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Commonwealth of Pennsylvania

Department of Transportation

Office of Research and Special Studies

A PARAMETRIC STUDY ON THE OVERLOADING OF STEEL MULTIGIRDER HIGHWAY BRIDGES

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Research Project 77-1: Overloading Behavior of
Steel Highway Bridges

Fritz Engineering Laboratory Report No. 435.3

LEHIGH UNIVERSITY

Fritz Engineering Laboratory

COMMONWEALTH OF PENNSYLVANIA

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Project 77-1: Overloading Behavior of Steel Highway Bridges

A PARAMETRIC STUDY
ON THE
OVERLOADING OF STEEL MULTIGIRDER HIGHWAY BRIDGES

by

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LEHIGH UNIVERSITY

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ABSTRACT

This report presents the results of a parametric study on the overloading response of steel multigirder highway bridges with monolithic reinforced concrete deck. Six bridges with span lengths 60, 90, and 150 feet having 6 and 7 girders are designed in accordance with current specifications. These bridges are subjected to three overload vehicles each. Each bridge is loaded by the vehicles on predefined traffic lanes in order to produce maximum flexural response at the midspan of the bridge superstructure.

By using program BOVAS (Bridge OVerload Analysis - Steel) the response of the bridges when subjected to the vehicles is determined. For various load levels the damage that the superstructure will sustain, and the maximum tensile and compressive stresses are are also tabulated.

I. INTRODUCTION

1.1 Problem Statement

The purpose of the research project "Overloading of Steel Highway Bridges," (Pennsylvania Department of Transportation Research Project 77-1) was to develop a "tool" for the prediction of the overload behavior of bridge superstructures with reinforced concrete deck and steel girders. In addition, the project was to provide information on the elastic and inelastic response of typical highway bridges of the type referred to earlier. The research project required the development of a new finite element analysis scheme. The initial analytical developments were to assess the behavior of "deep girders" and the "composite interaction" (Ref. 11). The inelastic analytical model and its applications were reported in References 4 and 5. These reports presented select case studies in detail. Additional work on overloading behavior of steel bridges was reported in Reference 6.

The computer program which originated in the above referred studies was named BOVAS (<u>B</u>ridge <u>OV</u>erload <u>A</u>nalysis-<u>S</u>teel), and was thoroughly and successfully tested on Control Data Corporation's CDC-6400, CYBER-730, and CYBER-850 computers. The users' manual for the program was released as an interim report of this research project (Ref. 7).

At the inception of the research project it was decided that a "parametric study" would be conducted using the proposed computer program to be developed, i.e. BOVAS. Scope and details of this parametric study were determined by the representatives of the sponsoring agency of the research project. This report presents the summary of the completed parametric study.

In the reported study a select number of "typical" bridges were loaded by three different "vehicles." For simple span bridges the vehicle was located to cause maximum midspan flexural response. In some simple span bridges the analysis was conducted for vehicle on exterior lane and for the vehicle on "centerline" of the bridge. Some other simple span bridges were analyzed only for exterior lane loading. In three span continuous bridges the vehicular loading was always on the exterior lane. The analysis was repeated for maximum positive and negative moments. The analysis of any given bridge, for any given vehicle, for the specific placement of the vehicular loading corresponds to one case study. This report contains the results obtained from 38 separate case studies.

The description of the bridges investigated, vehicles considered, and the loading of the bridges are presented in Chapter II. The assumptions that were made for these analyses are presented in the next section.

1.2 Assumptions

Computer program BOVAS permits activation or de-activation of numerous "options" for the analysis. Activation or deactivation of these options modifies the "assumptions" involved with the computer simulation of the bridge superstructure. For example, one "input value" automatically answers the question of "Should the bending moments of the reinforced concrete slab be computed using the most conservative approach, or should they be computed using a realistic approach which does not have the assured conservatism?" If the analysis employs the former, then the results will be upper bound in the prediction of the damage to the slab; which will result in the overestimation of the damage and underestimation of the true strength of the superstructure. If the latter is used, then the results will be more realistic, but in some locations on the bridge deck slab it may give an unconservative estimation of the possible damage to the bridge deck.

The sponsoring agencies of this reported research program indicated that all assumptions shall be on the conservative side. Some of the key assumptions are listed below.

1.2.1 Impact Factor

Impact factor, as defined in the AASHTO Standard Specifications for Highway Bridges (Ref. 2), was applied to the vehicular loading employed in the parametric study. Earlier research on prestressed concrete highway bridges conducted at Lehigh University had indicated that this factor is unconservative only for the beam directly under the vehicle, and grossly overestimates the "dynamic amplification" of stresses elsewhere on the bridge superstructure (Ref. 12). Thus, it can be concluded that this assumption introduces conservatism into the results.

1.2.2 Damage to Slab and Slab Stresses

Two commonly employed "approaches" in finite element analysis in the computation of the deck slab stresses are "nodal values" and "smearing or integration." The former searches the four corner nodes of a plate element, i.e. slab finite element, to find the largest absolute valued bending moment. This moment is assumed to be "constant" throughout this particular plate bending finite element; whereas, the latter considers bending moments at all four corners of an element. An "averaging scheme" is used to assign the bending moment to the plate bending finite element under consideration. The former is always grossly conservative, and the latter is realistic, but can sometimes miss the "peak values." The analysis was conducted using the "nodal values," which introduces great conservatism in the prediction of the damage to the deck slab.

1.2.3 Support Conditions

The girders are assumed to be supported at each "end" of the girder. The "bottom flange" of the girders is assumed to be free for expansion in the longitudinal direction. This corresponds to a "perfect" support condition. Analytical research supervised at Lehigh University indicated that if the bottom flanges of the girders are partially or fully restrained against expansion at the supports, the "midspan" stresses of the girders and the slab will be less than the "free" model (Refs. 8 and 10). However, since the quantification of the support restraints is not known as yet, the parametric study employed a conservative approach. The ends of the girders are permitted to have longitudinal expansion, thereby resulting in an upper bound estimation of the girder and slab stresses.

1.2.4 Composite Action

The deck slab and the girders are assumed to have a full composite interaction. An earlier research indicated that even if the superstructure is designed as "partial-composite," or even noncomposite, the structural response is similar to that of fully composite (Ref. 11). This assumption is a realistic one.

1.2.5 Cross Bracings and Lateral Bracings

The analytical model which forms the basis for program BOVAS does not have provisions for the inclusion of the "out-of-plane" response of the steel girders. Thus, the analysis did not include the contribution of the X-bracings, diaphragms, and lateral bracings. This is a conservative assumption. Pilot studies conducted have indicated that under extreme conditions X-bracings may reduce the stresses at the bottom flange by about 5-10% (Ref. 11).

1.2.6 Placement of Vehicles

The analyses of the bridges were carried out for two "types" of loading of the bridges. In the first type the vehicle was placed as close to the "edge" of the bridge as possible. The placement of the load was in accordance with the provisions of the AASHTO Specifications (Ref. 1 and 2). In the second type of loading, the vehicle was placed in such a way that it straddled the "centerline" of the bridge. Neither type of loading yields results that are categorically conservative or nonconservative. However, the use of "nodal values" in conjunction with the placement of the vehicle without any consideration regarding the "location of tributary nodes vs. the wheels of the vehicle" resulted either in correct results or in the overestimation of the slab stresses.

1.3 Reported Results

Each case study in this report resulted in an output that contains approximately 200,000 pieces of data. Inclusion of all the pertinent information is impractical. Initially, consideration was given to present the pertinent results in a graphical format through the use of computer-graphics. It was realized that this also corresponds to an impractical proposition. An in-depth study of only one multigirder bridge resulted in about 150 different graphs (Ref. 8). Since the reported study encompasses 38 case studies, the use of graphical depiction could have resulted in 5,000-6,000 graphs. Such a report would have been to voluminous to have any use.

In the presentation of the results only the following data is given for any load level of any case study:

1. Total weight of the vehicle modified by the impact factor.
2. Total weight of the vehicle without modification by the impact factor.
3. Maximum tensile stress in the "tension flange."
4. Maximum compressive stress in the "compression flange."
5. Maximum tensile stress in the web.
6. Maximum compressive stress in the web.
7. Summary of deck damage, if any.

II. TEST BRIDGES AND VEHICLES

2.1 Test Bridges

The bridges employed in this parametric investigation are taken from Reference 3. Since the aforementioned reference contains detailed drawings of all bridge components, no attempts will be made here to re-describe the bridges and to duplicate the drawings. However, for the sake of completeness, characteristic features of the bridges are listed below.

1.SIMPLE SPAN BRIDGES (ROLLED SECTIONS)

BRIDGE NO. 1.1
Span length= 90 ft.
Out-to-out width= 44 ft.
Number of girders= 6
Girder spacing= 7'- 10"
Girder cross sections= WF 36 x 245
Cover plates= 15" x 1" x 58'

BRIDGE NO. 1.2
Span length= 60 ft.
Out-to-out width= 44 ft.
Number of girders= 6
Girder spacing= 7' - 10"
Girder cross sections= WF 33 x 130
Cover plates= 10" x 1" x 41'

BRIDGE NO. 1.3
Span length= 90 ft.
Out-to-out width= 44 ft.
Number of girders= 7
Girder spacing= 6 ft.
Girder cross sections= WF 36 x 230
Cover plates= 15" x 1" x 58'

BRIDGE NO. 1.4
Span length= 60 ft.
Out-to-out width= 44 ft.
Number of girders= 7
Girder spacing= 6 ft.

Girder cross sections= WF 33 x 118
Cover plates= 10" x 13/16" x 40'

2. SIMPLE SPAN BRIDGES (WELDED GIRDERS)

BRIDGE NO. 2.1
Span length= 90 ft.
Out-to-out width= 44 ft.
Number of girders= 6
Girder spacing= 7' - 10"
Height of the web= 64"
Web thickness= 3/8"

Top and Bottom Flanges:
    For 20 ft. + 20 ft.
    Thickness= 13/8"
    Width= 14"

    For 10 ft. + 10 ft.
    Thickness= 1 1/8"
    Width= 14"

    For 15 ft. + 15 ft.
    Thickness= 3/4"
    Width= 14"

(Stiffeners are in accordance with Ref. 3.)

BRIDGE NO. 2.2
Span length= 150 ft.
Out-to-out width= 44 ft.
Number of girders= 6
Girder spacing= 7' - 10 "
Height of the web= 106"
Web thickness= 3/8"

Top and bottom flanges:
    For 27 ft. + 27 ft.
    Thickness= 1 1/2"
    Width= 19"

    For 18 ft. + 18 ft.
    Thickness= 1 1/2"

Width= 19"

For 30 ft. + 30 ft.
Thickness= 7/8"
Width= 19"

(Stiffeners are in accordance with Ref. 3.)

3. THREE SPAN CONTINUOUS BRIDGES

BRIDGE NO. 3.1
Span lengths= 100' + 120' + 100'
Out-to-out width= 40 ft.
Number of girders= 5
Height of the web= 58"
Web thickness= 3/8"
(Vertical and longitudinal stiffeners, flanges and cover plates are in accordance with Ref. 3.)

BRIDGE NO. 3.2
Span lengths= 190 ft. + 240 ft. + 190 ft.
Out-to-out width= 40 ft.
Number of girders= 5
Height of the web= 114"
Web thickness= 3/8"
(Vertical and longitudinal stiffeners, flanges and cover plates are in accordance with Ref. 3.)

The steel superstructures of the simple span bridges listed above employ ASTM A36 steel. All reinforced concrete decks will have a thickness of 7 1/2" plus 1/2" integral wearing surface. Deck concrete has 28-day cylinder compression strength of 3,000 psi. The reinforcement used in the reinforced concrete deck is in accordance with Pennsylvania Department of Transportation's BD-101 Design Aid (Ref. 9). The reinforcing bars employed are ASTM Grade 40.

2.2 Vehicles

The investigation employed three different vehicles: (1) AASHTO HS20-44 standard design truck, (2) Pennsylvania Department of Transportation's Permit Combination -abbreviated as PDT Comb.-, and (3) A "dolly." A detailed description of the HS20-44 can be found in numerous references (e.g. Ref. 2). For "positive moment" loading of the bridges, the spacing between the drive and rear axles was taken to be 14 ft.

PDT Combination vehicle contains 8 axles. The front axle of this vehicle applies a force of 15 kips. The remaining seven axles are 27 kips each. The out-to-out width of the vehicle, as far as the application of the loads is concerned, is taken to be 8 ft. The axle spacings are: 11 ft. + 4 ft. + 4 ft. + 24 ft. + 4 ft. + 4 ft. + 4 ft.

The dolly contains four axles that are spaced 4 ft. apart. Each axle is 32 kips. The area load applied by this dolly is assumed to be 14 ft. long and 8 ft. wide.

2.4 Load Placement

The placement of the vehicle in transverse direction was (a)exterior lane, and (b)centerline. In the case of the exterior lane loading the vehicle was placed to the free edge of the bridge as closely as permitted by AASHTO Specifications (Ref. 2). In the case of the "centerline" loading, the longitudinal axis of the vehicle coincided with the centerline of the bridge.

For various bridges, vehicles, and loaded lanes, the following table summarizes the cases considered.

VEHICLE	HS20-44		PDT COMB		DOLLY		HS20-44		DOLLY	
LOADED LANE	---------EXTERIOR LANE------						---CENTERLINE------			
LOAD PLACMNT.	+M	-M	+M	-M	+M	-M	+M	-M	+M	-M
Bridge 1.1	X		X		X		X		X	
Bridge 1.2	X		X		X		X		X	
Bridge 1.3	X		X		X		X		X	
Bridge 1.4	X		X		X		X		X	
Bridge 2.1	X		X		X					
Bridge 2.2	X		X		X					
Bridge 3.1	X	X	X	X	X	X				
Bridge 3.2	X	X	X	X	X	X				

III. RESULTS

The results of the parametric investigation are presented in tabular form. Since the contents of each table are self-descriptive through the captions provided, no attempt will be made to describe the contents of each table. However, a generic description of the meaning of the terms used in these table is in order.

3.1 Tabular Presentation of the Result

3.1.1 Vehicular Weight

The first column of each table is labeled "Ptot*I." This is the total live load on the superstructure multiplied by the AASHTO Impact Factor (Ref. 2). The tables for PennDOT Permit Combination vehicle also contain parenthetical values. Considering the span length vs. the "total length" of the vehicle, in some cases the front axle was not on the superstructure. These parenthetical values correspond to the total weight of the vehicle; and the values above these parenthetical values are the portion of the weight on the superstructure.

All the stresses reported in the tables are based on the dead load of the superstructure PLUS the live load multiplied by the impact factor. The second column contains the weight of the static vehicle, i.e. without using the impact factor.

3.1.2 Stresses

The third and the fourth columns contain the maximum tensile

(Ft,max) and maximum compressive stress (Fc,max) in the flanges of the girders. The fifth and the sixth columns contain the maximum tensile and maximum compressive stress in the web of the girder.

The last column contains comments regarding the expected "damage." In all the case studies a very conservative approach was employed in the determination of the slab stresses. Consequently, the reported damage is extremely conservative. Inspection of the girder stresses indicate that the girders will remain well within the linear elastic range. Thus, the "rebound" capability of the bridge is not lost. This observation implies that the cracks in the deck slab are "working cracks," i.e. after the passage of the vehicles the cracks will be closed.

3.1.3 Deck "Damage"

The "damage" to the deck slab is reported under three categories:

"Hairline cracks": The depth of these cracks is less than half the thickness of the concrete cover of the deck slab reinforcement.

"Slab cracking": The depth of the cracks is more than half the depth of the concrete cover of the deck slab reinforcement.

"Loss of concrete cover": The depth of the cracks reached the reinforcing bars, and/or the crack depth is slightly more than the thickness of the concrete cover of the deck slab reinforcement.

3.1.4 Girder Numbering

The structures analyzed have either 6 or 7 girders. Girder No.1 always refers to the exterior girder where the vehicular load is placed, if this is an "exterior lane loading." In this case Girder No. 6, would be the farthest from the loaded lane. In the case of "centerline" loading, girder Nos. 3 and 4 will be under the "vehicle."

3.2 Interpretation of the Tables

The nonlinear finite element analysis, as is the case for all nonlinear formulations, can handle only one "loading configuration" per case study. The computer program will perform the analysis for a small portion of the live load; and will compute stresses, etc. An additional live load will be automatically applied by the computer program and the analysis will be repeated. Inspection of Table 1 indicates that the program initially applied a total live load of 17 kips (including the modification by the impact factor). For the second set of analyses the load was incremented by 17 kips, i.e. the total load of 34 kips. For the third set of analysis the load was incremented by another 17 kips, i.e. total load of 51 kips. Etc.

It should be noted that in the automatic incremental "loading process" the "footprint" geometry of the load and the "percentage" of the total load carried by the axles are the same as the "original vehicle." For example, in Table 1, HS20-44 standard design truck is considered. The front axle carries the 11.1% of the gross vehicular weight, and drive and rear axles carry 44.4% of the gross weight each. In the case of 17 kips load, i.e. the first entry to the table, the loads carried by the front, drive , and rear axles are 1.887 kips (11.1% x 17 kips), 7.55 kips (44.4% x 17 kips), and 7.55 kips, respectively. For the last line of entry for this table the gross weight is 236 kips. The loads carried by front, drive and rear axles will be 26.2 kips, 104.8 kips and 104.8 kips, respectively.

3.4 Observations and Conclusions

The inspection of the tables reveals a number of findings. The reporting of these findings will be included in the final report of this research project. The reporting of the findings can, and will, be made in conjunction with extensive in-depth case studies conducted and reported prior to the inception and conduct of this parametric investigation.

TABLE. 1
BRI. 1.1 LOAD= HS20-44 EXTERIOR LANE

Ptot*I (KIPS)	Ptot (KIPS)	Ft,max Flange (KSI)	Fc,max Flange (KSI)	Ft,max Web (KSI)	Fc,max Web (KSI)	Comments
17	14	9.1	12.7	6.1	10.4	
34	28	13.2	9.8	6.5	10.8	
51	41	10.6	13.6	7.3	10.1	
68	55	11.7	14.1	8.2	11.4	
84	69	12.8	14.2	9.1	11.7	
101	82	13.9	14.5	10.1	12.1	
118	96	15.1	14.9	10.8	12.3	
135	109	15.6	15.7	11.7	12.6	Hairline slab cracking near G6.
152	123	17.3	12.7	12.6	12.9	Hairline slab cracking near G3. Slab cracking near G6.
168	137	18.4	16.4	13.6	13.1	Hairline slab cracking near G3.
185	150	19.5	16.9	14.4	13.4	Hairline slab cracking near G3.
202	164	20.6	17.4	15.2	13.7	Slab cracking between G1 & G2.
219	178	21.7	17.9	16.1	14.1	Additional slab cracking near G4.
236	1[illegible]	22.9	18.4	17.1	14.2	Loss of concrete cover near G4 & G6.

TABLE. 2

BRI. 1.1 LOAD= HS20-44 INTERIOR LANE

Ptot*I (KIPS)	Ptot (KIPS)	Ft,max Flange (KSI)	Fc,max Flange (KSI)	Ft,max Web (KSI)	Fc,max Web (KSI)	Comments
13	11	8.9	12.5	5.9	10.3	
25	21	9.4	12.7	6.2	10.4	
38	31	10.1	12.9	6.7	10.9	
50	41	10.5	13.1	7.2	10.7	Hairline slab cracking near G3.
63	51	11.1	13.3	7.4	10.9	Hairline slab cracking near G2.
75	61	11.5	13.5	8.1	11.1	Slab cracking near G3.

TABLE. 3

BRI. 1.1 LOAD= PDT COMB.EXTERIOR LANE

Ptot*I (KIPS)	Ptot (KIPS)	Ft,max Flange (KSI)	Fc,max Flange (KSI)	Ft,max Web (KSI)	Fc,max Web (KSI)	Comments
22 (24)	18 (20)	9.2	12.8	6.1	10.5	
43 (47)	35 (38)	10.1	13.3	6.7	10.9	
64 (69)	52 (56)	10.6	13.9	7.3	11.3	
85 (92)	69 (75)	11.6	14.4	8.1	11.7	
106 (114)	86 (93)	12.5	15.1	8.6	12.1	**Hairline slab cracking between G2 & G3.**
127 (137)	103 (111)	13.4	15.5	9.4	12.5	**Hairline slab cra between G1 & G2.**
148 (159)	120 (129)	14.5	16.1	10.2	12.9	**Slab cracking between G1 & G2.**
169 (182)	137 (148)	15.5	16.6	11.1	13.3	**Slab cracking near G1.**
190 (204)	154 (166)	16.6	17.4	11.8	13.9	**Slab cracking between G5 & G6.**
211 (227)	170 (183)	17.6	18.2	12.6	14.5	**Cracking of concrete cover between G1 & G2.**

TABLE. 4

BRI. 1.1 LOAD= PDT COMB.INTERIOR LANE

Ptot*I (KIPS)	Ptot (KIPS)	Ft,max Flange (KSI)	Fc,max Flange (KSI)	Ft,max Web (KSI)	Fc,max Web (KSI)	Comments
5 (6)	4 (5)	8.7	12.4	5.6	10.5	
10 (11)	8 (8)	8.9	12.5	5.7	10.5	
15 (17)	13 (14)	9.1	12.6	5.8	10.5	
20 (22)	17 (19)	9.4	12.7	6.2	10.5	
25 (27)	21 (23)	9.6	12.8	6.4	10.7	Slab cracking between G3 & G4.
30 (33)	25 (27)	9.8	12.9	6.7	10.8	Additional slab cracking between G3 & G4.
35 (38)	28 (31)	10	13.1	6.8	10.8	Additional slab cracking between G3 & G4.

TABLE. 5

BRI. 1.1 LOAD= DOLLY EXTERIOR LANE

Ptot*I (KIPS)	Ptot (KIPS)	Ft,max Flange (KSI)	Fc,max Flange (KSI)	Ft,max Web (KSI)	Fc,max Web (KSI)	Comments
13	11	9.1	12.7	6.1	10.5	
26	21	9.7	13.1	6.5	10.7	
39	31	10.4	13.4	7.1	10.9	
51	42	11.1	13.8	7.5	11.1	
64	52	11.6	14.1	8.1	11.4	
77	62	12.3	14.4	8.5	11.7	
89	73	12.9	14.7	9.1	11.7	Hairline cracking of the slab between G1 & G2.
102	83	13.7	14.9	9.8	11.9	
115	93	14.5	15.4	10.1	12.3	
127	103	15.3	15.7	11.1	12.6	Additional slab cracking between G1 & G2.
139	113	15.4	15.7	11.6	12.8	Cracking of concrete cover near G1.

TABLE. 6

BRI. 1.1 LOAD= DOLLY INTERIOR LANE

Ptot*I (KIPS)	Ptot (KIPS)	Ft,max Flange (KSI)	Fc,max Flange (KSI)	Ft,max Web (KSI)	Fc,max Web (KSI)	Comments
6	5	8.7	12.4	5.7	10.2	
11	9	8.9	12.5	5.9	10.3	
16	13	9.2	12.6	6.1	10.4	
22	18	9.4	12.8	6.3	10.5	Hairline cracking of the slab between G3 & G4.
27	22	9.7	12.9	6.4	10.5	Additional slab cracking between G3 & G4.
32	26	9.9	13.1	6.6	10.6	
38	31	10.2	13.1	6.9	10.7	Cracking of concrete cover between G3 & G4.

TABLE. 7

BRI. 1.2 LOAD= HS20-44 EXTERIOR LANE

Ptot*I (KIPS)	Ptot (KIPS)	Ft,max Flange (KSI)	Fc,max Flange (KSI)	Ft,max Web (KSI)	Fc,max Web (KSI)	Comments
95	74	11.2	8.3	8.8	6.6	
130	103	13.9	8.8	11.1	7.1	
167	131	16.5	9.4	13.3	7.3	
203	160	19.3	10.1	15.5	7.7	Hairline cracking of the slab between G2 & G3.
240	189	21.9	10.9	17.8	8.1	
276	217	24.7	11.1	20.1	8.3	Hairline cracking of the slab between G1 & G4.
312	246	27.4	12.6	22.3	8.7	Cracking of concrete cover near G1 & G3.

TABLE. 8
BRI. 1.2 LOAD= HS20-44 INTERIOR LANE

Ptot*I (KIPS)	Ptot (KIPS)	Ft,max Flange (KSI)	Fc,max Flange (KSI)	Ft,max Web (KSI)	Fc,max Web (KSI)	Comments
16	13	5.8	7.1	4.2	5.8	
31	25	6.5	7.1	4.8	5.9	
47	37	7.2	7.3	5.4	6.1	
62	49	7.9	7.4	6.1	6.1	
77	61	8.6	7.5	6.6	6.1	Hairline cracks between G3 & G4.
93	73	9.3	7.7	6.9	6.2	Slab cracking between G3 & G4.
108	85	10.1	7.8	7.5	6.2	Cracking of concrete cover between G3 & G4.

TABLE. 9

BRI. 1.2 LOAD= PDT COMB.EXTERIOR LANE

Ptot*I (KIPS)	Ptot (KIPS)	Ft,max Flange (KSI)	Fc,max Flange (KSI)	Ft,max Web (KSI)	Fc,max Web (KSI)	Comments
27 (51)	21 (40)	6.8	7.5	5.1	6.1	
53 (101)	42 (80)	8.3	8.1	6.4	6.4	
80 (152)	63 (120)	10.3	8.5	8.1	6.7	Slab cracking near G1.
106 (200)	84 (159)	12.3	9.1	9.6	7.1	Hairline cracks between G1 & G2.
133 (252)	104 (197)	14.3	9.6	11.3	7.4	
159 (301)	125 (236)	16.3	10.2	13.1	7.7	
185 (350)	145 (274)	18.3	10.9	14.6	8.1	Cracking of concrete cover near G1.

TABLE. 10

BRI. 1.2 LOAD= PDT COMB.INTERIOR LANE

Ptot*I (KIPS)	Ptot (KIPS)	Ft,max Flange (KSI)	Fc,max Flange (KSI)	Ft,max Web (KSI)	Fc,max Web (KSI)	Comments
7 (14)	6 (12)	5.5	6.9	3.9	5.7	
14 (27)	11 (21)	5.8	7.1	4.2	5.8	
20 (38)	16 (31)	6.2	7.1	4.6	5.8	
27 (51)	21 (40)	6.6	7.2	4.8	5.9	
33 (63)	26 (50)	7.1	7.2	5.2	5.9	
40 (76)	31 (59)	7.4	7.3	5.5	5.9	Slab cracking between G3 & G4.
46 (87)	37 (79)	7.7	7.4	5.8	6.2	Additional slab cracking between G3 & G4.
53 (101)	42 (80)	8.1	7.5	6.2	6.2	Cracking of concrete cover between G3 & G4.

TABLE. 11

BRI. 1.2 LOAD= DOLLY EXTERIOR LANE

Ptot*I (KIPS)	Ptot (KIPS)	Ft,max Flange (KSI)	Fc,max Flange (KSI)	Ft,max Web (KSI)	Fc,max Web (KSI)	Comments
27	21	6.8	7.6	5.1	6.2	
53	42	8.4	8.1	6.4	6.5	
80	63	10.4	8.6	8.1	6.8	
106	84	12.4	9.1	9.8	7.1	Cracking of concrete cover near G1.

TABLE. 12
BRI. 1.2 LOAD= DOLLY INTERIOR LANE

Ptot*I (KIPS)	Ptot (KIPS)	Ft,max Flange (KSI)	Fc,max Flange (KSI)	Ft,max Web (KSI)	Fc,max Web (KSI)	Comments
7	6	5.5	7.1	3.9	5.7	
14	11	5.9	7.1	4.2	5.8	
20	16	6.2	7.1	4.5	5.8	
27	21	6.6	7.2	4.9	5.9	
33	26	7.1	7.2	5.2	5.9	
40	31	7.3	7.3	5.5	5.9	Slab cracking between G3 & G4.
46	36	7.7	7.4	5.8	6.1	Additional slab cracking between G3 & G4.
53	42	8.1	7.4	6.1	6.2	Cracking of concrete cover between G3 & G4.

TABLE. 13

BRI. 1.3 LOAD= HS20-44 EXTERIOR LANE

Ptot*I (KIPS)	Ptot (KIPS)	Ft,max Flange (KSI)	Fc,max Flange (KSI)	Ft,max Web (KSI)	Fc,max Web (KSI)	Comments
30	24	9.5	12.1	6.8	9.8	
59	48	11.5	12.9	7.5	10.4	
89	72	12.1	13.6	10.5	11.1	
118	96	15.5	14.3	11.3	11.5	
148	120	17.5	15.1	13.2	12.1	
177	144	19.4	15.9	14.8	12.5	Hairline cracks between G1 & G4.
207	168	21.5	16.6	16.7	13.1	Hairline cracks near G7.
236	192	23.5	17.4	18.1	13.6	Slab cracking between G3 & G7.
266	216	25.6	18.2	19.8	14.2	Cracking of concrete cover near G7.

TABLE. 14

BRI. 1.3 LOAD= HS20-44 INTERIOR LANE

Ptot*I (KIPS)	Ptot (KIPS)	Ft,max Flange (KSI)	Fc,max Flange (KSI)	Ft,max Web (KSI)	Fc,max Web (KSI)	Comments
10	8	8.4	11.2	8.1	9.2	
20	16	8.7	11.3	8.3	9.3	
29	24	9.1	11.4	8.3	9.3	
39	32	9.5	11.5	8.3	9.4	
49	40	9.6	11.6	8.3	9.5	Hairline cracks near G3 & G4.
58	47	9.9	11.8	8.3	9.6	Slab cracking near G3 & G5.
68	55	10.5	11.8	8.3	9.6	
78	63	10.9	11.9	8.3	9.7	Cracking of concrete cover near G3 & G5.

TABLE. 15

BRI. 1.3 LOAD= PDT COMB.EXTERIOR LANE

Ptot*I (KIPS)	Ptot (KIPS)	Ft,max Flange (KSI)	Fc,max Flange (KSI)	Ft,max Web (KSI)	Fc,max Web (KSI)	Comments
36 (39)	29 (32)	9.3	11.9	6.5	9.5	
71 (77)	58 (63)	10.8	12.7	7.5	10.1	
107 (115)	87 (94)	12.4	13.5	9.1	10.9	Hairline cracks near G1.
142 (153)	115 (124)	14.1	14.2	10.4	10.9	Cracking of concrete cover near G1 & G2.

TABLE. 16

BRI. 1.3 LOAD= PDT COMB.INTERIOR LANE

Ptot*I (KIPS)	Ptot (KIPS)	Ft,max Flange (KSI)	Fc,max Flange (KSI)	Ft,max Web (KSI)	Fc,max Web (KSI)	Comments
11 (12)	9 (10)	8.3	11.2	5.8	9.2	
22 (24)	18 (20)	8.7	11.3	5.9	9.2	
33 (36)	27 (29)	9.1	11.4	6.3	9.3	
44 (48)	36 (39)	9.3	11.5	6.6	9.4	
55 (59)	45 (49)	9.6	11.6	6.8	9.5	
66 (71)	54 (54)	10.1	11.7	6.9	9.5	Hairline cracks near G3, G4 & G5.
77 (83)	63 (68)	10.3	11.8	7.4	9.6	Slab cracking between G3 & G5.
88 (95)	72 (78)	10.6	11.9	7.6	9.7	Slab cracking between G3 & G4.
99 (107)	81 (88)	10.9	12.1	7.9	9.8	Additional slab cracking between G3 & G5.
110 (119)	90 (97)	11.3	12.1	8.2	9.9	Cracking of concrete cover near G3.

TABLE. 17

BRI. 1.3 LOAD= DOLLY EXTERIOR LANE

Ptot*I (KIPS)	Ptot (KIPS)	Ft,max Flange (KSI)	Fc,max Flange (KSI)	Ft,max Web (KSI)	Fc,max Web (KSI)	Comments
37	29	10.1	12.4	7.1	10.1	
72	58	12.2	13.4	8.7	10.8	
107	87	14.5	14.5	10.7	11.6	
143	116	16.8	15.5	12.6	12.1	Hairline cracks near G3.
179	145	19.1	16.5	14.5	13.1	Hairline cracks between G1 & G5. Slab cracking between G1 & G2.
214	174	21.4	17.6	16.4	13.5	Slab cracking between G1 & G4.
250	203	23.8	18.5	18.3	14.5	Slab cracking between G6 & G7.
286	232	23.8	19.5	20.2	15.1	Slab cracking between G1 & G7. Cracking of concrete cover near G3.

TABLE. 18

BRI. 1.3 LOAD= DOLLY INTERIOR LANE

Ptot*I (KIPS)	Ptot (KIPS)	Ft,max Flange (KSI)	Fc,max Flange (KSI)	Ft,max Web (KSI)	Fc,max Web (KSI)	Comments
12	10	8.6	11.2	5.9	9.2	
24	20	9.1	11.4	6.4	9.3	
36	29	9.6	11.6	6.8	9.4	
48	39	10.2	11.8	7.3	9.6	
59	48	10.7	11.9	7.8	9.6	Slab cracking between G3 & G5.
71	58	11.3	12.1	8.2	9.7	
83	67	11.8	12.2	8.7	9.9	Cracking of concrete cover near G3 & G5.

TABLE. 19

BRI. 1.4 LOAD= HS20-44 EXTERIOR LANE

Ptot*I (KIPS)	Ptot (KIPS)	Ft,max Flange (KSI)	Fc,max Flange (KSI)	Ft,max Web (KSI)	Fc,max Web (KSI)	Comments
25	20	7.7	7.8	5.9	6.5	
49	39	10.1	8.5	7.9	6.9	
73	58	12.3	9.4	9.8	7.3	
98	77	14.6	10.1	11.7	7.6	
122	96	16.8	10.5	13.7	7.9	Hairline cracks between G2 & G3.
146	115	19.1	11.1	15.6	8.2	Slab cracking between G2 & G3.
171	134	21.3	11.6	17.5	8.4	Hairline cracks near G7.
195	154	23.5	12.1	19.4	8.7	Slab cracking near G7.
219	173	25.8	12.7	21.4	9.1	Cracking of concrete cover near G7.

TABLE. 20

BRI. 1.4 LOAD= HS20-44 INTERIOR LANE

Ptot*I (KIPS)	Ptot (KIPS)	Ft,max Flange (KSI)	Fc,max Flange (KSI)	Ft,max Web (KSI)	Fc,max Web (KSI)	Comments
10	8	6.3	7.4	4.6	6.1	
20	16	6.8	7.5	5.1	6.2	
30	24	7.4	7.6	5.7	6.2	
40	32	8.1	7.6	6.2	6.3	Slab cracking near G3.
50	40	8.5	7.8	6.7	6.3	Slab cracking between G4 & G5.
60	47	9.1	7.8	7.1	6.4	
70	55	9.6	7.9	7.6	6.4	Cracking of concrete cover between G4 & G5.

TABLE. 21

BRI. 1.4 LOAD= PDT COMB.EXTERIOR LANE

Ptot*I (KIPS)	Ptot (KIPS)	Ft,max Flange (KSI)	Fc,max Flange (KSI)	Ft,max Web (KSI)	Fc,max Web (KSI)	Comments
9 (17)	7 (14)	6.1	7.5	4.8	6.2	
17 (32)	13 (25)	7.1	7.8	5.4	6.3	
25 (47)	20 (38)	7.7	8.1	5.9	6.4	
33 (63)	26 (50)	8.5	8.2	6.6	6.6	
42 (80)	33 (63)	9.1	8.3	7.2	6.7	
50 (95)	39 (74)	10.1	8.5	7.9	6.8	Hairline cracks between G1 & G2.
58 (110)	46 (87)	10.9	8.8	8.6	6.9	
66 (125)	52 (99)	11.7	9.1	9.3	7.1	Slab cracking between G1 & G2.
74 (140)	59 (112)	12.4	9.3	10.1	7.2	
83 (157)	65 (123)	13.2	9.5	10.6	7.4	
91 (172)	72 (136)	14.1	9.7	11.3	7.7	
99 (187)	78 (148)	14.8	9.9	11.9	7.7	Slab cracking between G1 & G3.
108 (204)	8[illegible] (161)	15.5	10.2	12.6	7.7	
115 (218)	91 (172)	16.3	10.4	13.3	7.9	
124 (235)	97 (184)	17.1	10.6	13.9	8.1	Cracking of concrete cover between G1 & G3.

TABLE. 22

BRI. 1.4 LOAD= PDT COMB.INTERIOR LANE

Ptot*I (KIPS)	Ptot (KIPS)	Ft,max Flange (KSI)	Fc,max Flange (KSI)	Ft,max Web (KSI)	Fc,max Web (KSI)	Comments
14 (25)	11 (21)	6.7	7.5	5.1	6.1	
27 (51)	21 (42)	7.7	7.6	5.9	6.2	
40 (76)	32 (61)	8.6	7.7	6.1	6.3	
53 (101)	42 (80)	9.6	7.8	6.6	6.4	Slab cracking between G4 & G5.
67 (127)	53 (1001)	10.6	8.1	7.2	6.5	Slab cracking between G3 & G4.
80 (152)	63 (120)	11.4	8.1	7.8	6.6	Cracking of concrete cover between G3 & G5

TABLE. 23

BRI. 1.4 LOAD= DOLLY EXTERIOR LANE

Ptot*I (KIPS)	Ptot (KIPS)	Ft,max Flange (KSI)	Fc,max Flange (KSI)	Ft,max Web (KSI)	Fc,max Web (KSI)	Comments
9	7	6.4	7.5	4.3	6.2	
17	13	7.1	7.8	5.4	6.4	
25	20	7.8	8.1	5.9	6.5	
33	26	8.5	8.2	6.5	6.6	
42	33	9.1	8.4	7.3	6.8	
50	39	10.1	8.7	8.1	6.9	Hairline cracks between G1 & G2.
58	46	10.9	9.1	8.7	7.1	
66	52	11.7	9.3	9.3	7.3	Slab cracking between G1 & G2.
74	59	12.6	9.5	10.1	7.4	
83	65	13.3	9.8	10.7	7.6	
91	72	14.1	10.1	11.3	7.8	Additional slab cracking between G1 & G2.
99	78	14.9	10.3	12.1	7.9	Cracking of concrete cover between G1 & G2.

TABLE. 24

BRI. 1.4 LOAD= DOLLY INTERIOR LANE

Ptot*I (KIPS)	Ptot (KIPS)	Ft,max Flange (KSI)	Fc,max Flange (KSI)	Ft,max Web (KSI)	Fc,max Web (KSI)	Comments
14	11	6.7	7.5	5.1	6.1	
27	21	7.7	7.6	5.9	6.2	
40	32	8.7	7.7	6.8	6.3	
53	42	9.6	7.8	7.6	6.4	Slab cracking near G3.
67	53	10.6	7.9	8.5	6.5	Slab cracking between G3 & G5.
80	63	11.6	8.1	9.4	6.5	Cracking of concrete cover near G3.

TABLE. 25

BRI. 2.1 LOAD= HS20-44 EXTERIOR LANE

Ptot*I (KIPS)	Ptot (KIPS)	Ft,max Flange (KSI)	Fc,max Flange (KSI)	Ft,max Web (KSI)	Fc,max Web (KSI)	Comments
42	34	10.5	8.3	8.7	7.5	
84	66	13.6	9.6	10.3	8.1	
125	102	16.7	10.7	14.1	8.4	
167	136	19.8	11.7	16.9	10.8	Hairline cracks between G1 & G3.
209	167	21.7	12.7	19.6	10.8	
250	203	25.9	13.9	25.5	10.8	Cracking of concrete cover near G5.

TABLE. 26

BRI. 2.1 LOAD= PDT.COMB.EXTERIOR LANE

Ptot*I (KIPS)	**Ptot** (KIPS)	**Ft,max Flange** (KSI)	Fc,max Flange (KSI)	Ft,max Web (KSI)	Fc,max Web (KSI)	Comments
9 (10)	7 (8)	8.9	8.7	7.2	7.1	
17 (19)	14 (15)	9.1	8.7	7.5	7.1	
25 **(27)**	**20** **(22)**	**9.3**	**8.8**	**7.6**	**7.1**	
33 **(36)**	**27** **(29)**	**9.5**	**8.9**	**7.8**	**7.1**	
41 **(44)**	**34** **(37)**	**9.8**	**8.9**	**8.1**	**7.1**	
49 **(53)**	**40** **(43)**	**10.1**	**8.9**	**9.1**	**7.2**	**Slab cracking between G3 & G4.**
57 **(62)**	**47** **(51)**	**10.2**	**9.5**	**9.3**	**7.2**	
66 **(71)**	**53** **(57)**	**10.4**	**9.5**	**9.3**	**7.2**	
74 **(80)**	**60** **(65)**	**10.6**	**9.5**	**9.3**	**7.2**	
82 **(88)**	**67** **(72)**	**10.9**	**9.5**	**9.3**	**7.2**	**Cracking of concrete cover near G3.**

TABLE. 27

BRI. 2.1 LOAD= DOLLY EXTERIOR LANE

Ptot*I (KIPS)	Ptot (KIPS)	Ft,max Flange (KSI)	Fc,max Flange (KSI)	Ft,max Web (KSI)	Fc,max Web (KSI)	Comments
10	8	9.3	8.7	7.5	7.1	
20	16	9.8	9.1	8.1	7.2	
30	24	10.4	9.2	8.1	7.3	
40	32	10.9	9.2	9.1	7.4	Slab cracking between G1 & G2.
49	40	11.5	9.2	9.3	7.4	Cracking of concrete cover between G1 & G2.

TABLE. 28

BRI. 2.2 LOAD= HS20-44 EXTERIOR LANE

Ptot*I (KIPS)	Ptot (KIPS)	Ft,max Flange (KSI)	Fc,max Flange (KSI)	Ft,max Web (KSI)	Fc,max Web (KSI)	Comments
40	34	11.3	10.6	9.2	8.6	
79	67	12.9	10.7	10.8	9.1	
119	100	15.1	11.9	12.8	9.6	
158	134	17.4	12.6	14.7	10.1	Hairline cracks near G1.
197	167	19.6	13.3	16.7	10.6	Hairline cracks between G1 & G4.
237	200	21.9	14.1	18.8	11.1	Cracking of concrete cover near G1.

TABLE. 29

BRI. 2.2 LOAD= PDT COMB.EXTERIOR LANE

Ptot*I (KIPS)	Ptot (KIPS)	Ft,max Flange (KSI)	Fc,max Flange (KSI)	Ft,max Web (KSI)	Fc,max Web (KSI)	Comments
31 (34)	27 (30)	10.9	10.3	9.1	8.4	
62 (67)	53 (57)	11.9	10.8	9.8	8.7	
93 (100)	79 (85)	12.9	11.3	10.2	9.1	Cracking of concrete cover near G1.

TABLE. 30

BRI. 2.2 LOAD= DOLLY EXTERIOR LANE

Ptot*I (KIPS)	Ptot (KIPS)	Ft,max Flange (KSI)	Fc,max Flange (KSI)	Ft,max Web (KSI)	Fc,max Web (KSI)	Comments
12	10	10.4	10.1	8.4	8.2	
23	19	10.8	10.3	8.9	8.4	
34	29	11.3	10.5	9.3	8.5	
45	38	11.8	10.7	9.7	8.7	Slab cracking near G1.
56	48	12.2	10.9	10.1	8.8	
68	57	12.7	11.1	10.5	10.1	Cracking of concrete cover near G1.

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