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U.S. Department
of Transportation

**Federal Highway
Administration**

BOXCAR User and Programmer Manual,

Version 1.0

Research, Development, and Technology
Turner-Fairbank Highway Research Center
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McLean, Virginia 22101-2296

FOREWORD

This Implementation Package contains background information, user instructions, and technical reference material for BOXCAR, a microcomputer program for the structural analysis and design of single cell reinforced concrete box culverts. A similar manual is available for PIPECAR (FHWA-IP-89-019) a program for structural analysis and design of circular and horizontal elliptical reinforced concrete pipe. BOXCAR is intended to be a design tool for the practicing engineer. It designs buried reinforced concrete box culverts in accordance with AASHTO live load and reinforcing design requirements. This manual provides BOXCAR users with the information necessary to operate and interpret the program. BOXCAR and PIPECAR have been designated HY-10 in the FHWA Hydraulics Computer Program series.

Copies of each of the manuals are being distributed to Federal Highway Administration regional and division offices and each State highway agency. Program diskettes are being distributed under separate cover. Additional copies of the manuals and programs are available from McTrans, the Center for Microcomputers in Transportation, Gainesville, Florida 32611 and the National Technical Information Service, Springfield, Virginia 22161.

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Office of Engineering

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NOTICE

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16. Abstract

This Manual presents an overview, user instructions and technical backup for the computer program BOXCAR. BOXCAR is a program for the structural analysis and design of reinforced concrete box sections. It has been written to run on IBM or IBM compatible microcomputers. The input routines are user friendly; only minimal experience with computers is required prior to use. Most parameters can be controlled by the user. Knowledge of structural design codes for culverts is required.

BOXCAR completes structural analysis for loads due to box weight, soil weight, internal gravity fluid weight, live loads and user specified surcharge loads.

Forces resulting from each load condition may be printed out separately. Structural design is in accordance with AASHTO. Design criteria include ultimate flexure, diagonal tension, service load crack control, and service load fatigue.

The quantity of output is controlled by the user. All output is formatted for 8.5-by 11-inch paper.

User instructions include descriptions of all input variables and design examples. The programmer manual includes listings of all technical subroutines.

17. Key Words
Culverts, structural design, reinforced concrete, computer programs, box sections

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CONVERSION FACTORS TO SI METRIC UNITS

Multiply	by	to obtain
inches (in)	0.0254	meters (m)
inches (in)	2.54	centimeters (cm)
inches (in)	25.4	millimeters (mm)
feet (ft)	0.3048	meters (m)
yards (yd)	0.9144	meters (m)
miles (mi)	1.609	kilometers (km)
degrees (°)	0.01745	radians (rad)
acres (acre)	0.4047	hectares (ha)
acre-feet (acre-ft)	1233.	cubic meters (m^3)
gallons (gal)	3.785×10^{-3}	cubic meters (m^3)
gallons (gal)	3.785	liters (l)
pounds (lb)	0.4536	kilograms (kg)
tons (2000 lb)	907.2	kilograms (kg)
pounds force (lbf)	4.448	newtons (N)
pounds per sq in (psi)	6895.	newtons per sq m (N/m^2)
pounds per sq ft (psf)	47.88	newtons per sq m (N/m^2)
foot-pounds (ft-lb)	1.356	joules (J)
horsepowers (hp)	746.	watt (W)
British thermal units (Btu)	1055.	joules (J)

Some Definitions

newton - force that will accelerate a 1 kg mass at 1 m/s^2

joule - work done by a force of 1 N moving through a displacement of 1 m

1 newton per sq m (N/m^2) = 1 pascal (Pa)

1 kilogram force (kgf) = 9.807 N

1 gravity acceleration (g) = 9.807 m/s^2

1 hectare (ha) = 10.000 m^2

1 kip (k) = 1000 lb = 4448 N = 453.6 kgf = 0.5 ton

BOXCAR - Version 1.0

A Microcomputer Program for the Structural Design of Reinforced Concrete Box Sections

USER AND PROGRAMMER MANUAL

Developed by

Simpson Gumpertz & Heger Inc.
Alrington, Massachusetts

in Cooperation with

The Federal Highway Administration
and
The American Concrete Pipe Association

To Potential Users of BOXCAR:

This Manual provides user and programmer information for the computer program BOXCAR. To use this program you will need the following hardware and software:

- IBM PC, XT, AT or a similar IBM compatible computer.
- Printer. The output is formatted for 8.5 in. wide paper.
- An operating system equivalent to PC DOS Version 2.0 or higher.
- An 8087 or 80287 math coprocessor.
- A minimum of 640k bytes of memory.
- Two double density disk drives or a single double density disk drive and a hard disk drive.
- A minimum of 3 FILES and 1 BUFFER must be specified in the CONFIG.SYS file on the operating system boot disk. The number of FILES and BUFFERS are normally set to values higher than these. If you have not made any changes since the purchase of your computer, the number of each should be adequate. Refer to your DOS Manual for further information on FILE and BUFFER sizes.

BOXCAR is a computer program that is easy to use. A user with little computer experience may operate the program very quickly and with minimal reference to this manual; however, please do not be deceived by the simple operating characteristics of the program. Virtually all input parameters are user controlled and many are specified by various design codes and change for different applications and load conditions. Users should be qualified engineers capable of selecting proper input values based on the appropriate design code and capable of interpreting and evaluating the program output. To emphasize this, the following warning is printed during program start up and with each output file:

> The application of this non-proprietary software is the responsibility of the user. The user must select input values suitable to his specific installation. The use of default parameters does not assure a safe design for all installations. The information presented in the computer output is for review, interpretation, application and approval by a qualified engineer who must assume full responsibility for verifying that said output is appropriate and correct. There are no express or implied warranties. Use of this product does not constitute endorsement by FHWA or any other agents.

Users should note that box sections designed with BOXCAR will not require the same reinforcing as shown in current ASTM and AASHTO standards for precast box sections. Appendix C provides a brief explanation of the changes in analysis and design that result in these changes.

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PART I – GENERAL

1. INTRODUCTION

BOXCAR is a computer program that performs structural analysis and design of single cell reinforced concrete box culverts. The name BOXCAR is derived from the phrase "BOX Culvert Analysis and Reinforcing design." Internal dimensions of box culverts are sized based on consideration of hydraulic requirements and site characteristics and are then structurally designed to support the weight of earth, live and other loads that are imposed on them. A large number of references are available for the hydraulic design of box culverts. BOXCAR provides the structural analysis and reinforcing design. This computerized method of design allows the user to obtain reinforcing steel areas for user-specified box geometry, material properties and loading data.

BOXCAR completes the structural analysis and design of box sections by the following steps:

- Compute loads on the structure.
- Apply the calculated load to the structure through an assumed pressure distribution.
- Complete a structural analysis.
- Design reinforcing to carry the resulting moments thrusts and shears.

Other structural analysis programs are available that model the structure and the soil using the finite element technique; however, these programs offer a level of sophistication that is not required for the typical design situation and while some finite element programs are being written for microcomputers, they require considerable computer time to process.

BOXCAR is intended to be a design tool for the practicing engineer. For routine designs the engineer may input as little information as the span, rise, and depth of fill, and utilize a default file to generate the remainder of the input. For non-standard designs the engineer can override the default input parameters and use all the input menus to address the special conditions of his project. The user may quickly evaluate the effects of varying any of the input parameters in order to select the optimum design for a particular set of conditions. Because of its flexibility, BOXCAR is intended for use by engineers. Many of the input values require knowledge of design specifications which the user must be familiar with. To emphasize this BOXCAR prints the following warning with all output files:

> The application of this non-proprietary software product is the responsibility of the user. The user must select input values suitable to his specific installation. Use of default parameters does not assure a safe design for all installations. The information presented in the computer output is for review, interpretation, application, and approval by a qualified engineer who must assume full responsibility for verifying that said output is appropriate and correct. There are no express or implied warranties. Use of this product does not constitute endorsement by FHWA or any other agents.

This manual assumes the user has some basic understanding of computer usage. The user should be familiar with turning the computer on, activating the disk operating system (DOS), changing disk drives, and basic DOS commands.

1.1 Purpose of Manual

This User and Programmer Manual provides BOXCAR users with the information necessary to operate and interpret the program. The user information includes step-by-step procedures for running the program, entering data, and obtaining structural designs. Programming information includes general information on the program structure, Input/Output (I/O) generation, and descriptive program listings. This manual is organized as follows:

- Section 1 introduces the Manual and provides background information.
- Section 2 summarizes the program in general detail.
- Section 3 is the User Manual which provides step-by-step operating procedures.
- Section 4 describes the program output.
- Section 5 offers four example designs.
- Section 6 describes the program structure including general flow charts and program listings.
- Appendix A lists all BOXCAR input parameters and their initial default settings.

- Appendix B lists the reinforcing design method used in BOXCAR.
- Appendix C lists differences in the load assumptions and structural analysis that result in reinforcing areas that are different than those used to develop the current ASTM and AASHTO Standards.

1.2 Program History

BOXCAR and a similar program PIPECAR (for the design of reinforced concrete pipe culverts) were first released in 1982 as part of a Federal Highway Administration (FHWA) project to develop standard designs for improved inlets. This project was initiated to produce a design method for tapered culvert end structures. After an initial review, however, the method selected was to analyze and design one foot wide slices without consideration of the taper. This resulted in a program that was applicable to all box culverts, and hence the project report was titled "Structural Design Manual for Improved Inlets and Culverts" (Reference 1). As originally released, BOXCAR ran only on mainframe computers, and did not include any provisions for treatment of live loads.

BOXCAR is an extension of the programs that were used to develop the standard box culvert designs that are contained in American Association of State Highway and Transportation Officials (AASHTO) Standards M 259 and M 273, which are the same standards as ASTM C 789 and C 850, respectively. These standards provide reinforcing designs for precast concrete box sections reinforced with welded wire fabric and buried between zero and about twenty feet. These programs used the American Concrete Institute ultimate strength design method for obtaining steel areas. The development of these programs and test programs used to verify their designs is well documented (References 2, 3, and 4). This work was carried out under the sponsorship of the American Concrete Pipe Association and Wire Reinforcement Institute.

Subsequent to the development of the AASHTO Culvert Standards, a new design method was developed for reinforced concrete box and pipe culverts by Heger and McGrath (Reference 5). This method is included in Section 17 of the 13th Edition of the AASHTO Standard Specifications for Highway Bridges (Reference 6, referred to here as "AASHTO") and is the design method used by BOXCAR for obtaining steel reinforcing areas. The upgraded version of BOXCAR presented in this manual has the following new features:

- BOXCAR now runs on an IBM or IBM compatible personal computer (PC).
- Input and output routines are designed to make the program accessible to the inexperienced computer user.
- Capability of analysis and design for truck loading in accordance with AASHTO specifications and for railroad locomotives in accordance with American Railway Engineering Association (AREA) Manual for Railway Engineering (Reference 6).
- Capability for analysis and design of vertical and horizontal surcharge loads.
- Interactive stirrup design when stirrups are required.

These additional features provide greater usefulness and versatility as well as ease of use to BOXCAR users. The related program for pipe culverts called PIPECAR has also been upgraded.

2. PROGRAM OVERVIEW

2.1 Application

BOXCAR designs buried reinforced concrete box culverts in accordance with AASHTO or AREA live load requirements and AASHTO reinforcing design requirements. The program is general and can be used to design any single cell rectangular box culvert with or without haunches. Parameters that may be specified by the user include the following:

- Culvert geometry – span, rise, wall thicknesses and top and bottom haunch dimensions.
- Loading data – depth of fill, density of fill, minimum and maximum lateral pressure coefficients, soil-structure interaction factor, depth of internal fluid, density of fluid, truck loading, direction of truck loading, and vertical and lateral surcharge loads.
- Material properties – reinforcing tensile yield strength, concrete compressive strength, and concrete density.
- Design data – load factors, concrete cover over reinforcement, reinforcing diameter, reinforcing spacing, type of reinforcement used, layers of reinforcing used, and capacity reduction factors.

Only the span, rise, and depth of fill need to be specified by the user. If no values are specified for the remaining parameters the computer program will use standard default values. These default values may be easily changed to suit the user's particular needs.

The program has the following limitations.

- Only single cell box culverts can be considered;
- The range of spans permitted is 3 to 14 feet;
- The range of rises permitted is 2 to 14 feet;
- Longitudinal reinforcing requirements for shrinkage and temperature are not calculated.
- Anchorage and splice lengths of steel reinforcement must be calculated manually.

2.2 Method of Analysis and Design

2.2.1 Load Cases

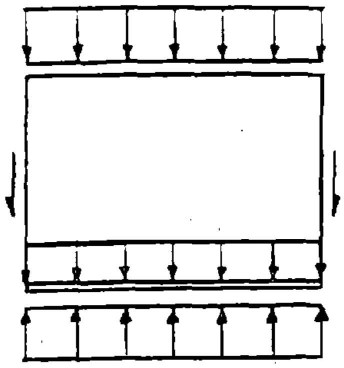
BOXCAR completes a separate structural analysis for each of the load conditions listed in Table 2-1 and shown graphically in Figure 2-1. For purposes of computing maximum design forces at each design location, the load cases are grouped into three categories:

- Permanent Dead Loads – Permanent dead loads are considered to be acting on the structure at all times. Service forces due to permanent dead loads are modified by the dead load factors to determine the ultimate forces.
- Additional Dead Loads – Additional dead loads are considered to be acting on the structure only if they increase the design force at the design section being considered. Service forces due to additional dead loads are modified by the dead load factors to determine the ultimate forces.
- Live Loads – Live loads are considered to be acting on the structure only if they increase the design force at the design section being considered. Service forces due to live loads are modified by the live load factors to determine the ultimate forces.

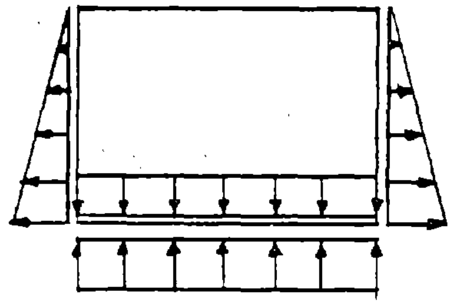
Culvert weight is computed based on the user specified wall thicknesses and concrete density.

Vertical soil load is computed as the soil prism load modified by a soil structure interaction factor. This allows the use of load theories other than the soil prism load when required by a particular installation condition.

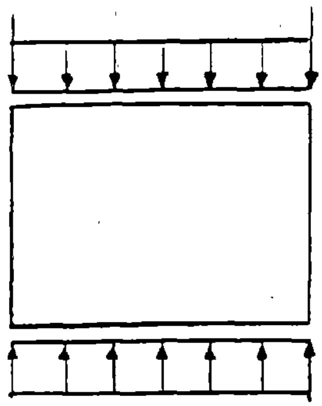
Lateral soil loads are taken as the vertical soil pressure times the user input lateral soil pressure coefficient. Separate values for the lateral soil pressure are computed at the top and bottom of the section, creating a linearly varying load. Computation of lateral loads neglects the effect of the soil structure interaction factor. Load case 5 applies the amount of lateral load that represents the difference between the minimum lateral pressure condition and the maximum lateral pressure condition.



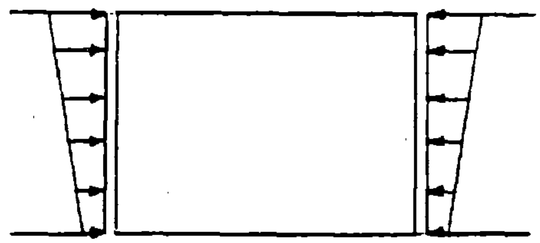
1. Culvert Weight



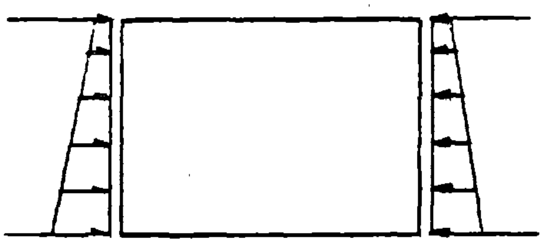
4. Internal Fluid Load



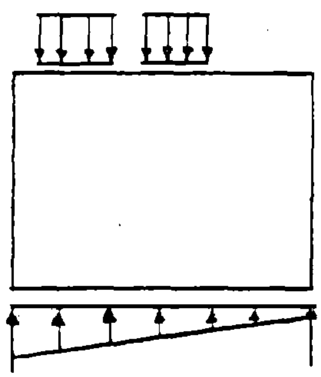
2. Vertical Earth Load
6. Uniform HS-Series Truck or Cooper E-Series Train
7. Uniform Interstate Truck
9. Vertical Surcharge Load



8. Approaching Truck or Train



3. Min. Lateral Soil Load
5. Max. Lateral Soil Load
10. Lateral Surcharge Load



11-21. Moving HS-Series Truck Wheel Loads
22-32. Moving Interstate Truck Wheel Loads

FIGURE 2-1 SINGLE CELL BOX SECTION LOAD CASES

TABLE 2-1
BOXCAR LOAD CASES

Load Case	Load Category (1)	Description
1	P	Culvert weight
2	P	Vertical soil weight
3	P	Minimum lateral soil pressure
4	A	Internal fluid weight (gravity only)
5	A	Additional lateral soil pressure
6	L	Uniform HS-Series truck load or railroad locomotive load
7	L	Uniform interstate truck load
8	L	Approaching vehicle load
9	P,A,L (2)	Uniform vertical surcharge load
10	P,A,L (2)	Linearly varying lateral surcharge load
11 to 21	L	Non-uniform HS-Series truck load (11 truck positions over culvert)
22 to 32	L	Non-uniform interstate truck load (11 truck positions over culvert)

Notes:
1. P = Permanent dead load
   A = Additional dead load
   L = Live load
2. User specifies load category for surcharge conditions

The internal fluid load is computed based on the user specified depth and density of fluid in the culvert. This is a gravity force only, no internal pressure may be specified.

BOXCAR provides two truck loading options: the HS-series truck, where the user may specify the magnitude (i.e. HS-20, HS-15, etc.) and the interstate truck, called the alternate military loading by AASTHO. When the interstate truck is specified BOXCAR also checks the HS-20 truck and designs for the most conservative condition. BOXCAR distributes truck loads through earth fills in accordance with AASHTO 3.24.3.2 for culverts with less than two feet of fill and Section 6.4 for culverts with more than two feet of fill. Two conditions are considered to allow for passing trucks:

Condition A - Condition A is a single lane with a fully overloaded truck.

Condition B - Condition B is a four lane road with a truck in each lane; however, to consider the low probability of overloaded trucks being in each lane at the same time, the beta factor (see AASHTO Section 3.22) is taken as 1.0.

Condition B controls service loads at all depths. Condition A controls the ultimate loads to a depth of about 10 ft.

For culverts where the load distribution length is less than the outside span of the culvert, eleven different truck positions (Load cases 11 to 21 or 22 to 32) are analyzed. If the load distribution width is more than the outside span of the culvert the analysis is based on a uniformly distributed load (Load cases 6 and 7). The effect of live load is considered at all depths of cover unless the user specifies no live load. Loads from individual wheels are only allowed to spread laterally to a width of 6 ft, which represents half of a lane width. This provides consideration of the passing truck condition. For HS vehicles only, the user may specify if the truck is moving transverse to the culvert flow (the typical load condition) or parallel to the culvert flow.

AREA locomotive loads are considered as uniform loads and are distributed through earth fill in accordance with AREA Section 8-16. Due to the stiffness of the ties and rails, a railroad loading is treated as a uniform load at depths greater than 1.5 ft. BOXCAR does not complete designs for railroad loadings with less than 1.5 ft of cover.

Loads due to approaching trucks are calculated using the method prescribed in AASHTO Specification M 259 and M 273. The lateral load pressure is equal to 700 psf divided by the depth of fill. For depths of fill less than 1 ft, a maximum value of 800 psf is applied. When the live load condition "Other" is used, the approaching wheel load lateral pressure distribution is the same as for HS-20 loading, modified by the magnitude of the user-specified wheel load magnitude relative to a HS-20 wheel load. For the approaching locomotive live load condition, the lateral pressure is 40 percent of the vertical live load pressure at the depth of the culvert in accordance with AREA Specifications.

Surcharge loads are user specified vertical and lateral pressures. The vertical surcharge load is a uniform load. The lateral surcharge load may vary linearly according to the user specified top and bottom load magnitudes. The load category is also user specified.

If the surcharge load is specified as a live load, the program assumes that the vertical and horizontal surcharges can act at once but not at the time as a vehicle live load.

2.2.2 Structural Analysis

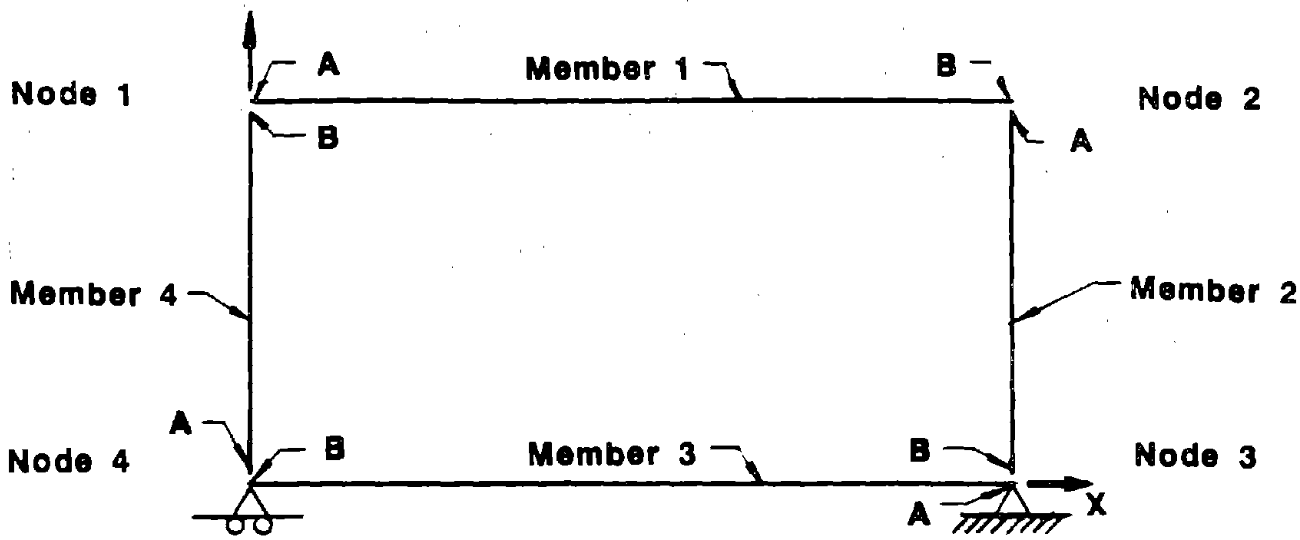
Design moments, thrusts, and shears, are determined by the stiffness matrix method of analysis. Box culverts are idealized as 4 member frames with a one foot unit width. The computer model coordinate system, member and joint designations, and support conditions are shown in Figure 2-2. For a given frame, member stiffness matrices are assembled into a global stiffness matrix; a joint load matrix is assembled; and conventional methods of matrix analysis are employed. Flexibility coefficients for a member with linearly varying haunches are determined by numerical integration. The trapezoidal rule with 50 integration points is used and a sufficiently high degree of accuracy is obtained.

The moments, thrusts, and shears due to each load case are summed separately for each design section. There are 11 design sections for the evaluation of flexural criteria and 12 design sections for the evaluation of diagonal tension strength (Figure 2-3). Design forces are determined by assuming the forces due to permanent load cases always act on the structure and adding the forces due to additional dead load and live load cases if they increase the maximum force.

2.2.3 Design of Reinforcing

Reinforcing design is in accordance with AASHTO design criteria. At flexural design locations the following criteria are evaluated:

- Ultimate flexural strength based on yielding of the tensile reinforcement.
- Minimum reinforcement.
- Maximum reinforcement based on concrete compression to ensure ductile behavior.
- Control of cracking at service loads.
- Fatigue.



Notes : 1. Member directions are taken clockwise. Thus end A of member 1 is at node 1 and end A of member 3 is at node 3.

2. Rotations are positive counterclockwise.

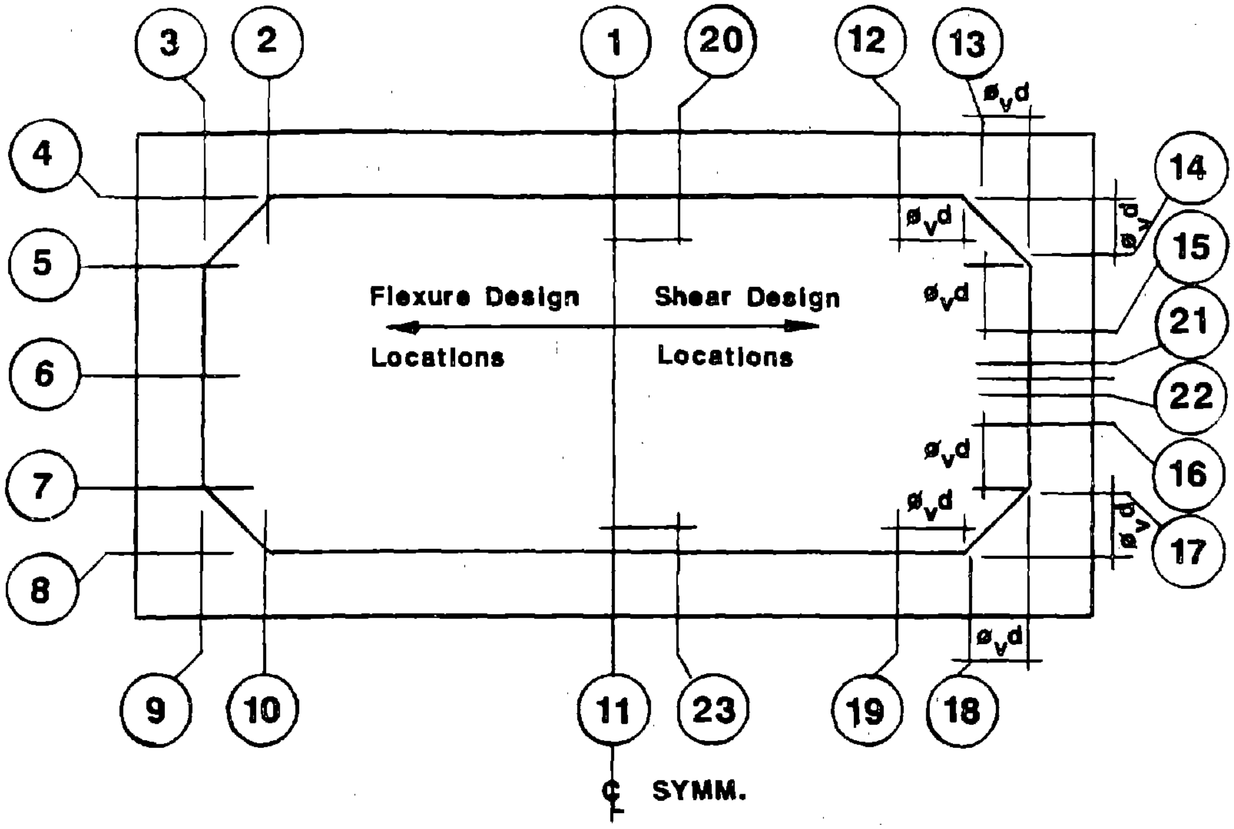
FIGURE 2-2 FRAME MODEL USED FOR COMPUTER ANALYSIS OF BOX SECTIONS

If maximum reinforcement governs, an informative message is printed, warning the user that concrete compression governs, and the design is halted for that particular design section.

BOXCAR incorporates the basic design equations of AASHTO Section 17.4.6. Although AASHTO has adopted this design method for reinforced concrete pipe, the equations are applicable to all reinforced concrete sections and in some instances are simpler to use in computer programs. For instance AASHTO Equation 17-9 for ultimate flexural strength is a direct solution of AASHTO Equations 8-16 and 8-17 with the additional consideration of the effect of axial thrust. The derivation of AASHTO Eq. 17-9 is presented in Reference 5. The use of this equation in the program eliminates the need to use an iterative solution.

Flexural reinforcing is designed for the negative moments at Sections 1 to 11 and for the positive moments at Sections 1, 6, and 11. Final reinforcing is selected based on the assumed reinforcing layout presented in Figure 2-4. This is accomplished as follows:

- Reinforcing area AS1 is taken as the maximum reinforcing area required for negative moments at Sections 2, 3, 4, 5, 6, 7, 8, 9, and 10.
- Reinforcing area AS2 is taken as the reinforcing required for positive moments at Section 1.
- Reinforcing area AS3 is taken as the reinforcing required for positive moments at Section 11.
- Reinforcing area AS4 is taken as the reinforcing required for positive moments at Section 6.
- Reinforcing area AS7 is taken as the reinforcing required for negative moments at Section 1.
- Reinforcing area AS8 is taken as the reinforcing required for negative moments at Section 11.



Flexure Design Locations: 1–11

Shear Design Locations:

Method 1: 12–19

Method 2: 20–23 (Occurs where moment is positive and $\frac{M}{Vd}$ = 3.0)

Note: For 45 degree haunches sections $\phi_v d$ from the face of the wall, such as 13 occur at the same location as the section $\phi_v d$ from the tip of the haunch such as 12.

FIGURE 2-3 LOCATIONS OF CRITICAL SECTIONS FOR SHEAR AND FLEXURE DESIGN IN SINGLE CELL BOX SECTIONS

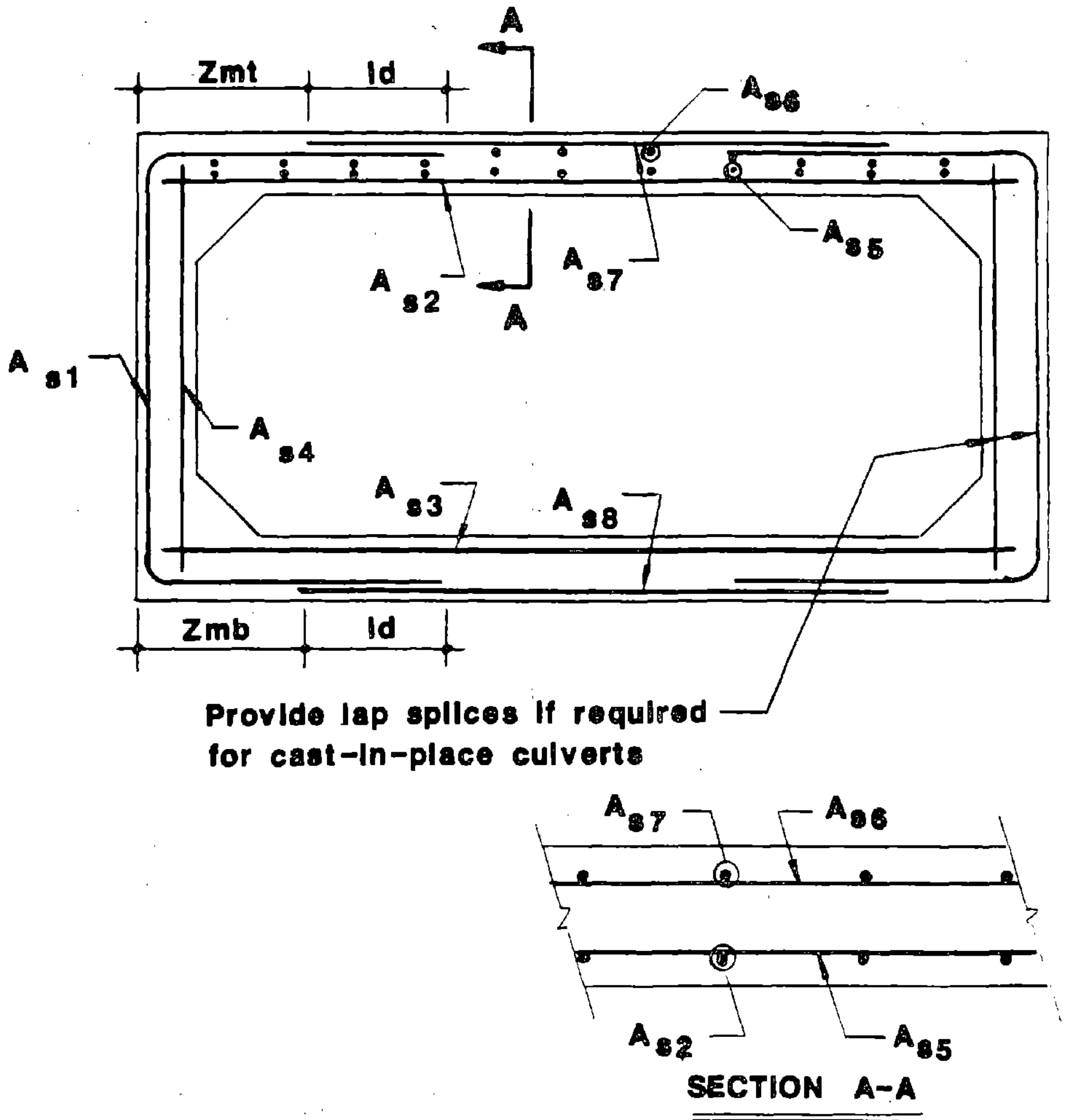


FIGURE 2-4 TYPICAL REINFORCING LAYOUT FOR SINGLE CELL BOX CULVERTS

BOXCAR determines the required extension of AS1 into the top and bottom slabs (Zmt and Zmb in Figure 2-4) by comparing the required reinforcing area for negative moment along the slab with the required area for AS7 or AS8. AS1 must be extended to the point where AS7 or AS8 provide adequate reinforcement. Since BOXCAR does not select specific reinforcement bar sizes and it does not require a specific reinforcing layout, it cannot design splices or determine required development lengths. Therefore, the user must calculate the required lap length (l_d in Figure 2-4) to meet AASHTO requirements. For many designs AS7 and AS8 provide adequate negative reinforcement for the entire top or bottom slab, thus AS1 need only be extended into the slabs sufficiently to make a tension lap splice with AS7 or AS8 as required by AASHTO. The design summary sheet provides a note giving the required extension of AS1. The user must add the development or splice length.

Shear strength is evaluated by two methods. Method 1 evaluates shear strength in accordance with AASHTO Sections 8.16.6.2.1 Eq. 8-49 and Section 8.16.6.7. Only the minimum shear strength requirement $3 \sqrt{f'c}$ of Section 8.16.6.7 is checked. AASHTO allows the use of Section 8.16.6.7 whenever the depth of fill is greater than 2 ft.; however, BOXCAR does not apply the provisions of this section until the live load is uniformly distributed over the entire top slab. Method 2 applies the shear strength equation of AASHTO Section 17.4.6.4.5. Method 2 is more comprehensive than Method 1 and more accurately reflects the true shear strength of reinforced sections. If either Method 1 or 2 indicates that the shear strength of the section is exceeded, informative messages are printed and the interactive stirrup design routine of BOXCAR is activated (see Section 3.3).

Method 1 evaluates shear strength at design sections 12 to 19 which are a distance equal to the strength reduction factor times the depth of the reinforcing $\phi_v d$ from the faces of walls and the tips of haunches. For sections with 45 degree haunches these are the same location. Method 2 checks the shear strength at all Method 1 locations as well as at Sections 20 to 23 which are where the ratio of moment to shear, taken as $M/V\phi_v d$, equals 3.0

2.3 Input/Output Description

2.3.1 Input

BOXCAR data input files are created or modified through a series of displayed menus and screens that prompt the user for the various input parameters. Section 3 of this manual gives detailed instructions for entering data into the program. The amount of data that the user needs to enter is flexible. Only the span, rise, and depth of fill are required as input for the program to run. Parameters not specified by the user are assigned default values that are stored in a file on the Program Disks. A list of the parameters the user may specify along with their initial default values are listed in Appendix A of this manual. The user may change default parameters to structure the program for his or her typical design requirements such as cast-in-place or precast box sections as discussed in Section 3.2.6 of this manual.

The input parameters listed in Appendix A are grouped into categories such as Culvert Geometry, Material Properties, Loads, etc. Each screen that is displayed corresponds to a different category. Menus and screens used in the program are discussed in Section 3.2 of this manual. For each screen, input parameters are displayed along with the default values assigned to them. The user may overwrite or accept the values displayed. After data is entered, the program will store the created or modified input file on a disk for execution and later modifications.

2.3.2 Output

Upon completion of program execution, BOXCAR will write the reinforcing requirements to the screen. At this time the user may elect to save the file, using one of the several possible output levels, or, if a visual examination is adequate, to destroy the output file. The amount of output is controlled by the user as discussed in Section 4.1 of this manual. The minimum amount of output printed is an echo of the input data and a one page summary of the design. Additional available output includes displacements, member end forces, moments, thrusts and shears at critical sections, and shear and flexure design tables. Output is printed to a disk file. The complete output file can be reviewed using a text editor (not part of this software package) or sent to a printer for a hard copy. Printer output is formatted for 8.5 x 11 in. paper.

2.4 Hardware and Software Requirements

The following is a list of the hardware and software required to run the program:

- IBM PC, XT, AT or a similar IBM compatible computer.
- Printer. The output is formatted for 8.5 in. wide paper.
- An operating system equivalent to PC DOS Version 2.0 or higher.
- An 8087 or 80287 math coprocessor.
- A minimum of 640k bytes of memory.
- Two double density disk drives or a single double density disk drive and a hard disk drive.
- A minimum of 3 FILES and 1 BUFFER must be specified in the CONFIG.SYS file on the operating system boot disk. The number of FILES and BUFFERS are normally set to values higher than these. If you have not made any changes since the purchase of your computer, the number of each should be adequate. Refer to your DOS Manual for further information on FILE and BUFFER sizes.

3. OPERATION

3.1 Installation and Start-up

BOXCAR is supplied on three double sided, double density floppy diskettes. To use BOXCAR you must have the hardware and software described in Section 2.4 of this manual. Before running BOXCAR, make a working copy of Program Disks 1, 2, and 3 so that the original disks may be used as backups. The procedure for this and for program installation and start-up is as follows:

Dual Disk Drives:

1. Use the DOS command "FORMAT" to format four blank diskettes. If you are unfamiliar with this procedure refer to your DOS manual for instruction. Three of these diskettes will be used for making working copies of the Program Disks. The fourth disk will be your Data Disk and will be used for storing input and output files.

2. Set your default drive to A. Place one of the formatted blank diskettes in drive B and Program Disk 1 in drive A.

3. Copy the contents of Program Disk 1 to the new blank diskette by typing the following:

   COPY A:*.* B: [Enter]

4. Place the second formatted blank diskette in drive B and Program Disk 2 in drive A and copy the contents of Program Disk 2 to the blank diskette with the same "COPY" command. Repeat this procedure for Program Disk 3.

5. The new diskettes are now your working Program Disks. You should use these diskettes when running BOXCAR and keep the original diskettes in a safe place.

6. Copy the "COMMAND.COM" file that resides on your DOS diskette onto Program Disks 1, 2, and 3. Do this for each disk by placing your DOS disk in drive A, your program disk in drive B and typing:

   COPY A:COMMAND.COM B: [Enter]

7. With your default drive still set to A, insert the working copy of Program Disk 3 into drive A and type the following:

   INSTALL [Enter]

When prompted, select the option that you will use to execute BOXCAR. Press "4" to run BOXCAR on dual floppy disk drives. The Program Disks must always be run from drive A and the Data Disk from drive B.

8. When execution of the INSTALL Program is completed, insert Program Disk 1 into drive B and copy the "SYSTEM.DEF" file that resides on Program Disk 3 to Program Disk 1 in the same manner that you copied COMMAND.COM above. Replace Program Disk 1 with Program Disk 2 and repeat the above procedure.

9. To begin execution of BOXCAR, insert Program Disk 1 into drive A and the Data Disk into drive B and type:

   BOXCAR [Enter]

   After executing this statement the Introductory Screen of BOXCAR appears. You may now run the program as shown in Section 3.2.

Hard Drive

1. Start from the main directory of your hard drive and create a subdirectory called "BOXCAR" by typing the following:

   MD\BOXCAR [Enter]

2. Log into the newly created subdirectory by typing:

   CD\BOXCAR [Enter]

3. Place Program Disk 3 in drive A and type the following:

   A: [Enter]
   INSTALL [Enter]

   When prompted, select the option that specifies the system configuration you will use to execute BOXCAR. Options 1, 2, or 3 are to run BOXCAR with a hard disk drive. Follow the displayed instructions for inserting the Program Disks. If option 2 or 3 is selected, refer to dual disk drive instructions for making working copies of the program and copying the COMMAND.COM and SYSTEM.DEF files onto the floppy disks.

4. Log back into the BOXCAR subdirectory of your hard disk by typing:

   C: [Enter]

   The hard disk is now your working Program Disk. The original Program Disks should be stored in a safe place. Always log into the BOXCAR subdirectory whenever running BOXCAR.

5. To begin execution of BOXCAR, type:

BOXCAR [Enter]

After executing this statement the Introductory Screen of BOXCAR appears. You may now run the program as discussed below.

Running the Program

After typing BOXCAR program execution begins by printing the Introductory Screen. This lists the version number and date of the program that you are using. By pressing any key the user warning will be printed to the screen. This screen reminds the user of the responsibility they have when using BOXCAR, as discussed in Section 1. of this Manual. By again pressing any key the Main Menu will appear. The Main Menu controls the execution of BOXCAR. It offers seven choices that lead to additional screens.

For each screen displayed, enter the input data when prompted. General features of the program are:

- The number of characters for each parameter input must be less than or equal to the highlighted space provided on the screen for that parameter.
- After typing in the data requested for any field, press the [Enter] key to move on to the next input parameter.
- Within each screen, the arrow, [Home], and [End] keys may be used to move around to the different input fields displayed.
- To move to the next screen or to view a previous screen, press the [PgDn] or [PgUp] key, respectively.
- Help screens are available for each input menu. These screens are quick references for explaining the input parameters for that particular screen. To display a help screen, press the [F2] key. To leave a help screen, press any key.
- You may leave the input menu at any time by pressing the [F1] key. The program will ask if you wish to save the file and execute BOXCAR, save the file and return to the Main Menu or not save the file and return to the Main Menu.
- Decimal points are optional for whole number input.

Before the program can be executed, you must first create an input file. The data that you enter is stored on your disk with the filename you assign to it.

All input and output files are stored on your data disk. If a file is no longer needed, you may use the DOS command ERASE to delete it from your disk.

3.2 Main Menu Choices

```
══════════════════════ PROGRAM: BOXCAR ══════════════════════

                         MAIN MENU

Input Options      1.  Create a new box culvert file
                   2.  Retrieve an old box culvert file

Execute Option     3.  Execute BOXCAR

Print Options      4.  Print input file
                   5.  Print output file

System Options     6.  Reconfigure default parameters
                   7.  Exit


                   Selection

═════════════════════════════════════════════════════════════
                         <F2> HELP
```

The seven options provide the following functions:

1. Selection 1 allows you to create a new input file. The input data you supply is saved on disk for program execution and for later modifications.

2. Selection 2 allows you to retrieve a previously created input file that you may wish to review or modify. The file may then be re-saved with the same file name or a different name as you desire.

3. Selection 3 executes the program and completes the analysis and design of a box section based on the specified input file.

4. Selection 4 allows you to print any previously created input file. This selection also formats the file for printing on 8.5 by 11 in. paper. It puts headings and page numbers on each page and inserts form feed commands where appropriate.

5. Selection 5 allows you to print an output file after program execution. This selection also formats the file for printing on 8.5 by 11 in. paper. It puts headings and page numbers on each page and inserts form feed commands where appropriate.

6. Selection 6 allows you to change the default values that are stored on the Program Disk. The default values supplied with the BOXCAR program you have received are listed in Appendix A.

7. Selection 7 exits the program and returns you to the operating system.

Additional details on each of these selections is provided in the following sections.

3.2.1 Main Menu Selection 1: Create a File

Entering Selection 1 from the Main Menu leads to a series of screens that create a new box culvert input file.

```
==============PROGRAM: BOXCAR ==============================================


          Filename                    .BOX
          Job Description


          Span                             ft
          Rise                             ft
          Depth of Fill            0       ft
          to Culvert Top




                                                                   SCREEN 1
============================================================================
     <F1> = FINISHED EDITING → RETURN TO MAIN MENU           <F2> = HELP
                         <PgDn> View Next Screen
```

Filename – Enter the name under which you wish to save the input file. Do not provide an extension because the extension .BOX is automatically appended. See your DOS manual for rules pertaining to filenames.

Job Description – Any project description containing up to 50 characters of text. The job descriptions must not contain any quotations (").

Span – Interior span of the culvert (ft). The allowable range of spans is 3 to 14 ft. See Figure 3-1.

Rise – Interior of the culvert (ft). The allowable range of rises is 2 to 14 ft. See Figure 3-1.

Depth of Fill – Height of earth cover (ft) from the ground or highway surface to the top of the culvert. For railroad loading, depth of fill is measured from bottom of tie. See Figure 3-1.

After entering the depth of fill, the program will compute all remaining parameters using the default file. At this point you may accept the default values by pressing [F1] or you may view the remaining input screens by pressing [Enter] or [PgDn].

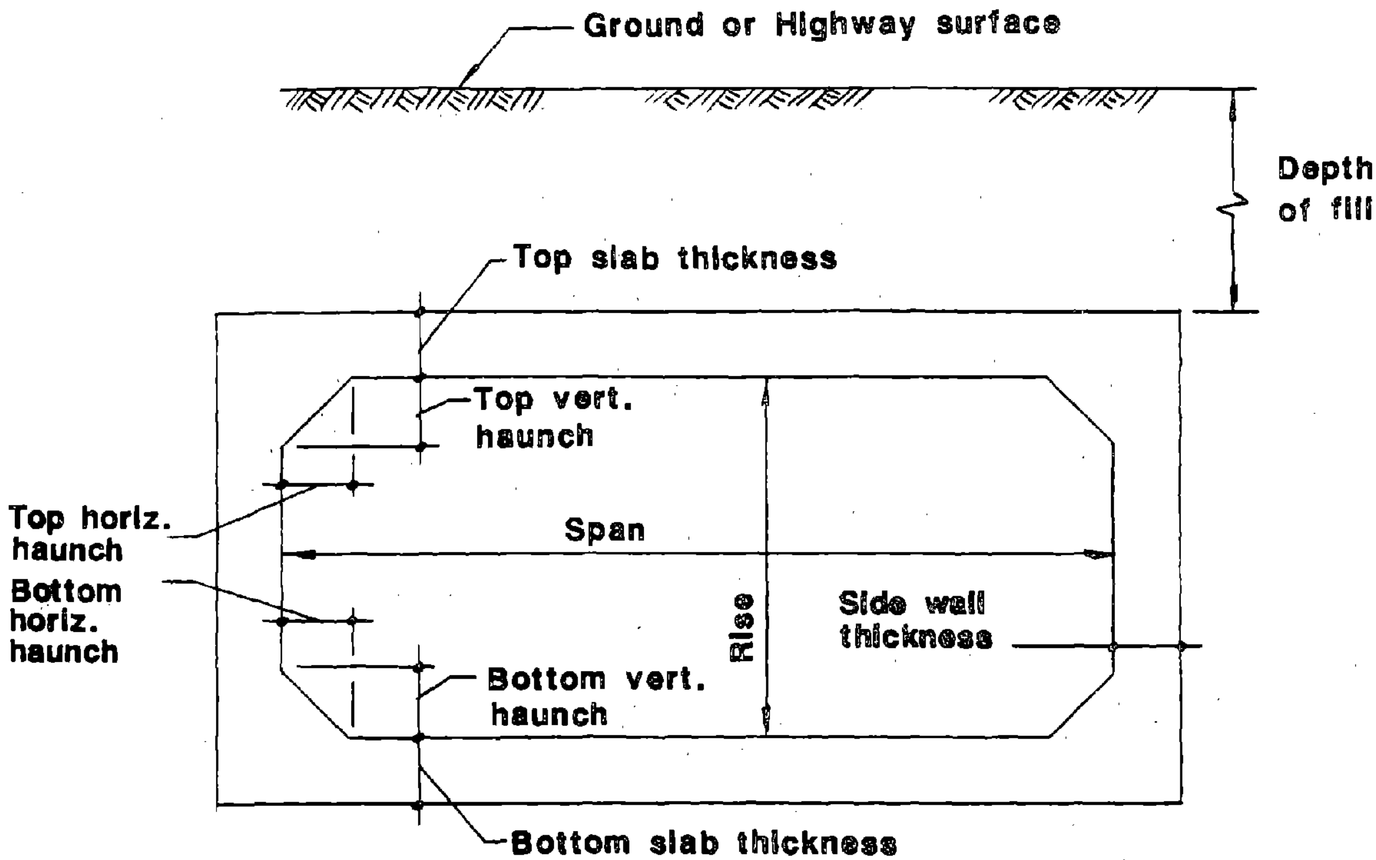
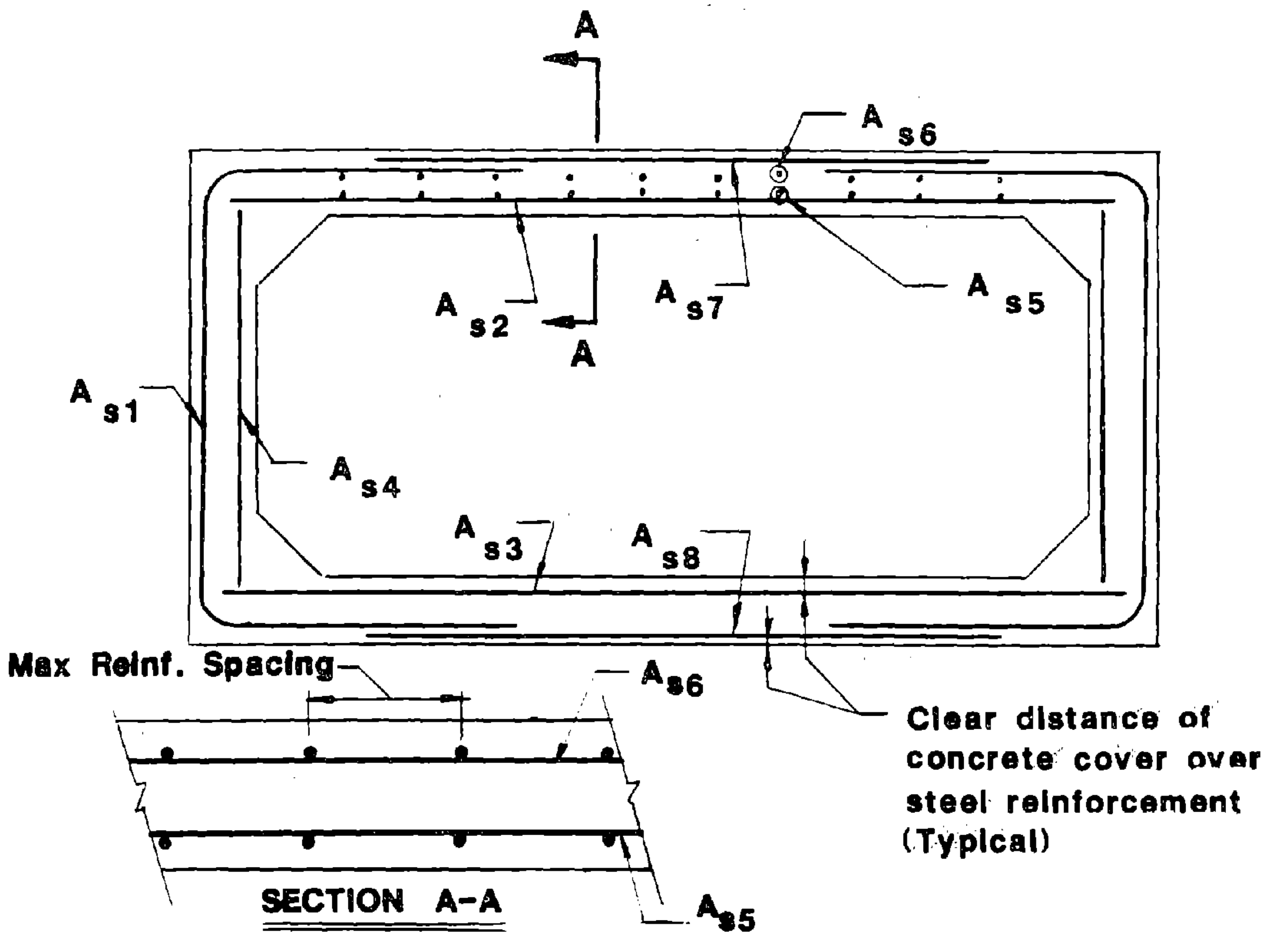


FIGURE 3-1 SINGLE CELL BOX CULVERT GEOMETRY

```
======== PROGRAM: BOXCAR ========== CURRENT FILE:              ========
PROJECT:


        BOX GEOMETRY

         SLAB THICKNESSES         HAUNCH DIMENSIONS

         Top Slab           in.  Top Haunches           Bottom Haunches
         Bottom Slab        in.  Horizontal        in. Horizontal        in.
         Sidewall           in.  Vertical          in. Vertical          in.

        CONCRETE COVERS

                 Top Slab Outside Face            in.
                 Bottom Slab Outside Face         in.
                 Sidewall Outside Face            in.
                 Top Slab Inside Face             in.
                 Bottom Slab Inside Face          in.
                 Sidewall Inside Face             in.
                                                                SCREEN 2
=========================================================================
     <F1> = FINISHED EDITING → RETURN TO MAIN MENU           <F2> = HELP
       <PgUp> View Previous Screen            <PgDn> View Next Screen
```

Slab and Wall Thicknesses –	(in.), See Figure 3-1.
Haunch Dimensions –	(in.), See Figure 3-1.
Concrete Cover Over Steel Reinforcement –	Clear concrete over tensile reinforcing (in.). See Figure 3-2.



Notes : 1. A_{s5} and A_{s6} are provided in the top slab of box culverts having a burial depth less than two feet

2. The actual reinforcing layout may vary depending on the needs of the local manufacturer or the casting method.

FIGURE 3-2 SINGLE CELL BOX CULVERT REINFORCEMENT NOTATION

```
========== PROGRAM: BOXCAR ========== CURRENT FILE:              ==========
PROJECT:

        MATERIAL PROPERTIES


              Main Reinforcing Yield Strength                        ksi
              Main Reinforcing Type 3   No. of Layers
              Design Concrete Strength                               ksi
              Concrete Density                                       pcf

        LOAD FACTORS

              Dead Load Factor (Shear and Moment)
              Dead Load Factor (Thrust)
              Live Load Factor (Shear and Moment)
              Live Load Factor (Thrust)

        PHI FACTORS

              Shear
              Flexure                                                  SCREEN 3

    <F1> = FINISHED EDITING → RETURN TO MAIN MENU          <F2> = HELP
      <PgUp> View Previous Screen            <PgDn> View Next Screen
```

Main Reinforcing Yield Strength –	Yield strength of reinforcement parallel with the direction of the span of the box culvert, (ksi).
Main Reinforcing Type –	1) Smooth wire 2) Smooth welded wire fabric 3) Deformed welded wire fabric, deformed bars, or any reinforcing with stirrups
No. of Layers –	Enter the number of layers of reinforcing that you anticipate will be required to achieve the required design steel areas. The choices are limited to 1 or 2.
Design Concrete Strength –	28 day compressive strength of concrete (ksi).
Concrete Density –	(pcf).
Load Factors –	Load factors used for ultimate strength design. Note that AASHTO and AREA require different dead and live load factors.
Phi Factors –	Capacity reduction factor used in ultimate strength design.

```
PROGRAM: BOXCAR            CURRENT FILE:
PROJECT:

        REINFORCING DIAMETERS

                Top Slab Outside Face,(AS7)          in.
                Bottom Slab Outside Face,(AS8)       in.
                Sidewall Outside Face,(AS1)          in.
                Top Slab Inside Face,(AS2)           in.
                Bottom Slab Inside Face,(AS3)        in.
                Sidewall Inside Face,(AS4)           in.

                                                            SCREEN 4
    <F1> = FINISHED EDITING → RETURN TO MAIN MENU           <F2> = HELP
      <PgUp> View Previous Screen           <PgDn> View Next Screen
```

Reinforcing Diameters – Diameter of wire or bar used for reinforcement (in.). See Figure 3-2 for steel designations. The wire diameter is used to compute the depth from the compression face to the centroid of the tension reinforcing.

```
PROGRAM: BOXCAR          CURRENT FILE:
PROJECT:

        MAXIMUM REINFORCING SPACING

                Top Slab Outside Face,(AS7)          in.
                Bottom Slab Outside Face,(AS8)       in.
                Sidewall Outside Face,(AS1)          in.
                Top Slab Inside Face,(AS2)           in.
                Bottom Slab Inside Face,(AS3)        in.
                Sidewall Inside Face,(AS4)           in.

                                                        SCREEN 5

<F1> = FINISHED EDITING → RETURN TO MAIN MENU          <F2> = HELP
  <PgUp> View Previous Screen          <PgDn> View Next Screen
```

Maximum Reinforcing Spacing – Center to center spacing of main reinforcement (in.). See Figure 3-2 for steel designations.

Note: If the reinforcing design is governed by the crack control equations (see 4.1.2 for instructions on determining this) the user may be able to reduce the required area by decreasing the reinforcing spacing.

```
═══════════ PROGRAM: BOXCAR ═════════ CURRENT FILE:
PROJECT:

        SOIL LOAD DATA

                Soil Density                                    pcf
                Minimum Lateral Pressure Coefficient
                Maximum Lateral Pressure Coefficient
                Soil Structure Interaction Factor

        LIVE LOAD DATA

                Live Load       (H/T/C/O/N)     HS-SERIES
                                                INTERSTATE
                                                COOPER E-SERIES
                                                OTHER
                                                NONE

                                                                SCREEN 6

    <F1> = FINISHED EDITING → RETURN TO MAIN MENU        <F2> = HELP
     <PgUp> View Previous Screen          <PgDn> View Next Screen
```

Soil Density – Density of fill material above the box culvert (pcf).

Minimum Lateral Pressure Coefficient – Minimum fraction of vertical earth pressure acting as lateral pressure. Allowable range is 0 to 1.

Maximum Lateral Pressure Coefficient – Maximum fraction of vertical earth pressure acting as lateral pressure. Allowable range is from minimum lateral pressure coefficient to 9. Lateral pressure that is additional to the minimum lateral pressure specified above will be considered as additional dead load.

Soil Structure Interaction Factor – Ratio of actual load imposed on the box culvert to the soil prism load.

Live Loads –

- H) AASHTO HS-series truck load
- T) AASHTO interstate truck load (See AASHTO Section 3.7.4.) This live load case also evaluates loads due to a HS-20 truck.
- C) Cooper E-series railroad load
- O) User specified load
- N) No live load

If "H," "C," or "O" is selected, a screen will appear prompting you for additional input pertaining to the type of live load you selected.

```
============ PROGRAM: BOXCAR ========== CURRENT FILE:            ==========
PROJECT:

          LIVE LOAD DATA

                  You have chosen an AASHTO HS-SERIES load condition.

                  Enter the series magnitude (i.e. 10,20, etc.)

                            tons

                  Enter the direction of travel of the truck

                            (P/T)    Parallel to culvert flow
                                     Transverse to culvert flow



                                                                     SCREEN 6H
==============================================================================
     <F1> = FINISHED EDITING → RETURN TO MAIN MENU            <F2> = HELP
       <PgUp> View Previous Screen            <PgDn> View Next Screen
```

AASHTO HS-Series Truck Load

Magnitude –	Weight of truck as defined by AASHTO Specifications (tons).
Direction of Travel –	P) Truck moves in the direction parallel to the culvert flow. T) Truck moves in the direction transverse to the culvert flow.

```
═══════════ PROGRAM: BOXCAR ═══════════ CURRENT FILE:              ════════════
PROJECT:

        LIVE LOAD DATA

                You have chosen a COOPER E-SERIES load condition.

                Enter the series magnitude (i.e. 72,80, etc.)

                     kips

                                                                    SCREEN 6C
    <F1> = FINISHED EDITING → RETURN TO MAIN MENU           <F2> = HELP
     <PgUp> View Previous Screen              <PgDn> View Next Screen
```

Cooper E-Series Railroad Loading

Magnitude – Locomotive axle weight as defined by AREA Specifications (kips).

```
PROGRAM: BOXCAR          CURRENT FILE:
PROJECT:

      LIVE LOAD DATA

            You have chosen a wheel load OTHER than the
            standard AASHTO load conditions given.

            Enter the magnitude of the live load          kips


            Live Load Width                               in.
            Live Load Length                              in.


            This load will be modelled as a single wheel
            load distributed over the indicated area.
            No increase in load will be made for impact.

                                                     SCREEN 60

    <F1> = FINISHED EDITING → RETURN TO MAIN MENU        <F2> = HELP
     <PgUp> View Previous Screen          <PgDn> View Next Screen
```

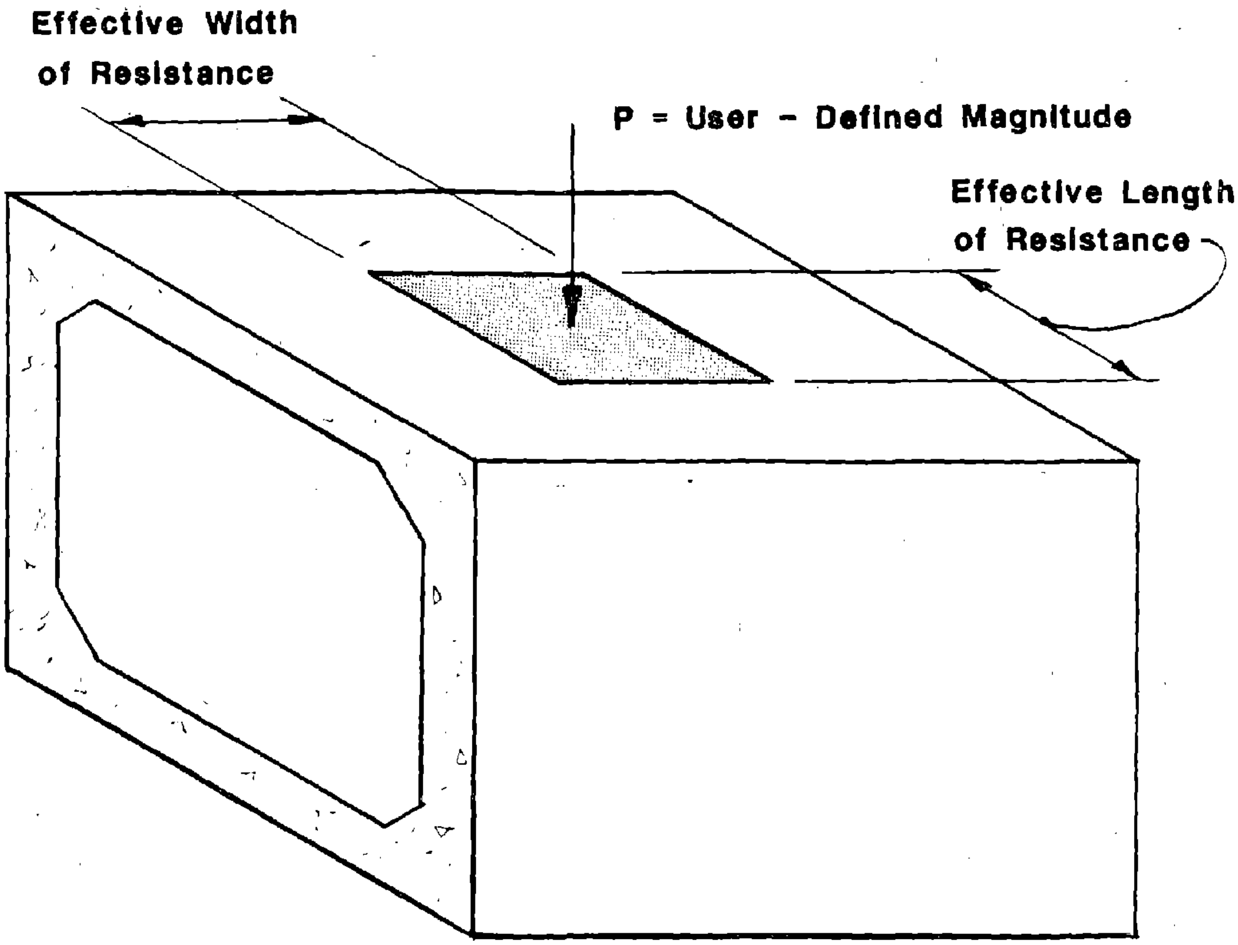
User Specified Live Load

Magnitude – (kips).

Effective Width of Resistance – The distance parallel to the direction of culvert flow over which the load will be applied to the culvert surface, (in.). See Figure 3-3.

Effective Length of Resistance – The distance transverse to the direction of culvert flow over which the load will be applied to the culvert surface, (in.).

NOTE: The specified length and width of load are applied at the culvert surface. The load is not spread through the fill.



$$\text{Applied Pressure to Culvert Surface} = \frac{P}{\text{Width x Length}}$$

FIGURE 3-3 TERMINOLOGY FOR USER - SPECIFIED LIVELOAD

```
================ PROGRAM: BOXCAR ============ CURRENT FILE:              ===============
PROJECT:

          SURCHARGE LOADS

                  UNIFORM VERTICAL LOAD

                  Magnitude                                   psf

                  VARYING LATERAL LOAD

                  Magnitude at Top                            psf
                  Magnitude at Bottom                         psf


                  APPLICATION CODE                   (P/A/L)  PERMANENT DEAD LOAD
                                                              ADDITIONAL DEAD LOAD
                                                              LIVE LOAD
          FLUID LOADS

                  Depth of Fluid                            ft
                  Fluid Density                             pcf              SCREEN 7
=========================================================================================
      <F1> = FINISHED EDITING → RETURN TO MAIN MENU            <F2> = HELP
        <PgUp> View Previous Screen               <PgDn> View Screen 1
```

Vertical Surcharge Load –	An additional uniform vertical pressure imposed on the box culvert.
Magnitude –	(psf).
Lateral Surcharge Load –	An additional linearly varying lateral load imposed on the culvert with top and bottom magnitudes as specified.
Magnitude at Top –	(psf).
Magnitude at Bottom –	(psf).
Application Code –	P) Treated as permanent dead load A) Treated as additional dead load L) Treated as live load
Depth of Fluid –	Depth of fluid inside the box culvert (ft).
Fluid Density –	Density of fluid inside the box culvert (pcf).

NOTE: This is the last input screen. After entering the last parameter you may end the file create mode by pressing [F1] or you may review your input by pressing [PgDn], which returns to Screen 1. If you press [F1] you are asked if you wish to save and execute the file, save the file and return to the main menu or destroy the file and return to the main menu.

3.2.2 Main Menu Selection 2: Retrieve a File

You may retrieve input files for review or modification by selecting Option 2. When you make this selection, a list of all available input files appears on the screen. Type in the name of the input file you wish to review, omitting the .BOX filename extension, and press [Enter]. When Screen 1 appears, you may make modifications to the input file by proceeding through the input screens as discussed in Section 3.2.1. When you select the retrieve mode, the default file is not activated. Any changes you wish to make to the retrieved file must be input manually. If you wish to save both the original file and the modified file, you must change the filename on Screen 1. You may return to the main menu at any time by pressing the [F1] key. When returning to the main menu, you are asked if you want to save (and execute if desired) the input file. If you are saving a file that already exists, you are also asked if you wish to overwrite the existing file. If you choose not to overwrite the existing file, the program returns back to Screen 1 for you to change the filename.

3.2.3 Main Menu Selection 3: Program Execution

Execution of the program from the Main Menu is performed by selecting Option 3. When this selection is made, a list of all the available input files appears on the screen. Type in the filename of the desired input file, omitting the .BOX filename extension, and press [Enter].

After completion of the design of the flexural reinforcing the program will print the required reinforcing areas to the screen for review by the user. This screen also indicates if stirrups are required to provide adequate shear strength. After reviewing this screen the user may select the level of output that he desires (Output options are presented in Section 4. of this Manual) or elect not to save any output and return to the Main Menu. If the file is saved and stirrups are required then the stirrup design module is activated and the user completes the stirrup design, which is appended to the output file. The stirrup design module is described in Section 3.3 of this Manual.

3.2.4 Main Menu Selection 4: Print an Input File

You may obtain a hardcopy of any input file by selecting Option 4. When you make this selection, a list of all available input files appears on the screen. Type in the name of the input file, omitting the .BOX filename extension and press [Enter]. A listing of the input, formatted for 8.5 in. by 11 in. paper is sent to your printer. The print subroutine inserts form feeds where appropriate and places headers and page numbers on each page.

3.2.5 Main Menu Selection 5: Print an Output File

After program execution, the output is stored as a file on your disk. You may obtain a hardcopy of the output by selecting Option 5 on the main menu or you may view the file by using text editor software (not included in this software package). When you select Option 5, a list of all the available output files is displayed on the screen. Output files have the same filename as the input files except that they are given the filename extension .OUT. Type in the name of the output file, omitting the filename extension, and press [Enter]. The program will first process the output for printing on 8.5 by 11 inch paper. Form feeds are inserted where needed, and headers and page numbers are placed on the top of each page. After processing, the output is sent to the printer.

3.2.6 Main Menu Selection 6: Changing Default Values

The default values listed in Appendix A of this manual are stored as a file that you may change to meet your own particular typical design requirements. You may change the default parameters by selecting Option 6 on the main menu. The default parameter menus are used in the same manner as the menus for creating a new file using Selection 1.

The default screens use equations to determine some parameters as follows:

- Defaults for wall thicknesses and haunch dimensions are a function of the culvert span:

$$\text{Thickness} = \text{SPAN(in.)}/x + y$$

The user may specify values for x and y. To set a default to an absolute number, set x equal to 99. This will cause the program to ignore the first term of the equation.

- Defaults for wire diameter are a function of the thickness of the member in which they are placed:

$$\text{Wire Diameter} = x * \text{Thickness(in.)} + y$$

The user may specify values for x and y. This allows the wire diameter to default to either a fraction of the wall thickness by specifying y = 0 or to an absolute diameter by specifying x = 0.

- The depth of fluid is determined as a fraction of the culvert rise. The user inputs the desired fraction.

To exit the default screens, press [Esc] and [PgDn].

3.2.7 Main Menu Selection 7: Exiting the Program

Selection 7 on the main menu exits the program and returns you to the operating system.

3.3 Stirrup Design

If BOXCAR determines that the shear strength of the top, bottom, or sidewalls is inadequate for resisting the applied loads, it activates a subroutine to design stirrups. The following screen will appear:

```
================ PROGRAM: BOXCAR STIRRUP DESIGN ROUTINE ================

        Stirrups required in                     TOP SLAB

        Developable Stirrup Yield Stress         ksi

        Ultimate Applied Shear                      k/ft
        Shear Capacity of Concrete                  k/ft
        Required Shear Capacity of Stirrups         k/ft
        Stirrup Spacing (maximum=d/2)               in.
        Required Steel Area for Stirrups            in.²/ft/line <— CONTROLS
        Minimum Steel Area for Stirrups             in.²/ft/line
        Uniform Ultimate Load                       k/in.
        Required Number of Lines
        Location of First Line of Stirrups       TIP OF HAUNCHES
```

User input for this routine is the developable stirrup yield strength and the stirrup spacing. All other information on the screen is taken from program output. Note that some concrete producers use bent sections of smooth cold drawn wire for stirrup reinforcement that do not provide sufficient anchorage to develop the full yield strength of the wire. This is why BOXCAR uses the terminology "developable" yield strength and defaults to a value of 40 ksi. Users should be cautious in selecting a design value for the stirrup yield strength.

You may accept the stirrup yield strength and spacing displayed by pressing the [Enter] key or make changes to these values as required. Press the [Enter] key after making changes to each parameter. The program will compute the required stirrup area and number of lines required, display the information on the screen, and ask if this is a final design. If you say no by pressing "N", the program allows you to make changes to the stirrup yield strength and spacing. The arrow keys allow you to move from one parameter to the other to make changes. If you say yes by pressing "Y", then the program appends the design information to the output file. This design procedure is iterated for the top, bottom, and sidewall, as required.

4. REPORT OUTPUT

4.1 Output Control

The first program output that the user sees is the summary of the flexural reinforcing that is printed to the screen after program execution:

```
R E I N F O R C I N G   S T E E L   D A T A
------------------------------------------------------------------------
                                            AREA
              LOCATION                      SQ. IN.      STIRRUPS
                                            PER FT       REQUIRED?
-----------------------------------------------------------------------
TRANSVERSE
    SIDE WALL    - OUTSIDE FACE (As1)       .259            NO
    TOP SLAB     - INSIDE  FACE (As2)       .372            NO
    BOTTOM SLAB  - INSIDE  FACE (As3)       .413            NO
    SIDE WALL    - INSIDE  FACE (As4)       .240            NO
    TOP SLAB     - OUTSIDE FACE (As7)       .240            NO
    BOTTOM SLAB  - OUTSIDE FACE (As8)       .240            NO

          DO YOU WISH TO SAVE AND/OR PRINT THIS OUTPUT ? (D/P/N)

          D = WRITE TO DISK AND RETURN TO MAIN MENU.
          P = WRITE TO DISK AND PRINTER AND RETURN TO MAIN MENU.
          N = RETURN TO MAIN MENU WITHOUT SAVING OUTPUT.

            Make Selection....Then Press Enter
```

At this time the user selects "D" to save the output file on disk, "P" to save the file on disk and post-process the file for printing, or "N" to return to the Main Menu without saving the file. If the user elects to save the output file the following screen appears, allowing selection of an output level:

```
OUTPUT SELECTIONS

       1.  Print Input data and summary sheet.
       2.  Print Above + ultimate forces at design locations,
           flexure and shear design tables.
       3.  Print Above + service forces at design locations.
       4.  Print Above + displacement matrix, service forces for
           each load case and end forces.




       Make Selection....Then Press Enter
```

The four options give the user control of the type and amount of data written to the output file. Options 1 through 4 may be specified. Each increasing option number provides more output, as listed below. Tables 4-1a to 4-1i show sample output in the order that it is printed.

4.1.1 Output Option 1

Listing of input data: The program prints the input screens with the assigned values for each parameter, allowing the designer to check the input and to identify the design (Table 4-1a).

Summary table for design: Table 4-1i presents all important design input and output parameters for the box section. A row of stars (****) under the steel area column indicates that the steel design at the particular location is governed by concrete compression and the member must either be designed with a thicker section, or as a compression member according to AASHTO ultimate strength design methods. If stirrups are required, the program prints the shear reinforcement design as part of this table.

4.1.2 Output Option 2

Ultimate forces at design locations: Table 4-1f presents the forces at the 23 design locations in the box section shown in Figure 2-3. Locations 1 through 11 are flexural design locations. Locations 12 through 19 are locations where shear stresses are checked by Method 1 and Method 2 as discussed in Section 2.2.3. Locations 20 through 23 are positive moment locations where shear stresses are evaluated only by Method 2 shear design. The table lists both maximum and minimum ultimate design forces that occur at each section. This range occurs because the program considers different combinations of the three load categories; permanent dead loads, additional dead loads, and live loads to obtain the maximum and minimum critical design forces as discussed in Section 2.2.1.

For any given design section these forces can be derived from the service forces listed in Table 4-1e as follows:

Max M+ = Moments due to
(permanent dead load x dead load factor + positive additional dead load x dead load factor + positive live load x live load factor).

Max M- = Moments due to
(permanent dead load x dead load factor + negative additional dead load x dead load factor + negative live load x live load factor).

If no positive moment exists at a section, M+ is set to zero, and if no negative moment exists at a section, M- is set to zero.

Shear and thrust forces are totalled in the same manner except that thrust forces are not set to zero regardless of sign.

The sign convention on the forces is as follows: positive thrust is tensile, positive shear decreases the moment from the A to the B end of the member, and positive moment causes tension on the inside steel.

Summary table for flexure design: Table 4-1g presents information required to design steel reinforcing based on flexure, minimum steel, maximum steel, crack control, and fatigue. AS1 is taken as the maximum of the steel areas required to resist negative moments at Section 2, 3, 4, 5, 6, 7, 8, 9, and 10. AS2, AS3, and AS4 are the steel areas required to resist positive moments at Sections 1, 11, and 6, respectively, and AS7 and AS8 are provided to resist negative moments at Sections 1, and 11, respectively. The table also lists the governing design criteria at each section. The governing output notes are defined as follows:

- MIN STL – The amount of flexural reinforcing is governed by the minimum steel requirement of AASHTO 17.7.4.7 (0.002 times the gross section area).
- FLEXURE – The amount of reinforcing steel is governed by requirements for ultimate flexural strength.
- CRACK – The amount of flexural reinforcing is governed by the crack control requirements.
- COMPRES – The amount of reinforcing required to meet the flexural reinforcing requirements causes excessive concrete compression. No reinforcing area is provided. The user must redesign using a thicker wall or some other adjustment to the input.
- STL STRS – The amount of flexural reinforcing is governed by AASHTO fatigue requirements that limit cyclic stress under live load.

Summary tables for shear design: Table 4-1h presents information used to evaluate the diagonal tension strength. Design Sections 12 through 19 are for shear design by Method 1 which compares the ultimate shear stresses at a location $\phi_V d$ from the face of the wall or haunch against the allowable shear stress value of $2\sqrt{f'c}$ or $3\sqrt{f'c}$ as discussed in Section 2.2.3 and by Method 2. Design Sections 20 through 23 are for shear design by Method 2 when $M/V\phi_V d$ equals 3, live loads are uniform, and the moment is positive.

4.1.3 Output Option 3

Service forces at design locations: Table 4-1e presents the service load moments, thrusts, and shears at each of the design locations shown in Figure 2-3. Maximum and minimum forces due to permanent dead loads, additional dead loads, and live loads are listed separately.

Thrust due to additional dead and live loads is considered if the associated moment (for flexure design locations 1 to 11) or the associated shear (for shear design locations 12 to 23) is included in the design force. Consider, for example, design section 1, load case 5. If the moment is positive, then it is treated as a positive additional dead load. In this case the thrust at design section 1 due to load case 5 will also be treated as a positive additional dead load even though it has a negative sign.

4.1.4 Output Option 4

Displacements: Table 4-1b presents the joint displacement for each load condition in a global coordinate system, as shown in Figure 2-2. These displacements are based on an elastic analysis of an uncracked concrete section and are not estimates of expected field displacements. They are used only for consistency checks.

Service forces for each load case: Table 4-1d presents the service load moments, thrusts, and shears for each load case at each of the design locations. Load cases are discussed in Section 2.2.1.

Member end forces: Table 4-1c presents the member end forces resulting from the analysis.

B O X C A R

A Microcomputer Program for the Analysis and
Design of Reinforced Concrete Box Culverts
VERSION 1.0 - 1 NOVEMBER 1988

Developed by

Simpson Gumpertz & Heger Inc.
Arlington Massachusetts
in cooperation with

The Federal Highway Administration
and
The American Concrete Pipe Association

The application of this non-proprietary software product is the responsibility of the user. The user must select input values suitable to his specific installation. Use of default parameters does not assure a safe design for all installations. The information presented in the computer output is for review, interpretation, application, and approval by a qualified engineer who must assume full responsibility for verifying that said output is appropriate and correct. There are no express or implied warranties. Use of this product does not constitute endorsement by FHWA or other agents.

DATE: 12-14-1988
TIME: 14:49:20

TABLE 4-1a LISTING OF INPUT DATA

Filename	OUTPUT.BOX
Job Description	Description of Output

Span	8 ft
Rise	6 ft
Depth of Fill to Culvert Top	10 ft

BOX GEOMETRY

Top Slab Thickness	8 in.
Bottom Slab Thickness	8 in.
Sidewall Thickness	8 in.

HAUNCH DIMENSIONS

	Horizontal	Vertical
Top haunches	8 in.	8 in.
Bottom haunches	8 in.	8 in.

CONCRETE COVERS

Top Slab Outside Face	1.5 in.
Bottom Slab Outside Face	1.5 in.
Sidewall Outside Face	1.5 in.
Top Slab Inside Face	1.5 in.
Bottom Slab Inside Face	1.5 in.
Sidewall Inside Face	1.5 in.

MATERIAL PROPERTIES

Main Reinforcing Yield Stress	60	ksi
Main Reinforcing Type 3 No. of Layers	1	
Design Concrete Strength	4	ksi
Concrete Density	150	pcf

LOAD FACTORS

Dead Load Factor (Shear and Moment)	1.5
Dead Load Factor (Thrust)	1
Live Load Factor (Shear and Moment)	2.17
Live Load Factor (Thrust)	1

PHI FACTORS

Shear	.85
Flexure	.9

TABLE 4-1a CONTINUED

REINFORCING DIAMETERS

Top Slab Outside Face(AS7)	.4	in.
Bottom Slab Outside Face(AS8)	.4	in.
Sidewall Outside Face(AS1)	.4	in.
Top Slab Inside Face(AS2)	.4	in.
Bottom Slab Inside Face(AS3)	.4	in.
Sidewall Inside Face(AS4)	.4	in.

These diameters are used to estimate depth to tension reinforcing from compression face. They do not represent required reinforcing diameters.

MAXIMUM REINFORCING SPACING

Top Slab Outside Face(AS7)	8	in.
Bottom Slab Outside Face(AS8)	8	in.
Sidewall Outside Face(AS1)	8	in.
Top Slab Inside Face(AS2)	8	in.
Bottom Slab Inside Face(AS3)	8	in.
Sidewall Inside Face(AS4)	8	in.

SOIL LOAD DATA

Soil Density	120	pcf
Minimum Lateral Pressure Coefficient	.25	
Maximum Lateral Pressure Coefficient	.5	
Soil Structure Interaction Factor	1	

LIVE LOAD DATA

Live Load HS- 20

Direction of travel Transverse to culvert flow

TABLE 4-1a CONTINUED

SURCHARGE LOADS

UNIFORM VERTICAL LOAD	
Magnitude	0 psf
VARYING LATERAL LOAD	
Magnitude at Top	0 psf
Magnitude at Bottom	0 psf
APPLICATION CODE	PERMANENT DEAD LOAD

FLUID LOADS

Depth of Fluid	6 ft
Fluid Density	62.5 pcf

AASHTO HS-20. 120.00 INCHES OF FILL
TRAFFIC TRANSVERSE TO CULVERT FLOW

CONDITION B GOVERNS SERVICE LIVE LOADS
CONDITION B GOVERNS ULTIMATE LIVE LOADS

TABLE 4-1a CONTINUED

DISPLACEMENT MATRIX - INCHES AND RADIANS

NODE	LOAD	HORIZONTAL	VERTICAL	ROTATION
1	1	-.1444E-08	-.1739E-03	-.1256E-03
	2	.5579E-08	-.1217E-02	-.9601E-03
	3	.4248E-03	.7971E-11	.1964E-03
	4	-.1589E-03	-.2655E-12	-.7540E-04
	5	.4248E-03	.7971E-11	.1964E-03
	6	-.2167E-08	-.1027E-03	-.8102E-04
	7	.0000E+00	.0000E+00	.0000E+00
	8	.5718E-04	.9663E-14	.2746E-04
	9	.0000E+00	.0000E+00	.0000E+00
	10	.0000E+00	.0000E+00	.0000E+00
2	1	.4430E-04	-.1739E-03	.1256E-03
	2	.5588E-08	-.1217E-02	.9601E-03
	3	.4611E-04	.0000E+00	-.1964E-03
	4	-.5749E-04	.0000E+00	.7540E-04
	5	.4611E-04	.0000E+00	-.1964E-03
	6	-.2154E-08	-.1027E-03	.8102E-04
	7	.0000E+00	.0000E+00	.0000E+00
	8	-.6208E-05	.0000E+00	-.2746E-04
	9	.0000E+00	.0000E+00	.0000E+00
	10	.0000E+00	.0000E+00	.0000E+00
3	1	.0000E+00	.0000E+00	-.1698E-03
	2	.0000E+00	.0000E+00	-.9601E-03
	3	.0000E+00	.0000E+00	.2040E-03
	4	.0000E+00	.0000E+00	-.8246E-04
	5	.0000E+00	.0000E+00	.2040E-03
	6	.0000E+00	.0000E+00	-.8102E-04
	7	.0000E+00	.0000E+00	.0000E+00
	8	.0000E+00	.0000E+00	.2643E-04
	9	.0000E+00	.0000E+00	.0000E+00
	10	.0000E+00	.0000E+00	.0000E+00
4	1	.4431E-04	.0000E+00	.1698E-03
	2	.5821E-10	.0000E+00	.9601E-03
	3	.4709E-03	.0000E+00	-.2040E-03
	4	-.2164E-03	.0000E+00	.8246E-04
	5	.4709E-03	.0000E+00	-.2040E-03
	6	.3638E-11	.0000E+00	.8102E-04
	7	.0000E+00	.0000E+00	.0000E+00
	8	.5097E-04	.0000E+00	-.2643E-04
	9	.0000E+00	.0000E+00	.0000E+00
	10	.0000E+00	.0000E+00	.0000E+00

TABLE 4-1b DISPLACEMENTS

END FORCES, KIPS/FT AND INCH-KIPS/FT

		LOAD CASE	A-END AXIAL FX	A-END SHEAR FY	A-END MOMENT M
MEMBER	1	1	-.15681	.43333	2.92450
MEMBER	1	2	.00000	5.20000	59.78034
MEMBER	1	3	1.34013	.00000	8.85528
MEMBER	1	4	-.35904	.00000	-3.40057
MEMBER	1	5	1.34013	.00000	8.85528
MEMBER	1	6	.00000	.43881	5.04461
MEMBER	1	7	.00000	.00000	.00000
MEMBER	1	8	.22434	.00000	1.23848
MEMBER	1	9	.00000	.00000	.00000
MEMBER	1	10	.00000	.00000	.00000
MEMBER	2	1	.80000	-.15681	2.92449
MEMBER	2	2	5.60000	.00000	59.78035
MEMBER	2	3	.00000	1.24013	8.85528
MEMBER	2	4	.00000	-.35904	-3.40057
MEMBER	2	5	.00000	1.24013	8.85528
MEMBER	2	6	.47256	.00000	5.04461
MEMBER	2	7	.00000	.00000	.00000
MEMBER	2	8	.00000	.20101	1.23848
MEMBER	2	9	.00000	.00000	.00000
MEMBER	2	10	.00000	.00000	.00000
MEMBER	3	1	.15681	1.16667	15.46945
MEMBER	3	2	.00000	5.20000	59.78033
MEMBER	3	3	1.66653	.00000	9.20012
MEMBER	3	4	-.76596	-.11538	-6.17773
MEMBER	3	5	1.66653	.00000	9.20012
MEMBER	3	6	.00000	.43881	5.04461
MEMBER	3	7	.00000	.00000	.00000
MEMBER	3	8	.18040	.00000	1.19206
MEMBER	3	9	.00000	.00000	.00000
MEMBER	3	10	.00000	.00000	.00000
MEMBER	4	1	.80000	.15681	15.46946
MEMBER	4	2	5.60000	.00000	59.78032
MEMBER	4	3	.00000	1.49320	9.20012
MEMBER	4	4	.00000	-.76596	-6.17773
MEMBER	4	5	.00000	1.49320	9.20012
MEMBER	4	6	.47256	.00000	5.04461
MEMBER	4	7	.00000	.00000	.00000
MEMBER	4	8	.00000	.16694	1.19206
MEMBER	4	9	.00000	.00000	.00000
MEMBER	4	10	.00000	.00000	.00000

TABLE 4-1c MEMBER END FORCES

		LOAD CASE	B-END AXIAL FX	SHEAR FY	MOMENT M
MEMBER	1	1	.15681	.43333	-2.92450
MEMBER	1	2	.00000	5.20000	-59.78034
MEMBER	1	3	-1.34013	.00000	-8.85528
MEMBER	1	4	.35904	.00000	3.40057
MEMBER	1	5	-1.34013	.00000	-8.85528
MEMBER	1	6	.00000	.43881	-5.04461
MEMBER	1	7	.00000	.00000	.00000
MEMBER	1	8	-.22434	.00000	-1.23848
MEMBER	1	9	.00000	.00000	.00000
MEMBER	1	10	.00000	.00000	.00000
MEMBER	2	1	-.80000	.15681	-15.46945
MEMBER	2	2	-5.60000	.00000	-59.78035
MEMBER	2	3	.00000	1.49320	-9.20012
MEMBER	2	4	.00000	-.76596	6.17773
MEMBER	2	5	.00000	1.49320	-9.20012
MEMBER	2	6	-.47256	.00000	-5.04461
MEMBER	2	7	.00000	.00000	.00000
MEMBER	2	8	.00000	.16694	-1.19206
MEMBER	2	9	.00000	.00000	.00000
MEMBER	2	10	.00000	.00000	.00000
MEMBER	3	1	-.15681	1.16667	-15.46946
MEMBER	3	2	.00000	5.20000	-59.78035
MEMBER	3	3	-1.66653	.00000	-9.20012
MEMBER	3	4	.76596	-.11538	6.17773
MEMBER	3	5	-1.66653	.00000	-9.20012
MEMBER	3	6	.00000	.43881	-5.04461
MEMBER	3	7	.00000	.00000	.00000
MEMBER	3	8	-.18040	.00000	-1.19206
MEMBER	3	9	.00000	.00000	.00000
MEMBER	3	10	.00000	.00000	.00000
MEMBER	4	1	-.80000	-.15681	-2.92450
MEMBER	4	2	-5.60000	.00000	-59.78034
MEMBER	4	3	.00000	1.24013	-8.85528
MEMBER	4	4	.00000	-.35904	3.40057
MEMBER	4	5	.00000	1.24013	-8.85528
MEMBER	4	6	-.47256	.00000	-5.04461
MEMBER	4	7	.00000	.00000	.00000
MEMBER	4	8	.00000	.20101	-1.23848
MEMBER	4	9	.00000	.00000	.00000
MEMBER	4	10	.00000	.00000	.00000

TABLE 4-1c CONTINUED

SERVICE FORCES FOR EACH LOAD CONDITION

DES. SECT.	DIST. FROM A-END(IN.)	LOAD CONDITION, MOMENT(IN-KIP/FT)									
1	52.00										
		1	8.34	2	75.42	3	-8.86	4	3.40	5	-8.86
		6	6.36	7	.00	8	-1.24	9	.00	10	.00
2	12.00										
		1	1.68	2	-4.58	3	-8.86	4	3.40	5	-8.86
		6	-.39	7	.00	8	-1.24	9	.00	10	.00
3	4.00										
		1	-1.26	2	-39.78	3	-8.86	4	3.40	5	-8.86
		6	-3.36	7	.00	8	-1.24	9	.00	10	.00
4	76.00										
		1	-3.55	2	-59.78	3	-4.10	4	1.96	5	-4.10
		6	-5.04	7	.00	8	-.48	9	.00	10	.00
5	68.00										
		1	-4.81	2	-59.78	3	4.16	4	-.87	5	4.16
		6	-5.04	7	.00	8	.76	9	.00	10	.00
6	40.70										
		1	-9.09	2	-59.78	3	18.26	4	-7.53	5	18.26
		6	-5.04	7	.00	8	2.47	9	.00	10	.00
7	12.00										
		1	-13.59	2	-59.78	3	5.66	4	-2.05	5	5.66
		6	-5.04	7	.00	8	.56	9	.00	10	.00
8	4.00										
		1	-14.84	2	-59.78	3	-3.57	4	3.11	5	-3.57
		6	-5.04	7	.00	8	-.55	9	.00	10	.00
9	100.00										
		1	-10.98	2	-39.78	3	-9.20	4	5.72	5	-9.20
		6	-3.36	7	.00	8	-1.19	9	.00	10	.00
10	92.00										
		1	-3.08	2	-4.58	3	-9.20	4	4.87	5	-9.20

TABLE 4-1d SERVICE FORCES FOR EACH LOAD CASE

		6	-.39	7	.00	8	-1.19	9	.00	10	.00
11	52.00										
		1	14.86	2	75.42	3	-9.20	4	2.95	5	-9.20
		6	6.36	7	.00	8	-1.19	9	.00	10	.00
12	17.35										
		1	3.34	2	15.41	3	-8.86	4	3.40	5	-8.86
		6	1.30	7	.00	8	-1.24	9	.00	10	.00
13	17.35										
		1	3.34	2	15.41	3	-8.86	4	3.40	5	-8.86
		6	1.30	7	.00	8	-1.24	9	.00	10	.00
14	62.65										
		1	-5.65	2	-59.78	3	8.70	4	-2.66	5	8.70
		6	-5.04	7	.00	8	1.40	9	.00	10	.00
15	62.65										
		1	-5.65	2	-59.78	3	8.70	4	-2.66	5	8.70
		6	-5.04	7	.00	8	1.40	9	.00	10	.00
16	17.35										
		1	-12.75	2	-59.78	3	10.39	4	-4.50	5	10.39
		6	-5.04	7	.00	8	1.17	9	.00	10	.00
17	17.35										
		1	-12.75	2	-59.78	3	10.39	4	-4.50	5	10.39
		6	-5.04	7	.00	8	1.17	9	.00	10	.00
18	86.64										
		1	1.40	2	15.41	3	-9.20	4	4.39	5	-9.20
		6	1.30	7	.00	8	-1.19	9	.00	10	.00
19	86.64										
		1	1.40	2	15.41	3	-9.20	4	4.39	5	-9.20
		6	1.30	7	.00	8	-1.19	9	.00	10	.00
20	26.73										
		1	5.68	2	43.50	3	-8.86	4	3.40	5	-8.86
		6	3.67	7	.00	8	-1.24	9	.00	10	.00
21	62.70										
		1	-15.47	2	-59.78	3	-9.20	4	6.18	5	-9.20
		6	-5.04	7	.00	8	-1.19	9	.00	10	.00
22	17.34										

TABLE 4-1d CONTINUED

		1	-15.47	2	-59.78	3	-9.20	4	6.18	5	-9.20
		6	-5.04	7	.00	8	-1.19	9	.00	10	.00
23	76.74										
		1	8.00	2	44.81	3	-9.20	4	3.68	5	-9.20
		6	3.78	7	.00	8	-1.19	9	.00	10	.00

TABLE 4-1d CONTINUED

DES. SECT.	DIST. FROM A-END(IN.)	LOAD CONDITION, SHEAR(KIPS/FT)									
12	17.35										
		1	.29	2	3.46	3	.00	4	.00	5	.00
		6	.29	7	.00	8	.00	9	.00	10	.00
13	17.35										
		1	.29	2	3.46	3	.00	4	.00	5	.00
		6	.29	7	.00	8	.00	9	.00	10	.00
14	62.65										
		1	.16	2	.00	3	-.77	4	.32	5	-.77
		6	.00	7	.00	8	-.10	9	.00	10	.00
15	62.65										
		1	.16	2	.00	3	-.77	4	.32	5	-.77
		6	.00	7	.00	8	-.10	9	.00	10	.00
16	17.35										
		1	.16	2	.00	3	.78	4	-.39	5	.78
		6	.00	7	.00	8	.10	9	.00	10	.00
17	17.35										
		1	.16	2	.00	3	.78	4	-.39	5	.78
		6	.00	7	.00	8	.10	9	.00	10	.00
18	86.64										
		1	-.78	2	-3.46	3	.00	4	.08	5	.00
		6	-.29	7	.00	8	.00	9	.00	10	.00
19	86.64										
		1	-.78	2	-3.46	3	.00	4	.08	5	.00
		6	-.29	7	.00	8	.00	9	.00	10	.00
20	26.73										
		1	.21	2	2.53	3	.00	4	.00	5	.00
		6	.21	7	.00	8	.00	9	.00	10	.00
21	62.70										
		1	.16	2	.00	3	1.49	4	-.77	5	1.49

TABLE 4-1d CONTINUED

		6	.00	7	.00	8	.17	9	.00	10	.00
22	17.34										
		1	.16	2	.00	3	1.49	4	-.77	5	1.49
		6	.00	7	.00	8	.17	9	.00	10	.00
23	76.74										
		1	-.56	2	-2.47	3	.00	4	.06	5	.00
		6	-.21	7	.00	8	.00	9	.00	10	.00

TABLE 4-1d CONTINUED

LOCATION	LOAD CONDITION, THRUST(KIPS/FT)									
TOP										
	1	.16	2	.00	3	-1.34	4	.36	5	-1.34
	6	.00	7	.00	8	-.22	9	.00	10	.00
SIDE										
	1	-.80	2	-5.60	3	.00	4	.00	5	.00
	6	-.47	7	.00	8	.00	9	.00	10	.00
BOTT										
	1	-.16	2	.00	3	-1.67	4	.77	5	-1.67
	6	.00	7	.00	8	-.18	9	.00	10	.00

TABLE 4-1d CONTINUED

FORCES DUE TO
SERVICE AND ULTIMATE LOADS

SERVICE LOAD FORCES

SERVICE LOAD MOMENTS (IN-KIPS/FT)

DES. SECT.	MEMBER	DIST. TO A-END	PERM. DL.	ADD. DL. POS.	ADD. DL. NEG.	LIVELOAD POS.	LIVELOAD NEG.
1	TOP	52.00	74.91	3.40	-8.86	6.36	-1.24
2	TOP	12.00	-11.76	3.40	-8.86	.00	-1.62
3	TOP	4.00	-49.89	3.40	-8.86	.00	-4.60
4	SIDE	76.00	-67.43	1.96	-4.10	.00	-5.53
5	SIDE	68.00	-60.43	4.16	-.87	.76	-5.04
6	SIDE	40.70	-50.61	18.26	-7.53	2.47	-5.04
7	SIDE	12.00	-67.70	5.66	-2.05	.56	-5.04
8	SIDE	4.00	-78.19	3.11	-3.57	.00	-5.60
9	BOTT	100.00	-59.96	5.72	-9.20	.00	-4.55
10	BOTT	92.00	-16.87	4.87	-9.20	.00	-1.58
11	BOTT	52.00	81.08	2.95	-9.20	6.36	-1.19
12	TOP	17.35	9.89	3.40	-8.86	1.30	-1.24
13	TOP	17.35	9.89	3.40	-8.86	1.30	-1.24
14	SIDE	62.65	-56.72	8.70	-2.66	1.40	-5.04
15	SIDE	62.65	-56.72	8.70	-2.66	1.40	-5.04
16	SIDE	17.35	-62.14	10.39	-4.50	1.17	-5.04
17	SIDE	17.35	-62.14	10.39	-4.50	1.17	-5.04
18	BOTT	86.64	7.60	4.39	-9.20	1.30	-1.19
19	BOTT	86.64	7.60	4.39	-9.20	1.30	-1.19
20	TOP	26.73	40.33	3.40	-8.86	3.67	-1.24
21	SIDE	62.70	.00	.00	.00	.00	.00
22	SIDE	17.34	.00	.00	.00	.00	.00
23	BOTT	76.74	43.60	3.68	-9.20	3.78	-1.19

TABLE4-1e SERVICE FORCES AT DESIGN LOCATIONS

SERVICE LOAD SHEARS (KIPS/FT)

DES. SECT.	MEMBER	DIST. TO A-END	PERM. DL.	ADD. DL. POS.	ADD. DL. NEG.	LIVELOAD POS.	LIVELOAD NEG.
12	TOP	17.35	3.75	.00	.00	.29	.00
13	TOP	17.35	3.75	.00	.00	.29	.00
14	SIDE	62.65	-.61	.32	-.77	.00	-.10
15	SIDE	62.65	-.61	.32	-.77	.00	-.10
16	SIDE	17.35	.93	.78	-.39	.10	.00
17	SIDE	17.35	.93	.78	-.39	.10	.00
18	BOTT	86.64	-4.24	.08	.00	.00	-.29
19	BOTT	86.64	-4.24	.08	.00	.00	-.29
20	TOP	26.73	2.74	.00	.00	.21	.00
21	SIDE	62.70	.00	.00	.00	.00	.00
22	SIDE	17.34	.00	.00	.00	.00	.00
23	BOTT	76.74	-3.03	.06	.00	.00	-.21

TABLE 4-1e CONTINUED

SERVICE LOAD THRUSTS (KIPS/FT)

DES. SECT.	MEMBER	DIST. TO A-END	PERM. DL.	ADD. DL. POS.	ADD. DL. NEG.	LIVELOAD POS.	LIVELOAD NEG.
1	TOP	52.00	-1.18	.36	-1.34	.00	-.22
2	TOP	12.00	-1.18	.36	-1.34	-.22	.00
3	TOP	4.00	-1.18	.36	-1.34	-.22	.00
4	SIDE	76.00	-6.40	.00	.00	.00	-.47
5	SIDE	68.00	-6.40	.00	.00	.00	-.47
6	SIDE	40.70	-6.40	.00	.00	.00	-.47
7	SIDE	12.00	-6.40	.00	.00	.00	-.47
8	SIDE	4.00	-6.40	.00	.00	.00	-.47
9	BOTT	100.00	-1.82	.77	-1.67	-.18	.00
10	BOTT	92.00	-1.82	.77	-1.67	-.18	.00
11	BOTT	52.00	-1.82	.77	-1.67	.00	-.18
12	TOP	17.35	-1.18	.00	.00	.00	-.22
13	TOP	17.35	-1.18	.00	.00	.00	-.22
14	SIDE	62.65	-6.40	.00	.00	.00	.00
15	SIDE	62.65	-6.40	.00	.00	.00	.00
16	SIDE	17.35	-6.40	.00	.00	.00	.00
17	SIDE	17.35	-6.40	.00	.00	.00	.00
18	BOTT	86.64	-1.82	.77	.00	-.18	.00
19	BOTT	86.64	-1.82	.77	.00	-.18	.00
20	TOP	26.73	-1.18	.00	.00	.00	-.22
21	SIDE	62.70	.00	.00	.00	.00	.00
22	SIDE	17.34	.00	.00	.00	.00	.00
23	BOTT	76.74	-1.82	.77	.00	-.18	.00

TABLE 4-1e CONTINUED

ULTIMATE LOAD FORCES

SECTION	MAX M+ (IN.-K/FT)	MAX V+ (K/FT)	MAX P+ (K/FT)	MAX M- (IN.-K/FT)	MAX V- (K/FT)	MAX P- (K/FT)
1	127.01	.00	-.82	.00	.00	-2.75
2	.00	7.01	-1.05	-33.36	.00	-2.52
3	.00	8.41	-1.05	-95.02	.00	-2.52
4	.00	.00	-6.40	-115.58	-3.45	-6.87
5	.00	.00	-6.40	-99.51	-2.74	-6.87
6	.00	.25	-6.40	-94.77	-.00	-6.87
7	.00	3.39	-6.40	-112.20	.00	-6.87
8	.00	4.43	-6.40	-131.04	.00	-6.87
9	.00	.00	-1.24	-110.57	-9.42	-3.49
10	.00	.00	-1.24	-41.47	-7.85	-3.49
11	135.59	.00	-1.06	.00	.00	-3.67
12	21.89	6.07	-1.18	-.30	.00	-1.41
13	21.89	6.07	-1.18	-.30	.00	-1.41
14	.00	.00	-6.40	-96.64	-2.24	-6.40
15	.00	.00	-6.40	-96.64	-2.24	-6.40
16	.00	2.72	-6.40	-107.53	.00	-6.40
17	.00	2.72	-6.40	-107.53	.00	-6.40
18	19.94	.00	-1.24	-4.18	-6.80	-1.82
19	19.94	.00	-1.24	-4.18	-6.80	-1.82
20	71.10	4.43	-1.18	.00	.00	-1.41
21	.00	.00	.00	.00	.00	.00
22	.00	.00	.00	.00	.00	.00
23	76.60	.00	-1.24	.00	-4.77	-1.82

TABLE 4-1f ULTIMATE FORCES AT DESIGN LOCATIONS

****** FLEXURE DESIGN TABLE ******

DES. SEC.	WALL, SIGN OF MOMENT	DEPTH TO STEEL (IN)	ULT. MOMENT (IN-K/FT)	ULT. THRUST (K/FT)	FLEX. REINF. ULT.(1) (SQ.IN/FT)	FLEX. REINF. MIN.(2) (SQ.IN/FT)	CRACK INDEX	GOV. STEEL (3) (SQ.IN/FT)	GOV. MODE (4)
1	TOP-NEG	6.30	.0	2.7	.000	.192	.0	.192	MIN STL
2	TOP-NEG	6.30	33.4	2.5	.070	.192	.0	.192	MIN STL
3	TOP-NEG	14.30	95.0	2.5	.098	.192	.0	.192	MIN STL
4	SIDE-NEG	14.30	115.6	6.9	.081	.192	.0	.192	MIN STL
5	SIDE-NEG	6.30	99.5	6.9	.227	.192	.0	.227	FLEXURE
6	SIDE-NEG	6.30	94.8	6.9	.212	.192	.0	.212	FLEXURE
7	SIDE-NEG	6.30	112.2	6.9	.268	.192	.0	.268	FLEXURE
8	SIDE-NEG	14.30	131.0	6.9	.101	.192	.0	.192	MIN STL
9	BOTTOM-NEG	14.30	110.6	3.5	.109	.192	.0	.192	MIN STL
10	BOTTOM-NEG	6.30	41.5	3.5	.083	.192	.0	.192	MIN STL
11	BOTTOM-NEG	6.30	.0	3.7	.000	.192	.0	.192	MIN STL
1	TOP-POS	6.30	127.0	.8	.384	.192	.0	.384	FLEXURE
6	SIDE-POS	6.30	.0	6.4	.000	.192	.0	.192	MIN STL
11	BOTTOM-POS	6.30	135.6	1.1	.410	.192	.1	.410	FLEXURE

NOTES:
1. REQUIRED REINFORCING TO DEVELOP ULTIMATE FLEXURAL STRENGTH.
2. MINIMUM FLEXURAL REINFORCING ALLOWED.
3. REINFORCING REQUIRED TO MEET ALL DESIGN CRITERIA. THE GOVERNING CRITERIA IS INDICATED UNDER THE COLUMN "GOVERNING MODE".
4. IF GOVERNING MODE IS LISTED AS CRACK, THE REINFORCING MAY BE REDUCED BY DECREASING THE MAXIMUM REINFORCING SPACING.

TABLE 4-1g SUMMARY OF TABLE FOR FLEXURE DESIGN

*******SHEAR DESIGN METHOD 1 - AASHTO*********

LOCATION	ULTIMATE SHEAR (K/FT)	ALLOWABLE SHEAR (K/FT)	DIAGONAL TENSION INDEX	DEPTH TO STEEL (IN.)	STIRRUPS REQD?
12	6.1	12.2	.50	6.30	NO
13	6.1	12.2	.50	6.30	NO
14	2.2	12.2	.18	6.30	NO
15	2.2	12.2	.18	6.30	NO
16	2.7	12.2	.22	6.30	NO
17	2.7	12.2	.22	6.30	NO
18	6.8	12.2	.56	6.30	NO
19	6.8	12.2	.56	6.30	NO

CONCRETE SHEAR STRENGTH TAKEN AS 3.SQUARE ROOTS f'c

TABLE 4-1h SUMMARY TABLE FOR SHEAR DESIGN

****** SHEAR DESIGN TABLE - METHOD 2 ******

DESIGN SECTION	12	13	14	15
M/(V*PHI*D)	.889	.930	2.759	6.793
ULTIMATE SHEAR (KIPS/FT)	6.068	6.068	2.237	2.237
ULTIMATE THRUST (KIPS/FT)	2.523	2.523	6.873	6.873
STEEL RATIO	.002540	.001119	.001562	.003545
DEPTH TO STEEL (IN.)	6.300	14.300	14.300	6.300
DISTANCE FROM A-END, (IN.)	17.355	17.355	62.645	62.645
THRUST FACTOR (FN)	.944	.952	.768	.750
DIAGONAL TENSION STRENGTH, (KIPS/FT)	12.626	21.892	14.270	7.879
ULTIMATE SHEAR/ ALLOWABLE SHEAR	.481	.277	.157	.284
NEW STEEL AREA DUE TO DIAGONAL TENSION (SQ.IN./FT)	.000	.000	.000	.000

TABLE 4-1h CONTINUED

****** SHEAR DESIGN TABLE - METHOD 2 ******
****** CONTINUED ******

DESIGN SECTION	16	17	18	19
M/(V*PHI*D)	6.179	2.434	.965	.986
ULTIMATE SHEAR (KIPS/FT)	2.718	2.718	6.801	6.801
ULTIMATE THRUST (KIPS/FT)	6.873	6.873	3.490	3.490
STEEL RATIO	.003545	.001562	.001119	.002540
DEPTH TO STEEL (IN.)	6.300	14.300	14.300	6.300
DISTANCE FROM A-END, (IN.)	17.355	17.355	86.645	86.645
THRUST FACTOR (FN)	.766	.804	.942	.931
DIAGONAL TENSION STRENGTH, (KIPS/FT)	7.719	14.917	21.733	12.167
ULTIMATE SHEAR/ ALLOWABLE SHEAR	.352	.182	.313	.559
NEW STEEL AREA DUE TO DIAGONAL TENSION NN(SQ.IN./FT)	.000	.000	.000	.000

TABLE 4-1h CONTINUED

****** SHEAR DESIGN TABLE - METHOD 2 ******
****** CONTINUED ******

DESIGN SECTION	20	21	22	23
M/(V*PHI*D)	3.000	.000	.000	3.000
ULTIMATE SHEAR (KIPS/FT)	4.426	.000	.000	4.768
ULTIMATE THRUST (KIPS/FT)	1.183	.000	.000	1.238
STEEL RATIO	.005082	.000000	.000000	.005421
DEPTH TO STEEL (IN.)	6.300	.000	.000	6.300
DISTANCE FROM A-END, (IN.)	26.734	.000	.000	76.743
THRUST FACTOR (FN)	.957	.000	.000	.959
DIAGONAL TENSION STRENGTH, (KIPS/FT)	6.624	.000	.000	6.715
ULTIMATE SHEAR/ ALLOWABLE SHEAR	.668	.000	.000	.710
NEW STEEL AREA DUE TO DIAGONAL TENSION (SQ.IN./FT)	.000	.000	.000	.000

TABLE 4-1h CONTINUED

BOX CULVERT DESIGN SUMMARY SHEET
8.00 FT. SPAN X 6.00 FT. RISE

****

I N S T A L L A T I O N   D A T A

HEIGHT OF FILL OVER CULVERT,FT	10.000
SOIL UNIT WEIGHT, PCF	120.000
MINIMUM LATERAL SOIL PRESSURE COEFFICIENT	.250
MAXIMUM LATERAL SOIL PRESSURE COEFFICIENT	.500
SOIL - STRUCTURE INTERACTION COEFFICIENT	1.000

L O A D I N G   D A T A

DEAD LOAD FACTOR - MOMENT AND SHEAR	1.500
DEAD LOAD FACTOR - THRUST	1.000
LIVE LOAD FACTOR - MOMENT AND SHEAR	2.170
LIVE LOAD FACTOR - THRUST	1.000
STRENGTH REDUCTION FACTOR-FLEXURE	.900
STRENGTH REDUCTION FACTOR-DIAGONAL TENSION	.850
LIVE LOAD TYPE	AASHTO HS-20.
DIRECTION OF VEHICLE TRAVEL RELATIVE TO CULVERT FLOW	TRANSVERSE
VERTICAL SURCHARGE PRESSURE, PSF	.0
HORIZ. SURCHARGE PRESSURE AT CULVERT TOP, PSF	.0
HORIZ. SURCHARGE PRESSURE AT CULVERT BOTTOM, PSF	.0

M A T E R I A L   P R O P E R T I E S

MINIMUM SPECIFIED REINFORCING YIELD STRENGTH, KSI	60.000
CONCRETE - SPECIFIED COMPRESSIVE STRENGTH, KSI	4.000
REINFORCING TYPE	DEFORMED WIRE OR BAR

G E O M E T R Y

TOP SLAB THICKNESS, INCHES	8.000
SIDE WALL THICKNESS, INCHES	8.000
BOTTOM SLAB THICKNESS, INCHES	8.000
HORIZONTAL HAUNCH DIMENSION, INCHES	8.000
VERTICAL HAUNCH DIMENSION, INCHES	8.000
CONCRETE COVER OVER STEEL, INCHES	
TOP SLAB - OUTSIDE FACE	1.500
SIDE WALL - OUTSIDE FACE	1.500
BOTTOM SLAB - OUTSIDE FACE	1.500
TOP SLAB - INSIDE FACE	1.500
SIDE WALL - INSIDE FACE	1.500
BOTTOM SLAB - INSIDE FACE	1.500

TABLE 4-1i SUMMARY TABLE FOR DESIGN

R E I N F O R C I N G   S T E E L   D A T A

LOCATION	AREA SQ. IN. PER FT	STIRRUPS REQUIRED?
TRANSVERSE		
SIDE WALL - OUTSIDE FACE (As1)	.268	NO
TOP SLAB - INSIDE FACE (As2)	.384	NO
BOTTOM SLAB - INSIDE FACE (As3)	.410	NO
SIDE WALL - INSIDE FACE (As4)	.192	NO
TOP SLAB - OUTSIDE FACE (As7)	.192	NO
BOTTOM SLAB - OUTSIDE FACE (As8)	.192	NO

NOTES: 1 TOP SLAB OUTSIDE FACE STEEL (AS7) MUST EXTEND COMPLETELY ACROSS THE TOP SLAB. THE SIDEWALL OUTSIDE FACE STEEL (AS1) MUST BE BENT AT THE CORNER AND EXTENDED ACROSS THE TOP SLAB SUFFICIENTLY TO MEET AASHTO REQUIREMENTS FOR TENSION LAPS.

2 BOTTOM SLAB OUTSIDE FACE STEEL (AS8) MUST EXTEND COMPLETELY ACROSS THE BOTTOM SLAB. THE SIDEWALL OUTSIDE FACE STEEL (AS1) MUST BE BENT AT THE CORNER AND EXTENDED ACROSS THE BOTTOM SLAB SUFFICIENTLY TO MEET AASHTO REQUIREMENTS FOR TENSION LAPS.

3 ASMIN = 0.002 x GROSS SECTION AREA

4 THERE MAY BE NEGATIVE MOMENT FROM THE OUTSIDE CORNER OF THE BOX TO 24. INCHES ACROSS THE TOP SLAB.

5 THERE MAY BE NEGATIVE MOMENT FROM THE OUTSIDE CORNER OF THE BOX TO 27. INCHES ACROSS THE BOTTOM SLAB.

TABLE 4-1i CONTINUED

5. DESIGN EXAMPLES

5.1 Example Problem 1

This example problem demonstrates how to obtain a design with the minimum amount of input. Before trying this example problem, be sure that you have the hardware and software requirements described in Section 2.4 of this manual, and the program is installed using the procedures listed in Section 3.1 of this manual. This example demonstrates the design of a culvert with a 10 ft span and an 8 ft rise as shown in Figure 5-1. The culvert is buried under 6 ft of fill. The remaining design parameters are the program default parameters listed in Appendix A of this manual. To obtain a printed design for this problem, perform the following steps.

1) To begin execution of BOXCAR, type:

   BOXCAR [Enter]

2) The Introductory Screen will appear. Press any key and the user warning will appear. Read this carefully, as it states your responsibility while using the program. Again press any key and Main Menu of the program will appear as shown in Table 5-1a. To create a new box culvert input file for this example problem, press "1".

3) Screen 1 now appears. Enter a filename that the input will be stored under on the computer disk. If you call the file EXAMPLE1, then type:

   EXAMPLE1

   Because you completely filled the highlighted field the cursor automatically moves to the next input item. If you selected a filename of less than eight characters you will need to press [Enter].

4) Enter a brief description of the design problem for future identification. The description in this case is:

   Example 1: 10 x 8 Box Culvert with 6 ft of Fill [Enter]

5) Enter the Span, Rise, and Depth of Fill by typing:

   10.0 [Enter]
   8.0 [Enter]
   6.0 [Enter]

6) At this point, you have entered the minimum amount of data required for the program to execute. If you have entered the data as described above, your computer screen should appear identical to that shown in Table 5-1b. Finish editing

by pressing the [F1] key. The screen shown on Table 5-1c will appear. To save and execute the file press 2.

7) Once execution is complete, the program will print the required reinforcing areas to the screen and ask if you wish to save the output. This screen is shown in Table 5-1d.

8) Press "P" [Enter] to save your output. The Print Option Screen (Table 5-1e) will appear. Press "1" [Enter] to obtain minimum output. The program will write the requested information to the disk and will post process the information for printing.

9) After the output is processed press "1" to send the output to the printer. Table 5-1f shows the output you should get for Example 1. See Section 4 of this manual for a description of the output. After the output is finished being printed, the main menu will appear again. Go to example 2 or exit the program and return to the main operating system by pressing "7".

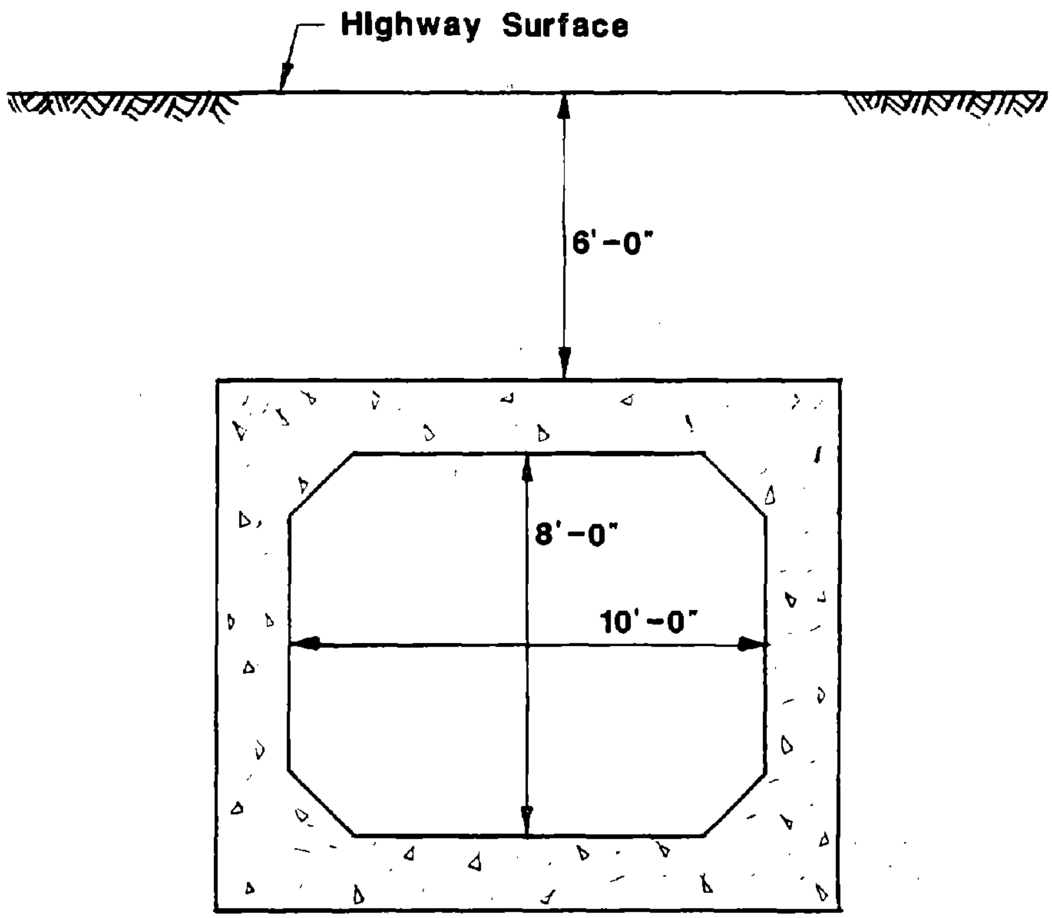


FIGURE 5-1 EXAMPLE PROBLEM 1

```
============================ PROGRAM: BOXCAR ============================

                              MAIN MENU

Input Options     1.  Create a new box culvert file
                  2.  Retrieve an old box culvert file

Execute Option    3.  Execute BOXCAR

Print Options     4.  Print input file
                  5.  Print output file

System Options    6.  Reconfigure default parameters
                  7.  Exit


                  Selection 1

=========================================================================
                              <F2> HELP
```

TABLE 5-1a MAIN MENU

```
===============PROGRAM: BOXCAR ===========================================



      Filename          EXAMPLE1.BOX
      Job Description   Example 1: 10 x 8 Box Culvert with 6 Ft of Fill


      Span                    10.0    ft
      Rise                    8.0     ft
      Depth of Fill           6.0     ft
      to Culvert Top




                                                                  SCREEN 1
=========================================================================
    <F1> = FINISHED EDITING → RETURN TO MAIN MENU          <F2> = HELP
                         <PgDn> View Next Screen
```

TABLE 5-1b SCREEN 1

```
═════════════ PROGRAM: BOXCAR ══════════ CURRENT FILE: EXAMPLE1 ═══════════
PROJECT: Example 1: 10 x 8 Box Culvert with 6 ft of Fill




                 Editing Options

                 1. Save and return to main menu.
                 2. Save and execute.
                 3. Return to main menu without saving data.

                 Enter selection.....
```

TABLE 5-1c SAVE SCREEN

```
R E I N F O R C I N G   S T E E L   D A T A
------------------------------------------------------------------------
                                                  AREA
              LOCATION                          SQ. IN.       STIRRUPS
                                                PER FT        REQUIRED?
------------------------------------------------------------------------
 TRANSVERSE
     SIDE WALL    - OUTSIDE FACE (As1)           .259            NO
     TOP SLAB     - INSIDE  FACE (As2)           .372            NO
     BOTTOM SLAB  - INSIDE  FACE (As3)           .413            NO
     SIDE WALL    - INSIDE  FACE (As4)           .240            NO
     TOP SLAB     - OUTSIDE FACE (As7)           .240            NO
     BOTTOM SLAB  - OUTSIDE FACE (As8)           .240            NO

             DO YOU WISH TO SAVE AND/OR PRINT THIS OUTPUT ? (D/P/N)

             D = WRITE TO DISK AND RETURN TO MAIN MENU.
             P = WRITE TO DISK AND PRINTER AND RETURN TO MAIN MENU.
             N = RETURN TO MAIN MENU WITHOUT SAVING OUTPUT.

               Make Selection....Then Press Enter
```

TABLE 5-1d REINFORCING SCREEN

```
OUTPUT SELECTIONS

        1.  Print Input data and summary sheet.
        2.  Print Above + ultimate forces at design locations,
            flexure and shear design tables.
        3.  Print Above + service forces at design locations.
        4.  Print Above + displacement matrix, service forces for
            each load case and end forces.



        Make Selection....Then Press Enter
```

TABLE 5-1e OUTPUT OPTIONS SCREEN

B O X C A R

A Microcomputer Program for the Analysis and
Design of Reinforced Concrete Box Culverts
VERSION 1.0 - 1 NOVEMBER 1988

Developed by

Simpson Gumpertz & Heger Inc.
Arlington Massachusetts
in cooperation with

The Federal Highway Administration
and
The American Concrete Pipe Association

DATE: 12-14-1988
TIME: 16:17:23

TABLE 5-1f OUTPUT FOR EXAMPLE PROBLEM 1

Filename	EXAMPLE1.BOX
Job Description	Example 1: 10 x 8 Box Cul vert with 6 ft of Fill

Span	10 ft
Rise	8 ft
Depth of Fill to Culvert Top	6 ft

BOX GEOMETRY

Top Slab Thickness	10 in.
Bottom Slab Thickness	10 in.
Sidewall Thickness	10 in.

HAUNCH DIMENSIONS

	Horizontal	Vertical
Top haunches	10 in.	10 in.
Bottom haunches	10 in.	10 in.

CONCRETE COVERS

Top Slab Outside Face	1.5 in.
Bottom Slab Outside Face	1.5 in.
Sidewall Outside Face	1.5 in.
Top Slab Inside Face	1.5 in.
Bottom Slab Inside Face	1.5 in.
Sidewall Inside Face	1.5 in.

MATERIAL PROPERTIES

Main Reinforcing Yield Stress	60	ksi
Main Reinforcing Type 3 No. of Layers	1	
Design Concrete Strength	4	ksi
Concrete Density	150	pcf

LOAD FACTORS

Dead Load Factor (Shear and Moment)	1.5
Dead Load Factor (Thrust)	1
Live Load Factor (Shear and Moment)	2.17
Live Load Factor (Thrust)	1

PHI FACTORS

Shear	.85
Flexure	.9

TABLE 5-1f CONTINUED

REINFORCING DIAMETERS

Top Slab Outside Face(AS7)	.5	in.
Bottom Slab Outside Face(AS8)	.5	in.
Sidewall Outside Face(AS1)	.5	in.
Top Slab Inside Face(AS2)	.5	in.
Bottom Slab Inside Face(AS3)	.5	in.
Sidewall Inside Face(AS4)	.5	in.

These diameters are used to estimate depth to tension reinforcing from compression face. They do not represent required reinforcing diameters.

MAXIMUM REINFORCING SPACING

Top Slab Outside Face(AS7)	8	in.
Bottom Slab Outside Face(AS8)	8	in.
Sidewall Outside Face(AS1)	8	in.
Top Slab Inside Face(AS2)	8	in.
Bottom Slab Inside Face(AS3)	8	in.
Sidewall Inside Face(AS4)	8	in.

SOIL LOAD DATA

Soil Density	120	pcf
Minimum Lateral Pressure Coefficient	.25	
Maximum Lateral Pressure Coefficient	.5	
Soil Structure Interaction Factor	1	

LIVE LOAD DATA

Live Load	HS- 20
Direction of travel	Transverse to culvert flow

TABLE 5-1f CONTINUED

SURCHARGE LOADS

UNIFORM VERTICAL LOAD	
Magnitude	0 psf
VARYING LATERAL LOAD	
Magnitude at Top	0 psf
Magnitude at Bottom	0 psf
APPLICATION CODE	ADDITIONAL DEAD LOAD

FLUID LOADS

Depth of Fluid	8 ft
Fluid Density	62.5 pcf

TABLE 5-1f CONTINUED

BOX CULVERT DESIGN SUMMARY SHEET
10.00 FT. SPAN X 8.00 FT. RISE

INSTALLATION DATA

HEIGHT OF FILL OVER CULVERT,FT	6.000
SOIL UNIT WEIGHT, PCF	120.000
MINIMUM LATERAL SOIL PRESSURE COEFFICIENT	.250
MAXIMUM LATERAL SOIL PRESSURE COEFFICIENT	.500
SOIL - STRUCTURE INTERACTION COEFFICIENT	1.000

LOADING DATA

DEAD LOAD FACTOR - MOMENT AND SHEAR	1.500
DEAD LOAD FACTOR - THRUST	1.000
LIVE LOAD FACTOR - MOMENT AND SHEAR	2.170
LIVE LOAD FACTOR - THRUST	1.000
STRENGTH REDUCTION FACTOR-FLEXURE	.900
STRENGTH REDUCTION FACTOR-DIAGONAL TENSION	.850
LIVE LOAD TYPE	AASHTO HS-20.
DIRECTION OF VEHICLE TRAVEL RELATIVE TO CULVERT FLOW	TRANSVERSE
VERTICAL SURCHARGE PRESSURE, PSF	.0
HORIZ. SURCHARGE PRESSURE AT CULVERT TOP, PSF	.0
HORIZ. SURCHARGE PRESSURE AT CULVERT BOTTOM, PSF	.0

MATERIAL PROPERTIES

MINIMUM SPECIFIED REINFORCING YIELD STRENGTH, KSI	60.000
CONCRETE - SPECIFIED COMPRESSIVE STRENGTH, KSI	4.000
REINFORCING TYPE	DEFORMED WIRE OR BAR

GEOMETRY

TOP SLAB THICKNESS, INCHES	10.000
SIDE WALL THICKNESS, INCHES	10.000
BOTTOM SLAB THICKNESS, INCHES	10.000
HORIZONTAL HAUNCH DIMENSION, INCHES	10.000
VERTICAL HAUNCH DIMENSION, INCHES	10.000
CONCRETE COVER OVER STEEL, INCHES	
TOP SLAB - OUTSIDE FACE	1.500
SIDE WALL - OUTSIDE FACE	1.500
BOTTOM SLAB - OUTSIDE FACE	1.500
TOP SLAB - INSIDE FACE	1.500
SIDE WALL - INSIDE FACE	1.500
BOTTOM SLAB - INSIDE FACE	1.500

TABLE 5-1f CONTINUED

REINFORCING STEEL DATA

LOCATION	AREA SQ. IN. PER FT	STIRRUPS REQUIRED?
TRANSVERSE		
SIDE WALL - OUTSIDE FACE (As1)	.259	NO
TOP SLAB - INSIDE FACE (As2)	.372	NO
BOTTOM SLAB - INSIDE FACE (As3)	.413	NO
SIDE WALL - INSIDE FACE (As4)	.240	NO
TOP SLAB - OUTSIDE FACE (As7)	.240	NO
BOTTOM SLAB - OUTSIDE FACE (As8)	.240	NO

NOTES: 1 TOP SLAB OUTSIDE FACE STEEL (AS7) MUST EXTEND COMPLETELY ACROSS THE TOP SLAB. THE SIDEWALL OUTSIDE FACE STEEL (AS1) MUST BE BENT AT THE CORNER AND EXTENDED ACROSS THE TOP SLAB SUFFICIENTLY TO MEET AASHTO REQUIREMENTS FOR TENSION LAPS.

2 BOTTOM SLAB OUTSIDE FACE STEEL (AS8) MUST EXTEND COMPLETELY ACROSS THE BOTTOM SLAB. THE SIDEWALL OUTSIDE FACE STEEL (AS1) MUST BE BENT AT THE CORNER AND EXTENDED ACROSS THE BOTTOM SLAB SUFFICIENTLY TO MEET AASHTO REQUIREMENTS FOR TENSION LAPS.

3 ASMIN = 0.002 x GROSS SECTION AREA

4 THERE MAY BE NEGATIVE MOMENT FROM THE OUTSIDE CORNER OF THE BOX TO 30. INCHES ACROSS THE TOP SLAB.

5 THERE MAY BE NEGATIVE MOMENT FROM THE OUTSIDE CORNER OF THE BOX TO 34. INCHES ACROSS THE BOTTOM SLAB.

TABLE 5-1f CONTINUED

5.2 Example Problem 2

This example problem demonstrates the use of additional input screens for designing a culvert. This example designs a box culvert having the geometry shown in Figure 5-2. The culvert is buried under 2 ft 6 in. of fill and will be designed for an AASHTO interstate or HS-20 truck wheel load. The concrete compressive strength is 5 ksi and the concrete cover over the tensile steel reinforcement is 1 in. typical.

1) Begin at the Main Menu (see example 1 if you are not at the Main Menu). To create a new box culvert input file for this example problem, press "1".

2) Screen 1 now appears. Enter a filename that the input will be stored under on the computer disk. If you call the file "EXAMPLE2", type:

   EXAMPLE2

3) Enter a brief description of the design problem by typing:

   Example 2: 8 x 8 Box Culvert with 2.5 ft of Fill [Enter]

4) Enter the Span, Rise, and Depth of Fill by typing:

   8.0 [Enter]
   8.0 [Enter]
   2.5 [Enter]

   The displayed screen on your computer should be identical to that shown in Table 5-2a.

5) Press the [PgDn] key to move to the next input screen. For each of the subsequent input screens that appear, enter the data where prompted as shown in Tables 5-2b through 5-2h. The general rules for entering data are discussed in Section 3.1 of this manual.

6) At the end of Screen 7, press the [PgDn] key and go through all the screens again to check that you have entered the data correctly. Then press the [F1] key to get the save option section (see Table 5-1c). Press "2".

7) When program execution is complete the reinforcing requirements should be printed to the screen, which should appear as shown in Table 5-2i. Do not save the output from this example. Press "N" [Enter] to return to the Main Menu.

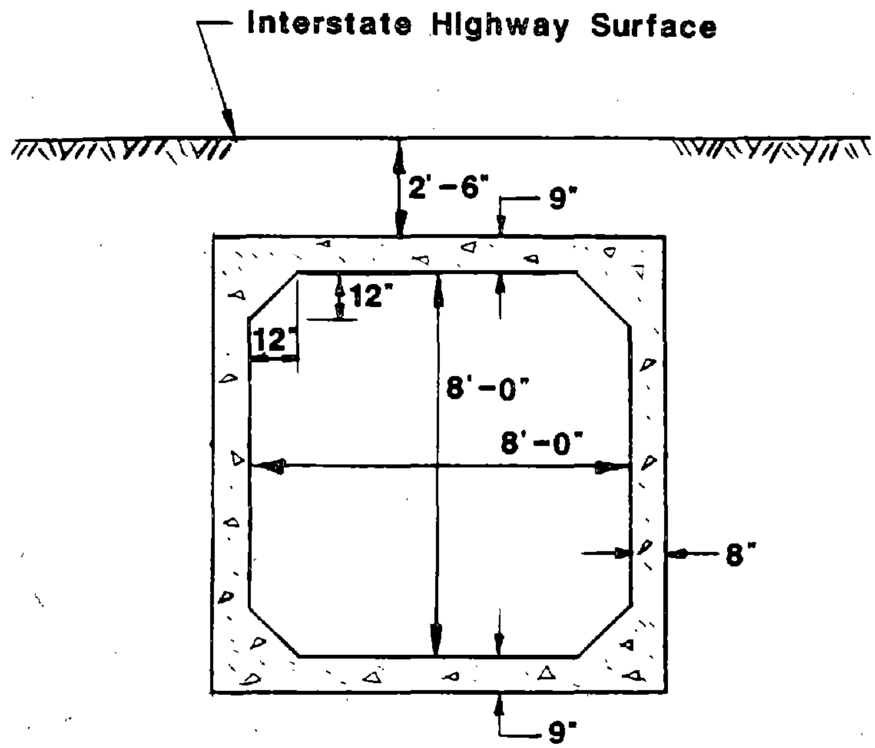


FIGURE 5-2 EXAMPLE PROBLEM 2

```
==========PROGRAM: BOXCAR ============================================

     Filename          EXAMPLE2.BOX
     Job Description   Example 2: 8 x 8 Box Culvert with 2.5 ft of Fill

     Span                    8.0    ft
     Rise                    8.0    ft
     Depth of Fill           2.5    ft
     to Culvert Top

     You have now entered the minimum input requirements. At this
     point you may save the file using <F1> and all other parameters
     will default or press <PgDn> to go to SCREEN 2.
                                                            SCREEN 1
=====================================================================
   <F1> = FINISHED EDITING → RETURN TO MAIN MENU         <F2> = HELP
                      <PgDn> View Next Screen
```

TABLE 5-2a SCREEN 1

```
======== PROGRAM: BOXCAR ========== CURRENT FILE: EXAMPLE2 =========
PROJECT: Example 2: 8 x 8 Box Culvert with 2.5 ft of Fill

     BOX GEOMETRY

      SLAB THICKNESSES        HAUNCH DIMENSIONS

      Top Slab     9     in.  Top Haunches           Bottom Haunches
      Bottom Slab  9     in.  Horizontal 12     in.  Horizontal 12     in.
      Sidewall     8     in.  Vertical   12     in.  Vertical   12     in.

     CONCRETE COVERS

             Top Slab Outside Face        1     in.
             Bottom Slab Outside Face     1     in.
             Sidewall Outside Face        1     in.
             Top Slab Inside Face         1     in.
             Bottom Slab Inside Face      1     in.
             Sidewall Inside Face         1     in.
                                                            SCREEN 2
=====================================================================
   <F1> = FINISHED EDITING → RETURN TO MAIN MENU         <F2> = HELP
     <PgUp> View Previous Screen        <PgDn> View Next Screen
```

TABLE 5-2b SCREEN 2

```
============ PROGRAM: BOXCAR ========== CURRENT FILE: EXAMPLE2 ========
PROJECT: Example 2: 8 x 8 Box Culvert with 2.5 ft of Fill

          MATERIAL PROPERTIES


                  Main Reinforcing Yield Strength          60      ksi
                  Main Reinforcing Type 2   No. of Layers  1
                  Design Concrete Strength                 5.000   ksi
                  Concrete Density                       150.000  pcf

          LOAD FACTORS

                  Dead Load Factor (Shear and Moment)      1.5
                  Dead Load Factor (Thrust)                1
                  Live Load Factor (Shear and Moment)      2.17
                  Live Load Factor (Thrust)                1

          PHI FACTORS

                  Shear                                    .85
                  Flexure                                  .90        SCREEN 3

     <F1> = FINISHED EDITING → RETURN TO MAIN MENU            <F2> = HELP
       <PgUp> View Previous Screen           <PgDn> View Next Screen
```

TABLE 5-2c SCREEN 3

```
============ PROGRAM: BOXCAR ========== CURRENT FILE: EXAMPLE2 ========
PROJECT: Example 2: 8 x 8 Box Culvert with 2.5 ft of Fill



          REINFORCING DIAMETERS



                  Top Slab Outside Face,(AS7)       .4     in.
                  Bottom Slab Outside Face,(AS8)    .4     in.
                  Sidewall Outside Face,(AS1)       .4     in.
                  Top Slab Inside Face,(AS2)        .4     in.
                  Bottom Slab Inside Face,(AS3)     .4     in.
                  Sidewall Inside Face,(AS4)        .4     in.






                                                             SCREEN 4

     <F1> = FINISHED EDITING → RETURN TO MAIN MENU            <F2> = HELP
       <PgUp> View Previous Screen           <PgDn> View Next Screen
```

TABLE 5-2d SCREEN 4

```
============ PROGRAM: BOXCAR ========== CURRENT FILE: EXAMPLE2 ======
PROJECT: Example 2: 8 x 8 Box Culvert with 2.5 ft of Fill


        MAXIMUM REINFORCING SPACING


                Top Slab Outside Face,(AS7)      8     in.
                Bottom Slab Outside Face,(AS8)   8     in.
                Sidewall Outside Face,(AS1)      8     in.
                Top Slab Inside Face,(AS2)       8     in.
                Bottom Slab Inside Face,(AS3)    8     in.
                Sidewall Inside Face,(AS4)       8     in.





                                                                SCREEN 5
=========================================================================
   <F1> = FINISHED EDITING → RETURN TO MAIN MENU             <F2> = HELP
     <PgUp> View Previous Screen            <PgDn> View Next Screen
```

TABLE 5-2e SCREEN 5

```
============ PROGRAM: BOXCAR ========== CURRENT FILE: EXAMPLE2 ======
PROJECT: Example 2: 8 x 8 Box Culvert with 2.5 ft of Fill


        SOIL LOAD DATA

                Soil Density                              120      pcf
                Minimum Lateral Pressure Coefficient      .25
                Maximum Lateral Pressure Coefficient      .5
                Soil Structure Interaction Factor         1


        LIVE LOAD DATA

                Live Load     H (H/T/C/O/N)     HS-SERIES
                                                INTERSTATE
                                                COOPER E-SERIES
                                                OTHER
                                                NONE


                                                                SCREEN 6
=========================================================================
   <F1> = FINISHED EDITING → RETURN TO MAIN MENU             <F2> = HELP
     <PgUp> View Previous Screen            <PgDn> View Next Screen
```

TABLE 5-2f SCREEN 6

```
================ PROGRAM: BOXCAR ============ CURRENT FILE: EXAMPLE2 ================
PROJECT: Example 2: 8 x 8 Box Culvert with 2.5 ft of Fill


          LIVE LOAD DATA

                  You have chosen an AASHTO HS-SERIES load condition.

                  Enter the series magnitude (i.e. 10,20, etc.)

                         20 tons

                  Enter the direction of travel of the truck

                         T (P/T)     Parallel to culvert flow
                                     Transverse to culvert flow




                                                                          SCREEN 6H
=====================================================================================
     <F1> = FINISHED EDITING → RETURN TO MAIN MENU             <F2> = HELP
       <PgUp> View Previous Screen               <PgDn> View Next Screen
```

TABLE 5-2g SCREEN 6H

```
================ PROGRAM: BOXCAR ============ CURRENT FILE: EXAMPLE2 ================
PROJECT: Example 2: 8 x 8 Box Culvert with 2.5 ft of Fill

          SURCHARGE LOADS

                  UNIFORM VERTICAL LOAD

                  Magnitude                    0          psf

                  VARYING LATERAL LOAD

                  Magnitude at Top             0          psf
                  Magnitude at Bottom          0          psf


                  APPLICATION CODE             A (P/A/L)  PERMANENT DEAD LOAD
                                                          ADDITIONAL DEAD LOAD
                                                          LIVE LOAD
          FLUID LOADS

                  Depth of Fluid                8       ft
                  Fluid Density                62.5     pcf                SCREEN 7
=====================================================================================
     <F1> = FINISHED EDITING → RETURN TO MAIN MENU             <F2> = HELP
       <PgUp> View Previous Screen               <PgDn> View Screen 1
```

TABLE 5-2h SCREEN 7

R E I N F O R C I N G   S T E E L   D A T A

LOCATION	AREA SQ. IN. PER FT	STIRRUPS REQUIRED?
TRANSVERSE		
SIDE WALL - OUTSIDE FACE (As1)	.216	NO
TOP SLAB - INSIDE FACE (As2)	.310	NO
BOTTOM SLAB - INSIDE FACE (As3)	.309	NO
SIDE WALL - INSIDE FACE (As4)	.192	NO
TOP SLAB - OUTSIDE FACE (As7)	.216	NO
BOTTOM SLAB - OUTSIDE FACE (As8)	.216	NO

DO YOU WISH TO SAVE AND/OR PRINT THIS OUTPUT ? (D/P/N)

D = WRITE TO DISK AND RETURN TO MAIN MENU.
P = WRITE TO DISK AND PRINTER AND RETURN TO MAIN MENU.
N = RETURN TO MAIN MENU WITHOUT SAVING OUTPUT.

Make Selection....Then Press Enter

TABLE 5-2i REINFORCING SCREEN

5.3 Example Problem 3

This example problem demonstrates how to make changes to an input file and save the modified file under a new name. Before trying this example problem, you must first have the input file of Example Problem 2 stored on your computer disk. In this example, the depth of burial for the culvert shown in Figure 5-3 is 4 ft. In addition, a vertical surcharge load of 50 psf is to be considered as permanent dead load.

1) Beginning at the Main Menu (see Example 1 if you are not at the Main Menu) press "2" to retrieve the previous file from your computer disk.

2) A list of the available input files that are stored on your computer disk are displayed on your screen as shown in Table 5-3a. When prompted, enter the name of the file you wish to modify omitting the .BOX filename extension by typing:

   EXAMPLE2

3) Screen 1 appears with the input data you saved for Example Problem 2. To store the changes you make to this input file under a new file name, change the file name by typing:

   EXAMPLE3

4) Change the job description by typing:

   Example 3: 8 x 8 Box Culvert with 4 ft of Fill [Enter]

5) Use the arrow keys or the [Enter] key to position the cursor at the Depth of Fill input location. Enter the new depth by typing:

   4.0 [Enter]

   Screen 1 should appear as shown in Table 5-3b.

6) The next parameter to modify is the vertical surcharge load on Screen 7. Use the [PgDn] key to move to this input screen. Where prompted, enter the magnitude of the vertical surcharge by typing:

   50.0 [Enter]

   Screen 7 should appear as shown in Table 5-3c.

7) You may now go to the save options by pressing the [F1] key. Press "2" to save and execute.

8) When program execution is complete the reinforcing requirements should be printed to the screen, which should appear as shown in Table 5-3d. Do not save the output from this example. Press "N" to return to the Main Menu.

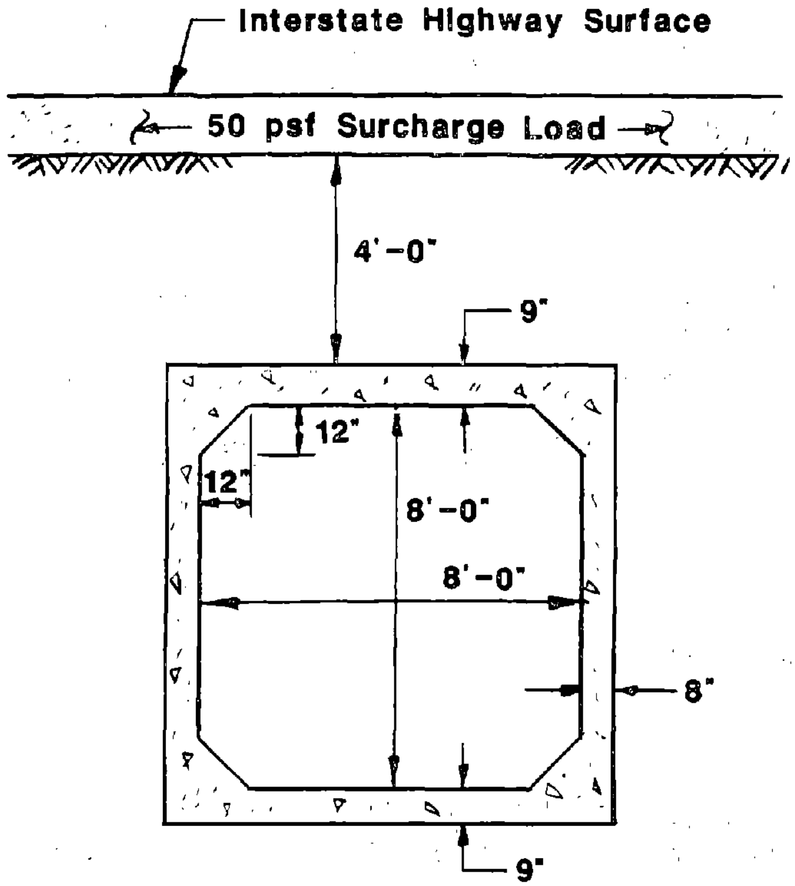


FIGURE 5-3 EXAMPLE PROBLEM 3

```
=============== PROGRAM: BOXCAR ===============

        The following are the available data files:
```

```
 Volume in drive C has no label
 Directory of  C:OXCAR

EXAMPLE1 BOX    EXAMPLE2 BOX
        2 File(s)  20965376 bytes free
```

```
        Retrieve file          .BOX
```

TABLE 5-3a INPUT FILES

```
===============PROGRAM: BOXCAR ===============

        Filename           EXAMPLE3.BOX
        Job Description    Example 3: 8 x 8 Box Culvert with 4 ft of Fill

        Span                     8       ft
        Rise                     8       ft
        Depth of Fill            4.0     ft
        to Culvert Top

                                                         SCREEN 1
      <F1> = FINISHED EDITING → RETURN TO MAIN MENU           <F2> = HELP
                           <PgDn> View Next Screen
```

TABLE 5-3b SCREEN 1

```
═══════════ PROGRAM: BOXCAR ═══════════ CURRENT FILE: EXAMPLE3 ═══════════
PROJECT: Example 3: 8 x 8 Box Culvert with 4 ft of Fill

        SURCHARGE LOADS

                UNIFORM VERTICAL LOAD

                Magnitude                    50        psf

                VARYING LATERAL LOAD

                Magnitude at Top              0        psf
                Magnitude at Bottom           0        psf

                APPLICATION CODE             P (P/A/L) PERMANENT DEAD LOAD
                                                       ADDITIONAL DEAD LOAD
                                                       LIVE LOAD
        FLUID LOADS

                Depth of Fluid               8       ft
                Fluid Density                62.5    pcf              SCREEN 7
═══════════════════════════════════════════════════════════════════════════
    <F1> = FINISHED EDITING → RETURN TO MAIN MENU          <F2> = HELP
      <PgUp> View Previous Screen                 <PgDn> View Screen 1
```

TABLE 5-3c SCREEN 7

```
R E I N F O R C I N G   S T E E L   D A T A
-------------------------------------------------------------------------
                                                  AREA
              LOCATION                          SQ. IN.      STIRRUPS
                                                PER FT       REQUIRED?
-------------------------------------------------------------------------
TRANSVERSE
    SIDE WALL   - OUTSIDE FACE (As1)            .216           NO
    TOP SLAB    - INSIDE  FACE (As2)            .290           NO
    BOTTOM SLAB - INSIDE  FACE (As3)            .321           NO
    SIDE WALL   - INSIDE  FACE (As4)            .192           NO
    TOP SLAB    - OUTSIDE FACE (As7)            .216           NO
    BOTTOM SLAB - OUTSIDE FACE (As8)            .216           NO

             DO YOU WISH TO SAVE AND/OR PRINT THIS OUTPUT ? (D/P/N)

             D = WRITE TO DISK AND RETURN TO MAIN MENU.
             P = WRITE TO DISK AND PRINTER AND RETURN TO MAIN MENU.
             N = RETURN TO MAIN MENU WITHOUT SAVING OUTPUT.

               Make Selection....Then Press Enter
```

TABLE 5-3d REINFORCING SCREEN

5.4 Example Problem 4

This example problem demonstrates how to change the default values of the program. The default values for each input parameter supplied with BOXCAR are tabulated in Appendix A of this manual. This example will demonstrate how to make the following changes to the default file:

- Steel reinforcing yield strength, Fy = 65 ksi (welded wire fabric)
- Concrete compressive strength, F'c = 5 ksi
- Maximum reinforcing spacing, s = 4 in.
- Concrete cover over steel reinforcement, t_C = 1 in.

1) Beginning at the Main Menu (see Example 1 if you are not at the Main Menu) press "6" to make changes to the program default values.

3) Screen 1D will appear. Move the cursor to the concrete cover input location using the arrow keys or the [Enter] key. Type "1 [Enter]" for each of the concrete covers listed. When you have finished, Screen 1D should be identical to that shown in Table 5-4a.

4) Press the [PgDn] key to move to Screen 2D. Change the steel reinforcing yield strength and the concrete compressive strength to 65 and 5, respectively. Screen 2D should appear identical to that shown in Table 5-4b when you are done.

5) Use the [PgDn] key to move to Screen 4D. Change the reinforcing spacing to 4 in. for each location listed. Screen 4D should appear identical to that shown in Table 5-4c.

6) To return to the main menu, press the [Esc] key and then the [PgDn] key. The main menu will now appear. The modified default parameters are the values now assumed by the program whenever an input file is created and no value for a parameter is specified.

```
═══════════════════ PROGRAM: BOXCAR ═══════════════════
               DEFAULT CONFIGURATION UTILITY

   SYSTEM DEFAULTS           Data Drive C          Program Drive

   BOX GEOMETRY                   SPAN ≤ 7 ft        SPAN > 7 ft

     Top Slab Thickness        Span/12 + 1.0  in.   Span/12 + 0.0
     Bottom Slab Thickness     Span/12 + 1.0  in.   Span/12 + 0.0
     Sidewall Thickness        Span/12 + 1.0  in.   Span/12 + 0.0
     Horizontal Haunch Length  Span/12 + 1.0  in.   Span/12 + 0.0
     Vertical Haunch Length    Span/12 + 1.0  in.   Span/12 + 0.0

   CONCRETE COVERS

     Top Slab Outside Face      1.000 in.    (DEPTH OF FILL ≤ 2 ft
     Top Slab Outside Face      1.000 in.    (DEPTH OF FILL > 2 ft
     Bottom Slab Outside Face   1.000 in.
     Sidewall Outside Face      1.000 in.
     Top Slab Inside Face       1.000 in.
     Bottom Slab Inside Face    1.000 in.
     Sidewall Inside Face       1.000 in.                   SCREI
═══════════════════════════════════════════════════════
                    <F2> = HELP
              <PgDn> View Next Screen
```

TABLE 5-4a SCREEN 1D

```
═══════════════════ PROGRAM: BOXCAR ═══════════════════
               DEFAULT CONFIGURATION UTILITY

   MATERIAL PROPERTIES


        Main Reinforcing Yield Strength              65      ksi
        Main Reinforcing Type 3   No. of Layers      1
        Design Concrete Strength                     5.000   ksi
        Concrete Density                           150.000   pcf

   LOAD FACTORS

        Dead Load Factor (Shear and Moment)          1.50
        Dead Load Factor (Thrust)                    1.00
        Live Load Factor (Shear and Moment)          2.17
        Live Load Factor (Thrust)                    1.00

   PHI FACTORS

        Shear                                        0.85
        Flexure                                      0.90       SCR
═══════════════════════════════════════════════════════
                    <F2> = HELP
  <PgUp> View Previous Screen        <PgDn> View Next Screen
```

TABLE 5-4b SCREEEN 2D

```
PROGRAM: BOXCAR
DEFAULT CONFIGURATION UTILITY

MAXIMUM REINFORCING SPACING

        Top Slab Outside Face,(AS7)      4.000 in.
        Bottom Slab Outside Face,(AS8)   4.000 in.
        Sidewall Outside Face,(AS1)      4.000 in.
        Top Slab Inside Face,(AS2)       4.000 in.
        Bottom Slab Inside Face,(AS3)    4.000 in.
        Sidewall Inside Face,(AS4)       4.000 in.

                                                        SCREEN 4D

                        <F2> = HELP
<PgUp> View Previous Screen          <PgDn> View Next Screen
```

TABLE 5-4c SCREEN 4D

PART III – PROGRAMMER MANUAL

6. PROGRAM STRUCTURE

This section presents a brief description of the subroutines that make up the computer program BOXCAR and listings of the technical subroutines. This information is not necessary to use BOXCAR but provides additional background for those interested in learning more about the internal operation of BOXCAR.

6.1 Programming Languages – Hardware & Software

BOXCAR will operate on an IBM PC, XT, AT or a similar IBM compatible computer. All subroutines are compiled, and the user need only boot the computer and have DOS active in order to use the program. Specific hardware requirements are:

- An operating system equivalent to PC DOS Version 2.0 or higher.
- An 8087 or 80287 math coprocessor.
- A minimum of 640 k bytes of memory.
- Two double density disk drives or a single double density disk drive and a hard disk drive.

BOXCAR includes subroutines that process the output for printing on 8.5 in. by 11 in. paper. It also includes the commands to send it to a printer. Some users will find it useful to exit BOXCAR and use a text editor (not included with BOXCAR) to view files before printing.

BOXCAR is written in two programming languages. Most of the menus and file manipulation subroutines are written in BASIC and compiled with the IBM BASIC Compiler - Version 2.00. The structural analysis and design subroutines are written in FORTRAN, Micro Soft Version 3.3. Any user wishing to modify the code of BOXCAR will need to purchase compilers for these languages.

6.2 Disk Files

BOXCAR is provided on three disks. Each disk should contain the following files:

Program Disk 1

```
SCREEN6   SCR      3968  11-01-88   1:00a
SCREEN6M  SCR      3968  11-01-88   1:00a
BLANK     SCR      3968  11-01-88   1:00a
FILING    SCR      3968  11-01-88   1:00a
SCREEN6T  SCR      3968  11-01-88   1:00a
MAIN      SCR      3968  11-01-88   1:00a
SCREEN1   SCR      3968  11-01-88   1:00a
SCREEN15  SCR      3968  11-01-88   1:00a
SCREEN2   SCR      3968  11-01-88   1:00a
SCREEN3   SCR      3968  11-01-88   1:00a
SCREEN4   SCR      3968  11-01-88   1:00a
SCREEN5   SCR      3968  11-01-88   1:00a
SCREEN7   SCR      3968  11-01-88   1:00a
SCREEN8   SCR      3968  11-01-88   1:00a
SCREEN9   SCR      3968  11-01-88   1:00a
SCREEN10  SCR      3968  11-01-88   1:00a
SCREEN11  SCR      3968  11-01-88   1:00a
SCREEN12  SCR      3968  11-01-88   1:00a
SCREEN13  SCR      3968  11-01-88   1:00a
SCREEN14  SCR      3968  11-01-88   1:00a
SCREEN6C  SCR      3968  11-01-88   1:00a
PRINT     SCR      3968  11-01-88   1:00a
SCREEN6O  SCR      3968  11-01-88   1:00a
SCREEN6H  SCR      3968  11-01-88   1:00a
HELP6     TXT       534  11-01-88   1:00a
SCRN13    SCR      3968  11-01-88   1:00a
SCRN14    SCR      3968  11-01-88   1:00a
HELP4     TXT       859  11-01-88   1:00a
HELP8     TXT       883  11-01-88   1:00a
HELP9     TXT       298  11-01-88   1:00a
HELP10    TXT      1069  11-01-88   1:00a
HELP3     TXT       128  11-01-88   1:00a
HELP5     TXT       350  11-01-88   1:00a
HELP2     TXT       924  11-01-88   1:00a
HELP1     TXT       764  11-01-88   1:00a
HELP7     TXT       926  11-01-88   1:00a
BOXCAR    EXE    115674  11-01-88   1:00a
DCU       EXE     96554  11-01-88   1:00a
SYSTEM    DEF         7  11-01-88   1:00a
DCU       DEF       478  11-01-88   1:00a
       40 File(s)      29696 bytes free
```

Program Disk 2

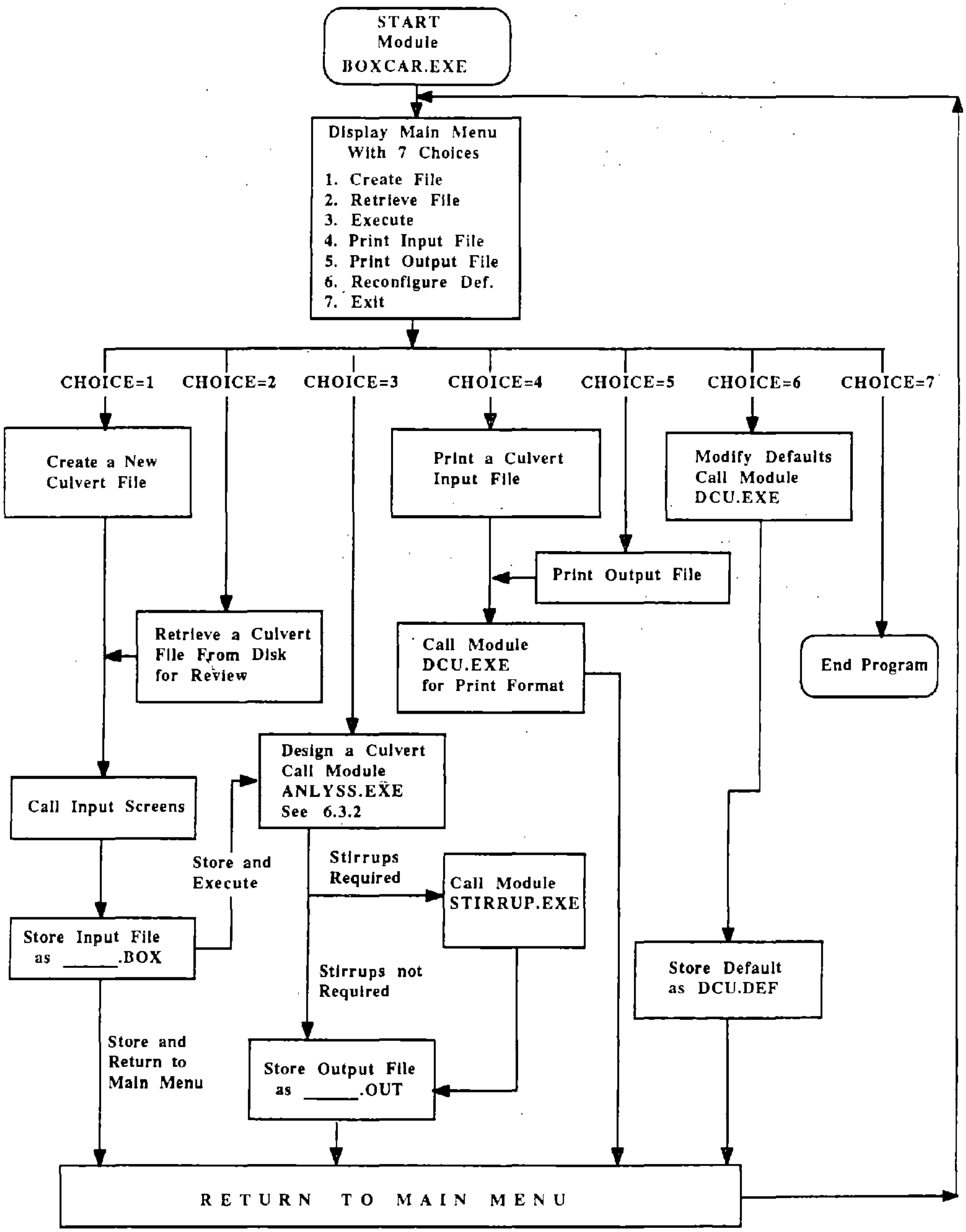
```
BOXDSK2   EXE     42010  11-01-88   1:00a
ANLYSS    EXE    276610  11-01-88   1:00a
SYSTEM    DEF         7  11-01-88   1:00a
        3 File(s)      40960 bytes free
```

Program Disk 3

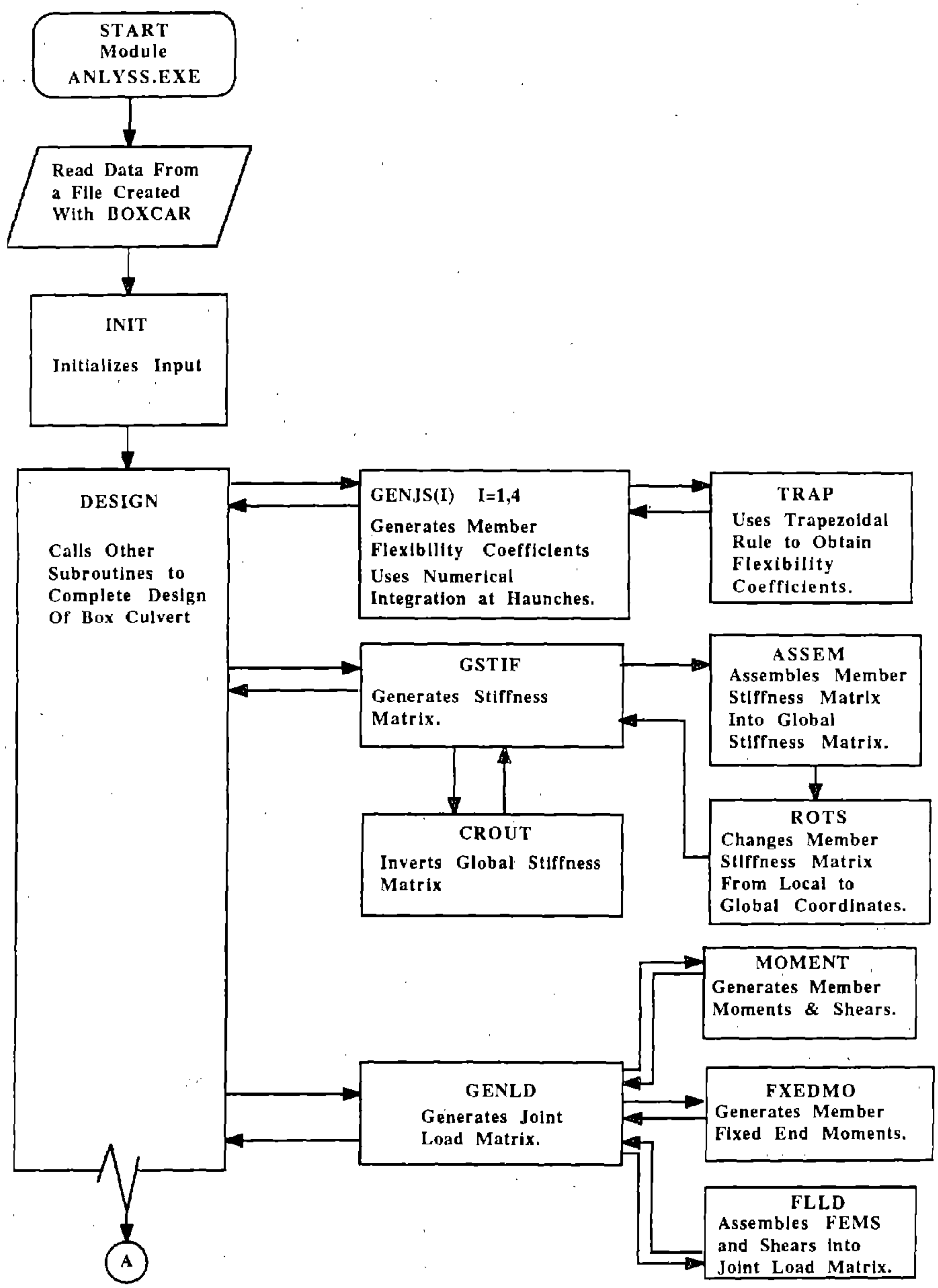
```
STIRRUP   EXE     89738  11-01-88   1:00a
INSTALL   EXE     52198  11-01-88   1:00a
STIRRUP   SCR      3968  11-01-88   1:00a
SYSTEM    DEF         7  11-01-88   1:00a
        4 File(s)     215040 bytes free
```

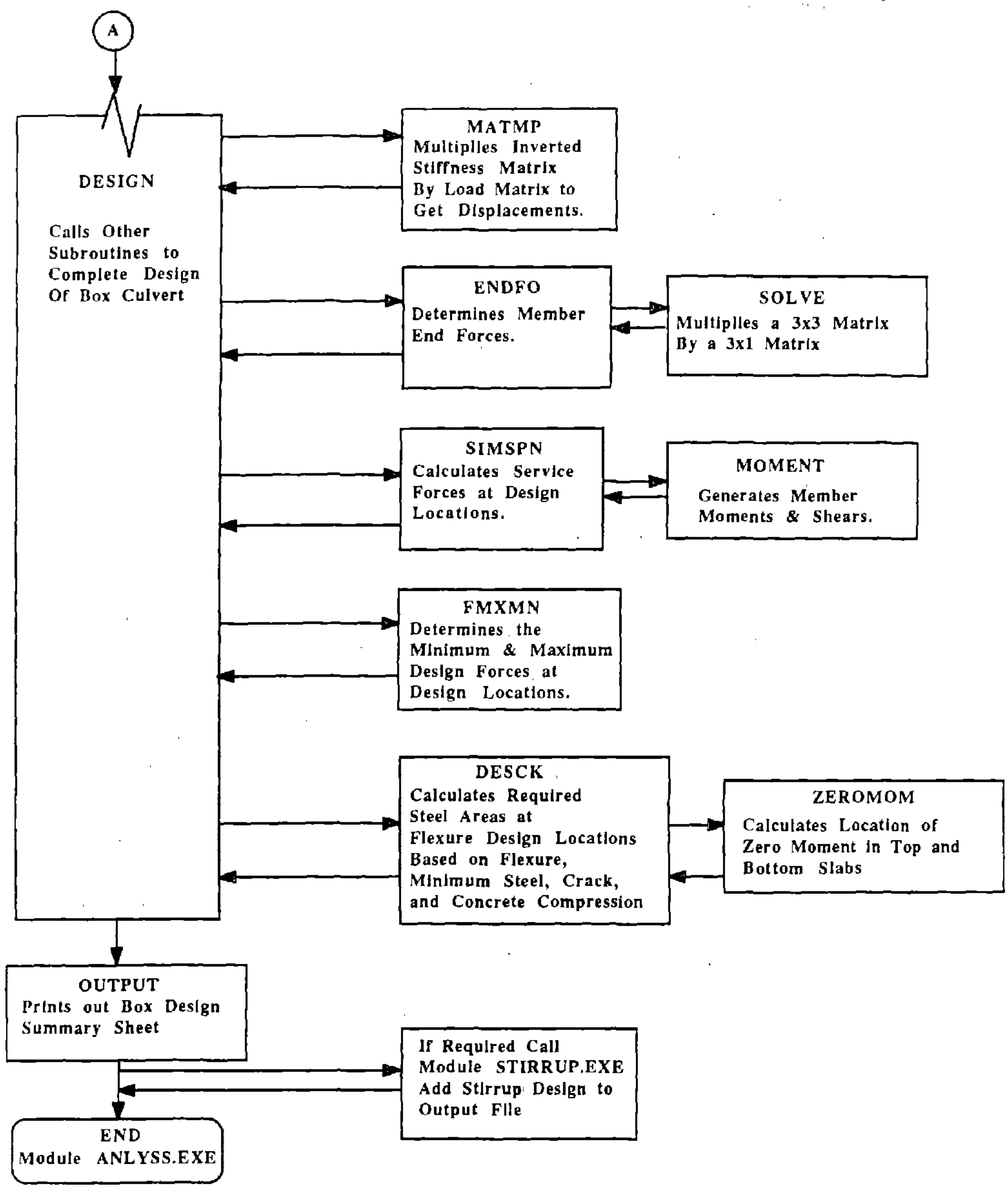
6.3 Flow Chart of Overall Program Structure

6.3.1 Menu Flow Chart



6.3.2 Box Culvert Design Flow Chart




A
DESIGN
Calls Other Subroutines to Complete Design Of Box Culvert
MATMP
Multiplies Inverted Stiffness Matrix By Load Matrix to Get Displacements.
ENDFO
Determines Member End Forces.
SOLVE
Multiplies a 3x3 Matrix By a 3x1 Matrix
SIMSPN
Calculates Service Forces at Design Locations.
MOMENT
Generates Member Moments & Shears.
FMXMN
Determines the Minimum & Maximum Design Forces at Design Locations.
DESCK
Calculates Required Steel Areas at Flexure Design Locations Based on Flexure, Minimum Steel, Crack, and Concrete Compression
ZEROMOM
Calculates Location of Zero Moment in Top and Bottom Slabs
OUTPUT
Prints out Box Design Summary Sheet
If Required Call Module STIRRUP.EXE Add Stirrup Design to Output File
END
Module ANLYSS.EXE

6.4 Program Structure for Each Subroutine

Subroutine: ANLYSS

Function:

This module initiates program execution.

I/O Generated By Subroutine:

None

Error Messages Generated:

None

```
$DEBUG
C
C       PROGRAM BOXCAR
C       MODULE ANLYSS
C       1 NOVEMBER 1988 - VERSION 1.0
C
C       PROGRAM FOR THE DESIGN AND ANALYSIS OF REINFORCED CONCRETE
C       BOX CULVERTS
C
C       PREPARED FOR
C       DEPARTMENT OF TRANSPORTATION
C       FEDERAL HIGHWAY ADMINISTRATION
C       FHWA CONTRACT NO. DTFH61-87-C-00032
C
C       PREPARED BY
C       SIMPSON GUMPERTZ AND HEGER INC.
C       297 BROADWAY
C       ARLINGTON,MASSACHUSETTS 02174
C
C
C    THIS IS THE MAIN PROGRAM. IT SEQUENTIALLY CALLS THE VARIOUS
C    SUBROUTINES NEEDED TO COMPLETE THE ANALYSIS AND DESIGN OF THE
C    ONE CELL BOX.
C
C
      REAL*4 JLOAD(12,40)
      REAL*4 INER(4,50),KAA(4,3,3),KAB(4,3,3),KBA(4,3,3),KBB(4,3,3)
      INTEGER ISDATA(35),IBDATA(35)
      INTEGER ICON(40)
      CHARACTER*4 Z2(8)
      CHARACTER*10 MEMBDS(40)
C
      COMMON/RSCALE/SPAN,RISE,TT,TB,TS,GAMAC,GAMAS,GAMAF,P0,H,HH,HV,Q,
     1 ZETA,BETA,DF,Q1,EC,ES,FY,FCP,FLMV,FLN,Q2,Q3,NLAY,RTYPE,Q4,Q5,
     2 CT(6),SDATA(35)
      COMMON/RSCAL2/QFAC,RES,NTJD,HHT,HHB,HVT,HVB,FLLN,FLLMV
      COMMON/RSCAL2/HRT(4),DSHDL(4),TST
      COMMON/RSCAL3/SWDTH,VMAG,RLEN,RWID,SURV,SURHT,SURHB,AS5D,
     1              AS6D,AS5SP,AS6SP,CHHT,CHVT,CHHB,CHVB
      COMMON/RSCAL4/ITDIR
      COMMON/RSCAL5/ASBMAX,Z2,DSTEST(40),MEMBDS
C
      COMMON/RARRAY/U(12,40),W1(4,10),W2(4,10),A(4,10),B(4,10),C(4,10),
     1 PMEMB(4,25),X(50,4)
C
      COMMON/RARRAY/INER,KAA,KAB,KBA,KBB,W1WH(3,22,4),W2WH(3,22,4),
     1              AWH(3,22,4),BWH(3,22,4),CWH(3,22,4)
C
      COMMON/ANAL/JLOAD,STIF(12,12),FIXMO(4,40,4),DM(40),DV(40),DP(40),
     1 AS(40),SRATIO(40)
C
      COMMON/ISCALE/NIT,NOLD,IDBUG,IR,IW,ITAPE,IPATH,ICYC,NINT
```

```
      COMMON/ISCALE/NLD,LTYPE,NSDES,ISUR,NSTRES
C
      COMMON/IARRAY/MEMB(4,2) ,INDEX(40)
C
      COMMON/HARRAY/AMOM(40,40),V(40,40),P(40,40),FXLA(4,40),FYLA(4,40),
     1BMA(4,40),FXLB(4,40),FYLB(4,40),BMB(4,40),ENDM(40,40),ENDV(40,40),
     2 GRM1(40),GRV1(40),GRP1(40),GRV2NG(40),GRM2NG(40),GRV2PL(40)
     3 ,GRM2PL(40),GRP2PL(40),GRP2NG(40),FPMIN(40),FVMIN(40),FMMIN(40),
     4 FPMAX(40),FVMAX(40),FMMAX(40),ZMOMT,ZMOMB,XL(40),WHMXM(40),
     5 WHMNM(40),WHMXV(40),WHMNV(40),WHMXP(40),WHMNP(40)
C
      COMMON/IFLAGS/IBDATA,ISDATA,ICON
      COMMON/PRN/ IPP,IDBG,III
      COMMON/FACT/ FLLMVP,FLLNP
C     **********************END OF COMMON *****************************
C
C     INTERNAL UNITS ARE KIPS,AND INCHES
C
      OPEN(3,FILE='SHEAR.DAT',STATUS='UNKNOWN')
      OPEN(4,FILE=' ',STATUS='UNKNOWN')
      OPEN(5,FILE=' ')
      IW=4
      IPP=0
      III=4
      IPATH=1
    4 IF(IPATH .NE. 0) CALL TITLE
    1 CALL RREAD(ISTOP)
      GO TO (2,3),ISTOP
    2 CALL INIT
      IF(IPATH.LE.0)GO TO 4
    8 CALL DESIGN
      IF(IPATH.LE.0)GO TO 4
    9 CALL OUTPUT
      GO TO 3
    3 CONTINUE
      IF(IPRINT.EQ.1) GO TO 4000
      IPRINT=1
      WRITE(6,5566)
 5566 FORMAT(18X,'DO YOU WISH TO SAVE AND/OR PRINT THIS OUTPUT ? (D/P/N)
     1',///,18X,'D = WRITE TO DISK AND RETURN TO MAIN MENU.',/,
     218X,'P = WRITE TO DISK AND PRINTER AND RETURN TO MAIN MENU.',/,
     318X,'N = RETURN TO MAIN MENU WITHOUT SAVING OUTPUT.',//,
     120X,'Make Selection....Then Press Enter')
 5675 READ(6,5556) SAVE
 5556 FORMAT(A1)
      IF(SAVE.EQ.'N'.OR.SAVE.EQ.'n'.OR.SAVE.EQ.'D'.OR.SAVE.EQ.'P'.OR.SAV
     1E.EQ.'p'.OR.SAVE.EQ.'d') GO TO 5676
 5677 GO TO 5675
 5676 IF(SAVE.EQ.'N'.OR.SAVE.EQ.'n') GO TO 4000
  501 WRITE(6,500)
      IDBG=0
  500 FORMAT(/////////////////////,8X,'OUTPUT SELECTIONS',//,15X,
```

```
     $'1.  Print Input data and summary sheet.'
     1,/,15X,'2.  Print Above + ultimate forces at design locations,',/,
     219X,'flexure and shear design tables.',/,15X,
     3'3.  Print Above + service forces at design locations.'
     4,/,15X,'4.  Print Above + displacement matrix, service forces',
     5' for',/,19X,'each load case and end forces.',
     6//////////,15X,'Make Selection....Then Press Enter',//)
      READ(6,505) IDBG
  505 FORMAT(I1)
      IF(IDBG.EQ.9) GO TO 767
      IF(IDBG.LT.1.OR.IDBG.GT.4) GO TO 501
  767 WRITE(6,676)
  676 FORMAT(///////////////////,
     120X,'WRITING OUTPUT TO DISK.......',/,20X,'PLEASE WAIT
     1',/////////////)
      IF(IDBG.EQ.9) IDBG=10
      IDBUG=IDBG-1
      III=4
      IPP=1
      REWIND(5)
      REWIND(III)
      IF(IDBUG.EQ.0) GO TO 9
      IF(IDBUG.EQ.1.OR.IDBUG.EQ.2) GO TO 8
      GO TO 1
 4000 CONTINUE
      WRITE(3,5556) SAVE
      END
C
```

Subroutine: RREAD

Function:

This subroutine reads input data from a file created by the BOXCAR screen input routine. Data is transferred into program arrays.

I/O Generated By Subroutine:

Input that is read from the file created by the input screen routine is printed. Input consists of 16 lines of data containing all the input parameters, including the default values for input parameters not specified by the user.

Error Messages Generated:

None

```
      SUBROUTINE RREAD(ISTOP)
C
C    THIS ROUTINE READS ALL THE INPUT IN A SPECIFIED FORMAT AND
C    TRANSFERS THE DATA INTO THE BDATA AND SDATA ARRAYS. THE EXECUTION OF RREA
C    IS CONTROLLED BY THE KODE VARIABLE ON THE INPUT CARDS. A KODE
C    GREATER THAN 25 SIGNALS THE END OF THE INPUT DATA. RREAD REPRINTS
C    THE INPUT CARDS AS IT READS THEM AS A CHECK FOR THE USER.
C
      COMMON/IFLAGS/IBDATA(35),ISDATA(35),ICON(40)
      COMMON/RSCALE/BDATA(35),SDATA(35)
      COMMON/RSCAL2/QFAC,RES,NTJD,HHT,HHB,HVT,HVB,FLLN,FLLMV
      COMMON/RSCAL2/HRT(4),DSHDL(4),TST
      COMMON/RSCAL3/SWDTH,VMAG,RLEN,RWID,SURV,SURHT,SURHB,AS5D,
     1              AS6D,AS5SP,AS6SP,CHHT,CHVT,CHHB,CHVB
      COMMON/RSCAL4/ITDIR
      COMMON/ISCALE/NIT,NOLD,IDBUG,IR,IW,ITAPE,IPATH,ICYC,NINT
      COMMON/ISCALE/NLD,LTYPE,NSDES,ISUR,NSTRES
      COMMON/PRN/ IPP,IDBG,III
      COMMON/FACT/ FLLMVP,FLLNP
      DIMENSION D(6)
      DIMENSION LAT(25)
      CHARACTER*4 ATEXT(20),TEXT(5)
      DATA LAT/3,3,4,3,4,6,1,2,6,1,2,6,6,3,4,5,5,5,4,4,4,3,2,3,4/
C     * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C
      READ(5,1020,END=995)  (ATEXT(I),I=1,20),IDBUG
 1020 FORMAT(19A4,A3,I1)
      IF(IPP.EQ.1) IDBUG=IDBG-1
      DO 5 I=1,35
      SDATA(I)=0.
      ISDATA(I)=0
      BDATA(I)=0.
    5 IBDATA(I)=0
      IW=4
      IPATH=1
      NSDES=5
      NSTRES=10
      NTJD=4
      TST=0
      CHHT=0
      CHVT=0
      CHHB=0
      CHVB=0
      SLEN=12.
      SLEN2=SLEN*SLEN
      SLEN3=SLEN2*SLEN
      SLD=1000.
    1 READ(5,1000,END=995)  KODE,(TEXT(I),I=1,5),(D(I),I=1,6)
 1000 FORMAT(I2,4A4,A2,6F10.3)
      IF(KODE.GT.25)  GO TO 999
      K=LAT(KODE)
```

```
      IF(IDBUG .EQ. 9.AND.IPP.EQ.1) WRITE(III,2000) KODE,(TEXT(I),I=1,5)
     1,(D(I),I=1,K)
 2000 FORMAT(1X,I2,4A4,A2,6F9.3)
    6 CONTINUE
      GO TO (10,20,30,40,50,60,70,80,90,100,110,120,130,140,140,
     1       140,140,180,190,140,140,140,140,140,140),KODE
C
C     SPAN,RISE,DEPTH OF FILL KODE=1
   10 CONTINUE
      BDATA(1)=D(1)*SLEN
      BDATA(2)=D(2)*SLEN
      BDATA(10)=D(3)*SLEN
      IBDATA(1)=1
      IBDATA(2)=1
      IBDATA(10)=1
      GO TO 1
C
C     SLAB THICKNESSES,TT,TB,TS KODE=2
C
   20 CONTINUE
      BDATA(3)=D(1)
      BDATA(4)=D(2)
      BDATA(5)=D(3)
      DO 21 I=3,5
      IF (BDATA(I))  21,21,23
   23 IBDATA(I)=1
   21 CONTINUE
      GO TO 1
C
C     HAUNCH GEOMETRY,HHT,HVT,HHB,HVB KODE=3
   30 CONTINUE
      IF ( D(1).EQ.0.) D(1)=D(2)
      IF ( D(2).EQ.0.) D(2)=D(1)
      HHT=D(1)
      HVT=D(2)
      HHB=D(3)
      HVB=D(4)
      IBDATA(11)=1
      IBDATA(12)=1
      GO TO 1
C
C     DENSITIES, GAMAS,GAMAC,GAMAF, KODE=4
   40 CONTINUE
   47 BDATA(7)=D(1)/SLEN3/SLD
      IBDATA(7)=1
   42 BDATA(6)=D(2)/SLEN3/SLD
      IBDATA(6)=1
   44 BDATA(8)=D(3)/SLEN3/SLD
      IBDATA(8)=1
      GO TO 1
C
C     MINIMUM LATERAL SOIL COEFFICIENT (ZETA), MAXIMUM LATERAL SOIL
```

```
C     COEFFICIENT (CONVERTED TO RAT IN SDATA(25)), SOIL-STRUCTURE
C     INTERACTION COEFFICIENT (BETA), FLAG FOR PERMAMENT SIDE LOAD
C     KODE=5
   50 CONTINUE
      IF ( D(1) ) 51,57,52
   51 IBDATA(14)=-1
      BDATA(14)=0.25
      GO TO 53
   57 BDATA(14) = D(2)
      D(4) = 1
      GO TO 53
   52 BDATA(14)=D(1)
      IBDATA(14)=1
   53 IF ( D(1) .EQ. 0.0 ) GO TO 56
      SDATA(25)=D(2)/D(1) - 1.0
   56 ISDATA(25) = 1
      IF ( D(4).NE.0.) IBDATA(14)=2
      IF ( D(3)-.5 )  54,55,55
   54 BDATA(15)=1.2
      IBDATA(15)=-1
      GO TO 1
   55 BDATA(15)=D(3)
      IBDATA(15)=1
      GO TO 1
C
C     LOAD FACTORS, CAPACITY RED. FACTORS  KODE=6
C
   60 CONTINUE
      BDATA(22)=D(1)
      BDATA(23)=D(2)
      FLLMV=D(3)
      FLLN=D(4)
      BDATA(9)=D(5)
      BDATA(13)=D(6)
      IBDATA(22)=1
      IBDATA(23)=1
      IBDATA(9)=1
      IBDATA(13)=1
C
      GO TO 1
C
C     DEPTH OF FLUID,  KODE=7
   70 CONTINUE
      BDATA(16)=D(1)*SLEN
      IBDATA(16)=1
      GO TO 1
C
C     MATERIAL STRENGTHS, FY,FCP,  KODE=8
   80 CONTINUE
      IF ( D(1).EQ.0.)   GO TO 81
      BDATA(20)=D(1)
      IBDATA(20)=1
```

```
   81 IF ( D(2).EQ.0.)     GO TO 1
      BDATA(21)=D(2)
      IBDATA(21)=1
      GO TO 1
C
C     CONCRETE COVER, KODE=9
   90 CONTINUE
      DO 95 I=1,6
      IF ( D(I))95,95,92
   92 BDATA(29+I)=D(I)
      IF(I.EQ.6.AND.D(6).EQ.1.9) BDATA(29+I)=D(I)-.001
      IBDATA(29+I)=1
   95 CONTINUE
      IF(D(6).EQ.1.9) D(6)=1.899
      GO TO 1
C
C   CRACK FACTOR                                 KODE=10
C
  100 CONTINUE
      BDATA(24)=D(1)
      IBDATA(24)=1
      GO TO 1
C
C     REINFORCING TYPE AND NUMBER OF LAYERS
  110 CONTINUE
      BDATA(26)=D(1)
      BDATA(27)=D(2)
      IBDATA(26)=1
      IBDATA(27)=1
      GO TO 1
C
C     WIRE DIAMETERS KODE=12
  120 CONTINUE
      DO 121 I=1,6
      SDATA(I)=D(I)
  121 CONTINUE
      ISDATA(I)=1
      GO TO 1
C
C     WIRE SPACING, KODE=13
  130 CONTINUE
      DO 135 I=1,6
      SDATA(I+6)=D(I)
      ISDATA(I+6)=1
  135 CONTINUE
      GO TO 1
C
C     NOT USED KODE=14-17, 20-25
  140 CONTINUE
      GO TO 1
C
C
```

```
C     LIVELOAD TYPE, MAG., OTHER LOAD KODE=18
C     LTYPE = TYPE OF LIVELOAD
C
C            LTYPE    =1  NO LIVELOAD
C                     =2  OTHER
C                     =3  HS-SERIES
C                     =4  INTERSTATE
C                     =5  COOPER E-SERIES
C
  180 CONTINUE
      LTYPE=INT(D(1))
      VMAG=D(2)
      ITDIR=INT(D(3))
      RWID=D(4)
      RLEN=D(5)
      GO TO 1
C
C     SURCHARGE LOAD PARAMETERS  KODE=19
C
  190 CONTINUE
      SURV=D(1)/1000.
      SURHT=D(2)/1000.
      SURHB=D(3)/1000.
      ISUR=INT(D(4))
      GO TO 1
C
C     END OF DATA, KODE.GT.25
  999 CONTINUE
      IF(IDBUG .EQ. 9.AND.IPP.EQ.1) WRITE(III,2000) KODE,(TEXT(I),I=1,5)
  994 CONTINUE
      ISTOP=1
      GO TO 996
  995 ISTOP=2
  996 CONTINUE
      RETURN
      END
C
C
C
```

Subroutine: INIT

Function:

This subroutine fills out the remaining program main arrays with information used throughout the program. Also, user input errors are trapped and informative messages are printed.

I/O Generated By Subroutine:

None

Error Messages Generated:

None

```
      SUBROUTINE INIT
C
C    THIS SUBROUTINE FILLS OUT THE BDATA AND SDATA ARRAYS.WHERE
C    NEEDED, IT CALCULATES VALUES FROM INPUT AND INSERTS THEM INTO
C    THE APPROPRIATE ARRAY.
C
C
      REAL*4 INER,KAA,KAB,KBA,KBB
      INTEGER ISDATA(35),IBDATA(35)
      COMMON/IFLAGS/IBDATA,ISDATA,ICON(40)
      COMMON/RSCALE/BDATA(35),SDATA(35)
      COMMON/RSCAL2/QFAC,RES,NTJD,HHT,HHB,HVT,HVB,FLLN,FLLMV
      COMMON/RSCAL2/HRT(4),DSHDL(4),TST
      COMMON/RSCAL3/SWDTH,VMAG,RLEN,RWID,SURV,SURHT,SURHB,AS5D,
     1              AS6D,AS5SP,AS6SP,CHHT,CHVT,CHHB,CHVB
      COMMON/RSCAL4/ITDIR
      COMMON /ISCALE/NIT,NOLD,IDBUG,IR,IW,ITAPE,IPATH,ICYC,NINT
      COMMON/ISCALE/NLD,LTYPE,NSDES,ISUR,NSTRES
      COMMON /IARRAY/MEMB(4,2),INDEX(40)
      COMMON /RARRAY/ FIL(680),PMEMB(4,25),U(50,4),INER(6,50),KAA(4,11),
     1                W1WH(3,22,4),W2WH(3,22,4),AWH(3,22,4),BWH(3,22,4),
     2                CWH(3,22,4)
      COMMON/PRN/ IPP,IDBG,III
      COMMON/FACT/ FLLMVP,FLLNP
      EQUIVALENCE(H,BDATA(10))
      EQUIVALENCE (BDATA(1),SPAN),(BDATA(2),RISE)
      EQUIVALENCE(TT,BDATA(3)),(TB,BDATA(4)),(TS,BDATA(5)),(HH,
     1 BDATA(11)),(HV,BDATA(12))
      DIMENSION ASSUME(35)
C
C
      DO 5 I=1,4
      MEMB(I,1)=I
    5 MEMB(I,2)=I+1
      MEMB(4,2)=1
C
C
C     DETERMINE NUMBER OF LOAD CONDITIONS
      NLD=10
      IF(LTYPE .EQ. 3 .OR. LTYPE .EQ. 2) NLD=21
      IF(LTYPE .EQ. 4) NLD=32
      IF(LTYPE .EQ. 3 .AND. ITDIR .EQ. 0) NLD=32
      IF(H .GE. 120.) NLD=10
C
C     COMPUTE FLEXIBILITY MODIFICATION FACTOR
C
      RIRM=(TT+TB)/2.+RISE
      SPRM=SPAN+TS
      QFAC=50000.*((RIRM/TS)**3)*TT/SPRM
C
C
```

```
      BDATA(19)=29000.
C
C     CALCULATE CONCRETE MODULUS WITH f'c IF CONCRETE
C     IS ZERO
C
      IF(BDATA(6) .EQ. 0.) THEN
            BDATA(18)=57000*(BDATA(21)**0.5)
            GO TO 20
      ENDIF
      BDATA(18)=(BDATA(6)*1728000.)**1.5*33.*SQRT(BDATA(21)*1000.)/
     1   1000.
   20 IBDATA(19)=-1
      IBDATA(18)=-1
C
C     INITIALIZE PMEMB(I,J)
   80 CONTINUE
      Q1=0.0
      Q2=0.0
      IF(HHT.EQ.0..OR.HVT.EQ.0.) GO TO 81
      Q1=HHT/HVT
      Q2=HVT/HHT
   81 CONTINUE
      Q3=0.0
      Q4=0.0
      IF(HHB.EQ.0..OR.HVB.EQ.0.) GO TO 82
      Q3=HVB/HHB
      Q4=HHB/HVB
   82 CONTINUE
      D1=TS+HHT+0.5*TT*Q1
      D2=TT+HVT+0.5*TS*Q2
      D3=TB+HVB+0.5*TS*Q3
      D4=TS+HHB+0.5*TB*Q4
   83 IF(Q1 .EQ. 0. .OR. Q2.EQ.0.) GO TO 89
      D1S=TS+HHT+0.5*TT*(1/Q2)
      D2S=TT+HVT+0.5*TS*(1/Q1)
   89 IF(Q3 .EQ. 0. .OR. Q4.EQ.0.) GO TO 84
      D3S=TB+HVB+0.5*TS*(1/Q4)
      D4S=TS+HHB+0.5*TB*(1/Q3)
   84 CONTINUE
          D3S=D3
          D4S=D4
          D1S=D1
          D2S=D2
      PMEMB(1,1)=D2S
      PMEMB(2,1)=D1S
      PMEMB(3,1)=D3S
      PMEMB(4,1)=D4S
      PMEMB(1,2)=D2S
      PMEMB(2,2)=D4S
      PMEMB(3,2)=D3S
      PMEMB(4,2)=D1S
      PMEMB(1,3)=TT
```

```
      PMEMB(2,3)=TS
      PMEMB(3,3)=TB
      PMEMB(4,3)=TS
      Q1=SPAN+TS
      Q2=RISE+(TT+TB)/2.
      PMEMB(1,4)=Q1
      PMEMB(2,4)=Q2
      PMEMB(3,4)=Q1
      PMEMB(4,4)=Q2
      PMEMB(1,5)=HHT+TS/2.
      PMEMB(2,5)=HVT+TT/2.
      PMEMB(3,5)=HHB+TS/2.
      PMEMB(4,5)=HVB+TB/2.
      PMEMB(1,6)=HHT+TS/2.
      PMEMB(2,6)=HVB+TB/2.
      PMEMB(3,6)=HHB+TS/2.
      PMEMB(4,6)=HVT+TT/2.
      GO TO 149
  999 FORMAT(' *** INPUT ERROR ***')
 1010 FORMAT(      ' EXECUTION FOR THIS PROBLEM HAS BEEN TERMINATED.')
      GO TO 150
  149 CONTINUE
C
C     CALCULATE d FOR EACH WALL
C
C
      DO 33 I=1,6
      A=TT
      IF(I .EQ. 2 .OR. I .EQ. 6) A=TS
      IF (TST .NE. 0. .AND. (I .EQ. 2 .OR. I .EQ. 6)) A=TST
      IF(I .EQ. 3 .OR. I .EQ. 5) A=TB
      SDATA(29+I)=A-BDATA(29+I)-SDATA(I)/2
   33 CONTINUE
C
C
C
C

  150 CONTINUE
      RETURN
      END
C
C
```

Subroutine: DESIGN

Function:

This subroutine calls a series of other subroutines in order to complete the analysis and design of box culvert.

I/O Generated By Subroutine:

When output Option 4 is selected, joint displacements are printed for each load case.

Error Messages Generated:

None

```
      SUBROUTINE DESIGN
C
C   THIS SUBROUTINE SEQUENTIALLY CALLS OTHER SUBROUTINES IN ORDER TO
C   COMPLETE THE ANALYSIS AND DESIGN OF THE ONE CELL BOX.
C   A PRINTOUT OF THE X,Y DEFLECTIONS AND ROTATIONS FOR EACH MEMBER
C   AND LOADING CASE IS AVAILABLE WITH AN IDBUG VALUE GREATER THAN 2.
C
      CHARACTER*4 Z2(8)
C
C
      REAL*4 INER,KAA,KAB,KBA,KBB
      COMMON/RARRAY/U(12,40),FIL(200),PMEMB(4,25),X(50,4),INER(4,50)
     1 ,KAA(8,3,6),W1WH(3,22,4),W2WH(3,22,4),AWH(3,22,4),BWH(3,22,4),
     2 CWH(3,22,4)
      COMMON/RSCALE/SPAN,RISE,TT,TB,TS,GAMAC,GAMAS,GAMAF,P0,H,HH,HV,Q,
     1 ZETA,BETA,DF,Q1,EC,ES,FY,FCP,FLMV,FLN,Q2,Q3,NLAY,RTYPE,Q4,Q5,
     2 CT(6),SDATA(35)
      COMMON/RSCAL2/QFAC,RES,NTJD,HHT,HHB,HVT,HVB,FLLN,FLLMV
      COMMON/RSCAL2/HRT(4),DSHDL(4),TST
      COMMON/RSCAL3/SWDTH,VMAG,RLEN,RWID,SURV,SURHT,SURHB,AS5D,
     1              AS6D,AS5SP,AS6SP,CHHT,CHVT,CHHB,CHVB
      COMMON/ANAL/P(12,40),STIF(12,12),FIXMO(4,40,4),DM(40),DV(40),
     1 DP(40),AS(40),SRATIO(40)
      COMMON /ISCALE/NIT,NOLD,IDBUG,IR,IW,ITAPE,IPATH,ICYC,NINT
      COMMON/ISCALE/NLD,LTYPE,NSDES,ISUR,NSTRES
C
      COMMON/PRN/ IPP,IDBG,III
      COMMON/FACT/ FLLMVP,FLLNP
      ICYC=0
    1 CONTINUE
      DO 2 I=1,4
      CALL GENJS(I)
    2 CONTINUE
C
      CALL GSTIF
C
      CALL GENLD
C
      CALL MATMP(STIF,9,P,40,U,12)
C     EXPAND DISPLACEMENT MATRIX FOR REACTION COMPONENTS
      DO 10 J=1,40
      U(12,J)=U(9,J)
      U(10,J)=U(8,J)
      U(9,J)=U(7,J)
      U(7,J)=0.
      U(8,J)=0.
      U(11,J)=0.
   10 CONTINUE
  400 IF (IDBUG.LT.3)  GO TO 12
      IF(IPP.EQ.1) WRITE(III,99)
   99 FORMAT('1',//)
```

```
      IF(IPP.EQ.1) WRITE(III,1000)
 1000 FORMAT(18X,'DISPLACEMENT MATRIX - INCHES AND RADIANS',
     1 /,18X,40(1H-),//,' NODE  LOAD       HORIZONTAL       VERTICAL',
     2'       ROTATION')
      DO 11 J = 1 , 4
      DO 11 K = 1 , NLD
         JA = J*3-2
         JB = J*3-1
         JC = 3*J
         IF(K.EQ. 1.AND.IPP.EQ.1) WRITE(III,1002) J,K,U(JA,K),U(JB,K),U(
     1JC,K)
         IF(K.NE. 1.AND.IPP.EQ.1) WRITE(III,1003) K,U(JA,K),U(JB,K),U(JC
     1,K)
 1002 FORMAT(//,2X,I1,6X,I2,3X,3(E13.4,2X))
 1003 FORMAT(9X,I2,3X,3(E13.4,2X))
 1004 FORMAT('1',///)
   11 CONTINUE
   12 CONTINUE
C
      CALL ENDFO
      CALL SIMSPN
      CALL FMXMN
      IF (IPATH .LE. 0 ) RETURN
C
      CALL DESCK
      RETURN
      END
C
C
C
```

Subroutine: GENJS

Function:

This subroutine generates the flexibility coefficients for each member. For members with linearly varying haunches, these coefficients are determined by numerical integration.

I/O Generated By Subroutine:

None

Error Messages Generated:

None

```
      SUBROUTINE GENJS(M)
C
C   GENERATES FLEXIBILITY COEFICIENTS FROM ONE CELL BOX GEOMETRY.
C   FOR MEMBERS WITH LINEARLY VARYING HAUNCHES THESE COEFFICIENTS ARE
C   DETERMINED BY NUMERICAL INTEGRATION.
C
C     THE INTEGRATION POINTS ARE  N O T  AT EQUAL INTERVALS
      REAL*4 M1(50),M2(50),M3(50),M4(50),M5(50),M6(50)
      REAL*4 KAA,KAB,KBA,KBB
      REAL*4 INER(4,50)
      COMMON /RSCALE/ BDATA(35),SDATA(35)
      COMMON/RSCAL2/QFAC,RES,NTJD,HHT,HHB,HVT,HVB,FLLN,FLLMV
      COMMON/RSCAL2/HRT(4),DSHDL(4),TST
      COMMON /RARRAY/ FIL(680),PMEMB(4,25),XX(50,4),INER,KAA(8,3,6),
     1                W1WH(3,22,4),W2WH(3,22,4),AWH(3,22,4),
     2                BWH(3,22,4),CWH(3,22,4)
      COMMON /ISCALE/ N,NOLD,IDBUG,IR,IW,ITAPE,IPATH,ICYC,NINT
      COMMON/ISCALE/NLD,LTYPE,NSDES,ISUR,NSTRES
      COMMON/PRN/ IPP,IDBG,III
      COMMON/FACT/ FLLMVP,FLLNP
      EQUIVALENCE (BDATA(11),HH),(BDATA(12),HV),(BDATA(18),EC)
      N=50
      DA=PMEMB(M,1)
      DB=PMEMB(M,2)
      DC=PMEMB(M,3)
      SP=PMEMB(M,4)
      ALA=PMEMB(M,5)
      ALB=PMEMB(M,6)
      X1=ALA
      X2=SP-ALB
      CA=(DA-DC)/ALA
      CB=(DB-DC)/ALB
C
C NEW CODE ADDED 18 MARCH 87 FOR VARAIBLE T&B HAUNCHES
C
      IF (M.EQ.1.AND.HHT.EQ.0.) GO TO 5
      IF (M.EQ.3.AND.HHB.EQ.0.) GO TO 5
      IF (M.EQ.2.AND.(HVT.EQ.0..OR.HVB.EQ.0.)) GO TO 101
      IF (M.EQ.3.AND.(HVT.EQ.0..OR.HVB.EQ.0.)) GO TO 101
      DX1=ALA/5.
      DX2=(SP-ALA-ALB)/39.
      DX3=ALB/5.
      GO TO 6
    5 DX1=SP/49.
      DX2=DX1
      DX3=DX1
      GO TO 6
  101 CONTINUE
C
C NO HAUNCHES
C
```

```
      DX1=SP/49.
      DX2=DX1
      DX3=DX1
      IF(HVT.EQ.0..AND.HVB.EQ.0.) GO TO 6
      IF((HVB.EQ.0..AND.M.EQ.2).OR.(HVT.EQ.0..AND.M.EQ.3)) GO TO 102
C
C NO HAUNCH AT A END, HAUNCH AT B END
C
      DX1=(SP-ALB)/44
      DX2=DX1
      DX3=ALB/5
      GO TO 6
  102 CONTINUE
C
C NO HAUNCH AT B END, HAUNCH AT A END
C
      DX1=ALA/5
      DX2=(SP-ALA)/44
      DX3=DX2
      GO TO 6
    6 X=-DX1
      DO 10 I=1,6
      X=X+DX1
      D=DA-CA*X
      INER(M,I)=D*D*D*EC
      XX(I,M)=X
   10 CONTINUE
      DO 11 I=7,45
      X=X+DX2
      D=DC
      INER(M,I)=D*D*D*EC
      XX(I,M)=X
   11 CONTINUE
      DO 12 I=46,50
      X=X+DX3
      D=DC+CB*(X-X2)
      INER(M,I)=D*D*D*EC
      XX(I,M)=X
   12 CONTINUE
      DO 20 I=1,N
      X=XX(I,M)
      D=SP-X
      IF(D .LT. 0.) D=0.0001
      IF(X .GT. SP) X=SP-0.0001
      M1(I)=1.
      M2(I)=D
      M3(I)=X
      M4(I)=D*D
      M5(I)=D*X
      M6(I)=X*X
   20 CONTINUE
      PMEMB(M,7)=TRAP(M1,N,SP,M)
```

```
      PMEMB(M,8)=TRAP(M2,N,SP,M)
      PMEMB(M,9)=TRAP(M3,N,SP,M)
      PMEMB(M,10)=TRAP(M4,N,SP,M)
      PMEMB(M,11)=TRAP(M5,N,SP,M)
      PMEMB(M,12)=TRAP(M6,N,SP,M)
      RETURN
        END
C
C
C
```

Subroutine: TRAP

Function:

This subroutine uses the trapezoidal rule with 50 integration points to obtain the flexibility coefficients.

I/O Generated By Subroutine:

None

Error Messages Generated:

None

```
      FUNCTION TRAP(MOM,N,S,M)
C
C   USES THE TRAPEZOIDAL RULE WITH 50 INTEGRATION POINTS TO OBTAIN
C   THE FLEXIBILITY COEFFICIENTS
C
C     THIS IS THE 2ND VERSION OF THIS PROGRAM
C     THE INTEGRATION POINTS ARE  N O T  AT EQUAL INTERVALS
      REAL*4 KAA,KAB,KBA,KBB
      REAL*4 INER(4,50),MOM(1)
      COMMON /RARRAY/ FL(780),X(50,4),INER,KAA(8,3,6),W1WH(3,22,4),
     1                W2WH(3,22,4),AWH(3,22,4),BWH(3,22,4),
     2                CWH(3,22,4)
      K=N-1
      H=S/K
      TRAP=0.
      DO 1 I=1,K
      TRAP=TRAP+(MOM(I)/INER(M,I)+MOM(I+1)/INER(M,I+1))*
     1  (X(I+1,M)-X(I,M))
    1 CONTINUE
      TRAP=0.5*TRAP
      RETURN
      END
C
C
C
```

Subroutine: GSTIF

Function:

This subroutine generates the stiffness matrix for each member by inverting flexibility coefficients.

I/O Generated By Subroutine:

None

Error Messages Generated:

None

```
      SUBROUTINE GSTIF
C
C   GENERATES STIFFNESS MATRIX
C   FLEXIBILITY COEFFICIENTS ARE INVERTED AND ASSEMBLED TO OBTAIN
C   STIFFNESS MATRIX
C
      REAL*4 INER,KAA,KAB,KBA,KBB
      CHARACTER*4 Z2(8)
C
      COMMON/RSCALE/SPAN,RISE,TT,TB,TS,GAMAC,GAMAS,GAMAF,P0,H,HH,HV,Q,
     1 ZETA,BETA,DF,Q1,EC,ES,FY,FCP,FLMV,FLN,Q2,Q3,NLAY,RTYPE,Q4,Q5,
     2 CT(6),SDATA(35)
      COMMON/RSCAL2/QFAC,RES,NTJD,HHT,HHB,HVT,HVB,FLLN,FLLMV
      COMMON/RSCAL2/HRT(4),DSHDL(4),TST
      COMMON/RARRAY/U(12,40),W1(4,10),W2(4,10),A(4,10),B(4,10),C(4,10),
     1 PMEMB(4,25),X(50,4),INER(4,50),KAA(8,3,6),W1WH(3,22,4),
     2 W2WH(3,22,4),AWH(3,22,4),BWH(3,22,4),CWH(3,22,4)
      COMMON /ANAL/FIL(480) ,STIF(12,12),FIXMO(4,40,4),DM(200)
      COMMON /ISCALE/NIT,NOLD,IDBUG,IR,IW,ITAPE,IPATH,ICYC,NINT
      COMMON/ISCALE/NLD,LTYPE,NSDES,ISUR,NSTRES
      COMMON/PRN/ IPP,IDBG,III
      COMMON/FACT/ FLLMVP,FLLNP
      DIMENSION F(3,3),AK(3,3),UN(3,3)
C
      DO 8 I=1,12
      DO 8 J=1,12
    8 STIF(I,J)=0.
      DO 10 I=1,4
C     GENERATE SCRIPT F
      DO 6 J=2,3
      F(J,1)=0.
      F(1,J)= 0.
      AK(1,J)=0.
      AK(J,1)=0.
    6 CONTINUE
      F(3,3)=PMEMB(I,7)
      F(2,3)=PMEMB(I,8)
      F(2,2)=PMEMB(I,10)
      F(3,2)=F(2,3)
      DC=PMEMB(I,3)*12.
      SP=PMEMB(I,4)
      F(1,1)=SP/DC/EC
C     INVERT F TO GET AK
      DELTA=F(2,2)*F(3,3) -F(2,3)*F(3,2)
      AK(1,1)=1./F(1,1)
      AK(2,2)=F(3,3)/DELTA
      AK(3,3)=F(2,2)/DELTA
      AK(2,3)=-F(2,3)/DELTA
      AK(3,2)=AK(2,3)
      CALL ASSEM(I,AK)
   10 CONTINUE
```

```
C
C     PRINT STIFFNESS MATRIX FOR DEBUG
C
       DO 18 I=1,12
       IF(IPP.EQ.1.AND.IDBUG.EQ.9) WRITE(III,15) (STIF(I,J),J=1,12)
   18 CONTINUE
      IF(IPP.EQ.1.AND.IDBUG.EQ.9) WRITE(III,19)
   19 FORMAT(//////////,'MODIFIED STIFFNESS')
C
C     REMOVE REACTION COMPONENTS
      DO 12 J=1,12
      STIF(7,J)=STIF(9,J)
      STIF(8,J)=STIF(10,J)
      STIF(9,J)=STIF(12,J)
   12 CONTINUE
      DO 13 I=1,12
      STIF(I,7)=STIF(I,9)
      STIF(I,8)=STIF(I,10)
      STIF(I,9)=STIF(I,12)
   13 CONTINUE
C
C     PRINT STIFFNESS MATRIX FOR DEBUG
      DO 20 I=1,12
      IF(IPP.EQ.1.AND.IDBUG.EQ.9) WRITE(III,15) (STIF(I,J),J=1,12)
   15 FORMAT(12(E10.4,2X))
   20 CONTINUE
C
C
      CALL CROUT(STIF,9,12)
      RETURN
      END
C
C
```

Subroutine: ASSEM

Function:

This subroutine assembles the member stiffness matrices into a global stiffness matrix.

I/O Generated By Subroutine:

None

Error Messages Generated:

None

```
      SUBROUTINE ASSEM(M,AK)
C
C   ASSEMBLES THE MEMBER STIFFNESS MATRICES INTO A GLOBAL STIFFNESS
C   MATRIX
C
C
      CHARACTER*4 Z2(8)
      REAL*4 KAA(4,3,3),KAB(4,3,3),KBA(4,3,3),KBB(4,3,3)
      COMMON /RARRAY/FIL(680),PMEMB(4,25),FIL1(400),KAA,KAB,KBA,KBB,
     1               W1WH(3,22,4),W2WH(3,22,4),AWH(3,22,4),
     2               BWH(3,22,4),CWH(3,22,4)
      COMMON /IARRAY/MEMB(4,2),INDEX(40)
      COMMON /ISCALE/NIT,NOLD,IDBUG,IR,IW,ITAPE,IPATH,ICYC,NINT
      COMMON/ISCALE/NLD,LTYPE,NSDES,ISUR,NSTRES
      COMMON /ANAL/ FIL2(480) ,STIF(12,12),FIXMO(4,40,4),DM(200)
      COMMON/PRN/ IPP,IDBG,III
      COMMON/FACT/ FLLMVP,FLLNP
      DIMENSION D(3,3),AK(3,3)
C     * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
      JTA=MEMB(M,1)
      JTB=MEMB(M,2)
      SP=PMEMB(M,4)
      IRAA=3*(JTA-1)
      IRBB=3*(JTB-1)
C.....FORM KBA
      DO 1 I=1,3
      DO 1 J=1,3
    1 D(I,J)=-AK(I,J)
      DO 11 I=1,3
   11 D(I,3)=D(I,3)+SP*D(I,2)
      DO 26 I=1,3
      DO 26 J=1,3
   26 KBA(M,I,J)=D(I,J)
      IF ( M.NE.1)  CALL ROTS(M,D)
      DO 8 I=1,3
      IROW=IRAA+I
      DO 8 J=1,3
      ICOL=IRBB+J
    8 STIF(ICOL,IROW)=STIF(ICOL,IROW)+D(J,I)
C
C.....FORM KAB
      DO 3 I=1,3
      DO 3 J=1,3
    3 D(I,J)=KBA(M,J,I)
      DO 13 I=1,3
      DO 13 J=1,3
   13 KAB(M,I,J)=D(I,J)
      IF ( M.NE.1)  CALL ROTS(M,D)
      DO 6 I=1,3
      IROW=IRAA+I
      DO 6 J=1,3
      ICOL=IRBB+J
```

```
    6 STIF(IROW,ICOL)=STIF(IROW,ICOL)+D(I,J)
C
C.....FORM KBB
      DO 5 I=1,3
      DO 5 J=1,3
    5 D(I,J)= AK(I,J)
      DO 23 I=1,3
      DO 23 J=1,3
   23 KBB(M,I,J)=D(I,J)
      IF ( M.NE.1)  CALL ROTS(M,D)
      DO 4 I=1,3
      IROW=IRBB+I
      DO 4 J=1,3
      ICOL=IRBB+J
    4 STIF(IROW,ICOL)=STIF(IROW,ICOL)+D(I,J)
C
C.....FORM KAA
      DO 7 I=1,3
      DO 7 J=1,3
    7 D(I,J)= AK(I,J)
      DO 17 I=1,3
   17 D(I,3)=D(I,3)+SP*D(I,2)
      DO 27 J=1,3
   27 D(3,J)=D(3,J)+SP*D(2,J)
      DO 30 I=1,3
      DO 30 J=1,3
   30 KAA(M,I,J)=D(I,J)
      IF ( M.NE.1)  CALL ROTS(M,D)
      DO 2 I=1,3
      IROW=IRAA+I
      DO 2 J=1,3
      ICOL=IRAA+J
    2 STIF(IROW,ICOL)=STIF(IROW,ICOL)+D(I,J)
C
C.....MEMBER MATRICES ARE NOW IN THE GLOBAL STIFFNESS MATRIX
C
      RETURN
      END
C
C
```

Subroutine: ROTS

Function:

This subroutine changes the member stiffness matrices from the local coordinate system to the global coordinate system.

I/O Generated By Subroutine:

None

Error **Messages Generated:**

None

```
      SUBROUTINE ROTS(M,D)
C
C    CHANGES MEMBER STIFFNESS MATRICES FROM LOCAL COORDINATE SYSTEM TO
C    GLOBAL COORDINATE SYSTEM
C
      DIMENSION D(3,3)
      GO TO (1,2,3,4),M
    1 RETURN
    2 F=1.
      GO TO 5
    3 D(2,3)=-D(2,3)
      D(3,2)=-D(3,2)
      GO TO 1
    4 F=-1.
    5 D(1,3)=F*D(2,3)
      D(3,1)=F*D(3,2)
      T=D(2,2)
      D(2,2)=D(1,1)
      D(1,1)=T
      D(2,3)=0.
      D(3,2)=0.
      GO TO 1
      END
C
C
```

Subroutine: CROUT

Function:

This subroutine inverts the global stiffness matrix.

I/O Generated By Subroutine:

None

Error Messages Generated:

None

```
      SUBROUTINE CROUT(A,N,NF)
C
C    INVERTS STIFFNESS MATRIX
C
      DIMENSION A(144)
      B=A(1)
      JAA=1
      DO 1 J=2,N
      JAA=JAA+NF
    1 A(JAA) = A(JAA)/B
      JO = 0
      DO 2 J=2,N
      J1=J-1
      JO=JO+NF
      JB=J+JO
      DO 3 I=J,N
      S=0.
      IA=I-NF
      DO 4 K=1,J1
      IA = IA+NF
      KA=JO+K
    4 S=S+A(IA)*A(KA)
      JA=JO+I
    3 A(JA)=A(JA )-S
      IF (J-N) 7,2,2
    7 J2=J+1
      IO=JO
      DO 5 I=J2,N
      S=0.
      IO=IO+NF
      JA=J-NF
      DO 6 K=1,J1
      JA = JA+NF
      KA =K+IO
    6 S=A(JA)*A(KA)+S
      IB=J+IO
    5 A(IB)=(A(IB)-S)/A(JB)
    2 CONTINUE
      RETURN
      END
C
C

$DEBUG
C
C
C
```

Subroutine: GENLD

Function:

This subroutine generates the joint load matrix.

I/O Generated By Subroutine:

None

Error Messages Generated:

None

```
      SUBROUTINE GENLD
C
C   GENERATES JOINT LOAD MATRIX
C
      REAL*4 INER,KAA,KAB,KBA,KBB
      REAL*4 MOM(50)
      REAL*4 JLOAD(12,40)
      CHARACTER*4 Z2(8)
      COMMON/RSCALE/SPAN,RISE,TT,TB,TS,GAMAC,GAMAS,GAMAF,P0,H,HH,HV,POV
     1 ,ZETA,BETA,DF,Q1,EC,ES,FY,FCP,FLMV,FLN,Q2,Q3,NLAY,RTYPE,Q4,Q5,
     2 CT(6),SDATA(35)
      COMMON/RSCAL2/QFAC,RES,NTJD,HHT,HHB,HVT,HVB,FLLN,FLLMV
      COMMON/RSCAL2/HRT(4),DSHDL(4),TST
      COMMON/RSCAL3/SWDTH,VMAG,RLEN,RWID,SURV,SURHT,SURHB,AS5D,
     1              AS6D,AS5SP,AS6SP,CHHT,CHVT,CHHB,CHVB
      COMMON/RSCAL4/ITDIR
      COMMON/RARRAY/U(12,40),W1(4,10),W2(4,10),A(4,10),B(4,10),C(4,10),
     1 PMEMB(4,25),X(50,4),INER(4,50),KAA(8,3,6),W1WH(3,22,4),
     2 W2WH(3,22,4),AWH(3,22,4),BWH(3,22,4),CWH(3,22,4)
      COMMON /ISCALE/NIT,NOLD,IDBUG,IR,IW,ITAPE,IPATH,ICYC,NINT
      COMMON/ISCALE/NLD,LTYPE,NSDES,ISUR,NSTRES
      COMMON/ANAL/JLOAD,STIF(12,12),FIXMO(4,40,4),DM(200)
      COMMON /IFLAGS/IBDATA(35),ISDATA(35),ICON(40)
      COMMON/PRN/ IPP,IDBG,III
      COMMON/FACT/ FLLMVP,FLLNP
      REAL DISTA(4,22),WLOAD(4),LWH
      REAL LEN,DELTA,MIN,TIPHAUN,AIMP,HFT,POV
      REAL SPACE(4),MAG(4),AL1(4),POS(16),AL1N(4)
      CHARACTER*20 TRUCK,DIR
C
C
        FLLMVP=FLLMV
        FLLNP=FLLN
C
      MOMCALL=3
      MOMINC=2
      DO 250 I=1,4
      DO 250 J=1,40
      DO 250 K=1,4
      FIXMO(I,J,K)=0.
      IF(I. EQ. 4) GO TO 250
      IF (J .GT. 22) GO TO 250
      W1WH(I,J,K)=0.
      W2WH(I,J,K)=0.
      AWH(I,J,K)=0.
      BWH(I,J,K)=0.
      CWH(I,J,K)=0.
  250 CONTINUE
      DO 201 I=1,4
      DO 201 J=1,10
      W1(I,J)=0.
      W2(I,J)=0.
```

```
      A(I,J)=0.
      B(I,J)=0.
      C(I,J)=0.
  201 CONTINUE
      DO 215 I=1,12
      DO 215 J=1,40
  215 JLOAD(I,J)=0.
      DO 1000 L=1,9
      GO TO (10,20,30,40,1000,60,1000,1000,70),L
C
C     CONCRETE DEAD LOAD - LOADING CONDITION 1
   10 CONTINUE
      G=GAMAC*12.
      WT=TT*G
      PS=(TS*PMEMB(2,4)+0.5*(HHT*HVT+HHB*HVB))*G
      WB=TB*G
      SP=PMEMB(1,4)
      WR=WT+WB+2.*PS/SP
      PS = PS/2.
      W=WR-WB
      W1(1,1)=WT
      W1(3,1)=W
      W2(1,1)=WT
      W2(3,1)=W
      B(1,1)=SP
      B(3,1)=SP
      DO 11 M=1,MOMCALL,MOMINC
      CALL MOMENT(W1(M,L),W2(M,L),A(M,L),B(M,L),C(M,L),X(1,M),MOM,VA,
     1 VB,NIT)
      CALL FXEDMO(MOM,FMAB,FMBA,M)
      CALL FLLD(M,L,VA,VB,FMAB,FMBA)
   11 CONTINUE
      DO 12 I=1,4
      K=(I-1)*3+2
      JLOAD(K,1)=JLOAD(K,1)-PS
   12 CONTINUE
      GO TO 1000
C
C     VERTICAL SOIL PRESSURE - LOADING CONDITION 2
   20 CONTINUE
      WT=BETA*H*GAMAS*12.
      IF (LTYPE .EQ. 5) WT=WT+.2/(96+H)
      SP=PMEMB(1,4)
      P=WT*TS/2.
      DO 21 M=1,MOMCALL,MOMINC
      W1(M,2)=WT
      W2(M,2)=WT
      B(M,2)=SP
      CALL MOMENT(W1(M,L),W2(M,L),A(M,L),B(M,L),C(M,L),X(1,M),MOM,VA,
     1 VB,NIT)
      CALL FXEDMO(MOM,FMAB,FMBA,M)
      CALL FLLD(M,L,VA,VB,FMAB,FMBA)
```

```
   21 CONTINUE
      JLOAD(2,2)=JLOAD(2,2)-P
      JLOAD(5,2)=JLOAD(5,2)-P
      JLOAD(8,2)=JLOAD(8,2)+P
      JLOAD(11,2)=JLOAD(11,2)+P
      GO TO 1000
C
C             MINIMUM HORIZONTAL SOIL PRESSURE - LOADING CONDITION 3
C
   30 CONTINUE
      TB3=TB
      G=GAMAS*ZETA*12
      SP=PMEMB(2,4)
      WST=G*H
      WSB=G*(H+SP+TT/2.+TB3/2.)
      W1(2,3)=WST
      W1(4,3)=WSB
      W2(2,3)=WSB
      W2(4,3)=WST
      B(2,3)=SP
      B(4,3)=SP
      DO 31 M=2,4,2
      CALL MOMENT(W1(M,L),W2(M,L),A(M,L),B(M,L),C(M,L),X(1,M),MOM,VA,
     1 VB,NIT)
      CALL FXEDMO(MOM,FMAB,FMBA,M)
      CALL FLLD(M,L,VA,VB,FMAB,FMBA)
   31 CONTINUE
      PT=WST*TT/2.
      PB=WSB*TB3/2.
      JLOAD(1,3)=JLOAD(1,3)+PT
      JLOAD(4,3)=JLOAD(4,3)-PT
      JLOAD(7,3)=JLOAD(7,3)-PB
      JLOAD(10,3)=JLOAD(10,3)+PB
C
C ADDITIONAL LATERAL SOIL PRESSURE LOAD CASE 5
2-12-76
C
      IF (SDATA(25) .LT. 0.) SDATA(25)=0.
      W1(2, 5)=WST*SDATA(25)
      W1(4, 5)=WSB*SDATA(25)
      W2(2, 5)=WSB*SDATA(25)
      W2(4, 5)=WST*SDATA(25)
      B(2, 5)=SP
      B(4, 5)=SP
      DO 33 M=2,4,2
      CALL MOMENT(W1(M,5),W2(M,5),A(M,5),B(M,5),C(M,5),
     B        X(1,M),MOM,VA,VB,NIT)
      CALL FXEDMO (MOM,FMAB,FMBA,M)
      CALL FLLD (M,5,VA,VB,FMAB,FMBA)
   33 CONTINUE
      JLOAD(1,5)=JLOAD(1,5)+PT*SDATA(25)
      JLOAD(4,5)=JLOAD(4,5)-PT*SDATA(25)
```

```
      JLOAD(7,5)=JLOAD(7,5)-PB*SDATA(25)
      JLOAD(10,5)=JLOAD(10,5)+PB*SDATA(25)
      GO TO 1000
C
C     INTERNAL WATER LOAD - LOADING CONDITION 4
C
   40 CONTINUE
      MOMINCFL=1
             TB3=TB
      WSB=GAMAF*DF*12.
      SP=PMEMB(2,4)
      WR=WSB*SPAN/(SPAN+TS)
      W=WR-WSB
      S2=TB3/2.
      S1=SP-S2-DF
      S3=TS/2.
      W1(2,4)=0.
      W2(2,4)=-WSB
      A(2,4)=S1
      B(2,4)=DF
      C(2,4)=S2
      W1(3,4)=W
      W2(3,4)=W
      A(3,4)=S3
      B(3,4)=SPAN
      C(3,4)=S3
      W1(4,4)=-WSB
      W2(4,4)=0.
      A(4,4)=S2
      B(4,4)=DF
      C(4,4)=S1
      P=WR*TS
      JLOAD( 8,4)=JLOAD( 8,4)+P
      JLOAD(11,4)=JLOAD(11,4)+P
      DO 41 M=2,4,MOMINCFL
      CALL MOMENT(W1(M,L),W2(M,L),A(M,L),B(M,L),C(M,L),X(1,M),MOM,VA,
     1 VB,NIT)
      CALL FXEDMO(MOM,FMAB,FMBA,M)
      CALL FLLD(M,L,VA,VB,FMAB,FMBA)
   41 CONTINUE
      GO TO 1000
C
C
C DETERMINE LIVELOAD CONDITIONS
C POSSIBLE LOAD CONDITIONS ARE 6 TO 8 AND 11 TO 32
C
   60 CONTINUE
      DO 42 I=1,4
      MAG(I)=0.0
      SPACE(I)=0.0
      AL1(I)=0.0
   42 WLOAD(I)=0.0
```

```
      SPRM=PMEMB(1,4)
      GO TO (1000,92,93,93,95) LTYPE
C
C     AIMP  = IMPACT FACTOR
C     MAG   = MAGNITUDE OF WHEEL LOAD
C     SPACE = DISTANCE BETWEEN DISTRIBUTED LOAD CENTERS FOR AXLES
C
C     LTYPE = TYPE OF LIVELOAD
C
C            LTYPE    =1  NO LIVELOAD
C                     =2  OTHER
C                     =3  HS-20
C                     =4  INTERSTATE
C                     =5  COOPER E-80
C
   92 CONTINUE
C
C                          OTHER LIVELOAD - LTYPE=2
C                          NO IMPACT FACTOR IS USED FOR THIS LOAD CASE
C                          LOAD CASES WILL BE 6 AND 8 IF RLEN .LT. SPAN+TS
C                          OTHERWISE LOAD CASES WILL BE 8 AND 11 TO 21
C
      TRUCK='OTHER'
      IWHEEL=3
      WLOAD(2)=VMAG/RLEN/RWID*12.
      AL1(2)=RLEN
      AL2=RWID
      ISTART=11
      IEND=21
      MAG(2)=VMAG
      GO TO 372
C
C      CALCULATE IMPACT FACTOR
C
   93 CONTINUE
      AIMP=1.3
      IF(H .GT. 12.) AIMP=1.2
      IF(H .GT. 24.) AIMP=1.1
      IF(H .GE. 36.) AIMP=1.0
C
C     COMPUTE AASHTO BETA FACTOR
C
        BFCT=FLLMV/FLMV
        BFCTN=FLLN/FLN
C
C     TIRE FOOTPRINT (FEET)
C
        WWH=20.
        LWH=8.*BFCT
C
C     DETERMINE DEPTH AT WHICH CONDITION B GOVERNS LIVELOAD
C
```

```
         HGOV=((504.+WWH)*BFCT-4*(72.+WWH))/(7-1.75*BFCT)
C
C       REDUCE LIVE LOAD FACTOR FOR H FROM (29.71 TO HGOV) INCHES
C       BY REDUCING BETA FROM BFCT TO 1.0
C       FOR H GREATER THAN HGOV LIVELOAD FACTOR IS FLMV
C
         IF (H .GT. 29.71) THEN
                 FCT=1+(BFCT-1)*(H-29.71)/(HGOV-29.71)
                 FCTN=1+(BFCTN-1)*(H-29.71)/(HGOV-29.71)
                 FLLMV=FLLMV/FCT
                 IF ( H .GT. HGOV ) FLLMV=FLMV
                 FLLN=FLLN/FCTN
                 IF ( H .GT. HGOV ) FLLN=FLN
         ENDIF
C     CALCULATE DISTRIBUTION WIDTHS
C       AL1 IS ALONG SPAN
C
C       SET AL2 - LOAD DISTRIBUTION PARALLEL TO CULVERT FLOW
C
        AL2=WWH+1.75*H
        IF ( H   .GT. 29.71 ) AL2=(504+WWH+1.75*H)/8.
        IF ( H .LE. 24. ) AL2=48+0.06*(SPAN-HHT)+1.75*H+WWH
C
        IF (LTYPE .EQ. 4) GO TO 94
C
C*********************************************************
C
C        AASHTO HS-SERIES
C*********************************************************
C
   98   TRUCK='AASHTO HS-SERIES'
        VHCL=VMAG/20.
C
C
C
C       LESS THAN OR EQUAL TO 2 FT. OF FILL ASSUMES DISTRIBUTION STEEL
C
C
        IF( H  .LE. 24. ) THEN
          AL1(1)=LWH+1.75*H
          AL1(2)=LWH+1.75*H
          AL1(3)=LWH+1.75*H
          MAG(1)=16.*AIMP
          MAG(2)=16.*AIMP
          MAG(3)=4.*AIMP
          SPACE(1)=168.
          SPACE(3)=168.
        ENDIF
C
        IF ( H .GT. 24.  .AND. H  .LT.  (96.-LWH/1.75) ) THEN
          AL1(1)=LWH+1.75*H
          AL1(2)=LWH+1.75*H
```

```
        AL1(3)=LWH+1.75*H
        MAG(1)=16.*AIMP
        MAG(2)=16.*AIMP
        MAG(3)=4.*AIMP
        SPACE(1)=168.
        SPACE(3)=168.
      ENDIF
C
C     HEIGHT OF FILL BETWEEN 8 AND 10 FT.
C     STRAIGHT LINE INTERPOLATION USED TO THE TRANSITION BETWEEN
C     NO AXLE INTERACTION AND COMPLETE AXLE INTERACTION AND
C     AVOID A SUDDEN DROP IN WHEEL PRESSURE.
C
      IF ( H .GE. (96.-LWH/1.75) .AND.  H .LE. 120. ) THEN
            AL1(1)=336.+(0.875*(H-(96.-LWH/1.75)))
            AL1(2)=336.+(0.875*(H-(96.-LWH/1.75)))
            AL1(3)=168.+(0.875*(H-(96.-LWH/1.75)))
            MAG(1)=0
            MAG(2)=(32-8.593*(H-(96.-LWH/1.75))/(24+LWH/1.75))*AIMP
            MAG(3)=(4+8.593*(H-(96.-LWH/1.75))/(24+LWH/1.75))*AIMP
            SPACE(1)=0.
            SPACE(3)=252.+0.875*H
      ENDIF
C
C     ALL AXLES INTERACT
C
      IF ( H .GT. 120. ) THEN
        AL1(1)=336+1.75*H+LWH
        AL1(2)=336+1.75*H+LWH
        AL1(3)=336+1.75*H+LWH
        MAG(1)=0
        MAG(2)=36.*AIMP
        MAG(3)=0
        SPACE(1)=0.
        SPACE(3)=0.
      ENDIF
C
  307 CONTINUE
C
C     CALCULATE PRESSURES FOR EACH AXLE
C
      DO 386 I=1,3
            WLOAD(I)=(MAG(I)/AL1(I)/AL2)*12.*VHCL
  386 CONTINUE
C
      IWHEEL=3
      ISTART=11
      IEND=21
      GO TO 372
C
C ***********************************************************
C     INTERSTATE TRUCK
```

```
C ********************************************************
C
   94 CONTINUE
      TRUCK='AASHTO INTERSTATE'
C
C     LESS THAN 2 FT. OF FILL ASSUMES DISTRIBUTION STEEL
C
      IF( H .LE. 24. ) THEN
        AL1(1)=LWH+1.75*H
        AL1(2)=LWH+1.75*H
        AL1(3)=LWH+1.75*H
        AL1(4)=LWH+1.75*H
        IF (H .GT. 19.79) THEN
                AL1(1)=24+0.875*(H-19.79)
                AL1(2)=24+0.875*(H-19.79)
        ENDIF
        MAG(1)=12.*AIMP
        MAG(2)=12.*AIMP
        MAG(3)=16.*AIMP
        MAG(4)=4.*AIMP
        SPACE(2)=48.
        IF (H .GT. 19.79) SPACE(2)=48+.875*H
        SPACE(3)=192.
        SPACE(4)=360.
      ENDIF
C
C     CHECK INTERACTION OF AXLES
C
      IF ( H .GT. 24.  .AND.  H .LE. (96-(24+LWH)/1.75) ) THEN
C
C       TWO 24 KIP AXLES INTERACT
C
        AL1(1)=48+1.75*H+LWH
        AL1(2)=48+1.75*H+LWH
        AL1(3)=1.75*H+LWH
        AL1(4)=1.75*H+LWH
        MAG(1)=24.*AIMP
        MAG(2)=0.
        MAG(3)=16.*AIMP
        MAG(4)=4.*AIMP
        SPACE(2)=0.
        SPACE(3)=168.
        SPACE(4)=336.
      ENDIF
C
      IF( H .GT. (96-(24+LWH)/1.75) .AND. H .LE. (96.-LWH/1.75) ) THEN
C
C       32 & 2-24 KIP AXLES INTERACT
C
        AL1(1)=192.+0.875*(H-(96-(24+LWH)/1.75))
        AL1(2)=192.+0.875*(H-(96-(24+LWH)/1.75))
        AL1(3)=144+0.875*(H-(96-(24+LWH)/1.75))
```

```
          AL1(4)=1.75*H+LWH
          MAG(1)=24.*AIMP
          MAG(2)=0.
          MAG(3)=16.*AIMP
          MAG(4)=4.*AIMP
          SPACE(2)=0.
          SPACE(3)=168.+0.875*(H-(96-(24+LWH)/1.75))
          SPACE(4)=336.+0.4375*(H-(96-(24+LWH)/1.75))
        ENDIF
C
        IF ( H .GT. (96.-LWH/1.75) .AND.  H .LE. 120.) THEN
C
C         ALL AXLES INTERACT - STRAIGHT LINE INTERPOLATION
C
          AL1(1)=204.+0.875*(H-(96.-LWH/1.75))
          AL1(2)=204.+0.875*(H-(96.-LWH/1.75))
          AL1(3)=156.
          AL1(4)=168.+0.875*(H-(96.-LWH/1.75))
          MAG(1)=(24.-6.526*(H-(96.-LWH/1.75))/(24+LWH/1.75))*AIMP
          MAG(2)=0.
          MAG(3)=(16.-4.234*(H-(96.-LWH/1.75))/(24+LWH/1.75))*AIMP
          MAG(4)=(4.+10.76*(H-(96.-LWH/1.75))/(24+LWH/1.75))*AIMP
          SPACE(2)=0.
          SPACE(3)=180.+0.4375*(H-(96.-LWH/1.75))
          SPACE(4)=342.+0.875*(H-(96.-LWH/1.75))
        ENDIF
C
C       ALL AXLES INTERACT
C
        IF ( H .GT. 120.)  THEN
          AL1(1)=360.+1.75*H+LWH
          AL1(2)=360.+1.75*H+LWH
          AL1(3)=360.+1.75*H+LWH
          AL1(4)=360.+1.75*H+LWH
          MAG(1)=44.*AIMP
          MAG(2)=0.
          MAG(3)=0.
          MAG(4)=0.
          SPACE(2)=0.
          SPACE(3)=0.
          SPACE(4)=0.
        ENDIF
C
C       CALCULATE PRESSURES FOR EACH AXLE
C
        DO 387 I=1,4
              WLOAD(I)=(MAG(I)/AL1(I)/AL2)*12.
    387 CONTINUE
C
        IWHEEL=4
        ISTART=22
        IEND=32
```

```
C
  372 CONTINUE
C
C      CHECK TO SEE IF TRAFFIC IS ALONG AXIS OF CULVERT
C      AND MODIFY DISTRIBUTION AREAS ACCORDINGLY
C
       IF(ITDIR .NE. 0) GO TO 373
C
      SE=SPAN/12.
      IF ( SPAN .GE. 288. ) SE=24.
C
      IF ( H .LE. 24. ) AL2=((8*SE)/(SE+2))*12.
      IF(H .GT. 24. .AND. H .LE. 29.71 ) AL2=LWH+1.75*H
      DO 375 I=1,4
         AL1N(I)=WWH+1.75*H
         MAG(I)=16*AIMP
  375 CONTINUE
      SPACE(1)=72.
      SPACE(3)=72.
      SPACE(4)=144.
C
C
      IF( H .GT. 29.71 ) THEN
         AL2=LWH+1.75*H
         DO 377 I=1,4
         AL1N(I)=216.+1.75*H+WWH
         SPACE(I)=0.
  377    CONTINUE
         MAG(1)=0.
         MAG(2)=64*AIMP
         MAG(3)=0.
         MAG(4)=0.
      ENDIF
C
      IF(H .GT. 96) MAG(2)=(128. -(((H-96.)/24)*33.824))*AIMP
      IF(H .GT. 120.) MAG(2)=144.*AIMP
      DO 378 I=1,4
      AL1(I)=AL1N(I)
      WLOAD(I)=(MAG(I)/AL1(I)/AL2)*12.*VHCL
  378 CONTINUE
      IWHEEL=4
      ISTART=22
      IEND=32
C
  373 CONTINUE
C
C     LOCATE TRUCK POSITIONS ON TOP SLAB LTYPE=2,3 OR 4
C
C     POS() IS DISTANCE TO CENTER OF LOAD
C
      I=2
      IF(TRUCK .EQ. 'AASHTO INTERSTATE') I=1
```

```
      D=AMIN1(SDATA(30),SDATA(33))
      D=D*POV
      HAUN=CHHT
      IF(CHHT .EQ. 0.0) HAUN=HHT
      TIPHAUN=(TS/2.)+HAUN+D+AL1(I)/2
      POS(1)=0.
      POS(2)=(AL1(I)/2.)+D+(TS/2.)
      POS(6)=SPRM/2.
      DIF=(POS(6)-POS(2))/4.
      POS(3)=POS(2)+DIF
      POS(4)=POS(3)+DIF
      POS(5)=POS(4)+DIF
C
C
C       FIND WHICH LOCATION IS CLOSEST TO d FROM TIP OF
C       HAUNCH AND MOVE IT THERE.  IT IS POSSIBLE TO GET
C       TWO POSITIONS AT THE SAME LOCATION IF THERE IS
C       NO HAUNCH
C
C
      MIN=500.
      DO 326 J=3,5
            DELTA=ABS(POS(J)-TIPHAUN)
            IF(DELTA .LT. MIN) THEN
                  MIN=DELTA
                  ICT=J
            ENDIF
  326 CONTINUE
      POS(ICT)=TIPHAUN
C
C       OTHER LOCATIONS BY SYMMETRY
C
      POS(7)=SPRM-POS(5)
      POS(8)=SPRM-POS(4)
      POS(9)=SPRM-POS(3)
      POS(10)=SPRM-(AL1(I)/2.)-D-(TS/2.)
      POS(11)=SPRM
C
      DIR='TRANSVERSE'
      IF(ITDIR .EQ. 0.) DIR='PARALLEL'
      IF (TRUCK .EQ. 'AASHTO HS-SERIES'.AND.IPP.EQ.1) WRITE(III,799)
     1 VMAG,H,DIR
  799 FORMAT(//,5X,'AASHTO HS-',F3.0,1X,5X,F6.2,' INCHES OF FILL',/,
     1 5X,'TRAFFIC ',A13,' TO CULVERT FLOW',//)
      IF (TRUCK .EQ. 'AASHTO INTERSTATE'.AND.IPP.EQ.1) WRITE(III,798)
     1 TRUCK,H,DIR
  798 FORMAT(//,5X,A17,5X,F6.2,' INCHES OF FILL',/,
     1 5X,'TRAFFIC ',A13,' TO CULVERT FLOW',//)
C
      TRCON=' B'
      IF ( H .LT. HGOV ) TRCON=' A'
      IF ( IPP .EQ. 1 ) WRITE(III,797) TRCON
```

```
  797 FORMAT (//,5X,'CONDITION B GOVERNS SERVICE LIVE LOADS',
     1/,5X,'CONDITION',A2,' GOVERNS ULTIMATE LIVE LOADS')
C
C     BUILD UP COMPLETE DISTA ARRAY WHICH CONTAINS ALL
C     AXLE POSTIONS.
C
      DO 382 I=1,4
            DO 382 J=1,22
                  DISTA(I,J)=0.
  382 CONTINUE
C
C
C
      DO 311 I=1,11
            IF(ITDIR .EQ. 0) GO TO 383
            IF(TRUCK.EQ.'AASHTO INTERSTATE') GO TO 381
            DISTA(2,I)=POS(I)
            DISTA(1,I)=DISTA(2,I)-SPACE(1)
            DISTA(3,I)=DISTA(2,I)+SPACE(3)
                 GO TO 311
C
  381 CONTINUE
C
C           INTERSTATE WHEEL POSITIONS (UP TO 4 AXLES).
C
               LDWH=I+11
            DISTA(1,LDWH)=POS(I)
            DISTA(2,LDWH)=DISTA(1,LDWH)+SPACE(2)
            DISTA(3,LDWH)=DISTA(1,LDWH)+SPACE(3)
            DISTA(4,LDWH)=DISTA(1,LDWH)+SPACE(4)
            GO TO 311
C
  383 CONTINUE
C
C           TRAFFIC PARALLEL TO AXIS OF CULVERT (UP TO 4 AXLES)
C
            LDWH=I+11
            DISTA(2,LDWH)=POS(I)
            DISTA(1,LDWH)=DISTA(2,LDWH)-SPACE(1)
            DISTA(3,LDWH)=DISTA(2,LDWH)+SPACE(3)
            DISTA(4,LDWH)=DISTA(2,LDWH)+SPACE(4)
C
  311 CONTINUE
      GO TO 312
C
C                     COOPER SERIES LIVELOAD - LTYPE=5
C
   95 CONTINUE
      J=6
      SP=PMEMB(1,4)
      AIMP=1.4-0.04*H/12
      IF (AIMP .LT. 1.) AIMP=1.0
```

```
      WT=VMAG*AIMP/5/(96+H)
      W1(1,6)=WT
      W2(1,6)=WT
      B(1,6)=SP
      W1(3,6)=WT
      W2(3,6)=WT
      B(3,6)=SP
      AXIAL=WT*TS/2.
      GO TO 999
C
  312 CONTINUE
C
C             CHECK FOR UNIFORM LOAD OVER ENTIRE SPAN
C             THIS CORRESPONDS TO LOAD CASE 6 FOR HS-20
C             LOAD CASE 7 FOR INTERSTATE.  WE ARE INTERESTED
C             IN THE NUMBER TWO HS-20 WHEEL AND THE NUMBER
C             ONE INTERSTATE WHEEL.
C
C
              ITST=2
              IF(TRUCK .EQ. 'AASHTO INTERSTATE') ITST=1
              IF(AL1(ITST) .LT. SPRM) GO TO 391
              J=6
              NLD=10
              IF(TRUCK .EQ.'AASHTO INTERSTATE') J=7
              AXIAL=(TS/2.)*WLOAD(ITST)
              W1(1,J)=WLOAD(ITST)
              W2(1,J)=WLOAD(ITST)
              A(1,J)=0.
              B(1,J)=SPRM
              C(1,J)=0.
C
C                  THE FOLLOWING FIVE LINES FOR FOUR SIDED BOX ONLY
C
        W1(3,J)=W1(1,J)
        W2(3,J)=W1(1,J)
        A(3,J)=0.
        B(3,J)=SPRM
        C(3,J)=0.
C
C
  999 CONTINUE
                DO 800 M=1,MOMCALL,MOMINC
                     CALL MOMENT (W1(M,J),W2(M,J),A(M,J),B(M,J),
     1               C(M,J),X(1,M),MOM,VA,VB,NIT)
                     CALL FXEDMO (MOM,FMAB,FMBA,M)
                     CALL FLLD (M,J,VA,VB,FMAB,FMBA)
  800                CONTINUE
              JLOAD(5,J)=JLOAD(5,J)-AXIAL
              JLOAD(11,J)=JLOAD(11,J)+AXIAL
              JLOAD(2,J)=JLOAD(2,J)-AXIAL
              JLOAD(8,J)=JLOAD(8,J)+AXIAL
```

```
          GO TO 61
C
C
C
  391 CONTINUE
C
C
C     LOAD BETWEEN THE CENTERLINE OF THE SIDEWALLS IS TREATED AS
C     UNIFORM LOAD.  LOAD BETWEEN THE CENTERLINE OF A SIDEWALL
C     AND THE OUTSIDE OF THE CULVERT IS TREATED AS AXIAL LOAD ONLY.
C     LOAD OFF OF THE CULVERT IS IGNORED.
C
      IF (NLD .EQ. 10 .AND. LTYPE .EQ. 4.) NLD=21
      DO 324 J=ISTART,IEND
          PTOT=0.
          MTOT=0.
C
      DO 322 I=1,IWHEEL
C
C          CASES FOR LOAD PARTIALLY ON CULVERT
C
C
C          IGNORE WHEELS NOT OF INTEREST
C
           IF(MAG(I) .EQ. 0.) GO TO 322
C
C
C
           JWH=J-10
           AXIAL=0.
C
C
          LEN=0.
          ALEN=DISTA(I,JWH)-AL1(I)/2
          BLEN=DISTA(I,JWH)+AL1(I)/2
C
C         CASE 1  ENTIRE LOAD BETW/ CL.
C
C              WHEEL ON RIGHT SIDE
C
          IWHLFT=0
C
          IF(BLEN .LE. SPRM)THEN
                LEN=AL1(I)
                GO TO 702
          ENDIF
C
C         CASE 2 ENTIRE LOAD OFF CULVERT RIGHT SIDE
C
                IF(ALEN .GE. (SPRM + TS/2)) GO TO 322
C
C         CASE 3  PORTION OF LOAD BETW/ CL, LOAD EXTENDS OFF BOX
```

```
C
            IF(ALEN .LE. SPRM .AND. BLEN .GE. (SPRM + TS/2))THEN
                  LEN=SPRM-ALEN
                  DISTA(I,JWH)=ALEN+LEN/2
                  AXIAL=(TS/2)*WLOAD(I)
                  GO TO 750
            ENDIF
C
C           CASE 4 PORTION OF LOAD BETW/ CL, LOAD ON BOX
C
            IF(ALEN .LE. SPRM .AND. BLEN .LE. (SPRM + TS/2))THEN
                  LEN=SPRM-ALEN
                  DISTA(I,JWH)=ALEN+LEN/2
                  AXIAL=(BLEN-SPRM)*WLOAD(I)
                  GO TO 750
            ENDIF
C
C           CASE 5 NONE OF LOAD BETW/ CL, LOAD EXTENDS OFF BOX
C
            IF(ALEN .GE. SPRM .AND. BLEN .GE. (SPRM + TS/2))THEN
                  AXIAL=((SPRM + TS/2)-ALEN)*WLOAD(I)
                  GO TO 810
            ENDIF
C
C           ELSE CASE 6  LOAD IS JUST ON WALL
C
            AXIAL=AL1(I)*WLOAD(I)
            GO TO 810
C
C
  702       CONTINUE
            IWHLFT=1
C
C           CASE 1A  ENTIRE LOAD BETW/ CL.
C
            IF(ALEN .GE. 0.) GO TO 750
C
C           CASE 2A ENTIRE LOAD OFF CULVERT LEFT SIDE
C
            IF(BLEN .LE. (-TS/2)) GO TO 322
C
C           CASE 3A  PORTION OF LOAD BETW/ CL, LOAD EXTENDS OFF BOX
C
            IF((BLEN .GE. 0.) .AND. (ALEN .LE. (-TS/2.)))THEN
                  LEN=BLEN
                  DISTA(I,JWH)=LEN/2
                  AXIAL=(TS/2.)*WLOAD(I)
                  GO TO 750
            ENDIF
C
C           CASE 4A PORTION OF LOAD BETW/ CL, LOAD ON BOX
C
```

```
          IF((BLEN .GE. 0.) .AND. (ALEN .GE. (-TS/2.)))THEN
                LEN=BLEN
                DISTA(I,JWH)=LEN/2.
                AXIAL=ABS(ALEN)*WLOAD(I)
                GO TO 750
          ENDIF
C
C         CASE 5A NONE OF LOAD BETW/ CL, LOAD EXTENDS OFF BOX
C
          IF((BLEN .LE. 0.) .AND. (ALEN .LE. (-TS/2.)))THEN
                LEN=0.
                AXIAL=(TS/2.+BLEN)*WLOAD(I)
                GO TO 810
          ENDIF
C
C         ELSE CASE 6A  LOAD IS JUST ON WALL
C
          AXIAL=AL1(I)*WLOAD(I)
          GO TO 810
C
C
  750     W1WH(1,JWH,I)=WLOAD(I)
          W2WH(1,JWH,I)=WLOAD(I)
          AWH(1,JWH,I)=DISTA(I,JWH)-(LEN/2.)
          BWH(1,JWH,I)=LEN
          CWH(1,JWH,I)=SPRM-AWH(1,JWH,I)-LEN
C
C
  810     IF(IWHLFT .EQ. 1) GO TO 811
          JLOAD(5,J)=JLOAD(5,J)-AXIAL
          JLOAD(11,J)=JLOAD(11,J)+AXIAL
          GO TO 3438
  811     JLOAD(2,J)=JLOAD(2,J)-AXIAL
          JLOAD(11,J)=JLOAD(11,J)+AXIAL
C
C
C               SUM UP FORCES FOR BEDDING REACTIONS
C
 3438 CONTINUE
          PTOT=PTOT+BWH(1,JWH,I)*W1WH(1,JWH,I)
          MTOT=MTOT+(AWH(1,JWH,I)+BWH(1,JWH,I)/2.-SPRM/2.)
     1    *W1WH(1,JWH,I)*BWH(1,JWH,I)
C
  322 CONTINUE
C
C         DETERMINE ECCENTRICITY OF BEDDING REACTION
C         AND CALCULATE BEDDING REACTION ACCORDINGLY
C
          ECCEN=MTOT/PTOT
          W13=PTOT/SPRM*(1+6*ECCEN/SPRM)
          W23=PTOT/SPRM*(1-6*ECCEN/SPRM)
          A3=0.
```

```
          B3=SPRM
          C3=0.
C
C         IF ECCENTRICITY TO LARGE DISTRIBUTION IS
C         TRIANGLULAR. NO TENSION ALLOWED IN SOIL
C
          IF(ECCEN .GT. SPRM/6.) THEN
                     A3=0.
                B3=3*(SPRM/2.-ECCEN)
                C3=SPRM-B3
                W13=2*PTOT/B3
                W23=0.
          ENDIF
C
C
          IF(ECCEN .LT. -SPRM/6) THEN
                B3=3*(SPRM/2+ECCEN)
                A3=SPRM-B3
                C3=0.
                W13=0.
                W23=2*PTOT/B3
          ENDIF
          W1WH(3,JWH,1)=W13
          W2WH(3,JWH,1)=W23
          AWH(3,JWH,1)=A3
          BWH(3,JWH,1)=B3
          CWH(3,JWH,1)=C3
C
  898     CONTINUE
C
           DO 802 I=1,IWHEEL
           DO 802 M=1,MOMCALL,MOMINC
           IF(M .EQ. 3 .AND. I .GT. 1) GO TO 802
C
               CALL MOMENT (W1WH(M,JWH,I),W2WH(M,JWH,I),AWH(M,JWH,I),
     1         BWH(M,JWH,I),CWH(M,JWH,I),X(1,M),MOM,VA,VB,NIT)

               CALL FXEDMO (MOM,FMAB,FMBA,M)
               CALL FLLD (M,J,VA,VB,FMAB,FMBA)
  802     CONTINUE
C
  324 CONTINUE
   61 IF (TRUCK .EQ. 'AASHTO INTERSTATE') GO TO 98
C
C                APPROACHING VEHICLE LOAD - LOAD CONDITION 8
C                USED FOR LTYPE=2,3,4,5
C                FOR INTERSTATE APPROACHING WHEEL IS HS-20
C
      CONTINUE
      HA=H/12.
      TB3=TB
      SP=PMEMB(2,4)
```

```
      GO TO (1000,851,852,852,854) LTYPE
C
C          APPROACHING WHEEL= OTHER
C          PRESSURE=(WHEEL LOAD*MIN LAT. PRESS. COEFF)/(60+RWID)/H
C          H .GE. 12IN.
C
  851 CONTINUE
      IF(H .LT. 12.) HA=1.0
      WST=VMAG*ZETA/(60.+RWID)/HA
      WSB=VMAG*ZETA/(60.+RWID)/(H+SP+(TT+TB3)/2.)/12.
      PT=WST*TT/2.
      PB=WSB*TB3/2.
      GO TO 855
C
C          APPROACHING WHEEL = HS-SERIES/INTERSTATE
C          PRESSURE=700/H(FT)*(HS-SERIES/HS-20)
C          MAX PRESSURE=800 PSF
C
  852 CONTINUE
      IF (HA .LT. .875) HA=0.875
      WST=0.7/HA/12.*(VMAG/20)
      WSB=0.7/(H+SP+(TT+TB3)/2.)*(VMAG/20.)
      PT=WST*TT/2.
      PB=WSB*TB3/2.
      GO TO 855
C
C          APPROACHING WHEEL = COOPER
C          PRESSURE = 0.4*(VERTICAL LIVELOAD)
C
  854 CONTINUE
      WST=0.4*W1(1,6)/AIMP
      WSB=WST
      PT=WST*TS/2.
      PB=WST*TB3/2.
C
  855 W1(2,8)=WST
      W2(2,8)=WSB
      W1(4,8)=WSB
      W2(4,8)=WST
      B(2,8)=SP
      B(4,8)=SP
      J=8
      DO 856 M=2,4,2
      CALL MOMENT(W1(M,J),W2(M,J),A(M,J),B(M,J),C(M,J),X(1,M),
     1MOM,VA,VB,NIT)
      CALL FXEDMO(MOM,FMAB,FMBA,M)
      CALL FLLD(M,J,VA,VB,FMAB,FMBA)
  856 CONTINUE
      JLOAD(1,8)=JLOAD(1,8)+PT
      JLOAD(4,8)=JLOAD(4,8)-PT
      JLOAD(7,8)=JLOAD(7,8)-PB
      JLOAD(10,8)=JLOAD(10,8)+PB
```

```
      GO TO 1000
C
C                   SURCHARGE - LOAD CONDITIONS 9 AND 10
C
   70 CONTINUE
C
C           LOAD CONDITION 9 - VERTICAL SURCHARGE
C
      SP=PMEMB(1,4)
      WT=SURV/12.
      W1(1,9)=WT
      W2(1,9)=WT
      W1(3,9)=WT
      W2(3,9)=WT
      B(1,9)=SP
      B(3,9)=SP
      AXIAL=WT*TS/2.
      JLOAD(2,9)=JLOAD(2,9)-AXIAL
      JLOAD(5,9)=JLOAD(5,9)-AXIAL
      JLOAD(8,9)=JLOAD(8,9)+AXIAL
      JLOAD(11,9)=JLOAD(11,9)+AXIAL
C
C           LOAD CONDITION 10 - HORIZONTAL SURCHARGE
C
      TB3=TB
      SP=PMEMB(2,4)
      WT=SURHT/12.
      WB=SURHB/12.
      PT=WT*TT/2.
      PB=WB*TB3/2.
      W1(2,10)=WT
      W2(2,10)=WB
      W1(4,10)=WB
      W2(4,10)=WT
      B(2,10)=SP
      B(4,10)=SP
      JLOAD(1,10)=JLOAD(1,10)+PT
      JLOAD(4,10)=JLOAD(4,10)-PT
      JLOAD(7,10)=JLOAD(7,10)-PB
      JLOAD(10,10)=JLOAD(10,10)+PB
      DO 71 J=9,10
      DO 71 M=1,4
      CALL MOMENT(W1(M,J),W2(M,J),A(M,J),B(M,J),C(M,J),X(1,M),
     1MOM,VA,VB,NIT)
      CALL FXEDMO(MOM,FMAB,FMBA,M)
      CALL FLLD(M,J,VA,VB,FMAB,FMBA)
   71 CONTINUE
C
 1000 CONTINUE
 1010 CONTINUE
      DO 1003 J=1,40
      JLOAD(7,J)=JLOAD(9,J)
```

```
      JLOAD(8,J)=JLOAD(10,J)
      JLOAD(9,J)=JLOAD(12,J)
 1003 CONTINUE
      IF (IDBUG .LT. 9) GO TO 3300
      DO 3100 I=1,10
      DO 3100 M=1,4
      WRITE (IW,3200) M,I,W1(M,I),W2(M,I),A(M,I),B(M,I)
 3200   FORMAT (2I5,4F10.3)
 3100   CONTINUE
             IF (NLD .EQ. 10) GO TO 3300
             DO 3400 J=1,NLD-11
             DO 3400 M=1,3,2
             DO 3500 I=1,4
             IF (M .EQ. 3 .AND. I .GT. 1) GO TO 3501
             WRITE (IW,3201) M,J,I,W1WH(M,J,I),W2WH(M,J,I),AWH(M,J,I),
     1       BWH(M,J,I)
 3201   FORMAT (3I5,4F10.3)
 3500 CONTINUE
 3501 CONTINUE
 3400        CONTINUE
 3300        CONTINUE
      RETURN
      END
C
C
```

Subroutine: MOMENT

Function:

This subroutine generates member moments and shears.

I/O Generated By Subroutine:

None

Error Messages Generated:

None

```
      SUBROUTINE MOMENT(W1,W2,A,B,C,X,MOM,VA,VB,N)
C
C    GENERATES MEMBER MOMENTS AND SHEARS
C
C
      REAL*4 MOM(1),X(1)
      COMMON /ISCALE/NIT,NOLD,IDBUG,IR,IW,ITAPE,IPATH,ICYC,NINT
      COMMON/ISCALE/NLD,LTYPE,NSDES,ISUR,NSTRES
      COMMON/PRN/ IPP,IDBG,III
      COMMON/FACT/ FLLMVP,FLLNP
    1 CONTINUE
      IF ( W1.EQ.0. .AND. W2.EQ.0. )  GO TO 101
      QM=W2-W1
      QP=W1+W2
      S=A+B+C
C
C     COMPUTE B-BAR,VA,AND VB
      IF (QP)  9,10,9
   10 BBAR=B/2.
      GO TO 11
    9 BBAR=(W1*B+2.*QM*B/3.)/QP
   11 VA=QP*B*(B+C-BBAR)/2./S
      VB=QP*B*(A+BBAR)/2./S
C
C     GENERATE MOMENTS
      DO 100 I=1,N
      Y=X(I)
      IF (Y.LE.A) GO TO 3
      IF (Y.GE.A+B) GO TO 2
      XP=Y-A
      WX=W1*XP+QM*XP*XP/2./B
      XPBAR=(W1*XP+2.*QM*XP*XP/3./B)/(2.*W1+QM*XP/B)
      MOM(I)=VA*Y-WX*(XP-XPBAR)
      GO TO 100
    2 MOM(I)=VB*(S-Y)
      GO TO 100
    3 MOM(I)=VA*Y
  100 CONTINUE
      GO TO 110
  101 CONTINUE
      DO 102 I=1,N
  102 MOM(I)=0.
      VA=0.
      VB=0.
  110 CONTINUE
      RETURN
      END
C
$DEBUG
C
```

Subroutine: FXEDMO

Function:

This subroutine generates member fixed end moments.

I/O Generated By Subroutine:

None

Error Messages Generated:

None

```
      SUBROUTINE FXEDMO(MOM,FMAB,FMBA,M)
C
C    GENERATES MEMBER FIXED END MOMENTS.
C
      REAL*4 INER,KAA,KAB,KBA,KBB
      REAL*4 J4,J5,J6,MOM(1)
      COMMON /RARRAY/ FIL(680),PMEMB(4,25),X(50,4),INER(4,50),
     1 KAA(8,3,6), W1WH(3,22,4),W2WH(3,22,4),AWH(3,22,4),BWH(3,22,4),
     2 CWH(3,22,4)
      COMMON /ISCALE/ NIT,NOLD(8)
      COMMON/ISCALE/NLD,LTYPE,NSDES,ISUR,NSTRES
      COMMON/PRN/ IPP,IDBG,III
      COMMON/FACT/ FLLMVP,FLLNP
      DIMENSION A(50)
      DO 1 I=1,NIT
      A(I)=MOM(I)*X(I,M)
    1 CONTINUE
      J4=PMEMB(M,10)
      J5=PMEMB(M,11)
      S= PMEMB(M,4)
      J6=PMEMB(M,12)
      C1=S*TRAP(A,NIT,S,M)
      DO 2 I=1,NIT
      A(I)=MOM(I)*(S-X(I,M))
    2 CONTINUE
      C2=S*TRAP(A,NIT,S,M)
      D=-J5*J5+J4*J6
      FMAB=(-J5*C1+J6*C2)/D
      FMBA=(-J4*C1+J5*C2)/D
      RETURN
      END
C
C
```

Subroutine: FLLD

Function:

This subroutine assembles the fixed end moments and shears into a joint load matrix.

I/O Generated By Subroutine:

None

Error Messages Generated:

None

```
      SUBROUTINE FLLD(M,L,VA,VB,FMAB,FMBA)
C
C
C    ASSEMBLES MEMBER FIXED END MOMENTS AND SHEARS INTO JOINT LOAD MATRIX.
C
      REAL*4 INER,KAA,KAB,KBA,KBB
      REAL*4 JLOAD(12,40)
      CHARACTER*4 Z2(8)
      COMMON/ANAL/JLOAD,STIF(12,12),FIXMO(4,40,4),DM(200)
      COMMON /RARRAY/ FIL(680),PMEMB(4,25),X(50,4),INER(4,50),
     1 KAA(8,3,6),W1WH(3,22,4),W2WH(3,22,4),AWH(3,22,4),BWH(3,22,4),
     2 CWH(3,22,4)
      COMMON /ISCALE/NIT,NOLD,IDBUG,IR,IW,ITAPE,IPATH,ICYC,NINT
      COMMON/ISCALE/NLD,LTYPE,NSDES,ISUR,NSTRES
      COMMON/PRN/ IPP,IDBG,III
      COMMON/FACT/ FLLMVP,FLLNP
      DIMENSION ISUB(4,4),SV(4)
      DATA ISUB/2,5,3,6,4,7,6,9,8,11,9,12,10,1,12,3/
      DATA SV/-1.,-1.,1.,1./
      V=(FMAB+FMBA)/PMEMB(M,4)
      IF ( IDBUG.LT.3)  GO TO 1
    1 CONTINUE
      VA=VA+V
      VB=VB-V
      FIXMO(M,L,1)=FMAB+FIXMO(M,L,1)
      FIXMO(M,L,2)=FMBA+FIXMO(M,L,2)
      FIXMO(M,L,3)=VA+FIXMO(M,L,3)
      FIXMO(M,L,4)=VB+FIXMO(M,L,4)
      I1=ISUB(1,M)
      I2=ISUB(2,M)
      I3=ISUB(3,M)
      I4=ISUB(4,M)
      S=SV(M)
      JLOAD(I1,L)=JLOAD(I1,L)+S*VA
      JLOAD(I2,L)=JLOAD(I2,L)+S*VB
      JLOAD(I3,L)=JLOAD(I3,L)-FMAB
      JLOAD(I4,L)=JLOAD(I4,L)-FMBA
      RETURN
      END
C
C
```

Subroutine: MATMP

Function:

Multiplies the inverted stiffness matrix by the load matrix to get displacements for each load condition.

I/O Generated By Subroutine:

None

Error Messages Generated:

None

```
      SUBROUTINE MATMP(A,N,B,M,D,NF)
      COMMON/PRN/ IPP,IDBG,III
      COMMON/FACT/ FLLMVP,FLLNP
      DIMENSION A(144),B(480),D(480)
      REAL*4 A,B,C,D,S
C
C    MULTIPLIES INVERTED STIFFNESS MATRIX BY LOAD MATRIX TO GET DISPLACEMENTS
C    FOR EACH LOAD CONDITION.
C
C     DOUBLE PRECISION A,B,C,D,S
      C=A(1)
      JB=1-NF
      DO 10 J=1,M
      JB=JB+NF
   10 D(JB)=B(JB)/C
      IA=1
      DO 21 I=2,N
      II=I-1
      IA=IA+1+NF
      C=A(IA)
      JB=-NF
      DO 21 J=1,M
      S=0.
      JA=I-NF
      JB=JB+NF
      DO 22 K=1,II
      JA = JA+NF
      KB=K+JB
   22 S=S+A(JA)*D(KB)
      IB=I+JB
   21 D(IB)=(B(IB)-S)/C
      DO 100 I=2,N
      IP=N+1-I
      IP1=IP+1
      IA=(IP-1)*NF+IP
      IB=-NF
      DO 100 J=1,M
      S=0.
      IB=IB+NF
      KA=IA
      DO 102 K=IP1,N
      KA=KA+NF
      KB=K+IB
  102 S=S+A(KA)*D(KB)
      KB=IP+IB
  100 D(KB)=D(KB)-S
      RETURN
      END
C
C
```

Subroutine: ENDFO

Function:

This subroutine calculates member end forces.

I/O Generated By Subroutine:

When output Option 4 is selected, the member end forces are printed for each load condition. The forces printed are in the local coordinate system with the load x-axis along the member and positive from end A to end B. The local y-axis is always positive toward the inside of the box section and the moment follows the right hand rule from x to y for sign.

Error Messages Generated:

None

```
      SUBROUTINE ENDFO
C
C    DETERMINES MEMBER END FORCES PRINTS MEMBER END FORCES TABLE
C    FOR IDBUG EQUAL TO 3
C
      REAL*4 JLOAD(12,40)
      CHARACTER*4 Z2(8)
      REAL INER(4,50),KAA(4,3,3),KAB(4,3,3),KBA(4,3,3),KBB(4,3,3)
      INTEGER ISDATA(35),IBDATA(35)
      INTEGER ICON(40)
C
C
C     REAL SCALAR COMMON
      COMMON/RSCALE/SPAN,RISE,TT,TB,TS,GAMAC,GAMAS,GAMAF,P0,H,HH,HV,Q,
     1 ZETA,BETA,DF,Q1,EC,ES,FY,FCP,FLMV,FLN,Q2,Q3,NLAY,RTYPE,Q4,Q5,
     2 CT(6),SDATA(35)
      COMMON/RSCAL2/QFAC,RES,NTJD,HHT,HHB,HVT,HVB,FLLN,FLLMV
      COMMON/RSCAL2/HRT(4),DSHDL(4),TST
C
C     REAL COMMON ARRAYS
      COMMON/RARRAY/U(12,40),W1(4,10),W2(4,10),A(4,10),B(4,10),C(4,10),
     1 PMEMB(4,25),X(50,4)
      COMMON/RARRAY/INER,KAA,KAB,KBA,KBB,W1WH(3,22,4),W2WH(3,22,4),
     1              AWH(3,22,4),BWH(3,22,4),CWH(3,22,4)
      COMMON /ANAL/ JLOAD,STIF(12,12),FIXMO(4,40,4),DM(200)
C
      COMMON/HARRAY/AMOM(40,40),V(40,40),P(40,40),FXLA(4,40),FYLA(4,40),
     1BMA(4,40),FXLB(4,40),FYLB(4,40),BMB(4,40),ENDM(40,40),ENDV(40,40),
     2 GRM1(40),GRV1(40),GRP1(40),GRV2NG(40),GRM2NG(40),GRV2PL(40)
     3 ,GRM2PL(40),GRP2PL(40),GRP2NG(40),FPMIN(40),FVMIN(40),FMMIN(40),
     4 FPMAX(40),FVMAX(40),FMMAX(40),ZMOMT,ZMOMB,XL(40),WHMXM(40),
     5 WHMNM(40),WHMXV(40),WHMNV(40),WHMXP(40),WHMNP(40)
C
C
C     INTEGER SCALAR COMMON
      COMMON /ISCALE/NIT,NOLD,IDBUG,IR,IW,ITAPE,IPATH,ICYC,NINT
      COMMON/ISCALE/NLD,LTYPE,NSDES,ISUR,NSTRES
C
C     INTEGER COMMON ARRAYS
      COMMON /IARRAY/MEMB(4,2),INDEX(40)
      COMMON/IFLAGS/IBDATA,ISDATA,ICON
      COMMON/PRN/ IPP,IDBG,III
      COMMON/FACT/ FLLMVP,FLLNP
C
C    SCRATCH
      DIMENSION D(3,3),UA(3),UB(3),FB(3),IFAC(32)
      IF ( IDBUG .GE. 3.AND.IPP.EQ.1) WRITE(III,1099)
 1099 FORMAT('1',/,16X,'END FORCES, KIPS/FT AND INCH-KIPS/FT',/,
     1 16X,36(1H-),//,37X,'A-END',/,14X,'LOAD',9X,
     2 'AXIAL',9X,'SHEAR',
     3 10X,'MOMENT',/,14X,'CASE',8X,
```

```
      4 '  FX  ',9X,'  FY ',9X,'   M   ')
        DO 1 M=1,4
        DO 1 N=1,40
        FXLA(M,N)=0.0
        FYLA(M,N)=0.0
        FXLB(M,N)=0.0
        FYLB(M,N)=0.0
         BMA(M,N)=0.0
         BMB(M,N)=0.0
1       CONTINUE
        DO 100 M=1,4
        JTA = MEMB(M,1)
        JTB = MEMB(M,2)
        K = 3*(JTA-1)+1
        L = 3*(JTB-1)+1
        DO 5 N=1,NLD
        GO TO (10,11,12,13),M
10      UA(1) = U(K,N)
        UA(2) = U(K+1,N)
        UA(3) = U(K+2,N)
        UB(1) = U(L,N)
        UB(2) = U(L+1,N)
        UB(3) = U(L+2,N)
        GO TO 14
11      UA(1) =-U(K+1,N)
        UA(2) = U(K,N)
        UA(3) = U(K+2,N)
        UB(1) =-U(L+1,N)
        UB(2) = U(L,N)
        UB(3) = U(L+2,N)
        GO TO 14
12      UA(1) = -U(K,N)
        UA(2) = -U(K+1,N)
        UA(3) =  U(K+2,N)
        UB(1) = -U(L,N)
        UB(2) = -U(L+1,N)
        UB(3) =  U(L+2,N)
        GO TO 14
13      UA(1) =  U(K+1,N)
        UA(2) = -U(K,N)
        UA(3) =  U(K+2,N)
        UB(1) =  U(L+1,N)
        UB(2) = -U(L,N)
        UB(3) =  U(L+2,N)
14      CONTINUE
        DO 2 I=1,3
        DO 2 J=1,3
2       D(I,J) = KBA(M,I,J)
        CALL SOLVE(FB,UA,D)
        DO 3 I=1,3
        DO 3 J=1,3
3       D(I,J) = KBB(M,I,J)
```

```
      CALL SOLVE(UA,UB,D)
      DO 4 I=1,3
4     FB(I) = FB(I)+UA(I)
C
      FXLB(M,N)  = FB(1)
      FYLB(M,N)  = FB(2)
       BMB(M,N)  = FB(3)
C
      FXLA(M,N)  =-FB(1)
      FYLA(M,N)  =-FB(2)
       BMA(M,N)  =-FB(2)*PMEMB(M,4)-FB(3)
5     CONTINUE
100   CONTINUE
C
      DO 200 M=1,4
      IF(M .NE. 1 .AND. IDBUG .GE. 3) THEN
      IF(IPP.EQ.1) THEN
      WRITE(III,1101)
      ENDIF
      ENDIF
      DO 250 N=1,NLD
      FYLA(M,N)  = FYLA(M,N)+FIXMO(M,N,3)
       BMA(M,N)  =  BMA(M,N)+FIXMO(M,N,1)
C
C  DEBUG OUTPUT
C
      IF( IDBUG .LT. 3 ) GO TO 1102
      IF(IPP.EQ.1) WRITE(III,1100) M,N,FXLA(M,N),FYLA(M,N),BMA(M,N)
 1100 FORMAT(' MEMBER',2I5,3F15.5)
 1101 FORMAT(/,65(1H-),/)
 1102 CONTINUE
  250 CONTINUE
  200 CONTINUE
C
C  DEBUG OUTPUT
C
      IF (IDBUG .GE. 3.AND.IPP.EQ.1) WRITE(III,1103)
 1103 FORMAT('1',////,36X,' B-END',/,14X,'LOAD',9X,'AXIAL',9X,'SHEAR'
     1 ,10X,'MOMENT',/,14X,'CASE',10X,'FX',13X,'FY',10X,'     M    ')
      DO 260 M=1,4
      IF(M .NE. 1 .AND. IDBUG .GE. 3.AND.IPP.EQ.1) WRITE(III,1101)
      DO 270 N=1,NLD
      FYLB(M,N)=FYLB(M,N)+FIXMO(M,N,4)
       BMB(M,N)= BMB(M,N)+FIXMO(M,N,2)
      IF(IDBUG .LT. 3) GO TO 1104
      IF(IPP.EQ.1) WRITE(III,1105) M,N,FXLB(M,N),FYLB(M,N),BMB(M,N)
 1105 FORMAT(' MEMBER',2I5,3F15.5)
 1106 FORMAT('1',///)
 1104 CONTINUE
  270 CONTINUE
  260 CONTINUE
```

```
      DO 50 I=1,32
      IFAC(I)=1
   50 CONTINUE
C
C     IF IFAC=1  FORCE IS INCLUDED IN ADDITION
C
C
      VRWH=0.
      VRDED=0.
      HRWHR=0.
      HRWHL=0.
      HRDEDR=0.
      HRDEDL=0.
C
C     POSITIVE DEADLOAD SHEARS
C
      IF(IBDATA(14) .NE. 1) IFAC(3)=0
      IF(ISUR .EQ. 3) THEN
          IFAC(9)=0
          IFAC(10)=0
      ENDIF
C
      IF(ISUR .EQ. 2) IFAC(10)=0
C
      DO 60 I=5,8
      IFAC(I)=0
   60 CONTINUE
C
C
      DO 70 I=1,10
      HRDEDR=HRDEDR+FYLA(4,I)*IFAC(I)
   70 CONTINUE
C
C     NEGATIVE DEADLOAD SHEARS
C
      HRDEDL=FYLA(4,5)+FYLA(4,3)+FYLA(4,10)+FYLA(4,1)+FYLA(4,2)
C
C
C     DEADLOAD THRUSTS
C
      DO 80 I=1,5
      VRDED=VRDED+FXLB(4,I)
   80 CONTINUE
      IF(ISUR .NE. 3) VRDED=VRDED+FXLB(2,9)
C
C
C     LIVELOADS
C
      IF(ISUR .NE. 3) THEN
         IFAC(9)=0
         IFAC(10)=0
      ELSE
```

```
        IFAC(9)=1
        IFAC(10)=1
      ENDIF
C
C
C     POSITIVE SHEARS
C
      HRWHR=FYLA(4,6)+FYLA(4,7)+FYLA(4,9)*IFAC(9)
      BIG=0.
      DO 101 I=11,32
      IF(FYLA(4,I) .LT. BIG) BIG=FYLA(4,I)
  101 CONTINUE
      HRWHR=HRWHR+BIG
C
C     NEGATIVE SHEARS
C
      HRWHL=FYLA(4,8)+FYLA(4,10)*IFAC(10)
C
C     THRUSTS
C
      VRWH=FXLB(2,6)+FXLB(2,7)+FXLB(2,9)*IFAC(9)
      BIG=0.
      DO 110 I=11,32
      IF(FXLB(4,I) .LT. BIG) BIG=FXLB(4,I)
  110 CONTINUE
      VRWH=VRWH+BIG
C
C
      RETURN
      END
C
C
```

Subroutine: SOLVE

Function:

Multiplies a 3 x 3 member stiffness matrix by a 3 x 1 load matrix to get member end forces.

I/O Generated By Subroutine:

None

Error Messages Generated:

None

```
      SUBROUTINE SOLVE(DU,DF,AK)
C
C   MULTIPLIES 3X3 MATRIX BY 3X1 MATRIX.
C
      COMMON/PRN/ IPP,IDBG,III
      COMMON/FACT/ FLLMVP,FLLNP
      DIMENSION DU(3),DF(3),AK(3,3)
      DO 1 I=1,3
      DU(I)=0.
      DO 1 K=1,3
    1 DU(I)=DU(I)+AK(I,K)*DF(K)
      RETURN
      END

$DEBUG
C
C
```

Subroutine: SIMSPN

Function:

This subroutine takes the member end forces and applied member loads and calculates the service load forces at each design location.

I/O Generated By Subroutine:

When output Option 4 is selected, service load moments, thrusts, and shears are printed for each load case at each of the design locations.

Error Messages Generated:

None

```
      SUBROUTINE SIMSPN
C
C   GIVEN THE MEMBER END FORCES AND THE LOADING VALUES
C   THE SERVICE LOAD FORCES ARE CALCULATED AT THE CRITICAL DESIGN SECTIONS
C
C
      REAL*4 INER,KAA,KAB,KBA,KBB
      CHARACTER*4 Z2(8)
      CHARACTER*10 MEMBDS(40)
      COMMON/RSCALE/SPAN,RISE,TT,TB,TS,GAMAC,GAMAS,GAMAF,P0,H,HH,HV,
     1                                                           POV,
     1 ZETA,BETA,DF,Q1,EC,ES,FY,FCP,FLMV,FLN,Q2,Q3,NLAY,RTYPE,Q4,Q5,
     2 CT(6),SDATA(35)
      COMMON/RSCAL2/QFAC,RES,NTJD,HHT,HHB,HVT,HVB,FLLN,FLLMV
      COMMON/RSCAL2/HRT(4),DSHDL(4),TST
      COMMON/RSCAL3/SWDTH,VMAG,RLEN,RWID,SURV,SURHT,SURHB,AS5D,
     1              AS6D,AS5SP,AS6SP,CHHT,CHVT,CHHB,CHVB
      COMMON/RSCAL5/ASBMAX,Z2,DSTEST(40),MEMBDS
C
      COMMON/RARRAY/U(12,40),W1(4,10),W2(4,10),A(4,10),B(4,10),C(4,10),
     1 PMEMB(4,25),XX(50,4),INER(4,50),KAA(8,3,6),W1WH(3,22,4),
     2 W2WH(3,22,4),AWH(3,22,4),BWH(3,22,4),CWH(3,22,4)
C
      COMMON/IARRAY/MEMB(4,2)  ,INDEX(40)
C
      COMMON/HARRAY/AMOM(40,40),V(40,40),P(40,40),FXLA(4,40),FYLA(4,40),
     1BMA(4,40),FXLB(4,40),FYLB(4,40),BMB(4,40),ENDM(40,40),ENDV(40,40),
     2 GRM1(40),GRV1(40),GRP1(40),GRV2NG(40),GRM2NG(40),GRV2PL(40)
     3 ,GRM2PL(40),GRP2PL(40),GRP2NG(40),FPMIN(40),FVMIN(40),FMMIN(40),
     4 FPMAX(40),FVMAX(40),FMMAX(40),ZMOMT,ZMOMB,XL(40),WHMXM(40),
     5 WHMNM(40),WHMXV(40),WHMNV(40),WHMXP(40),WHMNP(40)
C
      COMMON/IFLAGS/IBDATA(35),ISDATA(35),ICON(40)
C
      COMMON/ISCALE/NIT,NOLD,IDBUG,IR,IW,ITAPE,IPATH,ICYC,NINT
      COMMON/ISCALE/NLD,LTYPE,NSDES,ISUR,NSTRES
      COMMON/PRN/ IPP,IDBG,III
      COMMON/FACT/ FLLMVP,FLLNP
      REAL LFCTR
C
      DIMENSION TM(40),TV(40)
      DIMENSION IINDEX(40)
C     6 DENOTES ADDITIONAL DESIGN LOCATION
C
      DATA IINDEX/1,1,1,4,4,4,4,4,3,3,3,1,1,4,4,4,4,3,3,1,4,4,3,
     1 6,6,6,6,6,6,6,6,6,6,6,6,6,6,6,6,6/
C
C
      ENDMO(BMOM,CMOM,X,SP)=-BMOM*(1.-X/SP)+CMOM*X/SP
      ENDSHR(BMOM,CMOM,X,SP)=(BMOM+CMOM)/SP
C
C                  INITIALIZE DATA
```

```
C
      DO 12 J=1,40
            INDEX(J)=IINDEX(J)
            DSTEST(J)=0
   12 CONTINUE
C
C
C
C
C
C
C     CALCULATE DESIGN LOCATIONS
C
C     FLEXURE DESIGN LOCATIONS
C
      TB3=TB
      XL(1)=(SPAN+TS)/2.
      XL(2)=TS/2.+HHT
      XL(3)=TS/2.+CHHT
      XL(4)=RISE+TB/2.-CHVT
      XL(5)=XL(4)-HVT+CHVT
      XL(7)=TB3/2.+HVB
C
C     COMPUTE LOCATION 6 - MAX POSITIVE SIDE MOMENT
C
C     SET LOAD FACTOR FOR SURCHARGE ACCORDING TO
C     HOW USER REQUESTED TO MODEL SURCHARGE
C
C
      SURI2=0.
      IF(ISUR .EQ. 1) SURI2=1.
      SURI=FLMV
      IF(ISUR .EQ. 3) SURI=FLLMV
C
C
      VMEM4A=(FYLA(4,1)+FYLA(4,2)+FYLA(4,3)+FYLA(4,5))*
     1        FLMV+FYLA(4,8)*FLLMV+FYLA(4,10)*SURI+
     2        FYLA(4,9)*SURI2*FLMV
      W1M4T=(W1(4,3)+W1(4,5))*FLMV+W1(4,8)*FLLMV+W1(4,10)*SURI+
     1       W1(4,9)*SURI2*FLMV
      W2M4T=(W2(4,3)+W2(4,5))*FLMV+W2(4,8)*FLLMV+W2(4,10)*SURI+
     1       W2(4,9)*SURI2*FLMV
      RIRM=RISE+(TT+TB)/2.
C
C     NO POS MOMENT OR POS MOMENT AT END OF MEMBER
C
      IF(VMEM4A .LT. 0.) THEN
             XL(6)=XL(7)
             GO TO 602
      ENDIF
C
C     NO POINT OF ZERO SHEAR
```

```
C
      TSH=(W1M4T+W2M4T)*RIRM/2.-VMEM4A
      IF(TSH .LT. 0.) THEN
            XL(6)=XL(5)
            GO TO 602
      ENDIF
C
C
      WRATE=(W1M4T-W2M4T)/RIRM
      XL(6)=VMEM4A/W1M4T
      IF (W1M4T .EQ. W2M4T) GO TO 602
      XL(6)=(W1M4T+(W1M4T**2.-2.*WRATE*VMEM4A)**0.5)/WRATE
      IF(XL(6) .LT. 0 .OR. XL(6) .GT. XL(7)) XL(6)=
     1 (W1M4T-(W1M4T**2.-2.*WRATE*VMEM4A)**0.5)/WRATE
      IF(XL(6) .LT. XL(7)) XL(6)=XL(7)
  602 XL(8)=TB3/2.+CHVB
      XL(9)=SPAN+TS/2.-CHHB
      XL(10)=XL(9)-HHB+CHHB
      XL(11)=XL(1)
C
C     SHEAR DESIGN LOCATIONS - METHOD 1
C
      DO 603 M=1,4
  603 HRT(M)=(PMEMB(M,1)-PMEMB(M,3))/PMEMB(M,5)
      D=AMIN1(SDATA(30),SDATA(33))
      D=D*POV
      XL(12)=XL(2)+D
      DSHDL(1)=POV*(PMEMB(1,1)-HRT(1)*(TS/2.+CHHT)-CT(1)-0.5*SDATA(1))
      XL(13)=XL(3)+DSHDL(1)
      IF(HRT(1) .GE. 1.) XL(13)=XL(12)
      D=AMIN1(SDATA(31),SDATA(35))
      D=D*POV
      DSHDL(2)=POV*(PMEMB(2,1)-HRT(2)*(TT/2.+CHVT)-CT(2)-0.5*SDATA(2))
      XL(14)=XL(4)-DSHDL(2)
      XL(15)=XL(5)-D
      IF(HRT(2) .GE. 1.) XL(14)=XL(15)
      XL(16)=XL(7)+D
      DSHDL(4)=POV*(PMEMB(4,1)-HRT(4)*(TB/2.+CHVB)-CT(2)-0.5*SDATA(2))
      XL(17)=XL(8)+DSHDL(4)
      IF(HRT(4) .GE. 1.) XL(17)=XL(16)
      D=AMIN1(SDATA(32),SDATA(34))
      D=D*POV
      DSHDL(3)=POV*(PMEMB(3,1)-HRT(3)*(TS/2.+CHHB)-CT(3)-0.5*SDATA(3))
      XL(18)=XL(9)-DSHDL(3)
      XL(19)=XL(10)-D
      IF(HRT(3) .GE. 1) XL(18)=XL(19)
C
C     ADDITIONAL SHEAR DESIGN LOCATIONS - METHOD 2
C
      XL(20)=0.
      XL(21)=0.
      XL(22)=0.
```

```
      XL(23)=0.
C
C
C
      DSTEST(24)=1
      XL(24)=TS/2.+CHHT
             IF (NSTRES .LT. 2) THEN
                     XSP=XL(1)-XL(24)
                     GO TO 15
      ENDIF
          XSP=(XL(1)-XL(24))/(NSTRES-1)
          N=25
      DO 14 I=1,NSTRES-1
      DSTEST(N)=1.
      Z=I*XSP+XL(24)
      IF (Z .GT. XL(2) .AND. XL(2) .GE. XL(N-1)) GO TO 13
      XL(N)=Z
      N=N+1
      GO TO 14
   13 XL(N)=XL(2)
      N=N+1
      DSTEST(N)=1.
      XL(N)=Z
      N=N+1
   14 CONTINUE
   15 CONTINUE
C
C     SIDE WALL DESIGN LOCATIONS
      ISTART=25
      IF(NSDES .EQ. 0) GO TO 16
      ZDIV=(XL(4)-XL(8))/NSDES
      ISTART=25+NSTRES
      IPS=ISTART-1
      DO 27 I=1,NSDES
      Z=I*ZDIV
      XL(IPS+I)=XL(4)-Z
      DSTEST(IPS+I)=4
   27 CONTINUE
C
C
   16 DO 11 I=1,40
      TV(I)=0.0
      TM(I)=0.0
      DO 11 J=1,40
        ENDM(J,I)=0.0
        ENDV(J,I)=0.0
        AMOM(J,I)=0.0
        V(J,I)=0.0
   11 CONTINUE
C
      NDLOC=24+NSTRES+NSDES
      IF(NDLOC .EQ. 24) NDLOC=23
```

```
      DO 107 LDCN=1,NLD
      DO 109 IX=1,NDLOC
      IF(NDLOC .GE. 20 .AND. NDLOC .LE. 23) GO TO 109
      M=INDEX(IX)
      IF (IX .GE. 24 .AND. IX .LE. IPS) M=1
      IF (IX .GE. ISTART) M=4
      ENDM(IX,LDCN) = ENDMO(BMA(M,LDCN),BMB(M,LDCN),XL(IX),
     1                PMEMB(M,4))
      ENDV(IX,LDCN) = ENDSHR(BMA(M,LDCN),BMB(M,LDCN),XL(IX),
     1                PMEMB(M,4))
      GO TO (112,109,312,412),M
  112 IF (LDCN .GE. 3 .AND. LDCN .LE. 5) GO TO 109
      IF (LDCN .EQ. 8 .OR. LDCN .EQ. 10) GO TO 109
      IF (LDCN .LE. 10) GO TO 341
      GO TO 349
  312 IF (LDCN .EQ. 3 .OR. LDCN .EQ. 5) GO TO 109
      IF (LDCN .EQ. 8 .OR. LDCN .EQ. 10) GO TO 109
      IF (LDCN .LE. 10) GO TO 341
      GO TO 349
  412 IF (LDCN .LT. 3 .OR. LDCN .GT. 10) GO TO 109
      IF (LDCN .EQ. 6 .OR. LDCN .EQ. 7) GO TO 109
      IF (LDCN .EQ. 9) GO TO 109
  341 CALL MOMENT(W1(M,LDCN),W2(M,LDCN),A(M,LDCN),B(M,LDCN),C(M,LDCN),
     1            XL(IX),AMOM(IX,LDCN),RL,RR,1)
      IF (XL(IX) .LE. A(M,LDCN)) V(IX,LDCN)=RL
      IF (XL(IX) .GT. A(M,LDCN) .AND. XL(IX) .LT. A(M,LDCN)+
     1 B(M,LDCN)) V(IX,LDCN)=RL-W1(M,LDCN)*(XL(IX)-A(M,LDCN))-
     2 (W2(M,LDCN)-W1(M,LDCN))*(XL(IX)-A(M,LDCN))**2./2./B(M,LDCN)
      IF (XL(IX) .GE. A(M,LDCN)+B(M,LDCN)) V(IX,LDCN)= -RR
      GO TO 109
  349 IWHEEL=3
      IF (LDCN .GE. 22) IWHEEL=4
      ILN=LDCN-10
      DO 363 II=1,IWHEEL
C
      IF(M .EQ. 3 .AND. II .GT. 1) GO TO 363
      CALL MOMENT(W1WH(M,ILN,II),W2WH(M,ILN,II),AWH(M,ILN,II),
     1 BWH(M,ILN,II),CWH(M,ILN,II),XL(IX),ATEMM,RL,RR,1)
      IF (XL(IX) .LE. AWH(M,ILN,II)) VTEM=RL
      IF (XL(IX) .GT. AWH(M,ILN,II) .AND. XL(IX) .LT. AWH(M,ILN,II)
     1 +BWH(M,ILN,II))
     1 VTEM=RL-W1WH(M,ILN,II)*(XL(IX)-AWH(M,ILN,II))-(W2WH(M,ILN,II)-
     2 W1WH(M,ILN,II))*(XL(IX)-AWH(M,ILN,II))**2./2./BWH(M,ILN,II)
      IF (XL(IX) .GE. AWH(M,ILN,II)+BWH(M,ILN,II)) VTEM= -RR
      AMOM(IX,LDCN)=AMOM(IX,LDCN)+ATEMM
      V(IX,LDCN)=V(IX,LDCN)+VTEM
  363 CONTINUE
  109 CONTINUE
  107 CONTINUE
C
C
C
```

```
      NCN=NSTRES+NSDES
      IF(NCN .EQ. 24) NCN=23
C
C
C             STORE AXIAL FORCES
C
      DO 210 I=1,NLD
      DO 210 J=1,NDLOC
            M=INDEX(J)
            IF(J .GE. 24) M=1
            IF(J .GE. ISTART) M=4
            P(J,I)=FXLB(M,I)
            V(J,I)=V(J,I)+ENDV(J,I)
            AMOM(J,I)=AMOM(J,I)+ENDM(J,I)
 210  CONTINUE
C
C             FIND XD IN TOP AND BOTTOM SLABS AND
C             CALCULATE M,V AT XD AWAY FROM CENTERSPAN
C
      DMT=0.0
      DMB=0.0
      WT=0.0
      WB=0.0
      NSTP=9
      IF(ISUR .EQ. 1) NSTP=10
      DO 300 I=1,NSTP
C
C
C           USE APPROPRIATE LOAD FACTORS AND ADD LOADS ONLY IF
C           PERMANENT IS REQUESTED
C
              LFCTR=FLMV
              IF(IBDATA(14) .EQ. 2 .AND. I .EQ. 3) GO TO 300
              IF(I .GT. 5) LFCTR=FLLMV
              IF(I .GT. 8 .AND. ISUR .LT. 3) LFCTR=FLMV
              IF(I .EQ. 5 .OR. I .EQ. 8) GO TO 300
              WT=WT+W1(1,I)*LFCTR
              WB=WB+W1(3,I)*LFCTR
              DMB=DMB+AMOM(11,I)*LFCTR
              DMT=DMT+AMOM(1,I)*LFCTR
 300  CONTINUE
C
C     ELIMINATE METHOD 2 FOR UNIFORM LOAD
C     OVER ENTIRE CULVERT CASES
C
      IF(NLD .GT. 10) GO TO 340
C
C
      IF(DMB .LE. 0.) GO TO 301
C
C
      XL(23)=3.0*(SQRT((SDATA(34)*POV)**2+2.*DMB/9./WB)-SDATA(34)*POV)
```

```
      XL(23)=(SPAN+TS)/2.+XL(23)
 301  CONTINUE
      IF(DMT .LE. 0.) GO TO 322
C
      XL(20)=3.0*(SQRT((SDATA(33)*POV)**2+2.*DMT/9./WT)-SDATA(33)*POV)
      XL(20)=(SPAN+TS)/2.-XL(20)

C
C        TOP
C
      IF ( XL(20) .LE. 0.) GO TO 320
      M=1
      J=20
  322 CONTINUE
      DO 327 LDCN=1,NLD
          CALL MOMENT(W1(M,LDCN),W2(M,LDCN),A(M,LDCN),B(M,LDCN),
     1    C(M,LDCN),XL(J ),AMOM(J ,LDCN),RL,RR,1)
C
          IF (XL(J ) .LE. A(M,LDCN)) V(J ,LDCN)=RL
          IF (XL(J ) .GT. A(M,LDCN) .AND. XL(J ) .LT. A(M,LDCN)+
     1                                                 B(M,LDCN))
     2    V(J ,LDCN)=RL-W1(M,LDCN)*(XL(J )-A(M,LDCN))-(W2(M,LDCN)
     3               -W1(M,LDCN))*(XL(J )-A(M,LDCN))**2/2./B(M,LDCN)
          IF (XL(J ) .GE. A(M,LDCN)+B(M,LDCN)) V(J ,LDCN)=-RR
C
        AMOM(J,LDCN)=AMOM(J,LDCN)+ENDMO(BMA(M,LDCN),BMB(M,LDCN),XL(J),
     1                                                 PMEMB(M,4))
        V(J,LDCN)=V(J,LDCN)+ENDSHR(BMA(M,LDCN),BMB(M,LDCN),XL(J),
     1                                                 PMEMB(M,4))
 327  CONTINUE
      IF ( M .NE. 1 ) GO TO 340
C
C        BOTTOM SLAB
C
 320  IF ( XL(23) .GE. SPAN+TS/2.) GO TO 340
      M=3
      J=23
      GO TO 322
 340  CONTINUE
C
C
C           FIND WHERE M/VD=3.0 IN THE SIDE WALL
C           NOT NECESSARY FOR NON-UNIFORM LOAD ON ENTIRE CULVERT CASES
C
      IF(NLD .GT. 10) GO TO 505
C
C
      D = SDATA(35)*POV
      IF (TST .NE. 0.) SLP=(TS-TST)/(RISE-HVT+TB/2.)
      IF(XL(6) .EQ. 0.) GO TO 505
      L=21
      SGN =1.
```

```
      IF (XL(6) .EQ. XL(4)) THEN
         L=22
         SGN=-1.
         END IF
   70 TEMP = 1.E15
      X=XL(6)
      IF (X .EQ. XL(4)) X=XL(14)
   71 X=X+SGN*RIRM/1000
      TM1=0.
      TV1=0.
      IF(X .LT. XL(17) .OR. X .GT. XL(14)) GO TO 477
      DO 74 K=1,10
      LFCTR=FLMV
      GO TO (73,73,73,74,73,74,74,72,72,72) K
   72 LFCTR=FLLMV
      IF(K .GE. 9 .AND. ISUR .LT. 3) LFCTR=FLMV
      IF(K .EQ. 9 .AND. ISUR .NE. 1) GO TO 74
   73   CALL MOMENT(W1(4,K),W2(4,K),A(4,K),B(4,K),C(4,K),X,TM(K),RL,RR
     1                                                                ,1)
        IF (X .LE. A(4,K)) TV(K)=RL
        IF (X .GT.A(4,K) .AND. X .LT. A(4,K)+B(4,K))
     1     TV(K)=RL-W1(4,K)*(X-A(4,K))-(W2(4,K)-W1(4,K))*(X-A(4,K))**2
     2           /2./B(4,K)
        IF (X .GT. A(4,K)+B(4,K) ) TV(K)=-RR
        TV(K)=TV(K)+ENDSHR(BMA(4,K),BMB(4,K),X,PMEMB(4,4))
        TM(K)=TM(K)+ ENDMO(BMA(4,K),BMB(4,K),X,PMEMB(4,4))
C
C        SUM UP FORCES
C
      TM1=TM1+TM(K)*LFCTR
      TV1=TV1+TV(K)*LFCTR
   74 CONTINUE
      IF (TST .EQ. 0.) GO TO 767
      D=(TST-CT(6)-SDATA(6)*0.5+X*SLP)*POV
  767 TEMP1=3.0-ABS(TM1/TV1/D)
      IF(ABS(TEMP1) .GT. 1.E14) GO TO 71
      IF(ABS(TEMP1) .GT. ABS(TEMP)) GO TO 77
      TEMP=TEMP1
      GO TO 71
C
C
   77 CONTINUE
      FVMAX(L)=TV1
      DO 475 J=1,10
            V(L,J)=TV(J)
            AMOM(L,J)=TM(J)
  475 CONTINUE
  477 XL(L)=X
  476 IF(L .EQ. 22) GO TO 505
      L=22
      SGN=-1.
      GO TO 70
```

```
  505 CONTINUE
C
C
      IF ( IDBUG .LT. 3 )  GO TO 506
      IF(IPP.EQ.1) WRITE(III,99)
   99 FORMAT('1',//)
      IF(IPP.EQ.1) WRITE(III,510)
 510  FORMAT (/,12X,'SERVICE FORCES FOR EACH LOAD ',
     1'CONDITION',//,5X,70(1H-),//,2X,'DES.',2X,'DIST. FROM',13X,
     1 'LOAD CONDITION, MOMENT(IN-KIP/FT)',
     2 /,1X,'SECT.',2X,'A-END(IN.)',1X,45(1H-))
      DO 507 I=1,23
      IF(IPP.EQ.1) WRITE(III,912) I,XL(I)
      IF(IPP.EQ.1) WRITE(III,513) (J,AMOM(I,J),J=1,NLD)
 507  CONTINUE
      IF(IPP.EQ.1) WRITE(III,99)
      IF(IPP.EQ.1) WRITE(III,511)
 511  FORMAT(///,2X,'DES.',2X,'DIST. FROM',13X,'LOAD CONDITION, '
     1'SHEAR(KIPS/FT)',/,
     2 1X,'SECT.',2X,'A-END(IN.)',1X,50(1H-),//)
      DO 512 I=12,23
      IF(IPP.EQ.1) WRITE(III,912) I,XL(I)
      IF(IPP.EQ.1) WRITE(III,513) (L,V(I,L),L=1,NLD)
 912  FORMAT (1X,I3,2X,F7.2,/)
 513  FORMAT(8(13X,5(2X,I2,1X,F8.2),/))
 512  CONTINUE
      IF(IPP.EQ.1) WRITE(III,99)
      IF(IPP.EQ.1) WRITE(III,611)
 611  FORMAT(///,6X,'LOCATION',22X,'LOAD CONDITION, '
     1'THRUST(KIPS/FT)',/,1X,75(1H-),//)
      DO 612 I=1,11,5
             TLOC='TOP'
             IF (INDEX(I) .EQ. 4) TLOC='SIDE'
             IF (INDEX(I) .EQ. 3) TLOC='BOTT'
      IF(IPP.EQ.1) WRITE(III,913) TLOC
      IF(IPP.EQ.1) WRITE(III,513) (L,P(I,L),L=1,NLD)
 913  FORMAT (1X,A4,/)
 612  CONTINUE
 506  CONTINUE
      RETURN
      END
C
C
C
C
C
```

Subroutine: FMXMN

Function:

This subroutine determines the minimum and maximum design forces and resulting ultimate forces at each of the critical design locations.

I/O Generated By Subroutine:

When output Option 2 is selected, a table of minimum and maximum ultimate design forces are printed for each of the design locations. In addition, when output Option 3 is selected, maximum and minimum service load moments, thrusts and shears at each of the design locations will be printed. Forces due to permanent dead loads, additional dead loads, and live loads are listed separately.

Error Messages Generated:

None

```
      SUBROUTINE FMXMN
C
C    DETERMINES THE MINIMUM AND MAXIMUM DESIGN FORCES AND RESULTING
C    ULTIMATE FORCES AT THE CRITICAL DESIGN LOCATIONS.
C
      REAL*4 JLOAD(12,40)
      REAL*4 INER(4,50),KAA(4,3,3),KAB(4,3,3),KBA(4,3,3),KBB(4,3,3)
      CHARACTER*4 Z2(8)
C
      COMMON/RSCALE/SPAN,RISE,TT,TB,TS,GAMAC,GAMAS,GAMAF,P0,H,HH,HV,Q,
     1 ZETA,BETA,DF,Q1,EC,ES,FY,FCP,FLMV,FLN,Q2,Q3,NLAY,RTYPE,Q4,Q5,
     2 CT(6),SDATA(35)
      COMMON/RSCAL2/QFAC,RES,NTJD,HHT,HHB,HVT,HVB,FLLN,FLLMV
      COMMON/RSCAL2/HRT(4),DSHDL(4),TST
      COMMON/RSCAL3/SWDTH,VMAG,RLEN,RWID,SURV,SURHT,SURHB,AS5D,
     1              AS6D,AS5SP,AS6SP,CHHT,CHVT,CHHB,CHVB
      COMMON/RARRAY/U(12,40),W1(4,10),W2(4,10),A(4,10),B(4,10),C(4,10),
     1 PMEMB(4,25),X(50,4)
      COMMON/RARRAY/INER,KAA,KAB,KBA,KBB,W1WH(3,22,4),W2WH(3,22,4),
     1              AWH(3,22,4),BWH(3,22,4),CWH(3,22,4)
C
      COMMON/ANAL/JLOAD,STIF(12,12),FIXMO(4,40,4),DM(40),DV(40),DP(40),
     1 AS(40),SRATIO(40)
C
      COMMON/ISCALE/NIT,NOLD,IDBUG,IR,IW,ITAPE,IPATH,ICYC,NINT
      COMMON/ISCALE/NLD,LTYPE,NSDES,ISUR,NSTRES
C
      COMMON/IARRAY/MEMB(4,2),INDEX(40)
C
      COMMON/HARRAY/AMOM(40,40),V(40,40),P(40,40),FXLA(4,40),FYLA(4,40),
     1BMA(4,40),FXLB(4,40),FYLB(4,40),BMB(4,40),ENDM(40,40),ENDV(40,40),
     2 GRM1(40),GRV1(40),GRP1(40),GRV2NG(40),GRM2NG(40),GRV2PL(40)
     3 ,GRM2PL(40),GRP2PL(40),GRP2NG(40),FPMIN(40),FVMIN(40),FMMIN(40),
     4 FPMAX(40),FVMAX(40),FMMAX(40),ZMOMT,ZMOMB,XL(40),WHMXM(40),
     5 WHMNM(40),WHMXV(40),WHMNV(40),WHMXP(40),WHMNP(40)
C
C
      COMMON/IFLAGS/IBDATA(35),ISDATA(35),ICON(40)
      COMMON/PRN/ IPP,IDBG,III
      COMMON/FACT/ FLLMVP,FLLNP
C
      CHARACTER*4 SIDE(40)
C
C
C
C     BUILD SIDE() ARRAY FOR DESIGN SECTION MEMBER LOCATION
C
      DO 86 J=1,40
            SIDE(J)='ADDN'
            IF(INDEX(J) .EQ. 1) SIDE(J)='TOP'
            IF(INDEX(J) .EQ. 4) SIDE(J)='SIDE'
```

```
          IF(INDEX(J) .EQ. 3) SIDE(J)='BOTT'
   86 CONTINUE
C
C
      I4=3
      COEF3=0.0
C
C
C     COEF3 IS FOR MIN LATERAL SOIL, WHICH CAN BE
C     MODELED AS ADDITIONAL LOADING. COEF3 OF ZERO
C     WILL EXCLUDE THE LOAD FROM GROUP IF REQUESTED
C     AS ADDITIONAL BY USER
C
C
      DO 100 L=1,40
        GRM1(L)=0.0
        GRV1(L)=0.0
        GRM2PL(L)=0.0
        GRV2PL(L)=0.0
        GRM2NG(L)=0.0
        GRV2NG(L)=0.0
        WHMXM(L)=0.
        WHMNM(L)=0.
        WHMXV(L)=0.
        WHMNV(L)=0.
        GRP1(L)=0.0
        GRP2PL(L)=0.0
        GRP2NG(L)=0.0
        WHMXP(L)=0.
        WHMNP(L)=0.
  100   CONTINUE
      IF (IBDATA(14) .EQ. 2) GO TO 102
        COEF3=1.0
      I4=4
 102  CONTINUE
      NCN=24+NSTRES+NSDES
      IF(NCN .EQ. 24) NCN=23
C
C     SURI1 DETERMINES IF LOAD WILL GO INTO GROUP1
C     SURI2 DETERMINES IF LOAD WILL GO INTO GROUP2
C     ACCORDING TO HOW USER REQUESTS LOAD BE MODELED
C     TESTP CAN BE SHEAR OR MOMENT
C
C
      GO TO (81,82,83) ISUR
   81 SURI1=1.0
      SURI2=0.0
      GO TO 84
   82 SURI1=0.0
      SURI2=1.0
      GO TO 84
   83 SURI1=0.0
```

```
      SURI2=0.0
   84 CONTINUE
C
C
      DO 1 I = 1, NCN
            GRM1(I)=AMOM(I,1)+AMOM(I,2)+AMOM(I,3)*COEF3
     1      +(AMOM(I,9)+AMOM(I,10))*SURI1
            GRV1(I)=V(I,1)+V(I,2)+V(I,3)*COEF3+(V(I,9)+V(I,10))*SURI1
            GRP1(I)=P(I,1)+P(I,2)+P(I,3)*COEF3+(P(I,9)+P(I,10))*SURI1
      DO 118 K=I4,5
            KSUR=K+5
            IF(KSUR .EQ. 8) KSUR=40
            TESTP=AMOM(I,K)
            TESTP2=AMOM(I,KSUR)
            IF(I .GE. 12 .AND. I .LE. 23) THEN
                        TESTP=-V(I,K)
                  TESTP2=-V(I,KSUR)
            ENDIF
            IF((I .GE. 16 .AND. I .LE. 19) .OR. I .GE. 22) THEN
                  TESTP=V(I,K)
                  TESTP2=V(I,KSUR)
            ENDIF
            GRM2PL(I)=GRM2PL(I)+(1.+SIGN(1.,AMOM(I,K)))/2.*AMOM(I,K)+
     1      (1.+SIGN(1.,AMOM(I,KSUR)))/2.*AMOM(I,KSUR)*SURI2
            GRM2NG(I)=GRM2NG(I)+(1.-SIGN(1.,AMOM(I,K)))/2.*AMOM(I,K)+
     1      (1.-SIGN(1.,AMOM(I,KSUR)))/2.*AMOM(I,KSUR)*SURI2
            GRV2PL(I)=GRV2PL(I)+(1.+SIGN(1.,V(I,K)))/2.*V(I,K)+
     1      (1.+SIGN(1.,V(I,KSUR)))/2.*V(I,KSUR)*SURI2
            GRV2NG(I)=GRV2NG(I)+(1.-SIGN(1.,V(I,K)))/2.*V(I,K)+
     1      (1.-SIGN(1.,V(I,KSUR)))/2.*V(I,KSUR)*SURI2
                 GRP2PL(I)=GRP2PL(I)+(1.+SIGN(1.,TESTP-0.001))/2.*P(I,K)+
     1      (1.+SIGN(1.,TESTP2))/2.*P(I,KSUR)*SURI2
                 GRP2NG(I)=GRP2NG(I)+(1.-SIGN(1.,TESTP+0.001))/2.*P(I,K)+
     1      (1.-SIGN(1.,TESTP2))/2.*P(I,KSUR)*SURI2

  118 CONTINUE
C
C
      WHMXP(I)=P(I,8)
      WHMNP(I)=P(I,8)
      KST=6
      KSTP=7
      IF(ISUR .EQ. 3) KSTP=10
      IF (NLD .LE. 10) GO TO 827
      KST=11
      KSTP=NLD
      IF(ISUR .EQ. 3) KST=9
  827 DO 829 K=KST,KSTP
C
C
C     SKIP LOAD CONDITION 8, ALREADY IN
C
```

```
      IF(K .EQ. 8) GO TO 829
             TESTP3=WHMNM(I)
             TESTP2=WHMXM(I)
        TESTP=AMOM(I,K)
             IF (I .GE. 12 .AND. I .LE. 23) THEN
                     TESTP3=WHMNV(I)
                     TESTP2=WHMXV(I)
                     TESTP=V(I,K)
             ENDIF
             IF (TESTP .GT. TESTP2) WHMXP(I)=P(I,K)
             IF (TESTP .LT. TESTP3) WHMNP(I)=P(I,K)
      WHMXM(I)=AMAX1(WHMXM(I),AMOM(I,K))
      WHMNM(I)=AMIN1(WHMNM(I),AMOM(I,K))
      WHMXV(I)=AMAX1(WHMXV(I),V(I,K))
      WHMNV(I)=AMIN1(WHMNV(I),V(I,K))
C
C     SHEAR LOCATIONS
C
      IF(I .GE. 12 .AND. I .LE. 23) GO TO 85
      IF(AMOM(I,K) .GT. WHMXM(I)) WHMXP(I)=P(I,K)
      IF(AMOM(I,K) .LT. WHMNM(I)) WHMNP(I)=P(I,K)
      GO TO 829
C
   85 IF( (V(I,K)) .GT. (WHMXV(I)) ) WHMXP(I)=P(I,K)
      IF( (V(I,K)) .LT. (WHMNV(I)) ) WHMNP(I)=P(I,K)
C
  829 CONTINUE
      WHMXM(I)=WHMXM(I)+(1.+SIGN(1.,AMOM(I,8)))/2.*AMOM(I,8)
      WHMNM(I)=WHMNM(I)+(1.-SIGN(1.,AMOM(I,8)))/2.*AMOM(I,8)
      WHMXV(I)=WHMXV(I)+(1.+SIGN(1.,V(I,8)))/2.*V(I,8)
      WHMNV(I)=WHMNV(I)+(1.-SIGN(1.,V(I,8)))/2.*V(I,8)
    1 CONTINUE
C
C
C     ZERO OUT M/Vd LOCATIONS IN SIDEWALL IF NO POSITIVE MOMENT
C
C
      DO 119 K =21,22
      IF(GRM1(K)+GRM2PL(K) .LE. 0.) THEN
         GRM1(K)=0.
         GRV1(K)=0.
         GRP1(K)=0.
         GRM2PL(K)=0.
         GRM2NG(K)=0.
         GRV2PL(K)=0.
         GRV2NG(K)=0.
         GRP2PL(K)=0.
         GRP2NG(K)=0.
         WHMXM(K)=0.
         WHMNM(K)=0.
         WHMXV(K)=0.
         WHMNV(K)=0.
```

```
            WHMXP(K)=0.
            WHMNP(K)=0.
         ENDIF
  119 CONTINUE
C
C
      DO 5 K=1,NCN
            FVMIN(K)=(GRV1(K)+GRV2NG(K))*FLMV+WHMNV(K)*FLLMV
            IF (K .EQ. 23) FVMIN(K)=FVMIN(K)+V(23,4)*FLMV
            FMMIN(K)=(GRM1(K)+GRM2NG(K))*FLMV+WHMNM(K)*FLLMV
C
            FVMAX(K)=(GRV1(K)+GRV2PL(K))*FLMV+WHMXV(K)*FLLMV
            FMMAX(K)=(GRM1(K)+GRM2PL(K))*FLMV+WHMXM(K)*FLLMV
            FPMAX(K)=(GRP1(K)+GRP2PL(K))*FLN+WHMXP(K)*FLLN
            FPMIN(K)=(GRP1(K)+GRP2NG(K))*FLN+WHMNP(K)*FLLN
C
            IF(K .EQ. 21 .OR. K .EQ. 22) GO TO 5
C
            IF (FMMIN(K) .GT. 0.0) FMMIN(K)=0.0
            IF (FVMIN(K) .GT. 0.0) FVMIN(K)=0.0
            IF (FMMAX(K) .LT. 0.0) FMMAX(K)=0.0
            IF (FVMAX(K) .LT. 0.0) FVMAX(K)=0.0
C
    5 CONTINUE
C
C
C  DEBUG OUTPUT
C
      IF(IDBUG.LT.2) GO TO 1126
 1498 CONTINUE
      IF(IPP.EQ.1) WRITE(III,900)
  900 FORMAT(1H1,////,30X,'FORCES DUE TO',/,
     1 24X,' SERVICE AND ULTIMATE LOADS',/,25X,26(1H-))
      IF(IPP.EQ.1) WRITE(III,1101)
 1101 FORMAT(//,26X,'SERVICE LOAD FORCES',/,1X,75(1H-),/)
      IF(IPP.EQ.1) WRITE(III,1123)
 1123 FORMAT(/,10X,'SERVICE LOAD MOMENTS (IN-KIPS/FT)',/)
      IF(IPP.EQ.1) WRITE(III,1103)
 1103 FORMAT(1X,'   DES.   MEMBER  DIST. TO   PERM. DL.          '
     1'  ADD. DL.          LIVELOAD',/,3X,'SECT.              A-END'
     1'                     POS.    NEG.     POS.     NEG.   ',/,
     2 27(1H-),3X,9(1H-),4X,14(1H-),4X,16(1H-))
C
C
C
      DO 1131 I=1,23
      IF(IPP.EQ.1) WRITE(III,1102)I,SIDE(I),XL(I),GRM1(I),GRM2PL(I)
     1 ,GRM2NG(I),WHMXM(I),WHMNM(I)

 1131 CONTINUE
 1102 FORMAT(1X,I5,6X,A4,3X,F7.2,3X,
     1 F8.2,2X,F8.2,2X,F8.2,2X,F8.2,2X,F8.2)
```

```
C
C
C
      IF(IPP.EQ.1) WRITE(III,1124)
 1124 FORMAT('1',/////,12X,'SERVICE LOAD SHEARS (KIPS/FT)',/)
      IF(IPP.EQ.1) WRITE(III,1103)
C
      DO 1132 I=12,23
      IF(IPP.EQ.1) WRITE(III,1102)I,SIDE(I),XL(I),GRV1(I),GRV2PL(I)
     1,GRV2NG(I),WHMXV(I),WHMNV(I)
 1132 CONTINUE
C
C
C
      IF(IPP.EQ.1) WRITE(III,1125)
 1125 FORMAT('1',/////,12X,'SERVICE LOAD THRUSTS (KIPS/FT)',/)
      IF(IPP.EQ.1) WRITE(III,1103)
      DO 1133 I=1,23
      IF(IPP.EQ.1) WRITE(III,1102)I,SIDE(I),XL(I),GRP1(I),GRP2PL(I)
     1,GRP2NG(I),WHMXP(I),WHMNP(I)
 1133 CONTINUE
C
C
C
 1126 CONTINUE
      IF(IDBUG .LT. 1) GO TO 1203
      IF(IPP.EQ.1) WRITE(III,901)
  901 FORMAT(1H1,///,22X,'ULTIMATE LOAD FORCES',/,
     1 1X,75(1H-),/,2X,'SECTION',
     1 6X,'MAX M+',5X,'MAX V+',4X,'MAX P+',4X,'MAX M-',5X,
     2 'MAX V-',4X,'MAX P-',/,13X,'(IN.-K/FT)',3X,'(K/FT)',4X,'(K/FT)',2
     3X,'(IN.-K/FT)',2X,'(K/FT)',4X,'(K/FT)',/)
C
C
C
      DO 1134 I=1,23
      IF(IPP.EQ.1) WRITE(III,902)I,FMMAX(I),FVMAX(I),FPMAX(I),FMMIN(I)
     1,FVMIN(I),FPMIN(I)
 1134 CONTINUE
C
C
C
  902 FORMAT(4X,I2,5X,6F10.2)
 1502 CONTINUE
      ZMOMBC=SPAN+TS-ZMOMB
 1203 CONTINUE
C
      RETURN
      END
C
C
```

Subroutine: DESCK

Function:

This subroutine calculates the required steel areas at the flexure design locations based on tensile yield strength of the reinforcement, minimum steel requirements, concrete compression, and 0.01 in crack width at service loads. Diagonal tension stresses are checked using Methods 1 and 2 of AASHTO.

I/O Generated By Subroutine:

When Options 2 through 4 are selected, summary tables for flexure and shear design are printed. The flexure design table presents all the information required to design steel reinforcing based on flexure, minimum steel, maximum steel, and crack control. This table also lists the governing design criteria for each section. The shear design table presents all the information used to evaluate the diagonal tension strength. Tables for both Method 1 and 2 of AASHTO are printed.

Error Messages Generated:

- o DESIGN NOT POSSIBLE AT SECTION __ DUE TO EXCESSIVE CONCRETE COMPRESSION...
- o WARNING - DESIGN NOT POSSIBLE AT SECTION __, STIRRUPS ARE REQUIRED...

```
      SUBROUTINE DESCK
C
C    CALCULATES THE REQUIRED STEEL AREA AT THE FLEXURE DESIGN
C    LOCATIONS BASED ON THE FOLLOWING:  FLEXURE
C                                       MINIMUM STEEL FOR FLEXURE
C                                       LIMITING CONCRETE COMPRESSION
C                                       0.01'' CRACK AT SERVICE LOADS
C    IT CHECKS FOR DIAGONAL TENSION SHEAR AT THE APPROPRIATE DESIGN
C    LOCATIONS USING METHODS 1(AASHTO) AND 2
C    A PRINTOUT OF THE FLEXURE DESIGN TABLE, SHEAR DESIGN TABLE METHOD 1
C    AND SHEAR DESIGN TABLE METHOD 2 ARE AVAILABLE WITH AN IDBUG VALUE
C    GREATER THAN 1.
C
      REAL*4 JLOAD(12,40)
      REAL*4 INER(4,50),KAA(4,3,3),KAB(4,3,3),KBA(4,3,3),KBB(4,3,3)
      CHARACTER*4 YES(1),NO(1),Z2(8),FLEXCODE
      CHARACTER*2 PRNT(42)
      CHARACTER*8 GOVERN(7)
      CHARACTER*10 MEMBDS(40)
C
      COMMON/RSCALE/SPAN,RISE,TT,TB,TS,GAMAC,GAMAS,GAMAF,POF,H,HH,HV,
     1 POV,
     1 ZETA,BETA,DF,Q1,EC,ES,FY,FCP,FLMV,FLN,FCR,Q3,NLAY,RTYPE,Q4,Q5,
     2 CT(6),SDATA(35)
      COMMON/RSCAL2/QFAC,RES,NTJD,HHT,HHB,HVT,HVB,FLLN,FLLMV
      COMMON/RSCAL2/HRT(4),DSHDL(4),TST
      COMMON/RSCAL3/SWDTH,VMAG,RLEN,RWID,SURV,SURHT,SURHB,ASSD,
     1              AS6D,AS5SP,AS6SP,CHHT,CHVT,CHHB,CHVB
C
      COMMON/RSCAL5/ASBMAX,Z2,DSTEST(40),MEMBDS
      COMMON/RARRAY/U(12,40),W1(4,10),W2(4,10),A(4,10),B(4,10),C(4,10),
     1 PMEMB(4,25),X(50,4)
      COMMON/RARRAY/INER,KAA,KAB,KBA,KBB,W1WH(3,22,4),W2WH(3,22,4),
     1              AWH(3,22,4),BWH(3,22,4),CWH(3,22,4)
C
      COMMON/ANAL/JLOAD,STIF(12,12),FIXMO(4,40,4),DM(40),DV(40),DP(40),
     1 AS(40),SRATIO(40)
C
      COMMON/ISCALE/NIT,NOLD,IDBUG,IR,IW,ITAPE,IPATH,ICYC,NINT
      COMMON/ISCALE/NLD,LTYPE,NSDES,ISUR,NSTRES
C
      COMMON/IARRAY/MEMB(4,2) ,INDEX(40)
C
      COMMON/HARRAY/AMOM(40,40),V(40,40),P(40,40),FXLA(4,40),FYLA(4,40),
     1BMA(4,40),FXLB(4,40),FYLB(4,40),BMB(4,40),ENDM(40,40),ENDV(40,40),
     2 GRM1(40),GRV1(40),GRP1(40),GRV2NG(40),GRM2NG(40),GRV2PL(40)
     3 ,GRM2PL(40),GRP2PL(40),GRP2NG(40),FPMIN(40),FVMIN(40),FMMIN(40),
     4 FPMAX(40),FVMAX(40),FMMAX(40),ZMOMT,ZMOMB,XL(40),WHMXM(40),
     5 WHMNM(40),WHMXV(40),WHMNV(40),WHMXP(40),WHMNP(40)
C
      COMMON/IFLAGS/IBDATA(35),ISDATA(35),ICON(40)
```

```
      COMMON/SHRM2/TENSPN
      COMMON/PRN/ IPP,IDBG,III
      COMMON/FACT/ FLLMVP,FLLNP
C
      REAL MU,NU,MO,NO,NLAY
      INTEGER IFLXCD(14),ISHR(24),ITHR(14)
      DIMENSION DS(40),SH(23,10),Z1(40,4),
     1 CRACK(40),AMIN(40),AMAX(40),AREAFL(40),DST(40)
      DIMENSION INDEX3(12),DINR(23),DOUTR(23),INDSH1(8),INDSH2(12)
      DIMENSION INDEX2A(12),THICK(4)
      DATA INDEX3/2,3,4,5,7,8,9,10,20,21,22,23/
C     DATA INDEX2A/2,3,6,7,9,10,13,14/
      DATA ISHR/1,1,2,2,2,2,3,3,1,2,2,3,4,4,6,6,6,6,5,5,4,6,6,5/,
     1 YES/' YES'/,NO/' NO ' /
      DATA GOVERN/'FLEXURE ','MIN STL','CRACK ','COMPRES',
     1            'STL STRS','PRESTRS','HANDLE'/
      DATA IFLXCD/1,1,1,2,2,2,2,2,3,3,3,4,6,5/
      DATA ITHR/1,1,1,2,2,2,2,2,3,3,3,1,2,3/
      DATA INDSH1/1,1,2,2,3,3,4,4/
      DATA INDSH2/1,1,2,2,3,3,4,4,5,6,7,8/
C
C
C     WRITE INFORMATION TO SHEAR OUTPUT FILE
C
      WRITE(3,4)SPAN,RISE,HHT,HVT,HHB,HVB,NLD,
     1          CHHT,CHVT,CHHB,CHVB,FCP,POV,
     1          XL(2),XL(3),XL(4),XL(5),XL(7),XL(8),XL(9),XL(10),TT,TB,
     2          TS
    4 FORMAT(6F10.3,I5,/,6F10.3,/,8F10.3,/,3F10.3)
C
C
      TENSPN=0.
C
C     ASSIGN VALUES TO THICK
C
      THICK(1)=TT
      THICK(2)=TS
      THICK(3)=TB
      THICK(4)=TS
      ASPSTRES=AS(12)
C
C
C
C        FIND DESIGN VALUES FOR EACH REINFORCING MEMBER
      DO 71 L=1,8
      DO 71 M=1,10
      SH(L,M)=0.0
   71 CONTINUE
C
C
      DS(1)=TT
      DS(2)=TT
```

```
      DS(3)=PMEMB(1,1)-HRT(1)*(TS/2.+CHHT)
      DS(4)=PMEMB(2,1)-HRT(2)*(TT/2.+CHVT)
      DS(5)=TS
      DS(6)=TS
      DS(7)=TS
      DS(8)=PMEMB(4,1)-HRT(4)*(TB/2.+CHVB)
      IF (TST .NE. 0.) DS(8)=TST
      DS(9)=PMEMB(3,1)-HRT(3)*(TS/2.+CHHB)
      DS(10)=TB
      DS(11)=TB
      DS(12)=TT
      DS(13)=DS(3)
      DS(14)=DS(4)
      DS(15)=TS
      DS(16)=DS(7)
      DS(17)=DS(8)
      DS(18)=DS(9)
      DS(19)=TB
      DS(20)=TT
      DS(21)=TS
      DS(22)=TS
      DS(23)=TB
      DST(13)=PMEMB(1,1)-XL(13)*HRT(1)-CT(1)-SDATA(1)*0.5
      IF (DST(13) .LT. TT) DST(13)=TT-CT(1)-SDATA(1)*0.5
      DST(14)=PMEMB(2,1)-(PMEMB(2,4)-XL(14))*HRT(2)-CT(2)-SDATA(2)*0.5
      IF (DST(14) .LT. TS) DST(14)=TS-CT(2)-SDATA(2)*0.5
      DST(17)=PMEMB(4,1)-XL(17)*HRT(4)-CT(2)-SDATA(2)*0.5
      IF (DST(17) .LT. TS) DST(17)=TS-CT(2)-SDATA(2)*0.5
      DST(18)=PMEMB(3,1)-(PMEMB(3,4)-XL(18))*HRT(3)-CT(3)-SDATA(3)*0.5
      IF (DST(18) .LT. TB) DST(18)=TB-CT(3)-SDATA(3)*0.5
C
C     COMPUTE DS AT ADDITIONAL DESIGN LOACTIONS
C
C     IPOS=1 FOR A POSITIVE DESIGN
C     DSTEST() CONTAINS MEMBER NUMBER FOR ADDNL LOCATIONS
C
C
      NCN=24+NSTRES+NSDES
      IF(NCN .EQ. 24) NCN=23
C
C
C     WRITE HEADER FOR ADDITIONAL DESIGNS
C
C
C
      DO 500 I=24,NCN
         DS(I)=TT
         IF(DSTEST(I) .EQ. 4) DS(I)=TS
         IF (DSTEST(I) .EQ. 4 .AND. TST .NE. 0.) DS(I)=TST+XL(I)*SLP
         IF(XL(I) .LT. (HHT+TS/2) .AND. DSTEST(I) .EQ. 1.)
     1      DS(I)=PMEMB(1,1)-((PMEMB(1,1)-TT)/(HHT+TS/2))*XL(I)
         IF(XL(I) .LT. (CHHT+TS/2) .AND. DSTEST(I) .EQ. 1.)
```

```
     1         DS(I)=(TT+CHVT)+((HVT-CHVT)/CHHT)*XL(I)
          IF(XL(I) .GT. (PMEMB(4,4)-HVT-(TT/2)) .AND. DSTEST(I) .EQ. 4.)
     1         DS(I)=PMEMB(4,2)-((PMEMB(4,2)-TS)/(HVT+TT/2))*
     2         (PMEMB(4,4)-XL(I))
          IF(XL(I) .GT. (PMEMB(4,4)-CHVT-(TT/2)) .AND. DSTEST(I) .EQ. 4.
     1    .AND. CHVT .NE. 0.)
     2         DS(I)=(TS+CHHT)+((HHT-CHHT)/CHVT)*
     3         (PMEMB(4,4)-XL(I))
  500 CONTINUE
C
C
      II=25+NSTRES
      FYPSI=FY*1000.
      FCPPSI=FCP*1000.
      B1=0.85-0.05*(FCP-4.)
      IF (B1 .GT. 0.85) B1=0.85
      IF (B1 .LT. 0.65) B1=0.65
      DO 510 J=1,NCN-9
      I=J
      IF(I .GT. 14) I=J+9
      IPOS=1
      AREA01=0.
      ARE012=0.
  503 CONTINUE
C
C
C
      ICNT=I
      MEMBDS(I)='TOP-NEG'
      IF(I .EQ. 12) ICNT=1
      IF(I .EQ. 13) ICNT=6
      IF(I .EQ. 14) ICNT=11
      IF(I .LE. 14) GO TO 501
      IF(IPOS .EQ. 1 .AND. DSTEST(I) .EQ. 1.) THEN
         IFLX=4
         IP=1
         MEMBDS(I)='TOP-POS'
      ENDIF
      IF(IPOS .EQ. 0 .AND. DSTEST(I) .EQ. 1.) THEN
         IFLX=1
         IP=1
         MEMBDS(I)='TOP-NEG'
      ENDIF
      IF(IPOS .EQ. 1 .AND. DSTEST(I) .EQ. 4.) THEN
         IFLX=6
         IP=4
         MEMBDS(I)='SIDE-POS'
      ENDIF
      IF(IPOS .EQ. 0 .AND. DSTEST(I) .EQ. 4.) THEN
         IFLX=2
         IP=4
         MEMBDS(I)='SIDE-NEG'
```

```
      ENDIF
      GO TO 502
C
C
  501 CONTINUE
      IFLX=IFLXCD(I)
      IP=ITHR(I)
  502 CONTINUE
      FLAY=0.
      C01=0.
      ICON(I)=1
      DST(ICNT)=(DS(ICNT)-0.5*SDATA(IFLX)-CT(IFLX))
      DM(I)= -FMMIN(I)
C
C  CHANGE SIGN CONVENTION FOR THRUSTS - COMPRESSION IS POSITIVE
C
      DP(I)= -FPMIN(I)
C
C        FIND STEEL AREA FOR FLEXURE
C
C
      DMEM=DS(ICNT)
      TH=THICK(IP)
      M0=((DM(I)+WHMNM(I)*FLLMV)/FLMV-WHMNM(I))*1000.
      N0=((DP(I)+WHMNP(I)*FLLN)/FLN-WHMNP(I))*1000.
      IF(IPOS .EQ. 1 .AND. I .GT. 14) THEN
         DM(I)=FMMAX(I)
         DP(I)=-FPMAX(I)
         M0=((DM(I)-WHMXM(I)*FLLMV)/FLMV+WHMXM(I))*1000.
         N0=((DP(I)+WHMXP(I)*FLLN)/FLN-WHMXP(I))*1000.
      ENDIF
C
C
C     ASSIGN ALPHA STRINGS ACCORDING TO DESIGN LOCATION
C
C
      IF(I .GT. 14) GO TO 555
      IF(I .GT. 3) MEMBDS(I)='SIDE-NEG'
      IF(I .GT. 8) MEMBDS(I)='BOTTOM-NEG'
      IF(I .EQ. 12) THEN
            MEMBDS(I)='TOP-POS'
            DM(I)=FMMAX(1)
                   DP(I)=-FPMAX(1)
            M0=((DM(I)-WHMXM(1)*FLLMV)/FLMV+WHMXM(1))*1000.
            N0=((DP(I)+WHMXP(1)*FLLN)/FLN-WHMXP(1))*1000.
      ENDIF
      IF(I .EQ. 13) THEN
            MEMBDS(I)='SIDE-POS'
            DM(I)=FMMAX(6)
                   DP(I)=-FPMAX(6)
            M0=((DM(I)-WHMXM(6)*FLLMV)/FLMV+WHMXM(6))*1000.
```

```
               NO=((DP(I)+WHMXP(6)*FLLN)/FLN-WHMXP(6))*1000.
               DMEM=DS(6)
         ENDIF
         IF(I .EQ. 14) THEN
               MEMBDS(I)='BOTTOM-POS'
               DM(I)=FMMAX(11)
                      DP(I)=-FPMAX(11)
               MO=((DM(I)-WHMXM(11)*FLLMV)/FLMV+WHMXM(11))*1000.
               NO=((DP(I)+WHMXP(11)*FLLN)/FLN-WHMXP(11))*1000.
               DMEM=DS(11)
         ENDIF
  555    CONTINUE
C
C
C
         PHIDF=DST(ICNT)*POF
         E0=10.2*FCPPSI
         FLEX =E0*PHIDF**2 - DP(I)*1000.*(2.*PHIDF-DMEM) -
     1      2000.0*DM(I)
         IF (FLEX .LT. 0.0 ) AS(I) = 1.0E15
         IF (FLEX .GE. 0.0) AS(I)=(E0*PHIDF - DP(I)*1000.0 -
     1      SQRT(E0*FLEX) ) / FYPSI
           SRATIO(I)=AS(I)/12./PHIDF
           AREAFL(I)=AS(I)
C
C           MINIMUM STEEL AREA FOR FLEXURE
C
         AMIN(I)=0.024*THICK(IP)
         IF (AS(I).GT.0.024*THICK(IP)) GO TO 2
             AS(I)=THICK(IP)*0.024
             SRATIO(I)=AS(I)/12./PHIDF
             ICON(I)=2
    2      AREAMF=6.6E5*B1*FCPPSI*PHIDF/FYPSI/(FYPSI+87000.)
     1           -(750.*DP(I)/FYPSI)
           AMAX(I)=AREAMF
           IF (AS(I) .LT. AREAMF) GO TO 3
         IF(IPP.EQ.1.AND.ICNT.LE.20) WRITE(III,1001) ICNT,MEMBDS(I),DM(I),D
     1P(I),AS(I),AREAMF
 1001    FORMAT(1X,67(1H*),/,'  DESIGN NOT POSSIBLE AT SECTION',I4,
     1'. DESIGN FOR ',A10,' MOMENT, ',/,'  DUE',
     2' TO EXCESSIVE CONCRETE COMPRESSION',/,'  DM=',F10.3,
     3 ' IN.KIPS/FT',5X,'DP= ',F10.3,' KIPS/FT.',/,2X,'REQUIRED STEEL
     4 AREA = ',F10.3,' SQ.IN./FT.',/,2X,'MAXIMUM STEEL AREA = ',F10.3,
     5 ' SQ.IN./FT.',/,1X,67(1H*) ,/,/,/)
         AS(I) = 1.0E15
         SRATIO(I) = 1.0E15
         ICON(I) =4
             GO TO 10
    3      CONTINUE
C
C           STEEL AREA BASED ON 0.01 INCH CRACK
```

```
C
        K=RTYPE+0.5
        GO TO (1000,2000,3000), K
 1000   C0=1.0
        B2=(0.5*CT(IFLX)**2*SDATA(6+IFLX)/NLAY)**(1./3.)
        GO TO 140
 2000   C0=1.5
        B2=1.0
        FLAY=CT(IFLX)**2*SDATA(6+IFLX)/NLAY
C
        GO TO 140
 3000   C0=1.9
        B2=(0.5*CT(IFLX)**2*SDATA(6+IFLX)/NLAY)**(1./3.)
  140   CONTINUE
 3123   FORMAT (6F10.3,/,I5,3F10.3,//)
        E=ABS(M0/N0)+DST(ICNT)-DS(ICNT)/2.
        AJ=0.74+0.1*E/DST(ICNT)
        IF (AJ .GT. 0.9 ) AJ=0.9
        AP=1./(1.-AJ*DST(ICNT)/E)
        IF (E/DST(ICNT).LT. 1.15) GO TO 13
    7   CONTINUE
      R2 = (M0 + N0*(DST(ICNT)-DMEM/2.))/AJ/AP
      R1 = C0*12.*DMEM**2*SQRT(FCPPSI)
      AREA01 = (R2-R1)*B2/30000./PHIDF/FCR
        IF ( C01 .EQ. 1 ) GO TO 9
        IF ( FLAY .LT. 3 ) GO TO 11
        C01=1.
        C0=1.9
        B2=(0.5*FLAY)**(1./3.)
        ARE012=AREA01
        GO TO 7
    9   IF ( ARE012 .GT. AREA01 ) AREA01=ARE012
   11   CONTINUE
        IF(AS(I) .EQ. 0.) AS(I)=-1
        CRACK(I)=AREA01/AS(I)
         IF ( CRACK(I) .LE. 1. ) GO TO 13
          ICON(I)=3
          AS(I)=AREA01
          SRATIO(I)=AS(I)/12./PHIDF
C
C
   13   CONTINUE
            ASNEW=0.
            SLS=23.4
            SIGN=1.
            IF (I .LE. 11 ) SIGN= -1.
            IF (I .GT. 14 .AND. IPOS .EQ. 0) SIGN= -1.
            IF (GRP1(ICNT) .EQ. 0.) GRP1(ICNT)=0.001
            E=ABS(GRM1(ICNT)/GRP1(ICNT))+DST(ICNT)-DS(ICNT)/2.
            AJ=0.74+0.1*E/DST(ICNT)
            IF (AJ .GT. 0.9 ) AJ=0.9
            AP=1./(1.-AJ*DST(ICNT)/E)
```

```
 8112       FMIN=(SIGN*GRM1(ICNT)-GRP1(ICNT)*(DST(ICNT)-0.5*DS(ICNT)))/
    1            (AS(I)*AJ*AP*DST(ICNT))
            FF=SLS-0.33*FMIN
            IF (FF .LT. 0.0) THEN
                AS(I)=(SLS-FF)/0.33*AS(I)/FMIN+.001
                ICON(I)=5
                GO TO 8112
            END IF
            SMOM= -1.*WHMNM(I)
            STHRST=WHMNP(I)
            IF(I .GT. 11 .AND. I .LT. 15) THEN
                  SMOM=WHMXM(ICNT)
                  STHRST=WHMXP(ICNT)
            ENDIF
            IF(I .GT. 14 .AND. IPOS .EQ. 1) THEN
                  SMOM=WHMXM(I)
                  STHRST=WHMXP(I)
            ENDIF
            IF (STHRST .EQ. 0.) STHRST=0.001
            E=ABS(SMOM/STHRST)+DST(ICNT)-DS(ICNT)/2.
            AJ=0.74+0.1*E/DST(ICNT)
            IF (AJ .GT. 0.9 ) AJ=0.9
            AP=1./(1.-AJ*DST(ICNT)/E)
            FFLS=(SMOM-STHRST*(DST(ICNT)-0.5*DS(ICNT)))/
    1            (AS(I)*AJ*AP*DST(ICNT))
            IF(FFLS .GT. FF) THEN
                 ASNEW=FFLS*AS(I)/FF
                 AS(I)=ASNEW
                 SRATIO(I)=AS(I)/12./PHIDF
                 ICON(I)=5
            ENDIF
C
C
C
   10 CONTINUE
      IF(I .LE. 14) GO TO 510
      IF(IDBUG .LT. 1) GO TO 511
      IF(AS(I) .LT. 0.) AS(I)=0.
      IF(AREAFL(I) .LT. 0.)AREAFL(I)=0.
      IF(CRACK(I) .LT. 0.) CRACK(I)=0.
      IF (I .LT. II .AND. IPOS .EQ. 0 .AND. ASBMAX .GT. AS(I)) THEN
      AS(I) = ASBMAX
      ICON(I)=7
      ENDIF
  511 IF(IPOS .EQ. 1) THEN
         IPOS=0
         GO TO 503
      ENDIF
  510 CONTINUE
C     DETERMINE IF HANDLING FORCES GOVERN
C
      IF(ASBMAX .GT. AS(1))THEN
```

```
         AS(1)=ASBMAX
         ICON(1)=7
      ENDIF
C
      IF(IDBUG.LT.1) GO TO 164
      IF(IPP.EQ.1) WRITE(III,2188)
 2007 CONTINUE
      DO 2834 I=1,14
      ICNT=I
      IF(I .EQ. 12) ICNT=1
      IF(I .EQ. 13) ICNT=6
      IF(I .EQ. 14) ICNT=11
      IFLX=IFLXCD(I)
      DST(ICNT)=DS(ICNT)-0.5*SDATA(IFLX)-CT(IFLX)
C
C
      IF(AS(I) .LT. 0.) AS(I)=0.
      IF(AREAFL(I) .LT. 0.)AREAFL(I)=0.
      IF(CRACK(I) .LT. 0.) CRACK(I)=0.
      IF(IPP.EQ.1) WRITE(III,2005) ICNT,MEMBDS(I),DST(ICNT),DM(I),DP(I)
     1,AREAFL(I),AMIN(I),CRACK(I),AS(I),GOVERN(ICON(I))
 2188 FORMAT(1H1,///,20X,'******  FLEXURE DESIGN TABLE  ******',//,
     1'DES.    WALL,     DEPTH   ULT.     ULT.    FLEX.  REINF.     CRACK',
     2'   GOV.   GOV.',/,
     3'SEC.   SIGN OF    TO   MOMENT   THRUST  -------------     INDEX',
     4'   STEEL   MODE',/,
     5'       MOMENT    STEEL                   ULT.(1) MIN.(2)',11X,'(3
     $)',4X,'(4)',/,
     6'                 (IN)  (IN-K/FT) (K/FT)   (SQ.IN/FT)           '
     7,'(SQ.IN/FT)',//,)
 2005 FORMAT(I3,2X,A10,2X,F5.2,1X,F6.1,2X,F5.1,2X,2(F6.3,4X),F4.1,
     1 2X,F6.3,2X,A8,/)
 2834 CONTINUE
      IF(IPP.EQ.1) WRITE(III,2824)
 2824 FORMAT(4X,'NOTES:',/,4X,
     1'1. REQUIRED REINFORCING TO DEVELOP ULTIMATE FLEXURAL STRENGTH.',/
     2,4X,'2. MINIMUM FLEXURAL REINFORCING ALLOWED.',/,4X,
     3'3. REINFORCING REQUIRED TO MEET ALL DESIGN CRITERIA. THE GOVERNIN
     4G',/,4X,'   CRITERIA IS INDICATED UNDER THE COLUMN "GOVERNING MODE
     5".',/,4X,'4. IF GOVERNING MODE IS LISTED AS CRACK, THE REINFORCING
     6 MAY',/,4X,'   BE REDUCED BY DECREASING THE MAXIMUM REINFORCING SP
     7ACING.',/)
C
C     DETERMINE CUTOFF LENGTH FOR AS1
C
      CALL ZEROMOM(IDIST1,IDIST2,TENSPN,1)
  164 CONTINUE
C
C
C        DIAGONAL TENSION CHECK
C
```

```
      FCPSI=FCPPSI
      IF ( FCPPSI .GT. 7000.) FCPSI=7000.0
C
C         AASHTO SHEAR CHECK - METHOD 1
C
      IF(IDBUG .GE. 1.AND.IPP.EQ.1) WRITE(III,434)
      DO 60 I=12,23
             ISH=I-11
        DINR(I)=DS(I)-CT(ISHR(I+1))-SDATA(ISHR(I+1))*0.5
        IF (I .EQ. 13) DINR(13)=DS(2)-CT(4)-SDATA(4)*0.5
        IF (I .EQ. 14) DINR(14)=DS(5)-CT(6)-SDATA(6)*0.5
        IF (I .EQ. 17) DINR(17)=DS(7)-CT(6)-SDATA(6)*0.5
        IF (I .EQ. 18) DINR(18)=DS(10)-CT(5)-SDATA(5)*0.5
        DOUTR(I)=DS(I)-CT(ISHR(ISH))-SDATA(ISHR(ISH))*0.5
        IF (I .EQ. 13 .OR. I .EQ. 14 .OR. I .EQ. 17 .OR. I .EQ. 18)
     1   DOUTR(I)=DST(I)
        DST(I)=AMIN1(DINR(I),DOUTR(I))
        N1=3
        IF (I .GE. 20) GO TO 60
        Z2(I-11)=NO(1)
        IF (FMMIN(I) .NE. 0.) GO TO 61
        DST(I)=DINR(I)
        N1=1
   61   IF (FMMAX(I) .NE. 0.) GO TO 62
        IF (DST(I) .EQ. DINR(I)) DST(I)=DOUTR(I)
        N1=2
   62   CONTINUE
        PHIDV = DST(I)* POV
        VU =AMAX1(FVMAX(I),-FVMIN(I))
        VP=0.
        IF (NLD .GT. 10 .AND. VU .EQ. FVMAX(I)) VP=WHMXV(I)
        IF (NLD .GT. 10 .AND. VU .EQ. -FVMIN(I)) VP= -WHMNV(I)
             SHRCRIT=3.
             IF(LTYPE .EQ. 5 .OR. NLD .GT. 10 .OR. H .LT. 24.)SHRCRIT=2.
             SHSTR=SHRCRIT*PHIDV*SQRT(FCPSI)*12./1000.
        IF ( VU .LT. SHSTR) GO TO 65
          IF(IPP.EQ.1) WRITE(III,9501) I
          IF (ISDATA(25+INDSH1(ISH)) .NE. 1) ISDATA(25+INDSH1(ISH))=1
          Z2(I-11) = YES(1)
   65   CONTINUE
        Z1(I-11,1) = VU
        Z1(I-11,2)= SHSTR
        Z1(I-11,3) = Z1(I-11,1) / Z1(I-11,2)
        Z1(I-11,4)= DST(I)
         IF (I .EQ. 12 .OR. I .EQ. 13) DDS=AMIN1(DST(1),DST(2))
         IF (I .GT. 13 .AND. I .LT. 18) DDS=AMIN1(DST(5),DST(6),DST(7))
         IF (I .EQ. 18 .OR. I .EQ. 19) DDS=AMIN1(DST(11),DST(10))
        IF (Z1(I-11,3) .GT. 1.) WRITE(3,7214) I,VU,SHRCRIT,DDS,XL(I),
     1                                        VP*FLLMV
 7214   FORMAT(I5,5F10.3)
  434 FORMAT(1H1,//,10X,
     1'*******SHEAR DESIGN METHOD 1 - AASHTO*********',//,
```

```
     2'LOCATION    ULTIMATE   ALLOWABLE   DIAGONAL   DEPTH       '
     3'STIRRUPS',/
     4,'             SHEAR       SHEAR      TENSION      TO          REQD?',
     5/,'            (K/FT)      (K/FT)      INDEX      STEEL   ',/,46X,'(
     6IN.)',/)
C
C
      IF(IDBUG .GE. 1.AND.IPP.EQ.1) WRITE(III,433) I,(Z1(I-11,J),J=1,4),
     1Z2(I-11)
C
C
  433   FORMAT(3X,I2,6X,F6.1,5X,F6.1,7X,F5.2,4X,F6.2,8X,A4)
   60 CONTINUE
C
C
      IF(IPP.EQ.1) WRITE(III,450)SHRCRIT
  450 FORMAT(/,5X,'CONCRETE SHEAR STRENGTH TAKEN AS 'F4.0,
     1 'SQUARE ROOTS f''c')
C
C
      DO 432 I=1,NCN
      SRATIO(I)=SRATIO(I)*POF
  432 CONTINUE
C
C
C
C     FIND GOVERNING STEEL AREAS
C
C
      TOPIN=AS(12)
      SIDEIN=AS(13)
      BOTTIN=AS(14)
      TOPOUT=AS(1)
      SIDEOUT=AMAX1(AS(2),AS(3),AS(4),AS(5),AS(6),AS(7),AS(8),
     1              AS(9),AS(10))
      BOTTOUT=AS(11)
      DO 460 I=2,10
      IF(SIDEOUT .EQ. AS(I)) ISIDE=I
  460 CONTINUE
      IMIKE = -1
      WRITE(3,8444) IMIKE
 8444 FORMAT(I5)
      DO 1500 I=12,23
      IF ((H .LT. 24 .OR. NLD .GT. 10.) .AND. (I .GE. 20.)) GO TO 1500
      IF(I .GE. 20 .AND. XL(I) .EQ. 0.) GO TO 1500
C
C
      IGTO=I-11
      RHO1=0.
      RHO2=0.
      GO TO (1100,1100,2100,2100,2100,2100,3100,3100,1100,
```

```
     1        2100,2100,3100)IGTO
C
C
C         TOP SLAB
C
 1100 CONTINUE
C
      RHO1=SRATIO(1)
      RHO2=SRATIO(12)
      IF (I .EQ. 13) RHO1=SRATIO(1)*DST(1)/DST(3)
      DIN=DST(1)
      DOUT=DST(INDEX3(I-11))
      GO TO 4000
C
C         SIDE WALL
C
 2100 CONTINUE
C
      IF (I .EQ. 14) RHO1=AS(ISIDE)/(12.*DST(4))
      IF (I .EQ. 15) RHO1=AS(ISIDE)/(12.*DST(5))
      IF (I .EQ. 16) RHO1=AS(ISIDE)/(12.*DST(7))
      IF (I .EQ. 17) RHO1=AS(ISIDE)/(12.*DST(8))
      IF (I .EQ. 21 .OR. I .EQ. 22) RHO2=SIDEIN/(12.*DINR(I))
      RHO2=SRATIO(13)
      DIN=DINR(I)
      DOUT=DST(INDEX3(I-11))
      GO TO 4000
C
C         BOTTOM SLAB
C
 3100 CONTINUE
C
      RHO2=SRATIO(14)
      RHO1=SRATIO(11)
      IF (I .EQ. 18) RHO1=SRATIO(11)*DST(11)/DST(9)
      DIN=DST(11)
      DOUT=DST(INDEX3(I-11))
C
 4000 CONTINUE
C
C
      K=I
      ISH = K-11
C
C
      IF((K .EQ. 12 ) .AND.
     1   (XL(I) .LT. IDIST1)) RHO1=AS(ISIDE)/(12.*DST(2))
      IF (K .EQ. 13 .AND. XL(I) .LT. IDIST1) RHO1=AS(ISIDE)/(12.*DST(3))
      IF((K .EQ. 19 ) .AND.
     1   ((PMEMB(1,4)-  XL(I)) .LT. IDIST2)) RHO1=AS(ISIDE)/(12.*DST(10)
     2    )
      IF (K .EQ. 18 .AND. (PMEMB(1,4)-XL(I)) .LT. IDIST2)
```

```
    1 RHO1=AS(ISIDE)/(12.*DST(9))
     IF(K .GE. 20) THEN
        IF(FMMAX(INDEX3(K-11)) .LE. 0) GO TO 1500
        VU=AMAX1(ABS(FVMAX(K)),ABS(FVMIN(K)))
        MU=FMMAX(INDEX3(K-11))
        NU=ABS(FPMAX(K))
        VU2=AMAX1(ABS(FVMAX(K)),ABS(FVMIN(K)))
        GO TO 5001
     ENDIF
C
C
C
C
       VU=AMAX1(FVMAX(INDEX3(K-11)),-FVMIN(INDEX3(K-11)))
       VU2 = AMAX1(FVMAX(K),-FVMIN(K))
       IF ( VU .EQ. 0.0 ) GO TO 1500
       IF (FMMAX(INDEX3(K-11))+FMMIN(INDEX3(K-11)) ) 5000, 6000, 7000

 5000  MU=FMMIN(INDEX3(K-11))
       NU=ABS(FPMIN(INDEX3(K-11)))
       RHO=RHO1
       D=DOUT
       FLEXCODE='NEG'
       N1=2
       GO TO 8000
C
 6000  RHO=AMIN1(RHO1,RHO2)
       MU=FMMAX(INDEX3(K-11))
       NU=ABS(FPMIN(INDEX3(K-11)))
       FLEXCODE='NEG'
       D=DOUT
       IF(RHO .EQ. RHO2) THEN
          D=DIN
          FLEXCODE='POS'
          NU=ABS(FPMAX(INDEX3(K-11)))
       ENDIF
       N1=3
       GO TO 8000
C
 7000  MU=FMMAX(INDEX3(K-11))
       NU=ABS(FPMAX(INDEX3(K-11)))
 5001  RHO=RHO2
       FLEXCODE='POS'
       D=DIN
       N1=1
C
 8000 CONTINUE
C
      IF ( VU .EQ. 0.0 ) GO TO 1500
      IF ( MU .EQ. 0.0 ) MU=AMAX1(FMMAX(INDEX3(K-11)),
     1                           -FMMIN(INDEX3(K-11)))
C
```

```
      SH(K,1)=ABS(MU/VU/D/POV)
      SH(K,2)=VU2
      SH(K,3)=NU
      SH(K,4)=RHO
      SH(K,5)=D
        IF ( RHO .GT. 0.02 ) RHO=0.02
        FD=0.8+1.6/(D*POV)
        IF ( FD .GT. 1.25 ) FD=1.25
        FN=0.5-NU/VU/6.0+SQRT(0.25+(NU/VU/6.0)**2)
      IF(FN.LT.0.75) FN=0.75
      AMVD=ABS(MU/VU/D/POV)
      IF(AMVD.GT.3.0) AMVD=3.0
      VC = (1.1+63.0*RHO) * SQRT(FCPSI) * POV *D *12.*FD/FN*
     1                                         4./(AMVD+1.)
      IF(VC .GT. 4.5*SQRT(FCPSI)*POV*12.*D) VC=4.5*SQRT(FCPSI)*POV*12.*D
      RDT = VU2*1000.0/VC
      SH(K,6)= XL(K)
      SH(K,7)=FN
      SH(K,8)=VC/1000.0
      SH(K,9)=RDT
        IF ( RDT .LE. 1.0 ) GO TO 1500
      ASINC=(3.968*VU2*FN*(AMVD+1.)/FD/SQRT(FCPSI)-0.2095*D*POV)/POV
      SH(K,10)=ASINC
      IF ( ASINC/12./D .LE. 0.02 .AND. Z1(I-11,3) .LT. 1.0 ) GO TO 9500
         IF (I .EQ. 12 .OR. I .EQ. 13) DDS=AMIN1(DST(1),DST(2))
         IF (I .GT. 13 .AND. I .LT. 18) DDS=AMIN1(DST(5),DST(6),DST(7))
         IF (I .EQ. 18 .OR. I .EQ. 19) DDS=AMIN1(DST(11),DST(10))
         IF(IPP.EQ.1) WRITE(III,9501) K
         WRITE(3,9502) K,VU2,SH(K,8),DDS,XL(K)
 9502 FORMAT(I5,4F10.3)
 9501 FORMAT(//,15X,50(1H*),/,15X,'*',48X,'*',/,15X,'*',20X,'WARNING',
     1  21X,'*',/,15X,'*',9X,'DESIGN NOT POSSIBLE AT SECTION ',I2,6X,
     2  '*',/,15X,'*',9X,     'STIRRUP REINFORCEMENT IS REQUIRED ',
     3 5X,'*',/,15X,50(1H*)   )
      IF(ISDATA(13+INDSH2(ISH)) .NE. 1) ISDATA(13+INDSH2(ISH))=1
      SH(K,10) = 1.0E15
        GO TO 1500
 9500   IF ( MU .LT. 0.0 .AND. I .GE. 20) GO TO 2001
        GO TO (1003,1003,1002,1002,1002,1002,1006,1006,
     1         1003,1002,1002,1006)IGTO
C
C        BOTTOM SLAB
C
 1006 CONTINUE
      IF(ASINC .GT. BOTTOUT .AND. FLEXCODE .EQ. 'NEG' .AND.
     1 (Z2(7) .NE. YES(1) .AND. Z2(8) .NE. YES(1))) THEN
        IF (IDIST2 .LT. INT(XL(19)+TS/2.+0.5)) THEN
          AS(11)=ASINC
          ICON(11)=4
          SRATIO(11)=ASINC/12./D
        ELSE
          AS(ISIDE)=ASINC
```

```
            ICON(ISIDE)=4
            SRATIO(ISIDE)=ASINC/12./D
            TENSPN=SPAN*0.1
         ENDIF
        ENDIF
        IF(ASINC .GT. BOTTIN .AND. FLEXCODE .EQ. 'POS' .AND.
     1 (Z2(7) .NE. YES(1) .AND. Z2(8) .NE. YES(1))) THEN
            AS(14)=ASINC
            ICON(14)=4
            SRATIO(14)=ASINC/12./D
        ENDIF
        GOTO 1500
C
C          SIDE WALL
C
C
 1002 CONTINUE
         IF(ASINC .GT. SIDEOUT .AND. FLEXCODE .EQ. 'NEG' .AND.
     1 (Z2(3) .NE. YES(1) .AND. Z2(4) .NE. YES(1) .AND. Z2(5) .NE.
     2 YES(1) .AND. Z2(6) .NE. YES(1))) THEN
            AS(ISIDE)=ASINC
            ICON(ISIDE)=4
            SRATIO(ISIDE)=ASINC/12./D
        ENDIF
        IF(ASINC .GT. SIDEIN .AND. FLEXCODE .EQ. 'POS' .AND.
     1 (Z2(3) .NE. YES(1) .AND. Z2(4) .NE. YES(1) .AND. Z2(5) .NE.
     2 YES(1) .AND. Z2(6) .NE. YES(1))) THEN
            AS(13)=ASINC
            ICON(13)=4
            SRATIO(13)=ASINC/12./D
        ENDIF
        GO TO 1500
C
C
C          TOP SLAB
C
 1003 CONTINUE
        IF(ASINC .GT. TOPOUT .AND. FLEXCODE .EQ. 'NEG' .AND.
     1 (Z2(1) .NE. YES(1) .AND. Z2(2) .NE. YES(1))) THEN
          IF (IDIST1 .LT. INT(XL(12)+TS/2.+0.5)) THEN
            AS(1)=ASINC
            ICON(1)=4
            SRATIO(1)=ASINC/12./D
          ELSE
            AS(ISIDE)=ASINC
            ICON(ISIDE)=4
            SRATIO(ISIDE)=ASINC/12./D
            TENSPN=SPAN*0.1
          ENDIF
        ENDIF
        IF(ASINC .GT. TOPIN .AND. FLEXCODE .EQ. 'POS' .AND.
     1 (Z2(1) .NE. YES(1) .AND. Z2(2) .NE. YES(1))) THEN
```

```
          AS(12)=ASINC
          ICON(12)=4
          SRATIO(12)=ASINC/12./D
      ENDIF
      GO TO 1500
C
 2001 CONTINUE
 1500 CONTINUE
       IMIKE = -2
       WRITE(3,8942) IMIKE
 8942  FORMAT(I5)
C
C      SDATA(19) = ZMOMT + TS/2. - CT(1) - SDATA(1)/2.
C      SDATA(20) = SPAN - ZMOMB + 1.5*TS - CT(3) - SDATA(3)/2.
C
C
      IF(IDBUG.LT.1) GO TO 174
      IF(IPP.EQ.1)WRITE(III,2006) (K,K=12,15),((SH(K,I),K=12,15),I=1,10)
 2006 FORMAT('1',///,15X,'******  SHEAR DESIGN TABLE - METHOD 2 ******'
     1 ,//,'  DESIGN SECTION',11X,4(I2,11X),///,
     2 '  M/(V*PHI*D)',8X,4(F10.3,3X),//,
     3 '  ULTIMATE SHEAR',5X,4(F10.3, 3X),/,2X,'(KIPS/FT)',//,
     4 '  ULTIMATE THRUST',4X,4(F10.3,3X),/,2X,'(KIPS/FT)',//,
     5 '  STEEL RATIO',11X,4(F10.6,3X),//,
     6 '  DEPTH TO STEEL',5X,4(F10.3,3X),/,2X,'(IN.)',//,
     7 '  DISTANCE FROM',6X,4(F10.3,3X),/,'  A-END, (IN.)',//,
     8 '  THRUST FACTOR (FN)',1X,4(F10.3,3X),//,
     9 '  DIAGONAL TENSION',3X,4(F10.3,3X),/,'  STRENGTH, (KIPS/FT)',//,
     1 '  ULTIMATE SHEAR/ ',3X,4(F10.3,3X),/,'  ALLOWABLE SHEAR',//,
     2 '  NEW STEEL AREA DUE',1X,4(F10.3,3X),/,'  TO DIAGONAL TENSION',
     3 /,'  (SQ.IN./FT)')
C
C
C

      IF(IPP.EQ.1)WRITE(III,2010) (K,K=16,19),((SH(K,I),K=16,19),I=1,10)
C
 2010 FORMAT('1',//,15X,'******  SHEAR DESIGN TABLE - METHOD 2 ******',
     1 /,24X,'******  CONTINUED  ******',/,//,
     1 '  DESIGN SECTION',11X,4(I2,11X),///,
     2 '  M/(V*PHI*D)',8X,4(F10.3,3X),//,
     3 '  ULTIMATE SHEAR',5X,4(F10.3, 3X),/,2X,'(KIPS/FT)',//,
     4 '  ULTIMATE THRUST',4X,4(F10.3,3X),/,2X,'(KIPS/FT)',//,
     5 '  STEEL RATIO',11X,4(F10.6,3X),//,
     6 '  DEPTH TO STEEL',5X,4(F10.3,3X),/,2X,'(IN.)',//,
     7 '  DISTANCE FROM',6X,4(F10.3,3X),/,'  A-END,  (IN.)',//,
     8 '  THRUST FACTOR (FN)',1X,4(F10.3,3X),//,
     9 '  DIAGONAL TENSION',3X,4(F10.3,3X),/,'  STRENGTH,  (KIPS/FT)',//,
     1 '  ULTIMATE SHEAR/ ',3X,4(F10.3,3X),/,'  ALLOWABLE SHEAR',//,
     2 '  NEW STEEL AREA DUE',1X,4(F10.3,3X),/,
     3 '  TO DIAGONAL TENSION',/,'  NN(SQ.IN./FT)')
C
```

```
C
C
C
  166 CONTINUE
      IF(XL(20) .EQ. 0) GO TO 174
C
C
C     K SHOULD VARY FROM 20 TO 23 FOR FOUR SIDED CULVERT
C
C
      IF(IPP.EQ.1)WRITE(III,2010) (K,K=20,23),((SH(K,I),K=20,23),I=1,10)
C
C
  174 RETURN
      END
C
C
C
C
C
```

Subroutine: ZEROMOM

Function:

This subroutine calculates the location of zero moment in the top and bottom slab to determine where the side wall outside steel reinforcement which is bent up into the top and bottom slabs is cut off.

I/O Generated By Subroutine:

The location where the side wall outside face reinforcement is cut off in the top and bottom slab is printed.

Error Messages Generated:

None

```
      SUBROUTINE ZEROMOM(IDIST1,IDIST2,TENSPN,IPRNT)
C
C
      CHARACTER*4 Z2(8)
      CHARACTER*10 MEMBDS(40)
      REAL*4 JLOAD(12,40),M0,N0,NLAY,M9,MP,MW
      COMMON/RSCALE/SPAN,RISE,TT,TB,TS,GAMAC,GAMAS,GAMAF,POF,H,HH,HV,Q,
     1 ZETA,BETA,DF,Q1,EC,ES,FY,FCP,FLMV,FLN,FCR,Q3,NLAY,RTYPE,Q4,Q5,
     2 CT(6),SDATA(35)
      COMMON/RSCAL2/QFAC,RES,NTJD,HHT,HHB,HVT,HVB,FLLN,FLLMV
      COMMON/RSCAL2/HRT(4),DSHDL(4),TST
      COMMON/RSCAL3/SWDTH,VMAG,RLEN,RWID,SURV,SURHT,SURHB,AS5D,
     1              AS6D,AS5SP,AS6SP,CHHT,CHVT,CHHB,CHVB
      COMMON/RSCAL5/ASBMAX,Z2,DSTEST(40),MEMBDS
      COMMON/HARRAY/AMOM(40,40),V(40,40),P(40,40),FXLA(4,40),FYLA(4,40),
     1BMA(4,40),FXLB(4,40),FYLB(4,40),BMB(4,40),ENDM(40,40),ENDV(40,40),
     2 GRM1(40),GRV1(40),GRP1(40),GRV2NG(40),GRM2NG(40),GRV2PL(40)
     3 ,GRM2PL(40),GRP2PL(40),GRP2NG(40),FPMIN(40),FVMIN(40),FMMIN(40),
     4 FPMAX(40),FVMAX(40),FMMAX(40),ZMOMT,ZMOMB,XL(40),WHMXM(40),
     5 WHMNM(40),WHMXV(40),WHMNV(40),WHMXP(40),WHMNP(40)
      COMMON/ISCALE/NIT,NOLD,IDBUG,IR,IW,ITAPE,IPATH,ICYC,NINT
      COMMON/ISCALE/NLD,LTYPE,NSDES,ISUR,NSTRES
      COMMON/ANAL/JLOAD,STIF(12,12),FIXMO(4,40,4),DM(40),DV(40),DP(40),
     1 AS(40),SRATIO(40)
      COMMON/PRN/ IPP,IDBG,III
      COMMON/FACT/ FLLMVP,FLLNP
      DIMENSION XX(10),DD(10)
C
C     THIS SUBROUTINE DETERMINES THE LENGTH OF THE SIDEWALL
C     OUTSIDE FACE STEEL (AS1) MUST BE EXTENDED ACROSS THE TOP SLAB
C
C

      ZRMMB=0.0
      ZRMMT=0.0
      IDIST1=0
      IDIST2=0
      DIST1=5000.
      DO 10 I=24,23+NSTRES
      IF(ZRMMT.GT.0.0) GO TO 1
      IF(FMMIN(I).EQ.0.0) ZRMMT=XL(I)+TS/2
    1 CONTINUE
             IF(AS(I) .LE. AS(1)) GO TO 10
      DIST1=XL(I+1)
   10 CONTINUE
C
C
      IF(DIST1 .EQ. 5000.) GO TO 20
      IF(DIST1 .LE. (TS/2)+CHHT) DIST1=(TS/2)+CHHT
C
      IDIST1=INT(DIST1+TS/2+0.5+TENSPN)
```

```
C
      IF (IPRNT .NE. 1.AND.IPP.EQ.1) WRITE(III,35)IDIST1
      GO TO 45
C
   20 IF (IPRNT .NE. 1.AND.IPP.EQ.1) WRITE(III,40)
      DIST1=5000.
      GO TO 45
C
   35 FORMAT(//,5X,'NOTES: 1  SIDEWALL OUTSIDE FACE STEEL (AS1) IS BENT'
     1,' AT THE CULVERT',/,15X,'CORNERS AND EXTENDED  ',I3,' INCHES FRO'
     2,'M THE BEND POINT INTO THE',/15X,
     3'TOP SLAB.  THE TOP SLAB OUTSIDE FACE STEEL (AS7) MUST LAP THE',
     4/,15X,'AS1 STEEL IN ACCORDANCE WITH AASHTO PROVISIONS.')
C
C
   40 FORMAT(//,5X,'NOTES: 1  TOP SLAB OUTSIDE FACE STEEL (AS7) MUST'
     1,' EXTEND COMPLETELY',/,15X,'ACROSS THE TOP SLAB.  THE SIDEWALL'
     2,' OUTSIDE FACE STEEL (AS1)',/,15X,
     3'MUST BE BENT AT THE CORNER AND EXTENDED ACROSS THE TOP SLAB',
     4/,15X,'SUFFICIENTLY TO MEET AASHTO REQUIREMENTS FOR TENSION'
     5,' LAPS.')
C
C
C     APPROXIMATE ANALYSIS TO DETERMINE THE CUTOFF LENGTH OF
C     THE BOTTOM STEEL
C
   45 WU= -2.*FVMIN(10)/(SPAN-2.*HHB)
      V9= WU*SPAN/2.
      M9= FMMIN(9)
      WP= -2.*GRV1(10)/(SPAN-2.*HHB)
      VP= WP*SPAN/2.
      MP= GRM1(9)
      WW= -2.*WHMNV(10)/(SPAN-2.*HHB)
      VW= WW*SPAN/2.
      MW= WHMNM(9)
      XX(1)= TS/2.
      AINC= SPAN/20.
      DIST2=5000.
      DD(1)= TB+HVB-CT(3)-SDATA(3)*0.5
      DO 50 I=2,10
      XX(I)= XX(I-1)+AINC
      DD(I)=TB
      IF (XX(I) .LT. (TS/2.+HHB)) DD(I)=TB+(HVB/HHB*(TS/2.+HHB-XX(I)))
      IF (CHVB .EQ. 0. .OR. CHHB .EQ. 0.) GO TO 55
      IF (XX(I) .LT. (TS/2.+HHB)) DD(I)=TB+(CHVB/(HHB-CHHB)*(TS/2.+HHB-
     1                             XX(I)))
      IF (XX(I) .LT. (TS/2.+CHHB)) DD(I)=TB+CHVB+((HVB-CHVB)/CHHB*(TS/2.
     1                             +CHHB-XX(I)))
   55 DD(I)=DD(I)-CT(3)-SDATA(3)*0.5
   50 CONTINUE
             DMMN19=((GRM1(19)+GRM2NG(19))*FLMV+WHMNM(19)*FLLMV)*(-1.)
             DMMN11=((GRM1(11)+GRM2NG(11))*FLMV+WHMNM(11)*FLLMV)*(-1.)
```

```
               FMMN9 =-FMMIN(9)
               FMMN10=-FMMIN(10)
      DO 60 I=2,10
      ASS=0.
      AREAFL=0.
      AREA01=0.
      ARE012=0.
      FLAY=0.
      C01=0.
      FYPSI=FY*1000.
      FCPPSI=FCP*1000.
      B1=0.85-0.05*(FCP-4.)
      IF (B1 .GT. 0.85) B1=0.85
      IF (B1 .LT. 0.65) B1=0.65
      DX=XX(I)-TS/2.
C
C     DESIGN FOR FLEXURE
C
      DMEM=DD(I)+CT(3)+SDATA(3)*0.5
      XXC=SPAN+TS-XX(I)
      IF (XXC .LE. XL(10)) GO TO 8801
               DMM=(FMMN9-(FMMN9-FMMN10)
     1  *((XXC-XL(9))/(XL(10)-XL(9))))
               GO TO 8803
 8801 IF (XXC .LE. XL(19)) GO TO 8802
               DMM=(FMMN10-(FMMN10-DMMN19)
     1  *((XXC-XL(10))/(XL(19)-XL(10))))
      GO TO 8803
 8802          DMM=(DMMN19-(DMMN19-DMMN11)
     1  *((XXC-XL(19))/(XL(11)-XL(19))))
 8803 CONTINUE
      DPP= -FPMIN(9)
      SM9= ((M9-WHMNM(9)*FLLMV)/FLMV+WHMNM(9))*1000.
      SV9= -1.*((FVMIN(9)-WHMNV(9)*FLLMV)/FLMV+WHMNV(9))*1000.
      SWU= 2.*SV9/SPAN
      M0= -1.*(SV9*DX-SWU*DX*DX*0.5+SM9)
      N0=-1.*((FPMIN(9)-WHMNP(9)*FLLN)/FLN+WHMNP(9))*1000.
      PHIDF=DD(I)*POF
      DMP= -1.*(VP*DX-WP*DX*DX*0.5+MP)
      DDP= -GRP1(9)
      DMW= -1.*(VW*DX-WW*DX*DX*0.5+MW)
      DPW= -WHMNP(9)
      E0=10.2*FCPPSI
      FLEX=E0*PHIDF**2.-DPP*1000.*(2.*PHIDF-DMEM)-2000.*DMM
      IF (FLEX .LT. 0.) ASS=1.0E15
      IF (FLEX .GE. 0.) ASS=(E0*PHIDF-DPP*1000.-SQRT(E0*FLEX))/FYPSI
      AREAFL = ASS
C
C     CHECK SIGN OF MOMENT
C
      IF(ZRMMB.GT.0.0) GO TO 2
      IF(DMM.LT.0.0) ZRMMB=DX+TS
```

```
C
C     MINIMUM STEEL
C
    2 AMIN=0.024*TB
      IF (ASS .GT. AMIN) GO TO 65
      ASS=AMIN
C
C     STEEL AREA BASED ON 0.01 INCH CRACK
C
   65 K=RTYPE+0.5
      GO TO (100,200,300)K
  100 C0=1.0
      B2=(0.5*CT(3)**2.*SDATA(9)/NLAY)**(1./3.)
      GO TO 140
  200 C0=1.5
      B2=1.0
      FLAY=CT(3)**2.*SDATA(9)/NLAY
      GO TO 140
  300 C0=1.9
      B2=(0.5*CT(3)**2.*SDATA(9)/NLAY)**(1./3.)
  140 CONTINUE
      E=ABS(M0/N0)+DD(I)-DMEM/2.
      AJ=0.74+0.1*E/DD(I)
      IF (AJ .GT. .9) AJ=0.9
      AP=1./(1.-AJ*DD(I)/E)
      IF (E/DD(I) .LT. 1.15) GO TO 13
    7 CONTINUE
      R2=(M0+N0*(DD(I)-DMEM/2.))/AJ/AP
      R1=C0*12.*DMEM**2.*SQRT(FCPPSI)
      AREA01=(R2-R1)*B2/30000./PHIDF/FCR
      IF (C01 .EQ. 1) GO TO 9
      IF (FLAY .LT. 3) GO TO 11
      C01=1.
      C0=1.9
      B2=(0.5*FLAY)**(1./3.)
      ARE012=AREA01
      GO TO 7
    9 IF (ARE012 .GT. AREA01) AREA01=ARE012
   11 CONTINUE
      IF (ASS .EQ. 0.) ASS= -1.
      CRACK=AREA01/ASS
      IF (CRACK .LE. 1) GO TO 13
      ASS= AREA01
   13 CONTINUE
            ASNEW=0.
            SLS=23.4
            SIGN=+1.
            IF (DDP .EQ. 0.) DDP=0.001
            E=ABS(DMP/DDP)+DD(I)-DMEM/2.
            AJ=0.74+0.1*E/DD(I)
            IF (AJ .GT. 0.9 ) AJ=0.9
            AP=1./(1.-AJ*DD(I)/E)
```

```
 8112       FMIN=(SIGN*DMP+DDP*(DD(I)-0.5*DMEM))/
     1           (ASS*AJ*AP*DD(I))
            FF=SLS-0.33*FMIN
            IF (FF .LT. 0.0) THEN
                ASS=(SLS-FF)/0.33*ASS/FMIN+.001
                ASNEW=ASS
                GO TO 8112
            END IF
            SMOM= DMW
            STHRST= -1.*DPW
            IF (STHRST .EQ. 0.) STHRST=0.001
            E=ABS(SMOM/STHRST)+DD(I)-DMEM/2.
            AJ=0.74+0.1*E/DD(I)
            IF (AJ .GT. 0.9 ) AJ=0.9
            AP=1./(1.-AJ*DD(I)/E)
            FFLS=(SMOM-STHRST*(DD(I)-0.5*DMEM))/
     1           (ASS*AJ*AP*DD(I))
            IF(FFLS .GT. FF) THEN
                 ASNEW=FFLS*ASS/FF
                 ASS=ASNEW
            ENDIF
C
      IF (ASS .LE. AS(11)) GO TO 60
      DIST2=XX(I+1)
   60 CONTINUE
C
C
      IF (DIST2 .EQ. 5000.) GO TO 240
      IF (DIST2 .LE. (TS/2.+CHHB)) DIST2=TS/2.+CHHB
      IDIST2= INT(DIST2+TS/2.+0.5+TENSPN)
      IF (IPRNT .NE. 1.AND.IPP.EQ.1) WRITE(III,350) IDIST2
      IF (IPRNT .NE. 1.AND.IPP.EQ.1) WRITE(III,448)
  353 GO TO 355
C
C
  240 IF (IPRNT .NE. 1.AND.IPP.EQ.1) WRITE(III,440)
      IF (IPRNT .NE. 1.AND.IPP.EQ.1) WRITE(III,448)
      DIST2=5000.
  355        CONTINUE
             IF(ZRMMT.EQ.0.0.OR.ZRMMT.GT.SPAN/2.0+TS-24.0) THEN
      IF(IPRNT .NE. 1.AND.IPP.EQ.1) THEN
      WRITE(III,352)
      GO TO 354
      ENDIF
      ELSE
      IF(IPRNT .NE. 1.AND.IPP.EQ.1) WRITE(III,351) ZRMMT
      ENDIF
  354 IF(ZRMMB.EQ.0.0.OR.ZRMMB.GT.SPAN/2.0+TS-24.0) THEN
      IF(IPRNT .NE. 1.AND.IPP.EQ.1) THEN
      WRITE(III,442)
      GO TO 443
      ENDIF
```

```
      ELSE
      IF(IPRNT .NE. 1.AND.IPP.EQ.1) WRITE(III,441) ZRMMB
      ENDIF
  443 RETURN
C
C
  350 FORMAT(/,12X,'2  SIDEWALL OUTSIDE FACE STEEL (AS1) IS BENT'
     1,' AT THE CULVERT',/,15X,'CORNERS AND EXTENDED  ',I3,' INCHES FRO'
     2,'M THE BEND POINT INTO THE',/15X,
     3'BOTTOM SLAB.  THE BOTTOM OUTSIDE FACE STEEL (AS8) MUST LAP THE',
     4/,15X,'AS1 STEEL IN ACCORDANCE WITH AASHTO PROVISIONS.')
C
C
  351 FORMAT(/,12X,'4  THERE MAY BE NEGATIVE MOMENT FROM THE OUTSIDE COR
     1NER',/,15X,'OF THE BOX TO',F5.0,' INCHES ACROSS THE TOP SLAB.')
C
  441 FORMAT(/,12X,'5  THERE MAY BE NEGATIVE MOMENT FROM THE OUTSIDE COR
     1NER',/,15X,'OF THE BOX TO',F5.0,' INCHES ACROSS THE BOTTOM SLAB.')
C
  352 FORMAT(/,12X,'4  NEGATIVE MOMENT MAY EXIST IN THE ENTIRE TOP SLAB'
     1)
C
  442 FORMAT(/,12X,'5  NEGATIVE MOMENT MAY EXIST IN THE ENTIRE BOTTOM SL
     1AB')
C
C
  440 FORMAT(/,12X,'2  BOTTOM SLAB OUTSIDE FACE STEEL (AS8) MUST'
     1,' EXTEND COMPLETELY',/,15X,'ACROSS THE BOTTOM SLAB. THE SIDEWALL'
     2,' OUTSIDE FACE STEEL (AS1)',/,15X,
     3'MUST BE BENT AT THE CORNER AND EXTENDED ACROSS THE BOTTOM SLAB',
     4/,15X,'SUFFICIENTLY TO MEET AASHTO REQUIREMENTS FOR TENSION'
     5,' LAPS.')
C
C
  448 FORMAT(/,12X,'3  ASMIN = 0.002 x GROSS SECTION AREA')
 1000 RETURN
      END
```

Subroutine: OUTPUT

Function:

This subroutine prints the design summary sheet.

I/O Generated By Subroutine:

A design summary table is printed listing all the important design parameters for the box section. Output table includes installation data, loading data, material properties, concrete data, and reinforcing steel data.

Error Messages Generated:

None

```
      SUBROUTINE OUTPUT
C
C    ORGANIZES AND PRINTS OUT A ONE CELL BOX DESIGN SUMMARY SHEET.
C    THE PRINT OUT INCLUDES THE FOLLOWING:
C      INSTALLATION DATA
C      LOADING DATA
C      MATERIAL PROPERTIES
C      CONCRETE DATA
C      REINFORCING STEEL DATA
C    THE OUTPUT IS AVAILABLE WITH ALL IDBUG VALUES.
C
      REAL JLOAD(12,40),MULT
      CHARACTER*4 Z2(8)
      CHARACTER*10 MEMBDS(40)
      COMMON /IFLAGS/ IBDATA(35),ISDATA(35),ICON(40)
      COMMON /ISCALE/NIT,NOLD,IDBUG,IR,IW,ITAPE,IPATH,ICYC,NINT
      COMMON/ISCALE/NLD,LTYPE,NSDES,ISUR,NSTRES
      COMMON/RSCALE/BDATA(35),SDATA(35)
      COMMON/RSCAL2/QFAC,RES,NTJD,HHT,HHB,HVT,HVB,FLLN,FLLMV
      COMMON/RSCAL2/HRT(4),DSHDL(4),TST
      COMMON/RSCAL3/SWDTH,VMAG,RLEN,RWID,SURV,SURHT,SURHB,AS5D,
     1              AS6D,AS5SP,AS6SP,CHHT,CHVT,CHHB,CHVB
      COMMON/RSCAL4/ITDIR
      COMMON/RSCAL5/ASBMAX,Z2,DSTEST(40),MEMBDS
      COMMON/ANAL/JLOAD,STIF(12,12),FIXMO(4,40,4),DM(40),DV(40),DP(40),
     1 AS(40),SRATIO(40)
      COMMON/SHRM2/TENSPN
      COMMON/PRN/ IPP,IDBG,III
      COMMON/FACT/ FLLMVP,FLLNP
      EQUIVALENCE (SPAN,BDATA(1))
      DIMENSION STAB(8,1),ISB(5)
      CHARACTER*4 STIRR(2),STAB2(8,1)
      CHARACTER*25 CLOAD,REINT(3)
      CHARACTER*13 CLOADIR
      DATA STIRR  /' NO ','*YES' /
      DATA ISB/3,1,4,2,5/
      DATA REINT/'             SMOOTH WIRE',
     1          'SMOOTH WELDED WIRE FABRIC',
     2          '      DEFORMED WIRE OR BAR'/
      IRTYPE=INT(BDATA(27))
      DLIMIT=ABS(DLIMIT)
      T=1.0E-06
      C=12.
      D=1.728E6
      OSPAN=BDATA(1)/C+T
      ORISE=BDATA(2)/C+T
      OH=BDATA(10)/C+T
      OGAMAS=BDATA(7)*D+T
      OZETA=BDATA(14)
      ALPHA = (1+SDATA(25))*BDATA(14)
      IF ( IBDATA(14).EQ.2) OZETA=0.
```

```
C
C     COMPUTE GOVERNING STEEL AREAS
C

      TOPIN=AS(12)
      SIDEIN=AS(13)
      BOTTIN=AS(14)
      TOPOUT=AS(1)
      SIDEOUT=AMAX1(AS(2),AS(3),AS(4),AS(5),AS(6),AS(7),AS(8))
      BOTTOUT=AS(11)

C
C     DISTRIBUTION STEEL
C
C
      SPRM=(BDATA(1)-2.*(CHHT+0.5*HHT))/12.
C
C
      MULT=(1 /SQRT(SPRM))
      IF(MULT .GT. 0.5) MULT=0.5
      IF(ITDIR .EQ. 0) MULT=2.2/(SQRT(SPRM))
      IF(MULT .GT. 0.67) MULT=0.67
C
C
      DISTIN=MULT*TOPIN
      DISTOUT=0.15*AS(12)
      IF(DISTOUT .LT. 0.125) DISTOUT=0.125
      IF(DISTOUT .LT. 0.024*BDATA(3)) DISTOUT=0.024*BDATA(3)
      IF(DISTIN .LT. 0.125) DISTIN=0.125
      IF(DISTIN .LT. 0.024*BDATA(3)) DISTIN=0.024*BDATA(3)
      STAB(1,1)=SIDEOUT
      STAB(2,1)=TOPIN
      STAB(3,1)=SIDEIN
      STAB(4,1)=TOPOUT
      STAB(5,1)=DISTIN
      STAB(6,1)=DISTOUT
      STAB(7,1)=BOTTIN
      STAB(8,1)=BOTTOUT
C
C
C     DETERMINE TYPE OF LIVELOAD
C
      GO TO (201,202,203,204,205),LTYPE
  201 CLOAD='                      NONE'
      GO TO 206
  202 CLOAD='                     OTHER'
      GO TO 206
  203 CLOAD='                AASHTO HS-'
      GO TO 206
  204 CLOAD='    AASHTO INTERSTATE/HS-'
      GO TO 206
  205 CLOAD='                 COOPER E-'
```

```
  206 CONTINUE
      CLOADIR='   TRANSVERSE'
      IF(ITDIR .EQ. 0) CLOADIR='     PARALLEL'
C
C
      STAB2(2,1)= STIRR(MAX0(ISDATA(14),ISDATA(18),ISDATA(26))+ 1 )
      STAB2(4,1)= STAB2(2,1)
      STAB2(7,1)= STIRR(MAX0(ISDATA(17),ISDATA(21),ISDATA(29))+1)
      STAB2(8,1)= STAB2(7,1)
      STAB2(1,1)= STIRR(MAX0(ISDATA(15),ISDATA(19),ISDATA(27),
     1 ISDATA(28),ISDATA(20),ISDATA(16))+1)
      STAB2(3,1)= STAB2(1,1)
C
      IF(IPP.EQ.1) WRITE(III,1)  OSPAN,ORISE
C
      IF(IPP.EQ.1) WRITE(III,4)
      IF(IPP.EQ.1) WRITE(III,97)
      IF(IPP.EQ.1) WRITE(III,5) OH,OGAMAS,OZETA,ALPHA,BDATA(15)
C
      IF(IPP.EQ.1) WRITE(III,6)
      IF(IPP.EQ.1) WRITE(III,97)
      IF (CLOAD .NE. '                   AASHTO HS-' .AND.
     1 CLOAD .NE. '                   COOPER E-'.AND.CLOAD.NE.
     2'    AASHTO INTERSTATE/HS-') THEN
      IF(IPP.EQ.1) THEN
      WRITE(III,7) BDATA(22),BDATA(23),FLLMVP,FLLNP,BDATA(9),
     1BDATA(13),BDATA(24),CLOAD,CLOADIR,VMAG,RLEN,RWID
      ENDIF
      ENDIF
C
      IF (CLOAD .EQ. '                   AASHTO HS-' .OR.
     1 CLOAD .EQ. '                   COOPER E-'.OR.CLOAD.EQ.
     2'    AASHTO INTERSTATE/HS-') THEN
      IF(IPP.EQ.1) THEN
      WRITE(III,83) BDATA(22),BDATA(23),FLLMVP,FLLNP,BDATA(9),BDATA(13),
     1BDATA(24),CLOAD,VMAG,CLOADIR
      ENDIF
      ENDIF
      IF(IPP.EQ.1) WRITE(III,103) SURV*1000.,SURHT*1000.,SURHB*1000.
C
      IF(IPP.EQ.1) WRITE(III,2)
      IF(IPP.EQ.1) WRITE(III,97)
      IF(IPP.EQ.1) WRITE(III,3) BDATA(20),BDATA(21),REINT(IRTYPE)
C
      IF(IPP.EQ.1) WRITE(III,8)
      IF(IPP.EQ.1) WRITE(III,97)
      IF (HHT .EQ. HHB .AND. HVT .EQ. HVB) THEN
      IF(IPP.EQ.1) THEN
      WRITE(III,190) BDATA(3),BDATA(5),BDATA(4),HHT,HVT,BDATA(30),
     1BDATA(31),BDATA(32),BDATA(33),BDATA(35),BDATA(34)
      ENDIF
      ENDIF
```

```
C
      IF (HHT .NE. HHB .OR. HVT .NE. HVB) THEN
      IF(IPP.EQ.1) THEN
      WRITE(III,192)BDATA(3),BDATA(5),BDATA(4),HHT,HHB,HVT,HVB,BDATA(30)
     1,BDATA(31),BDATA(32),BDATA(33),BDATA(35),BDATA(34)
      ENDIF
      ENDIF
C
      IF(IPP.NE.1) III=6
      WRITE(6,1212)
 1212 FORMAT(////////////////////////)
      WRITE(III,10)
      WRITE(III,97)
      WRITE(III,11)
      WRITE(III,180) STAB(1,1),STAB2(1,1),STAB(2,1)
     1,STAB2(2,1),STAB(7,1),STAB2(7,1),STAB(3,1),STAB2(3,1),STAB(4,1)
     2,STAB2(4,1),STAB(8,1),STAB2(8,1)
      IF(OH .LT. 2) WRITE(III,81) STAB(5,1),STAB(6,1)

C
      CALL ZEROMOM(IDIST1,IDIST2,TENSPN,2)
C
C
C..... F O R M A T S
C
   97 FORMAT(5X,72('-'))
C.....
    1 FORMAT(1H1,/////,26X,'BOX CULVERT DESIGN SUMMARY SHEET',/,
     1 25X,F5.2,' FT. SPAN X ',F5.2,' FT. RISE',/,5X,72('*'))
C.....
    4 FORMAT( /,5X,'I N S T A L L A T I O N   D A T A')
C.....
    5 FORMAT(7X,'HEIGHT OF FILL OVER CULVERT,FT',28X,F12.3,/,
     1 7X,'SOIL UNIT WEIGHT, PCF',37X,F12.3,/,
     2 7X,'MINIMUM LATERAL SOIL PRESSURE COEFFICIENT',17X,F12.3,/,
     3 7X,'MAXIMUM LATERAL SOIL PRESSURE COEFFICIENT',17X,F12.3,/,
     4 7X,'SOIL - STRUCTURE INTERACTION COEFFICIENT',18X,F12.3 )
C.....
    6 FORMAT( /,5X,'L O A D I N G   D A T A')
C.....
    7 FORMAT(7X,'DEAD LOAD FACTOR - MOMENT AND SHEAR',23X,F12.3,/,
     1 7X,'DEAD LOAD FACTOR - THRUST',33X,F12.3,/,
     2 7X,'LIVE LOAD FACTOR - MOMENT AND SHEAR',23X,F12.3,/,
     3 7X,'LIVE LOAD FACTOR - THRUST',33X,F12.3,/,
     4 7X,'STRENGTH REDUCTION FACTOR-FLEXURE',25X,F12.3,/,
     5 7X,'STRENGTH REDUCTION FACTOR-DIAGONAL TENSION',16X,F12.3,/,
     6 7X,'LIMITING CRACK WIDTH FACTOR',31X,F12.3,/,
     7 7X,'LIVE LOAD TYPE',31X,A25,/,
     8 7X,'DIRECTION OF VEHICLE TRAVEL RELATIVE',/,
     9 7X,'TO CULVERT FLOW',42X,A13,/,
     $ 7X,'TOTAL APPLIED LIVE LOAD, KIPS',29X,F12.3,/,
     $ 7X,'LIVE LOAD DISTRIBUTION TRANSVERSE TO FLOW, INCHES',9X,F12.3,/,
```

```
     $ 7X,'LIVE LOAD DISTRIBUTION PARALLEL TO FLOW, INCHES',11X,F12.3)
C.....
   83 FORMAT(7X,'DEAD LOAD FACTOR - MOMENT AND SHEAR',23X,F12.3,/,
     1 7X,'DEAD LOAD FACTOR - THRUST',33X,F12.3,/,
     2 7X,'LIVE LOAD FACTOR - MOMENT AND SHEAR',23X,F12.3,/,
     3 7X,'LIVE LOAD FACTOR - THRUST',33X,F12.3,/,
     4 7X,'STRENGTH REDUCTION FACTOR-FLEXURE',25X,F12.3,/,
     5 7X,'STRENGTH REDUCTION FACTOR-DIAGONAL TENSION',16X,F12.3,/,
     6 7X,'LIMITING CRACK WIDTH FACTOR',31X,F12.3,/,
     7 7X,'LIVE LOAD TYPE',28X,A25,F3.0,/,
     8 7X,'DIRECTION OF VEHICLE TRAVEL RELATIVE',/,
     9 7X,'TO CULVERT FLOW',42X,A13)
C.....
  103 FORMAT(7X,'VERTICAL SURCHARGE PRESSURE, PSF',26X,F12.1,/,
     1 7X,'HORIZ. SURCHARGE PRESSURE AT CULVERT TOP, PSF',13X,F12.1,/,
     2 7X,'HORIZ. SURCHARGE PRESSURE AT CULVERT BOTTOM, PSF',10X,F12.1)
C.....
    2 FORMAT( /,5X,'M A T E R I A L   P R O P E R T I E S')
C.....
    3 FORMAT(7X,'MINIMUM SPECIFIED REINFORCING YIELD STRENGTH, KSI',9X,
     1 F12.3/7X,'CONCRETE - SPECIFIED COMPRESSIVE STRENGTH, KSI',
     2 12X,F12.3,/,
     3 7X,'REINFORCING TYPE',29X,A25)
C.....
C.....
    8 FORMAT( /,5X,'G E O M E T R Y')
C.....
  190 FORMAT(7X,'TOP SLAB THICKNESS, INCHES',32X,F12.3,/,
     2 7X, 'SIDE WALL THICKNESS, INCHES',31X,F12.3,/,
     3 7X,'BOTTOM SLAB THICKNESS, INCHES',29X,F12.3,/,
     4 7X,'HORIZONTAL HAUNCH DIMENSION, INCHES',23X,F12.3,/,
     5 7X,'VERTICAL HAUNCH DIMENSION, INCHES',25X,F12.3,/,
     6 7X,'CONCRETE COVER OVER STEEL, INCHES ',25X,/,
     7 11X,'TOP SLAB - OUTSIDE FACE',31X,F12.3,/,
     8 11X,'SIDE WALL - OUTSIDE FACE',30X,F12.3,/,
     9 11X,'BOTTOM SLAB - OUTSIDE FACE',28X,F12.3,/,
     1 11X,'TOP SLAB - INSIDE FACE',32X,F12.3,/,
     2 11X,'SIDE WALL - INSIDE FACE',31X,F12.3,/,
     3 11X,'BOTTOM SLAB - INSIDE FACE',29X,F12.3,/)
C.....
  192 FORMAT(7X,'TOP SLAB THICKNESS, INCHES',32X,F12.3,/,
     2 7X, 'SIDE WALL THICKNESS, INCHES',31X,F12.3,/,
     3 7X,'BOTTOM SLAB THICKNESS, INCHES',29X,F12.3,/,
     4 7X,'HORIZONTAL HAUNCH DIMENSION, INCHES  TOP',F10.3,
     5    '    BOTTOM',F10.3,/,
     6 7X,'VERTICAL HAUNCH DIMENSION, INCHES    TOP',F10.3,
     7    '    BOTTOM',F10.3,/,
     8 7X,'CONCRETE COVER OVER STEEL, INCHES ',25X,/,
     9 11X,'TOP SLAB - OUTSIDE FACE',31X,F12.3,/,
     1 11X,'SIDE WALL - OUTSIDE FACE',30X,F12.3,/,
     2 11X,'BOTTOM SLAB - OUTSIDE FACE',28X,F12.3,/,
     3 11X,'TOP SLAB - INSIDE FACE',32X,F12.3,/,
```

```
     4 11X,'SIDE WALL - INSIDE FACE',31X,F12.3,/,
     5 11X,'BOTTOM SLAB - INSIDE FACE',29X,F12.3,/)
C.....
   10 FORMAT('1',/,5X,'R E I N F O R C I N G   S T E E L   D A T A')
C.....
   11 FORMAT(7X,43X,'AREA',19X,/,7X,12X,'LOCATION',22X,'SQ. IN.',6X,
     1'STIRRUPS',/,7X,42X,'PER FT',7X,'REQUIRED?',/,7X,70(1H-)  )
C.....
   12 FORMAT(6X,'TRANSVERSE',/,
     3 7X,'     SIDE WALL    - OUTSIDE FACE (As1)',6X,F5.3,10X,A4,/,
     1 7X,'     TOP SLAB     - INSIDE  FACE (As2)',6X,F5.3,10X,A4,/,
     4 7X,'     SIDE WALL    - INSIDE  FACE (As4)',6X,F5.3,10X,A4,/,
     2 7X,'     TOP SLAB     - OUTSIDE FACE (As7)',6X,F5.3,10X,A4,/)
C.....
  180 FORMAT(6X,'TRANSVERSE',/,
     1 7X,'     SIDE WALL    - OUTSIDE FACE (As1)',6X,F5.3,10X,A4,/,
     2 7X,'     TOP SLAB     - INSIDE  FACE (As2)',6X,F5.3,10X,A4,/,
     5 7X,'     BOTTOM SLAB - INSIDE  FACE (As3)',6X,F5.3,10X,A4,/,
     3 7X,'     SIDE WALL    - INSIDE  FACE (As4)',6X,F5.3,10X,A4,/,
     4 7X,'     TOP SLAB     - OUTSIDE FACE (As7)',6X,F5.3,10X,A4,/,
     6 7X,'     BOTTOM SLAB - OUTSIDE FACE (As8)',6X,F5.3,10X,A4,/)
   81 FORMAT( 6X,'DISTRIBUTION',/,
     6 7X,'     TOP SLAB     - INSIDE  FACE (As5)',6X,F5.3,/,
     7 7X,'     TOP SLAB     - OUTSIDE FACE (As6)',6X,F5.3,/,
     8 7X,70('-'))
C.....
   13 FORMAT(7X,'    *PROGRAM ASSIGNED VALUE',//,
     1 7X,'THE SIDE WALL OUTSIDE FACE STEEL IS BENT AT THE CULVERT CORNE
     2RS AND',/,7X,'EXTENDED INTO THE OUTSIDE FACE OF THE TOP AND BOTTOM
     3 SLABS.  THE',/,7X, 'THEORETICAL CUT-OFF LENGTHS MEASURED FROM',
     4 ' THE BEND POINT ARE',F5.1,/,7X,'AND',F5.1,' IN. RESPECTIVELY. ',
     6 'ANCHORAGE LENGTHS MUST BE ADDED.','1','1')
C.....
      RETURN
      END
$DEBUG
C
C
```

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APPENDIX A

INPUT PARAMETERS FOR BOXCAR

Screen No.	Description	Units	Default Value
1	Inside Span	ft	None
	Inside Rise	ft	None
	Depth of Fill	ft	None
2	Top Slab Thickness	in.	T (Note 1)
	Bottom Slab Thickness	in.	T (Note 1)
	Sidewall Thickness	in.	T (Note 1)
	Horizontal Haunch Length	in.	T (Note 1)
	Vertical Haunch Length	in.	T (Note 1)
2	Concrete Covers		
	Top - Outside	in.	Note 2
	Bottom - Outside	in.	1.5
	Side - Outside	in.	1.5
	Top - Inside	in.	1.5
	Bottom - Inside	in.	1.5
	Side - Inside	in.	1.5
3	Main Reinforcing Yield Stress	ksi	60
	Main Reinforcing Type (Note 3)	None	3
	No. of Layers	None	1
	Design Concrete Strength	ksi	4
	Concrete Density	pcf	150
3	Dead Load Factor (Shear and Moment)	None	1.5
	Dead Load Factor (Thrust)	None	1.0
	Live Load Factor (Shear and Moment)	None	2.17
	Live Load Factor (Thrust)	None	1.0
	Shear Capacity Reduction Factor	None	0.85
	Flexure Capacity Reduction Factor	None	0.90
4	Transverse Steel Wire Diameters		
	Top - Outside	in.	.08T (Note 1)
	Bottom - Outside	in.	.08T (Note 1)
	Side - Outside	in.	.08T (Note 1)
	Top - Inside	in.	.08T (Note 1)
	Bottom - Inside	in.	.08T (Note 1)
	Side - Inside	in.	.08T (Note 1)

APPENDIX A (continued)

INPUT PARAMETERS FOR BOXCAR

Screen No.	Description	Units	Default Value
5	Transverse Wire Spacing		
	Top - Outside	in.	8
	Bottom - Outside	in.	8
	Side - Outside	in.	8
	Top - Inside	in.	8
	Bottom - Inside	in.	8
	Side - Inside	in.	8
6	Soil Density	pcf	120
	Minimum Lateral Pressure Coefficient	None	0.25
	Maximum Lateral Pressure Coefficient	None	0.5
	Soil Structure Interaction Factor	None	1.0
6	Live Load Data Options:		
	HS-Series	None	HS-20
	Interstate (Also checks HS-20)		
	Cooper E-Series		
	Other (User Specified)		
	None		
6T	HS-Series Live Load Magnitude	tons	20
	Direction of Travel Options:		
	Transverse to Culvert Flow	None	Transverse
	Parallel to Culvert Flow		
6C	Cooper E-Series Live Load Magnitude	kips	80
6M	User Specified Live Load Magnitude	kips	0
	Effective Width of Resistance	in.	0
	Effective Length of Resistance	in.	0
7	Surcharge Loads		
	Uniform Vertical Load	psf	0
	Lateral Load - Top of Culvert	psf	0
	Lateral Load - Bottom of Culvert	psf	0
	Application Code Options:		
	Permanent		Additional
	Additional		
	Live Load		
7	Depth of Fluid	ft	Inside Rise
	Fluid Density	pcf	62.5

APPENDIX A (continued)

INPUT PARAMETERS FOR BOXCAR

NOTES:

1. For span $\leq$ 7.0 ft: T = span (in.)/12 +1
   For span > 7.0 ft: T = span (in.)/12 +0

2. For depths of fill < 2 top outside cover equals 2 in.
   For depths of fill > 2 top outside cover equals 1.5 in.

3. 1 - smooth reinforcing with longitudinals spaced greater than 8 in.
   2 - smooth reinforcing with longitudinals spaced less than or equal to 8 in.
   3 - deformed reinforcing or any reinforcing type with stirrups

APPENDIX B

REINFORCED CONCRETE DESIGN METHOD

This Appendix presents the reinforced concrete design methodology used in BOXCAR. It is presented as extracts from the AASHTO (Reference 5) and AREA (Reference 6) design specifications as appropriate. Some sections are taken from AASHTO Section 17.4.6 for the direct design of reinforced concrete pipe; however, past research (References 1 and 4) has shown these equations to be applicable to box sections also. All equations meet or exceed the requirements of AASHTO.

Equations and Section numbers refer to AASHTO.

B.1 Ultimate Strength Flexure Design

Reinforcement for flexural strength (Section 17.4.6.4.1)

$$A_s f_y = g\phi_f d - N_u - \sqrt{g[g(\phi_f d)^2 - N_u(2\phi_f d - h) - 2M_u]} \qquad (17\text{-}9)$$

where $g = 0.85\ bf'_c$

See Reference 4 for the derivation of Eq. 17-9.

Minimum flexural reinforcing

$$As_{min} = .002bh$$

Maximum flexural reinforcing limited by concrete compression (Section 17.4.6.4.3.2)

$$A_{s\ max}\cdot f_y = \left[\frac{5.5 \times 10^4 g\phi_f}{(87{,}000 + f_y)}\right] - 0.75N_u \qquad (17\text{-}14)$$

where:

$$g = bf'_c\left[0.85 - 0.05\ \frac{(f'_c - 4{,}000)}{1{,}000}\right]$$

$g_{max} = 0.85bf'_c$ and $g_{min} = 0.65\ bf'_c$

B.2 Service Load Flexural Requirements

Crack Width Control (Servcie Load Design) Section 17.4.6.4.4

$$F_{cr} = \frac{B_1}{30{,}000 \ \phi_f d A_s} \left[\frac{M_s + N_s\left(d - \frac{h}{2}\right)}{ij} - C_1 b h^2 \sqrt{f'c} \right] \quad (17\text{-}15)$$

where

F_{cr}	=	crack control factor, see Note c;
M_s	=	bending moment, service load;
N_s	=	thrust (positive when compressive). service load;
j	=	0.74 + 0.1 e/d;
j_{max}	=	0.9;
i	=	$\frac{1}{1 - \frac{jd}{e}}$
e	=	$\frac{M}{N} + d - \frac{h}{2}$
e/d_{min}	=	1.15;
s	=	spacing of circumferential reinforcment in inches;
t_b	=	clear cover over reinforcement in inches;
h	=	wall thickness of pipe in inches;
B_1 and C_1	=	crack control coefficients dependent on type of reinforcement used as follows:

Type Reinforcement:	B_1 (in.)	C_1 $\left(\frac{lb.}{in.^2}\right)$
1. Smooth wire or plain bars	$\sqrt[3]{\frac{0.5\ t_b^2 s}{n}}$	1.0
2. Welded smooth wire fabric. 8 inches maximum spacing of longitundials	$\sqrt[3]{\frac{0.5\ t_b^2 s}{n}}$	1.5

	B_1	C_1
3. Welded deformed wire fabric, deformed wire, deformed bars or any reinforcement with stirrups anchored thereto.	$\sqrt[3]{\frac{0.5t^2_b s}{n}}$	1.9

Notes:

a. Use n = 1 when the inner and the outer cages are each a single layer. Use n = 2 where the inner and the outer cages are each made up from multiple layers.

b. For type 2 reinforcement having $(t_b{}^2 s)/n > 3.0$. also check for F_{cr} using coefficients B^1 and C_1 for type 3 reinforcement, and use larger value for F_{cr}.

c. When F_c = 1.0 the reinforcement area, A_s, will produce an average maximum crack width of 0.01 inch. For F_{cr} values less than 1.0 the probability of a 0.01 inch crack is reduced, and for larger values, cracks greater than 0.01 inch may occur.

d. Higher values for C_1 may be used if substantiated by test data and approved by the Engineer.

Fatigue Stress Limits (Section 8.16.8.3

The range between a maximum tensile stress and minimum stress is straight reinforced caused by live load plus impact at service load shall not exceed:

$$f_f = 21 - 0.33\, f_{min} + 8(r/h) \qquad (8\text{-}60)$$

where:

f_f = stress range in kips per square inch;

f_{min} = Algebraic minimum stress level, tension position, compression negative in kips per square inch;

r/h = ratio of base radius to height of rolled-on transverse deformations; when the actual value is not known, use 0.3

BOXCAR computes f_{min} as the service load stress due to permanent dead loads and takes r/h as 0.3

B.3 Shear Strength Requirements

Method 1 Shear (Section 8.16.6.2.1)

$$V_c = 2\phi_v \sqrt{f'c} \quad b_w d \qquad (8\text{-}49)$$

For culverts subjected to highway loads (not railroad loads) BOXCAR considers AASHTO Section 8.16.6.7.

$$V_c = 3\phi_v \sqrt{f'c} \quad b_w d$$

BOXCAR only considers the provision of 8.16.6.7 if the live load is uniformly distributed over the entire top slab

Method 2 Shear

Method 2 shear design is taken from AASHTO 17.4.6.4.5, but modified for application to any M/Vd ratio. See References 1 and 4.

The area of reinforcement, A_S, must be checked for shear strength adequacy, so that the shear strength, V_C, is greater than the factored shear force, V_U, at the design location.

$$V_c = b\phi_v d F_{vp} \sqrt{f'c}(1.1+63\,\rho)\left[\frac{F_d}{F_c F_n}\right]\left[\frac{4}{1+M/V\phi_v d}\right] \qquad (17\text{-}16)$$

where

V_C = shear strength of section

F_{VP} = 1.0 unless a higher value substantiated by test data is approved by the Engineer:

$$\rho = \frac{A_s}{bd} \; ; \; \rho_{max} = 0.02$$

$f'_{c\,max}$ = 7,000 psi

(+) tension on the inside of the pipe
(-) tension on the outside of the pipe

$$F_d = 0.8 + \frac{1.6}{\phi_v d}$$

$$F_N = 1.0\text{-}0.12\,\frac{N_u}{V_u} \; ; \; F_{N\,min} = 0.75$$

$$V_{c\,max} \leq \frac{4.5\sqrt{f'_c}\;\phi_v bd}{F_N}$$

APPENDIX C

DIFFERENCES IN ANALYSIS BETWEEN BOXCAR AND THE PROGRAMS THAT GENERATED ASTM STANDARD DESIGNS

The purpose of this appendix is to set forth the known differences in the methods of analysis and design of box sections between the current version of BOXCAR and the programs that generated the standard designs in ASTM C 789 (called C 789 herein) and C 850 (called C 850 herein).

C.1 Loads

BOXCAR uses several assumptions about the distribution of live loads that result in lower culvert live loads than calculated by the original C 789 and C 850 design programs.

Truck Tire Footprint - The AASHTO Standard Specifications for Highway Bridges (called AASHTO herein) Section 3.30 specifies that tire contact should be taken as 100 psi (contact area equals 0.01 times P) and will have a direction of traffic/width of tire ratio of 1/2.5. For a 16,000 pound HS-20 wheel this results in a contact area of 160 sq in. distributed over a rectangle of 8 in. by 20 in.

In our work we have found that virtually all trucks have maximum tire pressures of about 80 psi and can only be overloaded by increasing the contact area or adding extra axles; thus, it is impossible to overload a truck without increasing the area over which the overload is distributed. To account for this, BOXCAR increases the tire footprint by the beta factor (live load factor/dead load factor). For a beta factor of 1.67 this results in a truck tire print of 13.4 in. by 20 in. BOXCAR considers the live load applied through a tire footprint at all depths of cover.

The original C 789 program for culverts with two feet or more fill assumed that live loads were applied as point loads. The original C 850 program for culverts with 2 ft or less fill assumed that live loads were distributed over 8 in. in the direction of traffic and over (4 + 0.06 span) ft transverse to traffic. BOXCAR distributes live loads over (4 + .06 span + 1.75h) ft transverse to traffic.

Lane Width/Multiple Lane Considerations - AASHTO does not contain specific provisions to reflect the low probability of fully overloaded trucks being in adjacent lanes over a box culvert. It does contain provision for this in the design of multiple lane bridges by providing lane load reduction factors that are based on the number of lanes.

BOXCAR does not have the number of lanes as an input parameter; however, it does provide for a reduction in load intensity for multiple lane roads by considering two load conditions:

A. A fully overloaded AASHTO truck over the culvert with no trucks in adjacent lanes.

B. AASHTO trucks that are not overloaded (beta = 1.0) centered in four 12 ft wide lanes.

Condition A governs the ultimate design for depths of fill up to about 10 ft. Condition B governs the service load at all depths and the ultimate design for depths greater than about 10 ft. As stated in the user manual, BOXCAR considers live loads to be acting at all depths of cover unless the user specifies no live load. The above conditions are handled internally in BOXCAR without the user separately specifying the gamma and beta factors. The beta factor is computed as the ratio of the live and dead load factors.

The original C 789 program considered fully overloaded trucks centered in multiple 10 ft wide lanes.

C.2 Reinforcing Design

Axial Thrust - BOXCAR considers the beneficial effect of axial compression on a member when designing flexural reinforcing. The original C 789 program also considered thrust; however, when determining the magnitude of the thrust force, the C 789 program only considered the forces due to the permanent dead load cases. BOXCAR considers the thrust due to all load cases that contribute to the design moment. This results in an increase in the sidewall thrust, and a reduction in the required steel area for the sidewall outside face.

Flexural Strength Reduction (Phi) Factor - The original C 789 and C 850 design programs used a variable phi factor for flexure in accordance with ACI practice for members under combined loading. BOXCAR uses a constant phi factor for flexural design in accordance with current AASHTO practice for box sections.

Flexural Design Equation - The flexure design equation used in the original C 789 and C 850 programs applies the axial thrust at the mid depth of the member. The equation incorporated into BOXCAR applies the thrust at d/2 from the compression face of the member. The derivation of this equation is presented in BOXCAR Reference 5. The equation used in BOXCAR is AASHTO Eq. 17-9.

Fatigue - The original C 789 program for box sections with more than 2 ft of cover did not consider the provisions contained in AASHTO for fatigue. The original C 850 program for box sections did consider these provisions. BOXCAR considers the AASHTO fatigue provisions at all depths of fill where such provisions are applicable.

C.3 Shear Strength

The original design tables of C 789 terminated at a depth where shear strength was exceeded. Since that time, the AASHTO Bridge Specification has been modified to allow a 50 percent increase in the shear strength of slabs. The new criteria is incorporated in BOXCAR. BOXCAR also checks shear strength based on the $M/V\phi d$ ratio. See the User Manual Section 2.2.3 and Appendix B for more details.