SECTION 3
LOADS

Part A
Type of Loads

3.1 NOTATIONS

A = maximum expected acceleration of bed rock at the site

a = length of short span of slab (Article 3.24.6)

B = buoyancy (Article 3.22)

b = width of pier or diameter of pile (Article 3.18.2.2.4)

b = length of long span of slab (Article 3.24.6)

C = combined response coefficient

C = stiffness parameter = K(W/L) (Article 3.23.4.3)

C = centrifugal force in percent of live load (Article 3.10.1)

CF = centrifugal force (Article 3.22)

C_n = coefficient for nose inclination (Article 3.18.2.2.1)

C_M = steel bending stress coefficient (Article 3.25.1.5)

C_R = steel shear stress coefficient (Article 3.25.1.5)

D = parameter used in determination of load fraction of wheel load (Article 3.23.4.3)

D = degree of curve (Article 3.10.1)

D = dead load (Article 3.22)

D.F. = fraction of wheel load applied to beam (Article 3.28.1)

DL = contribution dead load

E = width of slab over which a wheel load is distributed (Article 3.24.3)

E = earth pressure (Article 3.22)

EQ = equivalent static horizontal force applied at the center of gravity of the structure

E_c = modulus of elasticity of concrete (Article 3.26.3)

E_s = modulus of elasticity of steel (Article 3.26.3)

E_w = modulus of elasticity of wood (Article 3.26.3)

F = horizontal ice force on pier (Article 3.18.2.2.1)

\+ F = framing factor

F_b = allowable bending stress (Article 3.25.1.3)

F_v = allowable shear stress (Article 3.25.1.3)

g = 32.2 ft./sec.^{2}

I = impact fraction (Article 3.8.2)

ICE = ice pressure (Article 3.22)

J = gross Saint-Venant torsional constant of the precast member (Article 3.23.4.3)

K = stream flow force constant (Article 3.18.1)

K = stiffness constant (Article 3.23.4)

K = wheel load distribution constant for timber flooring (Article 3.25.1.3)

k = live load distribution constant for spread box girders (Article 3.28.1)

L = loaded length of span (Article 3.8.2)

L = load length of sidewalk (Article 3.14.1.1)

L = live load (Article 3.22)

L = span length (Article 3.23.4)

LF = longitudinal force from live load (Article 3.22)

M_D = moment capacity of dowel (Article 3.25.1.4)

M_x = primary bending moment (Article 3.25.1.3)

$\overline{M}_y$ = total transferred secondary moment (Article 3.25.1.4)

N_B = number of beams (Article 3.28.1)

N_L = number of traffic lanes (Article 3.23.4)

n = number of dowels (Article 3.25.1.4)

P = live load on sidewalk (Article 3.14.1.1)

P = stream flow pressure (Article 3.18.1)

P = total uniform force required to cause unit horizontal deflection of whole structure

P = load on one rear wheel of truck (Article 3.24.3)

P = wheel load (Article 3.24.5)

P = design wheel load (Article 3.25.1)

P_{15} = 12,000 pounds (Article 3.24.3)

P_{20} = 16,000 pounds (Article 3.24.3)

p = effective ice strength (Article 3.18.2.2.1)

p = proportion of load carried by short span (Article 3.24.6.1)

R = radius of curve (Article 3.10.1)

R = normalized rock response

R = rib shortening (Article 3.22)
R_D = shear capacity of dowel (Article 3.25.1.4)
R_x = primary shear (Article 3.25.1.3)
$\overline{R_y}$ = total secondary shear transferred (Article 3.25.1.4)
S = design speed (Article 3.10.1)
S = soil amplification spectral ratio
S = shrinkage (Article 3.22)
S = average stringer spacing (Article 3.23.2.3.1)
S = spacing of beams (Article 3.23.3)
S = parameter used in determining the load fraction to be applied to precast concrete beams (Article 3.23.4.3)
S = effective span length (Article 3.24.1)
S = span length (Article 3.24.8.2)
S = beam spacing (Article 3.28.1)
s = effective deck span (Article 3.25.1.3)
SF = stream flow (Article 3.22)
T = period of vibration
T = temperature (Article 3.22)
t = thickness of ice (Article 3.18.2.2.4)
t = deck thickness (Article 3.25.1.3)
V = variable spacing of truck axles (Figure 3.7.3A)
V = velocity of water (Article 3.18.1)
W = combined weight on the first two axles of a standard HS Truck (Figure 3.7.3A)
W = width of sidewalk (Article 3.14.1.1)
W = wind load on structure (Article 3.22)
W = total dead weight of the structure
W_e = width of exterior girder (Article 3.23.2.3.2)
W = overall width of bridge (Article 3.23.4.3)
W = roadway width between curbs (Article 3.28.1)
WL = wind load on live load (Article 3.22)
w = width of pier or diameter of circular-shaft pier at the level of ice action (Article 3.18.2.2.1)
X = distance from load to point of support (Article 3.24.5.1)
x = subscript denoting direction perpendicular to longitudinal stringers (Article 3.25.1.3)
Z = reduction for ductility and risk assessment
β = (with appropriate script) coefficient applied to loads for service load and load factor designs (Article 3.22)
γ = load factor (Article 3.22)
σ_{PL} = proportional limit stress perpendicular to grain (Article 3.25.1.4)
β_B = load combination coefficient for buoyancy (Article 3.22.1)
β_C = load combination coefficient for centrifugal force (Article 3.22.1)
β_D = load combination coefficient for dead load (Article 3.22.1)
β_E = load combination coefficient for earth pressure (Article 3.22.1)
β_{EQ} = load combination coefficient for earthquake (Article 3.22.1)
β_{ICE} = load combination coefficient for ice (Article 3.22.1)
β_L = load combination coefficient for live load (Article 3.22.1)
β_R = load combination coefficient for rib shortening, shrinkage and temperature (Article 3.22.1)
β_S = load combination coefficient for stream flow (Article 3.22.1)
β_W = load combination coefficient for wind (Article 3.22.1)
β_{WL} = load combination coefficient for wind on live load (Article 3.22.1)
μ = Poisson's ratio (Article 3.23.4.3)

3.2 GENERAL

3.2.1 Structures shall be designed to carry the following loads and forces:

Dead load.
Live load.
Impact or dynamic effect of the live load.
Wind loads.
Other forces, when they exist, as follows:
Longitudinal forces, centrifugal force, thermal forces, earth and drift pressure, buoyancy, shrinkage stresses, rib shortening, erection stresses, ice and current pressure, earthquake stresses, prestressing and friction forces. +

3.2.2 Members shall be proportioned using the allowable stresses permitted by the design procedure and the limitations imposed by the material. +

3.2.3 When stress sheets are required, a diagram or notation of the assumed loads shall be shown and the stresses due to the various loads shall be shown separately.

3.2.4 Where required by design conditions, the concrete placing sequence shall be indicated on the plans or in the special provisions.

3.2.5 The loading combination shall be in accordance with Article 3.22.

3.2.6 When a bridge is skewed, the loads and forces carried by the bridge through the deck system to pin connections and hangers should be resolved into vertical, lateral, and longitudinal force components to be considered in the design.

3.3 DEAD LOAD

3.3.1 The dead load shall consist of the weight of the entire structure, including the roadway, sidewalks, car tracks, pipes, conduits, cables, and other public utility services.

3.3.2 The snow and ice load is considered to be offset by an accompanying decrease in live load and impact and shall not be included except under special conditions.

3.3.2.1 If differential settlement is anticipated in a structure, consideration should be given to stresses resulting from this settlement.

3.3.3 If a separate wearing surface is to be placed when the bridge is constructed, or is expected to be placed in the future, adequate allowance shall be made for its weight in the design dead load.

3.3.4 Special consideration shall be given to the necessity for a separate wearing surface for those regions where the use of chains on tires or studded snow tires can be anticipated.

3.3.5 Where the abrasion of concrete is not expected, the traffic may bear directly on the concrete slab. If considered desirable, $^1/_4$ inch or more may be added to the slab for a wearing surface.

3.3.6 The following weights are to be used in computing the dead load:

	#/cu. ft
Steel or cast steel	490
Cast iron	450
Aluminum alloys	175
Timber (treated or untreated)	50
Concrete, plain or reinforced	150
Compacted sand, earth, gravel, or ballast	120
Loose sand, earth, and gravel	100
Macadam or gravel, rolled	140
Cinder filling	60
Pavement, other than wood block	150
Railway rails, guard rails, and fastenings (per linear foot of track)	200
Stone masonry	170
Asphalt plank, 1 in. thick	9 lb. sq. ft.

3.4 LIVE LOAD

The live load shall consist of the weight of the applied moving load of vehicles, cars, and pedestrians.

3.5 OVERLOAD PROVISIONS

Structures which carry vehicular traffic shall be analyzed for overloads that are represented by P loads as described in Article 3.7, and other specific loads where applicable. Application shall be in accordance with Article 3.22.

3.6 TRAFFIC LANES

3.6.1 The lane loading or standard truck shall be assumed to occupy a width of 10 feet.

3.6.2 The loads shall be placed in 12-foot wide design traffic lanes, spaced across the entire bridge roadway width measured between curbs.

3.6.3 Fractional parts of design lanes shall not be used, but roadway widths from 20 to 24 feet shall have two design lanes each equal to one-half the roadway width.

3.6.4 The traffic lanes shall be placed in such numbers and positions on the roadway, and the loads shall be placed in such positions within their individual traffic lanes, so as to produce the maximum stress in the member under consideration.

3.6.5 These provisions shall not apply to those superstructure members for which wheel load application without regard to placement in traffic lanes is specified in Articles 3.23 thru 3.28, 6.4 and 10.39.

3.7 HIGHWAY LOADS

3.7.1 Standard Truck and Lane Loads*

3.7.1.1 The highway live loadings on the roadways of bridges or incidental structures shall consist of standard trucks or lane loads that are equivalent to truck trains. Three systems of loading are provided. The H loadings and the HS loadings-the HS loadings being heavier than the corresponding H loadings and P loads based on permit vehicles for regulation of overloads.

3.7.1.2 Each lane load shall consist of a uniform load per linear foot of traffic lane combined with a single concentrated load (or two concentrated loads in the case of continuous spans-see Article 3.11.3), so placed on the span as to produce maximum stress. The concentrated load and uniform load shall be considered as uniformly distributed over a 10 foot width on a line normal to the centerline of the lane.

3.7.1.3 For the computation of moments and shears, different concentrated loads shall be used as indicated in Figure 3.7.6B. The lighter concentrated loads shall be used when the stresses are primarily bending stresses, and the heavier concentrated loads shall be used when the stresses are primarily shearing stresses.

3.7.2 Classes of Loading

There are four standard classes of highway loading: H 20, H 15, HS 20, and HS 15. Loading H 15 is 75 percent of loading H 20. Loading HS 15 is 75 percent of Loading HS 20. If loadings other than those designated are desired, they shall be obtained by proportionately changing the weights shown for both the standard truck and the corresponding lane loads.

*Note: The system of lane loads defined here (and illustrated in Figure 3.7.6.B) was developed in order to give a simpler method of calculating moments and shears than that based on wheel loads of the truck.

Appendix B shows the truck train loadings of the 1935 Specifications of AASHTO and the corresponding lane loadings.

In 1944, the HS series of trucks was developed. These approximate the effect of the corresponding 1935 truck preceded and followed by a train of trucks weighing three-fourths as much as the basic truck.

3.7.3 Designation of Loadings

The policy of affixing the year to loadings to identify them was instituted with the publication of the 1944 edition in the following manner:

H 15 Loading, 1944 Edition shall be
designated .... H 15-44
H 20 Loading, 1944 Edition shall be
designated .... H 20-44
H 15-S 12 Loading, 1944 Edition shall be
designated .... HS 15-44
H 20-S 16 Loading, 1944 Edition shall be
designated .... HS 20-44

The affix shall remain unchanged until such time as the loading specification is revised. The same policy for identification shall be applied, for future reference, to loadings previously adopted by the American Association of State Highway and Transportation Officials.

3.7.4 Minimum Loading

Bridges shall be designed for HS 20-44 loading or an Alternate Military Loading of two axles four feet apart with each axle weighing 24,000 pounds, whichever produces the greatest stress.

Transverse Reinforced Slabs shall be designed with a single 32k axle.

3.7.5 H Loading

The H loadings consist of a two-axle truck or the corresponding lane loading as illustrated in Figures 3.7.6A and 3.7.6B. The H loadings are designated H followed by a number indicating the gross weight in tons of the standard truck.

3.7.6 HS Loading

The HS loadings consist of a tractor truck with semitrailer or the corresponding lane load as illustrated in Figures 3.7.7A and 3.7.6B. The HS loadings are designated by the letters HS followed by a number indicating the gross weight in tons of the tractor truck. The variable axle spacing has been introduced in order that the spacing of axles may approximate more closely the tractor trailers now in use. The variable spacing also provides a more

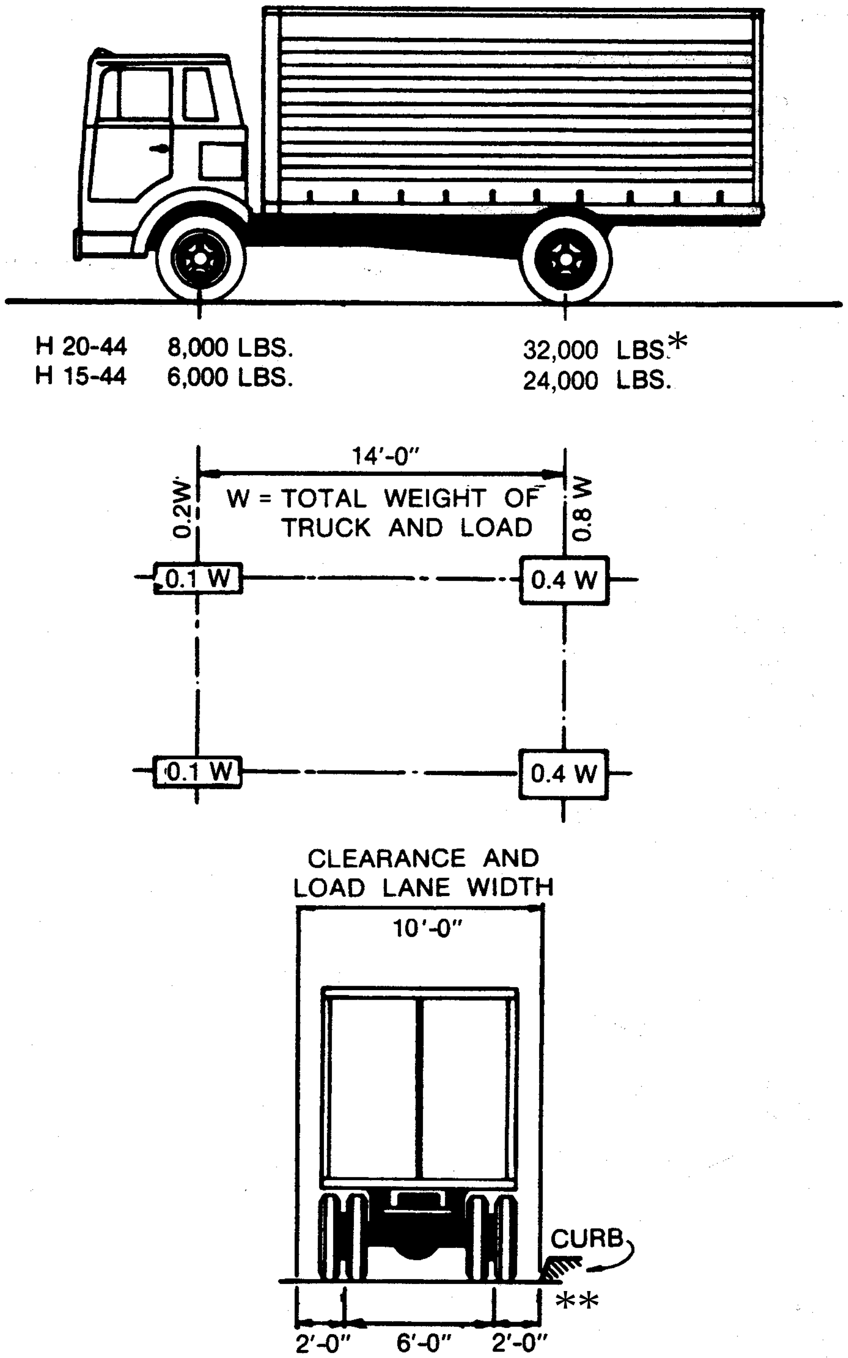

FIGURE 3.7.6A Standard H Trucks

* In the design of timber floors and orthotropic steel decks (excluding transverse beams) for H 20 loading, one axle load of 24,000 pounds or two axle loads of 16,000 pounds each spaced 4 feet apart may be used, whichever produces the greater stress, instead of the 32,000-pound axle shown.

** For slab design, the center line of wheels shall be assumed to be 1 foot from face of curb. (See Article 3.24.2)

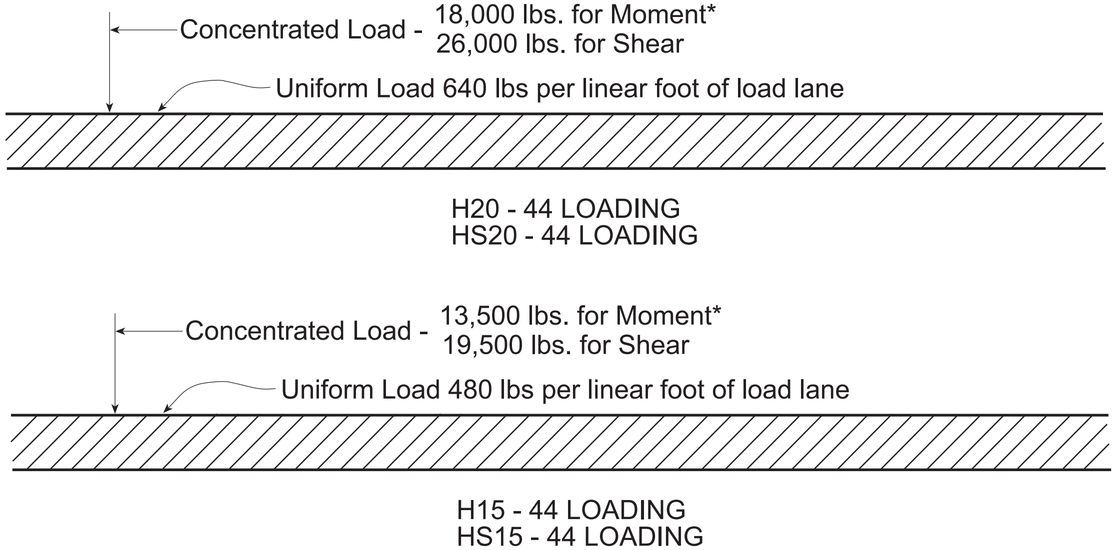

FIGURE 3.7.6B Lane Loading

* For the loading of continuous spans involving lane loading refer to Article 3.11.3 which provides for an additional concentrated load.

satisfactory loading for continuous spans, in that heavy axle loads may be so placed on adjoining spans as to produce maximum negative moments.

3.7.7 P Loading

P loads (permit design live loads) are special vehicular loads that shall be applied at the factored level in Load Factor Design and at service level for fatigue considerations in steel structures. See Figure 3.7.7B.

3.8 IMPACT

3.8.1 Application

Highway live loads shall be increased for those structural elements in Group A, below, to allow for dynamic, vibratory and impact effects. Impact allowances shall not be applied to items in Group B. It is intended that impact be included as part of the loads transferred from superstructure to substructure, but shall not be included in loads transferred to footings nor to those parts of piles or columns that are below ground.

3.8.1.1 Group A-Impact Shall be Included

(1) Superstructure, including legs of rigid frames.
(2) Piers, (with or without bearings regardless of type) excluding footings and those portions below the ground line.
(3) The portions above the ground line of concrete or steel piles that support the superstructure.

3.8.1.2 Group B-Impact Shall Not be Included

(1) Abutments, retaining walls, piers, piles, except as specified in 3.8.1.1 (3).
(2) Foundation pressures and footings.
(3) Timber structures.
(4) Sidewalk loads.
(5) Culverts and structures having 3 feet or more cover.

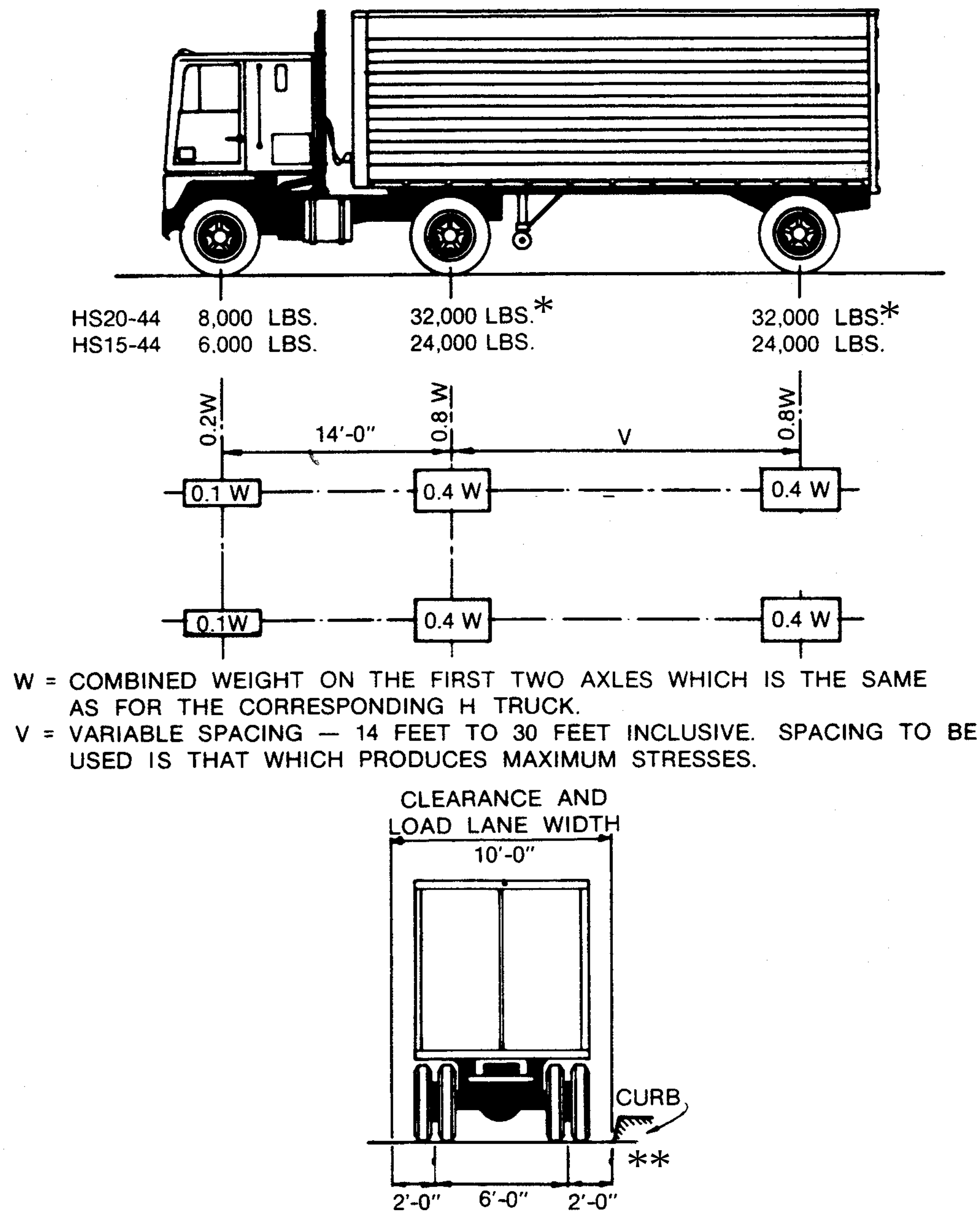

FIGURE 3.7.7A Standard HS Trucks

* In the design of timber floors and orthotropic steel decks (excluding transverse beams) for H 20 loading, one axle load of 24,000 pounds or two axle loads of 16,000 pounds each spaced 4 feet apart may be used, whichever produces the greater stress, instead of the 32,000-pound axle shown.

** For slab design, the center line of wheels shall be assumed to be 1 foot from face of curb. (See Article 3.24.2)

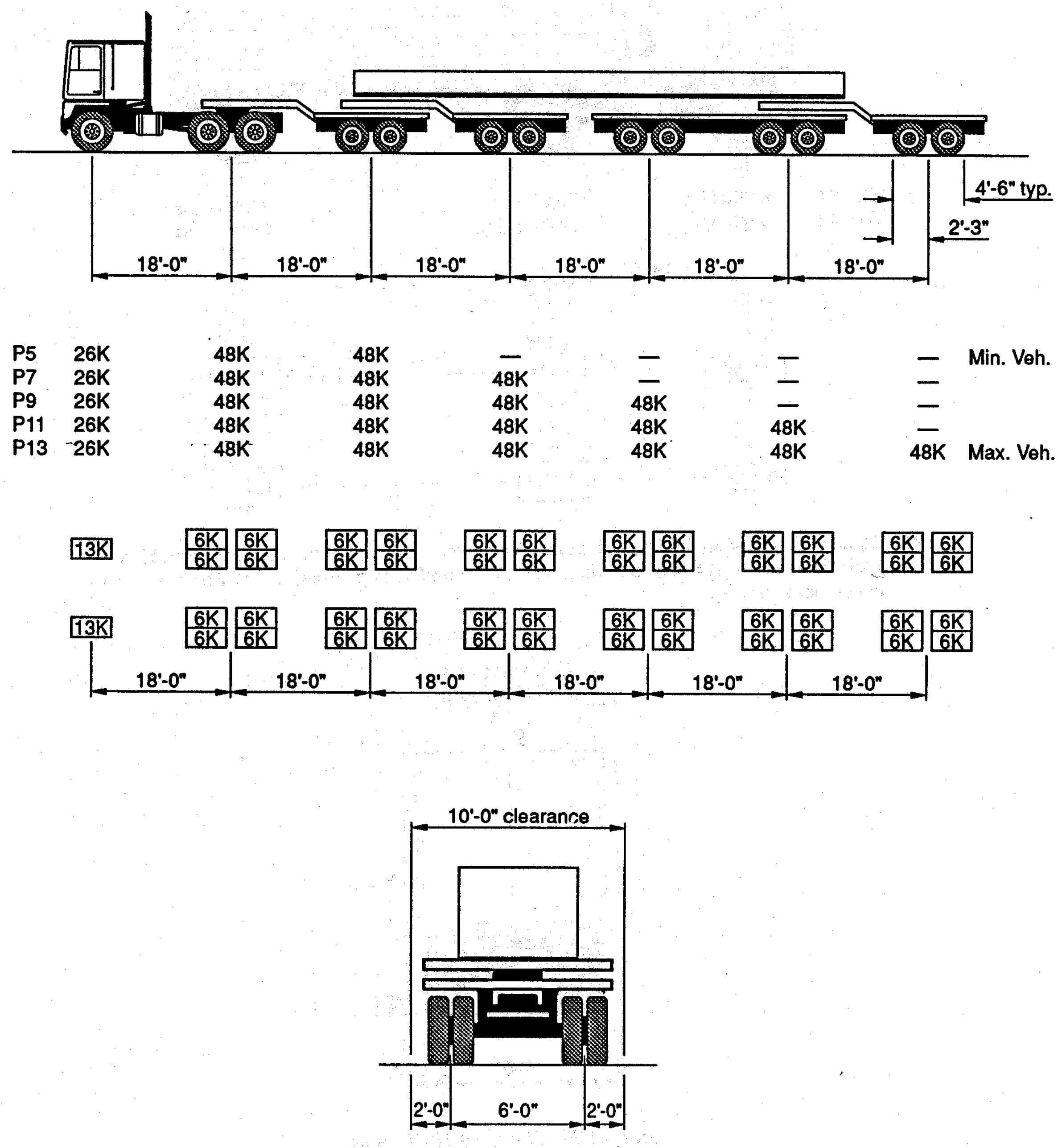

FIGURE 3.7.7B Permit Design Live Loads

3.8.2 Impact Formula

3.8.2.1 The amount of the impact allowance or increment is expressed as a fraction of the live load stress, and shall be determined by the formula:

$$I = \frac{50}{L + 125} \qquad (3\text{-}1)$$

in which,

I = impact fraction (maximum 30 percent);
L = length in feet of the portion of the span that is loaded to produce the maximum stress in the member as defined in 3.8.2.2..

3.8.2.2 For uniformity of application, in this formula, the loaded length, L, shall be as follows:

(a) For roadway floors: The design span length.
(b) For transverse members, such as floor beams: the span length of member center to center of supports.
(c) For computing truck load moments: the span length, or for cantilever arms the length from the moment center to the farthermost axle.
(d) For shear due to truck loads: the length of the loaded portion of span from the point under consideration to the far reaction. For cantilever arms use a 30 percent impact factor.
(e) For continuous spans: the length of span under consideration for positive moment, and the average of two adjacent loaded spans for negative moment and reaction.
(f) For culverts and other underground structures with cover of less than three feet use an impact fraction of 0.30.

3.8.2.3 *For Culverts See "SECTION 6 - CULVERTS".*

3.9 LONGITUDINAL FORCES

3.9.1 Provision shall be made for the effect of a longitudinal force of 5 percent of the live load in all lanes carrying traffic headed in the same direction. All lanes shall be loaded for bridges likely to become one directional in the future. The load used, without impact, shall be the lane load plus the concentrated load for moment specified in Article 3.7, with reduction for multiple-loaded lanes as specified in Article 3.12. The center of gravity of the longitudinal force shall be assumed to be located 6 feet above the floor slab and to be transmitted to the substructure through the superstructure.

3.10 CENTRIFUGAL FORCES

3.10.1 Structures on curves shall be designed for a horizontal radial force equal to the following percentage of the live load, without impact, in all traffic lanes:

$$C = 0.00117S^2D = \frac{6.68S^2}{R} \qquad (3\text{-}2)$$

where,

C = the centrifugal force in percent of the live load, without impact;
S = the design speed in miles per hour;
D = the degree of curve;
R = the radius of the curve in feet.

3.10.2 The effects of superelevation shall be taken into account.

3.10.3 The centrifugal force shall be applied 6 feet above the roadway surface, measured along the centerline of the roadway. The design speed shall be determined with regard to the amount of superelevation provided in the roadway. The traffic lanes shall be loaded in accordance with the provisions of Article 3.7.

3.10.4 The loads and the number and positions of lanes loaded for centrifugal force shall be the same as for live load in the case under consideration. Design speed for P loads shall be 25 mph (max.).

3.10.5 When a reinforced concrete floor slab or a steel grid deck is keyed to or attached to its supporting members, it may be assumed that the deck resists, within its plane, the shear resulting from the centrifugal forces acting on the live load.

3.11 APPLICATION OF LIVE LOAD

3.11.1 Traffic Lane Units

In computing stresses, each 10-foot lane load or single standard truck shall be considered as a unit, and fractions of load lane widths or trucks shall not be used.

3.11.2 Number and Position of Traffic Lane Units

The number and position of the lane load or truck loads shall be as specified in Article 3.7 and, whether lane or truck loads, shall be such as to produce maximum stress, subject to the reduction specified in Article 3.12.

3.11.3 Lane Loads on Continuous Spans

For the determination of maximum negative moment in the design of continuous spans, the lane load shown in Figure 3.7.6B shall be modified by the addition of a second, equal weight concentrated load placed in one other span in the series in such position to produce the maximum effect. For maximum positive moment, only one concentrated load shall be used per lane, combined with as many spans loaded uniformly as are required to produce maximum moment.

3.11.4 Loading for Maximum Stress

3.11.4.1 On both simple and continuous spans, the type of loading, whether lane load or truck load, to be used shall be the loading which produces the maximum stress. The moment and shear tables given in Appendix A show which type of loading controls for simple spans.

3.11.4.2 For continuous spans, the lane loading shall be continuous or discontinuous; only one standard H or HS truck per lane shall be considered on the structure.

+ **3.11.4.3 Loading for Load Factor**
+ **Design**

+ Apply H, HS, and Alternate Military Loadings, inter-
+ changeably, one per lane, for both strength and service-
+ ability considerations in all materials.

Apply P loads for strength considerations only in all +
materials, and for serviceability under fatigue in struc- +
tural steel. In Load Combination Ipc, distribution follows +
the same rules as Load Combination I_H. In Load Combi- +
nation Ipw, the P load shall be used alone or in conjunc- +
tion with one HS or Alternate Military Loading in a +
separate traffic lane depending upon which is most se- +
vere. +

3.12 REDUCTION IN LOAD INTENSITY

3.12.1 Where maximum stresses are produced in any member by loading a number of traffic lanes simultaneously, the following percentages of the live loads shall be used in view of the improbability of coincident maximum loading:

	Percent
One or two lanes	100
Three lanes	90
Four lanes or more	75

3.12.2 The reduction in intensity of loads on transverse members such as floor beams shall be determined as in the case of main trusses or girders, using the number of traffic lanes across the width of roadway that must be loaded to produce maximum stresses in the floor beam.

3.13 ELECTRIC RAILWAY LOADS

If highway bridges carry electric railway traffic, the railway loads shall be determined from the class of traffic which the bridge may be expected to carry. The possibility that the bridge may be required to carry railroad freight cars shall be given consideration.

3.14 SIDEWALK, CURB, AND RAILING LOADING

3.14.1 Sidewalk Loading

3.14.1.1 Sidewalk floors, stringers and their immediate supports, shall be designed for a live load of 85 pounds per square foot of sidewalk area. Girders, trusses, arches and other members shall be designed for the following sidewalk live loads:

Spans 0 to 25 feet in length 85 lb./ft.2
Spans 26 to 100 feet in length 60 lb./ft.2
Spans over 100 feet in length according to the formula

$$P = \left(30 + \frac{3{,}000}{L}\right)\left(\frac{55 - W}{50}\right) \qquad (3\text{-}3)$$

in which,

P = live load per square foot, max. 60-lb. per sq. ft.;
L = loaded length of sidewalk in feet;
W = width of sidewalk in feet.

3.14.1.2 In calculating stresses in structures that support cantilevered sidewalks, the sidewalk shall be fully loaded on only one side of the structure if this condition produces maximum stress.

3.14.1.3 Bridges for pedestrian, equestrian and/or bicycle traffic shall be designed for a live load of 85 PSF. Check equestrian bridge for 0.5(H20) = (H10) loading.

For (LL + I), use group (I_H) with β_L = 1.0 (see Table 8.22.1A). Apply impact according to Article 3.8.

3.14.1.4 Where bicycle or pedestrian bridges are expected to be used by maintenance vehicles, special design consideration should be made for these loads.

3.14.2 Curb Loading

3.14.2.1 Curbs shall be designed to resist a lateral force of not less than 500 pounds per linear foot of curb, applied at the top of the curb, or at an elevation 10 inches above the floor if the curb is higher than 10 inches.

3.14.2.2 Where sidewalk, curb, and traffic rail form an integral system, the traffic railing loading shall be applied and stresses in curbs computed accordingly.

3.14.3 Railing Loading

For Railing Loads, see Article 2.7.

3.15 WIND LOADS

The wind load shall consist of moving uniformly distributed loads applied to the exposed area of the structure. The exposed area shall be the sum of the areas of all members, including floor system and railing, as seen in elevation at 90 degrees to the longitudinal axis of the structure. The forces and loads given herein are for a base wind velocity of 100 mile per hour. For Group II and Group V loading, but not for Group III and Group VI loadings, they may be reduced or increased in the ratio of the square of the design wind velocity to the square of the base wind velocity provided that the maximum probable wind velocity can be ascertained with reasonable accuracy, or provided that there are permanent features of the terrain which make such changes safe and advisable. If a change in the design wind velocity is made, the design wind velocity shall be shown on the plans.

3.15.1 Superstructure Design

3.15.1.1 Group II and Group V Loadings

3.15.1.1.1 A wind load of the following intensity shall be applied horizontally at right angles to the longitudinal axis of the structure:

For trusses and arches ..... 75 pounds per square foot
For girders and beams ..... .50 pounds per square foot

3.15.1.1.2 The total force shall not be less than 300 pounds per linear foot in the plane of the windward chord and 150 pounds per linear foot in the plane of the leeward chord on truss spans, and not less than 300 pounds per linear foot on girder spans.

3.15.1.2 Group III and Group VI Loadings

Group III and Group VI loadings shall comprise the loads used for Group II and Group V loadings reduced by 70 percent and a load of 100 pounds per linear foot applied at right angles to the longitudinal axis of the structure and 6 feet above the deck as a wind load on a moving live load. When a reinforced concrete floor slab or a steel grid deck is keyed to or attached to its supporting members, it may be assumed that the deck resists, within its plane, the shear resulting from the wind load on the moving live load.

3.15.2 Substructure Design

Forces transmitted to the substructure by the superstructure and forces applied directly to the substructure by wind loads shall be as follows:

3.15.2.1 Forces from Superstructure

+ *3.15.2.1.1* For unusual or major structures the transverse and longitudinal forces transmitted by the superstructure to the substructure for various angles of wind direction shall be as set forth in the following table. The skew angle is measured from the perpendicular to the longitudinal axis and the assumed wind direction shall be that which produces the maximum stress in the substructure. The transverse and longitudinal forces shall be applied simultaneously at the elevation of the center of gravity of the exposed area of the superstructure.

	Trusses		Girders	
Skew Angle of Wind	Lateral Load	Longitudinal Load	Lateral Load	Longitudinal Load
Degrees	PSF	PSF	PSF	PSF
0	75	0	50	0
15	70	12	44	6
30	65	28	41	12
45	47	41	33	16
60	24	50	17	19

The loads listed above shall be used in Group II and Group V loading as given in Article 3.22.

3.15.2.1.2 For Group III and Group VI loadings, the loads may be reduced by 70 percent and a load per linear foot added as a wind load on a moving live load, as given in the following table:

Skew Angle of Wind	Lateral Load	Longitudinal Load
Degrees	lb./ft.	lb./ft.
0	100	0
15	88	12
30	82	24
45	66	32
60	34	38

This load shall be applied at a point 6 feet above the deck.

3.15.2.1.3 For the usual girder and slab bridges the following wind loading may be used. +

W (wind load on structure)
50 pounds per square foot, transverse;
12 pounds per square foot, longitudinal;
Both forces shall be applied simultaneously.

WL (wind load on live load)
100 pounds per linear foot, transverse;
40 pounds per linear foot, longitudinal;
Both forces shall be applied simultaneously.

3.15.2.2 Forces Applied Directly to the Substructure

The transverse and longitudinal forces to be applied directly to the substructure for a 100-mile per hour wind shall be calculated from an assumed wind force of 40 pounds per square foot. For wind directions assumed skewed to the substructure this force shall be resolved into components perpendicular to the end and front elevations of the substructure. The component perpendicular to the end elevation shall act on the exposed substructure area as seen in end elevation and the component perpendicular to the front elevation shall act on the exposed areas and shall be applied simultaneously with the wind loads from the superstructure. The above loads are for Group II and Group V loadings and may be reduced by 70 percent for Group III and Group VI loadings, as indicated in Article 3.22.

3.15.3 Overturning Forces

The effect of forces tending to overturn structures shall be calculated under Groups II, III, V, and VI of Article 3.22 assuming that the wind direction is at right angles to the longitudinal axis of the structure. In addition, an upward force shall be applied at the windward quarter point of the transverse superstructure width. This force shall be 20 pounds per square foot of deck and sidewalk plan area for Group II and group V combinations and 6 pounds per square foot for Group III and Group VI combinations.

3.16 THERMAL FORCES

Provisions shall be made for stresses or movements resulting from variations in temperature. The rise and fall in temperature shall be fixed for the locality in which the structure is to be constructed and shall be computed from an assumed temperature at the time of erection. Due consideration shall be given to the lag between air temperature and the interior temperature of massive concrete members or structures.

The range of temperature shall generally be as follows:

Air Temperature Range	Design Range	
	Steel	Concrete
Extreme: 120° F Certain mountain and desert locations	Rise or Fall 60° F Movement/Unit Length .00039	Rise or Fall 40° F Movement/Unit Length .00024
Moderate: 100° F Interior Valleys and most mountain locations	Rise or Fall 50° F Movement/Unit Length .00033	Rise or Fall 35° F Movement/Unit Length .00021
Mild: 80° F Coastal Areas, Los Angeles, and San Francisco Bay Area	Rise or Fall 40° F Movement/Unit Length .00026	Rise or Fall 30° F Movement/Unit Length .00018

Provisions shall be made in concrete structures for stresses and movements resulting from shrinkage, as follows:

Arches - Shrinkage Coefficient 0.0002

Prestressed Structures - See Division 1, Section 9 of this volume.

Other Structures - The temperature fall from a normal temperature as given above provides adequately for stress and movement caused by shrinkage.

3.17 UPLIFT

3.17.1 Provision shall be made for adequate attachment of the superstructure to the substructure by ensuring that the calculated uplift at any support is resisted by tension members engaging a mass of masonry equal to the largest force obtained under one of the following conditions:

(a) 100 percent of the calculated uplift caused by any loading or combination of loadings in which the live plus impact loading is increased by 100 percent.

(b) 150 percent of the calculated uplift at working load level.

(c) 100 percent of the calculated uplift for load factor design.

3.17.2 Anchor bolts subject to tension or other elements of the structures stressed under the above conditions shall be designed at 150 percent of the allowable basic stress.

3.18 FORCE FROM STREAM CURRENT, FLOATING ICE AND DRIFT

All piers and other portion so structures that are subject to the force of flowing water, floating ice, or drift shall be designed to resist the maximum stresses induced thereby.

3.18.1 Force of Stream Current on Piers

3.18.1.1 Stream Pressure

3.18.1.1.1 The effect of flowing water on piers and drift build-up, assuming a second degree parabolic velocity distribution and thus a triangular pressure distribution, shall be calculated by the formula:

$$P_{avg} = K(V_{avg})^{2} \qquad (3\text{-}4)$$

where:

P_{avg} = average steam pressure, in pounds per square foot;

V_{avg} = average velocity of water in feet per second; computed by dividing the flow rate by the flow area,

K = a constant, being 1.4 for all piers subjected to drift build-up and square-ended piers, 0.7 for circular piers, and 0.5 for angle-ended piers where the angle is 30 degrees or less.

The maximum stream flow pressure, P_{max}, shall be equal to twice the average stream flow pressure, P_{avg}, computed by Equation 3-4. Stream flow pressure shall be a triangular distribution with P_{max} located at the top of water elevation and a zero pressure located at the flow line.

3.18.1.1.2 The stream flow forces shall be computed by the product of the stream flow pressure, taking into account the pressure distribution, and the exposed pier area. In cases where the corresponding top of water elevation is above the low beam elevation, stream flow loading on the superstructure shall be investigated. The stream flow pressure acting on the superstructure may be taken as P_{max} with a uniform distribution.

3.18.1.2 Pressure Components

When the direction of stream flow is other than normal to the exposed surface area, or when bank migration or a change of stream bed meander is anticipated, the effects of the directional components of stream flow pressure shall be investigated.

3.18.1.3 Drift Lodged Against Pier

Where a significant amount of drift lodged against a pier is anticipated, the effects of this drift buildup shall be considered in the design of the bridge opening and the bridge components. The overall dimensions of the drift buildup shall reflect the selected pier locations, site conditions, and known drift supply upstream. When it is anticipated that the flow area will be significantly blocked by drift buildup, increases in high water elevations, stream velocities, stream flow pressures, and the potential increases in scour depths shall be investigated.

3.18.2 Force of Ice on Piers

+ Pressure of ice on piers shall be calculated at 400
+ pounds per square inch. The thickness of ice and height
+ at which it applies shall be determined by investigation at
+ the site of the structure.

3.19 BUOYANCY

Buoyancy shall be considered where it affects the design of either substructure, including piling, or the superstructure.

3.20 EARTH PRESSURE

3.20.1 Structures which retain level fills shall be proportioned to withstand pressure as given by Rankine's formula, or by other expressions given in Section 5, "Retaining Walls"; provided, however, that no vertical wall structure shall be designed for less than an
equivalent fluid unit weight of 36 pounds per cubic foot, +
except that the maximum load on the heels of wall footings +
shall be determined by using an equivalent fluid unit +
weight of 27 pounds per cubic foot. +

3.20.2 For rigid frames a maximum of one-half of the moment caused by earth pressure (lateral) may be used to reduce the positive moment in the beams, in the top slab, or in the top and bottom slab, as the case may be.

3.20.3 When highway traffic can come within a horizontal distance from the top of the structure equal to one-half its height, the pressure shall have added to it a live load surcharge pressure equal to not less than 2 feet of the earth.

3.20.4 Where an adequately designed reinforced concrete approach slab supported at one end by the bridge is provided, no live load surcharge need be considered.

3.20.5 All designs shall provide for the thorough drainage of the back-filling material by means of weep holes and crushed rock, pipe drains or gravel drains, or by perforated drains.

3.21 EARTHQUAKES

All structures shall be designed to resist earthquake +
motions by considering the relationship of the site to +
active faults, the seismic response of the soils at the site, +
and the dynamic response characteristics of the total +
structure and its individual components in accordance +
with the Caltrans Seismic Design Criteria. +

Part B
Combinations of Loads

3.22 COMBINATIONS OF LOADS

3.22.1 The following Groups represent various combination of loads and forces to which a structure may be subjected. Each component of the structure, or the foundation on which it rests, shall be proportioned to withstand safely all group combinations of these forces that are applicable to the particular site or type. Group loading combinations for Service Load Design and Load Factor Design are given by:

$$\text{Group (N)} = \gamma[\beta_D D + \beta_L (L + I) + \beta_C CF + \beta_E E + \beta_B B + \beta_S SF + \beta_W W + \beta_{PS} PS + \beta_{WL} WL + \beta_L LF + \beta_R (R + S + T) + \beta_{EQ} EQ + \beta_{ICE} ICE + \beta_{CT} CT] \quad (3\text{-}10)$$

where

N	=	group number;
γ	=	load factor, see Table 3.22.1A and B;
β	=	coefficient, see Table 3.22.1A and B;
D	=	dead load;
L	=	live load;
I	=	live load impact;
E	=	earth pressure;
B	=	buoyancy;
W	=	wind load on structure;
WL	=	wind load on live load-100 pounds per linear foot;
LF	=	longitudinal force from live load;
CF	=	centrifugal force;
R	=	rib shortening;
S	=	shrinkage;
T	=	temperature;
EQ	=	earthquake;
SF	=	stream flow pressure;
ICE	=	ice pressure;
PS	=	prestress.
CT	=	truck collision

3.22.2 For service load design, the percentage of the basic unit stress for the various groups is given in Table 3.22.1B.

The loads and forces in each group shall be taken as appropriate from Articles 3.3 to 3.21. The maximum section required shall be used.

3.22.3 For load factor design, the gamma and beta factors given in Table 3.22.1A are only intended for designing structural members by the load factor concept. The load factors are not intended to be used when checking the foundation stability (safety factors against overturning, sliding, etc.) of a structure.

3.22.4 When long span structures are being designed by load factor design, the gamma and beta factors specified for Load Factor Design represent general conditions and should be increased if, in the Engineer's judgment, expected loads, service conditions, or materials of construction are different from those anticipated by the specifications.

3.22.5 At the factored level all structures shall be analyzed for the effect of both HS and P Loads as defined in Article 3.7 using the group loading combinations of Table 3.22.1A. P Loads shall be considered as follows:

Group I_{PC} applies only for P Load application to superstructures for which Footnote f to Table 3.23.1 does not apply. The distribution follows the same rules as applies to H Loads, Article 3.23.

Group I_{PW} applies for P Load application for which Footnote f to Table 3.23.1 applies. Group I_{PW} also applies to all substructures including bents and pier caps entirely contained within the superstructure. Load combination I_{PW} is to be applied in accordance with Article 3.11.

Group I_{P3D} applies only for P load application to superstructures for which a three dimensional analysis for live loads has been conducted that explicitly considers the lateral stiffness and load transfer characteristics of the superstructure elements. Load combination I_{P3D} is to be applied in accordance with Article 3.11.

3.22.6 Load factor design methods of AASHTO using Load Group IB shall be used for the analysis of specific loads that do not conform to any design loading specified herein. Distribution of such loads shall be consistent with the nature of the load and provisions of these specifications.