0 - 13.3	66.7
3-axle with trailer	91	6.7 - 20.0	
		0.0 - 6.7	
		6.7 - 26.7	
		10.0 - 26.7	66.7
5-axle with trailer	110	6.7 - 16.7	
		13.3 - 26.7	
		6.7 - 16.7	
		10.0 - 26.7	66.7
6-axle vehicles:			
6-axle single unit	100	6.7 - 16.7	
		0.0 - 6.7	
		10.0 - 40.0	
		0.0 - 10.0	
		0.0 - 10.0	80.0
6-axle multi-trailer	120	6.7 - 16.7	
		0.0 - 6.7	
		13.3 - 26.7	
		6.7 - 13.3	
		10.0 - 26.7	80.0

DESCRIPTION	CLASS	SPACINGS (FT)	TOTAL LENGTH (FT)
7-axle vehicles:			
7-axle (or more) single trailer	101	6.7 - 16.7	
		0.0 - 6.7	
		13.3 - 40.0	
		0.0 - 13.3	
		0.0 - 13.3	
		0.0 - 13.3	80.0
7-axle	130	6.7 - 16.7	
		0.0 - 6.7	
		10.0 - 26.7	
		6.7 - 13.3	
		0.0 - 40.0	
		0.0 - 6.7	80.0
Any vehicles not meeting any of the criteria above.	140		