AUTOMATED DESIGN OF PRESTRESSED CONCRETE BOX GIRDERS

Harry L. Jones, Mike E. James and Terry W. Cline

Texas Transportation Institute
Texas A&M University
College Station, Texas 77843

Texas State Department of Highways and Public Transportation; Transportation Planning Division
P. O. Box 5051
Austin, Texas 78763

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Three computer programs have been developed or adapted to assist in the design of multi-beam prestressed concrete box girder bridges. Programs DBOXS5S and DBOXDS treat girders with straight and draped strands, respectively. Each program has a "design" option which selects concrete release strength and strand pattern for a specified cross section and 28-day concrete strength to minimize the total number of strands used. The programs also contain an "optimization" option which determines release and 28-day concrete strengths and strand pattern that minimize the total cost of the girder. An analysis program AMBB has also been developed to compute lateral load distribution factors for the members of a multi-beam bridge. Specifications governing the designs produced are from the American Association of State Highway and Transportation Officials, 1973 Bridge Specification and 1974 and 1975 Interim Specification.

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by

Harry L. Jones
Assistant Research Engineer

Mike E. James
Assistant Research Engineer

Terry W. Cline
Research Assistant

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PREFACE

This report consists of six Chapters and four Appendices. For those interested in the underlying mathematical formulations, Chapters II and III develop the design of straight and draped strand beams as mathematical programming problems. For those interested in how to use the straight and draped strand design computer programs, complete input instructions and output interpretation are presented in Chapters IV and V. Each of these two Chapters is self-contained and can be understood without referring to other sections of the report. Chapter VI is concerned with the analysis of multi-beam bridges, and deals primarily with instructions on the use of a computer program. This Chapter is also independent of others in the report. The Appendices deal with program documentation. Should the user wish to modify the programs, he will find subroutine descriptions, variable definitions and flow charts in Appendices B, C and D. Appendix E contains a listing of each program as it existed at the time of this report.

The equations required for problem formulation are extensive, since they are developed in their entirety. For clarity, highlighters (solid arrows) have been attached to those equations in the text which are the end result of manipulating preceding equations or which are especially significant.

Recently the Texas Highway Department (THD) became a part of the Texas Department of Highways and Public Transportation (TDHPT). References in the test to THD pertain to this latter organization.
ABSTRACT

Three computer programs have been developed or adapted to assist in the design of multi-beam prestressed concrete box girder bridges. Programs DBOXSS and DBOXDS treat girders with straight and draped strands, respectively. Each program has a "design" option which selects concrete release strength and strand pattern for a specified cross section and 28-day concrete strength to minimize the total number of strands used. The programs also contain an "optimization" option which determines release and 28-day concrete strengths and strand pattern that minimize the total cost of the girder. An analysis program AMBB has also been developed to compute lateral load distribution factors for the members of a multi-beam bridge. Specifications governing the designs produced are from the American Association of State Highway and Transportation Officials, 1973 Bridge Specification and 1974 and 1975 Interim Specification.

DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration. This report does not constitute a standard, specification or regulation.
SUMMARY

This report presents formulations for the automated design and analysis of multi-beam prestressed concrete box girder bridges and documentation of the computer programs implementing these formulations. Simple span box girders of specified cross sectional dimensions are considered. Computer programs DBOXSS and DBOXDS treat girders containing straight and draped strands, respectively. The design variables determined by the programs include the number of strands in each strand row, concrete release and 28-day strengths and stirrup spacing. For straight strand designs, the extent and location of bond breakage is determined and for draped strand designs, the end eccentricity of the strands are computed. Each program has a "design" option which, for a specified 28-day strength, determines the strand pattern and release strength which minimizes the total number of strands used. An "optimization" option is also available with each program which determines release and 28-day concrete strengths and strand patterns that minimizes the total cost of the girder, based on the costs of concrete and strands supplied by the user.

Specifications governing design are those of the American Association of State Highway and Transportation Officials, 1973 Bridge Specifications and 1974 and 1975 Interim Specifications. Design restrictions include limits on release and service load stresses, upper and lower bounds on camber at release, ultimate and cracking moment capacities and maximum and minimum concrete strengths.

An existing computer program for the rigorous analysis of multi-beam bridges has been modified to compute lateral distribution factors for maximum moment for individual beams in a multi-beam bridge. Standard
AASHTO truck and lane loadings as well as arbitrary multi-axle vehicles can be treated by the program AMBB.

All programs have standard, simplified input forms and concise output formats. The computer core requirements for the programs in source form are 170,000 bytes for DBOXDS, 264,000 for DBOXSS and 294,000 for AMBB.
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RECOMMENDATION FOR IMPLEMENTATION

These computer programs are available to assist the bridge designer in carrying out the routine calculations associated with his job. In addition, their optimization options automatically produce the optimum design under a rather restricted set of conditions. Because of the rapidity with which proposed designs can be processed, these programs will permit designers to explore a wider range of possible solutions to a design problem. The programs should be equally useful for routine designs utilizing standardized cross sections as well as to explore new concepts for possible future standardization.
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I. INTRODUCTION

The simple span multi-beam prestressed concrete box girder bridge is a special use structure which may be the most economical selection when traffic disruptions, limited clearance, or other unusual conditions exist. This type of bridge construction consists of a number of box girders (not necessarily of identical cross sectional dimensions) laid side by side across the bridge bents. Lateral continuity between the girders is established by placing a concrete key (Figure 1) and transverse post tensioning at one or more points along the span. The bridge is usually completed with the addition of an asphalt wearing surface.

The design of this type of bridge requires the selection of cross sectional dimensions of the box girder(s) to be used, the release and 28 day strengths of the concrete, the number and placement details of the pre-stressing strands, the spacing of stirrups and designation of other conventional reinforcing details. A number of "standard" box shapes have been established by various states, including Texas, and fabricators in those states usually have considerable capital invested in steel forms and other hardware peculiar to the standard beams used in highway construction there. Thus, it is generally necessary for the designer to utilize standard box girder dimensions (with the possible exceptions of box width or void size) in order to gain maximum economy. Therefore, the question of what cross sectional dimensions to use for a particular design has not been addressed in the research efforts reported herein. Likewise, the design of conventional reinforcing details (with the exception of stirrups)
FIGURE 1. CROSS SECTION OF TYPICAL MULTI-BEAM PRESTRESSED CONCRETE BOX GIRDER BRIDGE

FIGURE 2. NOTATION FOR DESCRIPTION OF BOND BREAKAGE ON PRESTRESSED STRANDS
has been omitted from consideration due to the difficulty of insuring that all necessary reinforcing can be fitted into a particular box design and fabrication still be feasible. While the design items listed above that were omitted from consideration are by no means unimportant, those items which remain lend themselves to an automated (computer designed) approach.

Two distinct types of prestressing cable arrangements are commonly used in box girders. The first incorporates straight cables, which may have bond breakage near the ends of the beam to control stresses and camber. The second utilizes draped cables, in combination with straight cables, to attain the same controls. The latter arrangement rarely uses bond breakage unless end splitting problems are encountered during fabrication. When bond breakage is used to alleviate end splitting, it generally only extends over a few feet adjacent to the ends of the beam. Two automated design computer programs were developed in this study to treat the two types of cable layouts. The first has been given the name DBOXSS (Design of Box girders with Straight Strands) and the other DBOXDS (Design of Box girders with Draped Strands). Each of these programs has two options available to the designer. The "optimization" option automatically selects the minimum cost design, based on the costs of concrete and prestressing strands used. If the designer wishes to exert more control over the design or does not have at hand the unit cost information required by the optimization option, he may select the "design" option which computes a design based on the minimum number of strands that can be used. The underlying mathematical formulations used in both the optimization and design options are taken from the theories of linear and integer programming. Chapters II and III of this report present a brief description of the mathematical structure
of these optimization formulations and develops the design of straight and draped strand box beams in these formats. The input to the programs has been simplified through the use of standard input forms. A description of program input and interpretation of output is contained in Chapters IV and V for DBOXSS and DBOXDS, respectively. Also presented there are several example problems to assist the designer in understanding the use of the programs.

The design programs produce a design for a single box girder from a complete bridge. The fraction of the total load carried by the bridge which is assigned to the box girder under consideration is determined automatically by the current (1974 Interim) AASHTO Specification provision covering lateral load distribution in multi-beam bridges. This provision is empirical and the limits of its applicability can be examined in the research reports on which the provision is based. Situations frequently arise where the use of this means of determining lateral load distribution is questionable. To assist the designer in such cases, this study has adapted a third computer program AMBB (Analysis of Multi-Beam Bridges) which carries out a rigorous analysis of a multi-beam bridge and determines the fraction of total bridge live loads carried by each beam. The designer may thus choose to exercise this program first to obtain the lateral load distribution factors for beams in a proposed bridge and input them to the appropriate design program. This analysis program can also compute forces acting on the joints between beams which may be of assistance in designing concrete keys and transverse post tensioning. The program has a simplified standard input form which is described in Chapter VI, together with interpretation of program output and several example problems.
II. Design of Box Girders with Straight Strands

The design of prestressed concrete girders with straight strands can be cast as a linear, constrained optimization problem in which the design variables are concrete strengths and prestressing strand layout, and the constraints are restrictions on structural behavior outlined below. Once the design problem has been cast in this format, standard computational procedures are available for its solution (1)*. The general form of the linear, constrained optimization problem (Linear Programming problem or LP problem) is:

\[
\begin{align*}
\text{minimize} & \quad c_1 x_1 + c_2 x_2 + \cdots + c_n x_n \quad (1) \\
\text{subject to:} & \quad a_{11} x_1 + a_{12} x_2 + \cdots + a_{1n} x_n \leq b_1 \\
& \quad \vdots \\
& \quad a_{m1} x_1 + a_{m2} x_2 + \cdots + a_{mn} x_n \leq b_m \\
& \quad x_1, x_2, \ldots, x_n \geq 0.
\end{align*}
\]

where \(x_1, \ldots, x_n\) are the variables, Eq. (1) the objective function and Eq. (2) the constraint set. This chapter is devoted to formulating the beam design problem in the mathematical form given above.

2.1 Design Considerations

The arrangement of prestressing strands in a beam have a direct effect on the stresses at release and under service loads and on camber of the beam. The position of strands in the beam and the extent of bond breakage (also referred to as "wrapping") can be described by a doubly subscripted variable \(N_{ij}\) for the general case shown in Figure 2. Here,

* Numerals in parenthesis refer to entries in the Reference section of this report.
wrapping is assumed to occur in lengths which are integer multiples of \( L/40 \), up to a maximum length of \( L/4 \). Wrapping is assumed to terminate just to the left of one of the 11 wrapping points. \( N_{ij} \) is defined as the number of bonded strands present in strand row \( i \), at wrapping point \( j \). In Figure 2, if the row shown in plain view were number 2, then

\[
\begin{align*}
NS_{2,1} &= NS_{2,2} = NS_{2,3} = 8 \\
NS_{2,4} &= NS_{2,5} = NS_{2,6} = 4 \\
NS_{2,7} &= NS_{2,8} = NS_{2,9} = 2 \\
NS_{2,10} &= NS_{2,11} = 0.
\end{align*}
\]

The wrapping of strands reduces the prestress induced stresses toward the end of the beam, where load induced stresses to offset them are small. The total stress at the top and bottom of the beam (taking tension stress as positive) at release at a wrapping point can be written as

\[
\begin{align}
\sigma_j^{(T)} &= (1 - \xi)F_o \sum_{i=1}^{NR} \left( \frac{1}{A} + \frac{d_i}{Z_t} \right) NS_{i,j} - \frac{M_j}{Z_t} \quad (3) \\
\sigma_j^{(B)} &= (1 - \xi)F_o \sum_{i=1}^{NR} \left( \frac{1}{A} - \frac{d_i}{Z_b} \right) NS_{i,j} + \frac{M_j}{Z_b} \quad (4)
\end{align}
\]

where

- \( NR \) = number of rows which can contain strands,
- \( F_o \) = force in a single prestress strand prior to release,
- \( \xi \) = fraction of initial prestress force lost immediately after release,
- \( A \) = cross sectional area of the box girder,
- \( d_i \) = distance from the c.g. axis of the beam to strand row \( i \) (positive if row \( i \) above c.g. of beam),
- \( Z_t \) & \( Z_b \) = section modulii of beam (both positive quantities),
- \( M_j \) = bending moment at point \( j \) due to beam weight.
Stresses at any location between quarter points can be obtained by setting subscript \( j = 1 \) and replacing \( M_j \) with the moment at that location. Equations (3) and (4) ignore the effect of strand development length. The cross sectional properties \( A \) and \( Z \) include the transformed area of conventional compression reinforcing in the top of the beam, if present. The stresses existing under service load conditions can be computed from

\[
\sigma_j^{(T)} = (1 - \eta) \frac{F_o \sum_{i=1}^{NR} \left( \frac{1}{A} + \frac{d_i}{Z_t} \right) \left( NS_{i,j} - \frac{M_j}{Z_t} - \frac{M_j}{Z_t} \right)}{1 - \eta}
\]

(5)

\[
\sigma_j^{(B)} = (1 - \eta) \frac{F_o \sum_{i=1}^{NR} \left( \frac{1}{A} - \frac{d_i}{Z_b} \right) \left( NS_{i,j} + \frac{M_j}{Z_b} + \frac{M_j}{Z_b} \right)}{1 - \eta}
\]

(6)

where

\( \eta \) = fraction of initial prestress force lost under service load conditions,

\( Z_t \) & \( Z_b \) = section modulii of beam plus shear key,

\( M_j \) = moment at point \( j \) due to beam and shear key weight

\( \bar{M}_j \) = total live and dead load moment acting on the composite section (i.e., with shear key) at point \( j \).

Stresses at any section between quarter points \(( j = 1 \) can be obtained from Eqs. (3) thru (6) by setting subscript \( j = 1 \) and substituting the moments acting at that section for \( M_j \) and \( \bar{M}_j \).

Camber control is an important consideration in the design of prestressed concrete box girders. If the beam camber is upward upon release, there is a tendency for the camber to increase with time due to creep and shrinkage effects in the concrete and because of the absence of significant additional dead load such as a deck slab. A downward camber on release may tend to become more downward with time. Although long term camber is the quantity the
designer seeks to control, its accurate computation is difficult. Generally accepted analytical means for its computation (2, 3) require a knowledge of the creep and shrinkage properties of the concrete, which in turn depend on the materials and mix design used as well as curing conditions. In the absence of accurate creep and shrinkage data, many designers rely on cambers computed at release as a guide to insuring satisfactory long term behavior. The release camber can be computed from previously defined quantities (see Figure 3) by

\[
\Delta = \Delta_{DL} - \frac{1}{E_{ci}} \left\{ (1 - \xi) F_0 \sum_{j=1}^{11} h_j \delta_j y_j \right\} 
\]

(7)

where

\[
h_j = \sum_{i=1}^{NR} d_i \cdot N_{Si,j}
\]

(8)

\[
y_j = \begin{cases} 
3L/8 & ; j=1 \\
(11 - j) \frac{L}{40} + \frac{L}{80} & ; j=2, \ldots, 11 
\end{cases}
\]

(9)

\[
\delta_j = \begin{cases} 
L/4 & ; j=1 \\
L/40 & ; j=2, \ldots, 11 
\end{cases}
\]

and

\[
\Delta = \text{midspan camber (positive upward),}
\]

\[
\Delta_{DL} = \text{midspan deflection due to beam weight (positive upward),}
\]

\[
E_{ci} = \text{modulus of elasticity of concrete at release.}
\]

In addition to satisfactory behavior under release and service load conditions, a box girder must have adequate ultimate moment capacity. The current AASHTO Specification (4) requires that the computed ultimate moment capacity of a section \(M_u\) be not less than \(M_{ur}\), where

\[
M_{ur} = 1.30 \left\{ M_{DL} + \frac{5}{3}(I \cdot M_{LL}) \right\}
\]

(10)
FIGURE 3. PRESTRESS INDUCED MOMENT DIAGRAM FOR CALCULATION OF RELEASE CAMBER IN BEAMS WITH STRAIGHT STRANDS

FIGURE 4. STRAIN PROFILE AND RESULTANT FORCES AT ULTIMATE MOMENT
$$M_{LL} = \text{maximum live load moment},$$
$$M_{DL} = \text{dead load moment},$$
$$I = \frac{50}{(L+125)}, \text{the impact factor},$$
$$L = \text{span length (ft)}.$$

The method of computing ultimate moment capacity at midspan depends upon the location of the neutral axis in the cross section. If the neutral axis falls within the deck slab (Figure 4), then $M_u$ is given by (4),

$$M_u = A* f* d \left\{ 1.0 - 0.6 \frac{P*f*}{f_c} \right\}$$

(11)

where

$$f*_{su} = f'_s \left[ 1.0 - 0.5 \frac{P*f'}{f_c} \right]$$

(12)

and

$$f*_{su} = \text{average stress in the prestressing strands at ultimate},$$
$$A*_{s} = \text{total area of prestressing steel},$$
$$f'_s = \text{ultimate strength of strand},$$
$$f'_c = \text{compressive strength of concrete},$$
$$P* = A*_{s}/bd,$$
$$b, d = \text{(See Figure 4)}.$$

This computation neglects the contribution of the compression steel to moment capacity and is justified on the basis of the proximity of the compression reinforcing to the neutral axis when the latter lies in the deck slab. When the neutral axis lies below the slab, as indicated in Figure 4, then a trial and error approach is required to determine $M_u$. For a prescribed location of the neutral axis (the dimension c), the total compressive force in the concrete $C$ is computed from
where $A_c$ is the area between the neutral axis and the top of the section and $\overline{d}$ is the location of the c.g. of this area. Equalibrium of horizontal forces requires that

$$C' + C = T$$

(14)

The force $C'$ is the force in the compression steel, given by

$$C' = \begin{cases} 
\varepsilon_s' E_s A' ; & \varepsilon_s' \leq \text{yield strain} \\
\sigma_s A' ; & \varepsilon_s' > \text{yield strain}
\end{cases}$$

(15)

The force in the tendons at ultimate is

$$T = f_{su} A$$

(16)

where $f_{su}$ is the average tendon stress, determined from the stress-strain characteristics of the tendon material, which can be approximated by (5)

$$\varepsilon_{su} = \begin{cases} 
\frac{f_{su}}{E_s} ; & f_{su} \leq f_{pl} \\
\frac{a_1 [a_2 - a_3 f_{su} (f_s' - f_{su})]}{a_1 a_2 f_{pl}} ; & f_{su} > f_{pl}
\end{cases}$$

(17)

where

- $\varepsilon_{su} =$ average strain in the prestress strands,
- $f_{pl} =$ proportional limit stress of strand material,
- $E_s =$ modulus of strand material,
- $a_1 = f_{pl}/E_s$
- $a_2 = 1 + (f_s' - f_{pl})/(f_s' - 2f_{pl})$
- $a_3 = f_{pl} (f_s' - f_{pl})^2/(f_s' - 2f_{pl})$
If the total tensile force $T$ exceeds the total compression $(C + C')$, then the neutral axis depth $c$ is too small. If $(C + C')$ exceeds $T$, then the correct $c$ value is less than that assumed. Once the proper $c$ has been obtained, the ultimate moment capacity can be computed from

$$M_u = C'(d - d') + C(d - d')$$  \hfill (18)

The average compressive stress over the concrete compression zone $(\frac{833f'_c}{C})$, and the stress-strain relationship for the tendon (Eq. (17)) were derived on the condition that Eqs. (11) and (18) give the same moment capacity when $A'_s = 0$ and the neutral axis is located in the deck slab (5).

It will later prove useful to have a relationship between the strand pattern in a box girder and its ultimate moment capacity. Let

$$\rho = -\sum_{i=1}^{NR} d_i \cdot N_{S_i},$$  \hfill (19)

define a positive parameter (the $d_i$ are normally negative quantities) which is a measure of the total available strand force eccentricity. For a specified concrete strength $f'_c$, the ultimate moment capacity of a section $M_u$ can be plotted against the parameter $\rho$, as shown schematically in Figure 5. For a specified required ultimate moment capacity $M_{ur}$, a minimum value of the strand force eccentricity $\bar{\rho}$ exists for each concrete strength. The plot of $\bar{\rho}$ vs. $f'_c$, shown in Figure 6, provides a convenient means of insuring that the final strand pattern and 28 day concrete strength selected will yield an adequate ultimate moment capacity.

Current prestress concrete design practice recognizes the importance of adequate warning of impending failure in an overloaded structural member. A natural means of achieving this end is to insure that signifi-
FIGURE 5. ULTIMATE MOMENT CAPACITY VS. TOTAL STRAND FORCE ECCENTRICITY

FIGURE 6. REQUIRED TOTAL STRAND FORCE ECCENTRICITY VS. 20 DAY CONCRETE STRENGTH
cant flexural cracking of the section occurs prior to failure. Thus, the AASHTO Specification (4) requires that

\[ M_u \geq 1.2 \cdot M_{cr} \]  

(20)

where \( M_{cr} \) is the moment required to produce a tensile stress at the bottom of the section equal to the modulus of rupture strength of the concrete.

The net prestress force in a strand at release and under service load conditions is dependent on the loss factors \( \xi \) and \( n \) (Eqs. 3 thru 6). The AASHTO Specification (6) provides a method of long term prestress loss calculation which includes all factors currently thought to have a significant effect. The loss may be written as

\[ \eta = \frac{[SH + ES + CR_c + CR_s]}{f_e} \]  

(21)

where

- \( f_e \) = stress in strand immediately after initial tensioning (ksi),
- \( SH \) = loss due to concrete shrinkage (ksi),
- \( ES \) = loss due to elastic shortening (ksi),
- \( CR_c \) = loss due to creep of concrete (ksi),
- \( CR_s \) = loss due to relaxation of prestressing strand (ksi).

The four components of prestress loss are computed from

\[ SH = 17.0 - 0.15RH \]  

(22)

\[ ES = E_s f_{cir}/E_{ci} \]  

(23)

\[ CR_c = 12 f_{cir} - 7 f_{cfs} \]  

(24)

\[ CR_s = 20 - 0.4ES - 0.2(SH + CR_c) \]  

(25)

where

- \( RH \) = average annual relative humidity in percent,
- \( E_s \) = modulus of elasticity of prestress strand,
\[ E_{ci} = \text{modulus of elasticity of concrete at time of strand release,} \]

\[ f_{cir} = \text{concrete stress at c.g. of strands due to prestress force immediately after release and beam weight. The stress is computed at the point of maximum moment.} \]

\[ f_{cds} = \text{concrete stress at c.g. of strands due to all dead loads except those present at release (i.e., beam weight).} \]

The prestress loss immediately after release can be estimated from

\[ \xi = \frac{[ES + 0.5CR_s]}{f_e} \quad (26) \]

The fraction of the total live load on a multi-beam bridge that is carried by a single box girder must be determined prior to design. In the absence of a rigorous analysis, the AASHTO Specification (8) suggests the following empirical estimate:

\[ \frac{S}{D} = \text{fraction of axle load carried by the girder} \quad (27) \]

where

\[ S = 0.5(12N_L + 9)/N_g \quad (28) \]

\[ D = \begin{cases} 
5 + N_L/10 + (3-2N_L/7)(1-C/3)^2 & ; \ C \leq 3 \\
5 + N_L/10 & ; \ C > 3 
\end{cases} \quad (29) \]

and

\[ N_L = \text{total number of traffic lanes,} \]
\[ N_g = \text{number of longitudinal beams,} \]
\[ C = K(W/L), \text{a stiffness parameter,} \]
\[ K = 1. \text{for box sections,} \]
\[ W = \text{overall bridge width,} \]
\[ L = \text{span length.} \]

A rigorous analysis for multi-beam bridges has been developed by Ghose and Powell (9) and programmed by Ghose. The method is based on Fourier series expansion representations of applied loads and individual beam
responses and compatibility of displacements at the juncture of adjacent beams. The computer program has been obtained from the authors and modified so that lateral distribution factors for each box girder in a bridge are automatically computed for AASHTO truck and lane loads and for an arbitrary axle train configuration. The designer may use this program to determine lateral load distribution factors in lieu of those computed from Eq. (27). The details of the program's use are contained in Chapter VI.

Stirrup requirements are computed from current AASHTO Specification provisions (4). The stirrup spacing $s_j$ at the $j$th tenth point is given by

$$s_j = 2A_v f_{sy} J d_j / (V_U - V_c)$$

(30)

where

$$V_c(j) = 0.06 f'_c b_{j} d_j \leq 180 b'_d_j$$

(31)

$$V_U(j) = \frac{1.30}{\phi} \left\{ V_{DL}(j) + \frac{5}{3} V_{LL}(j) \right\}$$

(32)

and

$$s_j = \text{stirrup spacing at } i\text{th tenth point},$$
$$A_v = \text{area of stirrup},$$
$$f_{sy} = \text{yield strength of stirrups},$$
$$b' = \text{total width of beam web},$$
$$d_j = \text{distance from c.g. of strands to top of section at } i\text{th tenth point},$$
$$J = \text{fraction of } d_j \text{ which gives the distance from the center of compression to the c.g. of strands; taken as 0.9},$$
$$V_{DL}(j) = \text{total dead load shear at } j\text{th tenth point},$$
$$V_{LL}(j) = \text{total live load shear at } j\text{th tenth point},$$
\( \phi = \text{strength factor, taken as 0.9,} \)

\[
I = \frac{50}{L + 125}, \quad \text{the impact factor,}
\]

\( L = \text{span length (ft).} \)

The "best" prestressed concrete beam (whose structural behavior is satisfactory) is the one with the lowest bid price. Bid price is influenced by some factors over which the designer has control and by others which he can not control. The latter category includes differences in pricing procedures among fabricators and little correlation between the geographical location of a bridge and the fabricator who produces the beams for it. However, despite the uncontrollable nature of some factors, it is believed that the cost model developed below provides a means of ranking beams according to expected bid price.

The final cost of a beam is assumed to consist of the cost of concrete, cost of strand and cost of strand wrapping. The cost of concrete is primarily a function of release strength. Higher release strengths require some additional materials (cement, admixtures, etc.) but the principle cause for increased cost is the additional curing time needed. This trend is evident from the results of a survey of producers of highway beams in the state of Texas. Four responses to the questionnaire shown in Appendix A were received. The questionnaire asked the fabricator to list the in-place cost of concrete with release strengths ranging from 4.0 to 8.0 ksi, assuming that the cost of 4.0 ksi release strength concrete is $1.00/cu.yd. This method of cost presentation was used in an attempt to circumvent fabricators' natural reluctance to divulging actual cost information. Concrete cost is plotted against release strength in Figure 7 for the four responses received.
FIGURE 7. RELATIVE CONCRETE COST VS. RELEASE STRENGTH FOR FOUR TEXAS FABRICATORS
Costs associated with prestressing strands consists of the cost of materials and cost of placing strands and wrapping them. The reported in-place cost of 1/2 in. diameter grade 270K 7 wire strand ranged from $0.20 to $0.25 per foot. Unfortunately, no cost figures on strand wrapping were sought in the questionnaire. Additional consideration is given to determining cost figures for design in Chapter IV.

Although the release strength $f'_{ci}$ and 28-day strength $f'_c$ of beam concrete frequently are treated as independent parameters in design, fabrication practices indicate a strong correlation between the two quantities. Most fabricators have a relatively small number of mix designs which are used to cover the usual range of required strengths. For a specific mix design, the release strength may vary considerably, depending on the method and length of time of curing, but the 28-day strength attained is largely independent of these factors. Thus, if one specifies a release strength of 6.0 ksi, and a 28-day strength of 6.5 ksi, he may actually get an $f'_c$ of 7.0 ksi, depending on the fabricator involved. Thus, the design does not take full advantage of the concrete strength available under service load conditions. For a particular fabricator, one can generally construct a plot of $f'_{ci}$ vs. $f'_c$ whose general form will follow that shown in Figure 8.

2.2 STRAIGHT STRAND DESIGN FORMULATION - OPTIMIZATION OPTION

In this section the problem of determining the concrete release and 28-day strengths and strand pattern layout which minimizes the total cost of a box girder is formulated as a linear programming problem whose mathematical structure was given in Eqs. (1) and (2). The notation used here differs slightly from Eqs. (1) and (2) in that the design variables $x_1, \ldots, x_n$
FIGURE 8. HYPOTHETICAL 28 - DAY RELEASE STRENGTH RELATIONSHIP
are represented by symbols defined in the preceding section in order to more clearly preserve the physical significance of the equations.

Before proceeding to the formulation of the objective function and constraints, additional notation must be introduced. Let the concrete release strength $f_{ci}'$ be given by:

$$f_{ci}' = 4.0 + \sum_{i=1}^{10} f_i$$  \hspace{1cm} (33)

where $f_1, \ldots, f_{10}$ are design variables whose values satisfy the inequalities:

$$0 \leq f_i \leq 0.5 \hspace{1cm} i=1, \ldots, 10$$ \hspace{1cm} (34)

$$f_{i+1} \leq f_i \hspace{1cm} i=1, \ldots, 9$$ \hspace{1cm} (35)

Note that by this definition, any release strength between 4.0 ksi ($f_1=f_2=\ldots=f_{10}=0$) and 9.0 ksi ($f_1=f_2=\ldots=f_{10}=0.5$) is admissible. For example, a release strength of 5.35 ksi would result if $f_1=f_2=0.5$, $f_3=0.35$, $f_4=f_5=\ldots=f_{10}=0$. A minimum release strength of 4.0 ksi was selected to conform with current AASHTO standards, while an upper limit of 9.0 ksi was selected because it is at the extreme upper limits of concrete strength which fabricators in the state of Texas are able to produce. The expression for $f_{ci}'$ given in Eq. (33) was derived on the basis of a need to maintain linearity in objective function and constraint equations which follow.

2.2.1 Objective Function

The total cost of the box girder is assumed to be the sum of concrete cost $C_c$, strand cost $C_s$ and strand wrapping cost $C_w$. As developed in Section 2.1, the cost of concrete is assumed to be a function of release strength. Let $c_0, c_1, \ldots, c_{10}$ denote the cost of concrete with $f_{ci}' = 4.0, 4.5, \ldots, 9.0$ ksi. Then the cost of one cubic yard of concrete can be written
as
\[ c_0 + 2 \sum_{i=1}^{10} (c_i - c_{i-1})f_i \]  
\[ (36) \]

where \( f_i \) are defined in Eqs. (33) thru (35). Note that Eq. (36) assumes a piecewise linear variation in concrete cost, as shown in Figure 9. The total cost of the concrete is then given by
\[ C_c = \frac{A \cdot L}{3888} \left[ c_0 + 2 \sum_{i=1}^{10} (c_i - c_{i-1})f_i \right] \]  
\[ (37) \]

where \( A \) is the area of the section in square inches and \( L \) is the length of the beam in feet. Note that Eq. (37) neglects additional concrete used in forming interior diaphragms and end closures.

The total number of strands used in the beam is given by \( \sum_{i=1}^{NR} NS_{i,1} \). If \( c_s \) is the cost per foot of strand, the total strand cost is given by
\[ C_s = c_s L \sum_{i=1}^{NR} NS_{i,1} \]  
\[ (38) \]

Taking \( c_w \) as the cost per foot of strand wrapping, the total cost of wrapping strands may be written as
\[ C_w = c_w \left\{ .5L \sum_{i=1}^{NR} NS_{i,1} - \frac{2L}{40} \sum_{j=2}^{11} \sum_{i=1}^{NR} NS_{i,j} \right\} \]  
\[ (39) \]

Thus, the total cost of the beam (objective function) becomes
\[ \text{Minimize} \ (c_s L + .5c_w L) \sum_{i=1}^{NR} NS_{i,1} - \frac{2c_w L}{40} \sum_{j=2}^{11} \sum_{i=1}^{NR} NS_{i,j} \]  
\[ + \frac{A \cdot L}{1944} \sum_{i=1}^{10} (c_i - c_{i-1})f_i + \frac{A \cdot L \cdot c_0}{3888} \]  
\[ (40) \]

Equation (40) is linear in the design variables \( NS_{i,j} \) and \( f_i \) as required by Eq. (1).
FIGURE 9. LINEARIZED REPRESENTATION OF CONCRETE COST VS. RELEASE STRENGTH
2.2.2 Constraints on Release Stresses [Constraints 1 thru 12]

When the strands are released, stresses are produced in the beam by prestress force and the weight of the beam. These stresses are generally tensile at points along the top of the beam and compressive at the bottom. In order to prevent damage to the beam, stresses must be held within certain limits which are a function of the concrete release strength. Generally the stress limits (in ksi) are of the form

\[ \sigma_{tj} = 0.031623S_{tj} \sqrt{f'_{ci}} \quad (f'_{ci} \text{ in ksi}) \]  

(41)

\[ \sigma_{cj} = S_{cj} f'_{ci} \]  

(42)

where \( S_{tj} \) and \( S_{cj} \) are constants, which in general may vary from point to point along the beam (hence the subscript \( j \)). The AASHTO Bridge Specifications (4) currently stipulate that \( S_{tj} = 7.5 \) and \( S_{cj} = 0.6 \). The square root in Eq. (41) causes difficulties since it applies to \( f'_{ci} \) which is a design variable and thus introduces a nonlinearity into the formulation. With little error, Eq. (41) can be written as

\[ \sigma_{tj} = S_{tj} \left\{ 0.007454 f'_{ci} + 0.03355 \right\} \quad (f'_{ci} \text{ and } \sigma_{tj} \text{ in ksi}) \]  

(43)

Equation (43) is obtained from Eq. (41) by replacing \( \sqrt{f'_{ci}} \) with a first order Taylor series expansion about the point \( f'_{ci} = 4.5 \) ksi. The error in this expression is 4.2% at \( f'_{ci} = 8.0 \) ksi, and decreases as \( f'_{ci} \) approaches 4.5 ksi.

Release stresses are checked top and bottom at the end of the beam \((j = 11 \text{ in Figure 2}), L/20 \ (j = 9), 2L/20 \ (j = 7), 3L/20 \ (j = 5), 4L/20 \ (j = 3) \text{ and } L/4 \ (j = 1). \) For points on the top of the beam, tensile stress is limited to \( \sigma_{tj} \) by
\[
\sigma_j^{(T)} - \sigma_{t,j} \leq 0 \quad j=1, 3, \ldots, 11
\]  
(44)

Substituting Eqs. (3) and (43) into (44) gives

\[
(1 - \varepsilon)F_0 \sum_{i=1}^{NR} \left( \frac{1}{A} + \frac{d_i}{Z} \right) N_{S,i,1} - 0.007454 S_{t,j} \sigma_{ci}' \leq \frac{M_j}{Z} + 0.03355 S_{t,j} \quad j=1, 3, \ldots, 11
\]  
(45)

Replacing \( \sigma_{ci}' \) in Eq. (45) with Eq. (33) results in the following linear inequality constraint in the design variables:

\[
(1 - \varepsilon)F_0 \sum_{i=1}^{NR} \left( \frac{1}{A} + \frac{d_i}{Z} \right) N_{S,i,1} - 0.007454 S_{t,j} \sum_{i=1}^{10} f_i \leq \frac{M_j}{Z} + 0.06337 S_{t,j} \quad j=1, 3, \ldots, 11
\]  
(46)

Replacing \( \sigma_{ci}' \) in Eq. (45) with Eq. (33) results in the following linear inequality constraint in the design variables:

\[
(1 - \varepsilon)F_0 \sum_{i=1}^{NR} \left( \frac{1}{A} + \frac{d_i}{Z} \right) N_{S,i,j} - 0.007454 S_{t,j} \sum_{i=1}^{10} f_i \leq \frac{M_j}{Z} + 0.06337 S_{t,j} \quad j=1, 3, \ldots, 11
\]  
(46)

Letting \( j \) in Eq. (46) range over \( 1, 3, 5, \ldots, 11 \) produces 6 constraints which limit release stresses in the top of the beam to the tensile allowable. For points on the bottom of the beam, compression stress is limited to \( \sigma_{c,j} \) by

\[
-\sigma_j^{(B)} - \sigma_{c,j} \leq 0 \quad j=1, 3, \ldots, 11
\]  
(47)

Substituting Eqs. (4), (33) and (42) into (47) yields

\[
-(1 - \varepsilon)F_0 \sum_{i=1}^{NR} \left( \frac{1}{A} + \frac{d_i}{Z} \right) N_{S,i,1} - S_{c,j} \sum_{i=1}^{10} f_i \leq \frac{M_j}{Z} + 4.0 S_{c,j} \quad j = 1, 3, \ldots, 11
\]  
(48)

Six constraints limiting compression stress in the bottom of the beam result from taking \( j=1, 3, \ldots, 11 \).
2.2.3 Constraints on Service Load Stresses [Constraints 13 thru 20]

Let

\[ \bar{\sigma}_{tj} = 0.031623 \, \sqrt{f'_c} \quad (f'_c \text{ in ksi}) \quad (49) \]

\[ \bar{\sigma}_{cj} = \frac{s_{cj}}{s_{tj}} \cdot f'_c \quad (50) \]

denote the allowable tension and compression stresses under service load conditions. Stress checks are made on compression in the top and tension in the bottom of the beam at midspan, 2/10 and 1/10 points, and for tension in the top and compression in the bottom at the end of the beam. Using the Taylor series expansion to eliminate the radical, Eq. (49) becomes

\[ \bar{\sigma}_{tj} = s_{tj} \left\{ 0.007454 f'_c + 0.03355 \right\} \quad (f'_c \text{ and } \bar{\sigma}_{tj} \text{ in ksi}) \quad (51) \]

The 28 day strength \( f'_c \) depends on release strength in a manner depicted in Figure 8. A piecewise continuous linear relationship between \( f'_c \) and \( f'_c \) is given by

\[ f'_c = g_0 + 2 \sum_{i=1}^{10} (g_i - g_{i-1}) f'_i \quad (52) \]

where \( g_0, g_1, \ldots, g_{10} \) are the 28 day strengths which correspond to release strengths of 4.0, 4.5, \ldots, 9.0 ksi (see Figure 10). Substitution of Eq. (52) into Eq. (51) gives

\[ \bar{\sigma}_{tj} = s_{tj} \left\{ 0.007454 [g_0 + 2 \sum_{i=1}^{10} (g_i - g_{i-1}) f'_i] + 0.03355 \right\} \quad (53) \]

Tension stresses in the bottom of the beam are limited by

\[ \frac{\sigma_{(B)}}{\sigma_{tj}} \leq 0 \quad (j=0, 3, 7) \quad (54) \]
FIGURE 10. LINEARIZED REPRESENTATION OF 28 DAY VS. RELEASE STRENGTH
The subscript value \( j = 0 \) denotes midspan of the beam. Substitution of Eqs. (5) and (53) into (54) gives

\[
(1 - \eta)F \sum_{i=1}^{NR} \left( \frac{1}{A} - \frac{d_i}{Z_b} \right) NS_{i,j} - 0.01491S_{tj} \sum_{i=1}^{10} (g_i - g_{i-1})f_i \\
\leq - \frac{M_j}{Z_b} - \frac{\overline{M}_j}{Z_b} + 0.007454S_{tj}g_0 + 0.03355S_{tj} \\
(j=1, 3, 7) \tag{55}
\]

A discrepancy in notation exists between Eqs. (54) and (55). In the former, the subscript \( j \) takes values of 0, 3, 7 while in the latter, \( j = 1, 3, 7 \). The use of \( j = 1 \) indicates that prestress force induced stress is computed with bonded strands at the quarter point (i.e., \( NS_{i,1} \)), which is valid since the number of bonded strands there is the same as that at midspan. The moments \( M_j \) and \( \overline{M}_j \) however, should be replaced with those occurring at midspan when \( j = 1 \).

The tensile stress in the top of the beam at the end is limited to \( \sigma_{t11} \) by

\[
\sigma_{t11} - \sigma_{t11} \leq 0 \tag{56}
\]

Noting that the load induced stresses are zero at the end, Eq. (56) becomes

\[
(1 - \eta)F \sum_{i=1}^{NR} \left( \frac{1}{A} + \frac{d_i}{Z_t} \right) NS_{i,11} - 0.01491S_{t11} \sum_{i=1}^{10} (g_i - g_{i-1})f_i \\
\leq 0.007454S_{t11}g_0 + 0.03355S_{t11} \tag{57}
\]

The compression stress in the top of the beam under service load is limited by

\[
\sigma_j - \sigma_{cj} \leq 0 \quad (j=0, 3, 7) \tag{58}
\]
The allowable compression stress $\bar{\sigma}_{cj}$ is

$$\bar{\sigma}_{cj} = \bar{\sigma}_{cj} f_c'$$

which, after the substitution of Eq. (52) becomes

$$\bar{\sigma}_{cj} = \bar{\sigma}_{cj} \left\{ g_0 + 2 \sum_{i=1}^{10} (g_i - g_{i-1}) f_i \right\}$$

Replacing $\sigma_j^{(T)}$ with Eq. (5) and $\bar{\sigma}_{cj}$ with Eq. (60) yields

$$-(1 - n) F_{o} \sum_{i=1}^{NR} \left\{ \frac{1}{A} + \frac{d_i}{Z_t} \right\} \text{NS}_{i,j} - 2 \sum_{i=1}^{10} (g_i - g_{i-1}) f_i \leq \frac{M_j}{Z_t} - \frac{M_j}{Z_t} + \bar{\sigma}_{cj} g_0 \quad (j=1, 3, 7)$$

As in Eq. (55), when $j=1$, $M_j$ and $M_j$ are taken as the moments at midspan.

The compression stress at the bottom of the beam at its end is limited to $\sigma_C$ by

$$-\sigma_{11}^{(B)} - \sigma_{c11} \leq 0$$

Substituting Eq. (6) for $\sigma_{11}$ and Eq. (60) for $\sigma_{c11}$ and noting that load induced stresses are zero at the end of the beam, gives

$$-(1 - n) F_{o} \sum_{i=1}^{NR} \left\{ \frac{1}{A} - \frac{d_i}{Z_b} \right\} \text{NS}_{i,11} - 2 \sum_{i=1}^{10} (g_i - g_{i-1}) f_i \leq \bar{\sigma}_{c11} g_0$$

2.2.4 Constraints to Insure Proper Strand Wrapping [Constraints 21 thru (20 + 10 \cdot NR)]

Bond breakage is initiated at the end of the beam and proceeds toward the quarter point (see Figure 2). The variables $\text{NS}_{i,j}$ give the number of bonded strands present in the $i$th strand row at point $j$. If
wrapping begins at the end of the beam and terminates just to the left of one of the wrapping points (denoted by \(j\)), then \(NS_{i,j}\) must be greater than or equal to \(NS_{i,j+1}\) for all rows and wrapping points. This requirement is imposed through the \((10 \cdot NR)\) inequality constraints.

\[
\begin{align*}
NS_{i,2} - NS_{i,1} &\leq 0 \\
NS_{i,3} - NS_{i,2} &\leq 0 \\
&\vdots \\
NS_{i,11} - NS_{i,10} &\leq 0 \\
\end{align*}
\]

\(i = 1, 2, \ldots, NR\) \(\ldots\)

2.2.5 Constraints Limiting the Number of Strands in Each Row

[Constraints \((21 + 10 \cdot NR)\) thru \((20 + 11 \cdot NR)\)]

The number of strands that may be placed in a row is limited by the dimensions of the box cross section and the necessity of maintaining adequate clearance between strands and between the strands and the edges of the section. If \(NM_i\) denotes the maximum number of strands that can be placed in row \(i\), then

\[
NS_{i,1} \leq NM_i \quad (i = 1, 2, \ldots, NR) \tag{65}
\]

2.2.6 Constraints to Insure Proper Release Strength Representation

[Constraints \((21 + 11 \cdot NR)\) thru \((39 + 11 \cdot NR)\)]

The concrete release strength representation used in Eq. (33) is valid only if the constraints given in Eqs. (34) and (35) are satisfied. Thus, to obtain a proper problem formulation, the constraint set must include

\[
\begin{align*}
f_i &\leq 0.5 \quad (i = 1, \ldots, 10) \\
f_{i+1} - f_i &\leq 0 \quad (i = 1, \ldots, 9)
\end{align*}
\]

\(\ldots\)

30
2.2.7 Bounds on Initial Beam Camber [Constraints (40 + 11·NR) and (41 + 11·NR)]

Let \( \Delta^+ \) and \( \Delta^- \) denote the maximum and minimum initial midspan deflections admissible in a particular design, with positive deflections taken as upward. If, for example, a designer wished to insure that a beam did not have an upward camber of more than 3.25 in. nor less 0.75 in. (the lower bound perhaps being imposed to insure that the long term camber under the additional weight of wearing surface and shear key was not downward), \( \Delta^+ \) would be 3.25 in. and \( \Delta^- \) would be 0.75 in. The initial camber \( \Delta \) is the sum of the deflections due to prestress and weight of the beam \( (\Delta_{DL}) \). The initial deflection \( \Delta_{DL} \) due to beam weight is

\[
\Delta_{DL} = -22.5 \frac{wL^4}{E_c I} \text{ (in.)} \quad (68)
\]

where

- \( w = \) beam weight (kips/ft),
- \( L = \) span length (ft),
- \( I = \) moment of inertia of beam section (in\(^4\)),
- \( E_c I = \) modulus of elasticity of beam concrete at release (ksi).

Substituting Eq. (68) into Eq. (7) yields the following expression for initial camber

\[
\Delta = \frac{1}{E_c I} \left\{ 22.5 w L^4 - (1 - \xi) F_0 \sum_{o,j=1}^{11} \left[ \sum_{i=1}^{NR} d_i \cdot N_{Si,j} \delta_{j}y_{j} \right] \right\} \quad (69)
\]

where \( y_{j} \) and \( \delta_{j} \) are given by Eq. (9). The upper bound on camber is enforced by

\[
\Delta \leq \Delta^+ \quad (70)
\]

which upon substitution of Eq. (69) and rearrangement becomes

\[
-(1 - \xi) F_0 \sum_{o,j=1}^{11} \left[ \sum_{i=1}^{NR} d_i \cdot N_{Si,j} \right] \delta_{j}y_{j} \leq E_c I \Delta^+ + 22.5 w L^4 \quad (71)
\]
The form of Eq. (71) is not yet acceptable because it involves the modulus of elasticity of the concrete at release, which depends on the release strength \( f_{ci}' \). The modulus of elasticity frequently is assumed to vary with the square root of cylinder strength; i.e.,

\[
E_{ci} = 0.031623K \sqrt{f_{ci}'} \quad (E_{ci} \text{ and } f_{ci}' \text{ in ksi}) \tag{72}
\]

Replacing the radical with a Taylor series expansion and substituting Eq. (33) for \( f_{ci}' \) gives

\[
E_{ci} = K \left\{ 0.007454 \sum_{i=1}^{10} f_i + 0.06337 \right\} \tag{73}
\]

The constant \( K \) depends on the unit weight of the concrete \((10)\) and can be taken as 57,000 for normal weight concrete. Substitution of Eq. (73) into (71) gives the final form of the constraint

\[
-(1 - \xi)F \sum_{j=1}^{11} \left\{ \sum_{i=1}^{NR} d_i \cdot NS_{i,j} \right\} \delta y_j - 0.007454 \Delta K \sum_{i=1}^{10} f_i
\]

\[
\leq 0.06337 K_{1A}^+ + 22.5wL^4 \tag{74}
\]

In a similar fashion, the lower bound constraint is given by

\[
(1 - \xi)F \sum_{j=1}^{11} \left\{ \sum_{i=1}^{NR} d_i \cdot NS_{i,j} \right\} \delta y_j + 0.007454 \Delta K \sum_{i=1}^{10} f_i
\]

\[
\leq 0.06337 K_{1A}^- - 22.5wL^4 \tag{75}
\]

2.2.8 Constraints to Insure Adequate Ultimate Moment Capacity

[Constraint \((42 + 11 \cdot NR)\)]

The computed ultimate moment capacity of the beam \( M_u \) must be greater than or equal to \( M_{ur} \), the required ultimate moment capacity defined in Eq. (10). This requirement can be written as

\[
-M_u \leq -M_{ur} \tag{76}
\]
The ultimate moment capacity \( M_u \) is not linearly related to the strand pattern at midspan (described by the design variables \( NS_{i,1} \)) nor the concrete strength (described by the design variables \( f_i \)). Thus, an indirect method, one which is linear in the design variables, must be used. The device for accomplishing this was developed in Section 2.1 (Eq. 19 and Figures 5 and 6). Figure 6 shows the relation between the parameter \( \bar{\rho} \), which is a measure of total strand force eccentricity, and concrete strength \( f_c' \). Those beams having a midspan strand pattern and concrete strength which yield a moment capacity in excess of \( M_{ur} \) are represented by points that lie above and to the right of the curve shown in Figure 6. Let \( \bar{\rho}_0, \bar{\rho}_1, \ldots, \bar{\rho}_{10} \) be the minimum total strand force eccentricities necessary for \( M_u = M_{ur} \), for 28 day concrete strengths corresponding to release strengths of 4.0, 4.5, ..., 9.0 ksi. The curve shown in Figure 6 can be approximated with the following relation

\[
\bar{\rho} = \bar{\rho}_0 + 2 \sum_{i=1}^{10} (\bar{\rho}_i - \bar{\rho}_{i-1})f_i
\]  

(77)

Note that Eq. (77) defines a piecewise linear approximation to the curve in Figure 6. That is, for \( f_i \) values which give a release strength that is an integer multiple of 0.5 ksi, the value of \( \bar{\rho} \) computed from Eq. (77) lies on the curve. In order to insure that adequate total strand force eccentricity is present, we write

\[
-\rho \leq \bar{\rho}
\]  

(78)

and substituting Eqs. (19) and (77) into (78) we have

\[
\sum_{i=1}^{NR} d_i \cdot NS_{i,1} + 2 \sum_{i=1}^{10} (\bar{\rho}_i - \bar{\rho}_{i-1})f_i \leq \bar{\rho}_0
\]  

(80)

Moving the design variables to the left of the inequality yields the final
The computational procedure for constructing the $\overline{\rho}_i$ in Eq. (80) is straightforward. Beginning with a release strength of 4.0, the corresponding 28 day strength $g_i$ is used to compute moment capacity. Strands are added to the section, 2 at a time, beginning with first (bottom) row and the ultimate moment capacity $M_u$ is computed using Eqs. (11) or (18). If $M_u < M_{ur}$ additional strands are added, progressively filling the first, then the second row, etc., until $M_u > M_{ur}$. The corresponding value of $\rho$ computed with Eq. (19) is then taken as $\overline{\rho}_i$.

2.2.9 Constraint to Insure $M_u \geq 1.2M_{cr}$ [Constraint (43 + 11·NR)]

The cracking moment capacity is defined as that moment which produces a tensile stress of $7.5\sqrt{f_c'}$ ($f_c'$ in psi) at the bottom of the beam (4). Using the strand pattern at midspan, the cracking moment is given by

$$M_{cr} = \sum_{i=1}^{NR} \left\{ -(1 - \eta)F_{0,i} \frac{d_i}{Z_b} + \frac{M_0}{Z_b} \right\} (81)$$

where $M_0 = $ midspan moment due to beam weight and $f_c'$ is in ksi. Once again an indirect approach to formulation of this constraint must be used to avoid introducing nonlinear terms. Figure 11 shows schematically the relationship between the ultimate moment capacity of the section $M_u$, 1.2 times the cracking moment $M_{cr}$ and the total strand force eccentricity (defined in Eq. (19)). For small values of $\rho$, the cracking moment capacity exceeds the ultimate moment capacity. As strands are added, $M_u$ rises more sharply than does $1.2M_{cr}$, and at the point $\rho'$, exceeds $1.2M_{cr}$. Thus, for the
FIGURE 11. CRACKING AND ULTIMATE MOMENTS PLOTTED AGAINST TOTAL STRAND FORCE ECCENTRICITY.

FIGURE 12. MINIMUM REQUIRED STRAND FORCE ECCENTRICITY VS. RELEASE STRENGTH.
particular $f'_c$ under consideration, the requirement that

$$-M_u \leq -1.2M_{cr}$$  \hspace{1cm} (82)$$
can be stated as

$$-\rho \leq -\rho'$$ \hspace{1cm} (83)$$

As $f'_c$ increases, the point of intersection of the $M_u$ and $1.2M_{cr}$ curves generally moves to the right. Figure 12 shows the variation of $\rho'$ with concrete strength. Let $\rho'_0, \rho'_1, \ldots, \rho'_{10}$ denote the minimum total strand force eccentricity necessary for $M_u \geq 1.2M_{cr}$, for 28-day strengths corresponding to release strengths $f'_c$ of 4.0, 4.5, ..., 9.0 ksi. The curve of Figure 12 is approximated with straight line segments by

$$\rho' = \rho'_0 + 2 \sum_{i=1}^{10} (\rho'_i - \rho'_{i-1})f_i$$ \hspace{1cm} (84)$$

Substituting Eqs. (19) and (84) into (83) yields

$$\sum_{i=1}^{NR} d_i \cdot N S_i,1 + 2 \sum_{i=1}^{10} (\rho'_i - \rho'_{i-1})f_i \leq -\rho'_0$$ \hspace{1cm} (85)$$

The computation of $\rho'_i$ can be carried out in a manner analogous to that for $\rho'_i$ in the ultimate moment constraint.

2.2.10 Lower and Upper Bounds on Concrete Strength [Constraints (44 + 11·NR) and (45 + 11·NR)]

If during the computation of the $\rho'_i$ for the ultimate moment capacity constraint, it is found that $M_{ur}$ can not be attained for a particular 28-day strength $g_i$, the release strength corresponding to $g_{i+1}$ must be taken as the minimum permissible release strength. That is,

$$-4.0 - \sum_{i=1}^{10} f_i \leq (f'_c)_{min}$$ \hspace{1cm} (86)$$
If $M_{ur}$ can be obtained for all prescribed 28 day strengths, $(f'_{ci})_{\text{min}}$ is taken as 4.0 ksi.

Release strengths in this formulation are assumed to range up to 9.0 ksi. Should this be greater than the actual release strength that can be obtained, the release strength variables must be bounded from above by

$$4.0 + \sum_{i=1}^{10} f_i \leq (f'_{ci})_{\text{max}}$$

where $(f'_{ci})_{\text{max}}$ is maximum attainable value of $f'_{ci}$.

2.3 STRAIGHT STRAND DESIGN FORMULATION - DESIGN OPTION

Should the designer wish to specify the 28 day strength $f'_{c}$ to be used and obtain the strand pattern and minimum release strength, he may specify the "design" option. For this problem formulation, the design variables are limited to those which define the strand pattern $(N_{si,j})$ and the release strength $f'_{ci}$.

2.3.1 Objective Function

The objective in this case is to minimize the total number of strands, while wrapping strands only where necessary to keep the release strength to a minimum or to control camber. Mathematically, this is equivalent to

$$\text{Minimize } (c_s L + 0.5c_w L) \sum_{i=1}^{NR} N_{si}^{1,1} - \frac{2L_c}{40} \sum_{j=2}^{11} \sum_{i=1}^{NR} N_{si,j}^{11}$$

$$+ c_{c} \cdot \frac{A \cdot L}{1944} f'_{ci}$$

By taking $c_s$, the cost per foot for strand, very large (say, $100.00$), we are assured of obtaining the minimum number of strands. Assigning a
cost of \( c_C \cdot A \cdot L/1944 \) to concrete insures that \( f'_{ci} \) will be as small as possible. We select \( c_C \) such that the total concrete cost will be a small fraction of the strand cost (say, equal to the cost of one strand). Finally, a small cost for wrapping (say \( c_w = \$0.01 \)) insures that strands will be wrapped only where necessary, but will always be used if it results in a lower release strength \( f'_{ci} \).

2.3.2 Constraints on Release Stresses [Constraints 1 thru 12]

Release stress constraints in this case differ from those developed in Section 2.2.2 in the concrete strength variable. Noting that the release strength is given by \( f'_{ci} \), Eq. (45) limits the tension stress at each section \((j=1, 3, \ldots, 11)\) to the allowable tension stress by

\[
(1 - \xi)F_{oi}^{NR} \left\{ \frac{1}{A} + \frac{d_i}{Z_t} \right\} N_{si,j} - 0.007454 S_{tj} f'_{ci} 
\leq \frac{M_i}{Z_t} + 0.03555 S_{tj} \quad (j=1, 3, \ldots, 11) \tag{89}
\]

Compression stress at points on the bottom of the beam are limited to the allowable compression stress through modification of Eq. (48) to obtain

\[
-(1 - \xi)F_{oi}^{NR} \left\{ \frac{1}{A} - \frac{d_i}{Z_b} \right\} N_{si,j} - S_{ci} f'_{ci} 
\leq \frac{M_i}{Z_b} \quad (j=1, 3, \ldots, 11) \tag{90}
\]

2.3.3 Constraints on Service Load Stresses [Constraints 13 thru 20]

The expression for 28-day strength used in Section 2.2.3 is replaced with the specified strength \( f'_{28} \). Tension stresses at the bottom for sections at midspan, \( j = 3 \), and \( j = 7 \) are limited by

\[
(1 - \eta)F_{oi}^{NR} \left\{ \frac{1}{A} - \frac{d_i}{Z_b} \right\} N_{si,j} \leq \frac{M_i}{Z_b} - \frac{M_i}{Z_b} + S_{tj} \sqrt{f'_{28}} 
\leq \frac{\bar{M}_i}{Z_b} + S_{tj} \sqrt{f'_{28}} \quad (j=1, 3, 7) \tag{91}
\]
As before, \(M_j\) and \(\bar{M}_j\) are taken as midspan moments when \(j = 1\).

The tensile stress in the top of the beam at its end is limited by

\[
(1 - \eta)F_0 \sum_{i=1}^{NR} \left[ \frac{1}{A} + \frac{d_i}{Z_t} \right] N_{S_i,1}\mathring{a}_1 \leq \bar{S}_t \mathring{f}'_{28} 
\]

(92)

while the compression stress at the bottom is limited by

\[
-(1 - \eta)F_0 \sum_{i=1}^{NR} \left[ \frac{1}{A} - \frac{d_i}{Z_b} \right] N_{S_i,1} \leq \bar{S}_c \mathring{f}'_{28} 
\]

(93)

Compression stresses in the top of the beam at midspan, \(j = 3\), and \(j = 7\) are limited by

\[
-(1 - \eta)F_0 \sum_{i=1}^{NR} \left[ \frac{1}{A} + \frac{d_i}{Z_t} \right] N_{S_i,j} \leq \bar{S}_c \mathring{f}'_{28} 
\]

(94)

2.3.4 Constraints to Insure Proper Strand Wrapping [Constraints 21 thru (20 + 10·NR)]

The constraint set to insure proper strand wrapping for this formulation is identical to that used in the optimization option and is given by Eq. (64).

2.3.5 Constraints Limiting the Number of Strands in Each Row [Constraints (21 + 10·NR) thru (20 + 11·NR)]

This constraint set is also identical to that defined previously, and is given by Eq. (65).

2.3.6 Bounds on Release Camber [Constraints (21 + 11·NR) and (22 + 11·NR)]

The revised form of these constraints is obtained by substituting the expression for modulus of elasticity at release

\[
E_{ci} = K \{ .007454f'_{ci} + .03355 \} (f'_{ci} & E_{ci} \text{ in ksi})
\]

(95)
into Eq. (71) to obtain

$$\sum_{j=1}^{11} \sum_{i=1}^{\text{NR}} (1 - \xi) F_i \xi \left[ \sum_{i=1}^{\text{NR}} d_i \cdot NS_{i,j} \right] y_j \Delta^+ + 0.007454 K \Delta^+ f_{c_i}$$

and

$$\sum_{j=1}^{11} \sum_{i=1}^{\text{NR}} (1 - \xi) F_i \xi \left[ \sum_{i=1}^{\text{NR}} d_i \cdot NS_{i,j} \right] y_j + 0.007454 K \Delta^- f_{c_i}$$

\[\leq 0.03355 K \Delta^+ + 22.5 w L^4 \] \hspace{1cm} (96)

\[\leq 0.03355 K \Delta^- - 22.5 w L^4 \] \hspace{1cm} (97)

2.3.7 Ultimate Moment Capacity [Constraint (23 + 11\cdot \text{NR})]

Letting $\bar{\rho}$ denote the minimum total strand force eccentricity which provides $M_\mu$ greater than or equal to $M_{ur}$ for the specified 28 day strength $f_{28}$, and altering Eq. (79), we have

$$\sum_{i=1}^{\text{NR}} d_i \cdot NS_{i,11} \leq -\bar{\rho} \hspace{1cm} (98)$$

2.3.8 Cracking Moment Capacity [Constraint (24 + 11\cdot \text{NR})]

Taking $\rho'$ as the minimum total strand force eccentricity which insures that for the concrete strength $f_{28}'$, the ultimate moment capacity is equal to or greater than $1.2 M_{cr}$, gives

$$\sum_{i=1}^{\text{NR}} d_i \cdot NS_{i,11} \leq -\rho' \hspace{1cm} (99)$$

2.3.9 Lower and Upper Bounds on Concrete Strength [Constraints (25 + 11\cdot \text{NR}) and (26 + 11\cdot \text{NR})]

The release strength $f_{c_i}'$ can not be less than the THD standard minimum of 4.0 ksi,

$$-f_{c_i}' \leq -4.0 \hspace{1cm} (100)$$
nor exceed the specified 28 day strength,

\[ f'_{ci} \leq f'_{28} \]  

(101)

2.4 DETERMINATION OF FINAL DESIGN - STRAIGHT STRANDS

The linear programming formulation used requires that prestress loss at release \( \xi \) and long term loss \( \eta \) be specified. These quantities are actually dependent, in part, on the design variables defining concrete strength and strand pattern. This shortcoming in the formulation can be treated through an iterative process. Initial values for \( \xi \) and \( \eta \) are assumed, and the linear program solved to obtain concrete strengths and strand pattern. Corrected values of \( \xi \) and \( \eta \) are then computed by the procedure described in Section 2.1. If the computed losses are less than those assumed, the design is adequate. If not, the new computed losses are incorporated in the constraint equations and the linear program resolved. Experience with the computer programs indicate that this process generally converges in 3 to 5 iterations, starting with \( \xi = 0.05 \) and \( \eta = 0.10 \).

The variables in a standard linear programming formulation are assumed to be continuous. Thus, one may obtain a non-integer number of strands in a solution. The final design is obtained by rounding the strand variables to the nearest integer number. In straight strand box beam designs there are normally a sufficient number of strands present in a strand row so that rounding does not significantly affect the final solution (for example, 12 strands in row 2 as opposed to 11.78 strands obtained from the L.P. solution).

The linear programming formulation permits the early detection of unrealistic design requirements that may inadvertently be imposed by the designer. These can occur in a variety of ways, such as too stringent
camber restrictions or insufficient number of strands permitted to sustain the loads which are to be carried. Such a condition is automatically detected by the Simplex algorithm (1) during an attempt to solve the linear program.

After a solution has been obtained for an L.P. problem, the behavior restrictions (allowable stresses, camber limits, ultimate moment capacity, etc.) which control the design can be easily determined. Those inequality constraints which are "tight" at the final solution (i.e., those which are satisfied as equalities) control, while those which are satisfied by some margin have no effect on the final design. This information can be used by the designer should he choose to alter some of initially specified properties of the design (such as section dimensions or maximum number of strands permitted in a row) in order to obtain a more efficient beam.

2.5 VARIABLE CORRESPONDENCE FOR STRAIGHT STRAND DESIGN

The linear programming problem format given in Eqs. (1) and (2) utilizes design variables \(x_1, \ldots, x_n\), while the notation used in the objective function and constraint relationships retained \(NS_{i,j}\) for the variables representing the number of bonded strands at each wrapping point and \(f_1, \ldots, f_{10}\) to denote variables associated with release strength (\(f'_{c,i}\) for the design option). Correspondence between these two sets of notation are as follows:

2.5.1 Optimization Option

The \(NS_{i,j}\) correspond to

\[x_1 = NS_{1,1}\]
\[x_2 = NS_{2,1}\]
\[
\begin{align*}
  x_{\text{NRAV}} &= x_{\text{NRAV},1} \\
  x_{\text{NRAV}+2} &= x_{\text{NRAV},2} \\
  \vdots & \quad \vdots \\
  x_{2\cdot\text{NRAV}} &= x_{\text{NRAV},2} \\
  \vdots & \quad \vdots \\
  x_{10\cdot\text{NRAV}} &= x_{\text{NRAV},11} \\
  x_{10\cdot\text{NRAV}+1} &= x_{\text{NRAV},11} \\
  \vdots & \quad \vdots \\
  x_{11\cdot\text{NRAV}} &= x_{\text{NRAV},11}
\end{align*}
\] (102)

and the \( f_i \) correspond to

\[
\begin{align*}
  x_{11\cdot\text{NRAV}+1} &= f_1 \\
  \vdots & \quad \vdots \\
  x_{11\cdot\text{NRAV}+11} &= f_{10}
\end{align*}
\] (103)

The total number of variables \( n \) is equal to \((11\cdot\text{NRAV} + 11)\).

2.5.2 Design Option

The correspondence between \( x_k \) and \( \text{NS}_{i,j} \) is the same as that given in Eq. (102). The release strength is \( x_{11\cdot\text{NRAV}+1} \) and the total number of variables \( n \) is \((11\cdot\text{NRAV} + 1)\).
III. Design of Box Girders With Draped Strands

In this section, the problem of determining the concrete release and 28-day strengths and strand pattern layout which minimizes the total cost of a box girder which may contain draped strands and has no strand bond breakage is formulated as an integer programming problem. The integer programming problem has the same mathematical structure as the linear program described by Eqs. (1) and (2) with the exception of the design variables \( x_1, \ldots, x_n \) which are required to take only integer values. While the integer programming formulation more closely reflects the true nature of the design problem, its solution requires considerably more computational effort than does the linear program. It is used here in lieu of the linear programming approach because of variable rounding difficulties inherent in the draped strand formulation. Draped strand design practice requires that a fixed number of strands be draped in a row (as many as six strands, depending on web width). If any drapable strands in a row are to be draped, all must be draped. Thus, if a linear programming formulation was used, and the final solution indicated that 2.9 strands were to be draped, this value would have to truncated to zero or raised to 6 (assuming 6 drapable strands per row). This obviously would lead to considerable differences between the L.P. optimum design and that obtained from it by rounding.

3.1 Design Considerations

Let \( N_{S_i} \) denote the total number of strands present in strand row \( i \) (row number 1 is the bottom most strand row) and \( I_i \) be a binary variable (either 0 or 1) indicating the presence of draped strands in row \( i \).
\[(I_i = 1) \text{ or their absence } (I_i = 0). \text{ For the case shown in Figure 13,}
\]
\[
\begin{align*}
NS_1 &= 10 & I_1 &= 0 \\
NS_2 &= 10 & I_2 &= 0 \\
NS_3 &= 6 & I_3 &= 1 \\
NS_4 &= 4 & I_4 &= 1 \\
NS_5 &= 4 & I_5 &= 1
\end{align*}
\]

Let NR equal the number of rows which may contain strands, NRAV equal the number of the top-most strand row in the section (NRAV = 10 in Figure 13), NB be the row number of the first row containing draped strands (NB = 3 in Figure 13), and EN be the product of the number of rows of draped strands and the number of rows by which the strands are raised at the end of the beam. In Figure 13, the number of rows of draped strands is 3 and the number of rows by which they are raised is 4, giving EN=12. Define NW as the number of drapable strands per row, e as the distance between the straight and draped strands in a row at the end of the beam, \(e_j\) as this distance at point \(j\) along the beam, and \(aL\) as the distance from the end of the beam to the holddown point (Figure 14).

The stress in the top of the beam at point \(j\) due to prestress in row \(i\) is given by
\[
\sigma_{i,j}^T = - (1 - \varepsilon) F_0 \frac{1}{A} NS_i + (1 - \varepsilon) F_0 (-d_i - e_j) NW \frac{1}{Z_t} I_i \\
+ (1 - \varepsilon) F_0 (-d_i) \frac{1}{Z_t} (NS_i - NW \cdot I_i)
\]

Collecting common terms and factoring yields
\[
\sigma_{i,j}^T = -(1 - \varepsilon) F_0 \left\{ \frac{1}{A} + \frac{d_i}{Z_t} \right\} NS_i - (1 - \varepsilon) F_0 \frac{NW}{Z_t} e_j I_i
\]
FIGURE 13. CENTER LINE AND END SECTIONS OF DRAPED STRAND BEAM

FIGURE 14. NOTATION DESCRIBING A STRAND ROW
Noting that $e_j = \tau_j e$, where $\tau_j$ is a factor dependent on the location of point $j$, Eq. (106) becomes

$$\Theta(T) = -(1 - \xi) F_0 \left\{ \frac{1}{A} + \frac{d_i}{Z_t} \right\} NS_i - (1 - \xi) F_0 \frac{NW}{Z_t} \tau_j e i_i \quad (107)$$

The total stress in the top of the beam at point $j$ due to all rows of strands is obtained by summing the effects of each row, i.e.

$$\Theta_j(T) = \sum_{i=1}^{NR} \Theta_{i,j} \quad (108)$$

Substituting Eq. (107) into (108) and collecting terms gives

$$\Theta_j(T) = -(1 - \xi) F_0 \sum_{i=1}^{NR} \left\{ \frac{1}{A} + \frac{d_i}{Z_t} \right\} NS_i - (1 - \xi) F_0 \frac{NW}{Z_t} \tau_j e \sum_{i=1}^{NR} I_i \quad (109)$$

The strand end eccentricity $e$ must be an integer multiple of the strand row spacing $GS$. The spacing between all rows must be the same in order that a given design can be fabricated with equal ease by hardware that depresses strands at the holddown points or that lifts strands at the ends of the beam. Thus, $e$ may be written as

$$e = N \cdot GS \quad (110)$$
where $N$ is the number of rows by which the draped strands are raised at the end of the beam. Substituting Eq. (110) into Eq. (109) gives

$$
\sigma_j^{(T)} = -(1 - \xi)F_o \sum_{i=1}^{NR} \left[ \frac{1}{A} + \frac{d_i}{Z_t} \right] NS_i - (1 - \xi)F_o \frac{NW}{Z_t} \quad \tau_j^{GS \cdot N} \sum_{i=1}^{NR} \frac{I_i}{N} \quad (111)
$$

It follows from the definition of $I_i$ that $\Sigma I_i$ is equal to the number of rows with draped strands, and that $N \Sigma I_i$ is equal to $EN$ which was defined previously. Thus Eq. (111) becomes

$$
\sigma_j^{(T)} = -(1 - \xi)F_o \sum_{i=1}^{NR} \left[ \frac{1}{A} + \frac{d_i}{Z_t} \right] NS_i - (1 - \xi)F_o \frac{NW}{Z_t} \quad \tau_j^{GS \cdot EN} \quad (112)
$$

At this point a comment is in order concerning the seemingly bizarre set of variables ($NS_i, I_i, NB$ and $EN$) used to arrive at an expression for prestress induced stress. The integer programming format used to formulate the beam design problem requires that all constraint expressions (including those developed later to limit beam stresses) be linear in the design variables. If the expression for stress given in Eq. (109) were used, it would contain the product of design variables ($e$ and the $I_i$). The introduction of transformed variables to produce a linear expression is not without its complications. As will be shown later, a rather complex set of additional constraints must be introduced to insure that the minimum cost design obtained in the transformed design space corresponds in a unique way to an obtainable design.

Using previously defined terminology and a procedure analogous to that just explained, the stress at point $j$ in a beam produced by all sources under release conditions can be written as
\[ \sigma_j^{(T)} = -(1 - \varepsilon) F_o \sum_{i=1}^{NR} \left\{ \frac{1}{A} + \frac{d_i}{Z_t} \right\} NS_i - (1 - \varepsilon) F_o \frac{NW}{Z_t} \tau_{j, GS} \cdot EN \]
\[ - \frac{M_j}{Z_t} \]  
\[ (113) \]

\[ \sigma_j^{(B)} = -(1 - \varepsilon) F_o \sum_{i=1}^{NR} \left\{ \frac{1}{A} - \frac{d_i}{Z_b} \right\} NS_i + (1 - \varepsilon) F_o \frac{NW}{Z_b} \tau_{j, GS} \cdot EN \]
\[ + \frac{M_j}{Z_b} \]  
\[ (114) \]

and for service load conditions

\[ \sigma_j^{(T)} = -(1 - \eta) F_o \sum_{i=1}^{NR} \left\{ \frac{1}{A} + \frac{d_i}{Z_t} \right\} NS_i - (1 - \eta) F_o \frac{NW}{Z_t} \tau_{j, GS} \cdot EN \]
\[ - \frac{M_j}{Z_t} - \frac{\bar{M}_j}{Z_t} \]  
\[ (115) \]

\[ \sigma_j^{(B)} = -(1 - \eta) F_o \sum_{i=1}^{NR} \left\{ \frac{1}{A} - \frac{d_i}{Z_b} \right\} NS_i + (1 - \eta) F_o \frac{NW}{Z_b} \tau_{j, GS} \cdot EN \]
\[ + \frac{M_j}{Z_b} + \frac{\bar{M}_j}{Z_b} \]  
\[ (116) \]

Camber at midspan after strand release can be written as

\[ \Delta = \Delta_{DL} - \frac{1}{E_{ci}} \left\{ \frac{L^2}{8} M_s + \frac{(aL)^2}{6} M_E + \left[ \frac{L^2}{8} - \frac{(aL)^2}{6} \right] M_D \right\} \]
\[ (117) \]

where \( M_s, M_E \) and \( M_D \) are shown in Figure 15 and given by

\[ M_s = (1 - \varepsilon) F_o \sum_{i=1}^{NR} d_i (NS_i - NW \cdot I_i) \]  
\[ (118) \]

\[ M_D = (1 - \varepsilon) F_o \sum_{i=1}^{NR} d_i I_i \]  
\[ (119) \]

\[ M_E = M_D + (1 - \varepsilon) F_o NW \cdot GS \cdot EN \]  
\[ (120) \]
FIGURE 15. PRESTRESS INDUCED MOMENT DIAGRAMS FOR CALCULATION OF RELEASE CAMBER IN BEAMS WITH DRAPED STRANDS
The computation of ultimate moment capacity, cracking moment and prestress loss is identical to that described in Section 2.1. The calculation of stirrup spacing differs from that previously developed only in that the shear force to be resisted by the stirrups $V_u^{(i)}$ is reduced by the amount of the vertical component of force exerted by draped strands at points between the end of the beam and holddown point.

3.2 DRAPE D STRAND FORMULATION - OPTIMIZATION OPTION

In this section, the problem of determining the concrete release strength, the mid-span strand pattern and end eccentricity of draped strands which minimizes the total cost of a box girder is formulated as an integer program. The variables $N_S$, $N_B$ and $E_N$ are integer, assuming any integer values which satisfy the constraints defined below. The variables $I_i$ and the variables $K_i$ (introduced below) are binary variables, which can assume only the values 0 or 1. The release strength of beam concrete can be written as

$$f'_{C i} = 4.0 + 0.5 \sum_{i=1}^{10} K_i$$

(121)

where $K_i$ are binary variables (taking values of either 0 or 1) satisfying the inequalities

$$-K_i + K_{i+1} \leq 0 \quad i=1,\ldots,9$$

(122)

This form renders discrete values of release strength in 0.5 ksi increments. The 28 day strength corresponding to a specific release strength can be
expressed as

\[ f'_c = g_0 + \sum_{i=1}^{10} (g_i - g_{i-1})K_i \]  \hspace{1cm} (123)

which is a discontinuous step approximation to the function relating release strength to 28-day strength (Figure 16). The cost per cubic yard of concrete as a function of release strength is given by the discontinuous step approximation

\[ c_0 + \sum_{i=1}^{10} (c_i - c_{i-1})K_i \]  \hspace{1cm} (124)

### 3.2.1 Objective Function

The total cost of the beam is assumed to consist of the cost of concrete and cost of strands. This can be written as

\[
\text{Minimize } c_{sL} \sum_{i=1}^{NR} NS_i \cdot A_{i-L} \cdot \frac{10}{1944} \sum_{i=1}^{10} (c_i - c_{i-1})K_i + A_{i-L} \cdot c_0
\]  \hspace{1cm} (125)

### 3.2.2 Constraints on Release Stresses [Constraints 1 thru 8]

Release stresses are checked at the top and bottom of the beam, at the holddown (j=8), 5L/40 (j=5), L/10 (j=6) and at the end (j=7)(see Figure 17). The point 5L/40 is used so that different allowable stresses could be imposed, at the designer's option, for points between the end of the beam and the first tenth point and for those points between the tenth point and the holddown. The points chosen are the end points of each of these two intervals. At release, if the allowable stresses are satisfied at each end of the interval, they will be satisfied at all points within the interval because the offsetting stresses produced by beam weight increase parabolically while those due to prestress increase linearly with position along the interval.
FIGURE 16. APPROXIMATION OF 28 DAY STRENGTH VS. RELEASE STRENGTH
FIGURE 17. STATIONS FOR STRESS CHECKS IN DRAPED STRAND DESIGN

FIGURE 18. CENTERLINE AND END SECTIONS OF BEAM WITH IMPROPER DRAPING OF STRANDS
To insure that the allowable tensile stress in the top of the beam is not exceeded, it is necessary that

\[-(1 - \xi) F_o \sum_{i=1}^{NR} \left\{ \frac{1}{A} + \frac{d_i}{Z_t} \right\} NS_i - (1 - \xi) F_o \sum_{i=1}^{NR} \frac{W_i}{Z_t} \tau_j GS\cdot EN\]

\[-0.003727S_t j \sum_{i=1}^{10} K_i \leq \frac{M_j}{Z_t} + 0.06387S_t j; \quad j=5, 6, 7, 8 \quad (126)\]

Referring to Figure 16, \( \tau_j \) is given by

\[
\begin{align*}
\tau_j &= \begin{cases} 
0. & \text{if } j=1 \\
\langle \alpha - 0.40 \rangle & \text{if } j=2 \\
\langle \alpha - 0.30 \rangle & \text{if } j=3 \\
\langle \alpha - 0.20 \rangle & \text{if } j=4 \\
\end{cases} \\
&= \begin{cases} 
\langle a - 0.125 \rangle & \text{if } j=5 \\
\langle a - 0.10 \rangle & \text{if } j=6 \\
\langle a - 0.30 \rangle & \text{if } j=7 \\
1. & \text{if } j=8 \\
\end{cases} \quad (127)
\end{align*}
\]

The bracketed quantity in Eq. (127) has the following interpretation:

\( \langle x \rangle = x \) if \( x > 0 \), \( \langle x \rangle = 0 \) if \( x < 0 \).

To insure that the allowable compressive stress in the bottom of the beam is not exceeded, it is necessary that

\[-(1 - \xi) F_o \sum_{i=1}^{NR} \left\{ \frac{1}{A} - \frac{d_i}{Z_b} \right\} NS_i - (1 - \xi) F_o \sum_{i=1}^{NR} \frac{W_i}{Z_b} \tau_j GS\cdot EN\]

\[-0.5S_{c j} \sum_{i=1}^{10} K_i \leq 4.0S_{c j} + \frac{M_j}{Z_b}; \quad j=5, 6, 7, 8 \quad (128)\]

3.2.3 Constraints on Service Load Stresses [Constraints 9 thru 22]

Service load stresses are checked top and bottom at midspan, 4L/10, 3L/10, 2L/10, 5L/40, L/10 and the end. To insure that the allowable tension stress in the bottom of the beam at all points except the end do not ex-
ceed the allowable tensile stress, it is necessary that

\[
-(1 - \eta) F_o \sum_{i=1}^{NR} \left\{ \frac{1}{A} - \frac{d_i}{Z_b} \right\} NS_i + (1 - \eta) F_o \sum_{j} \frac{NW}{Z_b} \tau_j GS \cdot EN = 0.007454 \sigma_{t7}.
\]

\[
10 \sum_{i=1}^{j} (g_i - g_{i-2}) K_i \leq -\frac{M_j}{Z_b} - \frac{M_j}{Z_b} + 0.007454 \sigma_{t7} g_o + 0.03355 \sigma_{t7};
\]

\[j=1, \ldots, 6\] (129)

At the end of the beam (j=7), tension stress in the top is limited by

\[
-(1 - \eta) F_o \sum_{i=1}^{NR} \left\{ \frac{1}{A} + \frac{d_i}{Z_t} \right\} NS_i - (1 - \eta) F_o \sum_{j} \frac{NW}{Z_t} \tau_j GS \cdot EN = 0.007454 \sigma_{t7} g_o + 0.03355 \sigma_{t7}.
\]

\[
10 \sum_{i=1}^{6} (g_i - g_{i-1}) K_i \leq 0.007454 \sigma_{t7} g_o + 0.03355 \sigma_{t7}.
\]

(130)

The compression stress in the top of the beam at all points except the end is limited to the allowable by

\[
(1 - \eta) F_o \sum_{i=1}^{NR} \left\{ \frac{1}{A} + \frac{d_i}{Z_t} \right\} NS_i + (1 - \eta) F_o \sum_{j} \frac{NW}{Z_t} \tau_j GS \cdot EN
\]

\[
- \sigma_{c7} \sum_{i=1}^{6} (g_i - g_{i-1}) K_i \leq \frac{M_j}{Z_t} - \frac{M_j}{Z_t} + \sigma_{c7} g_o;
\]

\[j=1, \ldots, 6\] (131)

and at the end of the beam, the compression stress in the bottom is limited by

\[
(1 - \eta) F_o \sum_{i=1}^{NR} \left\{ \frac{1}{A} - \frac{d_i}{Z_b} \right\} NS_i - (1 - \eta) F_o \sum_{j} \frac{NW}{Z_b} \tau_j GS \cdot EN
\]

\[
- \sigma_{c7} \sum_{i=1}^{6} (g_i - g_{i-1}) K_i \leq \sigma_{c7} g_o.
\]

(132)
3.2.4 Sufficient Number of Strands in Row for Draping [Constraints 23 thru (22 + NR)]

Two variables, \( Ns_i \) and \( I_i \) are associated with each strand row. If strands are to be draped in row \( i \) (\( I_i = 1 \)), then there must be at least \( NW \) strands present in that row (\( Ns_i \geq NW \)). This is assured by the constraint set

\[-Ns_i + NW \cdot I_i \leq 0 \quad i=1,\ldots,NR \tag{133} \]

3.2.5 Contiguous Draped Strands [Constraints (23 + NR) thru (21 + 2 \cdot NR)]

Fabrication practices require that strands which are draped must be in adjacent rows. For example, this condition would not be acceptable: row 1 with draped strands (\( I_1 = 1 \)), row 2 with no draped strands (\( I_2 = 0 \)) and rows 3, 4 and 5 with draped strands (\( I_3 = I_4 = I_5 = 1 \)). This situation is depicted in Figure 18, where it can be seen that the draped strands in row 1 would have to cross over those in the second row as the first row strands were raised. This condition is precluded by the constraint set

\[i(I_{i+1} - I_i) - NB \leq 0 \quad i=1,\ldots,(NR-1) \tag{134} \]

where \( NB \) is the row number of the first row containing draped strands.

3.2.6 Upper Bound on EN [Constraints (22 + 2 \cdot NR) thru (21 + 3 \cdot NR)]

The maximum number of rows by which draped strands can be raised at the end of the beam depends on how many of the \( NR \) possible rows that may contain strands actually have them. Referring to Figure 13, which has 5 rows filled, it can be seen that at most, the top most 3 rows that are draped can be raised by 5 rows. If there were six rows containing strands
(with the 3 top most draped), then the maximum lift at the end would be
4 rows. In the first case, the maximum value permitted for \( EN \) would be
15. For the latter case, \( EN \) could not exceed 12. Thus, the upper bound
on \( EN \) depends on the total number of rows containing strands, which is
given by

\[
EN \leq \frac{NR}{NB-1 + \sum_{i=1}^{NR} I_i}
\]  

(135)

and the total number of strand rows available, \( NRAV \). Upper bounds on
\( EN \) are imposed through the following set of constraints

\[
EN + [J + 1]NB - [NRAV - 2J - 1] \sum_{i=1}^{J} I_i \leq J^2 + 2J + 1;
\]

\( J=0, 1, \ldots, (NR-1) \)  

(136)

3.2.7 Upper and Lower Bounds on \( NB \) [Constraints (22 + 3\cdot NR) and
(23 + 3\cdot NR)]

The number of the first row containing draped strands, \( NB \), must
lie between 1 and \( NR \), i.e.,

\[
NB \leq NR
\]

(137)

\[
-NB \leq -1
\]

(138)

3.2.8 Constraints to Insure that if \( NB \geq i + 1 \), then \( I_i = 0 \)
[Constraints (24 + 3\cdot NR) thru (22 + 4\cdot NR)]

From the definition of \( NB \) and \( I_i \) it follows that for those rows below
row \( NB \), \( I_i = 0 \) (\( i=1, \ldots, NB-1 \)). The constraint set defined in Section 3.2.5
insured that draped strand rows are contiguous, that is, \( I_i = 0 \) for rows i
below the draped strand rows and above the top most draped strand. However, as yet, nothing ties the first draped strand row (the first row $i$ for which $I_1 \neq 0$) to $NB$. For example, at this point, nothing would prevent the occurrence of a situation where $NB=3$ and $I_1=I_2=I_3=...=1$. The following constraint set insures that this arrangement does not occur.

$$ NB + NR \cdot I_i \leq NR + i \quad i=1, 2, ..., (NR-1) \quad (139) $$

3.2.9 Constraints to Insure that if $NB = i$, then $I_i = 1$ [Constraints $(23 + 4 \cdot NR)$ thru $(22 + 5 \cdot NR)$]

The constraint sets in Sections 3.2.5 and 3.2.8 do not preclude the occurrence of a situation where $NB=i$ and $I_i \neq 1$. For example, $NB=3$ and $I_1=I_2=I_3=...=0$. This condition is prevented by

$$ -NB - (i+1) \sum_{j=1}^{i-1} I_j - I_i \leq -(i+1); \quad i=1, 2, ..., NR \quad (140) $$

3.2.10 Maximum Number of Strands per Row [Constraints $(23 + 5 \cdot NR)$ thru $(22 + 6 \cdot NR)$]

Letting the maximum number of strands that can be placed in row $i$ (straight strands plus draped strands) be denoted by $NM_i$, we have

$$ NS_i \leq NM_i \quad ; \quad i=1, 2, ..., NR \quad (141) $$

3.2.11 Constraints to Insure Proper Release Strength Representation [Constraints $(23 + 6 \cdot NR)$ thru $(31 + 6 \cdot NR)$]

The binary variable representation of $f_{ci}$ defined in Eq. (121) is valid only if the inequalities appearing in Eq. (122) are satisfied. Thus, it is required that
\[-K_i + K_{i+1} \leq 0 \quad i=1, \ldots, 9 \quad (142)\]

3.2.12 Bounds on Release Camber [Constraints (32 + 6\cdot NR) and (33 + 6\cdot NR)]

Letting \(\Delta^+\) and \(\Delta^-\) denote the maximum and minimum midspan camber allowed, and using Eq. (117) for the camber which occurs, we have

\[
E_{c_i}I\Delta_{DL} - \left\{ \frac{L^2}{8} M_s + \frac{(\alpha L)^2}{6} M_E + \left[ \frac{L^2}{8} - \frac{(\alpha L)^2}{6} \right] M_D \right\} < E_{c_i}I\Delta^+ \quad (143)
\]

for the upper bound constraint on camber. Substitution of Eqs. (118) thru (120) for \(M_s, M_E\) and \(M_D\) and noting that the modulus of the concrete \(E_c\) can be written approximately as

\[
E_{c_i} = K \left\{ .003727 \sum_{i=1}^{10} K_i + .06337 \right\} \quad (144)
\]

where \(K\) is defined in Eq. (72), we have

\[
\frac{L^2}{6} (1 - \xi) F_o \sum_{i=1}^{NR} d_i N_{S_i} NS_i
\]

\[
- \frac{(\alpha L)^2}{6} (1 - \xi) F_o NW - GS - EN - .003727 I \Delta^+ \sum_{i=1}^{10} K_i \]

\[
\leq .06373K\cdot I\Delta^+ + 22.5wL^4 \quad (145)
\]
In a similar manner, the lower bound $\Delta^-$ is imposed through

$$\frac{L^2}{8} (1 - \varepsilon) F_0 \sum_{i=1}^{NR} d_i N_S_i + \frac{(\alpha L)^2}{6} (1 - \varepsilon) F_0 N_{WW} G_{S\cdot EN} + 0.003727 K \Delta^- \sum_{i=1}^{10} K_i \leq 0.06337 K \cdot I \Delta^- - 22.5 L^4$$

(146)

3.2.13 Adequate Ultimate Moment Capacity [Constraint (34 + 6\cdot NR)]

The discussion in Section 2.2.8 applies in this case, with Eq. (80) being modified to give

$$\frac{NR}{\sum_{i=1}^{10} d_i N_S_i} + \sum_{i=1}^{10} (\bar{\rho}_i - \bar{\rho}_{i-1}) K_i \leq -\rho_0$$

(147)

3.2.14 Ultimate Moment Capacity $M_u \geq 1.2 M_{cr}$ [Constraint (35 + 6\cdot NR)]

The change of variables used above also applies for this constraint, giving

$$\frac{NR}{\sum_{i=1}^{10} d_i N_S_i} + \sum_{i=1}^{10} (\bar{\rho}_i - \bar{\rho}_{i-1}) K_i \leq \rho'$$

(148)

3.2.15 Lower and Upper Bounds on Concrete Strength [Constraints (36 + 6\cdot NR) and (37 + 6\cdot NR)]

The lower limit $(f'_{ci})_{\text{min}}$ and upper limit $(f'_{ci})_{\text{max}}$ on concrete release strength are enforced by

$$-0.5 \sum_{i=1}^{10} K_i \leq 4.0 - (f'_{ci})_{\text{min}}$$

(149)
accomplished by first solving the integer formulation of Section 3.2 or 3.3 as a standard linear programming problem (i.e., assuming all variables are continuous). A benefit derived from this approach is the possible detection of unrealistic design requirements as discussed in Section 2.4. There is no guarantee, however, that such a condition will be detected in the L.P. problem since it is theoretically possible to obtain a solution to a continuous problem where no feasible solution in integers exists.

3.5 VARIABLE CORRESPONDENCE FOR DRAPE STRAND DESIGN

The correspondence between the variable notation, \( x_1, \ldots, x_n \) used in Eqs. (1) and (2) and that incorporated in this chapter is as follows:

3.5.1 Optimization Option

\[
\begin{align*}
    x_1 & = NS_1 \\
    \vdots & \\
    x_{NR} & = NS_{NR} \\
    x_{NR+1} & = NB \\
    x_{NR+2} & = EN \\
    x_{NR+3} & = I_1 \\
    \vdots & \\
    x_{2\cdot NR+2} & = I_{NR} \\
    x_{2\cdot NR+3} & = K_1 \\
    \vdots & \\
    x_{2\cdot NR+12} & = K_{10}
\end{align*}
\]  

(162)
3.5.2 Design Option

\[ x_1 = f'_{C1} \]

\[ x_2 = NS_1 \]

\[ \vdots \]

\[ x_{NR+1} = NS_{NR} \]

\[ x_{NR+2} = NB \]

\[ x_{NR+3} = I_1 \]

\[ \vdots \]

\[ x_{2\cdot NR+3} = I_{NR} \]
IV. Program Documentation - DBOXSS

The computer program DBOXSS implements the box girder design formulation developed in Chapter II. Described below are the standard input form and its use, interpretation of program output and several example problems.

4.1 PROGRAM INPUT

Figure 19 shows the input form to be used with the program.

4.1.1 Title Cards

The first three input cards are title cards providing a means of job reference. The information preprinted on the form in various columns need not be punched on the data cards - it will be printed out automatically during output. The information on these cards is optional. The first two cards should only be input once per computer run. The third title card is the first card in a data pack when multiple problem runs are made, as explained below.

4.1.2 Load and Options Card

The type of standard AASHTO loading (H-15, H-20, HS-15 or HS-20) is entered in columns 5 - 6 and 8 - 9. The live load distribution factor entered in columns 13 - 16 is the fraction of an axle load to be carried by the beam. This distribution factor is applied to the axle train loading (if used) as well as AASHTO truck and lane loadings. If columns 13 - 16 are left blank, the program automatically computes lateral distribution using Eqs. (24) thru (26), (the AASHTO distribution factor). If a vehicle other than an AASHTO truck is to be used for design, enter a "1" in column 20 and complete the axle train data cards. If both axle train and AASHTO
TEXAS HIGHWAY DEPARTMENT  
BRIDGE DIVISION  

BOX BEAM DESIGN PROGRAM  
(STRAIGHT STRANDS)  

DISTRICT  

CONTROL NO.  

DESCRIPTION  

A.A.S.H.T.O.  

Live Load  

Distribution Factor  

Enter 1 For Axle Train  

Enter 1 if Concentrated Forces Applied To Single Beam  

Enter 1 For Optimization Option  

AXLE TRAIN  

Axle Loads (kips)  

CONCENTRATED LOADS ON SINGLE BEAM  

Beam Dimensions  

Span Length (ft)  

Bridge Width (ft)  

Number of Traffic Lanes  

Number of Beams  

Area of Compression Reinforcing (in²)  

Distance to c.g. of Compression Reinforcing (in)  

Maximum Initial Camber (in)  

Minimum Initial Camber (in)  

Distance From Bottom of Beam to Strand Row  

MAXIMUM NUMBER OF STRANDS PERMITTED IN ROW i  

FIGURE 19. INPUT FORM FOR DBOXSS
FIGURE 19. (CONTINUED)
loadings are specified, the larger of the axle train, AASHTO truck and AASHTO lane moments are used at each design point (Figure 2). A uniform dead load carried by a single box girder (i.e. with no lateral distribution of load) is entered in columns 24 - 27. This provision allows the user to include the weight of such things as a wearing surface in the design. Concentrated dead load forces applied to a single girder are indicated by placing a "1" in column 31 and completing the concentrated loads on a single beam data cards. Column 48 dictates which program option is to be used. If a "1" is entered, the program determines the minimum cost design, based on cost information input from part 2 of the form. This is the "optimization option". If column 48 is left blank, the program exercises the "design option", in which the strand pattern and release strength are selected which minimize the number of strands used, assuming the beam concentrate has the 28 day strength entered in columns 35 - 37.

4.1.3 Axle Train Cards (Use Only if "1" Entered in Column 20 of Load and Options Card)

A moving load pattern of up to 18 axles may be used for design. The first card contains the total load on each axle. To facilitate input, the user should sketch the axle train configuration, labeling either the right-most or left-most axle as axle 1 and numbering the remaining axles in sequential order. The weight of each axle is then placed in the appropriate columns of the first data card. The spacing of axles is input on the second data card, where axle spacing is defined as the distance from axle 1 to the axle under consideration. As an example, an AASHTO HS-20 truck (with rear axles separated 14 feet) whose
light axle was designated as axle 1, would require 8.0 in columns 4 - 6 on the first card and 32.0 in columns 8 - 10 and 12 - 14. The second card would contain 14. in columns 8 - 10 and 28. in columns 12 - 14. The program automatically scales axle train axle loads by the lateral distribution factor, but no impact factor is applied.

4.1.4 Concentrated Loads on Single Beam Cards (Use Only if Column 31 of Load and Options Card Contains "1")

Up to 10 concentrated forces acting on a single beam (no lateral distribution assumed) may be input. The first card contains the magnitude of the load, while the second card contains the distance of each load from the left support. This program provision is intended for small loads only. Service load stress checks are based on the assumption that the maximum moment due to all dead plus live load occurs either at the 1/10, 2/10 or 5/10 point. If large concentrated forces are entered, this assumption may be in error, resulting in an overstressed design.

4.1.5 Beam Dimensions Card

The dimensions of the beam cross section which are to be input are shown on the figure at the upper right corner of part 1 of the input form. The fillets (dimensions X and Y) are assumed to slope at 45 degrees. Most any cross sectional shape can be accommodated with the dimensions shown. An ordinary rectangular voided section can be obtained, for example, by inputing dimensions such that A=B=(2·W+M) and G=H=E=C=0 (or left blank).

4.1.6 Bridge and Beam Properties Card

The information input on this card is used to compute the lateral distribution factor (if columns 13 - 16 of the load and options card is left blank) and other quantities used to formulate the constraint set.
The span length is entered in columns 4 - 7, bridge width in columns 11 - 14, number of traffic lanes in columns 18 - 19 and number of longitudinal beams in columns 23 - 26. The number of longitudinal beams is input as a decimal number to accommodate unusual conditions (such as a mixture of two or more different box cross sections in the same bridge). Compression steel is sometimes used in box sections to help control long term camber. The area of this steel, which is input in columns 29 - 32, is considered in the computation of section properties, using a transformed steel area of \((n-1)\) for properties with shear key and \(2(n-1)\) without. The distance from the top of the beam to c.g. of compression steel is entered in columns 36 - 39. If left blank, the program assumes \(T/2\). Maximum and minimum acceptable release cambers are input in columns 43 - 47 and 51 - 55 (upward camber is positive, downward camber negative). These apply to the midspan camber at release produced by prestress and beam weight. A typical application of the lower bound camber would be to insure that a beam did not deflect downward under full dead load (say, shear key plus wearing surface). If an estimate of the final release strength is made, then a modulus of elasticity can be computed, and the midspan downward deflection under shear key and wearing surface weights determined. This value is entered (as a positive number in this case) under minimum initial camber. This will insure that the final design has enough upward initial camber to offset the downward deflection caused by the addition of shear key and wearing surface. If columns 43 - 47 or 51 - 55 are left blank, then the constraint is ignored during design. The distance from the bottom of the beam to the centerline of the first (bottom-most) strand row is input in columns 59 - 60. If column 64 is left blank, the spacing between all rows of strands is assumed
to be 2.0 inches. If this is not the case, enter "1" in column 64 and complete the non-standard grid spacing card. If column 68 is left blank, the program assumes normal weight concrete (150 lbs/ft\(^3\)), 50% relative humidity and .153 in.\(^2\) grade 270 strands. The allowable stress coefficients are taken as 0.6 for compression and 7.5 for tension at release and 0.4 and 6.0 under service loads.

4.1.7 Maximum Number of Strands per Row

The maximum number of strands, as well as the number of rows available for strands is determined from this input data. Strand rows are numbered consecutively, taking the bottom-most row as row 1. The computation time required to obtain a final design increases rapidly as the number of available strand rows increases. Thus, one should include only those rows which will likely be used. As written, the program is limited to 10 rows of strands.

4.1.8 Nonstandard Grid Spacing Card (Use Only if "1" Entered in Column 64 of Bridge and Beam Properties Card)

The spacings entered on the data card are the distance from the row under consideration to the row above. Thus, the center to center spacing between rows 1 and 2 would be placed in columns 4 - 5, between rows 2 and 3 in columns 7 - 8, etc. If a uniform spacing (different from 2.0 in.) is to be used, only columns 4 - 5 need be completed. The program will automatically assume this uniform spacing throughout if it encounters no other entries beyond columns 4 - 5.

4.1.9 Miscellaneous Properties Card (Use Only if "1" Entered in Column 68 of Bridge and Beam Properties Card)

If properties other than the standard values listed in Section 4.1.6 are to be used, they must be entered on this card. Only those properties which differ from standard values need be entered. If the program encounters
blanks on the card where a property is to be read, it automatically assumes the standard value. The unit weight of concrete, if different from .150 k/ft$^3$, is entered in columns 4 - 6. Relative humidity is entered in columns 11 - 12, strand area in columns 17 - 19 and ultimate strength of strands in columns 24 - 26. The coefficients used to specify allowable stresses are entered in columns 31 - 55. If the allowable compressive release stress differs from $0.6 f'_{ci}$ or the allowable tensile stress from $7.5 \sqrt{f'_{ci}}$, then the coefficients (those that replace 0.6 and 7.5) should be entered in columns 31 - 32 and 34 - 35 for the end 1/10 of the beam ($j = 8, 9, 10 \& 11$ in Figure 2) and in columns 37 - 38 and 40 - 41 for the remainder of the beam. If the allowable compressive long term stress differs from $0.4 f'_{c}$ or the allowable long term tensile stress from $6.0 \sqrt{f'_{c}}$, then the new coefficients should be entered in columns 45 - 46 and 48 - 49 for the end 1/10 of the beam and in columns 51 - 52 and 54 - 55 for the remainder of the beam.

The final beam camber at midspan after all prestress losses and creep and shrinkage effects have occurred is computed using the method developed in reference (2). Cambers are computed and displayed using four different sets of creep and shrinkage coefficients typical of concretes in highway beams produced in four localities in Texas. Should the designer have information on the creep and shrinkage properties of the concrete he expects to be used in a particular design, he may enter the appropriate coefficients in columns 58 - 75. The program will then compute and display the expected midspan camber for these conditions.
4.1.10 Concrete Cost Coefficients Cards (Use Only if "1" Entered in Column 48 of Load & Options Card)

The cost of concrete in dollars per cubic yard can be input for concrete release strengths up to 9.0 ksi. If an estimate of the cost per cubic yard for 4.0 ksi release strength can be made, Figure 7 can be used as a guide to establishing the cost of higher strengths in the absence of actual cost data. Should release strengths beyond some value (say, 7.0 ksi) not be feasible, then the values (7.5, 8.0, 8.5 and 9.0) beyond that point should be left blank.

4.1.11 Strand Cost Card (Use Only if "1" Entered in Column 48 of Load & Option Card)

The cost per foot for strand is entered in columns 14 - 16 and the cost of strand wrapping in columns 63 - 65.

4.1.12 28 Day Concrete Strength Cards (Use Only if "1" Entered in Column 48 of Load & Options Card)

The relationship between release strength and 28 day strength is defined by the data input from these cards. It isn't possible to construct a general relationship between release and 28 day strengths because of the many factors that influence it. There are similarities in the operations of the major producers of highway beams in the state of Texas (12) which permit a reasonable estimate of the relationship.

Fabricators generally use a 24 hour steam curing production sequence. Beams are cast in the afternoon, allowed to gain their initial set (minimum of 3 hours after casting before steam curing is begun (13)) and then steam cured overnight. A total steam curing period of 18 hours at 140° to 150° F.
is typical of most operations. Hanson (14) collected data on concretes made
with type III Portland cement and subjected to 15 hours of steam curing at
150° F. commencing 3 hours after casting. Concrete strengths were generally
around 4 ksi at 18 hours (release) and 5 ksi at 28 days. For the data
reported, the 18 hour strengths averaged 74% of the 28 day strengths.
This percentage is probably valid over the usual range of release strengths
utilized in THD prestressed designs, which is approximately 6 ksi. If this
percentage is applied to release strengths between 4 and 6 ksi, the first
straight line segment shown in Figure 20 is produced. Higher release
strengths generally demand longer periods of steam curing and result in
smaller percentage gains in release strength over 28 day strength. At the
extreme limit of 9 ksi release strength, the fabricator would no doubt be
forced to keep the beams under special cure for the majority of a 28 day
period before release strength was reached. Under these conditions, the
ratio of release strength to 28 day strength should be approximately 1.
If a linear variation in strength gain over release strength is assumed
between 6. and 9. ksi release strengths, the second straight line segment
shown in Figure 20 is obtained.

4.1.13 Multiple Problem Runs
The user may process more than one design in a single computer run.
The first problem must contain the three title cards described in Section
4.1.1. Each additional problem which is run should have the third title
card as the first card in the data set.

4.2 SAMPLE PROBLEMS
Described below are several example problems demonstrating the use of
FIGURE 20. PROPOSED RELATIONSHIP BETWEEN 28 DAY STRENGTH AND RELEASE STRENGTH
the standard input form.

4.2.1 Example Problem 1

A multibeam box girder bridge is to carry two lanes of traffic with HS-20 loading and span 35.0 ft. The girder cross section is to be formed using the THD type "B" side form and is to have an overall width of 4.0 ft. A 27 3/4 in. wide by 23 1/2 in. deep void is to be used, and the girder has one interior diaphragm weighing 440 lbs. Seven boxes will be used, with a 1.2 in. space between adjacent boxes, giving an overall bridge width of 28.6 ft. The bridge will be surfaced with a 2 in. asphaltic concrete topping. The design will incorporate a 5.0 ksi 28 day strength and 1/2 in. diameter grade 270k strands. The dimensions of the section are such that 5 rows of strands can be placed. The first row of strands is 2.5 in. above the bottom of the section and can accommodate a maximum of 22 strands. The remaining 4 rows are spaced uniformly at 2.0 in. increments and each can hold 6 strands. However, no more than one row of 22 strands should be required. Six number 9, grade 60 conventional reinforcing bars are to be placed in the deck slab, 2.5 in. down from the surface.

The shear key weighs approximately 180 lbs/ft. (1/2 key on either side of the beam) and the 2 in. wearing surface 90 lbs./ft. Assuming the release strength for the design will be approximately 4.0 ksi, the modulus of elasticity of the concrete will be 3.83 million psi. The moment of inertia of the cross section without shear key is approximately 122,000 in. The total downward deflection of a single girder, under the weight of shear key and topping based on the assumed modulus is computed to be 0.02 in. This value is specified as the minimum initial camber permitted. For this relatively
short span, excessive camber should not be a factor and is therefore to be ignored in design.

The bridge is to be situated in a coastal environment, so no tension will be allowed in the bottom of the beam, under service loads, where it is exposed to the air. Tension may occur in the top of the beam near the end, due to prestress, but since the top will be protected by a wearing surface, the usual tension allowable of $6.0 \sqrt{\frac{F_t}{C}}$ will be imposed for the end 1/10 of the beam.

The design option is used for this problem. The completed input form is shown in Figure 21, and the program output in Figure 24.

4.2.2 Example Problem 2

A 44 ft. wide by 50 ft. long bridge is to be constructed from 16 box girder units. The box cross section is that proposed as a standard by the Federal Highway Administration (15) and is shown in Figure 22. The vertical positioning of strand rows is that suggested in Reference (15); the first row 2 3/4 in. above the bottom of the beam and the second row 4 in. above the first. A lateral spacing of 2 in. center-to-center is used between strands in a row and thus permits a maximum of 17 strands in row 1 and 4 strands in row 2. Grade A-416, 7/16 in. diameter strands (ultimate strength of 250 ksi and cross sectional area of .1089 in.$^2$) are to be used. The section contains 5 No. 4 bars for compression reinforcing as shown. The completed structure will carry an asphaltic concrete wearing surface whose average thickness is 5 in. over the two beams at the center of the bridge. The resulting dead load is approximately 160 lbs./ft. per beam. The beam must have an upward camber at release, but can not exceed .75 in. to insure a relatively level riding surface under full dead load. Allowable release and service load stresses in the concrete are those specified in the AASHTO Bridge Specification.
TEXAS HIGHWAY DEPARTMENT
BRIDGE DIVISION

BOX BEAM DESIGN PROGRAM
(STRAIGHT STRANDS)

DISTRIBUTION
HI flat COUNTY HIGHWAY No. 46-64
CONTROL NO. 428-08 IPE 470 SUBMITTED BY HLS
DESCRIPTION EXAMPLE PROBLEM NO. 1

A.A.S.H.T.O. Live Load Distribution Factor

Enter 1 For Axle Train
Enter 1 if Concentrated Forces Applied To Single Beam
Enter 1 For Optimization Option

AXLE TRAIN
Axle Loads (kips)
Axle 1 Axle 2 Axle 3 Axle 4 Axle 5 Axle 6 Axle 7 Axle 8 Axle 9 Axle 10 Axle 11 Axle 12 Axle 13 Axle 14 Axle 15 Axle 16 Axle 17 Axle 18

CONCENTRATED LOADS ON SINGLE BEAM
Load (kips) Distance From Left Support (ft)

BEAM DIMENSIONS

Span Length (ft) Bridge Width (ft) Number Of Traffic Lanes Number Of Beams Area of Compression Reinforcing (in²) Distance to e.g. of Compression Reinforcing (in) Maximum Initial Camber (in) Minimum Initial Camber (in) Distance From Bottom of Beam to Strand Row

MAXIMUM NUMBER OF STRANDS PERMITTED IN ROW i

FIGURE 21. COMPLETED INPUT FORM FOR EXAMPLE PROBLEM NO. 1
### Box Beam Design Program

**Straight Strands**

#### Nonstandard Grid Spacing Card

(Enter this card only if previously specified)

<table>
<thead>
<tr>
<th>Distance from Row 1 to Row (i+1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>6</td>
</tr>
<tr>
<td>7</td>
</tr>
<tr>
<td>8</td>
</tr>
<tr>
<td>9</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>11</td>
</tr>
</tbody>
</table>

#### Miscellaneous Properties Card

(Enter this card only if previously specified)

<table>
<thead>
<tr>
<th>Unit Weight Concrete (k/ft³)</th>
<th>Relative Humidity (%)</th>
<th>Strand Area (in²)</th>
<th>Strand Ultimate Strength (ksi)</th>
<th>Allowable Stress Release Coefficients (ksi)</th>
<th>Creep &amp; Shrinkage Coefficients (μ - in. 8 Days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>6</td>
<td>17</td>
<td>19</td>
<td>24 26</td>
<td>CREEP 1 60 63 65 70 73 75</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CREEP 2 58 60 63 65 70 73 75</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SHRK 1 54 55 58 60 63 65 70 73 75</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SHRK 2 50 53 54 55 58 60 63 65 70 73 75</td>
</tr>
</tbody>
</table>

#### Concrete Cost Coefficients

(Include only for optimization option)

<table>
<thead>
<tr>
<th>Release Strength (ksi)</th>
<th>Cost YD</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.0 ksi / $</td>
<td>24</td>
</tr>
<tr>
<td>7.0 ksi / $</td>
<td>14</td>
</tr>
<tr>
<td>5.0 ksi / $</td>
<td>24</td>
</tr>
<tr>
<td>7.5 ksi / $</td>
<td>14</td>
</tr>
<tr>
<td>6.0 ksi / $</td>
<td>37</td>
</tr>
<tr>
<td>8.0 ksi / $</td>
<td>40</td>
</tr>
</tbody>
</table>

#### Strand Cost

(optimization only)

| Ends | 28 Day Concrete Strengths
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>16</td>
</tr>
</tbody>
</table>

#### Strand Wrapping Cost

(optimization only)

| Ends | 63 65                     |

---

**Figure 21 (continued)**
Figure 22. BEAM CROSS SECTION FOR EXAMPLE NO. 2
(4) for inland regions.

The in-place cost of beam concrete is assumed to be $150/cu.yd. for release strengths up to 5.5 ksi, $200 for $f'_{ci} = 6.0$ ksi and $230$ for $f'_{ci} = 6.5$ ksi. Release strengths greater than 6.5 ksi are assumed to be unavailable. The 28 day concrete strength corresponding to each release strength is assumed to be that given in Figure 20.

The optimization option is used for this problem with the completed input form shown in Figure 23. Program output for this problem is shown in Figure 25.

4.3 INTERPRETATION OF PROGRAM OUTPUT

The program first reads input data and performs basic checks for input errors. At present, the program checks include; proper AASHTO loading designation and omitted span length and omitted number of longitudinal beams (if no live load distribution factor is input). The input data is printed out before design calculations are begun so that the user can locate input errors which might cause the program to terminate abnormally before producing any other output. The output format is essentially the same for design and optimization options (see first sheet, Figures 24 and 25).

The second sheet of output summarizes the design results, as seen in Figures 24 and 25. The first items listed are the release and 28-day concrete strengths. For the design option, the 28-day strength is that specified on input, while the release strength is computed by the program. In the optimization option, release strength is computed and 28 day strength is obtained from 28-day vs. release strength input data. The modulus of elasticity listed is computed using the ACI equation (10) and the unit
TEXAS HIGHWAY DEPARTMENT
BRIDGE DIVISION

BOX BEAM DESIGN PROGRAM
(STRAIGHT STRANDS)

Part I of 2

DESCRIPTION: EXAMPLE PROBLEM NO. 2

A.A.S.H.T.O. Load Distribution Factor

AXLE TRAIN

Axle Loads (kips)

CONCENTRATED LOADS ON SINGLE BEAM

Beam Dimensions

MAXIMUM NUMBER OF STRANDS PERMITTED IN ROW i

FIGURE 23. COMPLETED INPUT FORM FOR EXAMPLE PROBLEM NO. 2
BOX BEAM DESIGN PROGRAM  
(STRAIGHT STRANDS)

NONSTANDARD GRID SPACING CARD (Enter This Card Only if Previously Specified)
Distance From Row I To Row (I+1)

<table>
<thead>
<tr>
<th>Row</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I</td>
<td>I+1</td>
<td>I+2</td>
<td>I+3</td>
<td>I+4</td>
<td>I+5</td>
<td>I+6</td>
<td>I+7</td>
<td>I+8</td>
<td>I+9</td>
</tr>
</tbody>
</table>

MISCELLANEOUS PROPERTIES CARD (Enter This Card Only if Previously Specified)

| Unit Weight Concrete (k/ft³) | Relative Humidity (%) | Strand Area (in²) | Strand Ultimate Strength (ksi) | Allowable Stress Coefficients (ksi) | Creep & Shrinkage Coefficients (µ-in./days)
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>6</td>
<td>1.0</td>
<td>252</td>
<td>C 31 32 34 35 37 38 40 41</td>
<td>C 45 46 48 49 51 52 54 55</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Release 1/10</td>
<td>Remainder</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>End 1/10</td>
<td>Remainder</td>
</tr>
</tbody>
</table>

CONCRETE COST COEFFICIENTS (Include Only for Optimization Option)

<table>
<thead>
<tr>
<th>Release Strength (ksi)</th>
<th>Cost (Yo)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.0 KSI / $</td>
<td>150/15</td>
</tr>
<tr>
<td>4.5 KSI / $</td>
<td>150/15</td>
</tr>
<tr>
<td>5.0 KSI / $</td>
<td>150/15</td>
</tr>
<tr>
<td>5.5 KSI / $</td>
<td>150/15</td>
</tr>
<tr>
<td>6.0 KSI / $</td>
<td>200/15</td>
</tr>
<tr>
<td>6.5 KSI / $</td>
<td>230/15</td>
</tr>
</tbody>
</table>

STRAND COST $2.15/Lineal Foot (Optimization Only)

STRAND WRAPPING COST $2.15/Lineal Foot (Optimization Only)

28 DAY CONCRETE STRENGTHS (Include Only for Optimization)

<table>
<thead>
<tr>
<th>Release Strength / 28 Day Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.0 KSI /</td>
</tr>
<tr>
<td>4.5 KSI /</td>
</tr>
<tr>
<td>5.0 KSI /</td>
</tr>
<tr>
<td>5.5 KSI /</td>
</tr>
<tr>
<td>6.0 KSI /</td>
</tr>
<tr>
<td>6.5 KSI /</td>
</tr>
</tbody>
</table>

FIGURE 23. (CONTINUED)
**DISTRICT 21**
**MIDALGOC COUNTY HIGHWAY NO. US 281**
**CONTROL NO. 220 02 IPE 670 SUBMITTED BY MLJ**
**DESCRIPTION EXAMPLE PROBLEM NO. 1**

<table>
<thead>
<tr>
<th>BEAM DIMENSIONS AND PROPERTIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIMENSIONS IN INCHES</td>
</tr>
<tr>
<td>A B C C E F G H</td>
</tr>
<tr>
<td>43.75</td>
</tr>
<tr>
<td><strong>COMPRESSION</strong></td>
</tr>
<tr>
<td>* REINFORCING</td>
</tr>
<tr>
<td>AREA CAMBER</td>
</tr>
<tr>
<td>(IN#2)</td>
</tr>
<tr>
<td>6.00</td>
</tr>
<tr>
<td><strong>STAND INFORMATION</strong></td>
</tr>
<tr>
<td><strong>RAW NUMBER</strong></td>
</tr>
<tr>
<td><strong>MAXIMUM NO. OF STRANDS</strong></td>
</tr>
<tr>
<td><strong>SPACING</strong> (ROW 1 TO 24)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ALLOWABLE STRESS COEFFICIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>RELEASE</td>
</tr>
<tr>
<td>C 0.60</td>
</tr>
<tr>
<td>T 7.50</td>
</tr>
<tr>
<td>SERVICE</td>
</tr>
<tr>
<td>C 0.40</td>
</tr>
<tr>
<td>T 6.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CREEP AND SHrinkage COEFFICIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CREEP1 = 0.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>BRIDGE PROPERTIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEAM LENGTH = 25.0 (FT)</td>
</tr>
</tbody>
</table>

**FIGURE 24. OUTPUT FOR EXAMPLE PROBLEM NO. 1**
### FIGURE 24. (CONTINUED)

#### THE COMMANDS IS TO SELECT STRANDS

#### DESIGN PROPERTIES

- **Release Strands**: 4,000 (kips)
- **Concrete ACUILLS (Release)**: 3,200 (kips)
- **Initial Prestress Loss**: 5.27 percent
- **Bending Strength**: 0.0 (kips)
- **Total Prestress Loss**: 16.72 percent

#### DESIGN RESULTS

#### STRAND LAYOUT

- **Pinned Supported (ft)**: 17.5
- **Uniform Load on Single Beam**: 0.00 (kips/ft)
- **Uniform Load on Single Beam**: 0.00 (kips/ft)

#### COMPUTED DEFORMATION

<table>
<thead>
<tr>
<th>Section</th>
<th>Short Term</th>
<th>Long Term</th>
</tr>
</thead>
<tbody>
<tr>
<td>0/10</td>
<td>0/0</td>
<td>0/0</td>
</tr>
<tr>
<td>1/10</td>
<td>0/0</td>
<td>0/0</td>
</tr>
<tr>
<td>2/10</td>
<td>0/0</td>
<td>0/0</td>
</tr>
<tr>
<td>3/10</td>
<td>0/0</td>
<td>0/0</td>
</tr>
<tr>
<td>4/10</td>
<td>0/0</td>
<td>0/0</td>
</tr>
<tr>
<td>5/10</td>
<td>0/0</td>
<td>0/0</td>
</tr>
</tbody>
</table>

**Stirrup Spacing** = AASHTO 1973
**Stirrup Area** = 0.11 in²

---

*LOADING CONDITIONS*

- **AASHTO LL = 15-20**
- **L.L. DISTRIBUTION FACTOR** = 0.363 (TRUCKS)
- **LOAD (KIPS)**
  - 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
- **Distance from Left Support (ft)**
  - 17.5 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
### Critical Design Factors

**Release Stresses** *(Symbol X denotes stress at allowable)*

<table>
<thead>
<tr>
<th>Section</th>
<th>Stress Top (ksi)</th>
<th>Stress Bottom (ksi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0/20</td>
<td>-0.1430E+00</td>
<td>0.5051E+00</td>
</tr>
<tr>
<td>1/20</td>
<td>-0.1623E+00</td>
<td>0.5536E+00</td>
</tr>
<tr>
<td>2/20</td>
<td>-0.4590E+01</td>
<td>0.4144E+00</td>
</tr>
<tr>
<td>3/20</td>
<td>-0.3763E+01</td>
<td>0.4826E+00</td>
</tr>
<tr>
<td>4/20</td>
<td>-0.5754E+02</td>
<td>0.4552E+00</td>
</tr>
<tr>
<td>5/20</td>
<td>-7.1984E+01</td>
<td>0.4212E+00</td>
</tr>
</tbody>
</table>

**Service Load Stresses** *(Symbol X denotes stress at allowable)*

<table>
<thead>
<tr>
<th>Section</th>
<th>Stress Top (ksi)</th>
<th>Stress Bottom (ksi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0/10</td>
<td>-0.1662E+00</td>
<td>-0.4077E+00</td>
</tr>
<tr>
<td>1/10</td>
<td>-0.2712E+00</td>
<td>-0.5176E+00</td>
</tr>
<tr>
<td>2/10</td>
<td>-0.2226E+00</td>
<td>-0.1177E+00</td>
</tr>
<tr>
<td>3/10</td>
<td>-0.3875E+00</td>
<td>-0.6066E+00</td>
</tr>
<tr>
<td>4/10</td>
<td>-0.3774E+00</td>
<td>-0.4692E+01</td>
</tr>
<tr>
<td>5/10</td>
<td>-0.3833E+00</td>
<td>-0.5071E+01</td>
</tr>
</tbody>
</table>

### List of Design Constraints

- Minimum Concrete Strength \( X \)
- Ultimate Moment
- Maximum Concrete Strength
- Cracking Moment
- Minimum Initial Camber
- Maximum Initial Camber

### Moment and Shear Summary

<table>
<thead>
<tr>
<th>Section</th>
<th>F.P.M. (ft)</th>
<th>L.P.M. (kip-ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0/10</td>
<td>0.6715E+02</td>
<td>0.7549E+02</td>
</tr>
<tr>
<td>1/10</td>
<td>0.5744E+02</td>
<td>0.8712E+02</td>
</tr>
<tr>
<td>2/10</td>
<td>0.1055E+02</td>
<td>0.1210E+02</td>
</tr>
<tr>
<td>3/10</td>
<td>0.1157E+02</td>
<td>0.1226E+02</td>
</tr>
<tr>
<td>4/10</td>
<td>0.1340E+02</td>
<td>0.1455E+02</td>
</tr>
<tr>
<td>5/10</td>
<td>0.1655E+02</td>
<td>0.1655E+02</td>
</tr>
</tbody>
</table>

**Ultimate Moment Required** = 0.5973E+03 kip-ft
**Ultimate Moment Capacity** = 0.7246E+03 kip-ft
**Cracking Moment Capacity** = 0.5364E+03 kip-ft

**Figure 24. (Continued)**
concrete weight and release strength indicated. The initial and total 
prestress losses shown are computed as described in Section 2.1. The 
strand pattern and strand wrapping requirements are listed under the heading 
of Design Results. The number of strands required in each strand row is 
printed, together with number and wrapping lengths for strands in that row. 
The wrapping distance is measured inward, from the end of the beam. Neither 
of the examples in Figures 24 and 25 contain wrapped strands. Deflections 
are displayed for short term (no creep and shrinkage effects) and long term 
(all creep and shrinkage effects have occurred) conditions. The long term 
deflections are computed using the method of Sinno and Furr (2). Positive 
deflections are upward. The stirrup spacing required at each tenth point 
of the beam which is output is based on No. 4, grade 60 stirrups. For the 
optimization option, the final items of design results are cost totals. 
The total beam cost and cost per foot figures shown are of course based 
only on concrete, strand and strand wrapping costs and therefore are incomplete. 

It may happen that the user inadvertently may seek a design which is 
impossible to obtain within the imposed restrictions. When the program 
determines that no feasible design exists, it prints the message

```
***************
*SORRY, THIS BEAM WILL NOT WORK*
***************
```

When this abnormal termination occurs, the user should inspect the input 
data on the first sheet of output for errors. This is the most frequent 
cause of abnormal termination. Other possible causes include; deflection
**EXAMPLE PROBLEM NO. 2**

**SECTION PROPERTIES (WITHOUT SHEAR KEY)**

<table>
<thead>
<tr>
<th>area</th>
<th>(AB)</th>
<th>(BC)</th>
<th>(CD)</th>
<th>(DE)</th>
<th>(EF)</th>
<th>(FG)</th>
<th>(GH)</th>
<th>(IJ)</th>
<th>(JK)</th>
<th>(KL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(100)</td>
<td>(100)</td>
<td>(100)</td>
<td>(100)</td>
<td>(100)</td>
<td>(100)</td>
<td>(100)</td>
<td>(100)</td>
<td>(100)</td>
<td>(100)</td>
<td>(100)</td>
</tr>
</tbody>
</table>

**CONCRETE**

<table>
<thead>
<tr>
<th>(f_{ck})</th>
<th>(f_{ct})</th>
<th>(f_{cd})</th>
<th>(f_{cu})</th>
<th>(f_{cd})</th>
<th>(f_{cd})</th>
<th>(f_{cd})</th>
<th>(f_{cd})</th>
<th>(f_{cd})</th>
<th>(f_{cd})</th>
<th>(f_{cd})</th>
</tr>
</thead>
<tbody>
<tr>
<td>(6000)</td>
<td>(6000)</td>
<td>(6000)</td>
<td>(6000)</td>
<td>(6000)</td>
<td>(6000)</td>
<td>(6000)</td>
<td>(6000)</td>
<td>(6000)</td>
<td>(6000)</td>
<td>(6000)</td>
</tr>
</tbody>
</table>

**REINFORCING BAR**

<table>
<thead>
<tr>
<th>(A_{rr})</th>
<th>(f_{y})</th>
<th>(f_{u})</th>
<th>(E_{s})</th>
<th>(E_{ml})</th>
</tr>
</thead>
<tbody>
<tr>
<td>(20)</td>
<td>(60000)</td>
<td>(60000)</td>
<td>(200000)</td>
<td>(200000)</td>
</tr>
</tbody>
</table>

**STRESS INFORMATION**

<table>
<thead>
<tr>
<th>(f_{y})</th>
<th>(f_{u})</th>
<th>(E_{s})</th>
<th>(E_{ml})</th>
</tr>
</thead>
<tbody>
<tr>
<td>(60000)</td>
<td>(60000)</td>
<td>(200000)</td>
<td>(200000)</td>
</tr>
</tbody>
</table>

**ALLOWABLE STRESS COEFFICIENTS**

<table>
<thead>
<tr>
<th>(f_{y})</th>
<th>(f_{u})</th>
<th>(E_{s})</th>
<th>(E_{ml})</th>
</tr>
</thead>
<tbody>
<tr>
<td>(60000)</td>
<td>(60000)</td>
<td>(200000)</td>
<td>(200000)</td>
</tr>
</tbody>
</table>

**CONCRETE COST COEFFICIENTS**

<table>
<thead>
<tr>
<th>(f_{ck})</th>
<th>(E_{c})</th>
<th>(E_{ml})</th>
</tr>
</thead>
<tbody>
<tr>
<td>(6000)</td>
<td>(4000)</td>
<td>(4000)</td>
</tr>
</tbody>
</table>

**STRAND INFORMATION**

<table>
<thead>
<tr>
<th>(A_{str})</th>
<th>(f_{str})</th>
<th>(E_{str})</th>
<th>(E_{ml})</th>
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</thead>
<tbody>
<tr>
<td>(10)</td>
<td>(12000)</td>
<td>(12000)</td>
<td>(12000)</td>
</tr>
</tbody>
</table>

**STRAIN AND SHRINKAGE COEFFICIENTS**

<table>
<thead>
<tr>
<th>(\varepsilon_{cr})</th>
<th>(\varepsilon_{s\text{r}1})</th>
<th>(\varepsilon_{s\text{r}2})</th>
<th>(\varepsilon_{s\text{r}3})</th>
</tr>
</thead>
<tbody>
<tr>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
</tr>
</tbody>
</table>

**CONCRETE COST COEFFICIENTS**

<table>
<thead>
<tr>
<th>(f_{ck})</th>
<th>(E_{c})</th>
<th>(E_{ml})</th>
</tr>
</thead>
<tbody>
<tr>
<td>(6000)</td>
<td>(4000)</td>
<td>(4000)</td>
</tr>
</tbody>
</table>

**28 DAY CONCRETE STRENGTH COEFFICIENTS**

<table>
<thead>
<tr>
<th>(f_{ck})</th>
<th>(E_{c})</th>
<th>(E_{ml})</th>
</tr>
</thead>
<tbody>
<tr>
<td>(6000)</td>
<td>(4000)</td>
<td>(4000)</td>
</tr>
</tbody>
</table>

**MAXIMUM STRESS LIMIT**

<table>
<thead>
<tr>
<th>(f_{y})</th>
<th>(f_{u})</th>
<th>(E_{s})</th>
<th>(E_{ml})</th>
</tr>
</thead>
<tbody>
<tr>
<td>(60000)</td>
<td>(60000)</td>
<td>(200000)</td>
<td>(200000)</td>
</tr>
</tbody>
</table>

**NUMBER OF BEAMS**

<table>
<thead>
<tr>
<th>(n)</th>
<th>(m)</th>
<th>(I)</th>
<th>(J)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(5)</td>
<td>(10)</td>
<td>(5)</td>
<td>(10)</td>
</tr>
</tbody>
</table>

**NUMBER OF LAYERS**

<table>
<thead>
<tr>
<th>(n)</th>
<th>(m)</th>
<th>(I)</th>
<th>(J)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(5)</td>
<td>(10)</td>
<td>(5)</td>
<td>(10)</td>
</tr>
</tbody>
</table>

**SPAN LENGTH**

<table>
<thead>
<tr>
<th>(L)</th>
<th>(B)</th>
<th>(C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(50)</td>
<td>(10)</td>
<td>(5)</td>
</tr>
</tbody>
</table>

**FIGURE 25. OUTPUT FOR EXAMPLE PROBLEM NO. 2**
LOADING CONDITIONS

- AS:TC LL = 0.5-2
- L.L. DISTRIBUTION FACTOR = 0.25
- UNIFOR C LOAD ON SINGLE BEAM = 0.15 (K/FT)

**FIGURE 25. (CONTINUED)**

THE COMMAND IS TO OPTIMIZE

**DESIGN PROPERTIES**

- RELEASE STRENGTH = 4.00 (ksi) CONCRETE ACTUAL (RELEASE) = 2824.2 (ksi)
- 28-DAY STRENGTH = 5.40 (ksi) INITIAL PRESTRESS LOSS = 0.02 PERCENT
- TOTAL PRESTRESS LOSS = 20.99 PERCENT

**DESIGN RESULTS**

**STRAINS LAYOUT**

<table>
<thead>
<tr>
<th>ROW NUMBER</th>
<th>STRAITS PER ROW</th>
<th>WRAPPED STRANDS IN EACH ROW</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
<td>THERE ARE NO WRAPPED STRANDS IN THIS ROW</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>THERE ARE NO WRAPPED STRANDS IN THIS ROW</td>
</tr>
</tbody>
</table>

**COMPUTED DEFORMATION**

- SHORT TERM
  - CONCITA
  - PGDULIS
  - DEFLECTION
  - 0.59 INCHES (BASED UPON DALLAS CONCRETE PROPERTIES)
- HDUT + KEY
  - 0.14 INCHES
  - 0.05 INCHES
  - 0.06 INCHES (BASED UPON DALLAS CONCRETE PROPERTIES)
- HDUT + KEY + MPN LOAD
  - 5 MILLIA
  - 4/10

- LONG TERM
  - STIRUP SPACING = 4/10
  - STIRUP AREA = 0.11 IN²
  - 1/10
  - 5/10
  - 13.20
  - 13.20
  - 13.20
  - 13.20

**COST AND MATERIAL REQUIREMENTS OF BEAM**

<table>
<thead>
<tr>
<th>STEP</th>
<th>MCM</th>
<th>COST</th>
<th>PERCENTAGE OF TOTAL COST</th>
<th>TOTAL COST OF BEAM</th>
<th>COST PER FOOT</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONCITA</td>
<td>7.21 YD²</td>
<td>8100.88</td>
<td>74.76%</td>
<td>1201.51</td>
<td>4.20</td>
</tr>
<tr>
<td>STRAITS</td>
<td>08.00 FT</td>
<td>20.00</td>
<td>15.61%</td>
<td>25.63</td>
<td>0.80</td>
</tr>
<tr>
<td>WAPPE 91000ft</td>
<td>0.0</td>
<td>0.0</td>
<td>0%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

+W  M K! N INCL UTE ERE Race
### Critical Design Factors

#### Service Load Stresses

<table>
<thead>
<tr>
<th>Section</th>
<th>Stress Top (ksi)</th>
<th>Stress Bottom (ksi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0/20</td>
<td>-0.25000 00</td>
<td>0.13166 01</td>
</tr>
<tr>
<td>1/20</td>
<td>-0.18200 00</td>
<td>0.13066 01</td>
</tr>
<tr>
<td>2/20</td>
<td>-0.85420 01</td>
<td>0.11066 01</td>
</tr>
<tr>
<td>3/20</td>
<td>-0.18420 03</td>
<td>0.10220 01</td>
</tr>
<tr>
<td>4/20</td>
<td>0.73020 01</td>
<td>0.56620 00</td>
</tr>
<tr>
<td>5/20</td>
<td>0.13200 00</td>
<td>0.68250 00</td>
</tr>
</tbody>
</table>

#### Release Stresses

<table>
<thead>
<tr>
<th>Section</th>
<th>Stress TCF (ksi)</th>
<th>Stress Bottom (ksi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0/20</td>
<td>-0.25000 00</td>
<td>0.13166 01</td>
</tr>
<tr>
<td>1/20</td>
<td>-0.18200 00</td>
<td>0.13066 01</td>
</tr>
<tr>
<td>2/20</td>
<td>-0.85420 01</td>
<td>0.11066 01</td>
</tr>
<tr>
<td>3/20</td>
<td>-0.18420 03</td>
<td>0.10220 01</td>
</tr>
<tr>
<td>4/20</td>
<td>0.73020 01</td>
<td>0.56620 00</td>
</tr>
<tr>
<td>5/20</td>
<td>0.13200 00</td>
<td>0.68250 00</td>
</tr>
</tbody>
</table>

### List of Design Constraints

- Minimum Concrete Strength \[ X \]
- Ultimate Moment \[ X \]
- Maximum Concrete Strength \[ Y \]
- Cracking Moment \[ Y \]
- Minimum Initial Camber \[ Z \]
- Maximum Initial Camber \[ Z \]

### Moment and Shear Summary

<table>
<thead>
<tr>
<th>Section</th>
<th>Beam Lt. Plus Shear Key Moments (Kip-ft)</th>
<th>Other D.L. Moments (Kip-ft)</th>
<th>L.L. Moments (Kip-ft)</th>
<th>Total Moments (Kip-ft)</th>
<th>Ultimate Shear (Kips)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0/10</td>
<td>C.C</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>C.74700 00</td>
</tr>
<tr>
<td>1/10</td>
<td>0.656700 02</td>
<td>0.180000 02</td>
<td>0.620000 02</td>
<td>0.860000 02</td>
<td>C.74700 00</td>
</tr>
<tr>
<td>2/10</td>
<td>0.117000 03</td>
<td>0.320000 02</td>
<td>0.530000 02</td>
<td>0.820000 02</td>
<td>C.74700 00</td>
</tr>
<tr>
<td>3/10</td>
<td>0.136000 03</td>
<td>0.375000 02</td>
<td>0.550000 02</td>
<td>0.865000 02</td>
<td>C.74700 00</td>
</tr>
<tr>
<td>4/10</td>
<td>0.152000 03</td>
<td>0.420000 02</td>
<td>0.600000 02</td>
<td>0.820000 02</td>
<td>C.74700 00</td>
</tr>
<tr>
<td>5/10</td>
<td>0.178000 03</td>
<td>0.480000 02</td>
<td>0.660000 02</td>
<td>0.840000 02</td>
<td>C.74700 00</td>
</tr>
</tbody>
</table>

**Ultimate Moment Required:** 0.78080 03 Kip-ft
**Ultimate Moment Capacity:** 0.78080 03 Kip-ft
**Cracking Moment Capacity:** 0.34500 02 Kip-ft

*Figure 25. (Continued)*
constraints are too "tight", i.e., upper bound too small or lower bound too large, inadequate number of strand rows provided, or inadequate concrete strength specified (design option).

The final sheet of output (see the third sheet in Figures 24 and 25) provides information on factors controlling the final design. Release and service load stresses are displayed first, with compression stress positive. An "x" beside a stress indicates that it is at the allowable (see Figure 25). Generally, the stresses shown may in some cases slightly exceed the allowables. This is the result of permitting a slight variation in computed prestress loss on successive iterations (see Section 2.4) and of rounding the final number of strands in each row to an integer value. This is demonstrated in Figure 24, sheet 3, where the service load stress at the bottom of the beam at midspan is slight tension where zero tension is permitted. Stress computations are based on the strand pattern, strand wrapping and prestress losses indicated on the second output sheet. For release stresses, beam weight and prestress forces are considered. Service load stresses are based on live load moment, dead load moment (beam weight, shear key, uniform and concentrated loads), and prestress force.

Active design constraints are denoted with an "x" under the List of Design Constraints section of the third output sheet. For example, the final design of the first example problem (Figure 24) is controlled by ultimate moment considerations. As shown at the bottom of the Moment and Shear Summary table, the required ultimate moment capacity is 788 k-ft., while that supplied is 815 k-ft. These two numbers are not identical because of rounding of the number of strands to an integer value.
Moments and shears used in design are listed in the Moment and Shear Summary. Live load moments include lateral distribution and impact factors. Ultimate shears are total live load plus dead load, with load factors defined in Section 2.1.
V. PROGRAM DOCUMENTATION - DBOXDS

The computer program DBOXDS implements the box girder design formulation developed in Chapter III. Described below are the standard input form and its use, interpretation of program output and several example problems.

5.1 PROGRAM INPUT

Figure 26 shows the input form to be used with the program.

5.1.1 Title Cards

The first three input cards are title cards providing a means of job reference. The information preprinted on the form in various columns need not be punched on the data cards - it will be printed out automatically during output. The information on these cards is optional. The first two cards should only be input once per computer run. The third title card is the first card in a data pack when multiple problem runs are made, as explained below.

5.1.2 Load and Options Card

The type of standard AASHTO loading (H-15, H-20, HS-15 or HS-20) is entered in columns 5 - 6 and 8 - 9. The live load distribution factor entered in columns 13 - 16 is the fraction of an axle load to be carried by the beam. This distribution factor is applied to the axle train loading (if used) as well as AASHTO truck and lane loadings. If columns 13 - 16 are left blank, the program automatically computes lateral distribution using Eqs. (24) thru (26), (the AASHTO distribution factor). If a vehicle other than an AASHTO truck is to be used for design, enter a "1" in column 20 and complete the axle train data cards. If both axle train and AASHTO loadings...
**TENAS HIGHWAY DEPARTMENT**
**BRIDGE DIVISION**

**BOX BEAM DESIGN PROGRAM**
(BOXED STRANDS)

---

**Part 1 of 2**

### District:

### County:

### Highway No.:

### Box Beam Design Program (Draped Strands)

---

**A.A.S.T.O. Live Load Distribution Factor**

<table>
<thead>
<tr>
<th>Axle 1</th>
<th>Axle 2</th>
<th>Axle 3</th>
<th>Axle 4</th>
<th>Axle 5</th>
<th>Axle 6</th>
<th>Axle 7</th>
<th>Axle 8</th>
<th>Axle 9</th>
<th>Axle 10</th>
<th>Axle 11</th>
<th>Axle 12</th>
<th>Axle 13</th>
<th>Axle 14</th>
<th>Axle 15</th>
<th>Axle 16</th>
<th>Axle 17</th>
<th>Axle 18</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>6</td>
<td>8</td>
<td>9</td>
<td>13</td>
<td>16</td>
<td>20</td>
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<td>48</td>
<td>48</td>
<td>48</td>
<td>48</td>
<td>48</td>
<td>48</td>
</tr>
</tbody>
</table>

---

**AXLE TRAIN**

<table>
<thead>
<tr>
<th>Axle 1</th>
<th>Axle 2</th>
<th>Axle 3</th>
<th>Axle 4</th>
<th>Axle 5</th>
<th>Axle 6</th>
<th>Axle 7</th>
<th>Axle 8</th>
<th>Axle 9</th>
<th>Axle 10</th>
<th>Axle 11</th>
<th>Axle 12</th>
<th>Axle 13</th>
<th>Axle 14</th>
<th>Axle 15</th>
<th>Axle 16</th>
<th>Axle 17</th>
<th>Axle 18</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>16</td>
<td>20</td>
<td>24</td>
<td>27</td>
<td>31</td>
<td>35</td>
<td>37</td>
<td>48</td>
<td>48</td>
<td>48</td>
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<td>48</td>
<td>48</td>
<td>48</td>
<td>48</td>
<td>48</td>
<td>48</td>
</tr>
</tbody>
</table>

---

**CONCENTRATED LOADS ON SINGLE BEAM**

<table>
<thead>
<tr>
<th>Load (kips)</th>
<th>Distance from Axle 1 to Axle 1 (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>14</td>
<td>16</td>
</tr>
<tr>
<td>18</td>
<td>20</td>
</tr>
<tr>
<td>22</td>
<td>24</td>
</tr>
<tr>
<td>26</td>
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</tr>
<tr>
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<td>32</td>
</tr>
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<td>56</td>
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<tr>
<td>58</td>
<td>60</td>
</tr>
<tr>
<td>62</td>
<td>64</td>
</tr>
<tr>
<td>66</td>
<td>68</td>
</tr>
<tr>
<td>70</td>
<td>72</td>
</tr>
<tr>
<td>74</td>
<td>76</td>
</tr>
</tbody>
</table>

---

**BEAM DIMENSIONS**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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<tr>
<td>4</td>
<td>7</td>
<td>9</td>
<td>12</td>
<td>14</td>
<td>16</td>
<td>17</td>
<td>19</td>
<td>22</td>
<td>24</td>
<td>27</td>
<td>29</td>
<td>32</td>
<td>34</td>
<td>37</td>
<td>39</td>
<td>42</td>
<td>44</td>
</tr>
</tbody>
</table>

---

**Span Length (ft)**

| 4      | 7      | 11     | 14     |

---

**Bridge Width (ft)**

| 4      | 7      |

---

**Number of Traffic Lanes**

| 10     | 14     |

---

**Number of Beams**

| 18     | 19     |

---

**Area of Compression Reinforcing (in²)**

| 18     | 22     |

---

**Distance to Centerline of Beam**

| 36     | 39     |

---

**Maximum Initial Camber (in)**

| 43     | 47     |

---

**Distance From Bottom Of Beam To Harping Point (ft)**

| 57     | 59     |

---

**Enter 1 for Axle Train Applied To Single Beam**

| 60     | 61     |

---

**Enter 1 for Concentrated Loads on Single Beam**

| 64     | 66     |

---

**Enter 1 for Optimization Option**

| 67     | 72     |

---

**MAXIMUM NUMBER OF STRANDS PERMITTED IN ROW i**

| 1      | 1      | 1      | 1      |

---

**FIGURE 26. INPUT FORM FOR DBOXDS**
## MISCELLANEOUS PROPERTIES CARD
(Enter This Card Only if Previously Specified)

<table>
<thead>
<tr>
<th>Unit Weight</th>
<th>Strand Area</th>
<th>Strand Ultimate Strength</th>
<th>Grid Spacing</th>
<th>Allowable Stress Coefficients (ksi)</th>
<th>Creep &amp; Shrinkage Coefficients (μ - in. / 8 Days)</th>
<th>Top-Most Grid Row</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete</td>
<td>Strand</td>
<td></td>
<td></td>
<td>Grid Release</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(lb/ft³)</td>
<td>(in²)</td>
<td>(ksi)</td>
<td>ft</td>
<td>C</td>
<td>T</td>
<td>C</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
<td>10</td>
<td>11</td>
<td>14</td>
<td>16</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>31</td>
<td>32</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>45</td>
<td>46</td>
<td>48</td>
</tr>
</tbody>
</table>

## CONCRETE COST COEFFICIENTS
(Include Only for Optimization Option)

<table>
<thead>
<tr>
<th>Release Strength (ksi)</th>
<th>Cost YD</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.0ksi/$</td>
<td>11</td>
</tr>
<tr>
<td>7.0ksi/$</td>
<td>14</td>
</tr>
<tr>
<td>4.5ksi/$</td>
<td>24</td>
</tr>
<tr>
<td>7.5ksi/$</td>
<td>27</td>
</tr>
<tr>
<td>5.0ksi/$</td>
<td>32</td>
</tr>
<tr>
<td>8.0ksi/$</td>
<td>35</td>
</tr>
<tr>
<td>5.5ksi/$</td>
<td>38</td>
</tr>
<tr>
<td>8.5ksi/$</td>
<td>40</td>
</tr>
<tr>
<td>6.0ksi/$</td>
<td>42</td>
</tr>
<tr>
<td>9.0ksi/$</td>
<td>43</td>
</tr>
<tr>
<td>6.5ksi/$</td>
<td>44</td>
</tr>
</tbody>
</table>

## STRAND COST
$/Linear Foot (Optimization Only)

## 28 DAY CONCRETE STRENGTHS
(Include Only for Optimization)

<table>
<thead>
<tr>
<th>Release Strength</th>
<th>28 Day Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.0ksi</td>
<td>11</td>
</tr>
<tr>
<td>7.0ksi</td>
<td>14</td>
</tr>
<tr>
<td>4.5ksi</td>
<td>24</td>
</tr>
<tr>
<td>7.5ksi</td>
<td>26</td>
</tr>
<tr>
<td>5.0ksi</td>
<td>32</td>
</tr>
<tr>
<td>8.0ksi</td>
<td>35</td>
</tr>
<tr>
<td>5.5ksi</td>
<td>38</td>
</tr>
<tr>
<td>8.0ksi</td>
<td>40</td>
</tr>
<tr>
<td>6.0ksi</td>
<td>42</td>
</tr>
<tr>
<td>9.0ksi</td>
<td>43</td>
</tr>
<tr>
<td>6.5ksi</td>
<td>44</td>
</tr>
</tbody>
</table>

FIGURE 26. (CONTINUED)
are specified, the larger of the axle train, AASHTO truck and AASHTO lane
moments are used at each design point (Figure 2). A uniform dead load carried
by a single box girder (i.e., with no lateral distribution of load) is
entered in columns 24 - 27. This provision allows the user to include the
weight of such things as a wearing surface in the design. Concentrated dead
load forces applied to a single girder are indicated by placing a "1" in
column 31 and completing the concentrated loads on single beam data
cards. Column 48 dictates which program option is to be used. If a "1"
is entered, the program determines the minimum cost design, based on cost
information input from part 2 of the form. This is the "optimization
option". If column 48 is left blank, the program exercises the "design
option", in which the strand pattern and release strength are selected
which minimize the number of strands used, assuming the beam concrete
has the 28-day strength entered in columns 35 - 37.

5.1.3 Axle Train Cards (Use Only if "1" Entered in Column 20 of
Load and Options Card)

A moving load pattern of up to 18 axles may be used for design.
The first card contains the total load on each axle. To facilitate
input, the user should sketch the axle train configuration, labeling
either the right-most or left-most axle as axle 1 and numbering the
remaining axles in sequential order. The weight of each axle is then
placed in the appropriate columns of the first data card. The spacing
of axles is input on the second data card, where axle spacing is defined
as the distance from axle 1 to the axle under consideration. As an ex-
ample, an AASHTO HS-20 truck (with rear axles separated 14 feet) whose
light axle was designated as axle 1, would require 8.0 in columns 4 - 6 on the first card and 32.0 in columns 8 - 10 and 12 - 14. The second card would contain 14. in columns 8 - 10 and 28. in columns 12 - 14. The program automatically scales axle train axle loads by the lateral distribution factor, but no impact factor is applied,

5.1.4 Concentrated Loads on Single Beam Cards (Use Only if Column 31 of Load and Option Card Contains "1")

Up to 10 concentrated forces acting on a single beam (no lateral distribution assumed) may be input. The first card contains the magnitude of the load, while the second card contains the distance of each load from the left support. This program provision is intended for small loads only. Service load stress checks assume that maximum moment due to total dead load plus live load occurs at a tenth point. If large concentrated forces not at tenth points are entered, this assumption may be in error, resulting in an overstressed design.

5.1.5 Beam Dimensions Card

The dimensions of the beam cross section which are to be input are shown on the figure at the upper right corner of part 1 of the input form. The fillets (dimensions X and Y) are assumed to slope at 45 degrees. Most any cross sectional shape can be accommodated with the dimensions shown. An ordinary rectangular voided section can be obtained, for example, by inputing dimensions such that A=B=(2·W+M) and C=H=E=C=0 (or left blank).

5.1.6 Bridge and Beam Properties Card

The information on this card is used to compute the lateral distribution factor (if columns 13 - 16 of the load and options card is
left blank) and other quantities used to formulate the constraint set.
The span length is entered in columns 4 - 7, bridge width in columns 11 - 14, number of traffic lanes in columns 18 - 19 and number of longitudinal beams in columns 23 - 26. The number of longitudinal beams is input as a decimal number to accommodate unusual conditions (such as a mixture of two or more different box cross sections in the same bridge). Compression steel is sometimes used in box sections to help control long term camber. The area of this steel, which is input in columns 29 - 32, is considered in the computation of section properties, using a transformed steel area of \((n-1)\) for properties with shear key and \(2(n-1)\) without. The distance from the top of the beam to c.g. of compression steel is entered in columns 36 - 39. If left blank, the program assumes \(T/2\). Maximum and minimum acceptable release cambers are input in columns 43 - 47 and 51 - 55 (upward camber is positive, downward camber negative). These apply to the midspan camber at release produced by prestress and beam weight. A typical application of the lower bound camber would be to insure that a beam did not deflect downward under full dead load (say, shear key plus wearing surface). If an estimate of the final release strength is made, then a modulus of elasticity can be computed, and the midspan downward deflection under shear key and wearing surface weights determined. This value is entered (as a positive number in this case) under minimum initial camber. This will insure that the final design has enough upward initial camber to offset the downward deflection caused by the addition of shear key and wearing surface. If columns 43 - 47 or 51 - 55 are left blank, then the constraint is ignored during design. The distance from the bottom of the beam to the centerline of the first (bottom-most) strand row is input in columns 60 - 61. The number of web strands, or the number of strands that may be draped in
any given row, is input in columns 66 - 67. The distance from the centerline of the beam to the harping point, should there be a need for draped strands, is input in columns 72 - 74. Should column 79 be left blank, the program assumes normal weight concrete (150 lbs/ft³), 50% relative humidity, 0.153 in.² grade 270 strands, and a standard grid spacing of 2.0 inches. The allowable stress coefficients are taken as 0.6 for compression and 7.5 for tension at release and 0.4 and 6.0 under service loads. In order to change any or all of these properties, enter "1" in column 79 and complete the miscellaneous properties card.

5.1.7 Maximum Number of Strands and Top-Most Grid Row Card

The maximum number of strands, the number of rows available for strands, and the top-most grid row (if less than or equal to 26) are determined from this input data. Strand rows are numbered consecutively, taking the bottom-most row as row 1. The maximum number of strands to be allowed in each row should be input in the columns corresponding to that row on the input form. The computation time required to obtain a final design increases rapidly as the number of available strand rows increases. Thus, one should include only those rows which will likely be used. The top-most grid row is the upper-most row to which strands may be draped at the ends of the beam. This is input by entering "TP" in the two columns corresponding to the row number of the top-most grid row. If the top-most row number is greater than 26, enter 1 in column 79 of the bridge and beam properties card and enter the row number in columns 79-80 of the miscellaneous properties card. At present the program is limited to 10 rows of strands.

5.1.8 Miscellaneous Properties Card (Use Only if "1" Entered in Column 79 of Bridge and Beam Properties Card)
If properties other than the standard values listed in Section 5.1.6 are to be used, they must be entered on this card. Only those properties which differ from standard values need to be entered. If the program encounters blanks on the card where a property is to be read, it automatically assumes the standard value. The unit weight of concrete, if different from 0.150 k/ft$^3$, is entered in columns 4 - 6. Relative humidity is entered in columns 10 - 11, strand area in columns 14 - 16, ultimate strength of strands in columns 19 - 21 and grid spacing in columns 25 - 26. The coefficients used to specify allowable stresses are entered in columns 31 - 55. If the allowable compressive release stress differs from 0.6 $f'_{ci}$ or the allowable tensile stress from 7.5 $\sqrt{f'_{ci}}$, then the coefficients (those that replace 0.6 and 7.5) should be entered in columns 31 - 32 and 34 - 35 for the end 1/10 of the beam ($j = 6 \& 7$ in Figure 17) and in columns 37 - 38 and 40 - 41 for the remainder of the beam. If the allowable compressive long term stress differs from 0.4 $f'_c$ or the allowable long term tensile stress from 6.0 $\sqrt{f'_c}$, then the new coefficients should be entered in columns 45 - 46 and 48 - 49 for the end 1/10 of the beam and in columns 51 - 52 and 54 - 55 for the remainder of the beam.

The final beam camber at midspan after all prestress losses and creep and shrinkage effects have occurred is computed using the method developed in Reference (2). Cambers are computed and displayed using four different sets of creep and shrinkage coefficients typical of concretes in highway beams produced in four localities in Texas. Should the designer have information on the creep and shrinkage properties of the concrete he expects to be used in a particular design, he may enter the appropriate coefficients in columns 58 - 75. The program will then compute and display the expected midspan camber for these conditions.
The number of the top-most grid row, if greater than 26, must be entered in columns 79 - 80.

5.1.9 Concrete Cost Coefficients Cards (Use Only if "1" Entered in Column 48 of Load & Options Card)

The cost of concrete in dollars per cubic yard can be input for concrete release strengths up to 9.0 ksi. If an estimate of the cost per cubic yard for 4.0 ksi release strength can be made, Figure 7 can be used as a guide to establishing the cost of higher strengths in the absence of actual cost data. Should release strengths beyond some value (say, 7.0 ksi) not be feasible, then the values (7.5, 8.0, 8.5 and 9.0) beyond that point should be left blank.

5.1.10 Strand Cost Card (Use Only if "1" Entered in Column 48 of Load & Option Card)

The cost per foot for strand is entered in columns 14 - 16.

5.1.11 28-Day Concrete Strength Cards (Use Only if "1" Entered in Column 48 of Load & Options Card)

The relationship between release strength and 28-day strength is defined by the data input from these cards. It isn't possible to construct a general relationship between release and 28-day strengths because of the many factors that influence it. There are similarities in the operations of the major producers of highway beams in the state of Texas (12) which permit a reasonable estimate of the relationship.

Fabricators generally use a 24 hour steam curing production sequence. Beams are cast in the afternoon, allowed to gain their initial set (minimum of 3 hours after casting before steam curing is begun (13)) and then steam cured overnight. A total steam curing period of 18 hours at 140° to 150° F.
is typical of most operations. Hanson (14) collected data on concretes made with type III Portland cement and subjected to 15 hours of steam curing at 150° F. commencing 3 hours after casting. Concrete strengths were generally around 4 ksi at 18 hours (release) and 5 ksi at 28 days. For the data reported, the 18 hour strengths averaged 74% of the 28-day strengths. This percentage is probably valid over the usual range of release strengths utilized in THD prestressed designs, which is approximately 6 ksi. If this percentage is applied to release strengths between 4 and 6 ksi, the first straight line segment shown in Figure 20 is produced. Higher release strengths generally demand longer periods of steam curing and result in smaller percentage gains in release strength over 28-day strength. At the extreme limit of 9 ksi release strength, the fabricator would no doubt be forced to keep the beams under special cure for the majority of a 28-day period before release strength was reached. Under these conditions, the ratio of release strength to 28-day strength should be approximately 1. If a linear variation in strength gain over release strength is assumed between 6. and 9. ksi release strengths, the second straight line segment shown in Figure 20 is obtained.

5.1.12 Multiple Problem Runs

The user may process more than one design in a single computer run. The first problem must contain the three title cards described in Section 5.1.1. Each additional problem which is run should have the third title card as the first card in the data set.

5.2 SAMPLE PROBLEMS

Described below are several example problems demonstrating the use of
5.2.1 Example Problem 3

A multibeam box girder bridge is to carry two lanes of traffic with HS-20 loading and span 80.0 ft. The girder cross section is to be formed using a standard FHWA design for an 80.0 ft. span and an overall beam width of 3.0 ft. Ten boxes will be used to support an overall bridge width of 30.0 ft. and a uniform dead load of 160 lbs./ft. The design will incorporate two strand rows, using 1/2 in. diameter grade 270k strands. A maximum of ten strands will be allowed in the first strand row, which is to be placed 2.5 in. above the bottom of the section. The second row is located the standard 2.0 in. above the first, and may also contain 10 strands. Since the section is 42. in. deep, with a standard grid spacing of 2.0 in., the top-most grid row available for draped strands will be taken as row number 18. Each 5 in. web width will accommodate 2 strands in each row, hence the number of web strands, or the number of strands available for draping, is taken as 4. Five number 4, grade 60 conventional reinforcing bars are to be placed in the deck slab, 2.5 in. down from the surface.

The beam dimensions C, E, G, and H have been specified as 0.0 in. on the input form, which effectively modifies the beam section shown on the input form to accommodate this specific beam cross section. For this design, there is essentially no shear key.

The midspan camber of the beam is assumed to be a non-controlling factor in the design, and is therefore ignored in the computations.

In order to prevent tension cracks in the concrete at the ends of the beam, there will be no tension stress allowed at the ends of the beam at release, however all other allowable stresses will be taken as the standard
values specified in section 5.1.6.

The in-place cost of beam concrete is assumed to be $150/cu.yd. for release strengths up to 5.5 ksi, $200 for \( f'_{ci} = 6.0 \) ksi and $230 for \( f'_{ci} = 6.5 \) ksi. Release strengths greater than 6.5 ksi are assumed to be unavailable. The 28 day concrete strength corresponding to each release strength is assumed to be that given in Figure 20.

5.2.2 Example Problem 4

A 48 ft. wide multibeam bridge consisting of 16 box girder units is to be constructed to accommodate 2 lanes of traffic and span 80 ft. The design loads consist of an HS-20 truck and a uniform load of 160 lbs./ft. The box cross section to be used is a 3 ft. wide bituminous surface beam proposed as a standard by the Commonwealth of Pennsylvania Department of Transportation. The vertical positioning of strand rows is such that the first row is placed 1.5 in. above the bottom of the section, with subsequent rows spaced evenly at 2.0 in. A lateral spacing of 2.0 in. center-to-center will permit a maximum of 15 strands per row. Grade A-416, 7/16 in. diameter strands (ultimate strength of 270k and cross sectional area of 0.117 in.\(^2\)) are to be used. The 5 in. web width and 42 in. depth of the section provide for 4 web strands and a top-most grid row of 18, should there be a need for draping. Compression reinforcing consists of 4 No. 4 grade A615 bars placed 2.5 in. from the top of the section. Downward camber of the beam at release will not be permitted, however the amount of upward camber is not critical. Allowable release and service load stresses in the concrete are those specified in the AASHTO Bridge Specification (4) for inland regions.

Due to the large number of boxes in the bridge and the standard allowable stress coefficients permitted, the design of each section should not be overly critical. Thus, there should not be a need for more than 2 strand
FIGURE 27. COMPLETED INPUT FORM FOR EXAMPLE PROBLEM 3.
**BOX BEAM DESIGN PROGRAM**  
**(DRAPE STRANDS)**

**Part 2 of 2**

### MISCELLANEOUS PROPERTIES CARD (Enter This Card Only if Previously Specified)

<table>
<thead>
<tr>
<th>Unit Weight Concrete (lbs/ft&lt;sup&gt;3&lt;/sup&gt;)</th>
<th>Relative Humidity (%)</th>
<th>Strand Area (in&lt;sup&gt;2&lt;/sup&gt;)</th>
<th>Strand Ultimate Strength (ksi)</th>
<th>Grid Spacing (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>6</td>
<td>14</td>
<td>19</td>
<td>25</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Allowable Stress Coefficients (ksi)</th>
<th>Creep &amp; Shrinkage Coefficients (µ - in. / 8 Days)</th>
<th>Top-Most Grid Row (if &gt; 26)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>T</td>
<td>58</td>
</tr>
<tr>
<td>T</td>
<td>C</td>
<td>60</td>
</tr>
<tr>
<td>T</td>
<td>C</td>
<td>62</td>
</tr>
<tr>
<td>C</td>
<td>T</td>
<td>65</td>
</tr>
<tr>
<td>C</td>
<td>T</td>
<td>68</td>
</tr>
<tr>
<td>T</td>
<td>C</td>
<td>70</td>
</tr>
<tr>
<td>C</td>
<td>T</td>
<td>73</td>
</tr>
<tr>
<td>T</td>
<td>C</td>
<td>75</td>
</tr>
<tr>
<td>C</td>
<td>T</td>
<td>78</td>
</tr>
<tr>
<td>T</td>
<td>C</td>
<td>80</td>
</tr>
</tbody>
</table>

**CONCRETE COST COEFFICIENTS** (Include Only for Optimization Option)

**Release Strength (ksi) / Cost YD**

<table>
<thead>
<tr>
<th>4.0ksi / $</th>
<th>4.5ksi / $</th>
<th>5.0ksi / $</th>
<th>5.5ksi / $</th>
<th>6.0ksi / $</th>
<th>6.5ksi / $</th>
</tr>
</thead>
<tbody>
<tr>
<td>150</td>
<td>150</td>
<td>150</td>
<td>150</td>
<td>200</td>
<td>230</td>
</tr>
</tbody>
</table>

**STRAND COST** $ 25 / Lineal Foot (Optimization Only)

**28 DAY CONCRETE STRENGTHS** (Include Only for Optimization)

<table>
<thead>
<tr>
<th>Release Strength / 28 Day Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.0ksi / $</td>
</tr>
<tr>
<td>4.5ksi / $</td>
</tr>
<tr>
<td>5.0ksi / $</td>
</tr>
<tr>
<td>5.5ksi / $</td>
</tr>
<tr>
<td>6.0ksi / $</td>
</tr>
<tr>
<td>6.5ksi / $</td>
</tr>
</tbody>
</table>

**FIGURE 27. (CONTINUED)**
rows and probably no reason to use draped strands.

The design option is to be used for this problem with the completed input form shown in Figure 28. Program output for this problem is shown in Figure 30.

5.3 INTERPRETATION OF PROGRAM INPUT

The program first reads input data and performs basic checks for input errors. At present, the program checks include: design option specified but no 28 day concrete strength given, proper AASHTO loading designation and omitted span length and omitted number of longitudinal beams (if no live load distribution factor is input), top-most grid row not specified, and an unrecognizable AASHTO truck loading. The input data is printed out before design calculations are begun so that the user can locate input errors which might cause the program to terminate abnormally before producing any other input. The output format is essentially the same for design and optimization options (see first sheet, Figures 29 and 30).

The second sheet of output summarizes the design results, as seen in Figures 29 and 30. The strength and modulus of the concrete, and the prestress losses in the strands are listed under the heading of Design Properties. The first items listed are the release and 28-day concrete strengths. For the design option, the 28-day strength is that specified on input, while the release strength is computed and 28-day strength is obtained from 28-day vs. release strength input data. The modulus of elasticity listed is computed using the ACI equation (10) and the unit concrete weight and release strength indicated. The initial and total prestress losses shown are computed as described in Section 2.1. The strand pattern, deflections, and stirrup spacing requirements are listed under the heading of Design Results. Under
TEXAS HIGHWAY DEPARTMENT
BRIDGE DIVISION

BOX BEAM DESIGN PROGRAM
(DRAPED STRANDS)

DISTRICT 02  Tarrant County  HIGHWAY NO. 3W-121
CONTROL NO. 31-152  IPE COR SUBMITTED BY (LJ)
DESCRIPTION Example Problem No. 4

A. A.S.H.T.O. L.L.

Load Distribution Factor

Uniform Load on Single Beam

28 Day Strength (ksi)

Enter 1 if Concentrated Forces Applied to Single Beam

Enter 1 if Optimization Option

AXLE TRAIN

Axle Loads (kips) Axle 1 Axle 2 Axle 3 Axle 4 Axle 5 Axle 6 Axle 7 Axle 8 Axle 9 Axle 10 Axle 11 Axle 12 Axle 13 Axle 14 Axle 15 Axle 16 Axle 17 Axle 18

CONCENTRATED LOADS ON SINGLE BEAM

Load (kips) Distance from Left Support (ft)

4 8 10 14 16 20 22 26 28 32 34 38 40 44 46 50 52 56 58 62

BEAM DIMENSIONS


Enter 1 To Read Misc. Properties Card

MAXIMUM NUMBER OF STRANDS PERMITTED IN ROW 1

Enter "TP" in Top-Most Row, If 1-26

Enter 1 For Axle Train

Enter 1 For Optimization Option

Distance to Centerline of Beam From Bottom of Beam

Distance From Harping Point

FIGURE 28. COMPLETED INPUT FORM FOR EXAMPLE PROBLEM 4.
# BOX BEAM DESIGN PROGRAM
## (DRAPEED STRANDS)

### MISCELLANEOUS PROPERTIES CARD
(Enter This Card Only if Previously Specified)

<table>
<thead>
<tr>
<th>Unit Weight Concrete (k/s/Cu Ft)</th>
<th>Relative Humidity (%)</th>
<th>Strand Area (in²)</th>
<th>Strand Ultimate Strength (ksi)</th>
<th>Grid Spacing (in)</th>
<th>Allowable Stress Coefficients (ksi)</th>
<th>Creep &amp; Shrinkage Coefficients (µ - in. &amp; Days)</th>
<th>Top-Most Grid Row (if .26)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>6</td>
<td>10</td>
<td>11</td>
<td>14</td>
<td>End 1/10</td>
<td>58 60</td>
<td>79 80</td>
</tr>
<tr>
<td></td>
<td></td>
<td>17</td>
<td>19</td>
<td>21</td>
<td>End 1/10</td>
<td>48 49</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>23 26</td>
<td>Remainder</td>
<td>51 52</td>
<td></td>
</tr>
</tbody>
</table>

### CONCRETE COST COEFFICIENTS
(Include Only for Optimization Option)

<table>
<thead>
<tr>
<th>Release Strength (ksi)</th>
<th>Cost YD</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.0ksi/$</td>
<td>11 14</td>
</tr>
<tr>
<td>4.5ksi/$</td>
<td>24 27</td>
</tr>
<tr>
<td>5.0ksi/$</td>
<td>37 40</td>
</tr>
<tr>
<td>5.5ksi/$</td>
<td>50 53</td>
</tr>
<tr>
<td>6.0ksi/$</td>
<td>63 66</td>
</tr>
<tr>
<td>6.5ksi/$</td>
<td>76 79</td>
</tr>
</tbody>
</table>

### STRAND COST $ / Lineal Foot
(Optimization Only)

- $14 16

### 28 DAY CONCRETE STRENGTHS
(Include Only for Optimization)

<table>
<thead>
<tr>
<th>Release Strength</th>
<th>28 Day Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.0ksi /</td>
<td>11 13</td>
</tr>
<tr>
<td>4.5ksi /</td>
<td>24 26</td>
</tr>
<tr>
<td>5.0ksi /</td>
<td>37 39</td>
</tr>
<tr>
<td>5.5ksi /</td>
<td>50 52</td>
</tr>
<tr>
<td>6.0ksi /</td>
<td>63 65</td>
</tr>
<tr>
<td>6.5ksi /</td>
<td>76 78</td>
</tr>
</tbody>
</table>

FIGURE 28. (CONTINUED)
**Figure 29. Output for Example No. 3**
**LOADING CONDITIONS**

- AASHTO LL = F-20
- L.L. DISTRIBUTION FACTOR = 0.25 (TRUCKS)
- UNIFORM LOAD ON SINGLE EFF = 0.12 (K/FT)

FIGURE 29. (CONTINUED)
THE COMMAND IS TO OPTIMIZE

DESIGN PROPERTIES

- RELEASE STRENGTH = 5.50 (ksi) CONCRETE MCCLUS(RELEASE) = 4496.1 (ksi) INITIAL PRESTRESS LOSS = 5.7 PERCENT
- 28-DAY STRENGTH = 7.40 (ksi)

DESIGN RESULTS

- STRAND LAYOUT

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>DISTANCE FROM END OF BEAM</th>
<th>DISTANCE FROM CF DRAPED STRANDS TO CG.</th>
<th>DISTANCE FROM TOP OF BEAM TO CG.</th>
<th>DISTANCE FROM STRAIGHT STRANDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CF TENSIONS</td>
<td>15.76</td>
<td>2.50</td>
<td>2.50</td>
<td></td>
</tr>
<tr>
<td>CF STEEL</td>
<td>7.25</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- TOTAL NUMBER OF STRANDS = 14
- NUMBER OF DRAPED STRANDS = 0
- NUMBER OF STRAINS IN ROW 2 = 4
- NUMBER OF STRINGS IN ROW 1 = 10
- AT THE END OF THE BEAM, BEGINNING WITH ROW 1, RAISE 4 STRANDS IN EACH ROW 12.0 INCHES ABOVE STRAIGHT STRANDS IN THAT ROW

- COMPUTER DEFLECTION

<table>
<thead>
<tr>
<th>SECTION</th>
<th>SPACING (IN.)</th>
<th>3/10</th>
<th>1/10</th>
<th>5/40</th>
<th>2/10</th>
<th>1/4</th>
<th>3/10</th>
<th>4/10</th>
<th>5/10</th>
<th>PCUT</th>
</tr>
</thead>
</table>

- COST AND MATERIAL REQUIREMENTS OF BEAM

<table>
<thead>
<tr>
<th>ITEM</th>
<th>AMOUNT</th>
<th>COST</th>
<th>PERCENTAGE OF TOTAL COST</th>
<th>TOTAL COST OF BEAM</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONCRETE</td>
<td>14.72 YD^3</td>
<td>$226.14</td>
<td>85.75%</td>
<td>$2486.14</td>
</tr>
<tr>
<td>STRAPS</td>
<td>1120 SQ FT</td>
<td>$300.60</td>
<td>11.25%</td>
<td>$31.10</td>
</tr>
</tbody>
</table>

*DOES NOT INCLUDE FADE SECTION

FIGURE 29. (CONTINUED)
<table>
<thead>
<tr>
<th>SECTION</th>
<th>STRESS TOP (ksi)</th>
<th>STRESS BOTTOM (ksi)</th>
<th>SECTION</th>
<th>STRESS TOP (ksi)</th>
<th>STRESS BOTTOM (ksi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0/10</td>
<td>-0.148E+01</td>
<td>0.192E+01</td>
<td>0/10</td>
<td>-0.951E+02</td>
<td>0.522E+00</td>
</tr>
<tr>
<td>1/10</td>
<td>0.237E+00</td>
<td>0.289E+00</td>
<td>1/10</td>
<td>0.628E+00</td>
<td>0.505E+00</td>
</tr>
<tr>
<td>2/10</td>
<td>0.414E+00</td>
<td>0.475E+02</td>
<td>2/10</td>
<td>0.914E+00</td>
<td>0.633E+00</td>
</tr>
<tr>
<td>3/10</td>
<td>0.519E+00</td>
<td>0.567E+00</td>
<td>3/10</td>
<td>0.105E+01</td>
<td>0.687E+00</td>
</tr>
<tr>
<td>4/10</td>
<td>0.618E+00</td>
<td>0.660E+00</td>
<td>4/10</td>
<td>0.129E+01</td>
<td>0.725E+00</td>
</tr>
<tr>
<td>5/10</td>
<td>0.759E+00</td>
<td>0.802E+00</td>
<td>5/10</td>
<td>0.130E+01</td>
<td>0.736E+00</td>
</tr>
<tr>
<td>HSPT</td>
<td>0.545E+00</td>
<td>0.590E+00</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**FIGURE 29. (CONTINUED)**
DISTRICT 02	TARGET COUNTY
HIGHWAY NO. SH-121
CENTERL. NO. 31-152
IPE 108 SUBMITTED BY H.L.
CECIFICTH EXAMPLE PROBLEM NO. 4

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>C</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>M</th>
<th>N</th>
<th>X</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>26.00</td>
<td>26.00</td>
<td>26.13</td>
<td>42.66</td>
<td>0.13</td>
<td>5.00</td>
<td>0.13</td>
<td>5.80</td>
<td>26.00</td>
<td>5.50</td>
<td>5.00</td>
<td>3.00</td>
</tr>
</tbody>
</table>

**SECTION PROPERTIES**

<table>
<thead>
<tr>
<th>I(IN^4)</th>
<th>A(IN^4)</th>
<th>Y(IN)</th>
<th>V(IN)</th>
<th>I(IN^4)</th>
<th>A(IN^4)</th>
<th>Y(IN)</th>
<th>V(IN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.00736</td>
<td>700.45</td>
<td>20.48</td>
<td>21.92</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**STRAIN INFORMATION**

| DISTANCE FROM CENTERLINE OF BEAM TO STRAND ROW 1 = 1.56 IN. |
| GRID SPACING = 2.00 IN. |
| NUMBER OF WEB STRANDS = 4 |
| TOP = MOST GRID ROW = 16 |
| ROW NUMBER | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 |
| PAX. NO. OF STRANDS | 15 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**ALLOWABLE STRESS COEFFICIENTS**

<table>
<thead>
<tr>
<th>COMPRESSION</th>
<th>SERVICE</th>
</tr>
</thead>
<tbody>
<tr>
<td>FA/B/SPIF.person</td>
<td>ENCI/1.0</td>
</tr>
<tr>
<td>C0.67</td>
<td>C0.60</td>
</tr>
<tr>
<td>TENSION</td>
<td>7.00</td>
</tr>
</tbody>
</table>

**EXAMPLE PROBLEM NO. 4**

| FIGURE 30. OUTPUT FOR EXAMPLE NO. 4 |
**FIGURE 30. (CONTINUED)**

**THE COMMAND IS TO SELECT STRANDS**

**DESIGN PROPERTIES**

- RELEASE STRENGTH = 4.0 ksi (kSI)
- CONCRETE MORTHUS (RELEA) = 3624 ksi (kSI)
- INITIAL PRESSTRESS LOSS = 5.61 PERCENT
- 28-DAY STRENGTH = 4.0 ksi (kSI)
- TOTAL PRESTRESS LOSS = 16.27 PERCENT

**DESIGN RESULTS**

**DISTANCE FROM END OF BEAM TO CENTERLINE**

<table>
<thead>
<tr>
<th>END OF BEAM</th>
<th>1.50</th>
</tr>
</thead>
<tbody>
<tr>
<td>CENTERLINE</td>
<td>1.50</td>
</tr>
</tbody>
</table>

**TOTAL NUMBER OF STRANDS**

- = 15

**NUMBER OF CRAPED STRANDS**

- = 0

**NUMBER OF STRANDS IN ROW 1**

- = 15

**STIRNLUP PHACING = AASHTC 1973**

**STIRNLUP AREA = 0.11 IN2**

**SECTION**

- 6/1C
- 1/1C
- 9/40
- 3/10
- 3/10
- 7/10
- 4/1C
- 5/1C

**SPACING (IN.)**

- 13.20
- 12.20
- 13.20
- 13.20
- 13.20
- 13.20
- 13.20

**COMPUTED DEFLECTION**

<table>
<thead>
<tr>
<th>SHORT TERM DEFLECTION (IN.)</th>
<th>LONG TERM DEFLECTION (IN.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WEIGHT (RELEASE) = 0.02</td>
<td>BASED ON DALLAS CONCRETE PROPERTIES = 2.59</td>
</tr>
<tr>
<td>DPT + SHAP KEY (E=5000) = 0.03</td>
<td>BASED ON ELLESA CONCRETE PROPERTIES = 3.27</td>
</tr>
<tr>
<td>DPT + KEY + DEAD LOADS (E=5000) = 0.22</td>
<td>BASED ON LFQIN CONCRETE PROPERTIES = 2.06</td>
</tr>
</tbody>
</table>

**FIGURE 30. (CONTINUED)**
Figure 30. (Continued)
Strand Layout, the total number of strands, number of draped strands, and the number of strands in each row are printed, together with the distance from the bottom of the beam section to the centroid of the straight and the draped strands, at the ends of the beam and at the centerline. Using the bottom-most strand row as row number 1, the number of the first row containing draped strands, the number of strands to be draped, and the distance the strands are raised at the end of the beam are also shown. Deflections are displayed for short term (no creep and shrinkage effects) and long term (all creep and shrinkage effects have occurred) conditions. The long term deflections are computed using the method of Sinno and Furr (2). Positive deflections are upward. The stirrup spacing required at each tenth point, 5L/40, and the holddown location of the beam is based on No. 4, grade 60 stirrups. For the optimization option, the final items of design results are cost totals. The total beam cost and cost per foot figures are based only on concrete and strand cost and therefore are incomplete.

It may happen that the user inadvertently may seek a design which is impossible to obtain within the imposed restrictions. When the program determines that no feasible design exists, it prints the message

```
*SORRY, THIS BEAM WILL NOT WORK*
*****************************************************************************
```

When this abnormal termination occurs, the user should inspect the input data on the first sheet of output for errors. This is the most frequent cause of abnormal termination. Other possible causes include; deflection constraints are too "tight", i.e., upper bound too small or lower bound too
large, inadequate number of strand rows provided, or inadequate concrete strength specified (design option).

The final sheet of output (see the third sheet in Figures 29 and 30) provides information on factors controlling the final design. Release and service load stresses are displayed first, with compression stress positive. An "x" beside a stress indicates that it is at the allowable. In the third example problem (see Figure 29), although there are no stresses at the allowable, the stress in the top of the beam at the end is very nearly 0.0, and due to the fact that no tension was allowed at this point, it is obvious that this stress was a critical factor in the design. Generally, the stresses shown may in some cases slightly exceed the allowables. This is the result of permitting a 3 percent variation in computed prestress loss on successive iterations (see Section 2.4). Stress computations are based on the strand pattern and prestress losses indicated on the second output sheet. For release stresses, beam weight and prestress forces are considered. Service load stresses are based on live load moment, dead load moment (beam weight, shear key, uniform and concentrated loads), and prestress force.

Active design constraints are denoted with an "x" under the List of Design Constraints section of the third output sheet. For example, the final design of the fourth example problem (Figure 30) is controlled by minimum concrete strength considerations, indicating that the design was not critical.

Moments and shears used in design are listed in the Moment and Shear Summary. Live load moments include lateral distribution and impact factors. Ultimate shears are total live load plus dead load, with load factors defined in Section 2.1.
VI. ANALYSIS OF MULTI-BEAM BRIDGES

When a load is placed on one of the beams of a multibeam bridge, the loaded beam deflects and due to the presence of shear keys, adjoining beams deflect with it. This action is transmitted to other beams in a similar way, deforming the entire cross-section of the structure and thus distributing the applied load to all beams in varying amounts. At each longitudinal joint between beams there are forces in three directions and one moment which tend to keep the beams together as shown in Figure 31. These joint forces are: vertical force \( v_i \), longitudinal force \( a_i \), transverse force \( h_i \) and transverse moment \( m_i \). These forces, of course, act in an opposite sense on the beams adjacent to the joint. The joint forces on each edge of a beam and the applied loads produce the forces \( V_i \), \( A_i \), \( H_i \) and moments \( M_{yi}, M_{zi}, M_{ti} \) shown in Figure 31 on the beam. The four components of joint forces and six components of beam forces vary with position, \( x \), along the beam. They have units of force or moment per unit length and are positive in the direction shown.

The method of analysis employed uses Fourier series to represent the loads applied to the structure and forces and deformations produced by them. The loading may consist of a number of point or patch loads acting vertically anywhere on the structure. These are approximated by Fourier series representations and the response of the structure obtained for each harmonic in the series. The total response is obtained from the superposition of harmonics.

The details of the method are treated adequately in References (9)
and (16). The purpose of this Chapter is to familiarize the reader with the use of a computer program AMBB developed by Ghose (9) implementing the method. Input to the program in its original form is explained in the next section. The program has been modified by the authors to compute lateral distribution factors for axle train and standard AASHTO loadings. The use of the program in this mode is described in Section 6.2.

6.1 ROUTINE ANALYSES USING PROGRAM AMBB

In its original form, the computer program computes displacement and the joint and beam forces (Figure 31) at points along the span specified by the user. The data cards necessary to utilize this portion of the program are described below.

6.1.1 Program Input

1. **Title Card** (15A4) - Columns 1-60. Title to be printed with output.

2. **Control Card** (3F10.0,4I5) - Use consistent length and force units.
   Col. 1-10 - Span of bridge
   11-20 - Young's modulus
   21-30 - Poisson's ratio
   31-35 - Number of beams (max. 20)
   36-40 - Number of different beam types (max 10)
   41-45 - Number of different joint types (max 10)
   46-50 - Number of harmonic terms of the Fourier series representation. 10-20 for uniformly distributed loads. 20-50 for concentrated forces.

3. **Beam Cards** - Two cards for each different beam type.
   First Card (4F10.0)
   Col. 1-10 - Moment of inertia about z (vertical) axis.
Col. 11-20 - Moment of inertia about y (transverse) axis.

Col. 21-30 - Area of cross section.

Col. 31-40 - St. Venant torsion constant of the beam.

Second Card (4F10.0)

Col. 1-10 - Vertical distance between center of gravity of the beam section and left shear hinge, measured positive downwards.

Col. 11-20 - Horizontal distance between center of gravity of beam section and left shear hinge, measured positive to the right.

Col. 21-30 - Vertical distance between center of gravity of the beam section and right shear hinge, measured positive downwards.

Col. 31-40 - Horizontal distance between center of gravity of beam section and right shear hinge, measured positive to the right.

4. **Beam-type Identification Card (2012)** For each beam, starting from the left, enter the beam type number in the above format.

5. **Hinge-flexibility Card (4F10.0)** One card for each different hinge type.

Col. 1-10 - Flexibility of hinge in the longitudinal (x) direction.

Col. 11-20 - Flexibility in the transverse (y) direction.

Col. 21-30 - Flexibility in the vertical (z) direction.

Col. 31-40 - Flexibility of hinge for transverse rotation.

For a rigid connection, enter zero flexibility. For zero restraint, enter a large number (say $10^8$).
6. **Hinge-type Identification Card (2012)** For each hinge, starting from the left, enter the hinge type number in the above format.

7. **Load Control Card (215)**
   Col. 1-5 - Number of load cases to be analyzed (no maximum).
   Col. 6-10 - Number of load cards (maximum 40).

8. **Load Cards (215, 4F10.0)** One card for each beam load.
   Col. 1-5 - Load case number.
   Col. 6-10 - Number of loaded beam.
   Col. 11-20 - Magnitude of load.
   Col. 21-30 - x-coordinate of the load centroid.
   Col. 31-50 - Eccentricity of the centroid of the load from the centroidal axis of the beam, measured positive in positive direction of y-axis (i.e. positive to the right).

A uniformly distributed load in the y direction should be reduced to equivalent line loads acting on the separate beams.

9. **Results Card I (215, 9F5.0)** One card per load case.
   Col. 1-5 - Load case number.
   Col. 6-10 - Number of output positions along span (max 9).
   Col. 11-55 - X-coordinates of positions, fields of 5 columns each.

10. **Results Card II (I5, 8F5.0)** One card for each beam type.
    Col. 1-5 - Number of output positions on the cross section for computation of longitudinal fiber stresses (max 4).
    Col. 6-45 - One pair of y and z coordinates respectively, for each output position, in fields of 5 columns for each coordinate.
FIGURE 31. JOINT AND BEAM FORCES IN MULTI-BEAM BRIDGE

FIGURE 32. MULTIPLE LANE BRIDGE
6.1.2 Example Problem 5

The bridge of example 4.2.1 is to be modified to carry a concrete median barrier (CMB). This is accomplished by adding one 4.0 ft. box to the cross section for a total of eight boxes. The CMB is to be placed over the shear key between beams 4 and 5. The base width of the CMB is 2 ft.-3 in. and it weighs 485 lbs./ft. The forces produced by a vehicle impact on the CMB are not considered. The analysis is to determine what fraction of the barrier's weight is carried by the center beams. The moment of inertia of the box section is approximately 129,000 in.\(^4\) about the horizontal centroidal axis and 191,000 in.\(^4\) about the vertical axis. The St. Venant torsional constant \(J\) is computed from (16)

\[
J = 2t_v t_h b^2 h^2 (1 - t_v/b)^2 (1 - t_h/h)^2 / (bt_v + ht_h - (t_v + t_h)^2)
\]  

(164)

where dimensions \(t_v, t_h, b\) and \(h\) pertain to a rectangular box inscribed within the box section under consideration and

- \(t_v\) = thickness of vertical walls,
- \(t_h\) = average thickness of top and bottom slab,
- \(b\) = width of section,
- \(h\) = depth of section.

For this section \(J\) is approximately 177,000 in.\(^4\). The input data are shown on the coding sheet in Figure 33. The loading is idealized as two uniformly distributed line loads of 242.5 lbs./ft., carried by beams 4 and 5 (the two center-most beams). The line of action of the two line loads is taken as 6 3/4 in. on either side off the middle of the shear key. The hinge joint between all beams is assumed to be at the c.g. of the shear key. The joint is assumed to transmit all shear and transverse forces but no transverse...
### DATA PROCESSING CENTER

**Problem:** ROUTINE INPUT FOR AMBE

**Texas A & M University**

**Programmer:** HLJ

---

**FORTRAN Statement:**

<table>
<thead>
<tr>
<th>EXAMPLE OF ROUTINE ANALYSIS WITH AMBE</th>
<th>← Title Card</th>
</tr>
</thead>
<tbody>
<tr>
<td>420. 5000. 0.164 8 1 1 15</td>
<td>← Control Card</td>
</tr>
<tr>
<td>191000. 129000. 859. 177000.</td>
<td>← Beam Card 1</td>
</tr>
<tr>
<td>5.5 -24. 5.5 24.</td>
<td>← Beam Card 2</td>
</tr>
<tr>
<td>1 1 1 1 1 1 0. 0. 0. 10000000.</td>
<td>← Hinge Flexibility Card</td>
</tr>
<tr>
<td>1 1 1 1 1 1</td>
<td>← Hinge Type I.D. Card</td>
</tr>
<tr>
<td>1 2</td>
<td>← Load Control Card</td>
</tr>
<tr>
<td>1 4 8.488 210. 420. 17.25</td>
<td>← Load Card 1</td>
</tr>
<tr>
<td>1 5 8.488 210. 420. -17.25</td>
<td>← Load Card 2</td>
</tr>
<tr>
<td>1 1 210.</td>
<td>← Results Card 1</td>
</tr>
<tr>
<td>2 0. -16.8 0. 17.2</td>
<td>← Results Card 2</td>
</tr>
</tbody>
</table>

**Figure 33:** Input for Example Problem No. 5
moment. The units chosen for input data are inches and kips.

The output for this example is shown in Figure 34. The fifth sheet of output lists the bending moment about the Y-axis for each beam at midspan. The moments carried by both beams 4 and 5 is 169.4 k-in. The moment produced by a uniform load of 485 lbs./ft. acting on a single 35 ft. long beam is 891.2 k-in. Thus, to include the effects of the CMB in design, a load of .485 k/ft X (169.4/891.2) = .092 k/ft would be input as uniform load on a single beam.

6.2 DETERMINATION OF LIVE LOAD LATERAL DISTRIBUTION FACTORS USING PROGRAM AMBB

Situations frequently occur where a rational approach (rather than an empirical expression) is needed for calculation of the lateral distribution of wheel loads on a multi-beam bridge. The analysis program, in its original form, could be used to accomplish this although it would be impractical because of the voluminous input required. The method by which it could be done manually (and which has been added to the program so that it is done automatically) is described below.

Current design practice stipulates that vehicles be confined to lanes on a bridge. Only one vehicle is permitted (laterally) within a lane for calculation of design moments. Lateral distribution factor is defined here as the ratio of the largest midspan moment produced in a beam by a vehicle or vehicles on the bridge to the maximum midspan moment of one vehicle carried entirely by that beam. Thus, lateral distribution is in terms of fractions of a vehicle (truck). It is assumed that the longitudinal position of a vehicle
*****ANALYSIS OF MULTI-BEAM BRIDGE*****

EXAMPLE OF ROUTINE ANALYSIS WITH AMBB
BRIDGE SPAN = 420.000
YOUNG'S MODULUS OF ELASTICITY = 50000
POISSON'S RATIO = 0.166
NUMBER OF BEAMS = 8
NUMBER OF BEAM-TYPES = 1
NUMBER OF JOINT-TYPES = 1
NUMBER OF HARMONICS = 15

FIGURE 34. OUTPUT FOR EXAMPLE PROBLEM NO. 5
### BEAM PROPERTIES

<table>
<thead>
<tr>
<th>TYPE</th>
<th>I-ZZ</th>
<th>I-YY</th>
<th>AREA</th>
<th>TORS J</th>
<th>ZHL</th>
<th>YHL</th>
<th>ZHR</th>
<th>YHR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>191000.0</td>
<td>129000.0</td>
<td>859.0</td>
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### HINGE FLEXIBILITIES

<table>
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<th>TYPE</th>
<th>LCNg.</th>
<th>MORiz.</th>
<th>VERT.</th>
<th>ROT.</th>
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<tr>
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**FIGURE 34. (CONTINUED)**
<table>
<thead>
<tr>
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<th>BEAM NO</th>
<th>LOAD</th>
<th>X COORD</th>
<th>LENGTH</th>
<th>ECC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4</td>
<td>8.488</td>
<td>210.000</td>
<td>420.000</td>
<td>17.250</td>
</tr>
<tr>
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<td>5</td>
<td>8.488</td>
<td>210.000</td>
<td>420.000</td>
<td>-17.250</td>
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<table>
<thead>
<tr>
<th>LOAD CASE</th>
<th>NO OF LOAD CASE POSITIONS</th>
<th>X1</th>
<th>X2</th>
<th>X3</th>
<th>X4</th>
<th>X5</th>
<th>X6</th>
<th>X7</th>
<th>X8</th>
<th>X9</th>
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</thead>
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<table>
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<th>Y1</th>
<th>Z1</th>
<th>Y2</th>
<th>Z2</th>
<th>Y3</th>
<th>Z3</th>
<th>Y4</th>
<th>Z4</th>
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FIGURE 34. (CONTINUED)
#### Beam Center-Line Displacements

**Load Case No. 1**

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<thead>
<tr>
<th>Locations on Beam</th>
<th>210.0</th>
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</thead>
<tbody>
<tr>
<td><strong>Beam No.</strong></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1.550E-03</td>
</tr>
<tr>
<td>2</td>
<td>2.359E-03</td>
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<td>3.355E-03</td>
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<td>4.951E-03</td>
</tr>
<tr>
<td>5</td>
<td>4.951E-03</td>
</tr>
<tr>
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</tr>
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<td>7</td>
<td>2.359E-03</td>
</tr>
<tr>
<td>8</td>
<td>1.550E-03</td>
</tr>
</tbody>
</table>

**Figure 34. (Continued)**
### Bending Moments About Y-Axis

**Load Case No 1**

<table>
<thead>
<tr>
<th>Locations on Beam</th>
<th>210×0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam No</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>7.02E 01</td>
</tr>
<tr>
<td>2</td>
<td>8.60E 01</td>
</tr>
<tr>
<td>3</td>
<td>1.19E 02</td>
</tr>
<tr>
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<tr>
<td>7</td>
<td>8.60E 01</td>
</tr>
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<td>8</td>
<td>7.02E 01</td>
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</table>

**Figure 34. (Continued)**
### BENDING MOMENTS ABOUT Z-AXIS LOAD CASE NO 1

**LOCATIONS ON BEAM**

210.0

<table>
<thead>
<tr>
<th>BEAM NO</th>
<th>LOCATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-1.28E+00</td>
</tr>
<tr>
<td>2</td>
<td>-4.056E+00</td>
</tr>
<tr>
<td>3</td>
<td>-7.426E+00</td>
</tr>
<tr>
<td>4</td>
<td>-9.392E+00</td>
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<tr>
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<td>7.426E+00</td>
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<td>7</td>
<td>4.056E+00</td>
</tr>
<tr>
<td>8</td>
<td>1.288E+00</td>
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</table>

**FIGURE 34. (CONTINUED)**
#### Vertical Shears
Load Case No 1

<table>
<thead>
<tr>
<th>Locations on Beam</th>
<th>210.0</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Beam No</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<tr>
<td>2</td>
<td>$7.556\times10^{-7}$</td>
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<tr>
<td>3</td>
<td>$1.170\times10^{-6}$</td>
</tr>
<tr>
<td>4</td>
<td>$6.837\times10^{-7}$</td>
</tr>
<tr>
<td>5</td>
<td>$6.837\times10^{-7}$</td>
</tr>
<tr>
<td>6</td>
<td>$1.170\times10^{-6}$</td>
</tr>
<tr>
<td>7</td>
<td>$7.556\times10^{-7}$</td>
</tr>
<tr>
<td>8</td>
<td>$6.713\times10^{-7}$</td>
</tr>
</tbody>
</table>

Figure 34. (Continued)
<table>
<thead>
<tr>
<th>BEAM NO</th>
<th>AXIAL FORCES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-9.946E-06</td>
</tr>
<tr>
<td>2</td>
<td>2.007E-06</td>
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<tr>
<td>3</td>
<td>1.019E-05</td>
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<tr>
<td>4</td>
<td>-4.816E-07</td>
</tr>
<tr>
<td>5</td>
<td>-1.702E-06</td>
</tr>
<tr>
<td>6</td>
<td>6.749E-06</td>
</tr>
<tr>
<td>7</td>
<td>-2.575E-06</td>
</tr>
<tr>
<td>8</td>
<td>-4.244E-06</td>
</tr>
<tr>
<td>BEAM NO</td>
<td>LOCATION ON BEAM</td>
</tr>
<tr>
<td>---------</td>
<td>----------------</td>
</tr>
<tr>
<td>1</td>
<td>1.696E-05</td>
</tr>
<tr>
<td>2</td>
<td>5.035E-05</td>
</tr>
<tr>
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<td>5.580E-05</td>
</tr>
<tr>
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</tr>
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<td>-5.580E-05</td>
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<td>7</td>
<td>-5.035E-05</td>
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<td>8</td>
<td>-1.566E-05</td>
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</tbody>
</table>

**TORSIONAL MOMENTS**

**LOAD CASE NO**

**FIGURE 34.** (CONTINUED)
### Forces Along Longitudinal Joint

**Load Case No 1**

#### Longitudinal Shear on Joint

<table>
<thead>
<tr>
<th>Joint No</th>
<th>Force</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-4.455E-14</td>
</tr>
<tr>
<td>2</td>
<td>-1.398E-13</td>
</tr>
<tr>
<td>3</td>
<td>-1.822E-13</td>
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<td>4</td>
<td>9.872E-15</td>
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<td>5</td>
<td>1.183E-13</td>
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<td>1.011E-13</td>
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</table>

#### Transverse Force on Joint

<table>
<thead>
<tr>
<th>Joint No</th>
<th>Force</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-1.478E-04</td>
</tr>
<tr>
<td>2</td>
<td>-1.619E-04</td>
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<tr>
<td>3</td>
<td>6.485E-04</td>
</tr>
<tr>
<td>4</td>
<td>4.917E-05</td>
</tr>
<tr>
<td>5</td>
<td>6.485E-04</td>
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<td>6</td>
<td>1.619E-04</td>
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<tr>
<td>7</td>
<td>1.478E-04</td>
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</tbody>
</table>

#### Vertical Shear on Joint

<table>
<thead>
<tr>
<th>Joint No</th>
<th>Force</th>
</tr>
</thead>
<tbody>
<tr>
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<td>-3.912E-03</td>
</tr>
<tr>
<td>2</td>
<td>-8.301E-03</td>
</tr>
<tr>
<td>3</td>
<td>1.417E-02</td>
</tr>
<tr>
<td>4</td>
<td>2.328E-09</td>
</tr>
<tr>
<td>5</td>
<td>1.417E-02</td>
</tr>
<tr>
<td>6</td>
<td>8.301E-03</td>
</tr>
<tr>
<td>7</td>
<td>3.912E-03</td>
</tr>
</tbody>
</table>

#### Transverse Moment on Joint

<table>
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<th>Force</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-5.644E-13</td>
</tr>
</tbody>
</table>
****AXIAL STRESS LOAD CASE NO 1*****

BEAM NO 1

LOCATIONS ON BEAM 210.0
0.0  -16.8  -9.151E-03
0.0   17.2   9.369E-03

BEAM NO 2

LOCATIONS ON BEAM 210.0
0.0  -16.8  -1.120E-02
0.0   17.2   1.147E-02

BEAM NO 3

LOCATIONS ON BEAM 210.0
0.0  -16.8  -1.561E-02
0.0   17.2   1.598E-02

BEAM NO 4

LOCATIONS ON BEAM 210.0
0.0  -16.8  -2.206E-02
0.0   17.2   2.259E-02

BEAM NO 5

LOCATIONS ON BEAM 210.0
0.0  -16.8  -2.206E-02
0.0   17.2   2.259E-02

BEAM NO 6

LOCATIONS ON BEAM 210.0
0.0  -16.8  -1.561E-02
0.0   17.2   1.598E-02

BEAM NO 7

LOCATIONS ON BEAM 210.0
0.0  -16.8  -1.120E-02
0.0   17.2   1.147E-02

BEAM NO 8

LOCATIONS ON BEAM 210.0
0.0  -16.8  -9.151E-03
0.0   17.2   9.369E-03

FIGURE 34. (CONTINUED)
on a bridge when it produces maximum midspan moment in a beam is independent of its transverse location on the bridge.

The first step is to determine the lateral position of a vehicle in each lane which produces maximum moment in each beam. This is an influence line problem. For convenience, the transverse expanse of the bridge is divided into one foot segments (Figure 32), using the c.g. location of beam 1 as a reference point. One line of wheels from the vehicle, positioned longitudinally for maximum moment, is moved transversely across the bridge and the moment produced in each beam for each station is stored. For a specific beam, the location of the vehicle in lane 1 that produces maximum moment can be found by moving the two wheel lines of the vehicle from the left to the right edge of the lane (observing required side clearances; e.g., 2 ft. for AASHTO trucks) and adding the two ordinates of the influence line to obtain the total moment. This process is repeated for all beams and all lanes and the results for each stored. The final step is to sum the effects, for a particular beam, of vehicles in each lane and applying a frequency of occurrence factor if appropriate. AASHTO, for example, allows the moment produced by three lanes loaded simultaneously to be reduced by 10 percent for design purposes.

6.2.1 Program Input

A standard input form shown in Figure 35 has been developed for use with the program in this mode. The input quantities are explained below.

1. Title Cards - Three title cards as indicated. Column 62 on the first title card must contain "1" in order that the input for this program mode can be distinguished from the conventional analysis mode.

2. Control Card - Span length, modulus, number of beams and traffic lanes input as indicated. AASHTO loading is designated in columns 38-42. If an axle train is to be used, complete columns 48-67. The
FIGURE 35. INPUT FORM FOR AMBB
Hinge Force Transmission (Enter Y or N)

<table>
<thead>
<tr>
<th>Hinge Type Number</th>
<th>Longitudinal Shear</th>
<th>Vertical Shear</th>
<th>Transverse Force</th>
<th>Transverse Moment</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

Hinge Type Identification Number For Hinge i

| i = 1 | i = 2 | i = 3 | i = 4 | i = 5 | i = 6 | i = 7 | i = 8 | i = 9 | i = 10 | i = 11 | i = 12 | i = 13 | i = 14 | i = 15 | i = 16 | i = 17 | i = 18 | i = 19 |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| 5     | 6     | 8     | 9     | 11    | 12    | 14    | 15    | 17    | 18     | 20     | 21     | 22     | 23     | 24     | 26     | 27     | 29     | 30     |
|       |       |       |       |       |       |       |       |       |        |        |        |        |        |        |        |        |        |        |
| 14    |       |       |       |       |       |       |       |       |        |        |        |        |        |        |        |        |        |        |
| 22    |       |       |       |       |       |       |       |       |        |        |        |        |        |        |        |        |        |        |
| 30    |       |       |       |       |       |       |       |       |        |        |        |        |        |        |        |        |        |        |
| 38    |       |       |       |       |       |       |       |       |        |        |        |        |        |        |        |        |        |        |

Distance (ft) From c.g. Axis of Beam 1 to

<table>
<thead>
<tr>
<th>Left Edge Lane 1</th>
<th>Left Edge Lane 2</th>
<th>Left Edge Lane 3</th>
<th>Left Edge Lane 4</th>
<th>Left Edge Lane 5</th>
<th>Right Edge Lane 1</th>
<th>Right Edge Lane 2</th>
<th>Right Edge Lane 3</th>
<th>Right Edge Lane 4</th>
<th>Right Edge Lane 5</th>
</tr>
</thead>
<tbody>
<tr>
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<td>61</td>
<td>64</td>
<td>69</td>
<td>72</td>
<td>77</td>
<td>80</td>
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</tbody>
</table>

Axle Train

<table>
<thead>
<tr>
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<th>Axle 2</th>
<th>Axle 3</th>
<th>Axle 4</th>
<th>Axle 5</th>
<th>Axle 6</th>
<th>Axle 7</th>
<th>Axle 8</th>
<th>Axle 9</th>
<th>Axle 10</th>
<th>Axle 11</th>
<th>Axle 12</th>
<th>Axle 13</th>
<th>Axle 14</th>
<th>Axle 15</th>
<th>Axle 16</th>
<th>Axle 17</th>
<th>Axle 18</th>
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<tbody>
<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**FIGURE 35. (CONTINUED)**
axle train side clearance is the minimum distance permitted between
a wheel line and an edge of a lane. The number of axle trains present
on the bridge is the maximum number of lanes that will be loaded in
attempting to produce maximum moment in a beam.

3. Beam Card - Moment of inertia about a horizontal axis refers to the
y-axis shown in Figure 31, which in most cases will be horizontal.
The vertical axis refers to the Z-axis in Figure 31. The torsional
stiffness in columns 45-52 can be computed from Eq. (164) for most
sections. HL and VL are the horizontal and vertical distances from
the centroid of the beam cross section to the left hinge. The hinge
can conveniently be taken at the centroid of the shear key. HL is
positive if the hinge is to the left of the centroid of the beam
(the negative y-direction in Figure 31) and VL is positive if the
hinge lies below the beam centroid. HR and VR define the position
of the right hinge, with VR positive if the right hinge is below the
beam centroid and HR positive if the hinge is to the right of the
beam centroid. Several typical situations are shown in Figure 36
with the various dimensions labeled.

4. Beam Type Identification Card - For each beam, starting from the left,
enter the beam type number.

5. Hinge Card - A hinge is assumed to be either completely flexible
(no force transmission) or completely rigid (full force transmission)
in each of its 4 possible modes of displacement. If the hinge
transmits longitudinal shear force (a_i in Figure 31), "Y" is
entered in column 14. If a_i must be zero, then column 14 should
contain "N" or left blank. The remaining components of joint force
FIGURE 36. TYPICAL BEAM AND HINGE ARRANGEMENTS
are vertical shear \(v_i\) in Figure 31), transverse force \(h_i\) and transverse moment \(m_i\).

6. **Hinge Type Identification Card** - For each hinge, beginning with the hinge between beams 1 and 2, enter the hinge type number.

7. **Lane Location Card** - The limits of traffic lanes are measured with respect to the centroid of the left-most beam (beam number 1) in the bridge. Distance is positive to the right of the centroid. Lane limits are shown as TR\(_i\) and TL\(_i\) in Figure 32.

8. **Axle Train Cards** - Enter only if column 48 of the control card contains "1". Either the leading or trailing axle may be designated as axle 1, with the remaining axles numbered in sequential order. The first card contains the axle loads. The second card contains axle spacings (See Section 4.1.3)

6.2.2 Example Problem 6

Lateral distribution factors are to be computed for the structure shown in Figure 32. The shallow boxes are 6 ft. wide by 2 ft.-3 in. deep with 5 1/2 in. thick horizontal walls and 5 in. vertical walls. The exterior and center beam are 3 ft. wide and 3 ft.-3 in. deep with the same wall thicknesses. A work sheet has been provided (Figure 37) to assist in data input. The completed work sheet for this example is seen in Figure 38. The structure is sketched to some convenient scale and the layout for beams, joints and traffic lanes are indicated. With the completed work sheet, it is a simple matter to complete the input form as shown in Figure 39. For this problem, four 12 ft. traffic lanes are utilized, with HS-20 loading.

The results of this analysis are shown in Figure 40. The first two sheets list input data. The location of loads within each lane which produce maximum moment for a beam are displayed at the top of the third sheet. For
MULTIBEAM BRIDGE ANALYSIS PROGRAM

TEXAS HIGHWAY DEPARTMENT
BRIDGE DIVISION

DATA INPUT WORK SHEET

Sketch of Bridge Cross Section

Beam Number
Beam Type Number
Hinge Number

Hinge Transmits: (Y or N)

Longitudinal Shear
Vertical Shear
Transverse Force
Transverse Moment

Hinge Type Number

FIGURE 37. DATA INPUT WORK SHEET FOR AMBB
### Sketch of Bridge Cross Section
![Bridge Sketch](image)

<table>
<thead>
<tr>
<th>Beam Number</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
</tr>
</thead>
<tbody>
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<td>Beam Type Number</td>
<td>1</td>
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<td>2</td>
<td>2</td>
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<td>2</td>
<td>2</td>
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<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Hinge Number</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>

**Hinge Transmits:** (Y or N)

<table>
<thead>
<tr>
<th>Longitudinal Shear</th>
<th>Y</th>
<th>Y</th>
<th>Y</th>
<th>Y</th>
<th>Y</th>
<th>Y</th>
<th>Y</th>
<th>Y</th>
<th>Y</th>
<th>Y</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical Shear</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Transverse Force</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
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<tr>
<td>Transverse Moment</td>
<td></td>
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<td></td>
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<td></td>
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</tr>
<tr>
<td>Hinge Type Number</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

**FIGURE 38. COMPLETED WORK SHEET FOR EXAMPLE PROBLEM NO. 6**
### General Information

**District:** 03  
**County:** 14  
**Highway No.:** SH 25  
**IPE Submitted by:** HLJ

<table>
<thead>
<tr>
<th>Span (ft.)</th>
<th>Modulus of Elasticity (ksi)</th>
<th>Number of Beams</th>
<th>Number of Traffic Lanes</th>
<th>AASHTO Loading</th>
<th>Enter 1 for Axle Train</th>
<th>Traversed Axle Train Spacing (ft.)</th>
<th>Axle Train Side Clearances (ft.)</th>
<th>Number of Axle Trains on Bridge</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>5000</td>
<td>14</td>
<td>4</td>
<td>HS-20</td>
<td>46</td>
<td>5-4-5-5</td>
<td>61-90</td>
<td>67</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Beam Type</th>
<th>Inertia About Horizontal Axis (in.4)</th>
<th>Inertia About Vertical Axis (in.4)</th>
<th>Area (in.2)</th>
<th>Torsional Stiffness (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>13,900.00</td>
<td>11,000.00</td>
<td>972.0</td>
<td>708.700.0</td>
</tr>
<tr>
<td>2</td>
<td>9,600.00</td>
<td>5220.00</td>
<td>952.0</td>
<td>754.600.0</td>
</tr>
</tbody>
</table>

*Beam Type Identification Number for Beam i*

<table>
<thead>
<tr>
<th>i=1</th>
<th>i=2</th>
<th>i=3</th>
<th>i=4</th>
<th>i=5</th>
<th>i=6</th>
<th>i=7</th>
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<th>i=17</th>
<th>i=18</th>
<th>i=19</th>
<th>i=20</th>
</tr>
</thead>
<tbody>
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<td>2</td>
<td>2</td>
<td>2</td>
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<td>2</td>
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<td>2</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

**Figure 39. Input for Example Problem No. 6**
### Hinge Force Transmission (Enter Y or N)

<table>
<thead>
<tr>
<th>Hinge Type Number</th>
<th>Longitudinal Shear</th>
<th>Vertical Shear</th>
<th>Transverse Force</th>
<th>Transverse Moment</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>-</td>
<td>14</td>
<td>22</td>
<td>30</td>
</tr>
</tbody>
</table>

### Hinge Type Identification Number For Hinge i

| i = 1 | i = 2 | i = 3 | i = 4 | i = 5 | i = 6 | i = 7 | i = 8 | i = 9 | i = 10 | i = 11 | i = 12 | i = 13 | i = 14 | i = 15 | i = 16 | i = 17 | i = 18 | i = 19 |
|--------|-------|-------|-------|-------|-------|-------|-------|-------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| 5      | 6     | 7     | 8     | 9     | 10    | 11    | 12    | 13    | 14     | 15     | 16     | 17     | 18     | 19     |

### Distance (ft) From c.g. Axis of Beam 1 to

#### Lane 1
- Left Edge: 15
- Right Edge: 135

#### Lane 2
- Left Edge: 135
- Right Edge: 252

#### Lane 3
- Left Edge: 285
- Right Edge: 408

#### Lane 4
- Left Edge: 406
- Right Edge: 525

#### Lane 5
- Left Edge: 61
- Right Edge: 77

### Axle Load (lb) Dist. From Axle 1 To Axle i (i = 1 to 18)

<table>
<thead>
<tr>
<th>Axle 1</th>
<th>Axle 2</th>
<th>Axle 3</th>
<th>Axle 4</th>
<th>Axle 5</th>
<th>Axle 6</th>
<th>Axle 7</th>
<th>Axle 8</th>
<th>Axle 9</th>
<th>Axle 10</th>
<th>Axle 11</th>
<th>Axle 12</th>
<th>Axle 13</th>
<th>Axle 14</th>
<th>Axle 15</th>
<th>Axle 16</th>
<th>Axle 17</th>
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</tr>
</tbody>
</table>
### Bridge Properties

<table>
<thead>
<tr>
<th>SPAN (Ft.)</th>
<th>NUMERICAL ELASTICITY (ksi)</th>
<th>NUMBER OF BEAMS</th>
<th>NUMBER OF LAKES</th>
<th>AASHTO LOAD AXLE TRAIN SIDE CLEARANCE (Ft.)</th>
<th>AXLE TRAIN NO. OF AXLE TRAINS ON BRIDGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>80.0</td>
<td>5000.0</td>
<td>11</td>
<td>4</td>
<td>HS-20</td>
<td>0</td>
</tr>
</tbody>
</table>

### Beam Dimensions and Properties

<table>
<thead>
<tr>
<th>REL. TYPE NUMBER</th>
<th>INERTIA ABOUT HORIZONTAL AXIS (in.**4)</th>
<th>INERTIA ABOUT VERTICAL AXIS (in.**4)</th>
<th>AREA (in.**2)</th>
<th>TORSIONAL STIFFNESS (in.***2)</th>
<th>ML (in.**3)</th>
<th>VL (in.**3)</th>
<th>VR (in.**3)</th>
<th>VR (in.**3)</th>
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<tbody>
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### Beam Type Identification Number for Beam 1

<table>
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<th>NP1</th>
<th>NP2</th>
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<th>NP4</th>
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</table>

### Pinch Force Transmission

<table>
<thead>
<tr>
<th>PINCE TYPE NUMER</th>
<th>LONGITUDINAL SHEAR</th>
<th>VERTICAL SPEAR</th>
<th>TRANSVERSE SPEAR</th>
<th>TRANSVERSE FORCE</th>
<th>TRANSVERSE Moment</th>
</tr>
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<tbody>
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</table>

### Pinch Type Identification Number for Pinch 1

<table>
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<tr>
<th>NP1</th>
<th>NP2</th>
<th>NP3</th>
<th>NP4</th>
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<th>NP16</th>
<th>NP17</th>
<th>NP18</th>
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<td>4</td>
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</tr>
</tbody>
</table>

**Figure 40. Output for Example Problem No. 6**
<table>
<thead>
<tr>
<th>LANE 1</th>
<th>LANE 2</th>
<th>LANE 3</th>
<th>LANE 4</th>
<th>LANE 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>LEFT</td>
<td>RIGHT</td>
<td>LEFT</td>
<td>RIGHT</td>
<td>LEFT</td>
</tr>
<tr>
<td>ECCF</td>
<td>EDGE</td>
<td>EDGE</td>
<td>EDGE</td>
<td>EDGE</td>
</tr>
</tbody>
</table>

| 12.5 | 13.5 | 13.5 | 25.5 | 28.5 | 40.5 | 40.5 | 52.5 |

**FIGURE 40. OUTPUT FOR EXAMPLE PROBLEM NO. 6**
### Lateral Position of Lanes

For Maximal Moment at Midspan

#### AASHTO Truck

<table>
<thead>
<tr>
<th>Beam No.</th>
<th>Lane 1</th>
<th>Lane 2</th>
<th>Lane 3</th>
<th>Lane 4</th>
<th>Lane 5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TC Left</td>
<td>TC Right</td>
<td>TC Left</td>
<td>TC Right</td>
<td>TC Left</td>
</tr>
<tr>
<td>1</td>
<td>3.5</td>
<td>6.5</td>
<td>15.5</td>
<td>21.5</td>
<td>30.5</td>
</tr>
<tr>
<td>2</td>
<td>3.5</td>
<td>6.5</td>
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</tr>
<tr>
<td>5</td>
<td>5.5</td>
<td>11.5</td>
<td>17.5</td>
<td>23.5</td>
<td>30.5</td>
</tr>
<tr>
<td>6</td>
<td>5.5</td>
<td>11.5</td>
<td>17.5</td>
<td>23.5</td>
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<tr>
<td>7</td>
<td>5.5</td>
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<td>17.5</td>
<td>23.5</td>
<td>30.5</td>
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<td>5.5</td>
<td>11.5</td>
<td>17.5</td>
<td>23.5</td>
<td>30.5</td>
</tr>
<tr>
<td>9</td>
<td>5.5</td>
<td>11.5</td>
<td>17.5</td>
<td>23.5</td>
<td>30.5</td>
</tr>
<tr>
<td>10</td>
<td>5.5</td>
<td>11.5</td>
<td>17.5</td>
<td>23.5</td>
<td>30.5</td>
</tr>
<tr>
<td>11</td>
<td>5.5</td>
<td>11.5</td>
<td>17.5</td>
<td>23.5</td>
<td>30.5</td>
</tr>
</tbody>
</table>

#### AASHTO Lane

(position of lane loading within load case with respect to C.G. of beam No. 1 = in ft.)

<table>
<thead>
<tr>
<th>Beam No.</th>
<th>Lane 1</th>
<th>Lane 2</th>
<th>Lane 3</th>
<th>Lane 4</th>
<th>Lane 5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TC Left</td>
<td>TC Right</td>
<td>TC Left</td>
<td>TC Right</td>
<td>TC Left</td>
</tr>
<tr>
<td>1</td>
<td>1.5</td>
<td>11.5</td>
<td>13.5</td>
<td>23.5</td>
<td>28.5</td>
</tr>
<tr>
<td>2</td>
<td>1.5</td>
<td>11.5</td>
<td>13.5</td>
<td>23.5</td>
<td>28.5</td>
</tr>
<tr>
<td>3</td>
<td>3.5</td>
<td>13.5</td>
<td>15.5</td>
<td>25.5</td>
<td>28.5</td>
</tr>
<tr>
<td>4</td>
<td>3.5</td>
<td>13.5</td>
<td>15.5</td>
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<td>28.5</td>
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<tr>
<td>5</td>
<td>3.5</td>
<td>13.5</td>
<td>15.5</td>
<td>25.5</td>
<td>28.5</td>
</tr>
<tr>
<td>6</td>
<td>3.5</td>
<td>13.5</td>
<td>15.5</td>
<td>25.5</td>
<td>28.5</td>
</tr>
<tr>
<td>7</td>
<td>3.5</td>
<td>13.5</td>
<td>15.5</td>
<td>25.5</td>
<td>28.5</td>
</tr>
<tr>
<td>8</td>
<td>3.5</td>
<td>13.5</td>
<td>15.5</td>
<td>25.5</td>
<td>28.5</td>
</tr>
</tbody>
</table>

**Figure 40. (Continued)**
<table>
<thead>
<tr>
<th>BEAM NO.</th>
<th>MOMENT FROM AASHTO TRUCK (KIP•FT.)</th>
<th>FRACTION OF FULL AASHTO TRUCK APPLIED</th>
<th>MOMENT FROM AASHTO LANE (KIP•FT.)</th>
<th>FRACTION OF FULL AASHTO LANE APPLIED</th>
<th>% MOMENT FROM AXLE TRAIN (KIP•FT.)</th>
<th>FRACTION OF FULL AXLE TRAIN APPLIED</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>408.5</td>
<td>0.339</td>
<td>366.2</td>
<td>0.338</td>
<td>0.205</td>
<td>0.265</td>
</tr>
<tr>
<td>2</td>
<td>262.2</td>
<td>0.265</td>
<td>287.5</td>
<td>0.265</td>
<td>0.205</td>
<td>0.265</td>
</tr>
<tr>
<td>3</td>
<td>400.1</td>
<td>0.277</td>
<td>299.9</td>
<td>0.276</td>
<td>0.205</td>
<td>0.275</td>
</tr>
<tr>
<td>4</td>
<td>266.1</td>
<td>0.276</td>
<td>298.3</td>
<td>0.275</td>
<td>0.205</td>
<td>0.275</td>
</tr>
<tr>
<td>5</td>
<td>277.1</td>
<td>0.261</td>
<td>283.7</td>
<td>0.262</td>
<td>0.205</td>
<td>0.262</td>
</tr>
<tr>
<td>6</td>
<td>458.6</td>
<td>0.346</td>
<td>372.2</td>
<td>0.344</td>
<td>0.205</td>
<td>0.265</td>
</tr>
<tr>
<td>7</td>
<td>277.1</td>
<td>0.261</td>
<td>283.7</td>
<td>0.262</td>
<td>0.205</td>
<td>0.262</td>
</tr>
<tr>
<td>8</td>
<td>398.1</td>
<td>0.276</td>
<td>299.9</td>
<td>0.276</td>
<td>0.205</td>
<td>0.275</td>
</tr>
<tr>
<td>9</td>
<td>408.5</td>
<td>0.339</td>
<td>366.2</td>
<td>0.338</td>
<td>0.205</td>
<td>0.265</td>
</tr>
<tr>
<td>10</td>
<td>382.2</td>
<td>0.265</td>
<td>287.5</td>
<td>0.265</td>
<td>0.205</td>
<td>0.265</td>
</tr>
<tr>
<td>11</td>
<td>408.5</td>
<td>0.339</td>
<td>366.2</td>
<td>0.338</td>
<td>0.205</td>
<td>0.265</td>
</tr>
</tbody>
</table>

**FIGURE 40. (CONTINUED)**
example, if only lane 2 were loaded, the truck wheels should be located 2 ft. from the left edge of the lane to produce maximum moment in beams 1 through 4 and 2 ft. from the right edge of the lane for the remaining beams. Comparable information on the location of the 10 ft. wide lane loading is also shown. The last entry on the last sheet displays maximum moment and lateral distribution factor for each beam. The maximum moments include the AASHTO impact factor for axle train as well as AASHTO loadings.
REFERENCES


2. Sinno, R., "The Time Dependent Deflections of Prestressed Concrete Bridge Beams", Dissertation, Texas A&M University, College Station, Texas, 1968.

3. Furr, H., Sinno, R., and Ingram, L., "Prestress Loss and Creep Camber in a Highway Bridge With Reinforced Concrete Slab on Pretensioned Prestressed Concrete Beams", Research Report, No. 69-3, Texas Transportation Institute, Texas A&M University, College Station, Texas, 1968.


10. ACI Standard Building Code Requirements for Reinforced Concrete (ACI 318-71), American Concrete Institute, Detroit, Michigan, 1971.


APPENDIX A

BEAM COST SURVEY DATA
1. The cost of one cubic yard of concrete in a completed highway beam is effected by the required release strength, especially when high release strengths are specified. Our objective is to produce a graph similar to that shown below, which would be representative of concrete cost changes with change in release strength.

We are asking that you provide us with costs of various release strength concretes so we can construct such a graph. Since we are interested only in relative costs, we have arbitrarily set the cost of one cubic yard of 4000 psi. release strength concrete at $1.00. Using this as a base, would you please complete table below, up through the highest release strength your company would be willing to produce.
<table>
<thead>
<tr>
<th>Release Strength (psi)</th>
<th>Concrete Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4000</td>
<td>$1.00</td>
</tr>
<tr>
<td>4500</td>
<td>$___</td>
</tr>
<tr>
<td>5000</td>
<td>$___</td>
</tr>
<tr>
<td>5500</td>
<td>$___</td>
</tr>
<tr>
<td>6000</td>
<td>$___</td>
</tr>
<tr>
<td>6500</td>
<td>$___</td>
</tr>
<tr>
<td>7000</td>
<td>$___</td>
</tr>
<tr>
<td>7500</td>
<td>$___</td>
</tr>
<tr>
<td>8000</td>
<td>$___</td>
</tr>
</tbody>
</table>

2. Indicate those items listed below that were considered in arriving at the costs computed for question 1.

- Yes ___ No ___ (a) Cost of materials (cement, aggregate, admixtures, etc.)
- Yes ___ No ___ (b) Cost of energy used in curing (e.g., natural gas, oil, electricity, etc.)
- Yes ___ No ___ (c) Cost of labor in placing concrete
- Yes ___ No ___ (d) Amortization of permanent equipment (such as forms, curing facilities, etc.) through periodic depreciation.
- Yes ___ No ___ (e) Increased cost due to decreased production associated with leaving beams in forms to obtain high release strength.
- Yes ___ No ___ (f) Increased overhead due to reduced production.
- (g) Other

3. What would be the in-place cost per foot of strand for 1/2 inch diameter, grade 270, 7 wire strand?
<table>
<thead>
<tr>
<th>Release Strength (psi)</th>
<th>Concrete Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4000</td>
<td>$1.00</td>
</tr>
<tr>
<td>4500</td>
<td>$1.00</td>
</tr>
<tr>
<td>5000</td>
<td>$1.00</td>
</tr>
<tr>
<td>5500</td>
<td>$1.00</td>
</tr>
<tr>
<td>6000</td>
<td>$1.22</td>
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<td>6500</td>
<td>$1.34</td>
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<tr>
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<tr>
<td>7500</td>
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</tr>
<tr>
<td>8000</td>
<td>$2.22</td>
</tr>
</tbody>
</table>

2. Indicate those items listed below that were considered in arriving at the costs computed for question 1.

- **(a)** Cost of materials (cement, aggregate, admixtures, etc.) **Yes x No**
- **(b)** Cost of energy used in curing (e.g., natural gas, oil, electricity, etc.) **Yes x No**
- **(c)** Cost of labor in placing concrete **Yes x No**
- **(d)** Amortization of permanent equipment (such as forms, curing facilities, etc.) through periodic depreciation. **Yes x No**
- **(e)** Increased cost due to decreased production associated with leaving beams in forms to obtain high release strength. **Yes x No**
- **(f)** Increased overhead due to reduced production. **Yes x No**
- **(g)** Other

3. What would be the in-place cost per foot of strand for 1/2 inch diameter, grade 270, 7 wire strand? **$.20 per ft.**

RESPONSE FROM COMPANY 1

162
<table>
<thead>
<tr>
<th>Release Strength (psi)</th>
<th>Concrete Cost ($)</th>
<th>(In place, finished product)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4000</td>
<td>$1.00</td>
<td></td>
</tr>
<tr>
<td>4500</td>
<td>$1.00</td>
<td></td>
</tr>
<tr>
<td>5000</td>
<td>$1.00</td>
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<td>5500</td>
<td>$1.25</td>
<td></td>
</tr>
<tr>
<td>6000</td>
<td>$1.80</td>
<td></td>
</tr>
<tr>
<td>6500</td>
<td>$2.00</td>
<td></td>
</tr>
<tr>
<td>7000</td>
<td>$2.50</td>
<td></td>
</tr>
<tr>
<td>7500</td>
<td>$3.00</td>
<td>$3.80 - Would be difficult to obtain in a reasonable production cycle.</td>
</tr>
<tr>
<td>Probably would not - 8000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. Indicate those items listed below that were considered in arriving at the costs computed for question 1.

Yes Yes No No (a) Cost of materials (cement, aggregate, admixtures, etc.)
Yes Yes No No (b) Cost of energy used in curing (e.g., natural gas, oil, electricity, etc.)
Yes No No No (c) Cost of labor in placing concrete
Yes No No No (d) Amortization of permanent equipment (such as forms, curing facilities, etc.) through periodic depreciation.
Yes Yes No No (e) Increased cost due to decreased production associated with leaving beams in forms to obtain high release strength.
Yes Yes No No (f) Increased overhead due to reduced production.
Yes No No No (g) Other - Due to long production time - would be unable to bid other work.

3. What would be the in-place cost per foot of strand for 1/2 inch diameter, grade 270, 7 wire strand?

25¢/lin. ft.
2. Indicate those items listed below that were considered in arriving at the costs computed for question 1.

Yes XX No ___ (a) Cost of materials (cement, aggregate, admixtures, etc.)
Yes XX No ___ (b) Cost of energy used in curing (e.g., natural gas, oil, electricity, etc.)
Yes ___ No XX (c) Cost of labor in placing concrete
Yes ___ No XX (d) Amortization of permanent equipment (such as forms, curing facilities, etc.) through periodic depreciation.
Yes XX No ___ (e) Increased cost due to decreased production associated with leaving beams in forms to obtain high release strength.
Yes XX No ___ (f) Increased overhead due to reduced production.
Yes ___ No ___ (g) Other

3. What would be the in-place cost per foot of strand for 1/2 inch diameter, grade 270, 7 wire strand? $.25
<table>
<thead>
<tr>
<th>Release Strength (psi)</th>
<th>Concrete Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4000</td>
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</tr>
<tr>
<td>4500</td>
<td>1.00</td>
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<tr>
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</tr>
<tr>
<td>8000</td>
<td>2.25</td>
</tr>
</tbody>
</table>

2. Indicate those items listed below that were considered in arriving at the costs computed for question 1.

- **Yes X** No (a) Cost of materials (cement, aggregate, admixtures, etc.)
- **Yes X** No (b) Cost of energy used in curing (e.g., natural gas, oil, electricity, etc.)
- **Yes X** No (c) Cost of labor in placing concrete
- Yes No (d) Amortization of permanent equipment (such as forms, curing facilities, etc.) through periodic depreciation.
- **Yes X** No (e) Increased cost due to decreased production associated with leaving beams in forms to obtain high release strength.
- Yes No (f) Increased overhead due to reduced production.
- (g) Other

3. What would be the in-place cost per foot of strand for 1/2 inch diameter, grade 270, 7 wire strand?

$0.22 /LF

RESPONSE FROM COMPANY 4

165
APPENDIX B

DEFINITION OF VARIABLES APPEARING IN LABELLED COMMON BLOCKS OF DBOXSS AND DBOXDS
Labelled common blocks used in both DBOXSS and DBOXDS are essentially identical. In a few cases, variable names are unique to one program or the other and in this situation both names are listed under the appropriate common block name.

COMMON/BLK1/

ADIM, BDIM, CDIM, DDIM, EDIM, FDIM, GDIM, HDIM, TDIM, XDIM, YDIM -
- the cross sectional dimensions A, B, ..., Y on input form (in).

WHDIM - the dimension M on input form (in).

WDDIM - the dimension W on input form (in).

ACONC - cross sectional area of beam (in²).

BINERT - moment of inertia of beam about c.g. axis of beam (in⁴).

DTOP - distance from c.g. of beam cross section to bottom of beam (in).

ZT - section modulus for computing stress in top of beam (in³).

ZB - section modulus for computing stress in bottom of beam (in³).

ACONCK - area of beam cross section plus shear key (in²).

BINERK - moment of inertia of beam cross section and shear key about c.g. axis of composite beam and shear key section (in⁴).

DTOPK - distance from c.g. of beam and shear key composite section to bottom of beam (in).

ZTK - section modulus for computing stress at top of composite beam and key section (in³).

ZBK - section modulus for computing stress at bottom of composite beam and key section (in³).

ZL - span length (ft).

F28 - 28 day concrete strength (ksi).
JOPT - program option code: if = 0, design option is performed; if = 1, optimization option performed.

ASSCLR - fraction of initial prestress lost immediately after strand release.

ASSPLS - fraction of initial prestress lost after all losses have occurred.

APRIME - area of compression steel reinforcing (in\(^2\)).

CBOT - distance from bottom of beam to center of first strand row (in).

COSTWP - cost of strand ($/FT) midspan.

DEMIN - minimum permissible midspan camber upon release (in).

ALDEF - maximum permissible midspan camber upon release (in).

NRAV - the number of rows available for strand placement in DBOXSS and the maximum number of strand rows that can be fitted in the beam cross section for DBOXDS.

NWHEEL - number of axles in axle train vehicle.

DISTF - lateral distribution factor applied to axle loads.

FPCMAX - maximum permissible concrete release strength (ksi).

FPCMIN - minimum permissible concrete release strength (ksi).

ELASC - constant which when multiplied times the square root of concrete strength (ksi) gives the modulus of elasticity in ksi (ksi\(^2\)).

ULTMRQ - required ultimate moment capacity (k-ft).

DCR - distance from top of beam to c.g. of compression reinforcing steel (in).

W - beam weight (k/ft).

WB - shear key weight (k/ft).

FO - initial strand force (kips).

NR - the number of rows available for placement of strands.

HDPT - distance from center line of beam to holddown point (ft).
NW - number of strands to be draped in strand rows.

ALPHA - fraction which when multiplied times the span length gives the distance from the end of the beam to the holddown point.

COMMON/BLK2/

PAXLE(I) - weight of Ith axle in axle train.

NWHL(I) - distance form axle 1 to axle I in axle train (ft).

STRMAX(I) - maximum number of strands permitted in strand row I.

FCONC(I) - magnitude of Ith concentrated force applied to a single beam (kips).

DCONC(I) - distance from the left end of the beam to the Ith concentrated force.

G(I) - cost of concrete with release strength of 3.5 + 0.5I($/yd³).

F(I) - 28-day strength of concrete with a release strength of 3.5 + 0.5I (ksi).

D(I) - distance from c.g. of beam cross section to strand row I (in).

Positive if strand row is above c.g. of beam.

GRIDS(I) - distance from strand row I to row (I + 1) (in).

BMMAX(I) - bending moment at points along beam due to live load. The locations are: I=1, end of beam; I=2, L/10; I=3, 2L/10; I=4, L/4; I=5, 3L/10; I=6, 4L/10; I=7, L/2 (k-ft).

BVMAX(I) - live load shears at points along the beam (kips).

DLMOM(I) - dead load moment at points along the beam due to uniform load and concentrated forces (kip-ft).

DLSHR(I) - ultimate dead load shear at points along the beam due to uniform load and concentrated forces (kip-ft).

CBRMAX(I) - array used to store long term camber computed for 4 sets of concrete properties and a set which is input.
PRLMAX(I) - array containing estimates of prestress loss computed for 4 sets of concrete properties and inputed properties in SUBROUTINE CAMBER.

ZLOS(I) - contains final prestress loss fractions 0.1, 0.2, 0.3, 0.4.

PECRK(I,J) - contains the total prestress force eccentricity at which the ultimate moment capacity first exceeds 1.2 times the cracking moment capacity for the 28 day concrete strength corresponding to a release strength of $3.5 + 0.5I$ and a prestress loss of $0.1J$ (k-in).

ZWRAP(I,J) - for strand row I, contains the number of wrapped strands in J=1 and the total length in feet (J=2) and inches (J=3) of wrapping.

NSDIF(I) - number of different wrapping lengths in strand row I.

**COMMON/DEFINE/**

UWC - unit weight of beam and shear key concrete (k/ft$^3$).

HUM - average relative humidity used in computing prestress loss due to shrinkage (%).

AS - area of a strand (in$^2$).

FPS - ultimate strength of the strand (ksi).

CTR1 - factor which when multiplied times the square root of concrete strength (in psi) gives the allowable tension stress in the concrete in psi for the end of the beam and the 1/10 point at release.

CTR2 - same as CTR1, but for points between the 1/10 and 5/10 points on the beam.
CTS1 - same as CTR1, but for service load conditions.

CTS2 - same as CTR2, but for service load conditions.

CBR1 - factor which when multiplied by concrete strength gives the allowable compression stress in the concrete at the end of the beam and the 1/10 point at release.

CBR2 - same as CBR1, but for points between the 1/10 and 5/10 points.

CBS1 - same as CBR1, but for service load conditions.

CBS2 - same as CBR2, but for service load conditions.

CREEP1 - constant appearing in the numerator of the hyperbolic function defining the unit creep function for the concrete.

CREEP2 - constant appearing in the denominator of the unit creep function.

SHRK1 - constant appearing in numerator of the hyperbolic function defining the shrinkage properties of the concrete.

SHRK2 - constant appearing in the denominator of the shrinkage function.

RATNOD - ratio of the modulus of elasticity of compression steel to that of concrete. Used in computing transformed section properties.

FPL - proportional limit stress for strand material (ksi).

FSY - yield strength of compression reinforcing and stirrups (ksi).

ASTIRP - total area of stirrup reinforcing (in²).

GSP - spacing between strand row for DBOXDS.

COMMON/YZ/

Y1, Y2, Y3, Y4, Z1, Z2, Z3, Z4 - characteristic widths and depths used in computing area and c.g. of compression zone for ultimate moment computations (see SUBROUTINE ULTMP).
COMMON/DUMP/

TITLE(I,J) - used to store input title cards.

YJ(I) - scratch storage.

FROW(I) - used to store number of strands placed in each row during generation of coefficients in ultimate and cracking moment constraints in SUBROUTINE EQGEN.

PEF(I,J) - used in EQGEN to form ultimate and cracking moment constraints. Row I corresponds to the placement of 2·I strands in the beam (except when one or more row has an odd maximum number of strands). Column 1 contains the total number of strands placed. Column 2 contains the sum of the products of the number of strands in each row times the distance of that row from the c.g. of beam. Column 3 contains the distance from the c.g. of PEF(I,1) strands to the c.g. of the beam.

ZNE(I) - contains the product of the number of strands in each row times their distance from the c.g. of beam when the ultimate moment capacity first exceeds that required, for a 28 day concrete strength corresponding to a release strength of 3.5 + 0.5I.

KKODE(I) - used in EQGEN to form cracking moment constraint. If KKODE(I) = 1, then for current total strand force eccentricity, the ultimate moment capacity just exceeds 1.2 times the cracking moment capacity for a final prestress loss of ZLOS(I).

ZMCR(I) - contains the cracking moment capacity when KKODE(I) set equal to 1.

COMMON/D314/

These variables are used in SUBROUTINES LPCODE and INTPRG and are defined in the subroutine descriptions.
## APPENDIX C

**DESCRIPTION OF SUBROUTINES USED**

**IN DBOXSS AND DBOXDS**

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<table>
<thead>
<tr>
<th>Subroutine Name</th>
<th>Page</th>
</tr>
</thead>
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<td>MAIN.</td>
<td>175</td>
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<tr>
<td>DEFINE.</td>
<td>184</td>
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<td>EQGEN</td>
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<td>LPCODE.</td>
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<tr>
<td>PLOSS</td>
<td>202</td>
</tr>
<tr>
<td>CAMBER.</td>
<td>204</td>
</tr>
<tr>
<td>SHEAR</td>
<td>206</td>
</tr>
</tbody>
</table>
The primary differences between programs DBOXSS and DBOXDS occur in the MAIN programs. The logic and storage requirements of DBOXDS are more involved than those in DBOXSS because it incorporates an integer programming solution (subroutine INTPRG) to obtain final designs, working from an approximate L.P. solution generated in subroutine LPCODE. During the project, two separate programs evolved as a natural result of our efforts to minimize programming complexities by dealing with each problem separately. The majority of the computer core storage requirements (with programs in object form) arise from the large arrays used in LPCODE and INTPRG. By dividing the programs, it was possible to overlay arrays in a straightforward way (see the shifts in variable names appearing in COMMON/D314/) and thus reduce the total storage needed by DBOXDS. The reader will find an almost complete correspondence between variable names used in the two programs, since DBOXDS was constructed from a reproduced version of DBOXSS. The flowcharts of logic for the MAIN programs are presented together, with branches indicated for each program. Variable names common to both programs as well as those used in only one or the other of the programs appear together in the definition of variables. The subroutines are for the most part self-contained and differences in them occur in the way in which calling parameters are formed. Each subroutine is described in a separate section, listing its function, the definition of variables which it uses and a macro level flowcharts of logic when necessary for understanding its operation.
MAIN PROGRAM

Function

The main program reads and checks input data, computes the quantities required by subroutines, iterates on prestress loss until an acceptable design is obtained and outputs the final design.

Variable Definitions

WIDTH - overall bridge width, used to compute AASHTO lateral distribution factor (ft).

JTNTL - number of traffic lanes, used in computation of AASHTO lateral distribution factor.

TNLB - number of longitudinal beams, used in computing AASHTO lateral distribution factor.

ZAXLE(I) - contains axles loads of designated AASHTO truck loading (kips).

ZNWHL(I) - contains axle spacings of designated AASHTO truck (ft).

NAXLE - number of axles in designated AASHTO truck.

ULOAD - lane load for designated AASHTO loading (k/ft).

CSLOAD - concentrated force used in computation of live load shear from designated AASHTO lane loading.

CMLOAD - concentrated force used in computation of live load moment from designated AASHTO lane loading.

ZIMP - live load impact factor.

STRESS(I,J) - contains stresses in beam due to all sources, for final design. J=1, release stress top; J=2, release stress bottom; J=3, service stress top; J=4, service stress bottom. I runs from 1 to 6 and for release stresses correspond to the
following points; end, L/20, L/10, 3L/20, 2L/10 and 1/4 point.
For service service stresses, I corresponds to end, L/10, 
2L/10, 3L/10, 4L/10 and midspan. Tension stresses are negative 
and compression stresses are positive.

KSYM(I,J) - array containing the symbol "x" to be printed with those stresses 
(either release or service) which are at their allowable value 
(I=1, . . , 6; J=1, . . , 4). Column 5 contains "x" for behavior 
constraints which are binding on the final design. The constraints 
are: minimum concrete strength (I=2), ultimate moment capacity 
(I=4), minimum initial camber (I=5), maximum concrete strength 
(I=1), cracking moment capacity (I=3), maximum initial camber 
(I=6).

NSTRMx(I) - the maximum number of strands permitted in strand row I, stored in 
integer form.

NWARP(I) - contains strand wrapping information used in output.

STRSP(I) - stirrups spacings (in). I=1, end; I=2, L/10; I=3, 2L/10; I=4, 
quarter point; I=5, 3L/10; I=6, 4L/10; I=7, midspan.
CALL DEFINE
Define Standard Parameter Values

Read Input Data

Check Input Data for Consistency. Print Message and Terminate if Error Found

Lateral Distribution Factor Input?

Yes

No

Compute Lateral Distribution Factor

CALL PROPTY
Compute Section Properties

Compute Characteristic Cross Sectional Dimensions for Use in ULTMP

Compute Strand Row Spacing Information

Print Input and Computed Data

Compute Design Moments and Shears

Select Truck and Lane Loads for Loading

AASHTO Loading?

No

FIGURE C1. Flow Chart for Main Program
Scale Moments and Shears by Lateral Distribution Factor and Impact Factor

Set Initial and Final Prestress Loss Factors to 0.05 to 0.1

Compute Parameters Required by LPCODE

Design Option Specified?

Yes

Define Strand and Concrete Costs

No

Go To 150 for DBOXSS

Go To 175 for DBOXDS

FIGURE C1. (continued)
CALL EQGEN
Generate Coefficients for L.P. Problem

CALL LPCODE
Solve L.P. Problem

Compute Quantities Required for Prestress Loss Using Solution from L.P. Problem

CALL PLOSS
Compute Initial & Final Prestress Losses

If Computed Final Loss $\leq 1.03$ times Assumed Loss

Yes

Go To 200

No

Read L.P. Coefficient Matrix from Tape

Update Stress Constraints to Reflect New Prestress Losses

Update Camber Constraints

Update Ultimate Moment and Cracking Moment Constraints

Store New Prestress Losses as Assumed Prestress Losses

FIGURE C1. (continued)

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Extract Strand Wrapping Pattern from L.P. Solution

Extract Concrete Strengths from L.P. Solution

Go To 300

FIGURE C1. (continued)
CALL EQGEN
Generate Coefficients for Integer Program in Rectangular Array Form for Call to LPCODE

CALL LPCODE
Solve Continuous L.P. Approximation to Integer Program
Round Continuous Solution to Integer Values for Initial Starting Solution for Integer Program

CALL SQUASH
Compress Coefficient Matrix for Integer Program to Column Array
Store Right-Hand-Side Vector for Constraint Set on Tape

CALL INTPRG
Solve Integer Program

CALL PLOSS
Compute Prestress Losses for Current Solution

Computed Final Losses \( \leq 1.03 \) times Assumed Losses

Yes Go To 200

No
Read Right-Hand-Side Vector from Tape

FIGURE Cl. (continued)
Update Stress Constraints to Reflect New Prestress Losses

Update Camber Constraints

Update Ultimate Moment and Cracking Moment Constraints

Store New Prestress Losses as Assumed Prestress Losses

Go To 180

FIGURE C1. (continued)
CALL CAMBER
Compute Long Term Camber
for 4 Typical Texas Concretes and
Input Creep & Shrinkage
Properties

Compute initial Cambers

CALL ULTMP
Compute Ultimate Moment
Capacity

Compute Cracking
Moment

CALL PLOSS
Compute Prestress Losses

CALL SHEAR
Compute Stirrup Spacings

Optimization
Option
Specified?

No

Compute Beam Cost
Data

Compute Stresses

Identify Binding
Constraints

Output Final Design
Information

Go To 100

Required
Data Set

E

FIGURE C1. (continued)
SUBROUTINE DEFINE

Subroutine Function

This subroutine defines standard parameter values used in the program. The subroutine is called before input data are read, for each data set processed. Thus, only non-standard values of input parameters need be entered on the program input forms. The parameters initialized are: unit weight of concrete, average relative humidity, ultimate strength of strand, proportional limit of strand, allowable stress coefficients, unit creep and shrinkage constants for the concrete, ratio of modulus of elasticity of compression reinforcing to that of the concrete, yield strength of stirrup and compression reinforcing and area of stirrups.

Definition of Variables

The variables used in this subroutine appear in COMMON/DEFINE/ and are described in Appendix B.
SUBROUTINE EQGEN

Subroutine Function

This subroutine name appears in both DBOXSS and DBOXDS. Its function in both programs is to generate the coefficients defining the objective function and constraint set for the programming problem. The coefficients used are contained in the equations of Chapter II for DBOXSS and Chapter III for DBOXDS.

Additional Considerations - DBOXDS

In addition to the basic function defined above, two other actions are contained in the version in DBOXDS. The coefficient matrix is the same, regardless of whether the problem is to be solved as a continuous linear programming (L.P.) problem or an integer program. DBOXDS uses an L.P. solution as a starting point for the solution to the integer program. To insure that the starting point is realistic, it is necessary to place an upper bound of 1.0 on binary variables (which take values of either 0 or 1) which appear in the integer formulation. This is done at the end of EQGEN by generating an additional set of upper bound constraints which are activated only when the coefficient matrix is passed to subroutine LPCODE. The coefficient matrix is destroyed during the solution of the linear program in LPCODE. Thus, to preserve the matrix for later iterations on prestress loss, it is necessary to store it on scratch tape (unit 3). This is done as the last step in the subroutine.

Variable Definitions

The coefficient matrix (which includes the objective function and right-hand-side vector as well as the constraints) is placed in the
variable name ARRAY(I,J). Other variable names which appear in this subroutine are defined either in the labeled commons (Appendix B) or in subroutine LPCODE and INTPRG.
SUBROUTINE LPCODE (NFRCE, NEQS, INDX, KODE)

Subroutine Function

This subroutine solves the linear program defined by Eqs. using the simplex method. It calls subroutine PIVOT to perform tableaux transformations. The principle variables used are those contained in COMMON/D314/ which are defined below.

Additional Considerations - DBOXSS

The coefficient matrix is destroyed during the solution process. To preserve it for later use in iterations on prestress loss (and thus save the computational effort of recomputing it each time) the matrix is stored on scratch tape (unit 4). This is performed immediately after entry to the subroutine.

Variable Definitions

NFRCE - number of unrestricted variables (those which may assume negative values). This parameter must be zero for the version of LPCODE incorporated in the program.

NEQS - number of equality constraints. Must be zero in this program.

INDX - parameter indicating whether the primal (INDX=0) or dual (INDX=1) problem is to be solved. Must be zero in this program.

KODE - code indicating whether this is the first call to LPCODE (KODE=0). On the first call, slack variables are added to the coefficient matrix and it is stored on tape unit 4.

N - the number of constraints plus 1.

M - the number of variables.

A(I,J) - the coefficient matrix.
$B(I), XD(I)$ - arrays used as flags during computation.

$X(I)$ - on return, contains the problem solution.

$OBJ$ - contains the objective function value.
SUBROUTINE INTPRG

Subroutine Function

This subroutine uses a heuristic algorithm to solve the integer programming problem. It calls subroutine PHASE1, PHASE2 and PHASE3. It is used only in DBOXDS. To improve computational efficiency, it works with a compressed version of the coefficient matrix which is obtained by deleting zero entries and "stacking" the columns of this matrix in the singly subscripted variable Y(I). In this form, several additional arrays (ROW(I) and COL(I)) are required to keep track of indexing. The compression of the coefficient matrix into a column vector is carried out in subroutine SQUASH.

Definition of Variables

N1 - number of continuous variables in the problem.
N2 - number of integer variables in the problem.
N3 - number of binary (0 or 1) variables in the problem.
TR - a tolerance on constraints. When the difference between the left and right side of an inequality is less than TR in absolute value, the constraint is assumed active.
TV - a tolerance on variables. When any variable takes a value less than TV, it is assigned the value zero.
NR - number of constraints in the problem.
DXMAX - the maximum amount by which any variable is incremented in testing for a potential solution point.
IT(I) - array containing the number of iterations used in each of the four phases of the algorithm.
X(I) - contains the values of the variables.
Y(I) - contains the nonzero terms of the coefficient matrix in "stacked" form.

ROW(I) - contains the row in the coefficient matrix from which the Ith element of Y(I) was taken.

COL(I) - contains the element number of Y(J) where the first nonzero element from row I of the coefficient matrix is stored.

BB(I) - scratch storage used to accumulate the value of each constraint.

C(I) - contains the coefficients of the objective function.

B(I) - contains the right-hand-side vector for the constraints.

XX(I) - scratch storage space.
SUBROUTINE PROPTY

Subroutine Function

This subroutine calculates the location of the centroid of the cross section, the moment of inertia with respect to the centroidal axis of bending, and the section modulii for the top and bottom of the cross section. Each of the computed quantities previously mentioned is calculated for the cross section with and without the shear key. If the dimension A is greater than or equal to B, the area of the shear key is taken as zero.

Definition of Variables

A, B, C, C1, C2, D, E, F, G, H, T, WD, WH, XDIM, YDIM - See Figure C2

AREA - area of cross section without shear key and with compression steel replaced with an equivalent area of concrete obtained by multiplying the area of steel by (RATNOD-1)(in.²).

AREAK - area of cross section with shear key and with compression steel transformed using (2·RATNOD-1)(in.²).

YB - distance from c.g. of beam to bottom of beam (in.).

YBK - distance from c.g. of beam to bottom of beam, with shear key (in.).

Y1 thru Y15 - distance from bottom of the cross section to the c.g. of the areas 1 thru 15 shown in Figure C2 (in.).

I1 thru I15 - moment of inertia of areas 1 thru 15 shown in Figure C2 (in.⁴).

JVKEY = 1 - shear key omitted.

JVKEY = 2 - shear key included.
ZT - section modulus at top excluding the shear key (in.³).
ZB - section modulus at bottom excluding the shear key (in.³).
ZTK - same as ZT except including shear key (in.³).
ZBK - same as ZB except including shear key (in.³).
APRIME - area of compression steel in the top flange (in.²).
RATNOD - modular ratio.
FIGURE C2. Component Areas Used In Computing Cross Sectional Properties
SUBROUTINE MOMSHR (DL, NWHL, NWHEEL, XSEC, PAXLE, MAXMOM, MAXSHR)

Subroutine Function

This subroutine determines the maximum bending moment and shear force at a point on a simply supported beam due to a series of moving concentrated forces.

Definition of Variables

DL - length of span (ft).

NWHL(I) - distance from concentrated force I to concentrated force I (ft).

NWHEEL - number of concentrated forces in moving force pattern.

XSEC* - distance from left end of beam to point where maximum effects to be computed as load pattern moves from right to left (ft).

PAXLE(I) - weight of Ith concentrated force (kips).

MAXMOM - on return, contains maximum bending moment at point of interest (kip-ft).

MAXSHR - on return, contains maximum shear force at point of interest (kips).

NS - shift number, which is the number of the force located over the point of interest on the beam.

NST - number of intervals between concentrated forces.

IPL(I) - array indicating which concentrated force is located over the section of interest for shift number I.

IPR(I)* - array indicating which concentrated force is located nearest the right end of the beam and still on the beam for shift I, as load pattern moves from right to left.
D2* - distance from any concentrated force to the right end of the beam for load pattern moving right to left (ft).

REACT(I)* - left reaction force for shift I, as load pattern moves from right to left (kips).

DM* - distance from point of interest on beam to any concentrated force to the left of the point and still on the beam when load pattern moves from right to left (ft).

SHEAR(I) - shear force at point of interest on beam for Ith shift (kips).

MOMENT(I) - bending moment at point of interest on beam for Ith shift (kip-ft).

II - a trigger used to indicate direction of movement of load pattern. When II = 1, load pattern moves right to left and when II = 2, movement is left to right.

* to obtain correct interpretation of the variable when the load pattern moves from left to right, substitute the word right for left and left-to-right for right-to-left.
SUBROUTINE LOCATE (DL, XSEC, NST, NWHL)

Subroutine Function

This subroutine calculates the number of the concentrated force in
the moving load pattern located at the point of interest on the beam and
the number of the concentrated force on the beam nearest the end of the
beam from which the load pattern is moving.

Definition of Variables

The variables used in this subroutine are defined in the description
of subroutine MOMSHR.
SUBROUTINE ULTMP (ASTAR, FPCBM, FPS, ASPRM, FPL, D, DPTH, FSY, DCR
Y1, Y2, Y3, Y4, Z1, Z2, Z3, Z4, ZMUL)

Subroutine Function

This subroutine computes the ultimate moment capacity of the section. Two cases are considered: the neutral axis in the slab and the neutral axis below the slab. The methodology used to compute moment capacity was developed in Chapter II. This subroutine calls function subprogram BRACK.

Definition of Variables

ASTAR - total area of prestressing strands (in^2).
FPCBM - 28 day concrete strength (ksi).
FPS - ultimate strength of strand (ksi).
ASPRM - total area of compression steel reinforcing present in slab (in^2).
FPL - proportional limit stress for strand material (ksi).
D - distance from top of section to c.g. of strands (in).
DPTH - depth of section (in).
FSY - yield strength of compression reinforcing steel (ksi).
DCR - distance from top of section to c.g. of compression steel (in).
Y1, Y2, Y3, Y4,
Z1, Z2, Z3, Z4 - dimensions used to compute area and c.g. of concrete compression zone (see Figure C3).
ZMUL - on return, contains the ultimate moment capacity (k-ft).
CLONG - fraction of prestress force lost due to elastic and inelastic effects.
ESINI - average strain in the strands after all losses (in/in).

BEFF - width of top of section (in).

THK - thickness of top slab (in).

CC - total compression force over concrete compression zone (kips).

T - total tension force in strands (kips).

X - distance from top of beam to neutral axis (in).

ES - average strain in strands (in/in).

ESP - average strain in compression reinforcing (in/in).

CS - total compression force in compression reinforcing.
FIGURE C3. Dimensions of Cross Section Used in Computing Concrete Compression Zone
Compute Average Initial Strand Strain

Compute Location of Neutral Axis by AASHTO Equation for Moment Capacity

Neutral Axis in Slab

Set Distance From Top of Section to Neutral Axis, x, equal to 0.

$x = x + 0.25$

Compute Strain in Compression Reinforcing and Strands

Use Stress-Strain Properties of Strand and Compression Reinforcing to Compute Stresses from Known Strains

Compute Concrete Compression Zone Area and its c.g.

Sum Total Compression Force from Concrete and Compression Steel (if in Compression)

Sum Total Tension Force from Strands and Compression Steel (if in Tension)

Total Compression Force exceeds Total Tension Force

Yes

Sum Moment about Neutral Axis to Obtain Moment Capacity

No

FIGURE C4. Flow Chart for Subroutine ULTMP
Use Linear Interpolation to Obtain Estimate of Neutral Axis Location

$x = x_{old}$

No

$x_{new} > x_{old} + .25$

Yes

$x = x_{new}$

Go To I50

Go To I00

FIGURE C4. (continued)
SUBROUTINE PLOSS (FPCR, ZMBW, ZMC, ZMNC, FSU, AS, AB, ZI, ZIC, YB, YBC, EC, HUM, SPAN, ZLOSS, ZINLOS, UWC)

Subroutine Function

This subroutine computes the fraction of initial strand stress lost immediately after release and when all creep, shrinkage and strand relaxation losses have occurred. The losses are computed using the expressions presented in Chapter II.

Definitions of Variables

FPCR - concrete strength at release (ksi).
ZMBW - moment at midspan due to beam weight (k-ft).
ZMC - other dead load moment at midspan acting on composite section (beam plus shear key) (k-ft).
ZMNC - other dead load moment at midspan acting on non-composite section (beam without shear key) (k-ft).
FSU - ultimate strength of strand (ksi).
AS - total area of strands (in.²).
AB - cross sectional area of beam (in.²).
ZI - moment of inertia of beam cross section (in.⁴).
ZIC - moment of inertia of composite section (in.⁴).
YB - distance from c.g. of beam to bottom of beam (in.).
YBC - distance from c.g. of composite section to bottom of beam (in.).
EC - distance from bottom of beam to c.g. of strands (in.).
HUM - average relative humidity present during life of beam (%).
SPAN - span length (ft).
ZINLOS - fraction of initial strand stress (.7 FSU) lost at release.
ZLOSS - fraction of initial strand stress lost under service load conditions.

UWC - unit weight of beam concrete (k/ft^3).

SH - prestress loss due to shrinkage of concrete (ksi).

ES - prestress loss due to elastic shortening (ksi).

CRC - prestress loss due to creep of concrete (ksi).

CRS - prestress loss due to strand relaxation (ksi).

ECI - modulus of elasticity of concrete at release (ksi).

Computed from ACI equation.
SUBROUTINE CAMBER (ES, EC, ASTRN, STRNS, UWB, AREA, SPANL, ECCL, IB, FO, ENDECC, PRLMAX, CBRMAX, HDPT)

Subroutine Function

This subroutine computes midspan camber under dead load due to elastic and inelastic (creep and shrinkage) behavior of the concrete. The method is developed in reference (2). Upward camber is positive.

Definitions of Variables

ACR - unit creep at time infinity (in./in./psi).
ASH - shrinkage at time infinity (in./in.).
AST - total area of prestressing strands (in.²).
BCR - time at which one-half ACR is reached (days).
BSH - time at which one-half ASH is reached (days).
ES - modulus of elasticity of steel (10⁶ psi).
EC - modulus of elasticity of concrete (10⁶ psi).
ASTRN - area of a single prestressing strand (in.²).
STRNS - total number of prestressing strands.
UWB - unit weight of beam concrete (lbs./ft³).
AREA - cross-sectional area of beam (in.²).
SPANL - span length (ft).
ECCL - eccentricity of the strand pattern at the center line of the beam measured from the cg (in.).
IB - beam moment of inertia (in.⁴).
FO - total initial prestressing force (lbs).
ENDECC - eccentricity of the strand pattern at the ends of the beam measured from the cg (in.).
PRLMAX - total prestress loss at time infinity (%).
CBRMAX - total camber at time infinity (in.).
HDPT - distance from the centerline of the beam to the
hold-down point (ft).
CNST(i,j) - creep and shrinkage coefficients based upon Dallas,
Odessa, San Antonio, and Lufkin concrete properties.
SUBROUTINE SHEAR (B, DEPTH, D, FPC, FSY, AREA, VU, SPACE)

Subroutine Function

This subroutine computes the stirrup spacing requirements at selected sections of the beam according to The American Association of State Highway Officials Specifications, 1973.

Definitions of Variables

B - width of a web of the beam cross-section (in.).
DEPTH - depth of the beam (in.).
D - distance from extreme compressive fiber to the centroid of the prestressing force (in.).
FPC - compressive strength of concrete at 28 days (ksi).
FSY - yield strength of non-prestressed conventional reinforcement in compression (ksi).
AREA - area of web reinforcement (in.²).
VU - shear due to ultimate load and effect of pre-stressing (kips).
SPACE - longitudinal spacing of the web reinforcement (in.).
AV - total area of web reinforcement (in.²).
RJ - ratio of distance between centroid of compression and centroid of tension to the depth D.
VC - shear carried by the concrete (kips).
APPENDIX D

DESCRIPTION OF MODIFICATIONS TO
GHOSE'S MULTIBEAM BRIDGE ANALYSIS PROGRAM
Chapter VI described briefly the computer program by Ghose (9) for the analysis of multibeam bridges and the modified version, AMBB, developed for the calculation of lateral distribution factors for axle train and standard AASHTO loadings. This Appendix describes the modifications to the program written by Ghose.

The modifications consist of changes in program input and output and three added subroutines, INPUT, OUTPUT, and INFLN. The appropriate input routine is called by the main program, based on the entry in column 62 of the first card in the data deck (see Figure 35). For input to the original program, subroutine INPTT is called. If a 1 is found in column 62, control is transferred to subroutine INPUT for reading of the data on the form in Figure 35. Output is handled in the same way, with subroutine OUTPTT being used when a blank is encountered in column 62 of the first card and subroutine OUTPUT utilized for output when the program is to be used to compute lateral distribution factors. The longitudinal position of vehicle axles (either axle train or AASHTO truck) is first computed. Next, the influence lines for midspan moment in each beam is computed by moving a single line of wheels transversely across the bridge in one foot moves. Finally, the maximum moment in each beam and the corresponding position of axle train, truck or lane loading is computed from the influence lines. Loadings for producing the influence lines are assembled in subroutine INPUT, and maximum moments and vehicle positions are computed in subroutine INFLN.

The variables listed below are used in the modifications to the original program.

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ZPAN - span length (ft.).

E - modulus of elasticity (ksi).

NBEAMS - number of beams in bridge.

NTRFL - number of traffic lanes.

KAXT - trigger: if 1, axle train loading input; if not equal to 1, no axle train considered.

NAXTSP - lateral spacing of wheel lines in axle train (ft. - an integer number).

NAXCL - side clearance of axle train vehicle. The distance between the wheel line and outside of the vehicle. The wheel line may be no closer than NAXCL feet from the edge of a traffic lane.

NAXT - number of axle trains that can simultaneously be located transversely on the bridge (NAXT < NTRFL).

YMI(I) - moment of inertia about y-axis (see Figure 31) of beam type I (in$^4$).

ZMI(I) - moment of inertia about z-axis of beam type I (in$^4$).

BMA(I) - cross sectional area of beam type I (in$^2$).

BMJ(I) - torsional stiffness (polar moment of inertia) of beam type I (see Eq. 164), (in$^4$).

YH(I,1) - distance, parallel to y-axis, between c.g. of beam type I and left hinge (HL on input form), (in).

YH(I,2) - distance, parallel to y-axis, between c.g. of beam type I and right hinge (HR on input form), (in).
ZH(I,1) - distance, parallel to z-axis, between c.g. of beam type I and left hinge (VL on input form), (in).

ZH(I,2) - distance, parallel to z-axis, between c.g. of beam type I and right hinge (VR on input form), (in).

NTYPES - number of different beam types.

NTY(I) - contains beam type number for beam I.

HINGTP(I,J) - for hinge type I: contains "Y" in J = 1 if hinge transmits longitudinal shear force or "N" if it does not; contains "Y" in J = 2 if hinge transmits vertical shear (shear in z-direction, Figure 31), "N" if not; contains "Y" in J = 3 if hinge transmits transverse force (y-direction Figure 31), "N" if not; contains "Y" in J = 4 if hinge transmits transverse moment (about x-axis Figure 31), "N" if not.

JTYPES - number of different hinge types.

JTY(I) - contains hinge type number for hinge I.

TLN(I,J) - contains distance between c.g. of beam 1 and left edge of traffic lane I in J = 1. Distance between c.g. of beam 1 and right edge of traffic lane I in J = 2. Distances are positive to the right of beam 1 c.g. and negative to left (ft).

NWHEEL - number of axles in axle train.

PWHEEL(I) - weight of axle I in axle train (kips).

ZNWHL(I) - distance between axle 1 and axle I (ft).
KASAST(I,J) - for traffic lane I, J = 1 contains load case number where AASHTO truck is as close to left edge of traffic lane I as side clearance (2 ft.) permits. For J = 2, contains load case number for truck as close as possible to right edge of traffic lane I.

KASASL(I,J) - for traffic lane I, J = 1 contains load case number where 10 ft. wide lane load is positioned at left edge of lane. J = 2 contains load case number where lane load is at right edge of traffic lane I.

KASAXT(I,J) - same as KASAST(I,J) but for axle train whose side clearance is NAXCL.

FULMAT - maximum moment at midspan due to single AASHTO truck (k-in).
FULMAL - maximum midspan moment due to full AASHTO lane load (k-in).
FULMAX - maximum moment at midspan due to full axle train (k-in).

ZIMP - impact factor.

ZMAST(I,J) - maximum midspan moment, beam I produced by AASHTO truck positioned in lane J (k-in).

ZMASL(I,J) - maximum midspan moment, beam I produced by AASHTO lane load in lane J (k-in).

ZMAXT(I,J) - maximum midspan moment, beam I, produced by axle train in Lane J (k-in).

ZMMAST(I) - maximum moment at midspan of beam I due to AASHTO trucks in one or more lanes, using AASHTO lane reduction factors (k-in).
ZMMASL(I) - same as ZMMAST(I), but for lane loads applied instead of AASHTO trucks (k-in).

ZMMAXT(I) - maximum midspan moment for beam I by placing from one up to NAXT axle trains simultaneously in the various traffic lanes. AASHTO lane reduction factors are not used (k-in).

POSAT(I,J) - contains the position of left and right wheel lines of AASHTO truck which produces maximum moment in beam I. J = 1 contains distance from c.g. of beam 1 to left wheel line for truck in lane 1. J = 2 contains distance to right wheel line of truck in lane 1. J = 3 contains distance from c.g. of beam 1 to left wheel line for truck in lane 2. J = 4 contains distance to right wheel line, etc. (ft).

POSLN(I,J) - see POSAT(I,J), but for AASHTO lane loading instead of AASHTO truck (ft).

POSAX(I,J) - see POSAT(I,J), but for axle train vehicle (ft).

NLLAST(I,J) - coded array: if NLLAST(I,J) ≠ 0, then lane J is loaded when maximum moment at midspan of beam I occurs under AASHTO truck loadings.

NLLALN(I,J) - same as NLLAST(I,J), but for AASHTO lane loading.

NLLAXT(I,J) - same as NLLAST(I,J), but for axle train vehicle.

DISTAT(I) - fraction of full AASHTO truck applied to single beam I which would produce same moment as that recorded in ZMMAST(I).

DISTAL(I) - same as DISTAT(I), but for AASHTO lane loading.

DISTAX(I) - same as DISTAT(I), but for axle train vehicle.
YMOU(I,J,K) - moment about y-axis in beam J, under load case I, for Kth x-coordinate position along beam. This variable occurs in Ghose's original program. When used in added subroutines described here, only $K = 1$ (which corresponds to midspan) is used ($k$-in).
APPENDIX E

Program Listings

dboxss . . . . . 215

dboxds . . . . . 268

ambb . . . . . 335
COMMON/BLK1/ ADIM,BDIM,CDIM,DDIM,EDIM,FDIM,GDIM,HDIM,TDIM,  SS000010
1WDIM,HDIM,XDIM,YDIM,ACONC,BINERT,DTFC,DBCT,IT,ZB,ACONCK,  SS000020
2BINERK,DTOPK,DBTK,XTK,ZBK,ZL,F28,JOPT,ASSCLR,ASSPLS,APRIME,  SS000030
3CBOT,OSTK,F,CCSTT,DEFWIN,ALDEF,NRAV,NWHEEL,DISTF,FPCMAX,  SS000040
4FPCMIN,ELASC,ULTM,CTOP,WB,FO,DCR  SS000050
COMMON/BLK2/ PAXLE(18),NWHL(18),STRMAX(26),FCONC(10),DCONC(10),  SS000060
1G(11),F(11),D(10),GIDMAX(16),BMAX(15),BMAX(7),BMAX(7),CBRMAX(5),PRMAX(5),  SS000070
2DLMAX(7),DLHRL(7),PEECR(11,4),ZLOS(4),ZWRAP(40,3),NSDF(10)  SS000080
COMMON/DEFINE/ UEC,HUM,AS,FPSE,CTR1,CTR2,CLRP,CL8E,CTS1,CTS2,  SS000090
1CBS1,CBS2,CMCEP1,CMCEP2,SHRK1,SHRK2,ROTNO,FPL,FSY,ASTRIP  SS000100
COMMON/YZ/ Z1,Z2,Z3,Z4,Y1,Y2,Y3,Y4  SS000110
COMMON/DUMP/TITLE3,54,YJ(J=154),FROW(26),  SS000120
1PEF(50,3),ZNE(11),KCODE(4),ZMCR(4)  SS000130
COMMON/I314/ N,ARRAY(156,276),B(276),X(276),X(276),D8J,KP1,K  SS000140
DIMENSION STRESS(6,4),NSTRM(26),ZNWHL(18),ZAXLE(18),VU(7)  SS000150
1EX(2),KSIM(6,5),STRSP(7),IAA(J=16),NWRAP(40,3)  SS000160
INTEGER ONE,TWO,BLANK,HHH,SSS,EX  SS000170
DATA EX/' *'X'  /  SS000180
DATA ONE,TWO,BLANK,HHH,SSS/'1','*2','*3','H','S'  /
NCOUNT=1  SS000190
SS000200
C***********************************************************************
C**** INPUT ROUTINE .  SS000220
C***********************************************************************
SS000230
CALL REREAD  SS000240
3007 FPC1=0.0  SS000250
IF(NCOUNT.NE.1) GO TO 573  SS000260
READ(5,500)(TITLE(1,J),J=1,54)  SS000270
READ(5,500)(TITLE(2,J),J=1,54)  SS000280
573 READ(5,500,END=2500) (TITLE(3,J1),J1=1,54)  SS000290
500 FORMAT(80A1)  SS000300
CALL DEFIN  SS000310
READ(5,501)ID,IA,IB,DISTF,LOAD,ULSB,FCONC,F28,JOPT  SS000320
501 FORMAT(A1,4X,A1,1X,A1,4X,F4.3,3X,11,3X,F4.2,3X,11,3X,F3.1,SS000330
*10X,I1)  SS000340
IF(JOPT.EQ.0.ANC,F28,EQ.0.) WRITE(6,525)  SS000350
IF(JOPT.EQ.0.ANC,F28,EQ.0.) STOP  SS000360
525 FORMAT(///,35X,*DESIGN OPTION SPECIFIED BUT NO 28 DAY CONCRETE
1STRENGTH GIVEN*)  SS000370
C AXLE TRAIN  SS000380
DO 927 I=1,18  SS000390
SS000400
PAXLE(I)=0.
NWHL(I)=0.
)
927 CONTINUE
  IF(JLOAD.NE.1)GO TO 861
  READ(5,502)(PAXLE(I),I=1,18)
  502 FORMAT(3X,1E(F3.1,1X))
  DO 503 N=1,18
        IF(PAXLE(N).NE.0.)NWHL=N
  503 CONTINUE
  READ(5,505)(NWHL(I),I=1,17)
  505 FORMAT(7X,17(F3.0,1X))
  CONCENTRATED FORCES APPLIED TO SINGLE BEAM
  861 DO 590 I=1,10
        FCONC(I)=0.
        DCONC(I)=0.
  590 CONTINUE
  IF(JCONC.NE.1) GO TO 925
  READ(5,591)(FCONC(I),I=1,10)
  591 FORMAT(3X,10(F5.2,1X))
  BEAM DIMENSIONS
  925 READ(5,907)ADIM,BDIM,CDIM,DDIM,EDIM,FDIM,GDIM,HDIM,WDIM,TDIM,WDDISS000620
      *M,DXIM,YDIM
  907 FORMAT(3X,13(F4.2,1X))
  GENERAL INFORMATION
  908 FORMAT(3X,F4.1,3X,F4.1,3X,F4.1,3X,I12,3X,F6.4,1F4.2,3X,F4.2,3X,F5.3,3X)
      IF5.3,3X,F2.1,3X,I11,3X,I11)
  909 FORMAT(3X,F4.1,3X,F4.1,3X,F4.2,3X,1F4.2,3X,F4.2,3X)
      IF(SLW.GT.10,.STOP
  4102 READ(99,9083)IAB,IAC,IAO,IAE
  9083 FORMAT(42X,4A4)
      IF(IAB.EQ.BLANK.AND.IAC.EQ.BLANK) ALDEF=1000.
      IF(IAD.EQ.BLANK.AND.IAE.EQ.BLANK) DEFMIN=-1000.
  MAXIMUM NUMBER OF STRANDS PER ROW
  9084 READ(5,505)(NSTRMx(I),I=1,26)
909 FORMAT(3X,25(I2 ,1X),I2 )
    DO 910 J=1,26
    STRMAX(J)=NSTRMX(J)
    IF(NSTRMX(J).NE.0)INRAV=J
910 CONTINUE
    DO 878 J=1,26
878 GRIDS(J1)=0.
    GRIDS(1)=CBOT
    IF(JGRID.NE.1) GO TO 862
    C NONSTANDARD GRID SPACING
    READ(5,880) (GRIDS(I),I=2,26)
880 FORMAT(3X,25(F2.1,1X))
    IF(GRIDS(2).EQ.0.) WRITE(6,897)
897 FORMAT(1X,130(1H*),/1X,2(1H*))
    *M STRAND ROW 1 TO ROW 2 IS 0 - CHECK INPUT CARD (NONSTANDARD GRID
    *SPACING), COLS. 4 & 5 . *3(1H*)/1X,130(1H*)
    IF(GRIDS(2).NE.0.) STOP
    C MISCELLANEOUS PROPERTIES
862 IF(JPROP.NE.1) GO TO 863
    READ(5,882) CUW,UHM,SA,SPF,BR2,TR2,BR1,TR1,BS2,TS2,BS1,TS1
    *,CREEP1,CREEP2,SHRK1,SHRK2
882 FORMAT(3X,F3.3*4X,F2.0*4X,F3.3*4X,F3.0*4X,F2.2*1X,F2.1*1X,F2.2*1X)
    *F2.1,3X,F2.2,1X,F2.1,1X,F2.2,1X,F2.1,4X,4(F3.0*2X))
    IF(SPF.NE.0.) FPS=SPF
    IF(SA.NE.0.) AS=SA
    IF(UHM.NE.0.) HUM=UHM
    IF(CUW.NE.0.) UCW=CUW
    READ(99,9082) (IAA(J1),J1=1,16)
9082 FORMAT(30X,2A1,1X,2A1,1X,2A1,1X,2A1,1X,2A1,1X,2A1,1X,2A1,1X,2A1)
    IF(IAA(1).NE.BLANK.OR.IAA(2).NE.BLANK) CBR2=BR2
    IF(IAA(3).NE.BLANK.OR.IAA(4).NE.BLANK) CTR2=TR2
    IF(IAA(5).NE.BLANK.OR.IAA(6).NE.BLANK) CBR1=BR1
    IF(IAA(7).NE.BLANK.OR.IAA(8).NE.BLANK) CTR1=TR1
    IF(IAA(9).NE.BLANK.OR.IAA(10).NE.BLANK) CBS2=BS2
    IF(IAA(11).NE.BLANK.OR.IAA(12).NE.BLANK) CTS2=TS2
    IF(IAA(13).NE.BLANK.OR.IAA(14).NE.BLANK) CBS1=BS1
    IF(IAA(15).NE.BLANK.OR.IAA(16).NE.BLANK) CTS1=TS1
    C CONCRETE COST COEFFICIENTS
863 IF(JOPT.NE.1) GO TO 1001
912 READ(5,915)(G(I),I=1,16)
READ(5,915)(G(I),I=7,11)
915 FORMAT(10X,5(F4.1,9X),F4.1)
C STRAND AND STRAND WRAPPING COST
READ(5,914)(COSTFT,COSTWP)
914 FORMAT(13X,F3.2,46X,F3.2)
913 FORMAT(10X,5(F3.1,10X),F3.1)
C 28 DAY CONCRETE STRENGTHS
READ(5,913)(F(I),I=1,6)
READ(5,913)(F(I),I=7,11)
DO 916 J=1,11
IF(F(J).NE.0.0) FFCMAX=4.0+(J-1)*0.5
IF(F(J).EQ.0.0) F(J)=F(J-1)
IF(G(J).EQ.0.0) G(J)=G(J-1)
916 CONTINUE
1001 CONTINUE
C C LIVE LOAD DISTRIBUTION FACTOR
C
IF(DISTF.NE.0.0) GO TO 933
C11 = CONSTN*WIDTH/ZL
D11=5.0*JNTNL/10+(3.0-2.0*JNTNL/7.0)**2*(1.0-C11/3.0)**2
IF(C11.GT.3.0) D11=5.0*JNTNL/10.
S11=(12.0*JNTNL+9.0)/TMLB
DISTF =S11/D11)*0.5
933 CONTINUE
IAASHO=1
C C AASHTO TRUCK LOADINGS
C
IF(IA.EQ.BLANK.AND.IB.EQ.BLANK) IAASHO=0
IF(IA.EQ.BLANK.AND.IB.EQ.BLANK) GO TO 6000
IF(IA.EQ.BLANK.AND.IB.EQ.ONE) GO TO 1000
IF(IA.EQ.ONE.AND.IB.EQ.ONE) GO TO 1000
IF(IA.EQ.ONE.AND.IB.EQ.ONE) GO TO 2000
IF(IA.EQ.ONE.AND.IB.EQ.TWO) GO TO 3000
IF(IA.EQ.ONE.AND.IB.EQ.TWO) GO TO 3000
IF(IA.EQ.ONE.AND.IB.EQ.TWO) GO TO 4000
WRITE(6,950)
950 FORMAT(1X,130(1H*))/1X,30(1H*)*UNRECOGNIZABLE AASHTO TRUCK LOADINGSS001600
*CHECK INPUT CARD 4 COLS 5 THRU 80, 30(1H*)/1X, 130(1H*)
STOP
C
H=15 TRUCK
C
1000 ZAXLE(1)=6.
ZAXLE(2)=24.
ZNWHL(1)=14.
NAXLE=2
ULOAD=0.480
CSLOAD=19.5
CMLOAD=13.5
GO TO 6000
C
H=20 TRUCK
C
2000 ZAXLE(1)=6.
ZAXLE(2)=24.
ZAXLE(3)=24.
ZNWHL(1)=14.
ZNWHL(2)=28.
NAXLE=3
ULOAD=0.480
CSLOAD=19.5
CMLOAD=13.5
GO TO 6000
C
H=20 TRUCK
C
3000 ZAXLE(1)=8.
ZAXLE(2)=32.
ZNWHL(1)=14.
NAXLE=2
ULOAD=0.640
CSLOAD=26.
CMLOAD=18.
GO TO 6000
C
H=20 TRUCK
C
SS0001610
SS0001620
SS0001630
SS0001640
SS0001650
SS0001660
SS0001670
SS0001680
SS0001690
SS0001700
SS0001710
SS0001720
SS0001730
SS0001740
SS0001750
SS0001760
SS0001770
SS0001780
SS0001790
SS0001800
SS0001810
SS0001820
SS0001830
SS0001840
SS0001850
SS0001860
SS0001870
SS0001880
SS0001890
SS0001900
SS0001910
SS0001920
SS0001930
SS0001940
SS0001950
SS0001960
SS0001970
SS0001980
SS0001990
SS0002000
4000 ZAXLE(1)=8.
ZAXLE(2)=32.
ZAXLE(3)=32.
ZNWHL(1)=14.
ZNWHL(2)=28.
NAXLE=3
ULOAD=0.640
CSLOAD=26.
CMLOAD=18.
6000 CONTINUE
CALL PROPTY
Z1=TDIM
Z2=TDIM+XDIM
Z3=HDIM
Z4=HDIM+GDIM
Y1=WHDIM/2.
Y2=WDDIM
Y3=ADIM/2.-Y1=Y2
Y4=XDIM
D(1)=-DBOT+GRIDS(1)
IF(NRAV.EQ.1) GO TO 588
IF(JGRID.EQ.1) GO TO 582
DO 580 J1=2,NRAV
580 GRID(S(J1)=2.0
582 DO 584 J1=2,NRAV
584 D(J1)=D(J1-1)+GRIDS(J1)
588 CONTINUE
C**************************************************************
C**** PRINT OUT INPUT QUANTITIES
WRITE(6,9080) (TITLE(1,J1),J1=10,11),(TITLE(1,J1),J1=14,26).
1(TITLE(1,J1),J1=48,54),(TITLE(2,J2),J2=13,19),(TITLE(2,J2),J2=26,2
28),(TITLE(3,J3),J3=13,54)
9080 FORMAT(1H1,37X,'DISTRICT ',2A1,1X,13A1,' COUNTY HIGHWAY NO. ',
238X,'DESCRIPTION ',42A1)
600 FORMAT(1H1)
WRITE(6,601)
601 FORMAT(//,1X,129('**'))
WRITE(6,610)
610 FORMAT('**',47X,'BEAM DIMENSIONS AND PROPERTIES*',50X,'**')
WRITE(6,602)
602 FORMAT(1X,129('*'))
WRITE(6,611)
611 FORMAT(1X,'**',26('**'),'(DIMENSIONS IN INCHES')**27('**'),**',5X,**',SS002460
6. SECTION PROPERTIES (WITHOUT SHEAR KEY)*****)
WRITE(6,613)
613 FORMAT(1X,'**',2X,'A*',5X,'B*',5X,'C*',5X,'D*',5X,'E*',5X,'F*',5X,'G*',5X,SS002490
**',4X,'M*',5X,'T*',5X,'W*',5X,'X*',5X,'Y*',9X,'I(IN**4)',5X,'A(IN**2)',SS002500
**',4X,'YT(IN)',5X,'YB(IN)**)'
WRITE(6,650) ADIM, BDIM, CDIM, DDIM, EDIM, FDIM, GDIM, HDIM, WDIM, TDIM, WDD
650 FORMAT(1X,'*',F5e2.12F6e2,5X,Fl0.0,6X,F5.2e,6X,Fl0.0) SS002470
WRITE(6,603)
603 FORMAT(1X,'**',127X,'**')
WRITE(6,614) EINERK, ACONCK, DTOPK, DBOTK
614 FORMAT(1X,'** COMPRESSION MAXIMUM MINIMUM',13X,'STRAND',14X,'COS')
& CONCRETE**,9X,****SECTION PROPERTIES (WITH SHEAR KEY)***/1X,**,SS002590
&** REINFORCING INITIAL INITIAL STRAND ULTIMATE RELATIVE**,SS002600
64X,
&'UNIT',13X,'I(IN**4)',5X,'A(IN**2)',4X,'YT(IN)',5X,'YB(IN)**/',SS002610
& AREA*,7X,CAMBER AREA STRENGTH HUMIDITY SS002630
&WEIGHT*,10X,F10.0,6X,F6.1,5X,F5.2,6X,F6.2**,*/1X,**(IN**2)**,SS002640
&3X,**)
WRITE(6,651) APRIME, AS, FPS, HUM, UWC
651 FORMAT('**',4X,F5.2,2X,20X,F10.3,5X,F4.0,7X,F3.0,7X,F5.3,55X,**)
IF(ALDEF,GT,999.,AND,DEFMIN,GT,999.) WRITE(6,7101) DEFMIN
7101 FORMAT('**',22X,F10.3)
IF(ALDEF,LT,999.,AND,DEFMIN,LT,999.) WRITE(6,7102) ALDEF
7102 FORMAT('**',12X,F10.3)
IF(ALDEF,LT,999.,AND,DEFMIN,GT,999.) WRITE(6,7103) ALDEF,DEFMIN
7103 FORMAT('**',12X,F10.3)
WRITE(6,603)
603 FORMAT(1X,5X,'ROW NUMBER',16X,1 2 3 4 5 6 7 8 9 10 11 SS002780
& 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26,**)
WRITE(6,652) (NSTRMX(I),I=1,26)
615 FORMAT('**',54('**'),'STRAND INFORMATION*',55('**'),**'**',127X,**,**,SS002770
&',/,'* ROW NUMBER',16X,'1 2 3 4 5 6 7 8 9 10 11 SS002780
& 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26,**)
WRITE(6,652) (NSTRMX(I),I=1,26)
615 FORMAT('**',54('**'),'STRAND INFORMATION*',55('**'),**'**',127X,**,**,SS002770
&',/,'* ROW NUMBER',16X,'1 2 3 4 5 6 7 8 9 10 11 SS002780
& 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26,**)
WRITE(6,652) (NSTRMX(I),I=1,26)
615 FORMAT('**',54('**'),'STRAND INFORMATION*',55('**'),**'**',127X,**,**,SS002770
&',/,'* ROW NUMBER',16X,'1 2 3 4 5 6 7 8 9 10 11 SS002780
& 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26,**)
WRITE(6,652) (NSTRMX(I),I=1,26)
652 FORMAT(1X,**), *MAXIMUM NO. OF STRANDS *,26(1X,13),***) SS002810
  IF(NRAY.EQ.1) WRITE(6,894) CBGT
  IF(NRAY.EQ.1) GO TO 891
  WRITE(6,894) (GRIDS(I),I=1,26)
894 FORMAT(1X,**), *SPACING (ROW I=1 TO I),1X,26(F4.1),***) SS002850
891 WRITE(6,603)
  WRITE(6,688)
888 FORMAT(1X,**),49('**'), *ALLOWABLE STRESS COEFFICIENTS*,49('**'),***) SS002880
  WRITE(6,603)
883 FORMAT(1X,**),15X,*RELEASER*,8X,*END 1/10*,2X,*REMAINDER*,29X,**
  ** SERVICE*,8X,*END 1/10*,2X,*REMAINDER*,15X,**
  WRITE(6,896) CBR2,CBRI,CBS2,CBS1,CTR2,CTR1,CTS2,CTS1
896 FORMAT(1X,**),27X,*C*,4X,F42,6X,F42,44X,*C*,4X,F42,6X,F42,2
  *18X,**/1X,**,27X,*T*,4X,F42,6X,F42,44X,*T*,4X,F42,6X,F42,2
  *18X,**)
  WRITE(6,603)
  WRITE(6,895) CREEP1,CREEP2,SHRK1,SHRK2
895 FORMAT(1X,**),47('**'), *CREEP AND SHRINKAGE COEFFICIENTS*,48('**'), SS002990
  ***/1X,**,27X,100X,**/1X,**,30X,CREEP1 = *,F4,0,5X,CREEP2 = *,F4,0,30X,**
  *F4,0,7X,SHRK1 = *,F4,0,5X,SHRK2 = *,F4,0,30X,**
  WRITE(6,603)
  IF(JOPT.NE.1) GO TO 695
  WRITE(6,616)
616 FORMAT(*,**),46('**'), *CONCRETE COST COEFFICIENTS($)YD**3),46('**'), SS003050
  ***)
  WRITE(6,653)(C(I),I=1,8)
653 FORMAT(*,4,0KSI/$*,F5.1,* 4,5KSI/$*,F5.1,* 5,0KSI/$*,F5.1,* E,SS003080
  6,5KSI/$*,F5.1,* 6,0KSI/$*,F5.1,* 6,5KSI/$*,F5.1,* 7,0KSI/$*,F5.1SS003090
  &** 7,5KSI/$*,F5.1,9X,***)
  WRITE(6,654)(G(I),I=9,11)
654 FORMAT(*,8,0KSI/$*,F5.1,* 8,5KSI/$*,F5.1,* 9,0KSI/$*,F5.1,84X,**
  **)\n  WRITE(6,603)
  WRITE(6,617)
617 FORMAT(*,**),28('**'), *28 DAY CONCRETE STRENGTH COEFFICIENTS (RELEASE SS003160
  6E STRENGTH/28 DAY STRENGTH),27('**'),***)
  WRITE(6,655)(F(I),I=1,8)
655 FORMAT(*,4,0KSI/*,F4.1,*KSI 4,5KSI/*,F4.1,*KSI 5,0KSI/*,F4.1,**
  6KSI 5,5KSI/*,F4.1,*KSI 6,0KSI/*,F4.1,*KSI 6,5KSI/*,F4.1,*KSI 7SS003200
WRITE(6,656)(F(I),I=9,11)  SS003210
WRITE(6,656)(F(I),I=1,18)  SS003220
WRITE(6,657)COSTFT, COSTWP, FPCMAX  SS003250
WRITE(6,657)COSTFT, COSTWP, FPCMAX  SS003260
WRITE(6,657)COSTFT, COSTWP, FPCMAX  SS003270
WRITE(6,657)COSTFT, COSTWP, FPCMAX  SS003280
WRITE(6,657)COSTFT, COSTWP, FPCMAX  SS003290
WRITE(6,657)COSTFT, COSTWP, FPCMAX  SS003300
WRITE(6,657)COSTFT, COSTWP, FPCMAX  SS003310
WRITE(6,657)COSTFT, COSTWP, FPCMAX  SS003320
WRITE(6,657)COSTFT, COSTWP, FPCMAX  SS003330
WRITE(6,657)COSTFT, COSTWP, FPCMAX  SS003340
WRITE(6,657)COSTFT, COSTWP, FPCMAX  SS003350
WRITE(6,657)COSTFT, COSTWP, FPCMAX  SS003360
WRITE(6,657)COSTFT, COSTWP, FPCMAX  SS003370
WRITE(6,657)COSTFT, COSTWP, FPCMAX  SS003380
WRITE(6,657)COSTFT, COSTWP, FPCMAX  SS003390
WRITE(6,657)COSTFT, COSTWP, FPCMAX  SS003400
WRITE(6,657)COSTFT, COSTWP, FPCMAX  SS003410
WRITE(6,657)COSTFT, COSTWP, FPCMAX  SS003420
WRITE(6,657)COSTFT, COSTWP, FPCMAX  SS003430
WRITE(6,657)COSTFT, COSTWP, FPCMAX  SS003440
WRITE(6,657)COSTFT, COSTWP, FPCMAX  SS003450
WRITE(6,657)COSTFT, COSTWP, FPCMAX  SS003460
WRITE(6,657)COSTFT, COSTWP, FPCMAX  SS003470
WRITE(6,657)COSTFT, COSTWP, FPCMAX  SS003480
WRITE(6,657)COSTFT, COSTWP, FPCMAX  SS003490
WRITE(6,657)COSTFT, COSTWP, FPCMAX  SS003500
WRITE(6,657)COSTFT, COSTWP, FPCMAX  SS003510
WRITE(6,657)COSTFT, COSTWP, FPCMAX  SS003520
WRITE(6,657)COSTFT, COSTWP, FPCMAX  SS003530
WRITE(6,657)COSTFT, COSTWP, FPCMAX  SS003540
WRITE(6,657)COSTFT, COSTWP, FPCMAX  SS003550
WRITE(6,657)COSTFT, COSTWP, FPCMAX  SS003560
WRITE(6,657)COSTFT, COSTWP, FPCMAX  SS003570
WRITE(6,657)COSTFT, COSTWP, FPCMAX  SS003580
WRITE(6,657)COSTFT, COSTWP, FPCMAX  SS003590
WRITE(6,657)COSTFT, COSTWP, FPCMAX  SS003600
WRITE(6,657)COSTFT, COSTWP, FPCMAX  SS003610
661 FORMAT(* *AXLE LCAD(KIPS)*',18F6.1,4X,***)          SS003610
       WRITE(6,662)(NWHL(I),I=1,17)                       SS003620
662 FORMAT(* *DISTANCE TO AXLE(FT)*',17F4.0,4X,***)     SS003630
       WRITE(6,603)                                        SS003640
697 IF(JCONC.NE.1) GO TO 698                             SS003650
       WRITE(6,621)                                        SS003660
621 FORMAT(* **45(*'),*CONCENTRATED FORCES ON SINGLE BEAM*48(*'),***) SS003670
       WRITE(6,664)(FCONC(I),I=1,10)                     SS003680
       WRITE(6,666)(ULSb,EQ.0.0) GO TO 699               SS003690
       WRITE(6,665)(DCCNC(I),I=1,10)                     SS003700
665 FORMAT(* *DISTANCE FROM*114X,*/*,/* *LEFT SUPPORT(FT) *',F5.1,9F5.2 SS003720
       89.1,23X,***)                                      SS003730
       WRITE(6,603)                                        SS003740
698 IF(ULSb,EQ.0.0) GO TO 699                             SS003750
       WRITE(6,666)ULSb                                    SS003760
666 FORMAT(* *UNIFORM LOAD ON SINGLE BEAM = *',F5.2,*K/FT*48(*'),86X,***) SS003770
699 CONTINUE                                             SS003780
       WRITE(6,602)                                        SS003790
C***********************************************************************S5003800
C**** COMPUTE DESIGN MOMENTS AND SHEARS                      SS003810
C***********************************************************************S5003820
DO 20 J1=1,7                                            SS003830
   DLMOM(J1)=0.                                         SS003840
   DLSHR(J1)=0.                                         SS003850
   IF(J1.EQ.1) ZX=0.                                     SS003860
   IF(J1.EQ.2) ZX=ZL/10.                                 SS003870
   IF(J1.EQ.3) ZX=ZL/10.                                 SS003880
   IF(J1.EQ.4) ZX=ZL/4.                                  SS003890
   IF(J1.EQ.5) ZX=3.*ZL/10.                              SS003900
   IF(J1.EQ.6) ZX=4.*ZL/10.                              SS003910
   IF(J1.EQ.7) ZX=ZL/2.                                  SS003920
   ZML=(ACONCK*UWC/144.)*ZL/2.*ZL=ZX                    SS003930
   IF(J1.EQ.7) ZMBW=ZMDL                                  SS003940
   ZSDL=(AONCK*UWC/144.)*(ZL/2.==ZX)                     SS003950
   IF(JCONC.NE.1) GO TO 14                               SS003960
   SUMM=0.                                              SS003970
   SUMV=0.                                              SS003980
   DO 12 J2=1,10                                         SS003990
   IF(DCONC(J2),EQ.0.) GO TO 14                          SS004000
20 CONTINUE
R=FCONC(J2)*(ZL-DCONC(J2))/ZL
SUMM=SUMM+R*Z
SUMV=R
IF(DCONC(J2)*GT.*ZX+.1) GO TO 10
SUMM=SUMM-FCONC(J2)*(ZX=DCONC(J2))
SUMV=SUMV-FCONC(J2)
10 DLMOM(J1)=DLMOM(J1)+SUMM
DLHR(J1)=DLHR(J1)+SUMV
12 CONTINUE
14 DLMOM(J1)=DLMOM(J1)+ULSB*ZX/2.*(ZL=ZX)
DLHR(J1)=DLHR(J1)+ULSB*(ZL/2.=ZX)
ZMOML=0.
ZMOMT=0.
ZSHRL=0.
ZSHRT=0.
ZMOMAX=0.
ZSHRA=0.
ZIMP=1.5+50./((125.+ZL)
IF(ZIMP*GT.*1.30) ZIMP=1.30
IF(AASHO*EQ.*0) GO TO 16
ZMOML=DISTF*ZIMP*ULOAD*ZX/2.*(ZL=ZX)
ZSHRL=DISTF*ZIMP*ULOAD*(ZL/2.=ZX)
R=CMLOAD*CZL*ZL/2e*(ZL=ZX)
ZMOML=ZMOML+R*Z*DISTF*ZIMP
ZSHRL=ZSHRL+R*DISTF*ZIMP
CALL MOMSHR(ZL,NWHL,NXLE,ZX,ZAXLE,ZMOMT,ZSHRT)
ZMOMT=ZMOMT*DISTF*ZIMP
ZSHRT=ZSHRT*DISTF*ZIMP
16 IF(JLOAD*EQ.*0) GO TO 18
CALL MOMSHR(ZL,NWHL,NWHEEL,ZX,PAXLE,ZMOMAX,ZSHRAX)
ZMOMAX=ZMOMAX*DISTF
ZSHRA=ZSHRA*DISTF
18 BMAX(J1)=AMAX1(ZMOML,ZMOMT,ZMOMAX)
BMAX(J1)=AMAX1(ZSHRL,ZSHRT,ZSHRA)
20 CONTINUE
ZMNC=ABS(ACONCK-ACONC)*(UWC*ZL**2)/(144.*8.)
ZMC=DLMOM(7)  SS004410
ULTMRQ=1.3*(ZMCL+DLMOM(7)+(5./3.)*ZMAX)  SS004420
C*************************************************************************************************** SS004430
C**** GENERATE OBJECTIVE FUNCTION AND INITIAL CONSTRAINT SET SS004440
C*************************************************************************************************** SS004450
ASSCLR=0.05  SS004460
ASSPLS=0.1
ZSSCLR=ASSCLR  SS004470
ZSSPLS=ASSPLS  SS004480
ELASC=1.04355*(1000.*UWC)**1.5
NFRCE=0
NEQS=0
INDX=0
IF(JDPT.EQ.0) GO TO 110  SS004490
N=1+45+11*NRAV  SS004500
M=11*NRAV+10  SS004510
GO TO 112  SS004520
110 N=1+26+11*NRAV  SS004530
M=11*NRAV+10  SS004540
GO TO 112  SS004550
112 KK=M+N=1  SS004560
K=N+M=1
IF(JOPT.EQ.1) GO TO 108  SS004570
C C DEFINE COST COEFFICIENTS FOR DESIGN OPTION  SS004580
C COSTFT=100.
G(1)=1944.*COSTFT/(4.*ACONC)  SS004590
COSTWP=0.1  SS004600
108 CALL EGEN  SS004610
KODE=0  SS004620
C C*************************************************************************************************** SS004630
C**** ITERATE ON PRESTRESS LOSS SS004640
C*************************************************************************************************** SS004650
700 CONTINUE  SS004660
CALL LPCOCE(NFRCE,NEQS,INDX,KODE,KBOMB)  SS004670
C C COMPUTE NEW PRESTRESS LOSSES  SS004680
C AMOM=0.  SS004690
ASUM=0.  SS004700
DO 706 J1=1,NRAV
ASUM=ASUM+X(J1)*AS
706 AMOM=AMOM+X(J1)*AS*D(J1)
DCG=DBOT=AMOM/ASUM
IF(JOPT.NE.0) GO TO 708
FPCR=X(11*NRAV+1)
GO TO 712
708 FPCR=4.0
KNT=11*NRAV
DO 710 J1=1,10
710 FPCR=FPFR*X(KNT+J1)
712 CALL PLCS(FPCR,ZMBW,ZMC,ZMNC,FPS,ASUM,Aconc,EINERT,Binerk,dbot,
+dbotk,dcg,hum,zl,zlcss,zinlos,wc)
C TERMINATE ITERATIONS IF COMPUTED LONG TERM LOSS DOES
C NOT EXCEED ASSUMED LOSS BY MORE THAN 3 PERCENT
C IF(KBOMB.NE.0) GO TO 740
IF(ZLOSS.LE.1.03*ASSPLS) GO TO 740
C UPDATE CONSTRAINTS TO REFLECT NEW PRESTRESS LOSSES
C READ(4) ARRAY
REWIND 4
JST=11*NRAV
C RELEASE AND SERVICE STRESS CONSTRAINTS
DO 714 J1=2,13
DO 714 J2=1,JST
714 ARRAY(J1,J2)=ARRAY(J1,J2)*(1.-zinlos)/(1.-zssclr)
DO 716 J1=14,21
DO 716 J2=1,JST
716 ARRAY(J1,J2)=ARRAY(J1,J2)*(1.-zloss)/(1.-zsspls)
C BOUNDS ON INITIAL CAMBER
JR=22+NRAV
IF(JOPT.NE.0) JR=41+NRAV
DO 718 J1=1,11
DO 718 J2=1,NRAV
ARRAY(JR,(J1-1)*NRAV+J2)=ARRAY(JR,(J1-1)*NRAV+J2)*(1.-zinlos)/
*(1.-zssclr)
718 ARRAY(JR+1,(J1-1)*NRAV+J2)=ARRAY(JR+1,(J1-1)*NRAV+J2)*(1.-zinlos)
*(1.=ZSSCLR)
C CRACKING MOMENT CAPACITY
JR=25+11*NRAV
IF(JOPT.NE.0) JR=44+11*NRAV
DO 719 JI=1,NRAV

719 ARRAY(JR,J1) = ARRAY(JR,J1)*(1.=ZLOSS)/(1.=ZSSPLS)
IF(ZLOSS.LE.0.2) I1=1
IF(ZLOSS.LE.0.2) I2=2
IF(JOPT.EQ.0) GO TO 720
ARRAY(25+11*NRAV,K+1) = (PECRK(1,I2)=PECRK(1,I1))*ZLOSS/0.1*(PECRK(1,I1)*S1=25+11*NRAV)
GO TO 726

720 CONTINUE
JC=11*NRAV+10
JR=44+11*NRAV
IF(JOPT.EQ.0) JC=11*NRAV+1
IF(JOPT.EQ.0) JR=25+11*NRAV
KODE=1
ASSPLS=ZLOSS
ASSCLR=ZLOSS
GO TO 700

740 CONTINUE
C CUNSCRAMBLE L.P. ACTATION FOR BOND BREAKAGE
C DO 402 J1=1,NRAV
DO 402 J2=1,11
IDX=J1+(J2-1)*NRAV
S1 = X(IDX)
S2 = AINT(S1)
IF(S1>S2.6.E.0.5) X(IDX) = S2+1
IF(S1>S2.5.E.0.5) X(IDX) = S2
402 CONTINUE
DEL=ZL/40.
JT = 0
DO 410 J1=1,NRAV
JS = 0
DO 408 J2=1,10
IDX=J1+(J2-1)*NRAV
IF(ABS(X(IDX)=X(IDX+NRAV)*.LE.0.001) GO TO 408
JS = JS + 1
ZWRAP(JS,1)=X(IDX)=X(IDX+NRAV)
NWRAP(JS,1)=ZWRAP(JS,1)
ZWRAP(JS,2) = (11-J2)*DEL
408 CONTINUE
NSDIF(J1) = JS
410 JT = JT + JS
IF(JT.EQ.0) GO TO 422
DO 414 J1=1,5
SS = ZWRAP(J1,2)
S1 = AINT(SS)
DEL = SS=S1
DO 412 J2=1,13
S2=(J2-1)/12.
IF(DEL*GT.S2) GO TO 412
ZWRAP(J1,2)=ABS(S1)
ZWRAP(J1,3)=J2=1
IF(ZWRAP(J1,3)=LT.12.) GO TO 414
ZWRAP(J1,2)=ZWRAP(J1,2)+1.
ZWRAP(J1,3)=0.
GO TO 414
412 CONTINUE
414 CONTINUE
422 CONTINUE
C 28-DAY CONCRETE STRENGTH
IF(JOPT.EQ.0) GO TO 648
F28=F(1)
DO 642 J3=2,11
\begin{verbatim}
642  F28=F28+2.*(F(J3=F(J3=1))*X(11*NRAV+J3=1)
C  LONG TERM CAMBER
648  SUMO=0.
    SUM10=0.0
    SUM11=0.0
    DO 432 J=1,NRAV
        SUM10=SUM10+AS*X(J)
        SUM11=SUM11+AS*D(J)*X(J)
    432  SUM=SUM+X(J)
    STRNS=SUM
    EC=ELASC*SQRT(F28)/1.E+03
    ES=29.
    ECCL=SUM11/SUM10
    ENDECC=ECCL
    FP=FO*1000.
    UWB=UWC*1000.
    CALL CAMBER(ES,EC,AS,STRNS,UWB,ACONC,ZL,ECCL,BINERT,FP,ESS006160
                  *NDECC,PRLMAX,CBRMAX)
C  DEFLECTION CALCULATIONS
   ECR=ELASC*SQRT(FPCR)
   SUM6=0.0
   DO 9057 J1=1,11
       SUM7=0.0
       DO 9058 J2=1,NRAV
           YJC=((11-J1)*ZL/40.+ZL/80.)*12.
           DJC=ZL/40.*12.
           IF(J1.EQ.1) YJC=3.*ZL/8.*12.
           IF(J1.EQ.1) DJC=ZL/4.*12.
       9058  SUM6=SUM6+SUM7*DJC*YJC
   9057  SUM6=SUM6+SUM7*DJC*YJC
   DEFBWK=(-22.*W8*ZL**4-(1.-ZLOSS)*FO*SUM6)/5000./BINERT
   DEFCF=0.
   IF(JCONC.EQ.1) GO TO 2445
   DO 2444 JN=1,10
       ZBX1=ZL-DCNC(JN)
       ZBX2=DCNC(JN)
       ZBX=AMIN1(ZBX1,ZBX2)*12.
   2444  DEFCF=DEFCF+FCONC(JN)*ZBX*(3.*ZL**2*144.+4.*ZEX**2)/48.
   2445  CONTINUE
   DEFBWU=(-22.*(UL8*W8)*ZL**4-(1.-ZLOSS)*FO*SUM6-DEFCF)/5000./ BINERT
\end{verbatim}
*BINERK

C ULTIMATE MOMENT AND CRACKING MOMENT CAPACITY
DD=DTOP+ECCL
CALL ULTMPS(SUM10,F28,FPS,APRIME,FPL,DD,DDIM,FSY,DCR,
*Y1,Y2,Y3,Y4,Z1,Z2,Z3,Z4,ZMUL)
SUM8=0.0
DO 9056 J2=1,NRAV
   9056 SUM8=SUM8+(1./ACONC-D(J2)/ZB)*X(J2)
ZCRACK=((1.-ZLOSS)*ZBK*FC*SUM8+7.5*ZBK*0.031623*SQRT(F28))/W
   *ZL**2
C******************************************************SS006500
C**** PRINT OUT RESULTS SS006510
C***********************************************************************SS006520
WRITE(6,600)
IF(KBOMB.NE.0) WRITE(6,70)
   70 FORMAT(50X,32('**'),/,50X,'*SORRY, THIS BEAM WILL NOT WORK*',/50X,SS006523
*32('**'))
IF(IOPT.EQ.0) WRITE(6,622)
   622 FORMAT( /,, '47X,*THE COMMAND IS TO SELECT STRANDS*,'48X,')
IF(IOPT.EQ.1) WRITE(6,623)
   623 FORMAT( /,, '50X,*THE COMMAND IS TO OPTIMIZE*,'51X,'')
WRITE(6,601)
WRITE(6,624)
WRITE(6,650)
624 FORMAT(*,**,54X,*DESIGN PROPERTIES*,56X,**)
WRITE(6,602)
WRITE(6,603)
   ZLS=ZLOSS*100.
   ZINL=ZINLOS*100.
WRITE(6,625) FPCR,ECR,ZINL,F28,ZLS
   625 FORMAT(*,**,4X,*RELEASE STRENGTH = ','F5.2,* (KSI)*,4X,*CONCRETE MSS006650
   100ULUS(RELEASE) = ','F7.1,* (KSI)*,4X,*INITIAL PRESTRESS LOSS = ','SS006660
   2F5.2,* PERCENT*4X,**/ *',4X,*28-DAY STRENGTH = ','F5.2,* (KSI)SS006670
   3*50X,*TOTAL PRESTRESS LOSS = ','F5.2,* PERCENT*4X,**)
WRITE(6,602)
WRITE(6,601)
WRITE(6,628)
   628 FORMAT(*,**,56X,*DESIGN RESULTS*,57X,**)
WRITE(6,602)
WRITE(6,603)
WRITE(6,629)
629 FORMAT(* *,56(* *,*) *,STRAND LAYOUT*,58(* *,*),**) WRITE(6,603) WRITE(6,630)
630 FORMAT(* *,31X,*ROW*,7X,*STRANDS WRAPPED STRANDS IN EACH ROW*,79X,**)
JCNT = 1 DO 631 K = 1,NRAV INTX=X(K) JSTP = NSDIF(K) + JCNT-1 IF(NSDIF(K) .EQ. 0) WRITE(6,640) K,INTX
640 FORMAT(* *,32X,12,9X,13,1X,6X,*THERE ARE NO WRAPPED STRANDS IN THIS ROW*,34X,**)
11S ROW*,34X,**) IF(NSDIF(K) .EQ. 0) GC TC 631 IF(NSDIF(K) .GT. 1) WRITE(6,632) K,INTX,(NWRAP(J3,1),ZWRAP(J3,2),
1ZWRAP(J3,3),J3=JCNT,JSTP) IF(NSDIF(K) .LE. 1) WRITE(6,9073) K,INTX,(NWRAP(J3,1),ZWRAP(J3,2),
1ZWRAP(J3,3),J3=JCNT,JSTP) 631 JCNT = JCNT + NSDIF(K)
632 FORMAT(* *,32X,12,9X,13,1X,6X,13)** STRANDS WRAPPED FOR * F4,1,* SS006930
1FT = * F4,1,* INCHES*,29X,***/(* *,53X,13** STRANDS WRAPPED FOR FSS006940
20R * F4,1,* FT = * F4,1,* INCHES*,29X,**)) 9073 FORMAT(* *,32X,12,9X,13,1X,6X,13)** STRANDS WRAPPED FOR * F4,1,* SS006960
1FT = * F4,1,* INCHES*,29X,**) 631 JCNT = JCNT + NSDIF(K)
631 WRITE(6,603) C PUT STIRRUP SPACING & CAMBER PRINT OUT ROUTINES HERE
WRITE(6,634)CBRMAX(1),CBR1,CBRMAX(2),DEFBWK,CBRMAX(3),DEBFWU,
ICBRMAX(4) IF(creep .NE. 0.) WRITE(6,9049) CBRMAX(5) 634 FORMAT(1X,**,53(* *,*) *COMPUTED DEFLECTION*,55(* *,*),**/1X,**,**,1127X,**/1X,**,22X,*SHORT TERM*,25X,**,29X,*LONG TERM*,30X,
2**/1X,**,57X,**,68X,**/1X,**,8X,*CONDITION*,9X,**,3X,
4'MODULUS',3X,**,3X,*DEFLECTION*,3X,**,68X,**/1X,**,26X,**,13SS007090
5X,**,2X,**,2X, F5,2,** INCHES (BASED UPON DALLAS CONCRETE PROPERTIES) SS007070
6RTIES)*,13X,**/ ** 2X,*BMWT*,20X,**,3X,*RELEASE*,3X,**,2X, SS007110
7F5,2,* INCHES*,2X,**,3X,F5,2,** INCHES (BASED UPON* SS007120
3* ODESSA CONCRETE PROPERTIES)*,13X,**/* 81X,**,2X,*BMWT + KEY*,14X,**,** 5 MILLION*,2X,**,2X,F5,2, SS007140
9* INCHES*,2X,**,3X,F5,2,** INCHES (BASED UPON SAN ANTONIO CONCRETE SS007150
NEW MATERIAL PROPERTIES

8X**1/X,**,2X,**,BMWT + KEY + DEAD LOAD**2X

5 MILLION, 2X,**,2X,F5.2,**,INCHES, 2X,**,3X,F5.2,**,INCHES

3S (BASED UPON LUFKIN CONCRETE PROPERTIES)**,13X,**

9049 FORMAT(1X,**,26X,**,13X,**,16X,**,3X,F5.2,**,INCHES (BASED UPON GIVEN CONCRETE PROPERTIES)**,13X,**)

C

STIRRUP SPACING OUTPUT

DO 9078 J1=1,7
ZX=(J1=1)*ZL/10.
IF(J1.EQ.3) ZX=(J1=2)*ZL/10.
IF(J1.EQ.4) ZX=ZL/4.
VU(J1)=1.444*(WB*(ZL/2.=ZX)+DLSHR(J1)+5./3.*BVMAX(J1))

9078 CONTINUE

WEB=2.*WDDIM
DO 9075 J1=1,7
J2=0
IF(J1.EQ.1) J2=10*NRAV
IF(J1.EQ.2) J2=6*NRAV
IF(J1.EQ.3) J2=2*NRAV
SUM1=0.0
SUM2=0.0
DO 9076 J3=1,NRAV
SUM1=SUM1+AS*X(J2+J3)
SUM2=SUM2+AS*D(J3)*X(J2+J3)
IF(SUM1.LT.0.001) DISTCG=DTOP+ECCL
IF(SUM1.LT.0.001) GO TO 9091
DISTCG=DTOP+SUM2/SUM1

9091 CALL SHEAR(WEB,DDIM,DISTCG,F28,FSY,ASTIRP,VU(J1),SPACE)

9075 CONTINUE

WRITE(6,603)
WRITE(6,9077) ASTIRP,(STRSP(J4),J4=1,7)

9077 FORMAT(1X,**,36(••••••),**STIRRUP SPACING = AASHTO 1973 = STIRRUP AREA

5A = ••••••F4.2•• IN2••••••36(••••••),**/
11X,**,127X,**,/1X,**,5X,**,SECTION,10X,**,5X,0/10,**,5X,**,5X
2'1/10,**,5X,**,5X,2/10,**,5X,**,5X,1/4,**,6X,**,5X,3/10,**,5X,**
35X,**,4/10,**,5X,**,5X,5/10,**,5X,**,22X,**,7(14X,**)/1X,**
4,5X,**,SPACING (IN.),4X,**,7(4X,F5.2,5X,**,**)

C

SUM1=0.0
SUM2=0.0
DO 9076 J3=1,NRAV
C COST DATA PRINTOUT

IF(JOPT.EQ.0) WRITE(6,603)
IF(JOPT.EQ.0) GC TO 9020
CONCV=ACO VC/144.*ZL/27.
STRFT=STRNS*ZL
WRPFT=0.0
J2=0
J3=1
DO 433 J1=NRAV
IF(NSDIF(J1).EQ.0) GO TO 433
J2=J2+NSDIF(J1)
J4=J3
DO 436 I=J4,J2
WRPFT=WRPFT+ZWRAP(I.1)*ZWRAP(I.2)*(ZWRAP(I.3)/12.)
J3=J3+NSDIF(J1)
436 CONTINUE
433 CONTINUE
JC1=11*NRAV+1
DO 434 J1=JC1,M
COSTC=G(J1=11*NRAV)+X(J1)*2.*(G(J1.11*NRAV+1)=G(J1.11*NRAV))
IF(X(J1).NE.0.5) GO TO 435
434 CONTINUE
435 CSTCON=CCSTC*CONCV
CSTSTR=STRFT*COSTFT
CSTWRP=WRPFT*CCSTWP*2.
CSTTOT=CSTCCN+CSTSTR+CSTWRP
CPRCST=CSTCON/CSTTOT*100.
SPRCST=CSTSTR/CSTTOT*100.
WPRCST=CSTWRP/CSTTOT*100.
CSTPFT=CSTTOT/ZL
WRITE(6,603)
WRITE(6,670)
670 FORMAT(1X,'**',44('*'), 'COST AND MATERIAL REQUIREMENTS OF BEAM',4SS007890
*5('*'), '**')
WRITE(6,603)
WRITE(6,671)
671 FORMAT(1X,'**',8X,'ITEM',15X,'AMOUNT',12X,'COST',8X,'PERCENTAGE OF TOTAL COST',8X,'**',39X,**)
WRITE(6,672) CSTTOT

SS007560
SS007570
SS007580
SS007590
SS007600
SS007610
SS007620
SS007630
SS007640
SS007650
SS007660
SS007670
SS007680
SS007690
SS007700
SS007710
SS007720
SS007730
SS007740
SS007750
SS007760
SS007770
SS007780
SS007790
SS007800
SS007810
SS007820
SS007830
SS007840
SS007850
SS007860
SS007870
SS007880
SS007890
SS007900
SS007910
SS007920
SS007930
SS007940
SS007950
FORMAT(1X, 'TOTAL COST OF BEAM $',F8.2, '2X', '**)  SS007960
WRITE(6,673) CONC, CSTCON, CPRCST  SS007970
673 FORMAT(1X, 'CONCRETE', 'F7.2', 'YD**3', 'F8.2', '14X', 'F5.2', 'SS007980
1.05% 15X', '39X', '**)  SS007990
WRITE(6,674) STRFT, CSTSTR, SPRCST, CSTPFT  SS008000
674 FORMAT(1X, 'STRAPPED STRANDS', 'F7.2', 'FT', '8X', 'F8.2', '14X', 'F5.2', 'SS008010
1.05% 15X', '7X', 'COST PER FOOT $', 'F8.2', '2X', '**)  SS008020
WRITE(6,675) WRPFT, CSTWRP, WPRCST  SS008030
675 FORMAT(1X, 'WRAPPED STRANDS', 'F7.2', 'FT', '8X', 'F8.2', '14X', 'F5.2', 'SS008040
15.20% 15X', '39X', '**)  SS008050
WRITE(6,676)  SS008060
676 FORMAT(1X, 'DOES NOT INCLUDE END SECTION', '9X', 'SS008070
*3X', '**)  SS008080
9020 WRITE(6,602)  SS008090
C
C CRITICAL DESIGN FACTORS OUTPUT
C
WRITE(6,600)  SS008100
DO 800 J1=1,6  SS008110
DO 800 J2=1,5  SS008120
800 KSYM(J1,J2)=EX(1)  SS008130
WRITE(6,601)  SS008140
WRITE(6,602)  SS008150
WRITE(6,603)  SS008160
WRITE(6,604)  SS008170
WRITE(6,605)  SS008180
WRITE(6,606)  SS008190
WRITE(6,607)  SS008200
WRITE(6,608)  SS008210
WRITE(6,609)  SS008220
WRITE(6,610)  SS008230
WRITE(6,611)  SS008240
WRITE(6,612)  SS008250
WRITE(6,613)  SS008260
WRITE(6,614)  SS008270
WRITE(6,615)  SS008280
WRITE(6,616)  SS008290
WRITE(6,617)  SS008300
WRITE(6,618)  SS008310
WRITE(6,619)  SS008320
DO 801 J1=1,6  SS008330
X1=(J1-1)/20.*ZL  SS008340
X2=(J1-1)/10.*ZL  SS008350
\[ ZMJ = w \times XS_1 + (ZL = XS_1) \]
\[ ZMB = wB \times XS_2 + (ZL = XS_2) \]
\[ ZMB = DLWCM(J1) + BMVX(J1) \]
\[ IF(J1.GT.3) ZMB = DLWCM(J1+1) + BMVX(J1+1) \]
\[ J3 = (10 - (J1-1) \times 4) \times NRAV \]
\[ IF(J1.GT.3) J3 = 0 \]
\[ SUM1 = 0.0 \]
\[ SUM2 = 0.0 \]
\[ SUM3 = 0.0 \]
\[ SUM4 = 0.0 \]
\[ DO 804 J2 = 1, NRAV \]
\[ SUM1 = SUM1 + ((1.0 / ACONC + D(J2) / ZT) \times ((12 - 2 \times J1) \times NRAV + J2)) \]
\[ SUM2 = SUM2 + ((1.0 / ACONC + D(J2) / ZB) \times ((12 - 2 \times J1) \times NRAV + J2)) \]
\[ SUM3 = SUM3 + ((1.0 / ACONC + D(J2) / ZTK) \times (J3 + J2)) \]
\[ SUM4 = SUM4 + ((1.0 / ACONC + D(J2) / ZBK) \times (J3 + J2)) \]
\[ STRESS(J1,1) = ((1.0 - ZINLOS) \times FO \times SUM1 = ZMJ*12.0 / ZT) \times (-1.0) \]
\[ STRESS(J1,2) = ((1.0 - ZINLOS) \times FO \times SUM2 = ZMJ*12.0 / ZB) \times (-1.0) \]
\[ STRESS(J1,3) = ((1.0 - ZLOSS) \times FO \times SUM3 = ZMB*12.0 / ZTK) \times (-1.0) \]
\[ STRESS(J1,4) = ((1.0 - ZLOSS) \times FO \times SUM4 = ZMB*12.0 / ZBK) \times (-1.0) \]
\[ STR = CTR1 \]
\[ SCR = CBR1 \]
\[ STS = CST1 \]
\[ SCS = CBS1 \]
\[ IF(XSX1.LE.ZL/10.0 + 0.1) STR = CTR2 \]
\[ IF(XSX1.LE.ZL/10.0 + 0.1) SCR = CBR2 \]
\[ IF(XSX2.LE.ZL/10.0 + 0.1) STS = CST2 \]
\[ IF(XSX2.LE.ZL/10.0 + 0.1) SCS = CBS2 \]
\[ IF STRESS WITHIN 1 PERCENT OF ALLOWABLE, CALL IT CRITICAL. \]
\[ IF(\text{STRESS}(J1,1) \leq 0.00099 \times \text{STR} \times \text{SQRT}(FPCR \times 1000.0)) \text{ KSYM}(J1,1) = \text{EX}(2) \]
\[ IF(\text{STRESS}(J1,2) \geq 0.99 \times \text{SCR} \times \text{FPCR}) \text{ KSYM}(J1,2) = \text{EX}(2) \]
\[ IF(\text{STRESS}(J1,3) \geq 0.99 \times \text{SCS} \times F28) \text{ KSYM}(J1,3) = \text{EX}(2) \]
\[ \text{IF(\text{STRESS}(J1,4) \leq 0.00099 \times \text{STS} \times \text{SQRT}(F28 \times 1000.0))} \text{ KSYM}(J1,4) = \text{EX}(2) \]
\[ \text{IF(J1.NE.1) GO TO 9053} \]
\[ \text{IF(\text{STRESS}(J1,3) \leq 0.00099 \times \text{STTS} \times \text{SQRT}(F28 \times 1000.0))} \text{ KSYM}(J1,3) = \text{EX}(2) \]
\[ \text{IF(\text{STRESS}(J1,4) \geq 0.99 \times \text{SCS} \times F28) KSYM(1,4) = EX(2)} \]
\[ \text{IF(\text{STRESS}(1,3) \leq 0.00099 \times \text{STS} \times \text{SQRT}(F28 \times 1000.0))} \text{ KSYM}(1,3) = \text{EX}(2) \]
\[ \text{IF(\text{STRESS}(1,4) \geq 0.99 \times \text{SCS} \times F28) KSYM(1,4) = EX(2)} \]
\[ 9053 \text{ CONTINUE} \]
\[ J4 = J1 = 1 \]
\[ \text{WRITE}(6,812) J4, \text{STRESS}(J1,1), \text{KSYM}(J1,1), \text{STRESS}(J1,2), \text{KSYM}(J1,2) \]
*J4*, STRESS(J1,3), KSYM(J1,3), STRESS(J1,4), KSYM(J1,4)
IF(X(KK=J1+1)*EQ.0) KSYM(J1,5)=EX(2)
801 CONTINUE
813 FORMAT(•*, 4X, I1, *'/20', 3X, *', 6X, E11.4, 3X, A1, 4X, *', 6X, E11.4, 3X, A1, SS008760
11, 4X, *', 4X, I1, *'/10', 3X, *', 6X, E11.4, 3X, A1, 4X, *', 6X, E11.4, 3X, A1, SS008770
24X, *')
WRITE(6, 814)
111(*'), *', 25(*'), *', 25(*'), *', 11(*'), *', 25(*'), *', 25(*'), SS008810
21, *')
WRITE(6, 603)
WRITE(6, 822)
822 FORMAT(1X, *', 50(''), 'LIST OF DESIGN CONSTRAINTS', '51(''), '*/1X, SS008850
1*, 37X, 'SYMBOL X INDICATES CONSTRAINT CONTROLS FINAL DESIGN*', SS008860
237X, *')
WRITE(6, 603)
IF(CBRI. GE. ALDEF=0.05) KSYM(6,5)=EX(2)
IF(CBRI. LE. ALDEF-0.05) KSYM(5,5)=EX(2)
WRITE(6, 805) KSYM(2,5), KSYM(4,5), KSYM(5,5), KSYM(1,5), KSYM(3,5), SS008900
* KSYM(6,5)
805 FORMAT(1X, *', 16X, 'MINIMUM CONCRETE STRENGTH', '3X, A1, 11X, 'ULTIMATE SS008910
1MOMENT', '3X, A1, 11X, 'MINIMUM INITIAL CAMBER', '3X, A1, 15X, *'/1X, SS008920
216X, 'MAXIMUM CONCRETE STRENGTH', '3X, A1, 11X, 'CRACKING MOMENT', '3X, A1, SS008930
311X, 'MAXIMUM INITIAL CAMBER', '3X, A1, 15X, *')
WRITE(6, 603)
WRITE(6, 602)
*DESIGN SHEAR AND MOMENTS AT TENTH POINTS SS008980
C
C
WRITE(6, 9045)
9045 FORMAT(/)
WRITE(6, 602)
WRITE(6, 9041)
9041 FORMAT(1X, *', 51X, 'MOMENT AND SHEAR SUMMARY', '52X, *')
WRITE(6, 602)
WRITE(6, 603)
WRITE(6, 9042)
9042 FORMAT(1X, *', 5X, 'SECTION', '5X, *', 6X, 'BEAM WT', '7X, *', 21X, *', 21X SS009080
1, *', 21X, *', 21X, **'/1X, **'/1X, **'/17X, **'/3X, 'PLUS SHEAR KEY', '4X, *', 6X, SS009090
DO 9040 J1=1,7
Zx=(J1-1)*ZL/10.
IF(J1.GT.3)ZX=(J1-2)*ZL/10.
IF(J1.EQ.4)ZX=ZL/4.
J2=J1-1
IF(J1.GT.4)J2=J1-2
ZMJB=W8*ZX/2.*(ZL-ZX)
ZMJT=ZMJB+DLMOM(J1)+BMMAX(J1)
VU(J1)=1.444*(W8*(ZL/2.-ZX)+DLSHR(J1)+S.5/3.*BMX(J1))
IF(J1.EQ.4)WRITE(6,9043)ZMJB,DLMCM(J1),BMMAX(J1),ZMJT,VU(J1)
IF(J1.NE.4)WRITE(6,9047)J2,ZMJB,DLMOM(J1),BMMAX(J1),ZMJT,VU(J1)
9040 CONTINUE

WRITE(6,603)
WRITE(6,6044)ULTMRQ,ZMUL,ZCRACK
9044 FORMAT(1X,**,6X,1/10,7X,**,S(4X,E12.5,5X,**))

WRITE(6,603)
WRITE(6,602)
WRITE(6,641)
641 FORMAT(1H1)
NCOUNT=NCOUNT+1
GO TO 3007

NCONTINUE
STOP
END
SUBROUTINE EQGEN
COMMON/BLK1/ ADIM,BDIM,CDIM,DDIM,EDIM,FDIM,HDIM,TDIM,
1WDIM,WHDIM,YDIM,ACONC,BINERT,DTOP,DOBT,ZT,ZB,ACONCK,
2BINERK,DTOPK,DOBTK,ZTK,ZBK,ZL,F28,JOPT,ASSCLR,ASSPLS,APrime,
3CBOT,COSTF,COSTFT,DEFMIN,ALDEF,NAV,FWheel,DISTF,FPCMAX,
4FPCMIN,ELAS,ULTMRG,CTOP,W,FB,F,C
COMMON/BLK2/ PAXL(E18),NWHL(E18),STRMA(E26),FCONC(10),DCONC(10),
1G(11),F(11),D(10),GRIDS(26),BMNX(7),EVMX(7),CBRMAX(5),PRLMAX(5),SS009490
2DLNM(7),CLTHR(11,4),ZLOS(4),ZWRAP(10,3),NSDIF(4),SS009510
COMMON/DEFINE/ UWC,HUM,ASFPS,CTR1,CTR2,CBR1,CBR2,CTS1,CTS2,
1CBS1,CBS2,CREEP1,CREEP2,SHRK1,SHRK2,RATNOO,FPL,FSY,ASTIR,
COMMON/YZ/Z1,Z2,Z3,Z4,Y1,Y2,Y3,Y4,SS009530
COMMON/DUMP/ TITLE(3,54),YJ(11),FROW(26),
1PEF(50,3),ZNE(11),KKODE(4),ZMCR(4),SS009550
COMMON/D314/ N,M,ARRAY(156,276),B(276),X(276),XD(276),OBJ,KP1,K,
JRR=28+11*NRAV,SS009570
JCC=1+11*NRAV,
IF(JOPT.EQ.0) JRR=46+11*NRAV,
IF(JOPT.EQ.0) JCC=10+11*NRAV,
DO 2 J1=1,JRR,
ARRAY(J1,K+1)=0.0,
DO 2 J2=1,JCC
2 ARRAY(J1,J2)=0.,SS009650
C***********************************************************************
C OBJECTIVE FUNCTION
C***********************************************************************
DO 4 J1=1,NRAV,SS009660
DO 5 J2=1,11,SS009670
5 ARRAY(1,(J1=1)*11+J2)=2.*COSTWP*ZL/40.,SS009680
4 ARRAY(1,J1)=-(COSTFT*ZL+0.5*COSTWP*ZL),SS009690
ARRAY(1,NRAV*11+1)=ACONC*ZL*G(1)/1944.,SS009700
IF(JOPT.EQ.0) GC TO 8,
DO 6 J1=1,10,SS009710
6 ARRAY(1,11*NRAV+J1)=ACONC*ZL*(G(J1+1)=G(J1))/1944.,SS009720
8 CONTINUE
C***********************************************************************
C RELEASE STRESSES - CONSTRAINTS 1 THRU 12
C***********************************************************************
FO = 0.7*ASFPS,SS009780
W=UWC*ACONC/144.
DO 16 J1=1,11,2
ZX=(11•J1)*ZL/40.
ZMJ=0.5*W*(ZL*ZX-ZX**2)*12.
JR=1+J1
ST=CTR1
SC=CBR1
IF(ZX.LE.ZL/10.+1) ST=CTR2
IF(ZX.LE.ZL/10.+1) SC=CBR2
DO 10 J2=1,NRAV
ARRAV(JR,1*NRAV+J2)=1.0-ASSCLR)*FO*(1./ACONC+D(J2)/ZT)
10 ARRAY(JR+1,(1•1)*NRAV+J2)=1.0-ASSCLR)*FO*(1./ACONC=I(D(J2)/ZB)
IF(JOPT.EQ.0) GO TO 14
DO 12 J2=1,10
ARRAY(JR,1*NRAV)=0.074535*ST
12 ARRAY(JR+1,1*NRAV)=ZMJ/ZB+0.063366*ST
ARRAY(JR+1,K+1)=ZMJ/ZB+4.0*ST
GO TO 16
14 ARRAY(JR+1,NRAV+1)=0.074535*ST
ARRAY(JR+1,NRAV+1)=ZMJ/ZB+0.33552*ST
ARRAY(JR+1,K+1)=ZMJ/ZB
CONTINUE
C***********************************************************************
C SERVICE LOAD STRESSES - CONSTRAINTS 13 THRU 20
C***********************************************************************
C CONSTRAINTS 13 THRU 18
WB=UWC*ACONCK/144.
DO 24 J1=1,7,2
IF(J1.EQ.5) GO TO 24
IF(J1.EQ.1) ZMJX=BMMAX(7)*12.+DLMOM(7)*12.
IF(J1.EQ.3) ZMJX=BMMAX(3)*12.+DLMOM(3)*12.
IF(J1.EQ.7) ZMJX=BMMAX(2)*12.+DLMOM(2)*12.
ZX=(11•J1)*ZL/40.
IF(J1.EQ.1) ZX=ZL/2.
ZMJ=0.5*W*(ZL+ZX-ZX**2)*12.
JR=13+J1
IF(J1.EQ.7) JR=18
ST=CTR1
SC=CBR1
```
IF(ZX.EQ.ZL/10.+1) ST=CTS2
IF(ZX.EQ.ZL/10.+1) SC=CBS2
DO 18 J2=1,NRAV
  ARRAY(JR+(J1=1)*NRAV+J2)=(1.*ASSPLS)*FO*(1./ACONC+D(J2)/ZT)
  IF(JOPT.EQ.0) GO TO 22
  DO 20 J2=1,10
    ARRAY(JR,NRAV*11+J2)=2.*SC*(F(J2+1)-F(J2))
  20 CONTINUE
  ARRAY(20,NRAV+1+J2)=.014907*ST*(F(J2+1)-F(J2))
  ARRAY(20,K+1)=ZMJ/ZT-ZMJB/ZTB+.0074535*ST*F(1)+.033552*ST
  GO TO 24
  ARRAY(JR+1,K+1)=ZMJ/ZT-ZMJB/ZTB+.031623*SQRT(F28)*ST
  ARRAY(JR+1,K+1)=CBS2*F(1)
  GO TO 32
  ARRAY(20,K+1)=CTS2*.031623*SQRT(F28)*ST
  ARRAY(20+10*NRAV)=.014907*CTS2*(F(J2+1)-F(J2))
  ARRAY(21,NRAV*11+J2)=.0074535*CTS2*F(1)+.033552*CTS2
  ARRAY(21+J1)*10+J2,NRAV+J2+J1)=1.
  ARRAY(21+J1)*10+J2,NRAV+J2+J1)=1.
C***********************************************************************
C CONSTRAINTS 19 AND 20
  DO 26 J2=1,NRAV
    ARRAY(20,NRAV*10+J2)=(1.*ASSPLS)*(1./ACONC+D(J2)/ZT)*FO
    IF(JOPT.EQ.0) GO TO 30
    DO 28 J2=1,10
      ARRAY(20,NRAV*11+J2)=.014907*CTS2*(F(J2+1)-F(J2))
      ARRAY(21,NRAV*11+J2)=.0074535*CTS2*F(1)+.033552*CTS2
      ARRAY(21,K+1)=CBS2*F(1)
      GO TO 32
      ARRAY(20,K+1)=CT52*.031623*SQRT(F28)*ST
      ARRAY(21,K+1)=CBS2*F28
C***********************************************************************
C MAXIMUM NUMBER OF STRANDS PER ROW = CONSTRAINTS 21 THRU (20+10*NRAV)
  DO 32 J1=1,NRAV
    DO 34 J2=1,10
      ARRAY(21+J1)*10+J2,NRAV+J2+J1)=1.
      ARRAY(21+J1)*10+J2,NRAV+J2+J1)=1.
C***********************************************************************
C STRAND WRAPPING CONSTRAINTS = CONSTRAINTS 21 THRU (20+10*NRAV)
  DO 32 J1=1,NRAV
    DO 34 J2=1,10
      ARRAY(21+J1)*10+J2,NRAV+J2+J1)=1.
    34 CONTINUE
      ARRAY(21+J1)*10+J2,NRAV+J2+J1)=1.
ARRAY(21+10*NRAV+1,J1)=1.
ARRAY(21+10*NRAV+1,K+1)=STRMAX(J1)  
36 CONTINUE  
C******************************************************************************SS010630  
C JOPT=1, PROPER RELEASE STRENGTH REPRESENTATION = CONSTRAINTS SS010640  
C (21+11*NRAV) THRU (39+11*NRAV)  
C******************************************************************************SS010650  
IF(JOPT.NE.1) GO TO 44  
DO 38 J1=1,10  
ARRAY(21+11*NRAV+1,J1+1)=1.  
38 ARRAY(21+11*NRAV+1,K+1)=0.5  
DO 40 J1=1,9  
ARRAY(31+11*NRAV+1,J1+1)=1.  
40 ARRAY(31+11*NRAV+1,K+1)=1.  
C*********************************************SS010660  
C BOUNDS ON INITIAL CAMBER  
C JOPT=0, CONSTRAINTS (21+11*NRAV) THRU (22+11*NRAV)  
C JOPT=1, CONSTRAINTS (40+11*NRAV) THRU (41+11*NRAV)  
C**************************************************************SS010670  
44 YJ(1)=3.*(ZL*12.)/8.  
DO 46 J1=2,11  
46 YJ(11)=((11-J1)*(ZL*12.))/40.+((ZL*12.)/80.  
IF(JOPT.EQ.0) JR=22+11*NRAV  
IF(JOPT.EQ.0) JR=41+11*NRAV  
DO 48 J1=1,11  
DELTAJ=ZL*12./40.  
IF(J1.EQ.1) DELTAJ=ZL*12./4.  
DO 48 J2=1,NRAV  
ARRAY(JR,(J1-1)*NRAV+J2)=(1.-ASSCLR)*FO*YJ(J1)*D(J2)*DELTAJ  
48 ARRAY(JR+1,(J1-1)*NRAV+J2)=ARRAY(JR,(J1-1)*NRAV+J2)  
IF(JOPT.EQ.0) GO TO 52  
DO 50 J1=1,10  
50 ARRAY(JR,11*NRAV+1)=.235252 *BINERT*ELASC*ALOEF  
50 ARRAY(JR+11*NRAV+1)=.235252 *BINERT*DEFMIN*ELASC  
ARRAY(JR,K+1)=2.0 *ELASC*ALOEF*BINERT+22.5*W*ZL**4  
ARRAY(JR+1,K+1)=2.0 *ELASC*DEFMIN*BINERT=22.5*W*ZL**4  
GO TO 60  
52 ARRAY(JR,11*NRAV+1)=.235252 *BINERT*ELASC*ALOEF  
ARRAY(JR+1,11*NRAV+1)=.235252 *BINERT*ELASC*DEFMIN  
ARRAY(JR,K+1)=1.058991 *BINERT*ELASC*ALOEF+22.5*W*ZL**4  
GO TO 60  
52 ARRAY(JR,11*NRAV+1)=.235252 *BINERT*ELASC*ALOEF  
ARRAY(JR+1,11*NRAV+1)=.235252 *BINERT*ELASC*DEFMIN  
ARRAY(JR,K+1)=1.058991 *BINERT*ELASC*ALOEF+22.5*W*ZL**4  
GO TO 60  
52 ARRAY(JR,11*NRAV+1)=.235252 *BINERT*ELASC*ALOEF  
ARRAY(JR+1,11*NRAV+1)=.235252 *BINERT*ELASC*DEFMIN  
ARRAY(JR,K+1)=1.058991 *BINERT*ELASC*ALOEF+22.5*W*ZL**4  
GO TO 60  
52 ARRAY(JR,11*NRAV+1)=.235252 *BINERT*ELASC*ALOEF  
ARRAY(JR+1,11*NRAV+1)=.235252 *BINERT*ELASC*DEFMIN  
ARRAY(JR,K+1)=1.058991 *BINERT*ELASC*ALOEF+22.5*W*ZL**4
C

ARRAY(JR+1,K+1)=-1.058991*BINERT*ELASC*DEFMIN=22.5*W*ZL**4

C

60 ARRAY(JR+K+1)=ARRAY(JR,K+1)/1.E+04

ARRAY(JR+1,K+1)=ARRAY(JR+1,K+1)/1.E+04

DO 56 J1=1,N

ARRAY(JR,J1)=ARRAY(JR,J1)/1.E+04

56 ARRAY(JR+J1)=ARRAY(JR+J1)/1.E+04

C

******************************************************************************

C ULTIMATE MOMENT AND CRACKING MOMENT CONSTRAINTS

C JOPT=0, CONSTRAINTS (23+11*NRAV) AND (24+11*NRAV)

C JOPT=1, CONSTRAINTS (42+11*NRAV) AND (43+11*NRAV)

C******************************************************************************

C

SET UP NO. STRANDS AND STRAND ECCENTRICITY ARRAY

C

DO 62 J1=1,NRAV

62 FROW(J1)=0.

SUM=0.

KNT=0

PF=0.

DO 64 J1=1,NRAV

64 CONTINUE

67 IF(FROW(J1)=EQ.,STRMAX(J1)) GO TO 64

IADD=2

IF(STRMAX(J1)=FROW(J1),LE.,1) IADD=1

FROW(J1)=FROW(J1)+IADD

PF=PF+IADD*(=D(J1))

SUM=SUM+IADD

KNT=KNT+1

PEF(KNT,1)=SUM

PEF(KNT,2)=PF

PEF(KNT,3)=PF/SUM

GO TO 67

CONTINUE

C

SET UP FOR CALLS TOULTMP

ZMDL=W*ZL**2/8.

DO 63 J1=1,4

63 ZLOS(J1)=0.1*J1

DO 65 J1=1,11

ZNE(J1)=0.*
DO 65 J2=1,4
65 PECRK(J1,J2)=0.
JSTOP=11
IF(JOPT*NE.0) GC TO 66
F(1)=F28
JSTOP=1
C GENERATE TOTAL FORCE ECCENTRICITIES FOR ULTIMATE MOMENT AND CRACKS
C MOMENT CONSTRAINTS
66 FPCM=4.0
DO 84 J1=1,JSTOP
IF(J1.EQ.1) GC TO 69
IF(F(J1),NE,F(J1-1)) GC TO 69
ZNE(J1)=ZNE(J1-1)
DO 68 J2=1,4
68 PECRK(J1,J2)=PECRK(J1-1,J2)
GO TO 84
69 FPCBM=F(J1)
DO 70 J2=1,4
70 KDE(J2)=0
KDEMU=0
ZMORD=0.
DO 82 J2=1,KNT
ASTL=AS*PEF(J2,1)
DD=DTOP*PEF(J2,3)
CALL UTLMP(ASTL,FPCBM,FPS,APRIQE,FPL,CD,DDIM,FSY,DCR,
* Y1,Y2,Y3,Y4,Z1,Z2,Z3,Z4,ZMUL)
DO 72 J3=1,4
ZMCR(J3)=(1.*ZLOS(J3))*ZBK*FO*{PEF(J2,1)/ACONC*PEF(J2,2)/ZB
1+7.5*ZBK*.031623*SQRT(FPCBM)*ZBK*ZMDL*12./ZB
72 ZMCR(J3)=ZMCR(J3)*1.2/12.
DO 73 J3=1,4
IF(KODE(J3),EQ.1) GC TO 73
IF(ZMUL,LT,ZMCR(J3)) GC TO 73
PECRK(J1,J3)=PEF(J2,2)
KODE(J3)=1
73 CONTINUE
74 IF(KODEMU,EQ.1) GC TO 78
IF(ZMUL,GE,ULTMRC) GC TO 76
E1=ZMORD
IF(E1,LZMUL) ZMORD=ZMUL
IF(E1.LT.ZMUL) GO TO 82
FPCMIN=4.0+(J1-1)*0.5
GO TO 84
76 ZNE(J1)=PEF(J2,J3)
    KODEMU=1
78 DO 80 J3=1,4
    IF(KODE(J3).EQ.0) GO TO 82
80 CONTINUE
    IF(KODEM,.EQ.1) GC TO 84
82 CONTINUE
84 CONTINUE

FORM ULTIMATE MOMENT AND CRACKING MOMENT CONSTRAINTS

IF(JOPT.EQ.0) JR=1+23+11*NRAV
    IF(JOPT.NE.0) JR=1+42+11*NRAV
    DO 86 J1=1,NRAV
        ARRAY(JR,J1)=D(J1)
    86 CONTINUE
    ARRAY(JR+J1)=C(J1)
    IF(JOPT.EQ.0) GO TO 90
    DO 88 J1=1,10
        ARRAY(JR,NRAV+J1)=2.*ZNE(J1)
    88 CONTINUE
    ARRAY(JR,K+1)=PECRK(J1)
    ARRAY(JR,K+1)=PECRK(J1)
    GO TO 92
90 ARRAY(JR,K+1)=ZNE(J1)
    ARRAY(JR,K+1)=PECRK(J1)
C***********************************************************************5S012110
C MINIMUM AND MAXIMUM CONCRETE STRENGTH CONSTRAINTS
C JOPT=0, CONSTRAINTS (25+11*NRAV) AND (26+11*NRAV)
C JOPT=1, CONSTRAINTS (44+11*NRAV) AND (45+11*NRAV)
C***********************************************************************5S012120
C IF(JOPT.EQ.0) GO TO 92
    ARRAY(26+11*NRAV,11*NRAV+1)=1.
    ARRAY(26+11*NRAV,K+1)=4.0
    ARRAY(27+11*NRAV,11*NRAV+1)=1.0
    ARRAY(27+11*NRAV,K+1)=F28
    GO TO 96
92 DO 94 J1=1,10
    ARRAY(27+11*NRAV,K+1)=F28
70 CONTINUE
94 CONTINUE
C********************************************************************************5S012130
C MINIMUM AND MAXIMUM CONCRETE STRENGTH CONSTRAINTS
C JOPT=0, CONSTRAINTS (25+11*NRAV) AND (26+11*NRAV)
C JOPT=1, CONSTRAINTS (44+11*NRAV) AND (45+11*NRAV)
C********************************************************************************5S012140
C IF(JOPT.EQ.0) GO TO 92
    ARRAY(26+11*NRAV,11*NRAV+1)=1.
    ARRAY(26+11*NRAV,K+1)=4.0
    ARRAY(27+11*NRAV,11*NRAV+1)=1.0
    ARRAY(27+11*NRAV,K+1)=F28
    GO TO 96
92 DO 94 J1=1,10
    ARRAY(27+11*NRAV,K+1)=F28
C********************************************************************************5S012150
C MINIMUM AND MAXIMUM CONCRETE STRENGTH CONSTRAINTS
C JOPT=0, CONSTRAINTS (25+11*NRAV) AND (26+11*NRAV)
C JOPT=1, CONSTRAINTS (44+11*NRAV) AND (45+11*NRAV)
C********************************************************************************5S012160
C IF(JOPT.EQ.0) GO TO 92
    ARRAY(26+11*NRAV,11*NRAV+1)=1.
    ARRAY(26+11*NRAV,K+1)=4.0
    ARRAY(27+11*NRAV,11*NRAV+1)=1.0
    ARRAY(27+11*NRAV,K+1)=F28
    GO TO 96
92 DO 94 J1=1,10
    ARRAY(27+11*NRAV,K+1)=F28
C********************************************************************************5S012170
C MINIMUM AND MAXIMUM CONCRETE STRENGTH CONSTRAINTS
C JOPT=0, CONSTRAINTS (25+11*NRAV) AND (26+11*NRAV)
C JOPT=1, CONSTRAINTS (44+11*NRAV) AND (45+11*NRAV)
C********************************************************************************5S012180
C IF(JOPT.EQ.0) GO TO 92
    ARRAY(26+11*NRAV,11*NRAV+1)=1.
    ARRAY(26+11*NRAV,K+1)=4.0
    ARRAY(27+11*NRAV,11*NRAV+1)=1.0
    ARRAY(27+11*NRAV,K+1)=F28
    GO TO 96
92 DO 94 J1=1,10
    ARRAY(27+11*NRAV,K+1)=F28
C********************************************************************************5S012190
C MINIMUM AND MAXIMUM CONCRETE STRENGTH CONSTRAINTS
C JOPT=0, CONSTRAINTS (25+11*NRAV) AND (26+11*NRAV)
C JOPT=1, CONSTRAINTS (44+11*NRAV) AND (45+11*NRAV)
C********************************************************************************5S012200
C IF(JOPT.EQ.0) GO TO 92
    ARRAY(26+11*NRAV,11*NRAV+1)=1.
    ARRAY(26+11*NRAV,K+1)=4.0
    ARRAY(27+11*NRAV,11*NRAV+1)=1.0
    ARRAY(27+11*NRAV,K+1)=F28
    GO TO 96
92 DO 94 J1=1,10
    ARRAY(27+11*NRAV,K+1)=F28
C********************************************************************************5S012210
C MINIMUM AND MAXIMUM CONCRETE STRENGTH CONSTRAINTS
C JOPT=0, CONSTRAINTS (25+11*NRAV) AND (26+11*NRAV)
C JOPT=1, CONSTRAINTS (44+11*NRAV) AND (45+11*NRAV)
C********************************************************************************5S012220
C IF(JOPT.EQ.0) GO TO 92
    ARRAY(26+11*NRAV,11*NRAV+1)=1.
    ARRAY(26+11*NRAV,K+1)=4.0
    ARRAY(27+11*NRAV,11*NRAV+1)=1.0
    ARRAY(27+11*NRAV,K+1)=F28
    GO TO 96
92 DO 94 J1=1,10
    ARRAY(27+11*NRAV,K+1)=F28
C********************************************************************************5S012230
ARRAY(45+11*NRAV,11*NRAV+J1)==1.

94       ARRAY(46+11*NRAV,11*NRAV+J1)==1.
         ARRAY(45+11*NRAV,K+1)=4.0=FPCMIN
         ARRAY(46+11*NRAV,K+1)=FPCMAX=4.0

96       CONTINUE
         RETURN
         END
SUBROUTINE OFlN
COMMON/DEFINE/ UWC, HUM, AS, FPS, CTR1, CTR2, CBR1, CBR2, CTS1, CTS2,
1 CBS1, CBS2, CREEP1, CREEP2, SHRK1, SHRK2, RATNOD, FPL, FSY, ASTIRP
UWC=.150
HUM=50.
AS=0.153
FPS=270.
FPL=0.63*FPS
CTR1=7.5
CTR2=7.5
CBR1=0.6
CBR2=0.6
CTS1=6.0
CTS2=6.0
CBS1=0.4
CBS2=0.4
CREEP1=0.
CREEP2=0.
SHRK1=0.
SHRK2=0.
RATNOD=6.0
FSY=60.
ASTIRP=0.11
RETURN
END
SUBROUTINE LPCODE (NRCE, NEQS, INDX, KODE, KBOMB)
COMMON/D314/ N, M, A (156, 276), B(276), X(276), XD(276), OBJ, KP1, K

LINEAR PROGRAMMING ALGORITHM

SET UP MATRIX

KBOMB = 0
KP1 = N + M
K = N + M + 1
KK = K - 1
IF (KODE, NE, 0) GOTO 200
DO 1 I = 1, N
DO 1 J = M, KK
1 A(I, J + 1) = 0.0
DO 2 I = 2, N
IPM = I + M - 1
2 A(I, IPM) = 1.0
WRITE(4) A
REWIND 4

FLAG BASIS

200 DO 5 I = 1, K
XD(I) = 0.0
5 X(I) = 0.0
DO 6 I = 1, N
IPM = I + M
6 X(IPM) = 1.0
DO 7 I = 1, N
7 B(I) = 0.0
10 CONTINUE

C***********************************************************************
C**** FEASIBILITY SECTION
C***********************************************************************
INEG = 2
11 DO 14 I = 2, N
IF (B(I)) 12, 12, 14
12 CONTINUE
IF (A(I, KP1) = A(INEG, KP1)) 13, 14, 14
13 INEG=1
14 CONTINUE
   IF (A(INEG,KP1)) 15,23,23
15 IF (B(INEG)) 16,16,23
16 JSM=1
   DO 19 J=2,K
   IF (XD(J)) 17,17,19
17 CONTINUE
   IF (A(INEG,J)=A(INEG,JSM)) 18,19,19
18 JSM=J
19 CONTINUE
   IF (XD(JSM)) 20,20,21
20 IF (A(INEG,JSM)) 22,23,23
C  NO FEASIBLE SOLUTION
C
21 KBOMB=51
   GO TO 38
22 CALL PIVOT (INEG,JSM)
   GO TO 10
C************** ******* OPTIMALITY SECTION ******* ******* ******
C
23 JBGST=1
C  SELECT INCOMING VECTOR
C
   DO 26 J=1,K
   IF (XD(J)) 24,24,26
24 CONTINUE
   IF (A(1,J)=A(1,JBGST)) 26,26,27
25 JBGST=J
26 CONTINUE
   IF (A(1,JBGST)) 30,30,31
C  CHECK FOR UNBOUNDED SOLUTION
C
27 DO 29 I=2,N
   ISPOT=I
   IF (B(I)) 28,28,29
CONTINUE IF (A(I,JBGST)) 29,29,30
CONTINUE
CONTINUE IF (A(ISPOT,JBGST)) 31,31,32
KBOMB=50
GO TO 38
SELECT OUTGOING VECTOR
KK=ISPOT
DO 36 I=KK,N
IF (B(I)) 33,33,36
CONTINUE
IF (A(I,JBGST)) 36,36,34
IF (A(I,K+1)/A(I,JBGST)=A(ISPOT,K+1)/A(ISPOT,JBGST)) 35,35,36
ISPOT=I
CONTINUE
IF (B(ISPCT)) 37,37,31
CALL PIVOT (ISPCT,JBGST)
GO TO 23
C***********************************************************************
C**** OUTPUT SECTION
C***********************************************************************
OBJ=-A(I,KPI)
IF (INDX=1) 40,39,40
OBJ=-OBJ
DO 45 I=1,K
IF (X(I)) 44,44,41
DO 42 J=2,N
IF (A(J,I)) 42,42,43
CONTINUE
X(I)=A(J,KP1)
GO TO 45
X(I)=0.
CONTINUE
DO 49 J=1,K
IF (J=N+1) 46,46,47
CONTINUE
JJ=J+N
GO TO 48
...
47 JJ = J - N + 1
48 XD(J) = -A(1, JJ)
49 CONTINUE
   IF(KBOMB.EQ.50) WRITE(6,50)
50 FORMAT (/ICHOUNBOUNDED)
   RETURN
END
SUBROUTINE PIVOT (I, J)

COMMON /D314/ N,M,A (156, 276), B(276), X(276), XD(276), OBJ, KP1, K

DO 2 JJ=1, K
1 IF (X(JJ)) 2, 2, 1
2 CONTINUE
3 X(JJ)=0.0
4 NM1=N=1
5 R=A(I,J)
6 DO 4 L=1, KP1
7 A(I,L)=A(I,L)/R
8 DO 5 L=2, I
9 F=A(L=1, J)
10 DO 5 M=1, KP1
11 A(L+M)=A(L+M)+A(I,M)*F
10 CONTINUE
11 X(I)=1.0
12 M=KP1=N
13 RETURN
14 END
SUBROUTINE PROPTY
REAL*4 X1,X2,X3,X4,X5,X6,X7,X8,X9,X10,X11,X12,X13,X14,X15
COMMON/BLK1/ ADIM,BDIM,CDIM,DDIM,EDIM,FDIM,GDIM,HDIM,TDIM,
1WDOIM,WHDIM,XDIM,YDIM,ACCNC,BINERT,DTCP,DOB7,DTZ,DOB7,ACONCK,
2BINERK,DTOPK,DOB7K,ZTK,DOB7K,ZLF,DOB7J,JOPT,ASSCLR,ASSPLS,APRIME,
3CBOT,COSTP,CSTFT,DEFMIN,ALDEF,NNAV,NWHEEL,DISTF,FPCMAX,
4FPCMIN,ELASC,ULTMGE,CTOP,W,MB,F,DCR,
COMMON/DEFINE/ UWC,HUM,A5,FPS,CTR1,CTR2,CR1,CR2,CTY1,CTY2,
1CBS1,CBS2,CREEP1,CREEP2,SHR1,SHR2,RATNC,D,FPL,FSY,ASTIRP,
*EQUIVALENCE (AREA,ACONC),(YB,DOB7),(YT,DTOP),(YB,DOB7K),
.*(YT,DTOPK),(AREA,K,ACONCK),(A,ADIM),(B,BDIM),(C,CDIM),(D,DDIM),
.*(E,EDIM),(F,FDIM),(G,GDIM),(T,TDIM),(W,WDCIM),(WH,WHDIM),(H,HDIM)
CTOP=DCR
C1 = (A=(WH+2*WD))/2.
C2 = (B=(WH +2*WD))/2.
A1 = WD*D
A2 = C1*H
A3 = C1*G/2.
A4 = E*C2/2.
A5 = C*C2
A6 = WH*T
A7 = WH*F
A8 = (C2=C1)*H
A9 = (C2=C1)*G
A10 = A3
A11 = C2*(D=H=G=E=C)
A12 = A4
IF(A,L,T,B) GC TO 80
A8=0.
A9=0.
A10=0.
A11=0.
A12=0.
80 CONTINUE
A14=(XDIM**2)/2.
A15=(YDIM**2)/2.
**2.*(RATNC=1.)*APRIME=.5625
**(RATNC=1.)*APRIME=.5625
SS014110
SS014120
SS014130
SS014140
SS014150
SS014160
SS014170
SS014180
SS014190
SS014200
SS014210
SS014220
SS014230
SS014240
SS014250
SS014260
SS014270
SS014280
SS014290
SS014300
SS014310
SS014320
SS014330
SS014340
SS014350
SS014360
SS014370
SS014380
SS014390
SS014400
SS014410
SS014420
SS014430
SS014440
SS014450
SS014460
SS014470
SS014480
SS014490
SS014500
\begin{align*}
\text{AREAK} & = \text{AREA1} + 2.0 \times \text{A8} + 2.0 \times \text{A9} + 2.0 \times \text{A10} + 2.0 \times \text{A11} + 2.0 \times \text{A12} \\
\text{Y1} & = \frac{D}{2} \\
\text{Y2} & = \frac{D}{H/2} \\
\text{Y3} & = \frac{D}{(H+G/3)} \\
\text{Y4} & = C + \frac{E}{3} \\
\text{Y5} & = \frac{C}{2} \\
\text{Y6} & = \frac{D}{T/2} \\
\text{Y7} & = F/2 \\
\text{Y8} & = \frac{D}{(H/2.0)} \\
\text{Y9} & = \frac{D}{(H+G/2.0)} \\
\text{Y10} & = \frac{D}{(H+2.0*G/3.0)} \\
\text{Y11} & = \frac{(C=H+G+E+C)}{2.0} \\
\text{Y12} & = C + 2.0*E/3.0 \\
\text{Y14} & = \frac{D}{T=XCIM/3} \\
\text{Y15} & = F+YDIN/3 \\
\text{YB} & = (Y1*A1*2 + Y2*A2*2 + Y3*A3*2 + Y4*A4*2 + Y5*A5*2 + Y6*A6) \\
\epsilon & + Y7*A7 + (D=CTOP)2.0*(RATNOD=1.0)*APRIME/AREA \\
\text{YT} & = D=YB \\
\text{YBI} & = (Y1*A1*2 + Y2*A2*2 + Y3*A3*2 + Y4*A4*2 + Y5*A5*2 + Y6*A6) \\
\epsilon & + Y7*A7 + (D=CTOP)2.0*(RATNOD=1.0)*APRIME/AREA \\
\text{YBK} & = (YBI*AREA1+Y8*A8*2 + Y9*A9*2 + Y10*A10*2 + Y11*A11*2 + Y12*A12*2) \\
\text{YIK} & = D=YBK \\
\text{DO} & = 10 \text{~J1=1.2} \\
\text{JVKEY} & = J1=1 \\
\text{DY} & = YB \\
\text{IF(JVKEY.EQ.1) DY = YBK} \\
\text{I1} & = WD*(D**3)/12 + A1*((Y1-DY)**2) \\
\text{I2} & = CI*(H**3)/12 + A2*((Y2-DY)**2) \\
\text{I3} & = CI*(G**3)/36 + A3*((Y3-DY)**2) \\
\text{I4} & = CI*((E**3)/36 + A4*((Y4-DY)**2) \\
\text{I5} & = CI*(C**3)/12 + A5*((Y5-DY)**2) \\
\text{I6} & = WH*(T**3)/12 + A6*((Y6-DY)**2) \\
\text{I7} & = WH*(F**3)/12 + A7*((Y7-DY)**2) \\
\text{I13} & = 2.0*(RATNOD=1.0)*APRIME*((D=CTOP-DY)**2) \\
\text{I131} & = \text{(RATNOD=1.0)*APRIME}\*(\text{(D=CTOP-DY)**2}) \\
\text{I14} & = (XCIM**4)/36 + A14*((Y14-DY)**2) \\
\text{I15} & = (YDIN**4)/36 + A15*((Y15-DY)**2) \\
\text{XINERT} & = I1*I2 + I2*I3 + I3*I4 + I4*I5 + I5*I6 + I6 + I7 + I13 + I14 + I15*2 \\
\text{..} & + I15*2 \\
\end{align*}
IF(JVKEY.EQ.0) GO TO 5
IF(A.GE.B) XINERK=XINERT+1131=113
IF(A.GE.B) GO TO 5
I8 = (C2=C1)*(T**3)/12. + A8*((Y8-DY)**2)
I9 = (C2=C1)*(G**3)/12. + A9*((Y9-DY)**2)
I10 = C1*(G**3)/36. + A10*((Y10-DY)**2)
I12 = C2*(E**3)/36. + A12*((Y12-DY)**2)
IF(JVKEY.EQ.1) XINERK =
&XINERT+I131=113 + I8*2.0 + I9*2.0 + I10*2.0 + I11*2.0 + I12*2.0
5 CONTINUE
IF(JVKEY.EQ.1) GO TO 8
ZT=XINERT/YT
ZB=XINERT/Y8
BINERT=XINERT
BINERT=BINERT=0.75**4/18. =2.*(.28125*(Y8=.50)**2)
GO TO 10
8 ZTK=XINERK/YTK
ZBK=XINERK/YBK
BINERK=XINERK
BINERK=BINERK=0.75**4/18. =2.*(.28125*(YBK=0.50)**2)
10 CONTINUE
RETURN
END
SUBROUTINE MOMSHR(DL, NWHL, NWHEEL, XSEC, PAXLE, MAXMOM, MAXSHR)  
REAL*4 MAXMOM, MAXSHR, NWHL, MOMENT  
COMMON/DUMP/ MOMENT(12), SHEAR(12), IPL(20), IPR(20), REACT(20)  
DIMENSION NWHL(18), PAXLE(18)  
NST = NWHEEL = 1  
DO 11 II = 1, 2  
11 IF(II.EQ.2) XSEC = DL = XSEC  
XSEC = DL = XSEC  
DO 3 NS = 1, NST  
IL = NS  
CALL LOCATE(DL, XSEC, NST, NS, NWHL)  
N1 = IPL(IL)  
N2 = IPR(IL)  
IF(N1.EQ.0 .AND. N2.EQ.0) PROD = PAXLE(IL+1)*XSECR  
IF(N1.EQ.0 .AND. N2.EQ.0) GO TO 33  
IF(N1.EQ.0) N1 = IL+1  
IF(N2.EQ.0) N2 = IL+1  

c  
OBTAIN THE LEFT REACTION FOR ANY SHIFT  
PROD = 0.  
DO 4 I = N1, N2  
4 IF(I.EQ.1) D2 = DL = (XSEC - NWHL(IL))  
IF(I.EQ.1) GO TO 36  
IF(I.EQ.1) D2 = XSECR  
IF(I.EQ.(IL+1) .AND. IPL(IL).EQ.0) D2 = XSECR  
IF(I.EQ.(IL+1) .AND. IPL(IL).EQ.0) GO TO 36  
IF(I.LE.IL) D2 = DL = (XSEC - (NWHL(IL) - NWHL(I-1)))  
IF(I.LE.IL) GO TO 36  
IF(I.GT.IL) D2 = XSECR = (NWHL(I-1) - NWHL(IL))  
36 CONTINUE  
DELT = PAXLE(I)*D2  
4 PROD = PROD+DELT  
33 CONTINUE  
REACT(IL) = PROD/DL  
SUMV = 0.  
SUMM = 0.  
IF(IPL(IL).EQ.0) SHEAR(IL) = REACT(IL)  
IF(IPL(IL).EQ.0) MOMENT(IL) = REACT(IL) * XSEC  
IF(IPL(IL).EQ.0) GO TO 3  
DO 5 I = N1, IL  
5 IF(I.EQ.1) DM = NWHL(IL)  
IF(I.EQ.1) GO TO 34
DM = NWHL(IL) - NWHL(I-1)
34 DELTM = PAXLE(I) * DM
DELTV = PAXLE(I)
SUMM = SUMM + DELTM
SUMV = SUMV + DELTV
5 CONTINUE
SHEAR(IL) = REACT(IL) - SUMV
MOMENT(IL) = REACT(IL) * XSEC = SUMM
3 CONTINUE
NA = 0
IF (II.EQ.1) MAXMOM = MOMENT(1)
IF (II.EQ.1) MAXSHR = SHEAR(1)
NSTA = NST = 1
IF (NSTA.EQ.0) GO TO 16
DO 13 LL = 1, NSTA
NA = NA + 1
NB = LL + 1
AAA = MOMENT(NA)
BBB = SHEAR(NA)
IF (II.EQ.2) AAA = MAXMOM
IF (II.EQ.2) BBB = MAXSHR
IF (MOMENT(NB) .GT. AAA) MAXMOM = MOMENT(NB)
IF (ABS(SHEAR(NB)) .GT. BBB) MAXSHR = ABS(SHEAR(NB))
IF (MOMENT(NB) .GT. AAA) GO TO 15
NA = NA + 1
GO TO 13
15 NA = NB = 1
13 CONTINUE
16 CONTINUE
11 CONTINUE
XSEC = DL * XSEC
RETURN
END
SUBROUTINE LOCATE(DL,XSEC,NST,NS,NWHL)
REAL*4 NWHL,MOMENT
COMMON/CUMPJ/MOMENT(12),SHEAR(12),IPL(20),IPR(20),REACT(20)
DIMENSION NWHL(18)
XSEC = DL*XSEC
DTERM = 0.
DO 1 I = 1,NST
  DLE = NWHL(NS)-DTERM
  IF(DLE.LE.XSEC) IPL(NS) = I
  IF(DLE.LE.XSEC) GO TO 2
  IF(I.EQ.NS) IPL(N5) = 0
  IF(I.EQ.NS) GO TO 2
  DTERM = NWHL(I)
1 CONTINUE
2 CONTINUE
DO 4 IC = 1,NST
  NSC = NS+IC
  IF((NS+1).EQ.(NST+1)) IPR(NS) = 0
  IF((NSC+NST).GT.NST) GO TO 5
  DELTR = NWHL(NS+IC)-NWHL(NS)
  IF(DELTR.GT.XSEC.AND.IC.EQ.1) IPR(NS) = 0
  IF(DELTR.GT.XSEC) GO TO 5
  IPR(NS) = NS+IC+1
4 CONTINUE
5 CONTINUE
RETURN
END
SUBROUTINE ULTMF(ASTAR,FPCBM,FPS,ASPRM,FPL,D,DPTH,FSY, DCR, *Y1,Y2,Y3,Y4,Z1,Z2,Z3,Z4,ZMUL)

CLONG=0.2
ESINI=0.7*FPS*(1.0-CLONG)/28.0-E+03
CON1=(FPL/28000.)*(1.+(FPS=FPL)/(FPS=2.0*FPL))
CON2=-(FPL/28000.)*FPS/FPL**2/(FPS=2.0*FPL)
BEFF=2.0*(Y1+Y2+Y3)
THK=Z1
Z4MZ3=Z4=Z3
IF(ABS(Z4-Z3).LE.1.E-06) Z4MZ3=1.E-06
Z2MZ1=Z2=Z1
IF(ABS(Z2-Z1).LE.1.E-06) Z2MZ1=1.E-06

C*********************************************************SS016270
C**** POSITIVE MOMENT CAPACITY = N.A. IN SLAB
C*********************************************************SS016290
C
PSTAR=ASTAR/(BEFF*D)
FSUSTR=FPS*(1.0-0.5*PSTAR*FPS/FPCBM)
T=ASTAR*FSUSTR
CC=.833*FPCBM*BEFF*THK
IF(CC.LT.T) GO TO 10

N.A. IN SLAB

ZMUL =ASTAR*FSUSTR*D*(1.0-0.6*PSTAR*FSUSTR/FPCBM) /12SS016410
RI=PSTAR*FSUSTR/FPCBM
IF(RI.GT.0.3)ZMUL =0.25*FPCBM
BEFF=D**2/12.
RETURN
C*********************************************************SS016450
C**** POSITIVE MOMENT CAPACITY = N.A. BELOW SLAB
C*********************************************************SS016470

10 CONTINUE
C
BEGIN ITERATION TO LOCATE N.A.
C
JCNT=0
X=0.
12 X=X+0.25
C
13 JCNT=JCNT+1
   IF(X.GT.DPTH) ZMUL=0.
   IF(X.GT.DPTH) RETURN
C
   COMPUTE STRAND STRAIN AND FORCE IN DECK STEEL
C
   ES=.003*(C*X)/X+ESINI
   ESP=.003*(X=DCR)/X
   CS=29.E+03*ABS(ESP)
   IF(CS.GT.FSY) CS=FSY
   IF(ESP.LE.0) CS=-CS
   CS=CS*ASPRM
C
   COMPUTE RESULTANT COMpressive FORCE ON CONCRETE AND ITS LOCATION
C
   KODE=1
   GO TO 1000
14 DBAR=D*YC
   CC=C*.833*FPCBM
   CTOT=CS+CC
   GO TO 2000
C
   COMPUTE STRAND STRESS AND STRAND FORCE
C
16 T=ASTAR*FS
   SUMFOR=T=CTOT
   IF(SUMFOR.LT.0.) GO TO 18
   IF(JCNT.EQ.2) GO TO 17
   SAVEF1=SUMFOR
   SAVEX1=X
   GO TO 12
17 SAVEF2=SUMFOR
   SAVEX2=X
   X=SAVEX1+(SAVEX2=SAVEX1)*SAVEF1/(SAVEF1=SAVEF2)
   IF(X<SAVEX1-.LT.25) X=SAVEX1-.LT.25
   JCNT=0
   GO TO 13
18 ZMUL=(CC*DBAR+CS*(D=DCR))/12.
   GO TO 20
C***********************************************************************SS016940
C** THIS SECTION COMPUTES CONCRETE COMPRESSION AREA AND ITS C.G.  
C***********************************************************************
1000 C = (Y1*BRACK(0, X, Z1) + Y2*X + Y3*BRACK(0, X, Z3) + BRACK(Z1, X, Z2)*Y4  
*   = 0.5*Y4*BRACK(Z1, X, Z2)**2/Z2MZ1 + BRACK(Z3, X, Z4)*Y3)*0.5*Y3*  
YC = (0.5*Y1*BRACK(0, X, Z1)**2 + 0.5*Y2*X**2 + 0.5*Y3*BRACK(0, X, Z3)**2  
*   + Y4*Z1*BRACK(Z1, X, Z2) + 0.5*Y4*BRACK(Z1, X, Z2)**2 = 0.5*Z1*Y4*  
*   BRACK(Z1, X, Z2)**2/Z2MZ1 = .33333*Y4*BRACK(Z1, X, Z2)**3/Z2MZ1  
*   + Y3*Z3*BRACK(Z3, X, Z4) + 0.5*Y3*BRACK(Z3, X, Z4)**2  
*   = 0.5*Z3*Y3*BRACK(Z3, X, Z4)**2/Z4MZ3 = .33333*Y3  
*   *BRACK(Z3, X, Z4)**3/Z4MZ3)*2./C  
GO TO 14  
C***********************************************************************
C** THIS SECTION COMPUTES STRAND STRESS  
C***********************************************************************
2000 FS=ES*28000  
   IF(FS, GT, FPL) GO TO 2002  
2002 FS = .5*FPS+.5*SQR(FPS**2 = 4.*CON2/(ES*CON1))  
   GO TO 16  
28 RETURN  
END
FUNCTION BRACK(ZL,X,ZU)  
IF(X.LE.ZL) BRACK=0.  
IF(ZL.LT.X.AND.X.LE.ZU) BRACK=X-ZL  
IF(X.GT.ZU) BRACK=ZU-ZL  
RETURN  
END
SUBROUTINE PLCSS(FPCR,ZMBW,ZMC,ZMNC,FSU,AS,AB,ZI,ZIC,YB,YBC,EC,*HUM,SPAN,ZLOSS,ZINLOS,UWC)

C
C   THIS SUBROUTINE COMPUTES PRESTRESS LOSS BY 1975 AASHTO
INTERIM SPEC.
C
C   FPCR = CONCRETE RELEASE STRENGTH (KSI)
C   ZMBW=D.L. MOMENT DUE TO BEAM WEIGHT AT MIDSPAN(K-FT)
C   ZMC = TOTAL D.L. MOMENT (EXCEPT BEAM WEIGHT) AT MIDSPAN
   ACTING ON COMPOSITE SECTION (K-FT)
C   ZMNC = TOTAL D.L. MOMENT (EXCEPT BEAM WEIGHT) AT MIDSPAN
   ACTING ON NONCOMPOSITE SECTION (K-FT)
C   FSU = ULTIMATE STRENGTH OF STRAND (KSI)
C   AS = TOTAL STRAND AREA (IN**2)
C   AB = CROSS SECTIONAL AREA OF BEAM (IN**2)
C   ZI = M. OF I. CF NONCOMPOSITE BEAM (IN**4)
C   ZIC = M. OF I. CF COMPOSITE BEAM (IN**4)
C   YB = DISTANCE FROM C.G. OF BEAM TO BOTTOM FIBER (IN)
C   YBC = DISTANCE FROM C.G. OF COMPOSITE BEAM TO BOTTOM FIBER (IN)
C   EC = DISTANCE FROM BOTTOM OF BEAM TO C.G. OF STRANDS (IN)
C   HUM = RELATIVE HUMIDITY (PERCENT)
C   SPAN = SPAN LENGTH (FT)
C   ZINLOS=FRAC'I'ON OF INITIAL STRESS(.7*FSU) LOST (RELEASE)
C   ZLOSS = FRACTION OF INITIAL STRESS (.7*FSU) LOST (SERVICE)
C   (COMPRESSION STRESS IS POSITIVE )
C
C   SHRINKAGE LOSS
C
C   SH=(17000.-150*HUM)/1000.
C
C   ELASTIC SHORTENING
C
C   A 10 PERCENT LOSS IN STRAND FORCE DUE TO RELAXATION AND ELASTIC
   SHORTENING PRIOR TO RELEASE IS ASSUMED AT TIME OF RELEASE
C
C   FEFF=0.9*0.7*FSU*AS
FCIR=FEFF/AB+FEFF*(YB-EC)*ABS(YB-EC)/ZI=12.*ZMBW*(YB-EC)/ZI
C
ECI=(UWC*1000.)**1.5*33.*SQRT(1000.*FPCR)
ES = (28E+06*FCIR/ECI)
  C  CREEP LCSS
  FCDS = 12.0*ZMNC*(YB=EC)/ZI+12.0*ZMC*(YBC=EC)/ZIC
  CRC = 12.0*FCIR-7.0*FCD5
  C STRAND RELAXATION LOSS
  CRS = 20.0-0.4*ES-0.2*(SH+CRC)
  C TOTAL LOSS
  DELTFS = SH+ES+CRC+CRS
  DELFSI = ES+0.5*CRS
  C LOSS FACTOR
  ZLOSS = DELTFS/(.7*FSU)
  ZINLOS = DELFSI/(.7*FSU)
RETURN
END
SUBROUTINE CAMBER(ES, EC, ASTR, STRN, UWB, AREA, SPANL, ECCL, IB, FO, ENDE)
*CC, PRLMAX, CBRMAX)
COMMON/DEFINE/ UWC, HUM, AS, FPS, CTR1, CTR2, CBR1, CBR2, CTS1, CTS2,
ICBS1, ICBS2, CREEP1, CREEP2, SHR1, SHR2, RATND, FPL, FSY, ASTIRP
DIMENSION CNST(4,5), PRLMAX(5), CBRMAX(5)
DATA CNST, 35.0, 20.0, 440.0, 60.0, 525.0, 10.0, 675.0, 40.0, 380.0, 25.0, 400.0, 50.0, 295
REAL IE

CAMBER AND STRESS LOSS CALCULATIONS
MIOSPA CAMBER AND STRESS LOSS DUE TO INITIAL PRESTRESS AND BEAMS

HDPT=5.0
IF(CREEF1.EQ.0.) J1=4
IF(CREEP1.EQ.0.) GO TO 2
CNST(1,5)=SHR1
CNST(2,5)=SHR2
CNST(3,5)=CREEP1
CNST(4,5)=CREEP2
J1=5

DO 1 N=1,J1
ASH=0.000001*CNST(1,N)
BSH=CNST(2,N)
ACRR=0.000001*CNST(3,N)
BCR=CNST(4,N)
ACR = ACRR*0.001
RN = ES/EC
AST = ASTR*STRN
W = UWB*AREA/144.
DLM = (W*SFANL*SPANL/8.)*12.
TEMP = 1.0+(RN*AST/AREA)+(RN*AST*ECCL*ECCL/IB)
FR = FO/TEMP +(DLM*ECCL*RN*AST/(IB*TEMP))
PLI = ((FC=FR)/FO)*100.
CONST = (1./AREA)+(ECCL*ECCL/IB)
FCSD = FR*CONST+(DLM*ECCL/IB)
STRN1 = ACR*FCSD+ASH
STRN2 = STRN1-STRN1*(RN*AST*CONST)
DFCS = STRN2*ES*AST*CONST * 10.0 ** 6
STRN4 = ACR*(FCSD=DFCS/2.)+ASH

SS017840
SS017850
SS017860
SS017870
SS017880
SS017890
SS017900
SS017910
SS017920
SS017930
SS017940
SS017950
SS017960
SS017970
SS017980
SS017990
SS018000
SS018010
SS018020
SS018030
SS018040
SS018050
SS018060
SS018070
SS018080
SS018090
SS018100
SS018110
SS018120
SS018130
SS018140
SS018150
SS018160
SS018170
SS018180
SS018190
SS018200
SS018210
SS018220
SS018230
STRN5 = STRN4 = STRN4*RN*AST*CONST
DFCS1 = STRN5*ES*AST*CCNST * 10.0 ** 6
STRN6 = ACR*(FCSD=DFCS1/2.) + ASH
STRN7 = STRN6 = STRN6*RN*AST*CONST
PLINF = (STRN7*ES*AST*10.0**6/FC)*100.
PLMAX = PLINF + PLI
PRLMAX(N)=PLMAX
CCONST = 1./(EC*IB*10.**6)
HSPAN = SPANL/2.
CI1 = CCONST*(FR*ENDECC * HSPAN*0.5*HSPAN*144.)
CI2 = CCONST*(FR*(ECCL-ENDECC )*(HSPAN=HDPT)*0.5*0.67*(HSPAN=HSPAN2)
CI3 = CCONST*(FR*(ECCL-ENDECC )*HDPT*(HSPAN=HDPT/2.)*144.)
CI4 = CCONST*((5./384.)* (W*SPANL*SPANL*SPANL*SPANL*12.*12.*12.))
CI = CI1 + CI2 + CI3 + CI4
STRAIN = FCSD/(EC*10.**6)
CMAX = CI*{(ACR*(FCSD=DFCS/2.)) + STRAIN)/STRAIN}*(1.-(PLINF/100.))
CBRMAX(N)=CMAX
CONTINUE
RETURN
END
SUBROUTINE SHEAR(B, DEPTH, D, FPC, FSY, AREA, VU, SPACE)
AV=2.*AREA
S1=(AV*FSY)/(0.100*B)
SMAX=0.75*DEPTH
IF(S1.LT.SMAX) SMAX=S1
RJ=0.90
VCMAX=0.180*B*RJ*D
VC=0.06*FPC*B*RJ*D
IF(VC.GT.VCMAX) VC=VCMAX
SPACE=(2.*AV*FSY*RJ*D)/(VU*VC)
IF(SPACE.LT.0.0 OR SPACE.GT.SMAX) SPACE=SMAX
RETURN
END
INTEGER*2 ROW, COL
COMMON/BLK1/ADIM, CDIM, D DIM, EDIM, F DIM, GODIM, HDIM, TDIM, W D DIM, IWHDIM, XDIM, Y D IM, ACONC, BINERT, DT OP, DBOT, ZT, ZB, ACONCK, BINERK, D TOPK, 2DBOTK, ZTK, ZBK, ZL, F28, JOPT, ASSCLR, ASSPLS, APRI ME, CBOT, COSTFT, 3DEFMIN, ALDEF, NRAY, NWHEEL, DISTF, FPCMAX, FPCMIN, ELASC, UL TMRG, CT OP, 4W, WB, FO, DCR, NR, HDPT, NW, ALPHA
COMMON/BLK2/PAXLE(18), NWHL(18), STRMAX(26), FC ONC(10), DCONC(10), 1G(11), F(11), D(11), BM AX(9), BM AX(9), CB RMAX(5), PRL MAX(5), DL M ON(9), 20LSHR(9), PECR K(11), ZLSO(4)
COMMON/DEF I N E / UWC, HUM, AS, FPS, CTR1, CT R2, CBR1, CBR2, CTS1, CTS2, 1CBS1, CBS2, CREEP1, CREEP2, SHRK1, SHRK2, RAT NOD, FPL, FSY, AST IRP, GSP
COMMON/YZ/Z1, Z2, Z3, Z4, Y1, Y2, Y3, Y4
COMMON/D314/N, M, OBJ, KPI, K, NCON, NC, N RAY, NCA, N1, N2, N3, DXMAX, IS, TV, TR
COMMON/YZ/21, Z2, Z3, Z4, Y1, Y2, Y3, Y4
COMMON/0314/N, M, 08, 1, KPT, I<• NCON, NC, 08, 1, N2, N3, OX MAX, 15, TR, O50001
3SUM, IGNOR, IT(4), JCONT, X(150), Y(3136), ROW(3136), COL(150), BB(150), 2C(150), E(150), XX(150)
COMMON/DUMP/
TITLE(3,54), YJ(11), FROW(26)
1PEF(50,3), ZNE(11), KKODE(4), ZMCR(4)
DIMENSION STRESS(9,4), NSTRMX(26), ZNWL(18), ZAXLE(18), VU(9)
1EX(2), KS YM(9,5), STRSP(9), IAA(16)
INTEGER ONE, TWO, BLANK, HH, SSS, EX
DATA NTP/'TP /
DATA EX/'X '/'
DATA ONE,TWO, BLANK, HHH, SSS, '/
CALL REREAD
NCOUNT::
C***********************************************************************
C**** INPUT ROUTINE
C***********************************************************************
3007 FPC1=4.0
IF(NCOUNT.NE.1) GO TO 573
READ(5,500)(TITLE(1,J),J=1,54)
READ(5,500)(TITLE(2,J),J=1,54)
573 READ(5,500,END=2500) (TITLE(3,J1),J1=1,54)
500 FORMAT(80A1)
CALL DEF I N
READ(5,500)I D, IA, IB, DISTF, JLOAD, ULSB, JCONC, F28, JOPT
501 FORMAT(A1,4X,A1,1X,A1,4X,F4.3,3X,11,3X,
F4.2,3X,11,3X,F3.1,DS000370
*10X,II)
IF(JOPT.EQ.0.AND.F28.EQ.0.) WRITE(6,525)
IF(JOPT.EQ.0.AND.F28.EQ.0.) STOP
FORMAT(///,*DESIGN OPTION SPECIFIED BUT NO 28 DAY CONCRETE STRENGTH GIVEN**) DS000410

AXLE TRAIN
DO 927 I=1,18
      PAXLE(I)=0.
      NWHL(I)=0.
927 CONTINUE
   IF(JLOAD.NE.1)GC TO 861
   READ(5,502)(PAXLE(I),I=1,18)
   DO 503 N=1,18
      IF(PAXLE(N).NE.0.)NWHEEL=N
503 CONTINUE
   READ(5,505)(NWHL(I),I=1,17)
   FORMAT(7X,17(F3.0,1X))
C CONCENTRATED FORCES APPLIED TO SINGLE BEAM
861 DO 590 I=1,10
      FCONC(I)=0.
      DCONC(I)=0.
590 CONTINUE
   IF(JCONC.NE.1) GO TO 925
   READ(5,591)(FCONC(I),I=1,10)
   READ(5,591)(DCCNC(I),I=1,10)
591 FORMAT(3X,10(F5.2,1X))
C BEAM DIMENSIONS
925 READ(5,907)ACIM,BDIM,CDIM,DDIM,EDIM,FDIM,GDIM,HDIM,WHDIM,TDIM,WDDID
   *M,XDIM,YDIM
   FORMAT(3X,13(F4.2,1X))
907 FORMAT(3X,13(F4.2,1X))
C GENERAL INFORMATION
   READ(5,908) ZL,WIDTH,JTNTL,TNLB,APRIME,DCR,ALDEF,DEFMIN,
   *CBOT,NW,HDPT,JPROP
   IF(ZL.LT.0. OR. TNLB.EQ.0) WRITE(6,917) ZL, TNLB
917 FORMAT(///,40X,*CHECK YOUR DATA = BEAM LENGTH AND NUMBER OF BEAMS ARE*,,/60X,F10.2,5X,F5.2)
   IF(ZL.LT.10. OR. TNLB.EQ.0) STOP
   READ(99,9083) IAB,IAC,IAD,IAE
9083 FORMAT(42X,4A4)
   IF(IAB.EQ.BLANK.AND.IAC.EQ.BLANK) ALDEF=1000.
```
C MAXIMUM NUMBER OF STRANDS PER ROW NMAX=1000.
NRAV=0
READ(5,9094) (NSTRMX(J1),J1=1,26)
909 FORMTAT(3X,25(A2,1X),A2)
DO 9100 J1=1,26
IF(NSTRMX(J1).EQ.NTP) J2=J1
IF(NSTRMX(J1).EQ.NTP) NRAV=J1
IF(NSTRMX(J1).EQ.NTP) GO TO 9101
9100 CONTINUE
9101 DO 9404 J1=1,26
NSTRMX(J1)=0
READ(99,909) (NSTRMX(J1),J1=1,J2)
909 FORMAT(3X,25(1X),1X),I2)
DO 910 J=1,26
STRMAX(J)=NSTRMX(J)
IF(NSTRMX(J).NE.0) NR=J
910 CONTINUE
C MISCELLANEOUS PROPERTIES
862 IF(.JPROP.NE.1) GO TO 863
READ(5,882) CUW,UHM,SA,SPF,PSG,TR2,TR1,BS2,TS2,BS1,TS1.
ICREEP1,CREEP2,SHRK1,SHRK2,NVR
882 FORMTAT(3X,F3.3,3X,F2.0,2X,F3.3,2X,F3.0,3X,F2.1,4X,F2.2,1X,F2.1,1X,DS001030
IF(2.1X,F2.1,3X,F2.2,1X,F2.1,1X,F2.1,4X,F2.2,1X,F2.4,4(F3.0,1X),1X,12) DS001040
IF(FSP.0,0,0) FPS=SPF
IF(SA.0,0,0) AS=SA
IF(UHM.0,0,0) HUM=UHM
IF(CUW.0,0,0) UWC=CW
IF(PSG.0,0,0) CSP=PSG
IF(NVR.0,0,0) NRAV=NVR
IF(NRAV.0,0) WRITE(6,9181)
IF(NRAV.0,0) STOP
9181 FORMTAT(1X,130((1H**),/1X,60('**))," INCORRECT DATA INPUT = TOP-MOST GRDS001130
1D ROW WAS NOT SPECIFIED = CHECK */60('**),/1X,60('**)," MAXIMUM NDS001140
2UMBER OF STRANDS CARD AND/OR MISCELLANEOUS PROPERTIES CARD */.60(*0." DS001150
3**))
READ(99,9082) (IAA(J1),J1=1,16)
9082 FORMTAT(30X,2A1,1X,2A1,1X,2A1,1X,2A1,1X,2A1,1X,2A1,1X,2A1,1X,2A1,1X,2A1)
IF(IAA(1).NE.BLANK.CR,IAA(2).NE.BLANK) CER2=BR2
IF(IAA(3).NE.BLANK.OR,IAA(4).NE.BLANK) CTR2=TR2
```
CONCRETE COST COEFFICIENTS

863 IF(JOPT.NE.1) GO TO 1001
912 READ(5,915)(G(I),I=1,6)
915 FORMAT(10X,5(F4.1,9X),F4.1)

28 DAY CONCRETE STRENGTHS
READ(5,913)(F(I),I=1,6)
DO 916 J=1,11
916 CONTINUE
CONTINUE

LIVE LOAD DISTRIBUTION FACTOR

933 CONTINUE
IAASHO=1

AASHTO TRUCK LOADINGS

IF(AA.EQ.BLANK.AND.IB.EQ.BLANK) IAASHO=0
IF(IA.EQ.BLANK.AND.IB.EQ.BLANK) GO TO 6000
IF(IA.EQ.BLANK.AND.IB.EQ.ONE) GO TO 1000
IF(IA.EQ.HH. A.ND.IB.EQ.ONE) GO TO 1000
IF(IA.EQ.SSS.AND.IB.EQ.ONE) GO TO 2000
IF(IA.EQ.BLANK.AND.IB.EQ.TWO) GO TO 3000
IF(IA.EQ.HH. A.ND.IB.EQ.TWO) GO TO 3000
IF(IA.EQ.SSS.AND.IB.EQ.TWO) GO TO 4000
WRITE(6,950)
950 FORMAT(1X,130(1H*))/1X,130(1H*),*UNRECOGNIZABLE AASHTO TRUCK LOADINGDS001690
** CHECK INPUT CARD 4*, COLS. 5 THRU 8*, 30(1H*)/1X,130(1H*)* DS001700
STOP
C
C H=15 TRUCK
C
1000 ZAXLE(1)=6.
ZAXLE(2)=24.
ZNWHL(1)=14.
NAXLE=2
ULOAD=0.480
CSLOAD=19.5
CMLOAD=13.5
GO TO 6000
C
C HS=15 TRUCK
C
2000 ZAXLE(1)=6.
ZAXLE(2)=24.
ZAXLE(3)=24.
ZNWHL(1)=14.
ZNWHL(2)=28.
NAXLE=3
ULOAD=0.480
CSLOAD=19.5
CMLOAD=13.5
GO TO 6000
C
C H=20 TRUCK
C
3000 ZAXLE(1)=8.
ZAXLE(2)=32.
ZNWHL(1)=14.
NAXLE=2
ULOAD=0.640
CSLOAD=26.
CMLOAD=18.
GO TO 6000

C
HS=20 TRUCK

4000 ZAXLE(1)=8.
ZAXLE(2)=32.
ZAXLE(3)=32.
ZNWHL(1)=14.
ZNWHL(2)=28.
NAXLE=3
ULOAD=0.640
CSLOAD=26.
CMLOAD=18.

6000 CONTINUE
CALL PROPTY
Z1=TDIM
Z2=TDIM+XDIM
Z3=HDIM
Z4=HDIM+GDIM
Y1=WHDIM/2.
Y2=WDIM
Y3=ADIM/2.-Y1=Y2
Y4=XDIM
D(1)=-DBOT+CBO
DO 9102 J1=2,NR

9102 D(J1)=D(J1-1)+GSP
ALPHA=0.5-HDPT/ZL

C********* PRINT OUT INPUT QUANTITIES
C************************************************************* DS002330
C************************************************************* DS002340
WRITE(6,9080) (TITLE(1,J1),J1=10,11),(TITLE(1,J1),J1=14,26).
1(TITLE(1,J1),J1=48,54),(TITLE(2,J2),J2=13,19),(TITLE(2,J2),J2=26,2DS002370
28),(TITLE(2,J2),J2=44,54),(TITLE(3,J3),J3=13,54) DS002380
9080 FORMAT(1H1,37X,"DISTRICT ",2A1,1X,13A1," COUNTY HIGHWAY NO. ",
238X,'DESCRIPTION '42A1) DS002410

600 FORMAT(1H1) DS002420
  WRITE(6,601) DS002430

601 FORMAT(/'X,1X,129(''*'')) DS002440
  WRITE(6,610) DS002450

610 FORMAT(* **,47X,*BEAM DIMENSIONS AND PROPERTIES*,50X,**)) DS002460
  WRITE(6,602) DS002470

602 FORMAT(1X,129(''*'')) DS002480
  WRITE(6,603) DS002490

603 FORMAT(1X,**,127X,**)) DS002500
  WRITE(6,611) ADIM,BDIM,CDIM,DDIM,EDIM,FDIM,GDIM,HDIM,WHDIM,TDIM, DS002510
  IWDIM,XDIM,YDIM DS002520

611 FORMAT(1X,**,8X,**,44(''*'),* DIMENSIONS IN INCHES ',43(''*'), DS002530
  1**',8X,***/1X,**,127X,***/1X,**,21X,'A',6X,'B',6X,'C',6X,'D', DS002540
  26X,'E',6X,'F',6X,'G',6X,'H',6X,'M',6X,'T',6X,'W',6X,'X',6X,'Y', DS002550
  321X,***/1X,**,19X,13(F5.2,2X),17X,**)) DS002560
  WRITE(6,603) DS002570

613 FORMAT(1X,**,8X,**,14(''*'),*WITOUT SHEAR KEY**),12(''*'),* SECTIDDS02590
  IN PROPERTIES ',17(''*'),*WITH SHEAR KEY'),12(''*'),*8X,***/1X, DS002600
  2**',127X,***/1X,**,14X,2'(IN**4)',5X,'A(IN**2)',5X,'YT(IN)',5X,DS002610
  3*V(IN)',13X),1X,***/1X,**',12X,2(F10.0,6X,F6.1,6X,F5.2,6X,F5.2, DS002620
  413X),1X,**)) DS002630
  WRITE(6,603) DS002640

650 FORMAT(1X,**,4X,*DISTANCE TO ',95X,*DISTANCE FROM ',4X,***/1X,**), DS002650
  17X,'CG OF ',8X,'COMPRESSION',5X,'MAXIMUM',5X,'MINIMUM',17X,'STRAND',DS002670
  2,19X,'CONCRETE',5X,'CENTERLINE OF ',4X,***/1X,**,4X,'COMPRESSION',DS002680
  35X,'REINFORCING',2(5X,'INITIAL'),5X,'STRAND',5X,'ULTIMATE',5X,DS002690
  4,'RELATIVE',7X,'UNIT',10X,'BEAM TO ',7X,***/1X,**,4X,'REINFORCING',DS002700
  56X,'AREA',9X,2'(CAMBER',6X),* AREA',6X,'STRENGTH',5X,'HUMIDITY', DS002710
  66X,'WEIGHT',6X,'HARPELLING POINT',4X,***/1X,**,8X,'(IN)',10X,'(IN**2)DS002720
  7)',2'(8X,'(IN**2)',7X,'(IN**2)',5X,'(KSI)',9X,'(IN)',8X,'(K/Ft**3)', DS002730
  86X,'(FT)',9X,***/1X,**',7X,F5.2,10X,F5.2,6X,9X,'3X',9X,7X,F5.3, DS002740
  97X,F4.0,9X,F3.0,9X,F5.3,10X,F5.2,9X,**)) DS002750
  IF(ALDEF.GT.999..AND.DEFIN.GT.999.) WRITE(6,9401) DEFIN
  IF(ALDEF.LT.999..AND.DEFIN.LT.999.) WRITE(6,9501) ALDEF DS002760
  IF(ALDEF.LT.999..AND.DEFIN.GT.999.) WRITE(6,9601) ALDEF,DEFIN

9401 FORMAT(* **,46X,F9.3) DS002790

9501 FORMAT(* **,34X,F9.3) DS002800
9601 FORMAT('***.34X,F9.3,3X,F9.3)  DS002810
WRITE(6,603)  DS002820
WRITE(6,614) NW,CBOT.GSP.NRAV  DS002830
614 FORMAT('1X,***.58X(',**),1X,'STRAND INFORMATION ,53(',**),**,1X,**, DS002840
1127X,**/1X,**,10X,**,DISTANCE FROM BOTTOM,**,56X,**,NUMBER OF WEB STRADS,002850
26S = '.*J3,14X,**/1X,**,10X,**,OF BEAM TO STRAND ROW = '*F5.2,' DS002860
3' IN. **,8X,**,GRID SPACING = '.*F5.2,' IN. **,9X,**,TOP = MOST GRID ROW, DS002870
43X,** = '.*I3,14X,**/1X,**,127X,**)  DS002880
WRITE(6,651) (J1,J1=1,26), (NTRMX,J1,J1=1,26)  DS002890
651 FORMAT('1X,***,2X,**,ROW NUMBER,**,9X,26I4,2X,**/1X,**,2X,**,MAX. NO. 005002900
1F STRANDS,26I4,2X,**/1X,**,127X,**)  DS002910
WRITE(6,615) CREEP,*SHR1,CR2,CSRt,CSS1,CREEP2,*SHRK2,1CTR2,1CTR1,CTS2,CTS1  DS002920
615 FORMAT('1X,***,17('**),1X,**,ALLOWABLE STRESS COEFFICIENTS ,13('**),1X,**,127X,**/ DS002940
1F CREEP AND SHRINKAGE COEFFICIENTS ,13('**),1X,**,127X,**/ DS002950
21X,**,27X,**,RELEASE ,19X,**,SERVICE ,67X,**/1X,**,21X,**,END 1/10 DS002960
2,3X,**,REMAINDER ,6X,**,CREEP1 = '.*F4.0,8X,**,SHRK1 = '.*F4.0,13X, DS002970
4,**/1X,**,4X,**,COMPRESSION ,8X,2(F4.2,7X,F4.2,11X),6X,**,CREEP2 = '.*F4.2, DS002980
5F4.0,8X,**,SHRK2 = '.*F4.0,13X,**/1X,**,4X,**,TENSION ,12X,2(F4.2, DS002990
67X,F4.2,11X),52X,**/1X,**,127X,**)  DS003000
IF(JOPT.NE.1) GO TO 695  DS003010
WRITE(6,616)  DS003020
616 FORMAT('1X,**,46('**),1X,**,CONCRETE COST COEFFICIENTS ($/YD**3),46('**), DS003030
6,***)  DS003040
WRITE(6,653)(G(I),I=1,8)  DS003050
653 FORMAT('1X,**,46('**),1X,**,CONCRETE COST COEFFICIENTS ($/YD**3),46('**), DS003060
6,***)  DS003070
WRITE(6,654)(G(I),I=9,11)  DS003080
654 FORMAT('1X,**,46('**),1X,**,CONCRETE COST COEFFICIENTS ($/YD**3),46('**), DS003090
6,***)  DS003100
WRITE(6,603)  DS003110
WRITE(6,617)  DS003120
617 FORMAT('1X,**,28('**),1X,**,28 DAY CONCRETE STRENGTH COEFFICIENTS (RELEASE), DS003130
6,***)  DS003140
WRITE(6,655)(F(I),I=1,8)  DS003150
655 FORMAT('1X,**,28('**),1X,**,28 DAY CONCRETE STRENGTH COEFFICIENTS (RELEASE), DS003160
6,***)  DS003170
WRITE(6,656)(F(I),I=9,11)  DS003180
656 FORMAT('1X,**,28('**),1X,**,28 DAY CONCRETE STRENGTH COEFFICIENTS (RELEASE), DS003190
6,***)  DS003200
656 FORMAT(' *8.0KSI/F4.1,*KSI  8.5KSI/F4.1,*KSI  9.0KSI/F4.1,*DS003210
 6KSI,80X,**')  DS003220
 WRITE(6,603)       DS003230
 WRITE(6,657) COSTFT,FPCMAX  DS003240
 657 FORMAT(' **,21X,STRAND COST = $',F4.2,'/FT',21X,'MAXIMUM RELEASE DS003250
 1STRENGTH ALLOWED =',F4.1,' KSI',21X,**')  DS003260
 695 WRITE(6,602)       DS003270
 WRITE(6,9007)       DS003280
 9007 FORMAT('/*1X,129(***)')  DS003290
 WRITE(6,618)       DS003300
 618 FORMAT(' **,53X,BRIDGE PROPERTIES',57X,**)
 WRITE(6,602)       DS003310
 WRITE(6,603)       DS003320
 WRITE(6,603)       DS003330
 WRITE(6,658)ZL   WIDTH,JOINT, TNLB  DS003340
 658 FORMAT(' *SPAN LENGTH = ',F5.1,'(FT)',5X,'BRIDGE WIDTH = ',F5.1,'(DS003350
 $FT)',5X,'NUMBER TRAFFIC LANES = ',12.5X,'NUMBER BEAMS = ',F5.2,'2XDS003360
 *,**')  DS003370
 WRITE(6,602)       DS003380
 WRITE(6,600)       DS003390
 WRITE(6,602)       DS003400
 WRITE(6,619)       DS003410
 619 FORMAT(' **,S2X,LOADING CONDITIONS',57X,**)
 WRITE(6,602)       DS003420
 WRITE(6,603)       DS003430
 WRITE(6,603)       DS003440
 IF(IA.EQ.BLANK).AND.(IE.EQ.BLANK) GO TO 696
 IF(1B.EQ.TWO) WRITE(6,659)IA,DISTF  DS003460
 659 FORMAT(' * AASHTO LL = H',A1,'=',20,'*',7X, 'L',1L, ' DISTRIBUTION FACTOR DS003470
 & = ',F5.3,'(TRUCKS)',62X,**)
 IF(1B.EQ.ONE) WRITE(6,660)IA,DISTF  DS003480
 660 FORMAT(' * AASHTO LL = H',A1,'=',15,'*',7X, 'L',1L, ' DISTRIBUTION FACTOR DS003500
 & = ',F5.3,'(TRUCKS)',62X,**)  DS003490
 WRITE(6,603)       DS003510
 696 IF(JLOAD.NE.1) GO TO 697
 WRITE(6,620)(I,I=1,18)  DS003520
 620 FORMAT(' **,S7(**),AXLE TRAIN',60(**),',**/) AXLE NUMBER ',DS003550
 61816,5X,**)
 WRITE(6,661)(PAXLX(I),I=1,18)  DS003560
 661 FORMAT(' **AXLE LOAD(KIPS)',18F6.1,4X,**)
 WRITE(6,662)(NWHL(I),I=1,17)  DS003570
 WRITE(6,662)  DS003580
 662 FORMAT(' **DISTANCE TO AXLE(FT)',17F4.0,4X,**)  DS003600
WRITE(6,603)
697 IF(JCONC.NE.1) GO TO 698
WRITE(6,621)
621 FORMAT('**45(*',*CONCENTRATED FORCES ON SINGLE BEAM',48(*',*')
       WRITE(6,664)(FCCNC(I),I=1,10)
664 FORMAT(' *LOAD(KIPS )',10F9.1,23X,**)
WRITE(6,665)(DCCNC(I),I=1,10)
665 FORMAT(' *DISTANCE FROM*,114X,**/,'*LEFT SUPPORT(FT) ',*F5.1,6FD5003690
698 IF(ULS5.EQ.0.0) GC TC 699
WRITE(6,602)ULSB
602 FORMAT(' *UNIFORM LOAD ON SINGLE BEAM = ',F5.2,18X,**)
699 CONTINUE
WRITE(6,603)

C***********************************************************************
C**** COMPUTE DESIGN MOMENTS AND SHEARS
C***********************************************************************
DO 8104 J1=1,9
DLMOM(J1)=C.
DLSHR(J1)=0.
ZX=(J1=1)*ZL/10.
IF(J1.EQ.3) ZX=5.*ZL/40.
IF(J1.EQ.4) ZX=2.*ZL/10.
IF(J1.EQ.5) ZX=ZL/4.
IF(J1.GE.6) ZX=(J1=3)*ZL/10.
IF(J1.EQ.9) ZX=ALPHA*ZL
ZMDL=(A CONCK*UWC/144.)*ZX/2.*(ZL=ZX)
IF(J1.EQ.8) ZMBW=ZMDL
ZSDL=(A CONCK*UWC/144.)*(ZL/2.-ZX)
IF(JCONC.NE.1) GO TO 10
SUMM=0.
SUMV=0.
DO 12 J2=1,10
IF(DCONC(J2).EQ.0.0) GO TO 14
R=FCONC(J2)*(ZL=DCONC(J2))/ZL
SUMM=SUMM+R*ZX
SUMV=R
IF(DCONC(J2).GT.ZX+.1) GO TO 10
DO 12
SUMM=SUMM+FCNC(J2)*(ZX-DCONC(J2))
SUMV=SUMV+FCNC(J2)
10 DLMOM(J1)=DLMOM(J1)+SUMM
DLNHR(J1)=CLNHR(J1)+SUMV
12 CONTINUE
14 DLMOM(J1)=DLMOM(J1)+ULSB*ZX/2.*(ZL-ZX)
DLNHR(J1)=CLNHR(J1)+ULSB*(ZL/2.*ZX)
20 OLMM(J1)=OLM(J1)+SUML
OLSHR(J1)=CLSHR(J1)+SUML
24 OLMM(J1)=OLMOM(J1)+ULSB*ZX/2e*(ZL*ZX)
OLSHR(J1)=CLSHR(J1)+ULSB*CZL/2e*ZX)
28 ZMOMJ=0.
ZMOT=0.
ZSHRL=0.
ZSHRT=0.
ZMOMAX=0.
ZSHRAX=0.
ZIMP=1.5+50./(125.+ZL)
IF(ZIMP.GT.1.30) ZIMP=1.30
IF(I2ASHO.EQ.0) GO TO 16
ZMOML=DISTF*ZIMP*ULoad*ZX/2.*(ZL-ZX)
ZSHRL=DISTF*ZIMP*ULoad*(ZL/2.*ZX)
R=CLOAD*(ZL*ZX)/ZL
ZMOML=ZMOML+R*ZX*DISTF*ZIMP
ZSHRL=ZSHRL+R*DISTF*ZIMP
CALL MOMSHR(ZL,NWHL,NAXLE,ZX,NAXLE,ZMOMT,ZSHRT)
ZMOMT=ZMOMT*DISTF*ZIMP
ZSHRT=ZSHRT*DISTF*ZIMP
16 IF(JLOAD.EQ.0) GO TO 18
CALL MOMSHR(ZL,NWHL,NWHEEL,ZX,PAXLE,ZMOMAX,ZSHRAX)
ZMOMAX=ZMOMAX*DISTF
ZSHRAX=ZSHRAX*DISTF
18 BMMAX(J1)=AMAX1(ZMOML, ZMOMT, ZMOMAX)
BVMAX(J1)=AMAX1(ZSHRL, ZSHRT, ZSHRAX)
8104 CONTINUE
ZMAX=0.0
DO 5106 J1=1,S
IF(BMMAX(J1).GT.ZMAX ) ZMAX =BMMAX(J1)
5106 CONTINUE
ZMNC=ABS(ACONCK-ACONC)*UWC*ZL**2/(144.*8.)
ZMC=DLMC(8)
ULTMRQ=1.3*(ZMBW+CLMC(8)+(S./3.)*ZMAX )
C********************************************************************
C**** GENERATE OBJECTIVE FUNCTION AND INITIAL CONSTRAINT SET
C**********************DS00410
ASSCLR=0.05
ASSPLS=0.1
ELASC=1.04355*(1000.*UWC)**1.5
IF(JOPT.EQ.0) GC TO 110
N=48+7*NR
M=12+2*NR
GO TO 112
110 N=29+7*NR
M=3+2*NR
112 KK=M+N-1
K=N+M+1
IF(JOPT.EQ.1) GC TO 108
C
C DEFINE COST CCEFFICIENTS FOR DESIGN OPTION
C
C
COSTFT=100.
G(1)=1944.*COSTFT/(4.0*AONC)
108 CALL EOGEN
C**********************DS004600
C CALL LPCODE FOR INITIAL SOLUTION
C
C
KODE=0
NFRCE=0
NEQS=0
INDX=0
CALL LPCODE(NFRCE,NEQS,INDX,KODE)
C
C ROUND LP SOLUTION FOR INTRODUCTION TO INTEGER ROUTINE
C
C
IF(JOPT.EQ.0) JR=M+1
IF(JOPT.EQ.0) JR=M
DO 402 JI=1,JR
S1=X(I+1-JOPT+J1)
S2=AINT(S1)
IF(S1=S2.*GE.0.5) X(I+1-JOPT+J1)=S2+1
IF(S1=S2.*LT.0.5) X(I+1-JOPT+J1)=S2
402 CONTINUE
C**********************DS004790
C SET UP FOR CALL TO INTEGER ROUTINE
C
C
C***************************~*******************************************DS004810
DXMAX=50. IS=0
IF(JOPT.EQ.0) GC TO 113
NCON=37+6*NR
N1=0
N2=NR+2
N3=NR+1
GO TO 114
113 NCON=28+6*NR
N1=1
N2=NR+2
N3=NR
114 NRA=NCON+1
NCA=N1+N2+N3+1
CALL SQUASH
WRITE(3) BB
REWIND 3
C*****************************************************************************DS004990
C ITERATE ON PRESTRESS LOSS
C*****************************************************************************DS005010
ZSSCLR=ASSCLR ZSSPLS=ASSPLS
700 CONTINUE
CALL INTPRG(KBCMB)
DO 192 J1=1,NC
192 X(J1)=XX(J1)
DO 5130 J1=1,NR
IF(NSTRMX(J1)/2*2.*NE.*NSTRMX(J1)) GC TO 5130
X(1-JOPT+J1)=X(1-JOPT+J1)*2.*
5130 CONTINUE
C
C COMPUTE NEW PRESTRESS LOSSES
C
IF(JOPT.EQ.0) GC TO 708
FPCR=X(1)
GO TO 712
708 FPCR=4.0
DO 710 J1=1,10
710 FPCR=FPCR+0.5*X(2*NR+2+J1)
712 AMOM=0.0
    ASUM=0.0
    DO 706 J1=1,NR
    ASUM=ASUM+AS*X(1=JOPT+J1)
706 AMOM=AMOM+AS*X(1=JOPT+J1)*D(J1)
    DCG=DBOT=AMOM/ASUM
    CALL PLOSS(FPCR,ZMB,ZMC,ZMC,FPS,ASUM,ACNC,BINERT,BINERK,DBOT,
            1DBOTK,DCG,HUM,ZL,ZLSS,ZINLOS,UWC)
C  TERMINATE ITERATIONS IF COMPUTED LONG TERM LOSS DOES
C  NOT EXCEED ASSUMED LOSS BY MORE THAN 3 PERCENT
C  IF(KBOMB.NE.0) GO TO 740
    IF(ZLOSS.LE.1.03*ZSSPLS) GC TO 740
C  UPDATE CONSTRAINTS TO REFLECT NEW PRESTRESS LOSSES
C
    READ(3) BB
    REWIND 3
    FACT1=(1./ZINLOS)/(1./ZSSCLR)
    FACT2=(1./ZLOSS)/(1./ZSSPLS)
    J11=0
    IF(JOPT.EQ.0) NR2=NR*2+3
    IF(JOPT.NE.0) NR2=NR*2+2+10
    DO 9300 J1=1,NR2
    IF(J1.EQ.1=JOPT+NR+1) GO TO 9300
        IA=COL(J1)
        IB=COL(J1+1)-1
        DO 9320 J2=IA,IB
    IF(J1,GE.1=JOPT+2*NR+3) GO TO 9013
        IF(J1,GE.1=JOPT+NR+3) GO TO 9310
C  RELEASE STRESSES
C  IF(ROW(J2).LE.8) Y(J2)=Y(J2)*FACT1
C  SERVICE STRESSES
C  IF(ROW(J2).GT.8.AND.ROW(J2).LE.22) Y(J2)=Y(J2)*FACT2
CRACKING MOMENT CAPACITY

JR=26+6*NR
IF(JOPT.EQ.1) JR=35+6*NR
IF(J11.NE.0) GC TO 724
J11=J11+1
IF(ZLOSS.LE.0.2) I1=1
IF(ZLOSS.LE.0.2) I2=2
IF(0.2.LT.ZLOSS.AND.ZLOSS.LE.0.3) I1=2
IF(0.2.LT.ZLOSS.AND.ZLOSS.LE.0.3) I2=3
IF(ZLOSS.GT.0.3) I1=3
IF(ZLOSS.GT.0.3) I2=4
S1=I1/10.
S2=I2/10.
IF(JOPT.NE.0) GC TO 720
BB(26+6*NR)=((PECRK(J4,12)-PECRK(J4,11))*ZLOSS/0.1-(PECRK(J4,12)*S1
1=PECRK(1,11)*S2)/0.1)
GO TO 726
720 DO 722 J4=1,11
722 ZNE(J4)=(PECRK(J4,12)-PECRK(J4,11))*ZLOSS/0.1-(PECRK(J4,12)*S1
1=PECRK(1,11)*S2)/0.1)
BB(35+6*NR)=ZNE(1)
724 IF(ROW(J2).NE.JR) GC TO 726
IF(J1.LT.1=JOPT+2*NR+3) Y(J2)=Y(J2)*FACT2
IF(J1.LT.1=JOPT+2*NR+3) GC TO 726
IF(JOPT.EQ.0) GC TO 726
Y(J2)=2.*(ZNE(J1=2*NR+2+1)-ZNE(J1=2*NR+2))
726 CONTINUE
IF(J1.GE.1=JOPT+2*NR+3) GC TO 9320

CAMBER CONSTRANTS

JR=32+6*NR
IF(JOPT.EQ.0) JR=23+6*NR
IF(ROW(J2).EQ.JR.OR.ROW(J2).EQ.JR+1) Y(J2)=Y(J2)*FACT1
9320 CONTINUE
9300 CONTINUE
ZSSPLS=ZLOSS
ZSSCLR=ZINLCOS
DO 5140 J1=1,NR
IF(NSTRMX(J1)/2*NE.NSTRMX(J1)) GO TO 5140
X(J=JOPT+J1)=C*5*X(1-JOPT+J1)

5140 CONTINUE
GO TO 700

740 CONTINUE

C******************************************************************************DS006050
C COMPUTE DESIGN RESULTS
C******************************************************************************DS006070
C
C ECCENTRICITIES
C
SUM1=0.0
SUM2=0.0
ISUM1=0
XMOM1=0.0
XMOM2=0.0

DO 9156 J1=1,NR
IF(X(NR+3-JOPT+J1).EQ.1.) ISUMI=ISUMI+1
SUM1=SUM1+X(1-JOPT+J1)
SUM2=SUM2+NW*X(1-JOPT+NR+2+J1)
XMOM1=XMOM1*X(1-JOPT+J1)*D(J1)
XMOM2=XMOM2+NW*X(1-JOPT+NR+2+J1)*D(J1)
9156
EN=X(NR+3-JOPT)
ENI=EN/ISUMI+0.5
DRAP1=AINT(ENI)*GSP
XMOM3=-NW*GSP*X(1-JOPT+NR+2)
IF(XXMOM3.EQ.0.0) XMOM2=0.0
IF(XXMOM3.EQ.0.0) SUM2=0.0
ECCL=XMOM1/SUM1
ENDECC=(XMOM1+XMOM3)/SUM1
SS1=DBOT=(XMOM1+XMOM2)/(SUM1+SUM2)
IF(SUM2.NE.0.0) DS1=DBOT*XMOM2/SUM2
IF(SUM2.NE.0.0) DS2=DBOT=(XMOM2+XMOM3)/SUM2
IF(SUM2.EQ.0.0) DS1=SS1
IF(SUM2.EQ.0.0) DS2=SS1
NSUM1=SUM1
NSUM2=SUM2

C
C 28-DAY CONCRETE STRENGTH

C
IF(JOPT.EQ.0) GC TO 648
F28=F(1) DO 642 J3=2,11
642 F28=F28+(F(J3)=F(J3-1))*X(2*NR+2+J3-1) 648 CONTINUE
C C DEFORMATION CALCULATIONS
ECR=ELASC*SQRT(FPCR)
CBRI=(-22.5*W*ZL**4+(1.+ZINLOS)*F0*ZL**2*(XMOM1/8.+ALPHA**2/6.*1
1XMOM3)*144.)*ECR/BINERT
DEFBWK=(-22.5*WB*ZL**4+(1.+ZLCS)*F0*ZL**2*(XMOM1/8.+ALPHA**2/6.*1
1XMOM3)*144.)/5000./BINERT
DEFCF=0.
IF(JCONC.NE.1) GC TO 2445
DO 2444 JN=1,10
ZBX1=ZL=DCNC(JN) ZBX2=DCNC(JN)
ZBX=AMIN1(ZBX1,ZBX2)*12.
2444 DEFCF=DEFCF+FCONC(JN)*ZBX*(3.*ZL**2*144.+.4.*ZBX**2)/48.
2445 CONTINUE
DEFBWU=-22.5*(WB+ULSB)*ZL**4+(1.+ZLOSS)*F0*ZL**2*(XMOM1/8.+1
ALPHA**2/6.*XMOM3)*144.-DEFCF)/5000./EINERT
C LONG TERM CAMBER
EC=ELASC*SQRT(F28)/1.E+03
ES=29.
FP=F0*1000.
UWB=UWC*1000.
CALL CAMBER(ES,EC,AS,SUM1,UWB,AONC,ZL,ECCL,BINERT,FP,ENOECC.
1PRLMAX,CBRMAX,HDP1)
C C ULTIMATE AND CRACKING MOMENT CALCULATIONS
DD=DTOP+ECCL
AREA=SUM1*AS
CALL ULTMAP(AREA,F28,FPS,APRIME,FPL,DD,DDIM,FSY,DCR.
1Y1,Y2,Y3,Y4,Z1,Z2,Z3,Z4,ZMUL)
SUM8=0.C
DO 9155 J1=1,1)
9155 SUM8=SUM8+(1./ACCNC=D(J1)/ZB)*X(1-JOPT+J1)
ZCRACK = ((1.0*ZLOSS)*ZBK*FO*SUM8+7.5*ZBK*0.031623*SQR(F28))

1-W*ZL**2/8.*12.*ZBK/ZB)/12.

STIRRUP SPACING

WEB=2.*WDDIM

IF(SUM2.EQ.0.0) PFORCE=0.0

IF(SUM2.NE.0.0) PFORCE=-XMOM3/SUM2/(ALPHA*ZL*12.)*FO*(1.0-ZLOSS)

DO 8103 J1=1,9

ZX=(J1=1)*ZL/10.

IF(J1.EQ.3) ZX=5.0*ZL/40.

IF(J1.EQ.4) ZX=2.0*ZL/10.

IF(J1.EQ.5) ZX=ZL/4.

IF(J1.GE.6) ZX=(J1-3)*ZL/10.

IF(J1.EQ.9) ZX=ALPHA*ZL

VU(J1)=1.444*(W*(ZL/2.)*ZX)+DLSHR(J1)+5.0/3.+BVMAX(J1)=PFORCE

TAU=(ALPHA*ZX/ZL)/ALPHA

IF(TAU.LT.0.0) TAU=0.0

DISTCG=OTOP+(XMOM1+TAU*XMCM3)/SUM1

CALL SHEAR(WEB,WDDIM,DISTCG,F28,FSY,ASTIRP,VU(J1),SPACE)

8103 CONTINUE

C

C COST AND MATERIAL REQUIREMENTS OF BEAM

IF(JOPT.EQ.0) GO TO 9183

CONCV=ACONV/144.*ZL/27.

STRFT=SUM1*ZL

COSTC=G(I)

DO 434 J1=1,10

COSTC=COSTC+(G(J1+1)-G(J1))*X(1-JOPT+2*NR+2+J1)

434 CONTINUE

435 CSTCON=COSTC*CONCV

CSTSTR=STRFT*COSTFT

CSTTOT=CSTCON+CSTSTR

CPRCST=CSTCCN/CSTTOT*100.

SPRCCST=CSTSTR/CSTTOT*100.

CSTPFT=CSTTOT/ZL

9183 CONTINUE
C** PRINT CUT RESULTS
C**************************************************************DS007200
WRITE(6,600) DS007210
IF(KBOM.B.EQ.0) WRITE(6,70) DS007211
70 FORMAT(50X,32('**'),/,'50X,**SORRY, THIS BEAM WILL NOT WORK**',/,'50X,** DS007212
*32(**))
IF(JOPT.EQ.0) WRITE(6,622) DS007214
622 FORMAT(,'**',47X,'THE COMMAND IS TO SELECT STRANDS',48X,**)) DS007220
IF(JOPT.EQ.1) WRITE(6,623) DS007230
623 FORMAT(,'**',50X,'THE COMMAND IS TO OPTIMIZE',51X,**)) DS007250
WRITE(6,601) DS007260
WRITE(6,624) DS007270
624 FORMAT(,'**',54X,'DESIGN PROPERTIES',56X,**)) DS007280
WRITE(6,602) DS007290
WRITE(6,625) DS007300
ZLS=ZLOSS*J00 \ ZINL=ZINLOS*100. 
WRITE(6,625) FPCR*ECR*ZINL*F28,ZLS DS007320 
WRITE(6,625) FPCR*ECR*ZINL*F28,ZLS DS007330 
625 FORMAT(,'**',4X,'RELEASE STRENGTH = ',F5.2,** (KSI)**,4X,**CONCRETE MDS007340 1ODULUS(RELEASE) = ',F7.1,** (KSI)**,4X,**INITIAL PRESTRESS LOSS = ',DS007350 2F5.2,** PERCENT**4X,**/*,**4X,**28-DAY STRENGTH = ',F5.2,** (KSI)**DS007360 3**50X,**TOTAL PRESTRESS LOSS = ',F5.2,** PERCENT**4X,**/*)) DS007370 
WRITE(6,602) DS007380
WRITE(6,601) DS007390
WRITE(6,628) DS007400 
628 FORMAT(,'**',56X,**DESIGN RESULTS',57X,**)) DS007410
WRITE(6,602) DS007420
WRITE(6,603) DS007430
WRITE(6,629) DS007440
629 FORMAT(,'**',56(****),**STRAND LAYOUT',58(****),**)) DS007450
WRITE(6,603) DS007460
WRITE(6,9157) DS007470 
9157 FORMAT(1X,**,**51X,**(DISTANCE FROM',12X),26X,**/1X,**,**34X, DS007480 1*LOCATION',5X,**(BOTTOM OF BEAM TO C.G.',3X),30X,**/1X,**,**49X, CS007490 2**OF DRAPE STRANDS',7X,**OF STRAIGHT STRANDS',35X,**/1X,**,**127X, DS007500 3**/1X,**,**33X,**END OF BEAM',10X,**(F6.2,20X),21X,**/*) DS007510
31X,**,**33X,**CENTERLINE **10X,**(F6.2,20X),21X,**/*1X,**,**127X, DS007520
4**/1X,**,**45X,**TOTAL NUMBER OF STRANDS',7X,**/13,47X,**/* DS007530
51X,**,**45X,**NUMBER OF DRAPE STRANDS',6X,**/13,47X,**/*) DS007540
DO 9159 J1=1,NR CS007550
J2=NR+1-J1
INTX=X(1=JOPT+NR+1-J1)
9159 WRITE(6,9160) J2, INTX
9160 FORMAT(1X, 'NUMBER OF STRANDS IN ROW ', I3, ' = ', I4, 47X, '***')
9161 FORMAT(1X, 'AT THE END OF THE BEAM, BEGINNING WITH ROW ', I3, ' 2X, ***)
9162 FORMAT(1X, 'STIRRUP SPACING = AASHTO 1973 - STIRRUP AREAS
9077 FORMAT(' 1 = ',F4.2, ' IN', I2, ' 35', F4.2, ' 127X, ***', /)
C STIRRUP SPACING OUTPUT
WRITE(6,603)
WRITE(6,9077) ASTIRP, (STRSP(J4), J4=1, 5)
C COST DATA PRINTOUT
IF(JOPT.EQ.0) WRITE(6,603)
IF(JOPT.EQ.0) GO TO 9020
WRITE(f,6C3)
WRITE(6,670)
9077 FORMAT(' 1 = ',F4.2, ' IN', I2, ' 35F4.2, '127X, ***', /)
C COST DATA PRINTOUT
IF(JOPT.EQ.0) WRITE(6,603)
IF(JOPT.EQ.0) GO TO 9020
WRITE(f,6C3)
WRITE(6,670)
C IF(JOPT.EQ.0) WRITE(6,603)
C IF(JOPT.EQ.0) GO TO 9020
WRITE(f,6C3)
WRITE(6,670)
C IF(JOPT.EQ.0) WRITE(6,603)
C IF(JOPT.EQ.0) GO TO 9020
WRITE(f,6C3)
WRITE(6,670)
C IF(JOPT.EQ.0) WRITE(6,603)
C IF(JOPT.EQ.0) GO TO 9020
WRITE(f,6C3)
WRITE(6,670)
C IF(JOPT.EQ.0) WRITE(6,603)
C IF(JOPT.EQ.0) GO TO 9020
WRITE(f,6C3)
WRITE(6,670)
670 FORMAT(1X,'*','44(*')*,COST AND MATERIAL REQUIREMENTS OF BEAM*), DS007960
*5(*'),***)
WRITE(6,603)   DS007970
WRITE(6,671)   DS007990
671 FORMAT(1X,***,8X,ITEM*,15X,AMOUNT*,12X,COST*,8X,PERCENTAGE OF
1TOTAL COST*,6X.*,39X,***)
WRITE(6,672) CSTTOT   DS008000
672 FORMAT(1X,***,87X,***,7X,TOTAL COST OF BEAM $ *,F8.2,2X,***)   DS008030
WRITE(6,673) CONCV,CSTCON,CPRCST  DS008040
673 FORMAT(1X,***,6X,CONCRETE*,9X,F7.2,* YD**3*,5X,*$,F8.2,14X,F5.2,DS008050
1*,%*,15X,***,39X,***)
WRITE(6,674) STRFT,CSTSTR,SPRCST,CSTPFT   DS008060
674 FORMAT(1X,***,7X,STRANDS*,10X,F7.2,  FT*,8X,*$,F8.2,14X,F5.2,* XDS008080
1*,15X,***,7X,CST PER FOOT $ *,F8.2,2X,***)  DS008090
WRITE(6,676)   DS008100
676 FORMAT(1X,***,127X,***/1X,***,5X,*DOES NOT INCLUDE END SECTION*), DS008110
*3X,***)
9020 WRITE(6,602)   DS008120
C**************************************************************************DS008140
C  COMPUTE AND PRINTOUT CRITICAL DESIGN FACTORS
C**************************************************************************DS008150
WRITE(6,600)   DS008170
DO 800 J1=1,9
DO 800 J2=1,5
800 KSYM(J1,J2)=EX(1)
WRITE(6,662)   DS008190
WRITE(6,6810)   DS008200
WRITE(6,610)   DS008210
810 FORMAT(1X,***,52X,'CRITICAL DESIGN FACTORS*',52X,***)   DS008220
WRITE(6,602)   DS008230
WRITE(6,603)   DS008240
WRITE(6,6811)   DS008250
WRITE(6,6812)   DS008260
811 FORMAT(' **','23(*'),RELEASE STRESSES*',24(*'),**',21(*'),SERVICDS008270
1E LOAD STRESSES*',21(*'),**'/ **',12X,'(SYMBOL X DENOTES STRESS AT DS008280
2 ALLOWABLE)*',13X,***,13X,'(SYMBOL X DENOTES STRESS AT ALLOWABLE)*',DS008290
312X,***/ **',63X,***,63X,***)  DS008300
WRITE(6,6812)   DS008310
812 FORMAT(' **',2X,'SFCTION **',7X,'STRESS TOP*',8X,**',6X,'STRESS BOTTDS008320
10M*6X,**',2X,'SECTION **',7X,'STRESS TOP*',8X,**',6X,'STRESS BOTTDS008330
2M*6X,**',11X,***,9X,'(KSI)*',11X,***,10X,'(KSI)*',10X,**',11X,DS008340
3**,9X,'(KSI)*',11X,***,10X,'(KSI)*',10X,**'/ **',11X,***,25X,**',25DS008350
4X•'*' ,tlX, '*' t25X •'
DO 8 1 0 1

*'

.25)(9

1

*')

J 1 = t • c;;

ZX=(Jl•l l*ZL/10.
IF(JleE0.3) ZX=5•*ZL/40.
1 F ( J 1 • E Q • 4 ) Z X= 2 • *Z L / 1 0 •
IF(Jt.EQ.S) ZX=ZL/4.
IF(JleGEe6) Z~=(Jl•3)*ZL/t0.
tF(Jl .E0.9) ZX=ALPHA*ZL
ZMJ=W*ZX/2•*(ZL•ZX)*12•
ZMJB~WB*ZX/2e$(ZL-ZXl*l2e

Z ~JBK= DL~C~ ( J 1) *12 • +BMMAX ( J 1)
TAU= ( ALPHA•ZX/ZL) /ALPHA
IF(TAUeLTeCeO) TAU=O.O

* 12 •

SUM l 0= 0 • 0 .

SUM20=0 .0
oo a·o4 J3=t. NR
SUM10=5UM10+(1~/ACONC+0(~3)/ZT)*X(J3+t-JOPT)

804 SUM20=5UM20+(le/ACONC•O(J3)/Z8)*X(J3+1-JOPT)

N

TERM1=SUM1C+N•*TAU/ZT*GSP*X(3•JOPT+NR)

(X)

\.0

TERM2=SUM20•NW*T~U/ZB*GSP*X(3~JOPT+NR)

5TRESS(Jl.t)::(•(le•ZINL05)*FO*TERM1-ZM.J/ZT)*(•le)
5TRESSCJt.2l=(•(le-ZINLOSl*FO*TERM2+Z~J/ZB)*(•l.)

STRESS1.Jt.3)=(•{1.-ZLOSS)*FO*TERMl•ZMJ/ZT-ZMJBK/ZTK)*(-1.)
STRESS(Jt.4):(•(t.-ZLC5S1*FC*TE~~2+ZMJ/ZB+ZMJSK/ZBKl*(•l•)

5TR:CTR 1

SCR!:::CBRt
S TS=C T51

SC5=CBS 1
IF(ZX.LE.ZL/10e+O.t)
IF(ZX.LEeZL/lOe+Oel)
tF(ZXeLEeZL/10.+0.1)
IF(ZX.LEeZL/tO.+Oe1)

c
c

STR=CTR2

SCR=CBR2
STS=CTS2
SCS=CBS2

050 083.60
05008370
05008380
05008390
05008400
05008410
05008420
050084 30
05008440
050 1)8450
05008460
050084 70
05008480
05008490
0500 8500
05008510
05008520
05008530
05008540
05008550
05008560
05008570
05008580
05008590
05008600
05008610
05008620
05008630
05008640
05008650
05008660
05008670

IF STRESS WITHIN 1 PERCENT OF ALLOWABLE. CALL IT CRITICAL•

c

05008680
05008690
05008700

IF(STRESS(Jlel)eLE.-.00099*STR*SORT(FPCR*l000.)} KSYM(Jlel)=EX(2}
IF(STRES5{Jt.2l.GE •• 99*5CR*FPCR) KSYM(J1~2)=EX(2)
IF(STRE5S(J1,3)eGE •• 99*SCS*F28) KSYM{J1.3):EX(2)
I F ( 5T R E S S ( J 1 • 4 ) • L E • • • 0 0 0 9 g S T S * S OR T ( F 2 B* 1 0 0 0 • ) ) K S Y M( J 1 • 4 ) =EX ( 2 )
IF(JleNEel) GO TO 9053

*

- -J--- -·-- -'-

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05008710
05008720

05008730
DS 0 0 8 7 4 0
05008750

-'--- -)--


IF(STRESS(1,3).LE.0.00099*ST*SQR(F28*1000.)) KSYM(1,3)=EX(2)
IF(STRESS(1,4).GE.99*SCS*F28) KSYM(1,4)=EX(2)
9053 CONTINUE
IF(BB(NCON+J1+1).LE.0.0) KSYM(J1,5)=EX(2)
J5=(ZX*t0.1+Oe001)/ZL
IF(J5.LE.0e03) WRITE(6,9110) STRESS(J1,1),KSYM(J1,1),STRESS(J1,2),KSYM(J1,2),STRESS(J1,3),KSYM(J1,3),STRESS(J1,4),KSYM(J1,4)
1KSYM(J1,2),STRESS(J1,3),KSYM(J1,3),STRESS(J1,4),KSYM(J1,4)
IF(J5.LE.99) WRITE(6,9111) STRESS(J1,1),KSYM(J1,1),STRESS(J1,2),KSYM(J1,2),STRESS(J1,3),KSYM(J1,3),STRESS(J1,4),KSYM(J1,4)
1KSYM(J1,2),STRESS(J1,3),KSYM(J1,3),STRESS(J1,4),KSYM(J1,4)
IF(J5.LE.3) AND(J1.LE.5) AND(J1.LE.9) WRITE(6,9112) J5,STRESS(J1,1),STRESS(J1,2),STRESS(J1,3),STRESS(J1,4)
2STRESS(J1,4),KSYM(J1,4)
8101 CONTINUE
9110 FORMAT(1X,'**',4X,'/40(4X,A1,4X,**),4X,
1*5/40,4X,**),2(6X,E11,4,3X,A1,4X,**))
9111 FORMAT(1X,'**',4X,'*HDPT',3X,**),2(6X,E11,4,3X,A1,4X,**))
9113 FORMAT(1X,'**',4X,'/4',3X,**),2(6X,E11,4,3X,A1,4X,**))
9112 FORMAT(1X,'**',4X,'/10',3X,**),2(6X,E11,4,3X,A1,4X,**))
814 FORMAT('**',11X,**,25X,**,25X,**,11X,**,25X,**,25X,**,**/**,**,
111,**/10*,3X,**,2(6X,E11,4,3X,A1,4X,**))
WRITE(6,814)
WRITE(6,803)
WRITE(6,822)
822 FORMAT(1X,'**',50(4X)'LIST OF DESIGN CONSTRAINTS',51(4X)**//2*X,DOS09050
1**.37X.'(SYMBOL X INDICATES CONSTRAINT CONTROLS FINAL DESIGN)*',
237X.'**)
WRITE(6,703)
WRITE(6,703)
IF(CBR1.**.50) KSYM(6,5)=EX(2)
1MOMENT**.3X,A1,11X,'MINIMUM INITIAL CAMBER',3X,A1,15X,**/1X,**,
216X,'MAXIMUM CONCRETE STRENGTH',3X,A1,11X,'CRACKING MOMENT',3X,A1,DOS09130
3 MAXIMUM INITIAL CAMBER, 3X, A1, 15X, *"
WRITE(6, 603)
WRITE(6, 602)

C***************************************************************************

RECALCULATE AND PRINTOUT DESIGN SHEARS AND MOMENTS

C***************************************************************************

WRITE(6, 603)
WRITE(6, 602)
WRITE(6, 9041)

9041 FORMAT(1X, '*', 51X, 'MOMENT AND SHEAR SUMMARY', 52X, '*')
WRITE(6, 603)
WRITE(6, 603)
WRITE(6, 9042)

9042 FORMAT(1X, '*', 2X, 'DISTANCE FROM', 2X, '*', BM, WT, ' + SHEAR KEY ',
1X, 6X, 'OTHER D, L, 5X, 9X, L, 8X, TOTAL, 8X, 7X, 000DR
2X, ULTIMATE, 6X, 1X, 3X, END OF BEAM, 3X, 4 (7X, MOMENTS)
37X, 4 (7X, MOMENTS, 8X, 8X, 1X, 6X, 7X, 4 (7X, (KIP=FT), 000DR
46X, 4 (KIP), 8X, 8X, 1X, 17X, 5 (21X, '))

DO 8102 J1 = 1, 9
ZX = (J1 = 1) * ZL / 10.
IF (J1 .EQ. 3) ZX = 5. * ZL / 40.
IF (J1 .EQ. 4) ZX = 2. * ZL / 10.
IF (J1 .EQ. 5) ZX = ZL / 4.
IF (J1 .EQ. 6) ZX = (J1 = 3) * ZL / 10.
IF (J1 .EQ. 9) ZX = ALPHAL * ZL.
ZMJB = WB * ZX / 2. (*ZL = ZX)
ZMJT = ZMJB + DLMOM(J1) + BMMAX(J1)
VU(J1) = 1.444 * (WB * (ZL / 2. = ZX) + DLSHR(J1) + 5/3. * BMVMAX(J1))
IF (J1 .NE. 9) WRITE(6, 9043) ZX, ZMJB, DLMOM(J1), BMMAX(J1), ZMJT, VU(J1)
IF (J1 .EQ. 9) WRITE(6, 9047) CONTINUE

8102 FORMAT(1X, '*', 6X, F5.2, 6X, 5 (4X, E12.5, 5X, *))
9043 FORMAT(1X, '*', 5X, HDPT, 7X, 5 (4X, E12.5, 5X, *))
WRITE(6, 603)
WRITE(6, 9044) ULTMRC, ZMUL, ZCRACK
9044 FORMAT(1X, '*', 42X, 'ULTIMATE MOMENT REQUIRED = ', E12.5, ' KIP=FT', 39 DS009500
1X, '*', 1X, '*', 42X, 'ULTIMATE MOMENT CAPACITY = ', E12.5, ' KIP=FT', 35 DS009510
2X, '*', 1X, '*', 42X, 'CRACKING MOMENT CAPACITY = ', E12.5, ' KIP=FT', 39 DS009520
3'**)

DS009140
DS009150
DS009160
DS009170
DS009180
DS009190
DS009200
DS009210
DS009220
DS009230
DS009240
DS009250
DS009260
DS009270
DS009280
DS009290
DS009300
DS009310
DS009320
DS009330
DS009340
DS009350
DS009360
DS009370
DS009380
DS009390
DS009400
DS009410
DS009420
DS009430
DS009440
DS009450
DS009460
DS009470
DS009480
DS009490
DS009500
DS009510
DS009520
DS009530
WRITE(6,603)
WRITE(6,602)
WRITE(6,641)
641 FORMAT(1H1)
NCOUNT=NCOUNT+1
GO TO 3007
2500 CONTINUE
STOP
END
SUBROUTINE EGGEN
COMMON/BLK1/ADI~,ED1~,CDI~,OOGM•EDIM.F01~.~DI~,HDIM.TDIM.WDDIM,
1WDB0K.ZTK.ZDK.ZL.F28.JOPT.ASCLR.ASPLS.APRIME.CBOT.COSTFT,
3DEFMIN.ALDEF.NRAW.NWHEEL.DISTF.FPCMAX.FPCMIN.ELASC.ULTRQ.0TOP,
4W,WB,FO.OCR.NR.HDPT.NW.0LPHA
COMMON/BLK2/PAXLE(18),NWHL(18),STRMAX(26),FCONC(10),DCONC(10),
1G(l),F(l),G(l),BMAX(9),BM2AX(9),CBRMX(5),PRLMX(5),DLMOM(9),
2DLHMR(l),PECRK(11,4),ZLOS(4)
COMMON/DEFINE/ UWC,HUM,AS,FP5,CTR1,CTR2,CSR1,CSR2,CTS1,CTS2,
1CBS1,CBS2,CREEP1,CREEP2,SHRK1,SHRK2,RATNOD,FPL,FSY,ASTIRP,GSP
COMMON/YZ/Zl,Z2,Z3,Z4,Yl,Y2,Y3,Y4
COMMON/D31/N,M,OBJS,PKP,K,NCON,NC,NRA,KCA,K1,K2,K3,N3,DXMAX.IS,TV,TR,
1SUM.IGNOR.IT(4),JCONT.X(150),ARRAY(118,150),0(150)
COMMON/0UMP/ TITLE(3,54),YJ(11),FROW(26),
1PEF(50,3),ZNE(11),KODE(4),ZMCR(4)
FO=0.7*AS*FPS
W=UWC*ACONC/144.
WB=UWC*ACONCK/144.
JRR=48+7*NR
JCC=12+2*NR
IF(JOPT.EQ.1) JRR=29+7*NR
IF(JOPT.EQ.1) JCC=3+2*NR
DO 2 J1=1,JRR
2 ARRAY(J1,K+1)=0.0
DO 2 J2=1,JCC
2 ARRAY(J1,J2)=0.0
C***********************************************************************DS009630
COBJECTIVE FUNCTION
C***********************************************************************DS009640
IF(JOPT.EQ.1) GO TO 3
ARRAY(1,1)=G(1)*ACONC*ZL/1944.
ARRAY(1,1+NR+2)=0.1*G(1)*ACONC*ZL/1944.
DO 5 J1=1,NR
5 ARRAY(1,J1+1)=COSTFT*ZL
GO TO 8
3 DO 4 J1=1,NR
4 ARRAY(1,J1)=COSTFT*ZL
C
CPUT IN TOKEN COST FCR DRAPING.
C
C
`C

ARRAY(1, NR+2) = (CCSTFT*ZL/NR*NRAV) * 0.1
DO 6 J1 = 1, 10
6 ARRAY(1, 2*NR+2+J1) = ACONC*ZL/1944.*(G(J1+1) = G(J1))
8 CONTINUE
DO 1 J1 = 1, M
1 ARRAY(1, J1) = ARRAY(1, J1)
C******************************************************************************DS010030
C RELEASE STRESSES = CONSTRAINTS 1 THRU 8******************************************************************************DS010100
C******************************************************************************DS010120
DO 10 J1 = 2, 9, 2
IF(J1.EQ.2) ZX = ALPHA*ZL
IF(J1.EQ.4) ZX = 5.*ZL/40.
IF(J1.EQ.6) ZX = ZL/10.
IF(J1.EQ.8) ZX = 0.0
IF(J1.EQ.2) TAU = 0.
IF(J1.EQ.4) TAU = (ALPHA*0.125)/ALPHA
IF(J1.EQ.6) TAU = (ALPHA*0.1)/ALPHA
IF(J1.EQ.8) TAU = 1.0
IF(TAU.LE.0.0) TAU = 0.0
ST = CTR1
SC = CBR1
IF(ZX.LE.ZL/10.*0.1) ST = CTR2
IF(ZX.LE.ZL/10.*0.1) SC = CBR2
DO 12 J2 = 1, NR
ARRAY(J1, 1+JOPT+J2) = (1. - ASSCLR)*FO*(1./ACONC+D(J2)/ZT)
12 ARRAY(J1+1, 1+JOPT+J2) = (1. - ASSCLR)*FC*(1./ACONC+D(J2)/ZB)
ARRAY(J1, 1+JOPT+NR+2) = (1. - ASSCLR)*FO*NW/ZT*TAU*GSP
ARRAY(J1+1, 1+JOPT+NR+2) = (1. - ASSCLR)*FO*NW/ZB*TAU*GSP
IF(JOPT.EQ.0) GC TO 9
DO 14 J2 = 1, 10
ARRAY(J1, 2*NR+2+J2) = 0.003727*ST
14 ARRAY(J1+1, 2*NR+2+J2) = 0.50*SC
ARRAY(J1, K+1) = 0.5C*W*ZX*(ZL-ZX)*12./ZT+0.063366*ST
ARRAY(J1+1, K+1) = 0.5C*W*ZX*(ZL-ZX)*12./ZB+4.0*SC
GO TO 10
9 ARRAY(J1, 1) = 0.0074535*ST
ARRAY(J1+1, 1) = SC
ARRAY(J1, K+1) = 0.5C*W*ZX*(ZL-ZX)*12./ZT+0.033552*ST
ARRAY(J1+1, K+1) = 0.50*W*ZX*(ZL-ZX)*12./ZB
GO TO 100
C******************************************************************************DS010030
C******************************************************************************DS010100`
C SERVICE LOAD STRESSES = CONSTRAINTS 9 TRU 22
C***********************************************************************DS010460
C POINTS 1, 2, 3, 4, AND 5 TENTHS; AND 5L/40
DO 18 J1=1, 6
JR=8+2*J1
TAU=(ALPHA=J1/10.)/ALPHA
IF(J1.EQ.6) TAU=(ALPHA=0.125)/ALPHA
IF(TAU.LT.0.0) TAU=0.0
ZX=J1/10.*ZL
IF(J1.EQ.6) ZX=5.*ZL/40.
ZMJ=0.5*WE*ZX*(ZL-ZX)*12.
ZMJJB=BMMA(1+2)*12.+DLMMOM(1+2)*12.
IF(J1.EQ.1) ZMJJB=BMMA(2)*12.+DLMMOM(2)*12.
IF(J1.EQ.2) ZMJJB=BMMA(3)*12.+DLMMOM(3)*12.
ST=CTS1
SC=CBS1
IF(ZX.LE.ZL/10.+0.1) ST=CTS2
IF(ZX.LE.ZL/10.+0.1) SC=CBS2
DO 20 J2=1, NR
ARRAY(JR+2,J1+10+J2)=(1.-ASSPLS)*FO*(1./ACONC+D(J2)/ZT)
20 ARRAY(JR,J1+10+J2)=(1.-ASSPLS)*FO*(1./ACONC+D(J2)/ZB)
ARRAY(JR+1,J1+10+NR+2)=(1.-ASSPLS)*FO*NW/ZT*TAU*GSP
ARRAY(JR+1,J1+10+NR+2)=(1.-ASSPLS)*FO*NW/ZB*TAU*GSP
IF(JOPT.EQ.0) GO TO 81
DO 22 J2=1, 10
ARRAY(JR+2*NR+2+J2)=SC*(F(J2+1)-F(J2))
22 ARRAY(JR+2+NR+2+J2)=0.0074535*ST*(F(J2+1)-F(J2))
ARRAY(JR+1,K+1)=ZMJ/ZE=ZMJJB/ZBK*0.0074535*ST*F(1)+0.033552*ST
GO TO 18
21 ARRAY(JR+1+K+1)=ZMJ/ZE=ZMJJB/ZBK+0.031623*ST*SQRT(F28)
ARRAY(JR+1+K+1)=ZMJ/ZE=ZMJJB/ZBK+0.031623*ST*SQRT(F28)
GO TO 21
18 CONTINUE
C ENDS OF THE BEAM
DO 24 J2=1, NR
ARRAY(22+1,J1+OPT+J2)=(1.-ASSPLS)*FO*(1./ACONC+D(J2)/ZT)
24 ARRAY(23+1,J1+OPT+J2)=(1.-ASSPLS)*FC*(1./ACONC+D(J2)/ZB)
GO TO 18
ARRAY(23,1-JOPT+NR+2)=(1.-ASSPLS)*F0*NW/ZB*GSP
IF(JOPT.EQ.0) GO TO 25
DO 23 J2=1,10
ARRAY(22,2*NR+2)=0.0074535*CTS2*(F(J2+1)=F(J2))
23 ARRAY(23,2*NR+2)=CBS2*(F(J2+1)=F(J2))
ARRAY(22,K+1)=0.0074535*CTS2*F(1)+0.033552*CTS2
ARRAY(23,K+1)=CBS2*F(1)
GO TO 27
25 ARRAY(22,K+1)=0.031623*CTS2*SQRT(F28)
ARRAY(23,K+1)=CBS2*F28
27 CONTINUE
C***********************************************************************DS010940
C SUFFICIENT NUMBER OF STRANDS IN ROW FOR DRAPPING
C CONSTRAINTS 23 THRU 22 + NR
C***********************************************************************DS010970
DO 26 J1=1,NR
ARRAY(23+J1,1-JOPT+J1)=1.
26 ARRAY(23+J1,1-JCPT+2+NR+J1)=NW
C***********************************************************************DS011010
C CONTIGUOUS DRAPED STRANDS
C CONSTRAINTS 23 + NR THRU 21 + 2*NR
C***********************************************************************DS011040
DO 28 J1=2,NR
ARRAY(23+NR+J1=1,1-JCPT+NR+2+J1)=J1=1.
ARRAY(23+NR+J1=1,1-JOPT+NR+2+J1)=J1=1.
28 ARRAY(23+NR+J1=1,1-JOPT+NR+1)=J1=1.
C***********************************************************************DS011090
C UPPER BOUND ON EN
C CONSTRAINTS 22 + 2*NR THRU 21 + 3*NR
C***********************************************************************DS011120
DO 30 J1=1,NR
ARRAY(22+2*NR+J1=1-JOPT+NR+2)=1.
ARRAY(22+2*NR+J1=1-JOPT+NR+1)=J1
ARRAY(22+2*NR+J1+1,K+1)=(J1+1)**2+J2*(J1=1)+1.
30 ARRAY(22+2*NR+J1=1-JOPT+NR+2+J2)=NRAV=2.*(J1=1=1)=1.
C***********************************************************************DS011190
C UPPER AND LOWER BOUNDS ON NB
C CONSTRAINTS 22+3*NR AND 23+3*NR
C***********************************************************************DS011220
ARRAY(23+3*NR, 1=JOPT+NR+1) = 1.
ARRAY(23+3*NR, K=1) = NR
ARRAY(24+3*NR, 1=JOPT+NR+1) = 1.
ARRAY(24+3*NR, K=1) = -1.

C**************************************************************************DS011230
C CONSTRAINTS TO INSURE THAT IF (NBGEI+1) THEN II = 0
C CONSTRAINTS 24 + 3*NR THRU 22 + 4*NR
C**************************************************************************DS011240

DO 32 J1 = 2*NR
ARRAY(24+3*NR+J1=1,1=JOPT+NR+1) = 1.
ARRAY(24+3*NR+J1=1,1=JOPT+NR+2+J1=1) = NR

32 ARRAY(24+3*NR+J1=1,K+1)=NR+J1=1.

C**************************************************************************DS011250
C CONSTRAINTS TO INSURE THAT IF (NBEQI) THEN II = 1
C CONSTRAINTS 23 + 4*NR THRU 22 + 5*NR
C**************************************************************************DS011260

DO 34 J1 = 2*NR
ARRAY(23+4*NR+J1=1,1=JOPT+NR+2+J1=1) = -(J1+1.)

34 CONTINUE

C**************************************************************************DS011270
C MAXIMUM NUMBER OF STRANDS PER ROW
C CONSTRAINTS 23 + 5*NR THRU 22 + 6*NR
C**************************************************************************DS011280

DO 38 J1 = 1*NR
ARRAY(23+5*NR+J1,1=JCPT+J1) = 1.
ARRAY(23+5*NR+J1,K+1)=STRMAX(J1)

38 ARRAY(23+5*NR+J1,1=JCPT+J1) = 1.

C**************************************************************************DS011290
C CONSTRAINTS TO INSURE PROPER RELEASE STRENGTH REPRESENTATION
C JOPT = 1, CONSTRAINTS 23 + 6*NR THRU 31 + 6*NR
C**************************************************************************DS011300

IF(JOPT.EQ.0) GO TO 39
DO 40 J1 = 1*9
ARRAY(23+6*NR+J1,2*NR+2+J1) = -1.

40 ARRAY(23+6*NR+J1,2*NR+2+J1+1) = 1.
**BOUNDS ON RELEASE CAMBER**

**JOPT = 0, CCNSRAINTS 23 + 6*NR THRU 24 + 6*NR**

**JOPT = 1, CCNSRAINTS 32+6*NR THRU 33+6*NR**

---

**C***********************************************************************DS011630**

**39 IF (JOPT .EQ. 0) JR = 24+6*NR**

**IF (JOPT .NE. 0) JR = 33+6*NR**

**DO 42 J1 = 1, NR**

**ARRAY (JR, J1) = (ZL*12.)**2/8.*((1.+ASSCLR)*FO*D(J1)**2/6.*((1.+ASSCLR)*FO*NW*GSP**

**42 ARRAY (JR+1, J1) = (ALPHA*ZL*12.)*2/6.*((1.+ASSCLR)*FO*NW*GSP**

**DS011650**

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**C***********************************************************************DS011670**

**40 IF (JOPT .EQ. 0) GO TO 41**

**DO 44 J1 = 1, NR**

**ARRAY (JR, 2*NR+2+J1) = 0.117634*BINERT*ELASC*ALDEF**

**44 ARRAY (JR+1, 2*NR+2+J1) = 0.117634*BINERT*ELASC*DEFMIN**

**ARRAY (JR, K+1) = 2.0**

**ARRAY (JR+1, K+1) = 2.0**

**DO TO 43**

---

**C***********************************************************************DS011680**

**41 ARRAY (JR, 1) = 0.2352523*ELASC*BINERT*ALDEF**

**ARRAY (JR+1, 1) = 0.2352523*ELASC*BINERT*DEFMIN**

**ARRAY (JR, K+1) = 1.058991*ELASC*BINERT*ALDEF+22.5**

**ARRAY (JR+1, K+1) = 1.058991*ELASC*BINERT*DEFMIN=22.5**

**43 ARRAY (JR, K+1) = ARRAY (JR, K+1)/1.E+04**

**ARRAY (JR+1, K+1) = ARRAY (JR+1, K+1)/1.E+04**

**DO 46 J1 = 1, M**

**ARRAY (JR, J1) = ARRAY (JR, J1)/1.E+04**

**ARRAY (JR+1, J1) = ARRAY (JR+1, J1)/1.E+04**

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**C***********************************************************************DS011690**

**C ADEQUATE ULTIMATE MOMENT CAPACITY**

**C ULTIMATE MOMENT CAPACITY WRT .GE. 1.2 * CRACKING MOMENT**

**C JOPT = 0, CCNSRAINTS 25+6*NR AND 26+6*NR**

**C JOPT = 1, CCNSRAINTS 34+6*NR AND 35+6*NR**

---

**C***********************************************************************DS011700**

**C SET UP NO. STRANCS AND STRAND ECCENTRICITY ARRAY**

**C***********************************************************************DS011710**

**DO 62 J1 = 1, NR**

**FROM (J1) = 0.**

**SUM = 0.0**

**KNT = 0**

**DS011720**

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**C***********************************************************************DS011730**

**C***********************************************************************DS011740**

**C***********************************************************************DS011750**

**C***********************************************************************DS011760**

**C***********************************************************************DS011770**

**C***********************************************************************DS011780**

**C***********************************************************************DS011790**

**C***********************************************************************DS011800**

**C***********************************************************************DS011810**

**C***********************************************************************DS011820**

**C***********************************************************************DS011830**

**C***********************************************************************DS011840**

**C***********************************************************************DS011850**

**C***********************************************************************DS011860**

**C***********************************************************************DS011870**

**C***********************************************************************DS011880**

**C***********************************************************************DS011890**

**C***********************************************************************DS011900**

**C***********************************************************************DS011910**

**C***********************************************************************DS011920**

**C***********************************************************************DS011930**

**C***********************************************************************DS011940**

**C***********************************************************************DS011950**

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**DS011960**

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**DS011970**

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**DS011980**

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**DS011990**

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**DS012000**

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**DS012010**

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**DS012020**
PF=0.
DO 64 J1=1, NR
67 IF(FROW(J1).EQ.STRMAX(J1)) GO TO 64
IADD=2
IF(STRMAX(J1)=FROW(J1).LE.1) IADD=1
FROW(J1)=FROW(J1)+IADD
PF=PF+IADD*(-D(J1))
SUM=SUM+IADD
KNT=KNT+1
PEF(KNT,1)=SUM
PEF(KNT,2)=PF
PEF(KNT,3)=PF/SUM
GO TO 67
64 CONTINUE
C SET UP FOR CALLS TO ULTMP
ZMDL=W*ZL**2/8.
DO 63 J1=1,4
63 ZLOS(J1)=0.1*J1
DO 65 J1=1,11
ZNE(J1)=0.0
DO 65 J2=1,4
65 PECRK(J1,J2)=0.
JSTOP=11
IF(JOPT.NE.0) GO TO 66
F(1)=F28
JSTOP=1
C GENERATE TOTAL FORCE ECCENTRICITIES FOR ULTIMATE MOMENT AND
C CRACKING MOMENT CONSTRAINTS
66 FPCMIN=4.0
DO 84 J1=1, JSTOP
69 IF(F(J1),.EQ.1) GO TO 69
IF(F(J1),.NE,F(J1-1)) GO TO 69
ZNE(J1)=ZNE(J1-1)
DO 68 J2=1,4
68 PECRK(J1,J2)=PECRK(J1-1,J2)
GO TO 84
69 FPCBM=F(J1)
DO 70 J2=1,4
70 KCODE(J2)=0
KODEMU=0
ZMOLD=0.
DO 82 J2=1,KNT
ASTL=AS*PEF(J2,1)
DD=DTOP+PEF(J2,3)
CALL ULMKP(ASTL,FPCBM,FPS,APRI,ME,FPL,DD,DDIM,FSY,DCR,
*Y1,Y2,Y3,Y4,Z1,Z2,Z3,Z4,ZMUL)
DO 72 J3=1,4
ZMCR(J3)=1-ZLOS(J3))*ZBK*FO*(PEF(J2,1)/ACONC+PEF(J2,2)/ZB)
1+7.5*ZBK*.03663*SQRT(FPCEM)-ZBK*ZMUL+12./ZB
72 ZMCR(J3)=ZMCR(J3)*1.2/12.
DO 73 J3=1,4
IF(KKODE(J3).EQ.1) GC TO 73
IF(ZMUL.LT.ZMCR(J3)) GO TO 73
PECRK(J1,J3)=PEF(J2,2)
KKODE(J3)=1
73 CONTINUE
74 IF(KODEMU.EQ.1) GC TO 78
IF(ZMUL.GE.ULTMRQ) GO TO 76
E1=ZMOLC
IF(E1.LT.ZMUL) ZMOLD=ZMUL
IF(E1.LT.ZMUL) GO TO 82
FPCMIN=4.0+(J1-1)*0.5
GO TO 84
76 ZNE(J1)=PEF(J2,2)
KODEMU=1
78 DO 80 J3=1,4
IF(KKODE(J3).EQ.0) GC TO 82
80 CONTINUE
IF(KODEMU.EQ.1) GC TO 84
82 CONTINUE
84 CONTINUE
C FORM ULTIMATE MOMENT AND CRACKING MOMENT CONSTRAINTS
C IF(JOPT.EQ.0) JR=26+6*NR
IF(JOPT.NE.0) JR=35+6*NR
DO 100 J1=1,NR
ARRAY(JR,1-JCPT+J1)=D(J1)
100 ARRAY(JR+1,1-JCPT+J1)=D(J1)
IF(JOPT.EQ.0) GC TO 101
DO 102 J1=1,10
ARRAY(JR,2*NR+2+J1)=ZNE(J1+1)=ZNE(J1)
102 ARRAY(JR+1,2*NR+2+J1)=PECRK(J1+1,1)=PECRK(J1,1)
101 ARRAY(JR,K1)=ZNE(1)
ARRAY(JR+1,K1)=PECRK(1,1)

**********************************************************************************************DS012880
C LOWER AND UPPER BOUNDS ON CONCRETE STRENGTH
C JOPT=0, CONSTRAINTS 27+6*NR AND 28+6*NR
C JOPT=1, CONSTRAINTS 36+6*NR AND 37+6*NR

C*****************************************************************************DS012890
IF(JOPT.EQ.0) GO TO 103
DO 104 J1=1,10
ARRAY(37+6*NR,2*NR+2+J1)=0.5
104 ARRAY(38+6*NR,2*NR+2+J1)=0.5
ARRAY(37+6*NR,K1)=4.0=FPCMIN
ARRAY(38+6*NR,K1)=FPCMAX=4.0
GO TO 105

103 ARRAY(28+6*NR,1)=1,
ARRAY(29+6*NR,1)=1.
ARRAY(28+6*NR,K1)=4.0
ARRAY(29+6*NR,K1)=F28
105 CONTINUE

C**************************************************************DS012900
C IF NSMAX IS ODD, NS1=NO. OF STRANDS
C IF NSMAX IS EVEN, NS1=1/2 NO. OF STRANDS

C*****************************************************************************DS012910
IF(JOPT.EQ.0) J4=29+6*NR
IF(JOPT.EQ.1) J4=38+6*NR
DO 120 J1=1,NR
NSMAX=STRMAX(J1)
IF(NSMAX/2*2.NE.NSMAX) GO TO 120
DO 121 J2=1,J4
121 J2=1,J4
DO 120 J1=1,NR
120 CONTINUE

C**************************************************************DS012920
C WRITE ARRAY ON UNIT (3)

C*****************************************************************************DS012930
DO 111 J2=1,M
111 WRITE(3) (ARRAY(J3,J2),J3=2,J4),ARRAY(1,J2)
WRITE(3) (ARRAY(J3,K1),J3=2,J4),ARRAY(1,K1)

C**************************************************************DS012940
REWIND 3
C******************************************************************************
C CONVERSIONS TO APPROXIMATE BINARY VARIABLES IN LP SOLUTION
C
C JOPT=0, CONSTRAINTS 29+6*NR THRU 28+7*NR
C JOPT=1, CONSTRAINTS 36+6*NR THRU 47+7*NR
C******************************************************************************

JR=39+6*NR

DO 106 J1=1,10
 ARRAY(JR+J1-1,1-JOPT+NR+2+J1)=1.
106 CONTINUE

IF(JOPT.EQ.0)
 GO TO 107

DO 108 J1=1,K+1
 ARRAY(JR+NR+J1-1,1+2*NR+2+J1)=1.
108 CONTINUE

CONTINUE
 RETURN
END
SUBROUTINE ULTMP(ASTAR,FPCBM,FPS,ASPRM,FPL,D,CPTH,FSY,DCR,*Y1,Y2,Y3,Y4,Z1,Z2,Z3,Z4,ZMUL)

CLONG=0.2
ESINI=0.7*FPS*(1.+CLONG)/28.*E+03
CON1=(FPL/28000.)*(1.+((FPS=FPL)/(FPS=2.*FPL)))
CON2=-(FPL/28000.)*FPL^2/(FPS-2.*FPL)
BEFF=2.*(Y1+Y2+Y3)

THK=Z1
Z4MZ3=Z4-Z3
IF(ABS(Z4-Z3)LE.1.E-06) Z4MZ3=1.E-06
Z2MZ1=Z2-Z1
IF(ABS(Z2-Z1)LE.1.E-06) Z2MZ1=1.E-06

C***********************************************************************DO13530
C.**** POSITIVE MOMENT CAPACITY = N.A. IN SLAB
C***********************************************************************DO13550
C
C CHECK TO SEE IF N.A. IN SLAB
C
PSTAR=ASTAR/(BEFF*D)
FSUSTR=FPS*(1.+0.5*PSTAR*FPS/FPCBM)
T=ASTAR*FSUSTR
CC=.833*FPCBM*BEFF*THK
IF(CC.LT.T) GO TO 10

N.A. IN SLAB

ZMUL =ASTAR*FSUSTR*D*(1.+0.6*PSTAR*FSUSTR/FPCBM)/12
RI=PSTAR*FSUSTR/FPCBM
IF(RI.GT.0.3)ZMUL =0.25*FPCBM *BEFF*D**2/12.
RETURN
C***********************************************************************DO13710
C.**** POSITIVE MOMENT CAPACITY = N.A. BELOW SLAB
C***********************************************************************DO13730
10 CONTINUE
C
C BEGIN ITERATION TO LOCATE N.A.
C
JCNT=0
X=0.
12 X=X+0.25
13 JCNT=JCNT+1
   IF(X.GT.DPTH) ZMUL=0.
   IF(X.GT.DPTH) RETURN
C
C   COMPUTE STRAND STRAIN AND FORCE IN DECK STEEL
C
   ES=.003*(D-X)/X+ESINI
   ESP=.003*(Y-DCR)/X
   CS=29.E+03*ABS(ESP)
   IF(CS.GT.FSY) CS=FSY
   IF(ESP.LE.0) CS=-CS
   CS=CS*ASPRM
C
C   COMPUTE RESULTANT COMPRESSIVE FORCE ON CONCRETE AND ITS LOCATION
C
   KODE=1
   GO TO 1000
14  DBAR=D=YC
    CC=C*.833*FPCBM
    CTOT=CS+CC
    GO TO 2000
C
C   COMPUTE STRAND STRESS AND STRAND FORCE
C
16  T=ASTAR*FS
    SUMFOR=T*CTOT
    IF(SUMFOR.LT.0.) GO TO 18
    IF(JCNT.EQ.2) GO TO 17
    SAVEF1=SUMFOR
    SAVEX1=X
    GO TO 12
17  SAVEF2=SUMFOR
    SAVEX2=X
    X=SAVEX1+(SAVEX2-SAVEX1)*SAVEF1/(SAVEF1-SAVEF2)
    IF(X-SAVEX1.LT.25) X=SAVEX1+.25
    JCNT=0
    GO TO 13
18  ZMUL=(CC*DBAR+CS*(D-DCR))/12.
    GO TO 28
C***********************************************************************
C*******THIS SECTION COMPUTES CONCRETE COMPRESSION AREA AND ITS C.G.  
1000 C = (Y1*BRACK(0.,X,Z1)+Y2*X+Y3*BRACK(0.,X,Z3)+BRACK(Z1,X,Z2)*Y4  
* -0.5*Y4*BRACK(Z1,X,Z2)**2/Z2MZ1+BRACK(Z3,X,Z4)*Y3=0.5*Y3*  
* BRACK(Z3,X,Z4)**2/Z4MZ3)*2.  
YC=(0.5*Y1*BRACK(0.,X,Z1)**2+0.5*Y2*X**2+0.5*Y3*BRACK(0.,X,Z3)**2  
* +Y4*Z1*BRACK(Z1,X,Z2)+0.5*Y4*BRACK(Z1,X,Z2)**2=0.5*Z1*Y4*  
* BRACK(Z1,X,Z2)**2/Z2MZ1=33333*Y4*BRACK(Z1,X,Z2)**3/Z2MZ1  
* +Y3*Z3*BRACK(Z3,X,Z4)+0.5*Y3*BRACK(Z3,X,Z4)**2  
* -0.5*Z3*Y3*BRACK(Z3,X,Z4)**2/Z4MZ3=33333*Y3  
* +BRACK(Z3,X,Z4)**3/Z4MZ3)*2./C  
GO TO 14  
C******************** THIS SECTION COMPUTES STRAND STRESS  
2000 FS=ES*28000  
IF(FS.GT.FPL) GO TO 2002  
2002 FS=-5*FPS+.5*SQR(FPS**2=4.*CON2/(ES=CON1))  
GO TO 16  
28 RETURN  
END
FUNCTION BRACK(ZL,X,ZU)
IF(X.LE.ZL) BRACK=0.
IF(ZL.LT.X.AND.X.LE.ZU) BRACK=X-ZL
IF(X.GT.ZU) BRACK=ZU-ZL
RETURN
END
SUBROUTINE CEFIN
COMMOM/DEFIN/ UWC,HUM,AS,FPS,CTR1,CTR2,CBR1,CBR2,CTS1,CTS2,CBS1,CBS2,CREEP1,CREEP2,SHRK1,SHRK2,RATNOD,FPL,FSY,ASTIRP,GSP
UWC=1.50
HUM=50.
AS=0.153
FPS=270.
FPL=0.63*FPS
CTR1=7.5
CTR2=7.5
CBR1=0.6
CBR2=0.6
CTS1=6.0
CTS2=6.0
CBS1=0.4
CBS2=0.4
CREEP1=0.
CREEP2=0.
SHRK1=0.
SHRK2=0.
RATNOD=6.0
FSY=60.
GSP=2.00
ASTIRP=0.11
RETURN
END
SUBROUTINE PROPTY
REAL*4 X1, X2, X3, X4, X5, X6, X7, X8, X9, X10, X11, X12
COMMON/BLK1/ADIM, BDIM, CDIM, DDIM, EDIM, FDIM, GDIM, HDIM, TDIM, WDDIM
COMMON/XDIM, YDIM, ACONC, BINERT, DTOP, DBOT, ZT, ZB, ACONCK, BINERK, DTOPK
COMMON/DEFINE/UWC, HUM, AS, FPS, CTR1, CTR2, CBR1, CBR2, CTS1, CTS2,
COMMON/BLK2/ADIM, BDIM, CDIM, DDIM, EDIM, FDIM, GDIM, HDIM, TDIM, WDDIM
COMMON/DEFINE/AREA, YB, YBCT, YBK, YBOTK, YTK, OTOP, OTOPK, YBCTK,
COMMON/DEFINE/AREA, YB, YBCT, YBK, YBOTK, YTK, OTOP, OTOPK, YBCTK,
COMMON/DEFINE/AREA, YB, YBCT, YBK, YBOTK, YTK, OTOP, OTOPK, YBCTK,
COMMON/DEFINE/AREA, YB, YBCT, YBK, YBOTK, YTK, OTOP, OTOPK, YBCTK,
COMMON/DEFINE/AREA, YB, YBCT, YBK, YBOTK, YTK, OTOP, OTOPK, YBCTK,

EQUIVALENCE (AREA, ACONC, YB, YBCT, YBK, YBOTK, YTK, OTOP, OTOPK, YBCTK),
EQUIVALENCE (AREA, ACONC, YB, YBCT, YBK, YBOTK, YTK, OTOP, OTOPK, YBCTK),
EQUIVALENCE (AREA, ACONC, YB, YBCT, YBK, YBOTK, YTK, OTOP, OTOPK, YBCTK),
EQUIVALENCE (AREA, ACONC, YB, YBCT, YBK, YBOTK, YTK, OTOP, OTOPK, YBCTK),
EQUIVALENCE (AREA, ACONC, YB, YBCT, YBK, YBOTK, YTK, OTOP, OTOPK, YBCTK),

CTOP=DCR
C1 = (A=WH+2.WD))/2.
C2 = (B=(WH+2.WD))/2.
A1 = WD*D
A2 = C1*H
A3 = C1*G/2.
A4 = E*C2/2.
A5 = C*C2
A6 = WH*T
A7 = WH*F
A8 = (C2=C1)*H
A9 = (C2=C1)*G
A10 = A3
A11 = C2*(C=H=G=E=C)
A12 = A4
IF(A.LT.B) GO TO 80
A8=0.
A9=0.
A10=0.
A11=0.
A12=0.
80 CONTINUE
A14=(XDIM**2)/2.
A15=(YDIM**2)/2.
**2.*(RATNOD=1.)*APRIME=.5625
**+(RATNOD=1.)*APRIME=.5625
\[ \text{AREAK} = \text{AREA} + 2.0*\text{A8} + 2.0*\text{A9} + 2.0*\text{A10} + 2.0*\text{A11} + 2.0*\text{A12} \]
\[ \text{Y1} = \frac{D}{2.0} \]
\[ \text{Y2} = \frac{D}{H/2.0} \]
\[ \text{Y3} = \frac{D}{(H+G/3.0)} \]
\[ \text{Y4} = C + \frac{E}{3.0} \]
\[ \text{Y5} = C/2.0 \]
\[ \text{Y6} = \frac{T}{2.0} \]
\[ \text{Y7} = \frac{F}{2.0} \]
\[ \text{Y8} = \frac{D}{(H/2.0)} \]
\[ \text{Y9} = \frac{D}{(H+G/2.0)} \]
\[ \text{Y10} = \frac{D}{(H+2.0*G/3.0)} \]
\[ \text{Y11} = \frac{(E-H+G+E+C)/2.0}{2.0} \]
\[ \text{Y12} = C + 2.0*E/3.0 \]
\[ \text{Y13} = T\times\text{DIM}/3.0 \]
\[ \text{Y14} = D\times\text{DIM}/3.0 \]
\[ \text{Y15} = F + \text{YDIM}/3.0 \]
\[ \text{Y16} = (\text{Y1} + \text{A1} + 2.0 + \text{Y2} + \text{A2} + 2.0 + \text{Y3} + \text{A3} + 2.0 + \text{Y4} + \text{A4} + 2.0 + \text{Y5} + \text{A5} + 2.0 + \text{Y6} + \text{A6})/2.0 \]
\[ \epsilon + \frac{\text{Y7} \times \text{A7}}{2} + \frac{(\text{D}\times\text{CTOP})*2}{(\text{RATNOD}/1.0)*\text{APRIME}}/\text{AREA} \]
\[ \text{Y17} = \frac{\epsilon + \frac{\text{Y7} \times \text{A7}}{2} + \frac{(\text{D}\times\text{CTOP})*2}{(\text{RATNOD}/1.0)*\text{APRIME}}}{\text{AREA}} \]
\[ \text{Y18} = \frac{\text{Y1} \times \text{A1} + 2.0 + \text{Y2} \times \text{A2} + 2.0 + \text{Y3} \times \text{A3} + 2.0 + \text{Y4} \times \text{A4} + 2.0 + \text{Y5} \times \text{A5} + 2.0 + \text{Y6} \times \text{A6} \times \text{CS015290}}{2.0} \]
\[ \epsilon + \frac{\text{Y7} \times \text{A7}}{2} + \frac{(\text{D}\times\text{CTOP})*2}{(\text{RATNOD}/1.0)*\text{APRIME}}/\text{AREA} \]
\[ \text{Y19} = (\text{Y1} + \text{A1} + 2.0 + \text{Y2} + \text{A2} + 2.0 + \text{Y3} + \text{A3} + 2.0 + \text{Y4} + \text{A4} + 2.0 + \text{Y5} + \text{A5} + 2.0 + \text{Y6} + \text{A6})/\text{CS015320} \]
\[ \epsilon + \frac{\text{Y7} \times \text{A7}}{2} + \frac{(\text{D}\times\text{CTOP})*2}{(\text{RATNOD}/1.0)*\text{APRIME}}/\text{AREA} \]
\[ \text{Y20} = (\text{Y1} + \text{A1} + 2.0 + \text{Y2} + \text{A2} + 2.0 + \text{Y3} + \text{A3} + 2.0 + \text{Y4} + \text{A4} + 2.0 + \text{Y5} + \text{A5} + 2.0 + \text{Y6} + \text{A6})/\text{CS015320} \]
\[ \epsilon + \frac{\text{Y7} \times \text{A7}}{2} + \frac{(\text{D}\times\text{CTOP})*2}{(\text{RATNOD}/1.0)*\text{APRIME}}/\text{AREA} \]
\[ \text{Y21} = (\text{Y1} + \text{A1} + 2.0 + \text{Y2} + \text{A2} + 2.0 + \text{Y3} + \text{A3} + 2.0 + \text{Y4} + \text{A4} + 2.0 + \text{Y5} + \text{A5} + 2.0 + \text{Y6} + \text{A6})/\text{CS015320} \]
\[ \epsilon + \frac{\text{Y7} \times \text{A7}}{2} + \frac{(\text{D}\times\text{CTOP})*2}{(\text{RATNOD}/1.0)*\text{APRIME}}/\text{AREA} \]
\[ \text{Y22} = (\text{Y1} + \text{A1} + 2.0 + \text{Y2} + \text{A2} + 2.0 + \text{Y3} + \text{A3} + 2.0 + \text{Y4} + \text{A4} + 2.0 + \text{Y5} + \text{A5} + 2.0 + \text{Y6} + \text{A6})/\text{CS015320} \]
\[ \epsilon + \frac{\text{Y7} \times \text{A7}}{2} + \frac{(\text{D}\times\text{CTOP})*2}{(\text{RATNOD}/1.0)*\text{APRIME}}/\text{AREA} \]
\[ \text{Y23} = (\text{Y1} + \text{A1} + 2.0 + \text{Y2} + \text{A2} + 2.0 + \text{Y3} + \text{A3} + 2.0 + \text{Y4} + \text{A4} + 2.0 + \text{Y5} + \text{A5} + 2.0 + \text{Y6} + \text{A6})/\text{CS015320} \]
\[ \epsilon + \frac{\text{Y7} \times \text{A7}}{2} + \frac{(\text{D}\times\text{CTOP})*2}{(\text{RATNOD}/1.0)*\text{APRIME}}/\text{AREA} \]
\[ \text{Y24} = (\text{Y1} + \text{A1} + 2.0 + \text{Y2} + \text{A2} + 2.0 + \text{Y3} + \text{A3} + 2.0 + \text{Y4} + \text{A4} + 2.0 + \text{Y5} + \text{A5} + 2.0 + \text{Y6} + \text{A6})/\text{CS015320} \]
\[ \epsilon + \frac{\text{Y7} \times \text{A7}}{2} + \frac{(\text{D}\times\text{CTOP})*2}{(\text{RATNOD}/1.0)*\text{APRIME}}/\text{AREA} \]
\[ \text{Y25} = (\text{Y1} + \text{A1} + 2.0 + \text{Y2} + \text{A2} + 2.0 + \text{Y3} + \text{A3} + 2.0 + \text{Y4} + \text{A4} + 2.0 + \text{Y5} + \text{A5} + 2.0 + \text{Y6} + \text{A6})/\text{CS015320} \]
IF(JVKEY.EQ.0) GO TO 5
IF(A.GE.B) XINERK=XINERT+I131-I13
IF(A.GE.B) GO TO 5
18 = (C2*C1)*(H**3)/12. + A8*((Y8-DY)**2)
19 = (C2*C1)*(G**3)/12. + A9*((Y9-DY)**2)
I10 = C1*(G**3)/36. + A10*((Y10-DY)**2)
I12 = C2*(E**3)/36. + A12*((Y12-DY)**2)
IF(JVKEY.EQ.1) XINERK =
&XINERT+I131-I13 + I8*2.0 + I9*2.0 + I10*2.0 + I11*2.0 + I12*2.0
5 CONTINUE
IF(JVKEY.EQ.0) GO TO 8
ZT=XINERT/YT
ZB=XINERT/YB
BINERT=XINERT
BINERT=BINERT*0.75**4/18.*2.*(.28125*(YB-.50)**2)
GO TO 10
8 ZTK=XINERK/YTK
ZBK=XINERK/YBK
BINERK=XINERK
BINERK=BINERK*0.75**4/18.*2.*(.28125*(YBK-.50)**2)
10 CONTINUE
RETURN
END
SUBROUTINE MOMSHR(DL,NWHL,NWHEEL,XSEC,PAXLE,MAXMOM,MAXSHR)
REAL*4 MAXMOM, MAXSHR,NWHL,MOMENT
COMMON/DUMP/ MOMENT(12),SHEAR(12),IPL(20),IPR(20),REACT(20)
DIMENSION NWHL(18),PAXLE(18)
NST=NWHEEL-1
DO 11 II = 1,2
IF(II.EQ.2) XSEC = DL * XSEC
XSECR = DL * XSEC
DO 3 NS = 1, NST
IL = NS
CALL LOCATE(DL,XSEC,NST,NS,NWHL)
N1 = IPL(IL)
N2 = IPR(IL)
IF(N1.EQ.0.AND.N2.EQ.0) PROD = PAXLE(IL+1)*XSECR
IF(N1.EQ.0.AND.N2.EQ.0) GO TO 33
IF(N1.EQ.0) N1 = IL+1
IF(N2.EQ.0) N2 = IL+1
C OBTAIN THE LEFT REACTION FOR ANY SHIFT
PROD = 0.
DO 4 I = N1,N2
IF(I .EQ. 1) D2 = DL*(XSEC-NWHL(IL))
IF(I .EQ. 1) GO TO 36
IF(I .EQ.(IL+1)) AND .IPL(IL).EQ.0) D2 = XSECR
IF(I .EQ.(IL+1)) AND .IPL(IL).EQ.0) GO TO 36
IF(I .LE. IL) D2 = DL*(XSEC-(NWHL(IL)-NWHL(I=1)))
IF(I .LE. IL) GO TO 36
IF(I .GT. IL) D2 = XSECR-(NWHL(I=1)-NWHL(IL))
DO 5 I = N1,IL
IF(I .EQ. 1) DM = NWHL(IL)
IF(I .EQ. 1) GO TO 34
CONTINUE
DELT = PAXLE(1)*D2
4 PROD = PROD+DELT
CONTINUE
33 REACT(IL) = PROD/DL
SUMV = 0.
SUMM = 0.
IF(IPL(IL).EQ.0) SHEAR(IL) = REACT(IL)
IF(IPL(IL).EQ.0) MOMENT(IL) = REACT(IL) *XSEC
IF(IPL(IL).EQ.0) GO TO 3
DO 5 I = N1,IL
IF(I .EQ. 1) DM = NWHL(IL)
IF(I .EQ. 1) GO TO 34
CONTINUE
```
DM = NWHL(IL) = NWHL(I=1)
34 DELTM = PAXLE(I) * DM
DELT = PAXLE(I)
SUMM = SUMM + DELTM
SUMV = SUMV + DELT
5 CONTINUE
SHEAR(IL) = REACT(IL) = SUMV
MOMENT(IL) = REACT(IL) * XSEC = SUMM
3 CONTINUE
NA = 0
IF(II.EQ.1) MAXMOM = MOMENT(1)
IF(II.EQ.1) MAXSHR = SHEAR(1)
NSTA = NST = 1
IF(NSTA.EQ.0) GO TO 16
DO 13 LL = 1, NSTA
NA = NA + 1
NB = LL + 1
AAA = MOMENT(NA)
BBB = SHEAR(NA)
IF(II.EQ.2) AAA = MAXMOM
IF(II.EQ.2) BBB = MAXSHR
IF(MOMENT(NB) .GT. AAA) MAXMOM = MOMENT(NB)
IF(ABS(SHEAR(NB)) .GT. BBB) MAXSHR = ABS(SHEAR(NB))
15 NA = NA = 1
GO TO 13
13 CONTINUE
16 CONTINUE
11 CONTINUE
XSEC = DL = XSEC
RETURN
END
```
SUBROUTINE LOCATE(CL,XSEC,NST,NS,NWHL)
REAL*4 NWHL,MOMENT
COMMON/DUMP/ MOMENT(12),SHEAR(12),IPL(20),IPR(20),REACT(20)
DIMENSION NWHL(18)
XSECR = DL*XSEC
DTERM = 0.
DO 1 I = 1,NST
DLE = NWHL(NS)=DTERM
IF(DLE.LE.XSEC) IPL(NS) = I
IF(DLE.LE.XSEC) GO TO 2
IF(I.EQ.NS) IPL(NS) = 0
IF(I.EQ.NS) GO TO 2
DTERM = NWHL(I)
1 CONTINUE
2 CONTINUE
DO 4 IC= 1,NST
NSC = NS+IC
IF((NS+1).EQ.(NST+1)) IPR(NS) = 0
IF(NSC.GT.NST ) GO TO 5
DELT = NWHL(NS+IC)-NWHL(NS)
IF(DELT.GT.XSECR.AND.IC.EQ.1) IPR(NS) = 0
IF(DELT.GT.XSECR) GO TO 5
IPR(NS) = NS+IC+1
4 CONTINUE
5 CONTINUE
RETURN
END
SUBROUTINE LPCCDE (KKRCE, NEGS, INDEX, KODE)

LINEAR PROGRAMMING ALGORITHM

COMMON/D314/K,K,MPJ1,K1,K2,K3,K4,K5,K6,K7,K8,K9,K10,K11,K12,
SUM,IGNOR,IT(4),JCONT,X(150),A(118,150),B(150),XD(150)

SET UP MATRIX

KBOMB=0
KP1=N+M
K=N+M+1
KK=K=1
IF(KODE.NE.0) GO TO 200
DO 1 I=1,N
DO 1 J=K,KK
1 A(I,J+1)=0.0
DO 2 I=2,N
IPM=I+M+1
2 A(I,IPM)=1.0
DO 10 I=1,N
10 CONTINUE

C***********************************************************************
C*** FEASIBILITY SECTION
C***********************************************************************
INEG=2
11 DO 14 I=2,N
IF (B(I)) 12,12,14
12 CONTINUE
IF (A(I,KP1)=A(INEG,KP1)) 13,14,14
13 INEG=1
14 CONTINUE
   IF (A(INEG,KPI)) 15,23,23
15 IF (B(INEG)) 16,16,23
16 JSM=1
  DO 19 J=2,K
   IF (X0(J)) 17,17,19
17 CONTINUE
   IF (A(INEG,J)=A(INEG,JSM)) 18,19,19
18 JSM=J
19 CONTINUE
   IF (X0(JSM)) 20,20,23
20 IF (A(INEG,JSM)) 22,21,21
C   NO FEASIBLE SOLUTION
C
21 KBOMB=51
   GO TO 38
22 CALL PIVOT (INEG,JSM)
   GO TO 10
C*********************-**************************************************CS017370
C**** OPTIMALITY SECTION
C*********************-**************************************************CS017390
23 JBGST=1
C   SELECT INCOMING VECTOR
C
  DO 26 J=1,K
   IF (X0(J)) 24,24,26
24 CONTINUE
   IF (A(1,J)=A(1,JBGST)) 26,26,25
25 JBGST=J
26 CONTINUE
   IF (A(1,JBGST)) 38,38,27
C   CHECK FOR UNBOUNDED SOLUTION
C
27 DO 29 I=2,N
   ISPOIT=1
   IF (B(I)) 28,28,29
28 CONTINUE
IF (A(I,JBGST)) 29,29,30
29 CONTINUE
30 CONTINUE
   IF (A(ISPOT,JBGST)) 31,31,32
31 KBOMB=50
   GO TO 28
C     SELECT OUTGOING VECTOR
C
32 KK=ISPOT
   DO 36 I=KK,N
      IF (B(I)) 33,33,36
   CONTINUE
33 CONTINUE
   IF(A(I,JBGST)) 36,36,34
34 IF (A(I,K+1)/A(I,JBGST)=A(ISPOT,K+1)/A(ISPOT,JBGST)) 35,36,36
35 ISPOT=I
36 CONTINUE
   IF (B(ISPOT)) 37,37,31
37 CALL PIVOT (ISPOT,JBGST)
   GO TO 23
C**********************************************************************•D5017780
C**** OUTPUT SECTION
C**********************************************************************•D5017790
38 OBJ=-A(1,KPI)
   IF (INDX=1) 40,39,40
39 OBJ=-OBJ
40 DO 45 I=1,K
   IF (X(I)) 44,44,41
41 DO 42 J=2,N
   IF (A(J,I)) 42,42,43
42 CONTINUE
43 X(I)=A(J,KPI)
   GO TO 45
44 X(I)=0.
45 CONTINUE
   DO 49 J=1,K
   IF (J=N+1) 46,46,47
46 JJ=J+M
   GO TO 48
47 JJ=J=N+1
48 XD(J) = A(1, JJ)
49 CONTINUE
      IF (KBOME .EQ. 50) WRITE(6, 50)
50 FORMAT (/ 'CHOUNBOUNDED')
RETURN
END
SUBROUTINE PIVOT (I,J)

COMMON/D314/N,M,OBJ,KP1,K,NR,NC,NRA,NCA,N1,N2,N3,DXMAX,IS,TV,TR,
1SUM,IGNOR,IT(4),JCONT,X(150),A(118,150),B(150),XD(150)

DO 2 JJ=1,K
  IF (X(JJ)) 2,2,1
  IF (A(I,JJ)) 2,2,3
2 CONTINUE
3 X(JJ)=0.0
  NM1=N-1
  R=A(I,J)
  DO 4 L=1,KP1
  4 A(I,L)=A(I,L)/R
  DO 5 L=2,I
    F=A(L-1,J)
    DO 5 M=1,KP1
    5 A(L-1,M)=A(L-1,M)-A(I,M)*F
    IF (I-N) 6,8,8
  6 DO 7 L=1,NM1
    F=A(L+1,J)
    DO 7 M=1,KP1
  7 A(L+1,M)=A(L+1,M)-A(I,M)*F
8 CONTINUE
X(J)=1.0
M=KP1-N
RETURN
END
SUBROUTINE CAMBER(ES, EC, ASTRN, STRNS, UWB, AREA, SPANL, ECCL, IB, FO, ENDED)
COMMON/DEFINE/ UWC,HUM, AS, FPS, CTR1, CTR2, CER1, CER2, CTS1, CTS2, 1CC, PRLMAX, CBRMAX, HDPT)
DIMENSION CNST(4,5), PRLMAX(5), CBRMAX(5)
DIMENSION CNST(4,5), PRLMAX(5), CBRMAX(5)

REAL IB
C
CAMBER AND STRESS LOSS CALCULATIONS
C MIDSPAN CAMBER AND STRESS LOSS DUE TO INITIAL PRESTRESS AND BEAMCS
C
IF(CREEP1.EQ.0.) J1=4
IF(CREEP1.EQ.0.) GO TO 2
CNST(1,5)=SHRK1
CNST(2,5)=SHRK2
CNST(3,5)=CREEP1
CNST(4,5)=CREEP2
J1=5
2 DO 1 N=1,J1
ASH=0.000001*CNST(1,N)
BSH=CNST(2,N)
ACRR=0.000001*CNST(3,N)
BCR=CNST(4,N)
ACR = ACRR*0.001
RN = ES/EC
AST = ASTRN*STRNS
W = UWB*AREA/144.
DLM = (W*SFANL*SPANL/8.)*12.
TEMP = 1.*+(RN*AST/AREA)+(RN*AST*ECCL*ECCL/IB)
FR = FO/TEMP + (DLM*ECCL*RN*AST/(IB*TEMP))
PLI = ((FC-FR)/FO)*100.
CONST = (1./AREA)+(ECCL*ECCL/IB)
FCSO = FR*CONST=(DLM*ECCL/IB)
STRN1 = ACR*FCSO+ASH
STRN2 = STRN1=STRN1*(RN*AST*CONST)
DFCS = STRN2*ES*AST*CONST * 10.0 ** 6
STRN4 = ACR*(FCS0+DFCS/2.)*ASH
STRN5 = STRN4=STRN4*RN*AST*CONST
C
C
DFCS1 = STRN5*ES*AST*CCNST * 10.0 ** 6
STRN6 = ACR*(FCSO-DFCS1/2.)+ASH
STRN7 = STRN6*STRN6*RN*AST*CCNST
PLINF = (STRN7*ES*AST*10.0**6/FC)*100.
PLMAX = PLINF+PLI
PRLMAX(N) = PLMAX
CCONST = 1./(EC*IB*10.***6)
HSPAN = SPANL/2.
C11 = CCONST*(FR*ENDECC *HSPAN*0.5*HSPAN*144.)
C12 = CCONST*(FR*(ECCL-ENDECC )*(HSPAN-HDPT)*0.5*0.67*(HSPAN))
C13 = CCONST*(FR*(ECCL-ENDECC )*HDPT*(HSPAN-HDPT/2.)*144.)
C14 = CCONST*((5./384.)*(W*SPANL*SPANL*SPANL*SPANL*12.*12.*12.))
C1 = C11 +C12 +C13 =C14
STRAIN=FCSO/(EC*10.***6)
CMAX = C1*((ACR*(FCSO-(DFCS/2.))+STRAIN)/STRAIN)*(1.*(PLINF/100.))
CBRMAX(N) = CMAX
1 CONTINUE
RETURN
END
SUBROUTINE SHEAR(E, DEPTH, D, FPC, FSY, AREA, VU, SPACE)

AV = 2. * AREA
S1 = (AV * FSY) / (0.100 * B)
SMAX = 0.75 * DEPTH
IF(S1 LT SMAX) SMAX = S1
RJ = 0.90
VCMAX = 0.180 * B * RJ * D
VC = 0.06 * FPC * B * RJ * D
IF(VC GT VCMAX) VC = VCMAX
SPACE = (2. * AV * FSY * RJ * D) / (ABS(VU) = VC)
IF(SPACE LT 0.0 OR SPACE GT SMAX) SPACE = SMAX
RETURN
END
SUBROUTINE INTPRG(KBCMB)
C HEURISTIC MIXED INTEGER LINEAR PROGRAMMING
C MAX WITH LE CONSTRAINTS
C PACKED DATA
INTEGER*2 ROW, COL
COMMON/D314/N,M,OBJ,KP1,K,NR,NC,NRA,NCA,N1,N2,N3,DXMAX,IS,TV,TR.
ISUM,IGNOR,IT(4),JCONT,X(150),Y(3136),ROW(3136),COL(150),BB(150).
2C(150),B(150),XX(150)
C TR = ROW TOLERANCE
TR=0.1
C TV = VARIABLE TOLERANCE
TV=1.E-2
C TITLE = TITLE INFORMATION
C NR = NUMBER OF CONSTRAINTS, N1 = NUMBER OF CONTINUOUS VARIABLES
C N2 = NUMBER OF INTEGER VARIABLES, N3 = NUMBER OF BINARY VARIABLES
C IS = 0#INITIAL SOLUTION TO BE PROVIDED
C IS = 1 OR 2#NO INITIAL SOLUTION TO BE PROVIDED
C IS = 0 OR 1#PHASE 4 USED IF NO FEASIBLE SOLUTION IS
C LOCATED. DXMAX = MAXIMUM INCREMENT OF ANY XX<
C INPUT ORDER
C CONT VAR, INTEGER, 0=1
C OBJ FUNC IS ROW NR + 1
C RHS IS IN NCA=N1 + N2 + N3 + 1
C BLANK CARD ENDS DATA
NRA=NR+1
NTWO=N2+N1
NC=NTWO+N3
NCA=NC+N1
C CONTINUOUS VARIABLES MUST BE ENTERED FIRST
MCOL=0
KKK=0
C COLUMN ENTRIES ALL TOGETHER
IC=0
IGNOR=0
JJ=0
OPT=-1.E30
DO 3 I=1,4
3 IT(I)=0
DO 4 J=1,NC
4 XX(J) = 0.
DS019070
DS019080
DS019090
DS019100
DS019110
DS019120
DS019130
DS019140
DS019150
DS019160
DS019170
DS019180
DS019190
DS019200
DS019210
DS019220
DS019230
DS019240
DS019250
DS019260
DS019270
DS019280
DS019290
DS019300
DS019310
DS019320
DS019330
DS019340
DS019350
DS019360
DS019370
DS019380
DS019390
DS019400
DS019410
DS019420
DS019430
DS019440
DS019450
DS019460
C
INITIAL SOLUTION (REQUIRED IF IS = 0)
DO 7 J=1,NC
IF(X(J).EQ.0.) GO TO 7
XX(J)=X(J)
C(NCA)=C(NCA)+X(J)*C(J)
IA=COL(J)
IB=COL(J+1)-1
DO 6 I=IA,IB
BB(ROW(I))=BB(ROW(I))-X(J)*Y(I)
6 CONTINUE
CONTINUE
7 SUM=0.
DO 15 I=1,MR
IF(ABS(EB(I)).LT.TT) BB(I)=0.
B(I)=BB(I)
15 IF(B(I).LT.0.) SUM=SUM+B(I)
SMIN=SUM
TOPT=C(NCA)
20 IF(SUM.EQ.0.) GO TO 24
CALL PHASE1
IF(SUM.GT.C.) IF(IC) 40,33,40
24 CALL PHASE2
IF(C(NCA).LE.OPT) IF(IC) 46,36,46
DO 30 J=1,NC
30 XX(J)=X(J)
DO 32 I=1,MR
B(I)=BB(I)
32 IF(OPT.EQ.(-1.E30)) JJ=0
OPT=C(NCA)
GO TO 36
33 IF(SUM.GE.SMIN) GO TO 36
DO 34 J=1,NC
34 XX(J)=X(J)
DO 35 I=1,MR
B(I)=BB(I)
35 SMIN=SUM
TOPT=C(NCA)
36 CALL PHASE3
IF(IGNOR.EQ.0) GO TO 40
IC=1
GO TO 22
40 IF(OPT.GT.(-1.E30)) GO TO 46
   IF(SUM.GE.SMIN) GO TO 48
   DO 42 J=1,NC
42 XX(J)=X(J)
   DO 44 I=1,NR
44 B(I)=BB(I)
   SMIN=SUM
   TOPT=C(NCA)
   GO TO 54
46 IF(IS.LT.2) GO TO 56
   C(NCA)=OPT
   SUM=0.
   GO TO 50
48 C(NCA)=TOPT
   SUM=SMIN
50 DO 52 J=1,NC
52 X(J)=XX(J)
   DO 53 I=1,NR
53 BB(I)=B(I)
  C PHASE 4 = PERTURB THE CURRENT SOLUTION
54 IF(JJ.EQ.NC) GO TO 56
   JJ=JJ+1
   IF(X(JJ).LT.TV) GO TO 54
   XS=X(JJ)
   X(JJ)=AMAX1(0.,XS-3.*DXMAX)
   DX=X(JJ)-XS
   IA=COL(JJ)
   IB=COL(JJ+1)-1
   DO 55 I=1,IB
    BB(ROW(I))=BB(ROW(I))+DX*Y(I)
55 IF(ABS(BB(ROW(I))).LT.TR) BB(ROW(I))=0.
   SUM=0.
   DO 155 I=1,NR
155 IF(BB(I).LT.0.) SUM=SUM+BB(I)
   C(NCA)=C(NCA)+DX*C(JJ)
   IC=0
   IGNOR=JJ
   IT(4)=IT(4)+1
GO TO 20
56 IF(OPT.EQ.(-1.E30)) GO TO 60
C OUTPUT FINAL FEASIBLE SOLUTION
KBOMB=0
RETURN
C OUTPUT FINAL INFEASIBLE SOLUTION
60 DO 57 I=1,NC
57 XX(I)=X(I)
DO 58 I=1,NR
58 B(I)=BB(I)
KBOMB=1
END
SUBROUTINE PHASE1
C
ATTEMPT TO REDUCE THE SUM OF INFEASIBILITIES

INTEGER*2 RCW,CCL
COMMON/D314/N,M,OBJ,KP1,K,NC,NCNR,NCRA,NCA,N1,N2,N3,DXMAX,IS,T,TV,TR,
1SUM,IGNCR,IT(4),JCONT,X(150),Y(3136),ROW(3136),COL(150),BB(150),
2C(150),E(15C),XX(15C)
NTWO=N2+N1
10 Q=-1.E38
P=-1.E38
DO 140 J=1,NC
IF(J.NE.IGNOR) GO TO 15
IGNOR=0
GO TO 140
15 R=-1.E38
IF(X(J).EQ.0.) GO TO 18
S=1.E38
IF (J.GT.NTWO) R = 0.
GO TO 20
18 S = 0.0
20 IA=COL(J)
IB=COL(J+1)-1
DO 60 I=IA,IB
IF(BB(ROW(I)).GE.0.) GO TO 60
V=BB(ROW(I))/Y(I)
IF(ABS(V).LT.TV) GO TO 60
IF(V.LT.0.) GO TO 30
IF (R.EQ.0.0) GC TO 60
IF(J.GT.N1) V=AINT(V+.999)
IF (J.GT.NTWO) V = 1.0
IF(V.GT.R) R=V
GO TO 60
30 IF(S.EQ.0.) GO TO 60
IF(J.GT.N1) V=AINT(V-.999)
IF(V.GE.S) GO TO 60
IF(V.LT.(X(J))) V=X(J)
S=V
60 CONTINUE
IF(R.EQ. -1.E38 .OR.R.EQ.0.0) GO TO 90
T=0.
K=IA
DO 70 I=1, NR
   IF(I.EQ.ROW(K)) GO TO 64
   IF(BB(I).GE.0.) GO TO 70
   T=T-BB(I)
   GO TO 66
64 F=BB(I)-R*Y(K)
   IF(ABS(F).LT.TR) F=0.
   K=K+1
   IF(K.GT.IB) K=IB
   IF(F.GE.0.) GO TO 70
   T=T-F
66 IF(T.GE.SUM) GC TO 90
70 CONTINUE
   IF(T.EQ.0.) GC TO 110
   W=R*C(J)
   IF(W.LE.Q) GC TO 90
   Q=W
80 DX=AMAX1(R,CXMAX)
   KK=J
90 IF(S.EQ.1,E38.0R,S.EQ.0.) GO TO 140
   T=0.
   K=IA
   DO 100 I=1, NR
      IF(I.EQ.ROW(K)) GC TO 94
      IF(BB(I).GE.0.) GO TO 100
      T=T-BB(I)
      GO TO 96
94 F=BB(I)-S*Y(K)
   IF(ABS(F).LT.TR) F=0.
   K=K+1
   IF(K.GT.IB) K=IB
   IF(F.GE.0.) GO TO 100
   T=T-F
96 IF(T.GE.SUM) GO TO 140
100 CONTINUE
   IF(T.EQ.0.) GO TO 120
   W=S*C(J)
   IF(W.LE.Q) GO TO 140
   Q=W
105 DX=AMAX1(S-.DXMAX)
KK=J
GO TO 140
110 TEMP=R*C(J)
   IF(TEMP.LE.P) GC TO 90
   P=TEMP
   Q=1.E38
   GO TO 80
120 TEMP=S*C(J)
   IF(TEMP.LE.P) GC TO 140
   P=TEMP
   Q=1.E38
   GO TO 105
140 CONTINUE
   IF(Q.EQ.(-1.E38)) RETURN
   X(KK)=X(KK)+DX
   IA=COL(KK)
   IB=COL(KK+1)=1
   DO 150 I=IA,IB
      BB(ROW(I))=BB(ROW(I))+DX*Y(I)
   150 IF(ABS(BB(ROW(I)))*LT.TR) BB(ROW(I))=0.
      SUM=0.
      DO 155 I=1,NR
         IF(BB(I)*LT.0.) SUM=SUM-BB(I)
      155 C(NCA)=C(NCA)+DX*C(KK)
      IT(1)=IT(1)+1
      IF(SUM.EQ.0.) RETURN
      GO TO 10
   END
SUBROUTINE PHASE2
C
ATTEMPT TO IMPROVE THE VALUE OF THE OBJECTIVE FUNCTION

INTEGER*2 ROW, COL
COMMON/D314/W,M,OBJ,KPI,K, NR, NC, NCA, N1, N2, N3, DMAX, IS, TV, TR,
SUM, IGNOR, IT(4), JCONT, X(150), Y(3136), ROW(3136), COL(150), BB(150),
2C(150), E(150), XX(150)
NTWO=N2+N1

10 ZZ=-1.
DO 30 J=1, NC
IF(J.LE.IGNCR) GO TO 12
IGNOR=0
GO TO 30

12 IF(C(J).GE.0.) GO TO 18
IF(X(J).EQ.0.) GO TO 30
R=-1.E38
IA=COL(J)
IB=COL(J+1)-1
DO 15 I=IA, IB
IF(BB(ROW(I)).EQ.0.) IF(Y(I)) 30, 30, 13
V=BB(ROW(I))/Y(I)
IF(V.GT.0.) GO TO 15
IF(V.GT.TV) GO TO 30
IF(J.GT.N1.AND.V.GT.1.) GO TO 30
IF(V.GE.(-X(J))) GO TO 14
13 V=-X(J)
14 IF(V.GT.R) R=V
15 CONTINUE
GO TO 21
30 CONTINUE
GO TO 19

18 IF (J.GT.NTWO) IF(X(J)) 19, 19, 30
19 R = 1.0.E38
IA=COL(J)
IB=COL(J+1)-1
DO 20 I=IA, IB
IF(BB(ROW(I)).EQ.0.) IF(Y(I)) 20, 30, 30
V=BB(ROW(I))/Y(I)
IF(V.LT.0.) GO TO 20
IF(V.LT.TV) GO TO 30
IF(J.GT.N1.AND.V.LT.1.) GO TO 30
IF (J.GT.NTWO) V = 1.0
IF(V.LT.R) R=V
20 CONTINUE
21 IF(ABS(R).EQ.1.3E8) GO TO 30
   IF(C(J).EQ.0.) R=AMIN1(1.,R)
   Q=R*C(J)
   IF(Q.LE.ZZ) GO TO 30
   ZZ=Q
   KK=J
   IF(J.GT.N1) R=AINT(R)
   IF(R.LT.0.) GO TO 25
   DX=AMIN1(R,.DXMAX)
   GO TO 30
25 DX=AMAX1(R,-.DXMAX)
30 CONTINUE
   IF(ZZ.EQ.(-1.)) RETURN
   X(KK)=X(KK)+DX
   IA=COL(KK)
   IB=COL(KK+1)-1
   DO 40 I=IA,IB
   BB(ROW(I))=BB(ROW(I))+DX*Y(I)
   IF(ABS(BB(ROW(I))).LT.TR) BB(ROW(I))=0.
40 CONTINUE
   C(NCA)=C(NCA)+DX*C(KK)
   IT(2)=IT(2)+1
   GO TO 10
END
SUBROUTINE PHASE3
C
PERTURB THE CURRENT SOLUTION
INTEGER*2 ROW, COL
COMMON/D314/B*, OBJ, KFL, K, NR, NC, NCA, N1, N2, N3, DMAX, IS, TV, TR,
SUM, IGNOR, IT(4), JCONT, X(150), Y(3136), ROW(3136), COL(150), BB(150),
C(150), E(150), XX(150)
NTWO=N2+N1
ZZ=1.
JJ=0
DO 10 J=1, NC
IF(X(J).LT.TV .AND. C(J).LT.0.) GO TO 10
IF(X(J).GE.1. .OR. C(J).GE.0.) GO TO 2
TEMP=C(J)*X(J)
IF(TEMP.LT.ZZ) GO TO 10
DO 10 CONTINUE
IF(JJ.EQ.0) GO TO 35
X(JJ)=X(JJ)+DX
IA=COL(JJ)
IB=COL(JJ+1)-1
DO 20 I=IA, IB
BB(ROW(I))=BB(ROW(I))+DX*Y(I)
20 IF(ABS(BB(ROW(I))).LT.TR) BB(ROW(I))=0.
SUM=0.
DO 30 I=1, NR
IF(BB(I).LT.0.) SUM=SUM+BB(I)
C(NCA)=C(NCA)+ZZ
30 IGNOR=JJ
IT(3)=IT(3)+1
RETURN
END
SUBROUTINE SQUASH

INTEGER*2 ROW, COL
COMMON/D314/N,M,OBJ,KP1,K,NR,NC,NRA,NCA,N1,N2,N3,DXMAX,IS,TV,TR,
1SUM,IGNOR,IT(4),JCONT,X(150),Y(3136),ROW(3136),COL(150),BB(150),
2C(150),B(150),XX(150)

DIMENSION STRCOL(150)
JCONT=0
J1=0
DO 2 J=1,NCA
K1=0
READ(3) (STRCOL(J2),J2=1, NRA)
C(J)=STRCOL(NRA)
DO 3 I=1,NR
IF(STRCOL(I).EQ.0.0) GO TO 3
IF(STRCOL(I).EQ.0.0) GO TO 3
6 J1=J1+1
K1=K1+1
IF(J.EQ.NCA) GO TO 50
Y(J1)=STRCOL(I)
JCONT=JCONT+1
ROW(J1)=1
50 CONTINUE
IF(K1.GT.1) GO TO 3
3 CONTINUE
2 CONTINUE
DO 10 J3=1,NR
10 BB(J3)=STRCOL(J3)
REWIND 3
RETURN
END
SUBROUTINE PLOSS(FPCR,ZMBW,ZMC,ZMNC,FSU,AS,AB,IZIC,YB,YBC,EC,HUM,SPAN,ZLOSS,ZINLOS,UWC)

C THIS SUBROUTINE COMPUTES PRESTRESS LOSS BY 1975 AASHTO INTERIM SPEC.
C
C FPCR = CONCRETE RELEASE STRENGTH (KSI)
C ZMBW = D.L. MOMENT DUE TO BEAM WEIGHT AT MIDSPAN (K-FT)
C ZMC = TOTAL D.L. MOMENT (EXCEPT BEAM WEIGHT) AT MIDSPAN ACTING ON COMPOSITE SECTION (K-FT)
C ZMNC = TOTAL D.L. MOMENT (EXCEPT BEAM WEIGHT) AT MIDSPAN ACTING ON NONCOMPOSITE SECTION (K-FT)
C FSU = ULTIMATE STRENGTH OF STRAND (KSI)
C AS = TOTAL STRAND AREA (IN**2)
C AB = CROSS SECTIONAL AREA OF BEAM (IN**2)
C ZI = M. OF I. CF NONCOMPOSITE BEAM (IN**4)
C ZIC = M. OF I. CF COMPOSITE BEAM (IN**4)
C YB = DISTANCE FROM C.G. OF BEAM TO BOTTOM FIBER (IN)
C YBC = DISTANCE FROM C.G. OF COMPOSITE BEAM TO BOTTOM FIBER (IN)
C EC = DISTANCE FROM BOTTOM OF BEAM TO C.G. OF STRANDS (IN)
C HUM = RELATIVE HUMIDITY (PERCENT)
C SPAN = SPAN LENGTH (FT)
C ZINLOS = FRACTION OF INITIAL STRESS (.7*FSU) LOST (RELEASE)
C ZLOSS = FRACTION OF INITIAL STRESS (.7*FSU) LOST (SERVICE)
C
C (COMPRESSION STRESS IS POSITIVE)
C
C SHRINKAGE LOSS
C
C SH=(17000.150*HUM)/1000.
C
C ELASTIC SHORTENING
C
C A 10 PERCENT LOSS IN STRAND FORCE DUE TO RELAXATION AND ELASTIC SHORTENING PRIOR TO RELEASE IS ASSUMED AT TIME OF RELEASE
C
C FEFF=0.9*0.7*FSU*AS
C FCIR=FEFF/AB+FEFF*(YB=EC)*ABS(YB=EC)/ZI=12.*ZMBW*(YB=EC)/ZI
C
C ECI=(UWC*1000.)*1.5*33.*SQRT(1000.*FPCR)

DS022800
DS022810
DS022820
DS022830
DS022840
DS022850
DS022860
DS022870
DS022880
DS022890
DS022900
DS022910
DS022920
DS022930
DS022940
DS022950
DS022960
DS022970
DS022980
DS022990
DS023000
DS023010
DS023020
DS023030
DS023040
DS023050
DS023060
DS023070
DS023080
DS023090
DS023100
DS023110
DS023120
DS023130
DS023140
DS023150
DS023160
DS023170
DS023180
DS023190
\( ES = (28E + 06*FCIR/ECI) \)

\( CRC = 12.*FCIR - 12.*FCDS \)

\( CRS = 20.*0.4*ES + 0.2*(SH + CRC) \)

\( DLTFS = SH + ES + CRC + CRS \)

\( DELFSI = ES + 0.5*CRS \)

\( ZLOSS = DLTFS/(.7*FSU) \)

\( ZINLOS = DELFSI/(.7*FSU) \)

RETURN

END
COMMON/BLOCK 1/ HEAT(15),YMI(20),BMA(20),
*ZSA(20),YSA(20),BMJ(20),YH(10,2),ZH(10,2),NTY(30),
*LC(500),NLB(500),LM(4),P(500),XL(500),PL(500),
*ECC(500),F11(10,4,4),F12(10,4,4),F22(10,4,4),SF(164,8),
*NPOS(500),XPOS(9,9),HF(19,4),JTY(30),YSTR(9,4),ZSTR(9,4),
*NOUT(9),YSSS(9,4),ZSSS(9,4),X(8)
COMMON/BLOCK 2/ NHARMS,SPAN,NBEAMS,E,G,NTYPES,NEQ,
*ALPHA,NLCAE,NLCARD,NX
COMMON/BLOCK 3/ XZERO(164),YMAMPL(20),ZMAMPL(20),
*FAMPL(20),SFAMPL(20),TAMPL(20),XAMPL(20),YAMPL(200,20,9),
*ZMOUT(9,20,9),FCOUT(9,20,9),SFOUT(9,20,9),TGOUT(9,20,9),
*OUT(9,20,9),XCLT(9,76,9),XS(4),X(4)

MULTIBEAM BRIDGE ANALYSIS.

NHARMS=30
CALL REREAD
1 READ(5,211,END=1900) (HEAT(J1),J1=1,15),KODE
211 FORMAT(15I4,1X,11)

LOAD INPUT DATA

IF(KODE,EQ,0)CALL INPT
IF(KODE,NE,0)CALL INPU

ZERO OUTPUT STORAGE AREA

NX = 4 * NBEAMS = 4
DO 220 I = 1, NLCAE
NP = NPOS(I)
DO 219 K = 1, NP
DO 210 J = 1, NBEAMS
YMOUT(I,J,K) = 0.0
IF(KODE,NE,0) GO TO 210
ZMOUT(I,J,K) = 0.0
SFOUT(I,J,K) = 0.0
FOUT(I,J,K) = 0.0
TOUT(I,J,K) = 0.0
DOUT(I,J,K) = 0.0
210 CONTINUE
IF(KODE .NE. 0) GO TO 219
DO 217 J = 1, NX
217 XOUT(I, J, K) = 0.
219 CONTINUE
220 CONTINUE

C  FORM STRUCTURE FLEXIBILITY MATRIX FOR EACH HARMONIC
C  DO 900 NH = 1, NHARMS
  HARM = NH
  ALPHA = HARM*3.14159265/SPAN
  CALL FLEX
C  REDUCE FLEXIBILITY MATRIX
C  CALL SYMSOL (SF, XZERO, NEQ, 8, 1)
C  SET UP XZERO FOR EACH CASE
C  DO 800 K = 1, NLCASE
    DO 510 J = 1, NEQ
      XZERO(J) = 0.0
  510 CONTINUE
C  ZERO DAMPL, TAMPL, SFAMPL, FAMPL, YMAMPL, ZMAMPL
C  DO 515 NB = 1, NBEAMS
    DAMPL(NB) = 0.0
    TAMPL(NB) = 0.0
    SFAMPL(NB) = 0.0
    FAMPL(NB) = 0.0
    YMAMPL(NB) = 0.0
    ZMAMPL(NB) = 0.0
  515 CONTINUE
C  FORM LOAD VECTOR FOR EACH LOAD CASE
C  DO 520 N = 1, NLCARD
    KK = LC(N)
    IF (KK .NE. K) GO TO 520
    NB = NLB(N)
    NT = NTY(NB)
PP = P(N) / PL(N)
PN = 4 * PP * SIN(ALPHA * XL(N)) * SIN(ALPHA * PL(N) / 2) / (3.14159265 * HARM)

C
NR = 4 * NB + 3
G1 = PN / (ALPHA ** 3 * YM1(N))
G2 = ECC(N) * PN / (ALPHA ** 2 * BMJ(N))
G3 = G1 / ALPHA
XZERO(NR) = XZERO(NR) + ZH(N, 1) * G1
NR = NR + 1
XZERO(NR) = XZERO(NR) + ZH(N, 1) * G2
NR = NR + 1
XZERO(NR) = XZERO(NR) + G3 + YH(N, 1) * G2
NR = NR + 1
XZERO(NR) = XZERO(NR) + G2
NR = NR + 1
XZERO(NR) = XZERO(NR) + G1
NR = NR + 1
XZERO(NR) = XZERO(NR) + G2
NR = NR + 1
XZERO(NR) = XZERO(NR) + G3 + YH(N, 1) * G2
NR = NR + 1
XZERO(NR) = XZERO(NR) + G2

C
STORE AMPLITUDES OF DISPL, MOMENT, SHEAR, AND TORSION DUE TO LOADS

AM000810
AM000820
AM000830
AM000840
AM000850
AM000860
AM000870
AM000880
AM000890
AM000900
AM000910
AM000920
AM000930
AM000940
AM000950
AM000960
AM000970
AM000980
AM000990
AM01000
AM01001
AM01002
AM01003
AM01004
AM01005
AM01006
AM01007
AM01008
AM01009
AM01100
AM01101
AM01102
AM01103
AM01104
AM01105
AM01106
AM01107
AM01108
AM01109
AM01110
AM01111
AM01112
AM01113
AM01114
AM01115
AM01116
AM01117
AM01118
AM01119
AM01120
TRANSFORM REDUNDANTS TO BEAM CENTER-LINE

DO 550 NB = 1, NBEAMS
NT = NTY(NB)
DO 540 I = 1, 8
NN = 4 * NB - 4 + I
540 X(I) = XZERO(NN)
X(4) = X(4) + YH(NT, 1) * X(3) = ZH(NT, 1) * X(2) = X(8) = YH(NT, 2) * X(7)
X(3) = X(3) = ALPHA * ZH(NT, 1) * X(1) = X(7) + ALPHA * ZH(NT, 2) * X(5)
X(2) = X(2) = ALPHA * YH(NT, 1) * X(1) = X(6) + ALPHA * YH(NT, 2) * X(5)
X(1) = X(1) = X(5)

STORE AMP. CF DISPL., MOMENTS, SHEAR, AXIAL FORCE AND TORSIONAL
MOMENT DUE TO REDUNDANTS

DAMP(NB) = DAMP(NB) + X(3) / (YH(NT) * ALPHA ** 4)
YMAMP(NB) = YMAMP(NB) = X(3) / ALPHA ** 2
ZMAMP(NB) = ZMAMP(NB) = X(2) / ALPHA ** 2
FAMP(NB) = FAMP(NB) + X(1) / ALPHA
SFAMP(NB) = SFAMP(NB) + X(3) / ALPHA

TAMP(NB) = TAMP(NB) + X(4) / ALPHA

 COMPUTE BM., SF, TCRS.,Mom., AND DISPL. FOR REQUIRED POSITIONS

NP = NPOS(K)
DO 700 I = 1, NP
ARG = ALPHA * SPAN / 2.
IF(KODE.EQ.0) ARG = ALPHA * XPOS(K, M)
SS = SIN(ARG)
CC = COS(ARG)
700 CONTINUE

600 CONTINUE
C  STORE AMPLITUDE OF REDUNDANTS
C
     IF(KODE,NE,0) GO TO 700
     DO 630 NN = 1,NX,4
       NM = NN + 4
       630 XOUT(K,NN,M) = XOUT(K,NN,M) + XZERO(NM)*CC
     DO 640 NN = 3,NX,4
       NM = NN + 4
       640 XOUT(K,NN,M) = XOUT(K,NN,M) + XZERO(NM)*SS
     DO 650 NN = 2,NX,2
       NM = NN + 4
       650 XOUT(K,NN,M) = XOUT(K,NN,M) + XZERO(NM)*SS
     CONTINUE
     700 CONTINUE
     800 CONTINUE
     900 CONTINUE
     IF(KODE,NE,0) CALL OUTPTT
     IF(KODE,EQ,0) CALL OUTPUT
     GO TO 1
    1900 CONTINUE
STOP
END
SUBROUTINE INPTT
COMMON/BLK 1/ HEAO(15),ZMI(20),YMI(20),BMA(20),
*ZSA(20),YSA(20),BMJ(20),YH(10,2),ZH(10,2),TY(30),
*LC( 500),NLB( 500),LM(4),PL( 500),XL( 500),
*ECC( 500),F11(10,4,4),F12(10,4,4),F22(10,4,4),SF(164,8),
*NPOS( 500),XPOS(9,9),HF(19,4),JTY(30),YSTR(9,4),ZSTR(9,4),
*NOUT(9),YSSS(9,4),ZSSS(9,4),X(8)
COMMON/BLK 2/ NHARMS,SPAN,NBEAMS,E,G,NTYPES,NEQ,
*ALPHA,NLCASE,NLCARD,NX
READ(99,1000) (HEAO(J),J=1,15)
1000 FORMAT(15A4)
READ 1010, SPAN,E,G,NBEAMS,NTYPES,JTYPES,NHARMS
1010 FORMAT (3F10.3)
WRITE(6,2000) (HEAO(J),J=1,15)
2000 FORMAT(20X,9X, "****ANALYSIS OF MULTI-BEAM BRIDGE****",/1X,15A)
14)
PRINT 2010, SPAN,E,G,NBEAMS,NTYPES,JTYPES,NHARMS
2010 FORMAT (10X,11HBRIDGE SPAN,29X,1H=,F12.3//
1 10X,2AHYOUNGS MODULUS OF ELASTICITY,12X,1H=,F12.0//
2 10X,14HPCISSONS RATIO,26X,1H=,F12.3//
3 10X,15HNUMBER OF BEAMS,25X,1H=,I6//
4 10X,20HNUMBER OF BEAM-TYPES,20X,1H=,I6//
5 10X,21HNUMBER OF JOINT-TYPES,19X,1H=,I6//
6 10X,19HNUMBER OF HARMONICS,21X,1H=,I6//)
C
G = E/(2.*(1. + G))
C
READ IN BEAM PROPERTIES FOR EACH TYPE
C
PRINT 2020
2020 FORMAT (1H1,9X,26H "****BEAM PROPERTIES****"///
1 1X,4HTYPE,7X,4HI=ZZ,7X,4HI=YY,7X,4HAREA,
2 5X,6HTORS J,8X,3HZHL,8X,3HYHL,8X,3HZHR,8X,3HYHR/) DO 150 N = 1, NTYPES
READ 1030, ZMI(N),YMI(N),EMA(N),BMJ(N),ZH(N,1),YH(N,1),ZH(N,2),
1 YH(N,2)
1030 FORMAT (4F10.0/4F10.0)
PRINT 2030, N,ZMI(N),YMI(N),BMA(N),BMJ(N),ZH(N,1),
1 YH(N,1),ZH(N,2),YH(N,2)
2030 FORMAT (/I5,4F11.1,4F11.2)
150 CONTINUE
C IDENTIFY BEAMS BY TYPE
C PRINT 2040
2040 FORMAT (///2X,7HBEAM,NO.,5X,4HTYPE/)
READ 1050, (NTY(N), N = 1, NBEAMS)
1050 FORMAT (20I2)
PRINT 2050, (N, NTY(N), N = 1, NBEAMS)
2050 FORMAT (///)
C READ IN HINGE FLEXIBILITIES
C PRINT 2060
2060 FORMAT (///10X,30H *****HINGE FLEXIBILITIES*****//)
1 1X,4HTYPE,15X,SHLONG.,14X,6HGIRIZ.,15X,5HVERT.,16X,4HROT./)AM002380
DO 160 J = 1, JTYPES
READ 1070, (HF(J,N), N = 1, N)
1070 FORMAT (4F10.0)
160 PRINT 2065, J, (HF(J,N), N = 1, N)
2065 FORMAT (15.1P4E20.5)
C IDENTIFY JOINTS BY TYPE
NJ = NBEAMS = 1
2070 FORMAT (///9H JOINT NC.,5X,4HTYPE/)
PRINT 2070
READ 1075, (JTY(J), J = 1, NJ)
1075 FORMAT (20I2)
PRINT 2050, (J,JTY(J), J = 1, NJ)
C READ IN LOAD DATA
C PRINT 1080, NLCASE,NLCARD
1080 FORMAT (21S)
PRINT 2080
2080 FORMAT (1H1,9X,29H *****LOADING CONDITIONS*****///)
1 1X,9LOAD CASE,1X,7BEAM NO.,9X,4LOAD,6X,7X COORD,7X,
2 6LENGTH,6X,4HECC.,///)
DO 175 N = 1, NLCARD
C
READ 1090, LC(N), NLB(N), P(N), XL(N), PL(N), ECC(N)
1090 FORMAT (215,4F10.0)
PRINT 2090, LC(N), NLB(N), P(N), XL(N), PL(N), ECC(N)
175 ECC(N) = ECC(N)
2050 FORMAT (/219,4F13.3)
C READ IN DATA SPECIFYING X COORDS FOR RESULTS
C PRINT 2100
2100 FORMAT (//////10X,37F ****JOINT X=COORDS FOR RESULTS****//
1 22X.5HNO OF/ 2 9X.9HLOAD CASE, 2X, 9HPOSITIONS, 9X, 2HX1, 7X, 2HX2, 7X, 2HX3, 7X, 2HX4, 7X, 2HX5, 7X, 2HX6, 7X, 2HX7, 7X, 2HX8, 7X, 2HX9)
DO 200 J = 1, NL CASE
READ 1110, L, NP, (XPOS(L,N), N = 1, NP)
1110 FORMAT (215, 9F5.0)
NPOS(L) = NP
200 PRINT 2110, L, NP, (XPCS(L,N), N = 1, NP)
2110 FORMAT (//////10X, 49H *****COORDINATES FOR OUTPUT OF AXIAL STRESS*****//
1 22X.5HNO OF/ 2 9X, 9HBEAM TYPE, 2X, 9HPOSITIONS, 11X, 2HY1, 7X, 2HZ1, 12X, 2HY2, 7X, 2HZ2, 12X, 2HY3, 7X, 2HZ3, 12X, 2HY4, 7X, 2HZ4/)
DO 225 NT = 1, N TYPES
READ 1130, NOUT(NT), (YSTR(NT,N), ZSTR(NT,N), N = 1, 4)
1130 FORMAT (15, 8F5.0)
NO = NOUT(NT)
225 PRINT 2130, NT, NO, (YSTR(NT,N), ZSTR(NT,N), N = 1, NO)
2130 FORMAT (/118, I7, F15.1, 8F9.1)
C READ IN COORDINATES SPECIFIED FOR STRESS OUTPUT
C PRINT 2120
2120 FORMAT (//////10X, 49H *****COORDINATES FOR OUTPUT OF AXIAL STRESS*****//
1 22X.5HNO OF/ 2 9X, 9HBEAM TYPE, 2X, 9HPOSITIONS, 11X, 2HY1, 7X, 2HZ1, 12X, 2HY2, 7X, 2HZ2, 12X, 2HY3, 7X, 2HZ3, 12X, 2HY4, 7X, 2HZ4/)
DO 225 NT = 1, N TYPES
READ 1130, NOUT(NT), (YSTR(NT,N), ZSTR(NT,N), N = 1, 4)
1130 FORMAT (15, 8F5.0)
NO = NOUT(NT)
225 PRINT 2130, NT, NO, (YSTR(NT,N), ZSTR(NT,N), N = 1, NO)
2130 FORMAT (/118, I7, 8X, 2F9.1, 5X, 2F9.1, 5X, 2F9.15X, 2F9.1, 5X, 2F9.1)
DO 300 NT = 1, N TYPES
DO 275 N = 1, 4
YSSS(NT,N) = YSTR(NT,N)/ZMI(NT)
275 ZSSS(NT,N) = ZSTR(NT,N)/YMI(NT)
ZMI(NT) = E * ZMI(NT)
YMI(NT) = E * YMI(NT)
BMJ(NT) = BMJ(NT) * G
BMA(NT) = E * BMA(NT)
300 CONTINUE
C
RETURN
C
END
SUBROUTINE SYMSCL (A,B,NN,MM,KKK)
DIMENSION A(164,8),B(164)

A = COEFFICIENT MATRIX.
B = RIGHT HAND SIDE MATRIX.
NN = NUMBER OF EQUATIONS (MAX 800 HERE).
MM = HALF BAND WIDTH (MAX 20 HERE).

GO TO (1000,2000),KKK

REDUCE COEFFICIENT MATRIX.

1000 NL = NN = 4
DO 280 N = 5, NL
DO 260 L=2,MM
C=A(N,L)/A(N,1)
I = N+L-1
IF(NL=I) 260, 240, 240
240 J=0
DO 250 K=L,MM
J=J+1
250 A(I,J)=A(I,J)-C*A(N,K)
260 A(N,L)=C
280 CONTINUE
GO TO 500

REDUCE RIGHT HAND SIDE MATRIX.

2000 DO 290 N = 5, NL
DO 285 L=2,MM
I=N+L-1
IF(NL=I) 290, 285, 285
285 B(I)=B(I)-A(N,L)*B(N)
290 B(N)=B(N)/A(N,1)

CARRY OUT BACK SUBSTITUTION.

N=NL
300 N = N-1
IF(N=4) 350,500,350
350 DO 400 K=2,MM
   L = N+K+1
   IF(N=L) 400,370,370
370 B(N) = B(N) = A(N,K) * B(L)
400 CONTINUE
   GO TO 300
C
500 RETURN
C
   END
SUBROUTINE INPUT
INTEGER*2 TITLE,HH,SS,DIGIT1,DIGIT2,BK,A1,A2,KEY,HINGTP,YES,NO,
* A3,A4
COMMON/BLK 1/ HEAD(15),ZMI(20),YMI(20),BMA(20),
* ZSA(20),YSA(20),BMJ(20),YH(10,2),ZH(10,2),NTY(30),
* L(500),NL(500),LM(4),P(500),XL(500),PL(500),
* ECC(500),F11(10,4,4),F12(10,4,4),F22(10,4,4),SF(164,2),
* NPOS(500),XPOS(9,9),HF(19,4),JTY(30),YSTR(9,4),ZSTR(9,4),
* NOUT(9),YSSS(9,4),ZZSS(9,4),X(8)
COMMON/BLK 2/ NHALMS,SPAN,NBEAMS,E,G,NTYPs,NEQ,
* ALPHA,NLCASE,NL,NCARD,NX
COMMON/BLK 3/ XZERO(164),YMAMPL(20),ZMAMPL(20),
* FAMPL(20),SFANFL(20),TAMPL(20),CAMPL(20),YMOUT(200),20,9),
* ZMOUT(9,20,9),FOUT(9,20,9),SFOUT(9,20,9),TOUT(9,20,9),
* DOUT(9,20,9),XOUT(9.76,9).XS(4),XA(4)
COMMON/BLK 4/ TITLE(3,54),HINGTP(19,4),PHEEL(18),ZNWHL(18),
* DIST(18),WHL(18),TLN(5,2),KAST(5,2),KASL(5,2),
* XCAST(5,2),ZMAST(20,5),ZMASL(20,5),ZMXT(20,5),ZMMAST(20),
* ZMAS(20),ZMMAST(20),PPOS(20,10),PS1(20,10),PASX(20,10),
* NLLAST(20,5),NLLALN(20,5),NLLAXT(20,5),DISTAT(20),
* DISTAL(20),DISTAX(20)
COMMON/BLK 5/ NWHS,NWHEEL,A1,A2,KAXT,FULMAT,FULMAL,FULMAX,PMAT,PMAX
* XAXT,NTRFL,NAXCL,NAXTSP,NTYPES,A3,A4,A5,A6,A7
DATA HH,SS,DIGIT1,DIGIT2,BK/#H","S",#1",#2","""
DATA YES,NO/#Y","N"/
READ(99,104) (TITLE(J1,J2),J2=1.54)
DO 102 J1=2,3
102 READ(5,104) (TITLE(J1,J2),J2=1.54)
104 FORMAT(54A1)
READ(5,106) ZPAN,E,NBEAMS,NTRFL,A1,A2,A3,A4,KAXT,NAXTSP,NAXCL,NAXT
106 FORMAT(4X,F4.1,4X,F6.1,5X,I2,5X,I2,5X,I2.5X,2A1,1X,2A1,5X,I1,5X,I2,5X,11AMO3900
*,5X,11)
SFAN=ZPAN*12.
NTYPES=0
108 READ(5,112) KEY
112 FORMAT(3X,A1)
IF(KEY.EQ.EBK) GO TO 116
READ(99,114) IBMN,YMI(IBMN),ZMI(IBMN),BMA(IBMN),BMJ(IBMN),
* YH(IBMN,1),ZH(IBMN,1),YH(IBMN,2),ZH(IBMN,2)
114 FORMAT(3X,I1,7X,F8.1,4X,F6.1,4X,F5.1,4X,F8.1,4X,F5.1,4X,F8.1,3X,4(F5.1,2,1X))
YH(IBMN,1) = YH(IBMN,1)
Ntypes = Ntypes + 1
Go to 108

116 READ(99,118) (NTY(J1),J1=1,NBEAMS)
118 FORMAT(4X,20(I2,1X))
JTYPES = 0

122 READ(5,112) KEY
IF(KEY.EQ.BK) GO TO 126
READ(99,124) IJTN, (HINGTP(IJTN,J1),J1=1,4)
124 FORMAT(3X,I1,9X,4(A1,7X))
JTYPES = JTYPES + 1
Go to 122

126 Do 132 J1 = 1, JTYPES
Do 128 J2 = 1, 4
128 HF(J1,J2) = 1.0E+08
IF(HINGTP(J1,1).EQ.YES) HF(J1,1) = 0.
IF(HINGTP(J1,2).EQ.YES) HF(J1,2) = 0.
IF(HINGTP(J1,3).EQ.YES) HF(J1,3) = 0.
IF(HINGTP(J1,4).EQ.YES) HF(J1,4) = 0.
132 Continue
NJ = NBEAMS - 1
READ(99,118) (JTY(J1),J1=1,NJ)
READ(5,134) (TLN(J1,J1),TLN(J1,2),J1=1,NTRFL)
134 FORMAT(4X,5(F4.1,4X,F4.1,4X))
IF(KAXT.EQ.0) Go to 150
READ(5,136) (PWHEEL(J1),J1=1,18)
READ(5,138) (ZNWHL(J1),J1=2,18)
136 FORMAT(4X,18(F3.0,1X))
138 FORMAT(8X,17(F3.0,1X))
NWHEEL = 0
Do 140 J1 = 1, 18
IF(PWHEEL(J1).EQ.0.) Go to 142
140 NWHEEL = NWHEEL + 1
142 Continue
150 NLCARD = 0
NLCASE = 0
IF(A1.EQ.BK.AND.A2.EQ.BK) Go to 514
C******************************************************************************AM004000
C SET UP INFLUENCE COEFFICIENT LOAD CASES = AASHTO TRUCK
C******************************************************************************AM004390
NW=2
IF(A1.EQ.HH.AND.A2.EQ.SS) NW=3
SCALE=0.5
IF(A3.EQ.DIGIT1) SCALE=0.375
WHLWMN(J1)=SCALE*8.
DO 156 J1=2,NW
WHLWMN(J1)=SCALE*32.
156 DIST(J1)=(J1-1)*14.
CALL MAXMIN(NW,WHLWMN,DIST,ZPAN,FULMAT)
FULMAT=FULMAT+2.*12.
DO 506 J1=1,NTRFL
KASAST(J1,J1)=NLCASE+1
YDIST=TLN(J1,1)*12.+12.
502 YDIST=YDIST+12.
IF(YDIST.GT.12.*TLN(J1,2)) GO TO 506
NLCASE=NLCASE+1
CALL LOCATE(YDIST,NBM,ECCEN,NBEAMS,YH,NTY)
DO 504 J2=1,NB
NLCARD=NLCARD+1
LC(NLCARD)=NLCASE
NLB(NLCARD)=NBM
P(NLCARD)=WHLWMN(J2)
XL(NLCARD)=DIST(J2)*12.
PL(NLCARD)=12.
ECC(NLCARD)=ECCEN
504 CONTINUE
GO TO 502
506 KASAST(J1,2)=NLCASE

****************************************************************************
SET UP INFLUENCE COEFFICIENT LOAD CASES=AASHTO LANE
****************************************************************************
WW=0.48
CONF=13.5
IF(A3.EQ.DIGIT2) WW=0.640
IF(A3.EQ.DIGIT2) CONF=18.
FULMAT=(WW/12.)*SPAN**2/8.+CONF*SPAN/4.
DO 512 J1=1,NTRFL
KASAST(J1,1)=NLCASE+1
YDIST=TLN(J1,1)*12.+12.
508 YDIST=YDIST+12.
IF(YDIST*GT.*12.*TLN(J1,2)) GO TO 512
NLCASE=NLCASE+1
CALL LOCATE(YDIST,NBM,ECCEN,NBEAMS,YH,NTY)
NLCARD=NLCARD+1
LC(NLCARD)=NLCASE
NLB(NLCARD)=NBM
P(NLCARD)=(WW/10.)*SPAN/12.
XL(NLCARD)=SPAN/2.
PL(NLCARD)=SPAN
ECC(NLCARD)=ECCEN
NLCARD=NLCARD+1
LC(NLCARD)=NLCASE
NLB(NLCARD)=NBM
P(NLCARD)=CONF/10.
XL(NLCARD)=SPAN/2.
PL(NLCARD)=12.
ECC(NLCARD)=ECCEN
GO TO 508
512 KASAAL(J1,2)=NLCASE
C
***********************************************************************************************
C SET UP INFLUENCE COEFFICIENT LOAD CASES=AXLE TRAIN
***********************************************************************************************
C
514 IF(KAXT.EQ.0) GO TO 526
NWHL=NWHEEL
WHLWM((1))=PWHEEL((1))/2.
DO 530 J1=2,NW
WHLWM((J1))=PWHEEL((J1))/2.
530 DIST(J1)=ZNWHL(J1)
CALL MAXMOM(NWHL,WHLWM,DIST,SPAN,FULMAX)
FULMAX=FULMAX*2.*12.
DO 524 J1=1,NTRFL
KASAXT(J1,1)=NLCASE+1
YDIST=TLN(J1,1)*12.*12.
516 YDIST=YDIST+12.
IF(YDIST*GT.*12.*TLN(J1,2)) GO TO 524
NLCASE=NLCASE+1
CALL LOCATE(YDIST,NBM,ECCEN,NBEAMS,YH,NTY)
DO 518 J2=1,NWHL
NLCARD=NLCARD+1
LC(NLCARD)=NLCASE
NLB(NLCAEC) = NEM
P(NLCAEC) = WhlWNM(J2)
XL(NLCAEC) = DIST(J2) * 12.
PL(NLCAEC) = 12.
ECC(NLCAEC) = ECCEN
518 CONTINUE
GO TO 516
524 KASAXT(J1,2) = NLCAEC
526 CONTINUE
C
PRINT OUT INPUT
C
WRITE(6,1100)
1100 FORMAT('1')
WRITE(6,1101)
WRITE(6,1103)
WRITE(6,1101)
WRITE(6,1104) (TITLE(1,J1),J1=10,11),(TITLE(1,J1),J1=14,26),
1(TITLE(1,J1),J1=48,54)
WRITE(6,1105) (TITLE(2,J2),J2=13,19),(TITLE(2,J2),J2=26,28),
1(TITLE(2,J2),J2=45,54)
WRITE(6,1106) (TITLE(3,J3),J3=13,54)
WRITE(6,1101)
WRITE(6,1107)
WRITE(6,1108) ZPAN,E,NBEAMS,NTFIL,A1,A2,A3,A4,NAXTSP,NAXCL,NAXT
WRITE(6,1102)
WRITE(6,1109)
WRITE(6,1104) IBNM,YMI(IBMN),ZMI(IBMN),BMA(IBMN),BMJ(IBMN),
1YH(IBMN,1),ZH(IBMN,1),YH(IBMN,2),ZH(IBMN,2)
1240 CONTINUE
WRITE(6,1102)
WRITE(6,1111)
WRITE(6,1112) (NTY(J1),J1=1,NBEAMS)
WRITE(6,1102)
WRITE(6,1113)
DO 1235 I'HING=1,JTYPES
WRITE(6,1114) IHING,(HINGTP(IHING,J1),J1=1,4)
WRITE(6,1102)
WRITE(6,1115)
WRITE(6,1116) (JTY(J1),J1=1,NJ)                        AM005600
WRITE(6,1102)                                        AM005610
WRITE(6,1117)                                        AM005620
WRITE(6,1118) (TLN(J1,1),TLN(J1,2),J1=1,NTRFL)      AM005630
WRITE(6,1102)                                        AM005640
IF(KALT.EQ.0) GC TO 1255                             AM005650
WRITE(6,1119)                                        AM005660
WRITE(6,1120) (PWHEEL(J1),J1=1,18)                  AM005670
WRITE(6,1112)                                        AM005680
WRITE(6,1111) (ZNWHL(J1),J1=2,18)                   AM005690
WRITE(6,1102)                                        AM005700
1255 WRITE(6,1123)                                    AM005710
WRITE(6,1101)                                        AM005720
1101 FORMAT(1X,129('**'))                             AM005730
1102 FORMAT(1X,129('**'))                             AM005740
1103 FORMAT(105X,'VALUES ASSIGNED TO INPUT DATA',/) AM005750
1104 FORMAT(105X,'DISTRICT',2A1,4X,13A1,' COUNTY HIGHWAY NO. ',AM005760
1,7A1,/)                                             AM005770
1105 FORMAT(105X,'CONTROL NO.',7A1,5X,'IPE ',3A1,4X,'SUBMITTED BY:',AM005780
1,1X,10A1,/)                                         AM005790
1106 FORMAT(105X,'DESCRIPTION: ',42A1,/)              AM005800
1107 FORMAT(105X,'BRIDGE PROPERTIES ...',//,25X,'MODULUS',AM005810
116X,'NUMBER',22X,'TRANSVERSE',5X,'AXLE TRAIN',//,28X,'OF',7X,
1'NUMBER',7X,'OF',24X,'AXLE TRAIN',7X,'SIDE',10X,'NUMBER OF',//,12X,AM005820
1'SPAN',8X,'ELASTICITY',5X,'OF',7X,'TRAFFIC',5X,'AASHTO',9X,
1'WHEEL SPACING CLEARANCE',6X,'AXLE TRAINS',//,12X,'(FT.)',10X,AM005830
1'(KSI)',6X,'BEAMS',6X,'LANES',6X,'LOADING',12X,'(FT.)',9X,'(FT.)',AM005840
19X,'ON BRIDGE',/)                                   AM005850
1108 FORMAT(105X,'AREA',8X,'STIFFNESS',10X,'HL',8X,'VL',8X,'HR',8X,'VR',//,10X,AM005860
1109 FORMAT(105X,'BEAM DIMENSIONS AND PROPERTIES ...',//,AM005880
1,18X,'INERTIA ABOUT INERTIA ABOUT',//,11X,'BEAM',4X,'HORIZONTAL',AM005890
16X,'VERTICAL',20X,'TORSIONAL',//,11X,'TYPE',7X,'AXIS',11X,'AXIS',AM005900
110X,'AREA',8X,'STIFFNESS',10X,'HL',8X,'VL',8X,'HR',8X,'VR',//,10X,AM005910
110X,4*((IN**))/,)                                     AM005930
1110 FORMAT(105X,'BEAM TYPE IDENTIFICATION NUMBER FOR BEAM IAM005940
1',14X,'I=1 I=2 I=3 I=4 I=5 I=6 I=7 I=8 I=9 I=10 AM005950
1I=11 I=12 I=13 I=14 I=15 I=16 I=17 I=18 I=19 I=20',/) AM005960
1111 FORMAT(105X,'BEAM TYPE IDENTIFICATION NUMBER FOR BEAM IAM005970
1',14X,'I=1 I=2 I=3 I=4 I=5 I=6 I=7 I=8 I=9 I=10 AM005980
1I=11 I=12 I=13 I=14 I=15 I=16 I=17 I=18 I=19 I=20',/) AM005990
1112 FORMAT(* '10X,2015,/') AM006000
1113 FORMAT(* '46X,'..... HINGE FORCE TRANSMISSION .....','28X, AM006010
1114 HINGE TYPE '5X,'LONGITUDINAL,'6X,'VERTICAL,'7X,2('TRANSVERSE','6X)AM006020
1115 *30X,'NUMBER','10X,2('SHEAR','11X, 'FORCE',11X,'MOMENT',') AM006030
1116 FORMAT(*0,31X,1,1X,4A16) AM006040
1117 HINGE TYPE IDENTIFICATION NUMBER FOR HINGEAM006050
1118 1 I ......,' /,17X,*=1 I=2 I=3 I=4 I=5 I=6 I=7 I=8 I=9 I=1AM006060
1119 10 I=11 I=12 I=13 I=14 I=15 I=16 I=17 I=18 I=19,/') AM006070
1119 FORMAT(*0,13X,1915) AM006080
1117 DISTANCE (FT.) FROM C.G. AXIS OF BEAM 1 TOAM006090
1120 1: ......,,'//12X,'E(••••••), 'LANE 1,6(••••••),1X,6(••••••), 'LANE 2,6(••••••)AM006100
1121 1,1X,6(••••••), 'LANE 3,6(••••••),1X,6(••••••), 'LANE 4,6(••••••),1X,6(••••••) AM006110
1122 1,LANE 5,6(••••••),1X,5('LEFT',7X,'RIGHT',4X),1X,5('EDGE',8X, AM006120
1123 1,EDGE*,4X),') AM006130
1124 FORMAT(*0,13X,10(F5.1,5X)) AM006140
1125 FORMAT(*,,'54X,'..... AXLE TRAIN .....','//15X,18(*AXLE',2X),// AM006150
1126 17X,,'1,5X,'2,5X,'3,5X,'4,5X,'5,5X,'6,5X,'7,5X,'8,5X,'9, AM006160
1127 14X,,'10,4X,'11,4X,'12,4X,'13,4X,'14,4X,'15,4X,'16,4X,'17, AM006170
1128 14X,,'18,4X,'5X,'AXLE*,5X,'LOAD*,4X,'KIPS*') AM006180
1129 FORMAT(*13X,18(F5.1,1X),/) AM006190
1130 FORMAT(*,,'DIST. FROM',4X,'AXLE 1 TO',4X,'AXLE 1 (FT.*)') AM006200
1131 FORMAT(*119X,17(F5.0,1X),/) AM006210
1132 FORMAT(*) AM006220
1133 DO 170 J1=1,NLCARD AM006230
1134 EEC(J1)=EEC(J1) AM006240
1135 G=E/(2*(1+E*166)) AM006250
1136 DO 172 J1=1,NTYPES AM006260
1137 ZMI(J1)=E*ZMI(J1) AM006270
1138 YMI(J1)=E*YMI(J1) AM006280
1139 BMJ(J1)=G*BMJ(J1) AM006290
1140 BMA(J1)=E*BMA(J1) AM006300
1141 DO 164 J1=1,NLCASE AM006310
1142 NPOS(J1)=1 AM006320
1143 RETURN AM006330
1144 END AM006340
SUBROUTINE OUTPTT

COMMON/BLK 1/ HEAD(15),ZMI(20),YWI(20),BMA(20),
*ZSA(20),YSA(20),BMJ(20),YM(10,2),ZM(10,2),NY(30),
*LC(500),NLB(500),LM(4),P(500),XL(500),PL(500),
*ECC(500),F11(10,4,4),F12(10,4,4),F22(10,4,4),SF(164,8),
*NPOS(500),XPOS(9,9),HF(19,4),JTY(30),YSSTR(9,4),ZSTR(9,4),
*OUT(9),YSSS(9,4),ZSSS(9,4),X(8)

COMMON/BLK 2/ NOUT(9),YSSS(9,4),ZSSS(9,4),X(8)

COMMON/BLK 3/ NOUT(9),YSSS(9,4),ZSSS(9,4),X(8)

*ALPHA,NLCASE,NLCA,SE,NLCASO,NX

PRINT RESULTS

DO 1000 K = 1, NLCASE
NP = NPOS(K)
PRINT 10, K

10 FORMAT (1H1,9X,51H *****BEAM CENTER-LINE DISPLACEMENTS *****/)

PRINT 20, (XPOS(K,J), J = 1, NP)
PRINT 25

20 FORMAT (18HLOCATIONS ON BEAM, 9F11.1)

PRINT 30, J, (DOUT(K,J,M), M = 1, NP)

30 FORMAT (/8X,13,7X,1P9E11.3)

PRINT 40, K

40 FORMAT (1H1,9X,49H *****BENDING MOMENTS ABOUT Y-AXIS *****/)

PRINT 20, (XPOS(K,J), J = 1, NP)
PRINT 25

43 FORMAT (1H1,9X,49H *****BENDING MOMENTS ABOUT Z-AXIS *****/)

PRINT 30, J, (YMOUT(K,J1,J2), M = 1, NP)

PRINT 45, K

45 FORMAT (1H1,9X,49H *****BENDING MOMENTS ABOUT Z-AXIS *****/)

DO 1000 K = 1, NLCASE
NP = NPOS(K)
PRINT 10, K

10 FORMAT (1H1,9X,51H *****BEAM CENTER-LINE DISPLACEMENTS *****/)

PRINT 20, (XPOS(K,J), J = 1, NP)
PRINT 25

20 FORMAT (18HLOCATIONS ON BEAM, 9F11.1)

PRINT 30, J, (DOUT(K,J,M), M = 1, NP)

30 FORMAT (/8X,13,7X,1P9E11.3)

PRINT 40, K

40 FORMAT (1H1,9X,49H *****BENDING MOMENTS ABOUT Y-AXIS *****/)

PRINT 20, (XPOS(K,J), J = 1, NP)
PRINT 25

43 FORMAT (1H1,9X,49H *****BENDING MOMENTS ABOUT Z-AXIS *****/)

PRINT 30, J, (YMOUT(K,J1,J2), M = 1, NP)

PRINT 45, K

45 FORMAT (1H1,9X,49H *****BENDING MOMENTS ABOUT Z-AXIS *****/)
10 I2, 5H****/*)
PRINT 20, (XPOS(K, J), J = 1, NP)
PRINT 25
DO 925 J = 1, NBEAMS
925 PRINT 30, J, (ZMOUT(K, J, M), M = 1, NP)
PRINT 50, K
50 FORMAT (1H1, 9X, 36H *****VERTICAL SHEARS LOAD CASE NO.I2, 1
SH*****/)
PRINT 20, (XPOS(K, J), J = 1, NP)
PRINT 25
DO 930 J = 1, NBEAMS
930 PRINT 30, J, (SFOUT(K, J, M), M = 1, NP)
PRINT 55, K
55 FORMAT (1H1, 9X, 33H *****AXIAL FORCES LOAD CASE NO.I2, 5H****/*))
PRINT 20, (XPOS(K, J), J = 1, NP)
PRINT 25
DO 935 J = 1, NBEAMS
935 PRINT 30, J, (FOUT(K, J, M), M = 1, NP)
PRINT 60, K
60 FORMAT (1H1, 9X, 38H *****TORSIONAL MOMENTS LOAD CASE NO.I2, 1
SH****/*))
PRINT 20, (XPOS(K, J), J = 1, NP)
PRINT 25
DO 940 J = 1, NBEAMS
940 PRINT 30, J, (TCUT(K, J, M), M = 1, NP)
PRINT 70, K
70 FORMAT (1H1, 9X, 52H *****FORCES ALONG LONGITUDINAL JOINT LOAD CASE
AM007010)
1 14 NO.12, 5H****/*))
PRINT 75
75 FORMAT (1H1, 9X, 52H *****LONGITUDINAL SHEAR ON JOINT)
PRINT 20, (XPOS(K, J), J = 1, NP)
MM = NX / 4
PRINT 95
DO 950 J = 1, MM
JJ = 4*J + 3
950 PRINT 100, J, (XOUT(K, JJ, M), M = 1, NP)
PRINT 80
80 FORMAT (1H1, 9X, 52H *****TRANSVERSE FORCE ON JOINT)
PRINT 20, (XPOS(K, J), J = 1, NP)
PRINT 95
DO 960 J = 1, MM
JJ = 4*J - 2
960 PRINT 100, J, (XOUT(K, JJ, M), M = 1, NP)
85 FORMAT (124H0VERTICAL SHEAR CN JOINT)
PRINT 85
PRINT 20, (XPOS(K, J), J = 1, NP)
PRINT 95
DO 970 J = 1, MM
JJ = 4*J - 1
970 PRINT 100, J, (XOUT(K, JJ, M), M = 1, NP)
PRINT 90
90 FORMAT (127H0TRANSVERSE MOMENT CN JOINT)
PRINT 20, (XPOS(K, J), J = 1, NP)
PRINT 95
DO 980 J = 1, MM
JJ = 4*J
980 PRINT 100, J, (XOUT(K, JJ, M), M = 1, NP)
95 FORMAT (19H0JOINT NO)
100 FORMAT (15, 13X, 1P9E11.3)
1000 CONTINUE

C
C COMPUTE AXIAL STRESS AT FOUR SPECIFIED POSITIONS
C
DO 1200 NE = 1, NBEAMS
NT = NTY(NB)
DO 1200 N = 1, 4
NS = 4*NB + 4 + N
DO 1200 K = 1, NLCASE
NP = NPOS(K)
DO 1200 M = 1, NP
1200 XOUT(K, NS, M) = YMOUT(K, NB, M)*ZSSS(N, K) + ZMOUT(K, NB, M)*
1 YSSS(N, T) + FOUT(K, NB, M)/BMA(N, T)*E

C
C PRINT STRESSES
C
DO 1300 K = 1, NLCASE
NP = NPOS(K)
PRINT 110, K
110 FORMAT (1H1, 9X, 33H *****AXIAL STRESS LOAD CASE NO, I2, 5H*****/)
DO 1300 NE = 1, NBEAMS
NT = NTY(NB)
NO = NOUT(NT)
PRINT 120, NB
120 FORMAT ('///HE BEAM NO., I2)
PRINT 130, (XPOS(K, J), J = 1, NP)
130 FORMAT (18H0LOCATIONS ON BEAM,4X,9F11.1/4X,1HY,9X,1HZ/)
DO 1300 N = 1, NO
NS = 4*NB+4*N
1300 PRINT 150, YSTR(NT, N), ZSTR(NT, N), (XOUT(K, NS, M), M = 1, NP)
150 FORMAT (2X,F5.1,F10.1,5X,1P9E11.3)
RETURN
END
SUBROUTINE OUTPUT

INTEGER*2 TITLE,A1,A2,HINGTP,A3,A4
COMMON/BLK 1/ HEAD(15),ZMI(20),YMI(20),BMA(20),
*ZSA(20),YSA(20),BMJ(20),YH(10,2),ZH(10,2),NTY(30),
*LC( 500),NLB( 500),LM( 4),P( 500),XL( 500),PL( 500),
*ECC( 500),F11(10,4,4),F12(10,4,4),F22(10,4,4),SF(164,8),
*NPOS( 500),XPOS(9,9),MF(19,4),JTY(30),YSTR(9,4),ZSTR(9,4),
*OUT(9),YSSS(9,4),ZSSS(9,4),X(8)
COMMON/BLK 2/ NHARMS,SPAN,NBEAMS,E,G,NTYPES,NEQ,
*ALPHA,NLCASE,NLCARD,NX
COMMON/BLK 3/ XZERO(164),YMAMPL(20),ZMAMPL(20),
*F11MPL(20),SFAMP1(20),TAMP1(20),DAMP1(20),YMOUT( 200,20,9),
*ZMOUT(9,20,9),FOUT(9,20,9),SFOUT(9,20,9),TCUT(9,20,9),
*DOU(9,20,9),XOUT(9,76,9),XS(4),XA(4)
COMMON/BLK 4/ TITLE(3,54),HINGTP(19,4),PWHEEL(18),ZNWHL(18),
*DIST(18),WHLWNM(18),TLN(5,2),KASAST(5,2),KASASL(5,2),
*KASAX(5,2),ZMAST(20,5),ZMASL(20,5),ZMAXT(20,5),ZMMAST(20),
*ZMMAST(20),ZMMAXT(20),POSAT(20,10),POSLN(20,10),POSAX(20,10),
*NLLAST(20,5),NLLALN(20,5),NLLAX(20,5),DISTAT(20),
*DIST(20),DISTAX(20),
COMMON/BLK 5/ NHWLS,NWHEEL,A1,A2,KAXT,FULMAT,FULMAL,FULMAX,PMAT,PMAMO0739790
*KAXT,NTRFL,NAXCL,NAXTSP,NAXT,JTYPES,A3,A4,ZPAN
BEGIN PRINTOUT
C CALL INFLN
C CONVERT MOMENTS TO KIP FEET FOR OUTPUT
C DO 180 J2=NBEAMS
IF(A3.NE.BK) ZMMAST(J2)=ZMMAST(J2)/12.
IF(A3 .NE. BK) ZMMASL(J2)=ZMMASL(J2)/12.
IF(KAXT.NE.0) ZMMAXT(J2)=ZMMAXT(J2)/12.
180 CONTINUE
J3=2*NTRFL
WRITE(6,1002)
WRITE(6,1003)
WRITE(6,1004)
WRITE(6,1005)
WRITE(6,1006)
DO 1207 J2=NBEAMS
```
1207 WRITE(6,1009) J2, (POSAT(J2,J4), J4=1,J3)
WRITE(6,1010)
WRITE(6,1003)
WRITE(6,1004)
WRITE(6,1005)
WRITE(6,1007)
DO 1208 J2=1,NBEAMS
1208 WRITE(6,1009) J2, (POSALN(J2,J4), J4=1,J3)
IF(KAXT.EQ.0) GO TO 1260
WRITE(6,1011)
WRITE(6,1003)
WRITE(6,1004)
WRITE(6,1005)
WRITE(6,1006)
DO 1209 J2=1,NBEAMS
1209 WRITE(6,1009) J2, (PCSAJ(J2,J4), J4=1,J3)
1260 WRITE(6,1012)
WRITE(6,1013)
WRITE(6,1012)
WRITE(6,1014)
WRITE(6,1012)
WRITE(6,1015)
WRITE(6,1005)
WRITE(6,1008)
IF(KAXT.EQ.0.OR.AJ.EQ.BK) GO TO 1265
DO 1245 J2=1,NBEAMS
WRITE(6,1016) J2,ZMMAST(J2),DISTAT(J2),ZMMSL(J2),DISTAL(J2),IZMMAST(J2),DISTAX(J2)
1245 CONTINUE
GO TO 1275
1265 IF(KAXT.EQ.0) GO TO 1270
DO 1280 J2=1,NBEAMS
WRITE(6,1018) J2,ZMMAST(J2),DISTAX(J2)
1280 CONTINUE
GO TO 1275
1270 IF(AJ.EQ.BK) GO TO 1275
DO 1285 J2=1,NBEAMS
WRITE(6,1019) J2,ZMMAST(J2),DISTAT(J2),ZMMSL(J2),DISTAL(J2)
1285 CONTINUE
1275 WRITE(6,1012)
```
WRITE(6,1017)
1002 FORMAT('I',129('**'),/,**',50X,'LATERAL POSITION OF LOADS',52X,AM008480
1**',/,1X,'**',48X,'FOR MAXIMUM MOMENT AT MIDSPAN',50X,1**,1X,AM008490
129('**'),1X,57('**'),AASHTO TRUCK',58('**'),21X,1X,(POSITION AM008500
1OF TRUCK WHEELS IN LOADED LINES WITH RESPECT TO C.G. OF BEAM NO.1 AM008510
1= IN FT.),/
AM008520
1003 FORMAT('I',12X,6(''),6(''),6(''),6(''),6(''),6(''),LATERAL POSITION OF LOADS',50X,AM008530
10X,6(''),6(''),6(''),6(''),6(''),6(''),LATERAL POSITION OF LOADS',50X,AM008540
10LX 5(''),6(''),AM008550
1004 FORMAT('I',14X,'TO LEFT TO RIGHT TO LEFT TO RIGHT TO LEFT',AM008560
1TO RIGHT TO LEFT TO RIGHT TO LEFT',AM008570
1TO RIGHT TO LEFT TO RIGHT TO LEFT',AM008580
1TO RIGHT TO LEFT TO RIGHT TO LEFT',AM008590
1TO RIGHT TO LEFT TO RIGHT TO LEFT',AM008600
1005 FORMAT('I',4X,'BEAM NO.'),
1006 FORMAT('I',16X,'WHEEL WHEEL'),/
1007 FORMAT('I',13X,'EDGE'),/
1008 FORMAT('I',15X,'(KIP=FT.) TRUCK APPLIED (KIP=FT.) LANE APPLIED',AM008610
11ED (KIP=FT.) TRAIN APPLIED,/) AM008620
10F9.1,F11.1) AM008640
1010 FORMAT('I',3X,1X,57('**'),57('**'),57('**'),20X,AM008650
10X,57('**'),57('**'),57('**'),57('**'),57('**'),57('**'),57('**'),AM008660
10OF BEAM NO.1 = IN FT.),/
1AM008670
1011 FORMAT('I',2X,30X,2X,57('**'),57('**'),57('**'),57('**'),57('**'),57('**'),AM008680
10X,57('**'),57('**'),57('**'),57('**'),57('**'),57('**'),AM008690
10G. OF BEAM NO.1 = IN FT.),/
1AM008700
1012 FORMAT('I',1X,130('**')) AM008710
1013 FORMAT(//) AM008720
1014 FORMAT('I',2X,2X,51X,'MAXIMUM MIDSPAN MOMENTS AND',50X,2X,2X,AM008730
151X,'LATERAL DISTRIBUTION FACTORS',49X,'**') AM008740
1015 FORMAT('I',15X,'MOMENT FROM FRACTION OF ',2X,MOMENT FROM AM008750
10FRACTION OF '1',15X,'AASHTO TRUCK FULL AASHTO AASHTO LANE AM008760
10FULL AASHTO AXLE TRAIN FULL AXLE') AM008770
1016 FORMAT('0',7X,12X,8X,6X,7X,17X,6X,8X,7X,6X,8X,7X,6X,3,8X,8X,7X,6X,3) AM008780
1017 FORMAT('I') AM008790
1018 FORMAT('0',7X,12X,63X,8X,17X,6X,3) AM008800
1019 FORMAT('0',7X,12X,5X,8X,6X,7X,17X,6X,8X,7X,6X,3) AM008810
10RETURN
10END

SUBROUTINE INFL
INTEGER*2 TITLE, A1, A2, HINGTP
COMMON/BLK 1/ HEAD(15), ZMI(20), YMI(20), BMA(20),
* ZSA(20), YSA(20), BMJ(20), YH(10, 2), ZH(10, 2), NTY(30),
* LC(500), NLB(500), LM(4), P(500), XL(500), PL(500),
* ECC(500), F11(10, 4, 4), F12(10, 4, 4), F22(10, 4, 4), SF(164, 8),
* NPOS(500), XPOS(9, 9), F1(9, 4, 4), JTY(30), YSTR(9, 4), ZSTR(9, 4),
* NOUT(9), YSSS(9, 4), ZSSS(9, 4), X(8)
COMMON/BLK 2/ NHAM, SPAN, NBEAMS, E, G, NTYPES, NEQ,
* ALPHA, NLCASE, NLCARD, NX
COMMON/BLK 3/ ZZERO(164), YMAMPL(20), ZMAMPL(20),
* FAMP(20), SFAMP(20), TAMPL(20), DAMP(20), YMOUT(200, 20, 9),
* ZMOUT(9, 20, 9), FOUT(9, 20, 9), SFOUT(9, 20, 9), TCUT(9, 20, 9),
* DOT(9, 20, 9), XOUT(9, 76, 9), XS(4), XA(4)
COMMON/BLK 4/ TITLE(3, 54), HINGTP(19, 4), PHEEL(18), ZNWHL(18),
* DIST(18), WHLWMN(18), TNL(5, 2), KASAST(5, 2), KASA5L(5, 2),
* KASAXT(5, 2), ZMASL(20, 5), ZMASCX(20, 5), ZMAMSL(20),
* ZMMASL(20), ZMMAXT(20), POSAT(20, 10), POSL(20, 10), POSAX(20, 10),
* NLLAST(20, 5), NLLALN(20, 5), NLLAXT(20, 5), DISTAT(20),
* DISTAL(20), DIStAX(20)
COMMON/BLK 5/ NWHS, NWHE, A1, A2, KAXT, FULMAT, FULMAL, FULMAX, PMAT, PMAM009040
* AXT, NTRFL, NAXCL, NAXTSP, NAXT, JTYPS, A3, A4, ZFAN
DATA BK/* */
DIMENSION ZZ(5), IZ(5)
ZIMP=50./(125.+SPAN/12.)
IF(ZIMP.GT.0.3) ZIMP=0.3
FULMAT=FULMAT*(1. +ZIMP)
FULMAL=FULMAL*(1. +ZIMP)
FULMAX=FULMAX*(1. +ZIMP)
DO 200 J1=1, NLCASE
DO 200 J2=1, NBEAMS
200 YMOUT(J1, J2, 1)=YMOUT(J1, J2, 1)*(1. +ZIMP)
C ADJUST YMOUT TO CLOSE EQUILIBRIUM OF MOMENTS GAP, SHOULD IT EXIST
C
IF(A3.EQ.BK) GO TO 254
JSTRT=KASAST(1, 1)
JSTP=KASAST(NTRFL, 2)
DO 204 J1=JSTRT, JSTP
SUM=0.
DO 204 J2=1,NBEAMS
204 SUM=SUM+YMOUT(J1,J2,1)
   SUM=SUM/(0.5*FULMAT)
DO 206 J2=1,NBEAMS
206 YMOUT(J1,J2,1)=YMOUT(J1,J2,1)/SUM
214 CONTINUE
   JSTRT=KASASL(1,1)
   JSTP=KASASL(NTRFL,2)
   DO 252 J1=JSTRT,JSTP
      SUM=0.
   DO 248 J2=1,NBEAMS
248 SUM=SUM+YMOUT(J1,J2,1)
   SUM=SUM/(0.1*FULMAT)
DO 253 J2=1,NBEAMS
253 YMOUT(J1,J2,1)=YMOUT(J1,J2,1)/SUM
252 CONTINUE
254 IF(KAXT.EQ.0) GO TO 264
   JSTRT=KASAXT(1,1)
   JSTP=KASAXT(NTRFL,2)
   DO 261 J1=JSTRT,JSTP
      SUM=0.
   DO 256 J2=1,NBEAMS
256 SUM=SUM+YMOUT(J1,J2,1)
   SUM=SUM/(0.5*FULMAX)
DO 258 J2=1,NBEAMS
258 YMOUT(J1,J2,1)=YMOUT(J1,J2,1)/SUM
261 CONTINUE
264 CONTINUE
   DO 202 J1=1,5
   DO 202 J2=1,NBEAMS
      NLLAST(J2,J1)=0
      NLLALN(J2,J1)=0
      NLLAXT(J2,J1)=0
      ZMAST(J2,J1)=0
      ZMASL(J2,J1)=0.
   202 ZMXT(J2,J1)=0.
C
C    DETERMINE MAXIMUM MOMENTS DUE TO AASHTO TRUCK
C
C IF(A1.EQ.BK.AND.A2.EQ.BK) GO TO 220
DO 208 LANE=1,NTRFL
JST=KASAST(LANE,1)+2
JSP=KASAST(LANE,2)-6=2
IF(JSP.LT.JST) WRITE(6,245) LANE
IF(JSP.LT.JST) STOP
249 FORMAT(//,10X,'****LANE NO. 1,2, WILL NOT CNT HCLD AASHTO TRUCK****')
*)
DO 208 J1=1,NEAMS
DO 208 J2=JST,JSP
SUM=YMOUT(J2,J1,1)+YMOUT(J2+6,J1,1)
IF(SUM.GT.ZMAST(J1,LANE)) POSLN(J1,2*LANE-1)=TLN(LANE,1)+2+(J2=JST)
*)
IF(SUM.GT.ZMAST(J1,LANE)) POSLN(J1,2*LANE=POSLN(J1,2*LANE-1)+6.
IF(SUM.GT.ZMAST(J1,LANE)) ZMAST(J1,LANE)=SUM
J6 = J2+6
208 CONTINUE

DO 212 LANE=1,NTRFL
JST=KASAST(LANE,1)
JSP=KASAST(LANE,2)-10
IF(JSP.LT.JST) WRITE(6,251) LANE
IF(JSP.LT.JST) STOP
251 FORMAT(//,10X,'****LANE NO. 1,2, LESS THAN 10 FT WIDE****')
*)
DO 212 J1=1,NEAMS
DO 212 J2=JST,JSP
SUM=(YMOUT(J2,J1,1)+YMOUT(J2+10,J1,1))*0.5
DO 210 J3=1,9
210 SUM=SUM+YMOUT(J2+J3,J1,1)
IF(SUM.GT.ZMASL(J1,LANE)) POSLN(J1,2*LANE-1)=TLN(LANE,1)+(J2=JST)
IF(SUM.GT.ZMASL(J1,LANE)) POSLN(J1,2*LANE=POSLN(J1,2*LANE-1)+10.
IF(SUM.GT.ZMASL(J1,LANE)) ZMASL(J1,LANE)=SUM
212 CONTINUE
IF(KAXT.EQ.0) GO TO 224

C DETERMINE MAXIMUM MOMENTS DUE TO AXLE TRAIN
C
C DO 222 LANE=1,NTRFL
JST=KASAXT(LANE,1)+NAXCL

C
JSP=KASAXT(LANE,2)-NAXTSP-NAXCL
IF(JSP.LT.JST) WRITE(6,255)LANE
255 FORMAT(/,10X,'LANE No. ',I2,' WILL NOT HOLD AXLE TRAIN VEHICLE***AM010060
***)
IF(JSP.LT.JST) STCP
DO 222 J1=1,NBEAMS
DO 222 J2=JST,JSP
SUM=YMOUT(J2,J1,1)+YMOUT(J2+NAXTSP, J1,1)
IF(SUM.GT.ZMAXT(J1,LANE)) POSAX(J1,2*LANE-1)=TIN(LANE,1)+(J2-JST)
* NAXCL
IF(SUM.GT.ZMAXT(J1,LANE)) POSAX(J1,2*LANE)=POSAX(J1,2*LANE-1)+NAXT
*SP
IF(SUM.GT.ZMAXT(J1,LANE)) ZMAXT(J1,LANE)=SUM
J6=J2+NAXTSP
222 CONTINUE
C
C COMPUTE TOTAL MOMENT ON BEAMS FROM AASHTO TRUCK
C
224 IF(A1.EQ.BK.AND.A2.EQ.BK) GO TO 242
DO 232 JB=1,NBEAMS
DO 226 J1=1,5
226 ZZ(J1)=0.
DO 228 J1=1,NTRFL
228 ZZ(J1)=ZMAST(JB,J1)
CALL SORT(ZZ,IZ)
SUM1=ZMAST(JB,IZ(1))
SUM2=SUM1+ZMAST(JB,IZ(2))
SUM3=(SUM2+ZMAST(JB,IZ(3)))*0.9
SUM4=(SUM2+ZMAST(JB,IZ(3))+ZMAST(JB,IZ(4)))*0.75
SUM5=(SUM2+ZMAST(JB,IZ(3))+ZMAST(JB,IZ(4))+ZMAST(JB,IZ(5)))*0.75
ZMAST(JB)=AMAX1(SUM1,SUM2,SUM3,SUM4,SUM5)
ZZ(1)=SUM1
ZZ(2)=SUM2
ZZ(3)=SUM3
ZZ(4)=SUM4
ZZ(5)=SUM5
DO 265 J1=1,5
IF(ZZ(J1).NE.ZMAST(JB)) GO TO 265
DO 263 J2=1,J1
263 NLLAST(JB,IZ(J2))=1
GO TO 232
265 CONTINUE
232 CONTINUE

C COMPUTE TOTAL MOMENT ON BEAMS FROM AASHTO LANE
C
DO 240 JB=1,NBEAMS
DO 234 J1=1,5
234 ZZ(J1)=0.
DO 236 J1=1,NTRFL
236 ZZ(J1)=ZMASL(JB,J1)
CALL SORT(ZZ,IZ)
SUM1=ZMASL(JB,IZ(1))
SUM2=ZMASL(JB,IZ(2))+SUM1
SUM3=(SUM2+ZMASL(JB,IZ(3)))*0.9
SUM4=(SUM2+ZMASL(JB,IZ(3))+ZMASL(JB,IZ(4)))*0.75
SUM5=(SUM2+ZMASL(JB,IZ(3))+ZMASL(JB,IZ(4))+ZMASL(JB,IZ(5)))*0.75
ZMMASL(JB)=AMAX1(SUM1,SUM2,SUM3,SUM4,SUM5)
ZZ(1)=SUM1
ZZ(2)=SUM2
ZZ(3)=SUM3
ZZ(4)=SUM4
ZZ(5)=SUM5
DO 269 J1=1,5
IF(ZZ(J1).NE.ZMMASL(JB)) GO TO 269
DO 267 J2=1,J1
267 NLLALN(JB,IZ(J2))=1
GO TO 240
269 CONTINUE
240 CONTINUE

C COMPUTE TOTAL MOMENT ON BEAMS FROM AXLE TRAIN
C
242 IF(KAXT.EQ.0) GC TO 260
DO 250 JB=1,NBEAMS
SUM2=0.
SUM3=0.
SUM4=0.
SUM5=0.
DO 244 J1=1,5
244  \( \text{ZM} = 0 \).
246  \( \text{ZM} = \text{ZMAXT(JB,J1)} \)
248  CALL SORT(ZM,IZ)
250  \( \text{SUM1} = \text{ZMAXT(JB,IZ(1))} \)
252  IF(NAXT.EQ.1) GO TO 289
254  \( \text{SUM2} = \text{ZMAXT(JB,IZ(2))) + SUM1} \)
256  IF(NAXT.EQ.2) GO TO 289
258  \( \text{SUM3} = \text{SUM2 + ZMAXT(JB,IZ(3))} \)
260  IF(NAXT.EQ.3) GO TO 289
262  \( \text{SUM4} = \text{SUM3 + ZMAXT(JB,IZ(4))} \)
264  IF(NAXT.EQ.4) GO TO 289
266  \( \text{SUM5} = \text{SUM4 + ZMAXT(JB,IZ(5))} \)
289  \( \text{ZMMAXT(JB)} = \text{AMAX1(SUM1,SUM2,SUM3,SUM4,SUM5)} \)
291  \( \text{ZM(1)} = \text{SUM1} \)
293  \( \text{ZM(2)} = \text{SUM2} \)
295  \( \text{ZM(3)} = \text{SUM3} \)
297  \( \text{ZM(4)} = \text{SUM4} \)
299  \( \text{ZM(5)} = \text{SUM5} \)
301  DO 277 J1=1,5
303  IF(ZZ(J1),NE,ZMMAXT(JB)) GO TO 277
305  DO 273 J2=1,J1
307  NLLAXT(JB,IZ(J2))=1
309  GO TO 250
311  277 CONTINUE
313  250 CONTINUE
C
260 CONTINUE
262 DO 40 J1=1,NBEAMS
264  DISTAT(J1)=ZMMAST(J1)/FULMAT
266 DO 42 J1=1,NBEAMS
268  DISTAL(J1)=ZMMASL(J1)/FULMAL
270 IF(KAXT.EQ.0) GO TO 46
272 DO 44 J1=1,NBEAMS
274  DISTAX(J1)=ZMMAXT(J1)/FULMAX
276  46 CONTINUE
278 RETURN
280 END
SUBROUTINE FLEX
COMMON/BLK 1/ HEAD(15),ZMI(20),YMI(20),BMA(20), C C
ZSA(20),YSA(20),BMJ(20),YH(10,2),ZH(10,2),NTY(30), AM011220
LC( 500),MLE( 500),ML( 4),P( 500),XL( 500),PL( 500), AM011230
ECC( 500),F11(10,4,4),F12(10,4,4),F22(10,4,4),SF(164,8), AM011240
NPOS( 500),XPOS(9,9),HF(15,4),JTY(30),YSTR(9,4),ZSTR(9,4), AM011250
NOUT(9),YSSS(9,4),ZSSS(9,4),X(8) AM011260
COMMON/BLK 2/ NHARS,SPAN,NBEAMS,E,G,NTYPES,NEQ, AM011270
*ALPHA,NLCASE,NLCA,UX AM011280
C C C C C C
SUBROUTINE FLEX Zero Structure Flexibility
C C C C C C
ZERO STRUCTURE FLEXIBILITY MATRIX, SF.
C C C C C C
NEQ = 4*(NBEAMS + 1)
DO 250 I = 1, NEQ
DO 250 J = 1, 8
250 SF(I,J) = 0.0
C C C C C C
FORM FLEXIBILITY MATRICES FOR EACH BEAM TYPE
C C C C C C
CALL BMFLEX (1, 1, 1, 1, F11)
C C C C C C
CALL BMFLEX (1, 1, 2, 2, F12)
C C C C C C
CALL BMFLEX (2, 2, 2, 2, F22)
C C C C C C
STORE BEAM FLEXIBILITY INTO STRUCTURE FLEX. FOR ALL BEAMS
C C C C C C
DO 400 N = 1, NBEAMS
NT = NTY(N)
C C C C C C
STORE F11 INTO SF
C C C C C C
NN = 4*(N = 1)
DO 320 I = 1, 4
320 LM(I) = NN + I
DO 340 I = 1, 4
II = LM(I)
DO 340 J = I, 4
JJ = LM(J) - II + 1

340 SF(I,J,J) = SF(I,J,J) + F11(NT,I,J)

STORE F12 INTO SF

DO 360 I = 1, 4
II = LM(I)
DO 360 J = 1, 4
JJ = LM(J) + 5 - II
360 SF(I,J,J) = SF(I,J,J) + F12(NT,I,J)

STORE F22 INTO SF

DO 380 I = 1, 4
II = LM(I) + 4
DO 380 J = 1, 4
JJ = LM(J) + 5 - II
380 SF(I,J,J) = SF(I,J,J) + F22(NT,I,J)

CONTINUE

ADD HINGE FLEXIBILITIES ALONG DIAGONAL OF SF

NJ = NBEAMS - 1

DO 450 J = 1, NJ
JT = JTY(J)
DO 450 N = 1, 4
I = 4*J + N
SF(I,1) = SF(I,1) + HF(JT,N)

CONTINUE

RETURN

END
SUBROUTINE BMFLEX (II, JJ, KK, LL, A)
COMMON/ELK 1/ HEAD(15), ZMI(20), YMI(20), BMA(20),
*ZSA(20), YSA(20), BMJ(20), YH(10,2), ZH(10,2), NTY(30),
*LC(500), NLB(500), LM(4), P(500), XL(500), PL(500),
*ECI(500), F11(10,4,4), F12(10,4,4), F22(10,4,4), SF(164,8),
*NPOS(500), XP0S(9,9), HF(19,4), JTY(30), YSTR(9,4), ZSTR(9,4),
*NOUT(9), YSSS(9,4), ZSSS(9,4), X(8)
COMMON/ELK 2/ NHAMS, SPAN, NBEAMS, E, G, NTYPES, NEQ,
*ALPHA, NLCASE, NLCARD, NX
DIMENSION A(10,4,4)

DO 10 K = 1, NTYPES
F1 = 1. / (ALPHA**2*BMA(K))
F2 = 1. / (ALPHA**4*ZMI(K))
F3 = 1. / (ALPHA**4*YMI(K))
F4 = 1. / (ALPHA**2*BMJ(K))

Y1 = YH(K,II) * ALPHA
Z1 = ZH(K, JJ) * ALPHA
Y2 = YH(K,KK) * ALPHA
Z2 = ZH(K, LL) * ALPHA

A(K,1,1) = F1 + Y1*Y2*F2 + Z1*Z2*F3
A(K,1,2) = -Y1*F2
A(K,1,3) = -Z1*F3
A(K,1,4) = 0.0
A(K,2,1) = -Y2*F2
A(K,2,2) = F2 + ZH(K, JJ) * ZH(K, LL) * F4
A(K,2,3) = -ZH(K, JJ) * YH(K, KK) * F4
A(K,2,4) = -ZH(K, JJ) * F4
A(K,3,1) = -Z2*F3
A(K,3,2) = -YH(K,II) * ZH(K, LL) * F4
A(K,3,3) = F3 + YH(K,II) * YH(K, KK) * F4
A(K,3,4) = YH(K,II) * F4
A(K,4,1) = 0.0
A(K,4,2) = -ZH(K, LL) * F4
A(K,4,3) = YH(K, KK) * F4
SUBROUTINE LOCATE(Y,N,EC,NBEAMS,YH,NTY)
DIMENSION YH(10,2),NTY(30)
SUM=0.
DO 20 J1=1,NBEAMS
  N=J1
  IF(SUM+YH(NTY(J1),1).LE.Y.AND.SUM+YH(NTY(J1),2).GE.Y) GO TO 22
  SUM=SUM+YH(NTY(J1),2)
  Y=SUM
RETURN
END

SUBROUTINE SORT(ZZ,IZ)
DIMENSION ZZ(5),IZ(5)
DO 100 J1=1,5
  S1=ZZ(1)
  S2=ZZ(2)
  S3=ZZ(3)
  S4=ZZ(4)
  S5=ZZ(5)
  ZMAX=AMAX1(S1,S2,S3,S4,S5)
DO 20 J2=1,5
  IF(ZMAX.NE.ZZ(J2)) GO TO 20
  IZ(J1)=J2
  ZZ(J2)=10.*(10.+J1)
  GO TO 100
20 CONTINUE
100 CONTINUE
RETURN
END
SUBROUTINE MAXCM(N*,P*,XSPC,SPAN,ZMAX)
DIMENSION P(18),XSPC(18),ZSPC(18),XSTCRE(18)
    XSPC(1)=0.
    DO 10 J1=1,N
        ZSPC(J1)=XSPC(J1)
        ZMAX=0.*
        DO 30 J1=1,N
            XSPC(1)=SPAN/2.*+ZSPC(J1)
            DO 12 J2=2,N
                XSPC(J2)=XSPC(1)=ZSPC(J2)
                ZM=0.*
                DO 20 J2=1,N
                    IF(0.*LE.XSPC(J2).AND.XSPC(J2).LE.SPA
                        NO GO TO 14
                        GO TO 20
                14 ZM=ZM+(SPAN-XSPC(J2))*P(J2)/2.*
                    IF(XSPC(J2).LT.SPA
                        NO ZM-=ZM.*((SPAN/2.)*XSPC(J2))
                20 CONTINUE
                    IF(ZM.LE.ZMAX) GO TO 30
                        ZMAX=ZM
                    DO 24 J2=1,N
                        XSTORE(J2)=XSPC(J2)
                30 CONTINUE
                        JSTRT=1
                        JSTOP=N
                        DO 36 J1=1,N
                            IF(XSTORE(J1).GE.SPA
                                NO JSTRT=JSTRT+1
                            IF(XSTORE(J1).LE.0.) JSTOP=JSTOP-1
                    36 CONTINUE
                        N=0
                        DO 38 J1=JSTRT,JSTOP
                            N=N+1
                        P(N)=P(J1)
                    38 XSPC(N)=XSTORE(J1)
                        RETURN
                END