STRESS PRODUCING EFFECTS OF EQUIVALENT DESIGN LOADS ON MODERN HIGHWAY BRIDGES

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FOREWORD

The progressive increases in both the numbers and frequencies of heavy axle loads and gross vehicle weights characterizing heavy motor vehicle operation during the past few years have emphasized the need for rapid and accurate methods for evaluating their effects on proposed and existing bridges and other highway structures. Research thinking has therefore been directed to serving this need. This has provided a simple, yet accurate method for evaluating the degree of overstress that would be produced in any of these proposed or existing bridges as a result of present-day highway loads. It is hoped that its detailed presentation in this publication will serve as a partial contribution toward the solution of certain problems associated with these loads and their stress producing effects on bridges and other highway structures.

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The degree of overstress (or understress) that would be produced at some critical point in a given highway bridge can be determined by comparing the total stress (dead load, live load, and impact) resulting from the passage of any particular heavy vehicle with the total design stress used at the same point. This is accomplished by converting a stress function such as moment, shear, or direct stress into an equivalent design load which is then used with any desired allowance for impact to determine the design stress ratio produced by it at some critical point in the bridge.

Part I

INTRODUCTION

This bulletin presents a rather simple, yet accurate method for determining the degree of overstress (or understress) that would be produced at some critical point in a given highway bridge by any particular heavy vehicle under consideration. Its object is to provide a rational procedure whereby the total stress (dead load, live load, and impact), resulting from the passage of any particular heavy vehicle, may be quickly and accurately compared with the total design stress used at the same point in the given bridge under consideration.

The method involves but two basic operations which may be described briefly as follows:

1. Based on some stress function such as moment, shear, or direct stress, the given heavy vehicle under investigation is converted into an equivalent design load on the particular span or bridge under consideration. The given heavy vehicle may be converted into an equivalent H truck loading, equivalent H-S truck loading, equivalent concentrated load, or some other equivalent load based on any other arbitrary standardized loading as may be desired.

2. The equivalent design load, corresponding to the given heavy vehicle on the particular span or bridge under consideration, is then used with any desired allowance for impact, to determine the design stress ratio produced by it at some critical point in the bridge. For example, if the passage of a particular heavy vehicle, with the desired allowance for impact, resulted in a design stress ratio of $X=1.20$ at some critical point in a given bridge, it would mean that the total stress for these conditions would be 1.20 times the total stress used for the design at that point. Another way to interpret this design stress ratio, $X=1.20$, would be to say that the given heavy vehicle would produce a 20 percent overstress at the point under consideration.

This method is perfectly general. That is, the method is not limited to any particular type of stress, type of bridge, or type of construction: it is equally valid for moment, shear, direct stress, or any other stress function used for the stress analysis and design of all types of simple span and continuous bridges. Although the method is perfectly general, the development of it as presented in this report is limited to an investigation of the overstress or understress in simple span bridges which result from the maximum bending moments produced by equivalent H truck loadings of various weights. The material presented is thus limited because once the method has been developed and demonstrated, based on maximum bending moments, it would be but a simple matter to duplicate the procedure using some other stress function such as shear or direct stress.

Bending moment is the stress function selected to illustrate the development and use of the method because it is the bending stresses that ordinarily determine the load carrying capacity of most highway bridges, which incidentally are predominantly simple spans of some 60 feet or less in length. It might be mentioned also that it is the spans of medium length, say from about 50 to 80 feet, which are more frequently subjected to overstress in bending as a result of the passage of the heavier gross vehicle weights.

The tables and charts presented herein, for determining the degree of overstress (or understress) in bending produced by equivalent H truck loadings of various weights, are based on the lightest type of construction ordinarily used for simple spans of H 15 loading design in order to minimize the effect of dead load on total stresses. The reason for this is, of course, that the smaller the ratio of dead load stress to total design stress the greater will be the relative effect of live load and impact stresses produced by a given heavy vehicle, particularly when they are in excess of those used in the original design. From a practical standpoint, therefore, this means that the design stress ratios—that is, the degrees of overstress or understress—indicated by the tables and charts given herein for equivalent H truck loadings of various weights are all on the conservative side. The only exceptions to this general statement would be for H 15 design simple spans of the lightest possible type of construction, such as a steel I-beam span with minimum thickness concrete deck; in which case, the design stress ratios would be about the same as those given by the tables and charts.

In Part II, the need of a method for determining the degree of overstress produced in highway bridges by present-day heavy motor vehicle loads is briefly discussed. Part III outlines the manner in which the stress producing characteristics of heavy vehicle types and loadings are measured in terms of equivalent design loads. Then in Part IV, the method for determining the degree of overstress in bridges produced by typical highway loads is developed and discussed. The use of the method is also illustrated in Part IV by showing the numerical work involved in the solution of several typical problems. The use of the method for determining the overstress produced in simple span bridges by six of the more common heavy vehicle types is illustrated in Part V, and the report then closes with Part VI which presents a number of tables and charts for solving a wide variety of practical problems associated with the determination of overstress in simple span deck girder bridges produced by present-day heavy motor vehicle types and loadings. The notations used in this report are given in Appendix A, and the coefficients for converting equivalent loadings on simple spans of various lengths are given in the tables and charts of Appendix B together with a brief explanation of their use.

Part II

NEED OF METHOD FOR DETERMINING OVERSTRESS IN HIGHWAY BRIDGES

The maximum sizes and weights of motor vehicles that should be permitted to operate over the nation's highways and bridges are matters which, for some years, have been of more than ordinary concern to practically everyone associated with the planning, construction, and maintenance of present-day highway facilities. The problem of determining maximum sizes and weights of vehicles is twofold. In the one case the strengths and capacities of present highway facilities must be taken into account; and in the other, the strengths and capacities that should be provided in new facilities, to accommodate both present and future traffic, must also be given due consideration.[1] The present bulletin, however, is concerned with the stresses produced by equivalent design loadings in existing bridges rather than the load carrying capacities that should be provided in newly constructed facilities.

In an effort to provide a reasonable solution to the first part of this problem — that of establishing maximum permissible vehicle sizes and weights consistent with the load carrying capacities of existing highways and bridges —the American Association of State Highway Officials undertook an extensive investigation of existing highways and bridges which resulted in the adoption by the association of a "Policy Concerning Maximum Dimensions, Weights and Speeds of Motor Vehicles to be Operated Over the Highways of the United States" dated April 1, 1946. This policy is in effect at the present time and is sometimes referred to simply as the AASHO Policy of 1946. The maximum sizes and weights of motor vehicles recommended by the present AASHO Policy are summarized briefly in Table 2.1.

Table 2.1

AASHO RECOMMENDATIONS OF 1946 FOR
MAXIMUM MOTOR VEHICLE SIZES AND WEIGHTS

Maximum width of vehicle	96 in.
Maximum height of vehicle	12 ft. 6 in.
Maximum length of vehicle:	
Single trucks	35 ft.
Single busses (with 2 axles)	35 ft.
Single busses (with not less than 3 axles)	40 ft.
Truck-tractor semitrailer combinations	50 ft.
Other combinations (not more than 2 units)	60 ft.
Maximum loads on vehicles:	
Single axles	18,000 lb.
Groups of axles — tabulated loads, W, varying with distance, L, between extreme axles of any group, measured to the nearest foot, ranging from 32,000 lb. for axles spaced 7 ft. or less apart, to 73,280 lb. for all axles within a distance of 57 ft. all in accordance with the formula $W=1025\ (L+24) - 3L^2$	32,000 lb to 73,280 lb.

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[1] Fairbank, H. S., "Sizes and Weights of Motor Vehicles Require Economic Study," **Civil Engineering**, pp. 40-43, June, 1949.

Although the group axle loads indicated in Table 2.1 provide a reasonable guide for determining in maximum gross vehicle weights that should, in general, be permitted on existing highways and bridges, they give no clue as to the actual stress that would be produced at some critical point in a given bridge by some particular vehicle type and loading. This, together with the continued trends toward more frequent and heavier axle loads and gross vehicle weights[2] have served to emphasize the need for accurate, yet simple and rapid, methods for analyzing the effects of both the magnitudes and frequencies of these heavier loads on existing highways and bridges.

As a partial contribution toward and as an approach to the solution of certain of these problems, the authors presented in a prior publication,[3] a method for measuring the stress producing characteristics of any given heavy vehicle in terms of some equivalent design loading such as those defined by the AASHO Design Specifications. For example, if a given heavy vehicle produced the same maximum bending moment on a 50-foot simple span bridge as a standard H truck weighing 26.7 tons, it would be rated as an equivalent H 26.7 truck which, based on moment, would provide an accurate measure of its stress producing characteristics on that span. It was also pointed out in Bulletin No. 127 that the frequency distributions of equivalent design loads obtained by this method from data reported by a loadometer survey would similarly provide a convenient means for appraising the cumulative effects of heavy motor vehicle operation on those sections or routes covered by such survey.

Although the H truck equivalence or the H-S truck equivalence of any particular vehicle on a given span provides an accurate measure of its stress producing characteristics, this information within itself gives no hint as to the total stresses which result from its passage over the given bridge under consideration. What is needed, therefore, is a simple method for evaluating the maximum total stress, which results from the passage of any particular heavy vehicle, in such a way that it may be directly compared with the total design stress at the point under consideration in the given bridge. The material presented in following parts of this report has been prepared in the hope that it will serve as a partial contribution toward the fulfillment of this need.

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[2] Lynch, J. T., and Dimmick, T. B., "Axle Loads and Gross Load Trends," **Public Roads**, Vol. 25, No. 12, February, 1950.

[3] Stephenson, Henson K., and Cloninger, Kriss, Jr., "Method of Converting Heavy Motor Vehicle Loads into Equivalent Design Loads on the Basis of Maximum Bending Moments," Bulletin No. 127, Texas Engineering Experiment Station, 1952.

Part III

HEAVY MOTOR VEHICLE LOADS MEASURED IN TERMS OF EQUIVALENT DESIGN LOADS

The method for measuring the stress producing characteristics of heavy motor vehicles, as presented in Station Bulletin No. 127,[4] is based on the observation that each of the many variations of heavy vehicle types and loadings has one thing in common—the capacity to induce a stress (bending, shear, or direct) of definite and calculable magnitude at any particular point in a given bridge. Consequently, a bridge of given type and span can be made to serve as a sort of weighing device by which the maximum stress (bending, shear, or direct stress) produced by any given heavy vehicle can be directly compared with that produced by any other vehicle or arbitrarily standardized loading. However, rather than directly comparing the actual stresses produced by a given heavy vehicle with those produced by others, it would be more convenient to appraise the stress producing effects of a given vehicle if they were expressed in terms of some arbitrary or standardized loading.

For this purpose a standard H truck, H-S truck, single concentrated load, or any other abritrary loading could be used as might be desired. In the present report, however, the standard H truck loading is used as a basis for measuring the stress producing characteristics of all other vehicles because the load carrying capacities of most existing highway bridges are rated in terms of the H loading design. And, as previously discussed, bending moment is the stress function selected to illustrate the development and use of the method presented herein for measuring overstress because it is the bending stresses that ordinarily determine the load carrying capacity of most highway bridges.

It should be mentioned here that the overstress resulting from any other equivalent loading, such as an equivalent concentrated load, equivalent H-S truck loading, or equivalent H-S design loading, can be determined by converting these equivalent loadings into an equivalent H truck by use of the conversion coefficients given in tabular and graphical form in Appendix B. Table B.1 and Fig. B.1 give the conversion coefficients based on maximum moments, and Table B.2 and Fig. B.2 give the conversion coefficients based on maximum shear. A brief explanation, together with several example problems, is included with the tables and charts presented in Appendix B.

On a 40-foot simple span, for example, if it was determined that a given heavy vehicle produced a maximum moment of 346.0 kip-feet, with no allowance for impact, it would be found to be the same as the maximum live load moment produced by an H 20 truck on the same span. Based on its capacity to produce bending stresses in a simple span having a length of 40 feet, therefore, the given heavy vehicle would be converted into or rated as an equivalent H truck loading weighing 20 tons, or simply an equivalent H 20 truck loading. In a similar manner, if a given heavy vehicle produced as much direct stress in a particular member of a given through truss bridge as an H 21.6 truck, it would be rated as an equivalent H 21.6 truck loading in so far as its capacity to produce direct stress in that particular member is concerned. The logic would be similar for any type of stress or stress function at any point that might be of interest in any type of simple span or continuous bridge. The manner in which these equivalent design loads can be used for determining the degree of overstress, or design stress ratio, produced by any given vehicle at some particular point in a given bridge is explained in some detail in the following article.

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[4] Stephenson, Henson K., and Cloninger, Kriss, Jr., "Method of Converting Heavy Motor Vehicle Loads into Equivalent Design Loads on the Basis of Maximum Bending Moments," Bulletin No. 127, Texas Engineering Experiment Station, 1952.

Part IV

METHOD FOR EVALUATING OVERSTRESS IN HIGHWAY BRIDGES PRODUCED BY HEAVY MOTOR VEHICLES

The method presented here for evaluating overstress (or understress) can be developed on the basis of any stress or stress function F—such as moment M, shear V, or direct stress P—as may be desired. However, since all of the tables, charts, and other supporting material included herein are based on maximum dead load, live load, and impact moments in simple spans, it is believed that the discussion will be somewhat simplified if the development of the method is also based on maximum moments in simple spans. Throughout the following development, therefore, wherever any one of the symbols for moment M appears, it may be replaced with the corresponding symbol for shear V, or direct stress P, if one finds it desirable to develop similar expressions for dealing with overstress (or understress) based on either of those stress functions. Similarly the symbol F may be used in these expressions as a general term for any type of stress or stress function.

Based on the bending moments M for one lane in a simple span bridge, the dead load ratio R_D is defined as the ratio that the maximum dead load moment M_D bears to the total moment M_T used for the design of the particular bridge under consideration. Symbolically, therefore, this dead load ratio would be given by the following equation.

$$R_D = \frac{M_D}{M_T} \qquad \text{4.1}$$

Similarly, the live load ratio R_L is defined as the ratio that the sum of the live load and impact moments KM_L bear to the total design moment M_T. Symbolically, therefore, the live load ratio would be given by the following equation.

$$R_L = \frac{KM_L}{M_T} \qquad \text{4.2}$$

in which M_L is the maximum moment for one lane produced by the standard live load of given designation as described and required by the design specifications for the particular span length under consideration; K is the coefficient by which the live load design moment M_L is increased to include the specified allowance for impact. That is, $K = 1.00 + I$, where I is the impact fraction as determined by the AASHO formula $I = 50/(S+125)$ and S is the length in feet of the portion of the span which is loaded to produce maximum stress in the member.

Since the sum of the design dead load, live load, and impact moments for a given span is equal to the total design moment, the sum of the dead load and live load ratios must equal 1.00 or

$$1.00 = R_L + R_D = \frac{KM_L + M_D}{M_T} = \frac{M_T}{M_T} \qquad \text{4.3}$$

By referring to Eq. 4.3, it will be seen that if the sum of the live load and impact moments $CK'M'_L$, produced[5] on the given span by the particular ve-

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[5] The coefficient $C=1.00$ if the bridge is loaded with identical vehicles, one vehicle only in each lane, and so placed to produce maximum stress. If only the given vehicle is on the bridge at one time, however, the coefficient C in general will be less than 1.00. In this case, C is the ratio of the maximum live load stress produced by one vehicle in one lane only to that produced by one vehicle in each lane simultaneously. $K'=(1.00+I')$, in which I' is the impact fraction allowed for the loading under consideration and may be varied from zero to full impact, depending on speed and other loading conditions. M'_L = the maximum live load for one lane produced by the given vehicle on the given span.

hicle (either identical vehicles, one in each lane simultaneously, or one vehicle in one lane only) is different from KM_L, the ratio of the total actual moment M'_T, resulting from the passage of this vehicle (or vehicles), to the total design moment M_T will no longer equal 1.00. If $CK'M'_L$ is greater than KM_L, this ratio will be greater than 1.00; if $CK'M'_L$ is less than KM_L, the ratio will be less than 1.00. This ratio of the total actual moment M'_T, resulting from the passage of a given vehicle (or vehicles) to the total design moment M_T, is defined as the design stress ratio X. Thus, if the sum of the live load and impact moments $CK'M'_L$ produced by a particular vehicle (or vehicles) on a given span results in a design stress ratio $X=1.15$, it would mean that this loading would produce a 15 percent overstress on the given bridge. Similarly, if the passage of a particular vehicle over a given bridge results in a design stress ratio $X=.90$ in a given member, the member would be understressed by 10 percent as compared with the stress for which it was designed. Therefore, if the live load plus impact moments KM_L in Eq. 4.3 is replaced by the sum of the live load and impact moments $CK'M_L$ produced by the given vehicle (or vehicles, if all lanes are loaded simultaneously), it results in the general equation for determining the design stress ratio X as follows:

$$X = \frac{CK'M'_L + M_D}{M_T} \qquad \text{4.4}$$

Now in the following development it will be convenient to note from Eq. 4.2 that

$$M_T = \frac{KM_L}{R_L} \qquad \text{4.5}$$

It will also be convenient to note that

$$M_D = M_T - KM_L = \frac{KM_L}{R_L} - KM_L \qquad \text{4.6}$$

Now by using the values for M_T and M_D in Eq. 4.5 and Eq. 4.6, respectively, and rearranging Eq. 4.4, it will be found that

$$M'_L = \frac{XM_T - M_D}{CK'} = \frac{KM_L(X - R_D)}{R_LCK'} \qquad \text{4.7}$$

But since M'_L is the live load moment for one lane produced by an equivalent H truck loading of H tons on a given span, it follows that

$$\frac{H}{M'_L} = \frac{N_1}{M_1} \qquad \text{4.8}$$

in which M_1 is the moment for one lane produced on the given span by a standard H truck of N_1 tons; N_1 being the H-design designation or rating of the bridge under construction. For example, for an H 15 design bridge, $N_1=15$, and for an H 20 design bridge $N_1=20$, irrespective of span length.

Now from Eq. 4.8, it will be seen that

$$H = \frac{N_1M'_L}{M_1} \qquad \text{4.9}$$

But by substituting the value of M'_L from Eq. 4.7 into Eq. 4.9, the equivalent H truck loading becomes

$$H = \frac{N_1KM_L(X - R_D)}{M_1R_LCK'} \qquad \text{4.10}$$

from which the design stress ratio is given by

$$X = \frac{HM_1R_LCK'}{N_1KM_L} + R_D \qquad \text{4.11}$$

Although the equation for the design stress ratio X as given by Eq. 4.11 may appear somewhat complicated at first glance, it is actually a very simple straight line equation of the form

$$y = mz + b \quad \text{.......} \quad 4.12$$

in which:

$y =$ the ordinate X
$m =$ the slope $(M_1R_LCK')/(N_1KM_L)$
$z =$ the equivalent H truck loading abscissa H, and
$b =$ the dead load ratio R_D.

Based on any type of stress or stress function the general equations corresponding to Eq. 4.10 and Eq. 4.11, respectively, become

$$H = \frac{N_1KF_L(X - R_D)}{F_1R_LCK'} \quad \text{.......} \quad 4.13$$

and

$$X = \frac{HF_1R_LCK'}{N_1KF_L} + R_D \quad \text{.......} \quad 4.14$$

in which F is a general term indicating stress or stress function such as moment M, shear V, or direct stress P. The subscripts and prime notations used with these stress functions have the same correponding meaning as those used and explained above for moment.

In connection with the above equations, it might be added that Eq. 4.10 provides a simple means for determining the maximum equivalent H truck loading that might be permitttd to pass over a given bridge, such that the resulting design stress ratio X would not exceed some predetermined allowable value. Similarly, Eq. 4.11 provides a simple means for determining the design stress ratio X — that is, the degree of overstress or understress — that would result from the passage of some particular heavy vehicle (or vehicles) over a given bridge of known design rating.

The use of Eqs. 4.10 and 4.11 will be illustrated presently by applying them to several typical situations having to do with overstress (or understress) in a conventional type of simple span bridge of H 15 design, consisting of a concrete deck of minimum thickness supported by steel stringers (beams or girders). For sake of discussion it will be assumed that the steel stringers in this bridge are of such size that the maximum design stress in bending is the same as that permitted by the design specifications or 18,000 psi.

Before undertaking to illustrate the use of Eqs. 4.10 and 4.11, however, a few words concerning the evaluation of the coefficient C for simple spans of conventional type with concrete deck supported by steel stringers, might be in order. If the stress producing effects of any particular vehicle are being investigated and one vehicle identical to the given vehicle is considered to be in each lane simultaneously, the maximum bending stress will occur in an interior stringer when one line of wheels of the vehicle in one lane is placed over the stringer and one line of wheels of the vehicle in the adjacent lane are placed 4 feet from the stringer in question and all vehicles on the span are so placed as to produce maximum moment. For this condition of loading, the coefficient $C = 1.00$, which is its maximum value for all lanes loaded with identical vehicles, one to each lane. However, if only the given vehicle is on the bridge at one time, the coefficient C in general will be less than 1.00. In this case the value of C is equal to the ratio of the maximum live load stress produced by one vehicle in one lane only to the maximum live load stress produced by one vehicle (identical to the given vehicle) in each lane simultaneously.

If the deck of the bridge described above is assumed to act as a simple beam between stringers, then the value of the coefficient C for one vehicle in one lane only at one time, and for one vehicle in each lane simultaneously would be as shown in the following table.

Table 4.1

VALUE OF COEFFICIENT C FOR VARIOUS STRINGER SPACING AND LOADING CONDITIONS

Stringer Spacing Feet	One Vehicle in One Lane Only	One Vehicle in Each Lane Simultaneously
4	1.000	1.00
5	.833	1.00
6	.750	1.00
7	.726	1.00
8	.714	1.00
9	.705	1.00
10	.700	1.00

From this table it will be seen that if only the given vehicle is considered to be on the span at one time, it would rarely produce more than 75 percent as much live load stress as would result from one vehicle, identical to the given vehicle, in each lane simultaneously. For this reason a value of $C = .75$ for one vehicle in one lane only at a time will be used in the examples and other supporting material which follow.

EXAMPLE 4.1

GIVEN: A 60-foot simple span bridge of H 15 design with minimum thickness concrete deck on steel stringers so spaced that the loading coefficient $C = 1.00$ for all lanes loaded and $C = .75$ for one lane loaded. Other pertinent design information is as follows:

Design Live Load Moment		$M_L = 418.5'K$
Impact Coefficient		$K = 1.27$
Assigned Impact Coefficient		$K' = \text{Variable}$
Numerical Bridge Rating		$N_1 = 15$
H 15 Truck Moment		$M_1 = 409.0'K$
Ratio KM_L/M_T	=	$R_L = .495$
Ratio M_D/M_T	=	$R_D = .505$

REQUIRED: Determine the maximum permissible equivalent H truck loading such that it would not produce an overstress in excess of 20 percent (i.e. design stress ratio $X = 1.20$) in an interior stringer for

A. One vehicle in each lane with full allowance for impact, that is $K' = K$.
B. One vehicle in each lane with no allowance for impact, that is $K' = 1.00$.
C. One vehicle in one lane only with full allowance for impact, that is $K' = K$.
D. One vehicle in one lane only with no allowance for impact, that is $K' = 1.00$.

SOLUTION: The solution to this problem can be obtained either by direct use of Equation 4.10 or by reading the values from the charts and tables presented in Part VI. The use of each method is illustrated below.

SOLUTION BY EQUATION 4.10

$$H = \frac{N_1 K M_L (X - R_D)}{M_1 R_L C K'} \quad \text{.......... 4.10}$$

4.1A: Maximum equivalent H truck loading required for design stress ratio $X = 1.20$, one vehicle in each lane ($C = 1.00$) with full allowance for impact ($K = K'$).

Substituting values into Equation 4.10 as given above gives

$$H = \frac{15 \times 1.27 \times 418.5\ (1.20 - .505)}{409.0 \times .495 \times 1.00 \times 1.27} = 21.5 \text{ Tons}$$

Therefore, an equivalent H 21.5 truck placed in each lane of the given bridge, with full allowance for impact would be required to produce an overstress of 20 percent.

4.1B: Maximum equivalent H truck loading required for design stress ratio $X = 1.20$, one vehicle in each lane ($C = 1.00$) with no allowance for impact ($K' = 1.00$).

Substituting values for this loading condition into Eq. 4.10 gives

$$H = \frac{15 \times 1.27 \times 418.5\ (1.20 - .505)}{409.0 \times .495 \times 1.00 \times 1.00} = 27.3 \text{ Tons}$$

Therefore, an equivalent H 27.3 truck placed in each lane of the given bridge with no allowance for impact would be required to produce an overstress of 20 percent.

4.1C: Maximum equivalent H truck loading required for design stress ratio $X = 1.20$, one vehicle in one lane only ($C = .75$) with full allowance for impact ($K' = K$).

Substituting values for this loading condition into Eq. 4.10 gives

$$H = \frac{15 \times 1.27 \times 418.5\ (1.20 - .505)}{409.0 \times .495 \times .75 \times 1.27} = 28.7 \text{ Tons}$$

Therefore, an equivalent H 28.7 truck placed in one lane only of the given bridge with full allowance for impact would be required to produce an overstress of 20 percent.

4.1D: Maximum equivalent H truck loading required for design stress ratio $X = 1.20$ one vehicle in one lane only ($C = .75$) with no allowance for impact ($K' = 1.00$).

Substituting the values for this loading condition into Equation 4.10 gives

$$H = \frac{15 \times 1.27 \times 418.5\ (1.20 - .505)}{409.0 \times .495 \times .75 \times 1.00} = 36.4 \text{ Tons}$$

Therefore, an equivalent H 36.4 truck placed in one lane only of the given bridge with no allowance for impact would be required to produce an overstress of 20 percent.

SUMMARY OF RESULTS BY EQUATION 4.10

Condition of Loading	Equivalent H Truck Required to Produce a 20 Percent Overstress
Example 4.1A	H 21.5
Example 4.1B	H 27.3
Example 4.1C	H 28.7
Example 4.1D	H 36.4

SOLUTION OF EXAMPLE 4.1 BY CHARTS AND TABLES

The values of equivalent H truck loadings required to produce an overstress of 20 percent in the given bridge may be obtained by referring to the tables and charts presented in Part VI. The numerical values of the equivalent H truck loadings as well as the tables and figures from which these values may be obtained are presented in the following table.

SUMMARY OF RESULTS OBTAINED FROM CHARTS AND TABLES

Condition of Loading	Table Number	Figure Number	Equiv. H Truck Required to Produce a 20 Percent Overstress in Given Bridge
Example 4.1A	6.1	6.1a or 6.5f	H 21.6
Example 4.1B	6.2	6.1f or 6.5f	H 27.4
Example 4.1C	6.3	6.2a or 6.6f	H 28.7
Example 4.1D	6.4	6.2f or 6.6f	H 36.5

EXAMPLE 4.2

GIVEN: The bridge described in Example 4.1.

REQUIRED: Determine the percent of overstress or understress (i.e., the design stress ratio X) resulting from the passage of an equivalent H 24.5 truck over the given bridge for

A. One vehicle in each lane ($C = 1.00$) with full allowance for impact ($K' = K$).
B. One vehicle in each lane ($C = 1.00$) with no allowance for impact ($K' = 1.00$).
C. One vehicle in one lane only ($C = .75$) with full allowance for impact ($K' = K$).
D. One vehicle in one lane only ($C = .75$) with no allowance for impact ($K' = 1.00$).

SOLUTION: The solution to this problem may be obtained either by use of Equation 4.11 or by reading the values directly from the charts and tables presented in Part VI. The use of each method is illustrated below.

SOLUTION BY EQUATION 4.11

$$X = \frac{HM_1R_LCK'}{N_1KM_L} + R_D \quad \text{.......} \quad 4.11$$

4.2A: Design stress ratio resulting from the passage of an equivalent H 24.5 truck in each lane simultaneously ($C = 1.00$) with full allowance for impact ($K' = K$).

$$X = \frac{24.5 \times 409.0 \times .495 \times 1.00 \times 1.27}{15 \times 1.27 \times 418.5} + .505 = 1.30$$

Therefore, an equivalent H 24.5 truck placed in each lane of the given bridge, with full allowance for impact would produce an overstress of 30 percent.

4.2B Design stress ratio resulting from the passage of an equivalent H 24.5 truck in each lane simultaneously ($C = 1.00$) with no allowance for impact ($K' = 1.00$).

$$X = \frac{24.5 \times 409.0 \times .495 \times 1.00 \times 1.00}{15 \times 1.27 \times 418.5} + .505 = 1.13$$

Therefore, an equivalent H 24.5 truck placed in each lane of the given bridge, with no allowance for impact would produce an overstress of 13 percent.

4.2C: Design stress ratio resulting from the passage of an equivalent H 24.5 truck in one lane only ($C = .75$) with full allowance for impact ($K' = K$).

$$X = \frac{24.5 \times 409.0 \times .495 \times .75 \times 1.27}{15 \times 1.27 \times 418.5} + .505 = 1.10$$

Therefore, an equivalent H 24.5 truck placed in one lane only of the given bridge with full allowance for impact would produce an overstress of 10 percent.

4.2D: Design stress ratio resultiing from the passage of an equivalent H 24.5 truck in one lane only ($C = .75$) with no allowance for impact ($K' = 1.00$).

$$X = \frac{24.5 \times 409.0 \times .495 \times .75 \times 1.00}{15 \times 1.27 \times 418.5} + .505 = .97$$

Therefore, an equivalent H 24.5 truck placed in one lane only of the given bridge with no allowance for impact would produce an understress of 3 percent, that is, the total stress would be 97 percent of the design stress.

SUMMARY OF RESULTS BY EQUATION 4.11

Condition of Loading	Design Stress Ratio X
Example 4.2A	1.30
Example 4.2B	1.13
Example 4.2C	1.10
Example 4.2D	.97

SOLUTION OF EXAMPLE 4.2 BY CHARTS AND TABLES

The values of the design stress ratio resulting from the passage of an equivalent H 24.5 truck over the given bridge may also be obtained by referring to the tables and charts presented in Part VI. The numerical values of the design stress ratio X, as well as the tables and figures from which these values are obtained, are presented in the following table.

SUMMARY OF RESULTS OBTAINED FROM CHARTS AND TABLES

Condition of Loading	Table Number	Figure Number	Stress Design Ratio X Resulting from Passage of An Equivalent H 24.5 Truck
Example 4.2A	6.1	6.1a or 6.5f	1.29*
Example 4.2B	6.2	6.1f or 6.5f	1.13*
Example 4.2C	6.3	6.2a or 6.6f	1.10*
Example 4.2D	6.4	6.2f or 6.6f	.97*

*By interpolation of tabular values.

Part V

OVERSTRESS IN SIMPLE SPAN BRIDGES PRODUCED BY TYPICAL HEAVY MOTOR VEHICLES

The continued growth of commercial traffic together with the almost incredible increases in both the numbers and frequencies of various intensities of heavy axle loads and gross vehicle weights, during the past ten or twelve years, has served to emphasize the need and to create an increasing demand for a simple, yet accurate procedure for measuring the degree of overstress, if any, produced by these loads on both the new and existing bridges of our present highway system. As a partial contribution toward the fulfillment of this need, therefore, the method outlined in Part IV is presented in the hope that it will provide a rational approach to the solution of certain of the more pressing problems associated with the stress producing characteristics of present-day heavy vehicle loads and how they are related to the load carrying capacity and safety of proposed and existing bridges and other highway structures.

One of the problems, for example, that frequently arises in the bridge division of a highway department is that of determining whether or not a given heavy vehicle should be permitted to operate over some particular bridge (or bridges) on a given route. For sake of simplifying the discussion, suppose the bridge under consideration is a 60-foot simple span of H 15 design consisting of a concrete deck supported by steel stringers which are so spaced that the maximum live load moment produced in an interior stringer by one vehicle only amounts to 75 percent of that produced by identical vehicles in each lane. Also assume that the ratio of dead load bending stress to the total design bending stress, say 18,000 psi, is 0.505 as shown in Fig. 5.2. With this information at hand, the first step in the solution of this problem would be to determine the H-equivalency of the given vehicle on a 60-foot simple span. This is done by finding the maximum live load moment for one lane produced by the given vehicle on this span; say it is 749.65 kip-feet. Either by calculation or by interpolation in Figs. 6.3 or 6.4, it will be found that this vehicle produced as much moment as an H truck weighing 27.5 tons. Therefore, based on moment, it would be rated as an equivalent H 27.5 truck on a 60-foot span.

For these conditions, then, the design stress ratio that would result from any one of several loading conditions, including various allowances for impact, could readily be determined by means of Eq. 4.11. For this case, however, no calculations are necessary since the desired information can be obtained directly from Fig. 6.5f for one equivalent H 27.5 truck in each lane with various allowances for impact, and from Fig. 6.6f for one equivalent H 27.5 truck in one lane only with various allowances for impact. Briefly, the results of such an investigation would be as given by the following table.

Table 5.1

DESIGN STRESS RATIOS FOR 60-FOOT SIMPLE SPAN BRIDGE OF H 15 DESIGN FOR SPECIFIED LOADING CONDITIONS

One Equivalent H 27.5 Truck in Each Lane Simultaneously		One Equivalent H 27.5 Truck in One Lane Only	
Full Allowance for Impact	No Allowance for Impact	Full Allowance for Impact	No Allowance for Impact
1.39	1.20	1.17	1.03

From this information, if it was decided that a 39 percent overstress was too much and the possibility of its occurrence was sufficiently great, the vehicle might be required to reduce its speed, to say 5 mph, while on the bridge, in which case, the overstress would probably not exceed about 20 percent. But with only the given vehicle on the span at one time, the overstress with full allowance for impact would be about 17 percent and with reduced speed the overstress would likely be about 3 or 4 percent. And though the decision in a case of this kind would depend somewhat on traffic conditions, it could be made on a realistic basis if reliable information of the type given in Table 5.1 were readily available.

It might be suggested that the type of information given in Table 5.1 can be made readily available for any particular bridge simply by determining the equivalent H truck loadings (or other standard loading) to which it might be safely subjected under certain typical or critical loading conditions that one might consider appropriate for his present or future purposes. The number of loading conditions and the degree of overstress accompanying them that should be determined and made available for any particular bridge, of course, is largely a matter of individual judgment and preference. The compilation of such overstress data for any particular bridge, therefore, could be made as elaborate or as simple as one might elect to have them or consider appropriate for his needs.

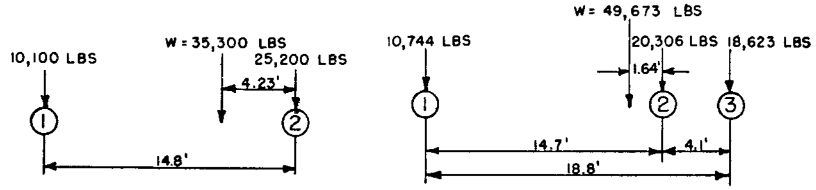
In any case though, it would seem that the minimum number of data for a given bridge should include the permissible equivalent H truck loadings that would obtain for maximum allowable overstress corresponding to each of the four loading conditions given in Table 5.1. For bending stresses, these values of equivalent H truck loadings for the various loading conditions and permissible overstress can be easily determined from Eq. 4.10. For any type of stress or stress function, including moment, similar data may be obtained by use of the more general expression as given by Eq. 4.13. For simple span deck girder bridges, however, no calculations are necessary since any or all of these and related data may be obtained directly from the tables and charts given in Part VI. With the aid of tables and charts, such as those included in Part VI, therefore, it would not be difficult to prepare a catalogue or a card index for the bridges on a given route or system which would include all pertinent data for each bridge pertaining to its load carrying capacity and permissible loads for various loading conditions that might be necessary for future investigations.

Such a catalogue or index, covering all of the data for each bridge pertaining to its load carrying capacity and permissible loads for various traffic and loading conditions, would undoubtedly contribute much toward the analysis and solution of certain of the more pressing problems that have been brought about as a result of the tremendous increases in the numbers and frequencies of heavy axle loads and gross vehicle weights which have characterized heavy motor vehicle operation during the past dozen years. This type of information, for example, would also provide a simple, yet effective means for investigating the cumulative effects of present-day heavy vehicle operation on the load carrying capacity and safety of the existing bridges on a given route or system. Once the H-equivalencies of the heavy vehicles reported by a loadometer survey had been determined, the numbers and relative frequencies of these equivalent loadings would provide the necessary information for investigating the cumulative effects of repeated overstress on a given bridge or bridges.

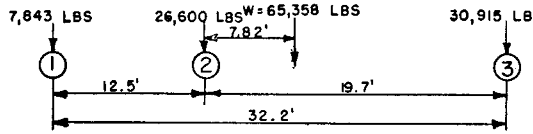
Perhaps the simplest way to illustrate how the method outlined in Part IV may be used for investigating overstress produced in bridges of a given type and class would be to apply it to a typical situation. For this purpose, a rather complete study is presented, herewith, of the maximum bending stress effects produced in simple span deck girder bridges of H 15 design by the six heavy vehicle types and loadings shown in Fig. 5.1 The sizes and weights of each of these six vehicle types, represent the average of the 10 heaviest vehicles of the type among those reported by the nation-wide loadometer survey of 1942.

SIZES AND WEIGHTS OF SIX HEAVY VEHICLE TYPES REPRESENTATIVE OF HEAVIEST VEHICLES REPORTED BY THE 1942 LOADOMETER SURVEY

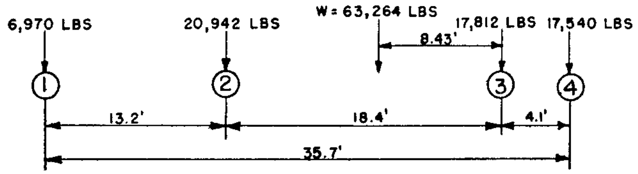
The Dimensions and Weights Given for Each Vehicle Represents the Average of the Ten Heaviest Vehicles of the Type Reported.



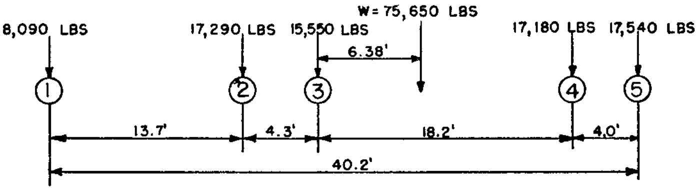
TYPE 2 HEAVY FREIGHT VEHICLE TYPE 3 HEAVY FREIGHT VEHICLE



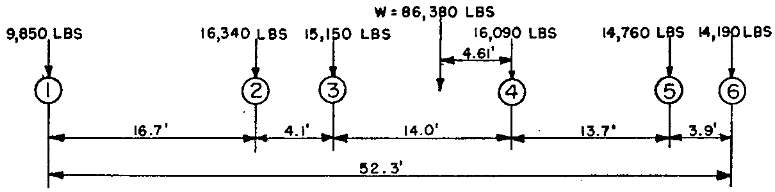
TYPE 2-S1 HEAVY FREIGHT VEHICLE



TYPE 2-S2 HEAVY FREIGHT VEHICLE



TYPE 3-S2 HEAVY FREIGHT VEHICLE



TYPE 3-3 HEAVY FREIGHT VEHICLE

Figure 5.1

The bridges selected for this study consist of a concrete deck of minimum thickness supported by unencased steel beams which are so spaced that the maximum live load bending stress produced in an interior stringer by a single vehicle in one lane only will amount to 75 percent of that produced by identical vehicles in each lane simultaneously. The reason for selecting this type of construction is because the ratio of dead load stresses to total design stresses is smaller than would obtain for any of the heavier types of construction such as reinforced concrete deck girder spans or simply supported deck spans in which the supporting steel beams are encased in concrete. On this basis, therefore, any conclusions arrived at concerning the stress producing effect of a given vehicle on any particular bridge will tend to be on the conservative rather than the unsafe side.

For example, if the maximum dead load bending stress in an interior stringer of one of the simple spans described above amounts to 9,000 psi and the maximum stress resulting from the design live load and impact amounts to 9,000 psi, the dead load stress of 9,000 psi would represent 50 percent of the 18,000 psi total design stress. Now if some other loading resulted in a 100 percent increase in the live load and impact stress or 18,000 psi, then the total stress would be increased to 27,000 psi which would represent a 50 percent overstress as compared with the design stress. In this case it will be seen that a 100 percent increase in the live load and impact design stress will produce a 50 percent overstress. However, in a similar bridge of heavier construction, a 100 percent increase in the live load and impact design stress would result in a lesser degree of overstress. In a given bridge, for example, if the dead load stress is 12,000 psi and the live load and impact design stress is 6,000 psi, the dead load stress would represent two-thirds of the total design stress of 18,000 psi. In this case, if another loading resulted in a 100 percent of the live load and impact design stress or 12,000 psi, the total stress would be 24,000 psi which would represent an overstress of 25 percent. From these data it will be seen, therefore, that the degree of overstress produced by any particular heavy vehicle or loading will be greatest in those bridges where the ratio of dead load stress to total design stress is a minimum, that is to say in the lighter types of construction such as the simple span deck girder spans described above. For this minimum type of light construction, the ratio of dead load stress to total design stress and the ratio of live load plus impact stresses to total design stress for each span of H 15 design up to 100 feet in length are substantially the same as those indicated by the curves given in Fig. 5.2.

ESTIMATED PERCENT OF TOTAL DESIGN STRESSES REPRESENTED BY LIVE LOAD PLUS IMPACT AND DEAD LOAD STRESSES FOR SIMPLE SPAN DECK GIRDER BRIDGES OF H-15 DESIGN

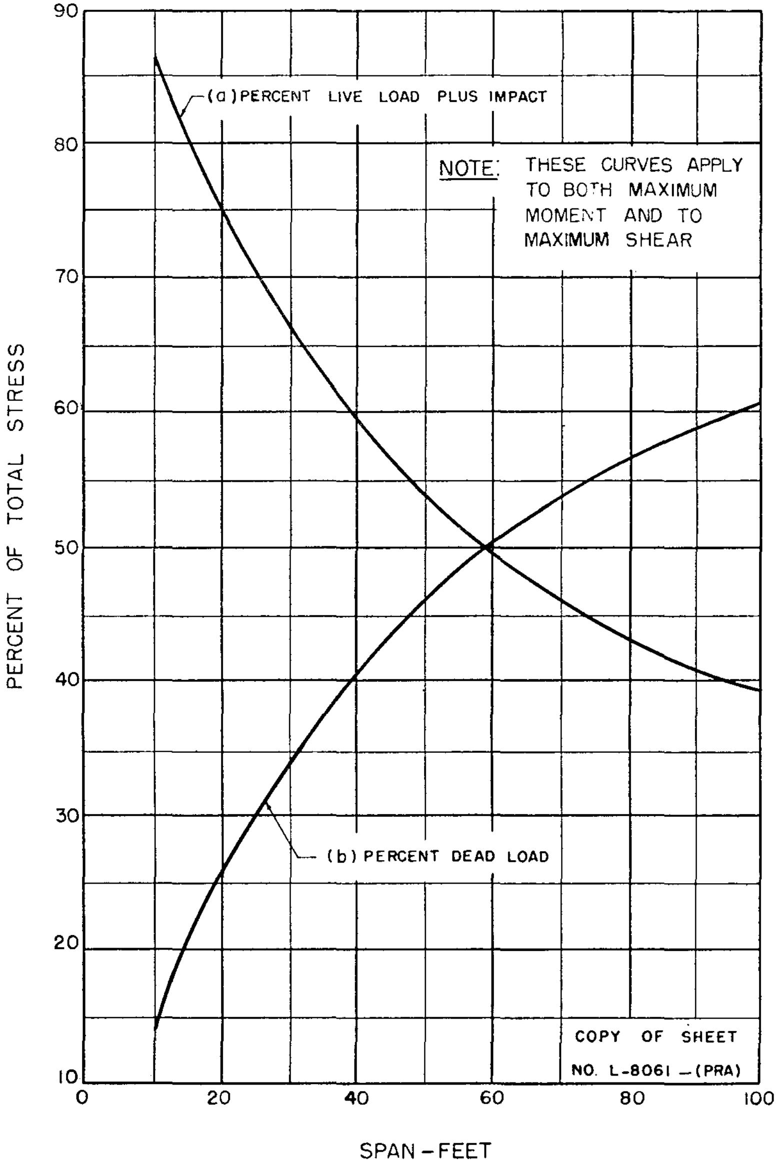


Figure 5.2

The first step involved in investigating the bending stress effects produced on simple spans by the heavy vehicle shown in Fig. 5.1 is that of determining the maximum moments for one lane produced by each of these vehicles on each span under consideration. The pertinent data resulting from this operation are given in Table 5.2. This table gives the gross vehicle weight, wheel base length, controlling conditions, and maximum moments for each of the six vehicles on each even 10-foot span from 10 feet to 100 feet in length. In each case the table gives the axle group G required to produce maximum moment, the axle number N under which the maximum moment occurs, the distance B in feet that the critical axle N is placed to the right or left of mid-span, and the maximum bending moment in kip-feet produced by this loading.

Table 5.2

CONTROLLING CONDITIONS AND MAXIMUM MOMENTS IN SIMPLE SPANS PRODUCED BY SIX TYPICAL VEHICLE TYPES REPRESENTATIVE OF HEAVIEST VEHICLES REPORTED BY THE 1942 LOADOMETER SURVEY

The dimensions and weights given for each vehicle represents the average of the ten heaviest vehicles of the type reported.

Truck type			2	3	2–S1	2–S2	3–S2	3–3
G. V. W.			35,306	49,673	65,359	63,266	75,650	86,380
Wheel Base L			14.8	18.8	32.2	35.7	40.2	52.5
Span-feet	10	G	2	2–3	3	3–4	4–5	2–3
		N	2	2	3	3	4	2
		B	0	.98L	0	1.02L	.99L	.99L
		M	63.02	62.94	77.32	56.12	55.83	50.71
	20	G	2	2–3	3	3–4	4–5	2–3
		N	2	2	3	3	4	2
		B	0	.98L	0	1.02L	.99L	.99L
		M	126.04	158.41	154.57	142.73	140.91	127.76
	30	G	1–2	1–3	3	3–4	4–5	2–4
		N	2	2	3	3	4	3
		B	2.12R	.82R	0	1.02L	.99L	1.68L
		M	195.38	256.56	231.89	230.54	227.18	214.71
	40	G	1–2	1–3	1–3	2–4	2–5	2–4
		N	2	2	2	3	4	3
		B	2.12R	.82R	3.91L	2.78R	4.45R	1.68L
		M	282.45	380.50	325.03	345.37	338.16	332.56
	50	G	1–2	1–3	1–3	2–4	2–5	2–6
		N	2	2	2	3	4	4
		B	2.12R	.82R	3.91L	2.78R	4.45R	.36R
		M	369.80	504.48	483.46	483.99	500.35	477.60
	60	G	1–2	1–3	1–3	1–4	1–5	2–6
		N	2	2	2	3	3	4
		B	2.12R	.82R	3.91L	4.22R	3.19L	.36R
		M	457.57	628.56	643.53	629.18	686.45	668.93
	70	G	1–2	1–3	1–3	1–4	1–5	1–6
		N	2	2	2	3	3	4
		B	2.12R	.82R	3.91L	4.22R	3.19L	2.31R
		M	545.45	752.70	804.50	784.69	873.68	867.43
	80	G	1–2	1–3	1–3	1–4	1–5	1–6
		N	2	2	2	3	3	4
		B	2.12R	.82R	3.91L	4.22R	3.19L	2.31R
		M	633.43	876.78	966.14	940.83	1061.45	1082.51
	90	G	1–2	1–3	1–3	1–4	1–5	1–6
		N	2	2	2	3	3	4
		B	2.12R	.82R	3.91L	4.22R	3.19L	2.31R
		M	721.48	1000.91	1128.16	1097.41	1249.51	1297.86
	100	G	1–2	1–3	1–3	1–4	1–5	1–6
		N	2	2	2	3	3	4
		B	2.12R	.82R	3.91L	4.22R	2.19L	2.31R
		M	809.57	1125.09	1290.45	1254.38	1437.80	1513.29

All dimensions are in feet and moments are in kip-feet.
G. V. W.—Gross vehicle weight in pounds.
G—Axle group causing maximum moment, thus, 1 3 means axles 1, 2, 3.
N—Number of critical axle under which maximum moment occurs.
B Distance to right or left of mid-span to point of maximum moment.
M—Maximum moment.

The second step is that of converting each of the vehicles on each span into an equivalent H truck based on the moments given in Table 5.2. This is accomplished by finding the weight of standard H truck in tons that would be required to produce the same moment on the same span as that given in the table. These H-equivalencies can be calculated or taken directly by interpolation from Figs. 6.3 or 6.4. The results of this operation are given in Table 5.3 for each vehicle on each span in the column entitled, equivalent H truck loading-tons.

The third step is that of determining the design stress ratio resulting from each vehicle, on each span for each condition of loading under consideration. In the present case, the four leading conditions under consideration are:

Case 1: One vehicle in **each** lane with **full** allowance for impact.
Case 2: One vehicle in **one** lane with **full** allowance for impact.
Case 3: One vehicle in **each** lane with **no** allowance for impact.
Case 4: One vehicle in **one** lane with **no** allowance for impact.

With the equivalent H truck loadings, as already determined in Step 2 and shown in Table 5.3, and the dead load design stress ratios from Fig. 5.2, the design stress ratio for each of the several vehicles, span lengths, and loading conditions can now be calculated by use of Eq. 4.11, or they may be read directly from any one of the following three sets of figures: Figs. 6.1 - 6.2, Figs. 6.3 - 6.4, or Figs. 6.5 - 6.6. The use of these figures is explained in connection with the numerical examples in Part IV, therefore, no further discussion of the matter is believed to be necessary at this point. The design stress ratios resulting from this operation are given in Table 5.3.

Although the design stress ratios as given in Table 5.3 are quite informative, a better visual comparison of the stress producing effects of the several vehicles with each other is obtained when these data are presented graphically as shown in Fig. 5.3a and Fig. 5.3b. The design stress data presented in Table 5.3 and in Figs. 5.3a - 5.3b are complimentary to each other and no doubt provide a better basis for interpreting overstress information when used together than could be obtained from either of the two used separately.

In Table 5.3 it will be seen that under the most severe conditions of loading—that is Case 1, when one vehicle is placed in each lane in exactly the proper position for maximum moment and with full allowance for impact—the maximum overstress produced by any of these vehicles on any span is 32 percent. This maximum overstress of 32 percent would be produced on a 60-foot span if one of the Type 3-S2 trucks were placed in each lane simultaneously with full allowance for impact. For Case 2, however,—with one vehicle in one lane only with full allowance for impact—it will be noted that the overstress nowhere exceeds the 11 percent overstress which obtains for the Type 3-S2 truck and the Type 3-3 truck on the 60-and 80-foot spans, respectively. Case 2, incidentally, is believed to represent approximately the most severe condition of loading likely to be encountered under ordinary traffic conditions. Actually though, under ordinary traffic conditions on main rural highways, with pneumatic tires and smooth roadway, it would seem logical to assume that the actual stresses produced would be somewhere between those indicated for Case 2, with full allowance for impact, and Case 4, with no allowance for impact.

Table 5.3

STRESS PRODUCING CHARACTERISTICS OF SIX HEAVY VEHICLE TYPES REPRESENTATIVE OF HEAVIEST VEHICLES REPORTED BY THE 1942 LOADOMETER SURVEY

Table shows equivalent H truck loadings for various span lengths; also percent of H 15 design stresses for:

Case 1: One vehicle in **each** lane with **full** allowance for impact.
Case 2: One vehicle in **one** lane with **full** allowance for impact.
Case 3: One vehicle in **each** lane with **no** allowance for impact.
Case 4: One vehicle in **one** lane with **no** allowance for impact.

Span feet	Type 2 truck GVW=35,306 pounds Wheelbase=14.8 feet					Type 3 truck GVW=49,673 pounds Wheelbase=18.8 feet				
	Equiv. H-Tr. Ldg. Tons	Percent of design stress				Equiv. H-Tr. Ldg. Tons	Percent of design stress			
		Case 1	Case 2	Case 3	Case 4		Case 1	Case 2	Case 3	Case 4
10	15.75	104	82	83	66	15.75	104	82	83	66
20	15.75	104	84	86	71	19.80	124	99	101	82
30	15.90	104	87	88	74	20.85	126	103	105	87
40	16.35	105	89	90	78	22.05	128	106	108	91
50	16.65	106	91	93	81	22.65	128	107	109	94
60	16.80	105	91	93	83	23.10	125	106	109	95
80	16.95	99	88	90	82	23.55	115	100	103	92
100	17.10	95	86	88	81	23.85	108	96	99	90

Span feet	Type 2–S1 truck GVW=65,359 pounds Wheelbase=32.2 feet					Type 2-S2 truck GVW=63,266 pounds Wheelbase=35.7 feet				
	Equiv. H-Tr. Ldg. Tons	Percent of design stress				Equiv. H-Tr. Ldg. Tons	Percent of design stress			
		Case 1	Case 2	Case 3	Case 4		Case 1	Case 2	Case 3	Case 4
10	19.35	125	97	99	78	14.10	95	75	76	61
20	19.35	122	98	99	81	17.85	114	92	94	77
30	18.75	117	96	98	82	18.75	117	96	98	82
40	18.75	115	96	98	83	19.95	120	100	101	86
50	21.75	124	105	107	92	21.75	124	105	107	92
60	23.55	127	108	110	95	23.10	125	106	109	95
80	25.95	121	105	108	95	25.20	119	103	107	94
100	27.30	115	101	105	94	26.55	113	100	104	93

Span feet	Type 3–S2 truck GVW=75,650 pounds Wheelbase=40.2 feet					Type 3-3 truck GVW=86,380 pounds Wheelbase=52.3 feet				
	Equiv. H-Tr. Ldg. Tons	Percent of design stress				Equiv. H-Tr. Ldg. Tons	Percent of design stress			
		Case 1	Case 2	Case 3	Case 4		Case 1	Case 2	Case 3	Case 4
10	13.95	94	74	76	60	12.75	87	69	70	56
20	17.55	113	91	93	76	15.90	105	85	86	71
30	18.45	115	95	97	81	17.40	111	92	93	78
40	19.50	118	99	100	85	19.20	117	98	99	85
50	22.50	127	107	109	93	21.45	123	104	106	91
60	25.70	132	111	115	99	24.60	130	110	113	97
80	28.50	127	110	113	99	29.10	129	111	115	100
100	30.45	121	106	110	98	32.10	124	108	113	100

STRESS PRODUCING CHARACTERISTICS OF SIX HEAVY VEHICLE TYPES REPRESENTATIVE OF HEAVIEST VEHICLES REPORTED BY THE 1942 LOADOMETER SURVEY

Case 1: One vehicle in **each** lane with **full** allowance for impact.

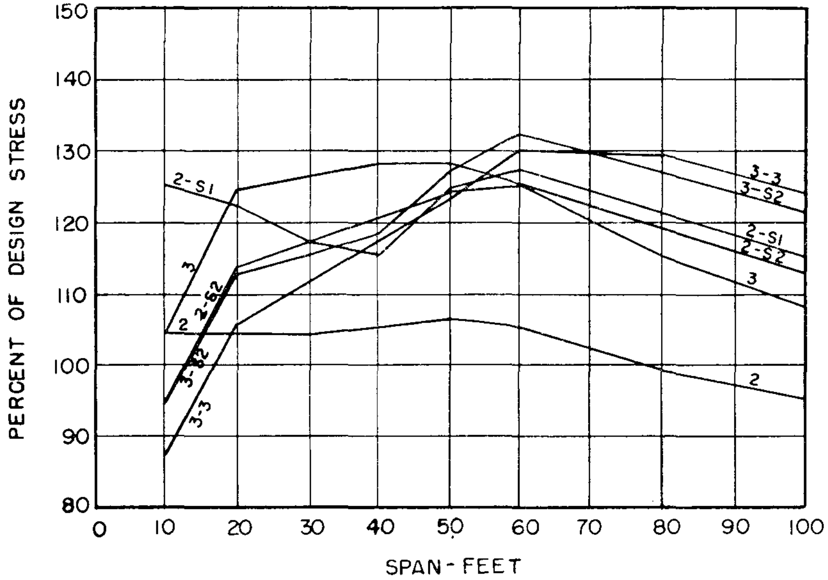


Figure 5.3a

Case 2: One vehicle in **one** lane with **full** allowance for impact.

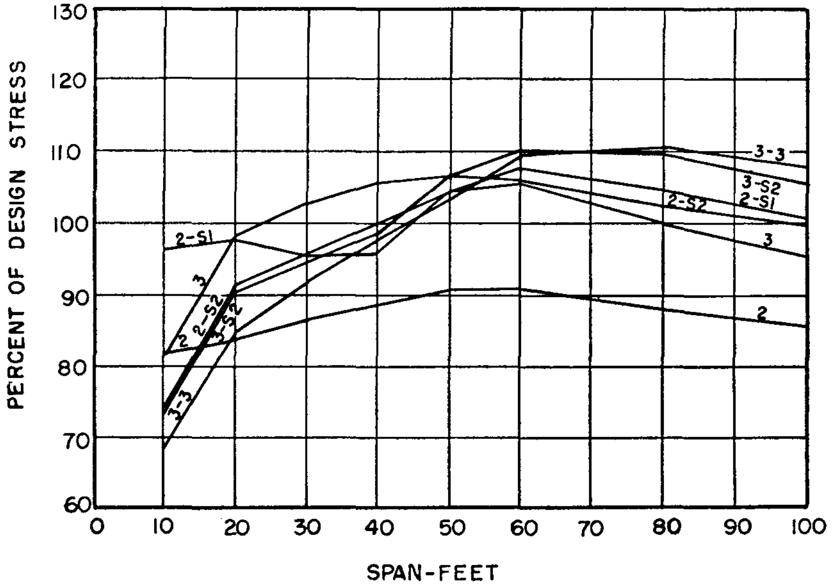


Figure 5.3b

STRESS PRODUCING CHARACTERISTICS OF SIX HEAVY VEHICLE TYPES REPRESENTATIVE OF HEAVIEST VEHICLES REPORTED BY THE 1942 LOADOMETER SURVEY

Case 3: One vehicle in **each** lane with **no** allowance for impact.

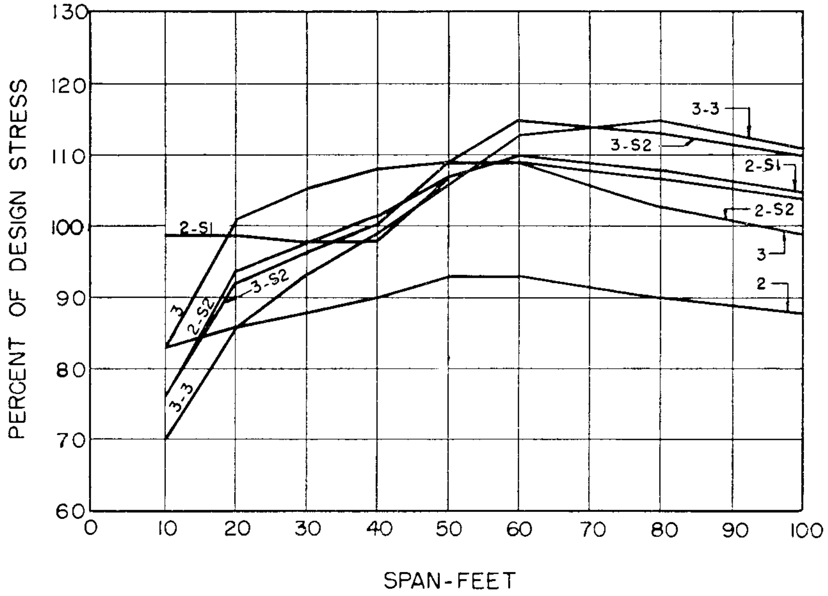


Figure 5.3c

Case 4: One vehicle in **one** lane with **no** allowance for impact.

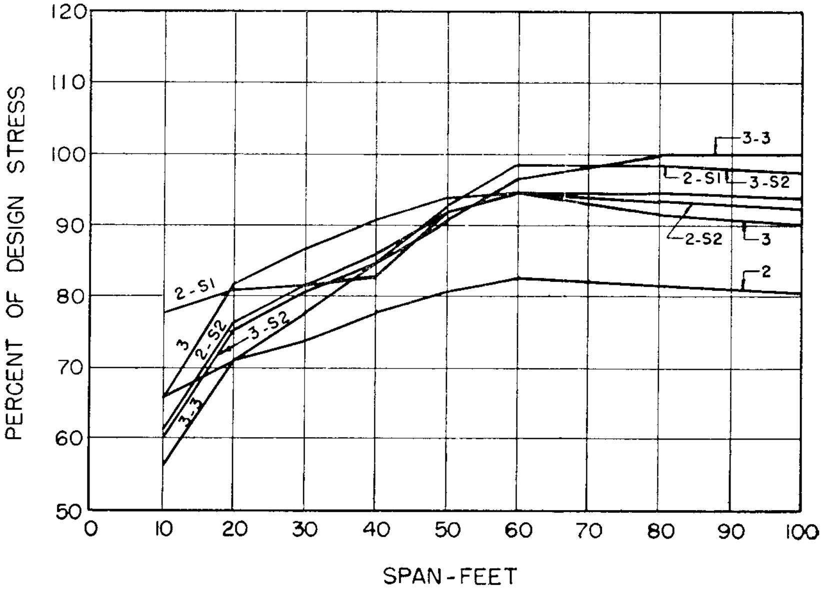


Figure 5.3d

Part VI

TABLES AND CHARTS FOR EVALUATING OVERSTRESS PRODUCED BY HEAVY MOTOR VEHICLE LOADS ON SIMPLE SPAN DECK GIRDER BRIDGES OF H 15 DESIGN

The tables and charts which follow provide the means for quickly determining the degree of overstress or understress (design stress ratio) in simple span deck girder bridges of H 15 design which results from the live load and impact stresses produced by any of the heavy vehicle types and loadings encountered in present-day highway traffic. The design stress ratios, indicating the degree of overstress or understress, given by these tables and charts are mathematically correct for the dead load ratios shown in Fig. 5.2. And since the dead load ratios shown in Fig. 5.2 are based on the lightest type of construction commonly used for simple span bridges of H 15 design, any estimate of overstress obtained from these tables or charts will be on the conservative side for the heavier types of bridge construction. For a more complete treatment of this subject, the reader is referred to the discussion in Part V concerning the type of construction upon which the dead load ratios given by Fig. 5.2 are based.

The tables and charts which follow consist of one set of tables—Tables 6.1 - 6.4—and three sets of charts—Figs. 6.1 - 6.2, Figs. 6.3 - 6.4, and Figs. 6.5 - 6.6—which will be discussed in the order of their presentation which is as follows:

A. Discussion of Tables 6.1 - 6.4 (4 Tables—total)
B. Discussion of Figs. 6.1 - 6.2 (12 Figs.—total)
C. Discussion of Figs. 6.3 - 6.4 (12 Figs.—total)
D. Discussion of Figs. 6.5 - 6.6 (20 Figs.—total)

Each of these sets of tables and charts give similar data concerning overstress or understress—design stress ratio—in simple span deck girder bridges of H 15 design but the variables are arranged somewhat differently in each set. The choice as to which set would be used in any particular case will depend on both the nature of the problem under consideration and the personal preference of the user. Only a casual examination of these several arrangements of the variables, however, will be required to determine the set most appropriate for use in the solution of a given problem.

A. Discussion of Tables 6.1 - 6.4

Tables 6.1 - 6.4 give the equivalent H truck loadings in tons required to produce maximum bending stresses in an interior stringer, corresponding to a given design stress ratio, for four different conditions of loading. The four conditions of loading are as follows:

1. One vehicle in **each** lane with **full** allowance for impact. (Table 6.1)
2. One vehicle in **each** lane with **no** allowance for impact. (Table 6.2)
3. One vehicle in **one** lane with **full** allowance for impact. (Table 6.3)
4. One vehicle in **one** lane with **no** allowance for impact. (Table 6.4)

Depending on the loading condition under consideration, each of these tables may be used to determine either the H-equivalence required to produce a given design stress ratio or the degree of overstress or understress that would result from a vehicle (or vehicles) of given H-equivalence.

For example, suppose it were desired to know the equivalent H truck loading that would be required, for each of the above four loading conditions, to produce an overstress of 20 percent—or a design stress ratio X = 1.20—in a 60-foot simple span deck girder bridge of H 15 design. The results would be as follows:

Case 1: One Eq. H 21.6 Tr. in **each** lane with **full** impact. (Table 6.1)
Case 2: One Eq. H 27.4 Tr. in **each** lane with **no** impact. (Table 6.2)
Case 3: One Eq. H 28.7 Tr. in **one** lane with **full** impact. (Table 6.3)
Case 4: One Eq. H 36.5 Tr. in **one** lane with **no** impact. (Table 6.4)

Similarly, if it were desired to know the design stress ratio that would be produced, for each of the above loading conditions, by an equivalent H 25 truck (or trucks) on the same 60-foot span, the results would be as follows:

Case 1: From Table 6.1, the design stress ratio X = 1.31
Case 2: From Table 6.2, the design stress ratio X = 1.14
Case 3: From Table 6.3, the design stress ratio X = 1.11
Case 4: From Table 6.4, the design stress ratio X = .98

B. Discussion of Figs. 6.1 - 6.2

Figs. 6.1 - 6.2 give the design stress ratios produced by equivalent H trucks on simple span deck girder bridges of H 15 design for 12 different conditions of loading. Six of these are covered by Figs. 6.1a - 6.1f which give the design stress ratios which result from six different allowances for impact when the bridge is fully loaded; that is, when loaded with one vehicle in each lane and all vehicles (identical) are so placed as to produce maximum moment. The remaining six loading conditions are covered by Figs. 6.2a - 6.2f which give the design stress ratios which result from six different allowances for impact when the bridge is loaded with one vehicle in one lane only at a time.

For example, suppose it were desired to know the design stress ratio that would be produced in a 60-foot simple span of H 15 design by one equivalent H 25 truck in each lane with a 10 percent allowance for impact. By consulting Fig. 6.1d, it will be found that this loading will produce a design stress ratio X = 1.20 or an overstress of 20 percent.

Other problems can be solved in a similar manner simply by selecting the figure corresponding to the loading condition under consideration.

C. Discussion of Figs. 6.3 - 6.4

Figs. 6.3 - 6.4 give the percent of design stress and the maximum moment in kip-feet produced by standard or equivalent H trucks having gross weights of from 10 to 60 tons on simple span bridges up to 100 feet in length for 12 different conditions of loading. Six of these loading conditions are covered by Figs. 6.3a - 6.3f which give the percent of design stress and maximum moment which result from six different allowances for impact when the bridge is fully loaded; that is, when one vehicle is placed in each lane and all vehicles (identical) are so placed as to produce maximum moment. The remaining six loading conditions are covered by Figs. 6.4a - 6.4f which give the percent of design stress and maximum moments which result from six different allowances for impact when the bridge is loaded with one vehicle in one lane only at a time.

For example, suppose it were desired to know the equivalent H truck loading and percent of design stress for a 60-foot simple span bridge of H 15 design resulting from the passing of one heavy vehicle in one lane only which produces a live load plus impact moment of 600 kip-feet and where the allowance for impact is 15 percent. By consulting Fig 6.4c it will be seen that the given vehicle would be rated as an equivalent H 22.1 truck and would produce a stress equal to 99 percent of the design stress.

Other problems of a similar nature can be solved simply by selecting the figure corresponding to the loading condition to be considered.

D. Discussion of Figs. 6.5 - 6.6

Figs. 6.5 - 6.6 give the design stress ratios produced by equivalent H trucks on simple span deck girder bridges of H 15 design for each 10-foot increment of span from 10 feet to 100 feet. Ten of these are covered by Figs. 6.5a - 6.5j which give the design stress ratios for each span which results from six different allowances for impact when the bridge is fully loaded; that is, when loaded with one vehicle in each lane and all vehicles (identical) are so placed as to cause maximum moment. The remaining ten figures (Figs. 6.6a - 6.6j give the design stress ratios for each span which result from six different allowances for impact when the bridge is loaded with one vehicle in one lane only.

For example, suppose it were desired to know the design stress ratio that would be produced in a 60-foot simple span bridge of H 15 design by one equivalent H 25 truck in each lane with 10 percent allowance for impact. By consulting Fig. 6.5f, it will be found that this loading will produce a design stress ratio of X = 1.20 on an overstress of 20 percent.

Other problems can be solved in a similar manner simply by selecting the figure corresponding to the loading condition under consideration.

Table 6.1

EQUIVALENT H TRUCK LOADING IN EACH LANE WITH FULL ALLOWANCE FOR IMPACT REQUIRED TO PRODUCE MAXIMUM STEEL STRESS CORRESPONDING TO GIVEN DESIGN STRESS RATIO

I' = I K' = 1.00 + I = K C = 1.00

Span		10	20	30	40	50	60	70	80	90	100
R_L		.862	.745	.660	.595	.540	.495	.462	.435	.410	.394
K		1.30	1.30	1.30	1.30	1.286	1.27	1.256	1.244	1.232	1.222
M_D		12.5	53.4	123.9	229.7	366.1	542.2	775.7	1056.7	1400.2	1762.0
KM_L		78.0	156.0	240.5	337.4	429.8	531.5	666.1	813.6	973.0	1145.6
M_T		90.5	209.4	364.4	567.1	795.9	1073.7	1441.8	1870.3	2373.2	2907.6
Design stress ratio—X	1.50	23.7	25.1	26.4	27.6	28.9	30.9	34.2	37.7	41.5	45.0
	1.40	22.0	23.1	24.1	25.1	26.1	27.8	30.7	33.7	36.9	40.0
	1.30	20.2	21.0	21.8	22.6	23.3	24.7	27.1	29.7	32.4	35.0
	1.20	18.5	19.0	19.5	20.1	20.6	21.6	23.6	25.6	27.8	29.9
	1.10	16.7	17.0	17.3	17.5	17.8	18.5	20.0	21.6	23.3	24.9
	1.00	15.0	15.0	15.0	15.0	15.0	15.4	16.4	17.6	18.7	19.9
	.90	13.3	13.0	12.7	12.5	12.2	12.2	12.9	13.5	14.1	14.8
	.80	11.5	11.0	10.5	10.0	9.4	9.1	9.3	9.5	9.6	9.8
	.70	9.8	9.0	8.2	7.4	6.7	6.0	5.8	5.4	5.0	4.7
	.60	8.0	6.9	5.9	4.9	3.9	2.9	2.2	1.4	.5	
	.50	6.3	4.9	3.6	2.4	1.1					

Table 6.2

EQUIVALENT H TRUCK LOADING IN EACH LANE WITH NO ALLOWANCE FOR IMPACT REQUIRED TO PRODUCE MAXIMUM STEEL STRESS CORRESPONDING TO GIVEN DESIGN STRESS RATIO

I' = 0.00 K' = 1.00 + I' = 1.00 C = 1.00

Span		10	20	30	40	50	60	70	80	90	100
R_L		.862	.745	.660	.595	.540	.495	.462	.435	.410	.394
K		1.30	1.30	1.30	1.30	1.286	1.27	1.256	1.244	1.232	1.222
M_D		12.5	53.4	123.9	229.7	366.1	542.2	775.7	1056.7	1400.2	1762.0
KM_L		78.0	156.0	240.5	337.4	429.8	531.5	666.1	813.6	973.0	1145.6
M_T		90.5	209.4	364.4	567.1	795.9	1073.7	1441.8	1870.3	2373.2	2907.6
Design stress ratio—X	1.50	30.8	32.6	34.3	35.9	37.2	39.2	43.0	47.0	51.1	55.0
	1.40	28.6	30.0	31.3	32.6	33.6	35.3	38.5	41.9	45.5	48.9
	1.30	26.3	27.4	28.4	29.3	30.0	31.3	34.0	36.9	39.9	42.7
	1.20	24.0	24.7	25.4	26.1	26.4	27.4	29.6	31.9	34.3	36.6
	1.10	21.8	22.1	22.4	22.8	22.9	23.4	25.1	26.9	28.6	30.4
	1.00	19.5	19.5	19.5	19.5	19.3	19.5	20.6	21.8	23.0	24.3
	.90	17.2	16.9	16.5	16.2	15.7	15.6	16.2	16.8	17.4	18.1
	.80	15.0	14.3	13.6	12.9	12.1	11.6	11.7	11.8	11.8	11.9
	.70	12.7	11.6	10.6	9.7	8.6	7.7	7.2	6.8	6.2	5.8
	.60	10.4	9.0	7.7	6.4	5.0	3.7	2.8	1.8	0.6	
	.50	8.2	6.4	4.7	3.1	1.4					

Table 6.3

EQUIVALENT H TRUCK LOADING IN ONE LANE WITH FULL ALLOWANCE FOR IMPACT REQUIRED TO PRODUCE MAXIMUM STEEL STRESS CORRESPONDING TO GIVEN DESIGN STRESS RATIO

$I' = I$ $K' = 1.00 + I = K$ $C = .75$

Span		10	20	30	40	50	60	70	80	90	100
R_L		.862	.745	.660	.595	.540	.495	.462	.435	.410	.394
K		1.30	1.30	1.30	1.30	1.286	1.27	1.256	1.244	1.232	1.222
M_D		12.5	53.4	123.9	229.7	366.1	542.2	775.7	1056.7	1400.2	1762.0
KM_L		78.0	156.0	240.5	337.4	429.8	531.5	666.1	813.6	973.0	1145.6
M_T		90.5	209.4	364.4	567.1	795.9	1073.7	1441.8	1870.3	2373.2	2907.6
Design stress ratio X	1.50	31.6	33.4	35.1	36.8	38.5	41.1	45.6	50.3	55.3	60.1
	1.40	29.3	30.7	32.1	33.5	34.8	37.0	40.9	45.0	49.2	53.3
	1.30	27.0	28.1	29.1	30.1	31.1	32.9	36.2	39.6	43.2	46.6
	1.20	24.6	25.4	26.1	26.7	27.4	28.7	31.4	34.2	37.1	39.9
	1.10	22.3	22.7	23.0	23.4	23.7	24.6	26.7	28.8	31.0	33.2
	1.00	20.0	20.0	20.0	20.0	20.0	20.5	21.9	23.4	24.9	26.5
	.90	17.7	17.3	17.0	16.7	16.3	16.3	17.2	18.0	18.8	19.8
	.80	15.4	14.6	13.9	13.3	12.6	12.2	12.4	12.7	12.8	13.0
	.70	13.0	11.9	10.9	9.9	8.9	8.1	7.7	7.3	6.7	6.3
	.60	10.7	9.3	7.9	6.6	5.2	3.9	2.9	1.9	.6	
	.50	8.4	6.6	4.9	3.2	1.5					

Table 6.4

EQUIVALENT H TRUCK LOADING IN ONE LANE WITH NO ALLOWANCE FOR IMPACT REQUIRED TO PRODUCE MAXIMUM STEEL STRESS CORRESPONDING TO GIVEN DESIGN STRESS RATIO

$I' = 0.00$ $K' = 1.00 + I' = 1.00$ $C = .75$

Span		10	20	30	40	50	60	70	80	90	100
R_L		.862	.745	.660	.595	.540	.495	.462	.435	.410	.394
K		1.30	1.30	1.30	1.30	1.286	1.27	1.256	1.244	1.232	1.222
M_D		12.5	53.4	123.9	229.7	366.1	542.2	775.7	1056.7	1400.2	1762.0
KM_L		78.0	156.0	240.5	337.4	429.8	531.5	666.1	813.6	973.0	1145.6
M_T		90.5	209.4	364.4	567.1	795.9	1073.7	1441.8	1870.3	2373.2	2907.6
Design stress ratio—X	1.50	41.1	43.5	45.7	47.9	49.5	52.3	57.3	62.6	68.2	73.4
	1.40	38.1	40.0	41.7	43.5	44.8	47.0	51.4	55.9	60.7	65.2
	1.30	35.1	36.5	37.8	39.1	40.0	41.8	45.4	49.2	53.2	57.0
	1.20	32.0	33.0	33.9	34.7	35.2	36.5	39.4	42.5	45.7	48.8
	1.10	**29.0**	**29.5**	**29.9**	30.4	30.5	31.3	33.5	35.8	38.2	40.5
	1.00	26.0	26.0	26.0	26.0	25.7	26.0	27.5	29.1	30.7	32.3
	.90	23.0	22.5	22.0	21.6	21.0	20.7	21.6	22.4	23.2	24.1
	.80	20.0	19.0	18.1	17.3	16.2	15.5	15.6	15.7	15.7	15.9
	.70	16.9	15.5	14.2	12.9	11.4	10.2	9.6	9.0	8.2	7.7
	.60	13.9	12.0	10.2	8.5	6.7	5.0	3.7	2.3	0.7	
	.50	10.9	8.6	6.3	4.1	1.9					

DESIGN STRESS RATIO PRODUCED BY EQUIVALENT H TRUCKS ON SIMPLE SPAN BRIDGES OF H 15 DESIGN WITH ONE VEHICLE IN EACH LANE AND STATED ALLOWANCE FOR IMPACT

C = 1.00 K′ = K = (1.00 + I) Span Length = Varies

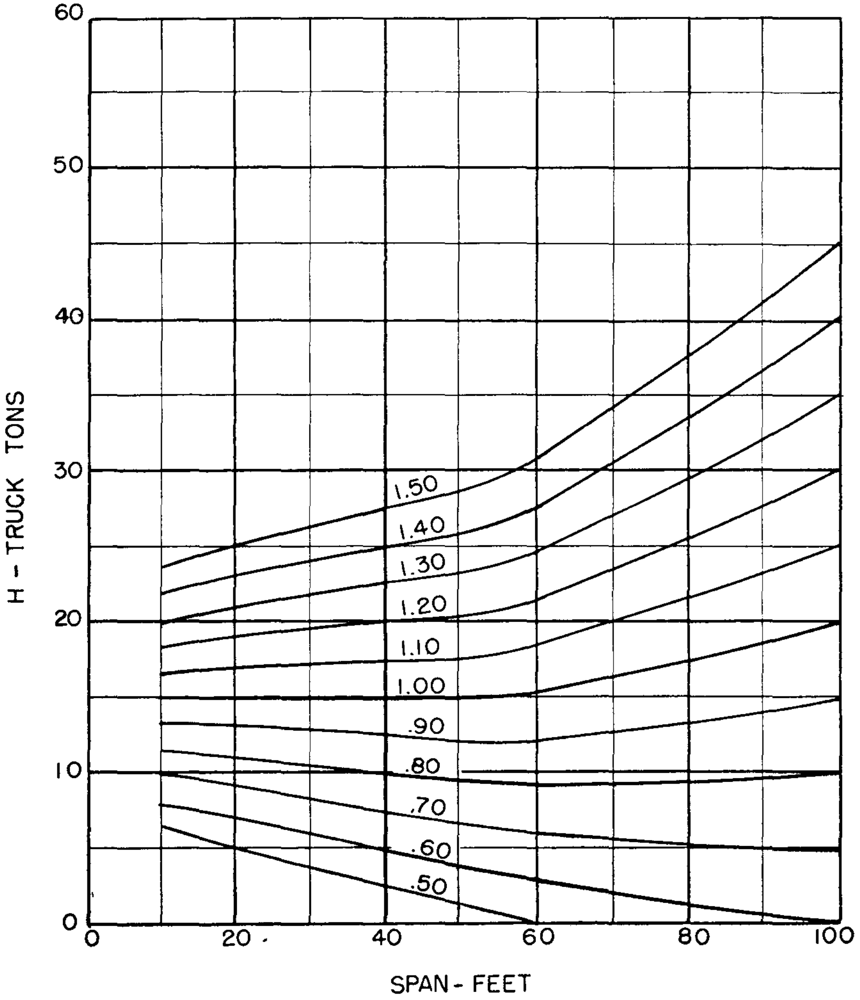


Figure 6.1a

DESIGN STRESS RATIO PRODUCED BY EQUIVALENT H TRUCKS ON SIMPLE SPAN BRIDGES OF H 15 DESIGN WITH ONE VEHICLE IN EACH LANE AND STATED ALLOWANCE FOR IMPACT

C = 1.00 K′ = 1.20 Span Length = Varies

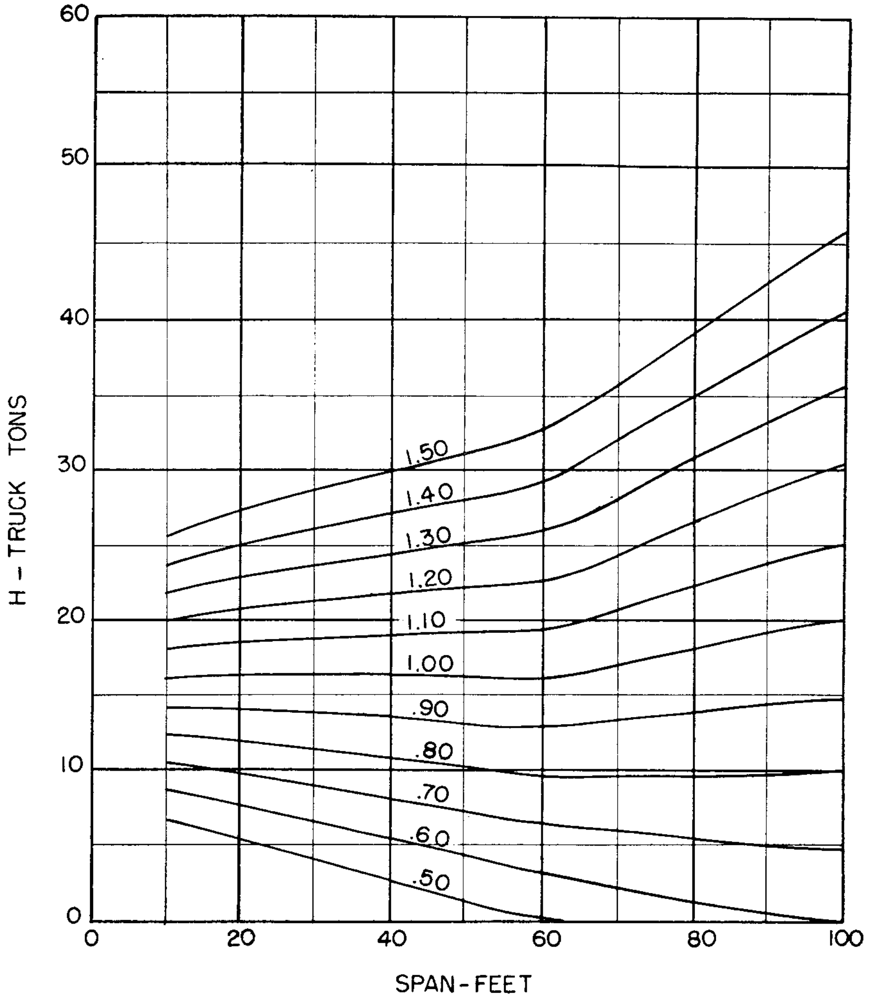


Figure 6.1b

DESIGN STRESS RATIO PRODUCED BY EQUIVALENT H TRUCKS ON SIMPLE SPAN BRIDGES OF H 15 DESIGN WITH ONE VEHICLE IN EACH LANE AND STATED ALLOWANCE FOR IMPACT

C = 1.00 K' = 1.15 Span Length = Varies

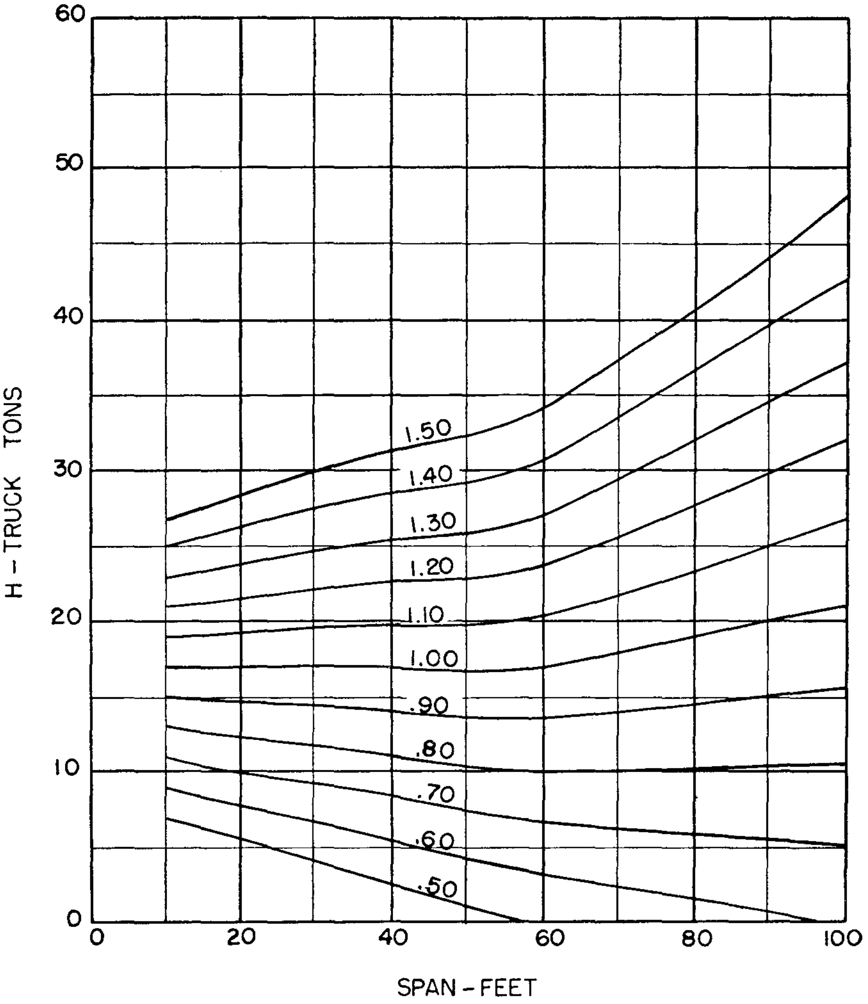


Figure 6.1c

DESIGN STRESS RATIO PRODUCED BY EQUIVALENT H TRUCKS ON SIMPLE SPAN BRIDGES OF H 15 DESIGN WITH ONE VEHICLE IN EACH LANE AND STATED ALLOWANCE FOR IMPACT

C = 1.00 K′ = 1.10 Span Length = Varies

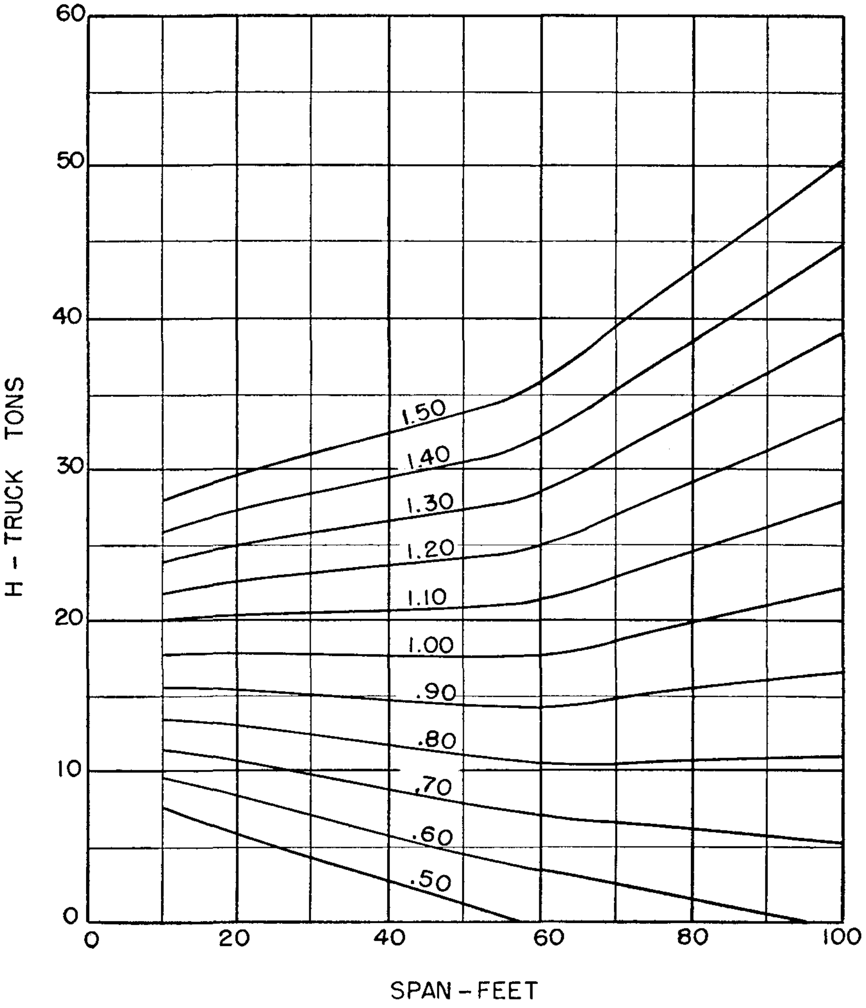


Figure 6.1d

DESIGN STRESS RATIO PRODUCED BY EQUIVALENT H TRUCKS ON SIMPLE SPAN BRIDGES OF H 15 DESIGN WITH ONE VEHICLE IN EACH LANE AND STATED ALLOWANCE FOR IMPACT

C = 1.00 K′ = 1.05 Span Length = Varies

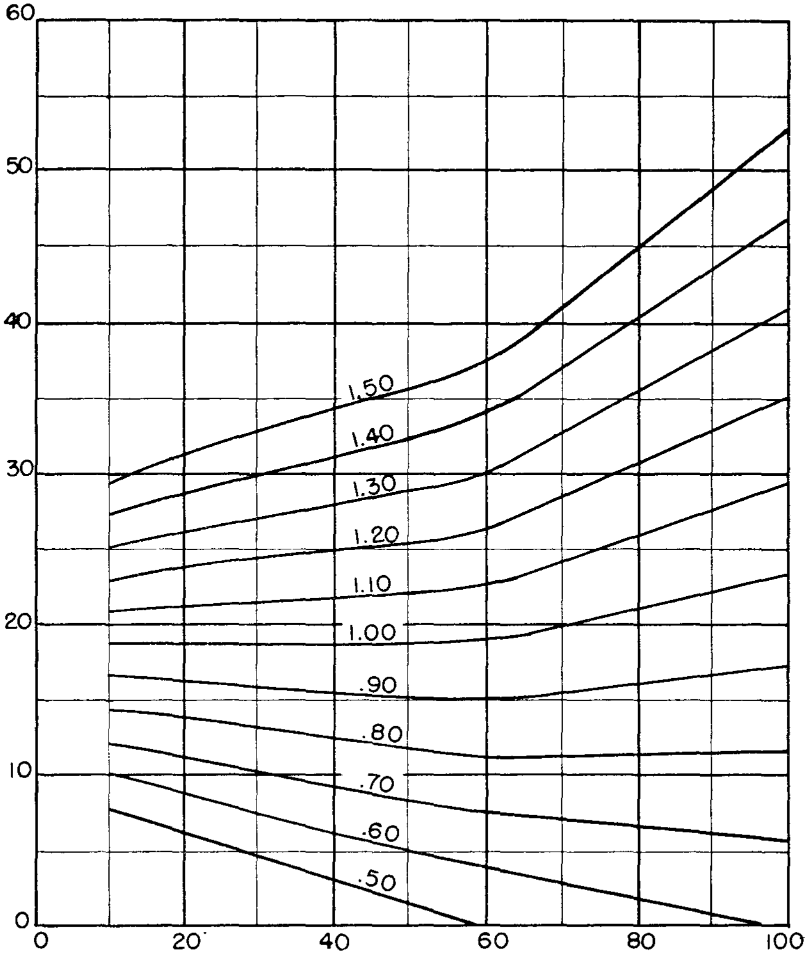


Figure 6.1e

DESIGN STRESS RATIO PRODUCED BY EQUIVALENT H TRUCKS ON SIMPLE SPAN BRIDGES OF H 15 DESIGN WITH ONE VEHICLE IN EACH LANE AND STATED ALLOWANCE FOR IMPACT

C = 1.00 K′ = 1.00 Span Length = Varies

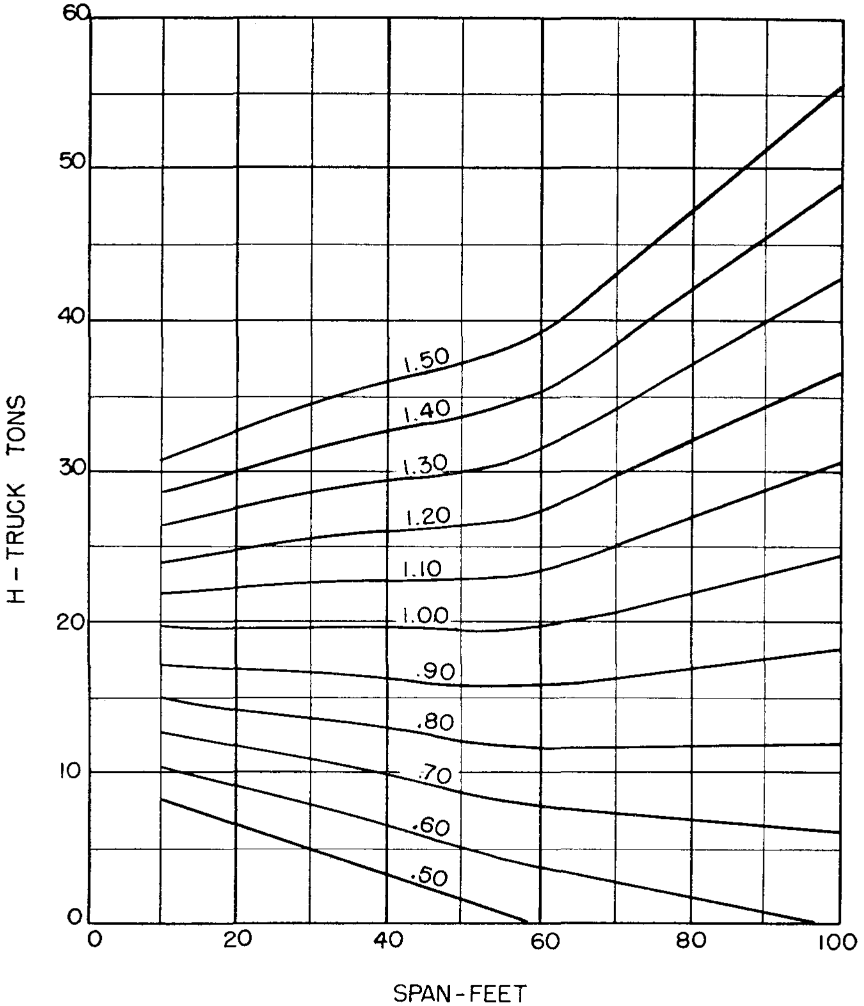


Figure 6.1f

DESIGN STRESS RATIO PRODUCED BY EQUIVALENT H TRUCKS ON SIMPLE SPAN BRIDGES OF H 15 DESIGN WITH ONE VEHICLE IN ONE LANE ONLY AND STATED ALLOWANCE FOR IMPACT

$C = 0.75$ $K' = K = (1.00 + I)$ Span Length = Varies

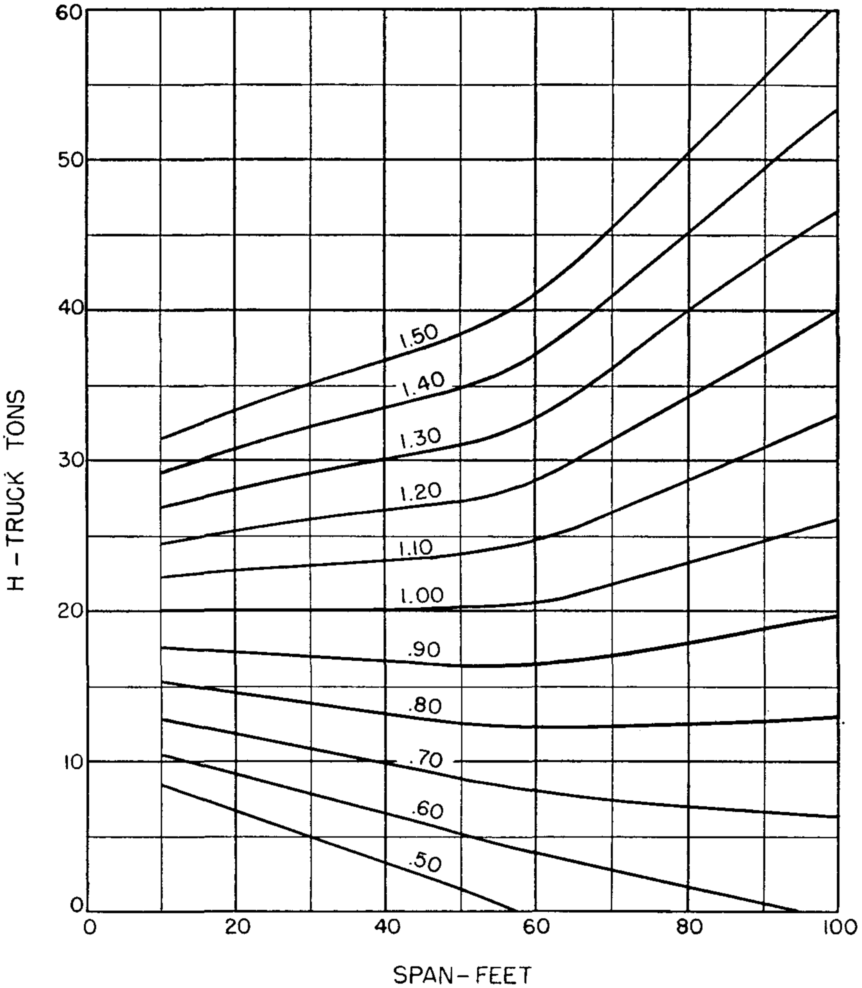


Figure 6.2a

DESIGN STRESS RATIO PRODUCED BY EQUIVALENT H TRUCKS ON SIMPLE SPAN BRIDGES OF H 15 DESIGN WITH ONE VEHICLE IN ONE LANE ONLY AND STATED ALLOWANCE FOR IMPACT

C = 0.75 K′ = 1.20 Span Length = Varies

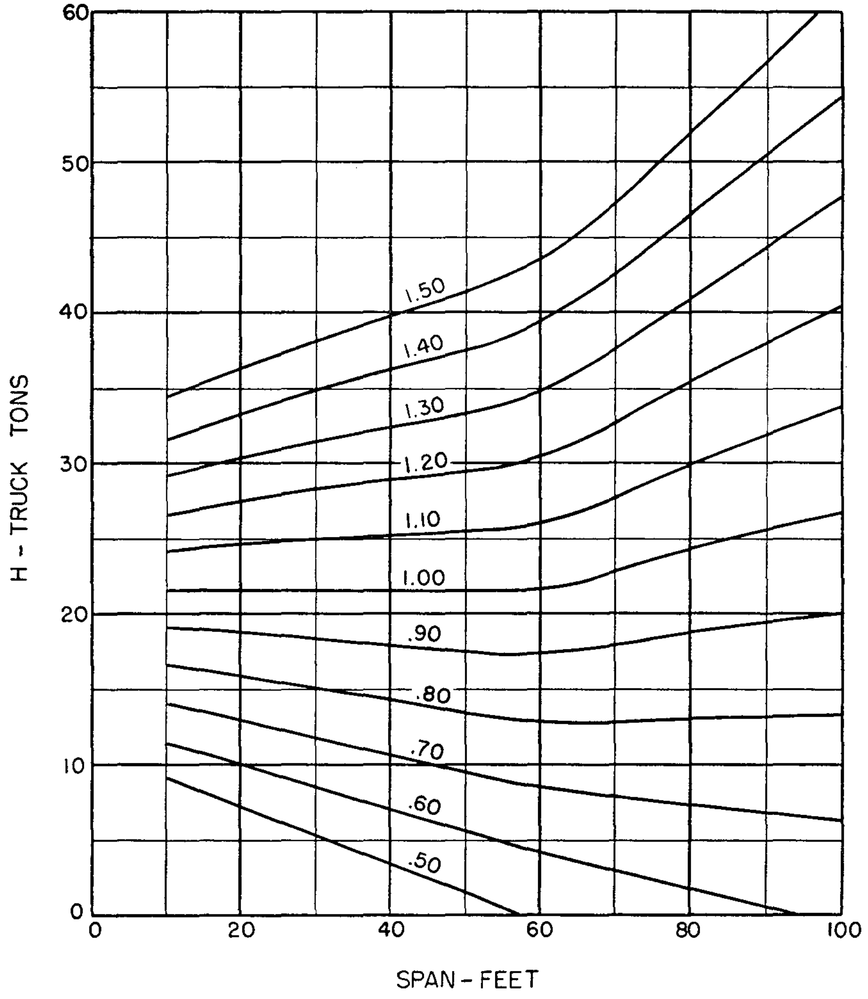


Figure 6.2b

DESIGN STRESS RATIO PRODUCED BY EQUIVALENT H TRUCKS ON SIMPLE SPAN BRIDGES OF H 15 DESIGN WITH ONE VEHICLE IN ONE LANE ONLY AND STATED ALLOWANCE FOR IMPACT

C = 0.75 K′ = 1.15 Span Length = Varies

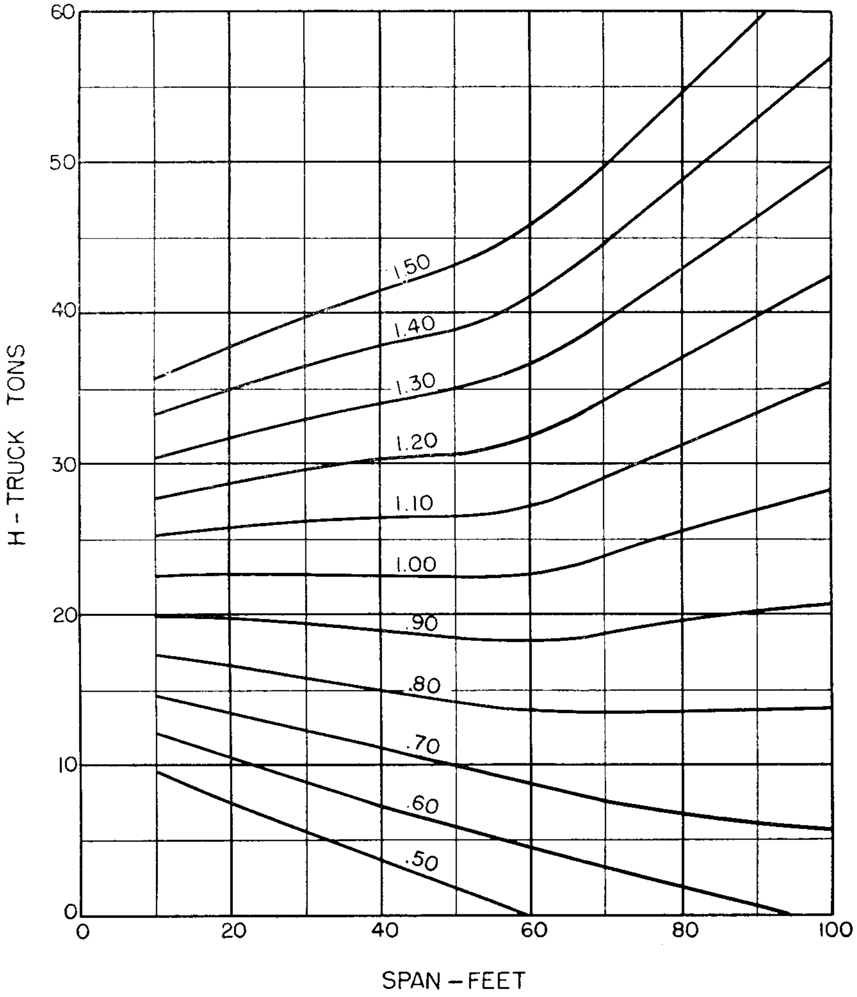


Figure 6.2c

DESIGN STRESS RATIO PRODUCED BY EQUIVALENT H TRUCKS ON SIMPLE SPAN BRIDGES OF H 15 DESIGN WITH ONE VEHICLE IN ONE LANE ONLY AND STATED ALLOWANCE FOR IMPACT

C = 0.75 K′ = 1.10 Span Length = Varies

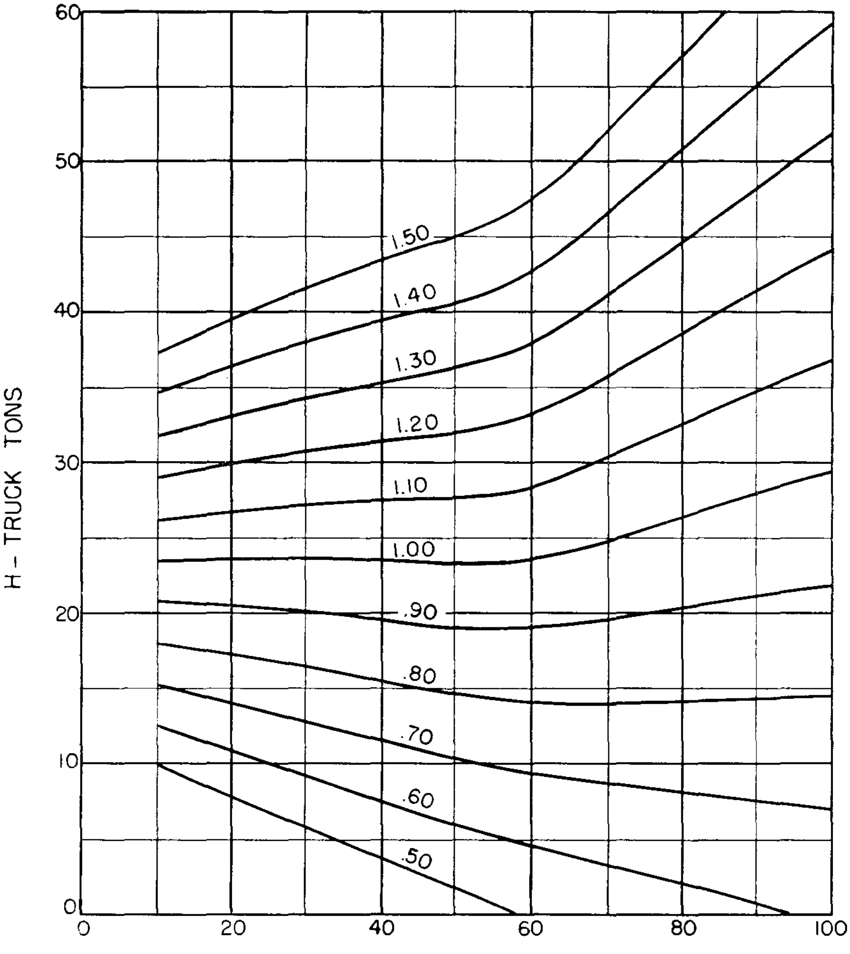


Figure 6.2d

DESIGN STRESS RATIO PRODUCED BY EQUIVALENT H TRUCKS ON SIMPLE SPAN BRIDGES OF H 15 DESIGN WITH ONE VEHICLE IN ONE LANE ONLY AND STATED ALLOWANCE FOR IMPACT

C = 0.75 K′ = 1.05 Span Length = Varies

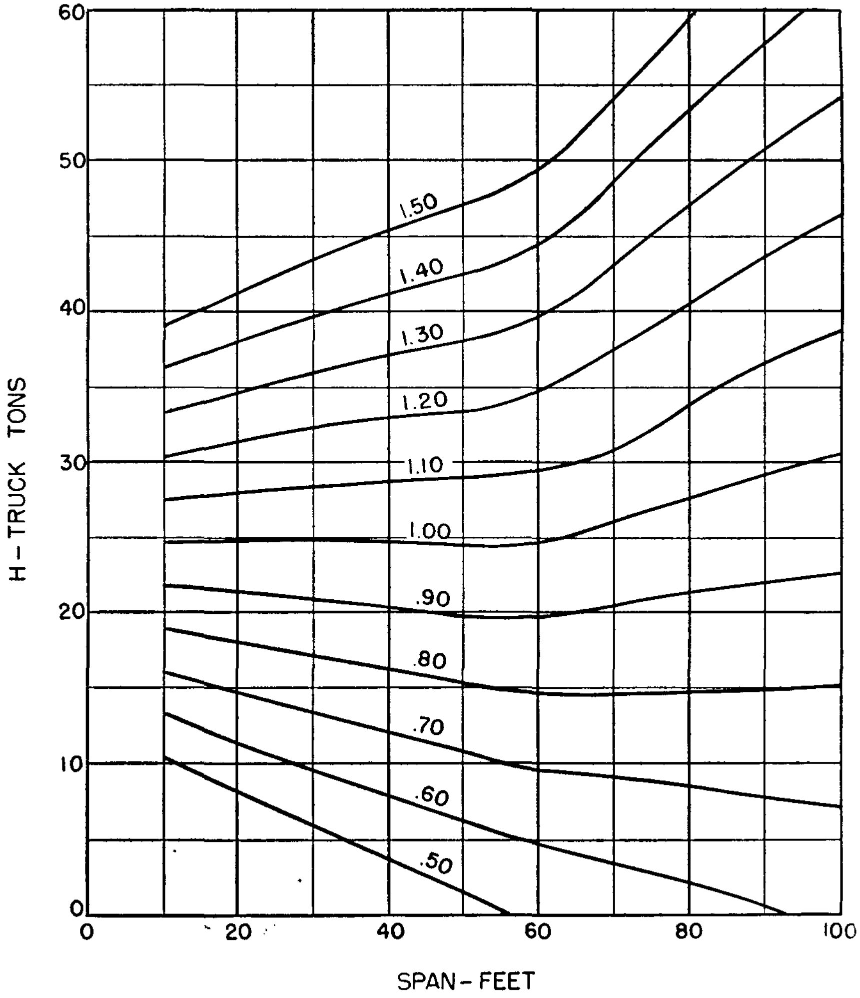


Figure 6.2e

DESIGN STRESS RATIO PRODUCED BY EQUIVALENT H TRUCKS ON SIMPLE SPAN BRIDGES OF H 15 DESIGN WITH ONE VEHICLE IN ONE LANE ONLY AND STATED ALLOWANCE FOR IMPACT

C = 0.75 K′ = 1.00 Span Length = Varies

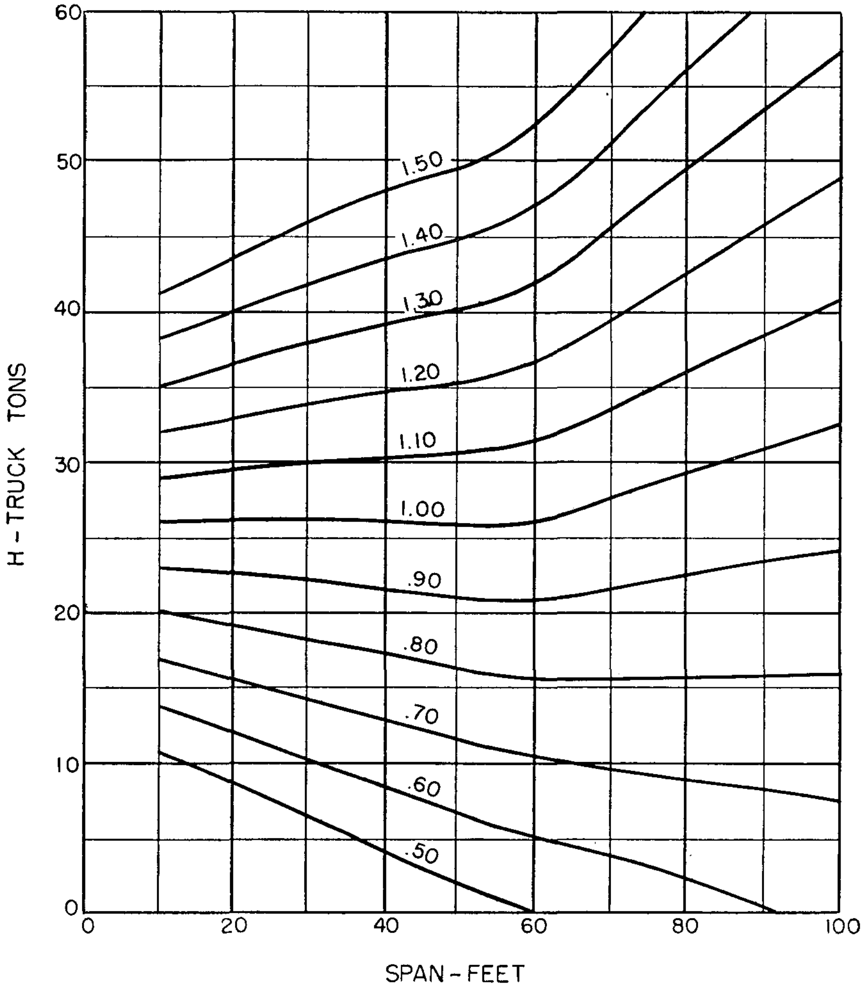


Figure 6.2f

PERCENT OF DESIGN STRESS PRODUCED BY EQUIVALENT H TRUCKS ON SIMPLE SPAN BRIDGES OF H 15 DESIGN WITH ONE VEHICLE IN EACH LANE AND STATED ALLOWANCE FOR IMPACT

Live Load Moments As Shown Are Those Produced by One Standard or Equivalent H Truck of Indicated Rating on Spans of Various Lengths

$C = 1.00$ $K' = K = (1.00 + I)$ Span Length = Varies

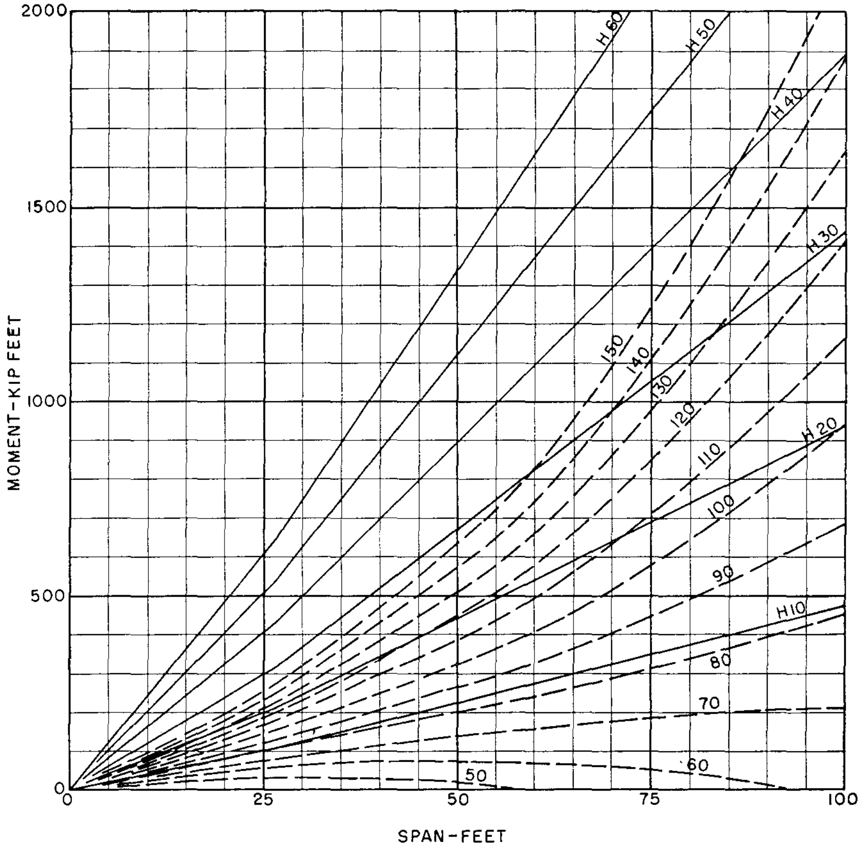


Figure 6.3a

PERCENT OF DESIGN STRESS PRODUCED BY EQUIVALENT H TRUCKS ON SIMPLE SPAN BRIDGES OF H 15 DESIGN WITH ONE VEHICLE IN EACH LANE AND STATED ALLOWANCE FOR IMPACT

Live Load Moments As Shown Are Those Produced by One Standard or Equivalent H Truck of Indicated Rating on Spans of Various Lengths

C = 1.00 K′ = 1.20 Span Length = Varies

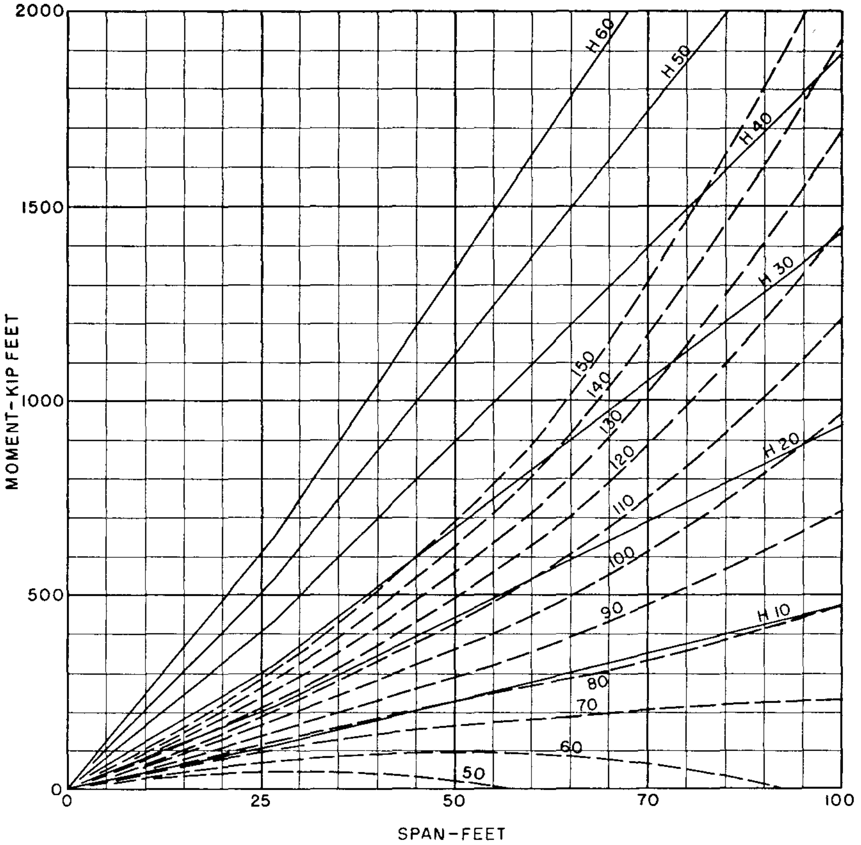


Figure 6.3b

PERCENT OF DESIGN STRESS PRODUCED BY EQUIVALENT H TRUCKS ON SIMPLE SPAN BRIDGES OF H 15 DESIGN WITH ONE VEHICLE IN EACH LANE AND STATED ALLOWANCE FOR IMPACT

Live Load Moments As Shown Are Those Produced by One Standard or Equivalent H Truck of Indicated Rating on Spans of Various Lengths

$C = 1.00$ $K' = 1.15$ Span Length = Varies

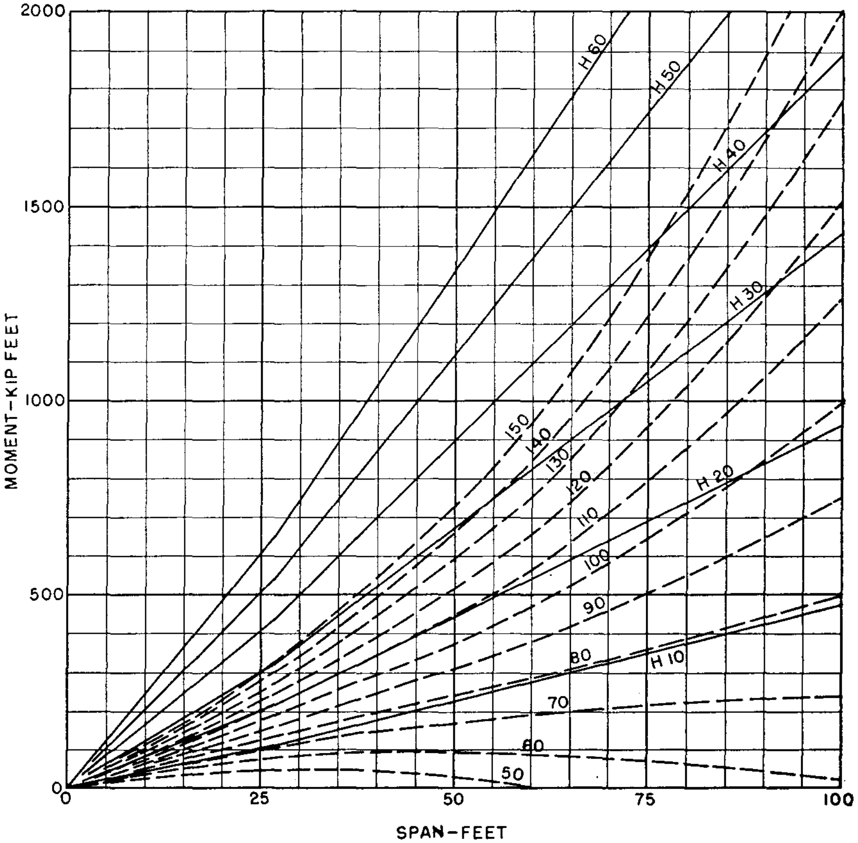


Figure 6.3c

PERCENT OF DESIGN STRESS PRODUCED BY EQUIVALENT H TRUCKS ON SIMPLE SPAN BRIDGES OF H 15 DESIGN WITH ONE VEHICLE IN EACH LANE AND STATED ALLOWANCE FOR IMPACT

Live Load Moments As Shown Are Those Produced by One Standard or Equivalent H Truck of Indicated Rating on Spans of Various Lengths

C = 1.00 K′ = 1.10 Span Length = Varies

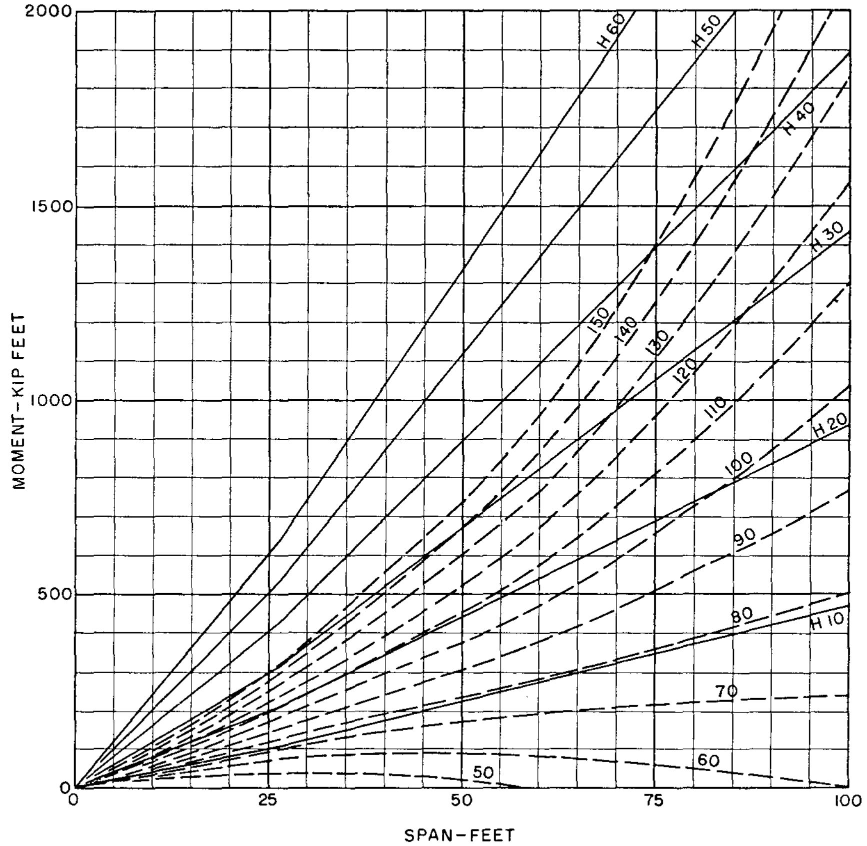


Figure 6.3d

PERCENT OF DESIGN STRESS PRODUCED BY EQUIVALENT H TRUCKS ON SIMPLE SPAN BRIDGES OF H 15 DESIGN WITH ONE VEHICLE IN EACH LANE AND STATED ALLOWANCE FOR IMPACT

Live Load Moments As Shown Are Those Produced by One Standard or Equivalent H Truck of Indicated Rating on Spans of Various Lengths

C = 1.00 K′ = 1.05 Span Length = Varies

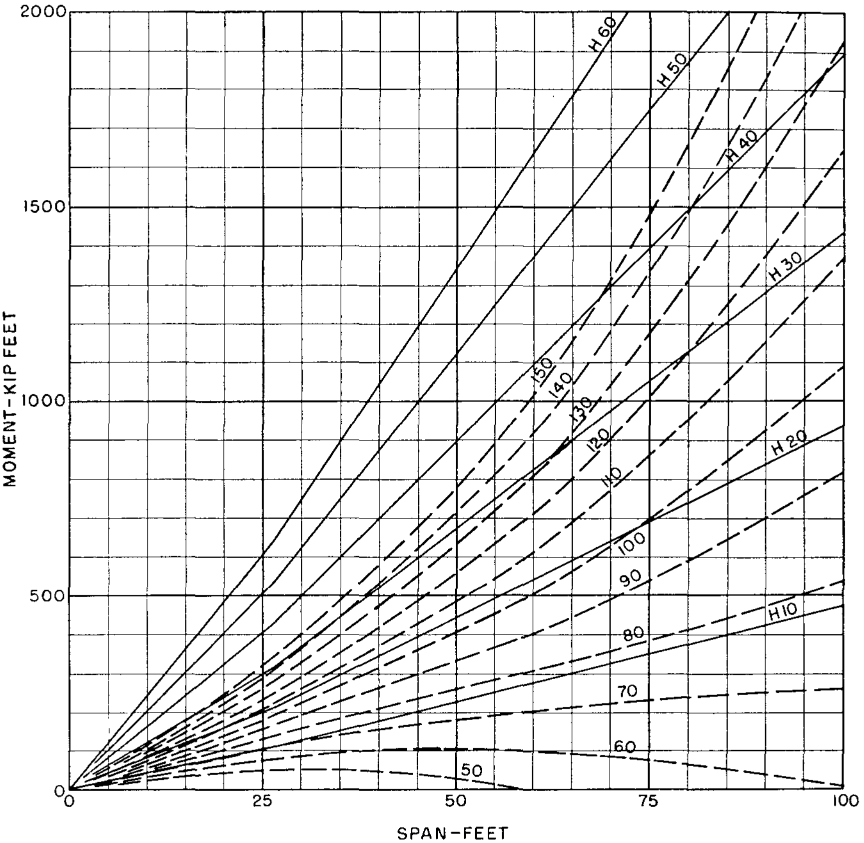


Figure 6.3e

PERCENT OF DESIGN STRESS PRODUCED BY EQUIVALENT H TRUCKS ON SIMPLE SPAN BRIDGES OF H 15 DESIGN WITH ONE VEHICLE IN EACH LANE AND STATED ALLOWANCE FOR IMPACT

Live Load Moments As Shown Are Those Produced by One Standard or Equivalent H Truck of Indicated Rating on Spans of Various Lengths

C = 1.00 K′ = 1.00 Span Length = Varies

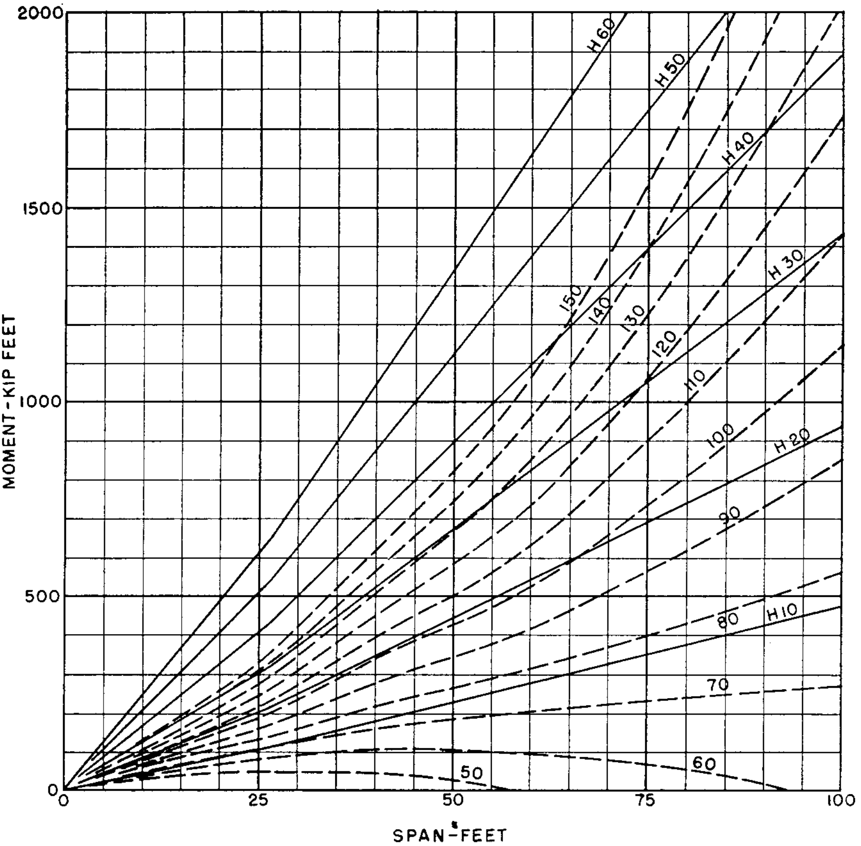


Figure 6.3f

PERCENT OF DESIGN STRESS PRODUCED BY EQUIVALENT H TRUCKS ON SIMPLE SPAN BRIDGES OF H 15 DESIGN WITH ONE VEHICLE IN ONE LANE ONLY AND STATED ALLOWANCE FOR IMPACT

Live Load Moments As Shown Are Those Produced by One Standard or Equivalent H Truck of Indicated Rating on Spans of Various Lengths

C = 0.75 K′ = K = (1.00 + I) Span Length = Varies

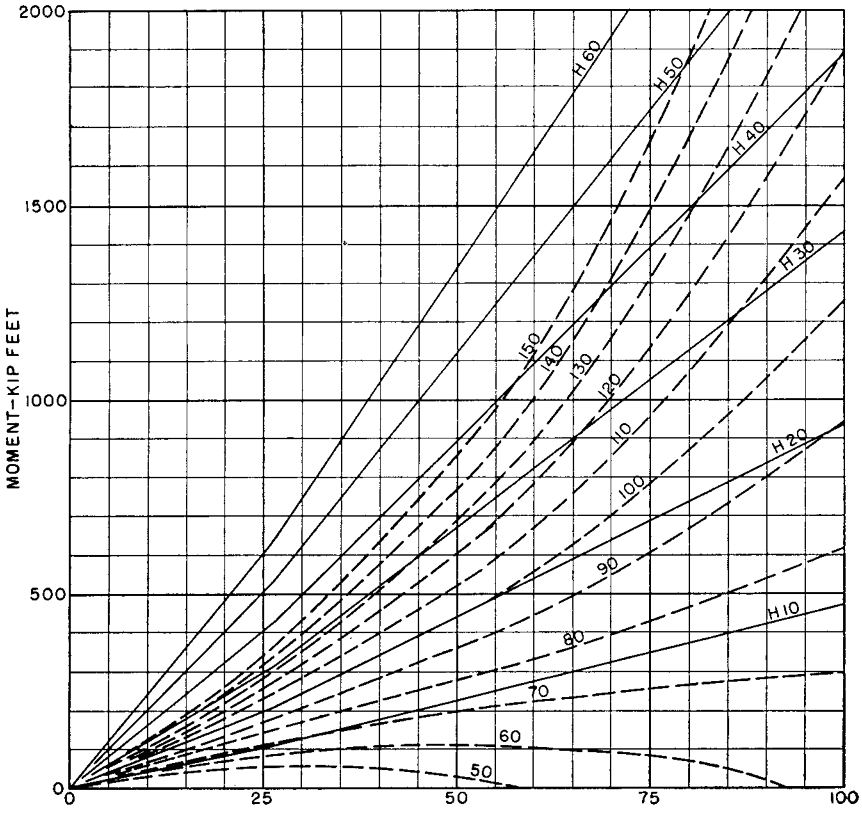


Figure 6.4a

PERCENT OF DESIGN STRESS PRODUCED BY EQUIVALENT H TRUCKS ON SIMPLE SPAN BRIDGES OF H 15 DESIGN WITH ONE VEHICLE IN ONE LANE ONLY AND STATED ALLOWANCE FOR IMPACT

Live Load Moments As Shown Are Those Produced by One Standard or Equivalent H Truck of Indicated Rating on Spans of Various Lengths

C = 0.75 K′ = 1.20 Span Length = Varies

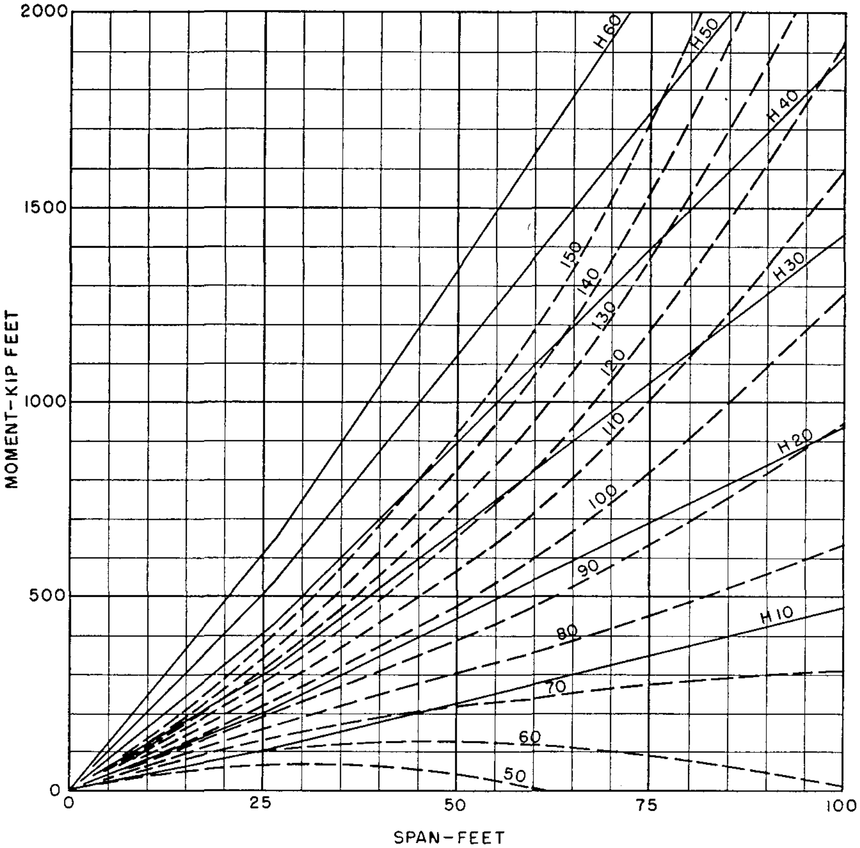


Figure 6.4b

PERCENT OF DESIGN STRESS PRODUCED BY EQUIVALENT H TRUCKS ON SIMPLE SPAN BRIDGES OF H 15 DESIGN WITH ONE VEHICLE IN ONE LANE ONLY AND STATED ALLOWANCE FOR IMPACT

Live Load Moments As Shown Are Those Produced by One Standard or Equivalent H Truck of Indicated Rating on Spans of Various Lengths

C = 0.75 K′ = 1.15 Span Length = Varies

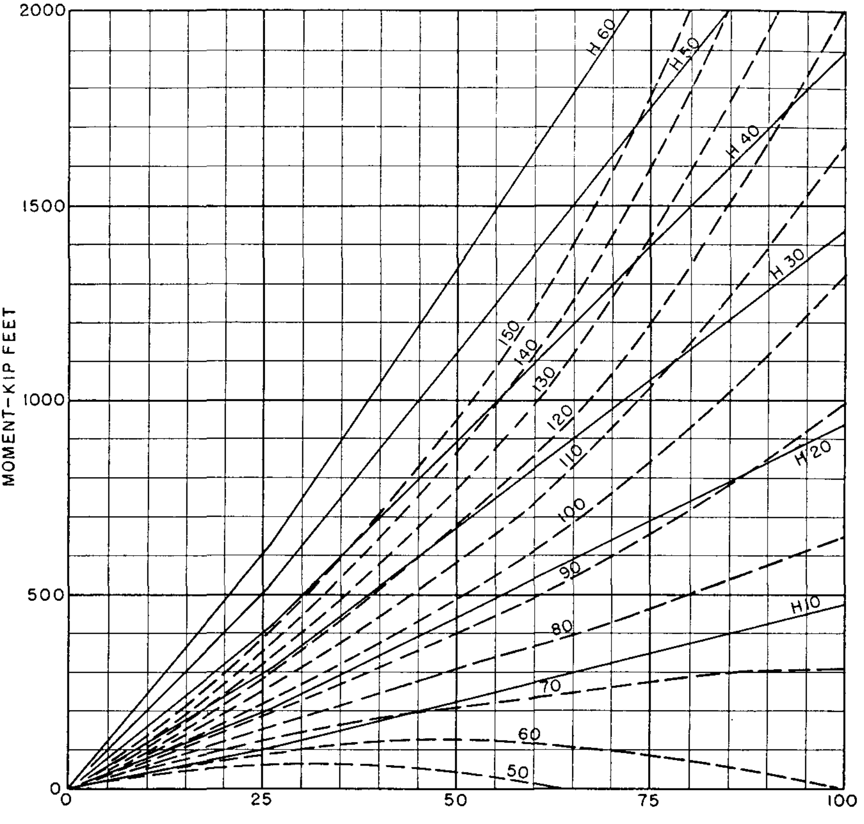


Figure 6.4c

PERCENT OF DESIGN STRESS PRODUCED BY EQUIVALENT H TRUCKS ON SIMPLE SPAN BRIDGES OF H 15 DESIGN WITH ONE VEHICLE IN ONE LANE ONLY AND STATED ALLOWANCE FOR IMPACT

Live Load Moments As Shown Are Those Produced by One Standard or Equivalent H Truck of Indicated Rating on Spans of Various Lengths

C = 0.75 K′ = 1.10 Span Length = Varies

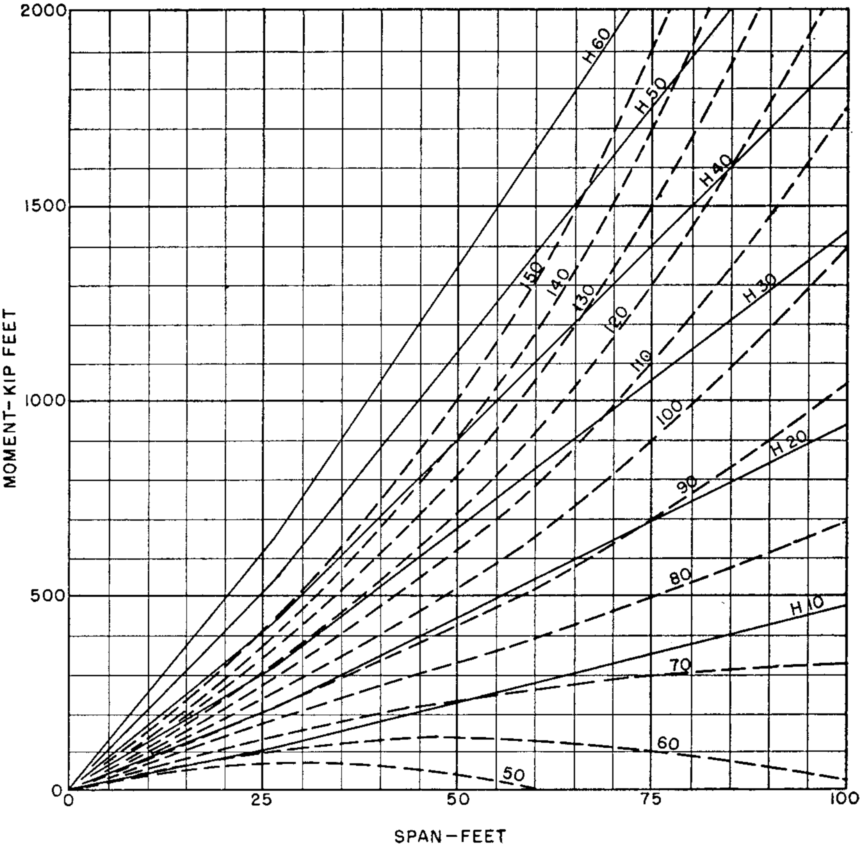


Figure 6.4d

PERCENT OF DESIGN STRESS PRODUCED BY EQUIVALENT H TRUCKS ON SIMPLE SPAN BRIDGES OF H 15 DESIGN WITH ONE VEHICLE IN ONE LANE ONLY AND STATED ALLOWANCE FOR IMPACT

Live Load Moments As Shown Are Those Produced by One Standard or Equivalent H Truck of Indicated Rating on Spans of Various Lengths

$C = 0.75$ $K' = 1.05$ Span Length = Varies

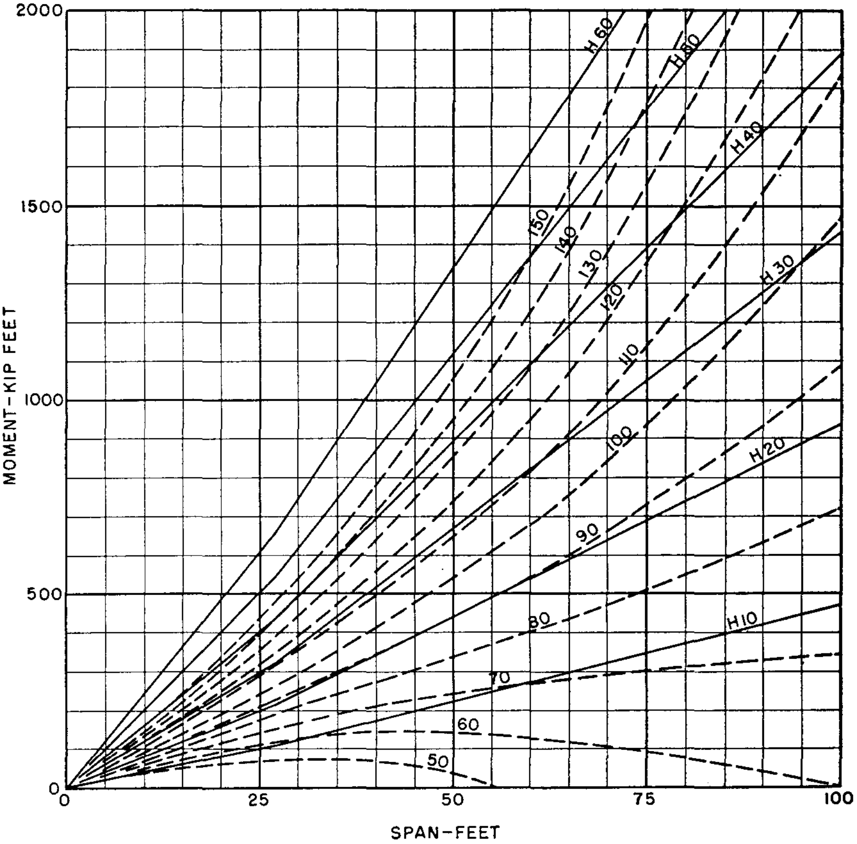


Figure 6.4e

PERCENT OF DESIGN STRESS PRODUCED BY EQUIVALENT H TRUCKS ON SIMPLE SPAN BRIDGES OF H 15 DESIGN WITH ONE VEHICLE IN ONE LANE ONLY AND STATED ALLOWANCE FOR IMPACT

Live Load Moments As Shown Are Those Produced by One Standard or Equivalent H Truck of Indicated Rating on Spans of Various Lengths

C = 0.75 K′ = 1.00 Span Length = Varies

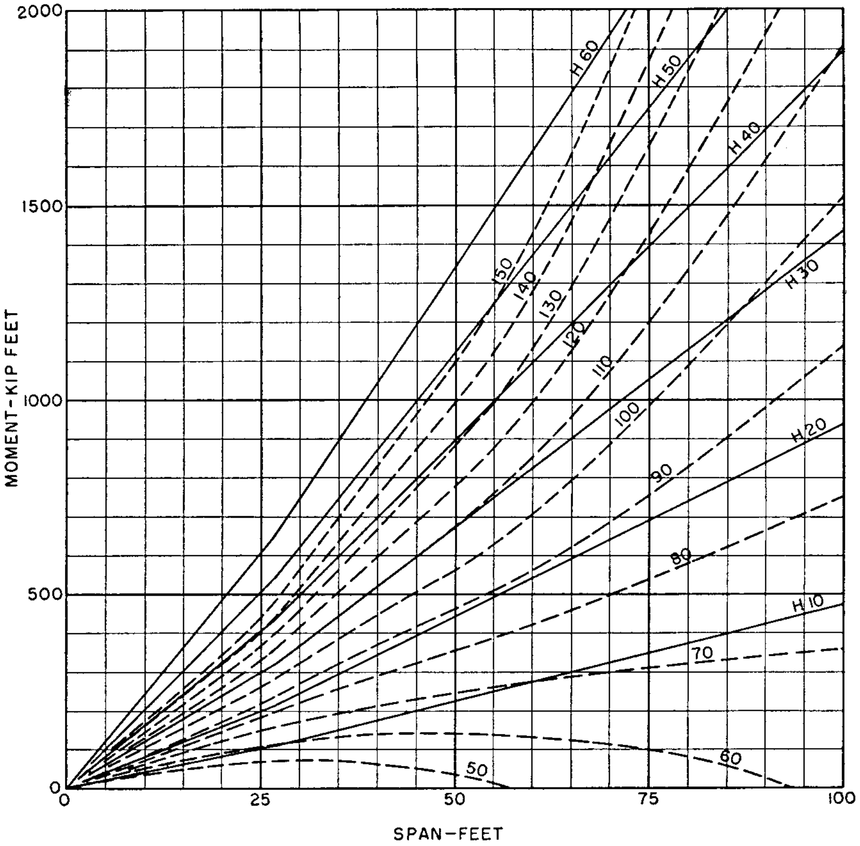
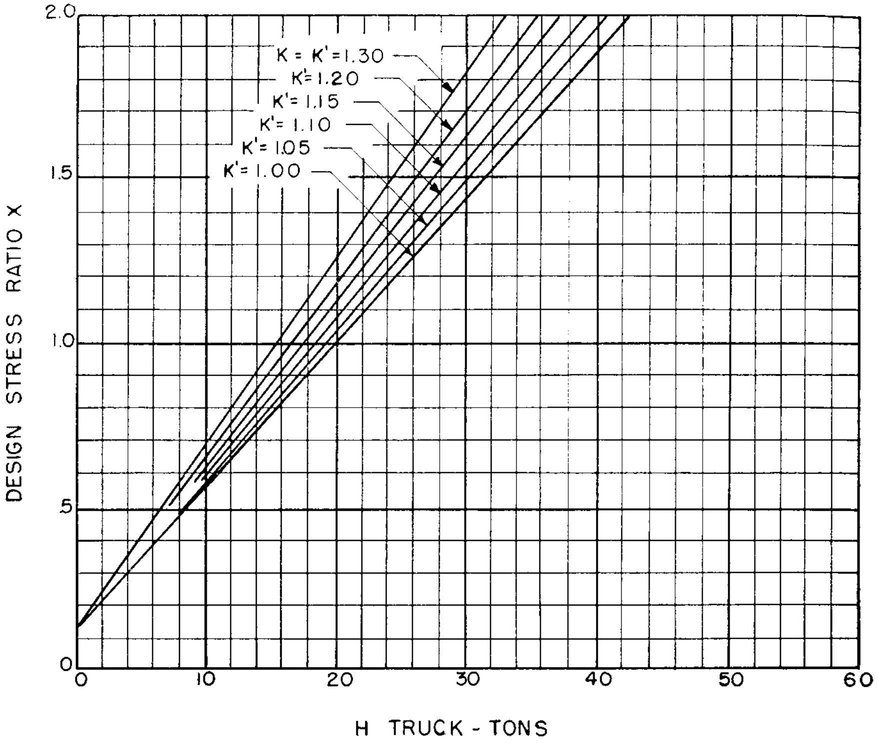


Figure 6.4f

DESIGN STRESS RATIO PRODUCED BY EQUIVALENT H TRUCKS ON SIMPLE SPAN BRIDGES OF H 15 DESIGN WITH ONE VEHICLE IN EACH LANE AND VARYING ALLOWANCE FOR IMPACT

C = 1.00 K′ = Varies Span Length = 10′



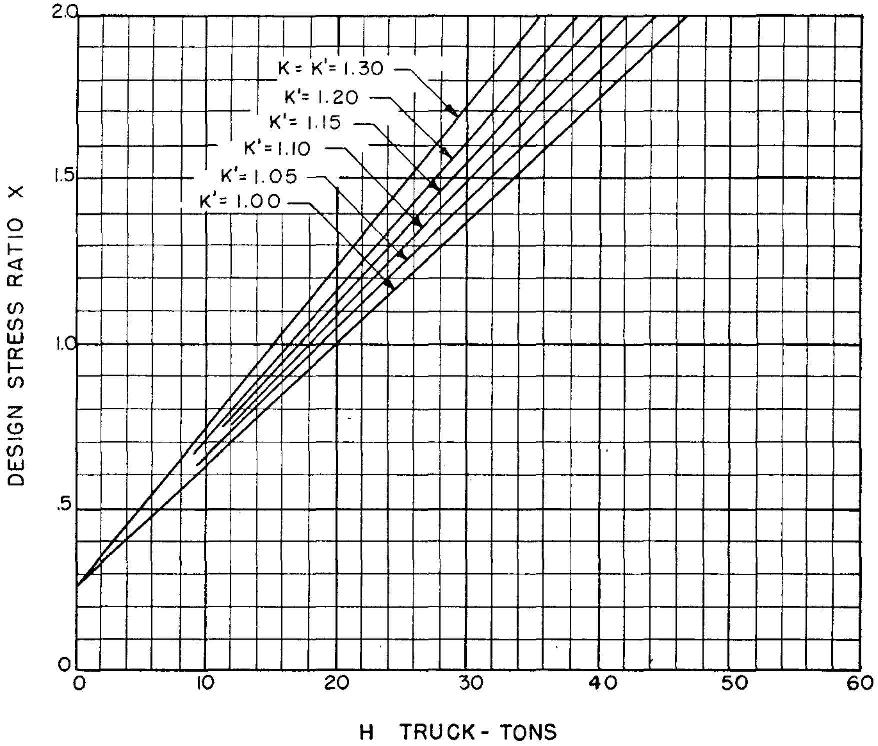
Equations for Design Stress Ratio

K = K′ = 1.300; X = .0575 H + .138
K′ = 1.200; X = .0530 H + .138
K′ = 1.150; X = .0508 H + .138
K′ = 1.100; X = .0486 H + .138
K′ = 1.050; X = .0464 H + .138
K′ = 1.000; X = .0442 H + .138

Figure 6.5a

DESIGN STRESS RATIO PRODUCED BY EQUIVALENT H TRUCKS ON SIMPLE SPAN BRIDGES OF H 15 DESIGN WITH ONE VEHICLE IN EACH LANE AND VARYING ALLOWANCE FOR IMPACT

C = 1.00 K′ = Varies Span Length = 20′



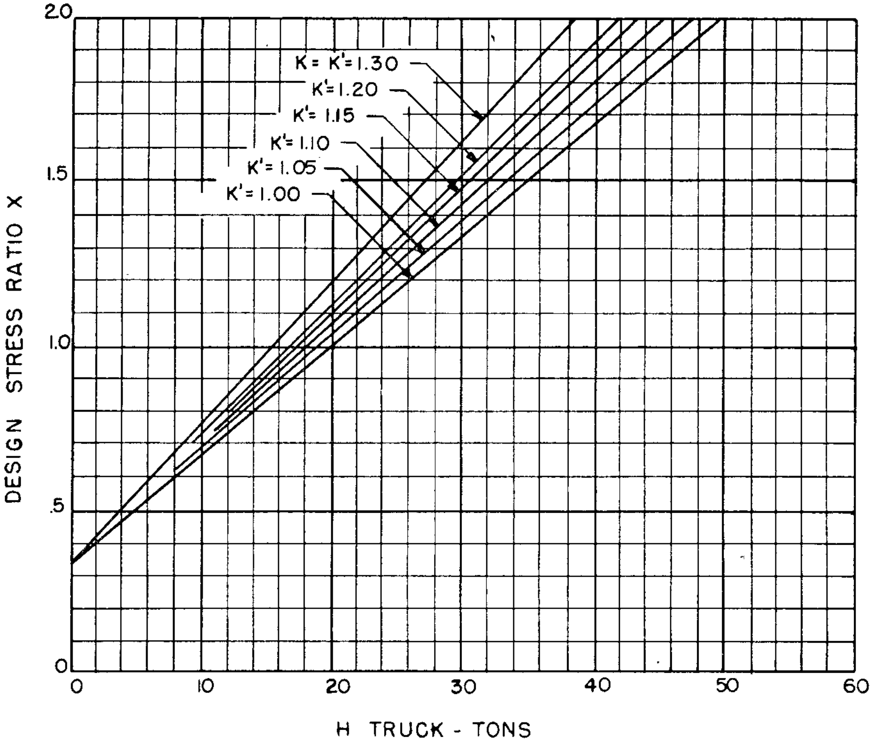
Equations for Design Stress Ratio

K = K′ = 1.300; X = .0497 H + .255
K′ = 1.200; X = .0458 H + .255
K′ = 1.150; X = .0439 H + .255
K′ = 1.100; X = .0420 H + .255
K′ = 1.050; X = .0401 H + .255
K′ = 1.000; X = .0382 H + .255

Figure 6.5b

DESIGN STRESS RATIO PRODUCED BY EQUIVALENT H TRUCKS ON SIMPLE SPAN BRIDGES OF H 15 DESIGN WITH ONE VEHICLE IN EACH LANE AND VARYING ALLOWANCE FOR IMPACT

C = 1.00 K′ = Varies Span Length = 30′



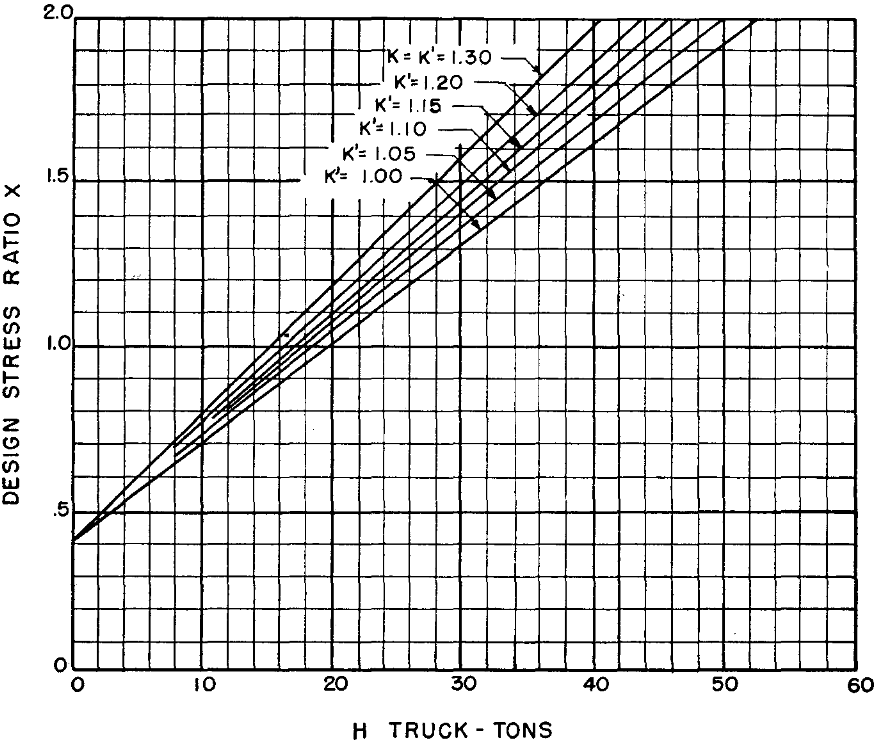
Equations for Design Stress Ratio

K = K′ = 1.300; X = .0439 H + .340
K′ = 1.200; X = .0406 H + .340
K′ = 1.150; X = .0389 H + .340
K′ = 1.100; X = .0372 H + .340
K′ = 1.050; X = .0355 H + .340
K′ = 1.000; X = .0338 H + .340

Figure 6.5c

DESIGN STRESS RATIO PRODUCED BY EQUIVALENT H TRUCKS ON SIMPLE SPAN BRIDGES OF H 15 DESIGN WITH ONE VEHICLE IN EACH LANE AND VARYING ALLOWANCE FOR IMPACT

C = 1.00 K′ = Varies Span Length = 40′



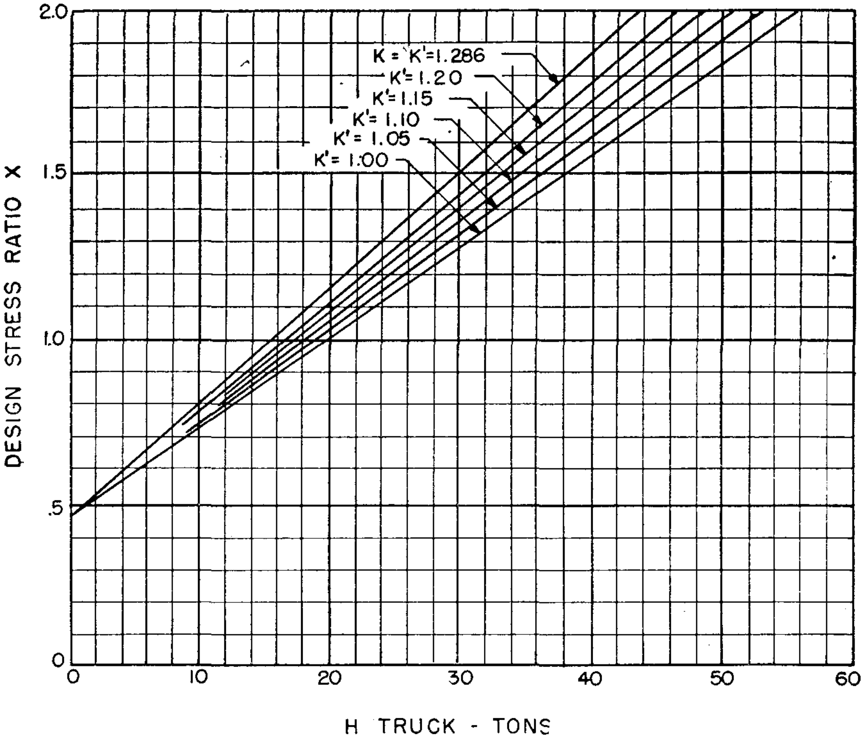
Equations for Design Stress Ratio

$K = K' = 1.300;\ X = .0397\,H + .405$
$K' = 1.200;\ X = .0366\,H + .405$
$K' = 1.150;\ X = .0351\,H + .405$
$K' = 1.100;\ X = .0336\,H + .405$
$K' = 1.050;\ X = .0320\,H + .405$
$K' = 1.000;\ X = .0305\,H + .405$

Figure 6.5d

DESIGN STRESS RATIO PRODUCED BY EQUIVALENT H TRUCKS ON SIMPLE SPAN BRIDGES OF H 15 DESIGN WITH ONE VEHICLE IN EACH LANE AND VARYING ALLOWANCE FOR IMPACT

$C = 1.00$ $K' = $ Varies Span Length $= 50'$



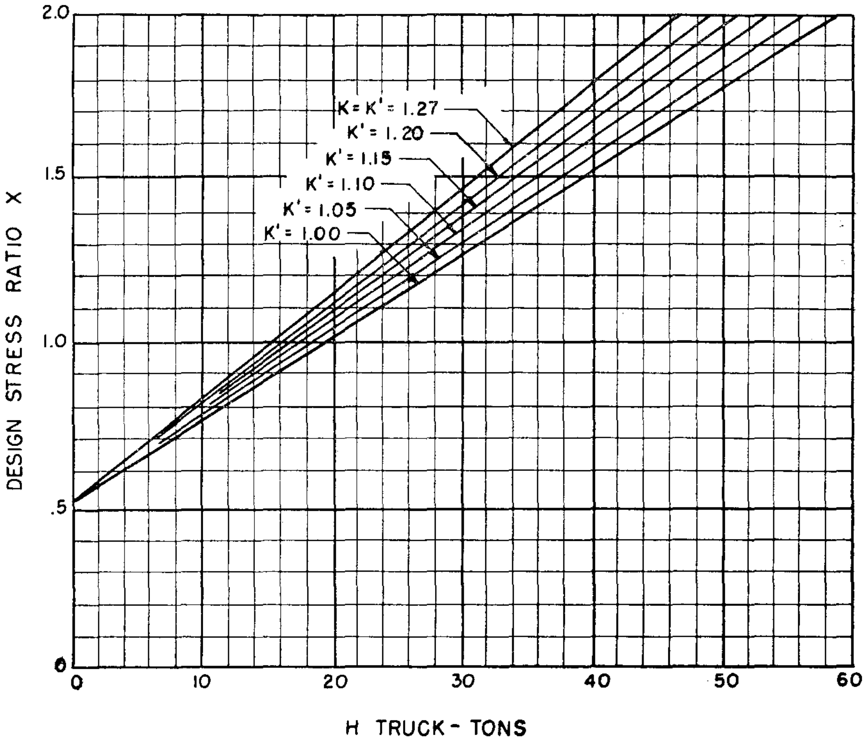
Equations for Design Stress Ratio

$K = K' = 1.286;\ X = .0360\ H + .460$
$K' = 1.200;\ X = .0336\ H + .460$
$K' = 1.150;\ X = .0322\ H + .460$
$K' = 1.100;\ X = .0308\ H + .460$
$K' = 1.050;\ X = .0294\ H + .460$
$K' = 1.000;\ X = .0280\ H + .460$

Figure 6.5e

DESIGN STRESS RATIO PRODUCED BY EQUIVALENT H TRUCKS ON SIMPLE SPAN BRIDGES OF H 15 DESIGN WITH ONE VEHICLE IN EACH LANE AND VARYING ALLOWANCE FOR IMPACT

C = 1.00 K′ = Varies Span Length = 60′



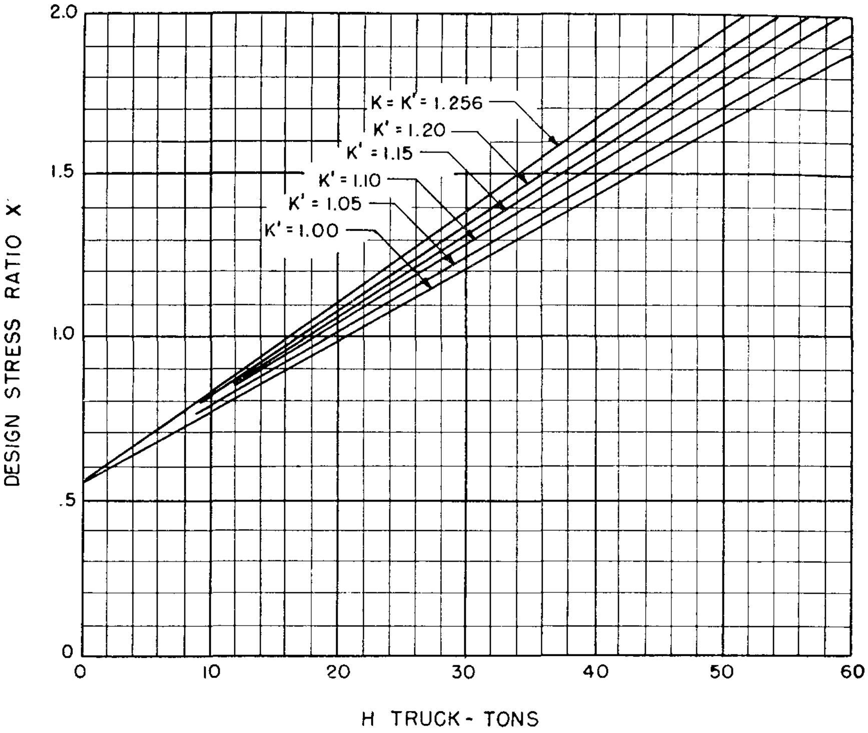
Equations for Design Stress Ratio

$K = K' = 1.270;\ X = .0323\,H + .505$
$K' = 1.200;\ X = .0305\,H + .505$
$K' = 1.150;\ X = .0292\,H + .505$
$K' = 1.100;\ X = .0279\,H + .505$
$K' = 1.050;\ X = .0267\,H + .505$
$K' = 1.000;\ X = .0254\,H + .505$

Figure 6.5f

DESIGN STRESS RATIO PRODUCED BY EQUIVALENT H TRUCKS ON SIMPLE SPAN BRIDGES OF H 15 DESIGN WITH ONE VEHICLE IN EACH LANE AND VARYING ALLOWANCE FOR IMPACT

C = 1.00 K′ = Varies Span Length = 70′



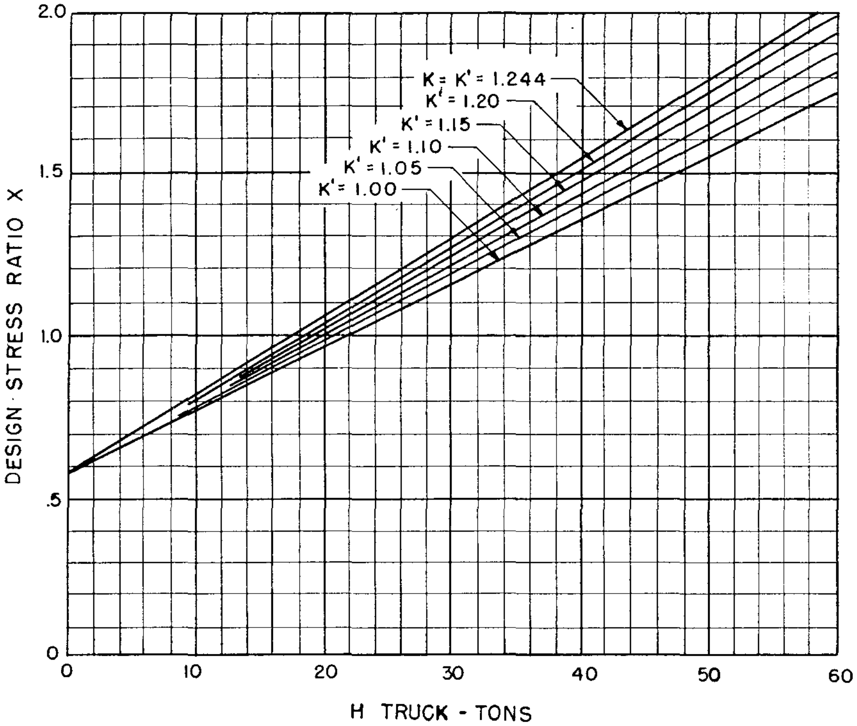
Equations for Design Stress Ratio

K = K′ = 1.256; X = .0281 H + .538
K′ = 1.200; X = .0268 H + .538
K′ = 1.150; X = .0257 H + .538
K′ = 1.100; X = .0246 H + .538
K′ = 1.050; X = .0235 H + .538
K′ = 1.000; X = .0224 H + .538

Figure 6.5g

DESIGN STRESS RATIO PRODUCED BY EQUIVALENT H TRUCKS ON SIMPLE SPAN BRIDGES OF H 15 DESIGN WITH ONE VEHICLE IN EACH LANE AND VARYING ALLOWANCE FOR IMPACT

C = 1.00 K′ = Varies Span Length = 80′



Equations for Design Stress Ratio

$K = K' = 1.244;\ X = .0248\,H + .565$

$K' = 1.200;\ X = .0239\,H + .565$

$K' = 1.150;\ X = .0229\,H + .565$

$K' = 1.100;\ X = .0219\,H + .565$

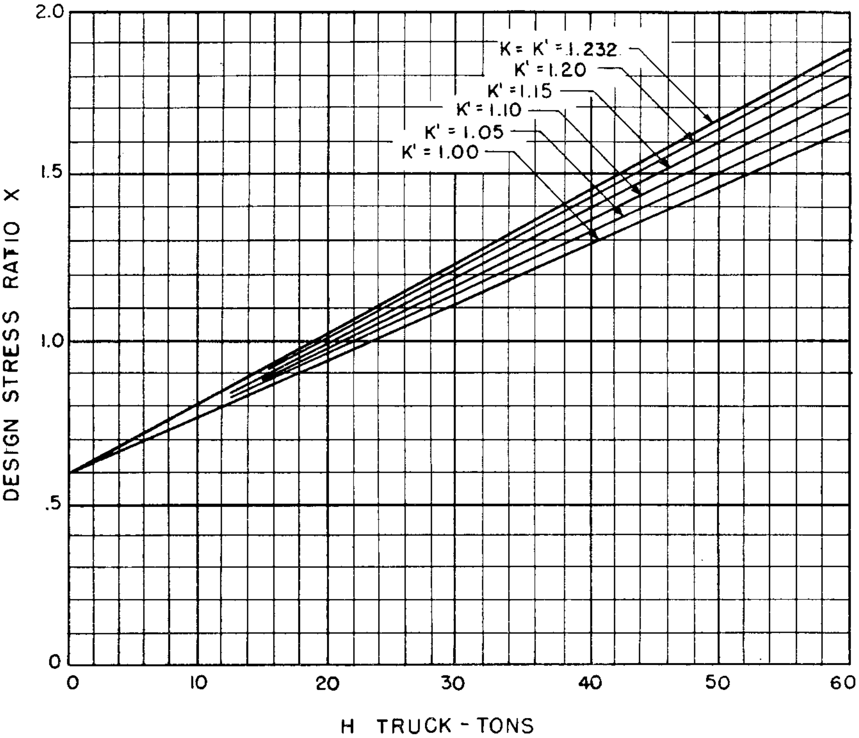
$K' = 1.050;\ X = .0209\,H + .565$

$K' = 1.000;\ X = .0199\,H + .565$

Figure 6.5h

DESIGN STRESS RATIO PRODUCED BY EQUIVALENT H TRUCKS ON SIMPLE SPAN BRIDGES OF H 15 DESIGN WITH ONE VEHICLE IN EACH LANE AND VARYING ALLOWANCE FOR IMPACT

C = 1.00 K′ = Varies Span Length = 90′



Equations for Design Stress Ratio

$K = K' = 1.232;\ X = .0219\,H + .590$

$K' = 1.200;\ X = .0214\,H + .590$

$K' = 1.150;\ X = .0205\,H + .590$

$K' = 1.100;\ X = .0196\,H + .590$

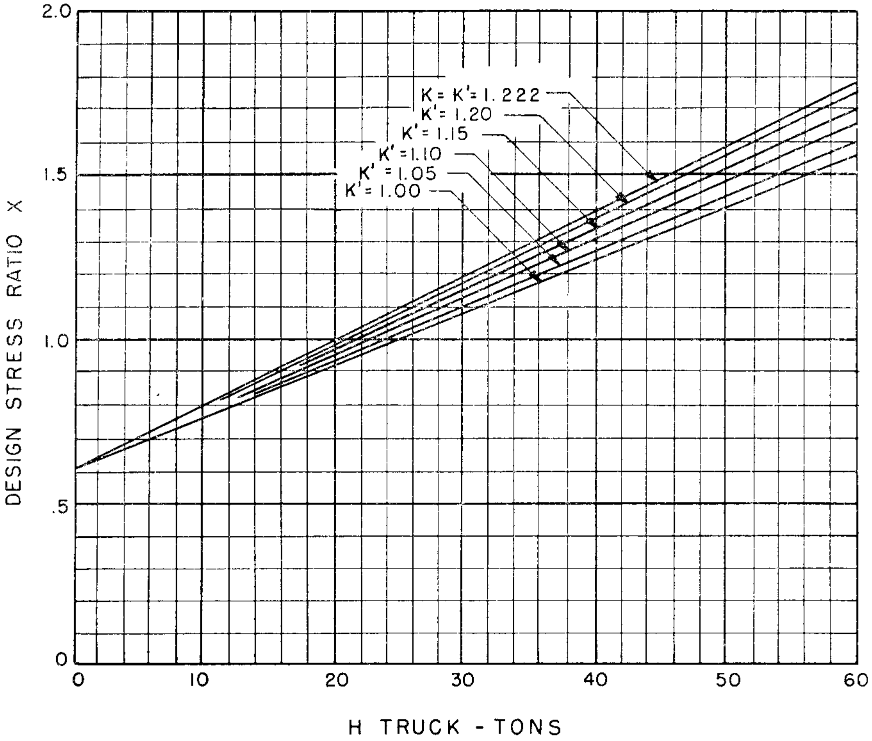
$K' = 1.050;\ X = .0187\,H + .590$

$K' = 1.000;\ X = .0178\,H + .590$

Figure 6.5i

DESIGN STRESS RATIO PRODUCED BY EQUIVALENT H TRUCKS ON SIMPLE SPAN BRIDGES OF H 15 DESIGN WITH ONE VEHICLE IN EACH LANE AND VARYING ALLOWANCE FOR IMPACT

C = 1.00 K′ = Varies Span Length = 100′



Equations for Design Stress Ratio

$K = K' = 1.222;\ X = .0198\,H + .606$

$K' = 1.200;\ X = .0194\,H + .606$

$K' = 1.150;\ X = .0186\,H + .606$

$K' = 1.100;\ X = .0178\,H + .606$

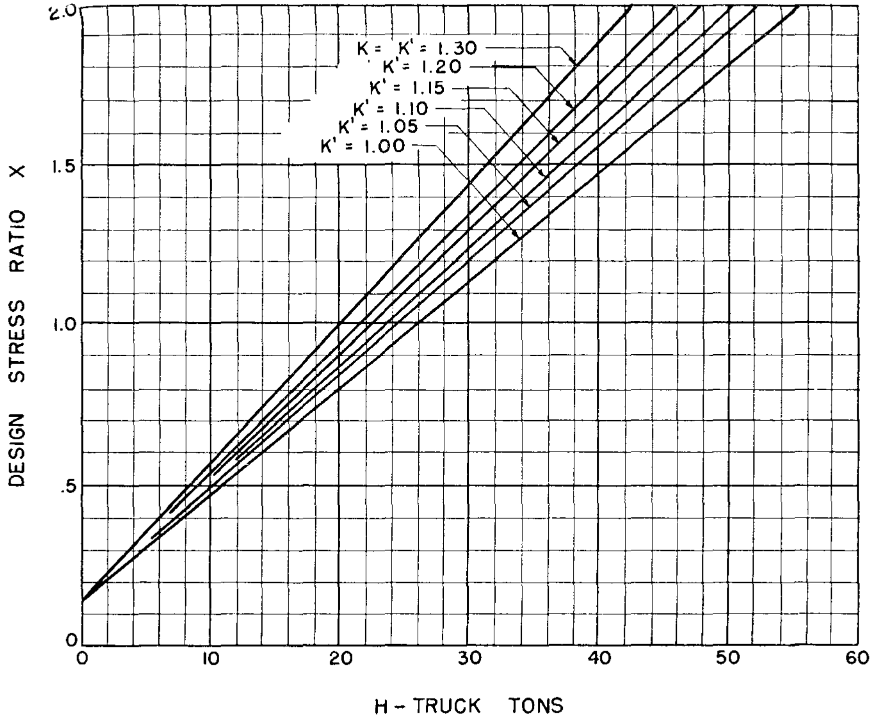
$K' = 1.050;\ X = .0170\,H + .606$

$K' = 1.000;\ X = .0162\,H + .606$

Figure 6.5j

DESIGN STRESS RATIO PRODUCED BY EQUIVALENT H TRUCKS ON SIMPLE SPAN BRIDGES OF H 15 DESIGN WITH ONE VEHICLE IN ONE LANE ONLY AND VARYING ALLOWANCE FOR IMPACT

C = .75 K′ = Varies Span Length = 10′



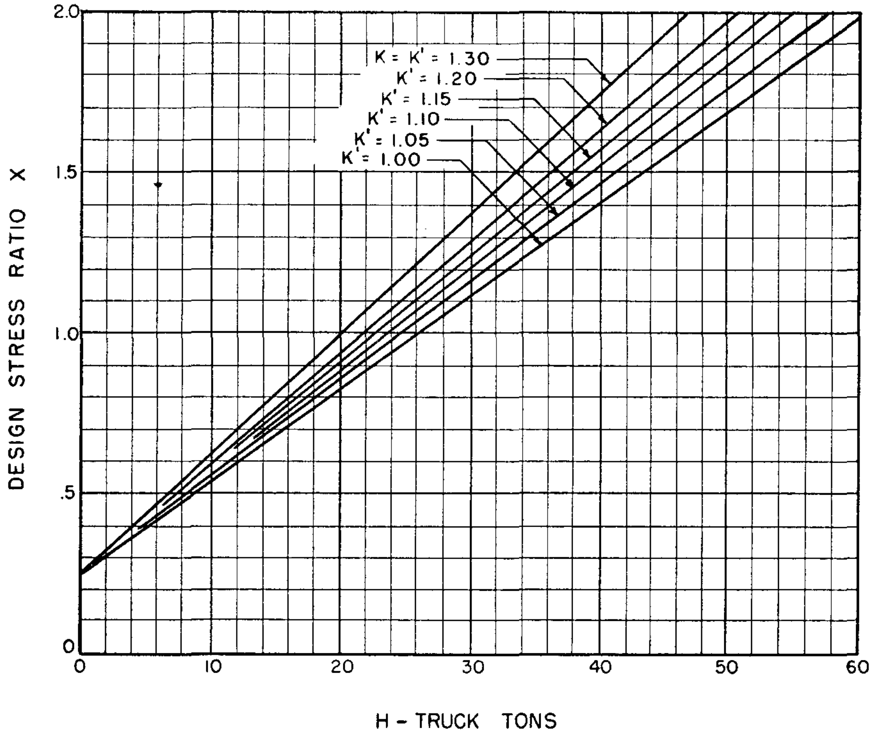
Equations for Design Stress Ratio

K = K′ = 1.300; X = .0432 H + .138
K′ = 1.200; X = .0398 H + .138
K′ = 1.150; X = .0381 H + .138
K′ = 1.100; X = .0365 H + .138
K′ = 1.050; X = .0348 H + .138
K′ = 1.000; X = .0332 H + .138

Figure 6.6a

DESIGN STRESS RATIO PRODUCED BY EQUIVALENT H TRUCKS ON SIMPLE SPAN BRIDGES OF H 15 DESIGN WITH ONE VEHICLE IN ONE LANE ONLY AND VARYING ALLOWANCE FOR IMPACT

$C = .75$ $K' = \text{Varies}$ Span Length = 20′



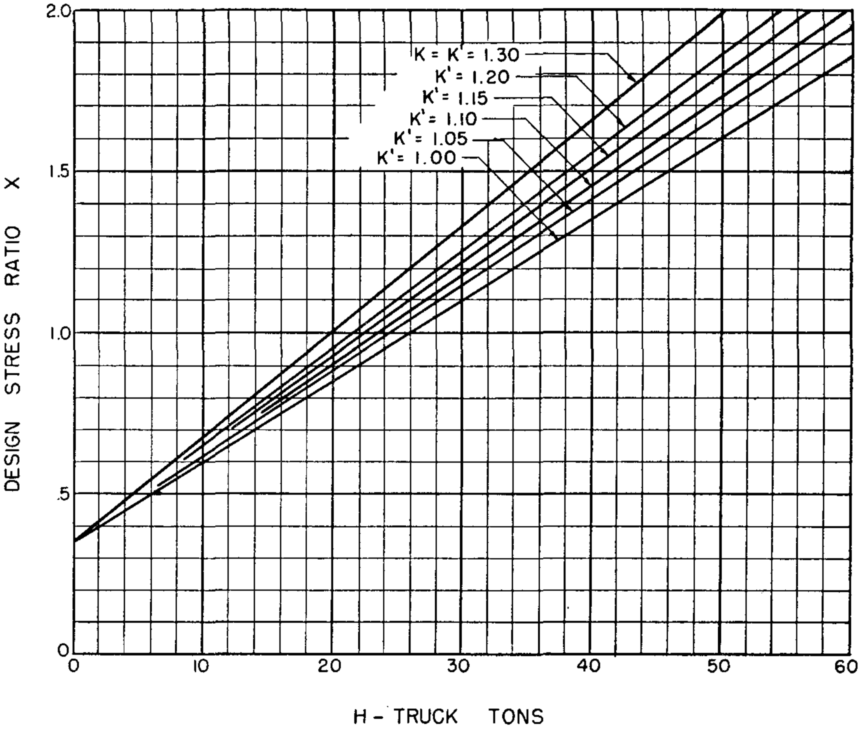
Equations for Design Stress Ratio

$K = K' = 1.300;\ X = .0373\ H + .255$
$K' = 1.200;\ X = .0344\ H + .255$
$K' = 1.150;\ X = .0329\ H + .225$
$K' = 1.100;\ X = .0315\ H + .255$
$K' = 1.050;\ X = .0301\ H + .255$
$K' = 1.000;\ X = .0287\ H + .255$

Figure 6.6b

DESIGN STRESS RATIO PRODUCED BY EQUIVALENT H TRUCKS ON SIMPLE SPAN BRIDGES OF H 15 DESIGN WITH ONE VEHICLE IN ONE LANE ONLY AND VARYING ALLOWANCE FOR IMPACT

C = .75 K′ = Varies Span Length = 30′



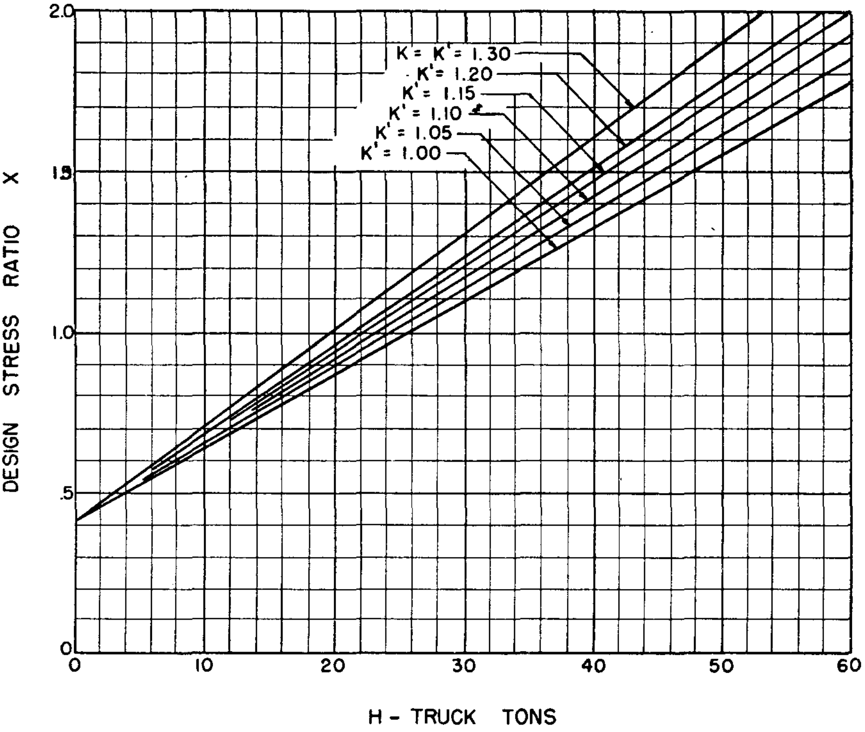
Equations for Design Stress Ratio

$K = K' = 1.300;\ X = .0329\,H + .340$
$K' = 1.200;\ X = .0305\,H + .340$
$K' = 1.150;\ X = .0292\,H + .340$
$K' = 1.100;\ X = .0279\,H + .340$
$K' = 1.050;\ X = .0266\,H + .340$
$K' = 1.000;\ X = .0254\,H + .340$

Figure 6.6c

DESIGN STRESS RATIO PRODUCED BY EQUIVALENT H TRUCKS ON SIMPLE SPAN BRIDGES OF H 15 DESIGN WITH ONE VEHICLE IN ONE LANE ONLY AND VARYING ALLOWANCE FOR IMPACT

C = .75 K′ = Varies Span Length = 40′



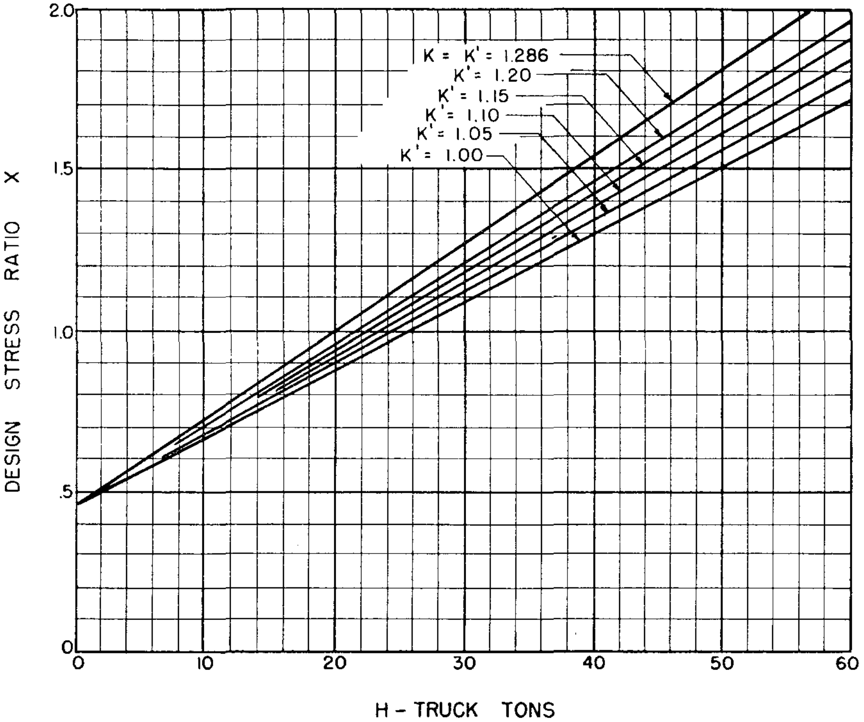
Equations for Design Stress Ratio

$K = K' = 1.300;\ X = .0298\ H + .405$
$K' = 1.200;\ X = .0275\ H + .405$
$K' = 1.150;\ X = .0263\ H + .405$
$K' = 1.100;\ X = .0252\ H + .405$
$K' = 1.050;\ X = .0240\ H + .405$
$K' = 1.000;\ X = .0229\ H + .405$

Figure 6.6d

DESIGN STRESS RATIO PRODUCED BY EQUIVALENT H TRUCKS ON SIMPLE SPAN BRIDGES OF H 15 DESIGN WITH ONE VEHICLE IN ONE LANE ONLY AND VARYING ALLOWANCE FOR IMPACT

C = .75 K′ = Varies Span Length = 50′



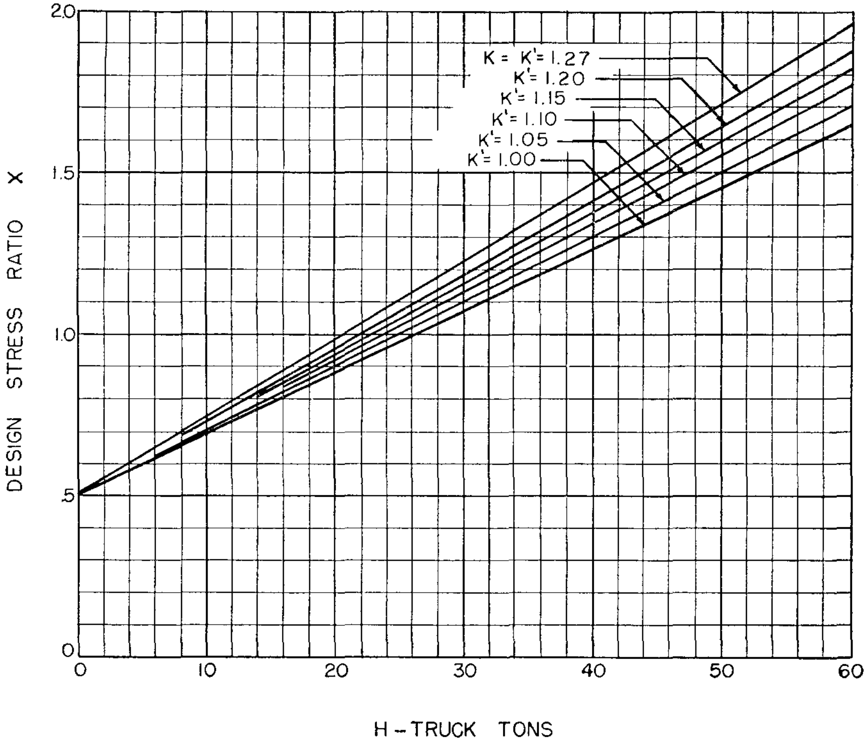
Equations for Design Stress Ratio

$K = K' = 1.286;\ X = .0270\,H + .460$
$K' = 1.200;\ X = .0252\,H + .460$
$K' = 1.150;\ X = .0242\,H + .460$
$K' = 1.100;\ X = .0231\,H + .460$
$K' = 1.050;\ X = .0221\,H + .460$
$K' = 1.000;\ X = .0210\,H + .460$

Figure 6.6e

DESIGN STRESS RATIO PRODUCED BY EQUIVALENT H TRUCKS ON SIMPLE SPAN BRIDGES OF H 15 DESIGN WITH ONE VEHICLE IN ONE LANE ONLY AND VARYING ALLOWANCE FOR IMPACT

C = .75 K′ = Varies Span Length = 60′



Equations for Design Stress Ratio

$K = K' = 1.270;\ X = .0242\,H + .505$

$K' = 1.200;\ X = .0229\,H + .505$

$K' = 1.150;\ X = .0219\,H + .505$

$K' = 1.100;\ X = .0209\,H + .505$

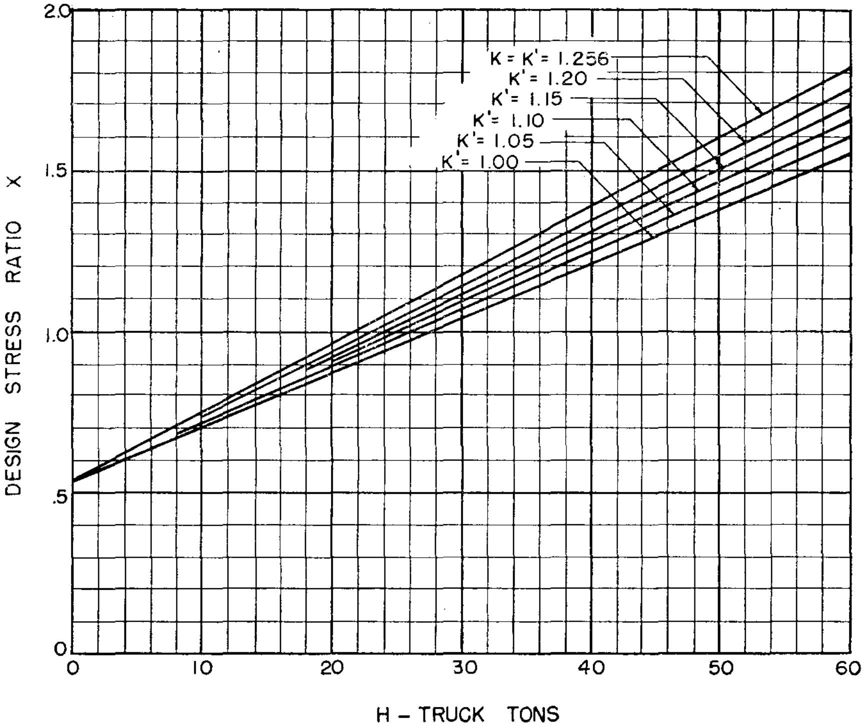
$K' = 1.050;\ X = .0200\,H + .505$

$K' = 1.000;\ X = .0191\,H + .505$

Figure 6.6f

DESIGN STRESS RATIO PRODUCED BY EQUIVALENT H TRUCKS ON SIMPLE SPAN BRIDGES OF H 15 DESIGN WITH ONE VEHICLE IN ONE LANE ONLY AND VARYING ALLOWANCE FOR IMPACT

C = .75 K′ = Varies Span Length = 70′



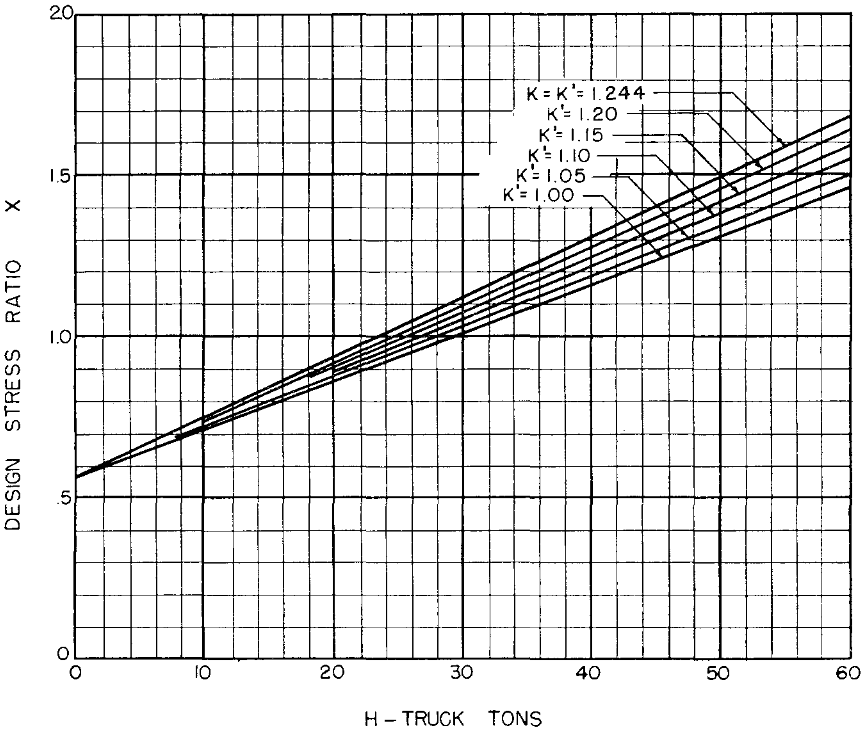
Equations for Design Stress Ratio

$K = K' = 1.256;\ X = .0211\,H + .538$
$K' = 1.200;\ X = .0201\,H + .538$
$K' = 1.150;\ X = .0193\,H + .538$
$K' = 1.100;\ X = .0185\,H + .538$
$K' = 1.050;\ X = .0176\,H + .538$
$K' = 1.000;\ X = .0168\,H + .538$

Figure 6.6g

DESIGN STRESS RATIO PRODUCED BY EQUIVALENT H TRUCKS ON SIMPLE SPAN BRIDGES OF H 15 DESIGN WITH ONE VEHICLE IN ONE LANE ONLY AND VARYING ALLOWANCE FOR IMPACT

C = .75 K′ = Varies Span Length = 80′



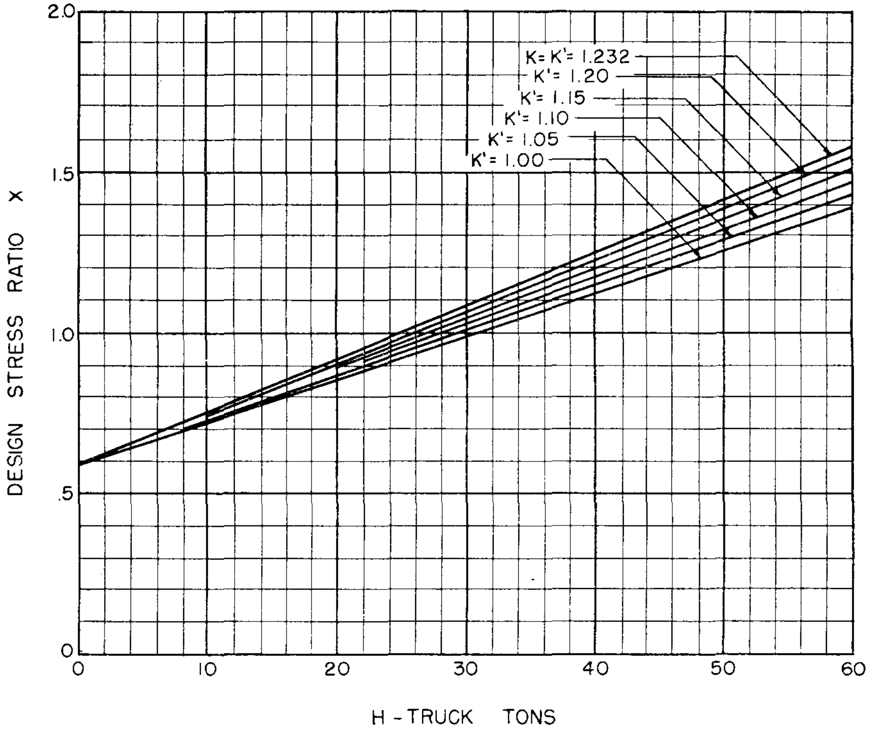
Equations for Design Stress Ratio

K = K′ = 1.244; X = .0186 H + .565
K′ = 1.200; X = .0179 H + .565
K′ = 1.150; X = .0172 H + .565
K′ = 1.100; X = .0164 H + .565
K′ = 1.050; X = .0156 H + .565
K′ = 1.000; X = .0149 H + .565

Figure 6.6h

DESIGN STRESS RATIO PRODUCED BY EQUIVALENT H TRUCKS ON SIMPLE SPAN BRIDGES OF H 15 DESIGN WITH ONE VEHICLE IN ONE LANE ONLY AND VARYING ALLOWANCE FOR IMPACT

C = .75 K' = Varies Span Length = 90'



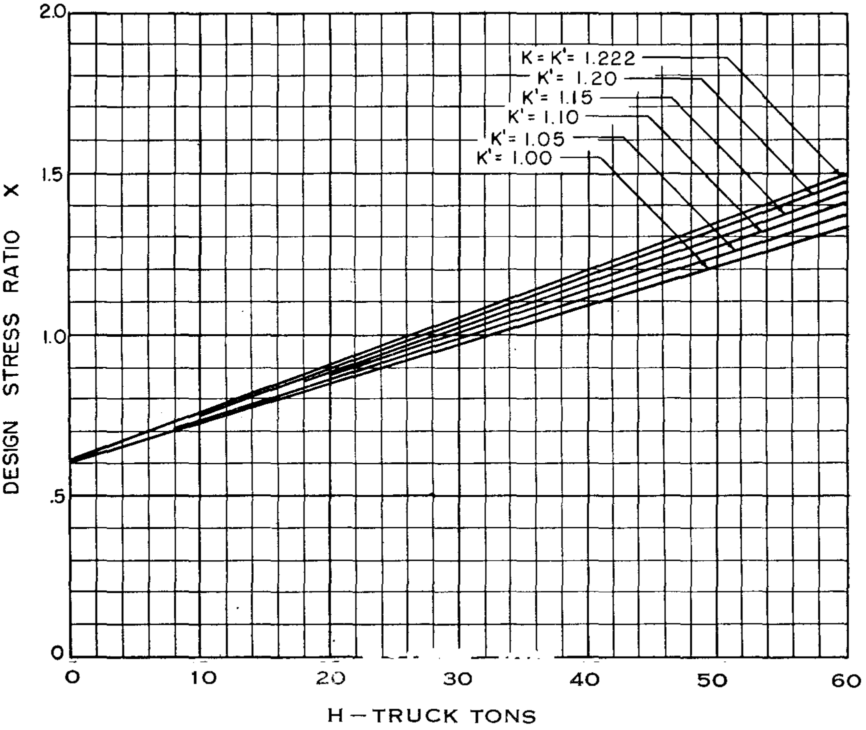
Equations for Design Stress Ratio

$K = K' = 1.232;\ X = .0164\,H + .590$
$K' = 1.200;\ X = .0161\,H + .590$
$K' = 1.150;\ X = .0154\,H + .590$
$K' = 1.100;\ X = .0147\,H + .590$
$K' = 1.050;\ X = .0140\,H + .590$
$K' = 1.000;\ X = .0134\,H + .590$

Figure 6.6i

DESIGN STRESS RATIO PRODUCED BY EQUIVALENT H TRUCKS ON SIMPLE SPAN BRIDGES OF H 15 DESIGN WITH ONE VEHICLE IN ONE LANE ONLY AND VARYING ALLOWANCE FOR IMPACT

C = .75 K′ = Varies Span Length = 100′



Equations for Design Stress Ratio

$K = K' = 1.222;\ X = .0149\ H + .606$
$K' = 1.200;\ X = .0146\ H + .606$
$K' = 1.150;\ X = .0140\ H + .606$
$K' = 1.100;\ X = .0134\ H + .606$
$K' = 1.050;\ X = .0128\ H + .606$
$K' = 1.000;\ X = .0122\ H + .606$

Figure 6.6j

APPENDIX A

NOTATIONS

F = General term indicating stress or stress function. It includes all types of stress or stress functions such as moment M, shear V, direct stress P, and so on. Therefore, F in the general equations may be replaced by M,V,P, or other stress function as may be required for particular stress under consideration. The subscripts and primes for F have the same corresponding meaning as those given for moment M, shear V, and direct stress P.

H = Equivalent H truck loading in tons. For example, if a given vehicle produces the same maximum moment (shear, or other stress function) in a given member as a standard H truck weighing 23.6 tons it would be rated as an equivalent H 23.6 truck loading, in which case $H = 23.6$ (tons).

H_s = Equivalent H-S truck loading in tons. For example, if a given vehicle produces the same maximum moment (shear, or other stress function) in a given member as a standard H-S truck weighing 34.8 tons it would be rated as an equivalent H_s 34.8 truck loading, in which case $H_s = 34.8$ (tons).

I = Impact fraction (maximum 0.30 or 30 percent) as determined by the AASHO formula

$$I = 50/(S + 125)$$

in which

S = Length in feet of the portion of the span which is loaded to produce the maximum stress in the member.

I' = Impact fraction assumed in connection with the determination of the stress producing effects of any given vehicle under consideration. For example, if the speed of a given vehicle were limited, to say 5 mph, this impact fraction might be considered so small as to be negligible, in which case I' might be assumed equal to zero. Depending on traffic and conditions, therefore, the impact fraction I' could be assumed at any reasonable value between zero and the full impact allowance I as defined by the AASHO design specifications.

K = $(1.00 + I)$ = Coefficient by which the design live load moment (shear, or other stress function) is multiplied to obtain the live load plus impact moment (shear, or other stress function) used for design. Thus, KM_L would be equal to the live load plus impact moment used for design: similarly, KV_L would be equal to the live load plus impact shear used for design.

K' = $(1.00 + I')$ = Coefficient by which the live load moment (shear, or other stress function) produced by a given vehicle is multiplied to obtain the live load plus impact moment (shear, or other stress function) produced on a given span or in a given member by the vehicle under consideration. Thus, $K'M'_L$ would be equal to the live load plus impact moment produced on a given span by any particular vehicle under consideration.

M_D = Dead load moment as included in total design moment.

M_L = Live load moment as included in total design moment.

M_T = Moment used for design or total design moment.

M'_L = Live load moment produced by given vehicle under consideration.

M_1 = Live load moment produced by a standard H truck of N_1 tons.

N_1 = Numerical H design designation or rating of a given bridge in tons.

N_2 = Numerical H-S design designation or rating of a given bridge in tons. For example, $N_2 = 27$ for an H 15 — S 12 design bridge.

P = Direct stress or axial force applied to a tension or compression member in a bridge truss or other framed structure, in pounds or kips as may be indicated.

P_D = Direct stress or axial force in a tension or compression member produced by dead load only, in pounds or kips as may be indicated.

P_L = Direct stress or axial force in a tension or compression member produced by the design live load only, in pounds or kips as may be indicated.

P_T = Direct stress or axial force in a tension or compression member produced by the total design load in pounds or kips as may be indicated.

P'_L = Direct stress or axial force in a tension or compression member produced by any given vehicle under consideration, in pounds or kips as may be indicated.

$R_D = (M_D/M_T)$ = Ratio of dead load moment M_D (shear, or other stress function) to total moment M_T used for design. In terms of shear this ratio would be $R_D = (V_D/V_T)$, and for other stress functions it would be similar.

$R_L = (KM_L/M_T)$ = Ratio of live load plus impact moment, KM_L, (shear, or other stress function) used for design, to the total design moment, M_T, or total moment (shear, or other stress function) used for design. In terms of shear, this ratio would be $R_L = (KV_L/V_T)$, and for other stress functions it would be similar.

V_D = Dead load shear as included in total design shear.

V_L = Live load shear as included in total design shear.

V'_L = Live load shear produced by given vehicle under consideration.

V_T = Shear used for design or total design shear.

X = Ratio of live load + impact + dead load moments (shear, or other stress function) to total design moment (shear, or other stress function, respectively).

APPENDIX B

CONVERSION COEFFICIENTS FOR EQUIVALENT LOADINGS ON SIMPLE SPANS OF VARIOUS LENGTHS

Owing to the fact that an H truck, an H-S truck, or a single concentrated load weighing one kip each produce maximum moments and shears, on a given span which are definite values, their relative magnitudes may be fully described by the ratios that each one bears to the other two. Thus, if these ratios are known for a given span, they may be thought of as coefficients which may be used for converting any one of the above loadings into equivalent loadings measured in terms of either or both of the other two. These ratios or coefficients for certain selected spans up to 100 feet in length are given in Table B.1 and Fig. B.1 based on maximum moments and in Table B.2 and Fig. B.2 based on maximum shears.

In Table B.1, for example, it will be seen that the coefficient based on maximum moment, for converting an equivalent H truck loading into an equivalent H-S truck loading on a 50-foot span is given as 1.28. This means that an H truck of given weight will produce 1.28 times as much moment as an H-S truck of equal weight on a 50-foot span. It also means that an H truck of given weight will produce as much moment as an H-S truck weighing 1.28 times as much on a 50-foot span. More specifically, suppose a given heavy vehicle has been found to produce the same moment on a 50-foot span as an H20 truck and rated accordingly as an equivalent H20 truck loading. Now suppose it is desired to convert the given heavy vehicle into an equivalent

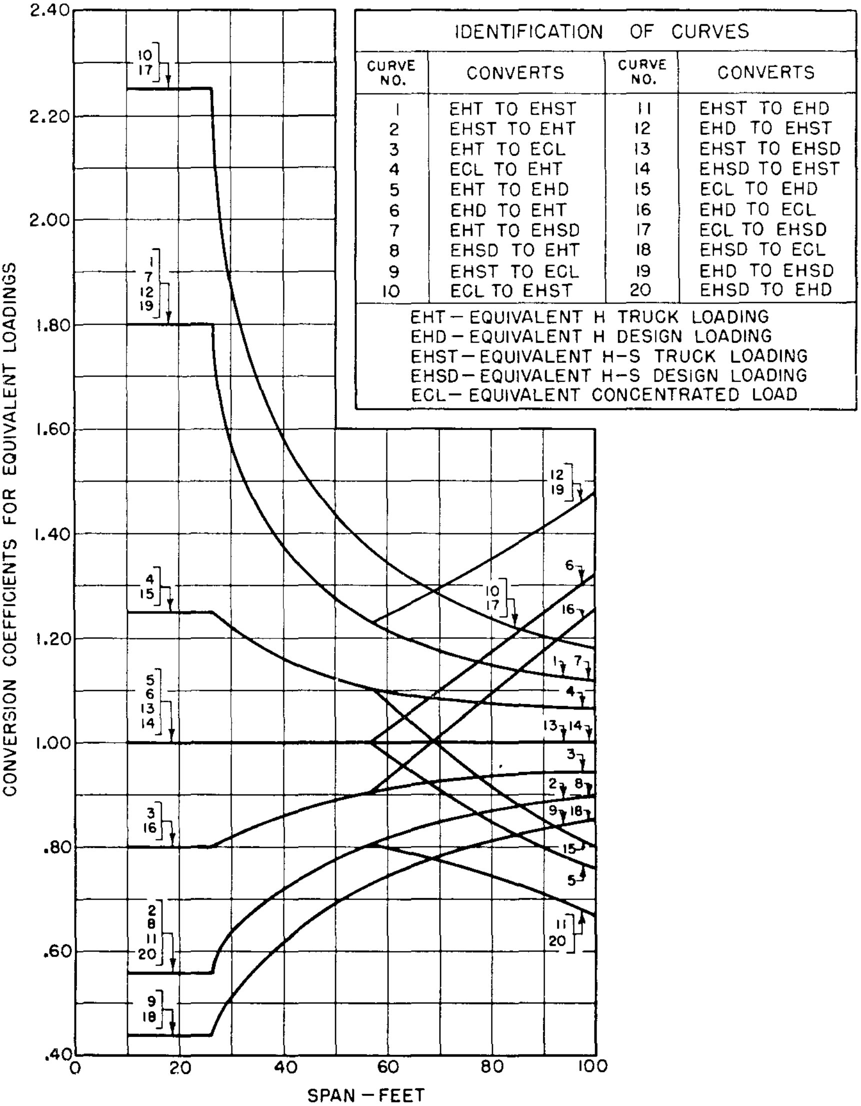
Table B.1

CONVERSION COEFFICIENTS BASED ON MOMENTS FOR EQUIVALENT LOADINGS ON SIMPLE SPANS OF VARIOUS LENGTHS

For	SPAN									
Converting	10	20	30	40	50	60	70	80	90	100
EHT to EHST	1.80	1.80	1.57	1.38	1.28	1.22	1.18	1.15	1.13	1.12
EHST to EHT	.56	.56	.64	.72	.78	.82	.85	.87	.88	.90
EHT to ECL	.80	.80	.82	.86	.89	.91	.92	.93	.94	.94
ECL to EHT	1.25	1.25	1.22	1.16	1.12	1.10	1.09	1.07	1.07	1.06
EHT to EHD	1.00	1.00	1.00	1.00	1.00	.98	.91	.85	.80	.76
EHD to EHT	1.00	1.00	1.00	1.00	1.00	1.02	1.10	1.17	1.25	1.32
EHT to EHSD	1.80	1.80	1.57	1.38	1.28	1.22	1.18	1.15	1.13	1.12
EHSD to EHT	.56	.56	.64	.72	.78	.82	.85	.87	.88	.90
EHST to ECL	.44	.44	.52	.62	.70	.75	.78	.81	.83	.85
ECL to EHST	2.25	2.25	1.91	1.60	1.43	1.34	1.28	1.24	1.21	1.18
EHST to EHD	.56	.56	.64	.72	.78	.80	.77	.74	.71	.68
EHD to EHST	1.80	1.80	1.57	1.38	1.28	1.25	1.29	1.35	1.41	1.48
EHST to EHSD	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
EHSD to EHST	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
ECL to EHD	1.25	1.25	1.22	1.16	1.12	1.08	.99	.92	.85	.80
EHD to ECL	.80	.80	.82	.86	.89	.93	1.01	1.09	1.17	1.25
ECL to EHSD	2.25	2.25	1.91	1.60	1.43	1.34	1.28	1.24	1.21	1.18
EHSD to ECL	.44	.44	.52	.62	.70	.75	.78	.81	.83	.85
EHD to EHSD	1.80	1.80	1.57	1.38	1.28	1.25	1.29	1.35	1.41	1.48
EHSD to EHD	.56	.56	.64	.72	.78	.80	.77	.74	.71	.67

EHT—Equivalent H truck loading.
EHD—Equivalent H design loading.
EHST—Equivalent H-S truck loading.
EHSD—Equivalent H-S design loading.
ECL—Equivalent concentrated load.

CONVERSION COEFFICIENTS FOR EQUIVALENT LOADINGS BASED ON MAXIMUM MOMENTS IN SIMPLE SPANS



IDENTIFICATION OF CURVES

CURVE NO.	CONVERTS	CURVE NO.	CONVERTS
1	EHT TO EHST	11	EHST TO EHD
2	EHST TO EHT	12	EHD TO EHST
3	EHT TO ECL	13	EHST TO EHSD
4	ECL TO EHT	14	EHSD TO EHST
5	EHT TO EHD	15	ECL TO EHD
6	EHD TO EHT	16	EHD TO ECL
7	EHT TO EHSD	17	ECL TO EHSD
8	EHSD TO EHT	18	EHSD TO ECL
9	EHST TO ECL	19	EHD TO EHSD
10	ECL TO EHST	20	EHSD TO EHD

EHT — EQUIVALENT H TRUCK LOADING
EHD — EQUIVALENT H DESIGN LOADING
EHST — EQUIVALENT H-S TRUCK LOADING
EHSD — EQUIVALENT H-S DESIGN LOADING
ECL — EQUIVALENT CONCENTRATED LOAD

Figure B.1

Table B.2

CONVERSION COEFFICIENTS BASED ON SHEAR FOR EQUIVALENT LOADINGS ON SIMPLE SPANS OF VARIOUS LENGTHS

For	SPAN									
Converting	10	20	30	40	50	60	70	80	90	100
EHT to EHST	1.80	1.49	1.32	1.21	1.16	1.13	1.11	1.10	1.09	1.08
EHST to EHT	.56	.67	.76	.83	.86	.88	.90	.91	.92	.93
EHT to ECL	.80	.86	.91	.93	.94	.95	.96	.97	.98	.98
ECL to EHT	1.25	1.16	1.10	1.08	1.06	1.05	1.04	1.03	1.02	1.02
EHT to EHD	1.00	1.00	1.00	.96	.90	.84	.79	.75	.71	.67
EHD to EHT	1.00	1.00	1.00	1.04	1.11	1.19	1.27	1.33	1.41	1.49
EHT to EHSD	1.80	1.49	1.32	1.21	1.16	1.13	1.11	1.10	1.09	1.08
EHSD to EHT	.56	.67	.76	.83	.86	.88	.90	.91	.92	.93
EHST to ECL	.44	.58	.69	.77	.81	.84	.87	.88	.90	.91
ECL to EHST	2.25	1.73	1.45	1.30	1.23	1.18	1.15	1.13	1.12	1.09
EHST to EHD	.56	.67	.76	.79	.77	.75	.72	.68	.65	.63
EHD to EHST	1.80	1.49	1.32	1.26	1.29	1.34	1.40	1.46	1.53	1.60
EHST to EHSD	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
EHSD to EHST	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
ECL to EHD	1.25	1.16	1.10	1.03	.95	.88	.83	.78	.73	.69
EHD to ECL	.80	.86	.91	.97	1.05	1.14	1.20	1.28	1.37	1.45
ECL to EHSD	2.25	1.73	1.45	1.30	1.23	1.18	1.15	1.13	1.12	1.10
EHSD to ECL	.44	.58	.69	.77	.81	.84	.87	.88	.90	.91
EHD to EHSD	1.80	1.49	1.32	1.26	1.29	1.34	1.40	1.46	1.53	1.60
EHSD to EHD	.56	.67	.76	.79	.78	.75	.71	.68	.65	.63

EHT—Equivalent H truck loading.
EHD—Equivalent H design loading.
EHST—Equivalent H–S truck loading.
EHSD—Equivalent H-S design loading.
ECL—Equivalent concentrated load.

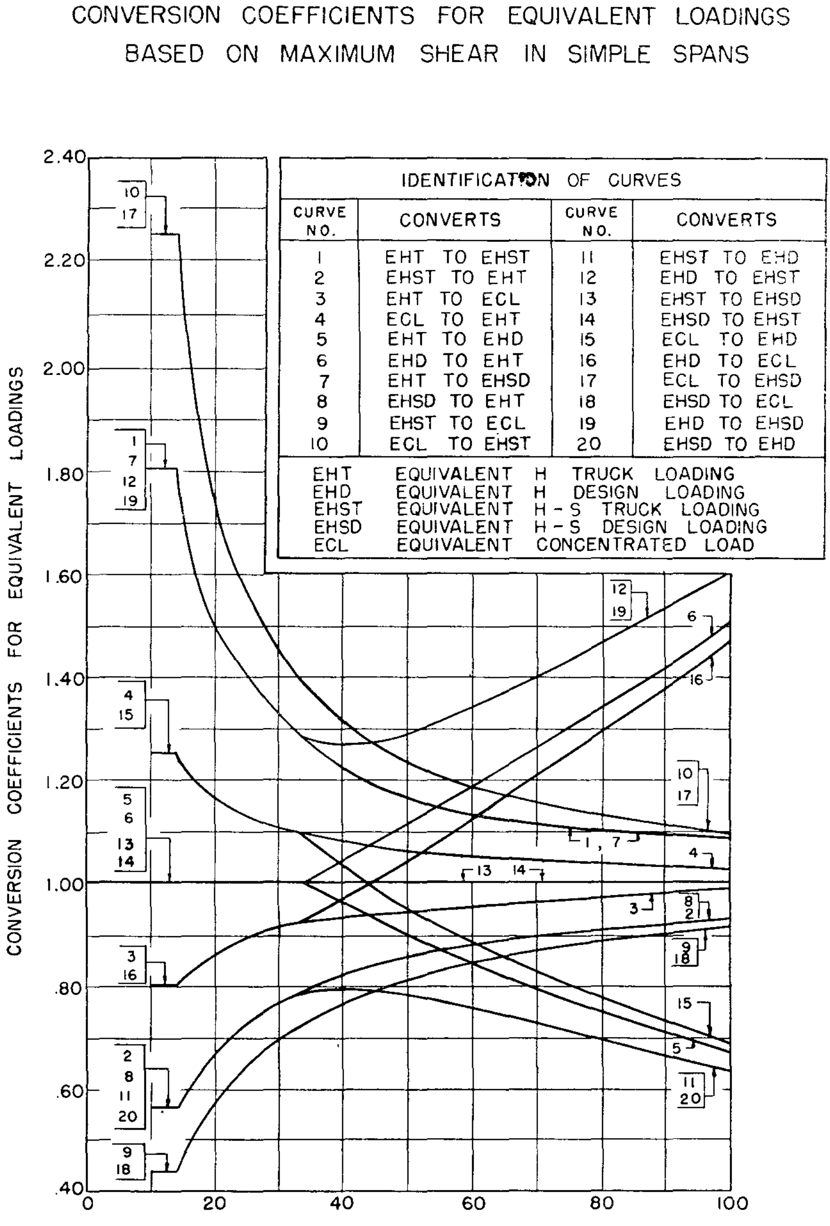
H-S truck loading. This may be done by noting that 1.28×20=25.6 tons would be required on an H-S truck to produce the same moment as the given vehicle on a 50-foot span. The given vehicle, therefore, would be rated as an equivalent 25.6 (ton) H-S truck loading or an equivalent 51.2 (kip) H-S truck loading.

In a similar manner, if it were desired to convert an equivalent 51.2 (kip) H-S truck loading into an equivalent H truck loading on a 50-foot span it would be done by multiplying the H-S truck rating by the coefficient 0.78 as shown in the fifth column of Table B.1, or 51.2×.78=40.0 kips. This means that the given vehicle could be rated as either an equivalent 51.2 (kip) H-S truck loading, or an equivalent 40.0 (kip) H truck loading on a 50-foot span.

Similarly, an equivalent 40.0 (kip) H truck loading may be converted into an equivalent concentrated load on a 50-foot span by multiplying the H truck rating by the coefficient 0.89 as shown in the fifth column of Table B.1, or 40.0×.89=35.6 kips. This means that the given vehicle would be rated as an equivalent 35.6 (kip) concentrated load on a 50-foot span.

Referring now to Table B.2 it will be seen that the coefficient based on maximum shear, for converting an equivalent H truck loading into an equivalent H-S truck loading on a 50-foot span is given as 1.16. This means that an H truck of given weight will produce 1.16 times as much shear as an H-S truck of equal weight on a 50-foot span. It also means that an H truck of given weight will produce as much shear as an H-S truck weighing 1.16 times as much on a 50-foot span. More specifically, suppose a given heavy vehicle has been found to produce the same shear on a 50-foot span as an H20 truck and rated accordingly as an equivalent H20 truck loading. Now suppose it

CONVERSION COEFFICIENTS FOR EQUIVALENT LOADINGS BASED ON MAXIMUM SHEAR IN SIMPLE SPANS



IDENTIFICATION OF CURVES

CURVE NO.	CONVERTS	CURVE NO.	CONVERTS
1	EHT TO EHST	11	EHST TO EHD
2	EHST TO EHT	12	EHD TO EHST
3	EHT TO ECL	13	EHST TO EHSD
4	ECL TO EHT	14	EHSD TO EHST
5	EHT TO EHD	15	ECL TO EHD
6	EHD TO EHT	16	EHD TO ECL
7	EHT TO EHSD	17	ECL TO EHSD
8	EHSD TO EHT	18	EHSD TO ECL
9	EHST TO ECL	19	EHD TO EHSD
10	ECL TO EHST	20	EHSD TO EHD

EHT	EQUIVALENT H TRUCK LOADING
EHD	EQUIVALENT H DESIGN LOADING
EHST	EQUIVALENT H-S TRUCK LOADING
EHSD	EQUIVALENT H-S DESIGN LOADING
ECL	EQUIVALENT CONCENTRATED LOAD

Figure B.2

is desired to convert the given heavy vehicle into an equivalent H-S truck loading. This may be done by noting that 1.16×20=23.2 tons would be required on an H-S truck to produce the same shear as the given vehicle on a 50-foot span. The given vehicle, therefore, would be rated as an equivalent 23.2 (ton) H-S truck loading or an equivalent 46.4 (kip) H-S truck loading.

In a similar manner, if it were desired to convert an equivalent 46.4 (kip) H-S truck loading into an equivalent H truck loading on a 50-foot span it would be done by multiplying the H-S truck rating by the coefficient 0.86 as shown in the fifth column of Table B.2, or 46.4×.86=40.0 kips. This means that the given vehicle would be rated as either an equivalent 46.4 (kip) H-S truck loading, or an equivalent 40.0 (kip) H truck loading on a 50-foot span.

Similarly, an equivalent 40.0 (kip) H truck loading may be converted into an equivalent concentrated load on a 50-foot span by multiplying the H truck rating by the coefficient 0.94 as shown in the fifth column of Table B.2, or 40.0×.94=37.6 kips. This means that the given vehicle would be rated as an equivalent 37.6 (kip) concentrated load on a 50-foot span.

From these illustrative examples, then, it will be seen that any given equivalent loading may be converted into any other loading equivalency simply by multiplying the rating of the given equivalent loading by the appropriate coefficient indicated for the span under consideration.

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