

**USER'S MANUAL FOR
CONTINUOUS BEAM ANALYSIS
(CBA)**



pennsylvania
DEPARTMENT OF TRANSPORTATION

Version 3.7.0.0

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**USER'S MANUAL FOR
COMPUTER PROGRAM CBA
CONTINUOUS BEAM ANALYSIS
Version 3.7.0.0**

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CONTINUOUS BEAM ANALYSIS

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SUMMARY OF AUGUST 1994 REVISIONS - VERSION 2.0

The Continuous Beam Analysis (CBA) program has been revised for the following:

1. New input parameters have been added to change the values of the axle loads and the uniform lane load for the LRFD or AASHTO loadings.
2. Live load distribution factors can now be entered for each span to calculate various effects based on different distribution factors.
3. A correction has been made to the calculation of live load deflection. It was using the distribution factor for moment rather than the distribution factor for deflection.
4. The axle load on the SI Design Tandem for PHL93 loading has been changed from 137.5 kN to 140 kN. The axle load on the USC Design Tandem is kept at 31.25 kips.
5. The negative moment between the points of dead load contraflexure and the reaction at an interior pier due to the PHL93 loading are now calculated using the 100% of the truck and lane load effects.
6. The SYMMETRY option has been revised. For a beam to be symmetric, now all input values must be symmetric. Previously only the section properties and span lengths had to be symmetric.
7. A correction has been made to fix a problem where unsymmetrical deflections were being calculated for a symmetrical simple span beam with section property changes at the twentieth points.
8. A correction has been made to the calculation of influence line effects for a very short uniform dead load.
9. CBA Version 2.0 is available for a PC application only.

CONTINUOUS BEAM ANALYSIS

SUMMARY OF JANUARY 1995 REVISIONS - VERSION 2.1

The Continuous Beam Analysis (CBA) program has been revised for the following:

1. The input form for live load distribution factors has been revised.
2. The input parameter REACTION DF has been deleted.
3. The program now requires two distribution factors for shear to be entered for each span. This will allow the user to apply appropriate correction factors to the distribution factors for shear for skewed bridges.
4. The positive and negative live load reactions are now broken down into truck effect and lane effect with no impact or distribution factors applied.
5. A new input type has been added to enter the modulus of elasticity by span.
6. An error correction has been made to fix a problem when hinges are entered using the SYMMETRY option.
7. An error correction has been made to allow a zero value to be entered for DESIGN LANE LOAD. The program was previously using the default lane loading (0.64 k/ft) when zero was entered.
8. For calculating the positive moment at an interior support, the program now uses the larger distribution factor (MOMENT DF1) of the adjacent two spans.
9. Example Problem 2 has been revised.

CONTINUOUS BEAM ANALYSIS

SUMMARY OF FEBRUARY 1995 REVISIONS - VERSION 2.2

The Continuous Beam Analysis (CBA) program has been revised for the following:

1. An option has been added to compute reactions only. This option will allow getting stringer reactions only for analyses of floorbeams, abutments and piers. A new input item REACT ONLY has been added to the Beam Data and Design Live Loads.
2. Three new loadings have been added. Input item LOADING on the Beam Data and Design Live Loads now uses codes 6, 7, and 8 to represent H20, HS20 and Pedestrian Load, respectively.
3. Input items CONC LOAD MOMENT and CONC LOAD SHEAR have been added to the Beam Data and Design Live Loads. These input items correspond to the concentrated loads which are used in conjunction with the H20 and HS20 lane loads.
4. For deflections due to the PHL93 loading, the program now computes the same as for the HL93 loading and multiplies the result by a factor of 1.25.

CONTINUOUS BEAM ANALYSIS

SUMMARY OF JUNE 1995 REVISIONS - VERSION 2.3

The Continuous Beam Analysis (CBA) program has been revised for the following:

1. A new input item DIRECT has been added to the Beam Data and Design Live Loads. This provides the user with an option to analyze a live load moving in only one direction.
2. Two new loadings have been added. Input item LOADING on the Beam Data and Design Live Loads now uses codes A and B to represent P-82 and ML80 Live Loads, respectively.
3. A new output option has been added to create a non-annotated output file for export to a spreadsheet program.

CONTINUOUS BEAM ANALYSIS

SUMMARY OF JANUARY 1996 REVISIONS - VERSION 2.4

The Continuous Beam Analysis (CBA) program has been revised for the following:

1. A new capability has been added so that the program can analyze user entered influence lines for a given loading condition. When influence line distances and ordinates are entered, the program does not generate influence lines. One set of influence line distances and five sets of influence line ordinates may be entered. The user entered influence lines can be analyzed for all loading conditions except support settlements, creep, shrinkage or temperature gradient.
2. A new capability has been added so that the user entered influence lines can be analyzed for a group of moving loads. This capability enables the user to analyze an influence line for a series of patch loads. The group of loads is moved over the influence line from right to left and from left to right to obtain the maximum and minimum effects and the corresponding position of the load group.
3. An error correction has been made to fix a problem when the difference in fixed-end moments is very small.
4. The User's Manual has been corrected and revised. The complete manual has been reprinted.

CONTINUOUS BEAM ANALYSIS

SUMMARY OF SEPTEMBER 1996 REVISIONS - VERSION 2.5

The Continuous Beam Analysis (CBA) program has been revised for the following:

1. A correction has been made so that the 0.9 factor is not applied for the HL93 tandem pair loading. The output for the HL93 code definitions has been changed to remove 90% for code 3 and clarify code 4.
2. Negative reactions at interior supports are now calculated for all pair loadings.
3. An error correction has been made to fix a problem with interpolation of dead load shear values at analysis points between twentieth points.
4. An error correction has been made to fix a problem with placing a concentrated load at the end of the last span and getting zero shear and reaction.
5. An error correction has been made to fix a problem with the calculation of simultaneous effects for a moving load group traveling in the reverse direction.
6. An error correction has been made to fix a problem with interpolation of dead load moment values at analysis points between twentieth points.
7. A modification has been made to the calculation of effects due to non-uniform (trapezoidal or triangular) distributed loads to achieve more accurate results.

CONTINUOUS BEAM ANALYSIS

SUMMARY OF SEPTEMBER 1997 REVISIONS - VERSION 3.0

The Continuous Beam Analysis (CBA) program has been revised for the following:

1. A new capability has been added so that the program can analyze floorbeams with or without cantilevers.
2. A correction has been made to the calculation of shear at a support for a concentrated dead load placed over the support.
3. The algorithm for processing a live load using influence lines has been refined. In some instances with four or more spans, the program may now calculate a slightly greater effect.
4. A change has been made to the concurrent effects for notional loads. If the axle is not included when calculating the primary effect, then the same axle is not included to calculate the concurrent effect.
5. The User's Manual has been corrected and revised. The complete manual has been reprinted.

CONTINUOUS BEAM ANALYSIS

SUMMARY OF SEPTEMBER 1997 REVISIONS - VERSION 3.1

The Continuous Beam Analysis (CBA) program has been revised for the following:

1. A correction has been made to floorbeam shear values reported by the program. Shear on the left cantilever portion of the floorbeam had the correct magnitude but had the wrong sign.
2. This revision was incorporated into the LRFD floorbeam program but was not officially released to the licensed user.
3. No changes were made to the User's Manual.

CONTINUOUS BEAM ANALYSIS

SUMMARY OF JUNE 1999 REVISIONS - VERSION 3.2

The Continuous Beam Analysis (CBA) program has been revised for the following:

1. The program has been revised to streamline the input necessary when running a job with known influence lines entered by the user. When the NO OF SPANS input item is entered as 99, then the program recognizes that input is for a known influence line and other unnecessary input items should not be entered.
2. An error correction has been made to the analysis of live loads using influence lines when creating loading arrays for concurrent effects for the H2O or HS20 Loadings. The program would not always calculate the concurrent effect correctly when the first axle was not on the influence line.
3. An error correction has been made to fix a situation where a symmetric problem did not give symmetrical output. The program was not always using the correct section properties (Moments of Inertia) when an analysis point fell on a property change point and there were multiple property changes between analysis points.
4. The program has been revised to print the dates in the MM/YYYY and the MM/DD/YYYY formats.
5. The User's manual has been corrected and revised. The complete manual has been reprinted.

CONTINUOUS BEAM ANALYSIS

SUMMARY OF MARCH 2000 REVISIONS - VERSION 3.3

The Continuous Beam Analysis (CBA) computer program has been revised to calculate the reaction at interior supports due to PHL-93 loading using 90% of the effect due to design truck pair plus design lane load or design tandem pair plus design lane load. The negative moment between the point of dead load contraflexure and an interior support remains at 100% of the above effects.

CONTINUOUS BEAM ANALYSIS

SUMMARY OF APRIL 2001 REVISIONS - VERSION 3.4

The Continuous Beam Analysis (CBA) program has been revised for the following:

1. Use the axle weight of 110 kN (25 kips) for the design tandem pair of the PHL93 loading for the calculation of negative moments and the positive reaction at the pier. The axle weight of the PHL93 design tandem for all other calculations remains 140 kN (31.25 kips). See table below.
2. Calculate the reaction at interior supports due to PHL-93 loading using 100% of the effect due to design tandem pair plus design lane load instead of the previous 90% of the effect. See table below.
3. Apply a rounding technique so that the results of a symmetrical problem are not unsymmetrical.
4. Correct a problem where a 24-axle special live load was causing an error.

CBA Version Comparisons – Tandem/Truck Pair

Version	Loading	Effect	Tandem Pair %	Truck Pair %	Comments
2.4	PHL93	Reaction	100	100	140kN (31.25K) for tandem axle load
		Moment	100	100	140kN (31.25K) for tandem axle load
	HL93	Reaction	90	90	
		Moment	90	90	
3.0	PHL93	Reaction	100	100	140kN (31.25K) for tandem axle load
		Moment	100	100	140kN (31.25K) for tandem axle load
	HL93	Reaction	100	90	
		Moment	100	90	
3.3	PHL93	Reaction	90	90	140kN (31.25K) for tandem axle load
		Moment	100	100	140kN (31.25K) for tandem axle load
	HL93	Reaction	100	90	
		Moment	100	90	
3.4	PHL93	Reaction	100	90	110kN (25K) for tandem axle load
		Moment	100	100	110kN (25K) for tandem axle load
	HL93	Reaction	100	90	
		Moment	100	90	

New PHL93 Loading Codes in Version 3.4

1 – TANDEM + LANE GOVERNS

5 – TRUCK ALONE GOVERNS

2 – TRUCK + LANE GOVERNS

6 – 25% TRUCK + LANE GOVERNS

3 – TANDEM PAIR + LANE GOVERNS

7 – 90% (TRUCK PAIR + LANE) GOVERNS

4 – TRUCK PAIR+ LANE GOVERNS

CONTINUOUS BEAM ANALYSIS

SUMMARY OF APRIL 2003 REVISIONS - VERSION 3.5

The Continuous Beam Analysis (CBA) program has been revised for the following:

1. Correct a problem where the program was inadvertently reporting a blank PHL93 loading code for an analysis point that has a non-zero live load effect.
2. Correct a problem where the program was inadvertently reporting duplicate zero analysis points.
3. Add rotations to the REACTIONS WITH NO IMPACT OR DISTRIBUTION FACTORS output.
4. Rename the original reactions output heading to REACTIONS AND ROTATIONS WITH IMPACT AND DISTRIBUTION FACTORS.
5. Add a new loading input code (T) to analyze a TK527 truck.

CONTINUOUS BEAM ANALYSIS

SUMMARY OF MARCH 2005 REVISIONS - VERSION 3.5.0.1

The Continuous Beam Analysis (CBA) program has been revised for the following:

1. Correct a problem where Output Option 8 was no longer producing a non-annotated output file for export to a spreadsheet program.
2. The program is modified to run as a dynamic link library (DLL).
3. Correct a problem where the program produced unsymmetrical results for a symmetrical problem. This occurred when there was a user-defined analysis point at a twentieth point for the condition where a concentrated dead load was located at the twentieth point.

CONTINUOUS BEAM ANALYSIS

SUMMARY OF APRIL 2005 REVISIONS - VERSION 3.5.0.7

The Continuous Beam Analysis (CBA) program has been revised for the following:

1. CBA v3.5.0.1 reported zero values for some points. When the program encountered user-defined analysis points coinciding with the program's generated 20th points, v3.5.0.1 did not store them in the user-defined analysis arrays.
2. Errors were encountered when interpolating moments and shears. When summing the dead loads between analysis points, the concentrated dead loads over the supports were being included.
3. The obsolete coding for the PC\$.INC include file was removed.
4. CBA was not being consistent when computing moments and shears at an analysis point where a concentrated dead load is applied.

CONTINUOUS BEAM ANALYSIS

SUMMARY OF FEBRUARY 2007 REVISIONS - VERSION 3.6.0.0

Since the release of CBA Version 3.5.0.7 several revision requests and user requested enhancements have been received. This release of CBA Version 3.6.0.0 contains the following revisions and enhancements.

General Revisions

1. The first axle of the ML-80 loading was changed from 13.7 to 13.68 (U.S. Units) to be consistent with all the other PENNDOT programs that use this loading (Request 008).
2. The maximum number of spans has been increased from 20 to 50 (Request 014).
3. The maximum number of axles for a special live load has been increased from 24 to 80 (Request 015).
4. Add the capability to analyze a problem with elastic supports (Request 016).
5. CBA now calculates moment and shear values at intermediate user-defined analysis points using influence lines instead of using interpolations based on the results at twentieth points (Request 017).
6. When reaction distribution factors are entered for supports, CBA will use them instead of the shear distribution factors. This will allow a skew correction factor to be applied for shear but not reaction in the same run. Also, a more accurate factor may now be entered for interior supports between spans of unequal length (Request 023).
7. Add the capability to analyze a special live load using the AASHTO Standard Specifications. A new input item STD was added to indicate that the special live load should be analyzed as a vehicle load or a lane load, whichever governs. The standard lane load consists of a uniform load plus one or two concentrated loads (Request 028).

Program Malfunctions

8. A problem was corrected where a 20-span job was causing an error because the program was trying to access a support beyond the maximum number of supports (Request 010).
9. A problem was corrected with the way CBA accessed some values for a Floorbeam. This was causing an error and the program would abnormally end (Request 011).
10. A problem was corrected where the program was sometimes reporting erroneous shear values when a concentrated load was applied exactly on an analysis point just to the left of a user-defined analysis point (Request 012).
11. CBA was producing inconsistent results when a concentrated dead load was applied exactly at a twentieth point. This sometimes caused effects of equal magnitude but opposite sign. The program logic was changed to consistently use the second value but with the sign based on the sign of the concentrated load (Request 013).
12. A problem was corrected where the program was sometimes ending prematurely without returning control back to the program that was calling CBA as an engine (Request 021).

CONTINUOUS BEAM ANALYSIS

13. CBA now uses the same loading conditions for calculating both the rotations and the deflections. Previously, the rotations were calculated using the same loading conditions used for moments (Request 024).
14. Make sure that all default Live Load Distribution Factors are set equal to 1.0. When left blank, the program was sometimes using 0.0 (Request 027).
15. A problem was corrected where the program was not printing the live load deflection code when multiple user-defined analysis points exist between a support and the first 20th point (Request 029).

Input Revisions

16. Add new input for support spring constants for use with elastic supports (Request 016).
17. Add the capability to input reaction distribution factors at supports (Request 023).
18. Add a new input option to indicate that a special live load should be analyzed based on the AASHTO Standard Specifications. The input item STD was added to the Project Identification input data (Request 028).

Output Revisions

19. An option was added so that the standard output may be sent to a temporary output file when CBA is called as an engine from another program (Request 018).
20. The program was corrected to make sure that all user-defined analysis points are printed when the Analysis Points input item is "09", even when the user-defined point falls on a twentieth point (Request 019).

Programming Revisions

21. The program was converted from the Compaq Visual Fortran Compiler 6.6 to the Intel Visual Fortran Compiler 9.0 (Request 009).
22. Avoid an error caused when a job contained the maximum number of spans. A combined program check needed to be split into two separate checks because of the difference in the way the new Intel Fortran Compiler processes the code (Request 022).

User Manual Revisions

23. Chapter 3 was enhanced to include a more detailed description of the Modified Flexibility Method and expanded to include figures and information concerning elastic supports (Request 016).
24. A new section was added to Chapter 5 for the description of the new input for Support Spring Constants (Request 016).

CONTINUOUS BEAM ANALYSIS

25. The new input field STD was added to the Project Identification data with appropriate descriptions and changes to the corresponding input forms (Request 028).

CONTINUOUS BEAM ANALYSIS

SUMMARY OF FEBRUARY 2015 REVISIONS - VERSION 3.6.0.5

Since the release of CBA Version 3.6.0.0, several error reports and user requested enhancements have been received. This release of CBA Version 3.6.0.5 contains the following revisions.

General Program Revisions

1. Corrected an error for invalid index (array out of bounds error) in Subroutine CBA_FLOORBEAM (CBAREV034).
2. Corrected an error (at subroutines CBA_INFLL, CBA_INFLR, ..) that reactions at supports were higher when INCLUDE = "Y" was selected for including all axles of a special live load instead of INCLUDE = "N". This revision will have no impacts on all LRFD programs using live load analysis with INCLUDE = "Y". But this revision will have impacts on all LRFD programs using live load analysis with INCLUDE = "N". However, these changes shall be small and the number of changes is limited (CBAREV037).
3. Corrected an error of unsymmetrical shear values of a symmetrical simple span bridge (CBAREV039).

Input Revisions

4. Added more input choices on the OUTPUT field of the BEAM DATA AND LIVE LOADS card to turn on/off output file in pdf for stand-alone version only (CBAREV035).

Output Revisions

5. When running the input file, CBA shall provide the option of output file in pdf for stand-alone version only (CBAREV035).

Program Revision

6. This program has been converted to the Intel(R) Visual Fortran Compiler XE on IA-32, version 14.0.4.237 using Microsoft Visual Studio 2012 (CBAREV038).

CONTINUOUS BEAM ANALYSIS

SUMMARY OF NOVEMBER 2018 REVISIONS - VERSION 3.7.0.0

Since the release of CBA Version 3.6.0.5, several error reports and user requested enhancements have been received. This release of CBA Version 3.7.0.0 contains the following revisions.

General Program Revisions

1. The program was revised to avoid a crash due to a zero-array subscript for a known influence line analysis when the load type is PHL93 (CBAREV040).
2. The Engineering Assistant configuration file (fields.ini) was revised to allow negative values for fixed-end moments and reactions (CBAREV045).
3. Update to the current GNDLL libraries (CBAREV044).
4. When the CONT at the BEAM DATA AND DESIGN LIVE LOADS card is equal to H, CBA adds the following edit checks to prevent the user from entering unstable hinge locations of HINGE LOCATIONS Card (CBAREV048).
 - a. The hinge location cannot be located at the begin bearing of the begin span (i.e. span 1)
 - b. The hinge location cannot be located at the end bearing of the end span (i.e. the last span)
 - c. More than two hinge locations in any interior span (including the locations on top of these supports at each end of the span) are not allowed.
 - d. More than one hinge locations in any begin or end span (including the locations on top of these supports at each end of the span) are not allowed.
 - e. The number of hinge locations in all spans cannot exceed the number of spans – 2.

When the CONT at the BEAM DATA AND DESIGN LIVE LOADS card is equal to H, CBA will allow hinge locations on top of the interior supports if the bridge is stable (CBAREV048).

Note: It is still possible to unstable hinge locations (such as two adjacent spans with one hinge at each span), which may cause a program crash. More work is required to prevent all possible unstable hinge scenarios.

Load Revisions

2. Added the following loading types (LOADING CODE) for these new standard live loads at the BEAM DATA AND DESIGN LIVE LOAD data card (CBAREV041).
D for PA58, risk-based posting vehicle

CONTINUOUS BEAM ANALYSIS

E for EV2, single rear axle emergency vehicle,
F for EV3, tandem rear axle emergency vehicle
G for SU6TV, heavy-duty tow and recovery vehicle.

3. Added a new loading type, H, to automatically evaluate the 13-axle, 330 kips GVW permit design vehicle: PA2016-13 which has two varying axle spacings between its truck axles 7-8 and 10-11. (CBAREV043).
4. The program shall use the following logic for Special Live Load (LOAD TYPE = 9) about the use of SEC LANE LOAD and H20 or HS20 uniform or concentrated lane loads (CBAREV047):

Case 1. STD = true (user enters S): (WSD or LFD) => truck load effect or lane load effect governs

1a. if the user enters nothing (i.e. BLANK) at SPEC LANE LOAD:

=> use the default value (0.64 kip/ft or 9.3 kN/m) of standard H or HS lane load.

=> use the default value [(18 kip and 26 kip) or (80 kN, and 115 kN)] of standard H or HS concentrated loads for moment and shear.

1b. if the user enters something at SPEC LANE LOAD:

=> use the user-entered value to represent the standard H or HS lane load,

=> use the values of CONC LOAD MOMENT and CONC LOAD SHEAR to represent the standard H or HS concentrated loads for moment and shear.

Case 2. STD = false (user enters N or leave it blank): (LRFD) => truck load effect plus lane load effect govern

2a. if the user enters nothing (i.e. BLANK) at SPEC LANE LOAD:

=> use 0 to represent the standard H or HS lane load.

=> use 0 to represent the standard H or HS concentrated load for moment and shear.

=> any user-entered values of design lane load, CONC LOAD MOMENT, and CONC LOAD SHEAR will be ignored.

2b. if the user enters something at SPEC LANE LOAD:

=> use the user-entered value to represent the standard H or HS lane load.

=> use the user-entered value of CONC LOAD MOMENT and /or CONC LOAD SHEAR to represent the standard H or HS concentrated loads for moment and shear

Program Revision

5. This program has been converted to the Intel(R) Visual Fortran Compiler (2017 Update 5) version 17.0.5.267 (IA-32) using Microsoft Visual Studio Professional 2017 version 15.4.4 (CBAREV046).

|

1 **GENERAL DESCRIPTION**

1.1 PROGRAM IDENTIFICATION

Program Title: Continuous Beam Analysis

Program Name: CBA

Version: 3.7.0.0

Subsystem: Structure Design - Superstructure

Authors: Hasmukh M. Lathia, P.E.
John A. Breon, P.E.
Shyhhann Ji, P.E.
Engineering **Software Section**
Bureau of **Solution Management**
Pennsylvania **Office of Administration**

ABSTRACT:

The Continuous Beam Analysis (CBA) program analyzes a continuous span longitudinal beam or a simple or cantilever floorbeam for one loading condition in each run and computes moments, shears, reactions, rotations and deflections at various analysis points on the beam. The moments, shears and deflections can be calculated at the tenth or twentieth points or at user-defined points on each span. The loading condition may be a uniform load, a series of uniform or trapezoidal loads, a series of concentrated loads or a moving live load or a support settlement or fixed-end actions due to creep and shrinkage or temperature gradient. A maximum of fifty spans can be analyzed. The spans can be simple or continuous or continuous with in-span hinges. The beam can have variable moments of inertia within each span. The live load can be an LRFD loading, an AASHTO loading, a pedestrian load, or a user-defined loading including a combination of truck over lane load. The floorbeam may act as a simple beam between two supports and may have one or two cantilevers that are fixed or continuous over the supports. A simple floorbeam may be analyzed for moments applied at the supports. The analysis is performed in accordance with the 1994 AASHTO LRFD Bridge Design specifications.

Chapter 1 General Description

1.2 ABBREVIATIONS

This section provides definitions of abbreviations that are commonly used throughout this User's Manual.

- AASHTO - American Association of State Highway and Transportation Officials.
- AASHTO Specifications - AASHTO Standard Specifications for Highway Bridges, Fifteenth Edition, 1992.
This publication can be ordered from:
American Association of State Highway and Transportation Officials
444 North Capitol Street, N.W., Suite 249
Washington, D.C. 20001
- AASHTO Manual - AASHTO Manual for Condition Evaluation of Bridges, Second Edition, 1994 as revised by the 1995, 1996, 1998 and 2000 Interim Revisions. This publication can be ordered from:
American Association of State Highway and Transportation Officials
444 North Capitol Street, N.W., Suite 249
Washington, D.C. 20001
- BD Standards - Standards for Bridge Design, Prestressed Concrete, Reinforced Concrete and Steel Structures, January 1989 Edition, Pennsylvania Department of Transportation.
- CBA - Continuous Beam Analysis Program.
- DM-4 - Pennsylvania Department of Transportation Design Manual Part 4, August 1993 Edition. This publication can be ordered from:
Pennsylvania Department of Transportation
Publication Sales
P.O. Box 2028
Harrisburg, PA 17105
- PENNDOT - Pennsylvania Department of Transportation.
- PUB 238(3-10) - Pennsylvania Department of Transportation Bridge Safety Inspection Manual, 2nd Edition, Revised March 2010.

2 PROGRAM DESCRIPTION

2.1 GENERAL

The CBA program analyzes a continuous span longitudinal beam or a simple or cantilever floorbeam for a given loading, and calculates reactions, rotations, moments, shears and deflections at various points on the beam. The loading condition may be a set of dead loads or a group of support settlements or the effect of creep and shrinkage or temperature gradient or a live loading. In each run, only one of the above loading conditions can be analyzed. The dead load can be a uniform load applied to the entire beam or a series of uniform or trapezoidal loads applied to partial lengths of the beam or a system of concentrated loads or any combination of these loads. The live load can be LRFD, AASHTO, pedestrian or user-defined loading including truck loads over lane loads. Truck loads may contain varying axle spacings. The program can analyze user-entered influence lines for a given loading condition.

The sections at which the load effects are calculated can be specified as tenth points or twentieth points and/or as user-defined points along the span. Either the actual live load effects that have the lateral distribution and impact factor applied or effects for one lane without impact can be obtained.

The input consists of beam data, live load distribution factors, impact factor, span lengths, hinge locations, definition of analysis points, moments of inertia, dead loads, user specified live loads, support settlements and fixed-end actions. The output consists of a repeat of all input values, moments, shears, moment-shear interactions and deflections at analysis points, support reactions, and support rotations. The computations can be specified in either metric (SI) or U.S. Customary units. However, support for metric may not be up to date. The analysis is performed in accordance with the 1994 AASHTO LRFD Bridge Design Specifications.

The computed values are printed out in a tabular form.

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3 METHOD OF SOLUTION

3.1 GENERAL

The primary purpose of this program is to analyze a continuous span longitudinal beam or a floorbeam used in a bridge for a system of dead loads or a moving live load. The program analyzes the beam for a given loading condition and calculates the load effects at various points on the beam. The program uses the Modified Flexibility Method, developed by the author, for continuous span longitudinal beams. In this method 1. a beam with continuous spans with or without in-span hinges or 2. a series of simple spans as a statically determinate structure which is a continuous span with in-span hinges at all intermediate supports can be analyzed for a given loading by solving a set of simultaneous equations. For a floorbeam analysis, the program uses the principles of statics since the types of floorbeams that can be analyzed are determinate structures.

3.2 MODIFIED FLEXIBILITY METHOD

The program begins by dividing each span into twenty segments and setting up an analysis point at the end of each segment. If there is an in-span hinge between two analysis points, the program introduces this as an additional analysis point. The unknowns in the solution of a continuous beam are assumed to be the reactions at support points. The following conditions give a set of simultaneous equations for the solution of unknown reactions. The first condition is that the sum of reactions must be equal to the sum of applied loads. The second condition is that the sum of moments due to reactions must be equal to the sum of moments due to applied loads at the right most support. If there are in-span hinges, the next NH (number of hinges) conditions are that the sum of moments due to unknown reactions at a given hinge point must be equal to the sum of moments due to applied loads at the same hinge point. The remaining conditions (if the beam is statically indeterminate) are that the deflection at each support due to applied loads is zero. The formulation of these equations and their solution by matrix algebra is the essence of the modified Flexibility Method. The deflections and rotations are by-products of this process.

Chapter 3 Method of Solution

A typical loading condition is a unit load applied at an analysis point. The effects (such as reaction, rotation, deflection, etc.) are then calculated at all analysis points for this loading condition. Applying this unit load at each analysis point in succession and then calculating the effects at all analysis points produces the ordinates of influence lines for support reactions, support rotations, and the deflections at analysis points. The influence lines for moments and shears at analysis points are generated from the reaction influence lines when needed for analysis of a given loading.

3.2.1 Required Steps

The following steps are required in analyzing a continuous beam by the Modified Flexibility Method.

1. Divide each span into 20 segments of equal length. Determine the coordinates (x distances from the leftmost support) of ends of segments. These are considered as 20th analysis points.
2. Determine the coordinates of hinge points if present. Insert these hinge points as analysis points.
3. Determine the coordinates and indices of support points.
4. Determine the number of redundant reactions which is equal to number of supports minus 2 minus number of hinges.
5. Choose the locations of redundant reactions. See Section 3.2.2.
6. Remove supports corresponding to redundant reactions. Determine new span lengths, support points, etc. for the reduced structure.
7. Solve for reactions (R_1' , R_2' ...) for the reduced structure. This will require a solution of simultaneous equations for a determinate structure. See Section 3.2.4.
8. Determine the moments at analysis points for the reduced structure. Construct M/EI ordinates for the reduced structure.
9. Find a conjugate structure for the reduced structure. Refer to any standard text book on structural analysis for how to determine a conjugate structure.
10. Using the M/EI ordinates found in step 8, load the conjugate structure with M/EI loading (a series of trapezoidal loads).
11. Solve for reactions of the conjugate structure like step 7 except that the structure configuration is different and the loading is different (it is M/EI loading). Finds the moments and shears at analysis points corresponding to redundant reactions of the original structure. These moments are the deflections of the reduced structure and shears are the rotations of the reduced structure.
12. Repeat steps 7 through 11 for different loading conditions. A typical loading condition is an application of a unit load at an analysis point. When all unit load conditions are solved, the elements $\delta_{i,j}$ of the coefficient matrix and the elements $\Delta_{i,j}$ of the load matrix required for the solution reactions ($R_1, R_2 \dots R_n$) of the original structure are assembled. See Section 3.2.3.

Note: The above procedure should also work for a continuous beam without hinges. The only difference would be in step 7 where the reduced structure is a simple span structure and thus the reactions can be determined by statics.

Chapter 3 Method of Solution

3.2.2 Rules for Reduced (Determinate) Structure

When the number of in-span hinges is more than the number of spans $- 1$ (or the number of supports $- 2$), the original structure is unstable.

When the number of in-span hinges = the number of spans $- 1$ = the number of supports $- 2$, the original structure is statically determinate. For example, a series of simple spans are modelling as a statically determinate structure which is a continuous span with in-span hinges at all intermediate supports.

When the number of in-span hinges is less than the number of spans $- 1$ (or the number of supports $- 2$), the original structure is statically indeterminate, CBA uses the following rules in reducing the original indeterminate structure to a determinate (or reduced structure) structure.

1. Determine how many supports are to be removed to make the structure a determinate structure. This is equal to the number of supports minus two minus the number of hinges in the structure.
2. Keep the extreme supports.
3. Keep the support to the right of a hinge.
4. If the hinge is in the last span, keep the support to the left of the hinge.
5. If there are two hinges in a span, keep both supports for that span.
6. Total number of supports to be kept is equal to two plus the number of hinges.
7. Remove the remaining supports.
8. The resulting structure should be a stable determinate structure.

For example, a continuous span without in-span hinges, all interior supports need to be removed.

3.2.3 Solution of the Reactions for Indeterminate Structure

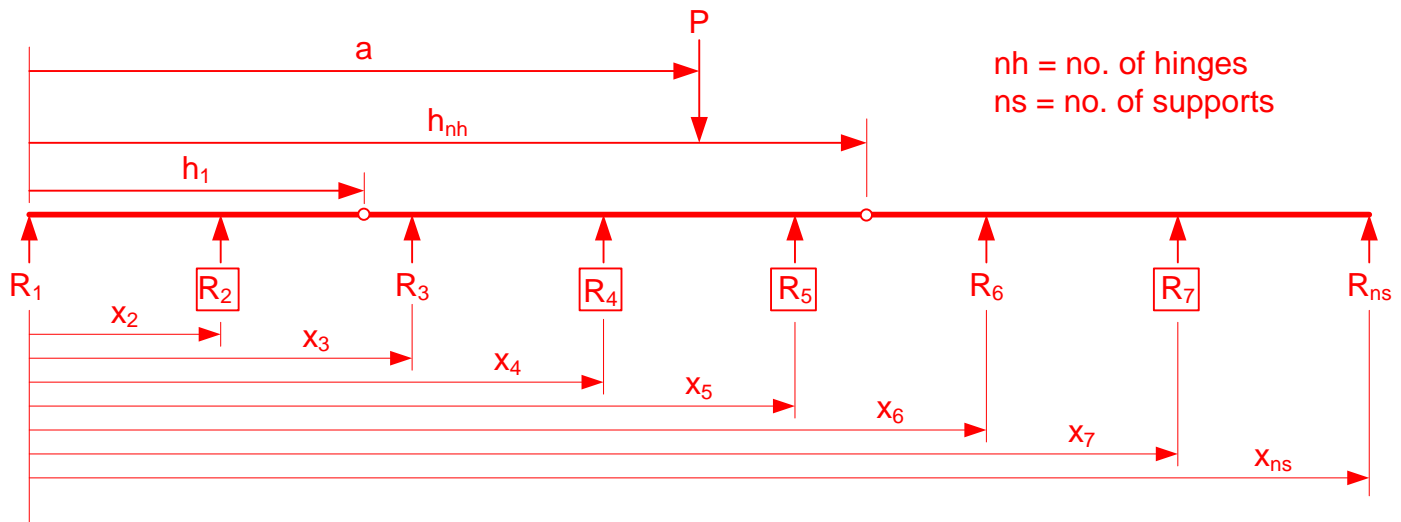


Figure 3.2-1 Indeterminate Structure

Chapter 3 Method of Solution

The above figure shows a generalized continuous beam with a typical load P , having n_h in-span hinges and n_s supports. The supports may be elastic and may have settlements. For this structure, two reactions can be determined by the principle of statics, and n_h reactions can be determined by the fact that moments at hinge points are zero. Thus, the number of redundant reactions is equal to $(n_s - 2 - n_h)$.

For the above structure, $R_2, R_4, R_5,$ and R_7 are boxed in the figure and chosen as redundant reactions. Reactions R_3 and R_6 are not chosen as redundant because of presence of hinges to their left. When these supports are removed, the reduced structure should become a determinate structure.

The following equations can be applied to provide a solution for the unknown reactions.

The first two equations are based on the principle of statics that states that the sum of reactions is equal to the applied load and the sum of moments due to reactions and the applied load about any point (left support) is equal to zero.

The next n_h equations are based on the fact that a hinge cannot resist a moment and thus the moment due to reactions and the applied load about a hinge is zero.

The last $(n_s - 2 - n_h)$ equations are based on the compatibility of deflections at the supports corresponding to redundant reactions. The compatibility equation is derived from the fact that the deflection of the reduced structure at a support corresponding to a redundant reaction is equal to upward deflection due to a unit load applied corresponding to each redundant reaction. The term δ_{ij} in these equations represent the deflection of the reduced structure at support i due to a unit load at support j . The term Δ_{iq} on the right-hand side of the equations represents the deflection due to load P at the point on the reduced structure corresponding to the redundant reaction of support i . The term Δ_{is} on the right-hand side of the equations represents the settlement of support i . The term rk_i represent the reciprocal of the spring constant for support i . If a support is rigid (non-elastic), its rk value is zero.

$$\begin{aligned}
 R_1 + R_2 + R_3 + \dots + R_{n_s} &= P \\
 R_1 X_1 + R_2 X_2 + R_3 X_3 + \dots + R_{n_s} X_{n_s} &= Pa \\
 R_1(h_1 - X_1) + R_2(h_1 - X_2) + R_3(h_1 - X_3) + \dots + R_{n_s}(h_1 - X_{n_s}) &= P(h_1 - a) \\
 R_1(h_2 - X_1) + R_2(h_2 - X_2) + R_3(h_2 - X_3) + \dots + R_{n_s}(h_2 - X_{n_s}) &= P(h_2 - a) \\
 \dots & \\
 \dots & \\
 R_1(h_{n_h - X_1}) + R_2(h_{n_h - X_2}) + R_3(h_{n_h - X_3}) + \dots + R_{n_s}(h_{n_h - X_{n_s}}) &= P(h_{n_h} - a) \\
 \delta_{21}R_1 + \delta_{22}R_2 + \delta_{23}R_3 + \dots + \delta_{2n_s}R_{n_s} &= \Delta_{2q} + \Delta_{2s} - rk_2 R_2 \\
 \delta_{41}R_1 + \delta_{42}R_2 + \delta_{43}R_3 + \dots + \delta_{4n_s}R_{n_s} &= \Delta_{4q} + \Delta_{4s} - rk_4 R_4 \\
 \delta_{51}R_1 + \delta_{52}R_2 + \delta_{53}R_3 + \dots + \delta_{5n_s}R_{n_s} &= \Delta_{5q} + \Delta_{5s} - rk_5 R_5 \\
 \delta_{71}R_1 + \delta_{72}R_2 + \delta_{73}R_3 + \dots + \delta_{7n_s}R_{n_s} &= \Delta_{7q} + \Delta_{7s} - rk_7 R_7
 \end{aligned}$$

Chapter 3 Method of Solution

Please note that the δ_{ij} terms corresponding to the R_i terms in the above equations are zero for the reactions that are not chosen as redundant.

The above equations can be represented in the following matrix form.

$$[CC][R] = [L]$$

Where, CC is the coefficient matrix, R is the matrix representing the unknown reactions, and L is the load matrix representing the right-hand side of above simultaneous equations.

The coefficient matrix CC is a square matrix of the size n_s by n_s shown below.

1	1	1	1	1	1	---	1
x_1	x_2	x_3	x_4	x_5	x_6	---	x_{n_s}
$h_1 - x_1$	$h_1 - x_2$	$h_1 - x_3$	$h_1 - x_4$	$h_1 - x_5$	$h_1 - x_6$	---	$h_1 - x_{n_s}$
$h_2 - x_1$	$h_2 - x_2$	$h_2 - x_3$	$h_2 - x_4$	$h_2 - x_5$	$h_2 - x_6$	---	$h_2 - x_{n_s}$
---	---	---	---	---	---	---	---
---	---	---	---	---	---	---	---
$h_{nh} - x_1$	$h_{nh} - x_2$	$h_{nh} - x_3$	$h_{nh} - x_4$	$h_{nh} - x_5$	$h_{nh} - x_6$	---	$h_{nh} - x_{n_s}$
δ_{21}	$\delta_{22} + rk_2$	δ_{23}	δ_{24}	δ_{25}	δ_{26}	---	δ_{2n_s}
δ_{41}	δ_{42}	δ_{43}	$\delta_{44} + rk_4$	δ_{45}	δ_{46}	---	δ_{4n_s}
δ_{51}	δ_{52}	δ_{53}	δ_{54}	$\delta_{55} + rk_5$	δ_{56}	---	δ_{5n_s}
δ_{71}	δ_{72}	δ_{73}	δ_{74}	δ_{75}	δ_{76}	---	δ_{7n_s}

The term $(\delta_{77} + rk_7)$, not shown in the last row above, should be accounted for.

The reaction matrix R is a column matrix of the size n_s by 1 as shown below.

R_1
R_2
R_3
R_4
R_5

R_{n_s}

The load matrix L is a column matrix of the size n_s by 1 as shown below.

Chapter 3 Method of Solution

$$\begin{bmatrix} P \\ Pa \\ P(h_1-a) \\ P(h_2-a) \\ \dots \\ \dots \\ P(h_{nh}-a) \\ \Delta_{2q} - \Delta_{2s} \\ \Delta_{4q} - \Delta_{4s} \\ \Delta_{5q} - \Delta_{5s} \\ \Delta_{7q} - \Delta_{7s} \end{bmatrix}$$

The deflection terms δ_{ij} for the coefficient matrix [CC] are calculated during the solution for the reduced structure. See Section 3.2.4.

The reactions are obtained by solving the following matrix equation.

$$[R] = [CC]^{-1}[L]$$

Where, $[CC]^{-1}$ is the inverse of the coefficient matrix [CC].

3.2.4 Solution of Reactions for the Statically Determinate Structure

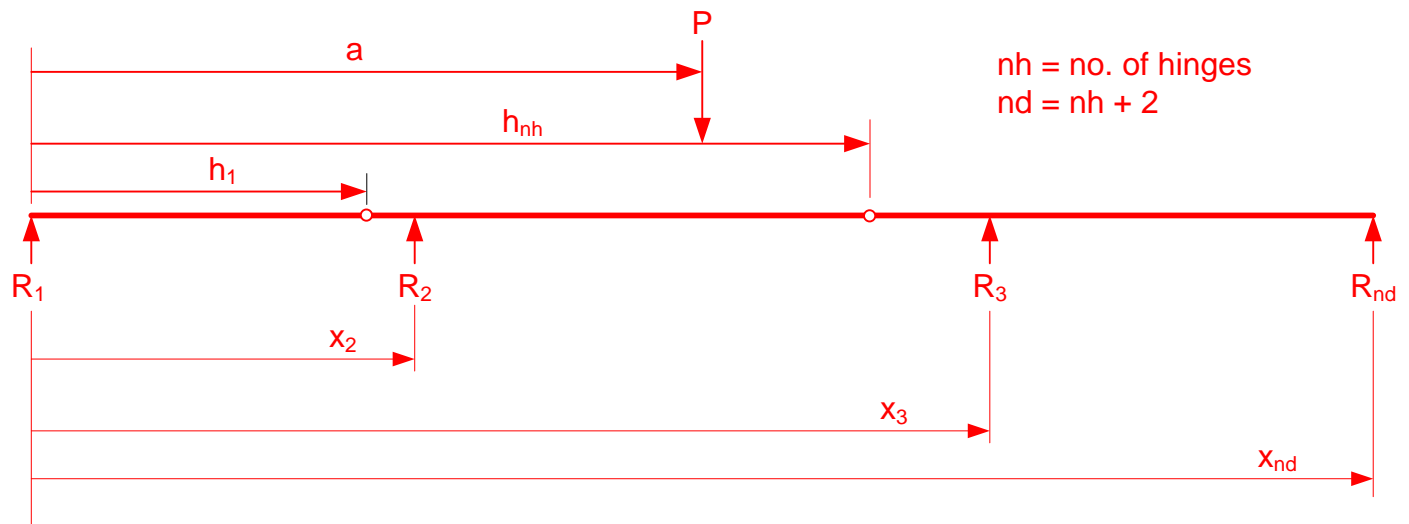


Figure 3.2-2 Statically Determinate Structure

Figure 3.2-2 shows a statically determinate original structure or the reduced structure obtained from an indeterminate structure after removing the supports corresponding to redundant reactions. The number of supports,

Chapter 3 Method of Solution

nd, for a statically determinate structure must be equal to $(nh + 2)$.

The following equations can be applied to provide a solution for the unknown reactions. The first two equations are based on the principle of statics that states that the sum of reactions is equal to the applied load and the sum of moments due to reactions and the applied load about any point (left support) is equal to zero. The next nh equations are based on the fact that a hinge cannot resist a moment and thus the moment due to reactions and the applied load about a hinge is zero.

$$\begin{aligned}
 R_1 + R_2 + R_3 + \dots + R_{nd} &= P \\
 R_1x_1 + R_2x_2 + R_3x_3 + \dots + R_{nd}x_{nd} &= Pa \\
 R_1(h_1-x_1) + R_2(h_1-x_2) + R_3(h_1-x_3) + \dots + R_{nd}(h_1-x_{nd}) &= P(h_1-a) \\
 R_1(h_2-x_1) + R_2(h_2-x_2) + R_3(h_2-x_3) + \dots + R_{nd}(h_2-x_{nd}) &= P(h_2-a) \\
 \dots & \\
 \dots & \\
 R_1(h_{nh}-x_1) + R_2(h_{nh}-x_2) + R_3(h_{nh}-x_3) + \dots + R_{nd}(h_{nh}-x_{nd}) &= P(h_{nh}-a)
 \end{aligned}$$

For the above equations, the terms (h_i-x_j) and (h_i-a) are taken as zero if they are less than zero.

The above equations can be represented in the following matrix form.

$$[CC][R] = [L]$$

Where, CC is the coefficient matrix, R is the matrix representing the unknown reactions, and L is the load matrix representing the right-hand side of above simultaneous equations.

The coefficient matrix CC is a square matrix of the size nd by nd shown below.

$$\begin{bmatrix}
 1 & 1 & 1 & 1 & \dots & 1 \\
 x_1 & x_2 & x_3 & x_4 & \dots & x_{nd} \\
 h_1 - x_1 & h_1 - x_2 & h_1 - x_3 & h_1 - x_4 & \dots & h_1 - x_{nd} \\
 h_2 - x_1 & h_2 - x_2 & h_2 - x_3 & h_2 - x_4 & \dots & h_2 - x_{nd} \\
 \dots & \dots & \dots & \dots & \dots & \dots \\
 \dots & \dots & \dots & \dots & \dots & \dots \\
 h_{nh} - x_1 & h_{nh} - x_2 & h_{nh} - x_3 & h_{nh} - x_4 & \dots & h_{nh} - x_{nd}
 \end{bmatrix}$$

The reaction matrix R is a column matrix of the size ns by 1 as shown below.

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$$\begin{bmatrix} R_1 \\ R_2 \\ R_3 \\ R_4 \\ \dots \\ \dots \\ R_{nd} \end{bmatrix}$$

The load matrix L is a column matrix of the size nd by 1 as shown below.

$$\begin{bmatrix} P \\ Pa \\ P(h_1-a) \\ P(h_2-a) \\ \dots \\ \dots \\ P(h_{nh}-a) \end{bmatrix}$$

The reactions are obtained by solving the following matrix equation.

$$[R] = [CC]^{-1}[L]$$

Where, $[CC]^{-1}$ is the inverse of the coefficient matrix $[CC]$.

Chapter 3 Method of Solution

3.2.5 Deflections in the Reduced Structure

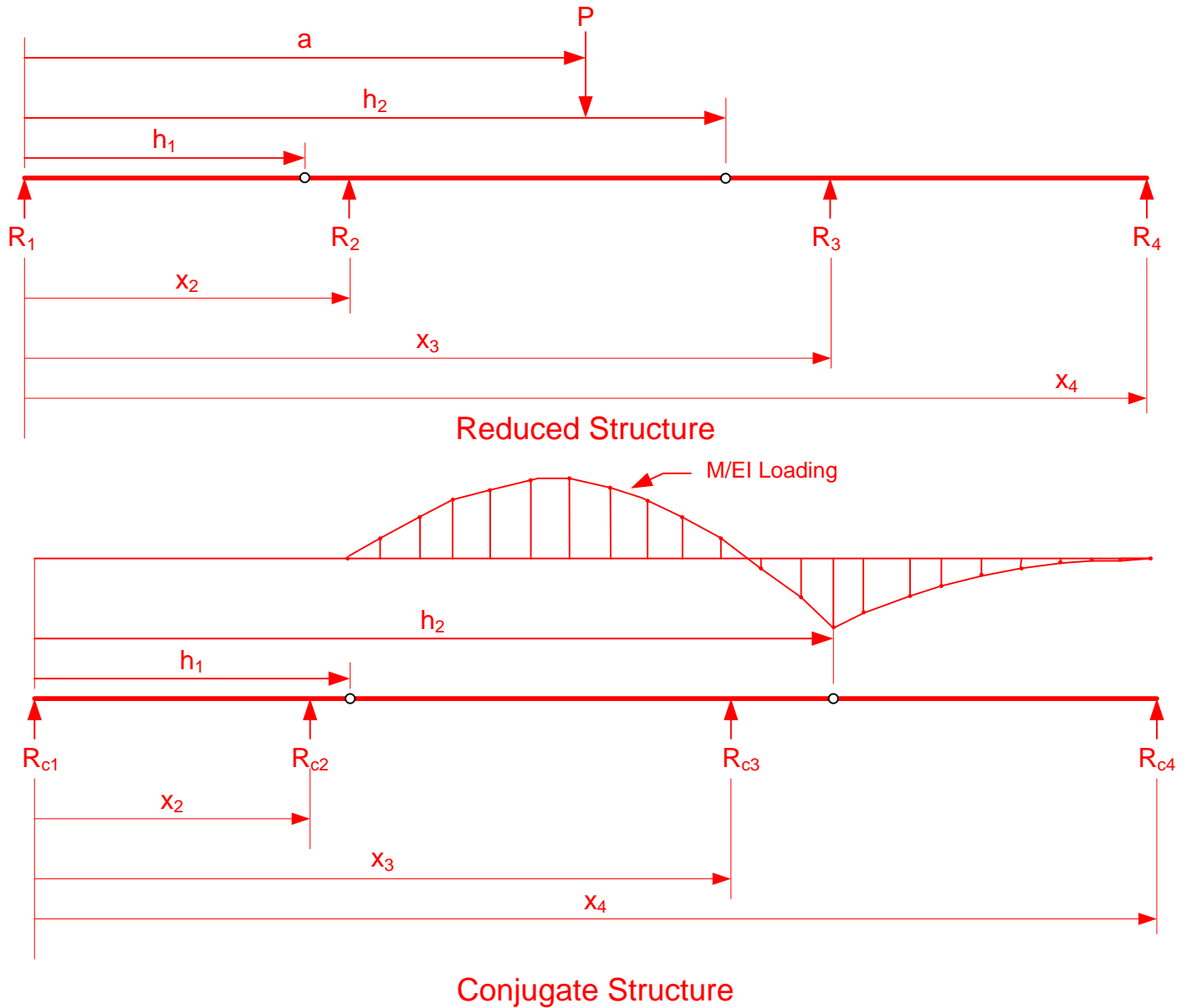


Figure 3.2-3 Conjugate Beam Analysis

One of the important tasks required in the solution of an indeterminate structure is to calculate deflections in the reduced structure corresponding to locations of redundant reactions in the original structure as outlined in step 11 of Section 3.2.1. The reactions in the reduced structure are obtained by the method described in Section 3.2.4 Solution of Reactions for the Statically Determinate Structure. Using these reactions and the applied loading, the moments in the reduced structure at all analysis points are calculated by statics. To calculate the deflections in the reduced structure, a conjugate structure for the reduced structure is configured. If the reduced structure has in-span hinges, a corresponding conjugate structure is configured by replacing the hinge with a support and introducing a hinge where the support was in the reduced structure as shown in Figure 3.2-3. The moment M calculated for the

Chapter 3 Method of Solution

reduced structure at each analysis point is divided by the quantity EI of the section at the analysis point. These provide the ordinates of the M/EI loading to be applied to the conjugate beam. The conjugate beam is analyzed for the M/EI loading using matrix solution described in Section 3.2.4. This solution provides reactions R_{c1} , R_{c2} , etc. for the M/EI loading on the conjugate structure. The moments and shears due to M/EI loading in the conjugate beam at all analysis points are then calculated by statics. The moment at an analysis point due to the M/EI loading on the conjugate beam represents the deflection in the reduced beam due to a P loading on the reduced structure. The shear at an analysis point due to at an analysis point due to the M/EI loading on the conjugate beam represents the rotation in the reduced structure due to a P loading.

Applying a unit load at each analysis point one at a time and storing the deflections obtained as described above provides the necessary elements, δ_{ij} , of the coefficient matrix and the elements, Δ_{iq} , of the load matrix required for the solution of reactions ($R_1, R_2 \dots R_n$) of the original indeterminate structure.

3.2.6 Deflections Due to Elastic Supports

The deflections calculated above need to be corrected for elastic supports if they exist in the reduced structure. The deflections of the reduced structure with elastic supports are calculated assuming a linear variation as shown in Figure 3.2-4 and Figure 3.2-5. In these figures, R_1, R_2 , etc. are the reactions in the reduced structure due to a P loading and the deflection at a support is equal to the reaction times the reciprocal of spring constant at that support. The deflections due to elastic supports in the reduced structure are added to the deflections calculated by the conjugate beam method described above to get the total deflections in the reduced structure. These adjustments are made to the δ_{ij} and the Δ_{iq} terms of the coefficient and load matrices respectively before the matrix solution is performed for the original structure.

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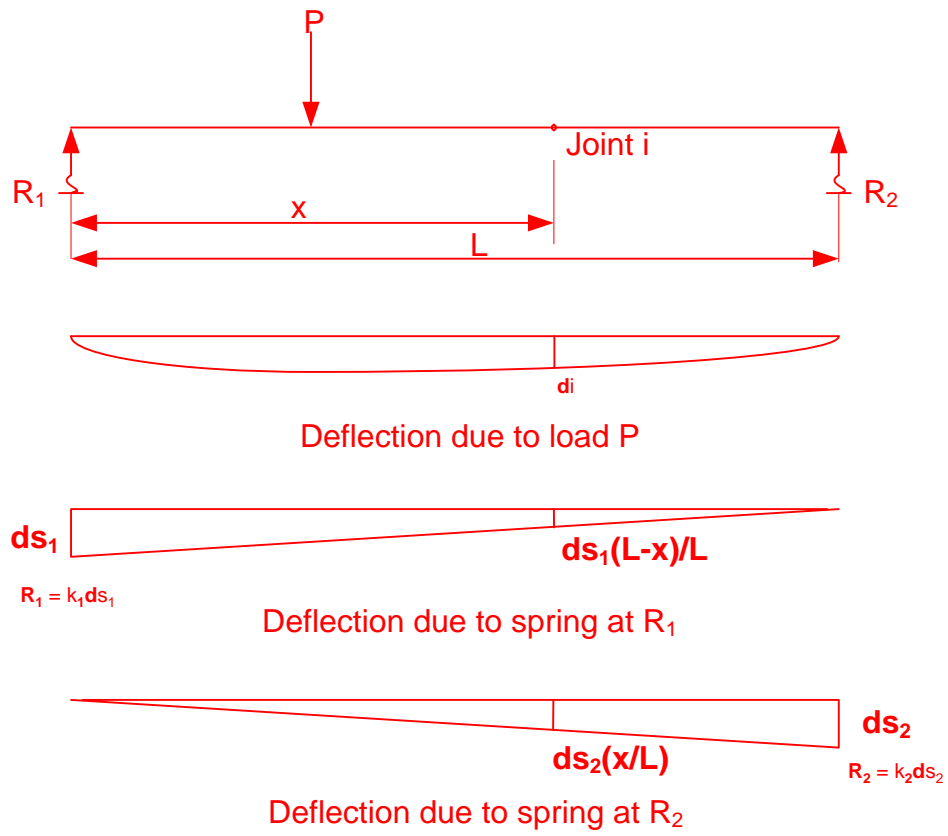


Figure 3.2-4 Deflection of Reduced Structure (Elastic Supports)

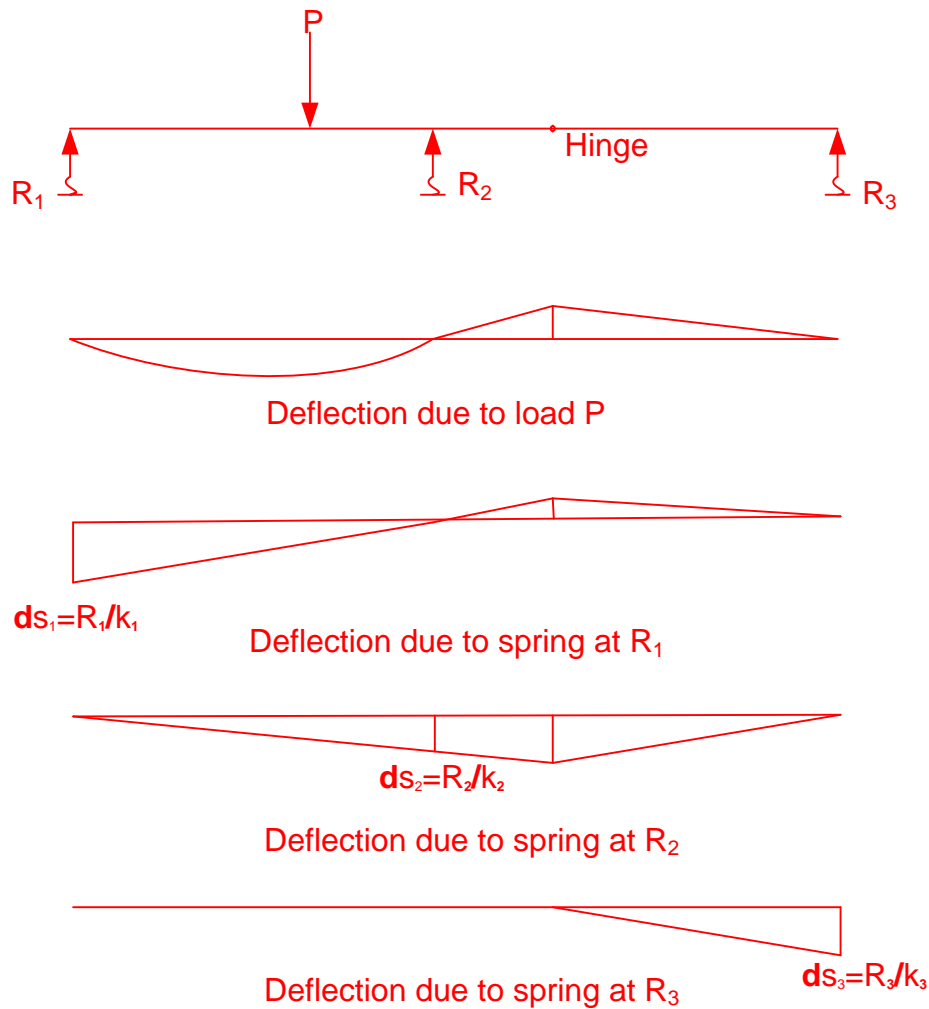


Figure 3.2-5 Deflection of Reduced Structure with Hinges (Elastic Supports)

3.2.7 Rotations Due to Elastic Supports

The rotations calculated as explained in Section 3.2.4 need to be corrected for elastic supports if they exist in the reduced structure. The rotations of the reduced structure with elastic supports are calculated assuming a linear variation as shown in Figure 3.2-4 and Figure 3.2-5. In these figures, R_1 , R_2 , etc. are the reactions in the reduced structure due to a P loading and the deflection at a support is equal to the reaction times the reciprocal of spring constant at that support. Using these deflections and mechanism of the reduced structure the rotations at the supports corresponding to the original structure are calculated using simple geometry shown in Figure 3.2-4 and Figure 3.2-5. The rotations due to elastic supports in the reduced structure are added to the rotations calculated by the conjugate beam method described above to get the total rotations in the original structure.

Chapter 3 Method of Solution

3.3 DEAD LOADS

The dead loads effect at a given analysis point is then calculated by placing the loads on the appropriate influence line and then adding the effect of each load as follows. If the dead load is a series of concentrated loads, the effect is the algebraic sum of the product of the load value and the influence line ordinate value under each concentrated load. If the dead load is a uniform load, the effect is the product of the area of the influence line under the load and the intensity of the uniform load. If the dead load is trapezoidal, the effect is the summation of A_i times P_i over the length of the trapezoid, where A_i is the area of influence line between two consecutive load intensities, P_i is the average of two consecutive load intensities, and i is the segment number of the trapezoidal load. The trapezoidal load is divided into the segments that correspond to the influence line ordinates.

3.4 SUPPORT SETTLEMENTS

The effects of support settlements are calculated in the same manner as explained in the Modified Flexibility Method using the following conditions for setting up the simultaneous equations for the solution of unknown reactions. The first condition is that the sum of reactions must be equal to zero since there are no applied external loads. The second condition is that the sum of moments due to reactions must equal zero at the right most support. If there are in-span hinges, then the next NH (number of hinges) conditions are that the sum of moments due to unknown reactions at a given hinge point is equal to zero. The remaining conditions (if the beam is statically indeterminate) are that the deflection at each support is equal to the amount of support settlement entered. The equations are formulated per the above conditions and then are solved by matrix algebra to determine the unknown reactions at supports. The moments, shears, deflections and rotations at analysis points are then computed in the same manner as the unit load condition.

3.5 ELASTIC SUPPORTS

The effects of elastic supports are calculated in the same manner as explained in the Modified Flexibility Method except that some of the terms of the coefficient matrix and the deflections of the reduced structure are to be accounted for presence of elastic supports. The user specifies elastic supports by entering spring constants k (force required to compress a spring for a unit length). The equations described in Section 3.2.2 that are affected by spring constants are the compatibility equations for deflections at the supports with redundant reactions. This compatibility condition is that the deflection at an elastic support with a redundant reaction is equal to the redundant reaction time the reciprocal of spring constant k for that support. The equations to solve for reactions for an indeterminate structure shown in Section 3.2.3 contain these terms. If the support for which the compatibility is formed does not have an elastic support the term described is zero. The other effect of elastic support is in the calculation of deflection in the reduced structure if any of the supports in the reduced structure is elastic. The correction for deflections is described in Section 3.2.5. The equations are formulated according to the above conditions and then are solved by matrix algebra to determine the unknown reactions at supports. The moments, shears, deflections and rotations at analysis points are then computed in the same manner as the unit load condition.

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3.6 CREEP AND SHRINKAGE OR TEMPERATURE GRADIENT EFFECTS

The effects of creep and shrinkage or temperature gradient on a continuous beam are calculated by entering the fixed-end actions due to these conditions. The user can calculate the moments and reactions generated at each end of the span due to creep and shrinkage or temperature gradient assuming one or both ends the span being fixed. The program converts these fixed-end actions into equivalent joint loads acting at each support. At a given support the equivalent joint moment is the moment required to balance the algebraic sum of the entered fixed-end moments at that support.

The effects of equivalent joint loads are then calculated in the same manner as explained in the Modified Flexibility Method except that the equivalent joint moments are treated as concentrated couples acting on the beam. The following conditions are used to set up the simultaneous equations for the solution of unknown reactions. The first condition is that the sum of reactions must be equal to the sum of equivalent vertical joint loads. The second condition is that the sum of moments due to reactions at the right most support must be equal to the sum of moments due to equivalent joint loads applied to the beam. If there are in-span hinges, then the next NH (number of hinges) conditions are that the sum of moments due to unknown reactions at a given hinge point is equal to the sum of moments due to equivalent joint loads to the left of the hinge. The remaining conditions (if the beam is statically indeterminate) are that the deflection at each support is equal to zero. The equations are formulated per the above conditions and then are solved by matrix algebra to determine the unknown reactions at supports. The moments, shears, deflections and rotations at analysis points are then computed in the same manner as the unit load condition except that the fixed end actions are added to get the final actions.

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3.7 HL93 LOADING AND PHL93 LOADING

For the purpose of this program, the vehicular live load consisting of the Design Truck, Design Tandem and Design Lane Load as defined in the LRFD Bridge Design Specifications is referred to as the HL93 loading. For the design of bridges PENNDOT has modified the HL93 loading and it is referred to as the PHL93 loading. Refer to Figure 3.8-1 on page 3-17 for live loads that are stored in the program. The PHL93 loading is the same as the HL93 loading except that the axle loads on the Design Tandem for the PHL93 loading are multiplied by a factor 1.25. Refer to Table 3.8-1 on page 3-19 for load combinations that are used to calculate various effects due to HL93 and PHL93 loadings.

3.8 TRUCK LOAD EFFECT

The effect of a truck load is calculated by placing the axle loads at various locations on the influence line to find the maximum combined positive or negative live load effect.

For this, the influence lines are generated for various effects at analysis points by placing the unit load at each analysis point and its results stored. The influence line is then divided into either positive regions of all positive ordinates or negative regions of all negative ordinates. For each region, the area and the locations of the maximum (peak) ordinate, of the middle of the region, and of the centroid of the region are computed and found. If the influence line has more than two regions, the locations of the two largest positive and the two largest negative (if they exist) peaks are stored.

For these two regions of the influence line having the largest areas, both positive and negative, the following load positions are tried.

1. The effect of moving the live load from the left to the right is achieved by moving the axles (truck front axle at right side and its associated axles at left side) from the left to the right. If the DIRECT = L, for each peak of the influence line, the following is done. First, the first axle is placed over the peak and the other axles are placed to the left in their respective positions. The ordinates under other axles are computed by interpolation assuming a straight-line variation of the influence line between two consecutive ordinates. Each axle load is then multiplied by the ordinate under it. For INCLUDE = N, all positive values are added and stored as a positive effect. Likewise, all negative values are added and stored as a negative effect. For INCLUDE = Y, all values are added and either stored as a positive effect if it is positive or stored as a negative effect if it is negative. The absolute maximum positive effect and the absolute maximum negative effect are stored. Next, the second axle is placed over the peak and the above procedure is repeated. The positive and negative effects are found again, and the maximum effects are stored after comparing with previous maximum effects. These steps are repeated until the last axle is placed over the peak.
2. Place the center of gravity of axle loads over the peak ordinate of the region and the maximum effects are found and saved if it is greater than the previously stored effect.
3. Place the center of gravity of axle loads over the middle of the region and the maximum effects are found

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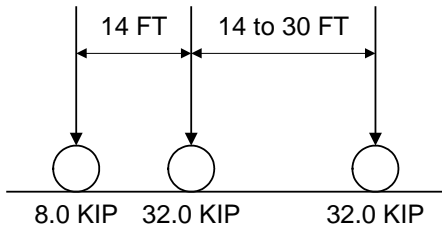
and saved if it is greater than the previously stored effect.

4. Place the center of gravity of axle loads over the centroid of the region and the maximum effects are found and saved if it is greater than the previously stored effect.
5. Place the center of gravity of axle loads over the middle of the combined regions (two positive regions or two negative regions) and the maximum effects are found and saved if it is greater than the previously stored effect.
6. If the region has two peaks, Steps 1 to 2 are repeated for the second peak.
7. The effect of moving the live load from the right to the left is achieved by moving the axles (truck front axle at left side and its associated axles at right side) from the left to the right. If the other direction is needed (DIRECT = Blank or R), the axle loads and spacing are then reversed (to consider the effect of the live load moving across the bridge in the other direction) and the procedure described above (Steps 1 to 6) is repeated. When this process is completed, the absolute maximum positive and the absolute maximum negative live effects are obtained.
8. For loads with variable axle spacings such as H20, HS20 and PA2016-13, the space between axles is increased one increment and Steps 1 to 7 are repeated.

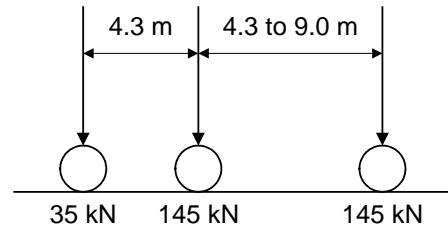
When the positive and negative effects are found, they are then multiplied by the distribution factor and impact factor to get the actual live load plus impact effects.

In calculating the effect of a Design Truck, Design Tandem, Fatigue Load, Design Truck Pair, or Design Tandem Pair for LRFD loading, the axle loads which do not contribute to the effect being sought are neglected, i.e. for a positive effect, the axles that fall on the negative region of the influence line are neglected, and for a negative effect, the axles that fall on the positive region of the influence line are neglected.

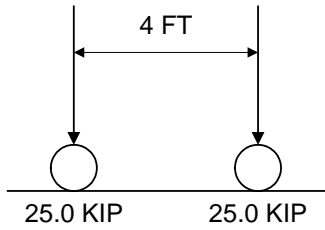
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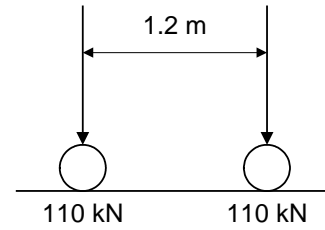
HL93 and PHL93 Design Truck (US)



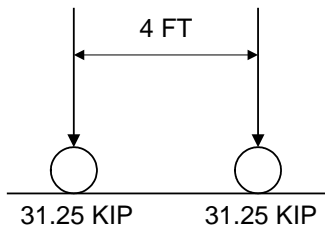
HL93 and PHL93 Design Truck (SI)



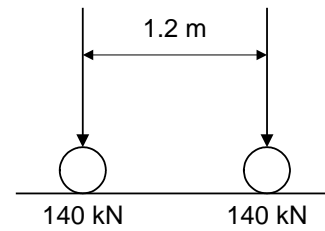
HL93 Design Tandem (US)



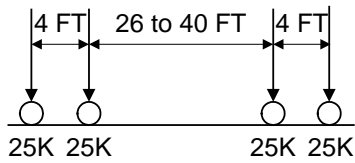
HL93 Design Tandem (SI)



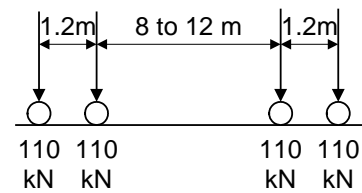
PHL93 Design Tandem (US)



PHL93 Design Tandem (SI)



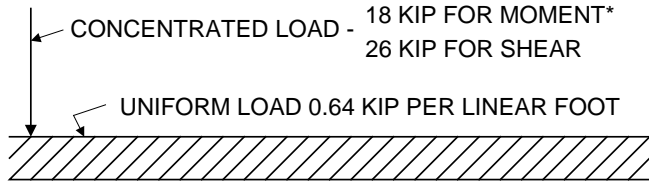
HL93 and PHL93
Design Tandem Pair (US)



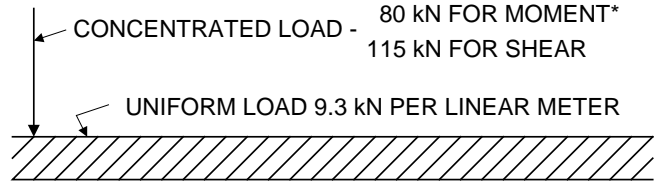
HL93 and PHL93
Design Tandem Pair (SI)

Figure 3.8-1 LRFD Live Loads

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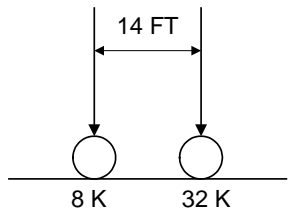


H20 or HS20 Lane Loading (US)

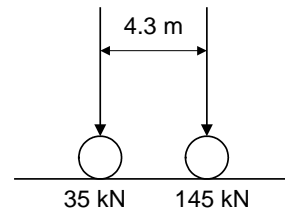


H20 or HS20 Lane Loading (SI)

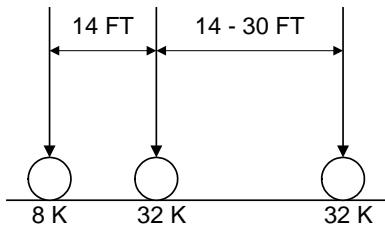
* use two concentrated loads for negative moment



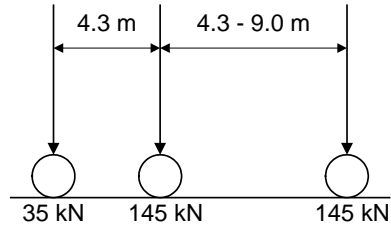
H20 TRUCK (US)



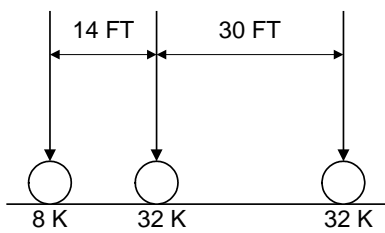
H20 TRUCK (SI)



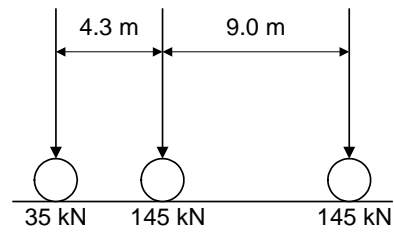
HS20 TRUCK (US)



HS20 TRUCK (SI)



FATIGUE TRUCK (US)



FATIGUE TRUCK (SI)

Figure 3.8-2 LRFD Live Loads (Cont.)

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Table 3.8-1 Live Load Effects due to HL93 and PHL93 Loadings

Effect	Loading	Tandem + Lane	Truck + Lane	Tandem Pair + Lane	Truck Pair + Lane	Truck Alone	25% Truck + Lane
Mom +	HL93	X	X			X	
	PHL93	X ¹	X			X	
Mom -	HL93			X	0.90X	X	
	PHL93			X ¹	X	X	
End React +	HL93	X	X			X	
	PHL93	X ¹	X			X	
End React -	HL93	X	X			X	
	PHL93	X ¹	X			X	
Pier React +	HL93			X	0.90X	X	
	PHL93			X ¹	0.90X	X	
Pier React -	HL93	X	X			X	
	PHL93	X ¹	X			X	
Deflection and Rotation	HL93					X	X
	PHL93					X	1.25X

¹ The axle loads for Design Tandem and Design Tandem Pair for PHL93 loading are different as shown in Figure 3.8-1 on page 3-17.

3.9 VARIABLE AXLE SPACING OF DESIGN TRUCK

The LRFD Specifications require that in calculating the effect of the design truck the spacing between the two 32 kip (145 kN) axles (rear axles) may vary from 14 to 30 feet (4.3 to 9.0 m). For this the program starts with a design truck with 14 feet (4.3 m) between the rear axles, and analyzes the influence line as explained under Truck Load Effect. The effect of the design truck so defined is stored. Next, a new design truck is defined by adding 0.5 feet (0.1 m) to the spacing between the rear axles. The effect of this new design truck is calculated again. The effect of the new design truck is compared with the previously stored effect, and the greater effect is stored. The above procedure is repeated until the spacing between the rear axles becomes 30 feet (9.0 m). The spacing between the

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rear axles is not varied if the lengths of the influence line regions adjacent to the region where the design truck is placed are greater than 30 feet (9.0 m).

3.10 VARIABLE SPACING OF TRUCK OR TANDEM PAIR

The LRFD Specifications require that in calculating the negative moment at any section between the point of dead load contraflexure and the interior support, and in calculating the reaction at the interior support, the spacing between the two trucks of the design truck pair may vary from 50 feet (15 m) to any distance that will produce the maximum effect. For this, the program replaces the truck pair with a single truck of six axles. The first three and the last three axles of this single truck are the same as the axles of the design truck. Initially the distance between the third axle and the fourth axle is set equal to 50 feet (15 m). The influence line is analyzed for so defined single truck as explained under Truck Load Effect. The effect of this load is stored. Next, the single truck is modified by increasing the distance between the third axle and the fourth axle by 0.5 feet (0.1 m), and its effect is calculated. The above procedure is repeated until the distance between the third axle and the fourth axle of the single truck becomes larger than the distance between two consecutive peak ordinates having the same sign. The spacing between the third axle and the fourth axle is not varied if the distance between two consecutive peak ordinates having the same sign is less than 50 feet (15 m) or if the effect being sought is a reaction at the interior support. The design tandem pair is analyzed in the same manner as the design truck pair. The single truck defined to represent a design tandem pair has four axles and the distance between the second and the third axle is varied from 26 to 40 feet (8.0 to 12.0 m).

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3.11 LANE LOAD EFFECT

The effect of a lane load is calculated by loading the appropriate regions of the influence line with the uniform lane load. If the positive lane load effect is being sought, the sum of the positive areas of the influence line is multiplied by the value of the uniform lane load, and the result is stored as the positive lane load effect. The negative lane load effect is calculated similarly using the negative areas of the influence line. In calculating the lane load effect, the load is placed only over the positive or negative areas of the influence line.

3.12 POSITIVE MOMENT, SHEARS, AND END REACTIONS - HL93 OR PHL93 LOADING

In calculating the positive moment, the positive area of the influence line is multiplied by the design lane load and it is stored as the design lane load effect. Next the maximum positive effect of the design truck is calculated by moving the load across the influence line as explained under Truck Load Effect. The design truck effect is multiplied by the impact factor, then added to the design lane load effect and is stored as the combined design truck and lane load effect. Next the same procedure is repeated for the design tandem and the design lane load. The larger of these two effects is stored as the positive moment. The positive and negative shears at a section, the negative reaction at an interior support, and the positive and negative reaction at an exterior support are calculated in the same manner as the positive moment except, in calculating the negative shear and reaction due to the design lane load, the negative area of the influence line is used.

3.13 NEGATIVE MOMENT AND PIER REACTION DUE TO HL93 LOADING

In calculating the negative moment at any section between the point of dead load contraflexure and the interior support, and in calculating the positive reaction at the pier, the influence line is analyzed for the following conditions.

Effect 1: One design tandem plus design lane load

Effect 2: One design truck plus design lane Load

Effect 3: Design tandem pair plus design lane load

Effect 4: Design truck pair plus design lane load

Effects 1 and 2 are calculated in the same manner as Positive Moment due to HL93 Loading. Effects 3 and 4 are calculated as follows. The maximum effect of the design tandem pair is calculated as explained under Variable Spacing of Truck or Tandem Pair. The negative area of the influence line is multiplied by the design lane load and it is stored as the design lane load effect. The design tandem pair effect is multiplied by the impact factor and is added to the design lane load effect to get Effect 3. Similarly Effect 4 is calculated using the design truck pair. The larger of Effect 1, Effect 2, Effect 3, and 90% of Effect 4 is stored as the governing effect.

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3.14 NEGATIVE MOMENT DUE TO PHL93 LOADING

In calculating the negative moment at any section between the point of dead load contraflexure and the interior support, the program identifies the largest of the following effects as the governing effect:

Effect 1: one design tandem plus design lane load,

Effect 2: one design truck plus design lane,

Effect 3: design PHL tandem pair (axle weight of 110kN or 25k) plus design lane load

Effect 4: design truck pair plus design lane load.

3.15 PIER REACTION DUE TO PHL93 LOADING

In calculating the positive live load reaction at a pier, the program identifies the largest of the following effects as the governing effect:

Effect 1: the reaction due to one design tandem plus design lane load,

Effect 2: the reaction due to one design truck plus design lane load,

Effect 3: 100% of the reaction due to PHL design tandem pair (axle weight of 110kN or 25k) plus design lane load

Effect 4: 90% of the reaction due to design truck pair plus design lane load is stored as the governing effect.

The negative live load reaction is calculated as per Section 3.12.

3.16 SIMULTANEOUS EFFECTS

For consideration of a moment-shear interaction, it is required to calculate the simultaneous effects of a given load, i.e. to calculate the live load shear at a section that occurs simultaneously with the maximum moment and the live load moment that occurs simultaneously with the maximum shear. This is obtained by analyzing two influence lines for the section under consideration. If the live load shear that occurs with the maximum live load moment is to be calculated, then the moment influence line is analyzed first. The position of the load that produces the maximum live load moment is saved from the moment influence line analysis. The saved loading with its position is now considered as a dead load condition for the shear influence line. The shear due to this loading condition is calculated in the same manner as explained under Dead Loads. The moment that occurs simultaneously with the maximum live load shear is calculated in a similar manner. For all simultaneous effects, the axle loads (with appropriately applied distribution factors and notional effects) that produce the primary effect are used to calculate the secondary (simultaneous) effect.

3.17 DEFLECTION OR ROTATION DUE TO HL93 LOADING

The live load deflection or rotation due to the HL93 loading is computed by analyzing the influence line for a design truck alone and a combination of 25% of the design truck and the design lane load. The larger of these two effects is stored as the live load plus impact deflection/rotation due to one lane. In calculating the above effect, the impact factor is applied to the design truck effect only. The actual live load plus impact deflection/rotation is then

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determined by multiplying the distribution factor for deflection/rotation and the live load plus impact deflection/rotation due to one lane calculated before.

3.18 DEFLECTION OR ROTATION DUE TO PHL93 LOADING

The live load deflection or rotation due to the PHL93 loading is computed in the same manner as the live load deflection/rotation due to the HL93 loading except that the deflection/rotation due to HL93 loading is multiplied by a factor of 1.25 to obtain the deflection/rotation due to the PHL93 loading **to be consistent with the Department's past use of the HS25 vehicle for computing deflections.** See 3.6.1.3.2 in PennDOT DM-4, Section 3 – Loads and Load Factors.

3.19 FATIGUE LOAD

The effects of a **HS20 Fatigue Truck** are calculated in the same manner as explained under Truck Load Effect. The distance between the rear axles of the Fatigue **Truck** is kept constant at 30 feet (9.0 m).

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3.20 OTHER STANDARD LIVE LOADINGS

Several standard live loadings (LOADING = 6, 7, A, B, D, E, F, G, H, and T) are built into the program. These are designated as H20, HS20, P-82, ML80, PA58, EV2, EV3, SU6TV, PA2016-13, and TK527. See Figure 3.20-1 on page 3-25 to Figure 3.20-3 on page 3-27.

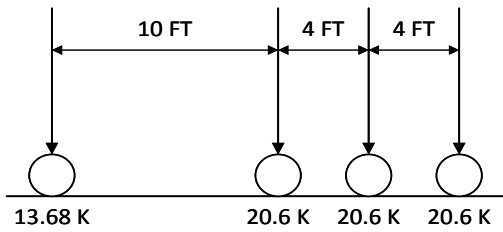
Pennsylvania Permit Load (P-82) is a design load that is used to correlate bridge design practice with the need to accommodate very heavy vehicles operating under a heavy hauling permit. When required, bridges are to be rated for the P-82 at the operating level only. This rating serves as an indication of the bridge's relative ability to carry heavy hauling permit vehicles. P-82 is a 102-ton struck with 8 Axle. The width of P-82 is the same as the Design Truck, HS20, and its transverse wheel location is the same as Design Truck. For LRFD, axles of P-82 which do not contribute to the extreme force effect under consideration shall be neglected.

An ML80 (GVW=36.64 tons) is the maximum legal load in Pennsylvania. The TK527 (GVW = 40 tons) is a new posting vehicle effective January 1, 2002. The width is the same as the Design Truck, HS20, and its transverse wheel location is the same as Design Truck (gage distance = 6 feet and passing distance = 4 feet). The axle weight of ML80 and TK527 include 3% additional axle weight for the tolerance allowed by the Vehicle Code for the portable scales used in truck weight enforcement efforts. The 3% scale tolerance used to compute the live load effect is included only in computing RF (Rating Factor). Both the ML80 and TK527 are not considered a notional load. Therefore, all the axles shall be considered when determining force effects. The rating tonnage was determined by $RF \cdot GVW$ in tons.

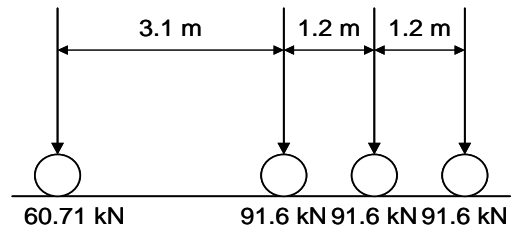
The PA58 is for risk-based posting. EV2, EV3, and SU6TV are described in FHWA FAST Act effective December 4, 2015.

PA2016-13 permit load was developed by the Penn State University in May 2016. It has 13 axles with two varying spacings followed by the axle 7 and axle 10. The first varying spacing between axle 7 and axle 8 ranges from 30' to 50'. The second varying spacing between axle 10 and axle 11 ranges from 5' to 14'. See Figure 3.20-3 on page 3-27.

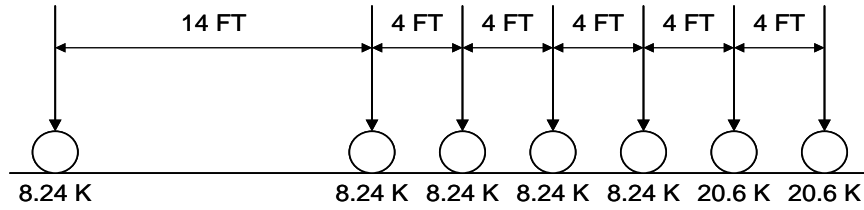
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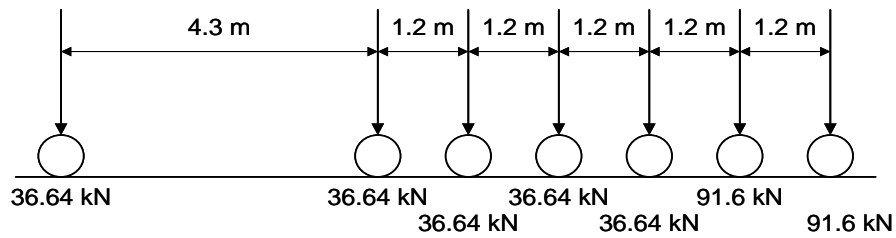
ML80 (US) (include 3% additional axle weight for scale tolerance)



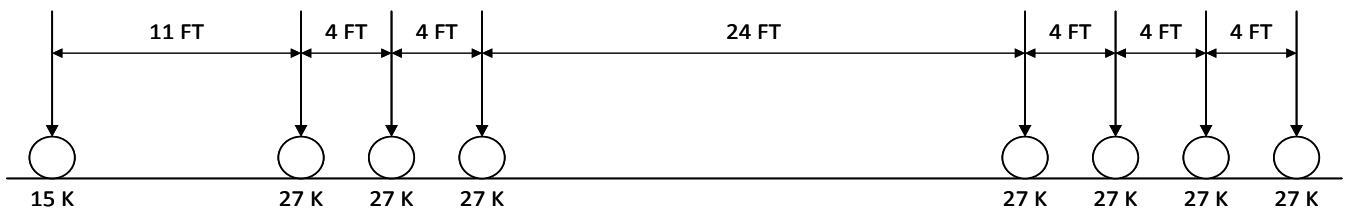
ML80 (SI) (include 3% additional axle weight for scale tolerance)



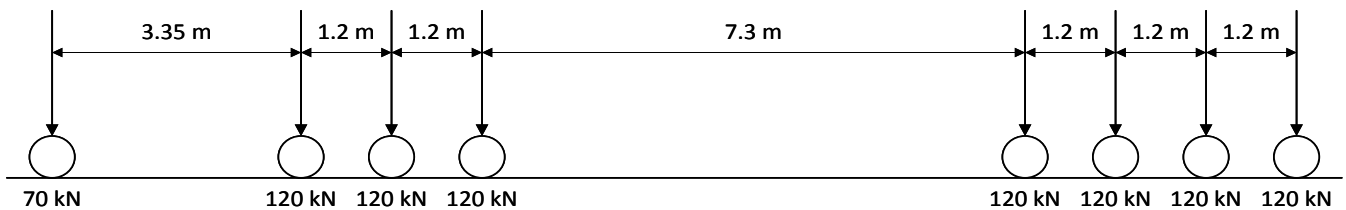
TK527 (US) (include 3% additional axle weight for scale tolerance)



TK527 (SI) (include 3% additional axle weight for scale tolerance)



P-82 (US) Design Permit Load



P-82 (SI) Design Permit Load

Figure 3.20-1 Other Standard Live Loads

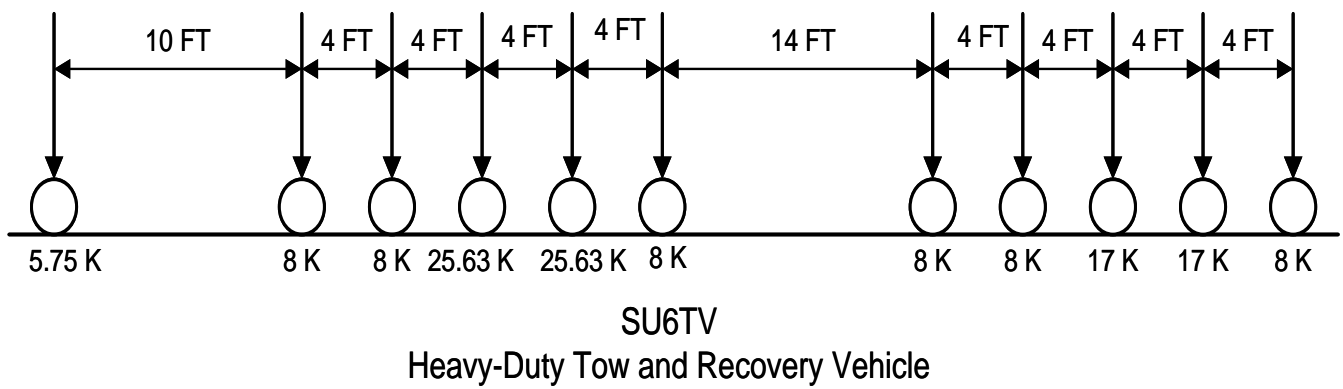
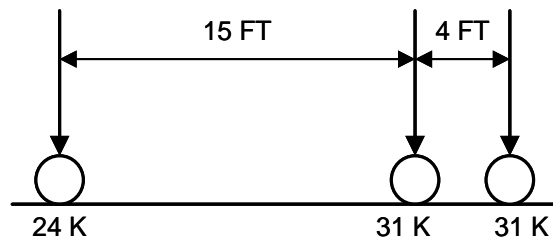
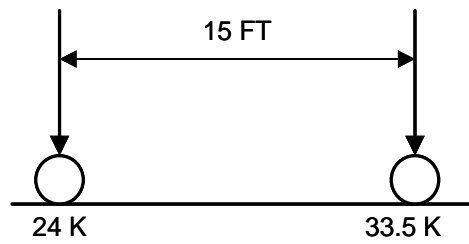
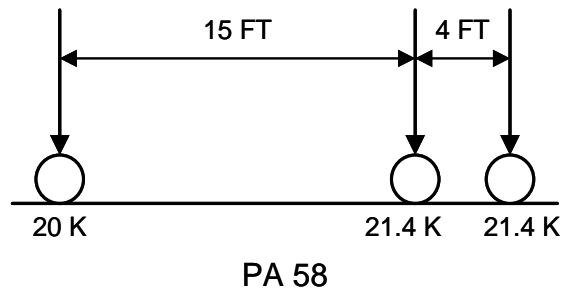


Figure 3.20-2 Other Standard Live Loads (Cont.)

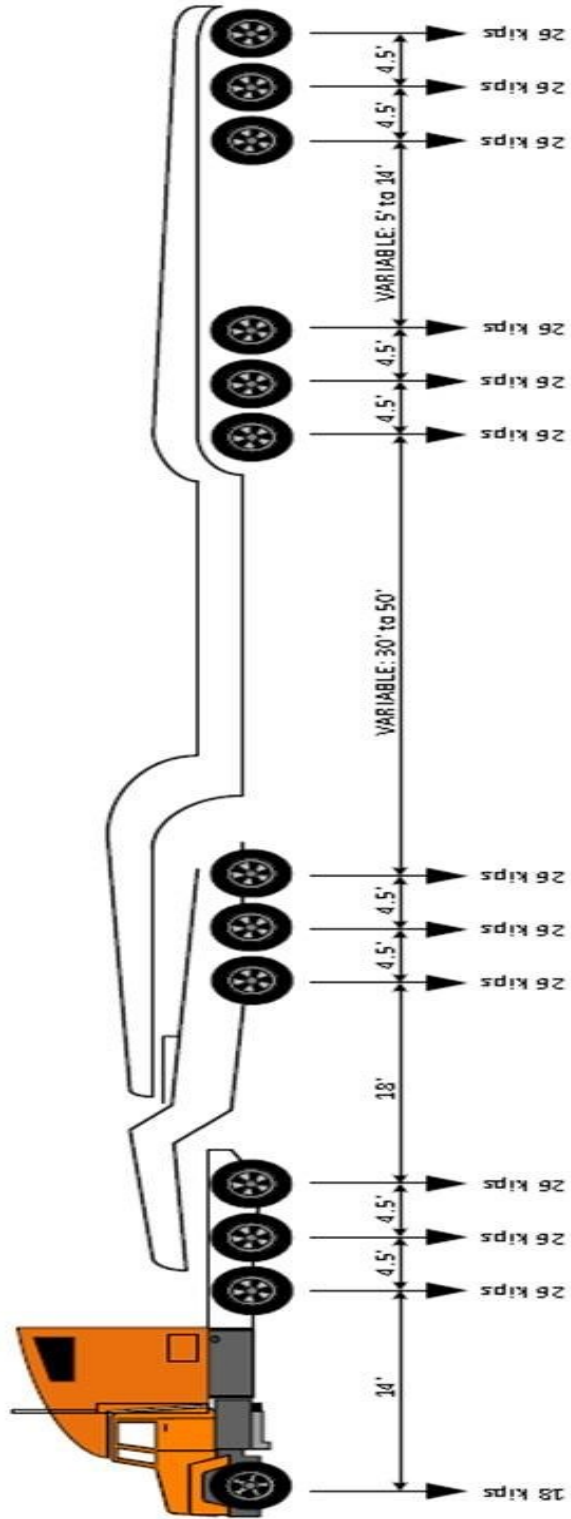


Figure 3.20-3 PA2016-13, 13-axle Permit Design Vehicle, GVW = 330 kips

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3.21 SPECIAL LIVE LOAD

In place of LRFD or non-LRFD standard loadings described above, the bridge can also be analyzed for a special live load that can be described by entering various parameters of the loadings. This may be useful in analyzing a permit load or a customized loading. A special live may have 2 to 80 axles for a truck loading and/or its associated lane loading. The special live load can be analyzed in accordance with non-LRFD AASHTO Specifications or LRFD Specifications depending upon the values of STD.

The effects of a Special Live Load are calculated in the same manner as explained under the Truck Load Effect. The effects of all axles are considered unless the user has specified to neglect the effects of those axles that do not produce the same effect as the effect being sought. Also, if the combined effect of the SPEC LANE LOAD and the Special Live Load is requested, the program computes these effects in a similar manner as the HL93 or PHL93 loading.

In calculating the effect of a Special Live Load, the effects of all axle loads are considered only if the user specifies to INCLUDE effects of all axles.

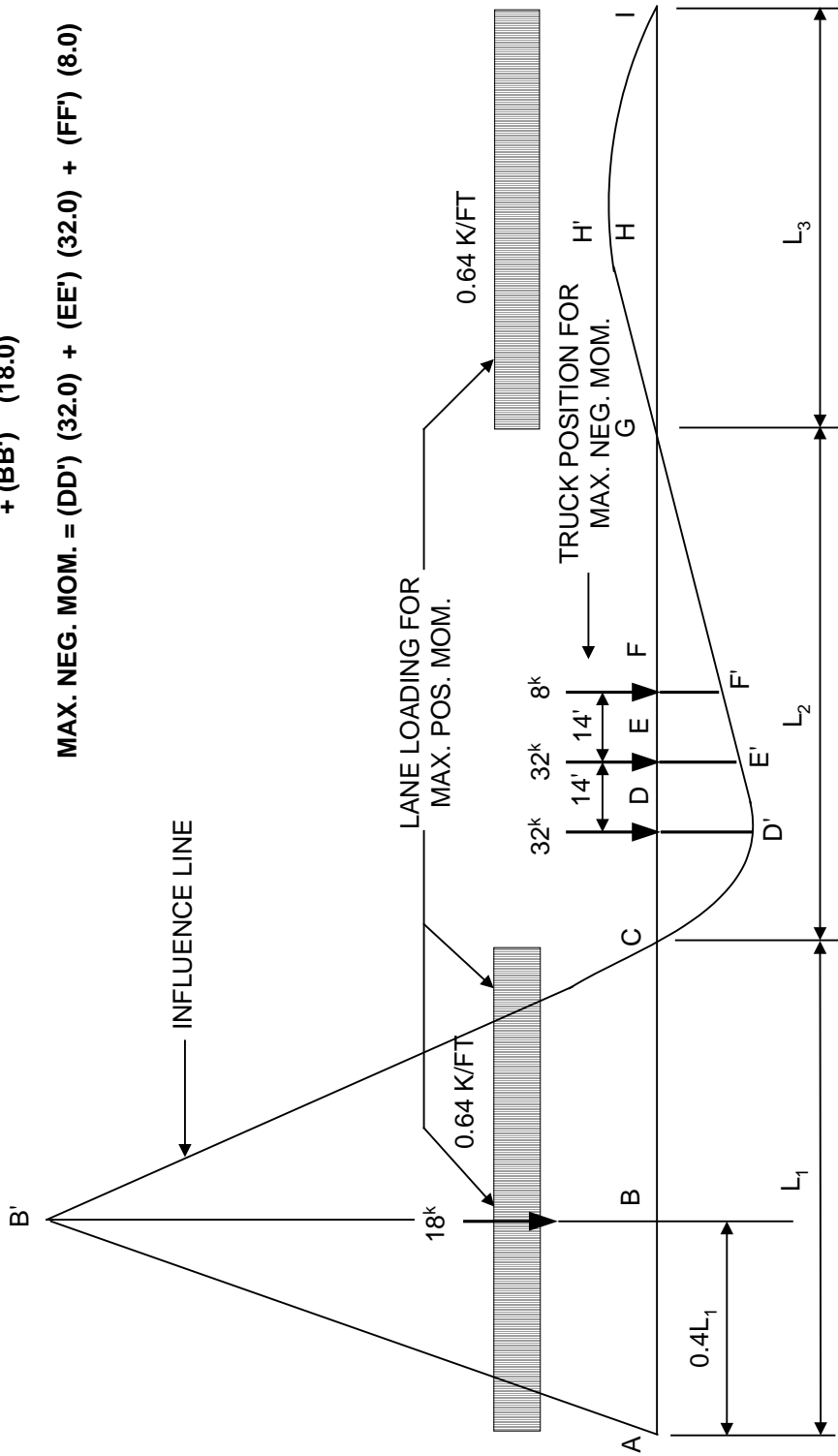
3.22 INFLUENCE LINE ANALYSIS FOR H20 AND HS20 LOADINGS

As described earlier in Section 3.8 , Effect of a H20 or HS20 truck load is calculated by placing the axle load at various locations on the influence line to find the maximum combined positive or negative live load effect.

The procedure described above is applicable for a truck load with or without varying axle spacings. However, for H or HS loading, the effects of equivalent lane loading must also be investigated. To find the effects of lane loading (uniform load plus one or two floating concentrated loads), the sum of all positive and the sum of all negative areas of the influence line are computed. Also, the absolute maximum positive ordinate and the absolute maximum negative ordinate are found. To find the positive lane loading effect, the sum of positive areas is multiplied by the uniform load and added to the product of the maximum positive ordinate and the applicable (moment or shear) concentrated load. The negative lane loading effect is found in the same manner, except that two floating concentrated loads are used for moment where applicable. The governing effects are stored. Refer to Figure 3.22-1 on page 3-29 and Figure 3.22-2 on page 3-30.

$$\text{MAX. POS. MOM.} = (\text{AREA A B' C} + \text{AREA G H' I}) (0.64) + (\text{BB}') (18.0)$$

$$\text{MAX. NEG. MOM.} = (\text{DD}') (32.0) + (\text{EE}') (32.0) + (\text{FF}') (8.0)$$



INFLUENCE LINE FOR MOMENT AT $0.4L_1$

Figure 3.22-1 Moment Influence Line

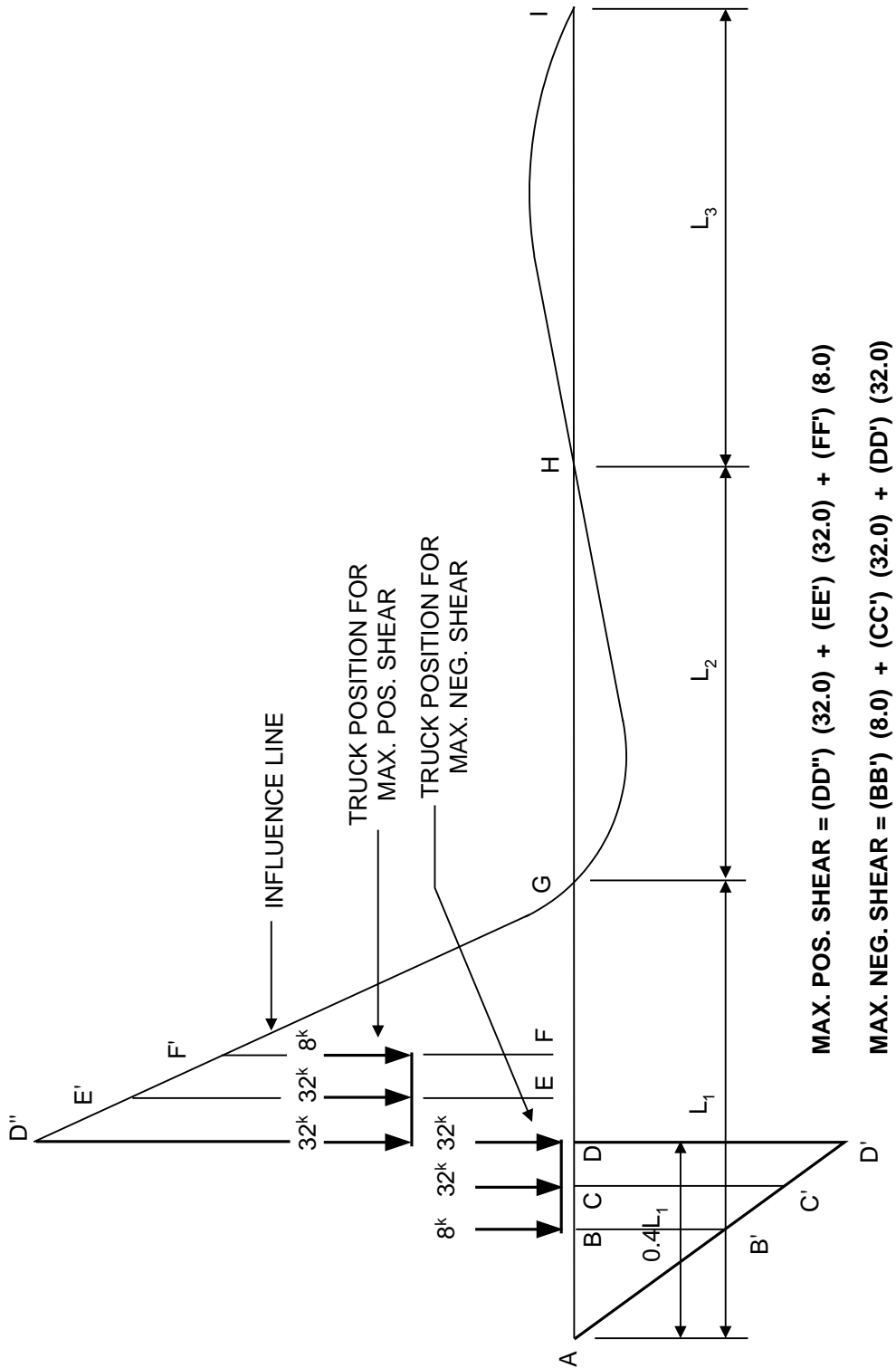


Figure 3.22-2 Shear Influence Line

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3.23 PEDESTRIAN LOAD

The effect of a pedestrian load is calculated in the same manner as explained under Lane Load Effect, except that the uniform lane load is replaced by the uniform pedestrian load.

3.24 LIVE LOAD DISTRIBUTION

The live load distribution factors to be used in calculating a given live load effect at an analysis point are calculated and entered by the user. These factors are for a positive moment in each span, a negative moment in an end span, a negative moment near the interior support, a negative moment near the middle of an interior span, a reaction at an exterior support, a reaction at an interior support, a shear (positive or negative) in each span and deflections at all analysis points. The distribution factor for moment, shear or reaction in a girder is a function of the span length/s and the location of the analysis point. The distribution factor for deflection is a function of the number of beams and the number of lanes on the bridge.

3.25 LIVE LOAD ROTATIONS

The live load rotations at the ends of each span are calculated by analyzing the influence lines for rotations at these points. The Distribution Factor for Moment DF1 is used to calculate the positive and negative rotations at the end support of an exterior span. The Distribution Factor for Moment DF2 is used to calculate the positive and negative rotations at an interior support. For HL93 and PHL93 loadings, the program checks the load cases that are used for calculating the live load deflections.

Please note that the distribution factors used for the calculation of live load rotations may be different than the distribution factor used for the calculation of live load deflections. Thus, there may not be a correlation between the live load rotations and deflections values reported by the program.

3.26 FLOORBEAM ANALYSIS

The program can analyze three types of floorbeams: a simple span floorbeam supported on ends; a cantilever floorbeam continuous over one or two supports; a floorbeam simply supported between two main girders and one or two overhangs which are fixed at the girder and free at the other ends. All three floorbeam types described above are assumed to be statically determinate. If the floorbeam between girders is to be assumed as partially fixed at its ends, the user can estimate the end moments due to partial or full fixity and can enter as applied moment loads assuming a simple floorbeam between girders.

The floorbeam is analyzed as follows. First the reactions at the supports due to a given load are determined by statics. The moments and shears at analysis points are then determined assuming a free body taking a section at the analysis point. The analysis points are defined by the user. Once the moments are calculated at all analysis

Chapter 3 Method of Solution

points, the M/EI value is calculated at each analysis point, where M is the moment acting at the analysis point and EI is the product of the modulus of elasticity (E) and the moment of inertia (I) at the section. The M/EI is then applied as a loading on a conjugate beam of the actual structure. The moments and shears at analysis points in the conjugate beam due to the M/EI loading are then computed using the principles of statics. The moment at a section in the conjugate beam due to the M/EI loading is equal to the deflection at that section of the actual beam. The shear at a section in the conjugate beam due to the M/EI loading is equal to the rotation of the section of the actual beam.

A typical loading condition is a unit load applied at an analysis point. The effects (such as reaction, rotation, deflection, etc.) are then calculated at all analysis points for this loading condition. Applying this unit load at each analysis point in succession and then calculating the effect at all analysis points produces the coordinates of an influence line for a given effect. These influence lines are then used to calculate the effect of a given dead load. The user can request an output of influence lines in addition to the output of dead load effects. Unlike an analysis of a continuous longitudinal beam, the program does not consider a moving live load as a loading condition

4 **GETTING STARTED**

4.1 INSTALLATION

This program is delivered via download from the Department's website. Once payment has been received by PennDOT you will receive a confirmation e-mail with instructions on how to download the software. The download file is a self-extracting installation file for the licensed PennDOT engineering software. The engineering program runs as a 32-bit application and is supported on Windows Vista, Windows 7 (32 and 64 bit versions), Windows 8, and Windows 10 operating systems.

Your license number, license key and registered company name, found in the e-mail received from the Department, are required to be entered when installing the program and must be entered exactly as shown in the e-mail. The license number, license key and registered company name will also be needed when requesting future versions of the program (i.e., enhancements, modifications, or error corrections), and requesting program support. A backup copy of the program download and e-mail instructions should be made and used for future installations. You may want to print the software license agreement, record the license number, license key and registered company name and keep it in a safe place.

To install the program, follow the installation instructions provided with the original e-mail from the Department.

The following files will be installed in the destination folder, which defaults to "C:\Program Files\PennDOT\CBA v<version number>\\" or "C:\Program Files (x86)\PennDOT\CBA v<version number>\\" for 64-bit operating systems:

1. CBA.exe, CBA_dll.dll => Executable program and Dynamic Link Library
2. CBA Users Manual.pdf => Program User's Manual (PDF Format).
3. CBARevReq.dotx => Revision Request form (MS Word template).
4. GettingStarted.pdf => A document describing installation and running of the program
5. LicenseAgreement.pdf => The program license agreement
6. *.dat => Example problem input file.
7. MSVCR71.dll => Runtime Dynamic Link Library

Chapter 4 Getting Started

The program example files (ex*.dat) will be installed in the program example folder, which defaults to "C:\PennDOT\CBA v<version number> Examples\". Users must have write access in order to run the input files from this folder.

4.2 PREPARING INPUT

The engineering program requires an ASCII input file. The input file consists of a series of command lines. Each command line defines a set of input parameters that are associated with that command. A description of the input commands can be found in Chapter 5 of the User's Manual. The input can be created using Engineering Assistant, described below, or any text editor.

4.3 ENGINEERING ASSISTANT

The Engineering Assistant (EngAsst) is a Windows application developed by the Pennsylvania Department of Transportation (PennDOT) to provide a graphical user interface (GUI) for PennDOT's engineering programs. The data for the input to the engineering program is presented in a user-friendly format, reflecting the implied structure of the data, showing each record type on a separate tab page in the display and showing each field on each record with a defining label.

With EngAsst the user can create a new input file, modify an existing input file, import input files, run the associated engineering program and view the output in a Windows environment. The help and documentation are provided, including text descriptions of each field, relevant images, and extended help text at both the record/tab level and the field level. Access to all parts of the Engineering Program User's Manual, where available, is also provided within EngAsst.

EngAsst is not included with this software. It requires a separate license that can be obtained through the Department's standard Engineering Software licensing procedures. Order forms can be obtained from program support website at <http://penndot.engrprograms.com>.

4.4 RUNNING THE PROGRAM WITHOUT ENGASST

The engineering programs are FORTRAN console application programs. They may be run from a command window, by double-clicking on the program icon from Windows Explorer, by selecting the shortcut from the Start menu under PennDOT Programs, or by double-clicking the shortcut icon on the desktop. To run the program in a command window, the user must specify the directory in which the program has been installed or change to the directory.

The program will prompt for an input file name, and the user should then enter the appropriate input file name. The input file must be created before running the program. The program will then prompt for whether the output should be reviewed on the screen. The user should enter Y if the output is to be reviewed on the screen after execution or N if the output is not to be reviewed on the screen. The program will then prompt for the name of the output file in which the output is to be stored, and the user should then enter the desired output file name. If a file with the specified output file name already exists, the program will ask the user whether to overwrite the existing file. The user should enter Y if the existing file is to be overwritten or N if the existing file is not to be overwritten. If the user enters N to specify that the existing file is not to be overwritten, the program will prompt the user for another output file name. The program will then execute.

To cancel the program during execution, press <Ctrl C> or <Ctrl Break>, and then press <Enter>.

When the program completes execution, the user is prompted to "Press <ENTER> to exit program." This allows the user to view the last messages written to the screen when the program was started by double-clicking on the program icon from Windows Explorer.

The user can view the *.OUT output file with a text editor and the *.PDF output file (for those programs that produce it) with Adobe Acrobat.

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5 ***INPUT DATA REQUIREMENTS***

5.1 INPUT FORMS

Ten input forms (see Figure 5.1-1 on page 5-2 through Figure 5.1-10 on page 5-11) have been prepared to facilitate data preparation for execution of this program. Each group of data has been assigned a unique data TYPE that must be entered in column 1 of each data line.

PENNSYLVANIA DEPARTMENT OF TRANSPORTATION
CBA
CONTINUOUS BEAM ANALYSIS

PROBLEM IDENTIFICATION	
1	72
*	
*	
*	

BEAM DATA AND DESIGN LIVE LOADS

TYPE	UNITS	NO. OF SPANS	ANALYSIS POINTS	CONT.	E	SYMMETRY	LOADING OUTPUT	DEFLECTION DF	IMPACT FACTOR	SPEC LANE LOAD	INCLUDE	DESIGN TRUCK			DESIGN TANDEM P	DESIGN LANE LOAD	CONC. LOAD MOMENT	CONC. LOAD SHEAR	REACT ONLY	DIRECT.	STD	
												P1	P2	P3								
1	2	3	5	7	8	14	15	16	17	22	27	33	34	40	46	52	58	64	70	76	77	78
1																						

SPAN LENGTHS

TYPE	UNITS	SPAN LENGTHS																				
		1	2	3	4	5	6	7	8	9	10											
1	2	8		14	20	26	32	38	44	50	56	61										
2																						
2																						

HINGE LOCATIONS

TYPE	SPAN NO.	HINGE LOCATIONS																			
		DISTANCE	SPAN NO.	DISTANCE	SPAN NO.	DISTANCE	SPAN NO.	DISTANCE	SPAN NO.	DISTANCE	SPAN NO.										
1	2	4	10	12	18	20	26	28	34	36	42	44	50	52	58	60	66				
3																					
3																					

Figure 5.1-1 Input Form 1 of 10

PENNSYLVANIA DEPARTMENT OF TRANSPORTATION CBA
 CONTINUOUS BEAM ANALYSIS

SPECIAL LIVE LOAD – TRUCK AXLE LOADS AND SPACINGS

TYPE	AXLE LOAD	DIST	AXLE LOAD	DIST	AXLE LOAD	DIST	AXLE LOAD	DIST	AXLE LOAD	DIST	
1	2	8	14	20	26	32	38	44	50	56	61
7											
7											
7											
7											
7											

Figure 5.1-5 Input Form 5 of 10

PENNSYLVANIA DEPARTMENT OF TRANSPORTATION
 CBA
 CONTINUOUS BEAM ANALYSIS

SUPPORT SETTLEMENTS

TYPE	SUPPORT NO.	SETTLEMENT	SUPPORT NO.	SETTLEMENT	SUPPORT NO.	SETTLEMENT	SUPPORT NO.	SETTLEMENT	SUPPORT NO.	SETTLEMENT	SUPPORT NO.	SETTLEMENT	SUPPORT NO.	SETTLEMENT			
1	2	4	10	12	18	20	26	28	34	36	42	44	50	52	58	60	65
8																	
8																	

FIXED-END ACTIONS

TYPE	SPAN NO.	FIXED END MOMENT		FIXED END REACTION		SPAN NO.	FIXED END MOMENT		FIXED END REACTION		
		LEFT	RIGHT	LEFT	RIGHT		LEFT	RIGHT	LEFT	RIGHT	
1	2	4	13	22	31	40	42	51	60	69	77
6											
6											
6											
6											

Figure 5.1-6 Input Form 6 of 10

Chapter 5 Input Data Requirements

Form 8 of 9

CBA
CONTINUOUS BEAM ANALYSIS

PENNSYLVANIA DEPARTMENT OF TRANSPORTATION
BUREAU OF INFORMATION SYSTEMS

INFLUENCE LINE DISTANCES									
TYPE	DISTANCE	DISTANCE	DISTANCE	DISTANCE	DISTANCE	DISTANCE	DISTANCE	DISTANCE	DISTANCE
1	9	16	23	9	16	23	9	16	23
2									
D									
D									
D									
D									
D									
D									
D									

INFLUENCE LINE ORDINATES									
TYPE	ORDINATE	ORDINATE	ORDINATE	ORDINATE	ORDINATE	ORDINATE	ORDINATE	ORDINATE	ORDINATE
1	11	18	25	32	39	46	53	60	67
2									
3									
4									
M									
M									
M									
M									
M									
M									
M									

Figure 5.1-9 Input Form 9 of 10

CBA
CONTINUOUS BEAM ANALYSIS

PENNSYLVANIA DEPARTMENT OF TRANSPORTATION
BUREAU OF INFORMATION SYSTEMS

ELASTIC SUPPORT SPRING CONSTANTS

TYPE	SUPPORT NO.	4	10	12	18	20	26	28	34	36	42	44	50	52	58	60	65		
	SUPPORT NO.	SPRING CONSTANT k	SUPPORT NO.	SPRING CONSTANT k	SUPPORT NO.	SPRING CONSTANT k	SUPPORT NO.	SPRING CONSTANT k	SUPPORT NO.	SPRING CONSTANT k	SUPPORT NO.	SPRING CONSTANT k	SUPPORT NO.	SPRING CONSTANT k	SUPPORT NO.	SPRING CONSTANT k	SUPPORT NO.	SPRING CONSTANT k	
1	2																		
S																			
S																			
S																			
S																			
S																			
S																			

Figure 5.1-10 Input Form 10 of 10

Chapter 5 Input Data Requirements

5.2 PROBLEM IDENTIFICATION

Lines are provided to enter user comments for problem identification. The first column of each line must contain an asterisk (*) to indicate that this is a user comment. Any number of these lines of data may be supplied within the input data, but only the first three lines will be printed on the output.

5.3 BEAM DATA AND DESIGN LIVE LOADS

This line describes the data related to the entire beam. Each input item is described below:

TYPE

The type of input data line. Enter "1" to identify that this is a BEAM DATA line.

UNITS

The units used for all input and output values is "U", U.S. Customary units.

NO. OF SPANS

Enter the number of spans of the longitudinal beam without the input of a set of known influence lines. A maximum of fifty (50) spans can be analyzed for a continuous beam.

Enter zero to indicate a floorbeam.

Enter 99 when running with the input of a set of known influence lines

ANALYSIS POINTS

The number of analysis points for which the computed values are to be printed. Enter one of the following codes for appropriate analysis points:

"01" – divide each span into ten equal parts for 10th points and report computed values at 10th points along each span of the bridge

"02" - divide each span into twenty equal parts for 20th points and report computed values at 20th points along each span of the bridge

"09" - report computed values at user-defined points only. User-defined points are defined in ANALYSIS DATA card.

"19" - divide each span into ten equal parts for 10th points and add user-defined points, and report computed values at 10th points and user-defined points.

"29" - divide each span into twenty equal parts for 20th points and add user-defined points, and report computed values at 20th points and user-defined points

Chapter 5 Input Data Requirements

Analysis points must be entered as "09" for a floorbeam.

Leave blank when running with the input of a set of known influence lines and NO. OF SPANS = 99.

CONT CODE

For a longitudinal beam, enter this continuity code as follows:

"C" if the span lengths being defined are for a continuous beam without in-span hinges.

"H" if the span lengths being defined are for a continuous beam with in-span hinges.

"S" if the span lengths being defined are for a simple span or a series of simple spans modelling as a statically determinate structure which is a continuous beam with in-span hinges at all intermediate supports. Program will set the necessary information for the in-span hinges internally.

If "H" is entered here, also enter data for HINGE LOCATIONS described later.

For a floorbeam, enter this continuity code as follows:

"C" if the floorbeam is to be analyzed with cantilevers that are continuous over the supports.

"F" if the floorbeam is to be analyzed as a simple beam between the supports and with cantilevers that are fixed at the supports. If the ends of the floorbeam between the girders are partially fixed, it can be represented by applied end moments to a simple span floorbeam with no cantilevers.

"S" for a simple span floorbeam with no cantilevers. A floorbeam with ends that are partially fixed can be analyzed as a simple span floorbeam with applied end moments that represent the fixity of the end.

Leave blank when running with a set of known influence lines.

Please refer to the proper hinge locations at the page 2-129, BEAM DIAGRAMS AND FORMULAS, Design properties of cantilevered beams of the Manual of Steel Construction, Eighth Edition, AISC, 1984.

E

The modulus of elasticity of the beam - ksi or MPa. If the beam is composite with slab, enter the modulus of elasticity of the beam. This value is used in calculating the beam deflections and rotations. If the modulus of elasticity is not constant for all spans, use the MODULUS OF ELASTICITY input (described later) to enter the modulus of elasticity for each span that is different.

Leave blank when running with a set of known influence lines.

Chapter 5 Input Data Requirements

SYMMETRY

Enter "Y" if the beam is symmetric about the center of the entire length (sum of all span lengths) of the beam. For a beam to be symmetric, the span lengths, hinge locations, analysis points, section properties, dead loads, points of contraflexure, support settlements, fixed end actions, and live load distribution factors must all be identical on both sides of the symmetry point.

If the beam is defined as symmetric, the program will only analyze and report the results up to the point of symmetry.

Leave blank if the beam is unsymmetrical.

Leave blank when running with a set of known influence lines.

OUTPUT

Enter 0 or leave blank to create an output text file (including input data echo and load effect) with annotations. No pdf will be generated.

Enter 1 to create an output text file (including input data echo and load effect) with annotations. Additional pdf will be generated.

Enter 2 to create an output text file without annotations for exporting to a spreadsheet program such as Microsoft Excel. Additional pdf will be generated.

Enter 8 to create an output text file without annotations for exporting to a spreadsheet program such as Microsoft Excel. No pdf will be generated.

Enter 3 if the output of influence lines (distance and ordinates for each analysis point) with load effect is desired. Influence lines cannot be generated when the LOADING code is entered as "2" for the floorbeam analysis. Additional pdf will be generated.

Enter 9 if the output of influence lines (distance and ordinates for each analysis point) with load effects is desired. Influence lines cannot be generated when the LOADING code is entered as "2" for the floorbeam analysis. No pdf will be generated.

LOADING CODE

Enter one of the following loading codes. The program can analyze for only one loading condition in each run.

Valid codes for a longitudinal beam are:

"0" - a system of dead loads

Chapter 5 Input Data Requirements

- "1" - support settlements
- "2" - creep and shrinkage or temperature gradient effects
- "3" - PHL93 Loading (Always Notional)
- "4" - Fatigue Load (Always Notional)
- "5" - HL93 loading (Always Notional)
- "6" - H20 loading
- "7" - HS20 loading
- "8" - Pedestrian load
- "9" - Special live load
- "A" – Pennsylvania Permit (P-82) live load (Notional by default)
- "B" - ML80 live load
- "C" - Moving Load Group (Known Influence Lines Only)
- "D" – PA58, risk-based posting vehicle
- "E" – EV2, single rear axle emergency vehicle
- "F" – EV3, tandem rear axle emergency vehicle
- "G" – SU6TV, heavy-duty tow and recovery vehicle
- "H" – PA2016-13, 13-axles, permit vehicle
- "T" – TK527 Live Load

Valid codes for a floorbeam are:

- "0" - a system of dead loads (concentrated, uniform and trapezoidal loads)
- "2" - applied moments at the points of support to account for partial fixity at that point of the floorbeam.
Influence lines for effects in the floorbeam cannot be generated when this loading code is used.

Other requirements for the above loading codes (applicable to both the longitudinal beam and the floorbeam) are:

- If "0" is entered, also enter DEAD LOADS on Form 4.
 - If "1" is entered, also enter SUPPORT SETTLEMENTS on Form 5.
 - If "2" is entered, also enter FIXED END ACTIONS on Form 5.
 - If "3", "4", "5", "6", "7", "9", "A", "B", "D", "E", "F", "G", "H", or "T" is entered, also enter POINTS OF CONTRAFLEXURE on Form 4.
 - If "9" is entered, also enter SPECIAL LIVE LOADS on Form 5.
- Loading codes "1" and "2" are not applicable when running with a set of known influence lines.

DEFLECTION DF

The distribution factor to be used in calculating the live load deflections. This is equal to the number of design lanes divided by the number of beams in a bridge. This factor is applied to calculate live load deflections at all

Chapter 5 Input Data Requirements

analysis points of the bridge.

Leave blank when running with a set of known influence lines.

IMPACT FACTOR

The factor to be applied to effects of a moving live load expressed as $(1 + IM/100)$, where IM is the Dynamic Load Allowance defined in Table 3.6.2.1-1 of LRFD Bridge Design Specifications. If load effects are desired without this factor, enter 1.0 here. All live load effects except the effects due to the Design Lane Load or SPEC LANE LOAD will be increased by this factor.

Leave blank when running with a set of known influence lines.

SPEC LANE LOAD

The uniform lane load to be applied in combination with a truck load entered as a special live load later - kips/ft or kN/m. This feature will allow the user to analyze a combination of a truck load and a lane load which could be different than the Vehicular Live Load defined in the LRFD Bridge Design Specifications.

The following rules for Special Live Load (LOADING CODE = 9) about the use of SEC LANE LOAD and H20 or HS20 uniform or concentrated lane loads (CBAREV047) are used:

Case 1. STD = true (user enters S): (WSD OR LFD) => truck load effect or lane load effect governs

1A. If the user enters nothing (i.e. BLANK) at SPEC LANE LOAD:

=> Use the default value (0.64 kip/ft or 9.3 kN/m) of standard H or HS lane load.

=> Use the default value [(18 kip and 26 kip) or (80 kN and 115 kN)] of standard H or HS concentrated load for moment and shear.

1B. If the user enters something at SPEC LANE LOAD:

=> Use the user-entered value to represent the standard H or HS lane load,

=> Use the values of CONC LOAD MOMENT and CONC LOAD SHEAR to represent the standard H or HS concentrated loads for moment and shear.

Case 2. STD = false (user enters others): (LRFD) => truck load effect plus lane load effect govern

2A. If the user enters nothing (i.e. BLANK) at SPEC LANE LOAD:

=> Use 0 to represent the standard H or HS lane load.

=> Use 0 to represent the standard H or HS concentrated load for moment and shear.

=> Any user-entered values of DESIGN LANE LOAD, CONC LOAD MOMENT, and CONC LOAD SHEAR will be ignored.

2B. If the user enters something at SPEC LANE LOAD:

=> Use the user-entered value to represent the standard H or HS lane load.

=> Use the user-entered value of CONC LOAD MOMENT and /or CONC LOAD SHEAR to represent

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the standard H or HS concentrated loads for moment and shear.

INCLUDE

Enter "Y" if the effects of all axle loads (as in the case of a special live load) are to be included in calculating a given live load effect. This is a non-LRFD approach.

Enter "N" if the axle loads that do not contribute to the effect being sought are to be neglected in calculating the effect of a given live load. This is a LRFD approach.

Leave it blank to use default.

For LOADING CODE = "3", "4", and "5" this must be left blank or entered as "N".

For LOADING CODE = "6" and "7", this must be left blank or entered as "Y".

The default is "N" for LOADING CODE = "A".

The default is "Y" for LOADING CODE = "9", "B", "D", "E", "F", "G", "H", and "T".

DESIGN TRUCK P1

If the LRFD Design Truck, LRFD Fatigue Truck or Standard H or HS Truck is to be modified for this analysis, enter total load on the front axle of the Truck - kips or kN. The default is 8 kips or 35 kN.

DESIGN TRUCK P2

If the LRFD Design Truck, LRFD Fatigue Truck or Standard HS Truck is to be modified for this analysis, enter total load on the middle axle of Truck - kips or kN. If the Standard H Truck is to be modified for this analysis, enter total load on the rear axle. The default is 32 kips or 145 kN.

DESIGN TRUCK P3

If the LRFD Design Truck, LRFD Fatigue Truck or Standard HS Truck is to be modified for this analysis, enter total load on the rear axle of the Truck - kips or kN. The default is 32 kips or 145 kN.

DESIGN TANDEM P

If the LRFD Design Tandem is to be modified for this analysis, enter total load on each axle of a pair of axles of the Design Tandem – kips or kN. The default for the HL93 loading is 25 kips or 110 kN. The default for the PHL93 loading is 31.25 kips or 140 kN for single and 25 kips or 110 kN for dual.

Chapter 5 Input Data Requirements

DESIGN LANE LOAD

If the LRFD Design Lane Load or Standard H or HS Lane Load is to be modified for this analysis, enter the uniformly distributed load - kips/ft or N/mm. The default is 0.64 kips/ft or 9.3 N/mm.

For LOADING CODE = 9, Please see SPEC LANE LOAD for more information.

CONC LOAD MOMENT

If the concentrated load to be used in conjunction with the Standard H or HS Lane Load for moment is to be modified for this analysis, enter the concentrated load - kips or kN. The default is 18 kips or 80 kN.

CONC LOAD SHEAR

If the concentrated load to be used in conjunction with the Standard H or HS Lane Load for shear is to be modified for this analysis, enter the concentrated load - kips or kN. The default is 26 kips or 115 kN.

REACT ONLY

Enter "Y" if the program should calculate reaction results only. Leave blank to compute all results. This option allows getting stringer reactions only for analyses of floorbeams, abutments and piers.

DIRECT

Normally the live load analysis is performed by moving the load in both directions and the critical effects are used for ratings. For the purpose of a special analysis where the live load is to be moved only in one direction, enter the following codes to restrict the direction of the moving load.

Enter L for moving the live load from left to right. This effect is achieved by moving the axles (truck front axle at right side and its associated axles at left side) from the left to the right.

Enter R for moving the live load from right to left. This effect is achieved by moving the axles (truck front axle at left side and its associated axles at right side) from the left to the right.

Leave blank to move the loads both directions.

STD

Live load analysis can be performed in accordance with the WSD, LFD, or LRFD Specifications, enter the following code to determine:

Chapter 5 Input Data Requirements

Enter S (i.e. `STD = .TRUE.` in the program) to analyze the live load in accordance with the Standard AASHTO Working Stress or Load Factor Design Specifications.

CBA will compute lane loading effect and truck loading effect separately and the governing effect is based on the lesser of these two ratings. For live loads and shears at end supports CBA will also consider the lateral distribution of the axle load adjacent to the end support assuming flooring to act as a simple span between stringers.

Enter N or leave blank (i.e. `STD = .FALSE.` in the program) to analyze the live load in accordance with the AASHTO LRFD Specifications.

CBA will add the lane loading effect to truck loading effect and the total effect is reported as the governing effect.

The AASHTO Standard H20 or HS20 lane loading consists of a uniform load plus one or two concentrated loads.

STD is valid for LOADING = 9, A, B, D, E, F, G, H, and T.

Chapter 5 Input Data Requirements

5.4 SPAN LENGTHS

Enter the center to center distance of bearings as span lengths. Do not enter Span Lengths when running with a set of known influence lines.

TYPE

The type of input data line. Enter "2" to identify that this is a SPAN LENGTHS line.

1,2....10

Span lengths - feet or m. A maximum of fifty (50) spans can be analyzed. If the beam is symmetric and SYMMETRY is entered as "Y" in the BEAM DATA line, enter the span lengths up to the point of symmetry. If the beam is symmetric and has an odd number of spans, enter the span lengths up to the center span.

For a floorbeam, there must be three entries for Span Lengths. The first is the length of the left cantilever, the second is the length of the floorbeam between the supports (center to center girder or truss spacing), and the third is the length of the right cantilever. If there is no cantilever on the left, the first span length should be entered as zero. If there is no cantilever on the right, the third span length should be entered as zero.

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5.5 HINGE LOCATIONS

If an "H" is entered for CONT in the BEAM DATA AND DESIGN LIVE LOADS line, enter the distances of in-span hinges.

The following edit checks were added to prevent the user from entering unstable hinge locations:

1. The hinge locations cannot be at the begin bearing of the begin span (i.e. span 1).
2. The hinge locations cannot be at the end bearing of the end span (i.e. the last span).
3. More than two hinge locations in any interior span (including the locations on top of these supports at each end of the span) are not allowed.
4. More than one hinge locations in any begin or end span (including the locations on top of these supports at each end of the span) are not allowed.
5. The number of hinge locations cannot exceed the number of spans – 2

When the CONT at the BEAM DATA AND DESIGN LIVE LOADS card is equal to H, CBA will allow hinge locations on top of the interior supports if the bridge is stable.

Note: The user still may enter unstable hinge locations (such as two adjacent spans with one hinge at each span) and crash the CBA.

Reference: BEAM DIAGRAMS AND FORMULAS Design properties of cantilevered beams at Page 2-129 of AISC Steel Construction Manual.

If the beam and the hinge locations are symmetric and SYMMETRY is entered as "Y" in the BEAM DATA line, enter the hinge locations up to the point of symmetry.

Hinge Locations are not allowed for a floorbeam.

TYPE

The type of input data line. Enter "3" to identify that this is a HINGE LOCATIONS line.

SPAN NO.

The span number in which the hinge is located. The begin span is span 1.

DISTANCE

The distance of the hinge measured from the centerline of the left bearing in the span where the hinge is located

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- feet or m.

When the distance = 0, the hinge is located on top of the left support.

When the distance = span length, the hinge is located on top of the right support.

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5.6 ANALYSIS POINTS

For a longitudinal beam, enter these data to define the analysis points other than the 10th or 20th points of each span. These data must be entered if the code "09" or "19" or "29" is entered for ANALYSIS POINT in the BEAM DATA line. A maximum of twenty (20) **user-defined analysis** points can be specified for a given span. Data need to be entered only for those spans where these analysis points are located. The effects printed for these analysis points are interpolated (linearly for shears and parabolically for moments and deflections) from the calculated influence-line values at these 10th or 20th analysis points.

For a floorbeam, the program does not divide the span to obtain analysis points, and therefore, all analysis points must be entered. Effects and influence lines are calculated only at the user defined analysis points placing unit loads at these points only. It is therefore important to enter sufficient analysis points (at least five for the overhangs and ten for the center span) to generate enough ordinates for an influence line. If an analysis point is not defined at the supports, the program will assume an analysis point at these locations. Floorbeam distances for the center span and left overhang are measured from the left support using negative values to locate points on the left overhang. Floorbeam distances for the right overhang are measured from the right support. Point distances should be entered from left to right along the floorbeam.

If the beam is symmetric and SYMMETRY is entered as "Y" in the BEAM DATA line, enter the analysis points up to the point of symmetry.

Do not enter Analysis Points when running with a set of known influence lines.

TYPE

The type of input data line. Enter "4" to identify that this is an ANALYSIS POINTS line.

SPAN NO.

The span number for which the analysis points are described.

X1, X2,.....X10

The distances of analysis points measured from the centerline of left bearing in the span for which the analysis points are described - feet or m. Distances must be entered sequentially beginning with the left end of the beam.

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5.7 SECTION PROPERTIES

Enter these data to define the section properties of the beam. For the purpose of describing section properties, each span may be divided into a number of segments with each segment having a constant cross section. Each segment is defined by entering the distance of the right end of the segment from the left support of the span where the segment lies. This distance is defined as the range of the section. For a segment where the properties vary within a segment (straight or parabolic haunch in a plate girder), the segment should be sub-divided such that each range coincides with the 20th point of the beam and the properties should be entered for these sub-divided segments. The program assumes that each segment is prismatic, and uses these properties to calculate the flexibility constant (EI) for each finite element whose length is equal to one-twentieth of the span length.

If SYMMETRY is entered as "Y" in the BEAM DATA line, enter the section properties of the beam up to the point of symmetry.

Use as many lines as needed to describe the properties within each span. However, the total number of ranges entered for a beam cannot be greater than 200 (100 for a symmetric beam).

Do not enter Section Properties when running with a set of known influence lines.

TYPE

The type of input data line. Enter "5" to identify that this is a SECTION PROPERTIES line.

SPAN NO.

The span number for which the section properties are described.

RANGE

The distances from the centerline of left bearing in this span to the right end of this segment - feet or m.

The RANGE cannot be greater than the span length. The RANGE for the last segment in each span must be equal to the span length. The last RANGE for the beam must be equal to the symmetry point or the end of the last span.

For a floorbeam, distances are referenced to the left support using negative values to locate RANGES on the left cantilever. RANGES should be entered from left to right along the floorbeam. For a floorbeam that has a left cantilever, the last RANGE for the first span must be zero.

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M OF I

The moment of inertia of the section in this RANGE – in⁴ or 10⁹mm⁴. Enter the appropriate moment of inertia that is applicable for a given loading condition. Please note that in a composite beam design, the section properties vary for each loading condition, i.e. certain loads act on a non-composite section and other loads act on a composite section with different modular ratios.

In a continuous beam analysis, the load effects are functions of flexibility constants (EI's). Thus, multiple runs must be made for different loading conditions applied to different section properties.

The entered value is multiplied by 10⁹ to obtain the moment of inertia in mm⁴ in SI units.

Chapter 5 Input Data Requirements

5.8 DEAD LOADS OR POINTS OF CONTRAFLEXURE

Enter these data if LOADING CODE in the BEAM DATA line is entered as 0, 3, 4, 5, 6, 7, 9, A, B, D, E, F, G, H, or T. The negative live load moments due to HL93 or PHL 93 loading are calculated only at sections between the point of dead load contraflexure and the interior support (pier).

When the LOADING CODE = 0, this line allows entering a series of dead loads acting on the beam. The dead load can be a uniform load on the entire beam, or patches of uniform or trapezoidal loads, or a system of concentrated loads, or any combination thereof. Each load is described by entering the distance and intensity at the beginning and end where the load is applied. One line is needed to describe up to two DEAD LOADS. Use as many lines as needed to describe the DEAD LOADS within each span. However, the total number of DEAD LOADS on a beam cannot be greater than 400.

When the LOADING CODE = 3, 4, 5, 6, 7, 9, A, B, D, E, F, G, or H, this line allows entering the points of contraflexure (POC) of the beam. One line is needed to describe up to two POCs in each span. The total number of POC lines must be equal to the number of spans. There is no POC for one-span simply supported bridge.

If the beam is symmetric and SYMMETRY is entered as "Y" in the BEAM DATA line, enter the dead loads or points of contraflexure up to the point of symmetry.

Do not enter Dead Loads or Points of Contraflexure when running with a set of known influence lines.

TYPE

The type of input data line. Enter "6" to identify that this is a DEAD LOADS OR POINTS OF CONTRAFLEXURE line.

SPAN NO.

The span number for which the DEAD LOADS OR POINTS OF CONTRAFLEXURE are described.

DISTANCE TO BEGIN OR POC

If the DEAD LOADS are being described, enter the distance from the centerline of the left bearing in this span to the beginning of the uniform or trapezoidal load - feet or m. If this is a concentrated load, enter the distance to the line of action of the load.

Floorbeam distances are measured from the left support using negative values to locate points on the left cantilever. Distances should be entered from left to right along the floorbeam.

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If the POINTS OF CONTRAFLEXURE are being described, enter the distance of the first POC in the span measured from the centerline of the left bearing in this span - feet or m. Enter zero if this is the first span.

DISTANCE TO END OR POC

If the DEAD LOADS are being described, enter the distance from the centerline of the left bearing in this span to the end of the uniform or trapezoidal load - feet or m. Leave blank for a concentrated load.

Floorbeam distances are measured from the left support using negative values to locate points on the left cantilever. Distances should be entered from left to right along the floorbeam.

If the POINTS OF CONTRAFLEXURE are being described, enter the distance of the second POC in the span measured from the centerline of the left bearing in this span - feet or m. Enter the span length if this is the last span.

LOAD AT BEGIN

The intensity of the uniform or trapezoidal load at the beginning of this load - kips/ft or kN/m. If this is a concentrated load, enter the value of the load - kips or kN.

LOAD AT END

The intensity of the uniform or trapezoidal load at the end of this load - kips/ft or kN/m. Leave blank for a concentrated load.

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5.9 SPECIAL LIVE LOAD – TRUCK AXLE LOADS AND SPACINGS

This form is used to describe the user-defined special live load. Enter these data if a "9" is entered for LOADING in the BEAM DATA line. The effects of a combination of truck and lane load (like LRFD loading) can be obtained by entering a proper value for SPEC LANE LOAD in the BEAM DATA line and axle weights of the truck load here. A maximum of 80 axle loads is allowed.

Special Live Load is not allowed for a floorbeam.

TYPE

The type of input data line. Enter "7" to identify that this is a SPECIAL LIVE LOAD line.

AXLE LOAD

The total load on the axle - kips or kN.

DIST

The distance from the axle under consideration to the next axle - feet or m. For example, the distance 4 is the distance between axle 4 and axle 5. The total number of distances entered must be one less than the total number of axle loads entered.

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5.10 SUPPORT SETTLEMENTS

If "1" is entered for LOADING in the BEAM DATA line, enter the settlements of supports. Supports are numbered from 1 to NSP+1 from left to right, where NSP is the number of spans.

If the beam is symmetric and SYMMETRY is entered as "Y" in the BEAM DATA line, enter the support settlements up to the point of symmetry.

Support Settlements are not allowed for a floorbeam.

Do not enter Support Settlements when running with a set of known influence lines.

TYPE

The type of input data line. Enter "8" to identify that this is a SUPPORT SETTLEMENTS line.

SUPPORT NO.

The support number for which the settlement is entered.

SETTLEMENT

The settlement of support from its original position - inches or mm. Before settlement, all supports are assumed level. A settlement in the downward vertical direction is positive. Uplift in the upward vertical direction is negative.

Chapter 5 Input Data Requirements

5.11 FIXED-END ACTIONS

If "2" is entered for LOADING in the BEAM DATA line, enter the fixed-end actions due to creep and shrinkage or a temperature gradient. These are the moment and reaction at each end of the span due to creep and shrinkage or temperature gradient assuming each span fixed at one or both ends. A counter clockwise fixed-end moment and an upward reaction are to be entered as positive numbers. A clockwise moment and a downward reaction are to be entered as negative numbers. The program converts these fixed-end moments into equivalent joint moments acting at each support. The equivalent joint moment at a given support is a negative value of the algebraic sum of entered fixed-end moments at that support.

If the beam is symmetric and SYMMETRY is entered as "Y" in the BEAM DATA line, enter the fixed-end actions up to the point of symmetry. If the beam is symmetric and has an odd number of spans, enter the fixed-end actions up to the left end of the center span. If the beam is symmetric and has an even number of spans, enter the fixed-end actions up to the point of symmetry including the right fixed-end actions.

For a floorbeam only, use this input type to enter the moments to be applied at the supports to represent the partial or full fixity between the floorbeam and the main girder. The effects due to this kind of loading can be combined with the effects of other loadings on a simple span to calculate the total effects for the actual condition of fixity. A counter clockwise moment is to be entered as a positive number and a clockwise moment is to be entered as a negative number.

Do not enter Fixed End Actions when running with a set of known influence lines.

TYPE

The type of input data line. Enter "9" to identify that this is a FIXED-END ACTIONS line.

SPAN NO.

The span number for which the fixed-end actions are entered.

FIXED- END MOMENT LEFT

The moment reaction at the left end of the span due to creep and shrinkage or temperature gradient assuming a fixed-end - kip-feet or kN-m. If this is a free end, enter a zero or leave blank.

For a floorbeam, enter the moment to be applied at the left support.

FIXED-END MOMENT RIGHT

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The moment reaction at the right end of the span due to creep and shrinkage or temperature gradient assuming a fixed end - kip-feet or kN-m. If this is a free end, enter a zero or leave blank.

For a floorbeam, enter the moment to be applied at the right support.

FIXED-END REACTION LEFT

The vertical reaction at the left end of the span due to creep and shrinkage or temperature gradient assuming a fixed end - kips or kN.

FIXED-END REACTION RIGHT

The vertical reaction at the right end of the span due to creep and shrinkage or temperature gradient assuming a fixed end - kips or kN.

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5.12 LIVE LOAD DISTRIBUTION FACTORS

If the beam is to be analyzed for a live load, enter these lines to define the distribution factors to be used in calculating the live load effects at various analysis points. The factors entered here are used to calculate moments, shears, reactions, and rotations at analysis points. **Please note the deflection due to live loads at analysis points is determined by the DEFLECTION DF at the BEAM DATA AND DESIGN LIVE LOADS card.** These distribution factors are to be calculated using appropriate span lengths, correction factors and other parameters as required by LRFD 4.6.2.2 **Beam-Slab Bridge**. Each distribution factor should be entered as a fraction of the axle (lane). Each factor is used by the program as described here. If any of the factors is not entered, it will be assumed to be equal to one. If the beam is not to be analyzed for a live load, these factors need not be entered.

For the purpose of this program and the application of live load distribution factors, the points of contraflexure are defined as points of zero moment due to a uniform load applied to the entire length of the beam.

These factors are to be entered for each span. If the beam is symmetric and SYMMETRY is entered as "Y" in the BEAM DATA line, enter the distribution factors up to the point of symmetry. If the beam is symmetric and has an odd number of spans, enter the distribution factor up to the center span.

Live Load Distribution Factors are not allowed for a floorbeam.

Do not enter Live Load Distribution Factors when running with a set of known influence lines.

TYPE

The type of input data line. Enter "A" to identify that this is a LIVE LOAD DISTRIBUTION FACTORS line.

SPAN NO.

The span number for which the live load distribution factors are entered.

MOMENT DF1

The distribution factor to be used in calculating the following effects:

1. Positive moment at any section in the span under consideration.
2. Negative moment in end spans **at sections** from the end support to the point of contraflexure.
3. Negative moment in an interior span at sections between the points of contraflexure.
4. Positive or negative moment at the analysis point which is at the point of contraflexure.
5. Rotation (positive or negative) at the end support of an exterior span.

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The value of "L" to be used in calculating the above distribution factor should be taken as the span length where the section is located.

Note: In calculating the positive moment at an interior support, the program will use the larger of DF1 for the span to the left and DF1 for the span to the right of the support.

MOMENT DF2

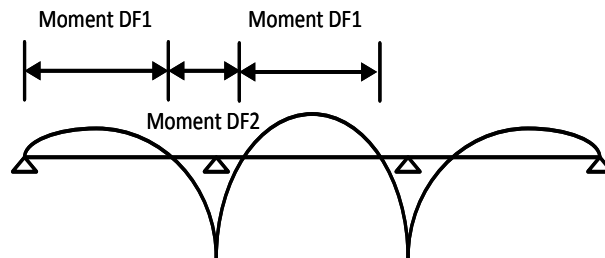
The distribution factor to be used in calculating the following effects:

1. Negative moment at sections between the points of contraflexure over the interior support.
2. Rotation (positive or negative) at an interior support.

The value of "L" to be used in calculating the above distribution factor should be taken as the average of two adjacent span lengths where the section is located.

Enter a value to be used for analysis points near the right end of the span.

If this is the last span, leave this blank.



SHEAR DF1

The distribution factor to be used in calculating the positive or negative shear at any section within the left half of the span, including the section at mid span.

The value of "L" to be used in calculating the above distribution factor should be taken as the span length where the section is located.

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SHEAR DF2

The distribution factor to be used in calculating the positive or negative shear at any section within the right half of the span, excluding the section at mid span.

The value of "L" to be used in calculating the above distribution factor should be taken as the span length where the section is located.

REACTION DF1

The distribution factor to be used in calculating the reaction at the left support of this span.

REACTION DF2

The distribution factor to be used in calculating the reaction at the right support of this span.

Note: REACTION DF2 should only be entered for the last span.

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5.13 MODULUS OF ELASTICITY

If the modulus of elasticity changes from span to span, this data must be entered. The program will use the modulus of elasticity entered in the BEAM DATA AND DESIGN LIVE LOAD for every span unless a value is entered here for a specific span or spans.

For a floorbeam, span one designates the left cantilever, span two is the section between the girders or trusses, and span three is for the right cantilever.

Do not enter Modulus of Elasticity when running with a set of known influence lines.

TYPE

The type of input data line. Enter "B" to identify that this is a MODULUS OF ELASTICITY line.

SPAN NO.

The span number for which the modulus of elasticity is entered.

E

The modulus of elasticity for this span - ksi or MPa.

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5.14 MOVING LOAD GROUP

If a known influence line is entered and the LOADING code is entered as "C", the effect of a group of loads moving over the influence line will be calculated. This group of loads can consist of patches of uniform or trapezoidal loads or a system of concentrated loads or any combination thereof. This group of loads will be marched across the influence line from right to left and then the group will be reversed to traverse the influence line from left to right.

Moving Load Group is not allowed for a floorbeam.

TYPE

The type of input data line. Enter "C" to identify that this is a MOVING LOAD GROUP line.

DISTANCE TO BEGIN

Enter the distance from the beginning of the load group to the beginning of the uniform or trapezoidal load - feet or m. If this is a concentrated load, enter the distance from the beginning of the load group to the line of action of the load.

DISTANCE TO END

Enter the distance from the beginning of the load group to the end of the uniform or trapezoidal load - feet or m. Leave blank for a concentrated load.

LOAD AT BEGIN

The intensity of the uniform or trapezoidal load at the beginning of this load - kips/ft or kN/m. If this is a concentrated load, enter the value of the load - kips or kN.

LOAD AT END

The intensity of the uniform or trapezoidal load at the end of this load - kips/ft or kN/m. Leave blank for a concentrated load.

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5.15 KNOWN INFLUENCE LINE DISTANCES

When entering a set of **known** influence lines to be analyzed, enter the distances at which the influence line ordinates are entered. These must be the same for each set of influence line ordinates entered next.

Influence Line Distances are not allowed for a floorbeam.

TYPE

The type of input data line. Enter "D" to identify that this is an INFLUENCE LINE DISTANCES line.

DISTANCE

The distance from the beginning of the influence line to the influence line ordinate - feet or m. **Up to 10 distances can be entered on a line.** The number of distances entered here must be equal to the number of ordinates entered for each influence line.

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5.16 KNOWN INFLUENCE LINE ORDINATES

Enter the ordinates **corresponding to the distances** for a set of known influence lines.

Influence Line Ordinates are not allowed for a floorbeam.

TYPE

The type of input data line. Enter "E" to identify that this is an INFLUENCE LINE ORDINATES line.

NUMBER

Enter the number for this set of influence lines, from 1 to 5. Each set of influence lines may consist of up to three types of influence line, moment, shear and/or thrust.

RESPONSE

Enter a code to indicate the type of response this influence line represents. Enter "M" for moment, "S" for shear, or "T" for thrust.

ORDINATE

Enter the influence line ordinates corresponding to the distances given in the INFLUENCE LINE DISTANCES - kips or kN. The number of ordinates entered here must equal the number of distances given in the INFLUENCE LINE DISTANCES. **Up to 10 ordinates can be entered on a line.**

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5.17 ELASTIC SUPPORT SPRING CONSTANTS

Enter the elastic spring constants of supports. Supports are numbered from 1 to NSP+1 from left to right, where NSP is the number of spans.

If the beam is symmetric and SYMMETRY is entered as "Y" in the BEAM DATA line, enter the Support Spring Constants up to the point of symmetry.

Support Spring Constants are not allowed for a floorbeam.

Do not enter Support Spring Constants when running with a set of known influence lines.

TYPE

The type of input data line. Enter "S" to identify that this is an ELASTIC SUPPORT SPRING CONSTANTS line.

SUPPORT NO.

The support number for which the spring constant is entered.

SPRING CONSTANT k

The spring constant of the support, - k – kips/ft or kN/m.

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6

DESCRIPTION OF OUTPUT

The printed output based on the user input consists of a repeat of all input values and the following computed values. These computed values are printed for each analysis point, range point, and transaction point (change in section properties) along the span. The distances of these points are measured from the left end of each span. Unless otherwise indicated, all distances are in feet or meters (m), reactions and shears are in kips or kilonewtons (kN), moments are in kip-feet or kN-m, and rotations are in radians depending upon the code entered for UNITS.

The sign conventions are as follows:

1. **Load:** a load acting in the upward direction is positive.
2. **Moment and rotation:** A counter clockwise moment or rotation is positive which cause a compressive stress in the extreme top fiber of a flexural member.
3. **Shear and reaction:** An upward reaction or shear force is positive. All shears are at a section to the right of the analysis point except the last section in the span where it is to the left of the analysis point.
4. **Deflection:** A downward vertical deflection is positive. Horizontal deflection to the right is positive.

6.1 DEAD LOAD CONDITION

The following values are printed for a system of dead loads, LOADING CODE = 0.

SUPPORT NO.

The support number for which the dead load reaction and dead load rotation are printed. The support number refers to the left end of the span under consideration. The last support number refers to the right end of the right most span.

DEAD LOAD REACTION

The reaction due to the dead loads entered for this loading condition.

DEAD LOAD ROTATION

The rotation of the section at the support due to the dead loads entered for this loading condition. For all supports except the last support, this is the rotation at the left end of the span under consideration. For the last support, this is the rotation at the right end of the last span.

For each span the following values are printed for all sections:

SPAN i

Self-explanatory.

X

The distance of the section from the left support of the span.

MOMENT

The moment due to the dead load.

SHEAR

The shear due to the dead load. For all sections except for the last section in the span, the value printed is the

Chapter 6 Description of Output

shear on the right side of the analysis point. For the last section in the span, the value printed is the shear on the left side of the analysis point.

DEFLECTION

The downward deflection of the analysis points due to dead loads.

6.2 SUPPORT SETTLEMENTS CONDITION

The following values are printed for support settlements, **LOADING CODE = 1**. All support settlements are assumed to occur simultaneously in calculating the support settlements effects.

SUPPORT NO.

The support number for which the reaction and rotation due to support settlements are printed. The support number refers to the left end of the span under consideration. The last support number refers to the right end of the right most span.

SETTLEMENT REACTION

The reaction due to the support settlements.

SETTLEMENT ROTATION

The rotation of the section at the support due to the support settlements. For all supports except the last support, this is the rotation at the left end of the span under consideration. For the last support, this is the rotation at the right end of the last span.

For each span the following values are printed for all sections:

SPAN i

Self-explanatory.

X

The distance of the section from the left support of the span.

MOMENT

The moment due to the support settlements.

SHEAR

The shear due to the support settlements. For all sections except for the last section in the span, the value

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printed is the shear on the right side of the analysis point. For the last section in the span, the value printed is the shear on the left side of the analysis point.

DEFLECTION

The downward deflection of the analysis points due to the support settlements.

6.3 CREEP AND SHRINKAGE OR TEMPERATURE GRADIENT EFFECTS WITH FIXED-END ACTIONS

The following values are printed for creep and shrinkage or temperature gradient effects, **LOADING CODE = 2**, when the loads are entered as **FIXED-END ACTIONS**.

SUPPORT NO.

The support number for which the reaction and rotation due to fixed end actions are printed. The support number refers to the left end of the span under consideration. The last support number refers to the right end of the right most span.

REACTION

The reaction at the support.

ROTATION

The rotation at the support. For all supports except the last support, this is the rotation at the left end of the span under consideration. For the last support, this is the rotation at the right end of the last span.

For each span the following values are printed for all sections:

SPAN i

Self-explanatory.

X

The distance of the section from the left support of the span.

MOMENT

The moment due to the fixed end actions.

SHEAR

The shear due to the fixed end actions. For all sections except for the last section in the span, the value printed is the shear on the right side of the analysis point. For the last section in the span, the value printed is the shear

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on the left side of the analysis point.

DEFLECTION

The downward deflection of the analysis points due to the fixed-end actions.

6.4 LIVE LOAD CONDITION

The following values are printed for a live load condition, **LOADING CODE** = 3, 4, 5, 6, 7, 8, 9, A, B, D, E, F, G, H, or T. When **OUTPUT** = 0 or 1, section 6.4.1 Reactions and Rotations with Impact and Distribution Factors, 6.4.2 Reactions and Rotations with No Impact or Distribution Factor, and 6.4.3 Span will be printed. When **OUTPUT** = 3 or 9, only section 6.4.4 Influence Lines will be printed.

6.4.1 Reactions and Rotations with Impact and Distribution Factors

REACTIONS AND ROTATIONS WITH IMPACT AND DISTRIBUTION FACTORS

SUPPORT NO.

The support number for which the live load reaction and the live load rotation are printed. The support number refers to the left end of the span under consideration. The last support number refers to the right end of the right most span.

+(LL+I) REACTION

The maximum positive reaction (upward force on beam) due to the live load plus impact.

-(LL+I) REACTION

The maximum negative reaction (downward force on beam - uplift) due to the live load plus impact.

+(LL+I) ROTATION

The maximum positive rotation due to live load plus impact. For all supports except the last support, this is the rotation at the left end of the span under consideration. For the last support, this is the rotation at the right end of the last span.

-(LL+I) ROTATION

The maximum negative rotation due to live load plus impact. For all supports except the last support, this is the rotation at the left end of the span under consideration. For the last support, this is the rotation at the right end of the last span.

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6.4.2 Reactions and Rotations with No Impact or Distribution Factors

REACTIONS AND ROTATIONS WITH NO IMPACT OR DISTRIBUTION FACTORS

REACTION +VEHICLE

The maximum positive reaction (upward force on beam) due to the designated truck load. No impact or distribution factors are applied.

REACTION +LANE

The maximum positive reaction (upward force on beam) due to the design lane loading. No impact or distribution factors are applied.

REACTION -VEHICLE

The maximum negative reaction (downward force on beam - uplift) due to the designated truck load. No impact or distribution factors are applied.

REACTION -LANE

The maximum negative reaction (downward force on beam - uplift) due to the design lane loading. No impact or distribution factors are applied.

ROTATION +TOTAL

The maximum positive rotation due to live load. For all supports except the last support, this is the rotation at the left end of the span under consideration. For the last support, this is the rotation at the right end of the last span.

ROTATION -TOTAL

The maximum negative rotation due to live load. For all supports except the last support, this is the rotation at the left end of the span under consideration. For the last support, this is the rotation at the right end of the last span.

Chapter 6 Description of Output

6.4.3 Span

For each span the following values are printed for all sections:

SPAN i

Self-explanatory.

X

The distance of the section from the left support of the span.

+(LL+I) MOMENT

The maximum positive moment due to the live load plus impact.

-(LL+I) MOMENT

The maximum negative moment due to the live load plus impact.

SIMULT V

The shear that occurs simultaneously with the live load plus impact moment. The value printed with code "V" is the shear that occurs simultaneously with the moment value printed above it.

+(LL+I) SHEAR

The maximum positive shear due to the live load plus impact. For all sections except for the last section in the span, the value printed is the shear on the right side of the analysis point. For the last section in the span, the value printed is the shear on the left side of the analysis point.

-(LL+I) SHEAR

The maximum negative shear due to the live load plus impact. For all sections except for the last section in the span, the value printed is the shear on the right side of the analysis point.

For the last section in the span, the value printed is the shear on the left side of the analysis point.

Chapter 6 Description of Output

SIMULT M

The moment that occurs simultaneously with the live load plus impact shear. The value printed with code "M" is the moment that occurs simultaneously with the shear value printed above it.

+(LL+I) DEFLECTION

The downward deflection of the analysis points due to the live load plus impact.

6.4.4 Influence Lines

For each support, influence lines for reaction and rotation are printed for a given live load.

1. INFLUENCE LINE FOR REACTION (1 KIP UNIT LOAD)
2. INFLUENCE LINE FOR ROTATION (1000 KIP UNIT LOAD)

For each analysis point in the span, influence lines for shear, moment, and deflection are printed for a given live load.

1. INFLUENCE LINE FOR SHEAR (1 KIP UNIT LOAD)
2. INFLUENCE LINE FOR MOMENT (1 KIP UNIT LOAD)
3. INFLUENCE LINE FOR DEFLECTION (10 KIP UNIT LOAD)

For each influence line the following values are printed for a given live load:

DIST

The distance of the analysis point from the beginning of the influence line to the influence line ordinate – feet or m. The DIST of every analysis points will be printed in the order from the left end to the right end.

ORDINATE

The influence line ordinate corresponding to the distance, DIST, above

LANE LOAD POS AREA

The total area under the positive regions of the influence line.

LANE LOAD POS EFFECT

The total positive effect due to the lane load.

LANE LOAD POS EFFECT equals the summation of the followings:

1. LANE LOAD POS AREA*UNIFORM LANE LOAD,
2. Peak value of positive Region 1*LANE_CONC_LOAD*DF,
3. Peak value of positive Region 2 if existed*LANE_CONC_LOAD*DF,

LANE LOAD NEG AREA

The total area under the negative regions of the influence line.

Chapter 6 Description of Output

LANE LOAD NEG EFFECT

The total negative effect due to the lane load.

LANE LOAD NEG EFFECT equals the summation of the followings:

1. LANE LOAD NEG AREA*UNIFORM LANE LOAD,
2. Peak value of negative Region 1*LANE_CONC_LOAD*DF,
3. Peak value of negative Region 2 if existed*LANE_CONC_LOAD*DF,

TRUCK LOAD POS EFFECT

The maximum positive effect due to the truck load.

TRUCK LOAD AXLE 1 @

The position of the first truck axle measured from the beginning of influence line when the maximum effect was found.

TRUCK LOAD MOVING

The direction in which the truck was moving when the maximum effect was found. L TO R is from left to right or R TO L is from right to left.

TRUCK LOAD NEG EFFECT

The maximum negative effect due to the truck load.

TRUCK LOAD AXLE 1 @

The position of the first truck axle measured from the beginning of influence line when the maximum effect was found.

TRUCK LOAD MOVING

The direction in which the truck was moving when the maximum effect was found. L TO R is from left to right or R TO L is from right to left.

For axles with varying axle spacings, the followings are printed:

THE GOVERNING LOAD POSITION FOR THE POSITIVE EFFECT IS:

List the analysis point number where the front axle of a truck was placed and the governing positive effect was produced.

THE GOVERNING AXLE LOADS ARE:

The first 16 axle loads of the above truck are listed here.

THE GOVERNING AXLE SPACINGS ARE:

The first 16 axle spacings of above truck are listed here.

THE COUNTERS FOR VARYING SPACING FOR THE POSITIVE EFFECT IS:

List the counter numbers for varying spacings where the governing positive effect was produced

THE GOVERNING LOAD POSITION FOR THE NEGATIVE EFFECT IS:

List the analysis point number where the front axle of a truck was placed and the governing negative effect was produced

THE GOVERNING AXLE LOADS ARE:

The first 16 axle loads of the above truck are listed here.

THE GOVERNING AXLE SPACINGS ARE:

The first 16 axle spacings of above truck are listed here.

THE COUNTERS FOR VARYING SPACING FOR THE NEGATIVE EFFECT IS:

List the counter numbers for varying spacings where the governing positive effect was produced

THE SPACING AFTER THE FIRST VARYING AXLE AT NO ? FOR THE POSITIVE EFFECT IS

List the first varying axle number and spacings where the governing positive effect was produced

THE SPACING AFTER THE FIRST VARYING AXLE AT NO ? FOR THE NEGATIVE EFFECT IS

List the first varying axle number and spacings where the governing negative effect was produced

THE SPACING AFTER THE SECOND VARYING AXLE AT NO ? FOR THE POSITIVE EFFECT IS

List the second varying axle number and spacings where the governing positive effect was produced

THE SPACING AFTER THE SECOND VARYING AXLE AT NO ? FOR THE
NEGATIVE EFFECT IS

List the second varying axle number and spacings where the governing negative effect was produced

6.5 KNOWN INFLUENCE LINE

When NO. OF SPAN = 99, a set of known influence lines will be analyzed for a given live load. For each known influence line, the following values are printed for a given live load:

LANE LOAD POS AREA

The total area under the positive regions of the influence line.

LANE LOAD POS EFFECT

The total positive effect due to the lane load.

LANE LOAD NEG AREA

The total area under the negative regions of the influence line.

LANE LOAD NEG EFFECT

The total negative effect due to the lane load.

TRUCK LOAD POS EFFECT

The maximum positive effect due to the truck load.

TRUCK LOAD AXLE 1 @

The position of the first truck axle measured from the beginning of influence line when the maximum effect was found.

TRUCK LOAD MOVING

The direction in which the truck was moving when the maximum effect was found. L TO R is from left to right or R TO L is from right to left.

TRUCK LOAD NEG EFFECT

The maximum negative effect due to the truck load.

Chapter 6 Description of Output

TRUCK LOAD AXLE 1 @

The position of the first truck axle measured from the beginning of influence line when the maximum effect was found.

TRUCK LOAD MOVING

The direction in which the truck was moving when the maximum effect was found. L TO R is from left to right or R TO L is from right to left.

6.6 MOVING LOAD GROUP (KNOWN INFLUENCE LINES ONLY)

For each known influence line, the following values are printed for a given moving load group:

LOAD GROUP FROM RIGHT TO LEFT and LOAD GROUP FROM LEFT TO RIGHT

The travelling direction of the load group when the maximum and minimum effect was found. This reflects the beginning and end of the load group relative to the beginning of the influence line.

MAXIMUM AND MINIMUM EFFECT

The maximum positive effect and the maximum negative effect due to the moving load group traversing the influence line in the designated direction.

CONCURRENT MOMENT, SHEAR OR THRUST

The concurrent effects computed by placing the critical position of the load group on the other influence lines in this set of known influence lines.

7

EXAMPLE PROBLEMS

This chapter contains six (6) example problems to aid users in preparing data for their problems. A general description, and a description of the required input, along with completed input forms, are given for each example. Refer to Chapter 5 Input Data Requirements when preparing data for your specific problem. The following six example problems are included in this chapter.

1. Example Problem 1 – Symmetrical two-span continuous wide-flange beam with a dead load condition.
2. Example Problem 2 – Three-span continuous beam with two in-span hinges at span 2 and with the PHL93 loading condition.
3. Example Problem 3 – Three-span continuous beam with support settlements as a loading condition.
4. Example Problem 4 – Four-span continuous beam to calculate the effects due to creep in a prestressed beam made continuous.
5. Example Problem 5 – Symmetrical continuous cantilevered floorbeam analyzed for dead loads acting at the stringer locations.
6. Example Problem 6 – Moving load group over a set of known influence lines generated by BXLRFD program.

The actual input data files and resulting output for the example problems are not listed in this manual, but input files are included electronically with the executable program and can be run so that the output can be viewed.

7.1 EXAMPLE PROBLEM 1

7.1.1 Problem Description

This is an example of a symmetrical two-span continuous beam with a dead load condition. A uniform load equal to the weight of a slab pour is positioned over the center support. The beams are wide flange W36x135 and each of the two spans is 89.0 feet in length. Input values and computed values are in U.S. Customary units. Refer to the sketch in Figure 7.1-1 on page 7-3.

7.1.2 Input

The following input lines are entered. Refer to the completed input data sheets shown in Figure 7.1-2 on page 7-4.

1. Beam Data and Design Live Loads

- TYPE is "1" to identify that this is a BEAM DATA line.
- UNITS is "U" indicating that all input values and computed values are to be in U.S. Customary units.
- NO. OF SPANS is 2.
- ANALYSIS POINTS is 29, indicating that values be reported at 20th points and user defined points.
- CONT is "C" indicating continuous spans with no in-span hinges.
- E is 29,000 ksi.
- SYMMETRY is "Y", indicating that beam is symmetric about the center support.
- OUTPUT is "0", indicating that an output file with annotations (including input data echo and load effects is desired. **No pdf will be created.**
- LOADING is "0" for a system of dead loads.

2. Span Lengths

- TYPE is "2" to identify that this is a SPAN LENGTHS line.
- The span length of 89.00 feet measured center-to-center of bearing is taken from plans.

Only one span length is entered because the 2-span continuous beam is symmetrical about the center support.

3. Section Properties

- TYPE is "5" to identify that this is a SECTION PROPERTIES line.
- SPAN NO. is 1 for the first span.
- RANGE is 89.00 indicating that the properties are uniform over the full length of the span.
- M OF I is 8900.00 in⁴.

Properties are entered for only one span because the 2-span continuous beam is symmetrical about the center support.

4. Dead Loads or Points of Contraflexure

Chapter 7 Example Problems

- TYPE is "6" to identify that this is a DEAD LOADS line.
- SPAN NO. is 1 for the first span.
- DISTANCE TO BEGIN is 39.00 feet indicating the point where the uniform dead load begins.
- DISTANCE TO END is 89.00 feet indicating that the uniform dead load ends at the end of the span.
- LOAD AT BEGIN is 0.59 k/ft indicating that the uniform load is acting in the downward direction
- LOAD AT END is 0.59 k/ft.

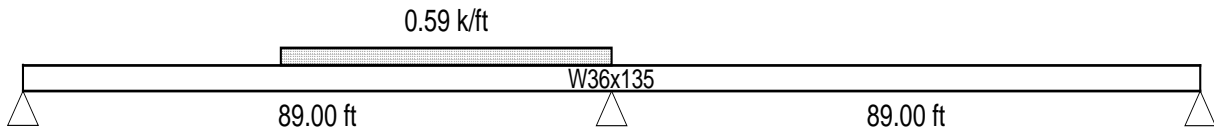


Figure 7.1-1 Example Problem 1 - Sketch

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PROBLEM IDENTIFICATION	
1	72
* CONTINUOUS BEAM ANALYSIS - EXAMPLE PROBLEM 1	
* 2 - SPAN, SYMMETRICAL CONTINUOUS WIDELANGE BEAM	
* PARTIAL DEAD LOAD CONDITION	

BEAM DATA AND DESIGN LIVE LOADS

TYPE	NO. OF SPANS	ANALYSIS POINTS	CONT.	E	SYMMETRY	LOADING OUTPUT	DEFLECTION DF	IMPACT FACTOR	SPEC LANE LOAD	DESIGN TRUCK			DESIGN TANDEM	DESIGN LANE LOAD	CONC. LOAD MOMENT	CONC. LOAD SHEAR	REACT ONLY	DIRECT.	STD
										P1	P2	P3							
1	2	9	C	2	9	0	0	0	0	0	0	0	0	58	64	70	76	77	78
1	2	3							27										
1	2	3							22										
1	2	3							14	15	16	17							
1	2	3							33	34									

SPAN LENGTHS

TYPE	1	2	3	4	5	6	7	8	9	10	
1	2	8	14	20	26	32	38	44	50	56	61
2	8	9	0								
2											

HINGE LOCATIONS

TYPE	SPAN NO.	DISTANCE	SPAN NO.	DISTANCE	SPAN NO.	DISTANCE	SPAN NO.	DISTANCE	SPAN NO.	DISTANCE	SPAN NO.	DISTANCE					
1	2	4	10	12	18	20	26	28	34	36	42	44	50	52	58	60	66
3																	
3																	

Figure 7.1-2 Example Problem 1 - Input

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SPAN NO.		SECTION PROPERTIES											
TYPE		RANGE	M OF I	RANGE	M OF I	RANGE	M OF I	RANGE	M OF I	RANGE	M OF I	RANGE	M OF I
1	2	4	10	18	24	32	38	46	52	60	66	73	
5	1	.891.00	7810.100										
5													
5													
5													
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Figure 7.1.2 Example Problem 1 – Input (cont.)

7.2 EXAMPLE PROBLEM 2

7.2.1 Problem Description

This is an example of a three-span continuous **beam** with the **LRFD** PHL93 loading condition. The center span has two hinges. There are numerous changes in section properties along the girder, and analysis points are defined at each of these sections. Input values and computed values are in SI (metric) units. Refer to the sketch in Figure 7.2-1 on page 7-9.

7.2.2 Input

The following input lines are entered. Refer to the completed input data sheets shown in Figure 7.2-2 on page 7-10.

1. Beam Data and Design Live Loads
 - TYPE is "1" to identify that this is a BEAM DATA line.
 - UNITS is "M" indicating that all input values and computed values are to be in Metric units.
 - NO. OF SPANS is 3.
 - ANALYSIS POINTS is 29, indicating that values be reported at 20th points and user-defined points.
 - CONT is "H" indicating continuous spans with in-span hinges.
 - E is 199,948 MPa.
 - SYMMETRY is left blank, indicating that the beam is unsymmetrical.
 - OUTPUT is "0", indicating that an output file with annotations (including input data echo and load effects) is desired. **No pdf will be created.**
 - LOADING is "3" for the PHL93 Loading.
 - DEFLECTION DF is 0.500 computed by dividing 2 lanes by 4 beams.
 - IMPACT FACTOR is 1.33.
2. Span Lengths
 - TYPE is "2" to identify that this is a SPAN LENGTHS line.
 - The span lengths of 44.425, 51.816 and 44.476 meters measured center-to-center of bearing are taken from plans.
3. Hinge Locations
 - TYPE is "3" to identify that this is a HINGE LOCATIONS line.
 - The first SPAN NO. is 2 because the hinge is in the second span.
 - The first DISTANCE is 9.525 indicating that the first hinge is 9.525 meters from the beginning of the span.
 - The second SPAN NO. is 2 because the next hinge is also in the second span.

Chapter 7 Example Problems

- The second DISTANCE is 43.053 indicating that the next hinge is 43.053 meters from the beginning of the span.

4. Analysis Points

- TYPE is "4" to identify that this is an ANALYSIS POINTS line.
- SPAN NO. is 1 for points in the first span.
- X1 through X9 are distances measured from the beginning of span 1 where moments, shears and deflections are desired.

These are specific points other than at the 10th or 20th points. This procedure is repeated to code analysis points for spans two and three.

5. Section Properties

- TYPE is "5" to identify that this is a SECTION PROPERTIES line.
- SPAN NO. is 1 for the first span.
- The first RANGE is 4.572 indicating that the properties from the beginning of the span up to 4.572 meters are being defined.
- The first M OF I is 27.87776 10⁹mm⁴ which is the moment of inertia for the first range of this continuous girder.

This procedure is repeated to code section properties for all ranges of all three spans. Note that the last range coded for each span is equal to the span length.

6. Dead Loads or Points of Contraflexure

- TYPE is "6" to identify that this is a DEAD LOADS OR POINTS OF CONTRAFLEXURE line.
- On the first line, SPAN is 1 indicating entry of the points of contraflexure for the first span.
- DISTANCE TO BEGIN OR POC is entered as zero because the first POC in the first span must be zero.
- DISTANCE TO END OR POC is entered as 35.5 meters indicating the distance to the point of dead load contraflexure in the first span measured from the centerline of the left bearing.
- On the next line, SPAN is 2 indicating entry of the points of contraflexure for the second span.
- DISTANCE TO BEGIN OR POC is entered as 9.525 meters indicating the distance to the first point of dead load contraflexure in the second span measured from the centerline of the left bearing.
- DISTANCE TO END OR POC is entered as 43.053 meters indicating the distance to the second point of dead load contraflexure in the second span measured from the centerline of the left bearing.
- On the next line, SPAN is 3 indicating entry of the points of contraflexure for the third span.
- DISTANCE TO BEGIN OR POC is entered as 8.5 meters indicating the distance to the point of dead load contraflexure in the third span measured from the centerline of the left bearing.
- DISTANCE TO END OR POC is entered as 44.476 meters because the second POC in the last span must be equal to the span length.

These dead load points of contraflexure were obtained by making a separate CBA run with a uniform dead load.

Chapter 7 Example Problems

7. Live Load Distribution Factors

- TYPE is "A" to identify that this is a LIVE LOAD DISTRIBUTION FACTORS line.
- On the first line, SPAN is 1 indicating entry of live load distribution factors for the first span.
- MOMENT DF1 is 0.965 as per LRFD 4.6.2.2.
- MOMENT DF2 is 0.958 as per LRFD 4.6.2.2. *It will be applied to the negative moments between the points of contraflexure over the interior support. The first area is from 35.5 m at span 1 to 9.525 m at span 2. The second area is from 43.054 m at span 2 to 8.5 m at span 3.*
- SHEAR DF1 is 1.098 as per LRFD 4.6.2.2.
- SHEAR DF2 is 1.098 as per LRFD 4.6.2.2.
- REACTION DF1 is blank
- REACTION DF2 is blank

This procedure is repeated to code live load distribution factors for spans two and three.

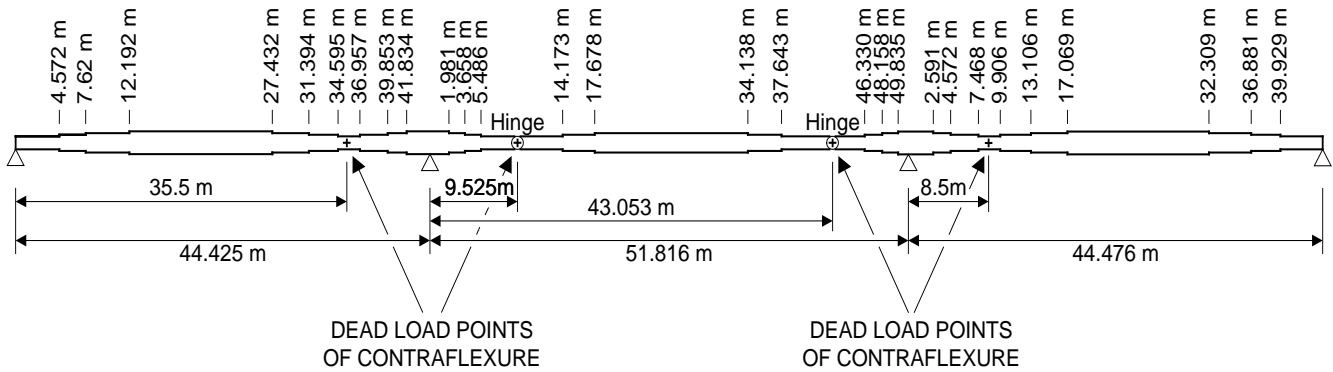


Figure 7.2-1 Example Problem 2 - Sketch

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PROBLEM IDENTIFICATION	
1	72
* CONTINUOUS BEAM ANALYSIS - EXAMPLE PROBLEM 2	
* 3 - SPAN CONTINUOUS GIRDER WITH TWO HINGES - S.I. UNITS	
* PHIL93, LOADING	

BEAM DATA AND DESIGN LIVE LOADS

TYPE	NO. OF SPANS	ANALYSIS POINTS	E	SYMMETRY	LOADING	DEFLECTION DF	IMPACT FACTOR	SPEC LANE LOAD	DESIGN TRUCK			DESIGN TANDEM P	DESIGN LANE LOAD	CONC. LOAD MOMENT	CONC. LOAD SHEAR	REACT ONLY	DIRECT.	STD			
									INCLUDE	P1	P2								P3		
1	2	3	5	7	8	14	15	16	17	27	33	34	40	46	52	58	64	70	76	77	78
1	M	3	2	9	H	1	9	9	4	8	0	3	0	1	5	0	0	1	1	3	3

SPAN LENGTHS

TYPE	1	2	3	4	5	6	7	8	9	10			
1	2	8	14	20	26	32	38	44	50	56	61		
2	4	1	2	5	1	8	1	6	4	4	1	7	6
2													

HINGE LOCATIONS

TYPE	SPAN NO.	DISTANCE	SPAN NO.	DISTANCE	SPAN NO.	DISTANCE	SPAN NO.	DISTANCE	SPAN NO.	DISTANCE							
1	2	4	10	12	18	20	26	28	34	36	42	44	50	52	58	60	66
3	2	9	5	2	5	2	4	3	0	5	3						
3																	

Figure 7.2-2 Example Problem 2 – Input

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SECTION PROPERTIES

TYPE	SPAN NO.	RANGE	M OF I	RANGE	M OF I	RANGE	M OF I	RANGE	M OF I	RANGE	M OF I	RANGE	M OF I
1	2	4	10	18	24	32	38	46	52	60	66	73	
5	1	4.5 7.2 2.7 .8 7.7 6	7 .6 2	3.8 .9 6.8 2.4	1.2 .1 9 2	5.0 .3 6 3.6 2	2.7 .4 3 2	6.2 .0 6.7 0.1	3.1 .3 9 4	5.0 .3 6 3.6 2			
5	1	3.4 .5 9.5 3.8 .9 6.8 2.4	3.6 .9 5.7	2.7 .8 7.7 7.6	3.9 .8 5.3 3.8	4.1 .8 3 4	5.0 .3 6 3.6 2	4.4 .4 2 5.6 2	4.4 .4 2 5.6 2	4.4 .4 2 5.6 2			
5	2	1 .9 8.1 6.2 .0 6.7 0.1	1 .6 5.8	5.0 .3 6 3.6 2	5 .4 8 6	3.8 .9 6.8 2.4	1.4 .1 7 3	2.7 .8 7.7 7.6	1.7 .6 7.8 3.7	5.0 .3 6 3.6 2			
5	2	3.4 .1 3.8 4.7 .4 8.6 0.2	3.7 .6 4.2	3.7 .5 6.5 3.2	4.6 .3 3 0.2	7 .8 7.7 7.6	4.8 .1 5.8	3.8 .9 6.8 2.4	4.9 .8 3.5 5.0	3.6 3.6 2			
5	2	5.1 .8 1.6	6.2 .0 6.7 0.1										
5	3	2 .5 9.1 6.2 .0 6.7 0.1	4 .5 7.2	5.0 .3 6 3.6 2	7 .4 6.8	3.8 .9 6.8 2.4	9 .9 0 6	2.7 .8 7.7 7.6	1.3 .1 0.6	3.8 .9 6.8 2.4			
5	3	1.7 .0 6.9 5.0 .3 6 3.6 2	3.2 .3 0.9	6.2 .0 6.7 0.1	3.6 .8 8.1	5.0 .3 6 3.6 2	3.9 .9 2 9	3.8 .9 6.8 2.4	4.4 .4 7.6 2.7	8.7 7.6			
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Figure 7.2.2 Example Problem 2 – Input (cont.)

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DEAD LOADS OR POINTS OF CONTRAFLEXURE

SPAN NO.	TYPE	4	10	16	22	28	34	40	46	51
		DISTANCE TO BEGIN OR POC	DISTANCE TO END OR POC	LOAD AT BEGIN	LOAD AT END	DISTANCE TO BEGIN	DISTANCE TO END	LOAD AT BEGIN	LOAD AT END	
1	6									
2	6	0.10	35.15							
3	6	9.525	43.053							
4	6	8.15	44.476							
5	6									
6	6									
7	6									
8	6									
9	6									
10	6									
11	6									
12	6									
13	6									
14	6									
15	6									
16	6									
17	6									
18	6									
19	6									
20	6									
21	6									
22	6									
23	6									
24	6									
25	6									
26	6									
27	6									
28	6									
29	6									
30	6									
31	6									
32	6									
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34	6									
35	6									
36	6									
37	6									
38	6									
39	6									
40	6									
41	6									
42	6									
43	6									
44	6									
45	6									
46	6									
47	6									
48	6									
49	6									
50	6									
51	6									

Figure 7.2.2 Example Problem 2 – Input (cont.)

7.3 EXAMPLE PROBLEM 3

7.3.1 Problem Description

This is an example of a 3-span continuous beam with support settlements as a loading condition. Refer to the sketch in Figure 7.3-1 on page 7-16.

7.3.2 Input

The following input lines are entered. Refer to the completed input data sheets shown in Figure 7.3-2 on page 7-17.

1. Beam Data and Design Live Loads

- TYPE is "1" to identify that this is a BEAM DATA line.
- UNITS is "U" indicating that all input values and computed values are to be in U.S. Customary units.
- NO. OF SPANS is 3.
- ANALYSIS POINTS is 19, indicating that values be reported at 10th points and user defined points.
- CONT is "C" indicating continuous spans with no in-span hinges.
- E is 29,000 ksi.
- SYMMETRY is left blank, indicating that the beam is unsymmetrical.
- OUTPUT is "0", indicating that a tabulated output file with annotations (including input data echo and load effects is desired. No pdf will be created.
- LOADING is "1" for support settlements.

2. Span Lengths

- TYPE is "2" to identify that this is a SPAN LENGTHS line.
- The span lengths of 82.03, 131.24 and 98.43 feet measured center-to-center of bearing are taken from plans.

3. Analysis Points

- TYPE is "4" to identify that this is an ANALYSIS POINTS line.
- SPAN NO. is 1 for points in the first span.
- X1 and X2 are distances measured from the beginning of span 1 where moments, shears and deflections are desired.

These are specific points other than at the 10th points. This procedure is repeated to code analysis points for spans two and three.

4. Section Properties

- TYPE is "5" to identify that this is a SECTION PROPERTIES line.
- SPAN NO. is 1 for the first span.
- The first RANGE is 82.03 indicating that the properties for the entire span length are being defined.

Chapter 7 Example Problems

- The first M OF I is $750,000 \text{ in}^4$ which is the moment of inertia for the first span of this continuous girder.

This procedure is repeated to code section properties for all ranges of all three spans. Note that the last range coded for each span is equal to the span length.

5. Support Settlements

- TYPE is "8" to identify that this is a SUPPORT SETTLEMENTS line.
- The first SUPPORT NO. is "2" to indicating settlement at the second support.
- SETTLEMENT is 0.75 inches at the second support.
- The second SUPPORT NO. is "3" to indicating settlement at the third support.
- SETTLEMENT is -0.5 inches at the second support. The negative value indicates that this support moved vertically upward.

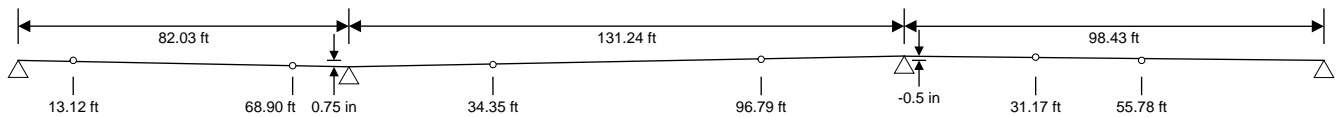


Figure 7.3-1 Example Problem 3 - Sketch

CBA
CONTINUOUS BEAM ANALYSIS

PENNSYLVANIA DEPARTMENT OF TRANSPORTATION
BUREAU OF INFORMATION SYSTEMS

PROBLEM IDENTIFICATION	
1	72
* CONTINUOUS BEAM ANALYSIS - EXAMPLE PROBLEM 3	
* 3 - SPAN CONTINUOUS GIRDER - U.S. CUSTOMARY UNITS	
* SETTLEMENT OF SUPPORTS	

BEAM DATA AND DESIGN LIVE LOADS

TYPE	UNITS	NO. OF SPANS	ANALYSIS POINTS	CONT.	E	SYMMETRY	LOADING OUTPUT	DEFLECTION DF	IMPACT FACTOR	SPEC LANE LOAD	DESIGN TRUCK			DESIGN TANDEM P	DESIGN LANE LOAD	CONC. LOAD MOMENT	CONC. LOAD SHEAR	REACT ONLY	DIRECT.	STD		
											P1	P2	P3									
1	2	3	5	7	8	14	15	16	17	27	33	34	40	46	52	58	64	70	76	77	78	
1	U	3	1	9	C	2	9	0	0	0	0	1										

SPAN LENGTHS

TYPE	1	2	3	4	5	6	7	8	9	10												
1	2	8	14	20	26	32	38	44	50	56	61											
2	8	2	0	3	1	3	1	2	4	9	8	1	4	3								
2																						

HINGE LOCATIONS

TYPE	SPAN NO.	DISTANCE	SPAN NO.	DISTANCE	SPAN NO.	DISTANCE	SPAN NO.	DISTANCE	SPAN NO.	DISTANCE	SPAN NO.	DISTANCE					
1	2	4	10	12	18	20	26	28	34	36	42	44	50	52	58	60	66
3																	

Figure 7.3-2 Example Problem 3 – Input

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CBA
CONTINUOUS BEAM ANALYSIS

SPAN NO.		SECTION PROPERTIES													
TYPE		RANGE	M OF I	RANGE	M OF I	RANGE	M OF I	RANGE	M OF I	RANGE	M OF I	RANGE	M OF I	RANGE	M OF I
1	2	4	10	18	24	32	38	46	52	60	66	73			
5	1	8,2,1,0,3	7,5,0,0,0,0,1,1												
5	2	1,3,1,1,2,4	7,5,0,0,0,0,0,1												
5	3	9,8,1,4,3	7,5,0,0,0,0,0,1												
5															
5															
5															
5															
5															
5															
5															
5															
5															
5															
5															
5															
5															
5															
5															
5															
5															
5															

Figure 7.3.2 Example Problem 3 – Input (cont.)

CBA
CONTINUOUS BEAM ANALYSIS

PENNSYLVANIA DEPARTMENT OF TRANSPORTATION
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SPECIAL LIVE LOAD

TYPE	AXLE LOAD	DIST	AXLE LOAD	DIST	AXLE LOAD	DIST	AXLE LOAD	DIST	AXLE LOAD	DIST	AXLE LOAD	DIST
1	2	8	14	20	26	32	38	44	50	56	61	61
7												
7												
7												
7												

SUPPORT SETTLEMENTS

TYPE	SUPPORT NO.	SETTLEMENT	SUPPORT NO.	SETTLEMENT	SUPPORT NO.	SETTLEMENT	SUPPORT NO.	SETTLEMENT	SUPPORT NO.	SETTLEMENT	SUPPORT NO.	SETTLEMENT
1	2	4	10	12	18	20	26	28	34	36	42	44
8	2	0.75	3	0.5								
8												

FIXED END ACTIONS

TYPE	FIXED END MOMENT		FIXED END REACTION		FIXED END REACTION		FIXED END MOMENT		FIXED END REACTION		
	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	
1	2	4	13	22	31	40	42	61	60	69	77
9											
9											
9											

Figure 7.3.2 Example Problem 3 – Input (cont.)

7.4 EXAMPLE PROBLEM 4

7.4.1 Problem Description

This is an example of a four-span continuous beam to calculate the effects due to creep in a prestressed beam made continuous. The fixed-end actions due to creep are calculated elsewhere and are entered here as a loading condition. Refer to the sketch in Figure 7.4-1 on page 7-22.

7.4.2 Input

The following input lines are entered. Refer to the completed input data sheets shown in Figure 7.4-2 on page 7-23.

1. Beam Data and Design Live Loads

- TYPE is "1" to identify that this is a BEAM DATA line.
- UNITS is "U" indicating that all input values and computed values are to be in U.S. Customary units.
- NO. OF SPANS is 4.
- ANALYSIS POINTS is 29, indicating that values be reported at 20th points and user defined points.
- CONT is "C" indicating continuous spans with no in-span hinges.
- E is 29,000 ksi.
- SYMMETRY is "Y", indicating that the beam is symmetrical about the center (3rd) support.
- OUTPUT is "0", indicating that a tabulated output file with annotations (including input data echo and load effects) is desired. **No pdf will be created.**
- LOADING is "2" for creep effects.

2. Span Lengths

- TYPE is "2" to identify that this is a SPAN LENGTHS line.
- Two span lengths of 100 feet each measured center-to-center of bearing are taken from plans.

3. Analysis Points

- TYPE is "4" to identify that this is an ANALYSIS POINTS line.
- SPAN NO. is 1 for points in the first span.
- X1 is the distance measured from the beginning of span 1 to where moments, shears and deflections are desired.

4. Section Properties

- TYPE is "5" to identify that this is a SECTION PROPERTIES line.
- The first SPAN NO. is 1 for the first span.
- RANGE is 100 indicating that the properties are for the entire span.
- M OF I is 50,000 in⁴ which is the moment of inertia for the entire girder.

This procedure is repeated to code section properties for span two. Since this girder has been designated as symmetrical, the properties are only entered to the point of symmetry which is the end

Chapter 7 Example Problems

of span two.

5. Fixed-End Actions

- TYPE is "9" to identify that this is a FIXED-END ACTIONS line.
- The first SPAN NO. is 1 indicating actions for the first span.
- FIXED-END MOMENT LEFT is 0 k-ft.
- FIXED-END MOMENT RIGHT is 150 k-ft.
- FIXED-END REACTION LEFT is 1.5 kips.
- FIXED-END REACTION RIGHT is -1.5 kips.

This procedure is repeated to code the actions for span two. Since this girder has been designated as symmetrical, the actions are only entered to the point of symmetry which is the right end of span two.

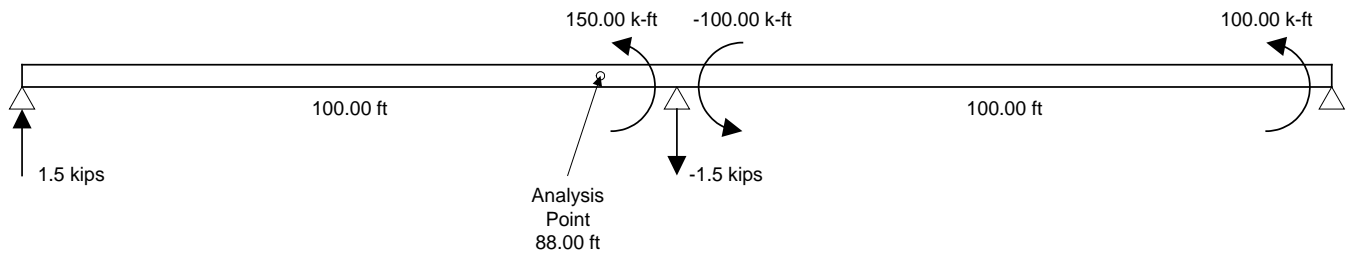


Figure 7.4-1 Example Problem 4 - Sketch

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CONTINUOUS BEAM ANALYSIS

PENNSYLVANIA DEPARTMENT OF TRANSPORTATION
BUREAU OF INFORMATION SYSTEMS

PROBLEM IDENTIFICATION

1	72
* CONTINUOUS BEAM ANALYSIS - EXAMPLE PROBLEM 4	
* 4 - SPAN SYMMETRIC CONTINUOUS BEAM U.S. CUSTOMARY UNITS	
* FIXED END ACTIONS	

BEAM DATA AND DESIGN LIVE LOADS

TYPE	UNITS	NO OF SPANS	ANALYSIS POINTS	CONT.	E	SYMMETRY	OUTPUT	LOADING	DEFLECTION DF	IMPACT FACTOR	SPEC LANE LOAD	DESIGN TRUCK			DESIGN TANDEM P	DESIGN LANE LOAD	CONC. LOAD MOMENT	CONC. LOAD SHEAR	REACT ONLY	DIRECT.	STD	
												P1	P2	P3								
1	2	3	5	7	8		14	15	16	17	27	33	34	40	46	52	58	64	70	76	77	78
1	U	4	2	9	C	2	9	0	0	1	0	2										

SPAN LENGTHS

TYPE	1	2	3	4	5	6	7	8	9	10
1	8									
1	2									
2	1	0	1	0	1	0	1	0	1	0
2										

HINGE LOCATIONS

TYPE	SPAN NO.	DISTANCE	SPAN NO.	DISTANCE	SPAN NO.	DISTANCE	SPAN NO.	DISTANCE	SPAN NO.	DISTANCE	SPAN NO.	DISTANCE
1	2	4	10	12	18	20	26	28	34	36	42	44
1	2	4	10	12	18	20	26	28	34	36	42	44
3												
3												

Figure 7.4-2 Example Problem 4 – Input

CBA
CONTINUOUS BEAM ANALYSIS

PENNSYLVANIA DEPARTMENT OF TRANSPORTATION
BUREAU OF INFORMATION SYSTEMS

SPECIAL LIVE LOAD

TYPE	AXLE LOAD	DIST	AXLE LOAD	DIST	AXLE LOAD	DIST	AXLE LOAD	DIST	AXLE LOAD	DIST	
1	2	8	14	20	26	32	38	44	50	56	61
7											
7											
7											
7											
7											

SUPPORT SETTLEMENTS

TYPE	AXLE LOAD	DIST	AXLE LOAD	DIST	AXLE LOAD	DIST	AXLE LOAD	DIST	AXLE LOAD	DIST						
1	2	4	10	12	18	20	26	28	36	42	44	50	52	58	60	65
8																
8																

FIXED END ACTIONS

TYPE	SPAN NO	FIXED END MOMENT		FIXED END REACTION		SPAN NO	FIXED END MOMENT		FIXED END REACTION		
		LEFT	RIGHT	LEFT	RIGHT		LEFT	RIGHT	LEFT	RIGHT	
1	2	4	13	22	31	40	42	51	60	69	77
9	1	0.	1,50.	1,5	-1,5	2	-1,0,0.	1,0,0.			
6											
6											
6											

Figure 7.4.2 Example Problem 4 – Input (cont.)

7.5 EXAMPLE PROBLEM 5

7.5.1 Problem Description

This is an example of a symmetrical continuous cantilevered floorbeam analyzed for dead loads acting at the stringer locations. A sketch of the floorbeam is shown in Figure 7.5.1 on page 7-29. All values are in U.S. customary units.

7.5.2 Input

The following input lines are entered. Refer to the completed input data sheets shown in Figure 7.5-2 on page 7-30.

1. Beam Data and Design Live Loads

- TYPE is "1" to identify that this is a BEAM DATA line.
- UNITS is "U" indicating that all input values and computed values are to be in U.S. Customary units.
- NO. OF SPANS is 0, indicating that this is a floorbeam.
- ANALYSIS POINTS is 09, indicating that values are to be reported at user defined points only.
- CONT is "C" indicating continuous spans with no in-span hinges.
- E is 29,000 ksi.
- SYMMETRY is "Y", indicating that the floorbeam is symmetrical about its center.
- OUTPUT is "0", indicating that a tabulated output file with annotations (including input data echo and load effects) is desired. **No pdf will be created.**
- LOADING is "0" for a system of dead loads (concentrated, uniform and/or trapezoidal loads).

2. Span Lengths

- TYPE is "2" to identify that this is a SPAN LENGTHS line.
 - The first span length is 7.83 feet which is the length of the left cantilever portion of the floorbeam.
 - The second span length is 67.00 feet which is the length of the floorbeam between supports.
- Because "Y" is entered for SYMMETRY, the third span length is assumed to be the same as the first.

3. Analysis Points

- TYPE is "4" to identify that this is an ANALYSIS POINTS line.
- The first SPAN NO. is 1 indicating points on the left cantilever.
- X1 through X6 are the distances measured from the left support. These values are negative indicating points to the left of the support. Points are entered from left to right along the floorbeam.
- The second SPAN NO. is 2 indicating points on the center span of the floorbeam.
- X1 through X6 are the distances measured from the left support.

Because "Y" is entered for SYMMETRY, the last distance entered is 33.50 feet which is the point of symmetry.

4. Section Properties

- TYPE is "5" to identify that this is a SECTION PROPERTIES line.
- The first SPAN NO. is 1 indicating properties on the left cantilever.
- The first RANGE is -7.80 feet indicating that the properties are for the segment of the left cantilever between the end of the cantilever and the next RANGE point (-6.33 feet).
- M OF I is 5626 in⁴ which is the moment of inertia for the first segment of the left cantilever.

This procedure is repeated to code section properties for all segments of the left cantilever. In this example, a second line of data is required to enter all left cantilever properties, so the SPAN NO. on the second line is still 1. Notice that the last RANGE entered for SPAN NO. 1 is 0.00 feet as required by the program.

- The SPAN NO. on the third line is 2 indicating properties for the center span of the floorbeam.
- The first RANGE for the center span of the floorbeam is 17.50 feet indicating that the properties are for the segment between the left support and this distance.
- M OF I is 54,324 in⁴ which is the moment of inertia for the first segment of the center span of the floorbeam.
- The second RANGE for the center span of the floorbeam is 33.50 feet indicating that the properties are for the segment between the previous RANGE point and this distance.
- M OF I is 66,751 in⁴ which is the moment of inertia for this segment.

Because "Y" is entered for SYMMETRY, the last RANGE entered is 33.50 feet which is the point of symmetry.

5. Dead Loads or Points of Contraflexure

- TYPE is "6" to identify that this is a DEAD LOADS line.
- The first SPAN NO. is 1 indicating loads on the left cantilever.
- DISTANCE TO BEGIN is -7.33 feet indicating that the load is at a point 7.33 feet to the left of the first support.
- DISTANCE TO END is left blank to indicate that this is a concentrated load.
- LOAD AT BEGIN is 43.37 kips which is the intensity of the concentrated load.
- LOAD AT END is left blank because this is a concentrated load.
- The next SPAN NO. is 2 indicating loads on the center span of the floorbeam.
- The first DISTANCE TO BEGIN for this span is 0.00 feet indicating that the load is over the left support.
- DISTANCE TO END is left blank to indicate that this is a concentrated load.
- The first LOAD AT BEGIN for this span is 53.903 kips which is the intensity of the concentrated load.
- LOAD AT END is left blank because this is a concentrated load.

The above procedure is repeated to enter the remaining loads on the center span of the floorbeam. Because "Y" is entered for SYMMETRY, the last RANGE entered is 33.50 feet which is the point of symmetry.

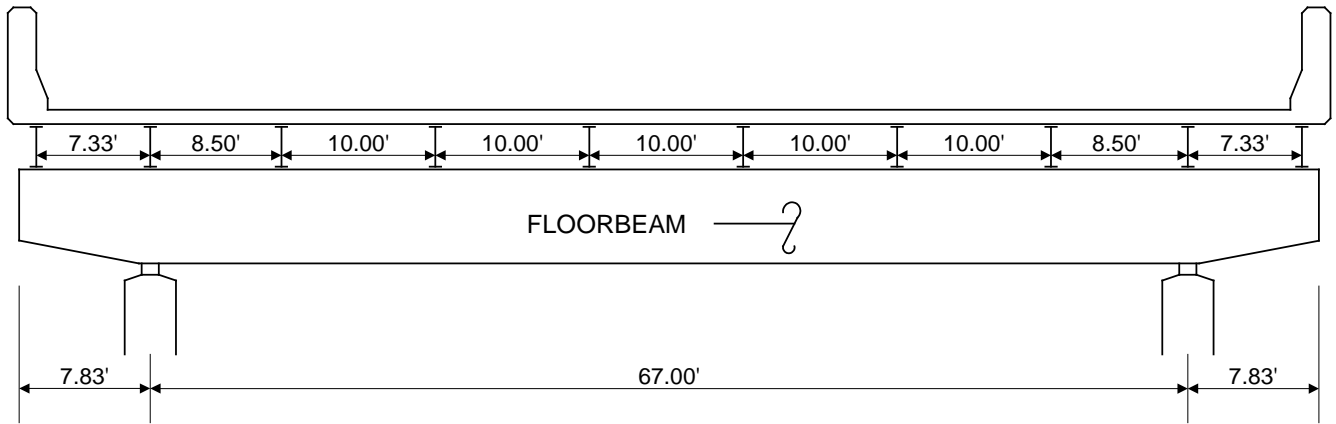


Figure 7.5-1 Example Problem 5 – Sketch

CBA
CONTINUOUS BEAM ANALYSIS

PENNSYLVANIA DEPARTMENT OF TRANSPORTATION
BUREAU OF INFORMATION SYSTEMS

PROBLEM IDENTIFICATION

1	72
* CONTINUOUS BEAM ANALYSIS - EXAMPLE PROBLEM 5	
* CONTINUOUS BEAM WITH SYMMETRICAL CANTILEVERS	
* DEAD LOAD CONDITION - CONCENTRATED LOADS AT STRINGER LOCATIONS	

BEAM DATA AND DESIGN LIVE LOADS

TYPE	UNITS	NO. OF SPANS	ANALYSIS POINTS	CONT.	E	SYMMETRY	OUTPUT	LOADING	DEFLECTION DF	IMPACT FACTOR	SPEC LANE LOAD	DESIGN TRUCK			DESIGN TANDEM P	DESIGN LANE LOAD	CONC. LOAD MOMENT	CONC. LOAD SHEAR	REACT ONLY	DIRECT.	STD	
												P1	P2	P3								
1	2	3	5	7	8	14	15	16	17	22	27	33	34	40	46	52	58	64	70	76	77	78
1	U	0	0	9	0	0	0	0	0													

SPAN LENGTHS

TYPE	1	2	3	4	5	6	7	8	9	10	
1	8		14	20	26	32	38	44	50	56	61
2	17	18	3								
2											

HINGE LOCATIONS

TYPE	SPAN NO.	DISTANCE	SPAN NO.	DISTANCE	SPAN NO.	DISTANCE	SPAN NO.	DISTANCE	SPAN NO.	DISTANCE	SPAN NO.	DISTANCE					
1	2	4	10	12	18	20	26	28	34	36	42	44	50	52	58	60	66
3																	
3																	

Figure 7.5-2 Example Problem 5 – Input

CBA
CONTINUOUS BEAM ANALYSIS

PENNSYLVANIA DEPARTMENT OF TRANSPORTATION
BUREAU OF INFORMATION SYSTEMS

TYPE		ANALYSIS POINTS										
		SPAN NO.	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10
1	2	4	10	16	22	28	34	40	46	52	58	63
4	1	-7.8,3	-6.2,6	-4.7,0	-3.1,3	-1.5,6	0.0,0					
4	2	0.0,0	6.7,0	1.3,4,0	2.0,1,0	2.6,.8,0	3.3,.5,0					
4												
4												
4												
4												
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4												
4												
4												

Figure 7.5.2 Example Problem 5 – Input (cont.)

7.6 EXAMPLE PROBLEM 6

7.6.1 Problem Description

This is an example that uses a moving load group over a set of known influence lines. The influence lines are for the low point of the fish channel in the bottom slab of a box culvert and were generated by PENNDOT's LRFD Box Culvert Design and Rating (BXLRFD) program. The moving group load represents the patch load due to the "Thru Fill" effect of the PHL93 Design Tandem Loading. The analysis point is designated "P" in the sketch of the structure shown in Figure 7.6-1 on page 7-36. All values are in SI (metric) units.

7.6.2 Input

The following input lines are entered. Refer to the completed input data sheets shown in Figure 7.6-2 on page 7-37.

1. Beam Data and Design Live Loads

- TYPE is "1" to identify that this is a BEAM DATA line.
- UNITS is "M" indicating that all input values and computed values are to be in SI (metric) units.
- NO. OF SPANS is 99, indicating that this job is running with a set of known influence lines.
- OUTPUT is "9", indicating output of influence lines with load effects is desired. **No pdf will be created.**
- LOADING is "C" for a Moving Load Group.

2. Moving Load Group

- TYPE is "C" to identify that this is a MOVING LOAD GROUP line.
- DISTANCE TO BEGIN is 0.0 meters which is the distance from the beginning of the load group to the start of the uniform load.
- DISTANCE TO END is 2.737 meters which is the distance from the beginning of the load group to the end of the uniform load.
- LOAD AT BEGIN is 102.30179 kN which is the intensity of the uniform load at the beginning of this load.
- LOAD AT END is 102.30179 kN which is the intensity of the uniform load at the end of this load.

3. **Known** Influence Line Distances

- TYPE is "D" to identify that this is an INFLUENCE LINE DISTANCES line.
- The first DISTANCE is 0.000 meters, the beginning of the influence line. This corresponds to the effect of a unit load being placed over the centerline of the left wall of the box culvert.
- The next DISTANCE is 0.1525 meters indicating that the next influence line ordinate corresponds to the effect of a unit load being placed 0.1525 meters from the beginning of the influence line which

is at the inside face of the left wall of the box culvert.

This procedure is repeated to code distances for each of the influence line ordinates. Notice that the last DISTANCE entered is 4.305 feet corresponding to placing a unit load over the centerline of the right wall of the box culvert.

4. **Known** Influence Line Ordinates

- TYPE is "E" to identify that this is an INFLUENCE LINE ORDINATES line.
- NUMBER is 1 indicating that this is the first set of INFLUENCE LINE ORDINATES.
- RESPONSE for the first line is "T" indicating that the type of response for these ordinates is thrust.
- The first ORDINATE on the first line is -0.07236 indicating that when a unit load is placed at the first distance (0.0000 meters), the corresponding thrust at the low point of the fish channel in the bottom slab of the box culvert is -0.07236 kN (compression).

This procedure is repeated to enter thrust ordinates corresponding to each of the distances. It takes 2 lines of data to code the 15 ordinates for thrust.

- NUMBER is 1 on the third line because this is still the first set of INFLUENCE LINE ORDINATES.
- RESPONSE for the third line is "S" indicating that the type of response for these ordinates is shear.
- The first ORDINATE on the third line is -0.12369 indicating that when a unit load is placed at the first distance (0.0000 meters), the corresponding shear at the low point of the fish channel in the bottom slab of the box culvert is -0.12369 kN.

This procedure is repeated to enter shear ordinates corresponding to each of the distances. It takes 2 lines of data to code the 15 ordinates for shear.

- NUMBER is 1 on the fifth line because this is still the first set of INFLUENCE LINE ORDINATES.
- RESPONSE for the fifth line is "M" indicating that the type of response for these ordinates is moment.
- The first ORDINATE on the fifth line is 0.13577 indicating that when a unit load is placed at the first distance (0.0000 meters), the corresponding moment at the low point of the fish channel in the bottom slab of the box culvert is 0.13577 kN-m.

This procedure is repeated to enter moment ordinates corresponding to each of the distances. It takes 2 lines of data to code the 15 ordinates for moment.

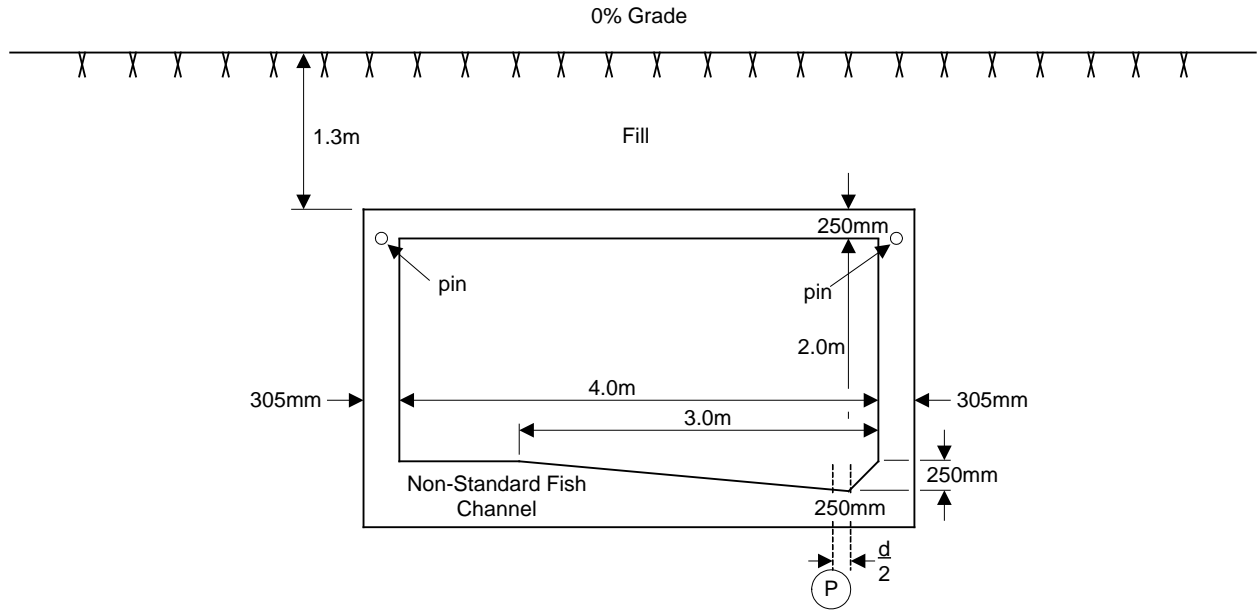


Figure 7.6-1 Example Problem 6 - Sketch

CBA
CONTINUOUS BEAM ANALYSIS

PENNSYLVANIA DEPARTMENT OF TRANSPORTATION
BUREAU OF INFORMATION SYSTEMS

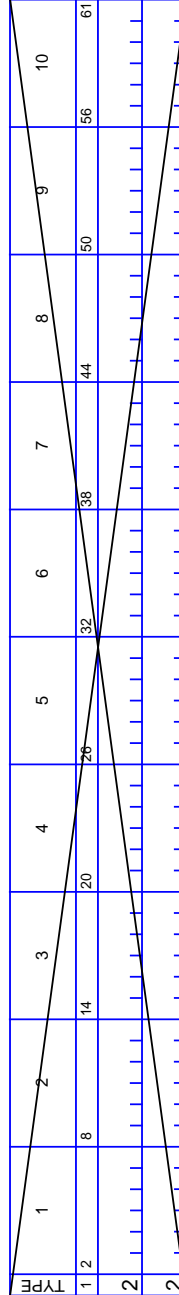
PROBLEM IDENTIFICATION

1	72
* CONTINUOUS BEAM ANALYSIS - EXAMPLE PROBLEM 6	
* MOVING GROUP LOAD	
* SET OF KNOWN INFLUENCE LINES	

BEAM DATA AND DESIGN LIVE LOADS

TYPE	NO OF SPANS	ANALYSIS POINTS	CONT.	E	SYMMETRY	LOADING OUTPUT	DEFLECTION DF	IMPACT FACTOR	SPEC LANE LOAD	DESIGN TRUCK			DESIGN TANDEM P	DESIGN LANE LOAD	CONC. LOAD MOMENT	CONC. LOAD SHEAR	REACT ONLY	DIRECT.	STD				
										INCLUDE	P1	P2								P3			
1	2	3	5	7	8	14	15	16	17	27	22	33	34	40	46	52	58	64	70	76	77	78	
1	M	9				9	C																

SPAN LENGTHS



HINGE LOCATIONS

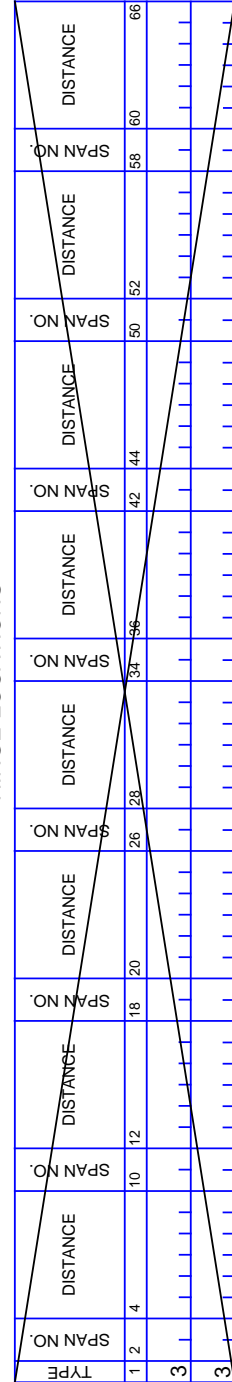


Figure 7.6-2 Example Problem 6 - Input

CBA
CONTINUOUS BEAM ANALYSIS

PENNSYLVANIA DEPARTMENT OF TRANSPORTATION
BUREAU OF INFORMATION SYSTEMS

INFLUENCE LINE DISTANCES

TYPE	DISTANCE	DISTANCE	DISTANCE	DISTANCE	DISTANCE	DISTANCE	DISTANCE	DISTANCE	DISTANCE	DISTANCE	DISTANCE	DISTANCE	
1	2	9	16	23	9	16	23	9	16	23	9	16	23
D	0	0	0	0	0	0	0	0	0	0	0	0	0
D	3	3	5	2	5	3	7	5	2	5	4	1	5
D													
D													
D													
D													
D													
D													

INFLUENCE LINE ORDINATES

TYPE	ORDINATE	ORDINATE	ORDINATE	ORDINATE	ORDINATE	ORDINATE	ORDINATE	ORDINATE	ORDINATE	ORDINATE	ORDINATE	ORDINATE	ORDINATE	ORDINATE	ORDINATE
1	2	3	4	11	18	25	32	39	46	53	60	67	73		
E	1	T		0	7	2	3	6	-	0	7	9	9	0	-
E	1	T		1	4	8	1	1	-	1	5	7	3	2	-
E	1	S		1	4	2	4	-	1	1	9	7	3	2	-
E	1	S		5	4	1	8	-	6	2	0	7	8	-	
E	1	M		1	3	5	7	0	1	1	7	3	0	1	1
E	1	M		0	1	3	5	8	0	0	0	2	8	6	0
E															
E															

Figure 7.6.2 Example Problem 6 – Input (cont.)

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8 TECHNICAL QUESTIONS AND REVISION REQUESTS

This chapter contains reply forms to make it easier for users to convey their questions, problems or comments to the proper unit within the Department. General procedures for using these forms are given. Users should keep the forms in the manual as master copies which can be reproduced as needed. They are also included as a Word template on the disk that has been provided for the program.

8.1 TECHNICAL QUESTIONS

Technical questions related to the interpretations of the design specifications as implemented in this program, why certain assumptions are made, applicability and limitations of this program, and other questions not related to the operation of this program can be directed to the appropriate person in PENNDOT using this form or the information provided on this form. Please review the information provided in this User's Manual and the references given in Chapter 1 before submitting this form for processing or calling for assistance. The completed form should be sent to the Bridge **Design and Technology** Division (see form for complete address).

8.2 REVISION REQUESTS

This form is to be used to report suspected program malfunctions that may require revisions to the program. It can also be used to request revisions that may be required due to changes in specifications and for the enhancement of the program. Unexpected or incorrect output, rejection of input data, endless program cycling, and program abortion are examples of program malfunctions. Users are requested to review their input data and the program User's Manual before submitting this form for processing.

This form may also be used to submit suggestions for improving the User's Manual for this program. Suggestions might include typographical error correction, clarification of confusing sections, expansion of certain sections, changes in format, and the inclusion of additional information, diagrams, or examples.

The completed form should be sent to the Engineering Unit via mail, fax, or e-mail.

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CBA

TECHNICAL QUESTIONS

This form is to be used to ask questions on technical issues related to this engineering program. Questions on the interpretations of the design specifications as implemented in this program, why certain assumptions are made by the program and other questions not related to the operation of this program may be submitted using this form or by calling the telephone number listed in this form. Users are requested to read the User's Manual, LRFD Specifications and DM-4 before submitting this form or calling to ask questions.

CONTACT PERSON: _____ DATE: _____
ORGANIZATION: _____ PHONE: _____
E-MAIL ADDRESS: _____ FAX: _____
PROGRAM VERSION: _____

Clearly state your question(s) and attach documentation you feel would be helpful in answering your question(s). If you require more space, use additional 8½ x 11 sheets of plain paper.

FORWARD COMPLETED FORM TO: Pennsylvania Department of Transportation
Bridge **Design and Technology** Division
P.O. Box 3560
Harrisburg, PA 17105-3560
PHONE: (717) 787-2881
FAX: (717) 787-2882

RECEIVED BY: _____ FOR DEPARTMENT USE ONLY
ASSIGNED TO: _____ DATE: _____

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CBA REVISION REQUEST

This form is to be used to report suspected program malfunctions, or to request revisions to the program or its documentation. Users are requested to review their input data and the program User's Manual before submitting this form.

CONTACT PERSON: _____ DATE: _____
ORGANIZATION: _____ PHONE: _____
E-MAIL ADDRESS: _____ FAX: _____
PROGRAM VERSION: _____

Define your problem and attach samples and/or documentation you feel would be helpful in correcting the problem. If the input data is more than 4 or 5 lines, Licensees should provide the input data file on a diskette. If you require more space, use additional 8½ x 11 sheets of plain paper.

FORWARD COMPLETED FORM TO: **Pennsylvania Office of Administration**
Bureau of **Business Solutions and Services**, Engineering Unit
P. O. Box 8213, Harrisburg, PA 17105-8213

PHONE: (717) 783-8822
FAX: (717) 705-5529
E-MAIL: PENNDOTBIEngineer@state.pa.us

FOR DEPARTMENT USE ONLY
RECEIVED BY: _____ ASSIGNED TO: _____ DATE: _____

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