

AASHTO 2001 Design of Overhead Cantilevered Sign Supports

By

Dr. Fouad H. Fouad and Ms. Elizabeth Calvert
Department of Civil and Environmental Engineering
The University of Alabama at Birmingham
Birmingham, Alabama

Prepared by

UTCA

University Transportation Center for Alabama

The University of Alabama, The University of Alabama at Birmingham,
and The University of Alabama at Huntsville

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16. Abstract <p>The American Association of State Highway and Transportation Officials (AASHTO) <i>Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals</i> was revised in its entirety through a major research project conducted under the auspices of the National Cooperative Highway Research Program (NCHRP Project 17-10). The new document was approved in 1999 by all state departments of transportation for adoption by AASHTO and was published in 2001. The revisions include updated provisions and criteria for extreme wind loads and new provisions and criteria on fatigue design. These provisions differ considerably from those in previous editions of the specifications. The impact of the new wind load and fatigue provisions on the design of cantilevered overhead sign supports from the standpoint of safety and economy had not been studied and was the main goal of this project. Wind load and fatigue calculations and design of a cantilevered overhead sign support in Alabama were performed using the design criteria in both the 2001 AASHTO specifications and the 1994 edition of the specifications, using SABRE, a structural analysis package for overhead sign support structures. The results were compared and the impact of the 2001 specifications on design of cantilevered overhead sign support structures in Alabama was illustrated.</p> <p>A companion technical appendix was published as UTCA Report 02216-1. It contains input and output files for SABRE, based on the 1994 specifications (Appendix A) and the 2001 Specifications (Appendix B). Copies of the Technical Appendix may be obtained from the authors.</p>			
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Executive Summary

The American Association of State Highway and Transportation Officials (AASHTO) *Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals (Supports Specifications)* was revised in its entirety through a major research project conducted under the auspices of the National Cooperative Highway Research Program (NCHRP Project 17-10). The new document was approved in 1999 by AASHTO for adoption by all state departments of transportation, and was published in 2001. The revisions included updated provisions and criteria for extreme wind loads, and new provisions and criteria on fatigue design. These provisions differed considerably from those in previous editions of the specifications. This research project studied the impact of the new wind load and fatigue provisions on the design of a cantilevered overhead sign support structure.

Wind load calculations in the 2001 *Supports Specifications* were revised to use a three-second gust wind speed, rather than a fastest-mile wind speed. A series of maps, representing 10, 25, and 50-year mean recurrence intervals, was updated to one 50-year mean recurrence interval map with importance factors used to adjust the intervals. Height factors were adjusted for the three-second gust wind speed, and drag coefficients were slightly modified. The increase or decrease in calculated wind pressures, which result from the use of the 2001 *Supports Specifications*, is primarily due to the differences in the 1994 and 2001 wind speed maps.

A new fatigue section was added to the 2001 *Supports Specifications* as a result of NCHRP Project 10-38 (Kaczinski, Dexter and Van Dien, 1998). As a result, new fatigue criteria have been established for the design of cantilevered sign, signal and light structures. Galloping, natural wind gust, and truck-induced wind gust fatigue criteria were reviewed to determine the effect of these loadings on the design of a cantilevered overhead sign support structure.

The tasks conducted during this research project included identifying the impact of the new wind criteria and the new fatigue provisions on the design of a cantilevered overhead sign support structure. The structural analysis package *Sign Bridge Analysis and Evaluation System (SABRE)* was selected to perform the analyses on the selected structure configuration. Design wind loads from the different wind speed maps for the 1994 and 2001 *Supports Specifications* were compared for a large number of cities across Alabama to determine the effect of the new wind provisions. The cantilevered overhead sign structure example was also designed to determine the effect of the new fatigue provisions for galloping, natural wind gusts and truck-induced wind gusts. For the northern 80 percent of Alabama, slight increase in structure weight is required for structures designed to meet the new 2001 wind provisions and the truck-induced wind gust fatigue provision for fatigue category I. Moderate increases in structure weight are required to meet the natural wind gust provision. Significant increases in structure weight are required to meet the galloping fatigue provision.

A companion technical appendix was published as UTCA Report 02216-1. It contains input and output files for SABRE, based on the 1994 specifications (Appendix A) and the 2001 Specifications (Appendix B). Copies of the Technical Appendix may be obtained from the authors.

Section 1 Introduction

AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals, 1994 (hereafter referred to as the *Supports Specifications*) (AASHTO, 1994) was totally revised based on work conducted under NCHRP Project 17-10 (Fouad *et al*, 1998). The project, which was completed in 1997, addressed a variety of technical topics and presented new wind maps, revised wind loading criteria, and new fatigue provisions. The revised *Supports Specifications* was submitted to the AASHTO Highway Subcommittee on Bridges and Structures (SCOBS) for adoption consideration. The standard specifications, which were balloted and approved for adoption by all states, were published in the summer of 2001 (AASHTO, 2001).

The changes in the wind loading criteria provided by the 2001 *Supports Specifications* represent a major and fundamental update to the wind loading criteria of the 1994 *Supports Specifications*. These changes represent over 20 years of progress in wind technology, and update the *Supports Specifications* to the most current wind methodology. Additionally, new fatigue design criteria were added for structures subjected to fatigue loads, which are expected to have a significant impact on the design of overhead cantilevered sign support structures.

Problem Statement

A major concern about the 2001 *Supports Specifications* is the use of a new wind map and wind provisions that may result in significant changes in the applied loads. Wind load calculations in the 2001 *Supports Specifications* are now based on a 3-second gust wind speed, rather than a fastest-mile wind speed. The previous series maps, representing 10-, 25-, and 50-year mean recurrence intervals, was reduced to one 50-year mean recurrence interval map with importance factors used to adjust the intervals. Height factors were adjusted for the 3-second-gust wind speed. The coefficients of drag were modified slightly. The increase or reduction in calculated wind pressures, which result from the use of the updated wind map, are primarily due to the differences in the 1994 and 2001 wind speed maps.

The new wind map for Alabama in the 2001 *Supports Specifications* can be divided into two wind speed regions: 1) 90 mph for the northern 80 percent of the state, and 2) 100 mph to 140 mph in the hurricane region. These regions correspond to fastest mile per hour wind speeds ranging from 70 to 100 mph depending on the site location and the mean recurrence interval. Differences in wind loads computed according to the two maps are therefore site-specific.

A second and major concern is that new fatigue criteria have been added to the 2001 *Supports Specifications* that could significantly impact the design of cantilevered overhead sign structures. This study evaluated the combined effect of the revised wind and new fatigue provisions on the

design of support structures and compared those structures to ones designed in accordance with the previous *Supports Specifications*.

Objective and Approach

The main objective of this study was to evaluate the safety and economy of cantilevered overhead sign supports in Alabama that are designed in accordance with the revised wind load and new fatigue provisions published in 2001 by AASHTO. The following tasks were performed as part of the project.

Task 1. Impact of New Wind Provisions on Design of Cantilevered Overhead Sign Supports

Analyses and design examples were performed on a cantilevered overhead sign support structure located at 10 sites in Alabama. Base shear and foundation forces were computed as part of the analyses. Designs included the selection of the main member sizes of the structure. The examples provided ample information for illustrating the impact of the new wind load provisions on the safety and economy of structural supports designed in accordance with the new wind load provisions.

Task 2. Impact of the New Fatigue Criteria on the Design of Cantilevered Overhead Sign Supports

Analyses and design examples were performed on a cantilevered overhead sign structure using the new fatigue criteria in the 2001 *Supports Specifications*. Design and selection of main members' sizes were compared to the results of Task 1. The example presented provides ample information to illustrate the impact of the new fatigue criteria on the safety and economy of structural supports designed in accordance with the revised wind load provisions and the new fatigue criteria.

Section 2 Historical Perspective

Wind Loads

The first wind load standard containing wind speed maps was published in 1972 by the American National Standards Institute (ANSI, formerly ASA), Standard A58.1 (ANSI, 1972). The design basis wind speed was given as the fastest-mile wind speed. Figure 2-1 provides the 50-year mean recurrence interval wind map (Thom, 1968) that was published by ANSI and later adopted by the AASHTO 1985 *Supports Specifications* (AASHTO, 1985). Until 1994, the AASHTO *Supports Specifications* (AASHTO, 1994) continued to use this map that was produced by Thom in the late 1960s. A revision to the wind load standard was published by ANSI in 1982 (ANSI, 1982). This standard separated loads for the main wind-force resisting system and the components and cladding of buildings. In addition, it used one wind speed map for the 50-year mean recurrence interval (MRI) and introduced the importance factor to obtain wind speeds for other MRIs. In the mid-1980s, the American Society of Civil Engineers (ASCE) assumed responsibility for the committee that establishes design loads for buildings and other structures. ASCE Committee 7 made minor changes to the ANSI A58.1-1982 provisions and published the revised version as ASCE 7-88 (ASCE, 1990). A revised version of ASCE 7-88 was published as ASCE 7-93 (ASCE, 1993) with no changes in wind load provisions.

In 1996, ASCE published ASCE 7-95 *Minimum Design Loads for Buildings and Other Structures* (ASCE, 1996), which included major changes to wind load provisions and featured a new wind map based on three-second gust wind speeds. Adopting the three-second gust design wind speed instead of fastest-mile wind speed required modification of exposure (height and terrain) coefficients, gust effect factors, importance factors, and some pressure coefficients. The ANSI/ASCE 7-95 is the basis for the wind load provisions of the 2001 AASHTO *Supports Specifications*, which includes modifications specific to the design of sign, signal, and light support structures. The ASCE 7-95 map was adopted for use in the 2001 *Supports Specifications* and is shown in Figure 2-2.

ASCE published new editions of the loading standard in 2000 and again in 2002. ASCE 7-98 (ASCE, 2000) and ASCE 7-02 (ASCE, 2002) included additional revisions to the wind load provisions such as refinement of wind speed contours in hurricane regions and the addition of a directionality factor. However, these changes were not as drastic as those presented in ASCE 7-95. The ASCE 7-98 wind map is now being considered by the AASHTO committee for possible inclusion in the next revision of the *Supports Specifications*.

Fatigue Loading Criteria

High-cycle, low-level stress fluctuations can cause fracture damage, which is termed fatigue. NCHRP Project 10-38 (Kaczinski, 1998) identified cantilevered support structures that were susceptible to fatigue failures, defined fatigue loading criteria, and determined the stress limit for typical connection details. The fatigue load criteria are based on an infinite life fatigue approach. This approach can be used when the number of load cycles for a given connection during the structure's lifetime exceeds the number of cycles at the constant amplitude fatigue limit (CAFL). The design check is that stresses due to fatigue loads, which represent nominal stress ranges, should be less than the CAFL for a particular connection.

Based on NCHRP Project 10-38, new fatigue loading criteria were included as Section 11 of the 2001 *Supports Specifications* for structures that were susceptible to fatigue failures. This new section presented new fatigue loadings for cantilevered overhead sign, signal and light structures. The fatigue criteria are specifically applied to cantilevered overhead sign structures, traffic signal mast arm structures, and high mast light poles that are made of steel or aluminum. The section does not apply to wood, prestressed concrete or fiberglass, nor does it apply to span wire traffic signal poles, street lighting poles or roadside sign structures.

Fatigue failures for cantilevered sign, signal and light support structures were determined to be caused by one or more of the following: galloping, vortex shedding, natural wind gusts, and truck-induced wind gusts. An equivalent static pressure was developed for each loading type. A stress limit was also defined for typical connection details.

Category Descriptions and Importance Factors

The equivalent static pressures are modified using importance factors, which are provided in Table 11-1 in the *Supports Specifications*. Importance factors vary by fatigue load (i.e., galloping, vortex shedding, natural wind gust, and truck-induced wind gust) and by category descriptions (i.e., I, II, or III), which are dependent on location and structure type, and which are defined as follows:

- I: critical cantilevered support structures installed on major highways
- II: other cantilevered support structures installed on major highways and all cantilevered support structures installed on secondary highways
- III: cantilevered support structures installed at all other locations

Typically, a cantilevered overhead sign structure would be located over a major highway, such as an interstate highway, and would therefore be classified under category I.

Galloping

Galloping in cantilevered overhead sign or traffic signal structures is due to a wind velocity of approximately 15 to 40 mph blowing on a rigidly attached sign or traffic signal. The cantilevered horizontal arm vibrates vertically, which is normal to the wind flow direction. An equivalent pressure range was determined to estimate stresses occurring due to this vertical vibration. The equation for the vertical shear pressure range provided in Eq. 11-1 of the *Supports Specifications* is:

$$P_G = 2I_F \text{ (psf)} \quad \text{Eq. 2-1}$$

where P_G is the galloping-induced shear pressure range in psf and I_F is the importance factor defined in Table 11-1 of the *Supports Specifications*. The calculated pressure is applied vertically to the surface area of the sign.

The 2001 *Supports Specifications* states that the owner may exclude the galloping fatigue loading for 4-chord trusses. This exclusion is allowed because 4-chord trusses do not appear to be susceptible to galloping, since they have three-dimensional stiffness.

Vortex Shedding

Vortex shedding is applied to nontapered lighting structures. For the selected example, a cantilevered overhead sign support structure, vortex shedding does not apply because the loading is not applicable to truss supports.

Natural Wind Gust

The natural wind gust loading applies to overhead sign and traffic signal structures and high mast lighting poles. The specified pressure range provided in Eq. 11-5 in the *Supports Specifications* is applied to the projected area normal to the wind. The equation is

$$P_{NW} = 5.2C_d I_F \text{ (psf)} \quad \text{Eq. 2-2}$$

where P_{NW} is the natural wind gust pressure range in psf, C_d is the drag coefficient, and I_F is the importance factor from Table 11-1 in the *Supports Specifications*. Eq. 11-5 in the *Supports Specifications* applies to locations where the yearly mean wind speed is 11.2 mph or less. Eq. C 11-5 in the commentary provides an adjustment for locations where the yearly mean wind speed is greater than 11.2 mph, and is written as:

$$P_{NW} = 5.2C_d \left(\frac{V_{mean}^2}{125} \right) I_F \text{ (psf)} \quad \text{Eq. 2-3}$$

where V_{mean} is the yearly mean velocity for a given area in mph.

Truck-Induced Wind Gust

The truck-induced wind gust applies to cantilevered sign and traffic signal structures. The section in the *Supports Specifications* pertaining to loading due to truck-induced gust was updated with the 2002 interim *Supports Specifications* (AASHTO, 2002). The specified pressure may be reduced for heights greater than 19.7 feet. The pressure is applied over a length of 12 feet at the most critical location for loading and represents a commercial truck passing beneath the sign. Reductions are also provided for locations where the vehicle speed is less than 65 mph. The pressure is applied vertically to the projected area in the horizontal plane. The equivalent static truck gust pressure provided is:

$$P_{TG} = 18.8C_d I_F \text{ (psf)} \quad \text{Eq. 2-4}$$

where P_{TG} is the equivalent static truck gust pressure range in psf, C_d is the drag coefficient, and I_F is the importance factor from Table 11-1 in the *Supports Specifications*. The pressure range is applied to the projected area of the horizontal supports and attachments over a 12-foot length that

maximizes stresses. A reduction can be used where vehicle speeds are less than 65 mph and is provided as follows:

$$P_{TG} = 18.8C_d \left(\frac{V}{65\text{mph}} \right)^2 I_F \text{ (psf)} \quad \text{Eq. 2-5}$$

where V is the truck speed in mph.

Fatigue Details

The various connection details that are typically used in sign, traffic signal and signs support structures are provided in Figure 11-1 and Table 11-1 of the *Supports Specifications*. A corresponding stress category is provided for each connection detail. The constant amplitude fatigue threshold is provided in Table 11-3 of the *Supports Specifications* for each detail category. The constant-amplitude fatigue limit (CAFL), also known as the endurance limit, is the stress range below which the fatigue life appears to be infinite. The CAFL is defined for the materials steel and aluminum for detail categories A through K2 in Table 11-3 in the *Supports Specifications*.

Continuing Fatigue Research

Research is continuing on fatigue design of support structures. Topics that are being reviewed are fatigue loadings for span-type overhead sign structures, vibration mitigation devices, and refinement fatigue loads and stress categories for the fatigue details.

Section 3

Wind Load Comparisons for 1994 vs. 2001 AASHTO *Supports Specifications*

The changes in the wind loading criteria in the 2001 AASHTO *Supports Specifications* represent a major and fundamental update to the wind loading criteria of the 1994 *Supports Specifications*. These changes, representing over 20 years of progress in the wind technology, update the *Supports Specifications* to the most current wind methodology. The effects of changing the wind loading criteria and wind map are reviewed in this section of this report. Differences in design wind loads as a result of using the new wind speed map and calculation method were compared for a large number of cities across Alabama to determine the effect of the new wind provisions on the design of structural supports. A comprehensive list of 69 cities in Alabama was selected for evaluation in this study. The list was representative of urban and rural areas in Alabama. Comparisons were made for the 2001 and 1994 *Supports Specifications* for counties that had the same wind speed design criteria and ice loading criteria. For each site, comparisons were made for the 2001 and 1994 *Supports Specifications* by calculating wind pressures for the 50-year mean recurrence interval (MRI), which is typical for the design of overhead sign structures. For the 1994 *Supports Specifications*, wind pressures were calculated per Section 1.2.5(A) with a drag coefficient of 1.0. For the 2001 *Supports Specifications*, wind pressures were calculated per Section 3.8.1 with a drag coefficient of 1.0.

Wind and Ice Maps for Alabama

For this project, the wind maps of the 1994 and 2001 *Supports Specifications* were trimmed and enlarged to focus on Alabama. For the 2001 *Supports Specifications*, Figure 3-1 provides the basic wind speed for Alabama. Importance factors are used to vary the mean recurrence interval, which is 1.0 for the 50-year MRI. The wind map for Alabama, based on the 1994 *Supports Specifications*, is shown in Figure 3-2. It represents the 50-year mean recurrence interval, which is generally used for high mast lighting poles and overhead sign structures.

Wind pressures calculated for the 50-year MRI for the 1994 and 2001 *Supports Specifications* are shown in Tables 3-1 and 3-2, respectively. Figure 3-3 provides a general comparison of wind pressures of the 1994 and 2001 *Supports Specifications* for the 50 MRI. By visual examination of Figure 3-3, design wind speeds of 70, 80, 90, and 100 mph in the 1994 *Supports Specifications* are comparable to 90, 100, 115, and 125 mph in the 2001 *Supports Specifications*.

The ice loading map, which appears in the 1994 and 2001 *Supports Specifications*, is provided in Figure 3-4. An enlarged map of Alabama is provided in Figure 3-5.

Selection of Cities

The list of 69 cities selected for study is shown in Table 3-3, sorted by county. This list provides wind sites that include population centers, as well as the rural parts of Alabama. The county seats for the 67 counties of Alabama, plus two coastline cities, are provided in the list.

Site Groupings

The basic wind speeds and importance factors for the 50-year mean recurrence intervals for the 2001 AASHTO *Supports Specifications*, as well as the 50-year wind speeds from the 1994 AASHTO *Supports Specifications*, were determined for each of the 69 cities, and are shown in Table 3-3. The 69 cities were sorted by three-second gust wind speed for the 2001 *Supports Specifications*, and by the 50-year wind speeds for the 1994 AASHTO *Supports Specifications* (Table 3-4). As shown in the table, the 69 cities can be grouped into 10 site-specific locations, which have the same three-second gust wind speed, as well as the same 50-year wind speed from the 1994 AASHTO *Supports Specifications*. The 10 wind sites that are the basis of this study are summarized in Table 3-5. It is interesting to note that approximately 80 percent of the cities are located in wind site number 1. Wind Site number 1 is further divided into two divisions: 1a and 1b, with and without an ice loading, respectively.

Wind Pressure Comparison

For each of the 10 site-specific locations, the wind pressure was calculated for heights from the ground line to 200 feet above the ground line for the 2001 and 1994 *Supports Specifications*. Figures 3-6 through 3-25 show the effective wind pressure for 50-year mean recurrence intervals, as well as the ratio of wind pressures for the 2001 to 1994 *Supports Specifications*. The numbers in parentheses are the number of cities out of 69 that are represented by the data. As shown in the graphs, the wind pressure distribution according to the 1994 *Supports Specifications* exhibits a step function, whereas the 2001 *Supports Specifications* has a gradual change of wind pressure with height. All graphs show higher wind pressure ratios for heights less than 15 feet than for heights greater than 15 feet.

Figure 3-26 shows the average and range of ratios of wind pressures for the 2001 to 1994 *Supports Specifications* for the 50-year mean recurrence intervals for the ten sites in Alabama. In general, the range of wind pressure ratios varies from approximately -12 percent to +14 percent from the average ratio, with a slightly larger range near the coastline. Changes in wind pressures for Site 1, which represents approximate 80 percent of the land area in Alabama, indicate, on average, a change in wind pressure of six percent increase for 50-year mean recurrence intervals. The change in wind pressure for all sites varies as much as -28 percent to +61 percent and is dependent on wind speed and elevation. The largest increase occurs near the coastline.

As shown in Figure 3-26 for the 50-year mean recurrence interval structures, Site 2 shows an average of 19 percent decrease in wind pressure. Sites 3, 7, and 9 show the greatest average

increase in wind pressure of 30 percent, 44 percent, and 33 percent, respectively. Sites 1, 4, and 8 show an average increase of 6 percent, zero percent, and 14 percent, respectively. For Sites 5, 6, and 10, wind pressures show an average increase of 21 percent, 21 percent and 25 percent.

Summary

Based upon this analysis, only a slight change in wind pressure will occur for 80 percent of Alabama, which is represented by Site 1. The greatest decrease in wind pressure will occur at Site 2. The greatest increase in wind pressure will occur near the coastline, as represented by Sites 3 through 10. For 50-year MRI structures, which include overhead signs and high mast lighting structures, the greatest increase in wind pressure occurs in Site 7. In comparing the 1994 versus the 2001 wind specifications, it is apparent that changes in wind pressure, either decreasing or increasing, are highly site-specific. These changes are also dependent on wind elevation.

Section 4

Design Comparisons for 1994 vs. 2001 AASHTO *Supports Specifications*

Structure Configuration

A cantilevered overhead sign structure, as shown in Figure 4-1, was selected so that designs could be compared between the 1994 and 2001 *Supports Specifications*. The flat sign panel dimensions are 11 feet by 24 feet. The sign is centered 24 feet from the vertical support. There are no provisions for a walkway or lighting. The vertical support is a hollow tubular post with a yield stress of 50 ksi. The horizontal support is composed of four-chord truss configuration shown in Figure 4-2. The horizontal truss members are composed of pipe with a yield stress of 35 ksi. Table 4-1 lists the yield stresses for various members. Table 4-2 lists member quantities and lengths. Figure 4-3 provides node numbers used in the analysis, while Figure 4-4 provides member numbers.

The selected structure configuration of Figure 4-2 was designed using the following criteria:

- 1) for the 1994 *Supports Specifications*,
 - a) group II load combination only (dead load plus wind)
 - b) group II and III load combinations only (dead load plus wind, dead load plus $\frac{1}{2}$ wind plus ice)
- 2) for the 2001 *Supports Specifications*,
 - a) group II load combination only (dead load plus wind)
 - b) group II and III load combinations only (dead load plus wind, dead load plus $\frac{1}{2}$ wind plus ice)
 - c) For each of the fatigue categories I, II and III
 - i) group II load combination plus galloping fatigue criteria
 - ii) group II and III load combination plus galloping fatigue criteria
 - iii) group II load combination plus natural wind gust fatigue criteria
 - iv) group II and III load combination plus natural wind gust fatigue criteria
 - v) group II load combination plus truck-induced wind gust fatigue criteria
 - vi) group II and III load combination plus truck-induced wind gust fatigue criteria
 - vii) group II load combination plus natural wind gust and truck-induced wind gust fatigue criteria
 - viii) group II and III load combination plus natural wind gust and truck-induced wind gust fatigue criteria
 - ix) group II load combination plus galloping, natural wind gust and truck-induced wind gust fatigue criteria
 - x) group II and III load combination plus galloping, natural wind gust and truck-induced wind gust fatigue criteria

Comparisons of these designs determined how the new wind and fatigue criteria in the 2001 *Supports Specifications* impacts the design of the selected structural configuration due to ice loading, the new wind load provisions, and the new fatigue criteria by fatigue category (i.e., I, II, and III) and by fatigue loading (i.e., galloping, natural wind gust, and truck-induced wind gust).

Structural Analysis Package

The structural analysis package *Sign Bridge Analysis and Evaluation System* (SABRE) was selected to perform analysis on the selected structure configuration. SABRE can analyze various configurations of support structures and runs on a personal computer with a Windows platform. The package includes a preprocessor for data entry, a frame analysis program, and a postprocessor for viewing results. Loads are automatically calculated. Analysis is performed using the general stiffness method to perform static analysis of space frames. Output includes applied stresses, allowable stresses and combined stress ratio (CSR) for each member. Two versions of SABRE were obtained. The older DOS version is based on the 1994 *Supports Specifications*. The more recent Windows version is based on the 2001 *Supports Specifications*, which includes the updates in wind loads and calculation of stresses due to fatigue loadings. On-screen graphing is also available.

Structure Sizes Designed Using 1994 *Supports Specifications*

The cantilever overhead sign structure in Figure 4-2 was designed for group II and III load combinations for wind speeds ranging from 60 to 110 mph using the 1994 *Supports Specifications*. Member sizes designed for group I and II load combinations only are provided in Table 4-3 for 60 mph to 110 mph. Ground line reactions for group II load combination for 1994 *Supports Specifications* (wind in +Z direction) are provided in Table 4-4. Member sizes designed for group I, II, and III load combinations are provided in Table 4-5. Sample input and output files for the 1994 edition of the SABRE program for a basic wind speed of 70 mph are provided in the Technical Appendix (UTCA Report 02216-1).

Structure Sizes Designed Using 2001 *Supports Specifications*

The cantilever overhead sign structure in Figure 4-2 was designed for group II and III load combinations for wind speeds ranging from 85 to 150 mph using the 2001 *Supports Specifications*. Member sizes designed for group I and II load combinations only for 2001 *Supports Specifications* are provided in Table 4-6. Ground line reactions for group II load combination for 2001 *Supports Specifications* (wind in +Z direction) are provided in Table 4-7. Member sizes designed for group I, II and III load combinations only for 2001 *Supports Specifications* are provided Table 4-8. Sample input and output files for the 2001 edition of the SABRE program for a basic wind speed for 90 mph are provided the Technical Appendix (UTCA Report 02216-1).

Impact of Ice Loading

Structure weights and members sizes, as shown in Tables 4-3 and 4-5 for the 1994 *Supports Specifications* and Tables 4-6 and 4-8 for the 2001 *Supports Specifications*, were compared for group II and III load combinations. Member sizes were unchanged, except for minor size changes in the diagonals and struts. Structure weight comparisons are provided in Tables 4-9 and 4-10. For both *Supports Specifications* the weight difference between the group II and III load combinations ranged from four percent for the lower wind speeds to zero percent for the higher wind speed. Therefore, the additional of the ice loading provides only a slight impact on the design of the selected example.

Impact of the New Wind Load Provisions

The impact of the new wind load provisions was determined for the 10 sites in Alabama. Structure weights and ground line reactions by site were compared for the 1994 and 2001 *Supports Specifications* for group II and III load combinations, as provided in Table 4-11 for the 1994 *Supports Specifications* and Table 4-12 for the 2001 *Supports Specifications*. Site 1a, which represents the northern third of Alabama, was designed for group II and III load combinations (DL+W,DL+1/2 W +Ice), while the remaining sites were design for group II load combination only. Figures 4-5 through 4-8 provide a comparison of structure weight, ground line moments, shears and torsion for the various sites. Percent differences in weight and reactions are provided in Table 4-13 and Figure 4-9.

Sites 1a and 1b, representing the northern 80 percent of Alabama, showed a two percent increase in structure weight and a three percent increase ground line shear. The greatest increases in structure weight and ground line reactions occurred near the coastline of Alabama, which is represented by Sites 5 through 10, with increases up to 26 percent in structure weight and 40 percent increase in ground line shear. Site 2 showed the greatest decrease in structure weight of 15 percent and ground line shear of 22 percent.

Impact of the New Fatigue Provisions

Member sizes and structure weights were also determined for the different fatigue loadings in the 2001 *Supports Specifications*: galloping, natural wind gust and truck-induced wind gust. Tables 4-14 through 4-19 provide member sizes for group I and II load combinations plus galloping and for group I, II and III load combinations plus galloping for fatigue categories I, II and III. Tables 4-20 through 4-25 provide member sizes for group I and II load combinations or group I, II and III load combinations plus natural wind gust for fatigue categories I, II and III. Tables 4-26 through 4-27 provide member sizes for group I and II load combinations or group I, II and III load combinations plus truck-induced wind gust for fatigue category I. Tables 4-28 through 4-29 provide member sizes for group I and II load combinations or group I, II and III load combinations plus truck-induced wind gust and natural wind gust for fatigue category I. Member sizes due to the truck-induced wind gust for fatigue categories II and III did not change member sizes for this structure configuration. Structure weight comparisons by sites in Alabama

were also made relative to the 1994 *Supports Specifications*. Table 4-30 provides structure weight comparisons by site, specifications, and fatigue category.

Fatigue Category I

For fatigue category I, Tables 4-31 and 4-32 provide structure weights for group I, II, and/or III load combinations plus one individual fatigue loading of galloping, natural wind gust, or truck-induced wind gust. Structures that met the galloping fatigue criteria weighed approximately 16,000 pounds. Structure weights that met the natural wind gust fatigue criteria ranged from 4500 to 6300 pounds, while structure weights that meet the truck-induced wind gust range from 2600 to 6000 pounds. Table 4-33 provides structure weights for group I, II and III load combinations plus natural wind gust and truck-induced wind gust for fatigue category I for the 2001 *Supports Specifications*, where weights ranged from 4500 to 6400 pounds.

Table 4-34 provides structure weight comparisons based on the 2001 *Supports Specifications* for group I and II load combinations only and for those that include galloping, natural wind gust and truck-induced wind gust for fatigue category I. Structure weights based on the 2001 *Supports Specifications* ranged from 2500 to 6000 pounds for group I and II load combinations only. Structure weights that include design for the natural wind gust and truck-induced wind gust ranged from 4400 to 6400 pounds. This was an increase in weight ranging from 73 percent to 6 percent, depending on the wind zone. Structure weights that include galloping, natural wind gust and truck-induced wind gust, were 16,000 pounds. This was an increase ranging from 524 percent to 167 percent, depending on the wind zone. Figure 4-10 provides structure weight comparisons for fatigue category I.

Fatigue Category II

For fatigue category II, Tables 4-35 and 4-36 provide structure weights for group I, II, and/or III load combinations plus one individual fatigue loading of galloping, natural wind gust, or truck-induced wind gust. Structures that met the galloping fatigue criteria weighed approximately 11,500 pounds. Structure weights that met the natural wind gust fatigue criteria ranged from 3400 to 6100 pounds, while structure weights that met the truck-induced wind gust ranged from 2500 to 6000 pounds. Table 4-37 provides structure weights for group I, II and III load combinations plus natural wind gust and truck-induced wind gust for fatigue category II for the 2001 *Supports Specifications*.

Table 4-38 provides structure weight comparisons based on the 2001 *Supports Specifications* for group I and II load combinations only and for those that include galloping, natural wind gust and truck-induced wind gust for fatigue category II. Structure weights based on the 2001 *Supports Specifications* ranged from 2500 to 6000 pounds for group I and II load combinations only. Structure weights that include design for the natural wind gust and truck-induced wind gust ranged from 3400 to 6100 pounds. This was an increase in weight ranging from 35 percent to one percent, depending on the wind zone. Structure weights that include designed for galloping, as well as natural wind gust and truck-induced wind gust, were 11,500 pounds. This was an increase ranging from 348 percent to 91 percent, depending on the wind zone. Figure 4-11 provides structure weight comparisons for fatigue category II.

Fatigue Category III

For fatigue category III, Tables 4-39 and 4-40 provide structure weights for group I, II, and/or III load combinations plus one individual fatigue loading of galloping, natural wind gust, or truck-induced wind gust. Structure weights that met the galloping fatigue criteria ranged from 5000 to 7000 pounds. Structure weights that met the natural wind gust fatigue criteria ranged from 2700 to 6000 pounds, while structure weights that met the truck-induced wind gust ranged from 2500 to 6000 pounds. Table 4-41 provides structure weights for group I, II and III load combinations plus natural wind gust and truck-induced wind gust for fatigue category III for the 2001 *Supports Specifications*.

Table 4-42 provides structure weight comparisons based on the 2001 *Supports Specifications* for group I and II load combinations only and for those that include galloping, natural wind gust and truck-induced wind gust for fatigue category III. Structure weights based on the 2001 *Supports Specifications* ranged from 2500 to 6000 pounds for group I and II load combinations only. Structure weights that included design for the natural wind gust and truck-induced wind gust ranged from 2700 to 6000 pounds. This represents an increase in weight from eight percent to zero percent, depending on the wind zone. Structure weights that included galloping, natural wind gust and truck-induced wind gust, ranged from 5000 to 7000 pounds. This was an increase range from 98 percent to 17 percent, depending on the wind zone. Figure 4-12 provides structure weight comparisons for fatigue category III.

Structure Weight Change by Fatigue Category

Figure 4-13 provides structure weight comparisons for the galloping fatigue criteria. Figure 4-14 provides structure weight comparisons for natural wind gust and truck-induced wind gust fatigue criteria. A significant increase in structure weight would be required to meet the galloping fatigue criteria for fatigue categories I and II.

Structure Weight Change by Site

Figures 4-15 through 4-25 provide structure weight comparisons for site numbers 1 through 10. Structure weights are provided for the following:

1. 1994 *Supports Specifications*
2. 2001 *Supports Specifications* for group I, II, and III load combinations only
3. 2001 *Supports Specifications* for group I, II, and III load combinations plus natural wind gust and truck-induced wind gust for fatigue category I
4. 2001 *Supports Specifications* for group I, II, and III load combinations plus natural wind gust and truck-induced wind gust for fatigue category II
5. 2001 *Supports Specifications* for group I, II, and III load combinations plus natural wind gust and truck-induced wind gust for fatigue category III
6. 2001 *Supports Specifications* for group I, II, and III load combinations plus galloping, natural wind gust and truck-induced wind gust for fatigue category I
7. 2001 *Supports Specifications* for group I, II, and III load combinations plus galloping, natural wind gust and truck-induced wind gust for fatigue category II

8. 2001 *Supports Specifications* for group I, II, and III load combinations plus galloping, natural wind gust and truck-induced wind gust for fatigue category III

Table 4-43 provides weight comparisons by site for 1994 and 2001 *Supports Specifications* for fatigue category I relative to 1994 *Supports Specifications*. For structures designed for the 2001 *Supports Specifications* using the group I, II and III load combinations only, the change in structure weight for the different sites ranges from a decrease of 15 percent to an increase of 26 percent, with the largest land area in Alabama, as represented by Sites 1a and 1b, increasing by two percent. For structures designed for group I, II, and III load combinations plus the fatigue criteria of natural wind gust and truck-induced wind gust, the changes in structure weight range from 13 percent to 57 percent increase. For structures designed for group I, II, and III load combinations plus the fatigue criteria of galloping, natural wind gust and truck-induced wind gust, the changes in structure weight range from 232 percent to 467 percent increase. Table 4-44 provides weight comparisons by site between 1994 and 2001 *Supports Specifications* for fatigue category I relative to 2001 *Supports Specifications* for structures designed for group I, II and III load combinations plus the fatigue criteria for natural wind gust and truck-induced wind gust.

Table 4-45 provides weight comparisons by site between 1994 and 2001 *Supports Specifications* for fatigue category II relative to 1994 specifications. For structures designed for the 2001 *Supports Specifications* using the group I, II and III load combinations only, the change in structure weight for the different sites ranges from a decrease of 15 percent to an increase of 26 percent, with the largest land area in Alabama, as represented by Sites 1a and 1b, increasing by two percent. For structures designed for group I, II, and III load combinations plus the fatigue criteria of natural wind gust and truck-induced wind gust, the changes in structure weight range from three percent to 30 percent increase. For structures designed for group I, II, and III load combinations plus the fatigue criteria of galloping, natural wind gust and truck-induced wind gust, the changes in structure weight range from 138 percent to 307 percent increase. Table 4-46 provides weight comparisons by site between 1994 and 2001 *Supports Specifications* for fatigue category II relative to 2001 specifications for structures designed for group I, II and III load combinations plus the fatigue criteria for natural wind gust and truck-induced wind gust.

Table 4-47 provides weight comparisons by site between the 1994 and 2001 *Supports Specifications* for fatigue category III relative to 1994 specifications. For structures designed for the 2001 *Supports Specifications* using the group I, II and III load combinations only, the change in structure weight for the different sites ranges from a decrease of 15 percent to an increase of 26 percent, with the largest land area in Alabama, as represented by Sites 1a and 1b, increasing by two percent. For structures designed for group I, II, and III load combinations plus the fatigue criteria of natural wind gust and truck-induced wind gust, the changes in structure weight range from a decrease of 11 percent to an increase of 26 percent. For structures designed for group I, II, and III load combinations plus the fatigue criteria of galloping, natural wind gust and truck-induced wind gust, the changes in structure weight range from 30 percent to 77 percent increase. Table 4-48 provides weight comparisons by site between 1994 and 2001 *Supports Specifications* for fatigue category III relative to 2001 specifications for structures designed for group I, II and III load combinations plus the fatigue criteria for natural wind gust and truck-induced wind gust.

Design Criteria Options for Fatigue

The owner has the option to select the fatigue category and to exclude the galloping criteria. Below is a discussion with citations from the 2001 *Supports Specifications*.

Design Category and Importance Factors

Structure weight and members sizes are affected by the selection of the fatigue importance factors and fatigue category. Based on the 2001 *Supports Specifications* in Section 11.6, *An importance factor, I_F , that accounts for the degree of hazard to traffic and damage to property shall be applied to the limit state wind load effects specified in Article 11.7. Importance factors for cantilevered traffic signal, sign, and luminaire support structures exposed to the four wind load effects are presented in Table 11-1.*

And, from the commentary,

Importance factors are introduced into the Specifications to adjust the level of structural reliability of cantilevered support structures. Importance factors should be determined by the owner.

Galloping

Structure weight and member sizes for the cantilevered overhead sign structure example have been provided to illustrate the significance of including the galloping fatigue criteria in the design requirement. Based on the 2001 *Supports Specifications*, other options are:

- 1) Owner may eliminate galloping as a design requirement for a cantilevered overhead sign support with a 4-chord truss.
Section 11.7.1, Supports Specifications: The owner may choose to exclude galloping loads for the fatigue design of overhead cantilevered sign support structures with quadric-chord (i.e., four-chord) horizontal trusses.
Section 11.7.1, Commentary: Overhead cantilevered sign support structures with quadric-chord horizontal trusses do not appear to be susceptible to galloping because of their inherent high degree of three-dimensional stiffness.
- 2) Owner may use an approved vibration mitigation device to reduce the galloping forces.
Section 11.7.1, Supports Specifications: In lieu of designing to resist periodic galloping forces, cantilevered sign and traffic signal structures may be erected with approved vibration mitigation devices. Vibration mitigation devices should be approved by the owner, and they should be based on historical or research verification of its vibration damping characteristics.

Conclusions

In general, the following conclusions can be made about the selected cantilevered overhead sign example:

1. Ice loading: The addition of the ice loading results in minimal increase in structure weight.

2. New wind load provisions: The changes in structure weights due to the new wind load provisions vary considerably by site. Structure weight due to 2001 AASHTO wind load provisions when compared to the 1994 *Supports Specifications*, increased by two percent for the northern 80 percent of Alabama, with changes in weight for all sites varying from a 15 percent decrease to a 26 percent increase.
3. New fatigue criteria: Changes in structure weight are dependent on the site, fatigue loading criteria (i.e., galloping, natural wind gust, truck-induced wind gust), and fatigue category (i.e., I, II and III).
 - a. Galloping: In general, the owner should exclude the galloping fatigue criteria for a quadric-chord truss. However, if galloping were included in the design criteria, increases in weight relative to the 1994 *Supports Specifications* design would range from 232 percent to 467 percent, 138 percent to 307 percent, and 30 percent to 77 percent for fatigue categories I, II, and III, respectively.
 - b. Natural wind gust plus truck-induced wind gusts: If galloping were excluded from the design criteria, increases in weight relative to the 1994 *Supports Specifications* design would be ranging from 13 percent to 57 percent, 3 percent to 30 percent, and -11 percent to 26 percent for fatigue categories I, II, and III, respectively.

Section 5

Summary and Recommendations

Summary

The impacts of the new wind load provisions and fatigue criteria in the 2001 *Supports Specifications* were determined in this project. Changes in design from the 1994 to 2001 *Supports Specifications* are dependent on site, wind speed, ice loading, fatigue category, and fatigue loadings. The effects of these changes on the design of a cantilevered overhead sign support structure were determined.

Recommended Future Work

Recommendations for future work include the following:

- 1) Present the impact of the 2001 *Supports Specifications* on the design of support structures in a workshop for the Alabama DOT.
- 2) Determine the impact on selected structure configuration when considering the use of a variable message sign (VMS), attachments for walkways and lighting, and different chord spacings.
- 3) Determine the impact of “Section 11: Fatigue” in the 2001 *Supports Specifications* on the design of other structure types, such as a traffic signal mast arm structure and high mast lighting poles.
- 4) Determine the impact of the 2001 *Supports Specifications* on other types of support structures, specifically overhead sign structures and traffic signal structures.
- 5) Study the new wind load provisions of ASCE 7-02, including the revised wind map, to determine if such changes should be incorporated in the future revisions of the AASHTO *Supports Specifications*.

Section 6

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**Section 8
Tables**

Table 3-1. Wind pressures for 1994 Supports Specifications

Wind Speed, mph	60	70	80	90	100	110
Height Above Grade (ft)	Wind Pressure (psf)	Wind Pressure (psf)	Wind Pressure (psf)	Wind Pressure (psf)	Wind Pressure (psf)	Wind Pressure (psf)
0	12.5	17.0	22.2	28.0	34.6	41.9
5	12.5	17.0	22.2	28.0	34.6	41.9
10	12.5	17.0	22.2	28.0	34.6	41.9
15	15.6	21.2	27.7	35.0	43.3	52.3
20	15.6	21.2	27.7	35.0	43.3	52.3
25	15.6	21.2	27.7	35.0	43.3	52.3
30	17.1	23.3	30.5	38.5	47.6	57.6
35	17.1	23.3	30.5	38.5	47.6	57.6
40	17.1	23.3	30.5	38.5	47.6	57.6
45	17.1	23.3	30.5	38.5	47.6	57.6
50	19.5	26.5	34.6	43.8	54.1	65.4
60	19.5	26.5	34.6	43.8	54.1	65.4
70	19.5	26.5	34.6	43.8	54.1	65.4
80	19.5	26.5	34.6	43.8	54.1	65.4
90	19.5	26.5	34.6	43.8	54.1	65.4
100	21.8	29.7	38.8	49.1	60.6	73.3
110	21.8	29.7	38.8	49.1	60.6	73.3
120	21.8	29.7	38.8	49.1	60.6	73.3
130	21.8	29.7	38.8	49.1	60.6	73.3
140	21.8	29.7	38.8	49.1	60.6	73.3
150	23.4	31.8	41.5	52.6	64.9	78.5
160	23.4	31.8	41.5	52.6	64.9	78.5
170	23.4	31.8	41.5	52.6	64.9	78.5
180	23.4	31.8	41.5	52.6	64.9	78.5
190	23.4	31.8	41.5	52.6	64.9	78.5
200	24.9	33.9	44.3	56.1	69.2	83.8

AASHTO (1994): $p_z = 0.00256 * (1.3 * V)^2 * (C_d = 1) * C_h$

Table 3-2. Wind pressures for 2001 *Supports Specifications* (50-year MRI)

Wind Speed, mph	85	90	100	110	120	130	140	150
Importance Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Height Above Grade (ft)	Wind Pressure (psf)	Wind Pressure (psf)	Wind Pressure (psf)	Wind Pressure (psf)	Wind Pressure (psf)	Wind Pressure (psf)	Wind Pressure (psf)	Wind Pressure (psf)
0	17.9	20.1	24.8	30.0	35.7	41.9	48.6	55.7
5	17.9	20.1	24.8	30.0	35.7	41.9	48.6	55.7
10	17.9	20.1	24.8	30.0	35.7	41.9	48.6	55.7
15	17.9	20.1	24.8	30.0	35.7	41.9	48.6	55.7
20	19.0	21.3	26.3	31.8	37.9	44.5	51.6	59.2
25	19.9	22.3	27.6	33.4	39.7	46.6	54.1	62.1
30	20.7	23.2	28.7	34.7	41.3	48.4	56.2	64.5
35	21.4	24.0	29.6	35.8	42.6	50.0	58.0	66.6
40	22.0	24.7	30.5	36.9	43.9	51.5	59.7	68.5
45	22.6	25.3	31.2	37.8	45.0	52.8	61.2	70.2
50	23.1	25.9	31.9	38.6	46.0	53.9	62.6	71.8
60	24.0	26.9	33.2	40.1	47.8	56.1	65.0	74.6
70	24.8	27.8	34.3	41.5	49.3	57.9	67.2	77.1
80	25.5	28.5	35.2	42.6	50.7	59.6	69.1	79.3
90	26.1	29.3	36.1	43.7	52.0	61.1	70.8	81.3
100	26.7	29.9	36.9	44.7	53.2	62.4	72.4	83.1
110	27.2	30.5	37.7	45.6	54.3	63.7	73.9	84.8
120	27.7	31.1	38.4	46.4	55.3	64.9	75.2	86.4
130	28.2	31.6	39.0	47.2	56.2	66.0	76.5	87.8
140	28.6	32.1	39.6	48.0	57.1	67.0	77.7	89.2
150	29.1	32.6	40.2	48.7	57.9	68.0	78.8	90.5
160	29.5	33.0	40.8	49.3	58.7	68.9	79.9	91.7
170	29.8	33.5	41.3	50.0	59.5	69.8	81.0	92.9
180	30.2	33.9	41.8	50.6	60.2	70.6	81.9	94.1
190	30.5	34.2	42.3	51.2	60.9	71.5	82.9	95.1
200	30.9	34.6	42.7	51.7	61.5	72.2	83.8	96.2

AASHTO (2001): $p_z = 0.00256 * K_z * G * V^2 * I_r * (C_d = 1)$

Table 3-3. Wind sites sorted by county

County	City	Site No.	Ice Loading	AASHTO 1994	AASHTO 2001	
				Wind Speed, 50-yr MRI (mph)	Wind Speed (mph)	Importance Factor, 50-yr MRI
Autauga	Prattville	1b	None	70	90	1.00
Baldwin	Bay Minette	8	None	90	120	1.00
Baldwin, Coastal Area	Gulf Shores	10	None	100	140	1.00
Barbour	Clayton	1b	None	70	90	1.00
Bibb	Centreville	1b	None	70	90	1.00
Blount	Oneonta	1a	Yes	70	90	1.00
Bullock	Union Springs	1b	None	70	90	1.00
Butler	Greenville	1b	None	70	90	1.00
Calhoun	Anniston	1a	Yes	70	90	1.00
Chambers	Lafayette	1b	None	70	90	1.00
Cherokee	Centre	1a	Yes	70	90	1.00
Chilton	Clanton	1b	None	70	90	1.00
Choctaw	Butler	2	None	80	90	1.00
Clarke	Grove Hill	4	None	80	100	1.00
Clay	Ashland	1a	Yes	70	90	1.00
Cleburne	Heflin	1a	Yes	70	90	1.00
Coffee	Elba	4	None	80	100	1.00
Colbert	Tuscumbia	1a	Yes	70	90	1.00
Conecuh	Evergreen	5	None	80	110	1.00
Coosa	Rockford	1b	None	70	90	1.00
Covington	Andalusia	5	None	80	110	1.00
Crenshaw	Luverne	3	None	70	100	1.00
Cullman	Cullman	1a	Yes	70	90	1.00
Dale	Ozark	3	None	70	100	1.00
Dallas	Selma	1b	None	70	90	1.00
De Kalb	Fort Payne	1a	Yes	70	90	1.00
Elmore	Wetumpka	1b	None	70	90	1.00
Escambia	Brewton	7	None	80	120	1.00
Etowah	Gadsden	1a	Yes	70	90	1.00
Fayette	Fayette	1a	Yes	70	90	1.00
Franklin	Russellville	1a	Yes	70	90	1.00
Geneva	Geneva	5	None	80	110	1.00
Greene	Eutaw	1b	None	70	90	1.00
Hale	Greensboro	1b	None	70	90	1.00
Henry	Abbeville	1b	None	70	90	1.00
Houston	Dothan	4	None	80	100	1.00
Jackson	Scottsboro	1a	Yes	70	90	1.00
Jefferson	Birmingham	1a	Yes	70	90	1.00
Lamar	Vernon	1a	Yes	70	90	1.00
Lauderdale	Florence	1a	Yes	70	90	1.00
Lawrence	Moulton	1a	Yes	70	90	1.00
Lee	Opelika	1b	None	70	90	1.00
Limestone	Athens	1a	Yes	70	90	1.00
Lowndes	Hayneville	1b	None	70	90	1.00

Wind sites sorted by county (continued)

County	City	Site No.	Ice Loading	AASHTO 1994	AASHTO 2001	
				Wind Speed, 50-yr MRI (mph)	Wind Speed (mph)	Importance Factor, 50-yr MRI
Macon	Tuskegee	1b	None	70	90	1.00
Madison	Huntsville	1a	Yes	70	90	1.00
Marengo	Linden	1b	None	70	90	1.00
Marion	Hamilton	1a	Yes	70	90	1.00
Marshall	Guntersville	1a	Yes	70	90	1.00
Mobile	Mobile	9	None	90	130	1.00
Mobile, Coastal Area	Dauphin Is.	10	None	100	140	1.00
Monroe	Monroeville	4	None	80	100	1.00
Montgomery	Montgomery	1b	None	70	90	1.00
Morgan	Decatur	1a	Yes	70	90	1.00
Perry	Marion	1b	None	70	90	1.00
Pickens	Carrollton	1a	Yes	70	90	1.00
Pike	Troy	1b	None	70	90	1.00
Randolph	Wedowee	1a	Yes	70	90	1.00
Russell	Phenix City	1b	None	70	90	1.00
Saint Clair	Pell City	1a	Yes	70	90	1.00
Shelby	Columbiana	1a	Yes	70	90	1.00
Sumter	Livingston	1b	None	70	90	1.00
Talladega	Talladega	1a	Yes	70	90	1.00
Tallapoosa	Dadeville	1b	None	70	90	1.00
Tuscaloosa	Tuscaloosa	1a	Yes	70	90	1.00
Walker	Jasper	1a	Yes	70	90	1.00
Washington	Chatom	6	None	80	110	1.00
Wilcox	Camden	1b	None	70	90	1.00
Winston	Double Springs	1a	Yes	70	90	1.00

Table 3-4. Wind sites sorted by wind speed and site number

Site No.	County	City	Ice Loading	AASHTO 1994	AASHTO 2001	
				Wind Speed, 50-yr MRI (mph)	Wind Speed (mph)	Importance Factor, 50-yr MRI
1a			Yes	70	90	1.00
	Blount	Oneonta				
	Calhoun	Anniston				
	Cherokee	Centre				
	Clay	Ashland				
	Cleburne	Heflin				
	Colbert	Tuscumbia				
	Cullman	Cullman				
	De Kalb	Fort Payne				
	Etowah	Gadsden				
	Fayette	Fayette				
	Franklin	Russellville				
	Jackson	Scottsboro				
	Jefferson	Birmingham				
	Lamar	Vernon				
	Lauderdale	Florence				
	Lawrence	Moulton				
	Limestone	Athens				
	Madison	Huntsville				
	Marion	Hamilton				
	Marshall	Guntersville				
	Morgan	Decatur				
	Pickens	Carrollton				
	Randolph	Wedowee				
	Saint Clair	Pell City				
	Shelby	Columbiana				
	Talladega	Talladega				
	Tuscaloosa	Tuscaloosa				
	Walker	Jasper				
	Winston	Double Springs				
1b			None	70	90	1.00
	Autauga	Prattville				
	Barbour	Clayton				
	Bibb	Centreville				
	Bullock	Union Springs				
	Butler	Greenville				
	Chambers	Lafayette				
	Chilton	Clanton				
	Coosa	Rockford				
	Dallas	Selma				
	Elmore	Wetumpka				
	Greene	Eutaw				
	Hale	Greensboro				
	Henry	Abbeville				
	Lee	Opelika				

Wind sites sorted by wind speed and site number (continued)

Site No.	County	City	Ice Loading	AASHTO 1994	AASHTO 2001	
				Wind Speed, 50-yr MRI (mph)	Wind Speed (mph)	Importance Factor, 50-yr MRI
	Lowndes	Hayneville				
	Macon	Tuskegee				
	Marengo	Linden				
	Montgomery	Montgomery				
	Perry	Marion				
	Pike	Troy				
	Russell	Phenix City				
	Sumter	Livingston				
	Tallapoosa	Dadeville				
	Wilcox	Camden				
2			None	80	90	1.00
	Choctaw	Butler				
3			None	70	100	1.00
	Crenshaw	Luverne				
	Dale	Ozark				
4			None	80	100	1.00
	Clarke	Grove Hill				
	Coffee	Elba				
	Houston	Dothan				
	Monroe	Monroeville				
5			None	80	110	1.00
	Conecuh	Evergreen				
	Covington	Andalusia				
	Geneva	Geneva				
6			None	80	110	1.00
	Washington	Chatom				
7			None	80	120	1.00
	Escambia	Brewton				
8			None	90	120	1.00
	Baldwin	Bay Minette				
9			None	90	130	1.00
	Mobile	Mobile				
10			None	100	140	1.00
	Baldwin, Coastal Area	Gulf Shores				
	Mobile, Coastal Area	Dauphin Is.				

Table 3-5. Wind site classifications for Alabama cities

Wind Site No.	No. of Cities	Ice Loading	AASHTO 1994	AASHTO 2001		Representing
			Wind Speed, 50-yr MRI (mph)	Wind Speed (mph)	Importance Factor, 50-yr MRI	
1a	29	Yes	70	90	1.0	Approximately northern 45% of Alabama
1b	24	No	70	90	1.0	Approximately middle 35% of Alabama
2	1	No	80	90	1.0	Transitional hurricane winds for approximately lower 20% of Alabama
3	2	No	70	100	1.0	
4	4	No	80	100	1.0	
5	3	No	80	110	1.0	
6	1	No	80	110	1.0	
7	1	No	80	120	1.0	
8	1	No	90	120	1.0	
9	1	No	90	130	1.0	
10	2	No	100	140	1.0	
Total	69					

Table 4-1. Yield stress for various members

Member	Yield Stress (ksi)
Post	50
Chord	35
Vertical Diagonals	35
Vertical Struts	35
Horizontal Diagonals	35
Horizontal Struts	35

Table 4-2. Member quantities and lengths

Member	Quantity (ea.)	Length (ft)
Post	1	25.0
Chord	4	34.0
Vertical Diagonals	16	5.66
Vertical Struts	18	4.0
Horizontal Diagonals	16	5.66
Horizontal Struts	18	4.0

Table 4-3. Member sizes and structure weights for group I and II load combinations only for 1994 Supports Specifications

Basic Wind Speed (mph)	Diameter (in) x Wall Thickness (in)						
	Post	Chord	Vertical Diagonals	Vertical Struts	Horizontal Diagonals	Horizontal Struts	Structure Weight (lb)
60	17.00 x 0.250	2.88 x 0.203	1.05 x 0.113	1.32 x 0.133	1.32 x 0.133	1.32 x 0.133	2,408
70	19.50 x 0.250	3.50 x 0.216	1.05 x 0.113	1.32 x 0.133	1.32 x 0.133	1.32 x 0.133	2,816
80	24.00 x 0.250	4.00 x 0.226	1.32 x 0.133	1.32 x 0.133	1.32 x 0.133	1.32 x 0.133	3,376
90	20.25 x 0.375	4.50 x 0.237	1.32 x 0.133	1.32 x 0.133	1.66 x 0.140	1.32 x 0.133	4,063
100	22.50 x 0.375	5.56 x 0.258	1.32 x 0.133	1.32 x 0.133	1.66 x 0.140	1.32 x 0.133	4,808
110	24.75 x 0.375	5.56 x 0.258	1.32 x 0.133	1.32 x 0.133	1.90 x 0.145	1.32 x 0.133	5,074

Table 4-4. Ground line reactions for group II load combination for 1994 Supports Specifications (wind in +Z direction)

Basic Wind Speed (mph)	X (k)	Y (k)	Z (k)	X-X (k-ft)	Y-Y (k-ft)	Z-Z (k-ft)
60	-0.98	4.05	-4.90	-107.2	109.1	84.8
70	-1.33	4.45	-6.78	-149.2	148.8	96.9
80	-1.79	4.99	-8.96	-197.1	194.8	112.0
90	-2.25	5.66	-11.32	-251.0	246.9	127.4
100	-2.84	6.38	-14.14	-313.6	305.6	149.8
110	-3.39	6.64	-17.25	-382.5	370.0	163.0

Table 4-5. Member sizes and structure weights for group I, II, and III load combinations for 1994 Supports Specifications

Basic Wind Speed (mph)	Diameter (in) x Wall Thickness (in)						
	Post	Chord	Vertical Diagonals	Vertical Struts	Horizontal Diagonals	Horizontal Struts	Structure Weight (lb)
60	17.00 x 0.250	2.88 x 0.203	1.32 x 0.133	1.32 x 0.133	1.32 x 0.133	1.66 x 0.140	2,500
70	19.50 x 0.250	3.50 x 0.216	1.32 x 0.133	1.32 x 0.133	1.32 x 0.133	1.66 x 0.140	2,908
80	24.00 x 0.250	4.00 x 0.226	1.32 x 0.133	1.32 x 0.133	1.32 x 0.133	1.66 x 0.140	3,418
90	20.25 x 0.375	4.50 x 0.237	1.32 x 0.133	1.32 x 0.133	1.66 x 0.140	1.32 x 0.133	4,063
100	22.50 x 0.375	5.56 x 0.258	1.32 x 0.133	1.32 x 0.133	1.66 x 0.140	1.32 x 0.133	4,808
110	24.75 x 0.375	5.56 x 0.258	1.32 x 0.133	1.32 x 0.133	1.90 x 0.145	1.32 x 0.133	5,074

Table 4-6. Member sizes and structure weights for group I and II load combinations only for 2001 Supports Specifications

Basic Wind Speed (mph)	Diameter (in) x Wall Thickness (in)						
	Post	Chord	Vertical Diagonals	Vertical Struts	Horizontal Diagonals	Horizontal Struts	Structure Weight (lb)
85	19.25 x 0.250	2.88 x 0.203	1.05 x 0.113	1.32 x 0.133	1.32 x 0.133	1.32 x 0.133	2,558
90	20.50 x 0.250	3.50 x 0.216	1.05 x 0.113	1.32 x 0.133	1.32 x 0.133	1.32 x 0.133	2,883
100	24.25 x 0.250	3.50 x 0.216	1.05 x 0.113	1.32 x 0.133	1.32 x 0.133	1.32 x 0.133	3,133
110	29.75 x 0.250	4.00 x 0.226	1.05 x 0.113	1.32 x 0.133	1.66 x 0.140	1.32 x 0.133	3,763
120	22.25 x 0.375	4.50 x 0.237	1.32 x 0.133	1.32 x 0.133	1.66 x 0.140	1.32 x 0.133	4,263
130	23.75 x 0.375	5.56 x 0.258	1.32 x 0.133	1.32 x 0.133	1.66 x 0.140	1.32 x 0.133	4,933
140	25.50 x 0.375	5.56 x 0.258	1.32 x 0.133	1.32 x 0.133	1.90 x 0.145	1.32 x 0.133	5,149
150	27.50 x 0.375	6.63 x 0.280	1.32 x 0.133	1.32 x 0.133	1.90 x 0.145	1.66 x 0.140	5,988

Table 4-7. Ground line reactions for group II load combination for 2001 Supports Specifications (wind in +Z direction)

Basic Wind Speed (mph)	X (k)	Y (k)	Z (k)	X-X (k-ft)	Y-Y (k-ft)	Z-Z (k-ft)
85	-1.22	4.20	-6.14	-134.4	134.8	90.4
90	-1.39	4.51	-6.95	-152.4	151.4	98.4
100	-1.74	4.76	-8.62	-188.9	186.9	106.5
110	-2.13	5.38	-10.66	-232.8	266.5	119.9
120	-2.50	5.86	-12.52	-276.4	270.1	133.1
130	-2.96	6.50	-14.87	-328.4	317.8	152.7
140	-3.44	6.71	-17.38	-383.6	368.8	164.1
150	-4.02	7.50	-20.16	-444.8	424.7	188.2

Table 4-8. Member sizes and structure weights for group I, II and III load combinations only for 2001 Supports Specifications

Basic Wind Speed (mph)	Diameter (in) x Wall Thickness (in)						
	Post	Chord	Vertical Diagonals	Vertical Struts	Horizontal Diagonals	Horizontal Struts	Structure Weight (lb)
85	19.25 x 0.250	2.88 x 0.203	1.32 x 0.133	1.32 x 0.133	1.32 x 0.133	1.66 x 0.140	2,650
90	20.50 x 0.250	3.50 x 0.216	1.32 x 0.133	1.32 x 0.133	1.32 x 0.133	1.66 x 0.140	2,975
100	24.25 x 0.250	3.50 x 0.216	1.32 x 0.133	1.32 x 0.133	1.32 x 0.133	1.66 x 0.140	3,226
110	29.75 x 0.250	4.00 x 0.226	1.32 x 0.133	1.32 x 0.133	1.66 x 0.140	1.32 x 0.133	3,813
120	22.00 x 0.375	4.50 x 0.237	1.32 x 0.133	1.32 x 0.133	1.66 x 0.140	1.32 x 0.133	4,238
130	23.75 x 0.375	5.56 x 0.258	1.32 x 0.133	1.32 x 0.133	1.66 x 0.140	1.32 x 0.133	4,933
140	25.50 x 0.375	5.56 x 0.258	1.32 x 0.133	1.32 x 0.133	1.90 x 0.145	1.32 x 0.133	5,149

Table 4-9. Structure weights for 1994 Supports Specifications

Basic Wind Speed (mph)	Weight (lb)		Percent Difference
	Group Load Combination		
	I and II only	I, II and III	
60	2,408	2,500	3.8%
70	2,816	2,908	3.3%
80	3,376	3,418	1.3%
90	4,063	4,063	0.0%
100	4,808	4,808	0.0%
110	5,074	5,074	0.0%

Table 4-10. Structure weights for group I, II, and III load combinations only for the 2001 Supports Specifications

Basic Wind Speed (mph)	Weight (lb)		Percent Difference
	Group Load Combination		
	I and II only	I, II and III only	
85	2,558	2,650	3.6%
90	2,883	2,975	3.2%
100	3,133	3,226	3.0%
110	3,763	3,813	1.3%
120	4,263	4,263	0.0%
130	4,933	4,933	0.0%
140	5,149	5,149	0.0%
150	5,988	--	--

Table 4-11. Structure weights and reactions by site for group I, II and III load combinations for 1994 Supports Specifications

Site No.	AASHTO 1994 (Group I, II and III)				
	Wind Speed, 50-year MRI (mph)	Structure Weight (lb)	Ground Line Reactions for Group II Load Combination, Load Case I, +Z Wind Direction		
			Moment (k-ft)	Shear (k)	Torsion (k-ft)
1a	70	2,908	178	6.91	149
1b	70	2,816	178	6.91	149
2	80	3,376	227	9.14	195
3	70	2,816	178	6.91	149
4	80	3,376	227	9.14	195
5	80	3,376	227	9.14	195
6	80	3,376	227	9.14	195
7	80	3,376	227	9.14	195
8	90	4,063	281	11.5	247
9	90	4,063	281	11.5	247
10	100	4,808	348	14.4	306

Table 4-12. Structure weight and reactions by site for group I, II and III load combinations for 2001 Supports Specifications

Site No.	AASHTO 2001 (Group I, II and III only)					
	Wind Speed (mph)	Importance Factor, 50-year MRI	Structure Weight (lb)	Ground Line Reactions for Group II Load Combination, Load Case I, +Z Wind Direction		
				Moment (k-ft)	Shear (k)	Torsion (k-ft)
1a	90	1.00	2,975	181	7.09	151
1b	90	1.00	2,883	181	7.09	151
2	90	1.00	2,883	181	7.09	151
3	100	1.00	3,133	217	8.79	187
4	100	1.00	3,133	217	8.79	187
5	110	1.00	3,763	262	10.9	267
6	110	1.00	3,763	262	10.9	267
7	120	1.00	4,263	307	12.8	270
8	120	1.00	4,263	307	12.8	270
9	130	1.00	4,933	362	15.2	318
10	140	1.00	5,149	417	17.7	369

Table 4-13. Difference in weight and reactions for group I, II and II load combinations

Site No.	Differences between AASHTO 1994 and 2001 (Group I, II, and III only)			
	Weight Increase / Decrease	G.L. Moment Increase / Decrease	G.L. Shear Increase / Decrease	G.L. Torsion Increase / Decrease
1a	2%	2%	3%	2%
1b	2%	2%	3%	2%
2	-15%	-20%	-22%	-22%
3	11%	22%	27%	26%
4	-7%	-4%	-4%	-4%
5	11%	15%	19%	37%
6	11%	15%	19%	37%
7	26%	35%	40%	39%
8	5%	9%	11%	9%
9	21%	29%	31%	29%
10	7%	20%	23%	21%

Table 4-14. Member sizes and structure weights for group I and II load combinations plus galloping for fatigue category I for 2001 Supports Specifications

Basic Wind Speed (mph)	Diameter (in) x Wall Thickness (in)						
	Post	Chord	Vertical Diagonals	Vertical Struts	Horizontal Diagonals	Horizontal Struts	Structure Weight (lb)
85	39.25 x 0.500	10.80 x 0.365	4.50 x 0.237	10.80 x 0.365	3.50 x 0.216	4.00 x 0.226	15,968
90	39.25 x 0.500	10.80 x 0.365	4.50 x 0.237	10.80 x 0.365	3.50 x 0.216	4.00 x 0.226	15,968
100	39.25 x 0.500	10.80 x 0.365	4.50 x 0.237	10.80 x 0.365	3.50 x 0.216	4.00 x 0.226	15,968
110	39.25 x 0.500	10.80 x 0.365	4.50 x 0.237	10.80 x 0.365	3.50 x 0.216	4.00 x 0.226	15,968
120	39.25 x 0.500	10.80 x 0.365	4.50 x 0.237	10.80 x 0.365	3.50 x 0.216	4.00 x 0.226	15,968
130	39.25 x 0.500	10.80 x 0.365	4.50 x 0.237	10.80 x 0.365	3.50 x 0.216	4.00 x 0.226	15,968
140	39.25 x 0.500	10.80 x 0.365	4.50 x 0.237	10.80 x 0.365	3.50 x 0.216	4.00 x 0.226	15,968
150	39.25 x 0.500	10.80 x 0.365	4.50 x 0.237	10.80 x 0.365	3.50 x 0.216	4.00 x 0.226	15,968

Table 4-15. Member sizes and structure weights for group I, II and III load combinations plus galloping for fatigue category I for 2001 Supports Specifications

Basic Wind Speed (mph)	Diameter (in) x Wall Thickness (in)						
	Post	Chord	Vertical Diagonals	Vertical Struts	Horizontal Diagonals	Horizontal Struts	Structure Weight (lb)
85	39.25 x 0.500	10.80 x 0.365	4.50 x 0.237	10.80 x 0.365	3.50 x 0.216	4.00 x 0.226	15,968
90	39.25 x 0.500	10.80 x 0.365	4.50 x 0.237	10.80 x 0.365	3.50 x 0.216	4.00 x 0.226	15,968
100	39.25 x 0.500	10.80 x 0.365	4.50 x 0.237	10.80 x 0.365	3.50 x 0.216	4.00 x 0.226	15,968
110	39.25 x 0.500	10.80 x 0.365	4.50 x 0.237	10.80 x 0.365	3.50 x 0.216	4.00 x 0.226	15,968
120	39.25 x 0.500	10.80 x 0.365	4.50 x 0.237	10.80 x 0.365	3.50 x 0.216	4.00 x 0.226	15,968
130	39.25 x 0.500	10.80 x 0.365	4.50 x 0.237	10.80 x 0.365	3.50 x 0.216	4.00 x 0.226	15,968
140	39.25 x 0.500	10.80 x 0.365	4.50 x 0.237	10.80 x 0.365	3.50 x 0.216	4.00 x 0.226	15,968

Table 4-16. Member sizes and structure weights for group I and II load combinations plus galloping for fatigue category II for 2001 Supports Specifications

Basic Wind Speed (mph)	Diameter (in) x Wall Thickness (in)						
	Post	Chord	Vertical Diagonals	Vertical Struts	Horizontal Diagonals	Horizontal Struts	Structure Weight (lb)
85	36.75 x 0.375	8.63 x 0.322	4.50 x 0.237	8.63 x 0.322	2.38 x 0.154	3.50 x 0.216	11,450
90	36.75 x 0.375	8.63 x 0.322	4.50 x 0.237	8.63 x 0.322	2.38 x 0.154	3.50 x 0.216	11,450
100	36.75 x 0.375	8.63 x 0.322	4.50 x 0.237	8.63 x 0.322	2.38 x 0.154	3.50 x 0.216	11,450
110	36.75 x 0.375	8.63 x 0.322	4.50 x 0.237	8.63 x 0.322	2.38 x 0.154	3.50 x 0.216	11,450
120	36.75 x 0.375	8.63 x 0.322	4.50 x 0.237	8.63 x 0.322	2.38 x 0.154	3.50 x 0.216	11,450
130	36.75 x 0.375	8.63 x 0.322	4.50 x 0.237	8.63 x 0.322	2.38 x 0.154	3.50 x 0.216	11,450
140	36.75 x 0.375	8.63 x 0.322	4.50 x 0.237	8.63 x 0.322	2.38 x 0.154	3.50 x 0.216	11,450
150	36.75 x 0.375	8.63 x 0.322	4.50 x 0.237	8.63 x 0.322	2.38 x 0.154	3.50 x 0.216	11,450

Table 4-17. Member sizes and structure weights for group I, II and III load combinations plus galloping for fatigue category II for 2001 Supports Specifications

Basic Wind Speed (mph)	Diameter (in) x Wall Thickness (in)						
	Post	Chord	Vertical Diagonals	Vertical Struts	Horizontal Diagonals	Horizontal Struts	Structure Weight (lb)
85	36.75 x 0.375	8.63 x 0.322	4.50 x 0.237	8.63 x 0.322	2.38 x 0.154	3.50 x 0.216	11,450
90	36.75 x 0.375	8.63 x 0.322	4.50 x 0.237	8.63 x 0.322	2.38 x 0.154	3.50 x 0.216	11,450
100	36.75 x 0.375	8.63 x 0.322	4.50 x 0.237	8.63 x 0.322	2.38 x 0.154	3.50 x 0.216	11,450
110	36.75 x 0.375	8.63 x 0.322	4.50 x 0.237	8.63 x 0.322	2.38 x 0.154	3.50 x 0.216	11,450
120	36.75 x 0.375	8.63 x 0.322	4.50 x 0.237	8.63 x 0.322	2.38 x 0.154	3.50 x 0.216	11,450
130	36.75 x 0.375	8.63 x 0.322	4.50 x 0.237	8.63 x 0.322	2.38 x 0.154	3.50 x 0.216	11,450
140	36.75 x 0.375	8.63 x 0.322	4.50 x 0.237	8.63 x 0.322	2.38 x 0.154	3.50 x 0.216	11,450

Table 4-18. Member sizes and structure weights for group I and II load combinations plus galloping for fatigue category III for 2001 Supports Specifications

Basic Wind Speed (mph)	Diameter (in) x Wall Thickness (in)						
	Post	Chord	Vertical Diagonals	Vertical Struts	Horizontal Diagonals	Horizontal Struts	Structure Weight (lb)
85	31.75 x 0.250	4.00 x 0.226	2.88 x 0.203	4.00 x 0.226	1.66 x 0.140	2.38 x 0.154	4,997
90	31.75 x 0.250	4.00 x 0.226	2.88 x 0.203	4.00 x 0.226	1.66 x 0.140	2.38 x 0.154	4,997
100	31.75 x 0.250	4.00 x 0.226	2.88 x 0.203	4.00 x 0.226	1.66 x 0.140	2.38 x 0.154	4,997
110	31.75 x 0.250	4.00 x 0.226	2.88 x 0.203	4.00 x 0.226	1.66 x 0.140	2.38 x 0.154	4,997
120	26.00 x 0.375	4.50 x 0.237	2.88 x 0.203	4.50 x 0.237	1.66 x 0.140	2.38 x 0.154	5,811
130	26.00 x 0.375	5.56 x 0.258	2.88 x 0.203	4.00 x 0.226	1.66 x 0.140	2.38 x 0.154	6,209
140	26.00 x 0.375	5.56 x 0.258	2.88 x 0.203	4.00 x 0.226	1.90 x 0.145	2.38 x 0.154	6,250
150	27.50 x 0.375	6.63 x 0.280	2.88 x 0.203	4.00 x 0.226	1.90 x 0.145	2.38 x 0.154	6,996

Table 4-19. Member sizes and structure weights for group I, II and III load combinations plus galloping for fatigue category III for 2001 Supports Specifications

Basic Wind Speed (mph)	Diameter (in) x Wall Thickness (in)						
	Post	Chord	Vertical Diagonals	Vertical Struts	Horizontal Diagonals	Horizontal Struts	Structure Weight (lb)
85	31.75 x 0.250	4.00 x 0.226	2.88 x 0.203	4.00 x 0.226	1.32 x 0.133	2.38 x 0.154	4,997
90	31.75 x 0.250	4.00 x 0.226	2.88 x 0.203	4.00 x 0.226	1.32 x 0.133	2.38 x 0.154	4,997
100	31.75 x 0.250	4.00 x 0.226	2.88 x 0.203	4.00 x 0.226	1.32 x 0.133	2.38 x 0.154	4,997
110	31.75 x 0.250	4.00 x 0.226	2.88 x 0.203	4.00 x 0.226	1.66 x 0.140	2.38 x 0.154	4,997
120	26.00 x 0.375	4.50 x 0.237	2.88 x 0.203	4.50 x 0.237	1.66 x 0.140	2.38 x 0.154	5,811
130	26.00 x 0.375	5.56 x 0.258	2.88 x 0.203	4.00 x 0.226	1.66 x 0.140	2.38 x 0.154	6,209
140	26.00 x 0.375	5.56 x 0.258	2.88 x 0.203	4.00 x 0.226	1.90 x 0.145	2.38 x 0.154	6,250

Table 4-20. Member sizes and structure weights for group I and II load combinations plus natural wind gust for fatigue category I for 2001 Supports Specifications

Basic Wind Speed (mph)	Diameter (in) x Wall Thickness (in)						
	Post	Chord	Vertical Diagonals	Vertical Struts	Horizontal Diagonals	Horizontal Struts	Structure Weight (lb)
85	30.75 x 0.250	4.50 x 0.237	1.32 x 0.133	1.32 x 0.133	2.88 x 0.203	1.32 x 0.133	4,429
90	30.75 x 0.250	4.50 x 0.237	1.32 x 0.133	1.32 x 0.133	2.88 x 0.203	1.32 x 0.133	4,429
100	30.75 x 0.250	4.50 x 0.237	1.32 x 0.133	1.32 x 0.133	2.88 x 0.203	1.32 x 0.133	4,429
110	30.75 x 0.250	4.50 x 0.237	1.32 x 0.133	1.32 x 0.133	2.88 x 0.203	1.32 x 0.133	4,429
120	25.50 x 0.375	4.50 x 0.237	1.32 x 0.133	1.32 x 0.133	2.88 x 0.203	1.32 x 0.133	4,909
130	25.50 x 0.375	5.56 x 0.258	1.32 x 0.133	1.32 x 0.133	2.88 x 0.203	1.32 x 0.133	5,429
140	25.50 x 0.375	5.56 x 0.258	1.32 x 0.133	1.32 x 0.133	2.88 x 0.203	1.32 x 0.133	5,429
150	27.50 x 0.375	6.63 x 0.280	1.32 x 0.133	1.32 x 0.133	2.88 x 0.203	1.66 x 0.140	6,268

Table 4-21. Member sizes and structure weights for group I, II and III load combinations plus natural wind gust for fatigue category I for 2001 Supports Specifications

Basic Wind Speed (mph)	Diameter (in) x Wall Thickness (in)						
	Post	Chord	Vertical Diagonals	Vertical Struts	Horizontal Diagonals	Horizontal Struts	Structure Weight (lb)
85	30.75 x 0.250	4.50 x 0.237	1.32 x 0.133	1.32 x 0.133	2.88 x 0.203	1.66 x 0.140	4,471
90	30.75 x 0.250	4.50 x 0.237	1.32 x 0.133	1.32 x 0.133	2.88 x 0.203	1.66 x 0.140	4,471
100	30.75 x 0.250	4.50 x 0.237	1.32 x 0.133	1.32 x 0.133	3.50 x 0.216	1.66 x 0.140	4,632
110	30.75 x 0.250	4.50 x 0.237	1.32 x 0.133	1.32 x 0.133	3.50 x 0.216	1.32 x 0.133	4,589
120	25.50 x 0.375	4.50 x 0.237	1.32 x 0.133	1.32 x 0.133	2.88 x 0.203	1.32 x 0.133	4,909
130	25.50 x 0.375	5.56 x 0.258	1.32 x 0.133	1.32 x 0.133	2.88 x 0.203	1.32 x 0.133	5,429
140	25.50 x 0.375	5.56 x 0.258	1.32 x 0.133	1.32 x 0.133	2.88 x 0.203	1.32 x 0.133	5,429

Table 4-22. Member sizes and structure weights for group I and II load combinations plus natural wind gust for fatigue category II for 2001 Supports Specifications

Basic Wind Speed (mph)	Diameter (in) x Wall Thickness (in)						
	Post	Chord	Vertical Diagonals	Vertical Struts	Horizontal Diagonals	Horizontal Struts	Structure Weight (lb)
85	26.50 x 0.250	3.50 x 0.216	1.05 x 0.113	1.32 x 0.133	2.38 x 0.154	1.32 x 0.133	3,463
90	26.50 x 0.250	3.50 x 0.216	1.05 x 0.113	1.32 x 0.133	2.38 x 0.154	1.32 x 0.133	3,463
100	26.50 x 0.250	3.50 x 0.216	1.05 x 0.113	1.32 x 0.133	2.38 x 0.154	1.32 x 0.133	3,463
110	29.75 x 0.250	4.00 x 0.226	1.05 x 0.113	1.32 x 0.133	2.38 x 0.154	1.32 x 0.133	3,888
120	22.25 x 0.375	4.50 x 0.237	1.32 x 0.133	1.32 x 0.133	2.38 x 0.154	1.32 x 0.133	4,389
130	23.75 x 0.375	5.56 x 0.258	1.32 x 0.133	1.32 x 0.133	2.38 x 0.154	1.32 x 0.133	5,059
140	25.50 x 0.375	5.56 x 0.258	1.32 x 0.133	1.32 x 0.133	2.38 x 0.154	1.32 x 0.133	5,235
150	27.50 x 0.375	6.63 x 0.280	1.32 x 0.133	1.32 x 0.133	2.38 x 0.154	1.66 x 0.140	6,073

Table 4-23. Member sizes and structure weights for group I, II and III load combinations plus natural wind gust for fatigue category II for 2001 Supports Specifications

Basic Wind Speed (mph)	Diameter (in) x Wall Thickness (in)						
	Post	Chord	Vertical Diagonals	Vertical Struts	Horizontal Diagonals	Horizontal Struts	Structure Weight (lb)
85	26.50 x 0.250	3.50 x 0.216	1.32 x 0.133	1.32 x 0.133	2.38 x 0.154	1.66 x 0.140	3,555
90	26.50 x 0.250	3.50 x 0.216	1.32 x 0.133	1.32 x 0.133	2.38 x 0.154	1.66 x 0.140	3,555
100	26.50 x 0.250	3.50 x 0.216	1.32 x 0.133	1.32 x 0.133	2.38 x 0.154	1.66 x 0.140	3,555
110	29.75 x 0.250	4.00 x 0.226	1.32 x 0.133	1.32 x 0.133	2.38 x 0.154	1.32 x 0.133	3,939
120	22.00 x 0.375	4.50 x 0.237	1.32 x 0.133	1.32 x 0.133	2.38 x 0.154	1.32 x 0.133	4,364
130	23.75 x 0.375	5.56 x 0.258	1.32 x 0.133	1.32 x 0.133	2.38 x 0.154	1.32 x 0.133	5,059
140	25.50 x 0.375	5.56 x 0.258	1.32 x 0.133	1.32 x 0.133	2.38 x 0.154	1.32 x 0.133	5,235

Table 4-24. Member sizes and structure weights for group I and II load combinations plus natural wind gust for fatigue category III for 2001 Supports Specifications

Basic Wind Speed (mph)	Diameter (in) x Wall Thickness (in)						
	Post	Chord	Vertical Diagonals	Vertical Struts	Horizontal Diagonals	Horizontal Struts	Structure Weight (lb)
85	21.50 x 0.250	2.88 x 0.203	1.05 x 0.113	1.32 x 0.133	1.66 x 0.140	1.32 x 0.133	2,761
90	21.50 x 0.250	3.50 x 0.216	1.05 x 0.113	1.32 x 0.133	1.66 x 0.140	1.32 x 0.133	3,003
100	24.25 x 0.250	3.50 x 0.216	1.05 x 0.113	1.32 x 0.133	1.66 x 0.140	1.32 x 0.133	3,186
110	29.75 x 0.250	4.00 x 0.226	1.05 x 0.113	1.32 x 0.133	1.66 x 0.140	1.32 x 0.133	3,763
120	22.25 x 0.375	4.50 x 0.237	1.32 x 0.133	1.32 x 0.133	1.66 x 0.140	1.32 x 0.133	4,263
130	23.75 x 0.375	5.56 x 0.258	1.32 x 0.133	1.32 x 0.133	1.66 x 0.140	1.32 x 0.133	4,933
140	25.50 x 0.375	5.56 x 0.258	1.32 x 0.133	1.32 x 0.133	1.90 x 0.145	1.32 x 0.133	5,149
150	27.50 x 0.375	6.63 x 0.280	1.32 x 0.133	1.32 x 0.133	1.90 x 0.145	1.66 x 0.140	5,988

Table 4-25. Member sizes and structure weights for group I, II and III load combinations plus natural wind gust for fatigue category III for 2001 Supports Specifications

Basic Wind Speed (mph)	Diameter (in) x Wall Thickness (in)						
	Post	Chord	Vertical Diagonals	Vertical Struts	Horizontal Diagonals	Horizontal Struts	Structure Weight (lb)
85	21.50 x 0.250	2.88 x 0.203	1.32 x 0.133	1.32 x 0.133	1.66 x 0.140	1.66 x 0.140	2,854
90	21.50 x 0.250	3.50 x 0.216	1.32 x 0.133	1.32 x 0.133	1.66 x 0.140	1.66 x 0.140	3,095
100	24.25 x 0.250	3.50 x 0.216	1.32 x 0.133	1.32 x 0.133	1.66 x 0.140	1.66 x 0.140	3,279
110	29.75 x 0.250	4.00 x 0.226	1.32 x 0.133	1.32 x 0.133	1.66 x 0.140	1.32 x 0.133	3,813
120	22.00 x 0.375	4.50 x 0.237	1.32 x 0.133	1.32 x 0.133	1.66 x 0.140	1.32 x 0.133	4,238
130	23.75 x 0.375	5.56 x 0.258	1.32 x 0.133	1.32 x 0.133	1.66 x 0.140	1.32 x 0.133	4,933
140	25.50 x 0.375	5.56 x 0.258	1.32 x 0.133	1.32 x 0.133	1.90 x 0.145	1.32 x 0.133	5,149

Table 4-26. Member sizes and structure weights for group I and II load combinations plus truck-induced wind gust for fatigue category I for 2001 *Supports Specifications*

Basic Wind Speed (mph)	Diameter (in) x Wall Thickness (in)						
	Post	Chord	Vertical Diagonals	Vertical Struts	Horizontal Diagonals	Horizontal Struts	Structure Weight (lb)
85	19.25 x 0.250	2.88 x 0.203	1.05 x 0.113	1.32 x 0.133	1.32 x 0.133	1.32 x 0.133	2,558
90	20.50 x 0.250	3.50 x 0.216	1.05 x 0.113	1.32 x 0.133	1.32 x 0.133	1.32 x 0.133	2,883
100	24.25 x 0.250	3.50 x 0.216	1.05 x 0.113	1.32 x 0.133	1.32 x 0.133	1.32 x 0.133	3,133
110	29.75 x 0.250	4.00 x 0.226	1.32 x 0.133	1.32 x 0.133	1.66 x 0.140	1.32 x 0.133	3,813
120	22.25 x 0.375	4.50 x 0.237	1.32 x 0.133	1.32 x 0.133	1.66 x 0.140	1.32 x 0.133	4,263
130	23.75 x 0.375	5.56 x 0.258	1.32 x 0.133	1.32 x 0.133	1.66 x 0.140	1.32 x 0.133	4,933
140	25.50 x 0.375	5.56 x 0.258	1.32 x 0.133	1.32 x 0.133	1.90 x 0.145	1.32 x 0.133	5,149
150	27.50 x 0.375	6.63 x 0.280	1.66 x 0.140	1.32 x 0.133	1.90 x 0.145	1.66 x 0.140	6,041

Table 4-27. Member sizes and structure weights for group I, II and III load combinations plus truck-induced wind gust for fatigue category I for 2001 *Supports Specifications*

Basic Wind Speed (mph)	Diameter (in) x Wall Thickness (in)						
	Post	Chord	Vertical Diagonals	Vertical Struts	Horizontal Diagonals	Horizontal Struts	Structure Weight (lb)
85	19.25 x 0.250	2.88 x 0.203	1.32 x 0.133	1.32 x 0.133	1.32 x 0.133	1.66 x 0.140	2,650
90	20.50 x 0.250	3.50 x 0.216	1.32 x 0.133	1.32 x 0.133	1.32 x 0.133	1.66 x 0.140	2,975
100	24.25 x 0.250	3.50 x 0.216	1.32 x 0.133	1.32 x 0.133	1.32 x 0.133	1.66 x 0.140	3,226
110	29.75 x 0.250	4.00 x 0.226	1.32 x 0.133	1.32 x 0.133	1.66 x 0.140	1.32 x 0.133	3,813
120	22.00 x 0.375	4.50 x 0.237	1.32 x 0.133	1.32 x 0.133	1.66 x 0.140	1.32 x 0.133	4,238
130	23.75 x 0.375	5.56 x 0.258	1.32 x 0.133	1.32 x 0.133	1.66 x 0.140	1.32 x 0.133	4,933
140	25.50 x 0.375	5.56 x 0.258	1.32 x 0.133	1.32 x 0.133	1.90 x 0.145	1.32 x 0.133	5,149

Table 4-28. Member sizes and structure weights for group I and II load combinations plus natural wind gust and truck-induced wind gust for fatigue category I for 2001 *Supports Specifications*

Basic Wind Speed (mph)	Diameter (in) x Wall Thickness (in)						
	Post	Chord	Vertical Diagonals	Vertical Struts	Horizontal Diagonals	Horizontal Struts	Structure Weight (lb)
85	30.75 x 0.250	4.50 x 0.237	1.32 x 0.133	1.32 x 0.133	2.88 x 0.203	1.32 x 0.133	4,429
90	30.75 x 0.250	4.50 x 0.237	1.32 x 0.133	1.32 x 0.133	2.88 x 0.203	1.32 x 0.133	4,429
100	30.75 x 0.250	4.50 x 0.237	1.32 x 0.133	1.32 x 0.133	2.88 x 0.203	1.32 x 0.133	4,429
110	30.75 x 0.250	4.50 x 0.237	1.32 x 0.133	1.32 x 0.133	2.88 x 0.203	1.32 x 0.133	4,429
120	25.50 x 0.375	4.50 x 0.237	1.32 x 0.133	1.32 x 0.133	2.88 x 0.203	1.32 x 0.133	4,909
130	25.50 x 0.375	5.56 x 0.258	1.32 x 0.133	1.32 x 0.133	2.88 x 0.203	1.32 x 0.133	5,429
140	25.50 x 0.375	5.56 x 0.258	1.32 x 0.133	1.32 x 0.133	2.88 x 0.203	1.32 x 0.133	5,429
150	27.50 x 0.375	6.63 x 0.280	1.66 x 0.140	1.32 x 0.133	2.88 x 0.203	1.66 x 0.140	6,321

Table 4-29. Member sizes and structure weights for group I, II and III load combinations plus natural wind gust and truck-induced wind gust for fatigue category I for 2001 Supports Specifications

Basic Wind Speed (mph)	Diameter (in) x Wall Thickness (in)						
	Post	Chord	Vertical Diagonals	Vertical Struts	Horizontal Diagonals	Horizontal Struts	Structure Weight (lb)
85	30.75 x 0.250	4.50 x 0.237	1.32 x 0.133	1.32 x 0.133	2.88 x 0.203	1.66 x 0.140	4,471
90	30.75 x 0.250	4.50 x 0.237	1.32 x 0.133	1.32 x 0.133	2.88 x 0.203	1.66 x 0.140	4,471
100	30.75 x 0.250	4.50 x 0.237	1.32 x 0.133	1.32 x 0.133	3.50 x 0.216	1.66 x 0.140	4,632
110	30.75 x 0.250	4.50 x 0.237	1.32 x 0.133	1.32 x 0.133	3.50 x 0.216	1.32 x 0.133	4,589
120	25.50 x 0.375	4.50 x 0.237	1.32 x 0.133	1.32 x 0.133	2.88 x 0.203	1.32 x 0.133	4,909
130	25.50 x 0.375	5.56 x 0.258	1.32 x 0.133	1.32 x 0.133	2.88 x 0.203	1.32 x 0.133	5,429
140	25.50 x 0.375	5.56 x 0.258	1.32 x 0.133	1.32 x 0.133	2.88 x 0.203	1.32 x 0.133	5,429

Table 4-30. Structure weight comparison by site, specification, and fatigue category

Site No.	AASHTO 1994		AASHTO 2001							
	Wind Speed, 50-year MRI (mph)	Structure Weight (lb)	Wind Speed (mph)	Group I, II, III Load Comb. only	Fatigue Category I		Fatigue Category II		Fatigue Category III	
					Groups I, II, III + Nat. Wind Gust and Truck-Induced Wind Gust	Groups I, II, III + Nat. Wind Gust, Truck-Induced Wind Gust, and Galloping	Groups I, II, III + Nat. Wind Gust and Truck-Induced Wind Gust	Groups I, II, III + Nat. Wind Gust, Truck-Induced Wind Gust, and Galloping	Groups I, II, III + Nat. Wind Gust and Truck-Induced Wind Gust	Groups I, II, III + Nat. Wind Gust, Truck-Induced Wind Gust, and Galloping
1a	70	2,908	90	2,975	4,471	15,968	3,555	11,450	3,095	4,997
1b	70	2,816	90	2,883	4,429	15,968	3,463	11,450	3,003	4,997
2	80	3,376	90	2,883	4,429	15,968	3,463	11,450	3,003	4,997
3	70	2,816	100	3,133	4,429	15,968	3,463	11,450	3,186	4,997
4	80	3,376	100	3,133	4,429	15,968	3,463	11,450	3,186	4,997
5	80	3,376	110	3,763	4,429	15,968	3,888	11,450	3,763	4,997
6	80	3,376	110	3,763	4,429	15,968	3,888	11,450	3,763	4,997
7	80	3,376	120	4,263	4,909	15,968	4,389	11,450	4,263	5,811
8	90	4,063	120	4,263	4,909	15,968	4,389	11,450	4,263	5,811
9	90	4,063	130	4,933	5,429	15,968	5,059	11,450	4,933	6,209
10	100	4,808	140	5,149	5,429	15,968	5,235	11,450	5,149	6,250

Table 4-31. Structure weights for group I and II load combinations plus fatigue category I for the 2001 Supports Specifications

Basic Wind Speed (mph)	Weight (lb)		
	Group I and II Load Combinations plus		
	Galloping	Natural Wind Gust	Truck-Induced Wind Gust
	I = 1.0	I = 1.0	I = 1.0
85	15,968	4,429	2,558
90	15,968	4,429	2,883
100	15,968	4,429	3,133
110	15,968	4,429	3,813
120	15,968	4,909	4,263
130	15,968	5,429	4,933
140	15,968	5,429	5,149
150	15,968	6,268	6,041

Table 4-32. Structure weights for group I, II and III load combinations plus fatigue category I for the 2001 Supports Specifications

Basic Wind Speed (mph)	Weight (lb)		
	Group I, II and III Load Combinations plus		
	Galloping	Natural Wind Gust	Truck-Induced Wind Gust
	I = 1.0	I = 1.0	I = 1.0
85	15,968	4,471	2,650
90	15,968	4,471	2,975
100	15,968	4,632	3,226
110	15,968	4,589	3,813
120	15,968	4,909	4,238
130	15,968	5,429	4,933
140	15,968	5,429	5,149
150	--	--	--

Table 4-33. Structure weights for group I, II and III load combinations plus natural wind gust and truck-induced wind gust for fatigue category I for the 2001 *Supports Specifications*

Basic Wind Speed (mph)	Weight (lb)	
	Group I and II Load Combinations plus Natural Wind Gust and Truck-Induced Wind Gust	Group I, II and III Load Combinations plus Natural Wind Gust and Truck-Induced Wind Gust
85	4,429	4,471
90	4,429	4,471
100	4,429	4,632
110	4,429	4,589
120	4,909	4,909
130	5,429	5,429
140	5,429	5,429
150	6,321	--

Table 4-34. Structure weight comparison for group I and II load combination plus galloping, natural wind gust and truck-induced wind gust for fatigue category I for the 2001 *Supports Specifications*

Basic Wind Speed (mph)	Group I and II Load Combinations only	Group I and II Load Combinations plus Natural Wind Gust and Truck-Induced Wind Gust		Group I and II Load Combinations plus Galloping, Natural Wind Gust and Truck-Induced Wind Gust		
	Weight (lb)	Weight (lb)	Increase in Weight over Group I and II	Weight (lb)	Increase in Weight over Group I and II	Increase in Weight over Group I and II plus Natural Wind Gust and Truck-Induced Wind Gust
85	2,558	4,429	73%	15,968	524%	261%
90	2,883	4,429	54%	15,968	454%	261%
100	3,133	4,429	41%	15,968	410%	261%
110	3,763	4,429	18%	15,968	324%	261%
120	4,263	4,909	15%	15,968	275%	225%
130	4,933	5,429	10%	15,968	224%	194%
140	5,149	5,429	5%	15,968	210%	194%
150	5,988	6,321	6%	15,968	167%	153%

Table 4-35. Structure weights for group I and II load combinations plus fatigue category II for the 2001 Supports Specifications

Basic Wind Speed (mph)	Weight (lb)		
	Group I and II Load Combinations plus		
	Galloping	Natural Wind Gust	Truck-Induced Wind Gust
	I = 0.65	I = 0.75	I = 0.89
85	11,450	3,463	2,558
90	11,450	3,463	2,883
100	11,450	3,463	3,133
110	11,450	3,888	3,763
120	11,450	4,389	4,263
130	11,450	5,059	4,933
140	11,450	5,235	5,149
150	11,450	6,073	5,988

Table 4-36. Structure weights for group I, II and III load combinations plus fatigue category II for the 2001 Supports Specifications

Basic Wind Speed (mph)	Weight (lb)		
	Group I, II and III Load Combinations plus		
	Galloping	Natural Wind Gust	Truck-Induced Wind Gust
	I = 0.65	I = 0.75	I = 0.89
85	11,450	3,555	2,650
90	11,450	3,555	2,975
100	11,450	3,555	3,226
110	11,450	3,939	3,813
120	11,450	4,364	4,238
130	11,450	5,059	4,933
140	11,450	5,235	5,149
150	--	--	--

Table 4-37. Structure weights for group I, II and III load combinations plus natural wind gust and truck-induced wind gust for fatigue category II for the 2001 *Supports Specifications*

Basic Wind Speed (mph)	Weight (lb)	
	Group I and II Load Combinations plus Natural Wind Gust and Truck-Induced Wind Gust	Group I, II and III Load Combinations plus Natural Wind Gust and Truck-Induced Wind Gust
85	3,463	3,555
90	3,463	3,555
100	3,463	3,555
110	3,888	3,939
120	4,389	4,364
130	5,059	5,059
140	5,235	5,235
150	6,073	--

Table 4-38. Structure weights comparison for group I and II load combinations plus galloping, natural wind gust and truck-induced wind gust for fatigue category II for the 2001 *Supports Specifications*

Basic Wind Speed (mph)	Group I and II Load Combinations only	Group I and II Load Combinations plus Natural Wind Gust and Truck-Induced Wind Gust		Group I and II Load Combinations plus Galloping, Natural Wind Gust and Truck-Induced Wind Gust		
	Weight (lb)	Weight (lb)	Increase in Weight over Group I and II	Weight (lb)	Increase in Weight over Group I and II	Increase in Weight over Group I and II plus Natural Wind Gust and Truck-Induced Wind Gust
85	2,558	3,463	35%	11,450	348%	231%
90	2,883	3,463	20%	11,450	297%	231%
100	3,133	3,463	11%	11,450	265%	231%
110	3,763	3,888	3%	11,450	204%	194%
120	4,263	4,389	3%	11,450	169%	161%
130	4,933	5,059	3%	11,450	132%	126%
140	5,149	5,235	2%	11,450	122%	119%
150	5,988	6,073	1%	11,450	91%	89%

Table 4-39. Structure weights for group I and II load combinations plus fatigue category III for the 2001 Supports Specifications

Basic Wind Speed (mph)	Weight (lb)		
	Group I and II Load Combinations plus		
	Galloping	Natural Wind Gust	Truck-Induced Wind Gust
	I = 0.31	I = 0.49	I = 0.77
85	4,997	2,761	2,558
90	4,997	3,003	2,883
100	4,997	3,186	3,133
110	4,997	3,763	3,763
120	5,811	4,263	4,263
130	6,209	4,933	4,933
140	6,250	5,149	5,149
150	6,996	5,988	5,988

Table 4-40. Structure weights for group I, II and III load combinations plus fatigue category III for the 2001 Supports Specifications

Basic Wind Speed (mph)	Weight (lb)		
	Group I, II and III Load Combinations plus		
	Galloping	Natural Wind Gust	Truck-Induced Wind Gust
	I = 0.31	I = 0.49	I = 0.77
85	4,997	2,854	2,650
90	4,997	3,095	2,975
100	4,997	3,279	3,226
110	4,997	3,813	3,813
120	5,811	4,238	4,238
130	6,209	4,933	4,933
140	6,250	5,149	5,149
150	--	--	--

Table 4-41. Structure weights for group I, II and III load combinations plus natural wind gust and truck-induced wind gust for fatigue category III for the 2001 *Supports Specifications*

Basic Wind Speed (mph)	Weight (lb)	
	Group I and II Load Combinations plus Natural Wind Gust and Truck-Induced Wind Gust	Group I, II and III Load Combinations plus Natural Wind Gust and Truck-Induced Wind Gust
85	2,761	2,854
90	3,003	3,095
100	3,186	3,279
110	3,763	3,813
120	4,263	4,238
130	4,933	4,933
140	5,149	5,149
150	5,988	--

Table 4-42. Structure weight comparison for group I and II load combinations plus galloping, natural wind gust and truck-induced wind gust for fatigue category III for the 2001 *Supports Specifications*

Basic Wind Speed (mph)	Group I and II Load Combinations only	Group I and II Load Combinations plus Natural Wind Gust and Truck-Induced Wind Gust		Group I and II Load Combinations plus Galloping, Natural Wind Gust and Truck-Induced Wind Gust		
	Weight (lb)	Weight (lb)	Increase in Weight over Group I and II	Weight (lb)	Increase in Weight over Group I and II	Increase in Weight over Group I and II plus Natural Wind Gust and Truck-Induced Wind Gust
85	2,558	2,761	8%	4,997	98%	83%
90	2,883	3,003	4%	4,997	73%	66%
100	3,133	3,186	2%	4,997	61%	59%
110	3,763	3,763	0%	4,997	33%	33%
120	4,263	4,263	0%	5,811	36%	36%
130	4,933	4,933	0%	6,209	26%	26%
140	5,149	5,149	0%	6,250	21%	21%
150	5,988	5,988	0%	6,996	17%	17%

Table 4-43. Weight comparison by site between 1994 and 2001 *Supports Specifications* for fatigue category I relative to 1994 specifications

Site No.	AASHTO 1994		AASHTO 2001						
			Group I, II, III Load Combinations only			Fatigue Category I			
	Wind Speed, 50-year MRI (mph)	Structure Weight (lb)				Wind Speed (mph)	Structure Weight (lb)	Change in Weight Relative to 1994 Spec.	Groups I, II, III plus Nat. Wind Gust and Truck-Induced Wind Gust
1a	70	2,908	90	2,975	2%	4,471	54%	15,968	449%
1b	70	2,816	90	2,883	2%	4,429	57%	15,968	467%
2	80	3,376	90	2,883	-15%	4,429	31%	15,968	373%
3	70	2,816	100	3,133	11%	4,429	57%	15,968	467%
4	80	3,376	100	3,133	-7%	4,429	31%	15,968	373%
5	80	3,376	110	3,763	11%	4,429	31%	15,968	373%
6	80	3,376	110	3,763	11%	4,429	31%	15,968	373%
7	80	3,376	120	4,263	26%	4,909	45%	15,968	373%
8	90	4,063	120	4,263	5%	4,909	21%	15,968	293%
9	90	4,063	130	4,933	21%	5,429	34%	15,968	293%
10	100	4,808	140	5,149	7%	5,429	13%	15,968	232%

Table 4-44. Weight comparison by site between 1994 and 2001 *Supports Specifications* for fatigue category I relative to 2001 specifications

Site No.	AASHTO 1994			AASHTO 2001					
				Wind Speed (mph)	Group I, II, III Load Combinations only		Fatigue Category I		
	Structure Weight (lb)	Change in Weight Relative to 2001 Spec. with Nat. Wind Gust and Truck-Induced Wind Gust	Groups I, II, III plus Nat. Wind Gust and Truck-Induced Wind Gust				Groups I, II, III plus Nat. Wind Gust, Truck-Induced Wind Gust, and Galloping		
Wind Speed, 50-year MRI (mph)			Structure Weight (lb)	Change in Weight Relative to 2001 Spec. with Nat. Wind Gust and Truck-Induced Wind Gust	Structure Weight (lb)	Change in Weight Relative to 2001 Spec. with Nat. Wind Gust and Truck-Induced Wind Gust	Structure Weight (lb)	Structure Weight (lb)	Change in Weight Relative to 2001 Spec. with Nat. Wind Gust and Truck-Induced Wind Gust
1a	70	2,908	-35%	90	2,975	-33%	4,471	15,968	257%
1b	70	2,816	-36%	90	2,883	-35%	4,429	15,968	261%
2	80	3,376	-24%	90	2,883	-35%	4,429	15,968	261%
3	70	2,816	-36%	100	3,133	-29%	4,429	15,968	261%
4	80	3,376	-24%	100	3,133	-29%	4,429	15,968	261%
5	80	3,376	-24%	110	3,763	-15%	4,429	15,968	261%
6	80	3,376	-24%	110	3,763	-15%	4,429	15,968	261%
7	80	3,376	-31%	120	4,263	-13%	4,909	15,968	225%
8	90	4,063	-17%	120	4,263	-13%	4,909	15,968	225%
9	90	4,063	-25%	130	4,933	-9%	5,429	15,968	194%
10	100	4,808	-11%	140	5,149	-5%	5,429	15,968	194%

Table 4-45. Weight comparison by site between 1994 and 2001 *Supports Specifications* for fatigue category II relative to 1994 specifications

Site No.	AASHTO 1994		AASHTO 2001						
			Group I, II, III Load Combinations only			Fatigue Category II			
	Wind Speed, 50-year MRI (mph)	Structure Weight (lb)				Wind Speed (mph)	Structure Weight (lb)	Change in Weight Relative to 1994 Spec.	Structure Weight (lb)
1a	70	2,908	90	2,975	2%	3,555	22%	11,450	294%
1b	70	2,816	90	2,883	2%	3,463	23%	11,450	307%
2	80	3,376	90	2,883	-15%	3,463	3%	11,450	239%
3	70	2,816	100	3,133	11%	3,463	23%	11,450	307%
4	80	3,376	100	3,133	-7%	3,463	3%	11,450	239%
5	80	3,376	110	3,763	11%	3,888	15%	11,450	239%
6	80	3,376	110	3,763	11%	3,888	15%	11,450	239%
7	80	3,376	120	4,263	26%	4,389	30%	11,450	239%
8	90	4,063	120	4,263	5%	4,389	8%	11,450	182%
9	90	4,063	130	4,933	21%	5,059	25%	11,450	182%
10	100	4,808	140	5,149	7%	5,235	9%	11,450	138%

Table 4-46. Weight comparison by site between 1994 and 2001 *Supports Specifications* for fatigue category II relative to 2001 specifications

Site No.	AASHTO 1994			AASHTO 2001					
				Wind Speed (mph)	Group I, II, III Load Combinations only		Fatigue Category II		
	Structure Weight (lb)	Change in Weight Relative to 2001 Spec. with Nat. Wind Gust and Truck-Induced Wind Gust	Groups I, II, III plus Nat. Wind Gust and Truck-Induced Wind Gust				Groups I, II, III plus Nat. Wind Gust, Truck-Induced Wind Gust, and Galloping		
Wind Speed, 50-year MRI (mph)			Structure Weight (lb)	Change in Weight Relative to 2001 Spec. with Nat. Wind Gust and Truck-Induced Wind Gust	Structure Weight (lb)	Change in Weight Relative to 2001 Spec. with Nat. Wind Gust and Truck-Induced Wind Gust	Structure Weight (lb)	Structure Weight (lb)	Change in Weight Relative to 2001 Spec. with Nat. Wind Gust and Truck-Induced Wind Gust
1a	70	2,908	-18%	90	2,975	-16%	3,555	11,450	222%
1b	70	2,816	-19%	90	2,883	-17%	3,463	11,450	231%
2	80	3,376	-3%	90	2,883	-17%	3,463	11,450	231%
3	70	2,816	-19%	100	3,133	-10%	3,463	11,450	231%
4	80	3,376	-3%	100	3,133	-10%	3,463	11,450	231%
5	80	3,376	-13%	110	3,763	-3%	3,888	11,450	194%
6	80	3,376	-13%	110	3,763	-3%	3,888	11,450	194%
7	80	3,376	-23%	120	4,263	-3%	4,389	11,450	161%
8	90	4,063	-7%	120	4,263	-3%	4,389	11,450	161%
9	90	4,063	-20%	130	4,933	-2%	5,059	11,450	126%
10	100	4,808	-8%	140	5,149	-2%	5,235	11,450	119%

Table 4-47. Weight comparison by site between 1994 and 2001 *Supports Specifications* for fatigue category III relative to 1994 specifications

Site No.	AASHTO 1994		AASHTO 2001						
			Group I, II, III Load Combinations only			Fatigue Category III			
	Wind Speed (mph)	Structure Weight (lb)				Change in Weight Relative to 1994 Spec.	Groups I, II, III plus Nat. Wind Gust and Truck-Induced Wind Gust	Groups I, II, III plus Nat. Wind Gust, Truck-Induced Wind Gust, and Galloping	
Wind Speed, 50-year MRI (mph)	Structure Weight (lb)	Wind Speed (mph)	Structure Weight (lb)	Change in Weight Relative to 1994 Spec.	Structure Weight (lb)	Change in Weight Relative to 1994 Spec.	Structure Weight (lb)	Change in Weight Relative to 1994 Spec.	
1a	70	2,908	90	2,975	2%	3,095	6%	4,997	72%
1b	70	2,816	90	2,883	2%	3,003	7%	4,997	77%
2	80	3,376	90	2,883	-15%	3,003	-11%	4,997	48%
3	70	2,816	100	3,133	11%	3,186	13%	4,997	77%
4	80	3,376	100	3,133	-7%	3,186	-6%	4,997	48%
5	80	3,376	110	3,763	11%	3,763	11%	4,997	48%
6	80	3,376	110	3,763	11%	3,763	11%	4,997	48%
7	80	3,376	120	4,263	26%	4,263	26%	5,811	72%
8	90	4,063	120	4,263	5%	4,263	5%	5,811	43%
9	90	4,063	130	4,933	21%	4,933	21%	6,209	53%
10	100	4,808	140	5,149	7%	5,149	7%	6,250	30%

Table 4-48. Weight comparison by site between 1994 and 2001 *Supports Specifications* for fatigue category III relative to 2001 specifications

Site No.	AASHTO 1994			AASHTO 2001					
				Wind Speed (mph)	Group I, II, III Load Combinations only		Fatigue Category III		
	Structure Weight (lb)	Change in Weight Relative to 2001 Spec. with Nat. Wind Gust and Truck-Induced Wind Gust	Groups I, II, III plus Nat. Wind Gust and Truck-Induced Wind Gust				Groups I, II, III plus Nat. Wind Gust, Truck-Induced Wind Gust, and Galloping		
Wind Speed, 50-year MRI (mph)			Structure Weight (lb)	Change in Weight Relative to 2001 Spec. with Nat. Wind Gust and Truck-Induced Wind Gust	Structure Weight (lb)	Change in Weight Relative to 2001 Spec. with Nat. Wind Gust and Truck-Induced Wind Gust	Structure Weight (lb)	Structure Weight (lb)	Change in Weight Relative to 2001 Spec. with Nat. Wind Gust and Truck-Induced Wind Gust
1a	70	2,908	-6%	90	2,975	-4%	3,095	4,997	61%
1b	70	2,816	-6%	90	2,883	-4%	3,003	4,997	66%
2	80	3,376	12%	90	2,883	-4%	3,003	4,997	66%
3	70	2,816	-12%	100	3,133	-2%	3,186	4,997	57%
4	80	3,376	6%	100	3,133	-2%	3,186	4,997	57%
5	80	3,376	-10%	110	3,763	0%	3,763	4,997	33%
6	80	3,376	-10%	110	3,763	0%	3,763	4,997	33%
7	80	3,376	-21%	120	4,263	0%	4,263	5,811	36%
8	90	4,063	-5%	120	4,263	0%	4,263	5,811	36%
9	90	4,063	-18%	130	4,933	0%	4,933	6,209	26%
10	100	4,808	-7%	140	5,149	0%	5,149	6,250	21%

Section 9
Figures



ISOTACH 0.02 QUANTILES, IN MILES PER HOUR: ANNUAL EXTREME-MILE 30 FT ABOVE GROUND, 50-YR MEAN RECURRENCE INTERVAL

Figure 2-1. Wind map: 50-year mean recurrence interval (Thom, 1968)

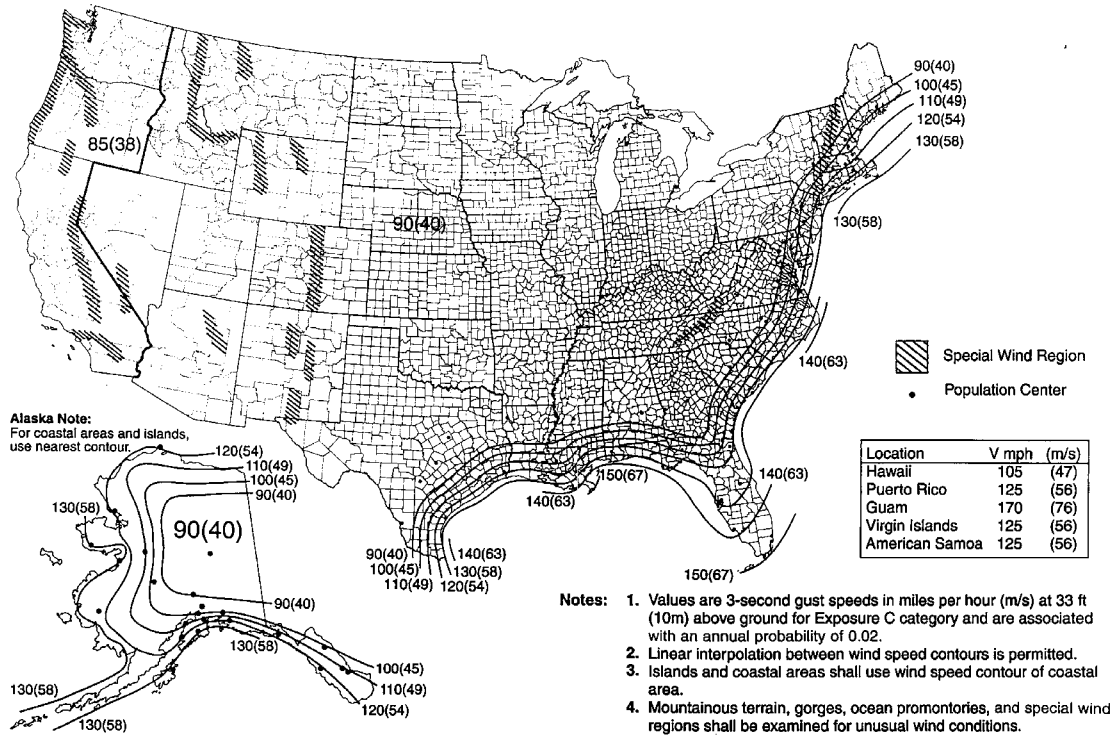


FIG. 6-1. Basic Wind Speed

Figure 2-2. Basic wind speed (ANSI/ASCE 7-95, 1996)

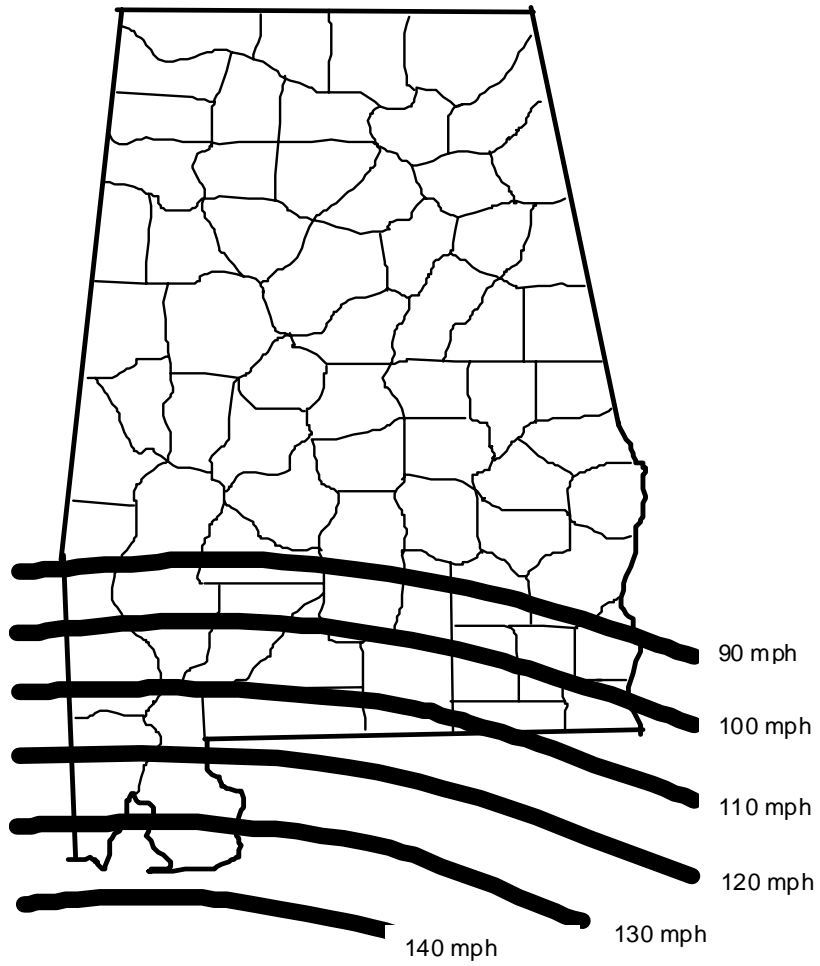


Figure 3-1. Basic wind speed for Alabama (AASHTO, 2001)

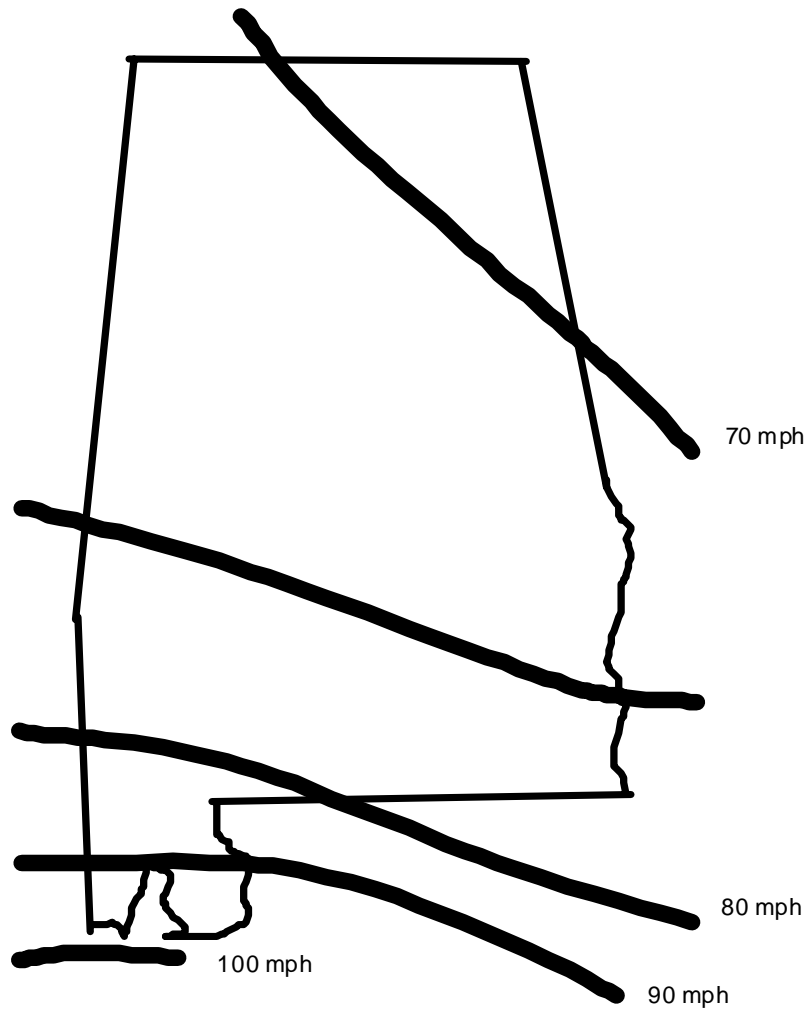


Figure 3-2. Wind speed for Alabama, 50-year mean recurrence interval (AASHTO, 1994)

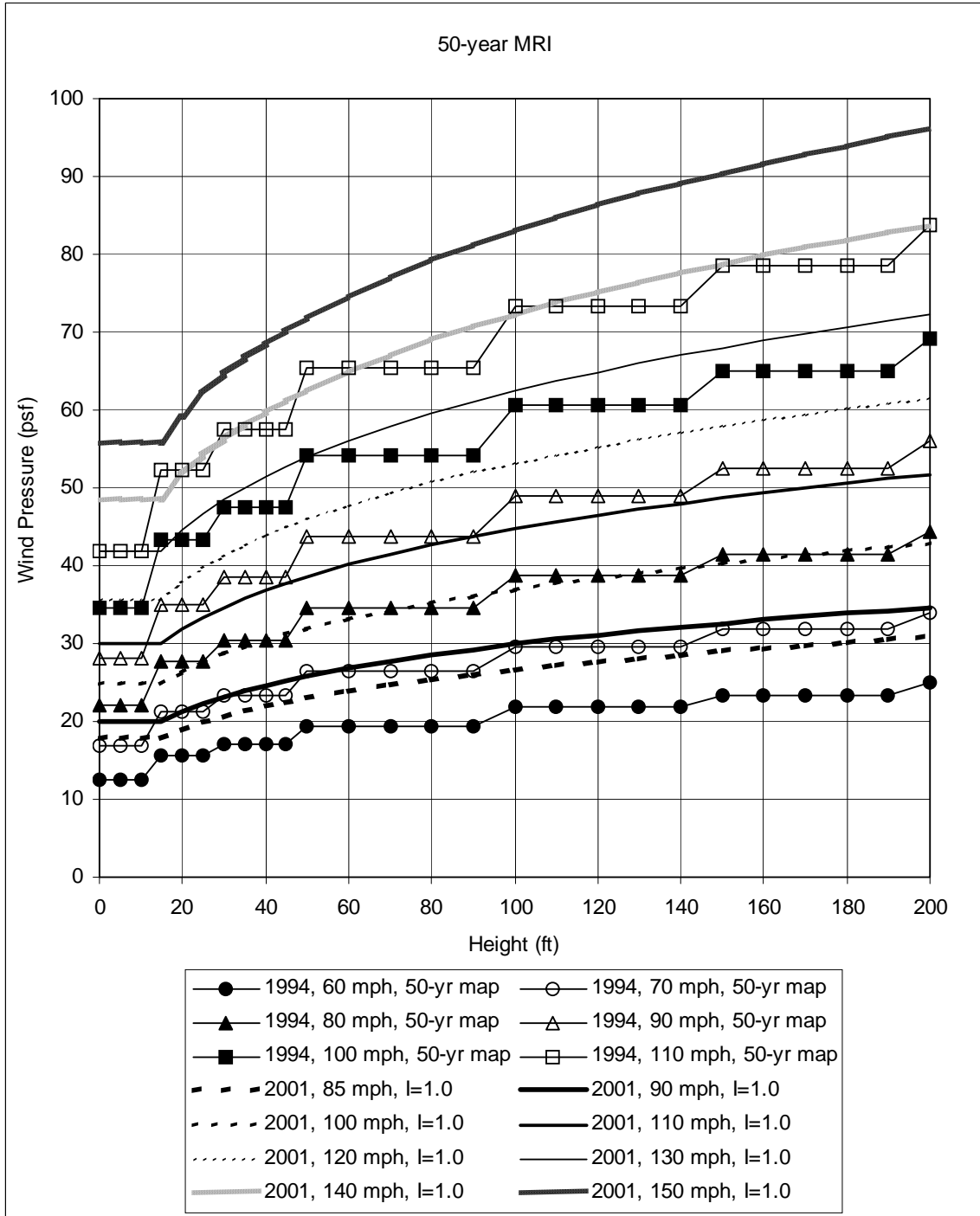


Figure 3-3. Wind pressure comparisons for 50-year mean recurrence interval

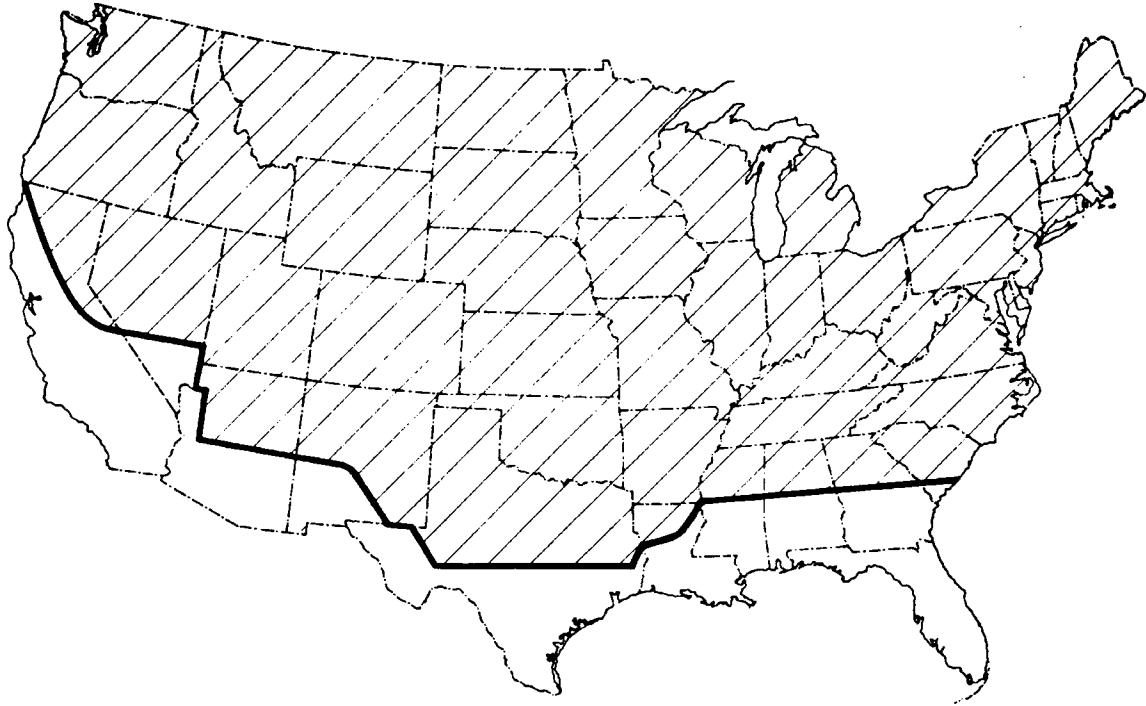


Figure 3-4. Ice loading map (AASHTO, 1994 and 2001)

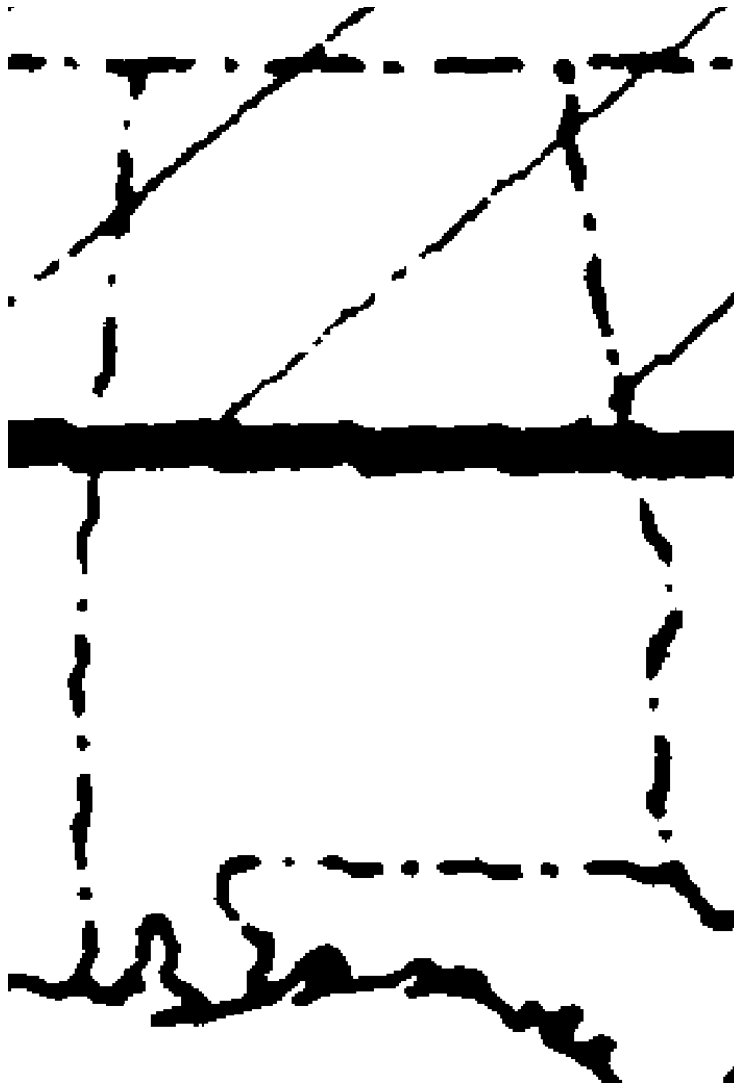


Figure 3-5. Ice loading for Alabama (AASHTO, 1994 and 2001)

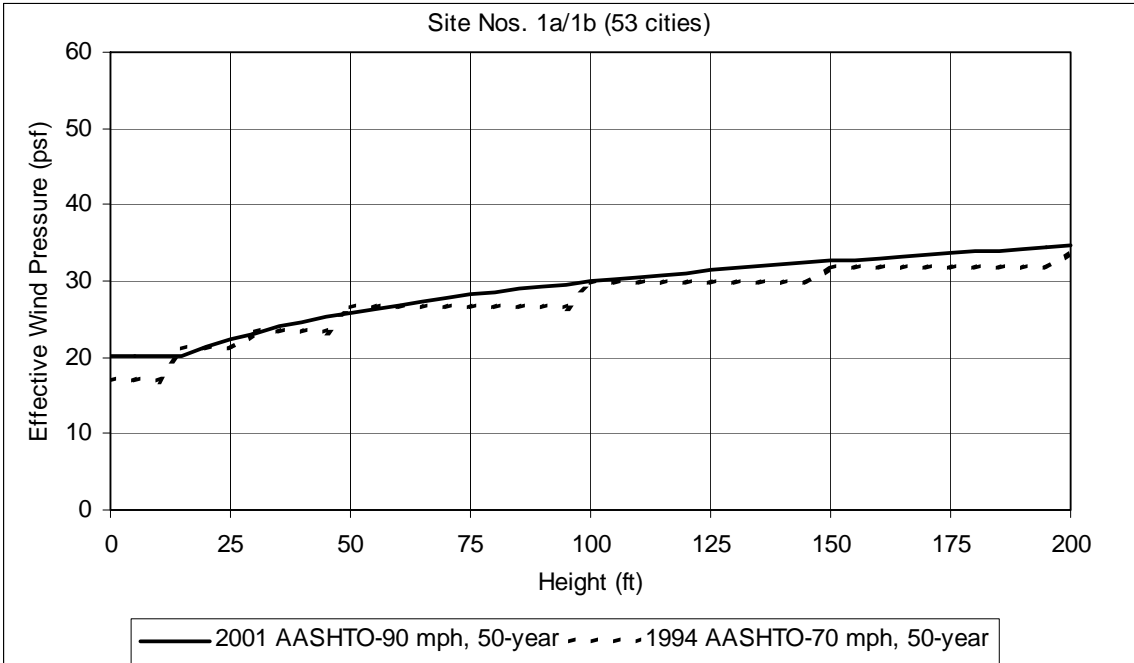


Figure 3-6. Site nos. 1a and 1b: effective wind pressure

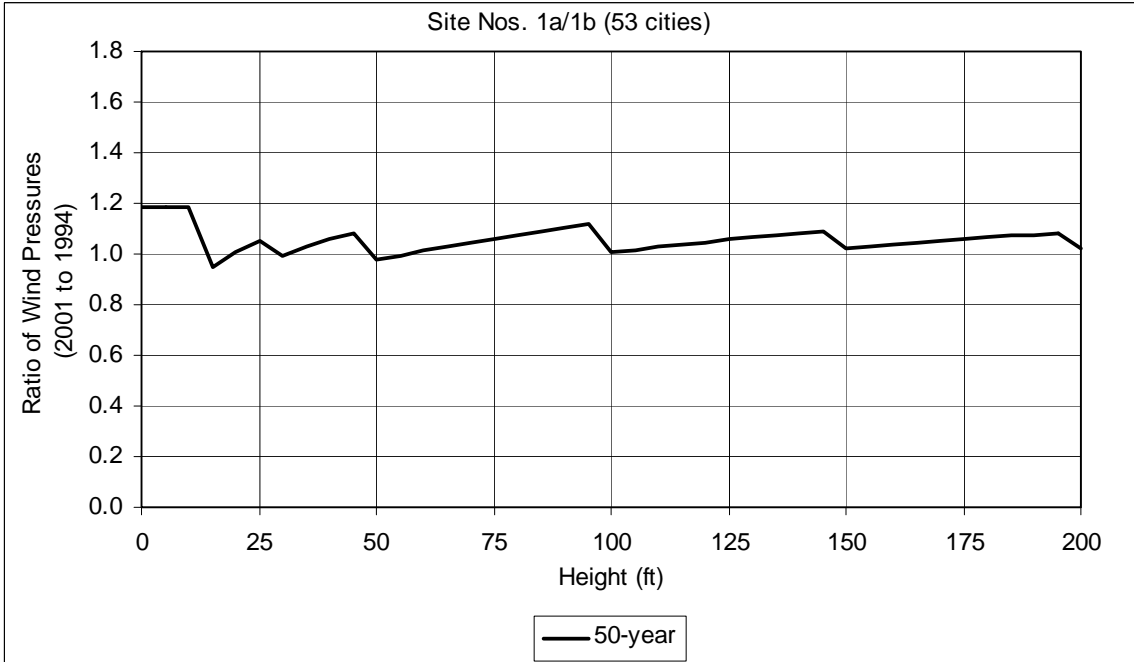


Figure 3-7. Site nos. 1a and 1b: ratio of wind pressures (2001 to 1994 specifications)

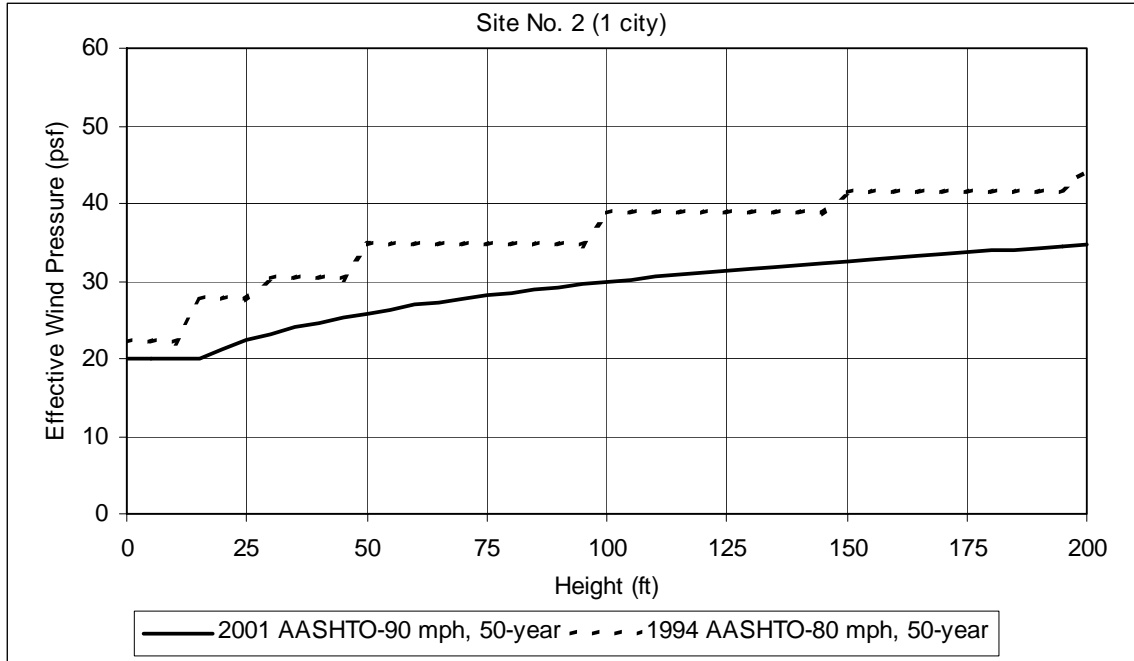


Figure 3-8. Site no. 2: effective wind pressure

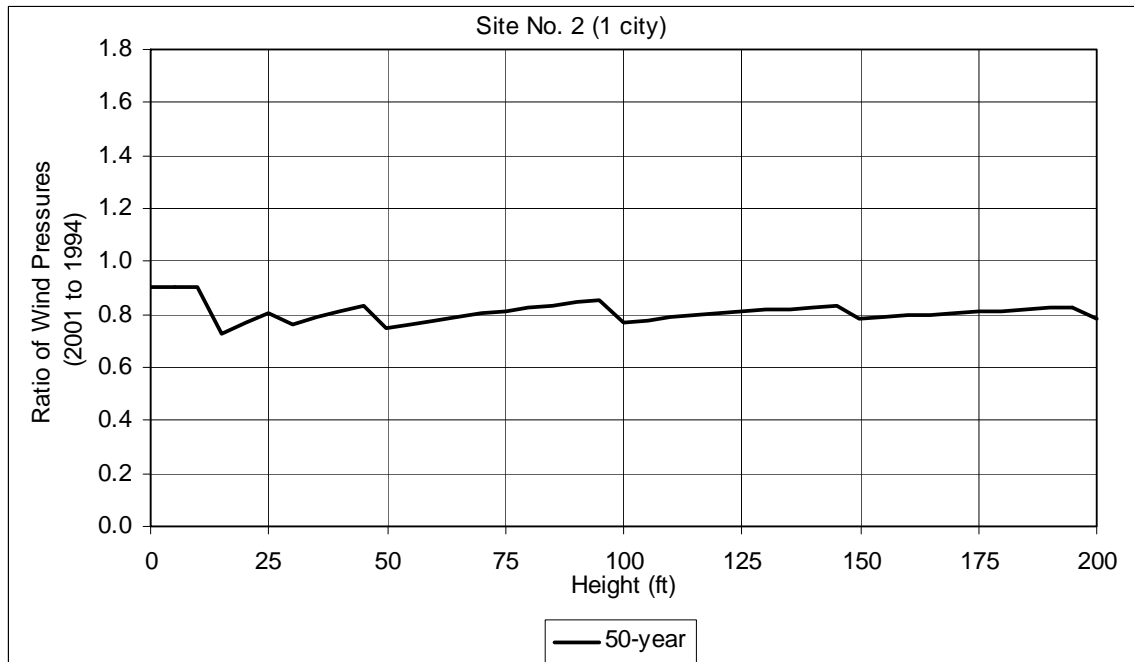


Figure 3-9. Site no. 2: ratio of wind pressures (2001 to 1994 specifications)

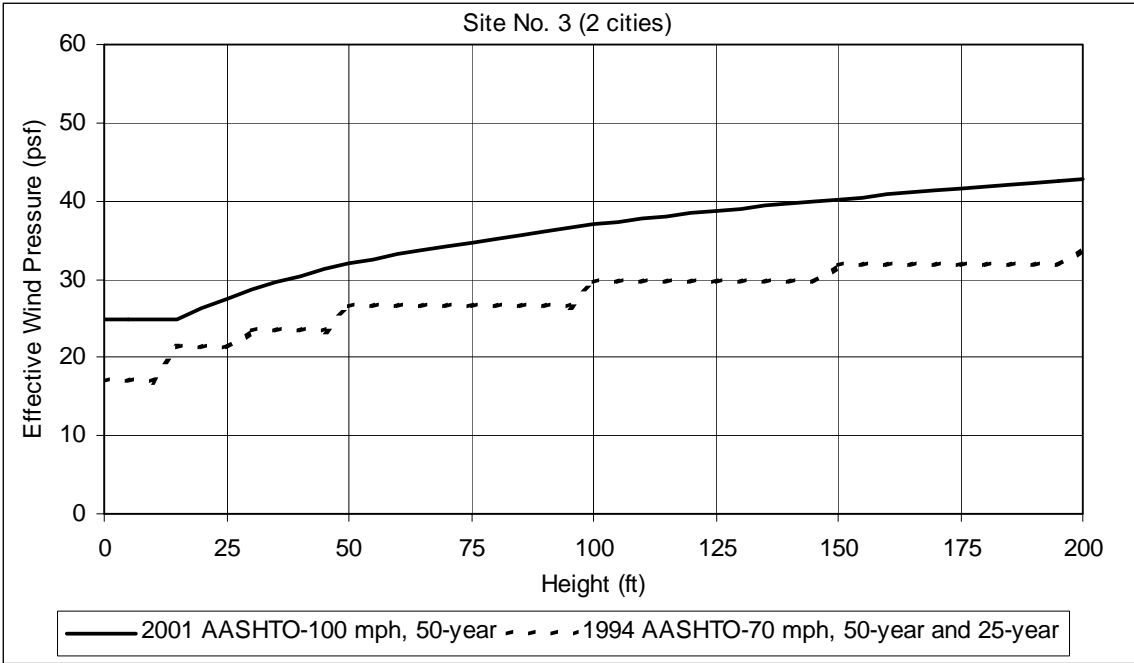


Figure 3-10. Site no. 3: effective wind pressure

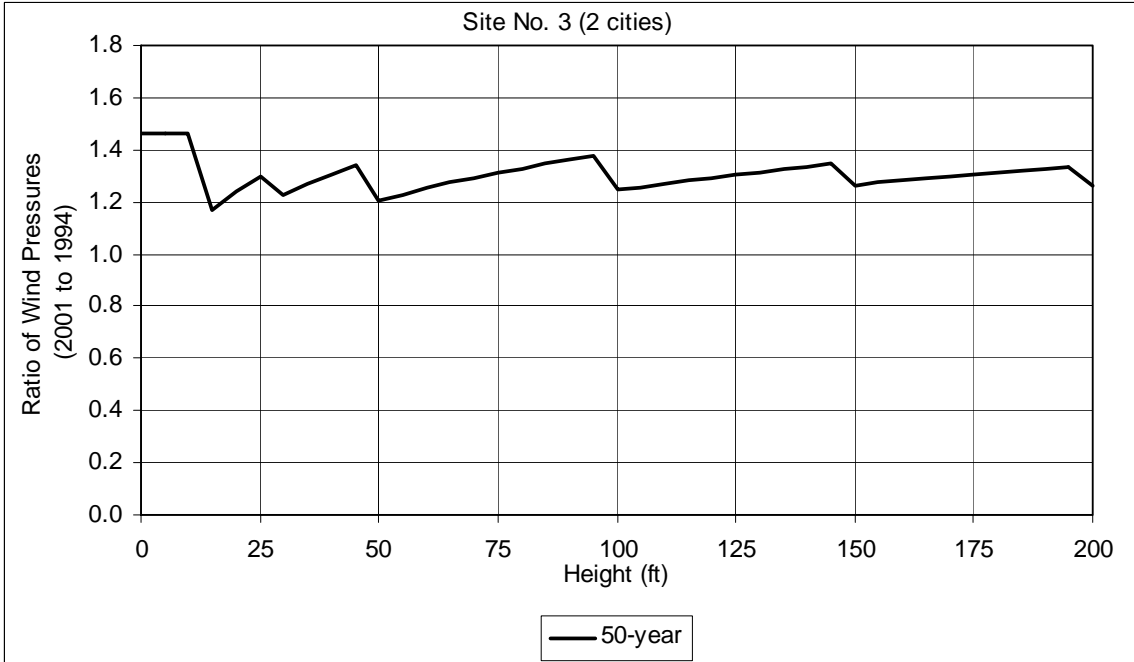


Figure 3-11. Site no. 3: ratio of wind pressures (2001 to 1994 specifications)

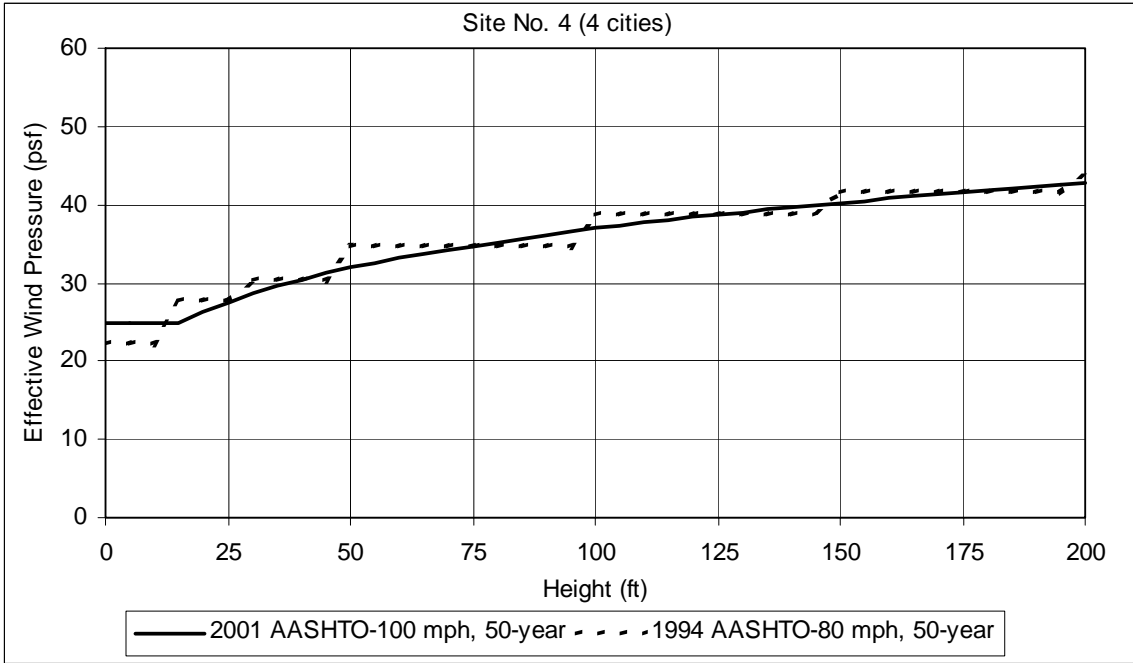


Figure 3-12. Site no. 4: effective wind pressure

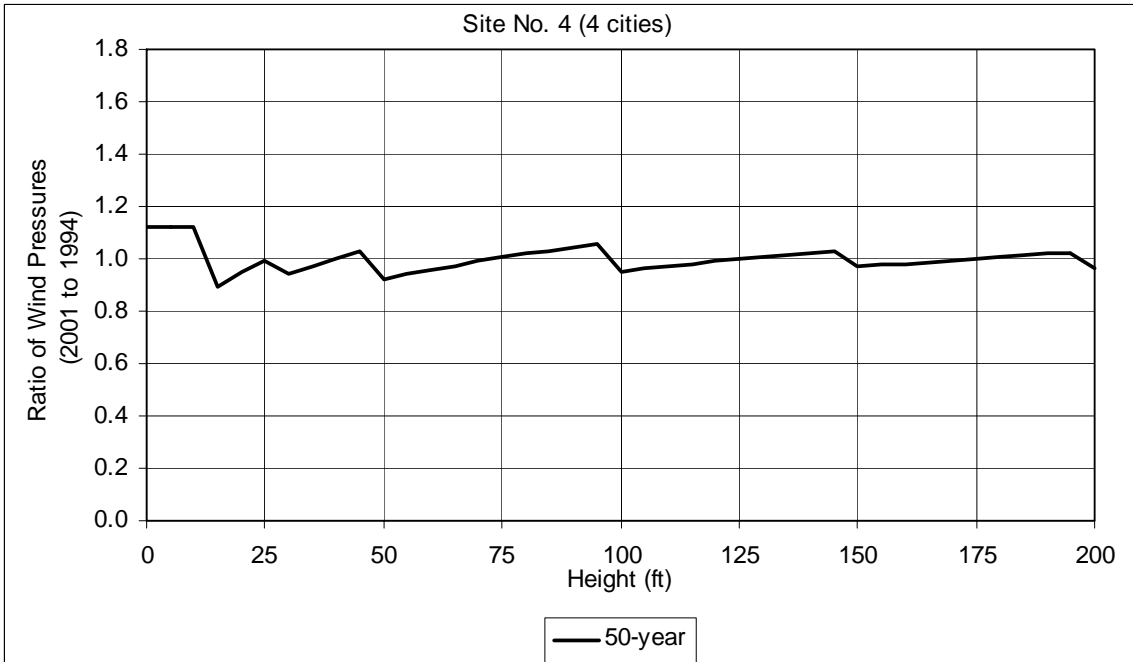


Figure 3-13. Site no. 4: ratio of wind pressures (2001 to 1994 specifications)

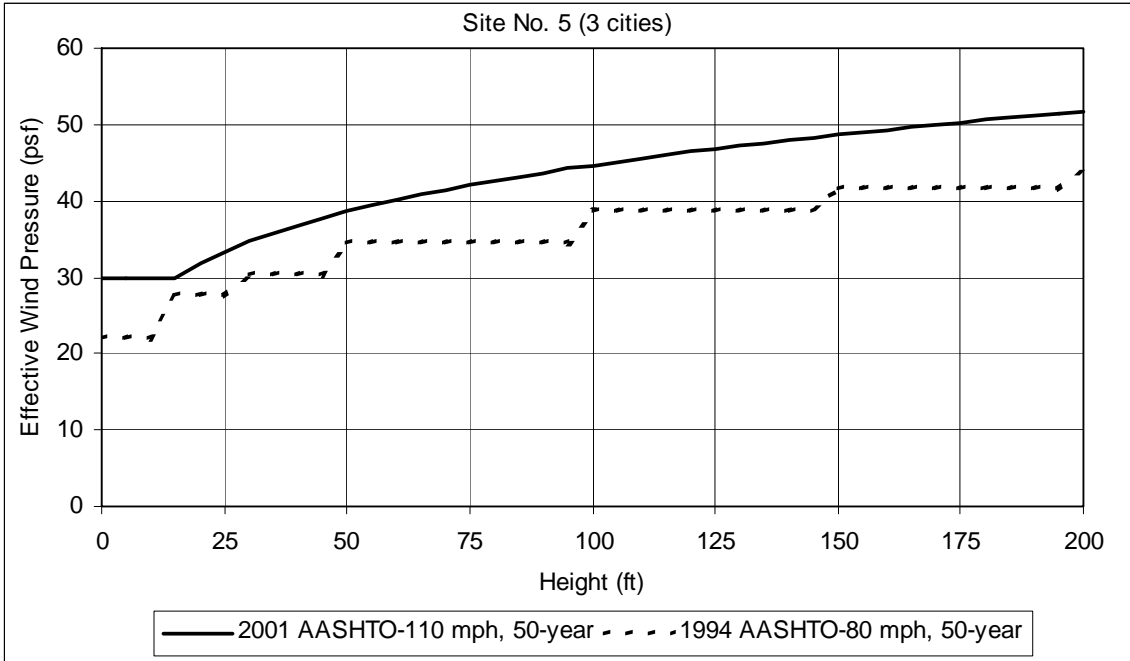


Figure 3-14. Site no. 5: effective wind pressure

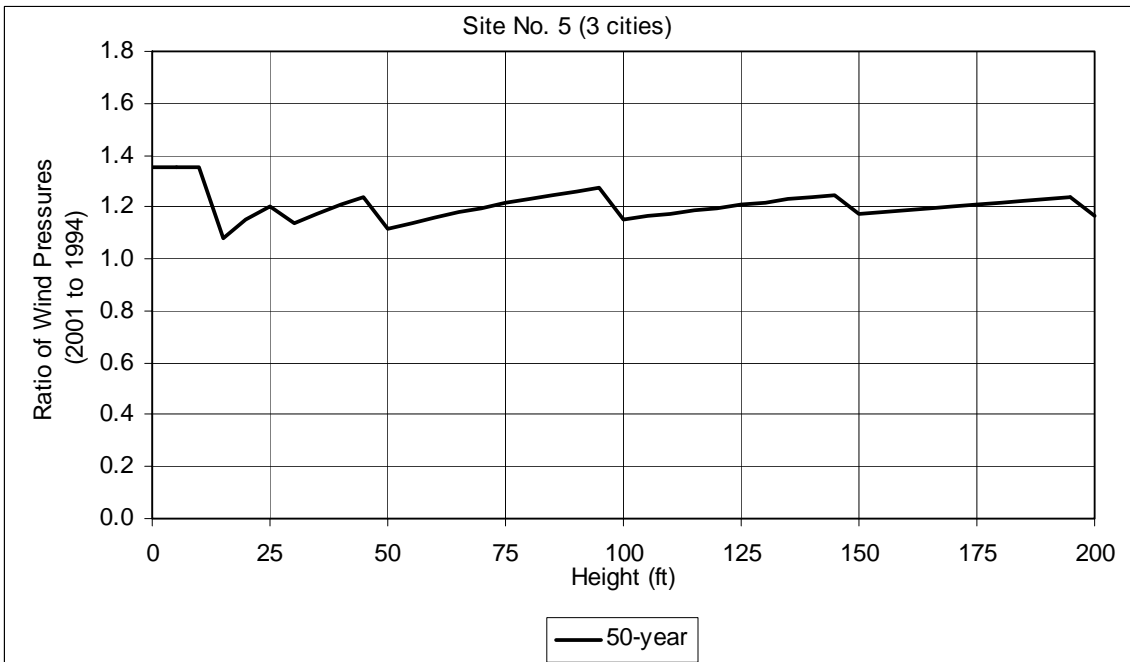


Figure 3-15. Site no. 5: ratio of wind pressures (2001 to 1994 specifications)

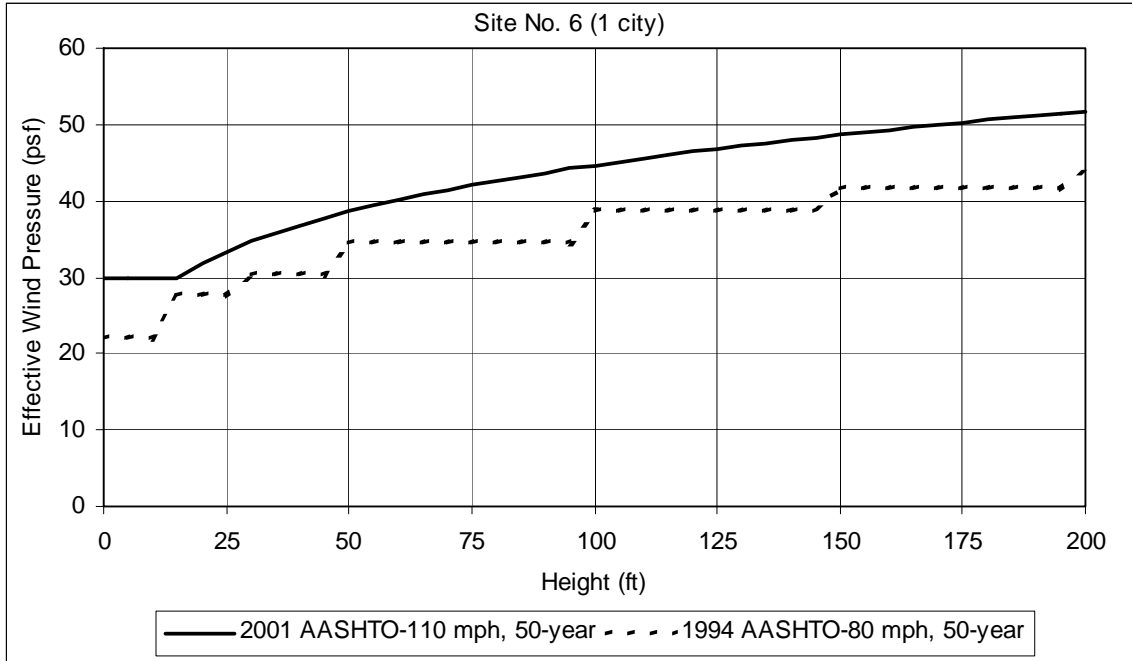


Figure 3-16. Site no. 6: effective wind pressure

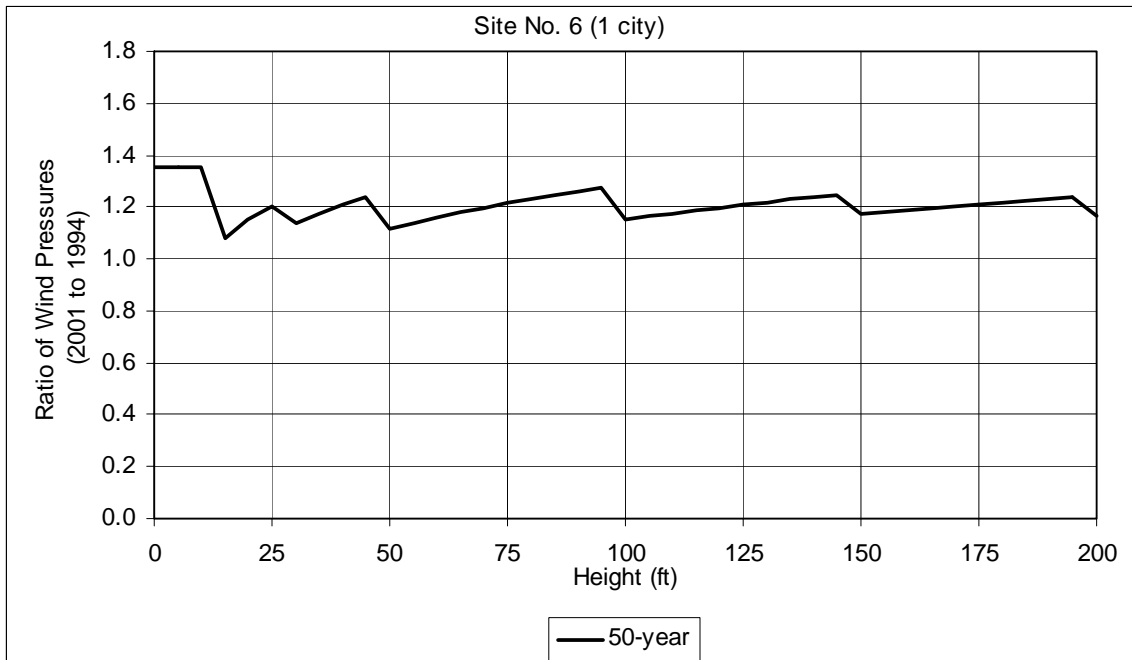


Figure 3-17. Site no. 6: ratio of wind pressures (2001 to 1994 specifications)

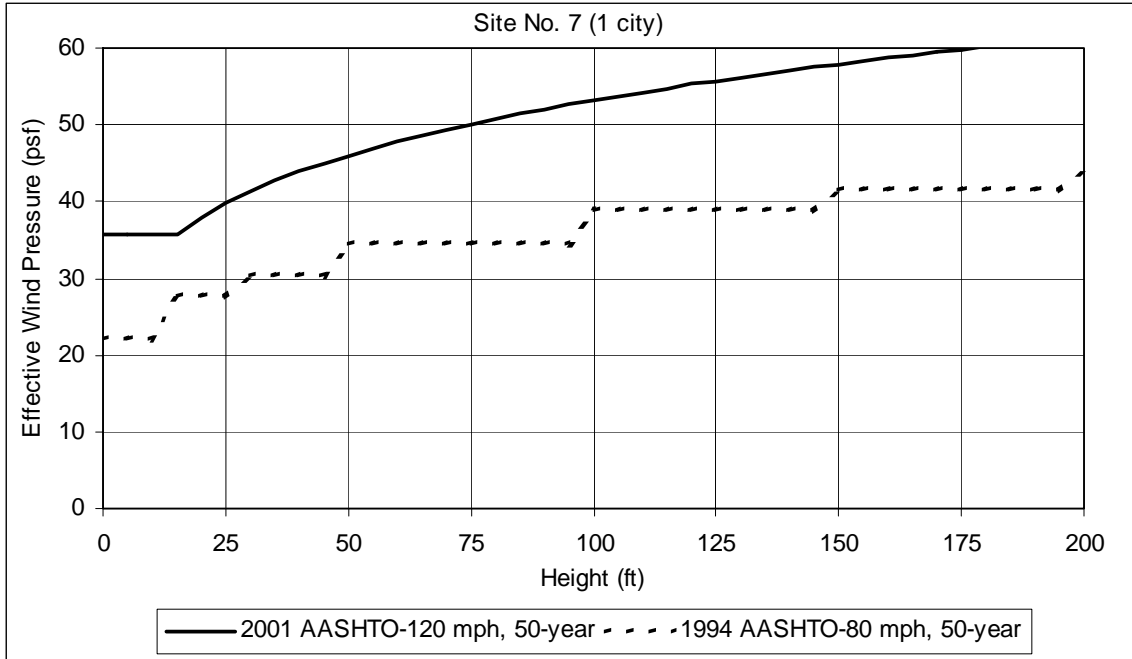


Figure 3-18. Site no. 7: effective wind pressure



Figure 3-19. Site no. 7: ratio of wind pressures (2001 to 1994 specifications)

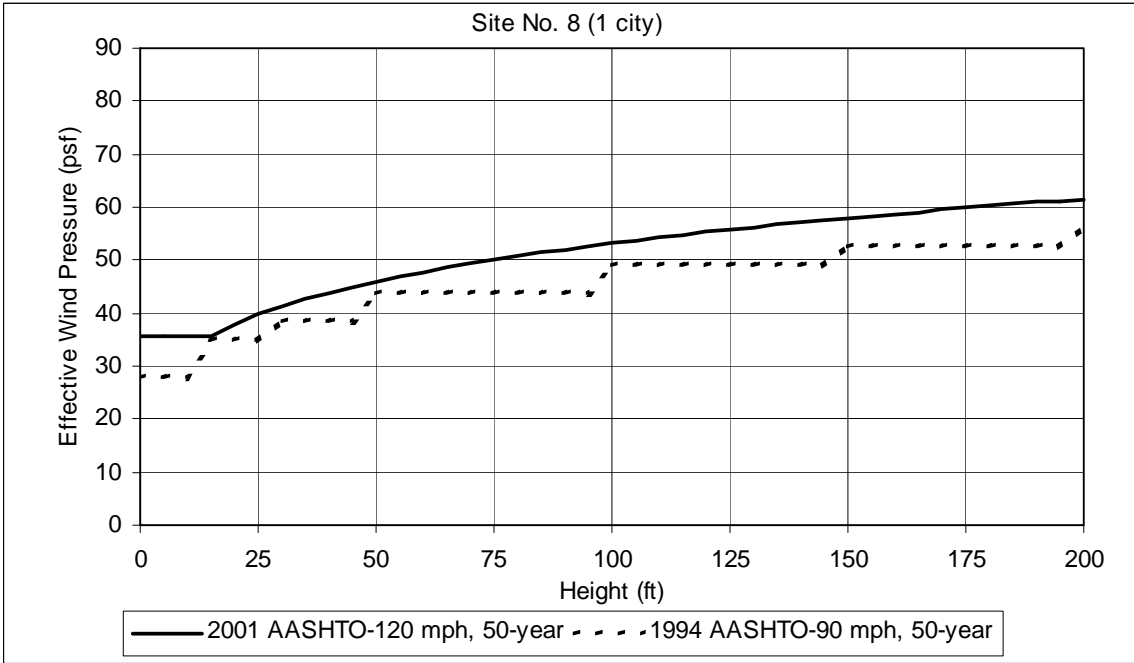


Figure 3-20. Site no. 8: effective wind pressure

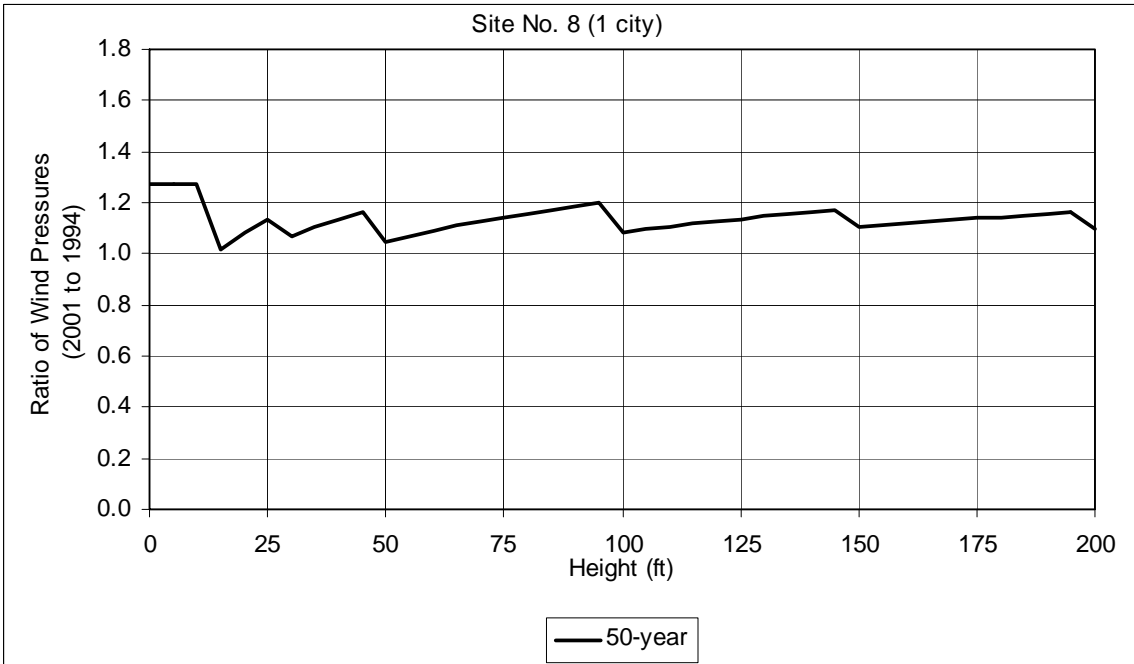


Figure 3-21. Site no. 8: ratio of wind pressures (2001 to 1994 specifications)

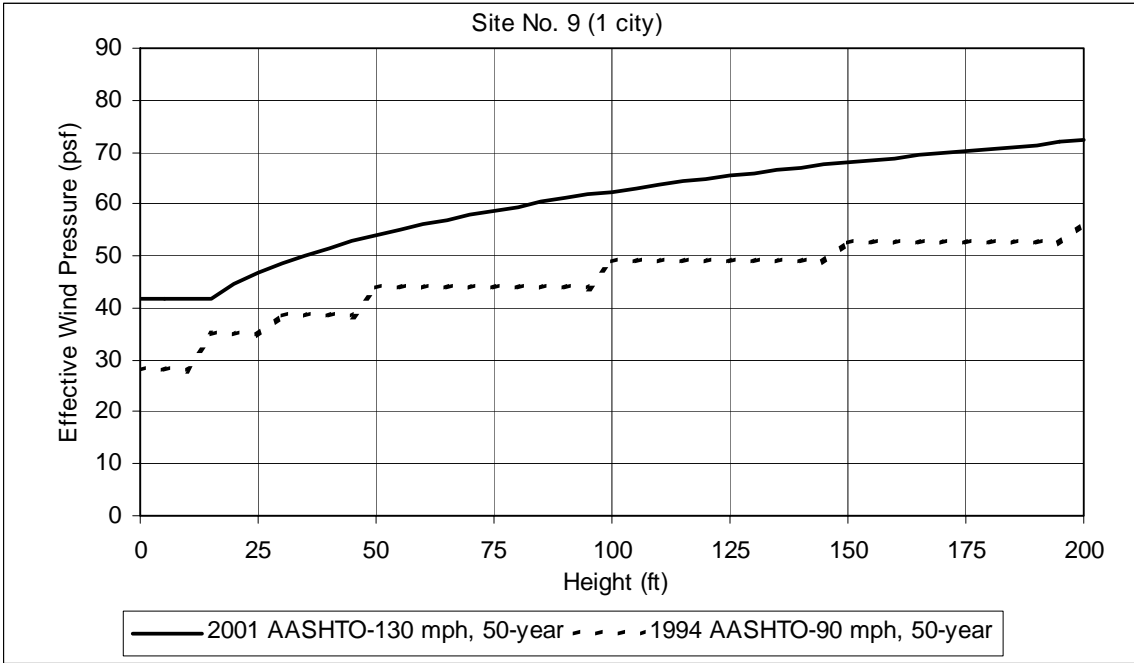


Figure 3-22. Site no. 9: effective wind pressure

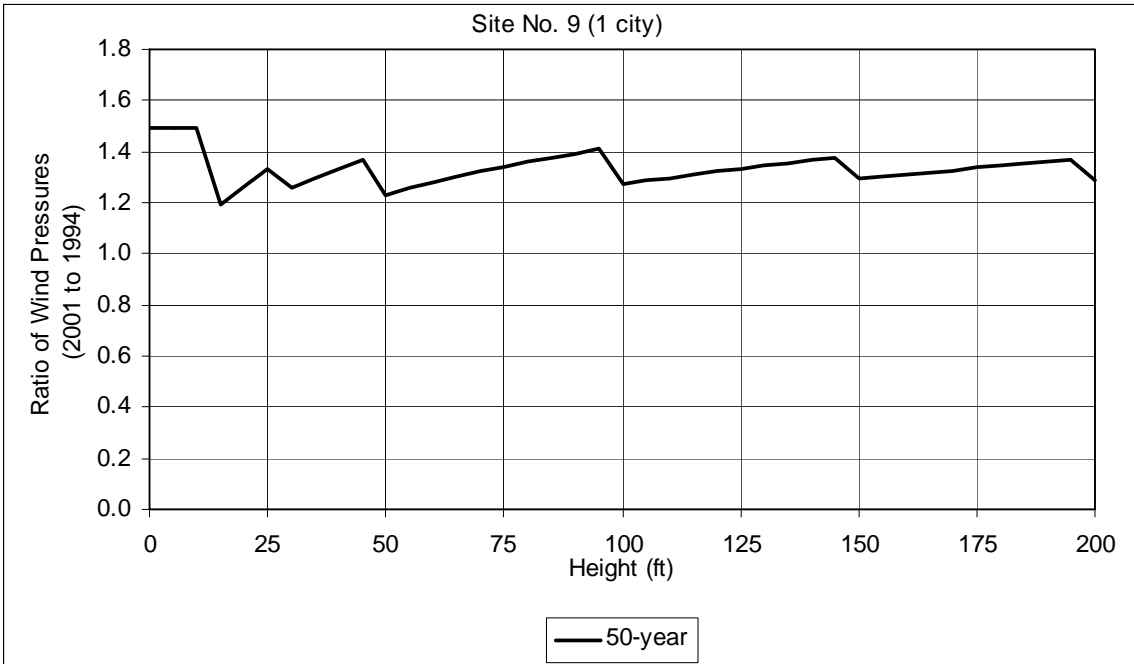


Figure 3-23. Site no. 9: ratio of wind pressures (2001 to 1994 specifications)

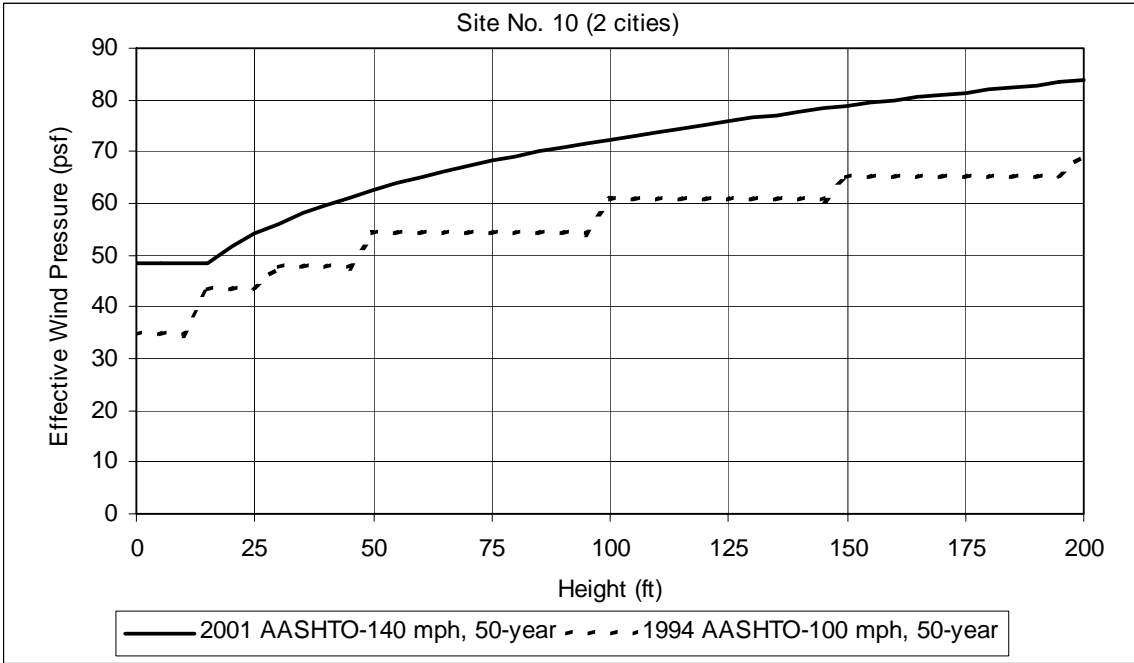


Figure 3-24. Site no. 10: effective wind pressure

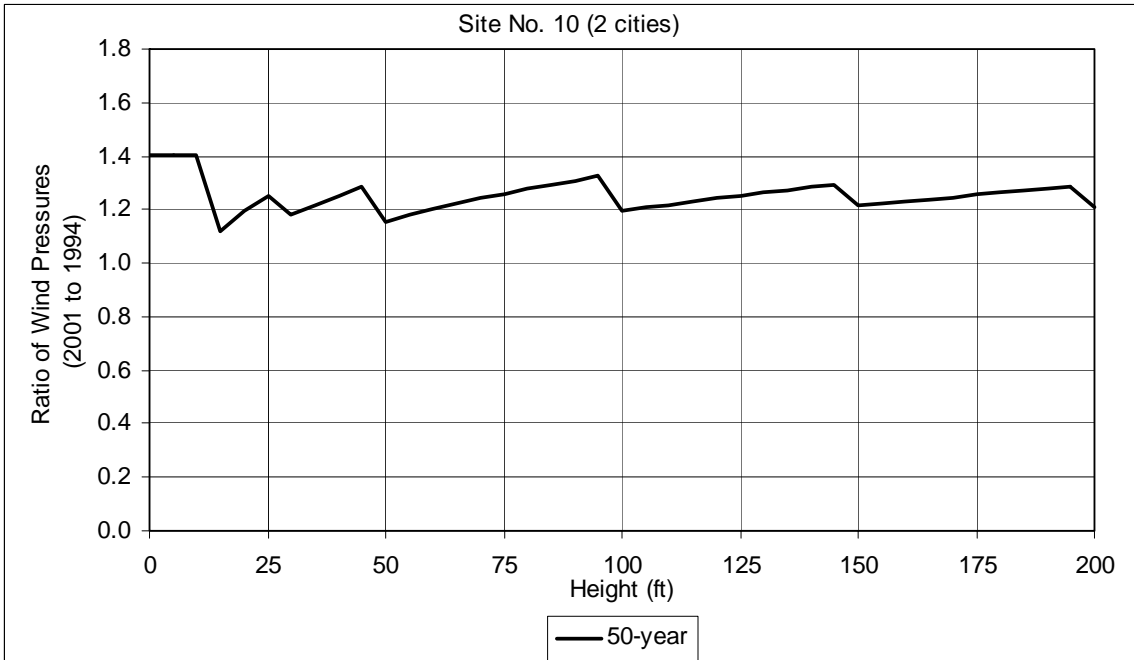


Figure 3-25. Site no. 10: ratio of wind pressures (2001 to 1994 specifications)

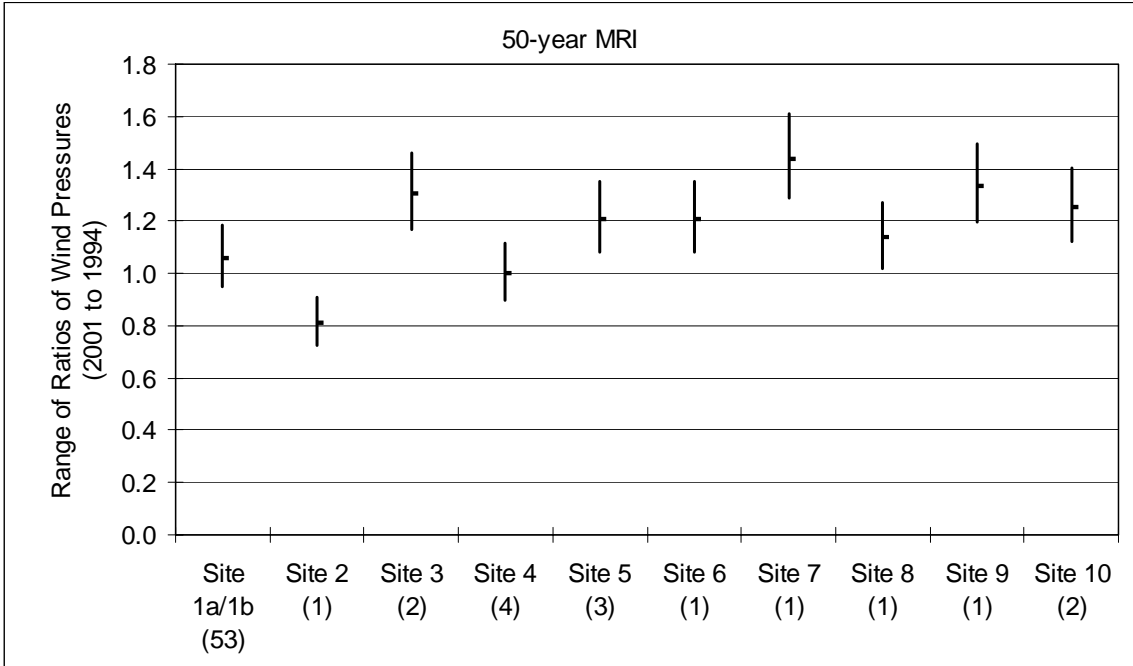


Figure 3-26. 50-year MRI: range of ratios of wind pressures (2001 to 1994 specifications)

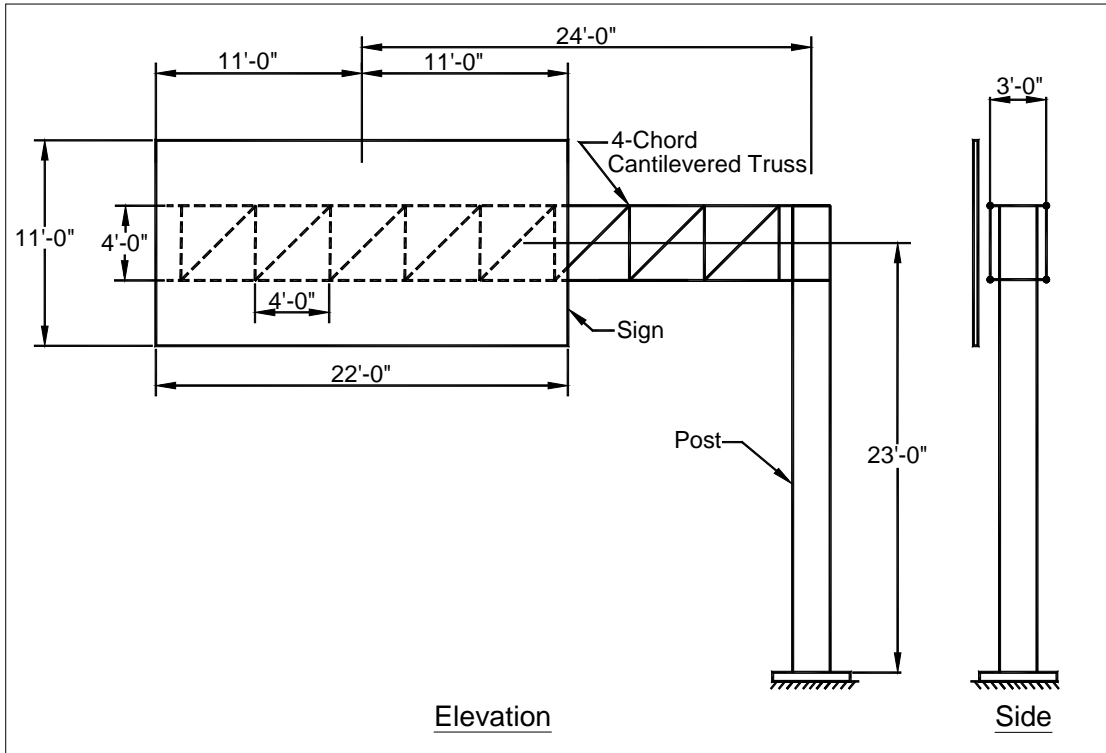


Figure 4-1. Structure configuration

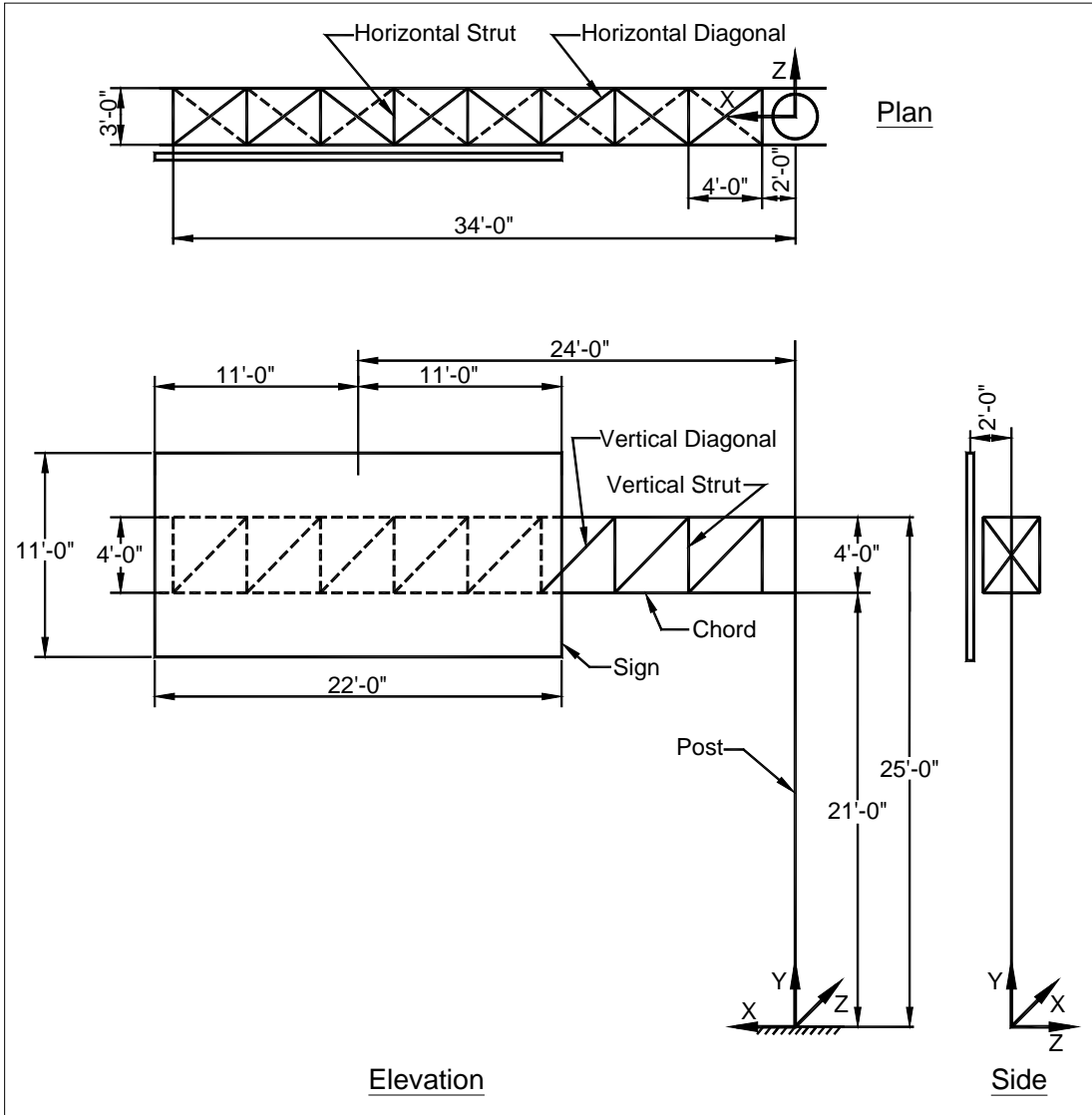


Figure 4-2. Detailed structure configuration

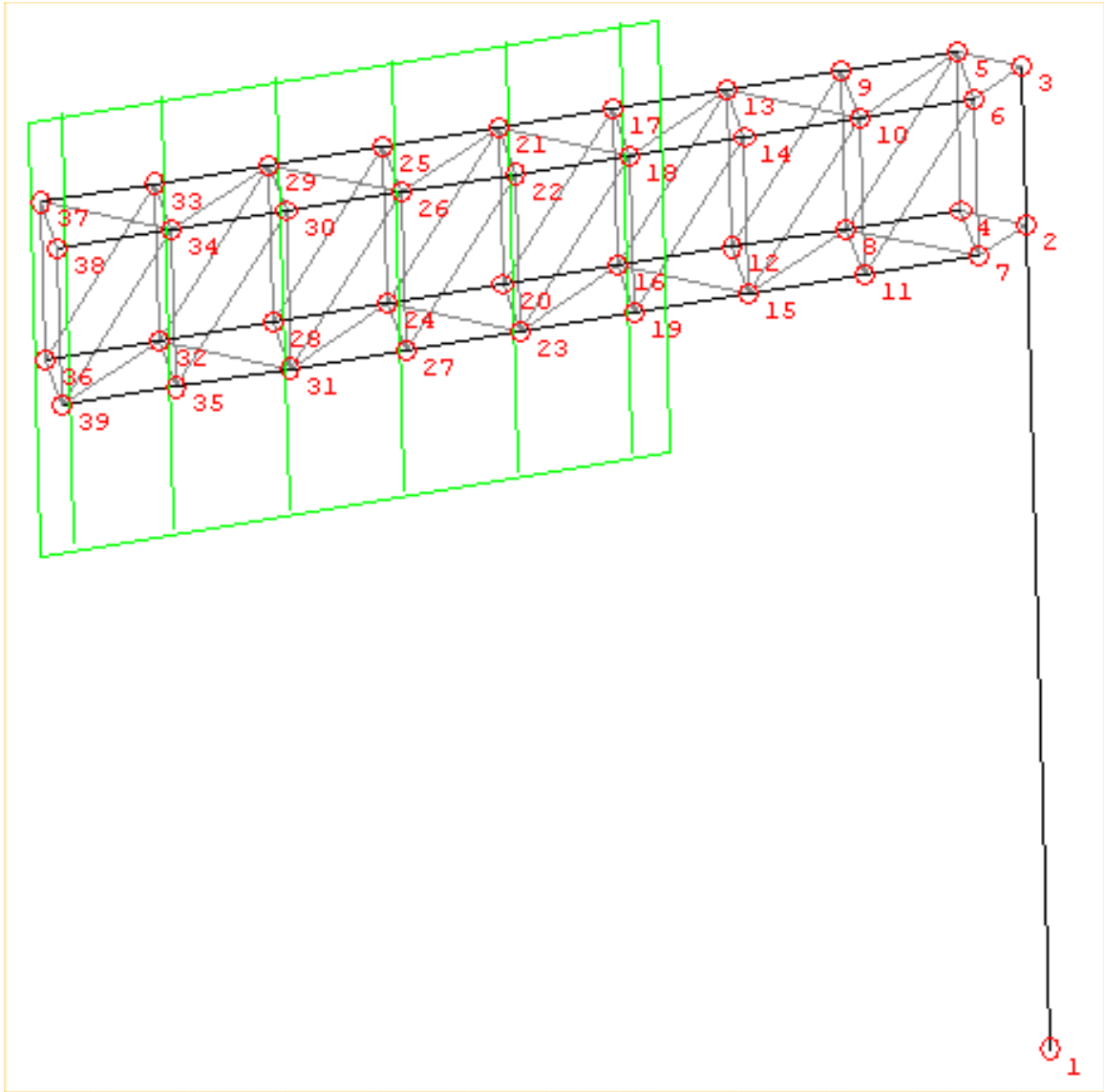


Figure 4-3. Node numbers

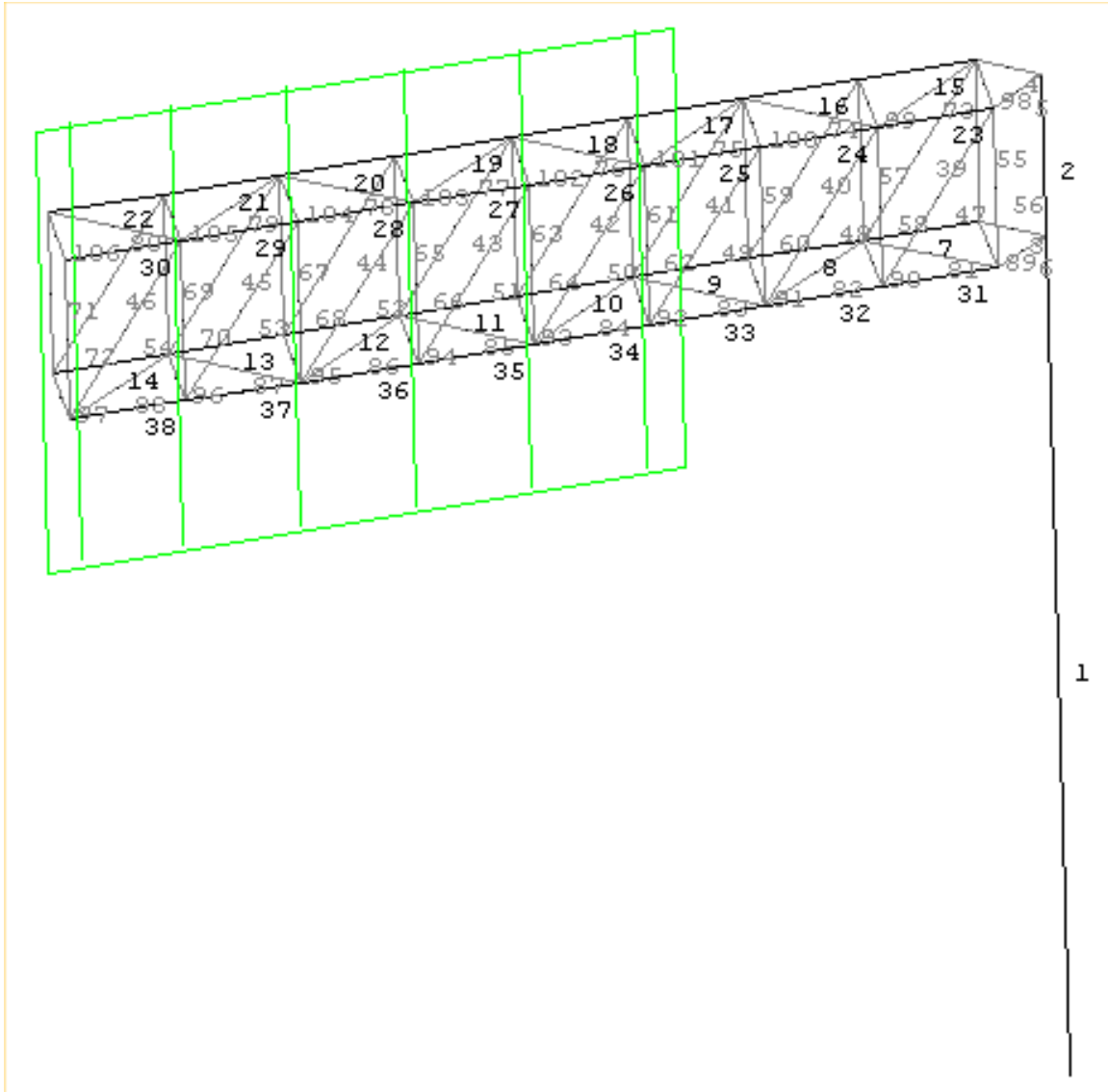


Figure 4-4. Member numbers

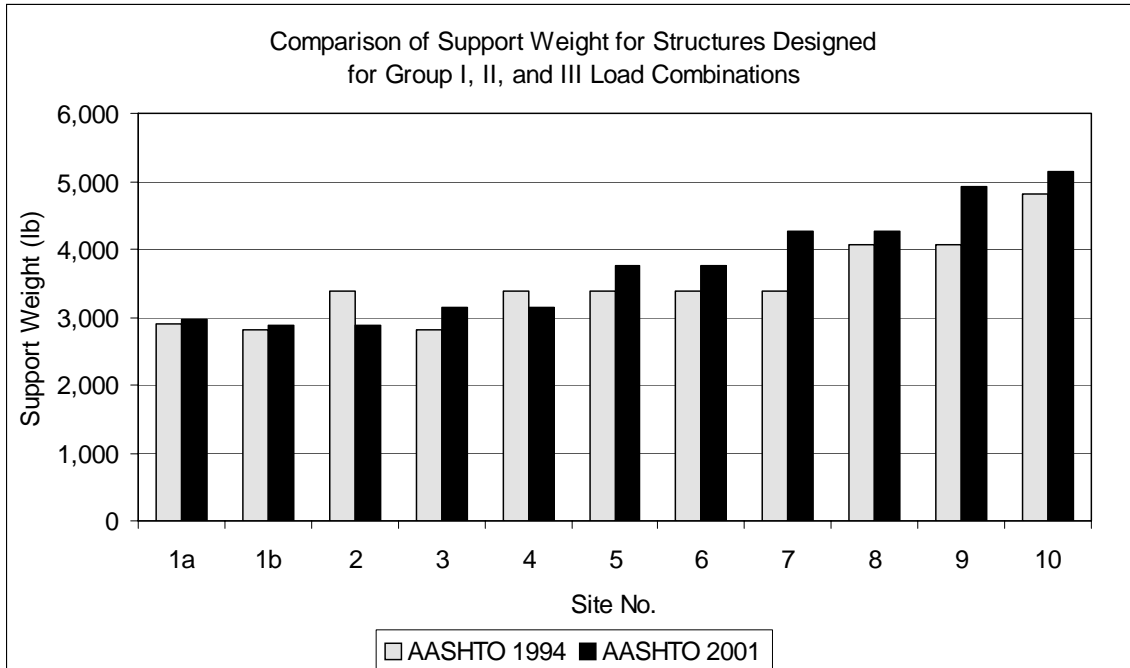


Figure 4-5. Comparison of support weight for structures designed for group I, II, and III load combinations

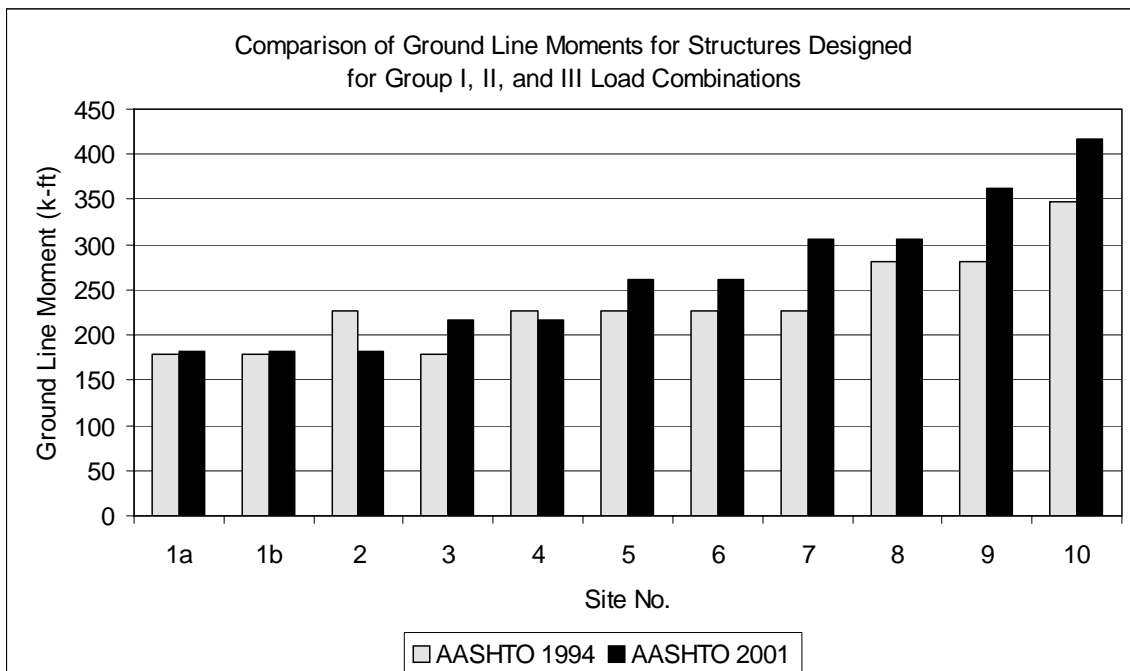


Figure 4-6. Comparison of ground line moments for structures designed for group I, II, and III load combinations

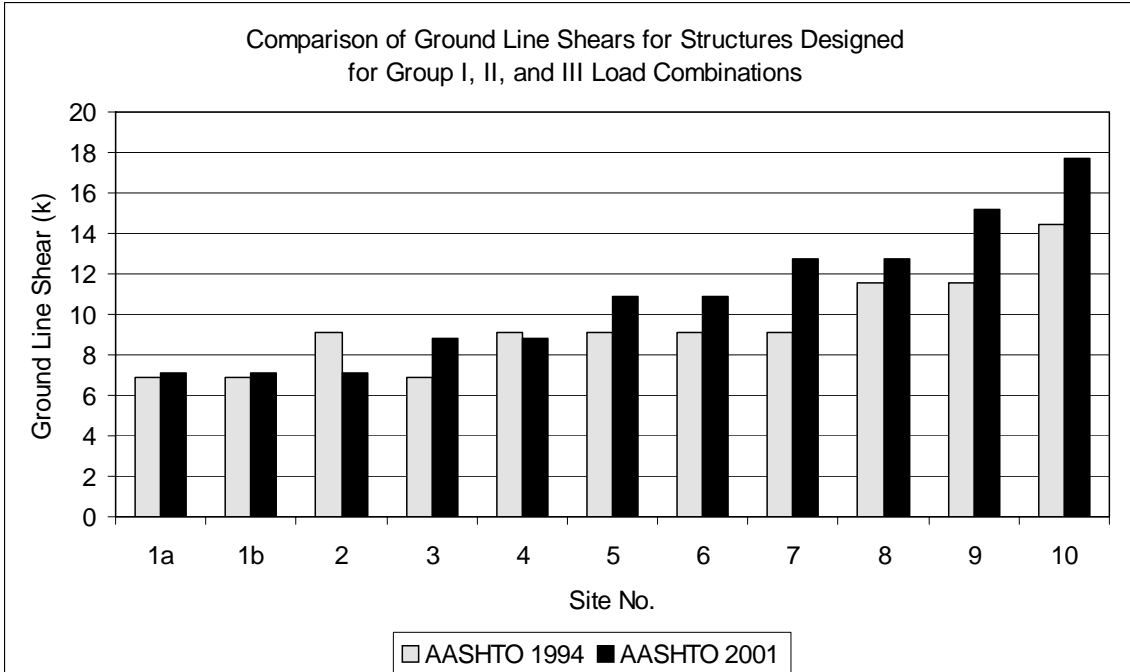


Figure 4-7. Comparison of ground line shears for structures designed for group I, II, and III load combinations

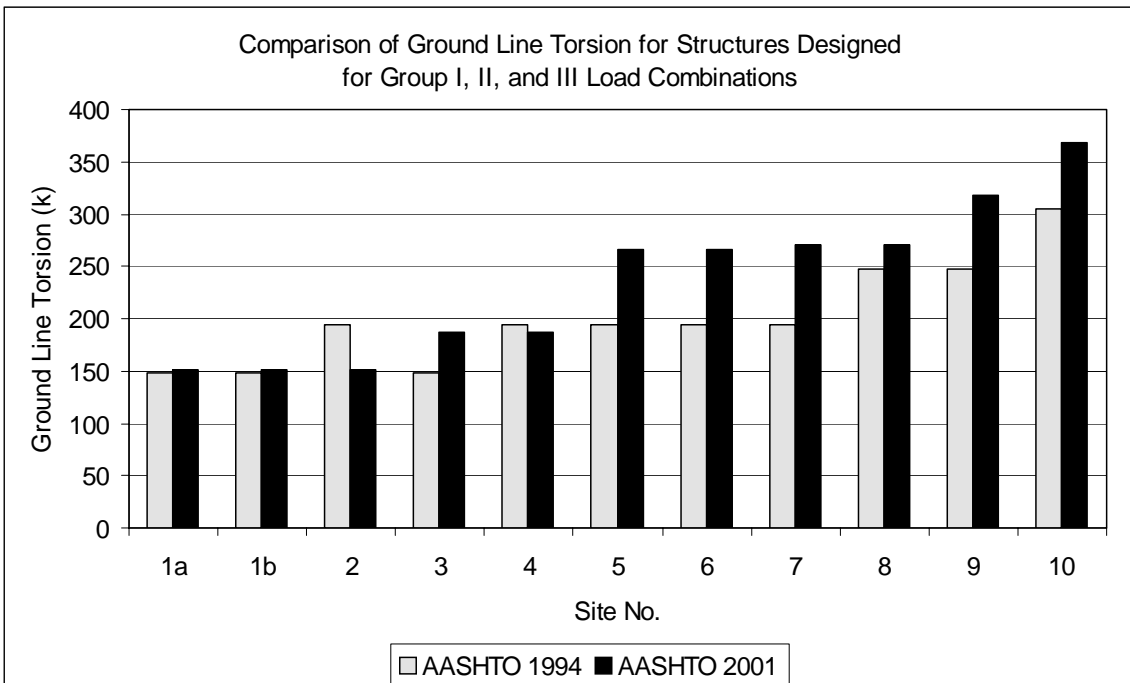


Figure 4-8. Comparison of ground line torsion for structures designed for group I, II, and III load combinations

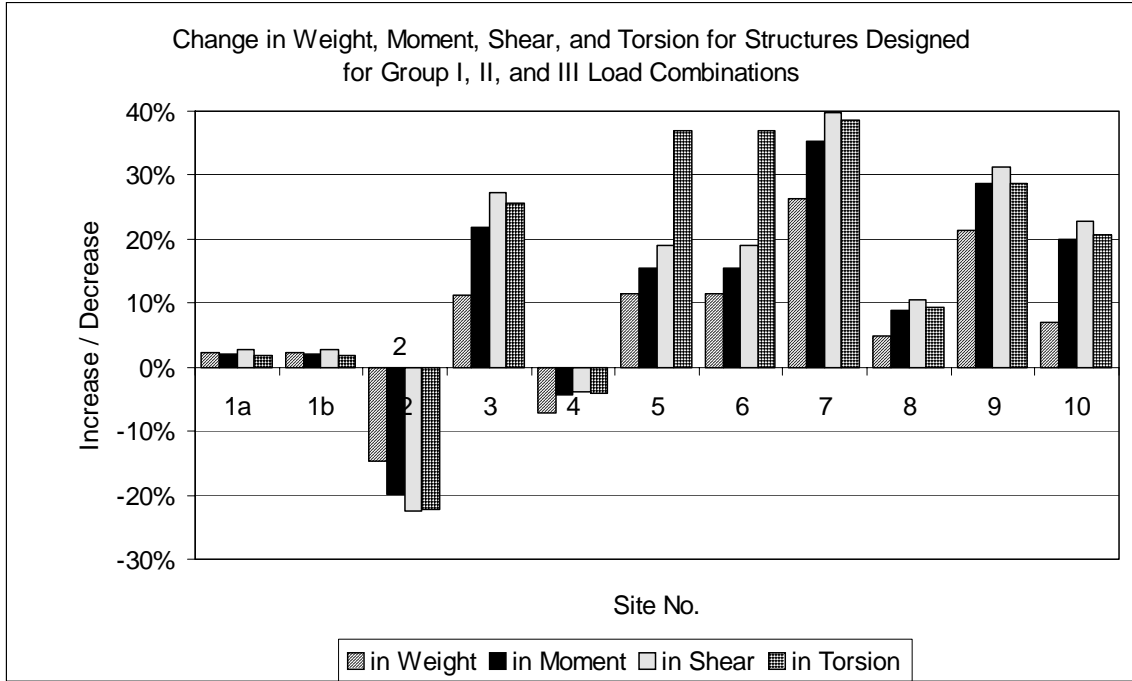


Figure 4-9. Change in weight, moment, shear, and torsion for structures designed for group I, II, and III load combinations

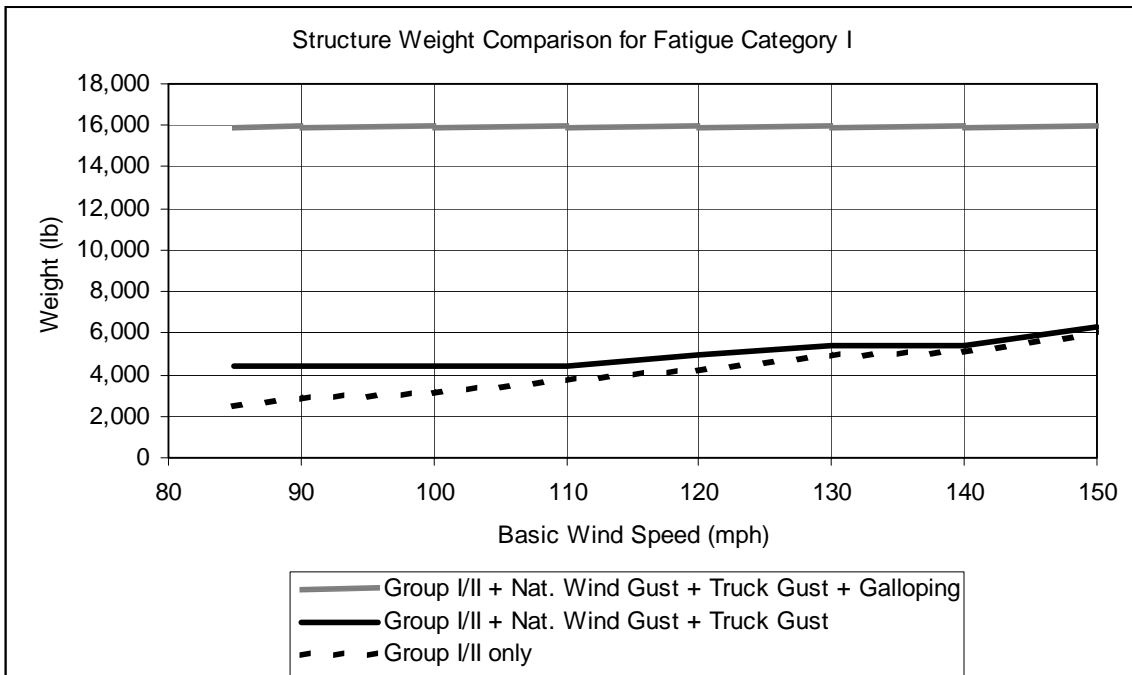


Figure 4-10. Structure weight comparison for fatigue category I for 2001 specifications

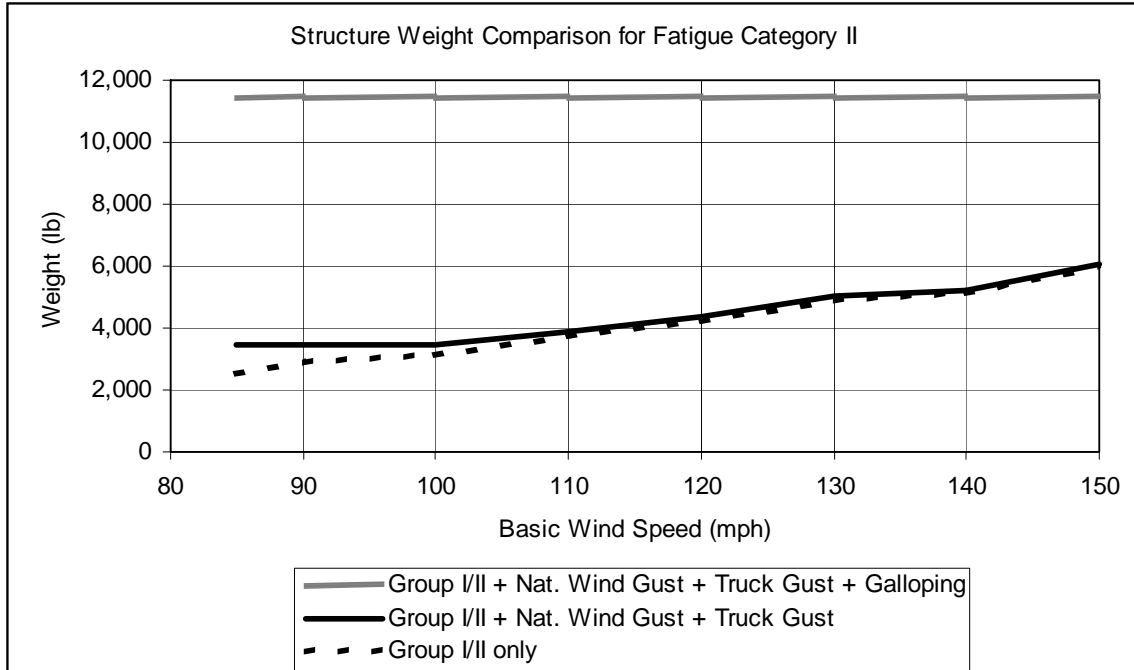


Figure 4-11. Structure weight comparison for fatigue category II for 2001 specifications

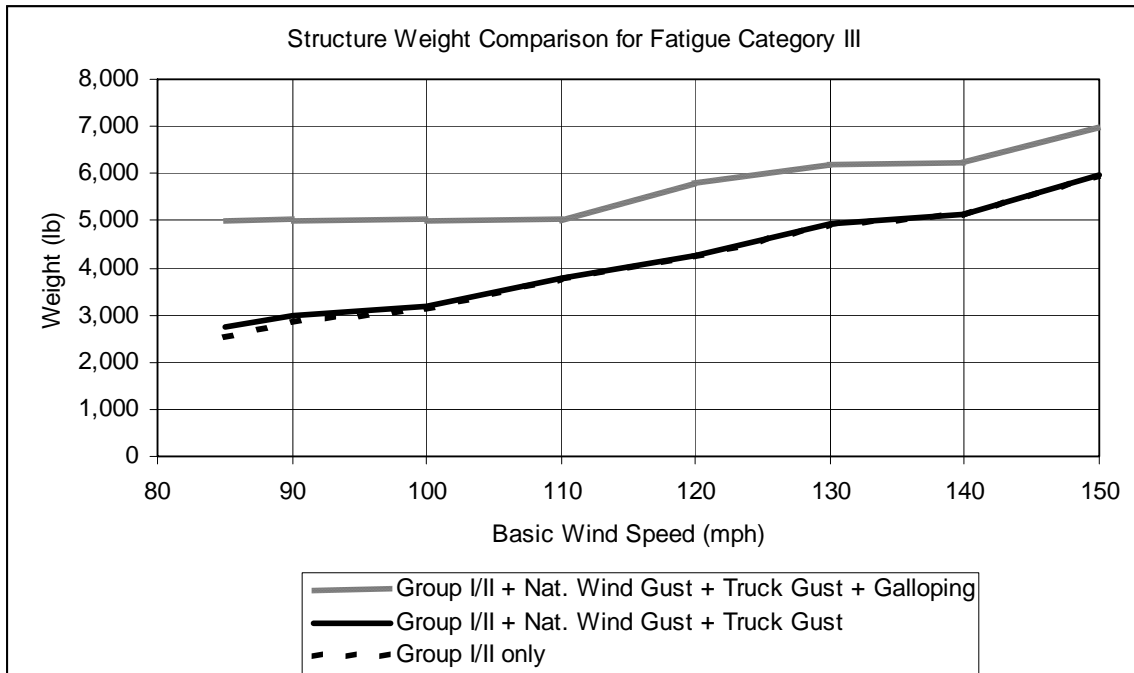


Figure 4-12. Structure weight comparison for fatigue category III for 2001 specifications

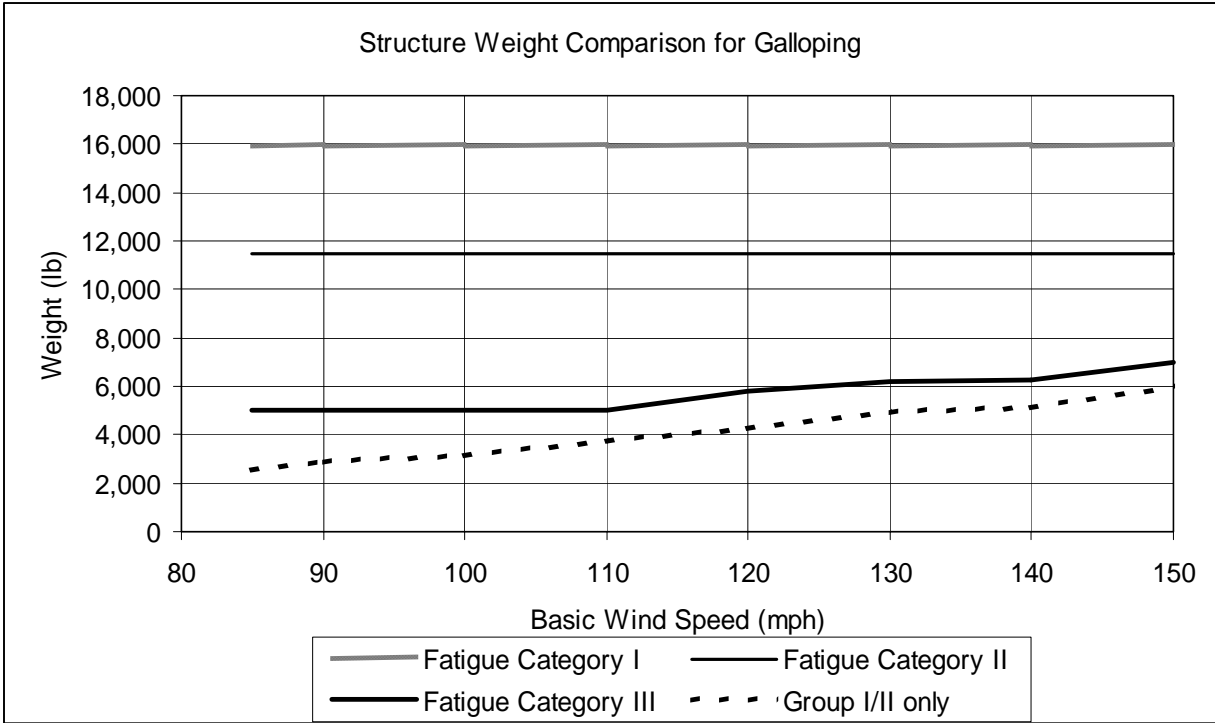


Figure 4-13. Structure weight comparison for galloping fatigue criteria for 2001 specifications

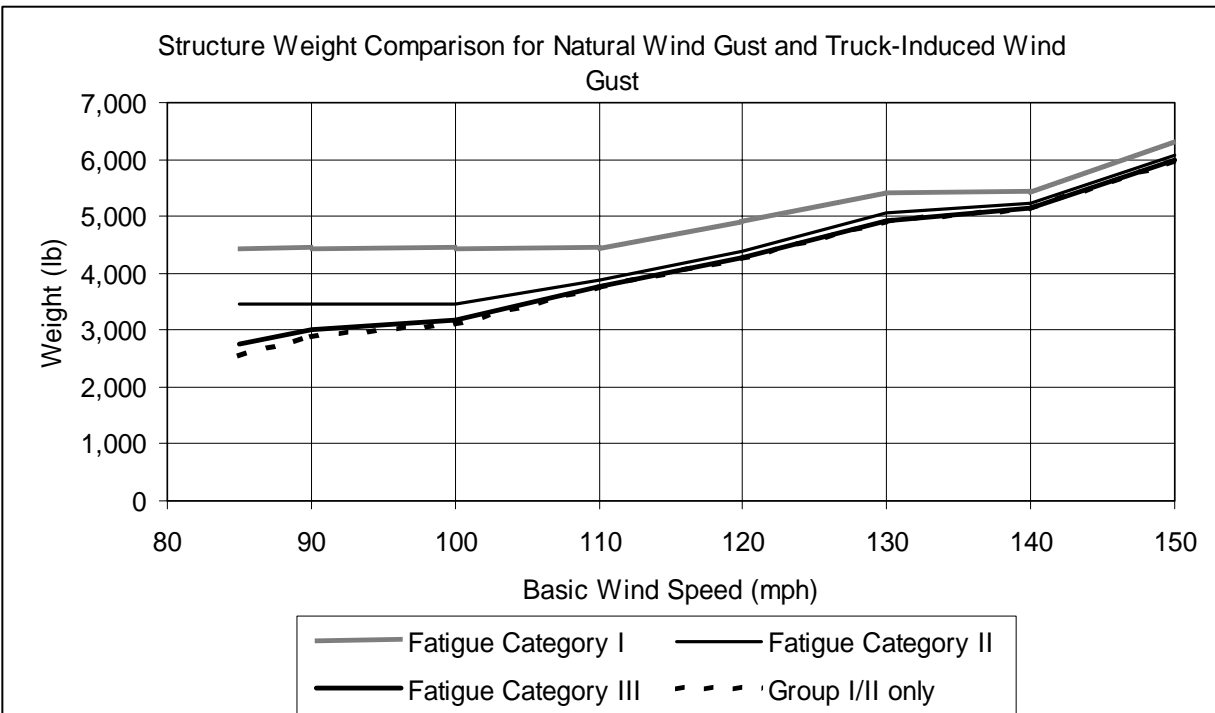


Figure 4-14. Structure weight comparison for natural wind gust and truck-induced wind gust fatigue criteria for 2001 specifications

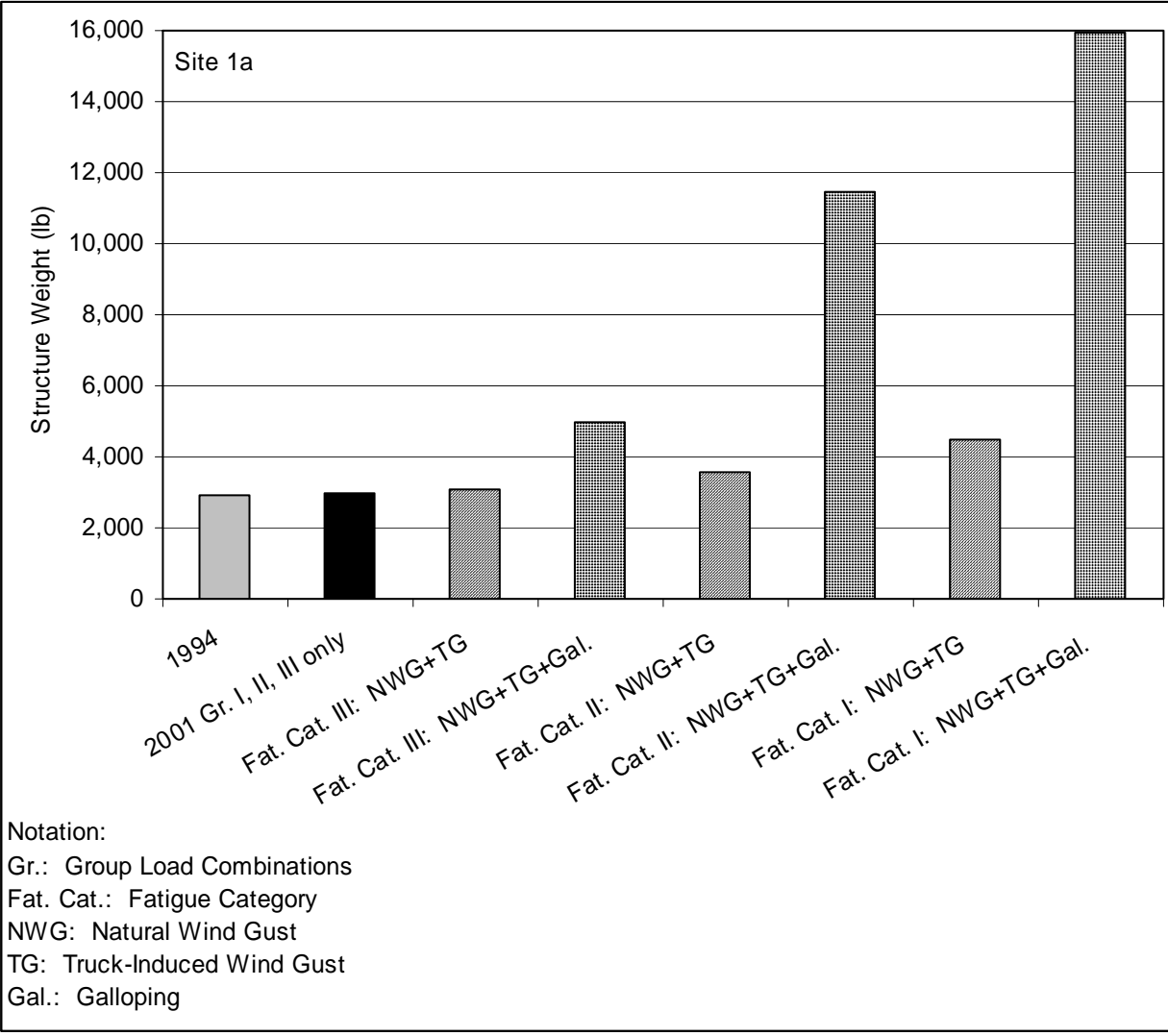


Figure 4-15. Structure weight comparison for site no. 1a

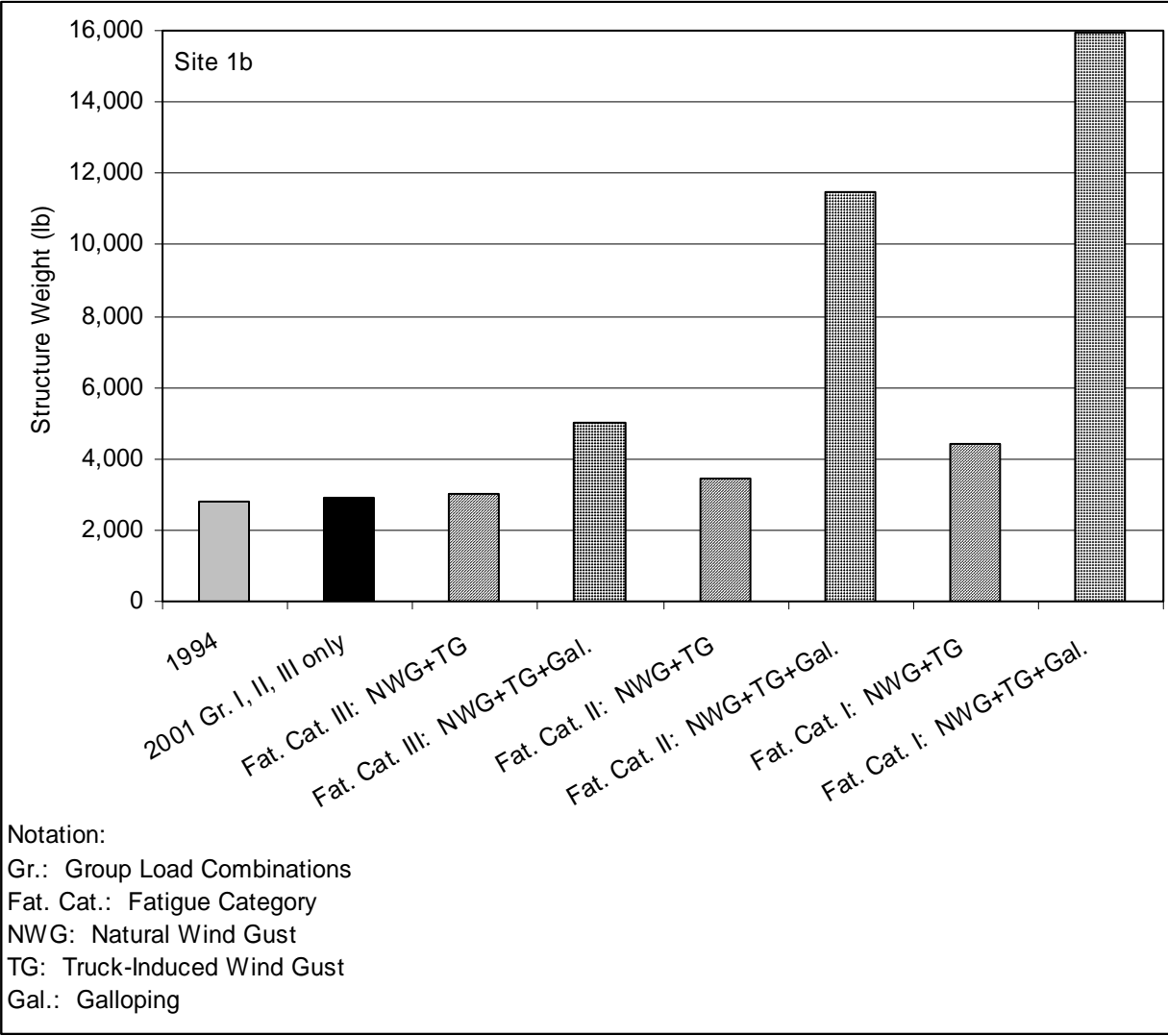


Figure 4-16. Structure weight comparison for site no. 1b

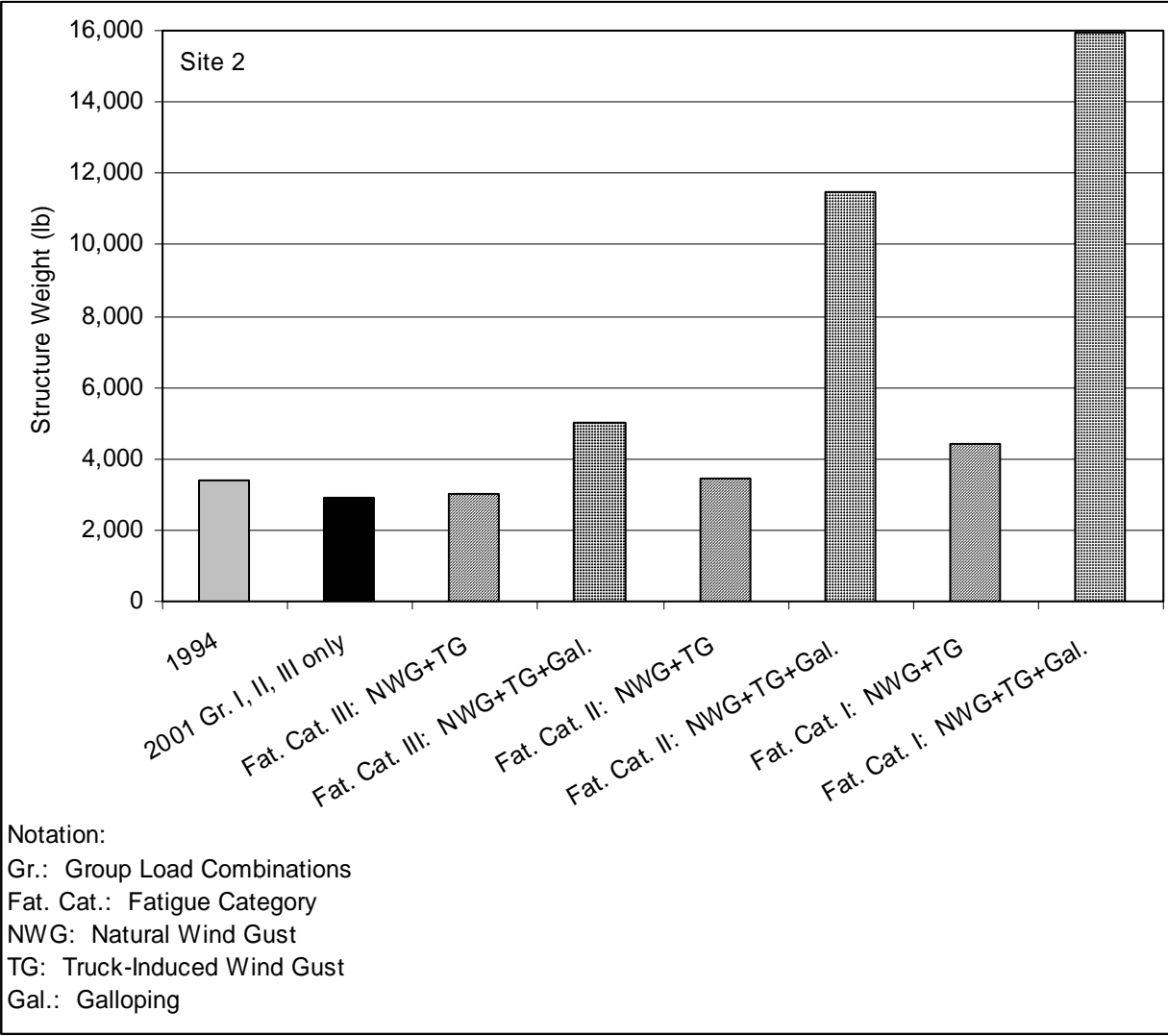


Figure 4-17. Structure weight comparison for site no. 2

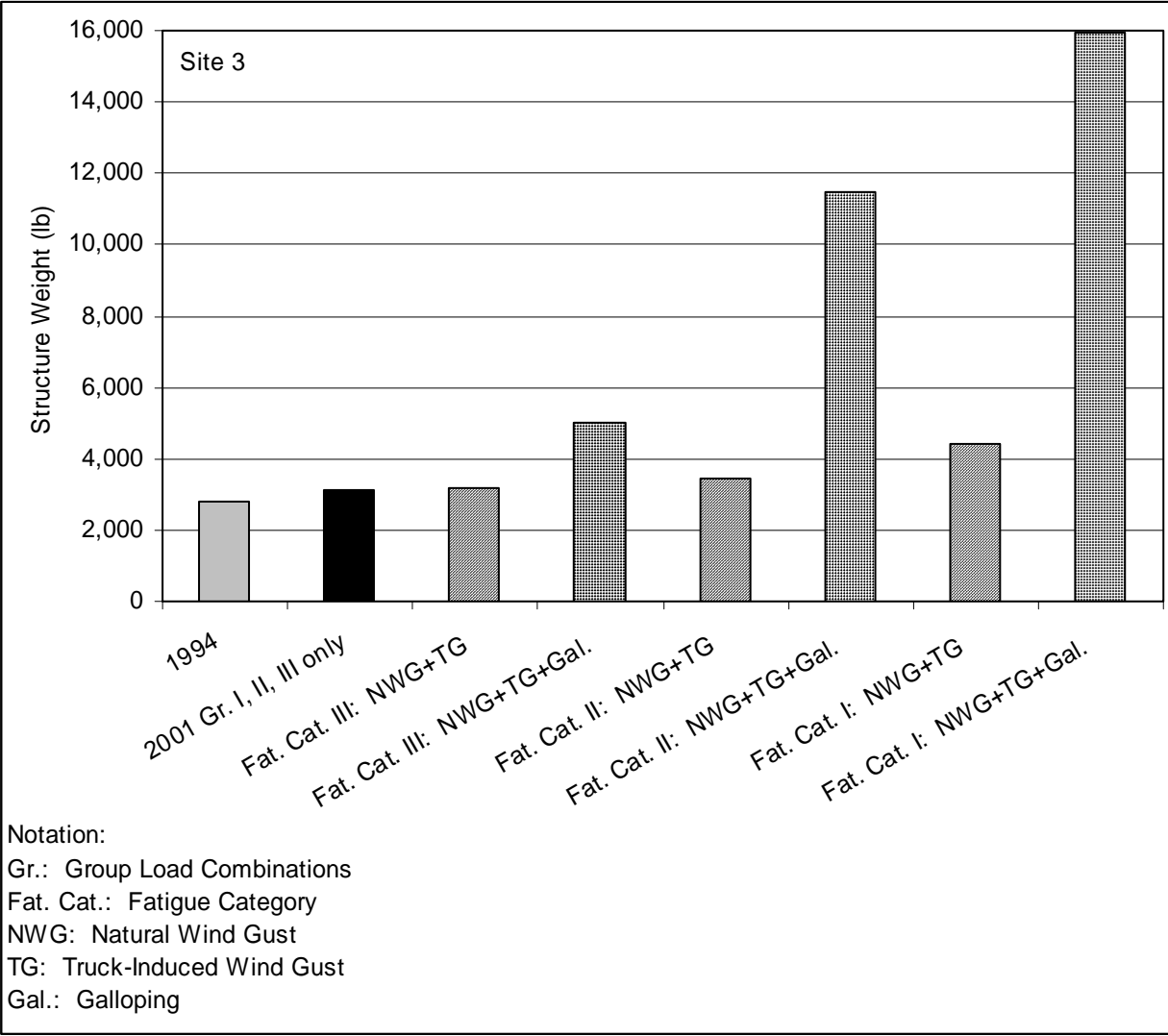


Figure 4-18. Structure weight comparison for site no. 3

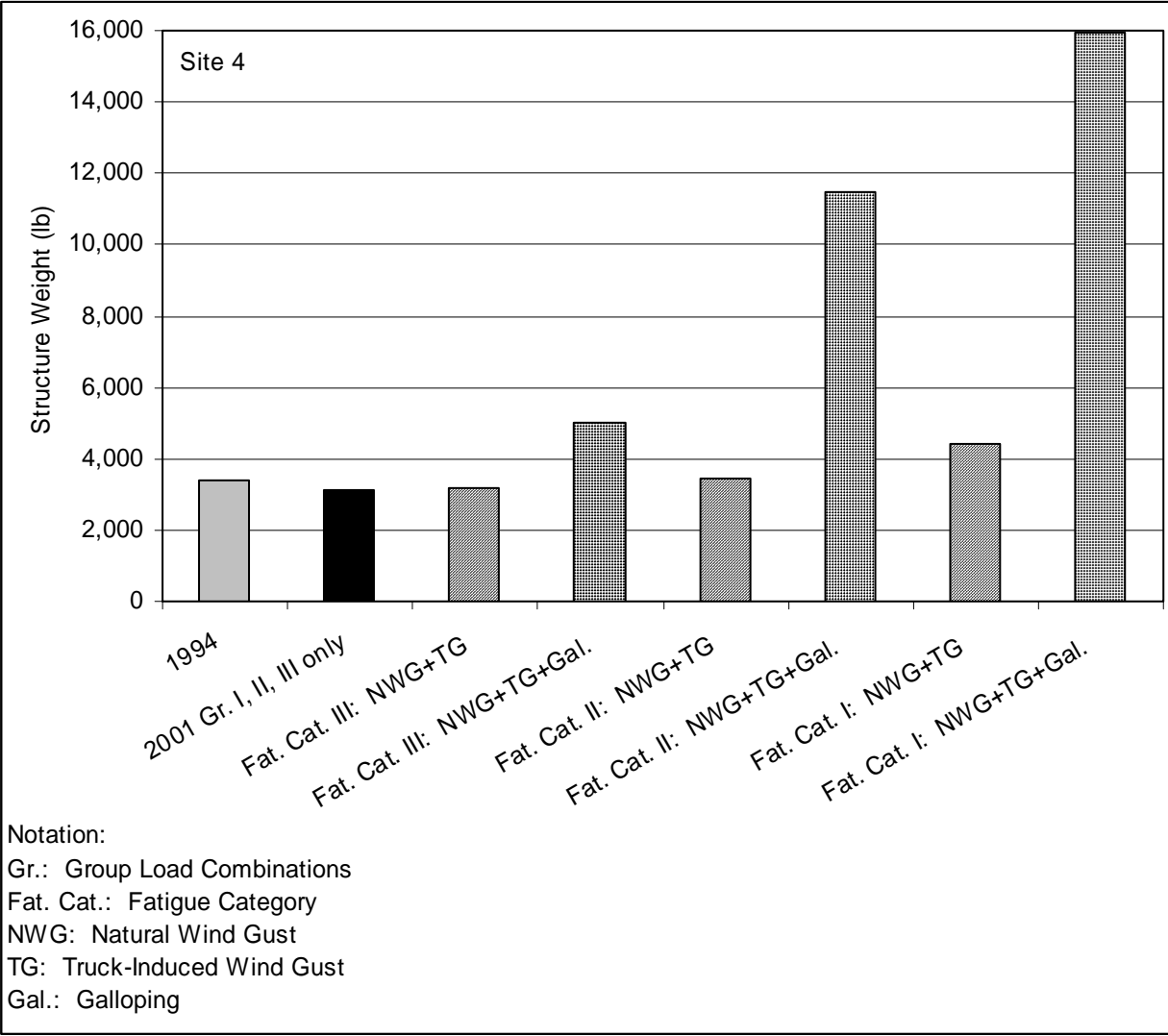


Figure 4-19. Structure weight comparison for site no. 4

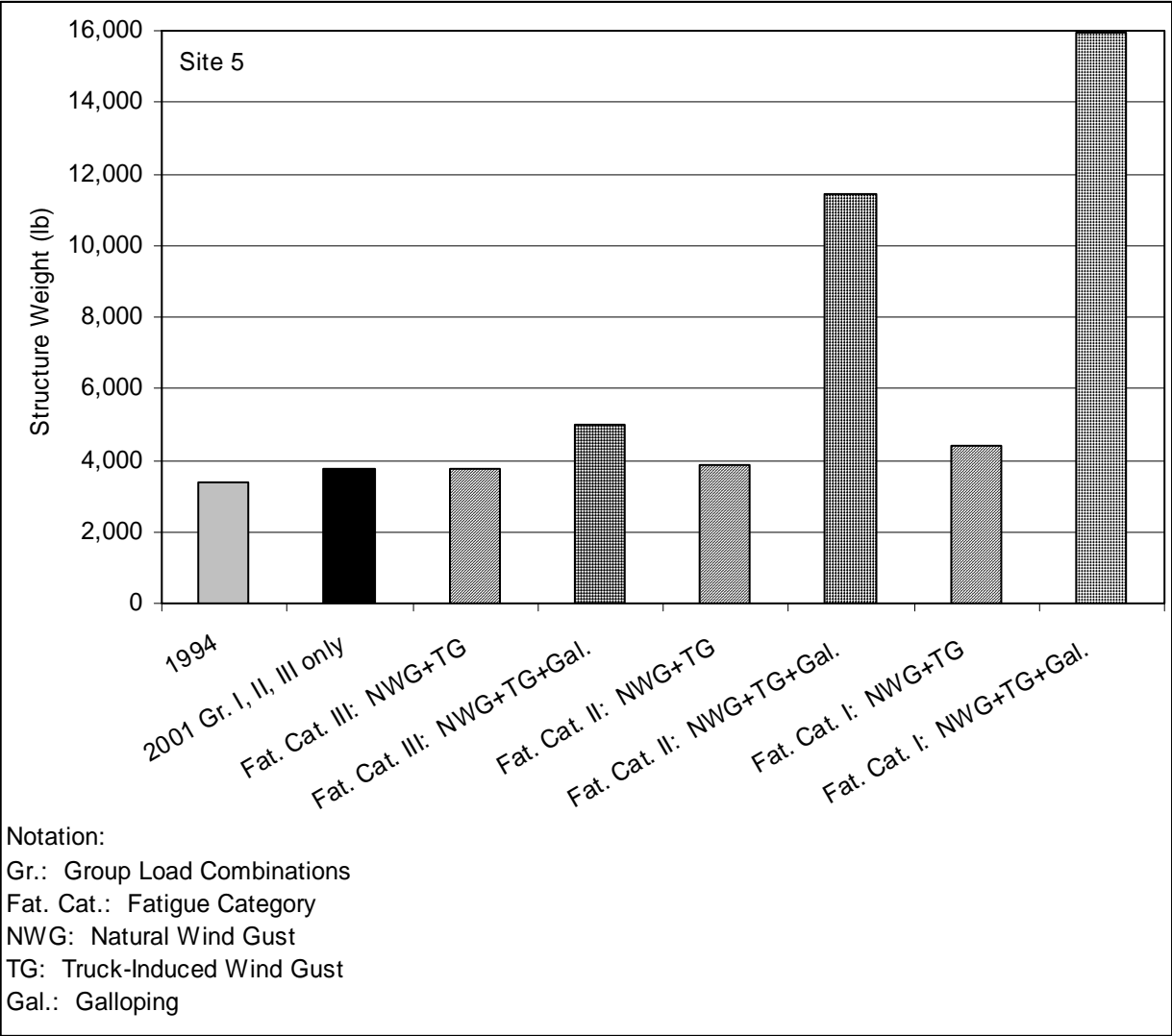


Figure 4-20. Structure weight comparison for site no. 5

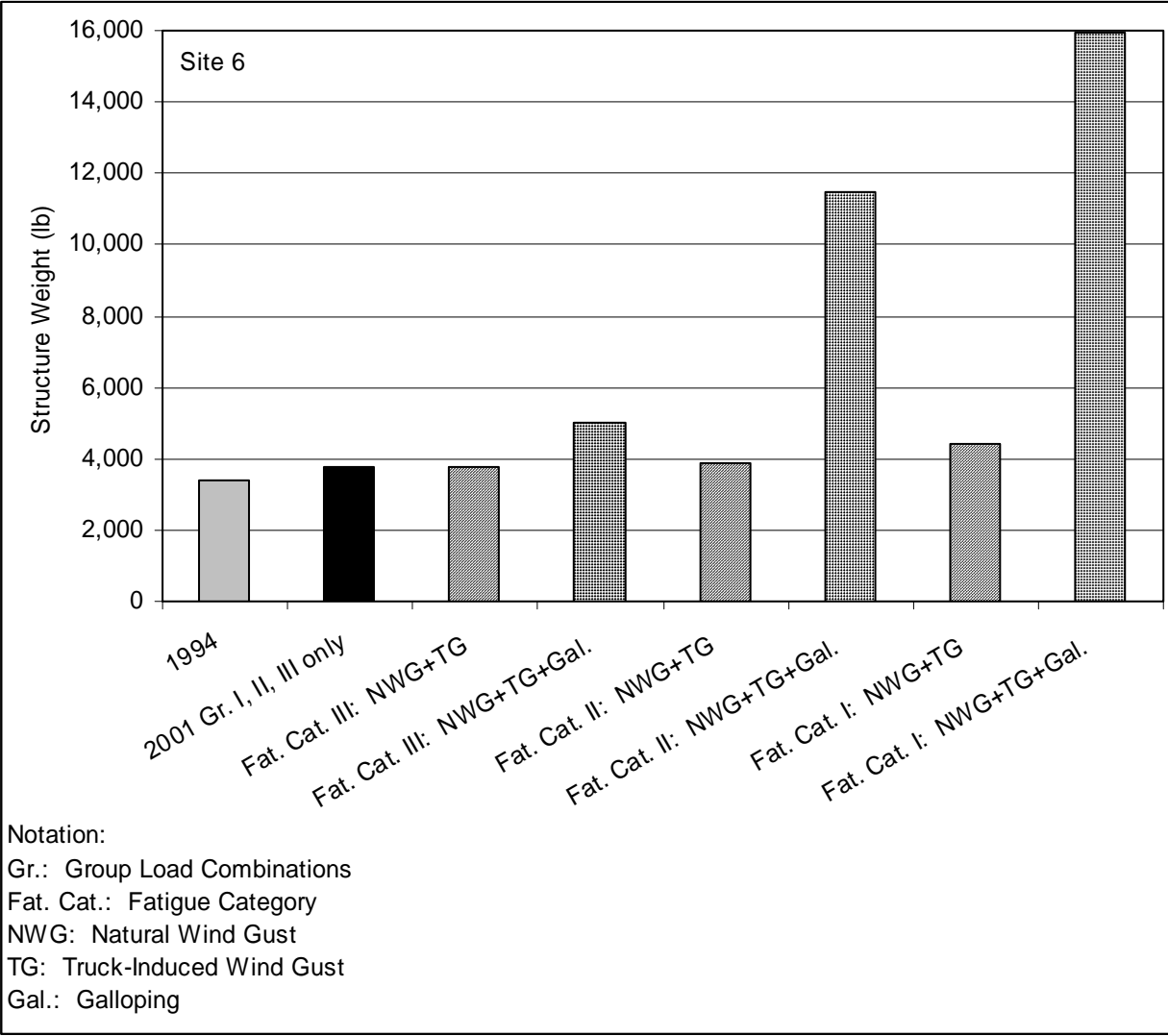


Figure 4-21. Structure weight comparison for site no. 6

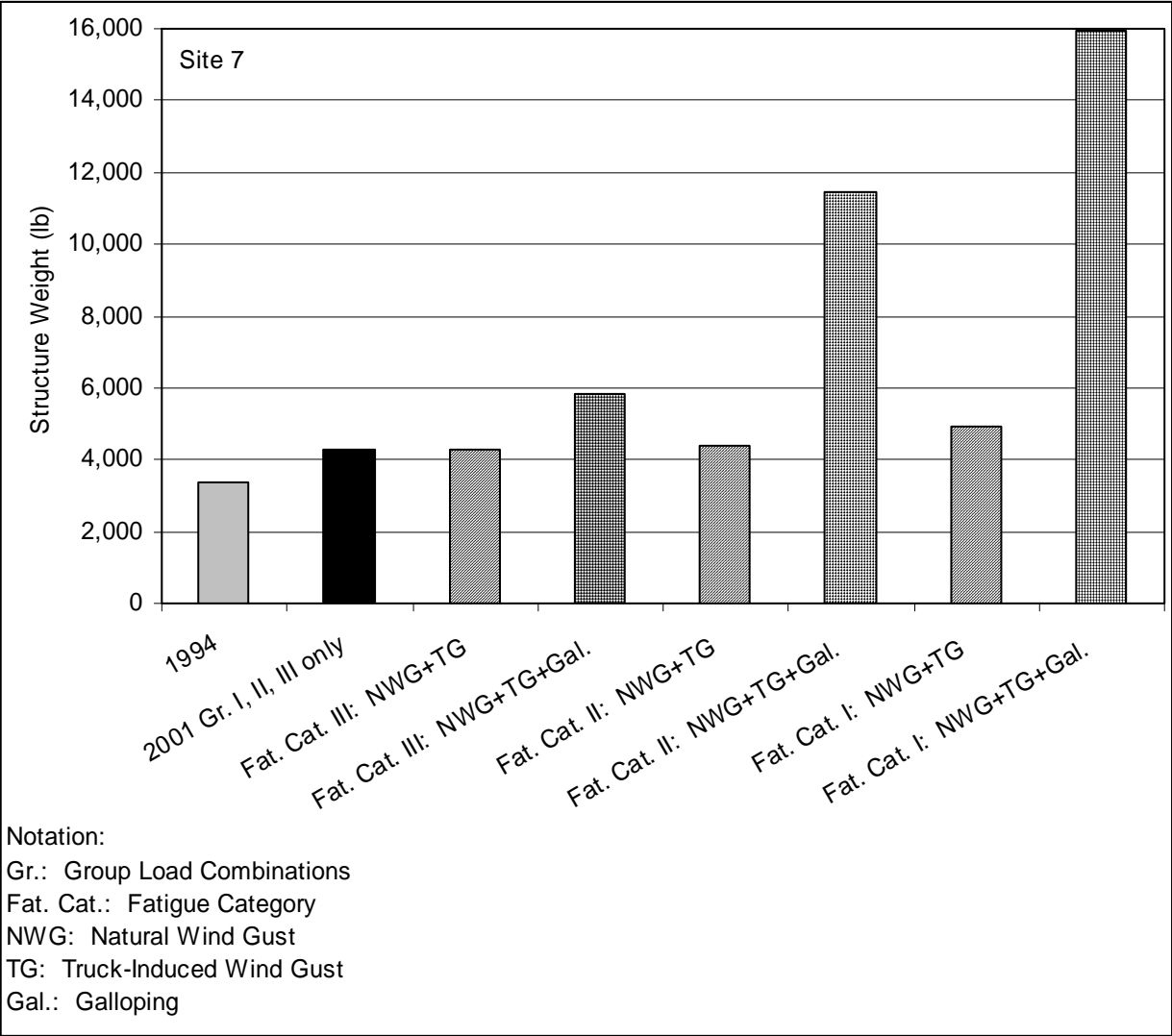


Figure 4-22. Structure weight comparison for site no. 7

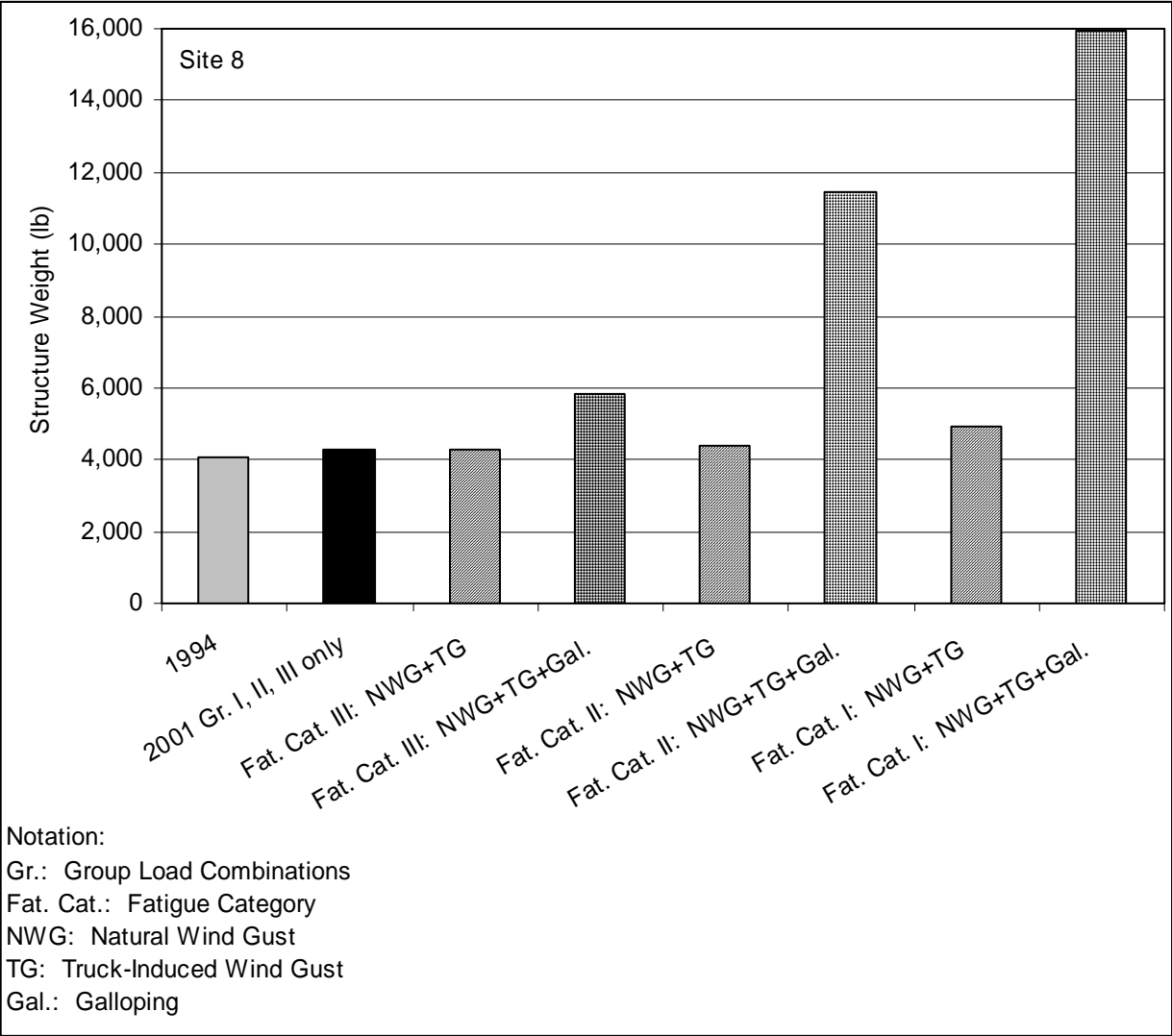


Figure 4-23. Structure weight comparison for site no. 8

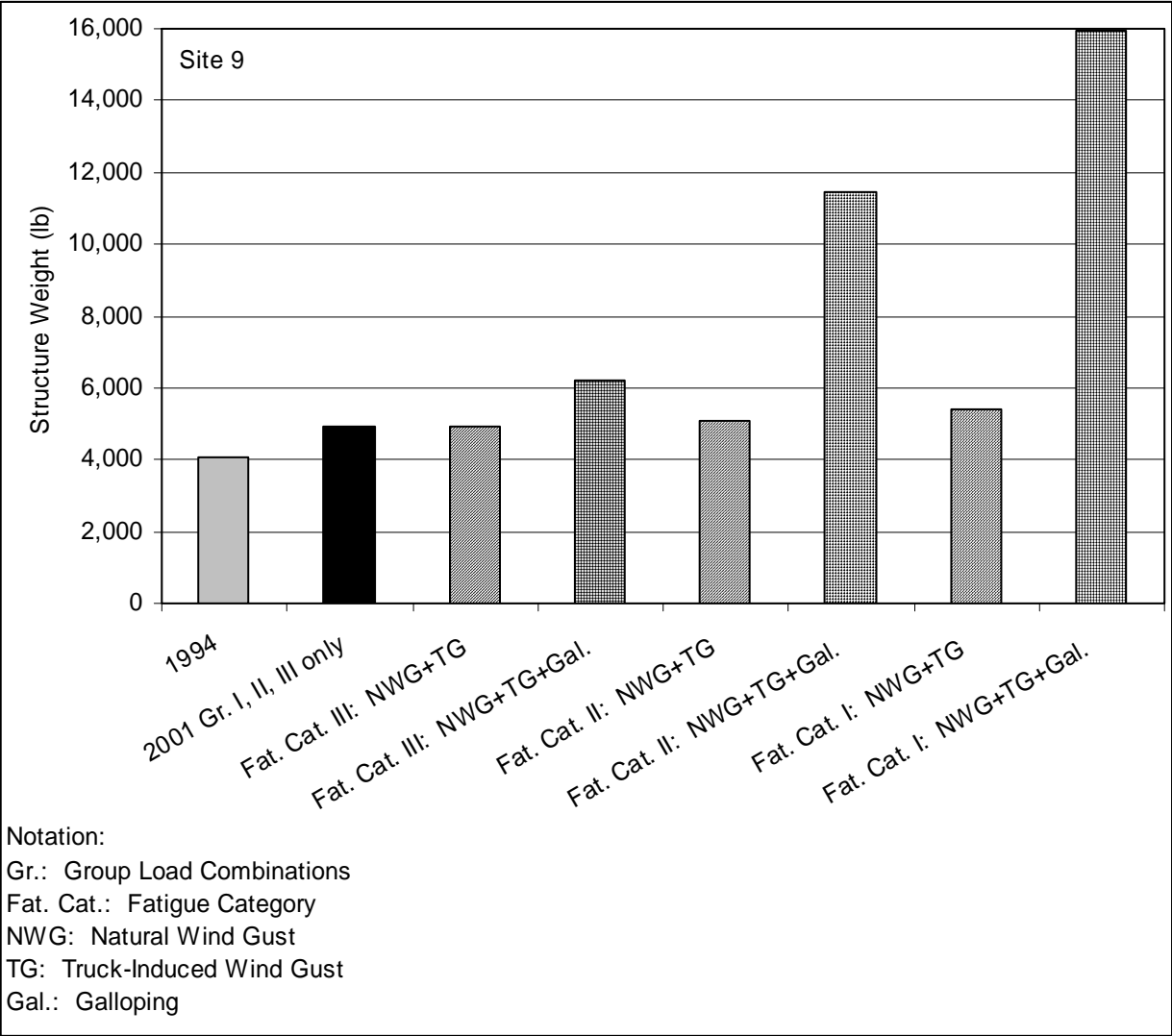


Figure 4-24. Structure weight comparison for site no. 9

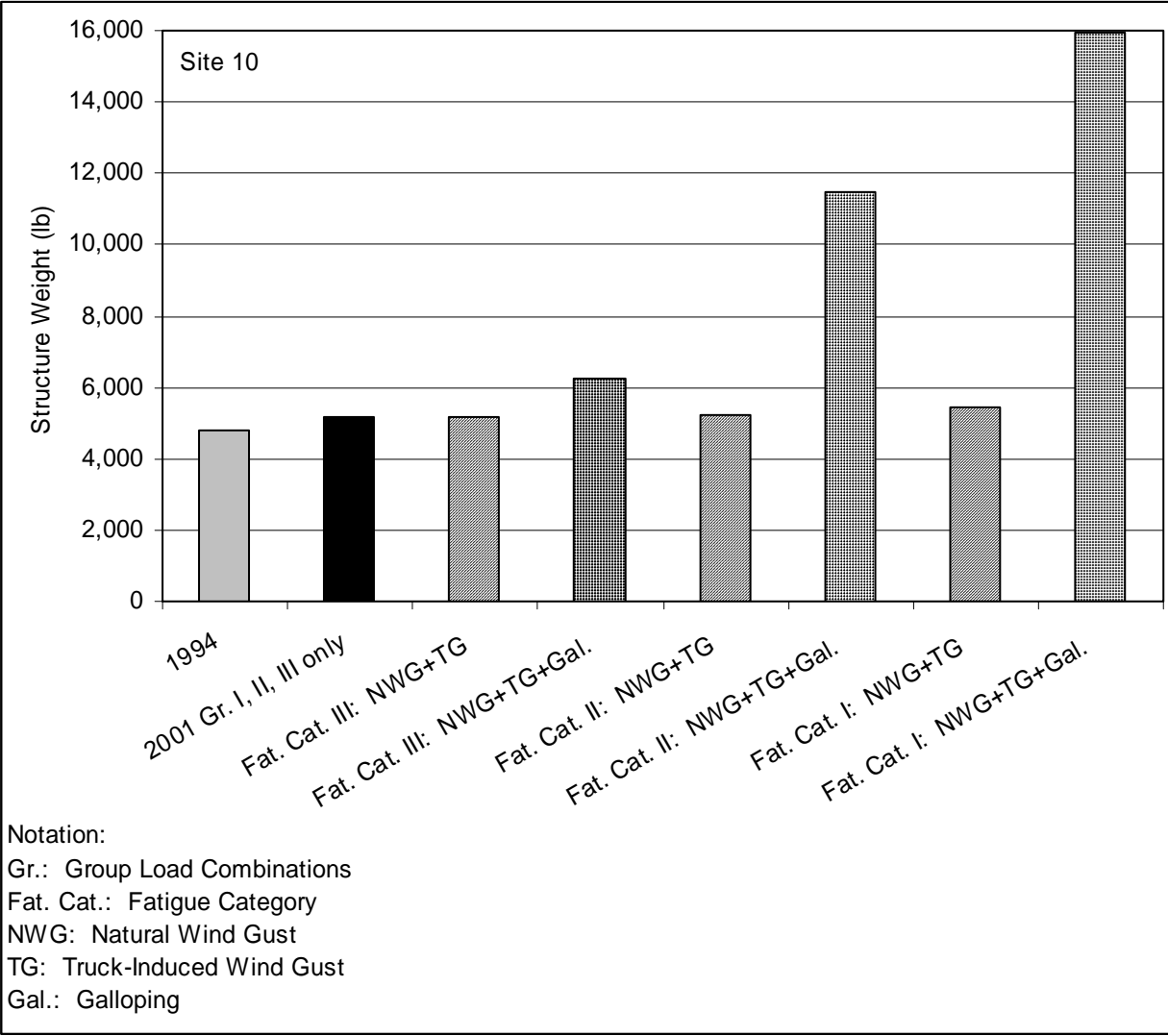


Figure 4-25. Structure weight comparison for site no. 10

Section 10

References to Technical Appendix

The appendices to this report have been published as a companion document, UTCA Report 02216-1, "Technical Appendix: AASHTO 2001 Design of Overhead Cantilevered Sign Supports." Within that document, Appendix A contains input and output files for the 1994 specifications version of SABRE, and Appendix B contains input and output files for the 2001 specifications version of SABRE.

An electronic copy of the Technical Appendix may be obtained by emailing Dr. Fouad H. Fouad at ffouad@eng.uab.edu or Elizabeth Calvert at bcalvert@bellsouth.net. A request can also be made to Dr. Fouad H. Fouad, The University of Alabama at Birmingham, Department of Civil and Environmental Engineering, 140 Hoehn Building, 1075 13 Street South, Birmingham, Alabama 35294-4440.