A METHOD OF ANALYSIS FOR NONLINEAR DYNAMIC RESPONSE OF PRESTRESSED CONCRETE BEAMS

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LIST OF SYMBOLS

a_i, b_i, c_i, d_i, e_i	coefficients in Equation (2.12)
A_b	transverse area of bottom reinforcement
A_i	area of cross section at joint i
A_i, B_i, C_i, D_i, E_i	coefficients in Equation (2.13)
A_j	area of segment j in a given cross section
A_{SL}	transverse area of any prestressing steel layer
A_t	transverse area of top reinforcement
B_1	width of section at the top
B_2	width of section at an intermediate depth
B_3	width of section at the bottom
c_i	distance from the top of the beam to neutral axis at joint i
d_b	distance of centroid of bottom reinforcement from the top of the section
$\bar{d}_i$	depth of the centroid at joint i from the top of the section
d_j	distance of centroid of segment j from the top of the section
d_{SL}	distance of centroid of prestressing steel layer from the top of the section
d_t	distance of centroid of top reinforcement from the top of the section
e_{iL}	eccentricity of prestressing steel layer from the elastic centroid of the section
E_c, E_s, E_{sp}	initial tangent modulus for concrete, nonprestressed steel and prestressing steel, respectively

$(EI)_e$	equivalent flexural stiffness
$(EI)_i$	flexural stiffness at joint i
f_i	load parameter in Equation (2.12)
$F(t)$	function of time
h	length of bar
h_k	distance of bottom of zone k to the top of the section
i	an integer index, generally indicator of bar or joint
I_m	impulse
j	an integer index or subscript
L	span of beam
m_i	concentrated point mass at joint i
M_i	bending moment due to stress resultants of concrete and nonprestressed steel at joint i
M_i^L	bending moment due to applied loads at joint i
M_i^P	bending moment due to prestress force at joint i
n	number of bars
p	fundamental natural circular frequency
q_{di}	dynamic load parameter at joint i
Q_{di}	vertical dynamic load at joint i
Q_i	vertical static load at joint i
t	elapsed time
T_ℓ	shortest natural period of vibration
v_i	vertical displacement of joint i
$\dot{v}_i$	vertical velocity of point mass at joint i
$\ddot{v}_i$	vertical acceleration of point mass at joint i
V_i	shear in bar i
z_k	a zone of the cross section, Figure 2

Δt	time interval
ε_b	strain in bottom reinforcement
ε_j	average strain in segment j of a section
ε_{SL}	strain in prestressing steel layer
ε_t	strain in top reinforcement
μ	mass per unit length
ϕ_i	average curvature at joint i
σ_b	stress in bottom reinforcement
σ_j	average stress in segment j of a section
σ_{SL}	stress in prestressing steel layer
σ_t	stress in top reinforcement
θ_i	slope of bar i

CHAPTER I

INTRODUCTION

1.1 Statement of the Problem

The technique of prestressing structural components has found its way from bridge girders to complex structures such as domes. These structures, during their lives, may be subjected to the effects of a high energy detonation in the vicinity of the structure. The continued safety of the structure depends on the ability of the various structural components, including prestressed components, to withstand the maximum deformations and forces due to the dynamic loads. Also, from the standpoint of demolition activities, a knowledge of the behavior of a structure under impulse loading is necessary for the efficient placement of a detonation to result in catastropic collapse. Since the integrity of the structure as a whole is dependent on the integrity of the structural components, the purpose of this study is to develop a method of analysis for prestressed concrete beams subjected to the effects of dynamic loads, or combined statis and dynamic loads.

1.2 Method of Approach

The differential equations describing the response of a beam subjected to various dynamic loadings have been derived and solved for simple cases (1) (2). The present study includes nonprismatic geometry and nonlinear stress-strain behavior of parts of the cross section of the beam which make the closed form solutions of the differential equations highly complex. Therefore, a numerical procedure has been adopted which permits a solution for a range of material properties and geometry and which accounts for the influence of the history of response of the beam.

The method developed herein takes into account material nonlinearity by constantly revising the flexural stiffness of the beam, as deformations occur. It is assumed that small deflection theory may be used for acceptable results before the collapse of the beam.

The analysis is simplified by replacing the actual structure by a discrete framework, consisting of a finite number of bars, joints, concentrated point masses and springs, with properties based on the parameters of the original structure, such as geometry, boundary conditons and material properties.

The material of the beam is of steel, or concrete with bonded tendons, with or without nonprestressed reinforcement. The cross section may be rectangular, I or T shaped and may vary in size along the beam.

The analysis involves the evaluation of internal forces due to static and dynamic loads. Two types of dynamic loads are considered--forces and impulses. The effects of dynamic loads are superimposed on the effects of static loads and collapse under specified collapse criteria is checked.

A computer program is developed to apply the method of analysis to the replacement structure, with numerical evaluation of bending moments, shears and deformations.

1.3 Previous Work

There has been some work reported on dynamic tests of prestressed concrete beams; however, very little work is found on the nonlinear analysis of prestressed concrete beams subjected to dynamic loads. The following paragraphs summarize the past work and the important findings.

Mukherjee (3) conducted tests on pretensioned concrete beams subjected to drop hammer impluse loads and to sinusiodal pulsating forces. A mathematical analysis was presented for the elastic range using a single degree of freedom system. It was reported that the prestress force has insignificant effect on the natural frequency in members with bonded tendons, and the damping coefficient can be considered 3 to 4 per cent of critical damping.

Dynamic tests were performed by Wadlin and Stewart (4) to compare the behavior of conventionally reinforced concrete beams and pretensioned concrete beams. It was found that reinforced and prestressed beams which have almost identical static ultimate strength absorb approximately equal amounts of energy before crushing of the concrete occurs. No reinforcing bars or prestressing strands were broken.

Miyamoto and Allgood (5) tested post-tensioned unbonded concrete beams in a blast simulator which applied an exponentially decaying load to the top surface of the beam. Based on the test results, a dynamic design procedure for blast type loading was presented.

Takahasi (6) performed similar tests in a blast simulator using pretensioned concrete beams. It was reported that tensile stresses are not produced in the top fiber of the beam at any time for either long- or short-duration dynamic loadings, and that the negative deflection due to rebound is not a great factor except for very short-duration loads.

Gladapo (7) compared the behavior of prestressed beams under static and dynamic loads, from test results. Under dynamic loading prestressed concrete is much more elastic and has a greater capacity for energy absorption than under static loading. Dynamic loading also causes significant increases in the ultimate moment, the cracking strength, and the curvature at rupture.

The damping characteristics of post-tensioned grouted beams under dynamic loading were investigated by Penzien (8). It was reported that under steady state conditions, internal damping may be less than 1 per cent of critical if tension cracks are absent, and can be of the order of 2 per cent if tension cracks are allowed to develop on a microscopic scale. Under transient conditions, when the members have been dynamically loaded only a few times to produce considerable cracking, damping can be in the range of 3 to 6 per cent of critical.

James, Lutes and Smith (9) reported that the damping characteristics of pretensioned and plain reinforced beams are in general the same. The damping does not appear to be viscous for small amplitudes of vibration, but does seem to approach a viscous state for higher amplitudes.

Hamilton (10) conducted dynamic tests on pretensioned concrete beams and found that the ultimate dynamic moment capacity is about one and one-third times the ultimate static moment capacity.

Coles and Hamilton (11) concluded from dynamic tests that bond failure does not seem to be a critical factor in pretensioned concrete beams subjected to repetitive dynamic loads.

A few investigators utilized mathematical models to analyze prestressed concrete beams. Atkins (12) and Pierce (13) presented mathematical analyses for nonlinear static response of pretensioned, and post-tensioned concrete beams, respectively, using numerical techniques. Dawkins (14) presented a method of analysis for the nonlinear dynamic response of reinforced concrete beam-columns. Guimaraes (15) and Riddle (16) extended the study performed by Dawkins (14) to analyze reinforced concrete arches and portal frames, respectively, subjected to dynamic loads.

The present work is an extension of the work of Dawkins (14) incorporating prestress forces into the system.

CHAPTER II

METHOD OF ANALYSIS

2.1 Mathematical Model

The response of a beam to dynamic loading is dependent on the material behavior, the geometry of the beam, and the time history of the response. In order to account for the effects of all of these variables, a procedure combining mathematical modeling techniques with numerical integration of the resulting differential equations of motion has been used. The model used in this study is similar to the lumped parameter model applied to tunnel liner-packing systems by Dawkins (17).

The lumped parameter model is composed of straight bars and spring elements which have force-deformation characteristics derived from the properties of the original member. A typical arrangement of bars and springs is shown in Figure 1. Each bar is considered massless, with its distributed mass concentrated as point masses at the ends of the bar. The bars are considered rigid and are interconnected by flexural hinges at their ends. The joints and the bars are identified with numbers from left to right, as shown in Figure 1.

2.2 Assumptions

In the solution for static and dynamic loadings, the following assumptions are made:

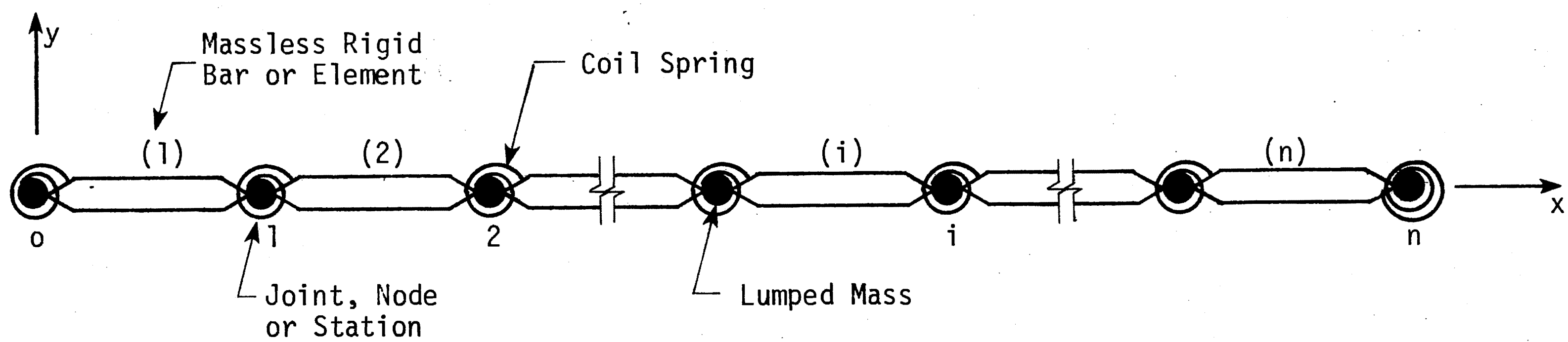


Figure 1. Mathematical Model

1. Plane sections remain plane;

2. Deflections are small;

3. Loads and masses are concentrated at the joints;

4. Loads and displacements occur in the plane of the beam;

5. Dynamic effects are superimposed on the deformations resulting from static loads;

6. Effects of shearing deformation and rotatory inertia are negligible;

7. Single degree of freedom at each joint (motion in the transverse direction only) is sufficient to describe the deflected shape of the beam; and

8. The beam does not fail due to bond.

2.3 Cross Section Description

Figure 2 shows the general cross section of the beam, as defined at the joints of the model. The cross section is divided into nine zones defined by lines parallel to the base. Each zone is further subdivided into segments, each segment with area A_j and with its centroid located at a distance d_j from the top of the section.

Several layers of prestressing steel with layer area A_{SL} at a distance d_{SL} from the top of the section may be provided. In addition, nonprestressed steel (reinforcement) at top and bottom with areas A_t and A_b may also be provided at distances d_t and d_b, respectively, from the top of the section.

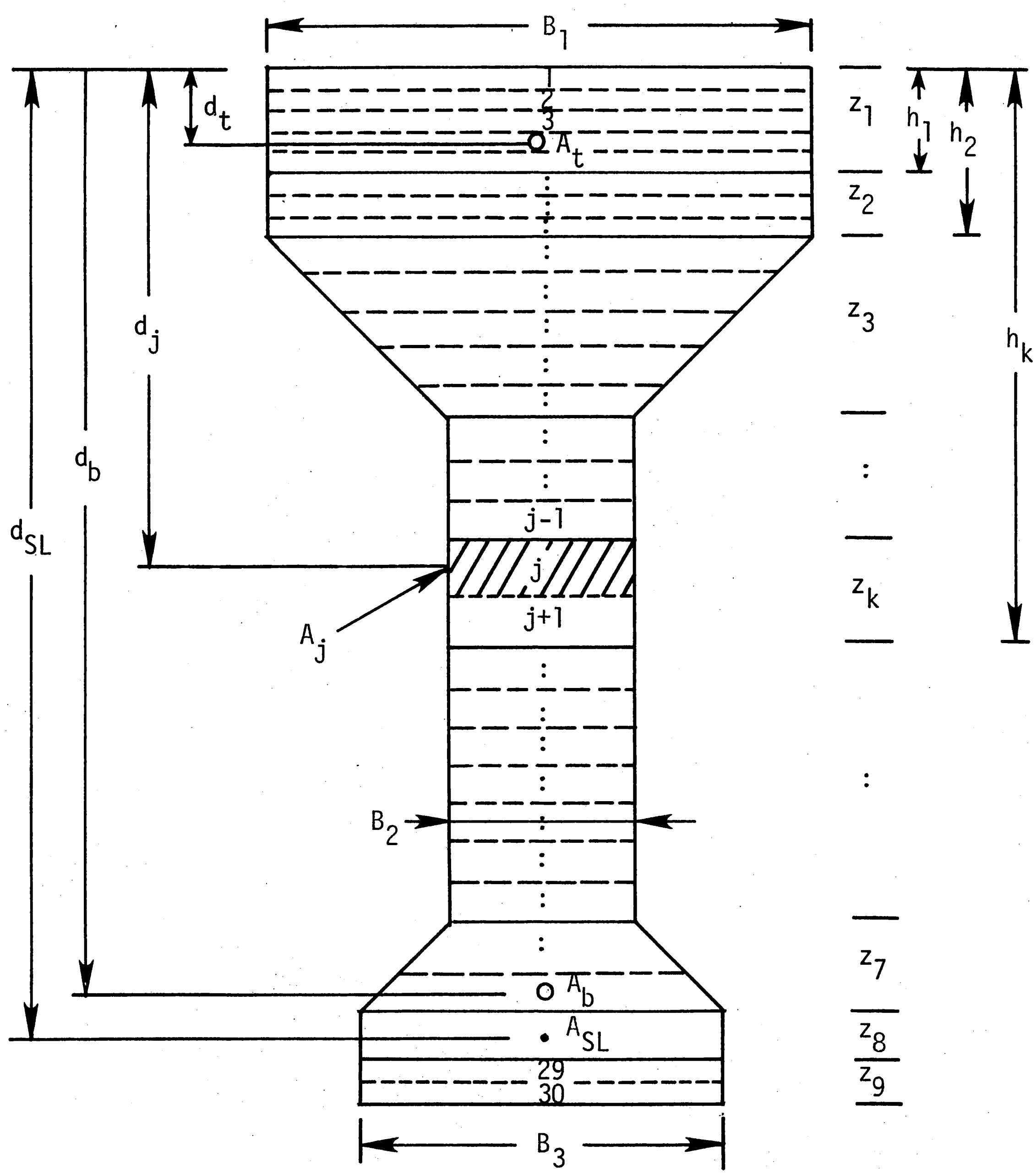


Figure 2. Cross Section

2.4 Stress-Strain Curves

A typical stress-strain curve for the materials of the cross section is shown in Figure 3. The curve is divided into ten regions, five for tension and five for compression.

2.5 Centroid of the Section

The elastic centroidal distance $\overline{d}_i$ for the cross section at joint i may be calculated considering the transformed area by the equation

$$\overline{d}_i = (\sum_{A_i} E_c A_j d_j + E_s A_t d_t + E_s A_b d_b + \sum_{A_{SL}} E_{sp} A_{SL} d_{SL}) / (\sum_{A_i} E_c A_j + E_s A_t + E_s A_b + \sum_{A_{SL}} E_{sp} A_{SL}) \qquad (2.1)$$

where E_c, E_s and E_{sp} refer to the initial tangent modulus of concrete, nonprestressed steel and prestressing steel, respectively. All the other variables have been defined in section 2.3. The summations are extended to all the segments of the section, plus all the layers of prestressing steel and the nonprestressed steel.

The elastic centroid of the section at any joint is used as the reference axis for summing the moments of the segmental concrete forces and steel forces. The shifting of the neutral axis as the structure deforms, due to the stresses in some of the segments of the cross section in the inelastic range, is accounted for in the development of moment-curvature relationships.

2.6 Moment-Curvature Relationships

For the static solution, the flexural stiffness at joint i, $(EI)_i$, is defined by the secant modulus of the moment-curvature relationship.

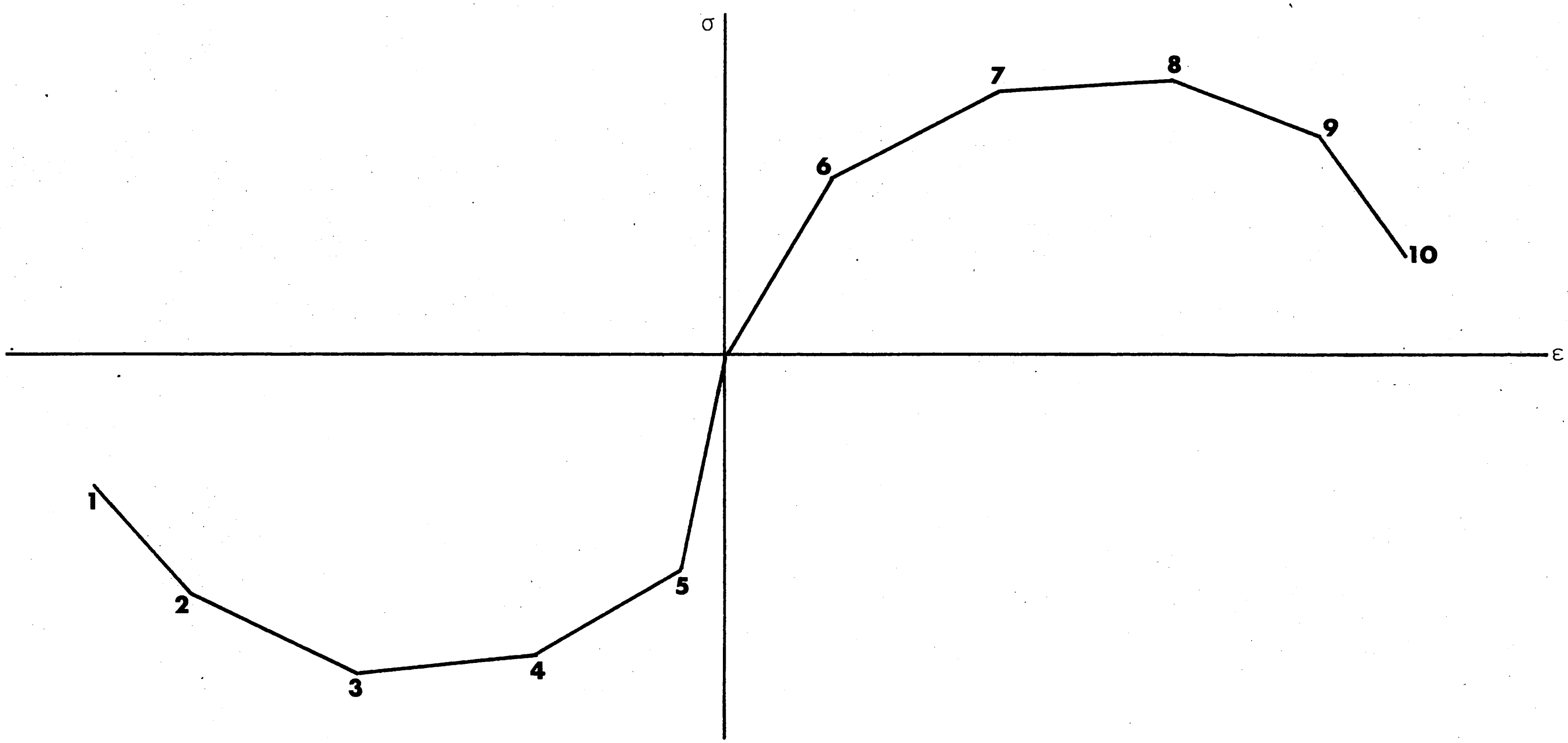


Figure 3. Typical Stress-Strain Curve

Numerical procedures have been developed which may be used to approximate the moment-curvature relationship for a known cross section with a specified value of prestrain in the prestressing tendon (12) (14). The prestrain value refers to the effective prestrain after all losses, except changes in strain due to bending of the member (18).

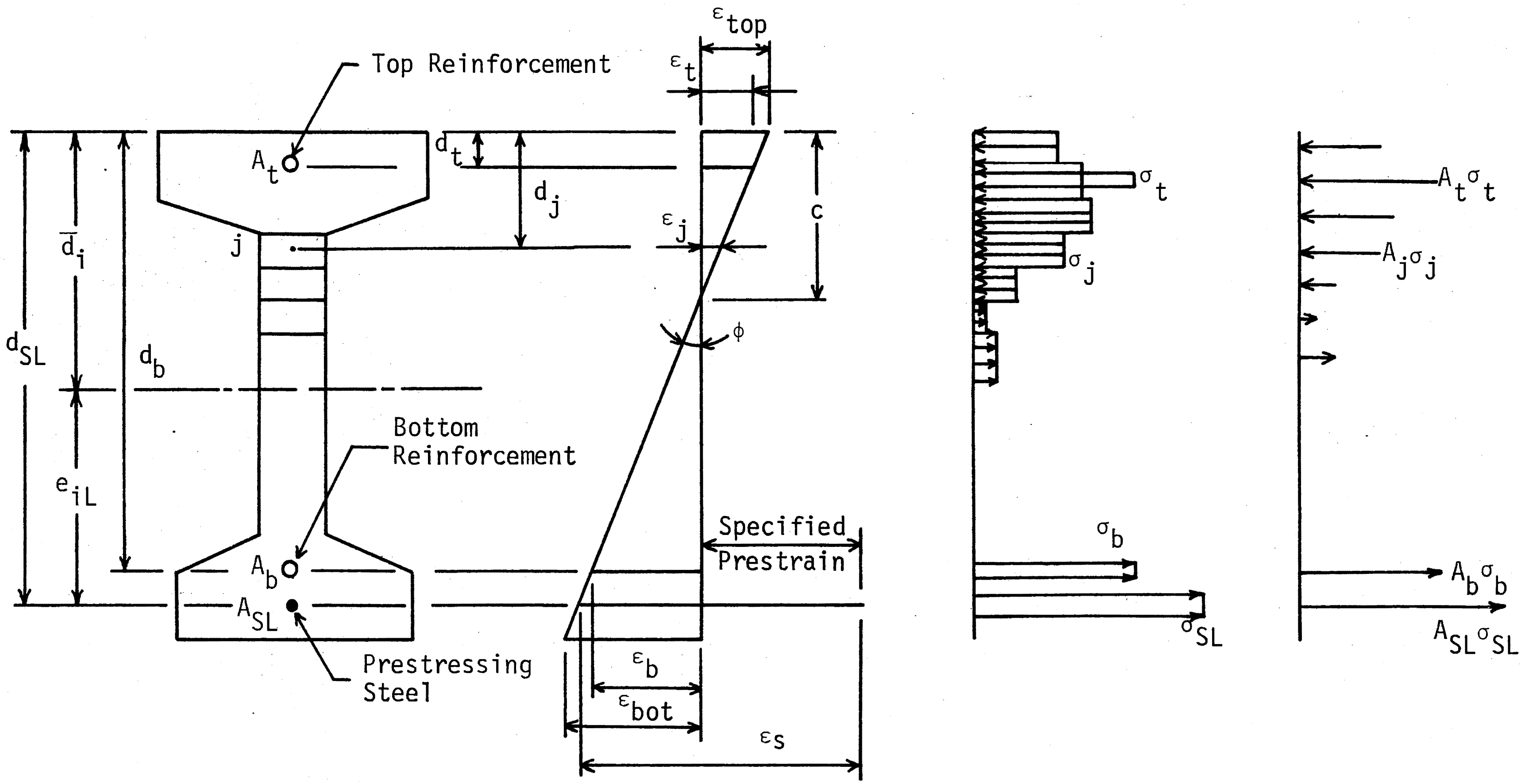
The procedure for the development of moment-curvature relationship may be outlined as follows:

1. A strain profile is assumed, as shown in Figure 4(b), and the strains at the center of each concrete segment ε_j, at the center of each prestressing steel level ε_{SL}, and at the center of top reinforcement ε_t, and bottom reinforcement ε_b, are calculated. The strain in the prestressing steel is equal to the strain in the concrete at the level of the steel plus the specified prestrain.

2. Using stress-strain relationships defined in section 2.4, the stress at the center of each concrete segment σ_j, at the center of each prestressing steel level σ_{SL}, and at the center of top and bottom reinforcement σ_b and σ_t, respectively, can be calculated. Considering the centerline stress of each concrete segment to act over the entire area of the respective segment, a stress distribution results as shown in Figure 4(c).

3. The force on each concrete segment is the product of the segment area and its stress, $A_j\sigma_j$. The force on each layer of prestressing steel is $A_{SL}\sigma_{SL}$ and the forces on the top and bottom reinforcement are $A_t\sigma_t$ and $A_b\sigma_b$, respectively. This results in a force distribution as shown in Figure 4(d).

4. The net axial force is now found by algebraically summing the forces shown in Figure 4(d). This axial force, within some specified



(a) Cross Section

(b) Assumed Strain Profile

(c) Stress Distribution

(d) Force Distribution

Figure 4. Forces Due to Assumed Strain Profile

tolerance, should be equal to zero for equilibrium.

5. If equilibrium is not achieved, a new strain profile is assumed and steps 1 through 4 are repeated.

Once the net axial force is within the specified tolerance, the moment on the section can be approximated by summing the moments of the segmental concrete forces and steel forces about the elastic centroid:

$$M_i^L = \sum_{A_i} (A_j \sigma_j)(d_j - \overline{d}_i) + \sum_{A_{SL}} A_{SL} \sigma_{SL} (d_{SL} - \overline{d}_i)$$

$$+ A_t \sigma_t (d_t - \overline{d}_i) + A_b \sigma_b (d_b - \overline{d}_i). \tag{2.2}$$

The curvature of the section at joint i can be computed as

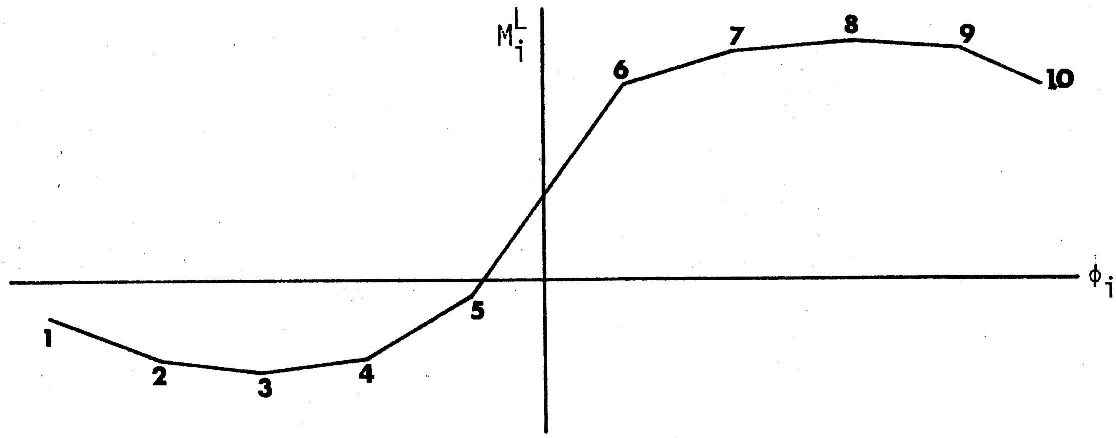
$$\phi_i = -\left(\frac{\varepsilon_{top}}{c}\right)_i \tag{2.3}$$

where ε_{top} is the strain in the concrete at the top fiber and c is the distance from the top of the beam to the neutral axis.

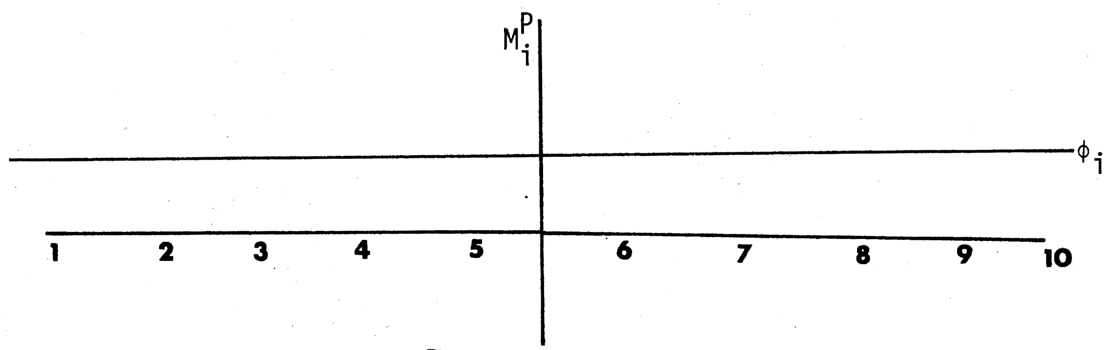
It is assumed that tensile strains are positive, and curvatures are positive if they produce compressive strains at the top of the section.

To represent the moment-curvature relationship at joint i, 10 values of curvature and the corresponding moments, 5 points for positive bending and 5 points for negative bending, are generated using the above procedure. The extreme points are generated to produce the strains at the extreme fiber, top or bottom, of the cross section as defined by the maximum compressive strain given by the stress-strain curve for concrete. The intermediate points are generated by defining their curvatures to be fractions of those at the extremes.

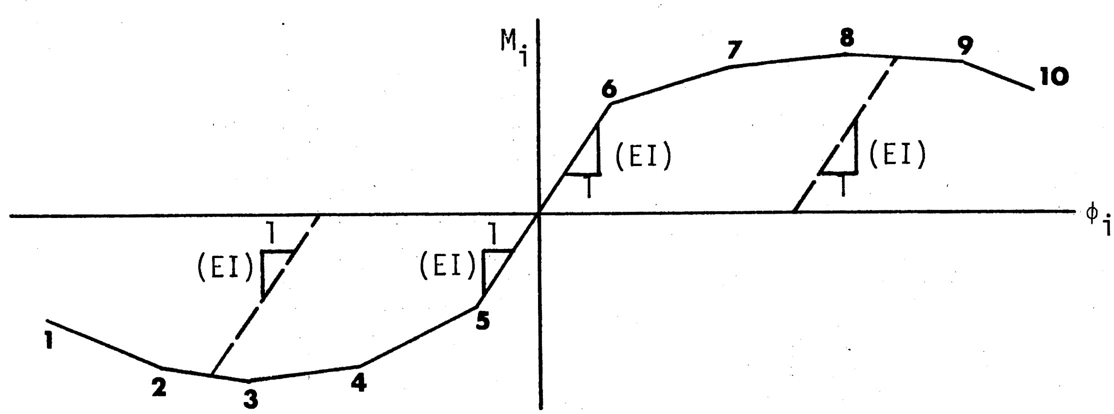
The moment-curvature relationship developed above, shown in Figure 5(a), relates M_i^L and ϕ_i, where M_i^L is the moment due to the applied loads, and ϕ_i is the curvature, at joint i.



(a) M_i^L - ϕ_i Relationship



(b) M_i^P - ϕ_i Relationship



(c) M_i - ϕ_i Relationship

Figure 5. Moment-Curvature Relationships

The $M_i^L - \phi_i$ curve for each cross section is replaced by two moment-curvature relationships: (1) the moment-curvature effects produced by the prestressing forces only; and (2) the moment-curvature effects produced by all other internal stress resultants.

The moment-curvature curve relating the moment due to the prestress forces to curvature, $M_i^P - \phi_i$, is generated simultaneously and at the same curvature values as for the $M_i^L - \phi_i$ relationship. Figure 5(b) illustrates the $M_i^P - \phi_i$ relationship.

The second moment-curvature relationship, illustrated in Figure 5(c), is obtained from

$$M_i = M_i^L + M_i^P \tag{2.4}$$

where M_i is the moment due to the stress resultants in the concrete and nonprestressed steel.

This separation of effects allows the moment on a cross section to be expressed as

$$M_i^L = (EI)_i \ \phi_i - M_i^P \tag{2.5}$$

where $(EI)_i$ is the bending stiffness at joint i. For monotonically increasing curvatures, $(EI)_i$ is the secant modulus obtained from the $M_i - \phi_i$ curve at any curvature. For unloading it is assumed that the M_i component of moment decreases according to the dashed line shown in Figure 5(c), in which case $(EI)_i$ is equal to the slope of the initial linear portion of the curve.

2.7 Effect of Prestress Force

Atkins (12) and Pierce (13) have shown that the effect of prestress moment can be represented by transverse loads at the joints of the model.

For the case where M_i^P is moment due to prestress at joint i, transverse forces are applied at joints i-1, i, and i+1 as shown in Figure 6.

2.8 Static Solution

2.8.1 Equilibrium Equations

Free body diagrams of bar i and joint i are shown in Figure 7. For equilibrium of bar i:

$$\sum M_i = 0$$

leads to

$$V_i = \frac{-M_{i-1} + M_i}{h} \qquad (2.6)$$

where

V_i = shear in bar i;

M_j = bending moment at joint j; and

h = length of the bar.

For equilibrium of joint i:

$$\sum F_{yi} = 0$$

leads to

$$V_i - V_{i+1} + Q_i - \frac{M_{i-1}^P}{h} + \frac{2M_i^P}{h} - \frac{M_{i+1}^P}{h} = 0 \qquad (2.7)$$

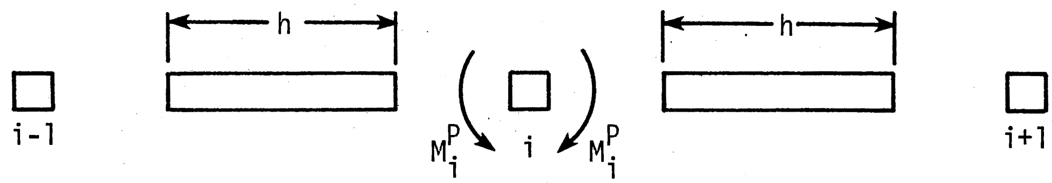
where

M_j^P = prestress moment at joint j; and

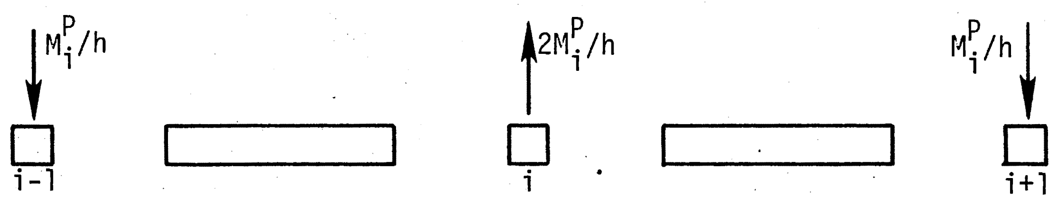
Q_i = applied external transverse static load.

Substituting Equation (2.6) into Equation (2.7) yields

$$M_{i-1} - 2M_i + M_{i+1} = h(Q_i - \frac{M_{i-1}^P}{h} + \frac{2M_i^P}{h} - \frac{M_{i+1}^P}{h}). \qquad (2.8)$$

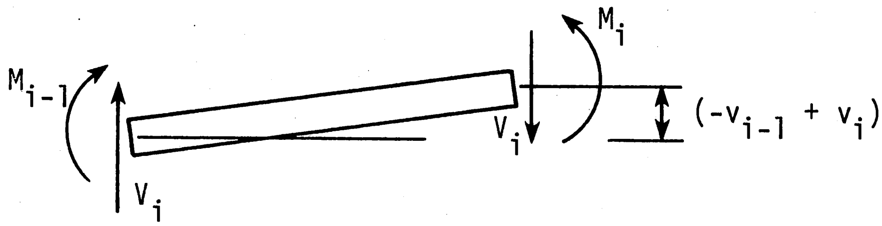


(a) Prestress Moment at Joint i

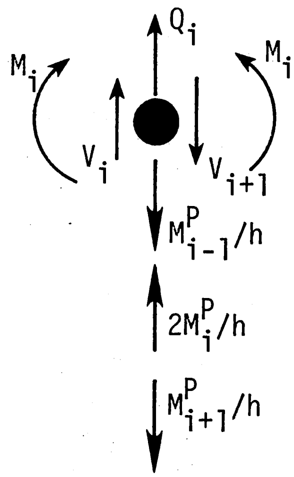


(b) Assumed Equivalent Forces

Figure 6. Effect of Prestress Moment



(a) Freebody of Bar i



(b) Freebody of Joint i

Figure 7. Freebody Diagrams for Static Solution

The change in angle between adjacent bars at joint i is obtained from

$$-\theta_i + \theta_{i+1} = -(-v_{i-1} + v_i)/h + (-v_i + v_{i+1})/h \tag{2.9}$$

where

θ_j = slope of bar j; and

v_j = deflection of joint j in y direction.

The average curvature at joint i, ϕ_i, is given by

$$\phi_i = \frac{-\phi_i + \phi_{i+1}}{h} . \tag{2.10}$$

The flexural stiffness at joint i, $(EI)_i$, is defined in section 2.6 as

$$(EI)_i = \frac{M_i}{\phi_i} . \tag{2.11}$$

Combining Equations (2.8), (2.9), (2.10), and (2.11) gives an equation of the form:

$$a_i v_{i-2} + b_i v_{i-1} + c_i v_i + d_i v_{i+1} + e_i v_{i+2} = f_i \tag{2.12}$$

where

$a_i = (EI)_{i-1}$;

$b_i = -2[(EI)_{i-1} + (EI)_i]$;

$c_i = (EI)_{i-1} + 4(EI)_i + (EI)_{i+1}$;

$d_i = -2[(EI)_i + (EI)_{i+1}]$;

$e_i = (EI)_{i+1}$; and

$f_i = h^3 Q_i - h^2(M^P_{i-1} - 2M^P_i + M^P_{i+1})$.

2.8.2 Solution of Equations

Evaluation of the coefficients in Equation (2.12) at every joint results in a set of simultaneous equations in the unknown joint displacement v. The form of the simultaneous equations is shown in Figure 8. These equations are efficiently solved by a two-pass elimination procedure, a variation of the well known Gauss elimination procedure for solving simultaneous equations. On the initial pass, the equations are reduced to the form:

$$v_i = A_i + B_i v_{i+1} + C_i v_{i+2} \tag{2.13}$$

where

$A_i = D_i(E_i A_{i-1} + a_i A_{i-2} - f_i);$

$B_i = D_i(E_i C_{i-1} + d_i);$

$C_i = D_i e_i;$

$D_i = -1/(E_i B_{i-1} + a_i C_{i-2} + c_i);$

and

$E_i = a_i B_{i-2} + b_i.$

At the initial joint 0, a_o and b_o are both equal to zero. The values of A_i, B_i and C_i may be obtained from the known values of the coefficients of Equation (2.12) starting at the initial joint 0 and proceeding to the final joint n. At joint n, the coefficients d_n and e_n are zero, resulting in zero values for both B_n and C_n. Therefore, a solution for v_n is obtained from Equation (2.13). Likewise, at joint n-1, C_{n-1} will be zero and v_{n-1} may be obtained from Equation (2.13). All other values of v_i, starting at joint n-2 and proceeding to joint 0 are calculated by Equation (2.13).

In the computer program to further simplify the complete solution, three fictitious nodes are added at each end of the beam. No load or stiffness data exists for these fictitious nodes. In the computation of

$$
\begin{aligned}
&c_o v_o + d_o v_1 + e_o v_2 &= f_o\\
&b_1 v_o + c_1 v_1 + d_1 v_2 + e_1 v_3 &= f_1\\
&a_2 v_o + b_2 v_1 + c_2 v_2 + d_2 v_3 + e_2 v_4 &= f_2\\
&a_3 v_1 + b_3 v_2 + c_3 v_3 + d_3 v_4 + e_3 v_5 &= f_3\\
&a_i v_{i-2} + b_i v_{i-1} + c_i v_i + d_i v_{i+1} + e_i v_{i+2} &= f_i\\
&a_{n-2} v_{n-4} + b_{n-2} v_{n-3} + c_{n-2} v_{n-2} + d_{n-2} v_{n-1} + e_{n-2} v_n &= f_{n-2}\\
&a_{n-1} v_{n-3} + b_{n-1} v_{n-2} + c_{n-1} v_{n-1} + d_{n-1} v_n &= f_{n-1}\\
&a_n v_{n-2} + b_n v_{n-1} + c_n v_n &= f_n
\end{aligned}
$$

Figure 8. Simultaneous Equations for Static Displacements

the coefficients A_i, B_i and C_i the fictitious extensions to the beam automatically generate the required zeros at each end of the Equation (2.12). These zero terms are the means by which the recursion process gets started and then turns around at the far end so that deflections may be calculated. This process eliminates the necessity for specializing the coefficients for the end conditions (19).

2.8.3 Iterative Procedure for Static Solution

To start the recursive solution described above, the beam is assumed to be linearly elastic and the prestress moment and elastic flexural stiffness at zero curvature, Figure 5, are introduced in Equation (2.12). The solution process is carried out as specified in section 2.8.2 and a trial deflected shape is obtained. The curvatures may now be calculated using Equations (2.9) and (2.10) for each joint. With these curvatures and the moment-curvature relationships for each joint, new values of flexural stiffness and prestress-moment are calculated and another trial solution is made. As the external loading and restraint conditions are held constant, each trial solution more closely approximates the actual nonlinear behavior of the beam. This iterative procedure is repeated until the deflection computed for each joint no longer changes, within some tolerance, for two successive trials.

2.8.4 Curvatures, Moments and Shears

The curvature at joint i can be obtained by combining Equations (2.9) and (2.10):

$$\phi_i = \frac{v_{i-1} - 2v_i + v_{i+1}}{h^2} . \qquad (2.14)$$

The moments M_i and M_i^P are obtained from the moment-curvature curves, for the curvature given by Equation (2.14).

Finally, the moment due to the applied loads at joint i, M_i^L, is obtained from Equation (2.4).

The shear force due to the applied loads for bar i can be computed from:

$$V_i^L = \frac{-M_{i-1}^L + M_i^L}{h}. \tag{2.15}$$

2.9 Dynamic Solution

2.9.1 Equilibrium Equations

Free body diagrams of bar i and joint i are shown in Figure 9. For equilibrium of bar i:

$$\sum M_i = 0$$

leads to

$$V_i = \frac{-M_{i-1} + M_i}{h}. \tag{2.16}$$

For equilibrium of joint i:

$$\sum F_{yi} = 0$$

leads to

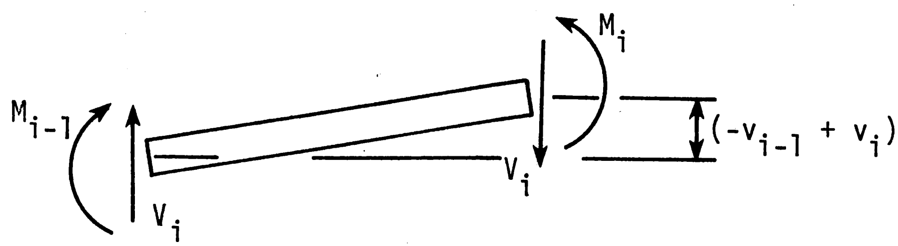
$$V_i - V_{i+1} + Q_i + Q_{di} - \frac{M_{i-1}^P}{h} + \frac{2M_i^P}{h} - \frac{M_{i+1}^P}{h} - m_i \ddot{v}_i = 0 \tag{2.17}$$

where

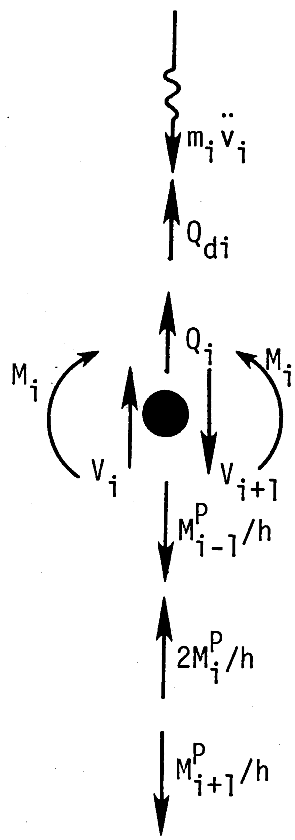
Q_{di} = applied dynamic load at joint i in y direction at time t;

$\ddot{v}_i$ = acceleration of mass m_i at joint i in y direction at time t;

and the other variables are defined in section 2.8.1.



(a) Freebody of Bar i



(b) Freebody of Joint i

Figure 9. Freebody Diagrams for Dynamic Solution

Equation (2.17) is the differential equation for motion and if all forces are known at time t, the acceleration can be calculated:

$$\ddot{v}_i = \frac{1}{m_i} (V_i - V_{i+1} + Q_i + Q_{di} - \frac{M^P_{i-1}}{h} + \frac{2M^P_i}{h} - \frac{M^P_{i+1}}{h}). \qquad (2.18)$$

2.9.2 Iterative Procedure for Dynamic Solution

At the beginning of the dynamic process, when a dynamic force is applied, it will transmit initial accelerations or initial velocities to the point masses of the structure. Initial dynamic displacements are zero, because the structure is at rest, although deformed under the static loads.

Subsequent values of dynamic displacements, velocities and accelerations are found by a step-by-step numerical integration procedure, using the "Beta Method" developed by Newmark (20). It is assumed that the accelerations of the joints vary linearly with time during a small time interval Δt. If the values of acceleration, velocity and displacement are known at any time t, then the values at time t + Δt may be determined from:

$$\dot{v}_{t+\Delta t} = \dot{v}_t + \frac{\Delta t}{2} (\ddot{v}_t + \ddot{v}_{t+\Delta t}) \qquad (2.19)$$

and

$$v_{t+\Delta t} = v_t + \Delta t\, \dot{v}_t + \frac{1}{3} (\Delta t)^2\, \ddot{v}_t + \frac{1}{6} (\Delta t)^2\, \ddot{v}_{t+\Delta t} \qquad (2.20)$$

The solution is started by assuming values of acceleration, $\ddot{v}_{t+\Delta t}$, at every joint in the beam. These assumed values enable values of velocities and displacements, $\dot{v}_{t+\Delta t}$ and $v_{t+\Delta t}$, respectively, to be obtained from the above Equations (2.19) and (2.20). The displacements calculated are then used to calculate curvatures from Equation (2.14).

The moments M_i and M_i^P are obtained from the moment-curvature curves, and the shears are calculated from Equation (2.16). New estimates of the accelerations $\ddot{v}_{t+\Delta t}$ are now obtained using Equation (2.18). These calculated values of accelerations are compared with the assumed values, and if agreement is not satisfactory, the process is repeated with the calculated accelerations being used as the new assumed values. When satisfactory agreement is obtained between the assumed and the calculated accelerations, the curvatures, moments and shears due to the combined action of static and dynamic loads can be obtained from the procedure described in section 2.8.4. Finally, the moment-curvature curves are adjusted for each joint to account for strain history and the iterative process is repeated for the next time interval.

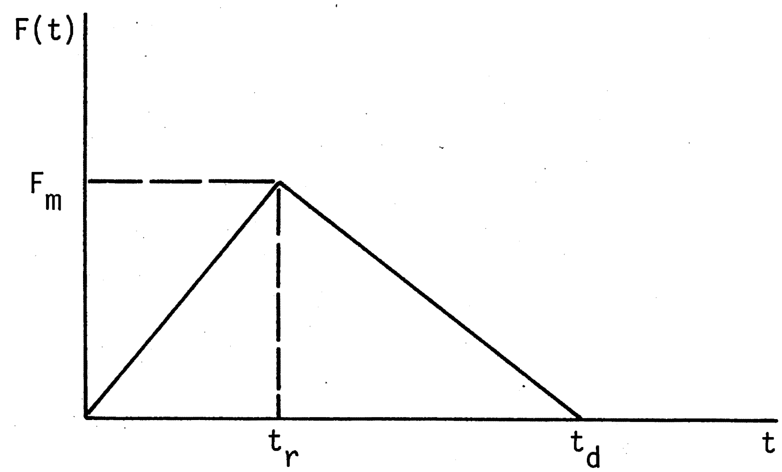
2.9.3 Dynamic Loads

The dynamic forces Q_{di} used in Equation (2.17) vary with time and may be considered as a product of a function of time F(t) by a constant load parameter:

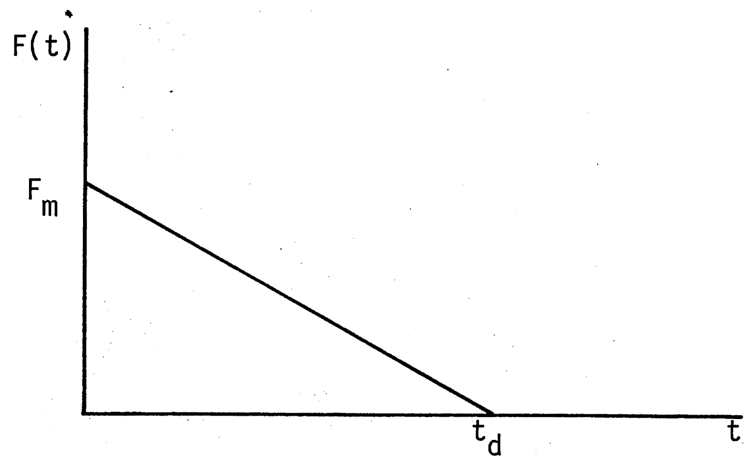
$$Q_{di} = F(t) \times q_{di}. \tag{2.21}$$

The parameter q_{di} is a function of x and has a maximum value of unity, and results in a sinusoidal or uniform pressure distribution.

The function F(t) considered in this study may be represented by the diagram shown in Figure 10(a), where F_m is the peak value of the pulse, t_r is the rise time, and t_d is the decay time. The diagram of Figure 10(b) may be obtained from the first diagram by setting $t_r = 0$, which will produce a force applied instantaneously at time $t = 0$ with its maximum value.



(a) Time Function for a Force Pulse



(b) Time Function for a Force Pulse With $t_r = 0$

Figure 10. Types of Time Functions

Two types of dynamic loadings are considered in this study: forces and impulses. For the first type of loading, the intensity of the force pulse at time t is given by Equation (2.21), where F(t) is evaluated at each time, according to diagrams of Figure 10.

The initial displacements, velocities and accelerations, at time t = 0, for a force pulse are:

$v_i = 0$;

$\dot{v}_i = 0$; and

$\ddot{v}_i = F(0) \times q_{di}/m_i$.

For impulse loading, F(t) is made equal to zero at all times. The initial displacements, velocities and accelerations at time t = 0 for an impulse are:

$v_i = 0$;

$\dot{v}_i = \text{peak} \times q_{di}/m_i$; and

$\ddot{v}_i = 0$.

2.9.4 Stability and Convergence of Numerical Integration

Stability and convergence of the iterative process outlined in section 2.9.2 are governed by the length of the time interval Δt. Newmark (20) has shown that stability and convergence are assured if Δt is approximately 1/5 to 1/6 of the shortest natural period of vibration of the model.

An equivalent uniform beam is used to determine the required time interval Δt. This equivalent beam has a bending stiffness given by

$$(EI)_e = \frac{1}{n} \sum_{i=1}^{n} (EI)_i$$

where

$(EI)_e$ = bending stiffness of equivalent uniform beam;

n = total number of joints in the model; and

$(EI)_i$ = bending stiffness of joint i obtained from Equation (2.11).

The mass per unit length of the equivalent beam is

$$\mu = \frac{1}{L} \sum_{i=1}^{n} (m_i)$$

where

μ = mass per unit length of equivalent beam;

L = total length of beam; and

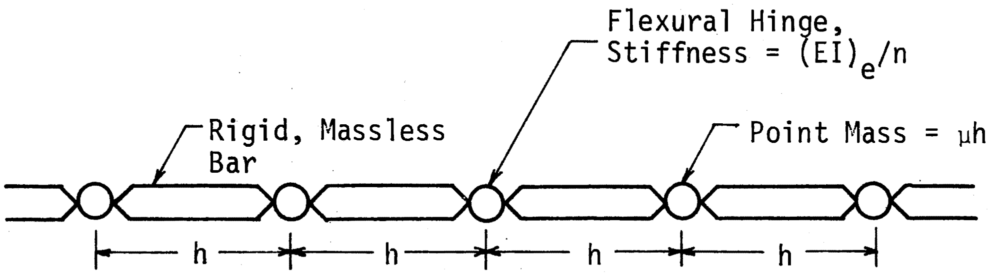
m_i = concentrated mass at joint i.

If the equivalent mass is replaced by a lumped parameter model having n joints as shown in Figure 11(a), the highest mode of lateral vibration of this model for small deflections will be as shown in Figure 11(b). The period of free vibration for this mode can be written as

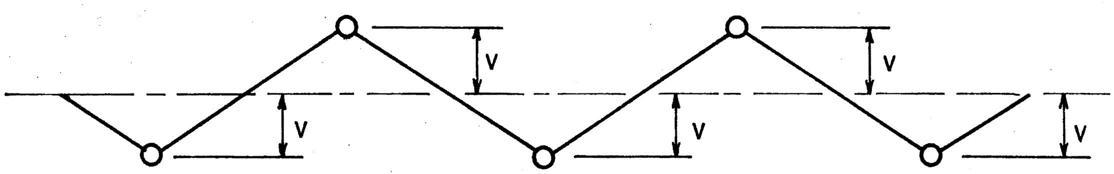
$$T_\ell = \frac{\pi L^2}{2(n-1)^2} \sqrt{\frac{\mu}{(EI)_e}}$$

and the time interval Δt for the dynamic solution is taken as $\frac{T_\ell}{10}$.

The procedure described above is sufficient for those structures which have only limited variations in cross section geometry along the length of the beam. For other cases, the time interval must be calculated from a more complete estimate of true structural behavior (17).



(a) Lumped Parameter Model of Equivalent Uniform Beam



(b) Assumed Displacements

Figure 11. System for Estimating Shortest Period of Vibration

CHAPTER III

DESCRIPTION OF COMPUTER PROGRAM

3.1 General

The analytical procedure described in the preceding chapter has been programmed for solution on a digital computer. The program is written in the ASA FORTRAN language and should require only minor revisions to be operable on any computer having a storage capacity of approximately 25,000 word equivalents. On machines operating with a word size of less than 60 binary bits (15 significant decimal figures), double precision arithmetic must be used.

A summary flow diagram for the program, named DYNPCB, is shown in Figure 12. The static solution is controlled by subroutine STATIC for which the summary flow diagram is shown in Figure 13. Subroutine DYNAM controls the dynamic solution process and the corresponding summary flow diagram is shown in Figure 14. A complete FORTRAN listing of the program is included in Appendix A.

3.2 Input Information

The program is developed to generate automatically as much of the required data as possible in order to minimize the amount of input data and to permit the solution of as many problems as desired on a single run. The specific formats of the input data are given in Appendix B.

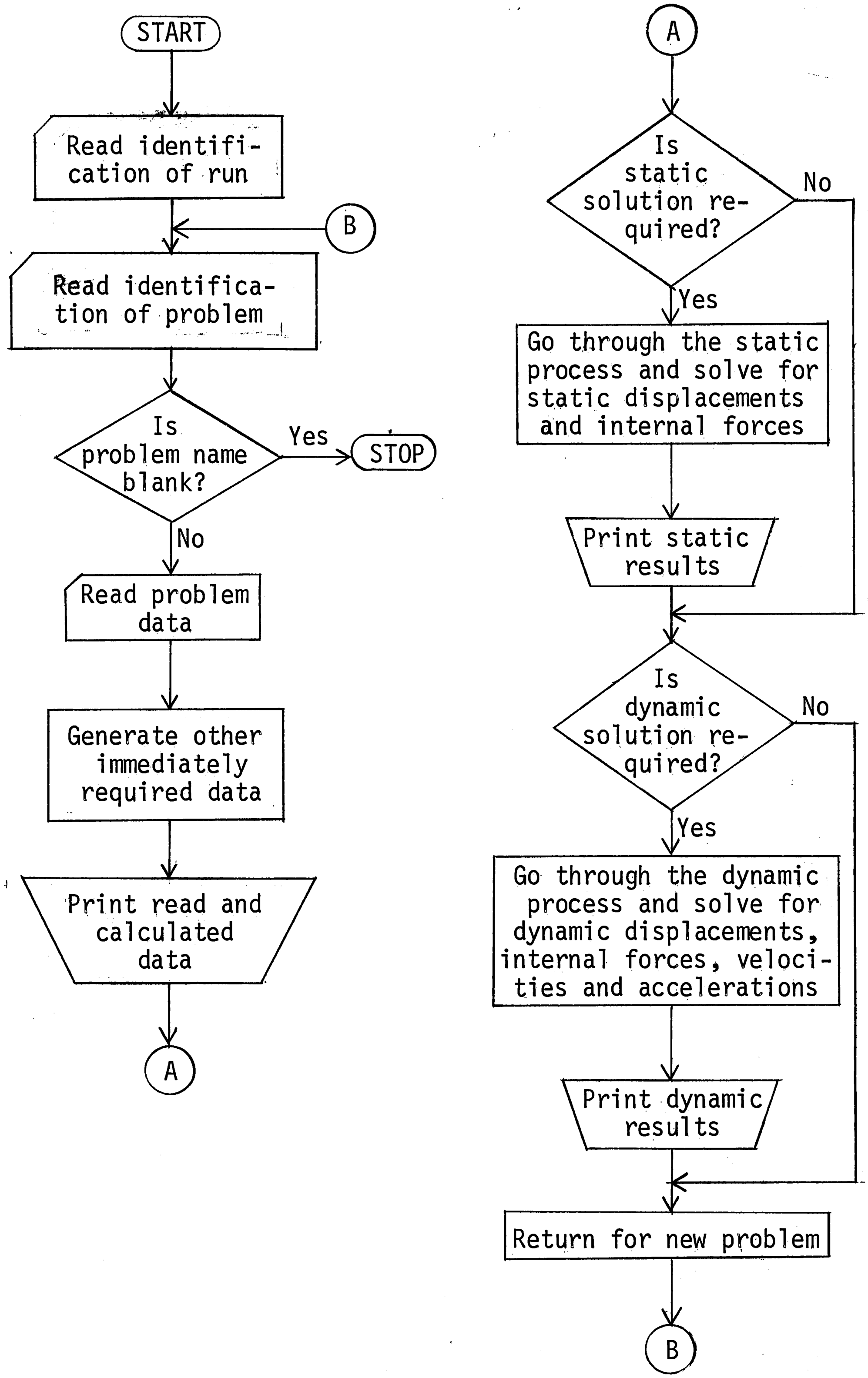


Figure 12. Summary Flowchart of Program DYNPCB

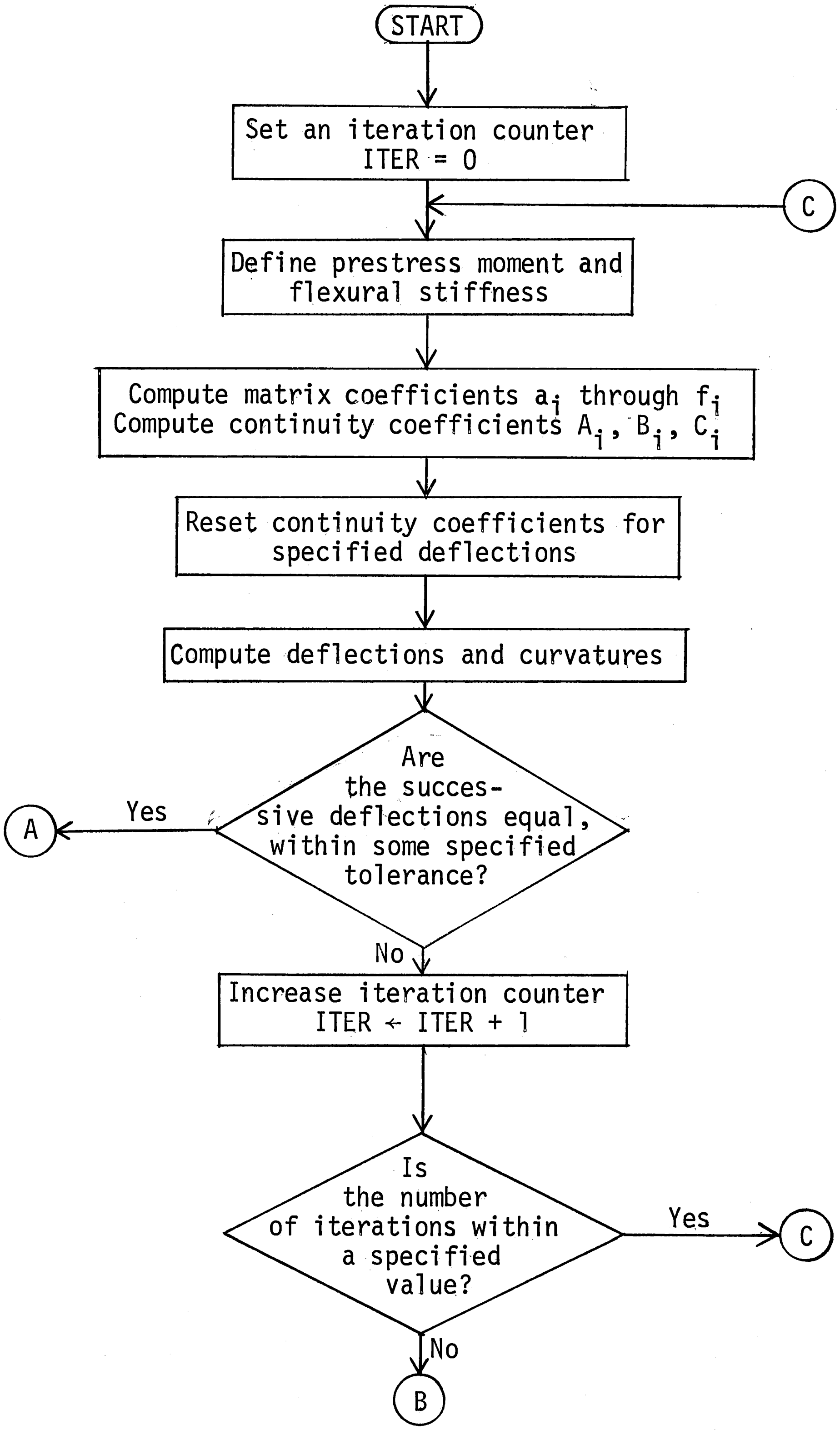


Figure 13. Summary Flowchart for the Static Solution

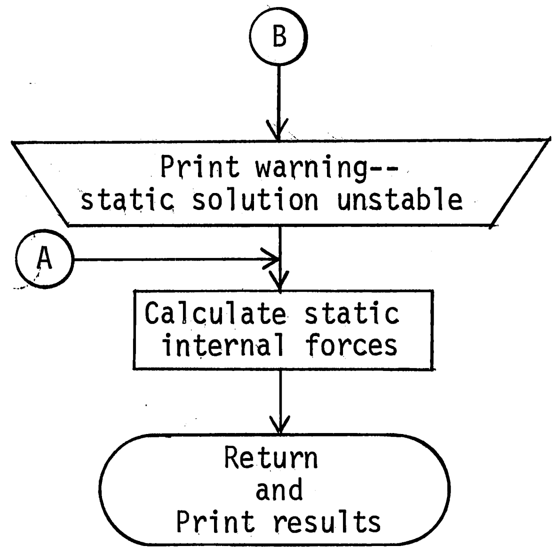


Figure 13. (Continued)

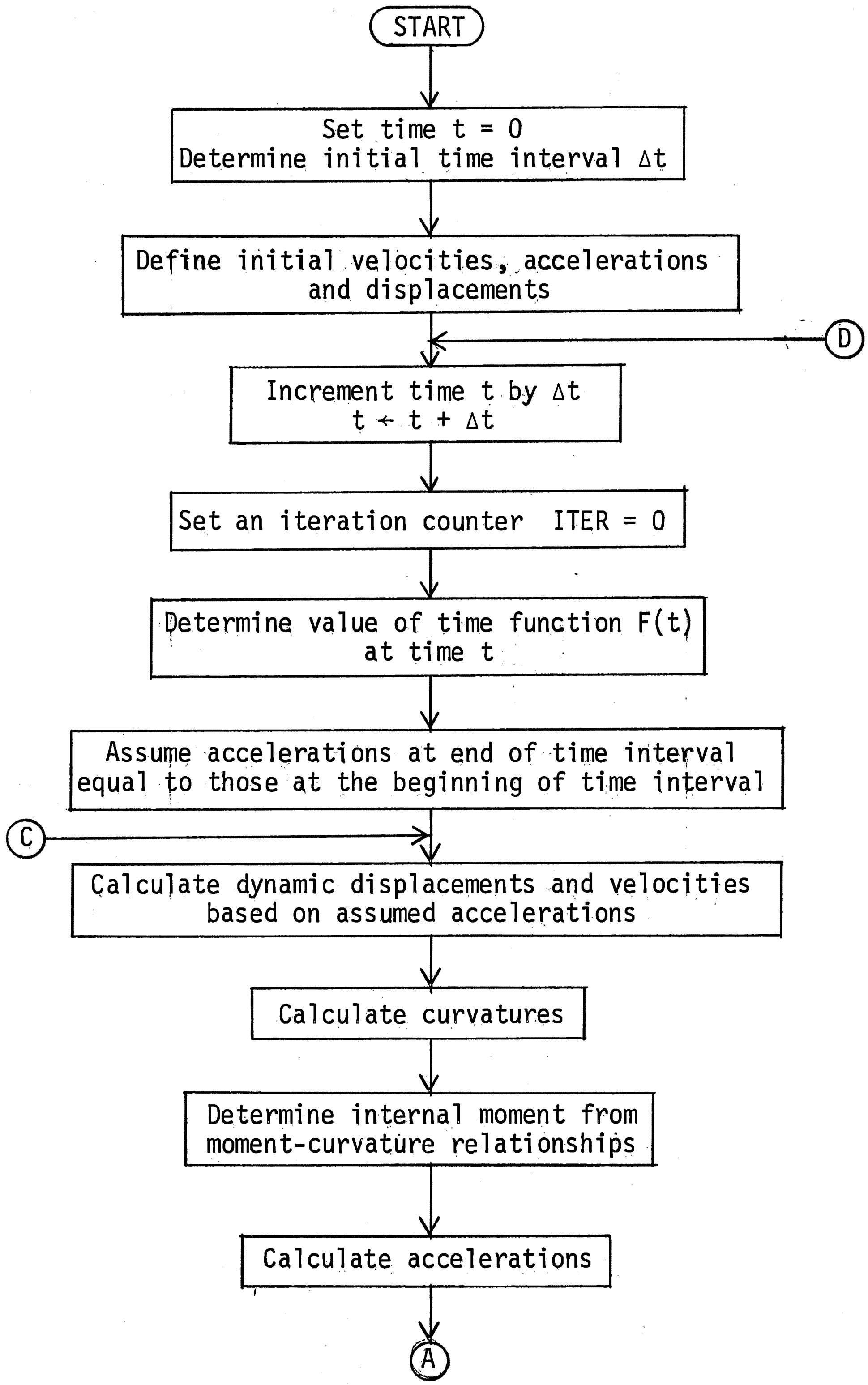


Figure 14. Summary Flowchart for the Dynamic Solution

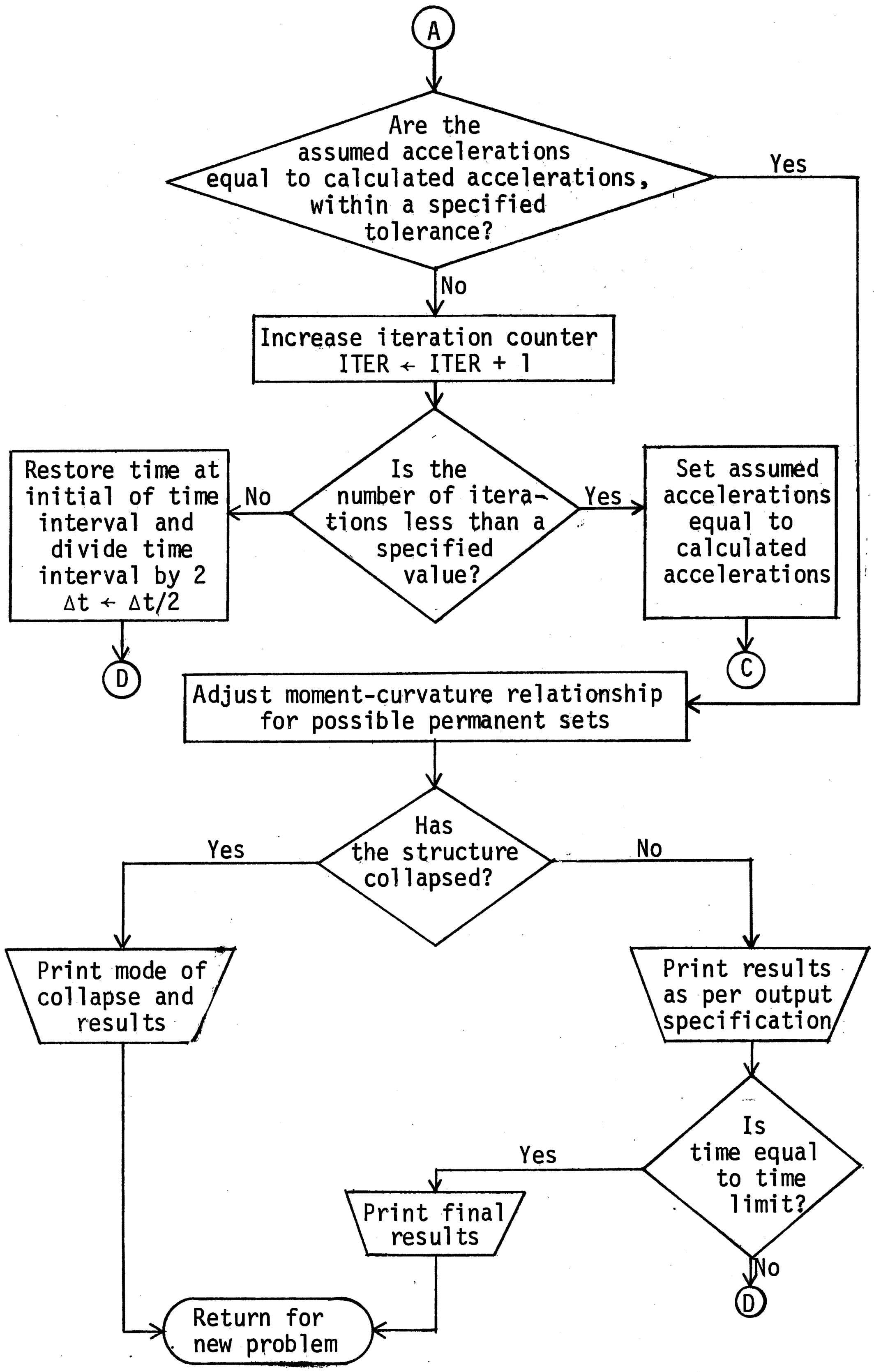


Figure 14. (Continued)

The input data are arranged in tabular form, and the general input sequence and the constraints to the program are described below.

3.2.1 Identification of Run

The execution of the program starts by reading the identification of the run.

3.2.2 Identification of Problem

The problem identification card enables the solution of as many problems as desired on a single run.

3.2.3 Table 1--Problem Control Data

If some of the input data for a succeeding problem is same as for the previous problem, those input data can be retained by a "KEEP" option.

At the option of the user, static solution and/or dynamic solution can be performed. The dynamic effects are superimposed on static effects.

A time limit is specified to determine the length of time to which the solution is to be carried for each dynamic loading. A time limit of two or three times the fundamental period of lateral vibration of the beam should be sufficient for most problems.

The time interval Δt for the numerical integration process may be approximately one-tenth of the shortest natural period of the lumped parameter model, as discussed in section 2.9.4. The user may input this time interval or may let the program calculate it internally. For the force-pulse type of loading, this interval may not be less than one-tenth of the time of rise or time of decay of the pulse.

The program automatically cuts the time interval by one-half if more than ten iterations are required during any time step before convergence of the numerical integration process is achieved. This condition is usually attributable to too large a time interval and can usually be corrected by reducing the time interval.

The solution process is made efficient by the "type" and "simplicity" specifications. For example, if a reinforced concrete beam is specified, the subroutines pertinent to a prestressed concrete beam are skipped; and, if the structure is specified as prismatic, the program calculates the centroid, moment-curvature relationship, etc, only once.

The program internally calculates the mass and self weight of the beam, and the effect of the self weight can be added to the solution through the "self weight" option.

The program assumes a maximum of 45 joints in the replacement structure. By changing only the dimension statements, an increased number of joints may be considered.

3.2.4 Table 2--Cross Section Description

The cross section is described at joints where changes in the cross section occur. The general form of the cross section assumed in the solution is shown in Figure 2. The cross section is divided into nine regions. Each region is further subdivided according to the Segment Number provided as input data and there are 30 such segments present. It is assumed that there are a maximum of three materials present in the beam: concrete, prestressed steel, and non-prestressed reinforcement.

The depth of each region may change from joint to joint; however, the segment number assigned to each region must be the same at every cross section. A region may be eliminated at any cross section by assigning the same depth to the top and bottom of the region. Top and bottom flange widths and the web thickness may vary along the beam.

Reinforcement description is required for every station at which a change in reinforcement occurs. If the reinforcement is absent in the beam, reinforcement description is not needed. The reinforcement can be specified at the top and/or bottom of the cross section, continuous or intermittent.

It is assumed that there are a maximum of 10 layers of prestressing steel across the cross section. The profile of a steel layer may vary as segments of a straight line or as a parabola.

3.2.5 Table 3--Stress-Strain Curves

A typical stress-strain curve for the material of the cross section is shown in Figure 3. A stress-strain curve needs to be specified for each material of the cross section. The curve is assumed to be made up of straight lines between the input values of stress and strain. The ten points required for each curve must include the coordinates of five points in the negative region and five points in the positive region. The curve is assumed to pass through the point stress equals zero and strain equals zero, and this point need not be included as input.

3.2.6 Table 4--Specified Deflections

The program can handle simple, continuous and overhanging beams.

Fixed support condition cannot be input. A sufficient number of supports must be provided to restrain all possible displacements of the beams as a rigid body. The program is developed to include only unyielding lateral supports at the joints. The accelerations and velocities of the masses at these supports are set equal to zero in the dynamic solution.

3.2.7 Table 5--Static Loads

Static loads are specified at the joints only in the transverse direction and may be either distributed or concentrated. Loads directed toward the positive direction of y-axis, Figure 1, are considered positive.

3.2.8 Table 6--Dynamic Loads

The effects of each dynamic loading are superimposed on the effects of static loads. The program is arranged to permit the solution for a number of different dynamic loadings and each dynamic solution is treated independently of other dynamic loadings.

Applied dynamic loads are assumed to act over the full length of the beam and may be either impulse loadings or forces having triangular force-time histories. Loads directed toward the positive direction of y-axis, Figure 1, are considered positive.

3.2.9 Collapse Parameters

Since the primary purpose of this study is to determine the magnitude of the dynamic load required to cause collapse of the beam, it is necessary to establish limits on the response of the beam which constitute collapse. The three collapse modes selected are excessive lateral displacement, shear failure, and excessive compressive strain in the outermost fiber of the cross section as established by the most negative strain value of the stress-strain curve. The limits on these collapse modes must be provided as input data for the computer program. The input shear strength may be calculated based on the shear strength of concrete and web reinforcement (21). Each limit is compared with the calculated response of the beam at every joint at the end of each time step and if any one of these limits is exceeded, the beam is considered to have collapsed due to the combined effects of static and dynamic forces.

3.2.10 End of Run

A blank card is required at the end of the data deck to terminate the program.

3.3 Output Information

The complete list of input data is printed as the data are read. Calculated results are printed according to an option specified by the user.

Two options are provided for output of effects due to static and dynamic loads. The first option includes a complete printing of the lateral displacements and bending moments at every joint, and the shear in each bar of the model for static loads. The second option provides only a printout of the location and magnitude of the maximum value of each of the above quantities. For the dynamic response, the above results are printed for every time step; in addition, the location, time and mode of collapse are also output.

Sample output for the example problems of Chapter IV is included in Appendix C.

CHAPTER IV

DEMONSTRATION OF PROGRAM

4.1 General

In order to illustrate the solution capability of the program and demonstrate its use, and also to verify the accuracy of the method of analysis, several problems have been solved, and the results compared with those obtained by conventional closed form solutions or by methods used by other investigators. These problems are described and the solutions from the computer program are discussed in this chapter. Sample coding listings for data input and selected printout sheets for all example problems are presented in Appendix C.

4.2 Example Solutions

4.2.1 Problem P1: Static and Dynamic Solution of a Wide Flange Steel Beam--Elastic Response

AISC W16x88 wide flange beam, shown in Figure 15, is simply supported on 40 ft span and subjected to a uniformly distributed static load of 1 kip/ft. This problem was also solved by Dawkins (14) using both closed form solution and his program IMPBC for analysis of beam-columns under impluse loadings. The results obtained by Dawkins and by this program DYNPCB are summarized in Figure 16. The slight difference in the calculated results can be reduced by increasing the number of

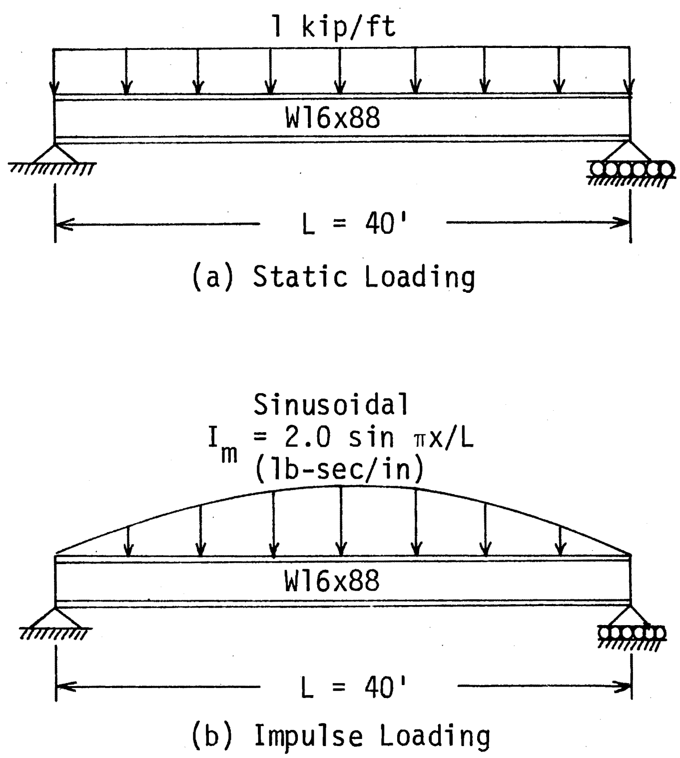


Figure 15. Data for Problem P1: Static and Dynamic Loading of Wide Flange Steel Beam

Quantity	Closed Form Solution	Results by Dawkins (14) from Program IMPBC	Results from Program DYNPCB
<u>Static Loading</u>			
Maximum moment at mid-span (in-lb)	2.4000×10^3	2.4000×10^3	2.400×10^3
Maximum deflection at mid-span (in)	-1.5738	-1.5954	-1.5936
<u>Dynamic Loading</u>			
Time = 2.6538×10^{-2}			
Maximum moment at mid-span (in-lb)	2.7803×10^3	2.7675×10^3	2.7568×10^3
Maximum deflection at mid-span (in)	-1.7715	-1.7885	-1.7806
Natural Period (sec)	0.1056	0.1062	0.1061

Figure 16. Problem P1: Static and Dynamic Solution of Wide Flange Steel Beam

joints in the beam; however, such an increase will result in increased computation time and, in view of the close agreement obtained, is unwarranted.

The above beam is subjected to a sinusoidal impulse loading as shown in Figure 15(b). No static load is applied. The results obtained by Dawkins(14) and by program DYNPCB are summarized in Figure 16. The period of vibration is obtained through the quarter period of vibration from the computer output.

The closed form solution for the deflection and bending moment at the mid-span of the beam in the elastic range due to the impulse load is obtained from:

$$v = \frac{I_m}{mp} \sin pt; \text{ and}$$

$$M^L = -\frac{\pi^2}{L^2} (EI) \frac{I_m}{mp} \sin pt$$

where

v = displacement;

I_m = Impulse at mid-span;

m = mass per unit length;

t = time;

L = length of span;

M^L = bending moment at mid-span;

(EI) = bending stiffness; and

p = fundamental natural circular frequency;

$$= \frac{\pi^2}{L^2} \sqrt{\frac{EI}{m}} .$$

4.2.2 Problem P2: Static and Dynamic Solution of a Reinforced Concrete Beam--Inelastic Response

A rectangular, singly reinforced concrete beam on simple supports with a span of 15 ft is subjected to static and dynamic loads as shown in Figure 17. The stress-strain curves for concrete and reinforcement are also shown in Figure 17. The response of the beam is observed by superimposing the effects of impulse loading and force pulse loading to the static effects separately.

The solution indicates that the beam undergoes inelastic deformation due to the combined static and impulse loads and fails due to the specified deflection limitation. The results obtained by Dawkins (14) and program DYNPCB are compared in Figure 18.

4.2.3 Problem P3: Static and Dynamic Solution of a Rectangular Prestressed Concrete Beam--Elastic Response

A rectangular prestressed concrete beam with parabolic tandon is subjected to static and combined static and impulse loads. The beam cross section, loading, and stress-strain curves for concrete and prestressing steel are shown in Figure 19. The closed form solution and the computer program solution are summarized for the mid-span of the beam in Figure 20.

The small error in static solution can be reduced by increasing the number of joints at the expense of added computer time. The closed form solution for the combined static and impulse loads is obtained by combining the closed form solution of impulse loading and the computer solution for static loading. This is done to eliminate any carry-over

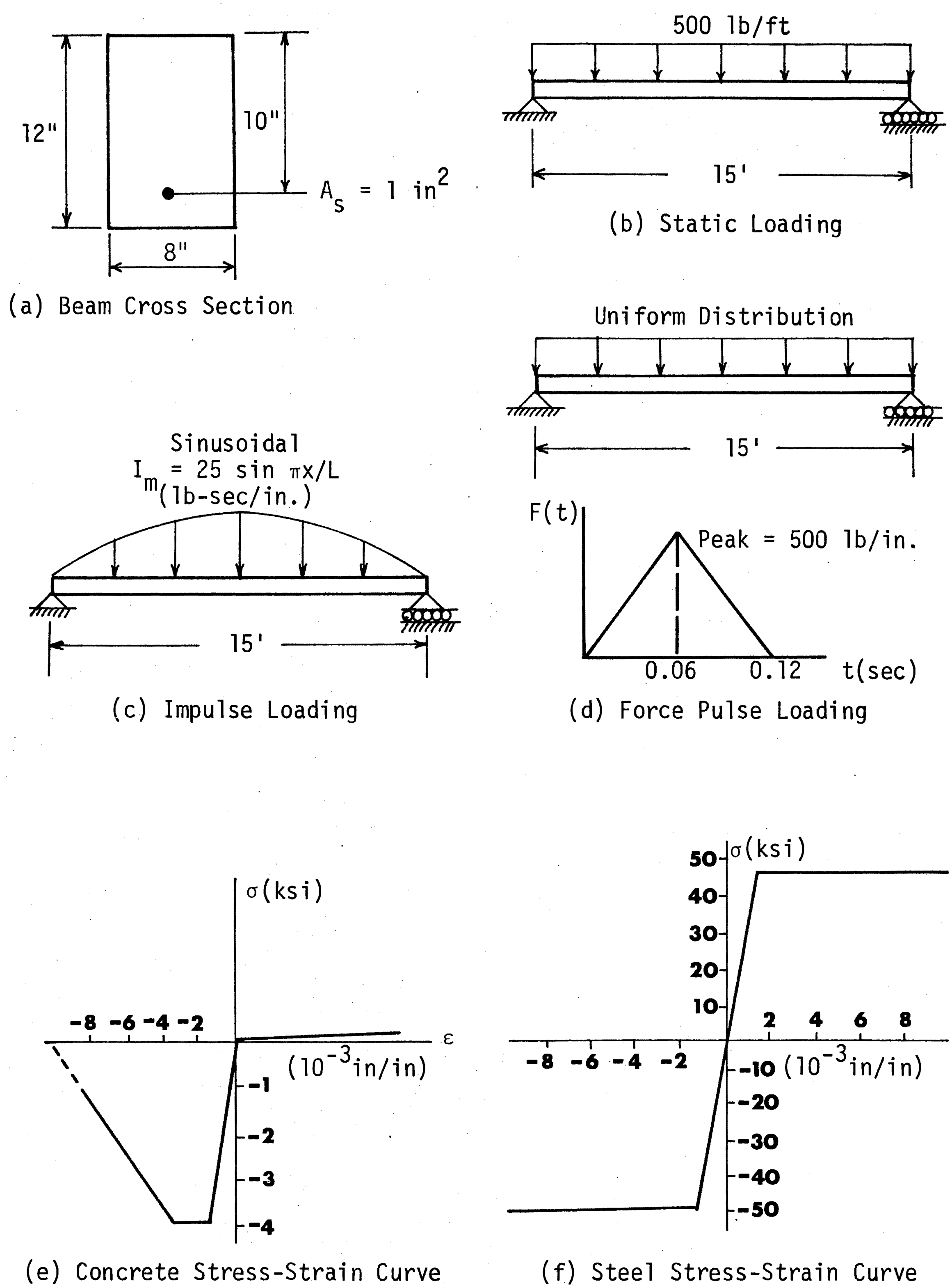


Figure 17. Data for Problem P2: Static and Dynamic Loading of Reinforced Concrete Beam

Quantity	Results from Dawkins (14) Program IMPBC	Results from Program DYNPCB
<u>Static Loading</u>		
Maximum moment at mid-span (in-lb)	1.6876×10^5	1.6876×10^5
Maximum deflection at mid-span (in)	-0.3728	-0.3728
<u>Combined Static and Impulse Loading</u>		
Time = 2.2980×10^{-3}		
Maximum moment at mid-span (in-lb)	4.3312×10^5	4.3397×10^5
Maximum deflection at mid-span (in)	-3.0040	-3.0283
<u>Combined Static and Force Pulse Loading</u>		
Time = 1.6756×10^{-3}		
Maximum moment at mid-span (in-lb)	1.6880×10^5	1.6881×10^5
Maximum deflection at mid-span (in)	-0.3731	-0.3731

Figure 18. Problem P2: Static and Dynamic Solution of Reinforced Concrete Beam

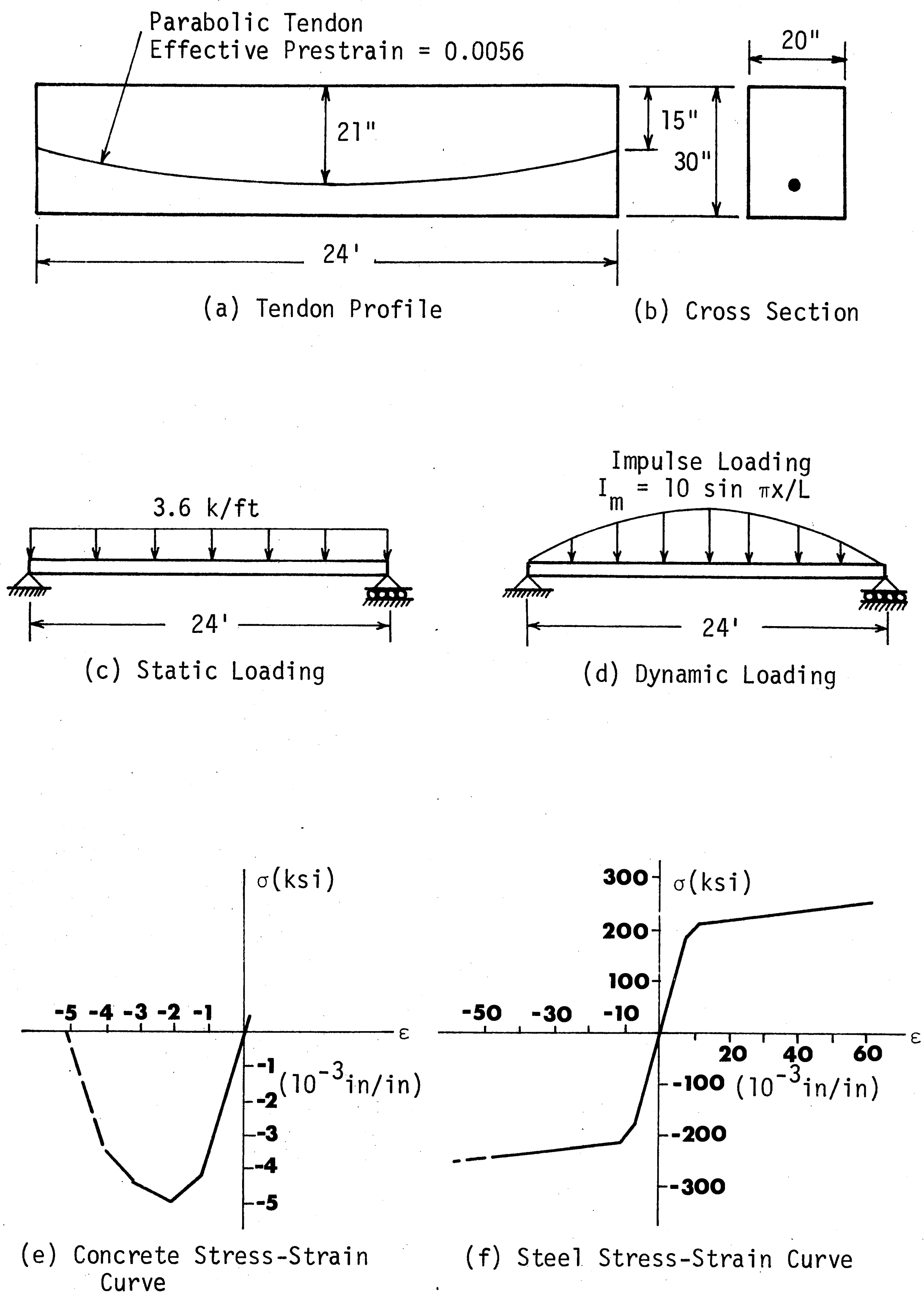


Figure 19. Data for Problem P3: Static and Dynamic Loading of Rectangular Prestressed Concrete Beam

Quantity	Closed Form Solution	Results from Program DYNPCB
Static Loading		
Maximum moment at mid-span (in-lb)	3.1104×10^6	3.1104×10^6
Maximum deflection at mid-span (in)	−0.0569	−0.0592
Combined Static and Dynamic Loading		
Time = 4.2050×10^{-4}		
Maximum moment at mid-span (in-lb)	3.6932×10^6	3.7021×10^6
Maximum deflection at mid-span (in)	−0.0908	−0.0908

Figure 20. Problem P3: Static and Dynamic Solution of Rectangular Prestressed Concrete Beam

errors from static results and to properly compare the dynamic results. The computer program predicts the response of the beam for static and dynamic effects satisfactorily, as is seen in Figure 20.

4.2.4 Problem P4: Static and Dynamic Solution of a Prestressed Concrete I-Beam

A prestressed concrete I-beam is subjected to a live load of 1000 lb/ft and to an impulse laod of 40 lb-sec/in., as shown in Figure 21. A self-weight option is specified to include the effects of dead load of the girder. The dyanamic effects are superimposed on the effects of the static loads. In addition to the prestressing strands, the girder has conventional reinforcement near the top of the section. The deflected shape of the beam at various time intervals is shown in Figure 22. The beam fails due to excessive shear forces. The input shear strength is based on the shear strength of concrete and web reinforcement (21). The shear failure made is due to the fact that the span-depth ratio is relatively small.

The peak value of the impulse load is varied to observe the time required for the failure of the beam, and to estimate the minimum impulse load necessary to cause failure. This variation is shown in Figure 23. The curve flattens at approximately 30 lb-sec/in. level, implying that the minimum impulse load necessary to cause failure of the beam is somewhat closer to this value.

Selected output sheets for a peak impulse value of 40 lb-sec/in. are included in Appendix C.

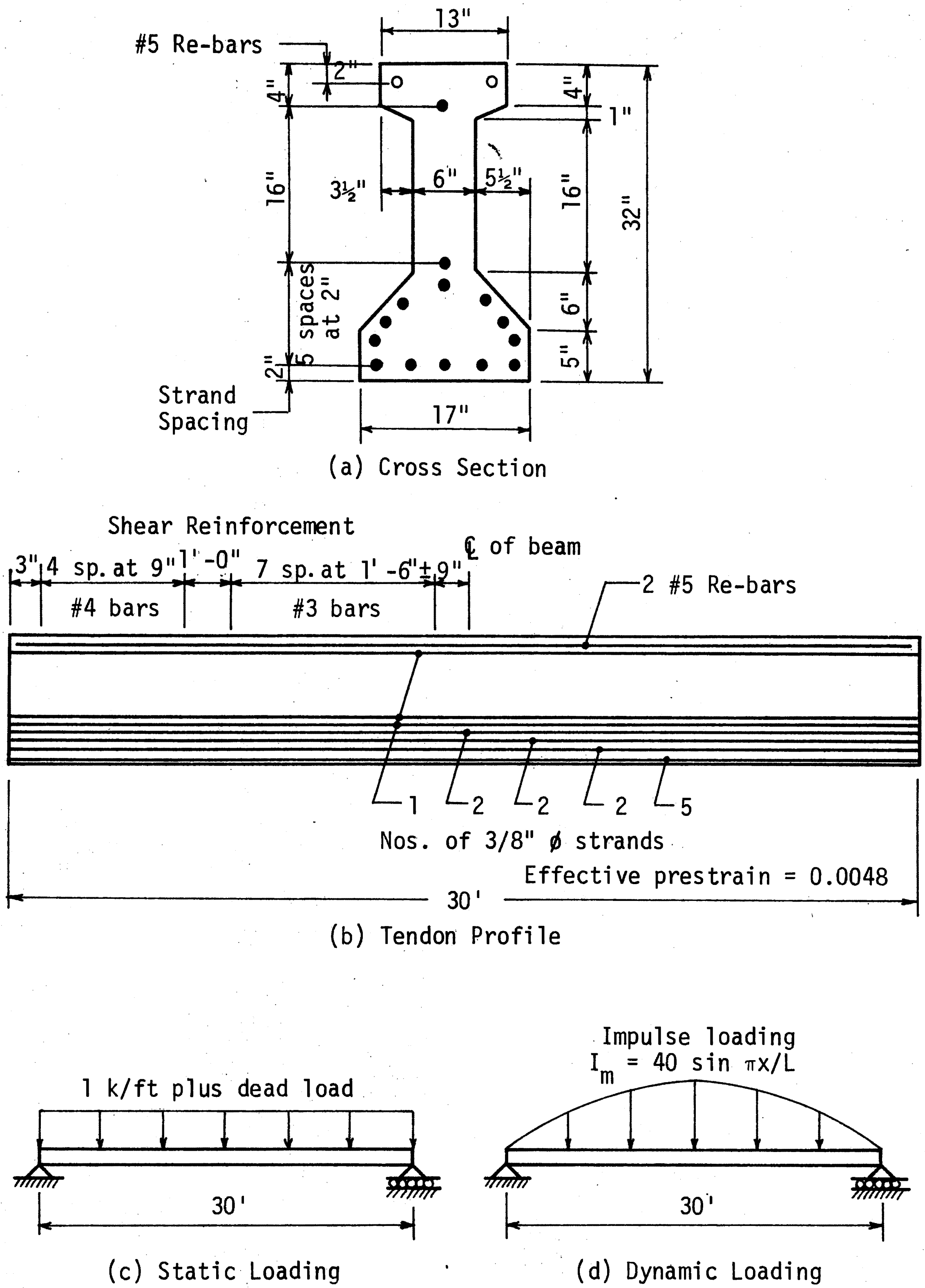


Figure 21. Data for Problem P4: Static and Dynamic Loading of a Prestressed Concrete I-Beam

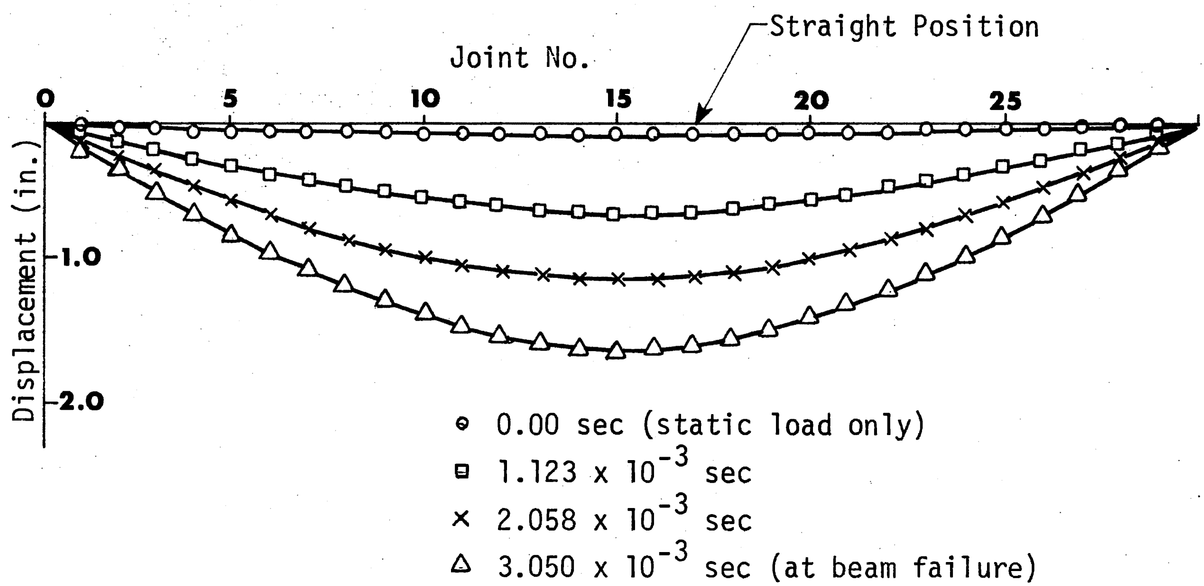


Figure 22. Deflected Shape of Beam at Various Time Intervals

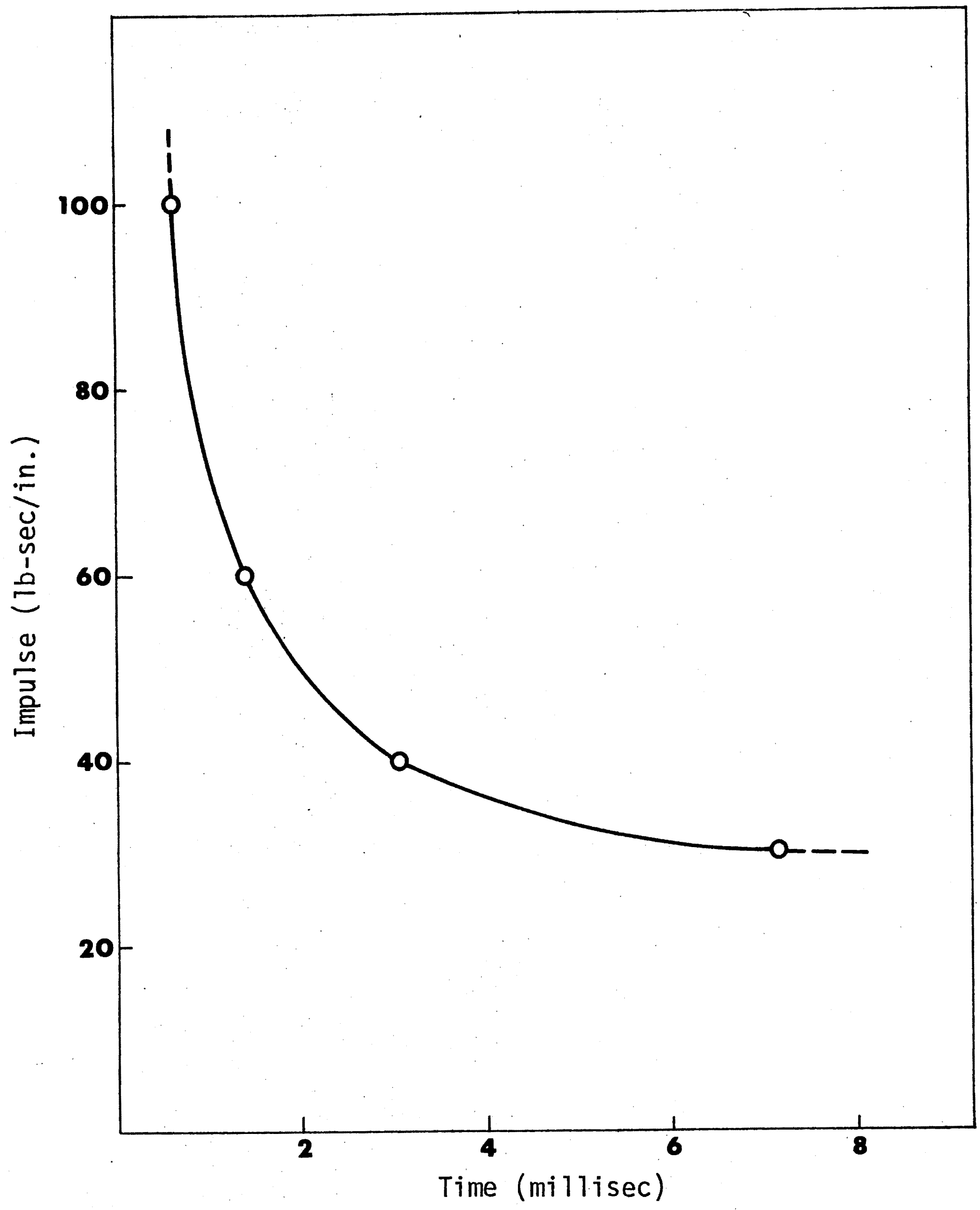


Figure 23. Variation of Impulse Load and Time for Failure of Beam

CHAPTER V

SUMMARY AND CONCLUSIONS

5.1 Summary

A method of analysis of prestressed concrete beams with bonded tendons subjected to dynamic loads or combined static and dynamic loads has been developed using a discrete-element model representing the actual structure.

The method employs small deflection theory and a single degree of freedom (motion in the transverse direction only), to determine the effects due to static and dynamic loads. However, the method takes into account material nonlinearity by constantly revising the flexural stiffness at selected sections of the structure, as deformations occur under transient loads.

Dynamic loadings may be taken in the forms of impulses or time dependent pulses. The dynamic solution is obtained using Newmark's Beta Method, based on linear variation of acceleration.

A computer program is written to handle a large variety of problems, such as steel, reinforced concrete, and prestressed concrete beams, with prismatic or variable cross sections. Solutions obtained using the program have compared satisfactorily with known solutions.

5.2 Conclusions

The following conclusions can be drawn based on the present study:

1. The small deflection theory and the single degree of freedom system are sufficient to predict the effects of dynamic loads on beams.

2. The computation time can be reduced significantly through the moment-curvature relationships, compared to working with the stress-strain curves of the materials of the structure throughout.

3. The model and the program developed can be utilized to predict the intensity of impulse loading necessary to cause collapse of individual structural members.

5.3 Recommendations

Future extensions of the model and the program may include the study of:

1. Deformations due to shear forces and the inertial resistance to rotational acceleration of the beam cross section. These two factors may influence the dynamic response appreciably if the span-depth ratio of the beam is relatively small (22).

2. The dynamic behavior of prestressed concrete beams with unbonded tendons. The behavior of these beams may be significantly different from that of beams with bonded tendons due to the relative slip between the tendon and the concrete.

3. The effect of rebound or reversal of curvature on the moment-curvature relationship. In section 2.6 it is assumed that unloading of the beam takes place according to the slope of the initial portion of the moment-curvature curve, Figure 5(c). For very short-duration dynamic loadings, rebound is found to be a significant factor (6). The energy

absorbed by the system is suddenly released when the beam rebounds and the beam may develop serious tension cracks due to negative deflection.

4. Effects of loadings other than those presently provided for in the program. The results obtained by the program cannot be compared with the test results mentioned in Section 1.3, since the test loadings differ greatly with the loadings shown in Figure 10.

Experimental research should also be performed with the purpose of evaluating the method developed and the results obtained with the program.

A SELECTED BIBLIOGRAPHY

(1) Biggs, J. M. Introduction to Structural Dynamics. New York: McGraw Hill Book Co., 1964.

(2) Timoshenko, S., D. H. Young, and W. Weaver, Jr. Vibration Problems in Engineering. 4th Ed., Princeton, N. J.: D. Van Nostrand Company, Inc., 1974.

(3) Mukherjee, A. K. "An Investigation of the Dynamic Behavior of Prestressed Concrete." (Unpub. Ph.D. dissertation, University of Minnesota, 1956.)

(4) Wadlin, G. K., and J. J. Stewart. "Comparison of Prestressed Concrete Beams and Conventionally Reinforced Concrete Beams Under Impulsive Loading." Journal of the American Concrete Institute, Vol. 58, No. 4 (October, 1961), pp. 407-421.

(5) Miyamoto, H. T., and J. R. Allgood. Blast Load Tests on Post-Tensioned Concrete Beams. Port Hueneme, California: U. S. Naval Civil Engineering Laboratory, Technical Report No. R-116, 1961.

(6) Takahasi, S. K. Static and Dynamic Loading of Pretensioned Concrete Beams. Port Hueneme, California: U. S. Naval Civil Engineering Laboratory, Technical Report No. R-192, 1962.

(7) Oladapo, I. O. "Dynamic Loading of Prestressed Concrete Beams." Magazine of Concrete Research, Vol. 14, No. 40 (March, 1962), pp. 25-32.

(8) Penzien, Joseph. "Damping Characteristics of Prestressed Concrete." Journal of the American Concrete Institute, Vol. 61, No. 9 (September, 1964), pp. 1125-1147.

(9) James, Merlin L., Loren D. Lutes and Gerald M. Smith. "Dynamic Properties of Reinforced and Prestressed Structural Components." Journal of the American Concrete Institute, Vol. 61, No. 11 (November, 1964), pp. 1359-1381.

(10) Hamilton, Wayne A. "Dynamic Response of Pretensioned Prestressed Concrete Beams." (Unpub. Ph.D. dissertation, Oklahoma State University, 1967.)

(11) Coles, Bruce C. and Wayne A. Hamilton. "Repetitive Dynamic Loading on Pretensioned Prestressed Beams." Journal of the American Concrete Institute, Vol. 92, No. 1 (February, 1966), pp. 327-350.

(12) Atkins, William D. "A Generalized Numerical Solution for Prestressed Concrete Beams." (Unpub. M. S. thesis, University of Texas, 1965.)

(13) Pierce, David M. "A Numerical Method of Analyzing Prestressed Concrete Members Containing Unbonded Tendons." (Unpub. Ph. D. dissertation, University of Texas, 1968.)

(14) Dawkins, William P. A Method of Analysis for Reinforced Concrete Beam Columns Subjected to Impulse Loading. Stillwater: Oklahoma State University, Preliminary Report, 1971.

(15) Guimaraes, Jerson D. "A Method of Analysis for Nonlinear Dynamic Response of Arches." (Unpub. Ph. D. dissertation, Oklahoma State University, 1974.)

(16) Riddle, George Mack. "Nonlinear and Large Displacement Behavior of Portal Frames Subjected to Impulse Loading." (Unpub. Ph. D. dissertation, Oklahoma State University, 1975.)

(17) Dawkins, William P. "Analysis of Tunnel Linear-Packing Systems." Journal of the Engineering Mechanics Division, ASCE, Vol. 95, No. EM3 (June, 1969), pp. 679-693.

(18) Lin, T. Y. Design of Prestressed Concrete Structures. 2nd Ed., New York: John Wiley & Sons, Inc., 1963, pp. 90-119.

(19) Matlock, H. and T. A. Haliburton. A Finite Element Method of Solution for Linearly Elastic Beam-Columns. Austin: Center of Highway Research, University of Texas, Research Report No. 56-1, 1965.

(20) Newmark, N. M. "A Method of Computation for Structural Dynamics." Transactions, ASCE, Vol. 127, Part I (1962), pp. 1406-1433.

(21) Building Code Requirements for Reinforced Concrete ACI 318-71. Detriot, Mich.: American Concrete Institute, 1971.

(22) Clough, Ray W. and Joseph Penzien. Dynamics of Structures. New York: McGraw Hill Book Company, 1975, p. 298.

APPENDIX A

LISTING OF PROGRAM DYNPCB

```
C>---->> MAIN PROGRAM DYNPCB
C
C
      IMPLICIT REAL * 8 ( A-H, O-Z )
      LOGICAL NDLS
      COMMON / IDNTFN / ID1(40), ID2(19), NPROB
      COMMON / CCNTRL / DTIME, TLIM, IDOPT, ISELFW, ISOPT, ISTAT,
     1                  ISTYPE, KEEP(7), NDL, NDLS, NOUT
      COMMON / TIMEFN / PEAK(20), TR, TD, IDTP, ILTP,
     1                  ITYPE(20), KEY1, NSETS
      COMMON / LOADIS / PHI(50), Q(45), QI(45), V(45), VD(45)
      DATA IBLANK, IYES / 4H    , 3HYES /
      DATA ZERO / 0.0D00 /
 1000 FORMAT ( 20A4 )
 2000 FORMAT ( //24X, 19A4 )
              NSETS = 0
C
C>---->> READ RUN IDENTIFICATION
C
      READ 1000, ID1
C
C>---->> READ PROBLEM IDENTIFICATION
C
  100 READ 1000, NPROB, ID2
C
C>---->> CHECK PROBLEM NAME AND STOP IF BLANK
C
            IF ( NPROB .NE. IBLANK ) GO TO 110
C
C>---->> PRINT TERMINATION MESSAGE AND STOP
C
      PRINT 2000, ID2
      STOP
C
C>---->> CALL SUBROUTINE INECHO TO READ IN AND ECHO PROBLEM DATA
C
  110 CALL INECHO
C
C>---->> CALL SUBROUTINE DIST TO GENERATE AND DISTRIBUTE DATA
C
      CALL DIST
C
C>---->> CALL SUBROUTINE BMPHI TO SET UP MOMENT CURVATURE RELATIONSHIP
C
      CALL BMPHI
C
C>---->> CHECK WHETHER STATIC SOLUTION IS REQUIRED
C
            IF ( ISTAT .NE. IYES ) GO TO 120
C
C>---->> CALL SUBROUTINE STATIC TO SOLVE FOR STATIC DISPLACEMENTS
C        AND INTERNAL FORCES
C
      CALL STATIC
              TIME = ZERO
C
C>---->> PRINT STATIC RESULTS
C
      CALL OUTPUT ( ISOPT, TIME, V )
C
C>---->> CHECK WHETHER DYNAMIC SOLUTION IS REQUIRED
C
            IF ( NSETS .EQ. 0 ) GO TO 100
  120       IF ( NDLS ) GO TO 130
                 NDLS = .TRUE.
C
C>---->> CALL SUBROUTINE DYNAM TO SOLVE FOR DYNAMIC DISPLACEMENTS
C        AND INTERNAL FORCES
C        CHECK FOR FAILURE AND PRINT DYNAMIC RESULTS
C
  130 CALL DYNAM
C
C>---->> RETURN FOR A NEW PROBLEM
C
            GO TO 100
      END
```

```
      SUBROUTINE INECHO
C-----READ AND ECHO INPUT DATA FOR DYNPCB
      IMPLICIT REAL * 8 ( A-H, O-Z )
      LOGICAL NDLS
      COMMON / CONSTT / GRAV, H, ITPREF, MAX, NB, NSLEV, NSSC
      COMMON / CONTRL / DTIME, TLIM, IDOPT, ISELFW, ISOPT, ISTAT,
     1                  ISTYPE, KEEP(7), NDL, NDLS, NOUT
      COMMON / TABL21 / B1N(10), B2N(10), B3N(10), XN(10),
     1                  JSN(10), NCT2
      COMMON / TABL22 / ABN(10), ATN(10), DBN(10), DN(9,10),
     1                  DTN(10), ISN(10), JRN(10), NRT2
      COMMON / TABL23 / PSTRNN(10), YST(10,10), IPN(10,10), NPT2(10)
      COMMON / TENDON / ARS(10), YSTL(10,45), TMOM(45), IOP(10)
      COMMON / CURVS1 / EPSMUL(3), EPSN(10,3), EPSU(3),
     1                  SIGMUL(3), SIGN(10,3)
      COMMON / CURVS2 / CEPS(10), CSIG(10), SEPS(10), SSIG(10),
     1                  TEPS(10), TSIG(10)
      COMMON / SUPPRT / VSN(10), JSDN(10), KEYS(50), NCT4
      COMMON / TABLE5 / QN(10), JI5(10), JL5(10), KONT5(10), NCT5
      COMMON / FAILUR / SMAX(45), SMAXN(10), VMAX, JS7N(10), NST7
      COMMON / TIMEFN / PEAK(20), TR, TD, IDTP, ILTP,
     1                  ITYPE(20), KEY1, NSETS
      COMMON / SEGMT1 / GAMMA(3), E(3,2), IS(9)
      COMMON / STRUCT / ISIMP
      DIMENSION II(7)
      DATA IEND, IYES, KEEPI/ 3HEND, 3HYES, 4HKEEP /
      DATA NEW / 4H NEW/, IUN / 2HUN /, ISI / 2HSI /
      DATA ZERO / 0.0D00 / , ISYM / 3HSYM / , IM / 2HIM /, IPR / 2HPR /
 1010 FORMAT ( 5X, 6(A4,1X) / , 5X, A3, 2X, 4I5, 2E10.3 /, 5X,
     1        2I5, E10.3, 2I5 )
 1020 FORMAT ( 5X, I5, E10.3, 10X, 3E10.3, 5X, A3 )
 1030 FORMAT ( 10X, I5, E10.3, 5X, I5, E10.3, 5X, I5, E10.3 )
 1040 FORMAT ( 5X, I5, 5X, 4E10.3 )
 1042 FORMAT ( 5X, I5 )
 1044 FORMAT ( 5X, 2I5, 5X, 2E10.3, 5X, I5 )
 1046 FORMAT ( 3(5X, I5, E10.3) )
 1052 FORMAT ( 10X, 2E10.3 )
 1056 FORMAT ( 10F8.0 )
 1060 FORMAT ( 5X, I5, E10.3, 5X, A3 )
 1070 FORMAT ( 5X, 2I5, 4X, I1, 10X, E10.3 )
 1080 FORMAT ( 10X, E10.3 )
 1090 FORMAT ( 5X, 2( A2, 3X ), 2(E10.3, 5X ) )
 1095 FORMAT ( 5X, A3, 12X, E10.3 )
 2010 FORMAT (///35H      TABLE 1. PROGRAM CONTROL DATA
     1 //        35H           NO KEEP OPTIONS EXERCISED      / )
 2020 FORMAT (///35H      TABLE 1. PROGRAM CONTROL DATA
     1 //        35H           RETAIN PRIOR DATA TABLES , 6( I1, 2H , )
 2030 FORMAT (   35H           STATIC SOLUTION REQUIRED , 5X, A4 )
 2040 FORMAT (   35H           STATIC OUTPUT OPTION     , 9X, I1 )
 2042 FORMAT (   35H           SELF WEIGHT OPTION       , 9X, I1,
     1         / 35H           STRUCTURE TYPE           , 9X, I1,
     2         / 35H           STRUCTURE SIMPLICITY     , 9X, I1,
     3         / 35H           NUMBER OF BARS           , 8X, I2,
     4         / 35H           ACCEL. DUE TO GRAVITY    , 1PD10.3 )
 2050 FORMAT (   36H           NUMBER OF DYNAMIC LOADINGS, 6X, I3,
     1 /         35H           DYNAMIC OUTPUT OPTION    , 9X, I1,
     2 /         35H           OUTPUT INTERVAL          , 8X, I2,
     3 /         35H           TIME LIMIT               ,1PD10.3  )
 2052 FORMAT (   35H           TIME INTERVAL            ,1PD10.3 )
 2056 FORMAT (   46H           TIME INTERVAL                INTERNAL   )
 2060 FORMAT (///40H      TABLE 2. CROSS SECTION DESCRIPTION          )
 2070 FORMAT ( / 45H           USING DATA FROM PREVIOUS PROBLEM     / )
 2080 FORMAT (// 45H           CONTROL DATA
     1 //        45H           STA     X-COORD          TOP FLANGE
     2           25H     WEB     BOT FLANGE    ,
     3 /         45H                                     WIDTH
     4           25H  THICKNESS     WIDTH      , //
     5     10X, I3,1PD12.3, 9X, 3D11.3 )
 2090 FORMAT (// 40H           SEGMENT, DEPTH DATA              ,
     1        // 39H           SEG      DEPTH    SEG      DEPTH
     2           20H    SEG     DEPTH    ,/,
     3        ( 9X, 3(I4, D12.3), / ) )
 2100 FORMAT (// 35H           REINFORCEMENT DESCRIPTION      ,
     1 //        45H           STA         TOP REINF          BOTTOM
     2           35H REINF
     3 /         45H                       DEPTH      AREA      DEPTH
     4           40H    AREA                                   , / )
 2110 FORMAT ( 10X, I3, 2X,1P4D10.3 )
 2112 FORMAT (// 35H           REINFORCEMENT DESCRIPTION, /
     1           40H           NON-PRESTRESSED STEEL ABSENT   )
 2114 FORMAT (// 40H           PRESTRESSING STEEL DESCRIPTION )
 2116 FORMAT (// 33H           NUMBER OF STEEL LAYERS ,I2 )
 2118 FORMAT (   47H           LAYER    GEOMETRY    AREA         STRAIN
     1           10H  SEGMENTS , / ,
     2        ( 10X, I3, 6X, I3, 4X, 1P2D12.3, 3X, I3 ) )
 2120 FORMAT (// 35H           LAYER    STA       DEPTH    )
 2124 FORMAT ( /, 10X, ( I3, 4X, I3, 4X, 1PD12.3 ) )
 2126 FORMAT (// 30H           NON-PRESTRESSED BEAM )
 2128 FORMAT (///35H      TABLE 3. STRESS-STRAIN CURVES        )
 2130 FORMAT (// 19H           CURVE NO , I1,
     1         / 36H           MATERIAL SPECIFIC WEIGHT  , 1PD10.3,
     2         / 36H           ULTIMATE STRAIN          ,1PD10.3,
     3         / 36H           STRESS VALUE SCALE FACTOR , 1PD10.3,
     4         / 36H           STRAIN VALUE SCALE FACTOR , 1PD10.3 )
 2140 FORMAT ( / 30H           STRESS INPUT VALUES ,/, 10X, 10F7.3 )
 2150 FORMAT ( / 30H           STRAIN INPUT VALUES , /, 10X, 10F7.3 )
 2160 FORMAT (///40H      TABLE 4. SPECIFIED DEFLECTIONS                )
 2210 FORMAT (// 30H           STA        DEFL                 / )
 2212 FORMAT (/, 10X, I3, 4X, 1PD12.3 )
 2230 FORMAT (///35H      TABLE 5. STATIC LOADS
     1        // 40H           FROM TO    CONT         LATERAL
     2         / 40H           STA  STA  CODE          LOAD      )
 2240 FORMAT ( /, 8X, 3I5, 6X, 1PD12.3 )
 2245 FORMAT ( / 45H           ADDITIONAL DATA FOR THIS PROBLEM    / )
 2250 FORMAT (///30H      TABLE 6. DYNAMIC LOADING                )
 2260 FORMAT ( / 19H           NONE / )
 2270 FORMAT (// 40H      IMPULSE, SINUSOIDAL DISTRIBUTION     /  )
 2275 FORMAT (// 40H      PRESSURE, SINUSOIDAL DISTRIBUTION        )
 2280 FORMAT (   30H           RISE TIME  . . . .  , 1PD10.3,
     1  /        30H           PULSE DURATION . .  , D10.3   , /  )
 2285 FORMAT (// 40H      PRESSURE, UNIFORM DISTRIBUTION           )
 2290 FORMAT (// 45H           LOAD NO.      TYPE              PEAK      /
 2340 FORMAT ( 9X, I5, 6X, 11HSYMMETRIC      , 2X, 1PD12.3  )
 2350 FORMAT ( 9X, I5, 6X, 11HUNSYMMETRIC    , 2X, 1PD12.3  )
 2360 FORMAT ( 9X, I5, 6X, 11HUNIFORM        , 2X, 1PD12.3  )
```

```
2410 FORMAT (///35H     TABLE 7. COLLAPSE PARAMETERS  )
2420 FORMAT (// 31H          DISPLACEMENT LIMIT = , 1PD12.3 )
24300FORMAT (// 25H          SHEAR LIMITS     ,
    1  //       35H                        TERM      SHEAR   ,
    2  /        35H                        STA      VALUE,
    3  /, ( 20X, I5,1PD12.3 ) )
C
      CALL HEADNG
C-----READ AND ECHO TABLE 1. PROGRAM CONTROL DATA
      READ 1010, ( KEEP(I), I = 2, 7 ), ISTAT, ISOPT, NDL, IDCPT, NOUT
     1           TLIM, DTIME, NB, ISELFW, GRAV, ISTYPE, ISIMP
                MAX    = NB + 1
                J = 0
               K = 1
           DO 110 I = 2, 7
                II(K) = 0
           IF ( KEEP(I) .NE. KEEPI ) GC TO 110
                II(K) = I
                J = J + 1
                K = K + 1
  110      CONTINUE
           IF ( J .GT. 0 ) GC TO 114
      PRINT 2010
           GO TC 116
  114 PRINT 2020, ( II(I), I = 1, J )
  116 PRINT 2030, ISTAT
           IF ( ISTAT .NE. IYES ) GO TO 120
      PRINT 2040, ISOPT
  120 PRINT 2042, ISELFW, ISTYPE, ISIMP, NB, GRAV
           IF ( NDL .EQ. 0 .AND. NSETS .EQ. 0 ) GO TO 130
           IF ( KEEP(6) .NE. KEEPI ) NSETS = 0
                NST = NSETS + NDL
      PRINT 2050, NST, IDOPT, NOUT, TLIM
           IF ( DTIME .EQ. ZERC) GC TO 122
  123 PRINT 2052, DTIME
           GO TC 125
  122 PRINT 2056
  125      CONTINUE
C-----READ AND ECHO TABLE 2. CROSS SECTION DESCRIPTION
  130 PRINT 2060
           IF ( KEEP(2) .EQ. KEEPI ) GO TO 170
                NCT2 = 1
                NDLS = .FALSE.
C-----READ CROSS SECTION DESCRIPTION
  140 READ 1C20,  JSN(NCT2), XN(NCT2), B1N(NCT2), B2N(NCT2),
     1            B3N(NCT2), IENDN
           DO 144 I = 1, 9, 3
      READ 1030, ISN(I), DN(I,NCT2), ISN(I+1), DN(I+1,NCT2), ISN(I+2),
     1           DN( I+2,NCT2)
  144      CONTINUE
           IF ( IENDN .EQ. IEND ) GO TO 150
                NCT2 = NCT2 + 1
           GO TC 140
  150           NRT2 = 1
           IF ( ISTYPE .EQ. 2 .OR. ISTYPE .EQ. 3 ) GO TO 160
           GC TC 162
C-----READ REINFORCEMENT DESCRIPTION
  160 READ 1040,  JRN(NRT2), DTN(NRT2), ATN(NRT2), DBN(NRT2), ABN(NRT2)
           IF ( JRN ( NRT2 ) .EQ. NB ) GO TO 162
                NRT2 = NRT2 + 1
           GO TO 16C
C-----READ PRESTRESS STEEL DATA
  162 READ 1042, NSLEV
           IF ( NSLEV .EQ. 0 ) GC TC 180
                ITPROF = 111
           DC 164 I = 1, NSLEV
      READ 1044, NSLV, IOP(I), ARS(I), PSTRNN(I), NPT2(I)
           IF ( IOP(I) .EQ. 2 .OR. IOP(I) .EQ. 3 ) ITPROF = 555
  164      CONTINUE
           DO 166 I = 1, NSLEV
                NPTT   = NPT2(I)
      READ 1046, ( IPN(I,J), YST(I,J), J = 1, NPTT )
  166      CONTINUE
C-----ECHO CROSS SECTION AND REINFORCEMENT DATA
  170 PRINT 2070
  180      DO 190 I = 1, NCT2
      PRINT 2080, JSN(I), XN(I), B1N(I), B2N(I), B3N(I)
      PRINT 2090, ( ISN(N), DN(N,I), N = 1, 9 )
  190      CONTINUE
           IF ( ISTYPE .EQ. 2 .OR. ISTYPE .EQ. 3 ) GO TO 189
           GO TO 191
  189 PRINT 2100
      PRINT 2110, ( JRN(I), DTN(I), ATN(I), DBN(I), ABN(I), I = 1, NRT2)
           GO TO 192
  191 PRINT 2112
  192 PRINT 2114
           IF ( NSLEV .EQ. 0 ) GO TO 198
      PRINT 2116, NSLEV
      PRINT 2118, ( I, IOP(I), ARS(I), PSTRNN(I), NPT2(I), I = 1, NSLEV)
      PRINT 2120
           DO 196 I = 1, NSLEV
                NPTT   = NPT2(I)
           DO 196 J = 1, NPTT
      PRINT 2124, I, IPN(I, J), YST(I,J)
  196      CONTINUE
           GC TC 199
  198 PRINT 2126
  199      CONTINUE
C-----READ AND ECHO TABLE 3. STRESS--STRAIN CURVES
      PRINT 2128
           IF ( KEEP(3) .EQ. KEEPI ) GC TU 210
                NDLS = .FALSE.
      READ 1C2C,  NSSC
           DO 200 I = 1, NSSC
      READ 1052, SIGMUL(I), GAMMA(I)
      READ 1056, ( SIGN(J,I), J = 1, 10 )
      READ 1052, EPSMUL(I), EPSU(I)
      READ 1056, ( EPSN(J,I), J = 1, 10 )
  200      CONTINUE
           GO TC 220
  210 PRINT 2070
  220      DO 230 I = 1, NSSC
      PRINT 2130, I, GAMMA(I), EPSU(I), SIGMUL(I) , EPSMUL(I)
      PRINT 2140, ( SIGN(J,I), J = 1, 10 )
      PRINT 2150, ( EPSN(J,I), J = 1, 10 )
  23C      CONTINUE
```

```
C>--->READ AND ECHO TABLE 4. SPECIED DEFLECTIONS
      PRINT 2160
          IF ( KEEP(4) .NE. KEEPI ) GO TO 240
      PRINT 2070
          GO TO 254
  240          J = 1
  244 READ 1060, JSDN(J), VSN(J), IENDN
          IF ( IENDN .EQ. IEND ) GO TO 250
               J = J+1
          GO TO 244
  250          NCT4 = J
  254 PRINT 2210
          DO 260 J = 1, NCT4
      PRINT 2212, JSDN(J), VSN(J)
  260     CONTINUE
C-----READ AND ECHO TABLE 5. STATIC LOADS
      PRINT 2230
          IF ( KEEP(5) .NE. KEEPI ) GO TO 280
      PRINT 2070
          DO 275 I = 1, NCT5
      PRINT 2240, JI5(I), JL5(I), KONT5(I), QN(I)
  275     CONTINUE
      PRINT 2245
          IF ( NCT5 .EQ. 1 ) GO TO 276
          IF ( KONT5(NCT5 - 1) .EQ. 1 ) GO TO 277
  276          KONT5 ( NCT5 ) = 3
          GO TO 278
  277          KONT5 ( NCT5 ) = 2
  278     CONTINUE
               NCI5 = NCT5 + 1
          GO TO 290
  280          NCI5 = 1
  290          NCT5 = NCI5
  300 READ 1070,  JI5(NCT5), JL5(NCT5), KONT5(NCT5), QN(NCT5)
          IF ( KONT5(NCT5) .LE. 0 ) GO TO 310
               NCT5 = NCT5 + 1
          GO TO 300
  310     DO 315 I = NCI5, NCT5
      PRINT 2240, JI5(I), JL5(I), KONT5(I), QN(I)
  315     CONTINUE
C-----READ AND ECHO TABLE 6. DYNAMIC LOADING
      PRINT 2250
               KEY = 0
          IF ( KEEP(6) .NE. KEEPI .AND. NDL .EQ. 0 ) GO TO 316
          IF ( KEEP(6) .NE. KEEPI ) GO TO 320
      PRINT 2070
          GO TO 330
  316 PRINT 2260
          GO TO 360
  320 READ 1090, IDTP, ILTP, TR, TD
  330     IF ( IDTP .EQ. ISI .AND. ILTP .EQ. IM ) KEY = 1
          IF ( IDTP .EQ. ISI .AND. ILTP .EQ. IPR ) KEY = 2
          IF ( IDTP .EQ. IUN  .AND. ILTP .EQ. IM ) GO TO 900
          IF ( IDTP .EQ. IUN  .AND. ILTP .EQ. IPR ) KEY = 3
          IF ( KEY .LT. 1 ) GO TO 900
          GO TO ( 332, 334, 338 ), KEY
  332 PRINT 2270
          GO TO 340
  334 PRINT 2275
      PRINT 2280, TR, TD
          GO TO 340
  338 PRINT 2285
      PRINT 2280, TR, TD
  340     CONTINUE
          IF ( KEEP(6) .NE. KEEPI ) NSETS = 0
               NSTRT = NSETS + 1
               NSETS = NSETS + NDL
          IF ( KEEP(6) .NE. KEEPI ) GO TO 341
      PRINT 2245
          IF ( NDL .NE. 0 ) GO TO 341
      PRINT 2260
          GO TO 360
  341 PRINT 2290
          DO 350 I = NSTRT, NSETS
      READ 1095, ITYPE(I), PEAK(I)
          IF ( IDTP .EQ. IUN ) GO TO 346
          IF ( ITYPE(I) .NE. ISYM ) GO TO 345
      PRINT 2340, I, PEAK(I)
          GO TO 350
  345 PRINT 2350, I, PEAK(I)
          GO TO 350
  346 PRINT 2360, I, PEAK(I)
  350     CONTINUE
  360     CONTINUE
C-----READ AND ECHO TABLE 7. COLLAPSE PARAMETERS
      PRINT 2410
          IF ( NSETS .EQ. 0 ) GO TO 460
  411     IF ( KEEP(7) .NE. KEEPI ) GO TO 412
      PRINT 2070
          GO TO 430
  412 READ 1080,  VMAX
               NST7 = 1
  414 READ 1040,  JS7N(NST7),SMAXN(NST7)
          IF ( JS7N(NST7) .EQ. NB ) GO TO 430
               NST7 = NST7 + 1
          GO TO 414
  430 PRINT 2420, VMAX
      PRINT 2430, ( JS7N(I), SMAXN(I), I = 1, NST7 )
          GO TO 470
  460 PRINT 2260
  470     CONTINUE
      RETURN
  900 PRINT 9000
 9999 CONTINUE
      STOP
 9000 FORMAT (///42H     ERROR IN DYNAMIC LOAD TYPE IDENTIFIER , /,1H1 )
      END
```

```
      SUBROUTINE DIST
C
C-----DISTRIBUTE INPUT DATA FOR DYNPCB
C
      IMPLICIT REAL * 8 ( A-H, O-Z )
      COMMON / CONSTT / GRAV, H, ITPROF, MAX, NB, NSLEV, NSSC
      COMMON / CONTRL / DTIME, TLIM, IDOPT, ISELFW, ISOPT, ISTAT,
     1                  ISTYPE, KEEP(7), NDL, NDLS, NOUT
      COMMON / TABL21 / B1N(10), B2N(10), B3N(10), XN(10),
     1                  JSN(10), NCT2
      COMMON / TABL22 / ABN(10), ATN(10), DBN(10), DN(9,10),
     1                  DTN(10), ISN(10), JRN(10), NRT2
      COMMON / TABL23 / PSTRNN(10), YST(10,10), IPN(10,10), NPT2(10)
      COMMON / EMFEEE / EM(45,10), EMP(45,10), FEE(45,10)
      COMMON / XSECT1 / AB(45), AT(45), B1(45), B2(45),
     1                  B3(45), DB(45), DT(45)
      COMMON / XSECT2 / AE(45), CG(45), D(9,45), EI(45)
      COMMON / TENDON / ARS(10), YSTL(10,45), TMOM(45), IOP(10)
      COMMON / BMDATA / BM(45), BMASS(45), X(45)
      COMMON / CURVS1 / EPSMUL(3), EPSN(10,3), EPSU(3),
     1                  SIGMUL(3), SIGN(10,3)
      COMMON / CURVS2 / CEPS(10), CSIG(10), SEPS(10), SSIG(10),
     1                  TEPS(10), TSIG(10)
      COMMON / SUPPRT / VSN(10), JSDN(10), KEYS(50), NCT4
      COMMON / TABLE5 / QN(10), JI5(10), JL5(10), KONT5(10), NCT5
      COMMON / SEGMT1 / GAMMA(3), E(3,2), IS(9)
      COMMON / SEGMT2 / DA(30), DI(30)
      COMMON / FAILUR / SMAX(45), SMAXN(10), VMAX, JS7N(10), NST7
      COMMON / TIMEFN / PEAK(20), TR, TD, IDTP, ILTP,
     1                  ITYPE(20), KEY1, NSETS
      COMMON / LOADIS / PHI(50), Q(45), QI(45), V(45), VD(45)
      COMMON / STRUCT / ISIMP
      DIMENSION YS(10), IP(10), BMWT(45), YSTT(45)
      DIMENSION DUM(10), DZON(9)
      DIMENSION AGAM(45)
      DATA ZERO, IENDN / 0.0D00, 3HEND /
      DATA TWO / 2.0D00 /
C-----SET UP CROSS SECTION DATA FOR EACH STATION
          IF (NCT2 .GT. 1 ) GO TO 50
          DO 40 I = 1, MAX
               B1(I) = B1N(1)
               B2(I) = B2N(1)
               B3(I) = B3N(1)
   40     CONTINUE
          GO TO 55
   50 CALL INTRP1 ( JSN, B1N, B1, NCT2 )
      CALL INTRP1 ( JSN, B2N, B2, NCT2 )
      CALL INTRP1 ( JSN, B3N, B3, NCT2 )
   55     CONTINUE
          IF ( ISTYPE .EQ. 2 .OR. ISTYPE .EQ. 3 ) GO TO 60
          GO TO 85
   60     IF ( NRT2 .GT. 1 ) GO TO 80
          DO 70 I = 1, MAX
               AB(I) = ABN(1)
               AT(I) = ATN(1)
               DB(I) = DBN(1)
               DT(I) = DTN(1)
   70     CONTINUE
          GO TO 90
   80     CONTINUE
      CALL INTRP1 ( JRN, ABN, AB, NRT2 )
      CALL INTRP1 ( JRN, ATN, AT, NRT2 )
      CALL INTRP1 ( JRN, DBN, DB, NRT2 )
      CALL INTRP1 ( JRN, DTN, DT, NRT2 )
          GO TO 90
   85     CONTINUE
          DO 88 N = 1, MAX
               AB(N) = ZERO
               AT(N)  = ZERO
               DB(N)  = ZERO
               DT(N)  = ZERO
   88     CONTINUE
   90     CONTINUE
      IF ( NSLEV .EQ. 0 ) GO TO 182
          DO 180 I = 1, NSLEV
               NPTT    = NPT2(I)
               IOPG    = IOP(I)
          GO TO ( 110, 130, 160 ), IOPG
  110     DO 120 J = 1, MAX
  120          YSTL(I,J) = YST(I,NPTT)
          GO TO 180
  130     DO 140 J = 1, NPTT
               YS(J)   = YST(I,J)
  140          IP(J)   = IPN(I,J)
      CALL INTRP1 ( IP, YS, YSTT, NPTT )
          GO TO 173
  160     DO 170 J = 1, NPTT
               YS(J)   = YST(I,J)
  170          IP(J)   = IPN(I,J)
      CALL INTRP3 ( IP, YS, YSTT, NPTT )
  173     DO 175 K = 1, MAX
  175          YSTL(I,K) = YSTT(K)
  180     CONTINUE
          GO TO 188
  182     CONTINUE
          DO 186 I = 1, 10
               PSTRNN(I) = ZERO
               ARS(I) = ZERO
               YS(I)   = ZERO
          DO 186 K = 1, MAX
  186          YSTL(I,K) = ZERO
  188     CONTINUE
          DO 190 I = 1, 9
               IS(I) = ISN(I)
  190     CONTINUE
          IF (NCT2 .GT. 1 ) GO TO 210
          DO 200 J = 1, MAX
          DO 200 I = 1, 9
               D(I,J) = DN(I,1)
  200     CONTINUE
          GO TO 250
  210     DO 240 I = 1, 9
          DO 220 J = 1, NCT2
               DUM(J) = DN(I,J)
  220     CONTINUE
```

```
      CALL INTRP1 ( JSN, DUM, X, NCT2 )
          DO 230 J = 1, 105
               D(I,J) = X(J)
  230     CONTINUE
  240     CONTINUE
  250     IF ( NCT2 .GT. 1 ) GO TO 270
               XNEL   = NB
               DX = XN(1) / XNEL
               X(1) = ZERO
          DO 260 I = 2, MAX
               X(I) = X(I-1) + DX
  260     CONTINUE
          GO TO 280
  270 CALL INTRP1 ( JSN, XN, X, NCT2 )
  280     CONTINUE
               BARS   = NB
               H      = X(MAX) / BARS
               NB5 = NB + 5
          DO 310 J = 3, NB5
               KEYS(J) = 1
  310     CONTINUE
          DO 340 N = 1, NCT4
               JS = JSDN(N) + 4
C-----SET INDEXES FOR FUTURE CONTROL OF SPECIFIED DEFLECTIONS
               KEYS(JS) = 2
  340     CONTINUE
C-----DISTRIBUTE SELF WEIGHT AND BEAM MASS
               BMWT(1) = ZERO
          DO 415 I = 1, MAX
          DO 410 J = 1, 9
  410          DZON(J) = D(J,I)
      CALL MASS ( DZON, B1(I), B2(I), B3(I), AB(I), AT(I), ARS, AGAM(I))
          IF ( I .EQ. 1 .AND. NCT2 .EQ. 1 .AND. NRT2 .EQ. 1 )
     1                                                 GO TO 420
  415     CONTINUE
          GO TO 428
  420     CONTINUE
          DO 425 K = 1, MAX
  425          AGAM(K) = AGAM(I)
  428     CONTINUE
          DO 430 I = 2, MAX
               HWT = AGAM ( I - 1 ) * H / TWO
               BMWT( I - 1 ) = BMWT ( I - 1 ) + HWT
               BMWT (I) = HWT
  430     CONTINUE
          DO 440 I = 1, MAX
               BMASS(I) = BMWT(I) / GRAV
  440     CONTINUE
C-----DISTRIBUTE STATIC LOAD DATA
      CALL INTRP2 ( JI5, JL5, KONT5, QN, Q, X, NCT5 )
          IF ( ISELFW .EQ. 0 ) GO TO 457
          DO 450 I = 1, MAX
               Q(I) = Q(I) - BMWT(I)
  450     CONTINUE
  457     CONTINUE
C
C-----CALCULATE CG OF EACH CROSS SECTION
C
```

```
          DO 460 I = 1, NSSC
               E(I,1) = SIGMUL(I) * SIGN(5,I) / ( EPSMUL(I) *
     1                                                 EPSN(5,I) )
      E(I,2) = SIGMUL(I) * SIGN(6,I) / (EPSMUL(I) *
     1                                               EPSN(6,I) )
  460     CONTINUE
          DO 462 I = 1, 10
               CSIG(I) = SIGMUL(1) * SIGN(I,1)
               CEPS(I) = EPSMUL(1) * EPSN(I,1)
          IF ( NSSC .EQ. 1 ) GO TO 461
               SSIG(I) = SIGMUL(2) * SIGN(I,2)
               SEPS(I) = EPSMUL(2) * EPSN(I,2)
               TSIG(I) = SIGMUL(NSSC) * SIGN(I,NSSC)
               TEPS(I) = EPSMUL(NSSC) * EPSN(I,NSSC)
          GO TO 462
  461          SSIG(I) = ZERO
               SEPS(I) = ZERO
               TSIG(I) = ZERO
               TEPS(I) = ZERO
  462     CONTINUE
          DO 490 I = 1, MAX
          DO 470 J = 1, 9
               DZON(J) = D(J,I)
  470     CONTINUE
          IF ( NSLEV .EQ. 0 ) GO TO 485
          DO 480 K = 1, NSLEV
  480          YS(K) = YSTL(K,I)
  485     CONTINUE
      CALL CENTER ( B1(I), B2(I), B3(I), DZON, AT(I), DT(I), AB(I),
     1            DB(I), CG(I), EI(I), YS, ARS, AE(I) )
          IF ( I .EQ. 1 .AND. ISIMP .EQ. 1 ) GO TO 491
  490     CONTINUE
          GO TO 494
  491     CONTINUE
          DO 492 K = 1, MAX
               CG(K) = CG(I)
               EI(K) = EI(I)
  492          AE(K) = AE(I)
  494     CONTINUE
          IF ( NSLEV .EQ. 0 ) GO TO 495
      CALL STAR
          GO TO 505
  495     DO 500 I = 1, MAX
               TMOM(I) = ZERO
  500     CONTINUE
  505     CONTINUE
C
C-----DISTRIBUTE FAILURE PARAMETERS
C
          IF ( NSETS .EQ. 0 ) GO TO 530
          IF ( NST7 .GT. 1 ) GO TO 520
          DO 510 I = 1, MAX
               SMAX(I) = SMAXN(1)
  510     CONTINUE
          GO TO 530
  520     CALL INTRP1 ( JS7N, SMAXN, SMAX, NST7 )
  530     CONTINUE
      RETURN
      END
```

```
      SUBROUTINE INTRP1 ( JS, ZN, Z, NC )
C
C-----LINEAR INTERPOLATION ROUTINE
C
      IMPLICIT REAL * 8 ( A-H, O-Z )
      DIMENSION JS(10), ZN(10), Z(45)
      DATA ZERO / 0.0D00 /
          DO 100 I = 1, 45
               Z(I) = ZERO
  100     CONTINUE
               Z(1) = ZN(1)
          DO 200 N = 2, NC
               NEL = JS(N) - JS(N-1)
               DENOM = NEL
               DELZ = ( ZN(N) - ZN(N-1) ) / DENOM
               ISTRT = JS(N-1) + 2
               ISTOP = JS(N) + 1
          DO 200 I = ISTRT, ISTOP
               Z(I) = Z(I-1) + DELZ
  200     CONTINUE
      RETURN
      END
```

```
      SUBROUTINE INTRP2  ( JI, JL, KONT, ZN, Z, X, NC )
C
C-----LINEAR INTERPOLATION ROUTINE
C
      IMPLICIT REAL * 8 ( A-H, O-Z )
      COMMON / CONSTT / GRAV, H, ITPROF, MAX, NB, NSLEV, NSSC
      DIMENSION JI(10), JL(10), KONT(10), ZN(10), Z(45), X(45)
      DATA ZERO, TWO, SIX / 0.0D00, 2.0D00, 6.0D00 /
          DO 100 I = 1, 45
               Z(I) = ZERO
  100     CONTINUE
               IS = 0
               I = 1
  110          K = KONT(I) + 1
          GO TO ( 120, 160, 140, 190 ), K
  120     IF ( IS .NE. 0 ) GO TO 230
           IF ( JL(I) .NE. JI(I) ) GO TO 200
  130          J = JI(I) + 1
               Z(J) = Z(J) + ZN(I)
          IF ( K .EQ. 1 ) GO TO 230
  140          IS = 0
  150          I = I + 1
          GO TO 110
  160     IF ( IS.EQ. 0 ) GO TO 170
               JSTRT = JL(I) + 1
          GO TO 180
  170          JSTRT = JI(I) + 1
               IS = 1
  180          JSTOP = JL(I+1) + 1
               ZL = ZN(I)
               ZR = ZN(I+1)
          GO TO 210
  190     IF ( JL(I) .EQ. JI(I) ) GO TO 130
  200          JSTRT = JI(I) + 1
               JSTOP = JL(I) + 1
               ZL = ZN(I)
               ZR = ZN(I)
  210          DZ = ( ZR - ZL ) / ( X(JSTOP) - X(JSTRT) )
               JSTOP = JSTOP - 1
          DO 220 J = JSTRT, JSTOP
               ZR = ZL + H * DZ
               Z(J) = Z(J) + H * ( TWO * ZL + ZR ) / SIX
               Z(J+1) = Z(J+1) + H * ( ZL + TWO * ZR ) / SIX
               ZL = ZR
  220     CONTINUE
          IF ( K .NE. 1 ) GO TO 150
  230     CONTINUE
      RETURN
      END
```

```
      SUBROUTINE INTRP3 ( JS, ZN, Z, NC )
C
C-----GEOMETRY OF PARABOLIC TENDON
C
      IMPLICIT REAL * 8 ( A-H, O-Z )
      DIMENSION JS(10), X(10), ZN(10), Z(45)
      DATA ZERO / 0.0D00 /
          DO 100 I = 1, 45
  100          Z(I) = ZERO
          DO 110 I= 1, NC
  110          X(I) = JS(I)
               Z(1) = ZN(1)
               NCC    = NC - 1
          DO 120 N = 2, NCC, 2
               Y12 = ZN(N-1) - ZN(N)
               Y23 = ZN(N)-ZN(N+1)
               X12 = X(N-1) - X(N)
               X23 = X(N) - X(N+1)
               X1 = X(N-1)
               X2 = X(N)
               X3 = X(N+1)
               X1S = X1 * X1
               X2S = X2 * X2
               X3S = X3 * X3
               XS12 = X1S - X2S
               XS23 = X2S - X3S
               BR = ( Y12 * XS23 - Y23 * XS12 ) / ( X12 * XS23 -
     1                                              X23 * XS12 )
               AR = ( Y12 - BR * X12 ) / XS12
               CR = ZN(N-1) - AR * X1S - BR * X1
               ISTRT = JS(N-1) + 2
               ISTOP = JS(N+1) + 1
          DO 120 I = ISTRT, ISTOP
               CON = I - 1
               CONS = CON * CON
               Z(I) = AR * CONS + BR * CON + CR
  120     CONTINUE
      RETURN
      END
```

```
      SUBROUTINE MASS ( DZON, B1, B2, B3, AB, AT, ARP, AGAM )
C-----CALCULATE SELF WEIGHT PER UNIT LENGTH AT GIVEN STATION
      IMPLICIT REAL * 8 ( A-H, O-Z )
      COMMON / CONSTT / GRAV, H, ITPRCF, MAX, NB, NSLEV, NSSC
      COMMON / SEGMT1 / GAMMA(3), E(3,2), IS(9)
      COMMON / SEGMT2 / DA(30), DI(30)
      DIMENSION ARP(10), DZON(9)
      DATA ZERO / 0.0D00 /
C-----DEFINE PROPERTIES OF THE SEGMENTS IN THE CROSS SECTION
      CALL SECT ( B1, B2, B3, DZON )
C-----CALCULATE SUM OF SEGMENTAL AREAS MULTIPLIED BY SPECIFIC WEIGHT
              AGAM = ZERO
          DO 100 J = 1, 30
              AGAM = AGAM + DA(J) * GAMMA(1)
  100     CONTINUE
          IF ( AT .EQ. ZERO ) GO TO 130
C-----ADD CONTRIBUTION OF TOP REINFORCEMENT, IF ANY
              AGAM = AGAM + AT * ( GAMMA(2) - GAMMA(1) )
  130     IF (AB .EQ. ZERO ) GO TO 160
C-----ADD CONTRIBUTION OF BOTTOM REINFORCEMENT, IF ANY
              AGAM = AGAM + AB * ( GAMMA(2) - GAMMA(1) )
  160         IF ( NSLEV .EQ. ZERO ) RETURN
C-----ADD CONTRIBUTION OF PRESTRESSING TENDON, IF ANY
              GAMAT  = GAMMA(NSSC) - GAMMA(1)
          DO 170 N = 1, NSLEV
              AGAM = AGAM + ARP(N) * GAMAT
  170     CONTINUE
      RETURN
      END
```

```
      SUBROUTINE CENTER ( B1, B2, B3, DZON, AT, DT, AB, DB, DBAR,
     1                   SEI, YST, ARS, SAE )
C
C-----CALCULATE CENTROID OF GENERAL CROSS SECTION
C
      IMPLICIT REAL * 8 ( A-H, O-Z )
      COMMON / CONSTT / GRAV, H, ITPRCF, MAX, NB, NSLEV, NSSC
      COMMON / SEGMT1 / GAMMA(3), E(3,2), IS(9)
      COMMON / SEGMT2 / DA(30), DI(30)
      COMMON / SEGMT3 / SEGD(30)
      DIMENSION YST(10), ARS(10), DZON(9)
      DATA ZERO, TWELV / 0.0D00, 12.0D00 /
C-----CALCULATE TRANSFORMED AREA OF CROSS SECTION AND FIRST AND SECOND
C     MOMENT ABOUT THE TOP
             SAE = ZERO
             SEI = ZERO
             SDAE = ZERO
      CALL SECT ( B1, B2, B3, DZON )
         DO 100 J = 1, 30
             DAE = DA(J) * E(1,1)
             SAE = SAE + DAE
             SDAE = SDAE + DAE * DI(J)
             SEI = SEI + DAE * DI(J) * DI(J) + DAE * SEGD(J) *
     1                                     SEGD(J) / TWELV
  100    CONTINUE
         IF ( AT .EQ. ZERO ) GO TO 130
C-----ADD CONTRIBUTION OF TOP REINFORCEMENT, IF ANY
             DAE = AT * ( E(2,1) - E(1,1) )
             SAE = SAE + DAE
             SDAE = SDAE + DAE * DT
             SEI = SEI + DAE * DT * DT
  130    IF ( AB .EQ. ZERO ) GO TO 160
C-----ADD CONTRIBUTION OF BOTTOM REINFORCEMENT, IF ANY
             DAE = AB * ( E(2,2) - E(1,1) )
             SAE = SAE + DAE
             SDAE = SDAE + DAE * DB
             SEI = SEI + DAE * DB * DB
  160    IF ( NSLEV .EQ. 0 ) GO TO 190
C-----ADD CONTRIBUTION OF PRESTRESSING STEEL
         DO 170 N = 1, NSLEV
             DAE = ARS(N) * ( E(NSSC,2) - E(1,1) )
             SAE = SAE + DAE
             SDAE = SDAE + DAE * YST(N)
             SEI = SEI + DAE * YST(N) * YST(N)
  170    CONTINUE
C
C-----CALCULATE DEPTH OF CENTROID
  190        DBAR = SDAE / SAE
C-----CALCULATE ELASTIC FLEXURAL STIFFNESS
             SEI = SEI - SAE * DBAR * DBAR
      RETURN
      END
```

```
      SUBROUTINE SECT ( B1, B2, B3, D )
C
C---->SET UP SEGMENT DEPTHS AND AREAS
C
      IMPLICIT REAL * 8 ( A-H, O-Z )
      COMMON / SEGMT1 / GAMMA(3), E(3,2), IS(9)
      COMMON / SEGMT2 / DA(30), DI(30)
      COMMON / SEGMT3 / SEGD(30)
      DIMENSION D(9)
      DATA ZERO, P5 / 0.0D00, 0.5D00 /
         DO 200 I = 1, 9
         GO TO ( 100, 150, 110, 120, 150, 150, 130, 140, 150 ), I
  100        DTOP = ZERO
             BTOP = B1
             BBOT = B1
             ISTRT = 1
             ITOP = 0
         GO TO 160
  110        BBOT = B2
         GO TO 150
  120        BTOP = B2
         GO TO 150
  130        BBOT = B3
         GO TO 150
  140        BTOP = B3
  150        ITOP = IS(I-1)
             DTOP = D(I-1)
             ISTRT = IS(I-1) + 1
  160        HN = IS(I) - ITOP
         IF ( D(I) .LE. DTOP ) GO TO 170
             HN = ( D(I) - DTOP ) / HN
             DELB = ( BTOP - BBOT ) / ( D(I) - DTOP )
         GO TO 180
  170        HN = ZERO
             DELB = ZERO
  180    CONTINUE
             ISTOP = IS(I)
         IF ( ISTRT .GT. ISTOP ) GO TO 200
         DO 190 N = ISTRT, ISTOP
             DA(N) = HN * ( BTOP - P5 * DELB * HN )
             DI(N) = DTOP + P5 * HN
             DTOP = DTOP + HN
             BTOP = BTOP - DELB * HN
             SEGD(N) = HN
  190    CONTINUE
  200    CONTINUE
      RETURN
      END
```

```
      SUBROUTINE STAF
C
C-----DETERMINE MCMENT DUE TO PRESTRESSING FORCE
C
      IMPLICIT REAL * 8 ( A-H, O-Z )
      COMMON / CONSTT / GRAV, H, ITPRCF, MAX, NB, NSLEV, NSSC
      COMMON / TABL23 / PSTRNN(10), YST(10,10), IPN(10,10), NPT2(10)
      COMMON / XSECT2 / AE(45), CG(45), D(9,45), EI(45)
      COMMCN / BMDATA / BM(45), BMASS(45), X(45)
      COMMON / TENDON / ARS(10), YSTL(10,45), TMOM(45), IOP(10)
      COMMON / CURVS1 / EPSMUL(3), EPSN(10,3), EPSU(3),
     1                  SIGMUL(3), SIGN(10,3)
      COMMON / CURVS2 / CEPS(10), CSIG(10), SEPS(10), SSIG(10),
     1                  TEPS(10), TSIG(10)
      DIMENSION FORCE(10)
      DATA ZERO / 0.0D00 /
          DO 130 N = 1, NSLEV
          IF ( PSTRNN(N) .GT. EPSU(NSSC) ) GO TO 120
          IF ( PSTRNN(N) ) 110, 120, 110
  110         FORCE(N) = STRESS ( PSTRNN(N), TSIG, TEPS ) * ARS(N)
          GO TO 130
  120         FORCE(N) = ZERO
  130     CONTINUE
          DO 180 I = 1, MAX
              TMOMT   = ZERC
              CGG     = CG(I)
          DO 170 N = 1, NSLEV
              YS      = YSTL(N,I)
              SMOM    = FORCE(N) * ( YS - CGG )
              TMOMT   = TMOMT + SMOM
  170     CONTINUE
              TMOM(I) = - TMCMT
  180     CONTINUE
      RETURN
      END
```

```
      SUBROUTINE BMPHI
C
C-----DRIVER FOR EMFEE GENERATOR
C
      IMPLICIT REAL * 8 ( A-H, C-Z )
      COMMON / CONSTT / GRAV, H, ITPRCF, MAX, NB, NSLEV, NSSC
      COMMON / TABL23 / PSTRNN(10), YST(10,10), IPN(10,10), NPT2(10)
      COMMCN / XSECT1 / AB(45), AT(45), B1(45), B2(45),
     1                  B3(45), DB(45), DT(45)
      COMMCN / XSECT2 / AE(45), CG(45), D(9,45), EI(45)
      COMMON / TENDCN / ARS(10), YSTL(10,45), TMOM(45), IOP(10)
      COMMON / SEGMT1 / GAMMA(3), E(3,2), IS(9)
      COMMCN / SEGMT2 / DA(30), CI(30)
      COMMON / EMFEEE / EM(45,10), EMP(45,10), FEE(45,10)
      COMMON / STRUCT / ISIMP
      COMMCN / EMFEET / EMT(45,10)
      DIMENSION TD(9), YS(10), PST(10), TEM(10), TEMP(10), TFEE(10)
      DATA ONE, TWO / 1.0D00, 2.0D00 /
      DATA ZERC / 0.0D00 /
          DO 140 I = 1, MAX
          DO 110 J = 1, 9
              TD(J) = D(J,I)
  110     CONTINUE
      CALL SECT ( B1(I), B2(I), B3(I), TD )
              DIV     = ONE
          IF ( NSSC .EQ. 1 ) DIV = TWC
          IF ( NSLEV .EQ. 0 ) GO TO 125
          DO 120 N = 1, NSLEV
              YS(N)  = YSTL(N,I)
              PST(N) = PSTRNN(N)
  120     CONTINUE
  125     CONTINUE
      CALL EMFEE ( CG(I), TD(9), DB(I), AB(I), DT(I), AT(I), IS(9), TEM,
     1             TEMP, TFEE, CIV, YS, PST, ARS, I )
              IF ( I .EQ. 1 .AND. ISIMP .EQ. 1 ) GO TO 145
          DO 130 J = 1, 10
              EM(I,J) = TEM(J)
              FEE(I,J) = TFEE(J)
              EMP(I,J) = TEMP(J)
  130     CONTINUE
  140     CONTINUE
          GC TC 160
  145     DO 150 K = 1, MAX
          DO 150 J = 1, 10
              EM(K,J) = TEM(J)
              FEE(K,J) = TFEE(J)
              EMP(K,J) = TEMP(J)
  150     CONTINUE
  160     CONTINUE
          DO 170 I = 1, MAX
          DO 170 J = 1, 10
          IF ( NSLEV .EQ. 0 ) EMP(I,J) = ZERO
              EMT(I,J) = EM(I,J) - EMP(I,J)
  170     CONTINUE
      CALL HEADNG
              K = NB / 2 + 1
      PRINT 2000, ( EM(K, JJ), EMT(K, JJ), EMP(K, JJ), FEE(K, JJ),
```

```
     1         JJ =1, 10 )
2000 FORMAT (// 35H           MOMENT - CURVATURE VALUES ,
     1         ///38H         MOMENT L            MOMENT T    ,
     2            37H         MOMENT P            CURVATURE   ,
     3         //      10(4(7X, 1PD12.5)//))
C-----REVISE FLEXURAL STIFFNESS TO REFLECT SLOPE OF LINEAR PART OF
C     EM - PHI DIAGRAM
         DO 90 L = 1, MAX
             EI(L) = EMT(L,6) / FEE(L,6)
   90    CONTINUE
      RETURN
      END
```

```
      SUBROUTINE EMFEE ( CG, TD, DB, AB, DT, AT, IS, EM, EMP, FEE,
     1                   DIV, YS, PST, ARS, L )
C
C-----CALCULATE MOMENT AND CURVATURE FOR A GIVEN CONCRETE STRAIN
C
      IMPLICIT REAL * 8 ( A-H, O-Z )
      COMMON / CONSTT / GRAV, H, ITPRCF, MAX, NB, NSLEV, NSSC
      COMMON / CURVS2 / CEPS(10), CSIG(10), SEPS(10), SSIG(10),
     1                  TEPS(10), TSIG(10)
      COMMON / SEGMT2 / DA(30), DI(30)
      DIMENSION YS(10), PST(10), EM(10), EMP(10), FEE(10)
      DIMENSION ARS(10)
      DATA ZERO, ONE, TWO / 0.0D00, 0.8D00, 2.0D00 /
      DATA HUNDRD / 1.00D02 /
      DATA P04 / 0.4D00 /
C-----POSITIVE HALF
              ITER   = 0
              ITM    = 1
              DSP    = ZERO
              ESP    = CEPS(1)
              PHI    = - ESP / TD * DIV
              IPLIM  = 6
              IP     = 10
              IPI    = - 1
              IBR    = 1
         GO TO 110
C-----NEGATIVE HALF
  100         IBR    = 1
              ITM    = 1
              DSP    = TD
              ESP    = CEPS(1)
              PHI    = ESP / TD * DIV
              IPLIM  = 5
              IP     = 1
              IPI    = 1
              ITER   = 0
  110 CALL THRUST ( ESP, DSP, PHI, DB, AB, DT, AT, IS, BM, TH, CG, YS,
     1                PST, BMPR, TEST, ARS )
              ITER   = ITER + 1
         IF ( ITER - 50 ) 115, 115, 200
  115    CONTINUE
         IF ( DABS ( TH ) .LT. TEST ) GO TO 170
         IF ( IBR .EQ. 2 ) GO TO 140
         IF ( DABS ( TH ) .LT. ZERO ) GO TO 120
         IF ( ITM .NE. 1 ) GO TO 130
              PHI1   = PHI
              PHI    = TWO * PHI
              ITM    = 2
              T1     = TH
         GO TO 110
  120    IF ( ITM .NE. 1 ) GO TO 130
              PHI1   = PHI
              PHI    = PHI / TWO
              ITM    = 2
              T1     = TH
         GO TO 110
  130         DPHI   = - TH * ( PHI1 - PHI ) / ( T1 - TH )
```

```
        PHI1    = PHI
        PHI     = PHI + DPHI
        T1      = TH
     GO TO 110
140  IF ( DABS ( TH ) .LT. ZERC ) GO TO 150
     IF ( ITM .NE. 1 ) GO TO 160
        ESP1    = ESP
        ESP     = ESP / TWC
        ITM     = 2
        T1      = TH
     GO TO 110
150  IF ( ITM .NE. 1 ) GO TO 160
        ESP1    = ESP
        ESP     = TWC * ESP
        ITM     = 2
        T1      = TH
     GO TO 110
160     DEPS    = - TH * ( ESP1 - ESP ) / ( T1 - TH )
        ESP1    = ESP
        ESP     = ESP + DEPS
        T1      = TH
     GO TC 110
170  IF ( IBR .EQ. 2 ) GC TC 180
        EM(IP) = BM
        EMP(IP) = BMPR
        FEE(IP) = PHI
        ITER    = 0
        IBR     = 2
        ITM     = 1
     IF ( NSLEV .EQ. 0 ) GO TO 175
        PHI     = P04 * PHI
     GO TO 177
175     PHI     = PHI / TWO
177  CONTINUE
        ESP     = CEPS(1)
        IP      = IP + IPI
     GC TC 110
180     EM(IP) = BM
        EMP(IP) = BMPR
        FEE(IP) = PHI
        ITER    = 0
     IF ( IP .EQ. IPLIM ) GO TO 190
        IP      = IP + IPI
     IF ( NSLEV .EQ. 0 ) GC TC 185
        PHI     = P04 * PHI
     GC TC 187
185     PHI     = PHI / TWO
187  CONTINUE
        ITM     = 1
     GO TC 110
190  IF ( IP .EQ. 5 ) RETURN
     GO TC 100
200 PRINT 1000, L, IP
1000 FORMAT ( //50H          EMFEE VALUES HAVE NOT STABILIZED
   1        /22H          FCR SECTION , I3,
   1         10H AND POINT ,I3 )
     GC TO 170
     END
```

```
      SUBROUTINE THRUST ( ESP, CSP, PHI, DB, AB, DT, AT, IS, BM, TH,
     1                    CG, YS, PST, BMPR, TEST, ARS )
C
C-----CALCULATE INTERNAL MOMENT
C
      IMPLICIT REAL * 8 ( A-H, O-Z )
      COMMON / CONSTT / GRAV, H, ITPRCF, MAX, NB, NSLEV, NSSC
      COMMON / CURVS2 / CEPS(10), CSIG(10), SEPS(10), SSIG(10),
     1                  TEPS(10), TSIG(10)
      COMMON / SEGMT2 / DA(30), DI(30)
      DIMENSION YS(10), PST(10)
      DIMENSION ARS(10)
      DATA ZERO / 0.0D00 /
      DATA P01 / 0.01D00 /
      DATA ONE / 1.0D00 /
         TH = ZERO
         BM = ZERO
      DO 100 I = 1, IS
         EPS = ESP - ( DSP - DI(I) ) * PHI
         DF = STRESS ( EPS, CSIG, CEPS ) * DA(I)
         TH = TH + DF
         BM = BM + DF * ( DI(I) - CG )
100   CONTINUE
         TEST   = DABS ( PC1 * TH )
      IF ( TEST .LT. ONE ) TEST = ONE
      IF ( AT .EQ. ZERO ) GO TO 120
         EPS = ESP - ( DSP - DT ) * PHI
         DF = STRESS ( EPS, SSIG, SEPS ) * AT
         TH = TH + DF
         BM = BM + DF * ( DT - CG )
120   CONTINUE
      IF ( AB .EQ. ZERO ) GO TO 125
         EPS = ESP - ( DSP - DB ) * PHI
         DF = STRESS ( EPS, SSIG, SEPS ) * AB
         TH = TH + DF
         BM = BM + DF * ( DB - CG )
125   CONTINUE
         BMPR   = ZERO
      IF ( NSLEV .EQ. 0 ) RETURN
      DO 140 I = 1, NSLEV
         EPS = ESP - ( DSP - YS(I) ) * PHI
         EPS = PST(I) + EPS
         DF     = STRESS ( EPS, TSIG, TEPS ) * ARS(I)
         TH     = TH + CF
         BMP    = DF * ( YS(I) - CG )
         BMPR = BMPR + BMP
         BM     = BM + BMP
140   CONTINUE
      RETURN
      END
```

```
      DOUBLE PRECISION FUNCTION STRESS ( EPS,TSIGN,TEPSN )
      IMPLICIT REAL * 8 ( A-H, O-Z )
      DIMENSION SIGN(12), EPSN(12), TSIGN(10), TEPSN(10)
      DATA ZERO / 0.0D00 /
          DO 90 I = 1, 5
               SIGN(I) = TSIGN(I)
               EPSN(I) = TEPSN(I)
               SIGN(I+7) = TSIGN(I+5)
               EPSN(I+7) = TEPSN(I+5)
   90     CONTINUE
               SIGN(6) = ZERO
               EPSN(6) = ZERO
               SIGN(7) = ZERO
               EPSN(7) = ZERO
          IF ( EPS .LE. EPSN(1) ) GO TO 130
          IF ( EPS .GE. EPSN(12) ) GO TO 120
          DO 100 I = 2, 12
          IF ( EPS .LE. EPSN(I) ) GO TO 110
  100     CONTINUE
      PRINT 1000
 1000 FORMAT (   30H      ERROR IN STRESS FUNCTION            )
      STOP
 1100          STRESS = SIGN(I-1) + ( SIGN(I) - SIGN(I-1) )
     1            / ( EPSN(I) - EPSN(I-1) ) * ( EPS - EPSN(I-1))
      RETURN
 1200          STRESS = SIGN(12) + ( SIGN(12) - SIGN(11) )
     1            / ( EPSN(12) - EPSN(11) ) *(EPS - EPSN(12) )
      RETURN
 1300          STRESS = SIGN(1) - ( SIGN(2) - SIGN(1) )
     1            / ( EPSN(2) - EPSN(1) ) * ( EPSN(1) - EPS )
      RETURN
      END
```

```
      SUBROUTINE PSTM ( EPS )
C
C-----REVISE PRESTRESS MOMENT TO REFLECT NEW CURVATURE TO USE IN
C     STATIC SOLUTION
C
      IMPLICIT REAL * 8 ( A-H, O-Z )
      COMMON / CONSTT / GRAV, H, ITPRCF, MAX, NB, NSLEV, NSSC
      COMMON / TENDON / ARS(10), YSTL(10,45), TMOM(45), IOP(10)
      COMMON / EMFEEE / EM(45,10), EMP(45,10), FEE(45,10)
      DIMENSION SIGN(10), EPSN(10), EPS(45), TEMPM(45)
          DO 150 K = 1, MAX
          DO 100 J = 1, 10
               SIGN(J) = EMP(K,J)
               EPSN(J) = FEE(K,J)
  100     CONTINUE
               EPSS   = EPS(K)
          IF ( EPSS .LE. EPSN(1) ) GO TO 140
          IF ( EPSS .GE. EPSN(10) ) GO TO 130
          DO 110 I = 2, 10
          IF ( EPSS .LE. EPSN(I) ) GO TO 120
  110     CONTINUE
      PRINT 1000
 1000 FORMAT (   30H      ERROR IN PSTM ROUTINE                    )
      STOP
  120          TEMPM(K) = SIGN(I-1) + ( SIGN(I) - SIGN(I-1) )
     1                   / ( EPSN(I) - EPSN(I-1) ) * ( EPSS - EPSN(I-1) )
          GO TO 150
  130          TEMPM(K) = SIGN(10) + ( SIGN(10) - SIGN(9) )
     1                   / ( EPSN(10) - EPSN(9) ) * ( EPSS - EPSN(10) )
          GO TO 150
  140          TEMPM(K) = SIGN(1) - ( SIGN(2) - SIGN(1) )
     1                   / ( EPSN(2) - EPSN(1) ) * ( EPSN(1) - EPSS )
  150          TMOM(K) = - TEMPM(K)
      RETURN
      END
```

```
      SUBROUTINE STIFF ( EPS )
C
C-----REVISE FLEXURAL STIFFNESS TO REFLECT NEW CURVATURE
C
      IMPLICIT REAL * 8 ( A-H, O-Z )
      COMMON / CONSTT / GRAV, H, ITPRCF, MAX, NB, NSLEV, NSSC
      COMMON / XSECT2 / AE(45), CG(45), D(9,45), EI(45)
      COMMON / EMFEEE / EM(45,10), EMP(45,10), FEE(45,10)
      COMMON / EMFEET / EMT(45,10)
      DIMENSION EPS(45), TSIGN(45), TEPSN(45)
      DATA SMAL1, SMAL2 / 1.00D-06, -1.00D-06 /
          DO 110 I = 1, MAX
          DO 100 J = 1, 10
               TSIGN(J) = EMT(I,J)
               TEPSN(J) = FEE(I, J )
  100     CONTINUE
          IF ( EPS(I) .LT. SMAL1 .AND. EPS(I) .GT. SMAL2 ) EPS(I)=SMAL1
               EPSS   = EPS(I)
               EI(I)  = STRESS ( EPSS, TSIGN, TEPSN ) / EPS(I)
               EI(I)  = DABS ( EI(I) )
  110     CONTINUE
      RETURN
      END
```

```
      SUBROUTINE STATIC
C
C-----CALCULATE FORCES AND DISPLACEMENTS DUE TO STATIC LOADS
C
      IMPLICIT REAL * 8 ( A-H, O-Z )
      COMMON / CONSTT / GRAV, H, ITPRCF, MAX, NB, NSLEV, NSSC
      COMMON / XSECT2 / AE(45), CG(45), D(9,45), EI(45)
      COMMON / TENDON / ARS(10), YSTL(10,45), TMOM(45), IOP(10)
      COMMON / BMDATA / BM(45), BMASS(45), X(45)
      COMMON / SUPPRT / VSN(10), JSDN(10), KEYS(50), NCT4
      COMMON / EMFEEE / EM(45,10), EMP(45,10), FEE(45,10)
      COMMON / LOADIS / PHI(50), Q(45), QI(45), V(45), VD(45)
      COMMON / PHIIFL / PHIINL, PHIFNL
      COMMON / EMFEET / EMT(45,10)
      COMMON / BMIFNL / BMINL, BMFNL
      DIMENSION F(50), Z(50), WTEMP(50), EPS(50), A(50), B(50),
     1          C(50), P(50), W(50)
      DIMENSION BMST(50)
      DATA ZERO, ONE, TWO, FOUR / 0.0D00, 1.0D00, 2.0D00, 4.0D00 /
      DATA P01 / 0.01D00 /
               HT2     = H + H
               HE2     = H * H
               HE3     = HE2 * H
               NB1     = NB + 1
               NB4     = NB + 4
               NB5     = NB + 5
               NB6     = NB + 6
               NB7     = NB + 7
               ITERST = 0
               NTSTBL = 0
          DO 100 J = 1, NB7
               F(J)    = ZERO
               P(J)    = ZERO
               Z(J)    = ZERO
               WTEMP(J) = ZERO
               PHI(J) = ZERO
  100     CONTINUE
          DO 110 K = 1, MAX
               I = K + 3
               F(I) = DABS( EI(K) )
               P(I)    = Q(K)
               Z(I)    = TMOM(K)
  110     CONTINUE
               Z(4)    = Z(4) / TWO
               Z(NB4) = Z(NB4) / TWO
               F(4)    = F(4) / TWO
               F(NB4) = F(NB4) / TWO
          GO TO 130
C-----REVISE PRESTRESS MOMENT DUE TO CHANGE IN CURVATURE
  120     CONTINUE
          DO 122 I = 1, MAX
               EPS(I) = PHI(I+3)
  122     CONTINUE
      CALL STIFF ( EPS )
          IF ( NSLEV .EQ. 0 ) GO TO 124
      CALL PSTM(EPS)
          GO TO 127
```

```
  124     DO 126 I = 1, NB7
                 TMOM(I) = ZERO
  126     CONTINUE
  127     CONTINUE
          DO 128 K = 1, MAX
                 I = K + 3
                 Z(I)    = TMOM(K)
                 F(I)    = EI(K)
  128     CONTINUE
                 Z(4) = Z(4) / TWO
                 Z(NB4) = Z(NB4) / TWO
                 F(4)    = F(4) / TWO
                 F(NB4) = F(NB4) / TWO
  130            NS = 1
                 A(1)    = ZERO
                 A(2)    = ZERO
                 B(1)    = ZERO
                 B(2)    = ZERO
                 C(1)    = ZERO
                 C(2)    = ZERO
          DO 210 J = 3, NB5
C-----COMPUTE MATRIX COEFFICIENTS AT EACH STATION
                 AA      = F(J-1)
                 BB      = - TWO * ( F(J-1) + F(J) )
                 CC      = F(J-1) + FOUR * F(J) + F(J+1)
                 DD = - TWO * ( F(J) + F(J+1) )
                 EE      = F(J+1)
                 FF      = HE3 * P(J) +HE2 * ( Z(J-1) - TWO * Z(J) +
     1                                                    Z(J+1) )
C-----COMPUTE CONTINUITY COEFFICIENTS AT EACH STATION
                 E       = AA * B(J-2) + BB
                 DENOM   = E * B(J-1) + AA * C(J-2) + CC
          IF ( DENOM ) 150, 145, 150
C-----NOTE- IF DENOM IS ZERO BEAM DOES NOT EXIST, D = 0; SET DEFL = ZERO
  145            DL      = ZERO
          GO TO 160
  150            DL      = - ONE / DENOM
  160            C(J)    = DL * EE
                 B(J)    = DL * ( E * C(J-1) + DD )
                 A(J)    = DL * ( E * A(J-1) + AA * A(J-2) - FF )
C-----CONTROL RESET ROUTINES FOR SPECIFIED CONDITIONS
                 KEYJ    = KEYS(J)
          GO TO ( 210, 170 ), KEYJ
C-----RESET FOR SPECIFIED DEFLECTION
  170            C(J)    = ZERO
                 B(J)    = ZERO
                 A(J)    = VSN(NS)
                 NS      = NS + 1
  210     CONTINUE
  220     CONTINUE
C-----COMPUTE DEFLECTIONS AND COMPARE WITH PREVIOUSLY COMPUTED DEFL.
                 W(NB7) = ZERO
                 W(NB6) = ZERO
                 IDEFL   = 0
          DO 250 L = 3, NB5
                 J       = NB + 8 - L
                 W(J)    = A(J) + B(J) * W(J+1) + C(J) * W(J+2)
                 DELW    = W(J) - WTEMP(J)
                 WTOL    = P01 * W(J)
          IF ( DABS(DELW) - DABS(WTOL) ) 240, 240, 230
  230            IDEFL   = 1
  240            WTEMP(J) = W(J)
  250     CONTINUE
C-----COMPUTE CURVATURES
                 W(2) = TWO * W(3) - W(4)
                 W(NB6) = TWO * W(NB5) - W(NB4)
                 DO 260 J = 3, NB5
                 PHI(J) = ( W(J-1) - TWO * W(J) + W(J+1) ) / HE2
  260     CONTINUE
                 ITERST = ITERST + 1
          IF ( IDEFL ) 290, 310, 270
  270            IF ( ITERST - 25 ) 120, 280, 290
  280            NTSTBL = 1
C-----END OF ITERATIVE BEAM SOLUTION
          IF ( NTSTBL ) 290, 310, 305
  290 PRINT 300
      STOP
  300 FORMAT ( / 45H     UNSPECIFIED ERROR IN DEFL. COMPUTATION          )
  305 PRINT 1000
  310     CONTINUE
 1000 FORMAT (// 50H     STATIC SOLUTION HAS NOT STABILIZED WITHIN ONE
     1        /,  50H     PERCENT  OF DEFLECTION IN 25 ITERATIONS        )
                 PHIINL = PHI(4)
                 PHIFNL = PHI(NB4)
                 BMINL = PHI(4) * F(4)
                 BMFNL = PHI(NB4) * F(NB4)
          DO 320 K = 4, NB4
                 I       = K -3
                 V(I)    = W(K)
                 BM(I)   = PHI(K) * F(K) - Z(K)
                 BMST(I) = PHI(K) * F(K)
                 PHI(I) = PHI(K)
  320     CONTINUE
      RETURN
      END
```

```
      SUBROUTINE OUTPUT ( IOPT, TIME, V )
C
C-----THIS SUBROUTINE CONTROLS OUTPUT FOR STATIC AND DYNAMIC SOLUTIONS
C
      IMPLICIT REAL * 8 ( A-H, O-Z )
      COMMON / CONSTT / GRAV, H, ITPROF, MAX, NB, NSLEV, NSSC
      COMMON / BMDATA / BM(45), BMASS(45), X(45)
      DIMENSION V(45)
      DATA ZERO, P5 / 0.0D00, 0.5D00 /
 1020 FORMAT (///30H     MAXIMUM RESPONSE, TIME = ,1PD12.4,
     1  //       42H          QUANTITY       BAR OR      X COORD
     2           15H          VALUE ,
     3   /       31H                         STATION ,
     5   /       20H          MOMENT    , 5X, I5, 2( 3X,   D12.4 ),
     6   /       20H          SHEAR     , 5X, I5, 2( 3X,   D12.4 ),
     8   /       20H          Y DISP    , 5X, I5, 2( 3X,   D12.4 ) )
 1030 FORMAT ( //31H     COMPLETE RESPONSE, TIME = ,1PD12.4,
     1  //       43H      STA  X COORD      MOMENT       SHEAR
     2           24H      Y DISP                                    / )
 1040 FORMAT ( 5X, I5, 1PD12.4, D12.4, 12X, D12.4 )
 1050 FORMAT ( 34X, D12.4 )
 1060 FORMAT ( 1H1, / )
      PRINT 1060
C-----IF IOPT = 1 ONLY MAXIMUM VALUES WILL BE PRINTED
C-----IF IOPT = 2 COMPLETE RESPONSE WILL BE PRINTED
              BM(1) = ZERO
              BM(MAX) = ZERO
          GO TO ( 100, 180 ), IOPT
C-----PRINT MAXIMUM VALUES ONLY
  100         BMMAX  = ZERO
              SMAX   = ZERO
              VMAX   = ZERO
          DO 150 J = 2, MAX
          IF ( DABS ( BM(J) ) .LT. DABS ( BMMAX ) ) GO TO 120
              BMMAX  = BM(J)
              JB = J - 1
              XB = X(J)
  120         SHEAR  = ( BM(J) - BM(J-1) ) / H
          IF ( DABS ( SHEAR ) .LT. DABS ( SMAX ) ) GO TO 130
              SMAX   = SHEAR
              JS = J - 1
              XS =  P5 * ( X(J) + X(J-1) )
  130     IF ( DABS ( V(J) ) .LT. DABS ( VMAX ) ) GO TO 150
              VMAX   = V(J)
              JV = J - 1
              XV = X(J)
  150     CONTINUE
          IF ( DABS ( V(1) ) .LT. DABS ( VMAX ) ) GO TO 170
              VMAX   = V(1)
              JV = 0
              XV = X(1)
  170 PRINT 1020, TIME, JB, XB, BMMAX, JS, XS, SHEAR, JV, XV, VMAX
          GO TO 200
C-----PRINT COMPLETE OUTPUT
  180         J = 0
      PRINT 1030, TIME
      PRINT 1040, J, X(1), BM(1), V(1)
          DO 190 J = 2, MAX
              SHEAR  = ( BM(J) - BM(J-1) ) / H
      PRINT 1050, SHEAR
              JJ = J - 1
      PRINT 1040, JJ, X(J), BM(J),V(J)
  190     CONTINUE
C
  200 RETURN
      END
```

```
      SUBROUTINE DYNAM
C
C-----SOLUTICN FOR DYNAMIC DISPLACEMENTS
C
      IMPLICIT REAL * 8 ( A-H, O-Z )
      COMMCN / CONSTT / GRAV, H, ITPROF, MAX, NB, NSLEV, NSSC
      COMMON / CONTRL / DTIME, TLIM, IDGPT, ISELFW, ISOPT, ISTAT,
     1                  ISTYPE, KEEP(7), NDL, NDLS, NOUT
      COMMCN / XSECT2 / AE(45), CG(45), D(9,45), EI(45)
      COMMON / BMDATA / BM(45), BMASS(45), X(45)
      COMMCN / SUPPRT / VSN(10), JSDN(10), KEYS(50), NCT4
      COMMCN / FAILUR / SMAX(45), SMAXN(10), VMAX, JS7N(10), NST7
      COMMON / EMFEEE / EM(45,10), EMP(45,10), FEE(45,10)
      COMMON / EMFEET / EMT(45,10)
      COMMON / TIMEFN / PEAK(20), TR, TD, IDTP, ILTP,
     1                  ITYPE(20), KEY1, NSETS
      COMMON / TENDON / ARS(10), YSTL(10,45), TMOM(45), IOP(10)
      COMMON / LOADIS / PHI(50), Q(45), QI(45), V(45), VD(45)
      DIMENSION DV(45), DDV(45), ADDV(45), PPHIJ(45), PHIJ(45), JI(20),
     1          DYQ(45), KONT(20), JM(20), PHIO(45), TPHIO(45), JL(20)
      DIMENSION PPPHIJ(45)
      DATA ZERO, P5, ONE, TWO / 0.0D00, 0.5D00, 1.0D00, 2.0D00 /
      DATA ALIM /1.0D-03 /, TPHIC(1) / 0.0D00 /
      DATA SIX, TEN, PI / 6.CD00, 1.0D01, 3.14159D0C /
      DATA BETA / 0.02D00 /, IPR / 2HPR / , IUN  / 2HUN  /
      DATA NO / 3H NO /
 1020 FORMAT (// 37H     SOLUTION FOR DYNAMIC LOADING NO. , I3,
     1         12H,    TYPE = , A3,     10H,  PEAK = , 1PD 10.3 / )
C-----CALCULATE TIME INTERVAL
C-----CALCULATE AVERAGE FLEXURAL STIFFNESS AND AVG MASS
              AEI = ZERO
              AMASS = ZERO
         DO 50 I = 1, MAX
              AEI = AEI + EI(I)
              AMASS = AMASS + BMASS(I)
   50    CONTINUE
              AMAX = MAX
              AMASS = AMASS / X(MAX)
              AEI = AEI / AMAX
         IF ( DTIME .GT. ZERO ) GO TC 102
              DTIME = PI *DSQRT ( AMASS / AEI ) * H * H / TWO / TEN
  102         CR = TWO * BETA / H * DSQRT( AEI * AMASS )
              CR = ZERO
         IF ( ISTAT .NE. NO ) GO TO 106
         DO 104 I = 1, MAX
              V(I) = ZERO
  104    CONTINUE
  106    CONTINUE
C-----CALCULATE IMPULSE AT EACH STATICN
  107    DO 260 N = 1, NSETS
      CALL HEADNG
      PRINT 1020, N, ITYPE(N), PEAK(N)
         IF ( IDTP .NE. IUN  ) GO TO 108
C-----UNIFORM LCAD DISTRIBUTICN
      CALL IMPLS1 ( PEAK(N), QI )
         GO TC 115
C-----SINUSOIDAL LOAD DISTRIBUTICN
  108 CALL IMPLS2 ( ITYPE(N), PEAK(N), QI )
  115    CONTINUE
C-----CALCULATE INITIAL DISPLACEMENTS, VELOCITIES AND ACCELERATIONS
         DO 120 I = 1, MAX
              VD(I) = V(I)
              DDV(I) = ZERO
              ADDV(I) = ZERO
              DV(I) = QI(I) / BMASS(I)
  120    CONTINUE
C-----REVISE DISPLACEMENTS AND VELOCITIES FOR UNYIELDING SUPPORTS
         DO 125 I = 1, NCT4
              IJ     = JSDN(I) + 1
              DV(IJ) = ZERO
  125    CONTINUE
C-----ENSURE SMOOTH TRANSITION FROM STATIC TO DYNAMIC SOLUTION
      CALL GEOM ( VD, PPHIJ )
         DO 130 I = 1, MAX
              PHIC(I) = ZERO
              TPHIO(I) = ZERO
  130    CONTINUE
      CALL FCRCE ( BM, PPHIJ, PHIO, PHIO, TPHIO )
      CALL ACCEL ( DDV, Q, DV, ZERO )
         DO 140 I = 1, MAX
              DYQ(I) = Q(I) - DDV(I) * BMASS(I)
              DDV(I) = ZERO
  140    CONTINUE
         IF ( ILTP .NE. IPR ) GO TO 145
         DO 141 I = 1, MAX
              DDV(I) = ZERO
              ADDV(I) = ZERO
              DV(I) = ZERO
  141    CONTINUE
         IF ( TR .GT. ZERO ) GO TO 145
         DO 142 I = 1, MAX
              DDV(I) = QI(I) / BMASS(I)
              ADDV(I) = DDV(I)
  142    CONTINUE
  145    CONTINUE
C-----REVISE DISPLACEMENTS AND VELOCITIES FOR UNYIELDING SUPPORTS
         DO 148 I = 1, NCT4
              IJ     = JSDN(I) + 1
              DV(IJ) = ZERO
              DDV(IJ) = ZERO
              ADDV(IJ) = DDV(IJ)
  148    CONTINUE
C-----START DYNAMIC SOLUTION
              KNOUT = 0
              TIME = ZERO
  150         TIME = TIME + DTIME
              NIT = 0
         IF ( ILTP .NE. IPR ) GC TC 155
C-----COMPUTE DYNAMIC LOADS DUE TO PRESSURE LOADING
      CALL DFORCE ( DYQ, QI, TIME, DTIME, TR, TD, MAX )
C-----ESTIMATE DISPL. AND VEL. AT TIME T
  155    DO 160 I = 1, MAX
     0        VD(I) = VD(I) + DTIME * DV(I) +  P5 * DTIME * DTIME *
     1                DDV(I)
              DV(I) = DV(I) + DTIME * DDV(I)
```

```
 160      CONTINUE
C-----CALCULATE STRAINS AND CURVATURES AT TIME T
 170  CALL GEOM ( VD, PHIJ )
               NIT = NIT + 1
C----> CALCULATE MOMENTS
      CALL FORCE ( BM, PHIJ, PPHIJ, PHIO, TPHIO )
          IF ( NSLEV .EQ. 0 ) GO TO 172
      CALL PSTM ( PHIJ )
          GO TO 176
 172      DO 174 L = 1, MAX
 174           TMOM(L) = ZERO
 176      CONTINUE
C-----CALCULATE ACCELERATIONS
      CALL ACCEL ( DDV, DYQ, DV, CR )
C-----TEST FOR CONVERGENCE
          DO 180 I = 1, MAX
               DELDD =DABS ( DDV(I) - ADDV(I) )
          IF ( DELDD .GT. ALIM ) GO TO 190
 180      CONTINUE
               KONVER = 1
          GO TO 200
 190           KONVER = 0
C-----REVISE DISPL. AND VEL.
 200      DO 210 I = 1, MAX
               DELDD = DDV(I) - ADDV(I)
               VD(I) = VD(I) + DTIME * DTIME * DELDD / SIX
               DV(I) = DV(I) +  P5 * DTIME * DELDD
               ADDV(I) = DDV(I)
 210      CONTINUE
          IF ( NIT .GT. 10 ) GO TO 270
          IF ( KONVER .EQ. 0 ) GO TO 170
C-----REVISE FOR NEXT TIME INTERVAL
          DO 230 J = 1, MAX
               PHIO(J) = TPHIO(J)
               PPHIJ(J) = PHIJ(J)
 230      CONTINUE
C-----TEST FOR END OF RUN
               KNOUT = KNOUT + 1
C-----TEST FOR COLLAPSE
      CALL FAIL ( VD, PHIJ, TIME, FEE, K )
          DO 235 L = 1, MAX
 235           BM(L) = BM(L) - TMOM(L)
          IF ( K .NE. 1 ) GO TO 240
      CALL OUTPUT ( IDOPT, TIME, VD )
          GO TO 260
 240      IF ( KNOUT .NE. NOUT ) GO TO 250
      CALL OUTPUT ( IDOPT, TIME, VD )
               KNOUT = 0
 250      IF ( TIME .LT. TLIM ) GO TO 150
C-----TIME LIMIT EXCEEDED
      PRINT 9010
      CALL OUTPUT ( IDOPT, TIME, VD )
 260      CONTINUE
      RETURN
 270           TIME = TIME - DTIME
               DTIME = P5 * DTIME
          GO TO 150
9010  FORMAT (///50H     BEAM DID NOT FAIL IN SPECIFIED TIME LIMIT     )
      END
```

```
      SUBROUTINE IMPLS1 ( PEAK, QI )
C
C-----UNIFORM LOAD DISTRIBUTION
C
      IMPLICIT REAL * 8 ( A-H, O-Z )
      COMMON / CONSTT / GRAV, H, ITPRCF, MAX, NB, NSLEV, NSSC
      DIMENSION QI(45)
      DATA ZERO, TWO / 0.0D00, 2.0D00 /
               CON1   = PEAK * H
               QI(1)   = CON1 / TWO
               QI(MAX) = CON1 / TWO
          DO 100 I = 2, NB
               QI(I)   = CON1
 100      CONTINUE
      RETURN
      END
```

```
      SUBROUTINE IMPLS2 ( ITYPE, PEAK, QI )
C
C---->EQUIV. CONC. IMPULSE
C
      IMPLICIT REAL * 8 ( A-H, O-Z )
      COMMON / CONSTT / GRAV, H, ITPROF, MAX, NB, NSLEV, NSSC
      COMMON / BMDATA / BM(45), BMASS(45), X(45)
      DIMENSION QI(45)
     0DATA ZERO, ONE, TWO, THREE, FOUR, FIVE, ATE, XNINE, TWEL
     1   / 0.0D00, 1.0D00, 2.0D00, 3.0D00, 4.0D00, 5.0D00, 8.0D00,
     2      9.0D00, 1.2D01 /, PI / 3.141592653D00/, ISYM / 3HSYM /
C---->TEST LOAD TYPE
           IF ( ITYPE .NE. ISYM ) GO TO 110
C---->SYMMETRIC SINUSOIDAL DISTRIBUTION
               XL = X(MAX)
               CON1 = XL / PI
               CON3 = PEAK * CON1
               CON2 = CON3 * CON1
               CON1 = PI / XL
               QI(1) = ZERO
               CR = ONE
               SR = ZERO
          DO 100 I = 2, MAX
               CL = CR
               SL = SR
               ANG = CON1 * X(I)
               SR = DSIN ( ANG )
               CR = DCOS ( ANG )
               CON4 = CON2 / H * ( SR - SL )
               QI(I-1) = QI(I-1) + CON3 * CL - CON4
               QI(I) = CON4 - CON3 * CR
  100     CONTINUE
      RETURN
C---->UNSYMMETRIC SINUSOIDAL DISTRIBUTION
  110          XL = X(MAX) * THREE / TWO
               DELTA = ZERO
               N = 1
  115          CON1 = XL / PI
               CON3 = PEAK * CON1
               CON2 = CON3 * CON1
               CON1 = PI / XL
          IF ( N .EQ. 2 ) GO TO 120
               QI(1) = ZERO
               CR = ONE
               SR = ZERO
               ISTRT = 2
               ISTOP = 3 * NB / 4 + 1
  120     DO 130 I = ISTRT, ISTOP
               CL = CR
               SL = SR
               ANG = CON1 * ( X(I) - DELTA )
               SR = DSIN ( ANG )
               CR = DCOS ( ANG )
               CON4 = CON2 / H * ( SR - SL )
               QI(I-1) = QI(I-1) + CON3 * CL - CON4
               QI(I) = CON4 - CON3 * CR
  130     CONTINUE
      IF ( N .EQ. 2 ) RETURN
           ISTRT = ISTOP + 1
           ISTOP = MAX
           XL = X(MAX) / TWO
           CR = ZERO
           SR = ONE
           DELTA = XL
           N = 2
      GO TO 115
      END
```

```
      SUBROUTINE DFORCE ( DYQ, QI, TIME, DTIME, TR, TD, NJ )
C---->SET UP DYNAMIC FORCES FOR APPLIED DYNAMIC PRESSURE
      IMPLICIT REAL * 8 ( A-H, O-Z )
      DIMENSION DYQ(45), QI(45)
          IF ( TIME .GT. TR ) GO TO 100
               PINC = DTIME / TR
          GO TO 130
  100     IF ( TIME - DTIME .GE. TR ) GO TO 110
               PINC = ( TD - TIME ) / ( TD - TR ) - ( TIME - DTIME )/TR
          GO TO 130
  110     IF ( TIME .GT. TD ) GO TO 120
               PINC = - DTIME / ( TD - TR )
          GO TO 130
  120     IF ( TIME - DTIME .GE. TD ) GO TO 150
               PINC = - ( TD - TIME + DTIME ) / ( TD - TR )
  130     DO 140 I = 1, NJ
               DYQ(I) = DYQ(I) + PINC * QI(I)
  140     CONTINUE
  150     CONTINUE
      RETURN
      END
```

```
      SUBROUTINE ACCEL (DDV, Q, DV, CR )
C
C-----CALCULATE Y ACCELERATION OF EACH STATION
C
      IMPLICIT REAL * 8 ( A-H, O-Z )
      COMMON / CONSTT / GRAV, H, ITPROF, MAX, NB, NSLEV, NSSC
      COMMON / TENDON / ARS(10), YSTL(10,45), TMOM(45), IOP(10)
      COMMON / SUPPRT / VSN(10), JSDN(10), KEYS(50), NCT4
      COMMON / BMDATA / BM(45), BMASS(45), X(45)
      DIMENSION DDV(45), Q(45), DV(45)
      DATA ZERO, TWO / 0.0000, 2.0000 /
               DVI     = ZERO
               DVR     = DV(1)
               VL      = ZERO
               TMOM(1) = TMOM(1) / TWO
               TMOM(MAX) = TMOM(MAX) / TWO
          DO 100 I = 1, NB
               DVL     = DVI
               DVI     = DVR
               DVR     = DV(I+1)
               VR      = ( BM(I+1) - BM(I) ) / H
          IF ( I .GT. 1 ) GO TO 90
               DDV(I) = ( - VR + VL + Q(I) + CR * ( DVR + DVL )
     1                    - DVI * TWO * CR + ( ( - TWO * TMOM(I)
     2                    + TMOM( I + 1 ) ) / H ) ) / BMASS(I)
          GO TO 95
   90          DDV(I) = ( - VR + VL + Q(I) + CR * ( DVR + DVL )
     1                    - DVI * TWO * CR +
     2                  ( ( TMOM(I-1) - TWO * TMOM(I) + TMOM(I+1) ) / H
     3                  ) ) / BMASS(I)
   95     CONTINUE
               VL      = VR
  100     CONTINUE
               DDV(NB+1) = ( VL + Q(NB+1) + CR * DVI - DVR * TWO * CR
     1                  + ( ( TMOM(NB) - TWO * TMOM(MAX) ) / H ) )
     2                  / BMASS(NB+1)
C-----REVISE ACCELERATIONS FOR UNYIELDING SUPPORTS
          DO 120 I = 1, NCT4
               J       = JSDN(I) + 1
               DDV(J) = ZERO
  120     CONTINUE
      RETURN
      END
```

```
      SUBROUTINE GEOM ( V, PHIJ )
C
C-----CALCULATE AVERAGE CURVATURES IN JOINTS
C
      IMPLICIT REAL * 8 ( A-H, O-Z )
      COMMON / CONSTT / GRAV, H, ITPRCF, MAX, NB, NSLEV, NSSC
      COMMON / PHIIFL / PHIINL, PHIFNL
      DIMENSION V(45), PHIJ(45)
      DATA ZERO, TWO / 0.0D00, 2.0D00 /
              PHIJ(1) = PHIINL
              PHIJ(MAX) = PHIFNL
          DO 100 I = 2, NB
              PHIJ(I) = ( V(I-1) - TWO * V(I) + V(I+1) ) / ( H * H )
  100     CONTINUE
      RETURN
      END
```

```
C
      SUBROUTINE FORCE ( BM, PHI, PPHI, PHIO, TPHIO )
C
C---->SOLVE FOR MOMENT AT EACH STATION
C
      IMPLICIT REAL * 8 ( A-H, O-Z )
      COMMON / CONSTT / GRAV, H, ITPRCF, MAX, NB, NSLEV, NSSC
      COMMON / EMFEEE / EM(45,10), EMP(45,10), FEE(45,10)
      COMMON / BMIFNL / BMINL, BMFNL
      COMMON / EMFEET / EMT(45,10)
      DIMENSION PHI(45), PPHI(45), PHIO(45), TPHIO(45), TEM(10),
     1          TFEE(10), BM(45)
      DATA ZERO /0.0D00/
              BM(1)   = BMINL
              BM(MAX) = BMFNL
          DO 110 I = 2, NB
          DO 100 J = 1, 10
              TEM(J) = EMT(I,J)
              TFEE(J) = FEE(I,J)
  100     CONTINUE
      CALL SEARCH ( TEM, TFEE, PPHI(I), PHIO(I), PHI(I), BM(I),
     1          TPHIO(I) , I )
  110     CONTINUE
              BM(MAX) = BMFNL
      RETURN
      END
```

```
      SUBROUTINE SEARCH ( ST, EP, PEPS, EPSO, EPS, SIG, TEPSO, L )
C---->SEARCH M - PHI CURVE FOR CURRENT LEVEL
      IMPLICIT REAL * 8 ( A-H, O-Z )
      DIMENSION ST(10), EP(10), TS(12), TE(12)
      DATA ZERO, ONE / 0.0D00, 1.0D00 /
C
C-----SET UP AUXILIARY POSITIVE CURVES
              KEY = 0
              TS(1) = ZERO
              TE(1) = ZERO
              TS(7) = ZERO
              TE(7) = ZERO
              J = 5
              K = 6
          DO 100 I = 2, 6
              TS(I) = - ST(J)
              TE(I) = - EP(J)
              TS(I+6) = ST(K)
              TE(I+6) = EP(K)
              J = J - 1
              K = K + 1
  100     CONTINUE
C-----DETERMINE PREVIOUS STRESS LEVEL
          IF ( PEPS .GE. EPSO ) GO TO 110
              ET = TS(2) / TE(2)
          GO TO 120
  110         ET = TS(8) / TE(8)
  120         PSIG = ( PEPS - EPSO ) * ET
C-----CHECK FOR POSITIVE OR NEGATIVE CURVE
          IF ( EPS - EPSO ) 320, 130, 140
  130         SIG = ZERO
              C = ONE
              I = 8
              IT = 12
              AEPS = EPS
          GO TO 250
  140     IF ( PSIG .LT. ZERO ) GO TO 330
          IF ( EPS .GT. PEPS ) GO TO 148
              I = 8
              IT = 12
              C = ONE
  144         SIG = ( EPS - EPSO ) * ET
              AEPS = EPS
          GO TO 250
  148         I = 8
              APEPS = PEPS
              IT = 12
              C = ONE
              AEPS = EPS
  150     IF ( PSIG - TS(I) ) 160, 170, 180
 1600         EPSS = APEPS - TE(I-1) - ( TE(I) - TE(I-1) )
    1              * ( PSIG - TS(I-1) ) / ( TS(I) - TS(I-1) )
          GO TO 190
  170         EPSS = APEPS - TE(I)
          GO TO 190
  180         I = I + 1
          GO TO 150
```

```
190         J = I
            TSIG = PSIG
            TEPS = APEPS
200      IF ( AEPS - ( TE(J) + EPSS ) ) 210, 220, 230
2100        SIG = TSIG + ( TS(J) - TSIG ) * ( AEPS - TEPS )
   1                / ( TE(J) + EPSS - TEPS )
         GO TO 250
220         SIG = TS(J)
         GO TO 250
230      IF ( J .GE. IT ) GO TO 240
            TSIG = TS(J)
            TEPS = TE(J) + EPSS
            J = J + 1
         GO TO 200
240         SIG = ZERO
C-----TEST OFF CURVE
250      IF ( KEY .EQ. 1 ) GO TO 305
         IF ( AEPS - TE(I) ) 26C, 27C, 280
2600        TSIG = TS(I-1) + ( TS(I) - TS(I-1) )
   1                * ( AEPS - TE(I-1) ) / ( TE(I) - TE(I-1) )
         GO TO 300
270         TSIG = TS(I)
         GO TO 300
280      IF ( I .GE. IT ) GO TO 290
            I = I + 1
         GO TO 250
290         TSIG = ZERO
300      IF ( TSIG .LT. SIG ) SIG = TSIG
305         SIG = C * SIG
         IF ( SIG ) 306,  306, 308
306         K = 2
         GO TO 310
308         K = 8
310         TEPSO = EPS - SIG * TE(K) / TS(K)
         GO TO 9999
320      IF ( PSIG .GT. ZERO ) GO TO 340
         IF ( EPS .GT. PEPS ) GO TO 325
            I = 2
            IT = 6
            AEPS = - EPS
            APEPS = - PEPS
            PSIG = - PSIG
            C = -ONE
         GO TO 150
325         C = -ONE
            SIG = DABS ( EPS - EPSO ) * ET
            AEPS = - EPS
            I = 2
            IT = 6
         GO TO 250
C-----REVERSAL NEGATIVE TO POSITIVE
330         EPSS = EPSO
            PSIG = ZERO
            I = 8
            J = I
            IT = 12
            APEPS = ZERO
            AEPS = EPS
            TSIG = ZERO
            TEPS = EPSO
            C = ONE
            ET = TS(8) / TE(8)
         IF ( EPSO .LT.  ZERO  ) KEY = 1
         GO TO 200
C-----REVERSAL POSITIVE TO NEGATIVE
340         I = 2
            J = I
            IT = 6
            EPSS = - EPSO
            PSIG = ZERO
            APEPS = ZERO
            AEPS = - EPS
            TSIG = ZERO
            TEPS = - EPSO
            C = - ONE
            ET = TS(2) / TE(2)
         IF ( EPSO .GT.  ZERO  ) KEY = 1
         GO TO 200
9999     CONTINUE
      RETURN
      END
```

```
      SUBROUTINE FAIL ( VD, PHI, TIME, FEE, K )
C
C-----CHECK FOR FAILURE DUE TC EXCESSIVE DEFLECTION, SHEAR,
C     AND BENDING
C
      IMPLICIT REAL * 8 ( A-H, C-Z )
      COMMON / CONSTT / GRAV, H, ITPROF, MAX, NB, NSLEV, NSSC
      COMMON / BMDATA / BM(45), BMASS(45), X(45)
      COMMON / FAILUR / SMAX(45), SMAXN(10), VMAX, JS7N(10), NST7
      COMMON / TIMEFN / PEAK(20), TR, TD, IDTP, ILTP,
     1                  ITYPE(20), KEY1, NSETS
      DIMENSION VD(45), PHI(45), FEE(45,10)
      DATA ZERO, P5 / 0.0D00, 0.5000 /
10000FORMAT ( //46H     FAILURE DUE TC LATERAL DEFLECTION AT X = ,
     1       1PD12.4 )
 1020 FORMAT( //34H      FAILURE DUE TO SHEAR AT X = ,1PD12.4 )
 1030 FORMAT( //35H      FAILURE DUE TO BENDING AT X = ,1PD12.4 )
 1070 FORMAT( //23H      FAILURE AT TIME = ,1PD12.4 )
 1080 FORMAT ( 1H1 )
C-----CHECK FOR FAILURE AT EACH STATICN AND IN EACH BAR
              KEY1   = 0
              KK = 0
              K = 0
C-----CHECK FOR FAILURE DUE TO EXCESSIVE DEFLECTION
          DO 120 J = 1, MAX
          IF ( DABS ( VD(J) ) .LT. VMAX ) GO TO 120
          IF ( KEY1 .EQ. 1 ) GO TO 110
              KEY1   = 1
          IF ( KK .EQ. 0 ) PRINT 1080
  110         KK = 1
              K = 1
      PRINT 1000, X(J)
  120     CONTINUE
C-----CHECK FOR FAILURE DUE TO SHEAR
          DO 130 J = 2, MAX
              SHEAR  = ( BM(J) - BM(J-1) ) / H
          IF ( DABS ( SHEAR ) .LT. SMAX(J) ) GO TO 130
              K = 1
              XB = P5 * ( X(J) + X(J-1 ) )
          IF ( KEY1 .EQ. 1 ) GO TO 125
              KEY1   = 1
          IF ( KK .EQ. 0 ) PRINT 1080
  125         KK = 1
      PRINT 1020, XB
  130     CONTINUE
C-----CHECK FOR FAILURE DUE TO BENDING
          DO 150 J = 2, NB
          IF ( PHI(J) .GT. FEE(J,1) .AND. PHI(J) .LT. FEE(J,10) )
     1                                                GO TO 150
              K = 1
          IF ( KEY1 .EQ. 1 ) GO TO 145
              KEY1   = 1
          IF ( KK .EC. 0 ) PRINT 1080
  145         KK = 1
      PRINT 1030, X(J)
  150     CONTINUE
          IF ( K .EQ. 1 ) PRINT 1070, TIME
      RETURN
      END
```

```
C
      SUBROUTINE HEADNG
C
C-----THIS SUBROUTINE ESTABLISHES HEADING ON PAGE OF OUTPUT
      IMPLICIT REAL * 8 ( A-H, O-Z )
      COMMCN / IDNTFN / ID1(40), ID2(19), NPROB
  110 FORMAT ( 1H1, //,
     1           20H      PROGRAM CYNPCB
     2        / 43H      ANALYSIS AND PREDICTION OF COLLAPSE OF
     3           21H PRESTRESSED CONCRETE
     4        / 45H      BEAMS UNDER STATIC AND DYNAMIC LOADING
     6        ///, 2( 5X, 20A4, / ) )
  120 FORMAT (    13H      PROBLEM , A4, //, 10X, 19A4 )
      PRINT 110, ( ID1(I), I = 1, 40 )
      PRINT 120, NPROB, ( ID2(I), I = 1, 19 )
      RETURN
      END
```

APPENDIX B

PROGRAM DYNPCB: GUIDE FOR DATA INPUT

IDENTIFICATION OF RUN

Two alphanumeric cards.

20A4
1 – 80

20A4
1 – 80

IDENTIFICATION OF PROBLEM

One alphanumeric card for each problem.

Program terminates execution if NPROB (Problem Name) is blank.

NPROB	Description of Problem
A4	19A4
1 – 4	11 – 80

TABLE 1. PROBLEM CONTROL DATA

Three cards for each problem.

First card.

2	3	4	5	6	7
A4	A4	A4	A4	A4	A4
6 – 9	11 – 14	16 – 19	21 – 24	26 – 29	31 – 34

where:

2 to 7 - Enter "KEEP" to retain data from previous problem for for TABLES 2 to 7.

Second card.

ISTAT	ISOPT	NDL	IDOPT	NOUT	TLIM	DTIME
A3	I5	I5	I5	I5	E10.3	E10.3
6 – 8	11 – 15	20	25	30	40	50

where:

ISTAT - Option for static solution
Enter "YES" or "ƀNO"

ISOPT - Option for output of static results
=1, Only maximum values are printed
=2, Complete response

NDL - Number of dynamic loadings for the problem or number of additional dynamic loadings, if TABLE 6 is retained from previous problem.

IDOPT - Option for output of dynamic results
=1, Only maximum values are printed
=2, Complete response

NOUT - Output interval for dynamic solution
Enter 1 if output is desired at the end of every time interval. Output is printed at the end of the 5th, 10th, etc. time interval if 5 is entered.

TLIM - Time limit for dynamic solution
Unit of time is always the second

DTIME - Initial interval of time for dynamic solution
If left blank, an approximate tentative value is internally calculated

Third card.

NB	ISELFW	GRAV	ISTYPE	ISIMP
I5	I5	E10.3	I5	I5
6–10	15	25	30	35

where:

NB - Number of bars in the model structure
Maximum: 44

ISELFW - Option to consider self-weight
=0, self-weight is not considered
=1, self-weight is calculated internally and added to static loads

GRAV - Acceleration of gravity, necessary for calculation of concentrated point masses. Compatible units must be used

ISTYPE - Type of structure
=2, Reinforced concrete beam or steel beam
=3, Prestressed concrete beam with nonprestressed reinforcement

=4, Prestressed concrete beam without nonprestressed reinforcement

ISIMP - Variation of properties across the structure
=1, Properties of the section are same throughout
=2, Properties vary across the structure

TABLE 2. CROSS SECTION DESCRIPTION

No card, if TABLE 2 is retained from previous problem

A) Control Card

Minimum of one card. Maximum of ten cards

JSN	XN	B1N	B2N	B3N	IENDN
I5	E10.3	E10.3	E10.3	E10.3	A3
6 10	20	31 40	50	60	66 68

where:

JSN - Station number (call initial station "0")
Enter last station number if cross section is constant

XN - X-coordinate at station JSN

B1N - Width of top flange at station JSN. See Figure 2

B2N - Thickness of web at station JSN

B3N - Width of bottom flange at station JSN

IENDN - Enter "END" if JSN is the number of last station

B) Zone Data Card

Three cards for each control card. See Figure 2

ISN(1)	DN(1)	ISN(2)	DN(2)	...	...
I5	E10.3	I5	E10.3	I5	E10.3
11 15	25	31 35	45	51 55	65

where:

ISN(K) - Number of the segment at the bottom of zone k. Segments are numbered 1 to 30, from top to bottom of the section, as shown in Figure 2. ISN(9), the last segment at the end of zone 9, must be entered as "30"

DN(K) - Depth of bottom of zone k, from top of section. DN(9) must be equal to total depth of section at station JSN

Remarks - Depths may change from station to station, but segment numbers may not.
Zone (3) and zone (7) can be used to represent tapering portions of I section

C) Nonprestressed Reinforcement Description

No card if reinforcement is not present. Maximum of ten cards for all problems

JRN		DTN	ATN	DBN	ABN
I5		E10.3	E10.3	E10.3	E10.3
6 10		16 25	35	45	55

where:

JRN - Number of station where a change in reinforcement occurs. For uniform distribution of reinforcement throughout the structure, set JRN equal to the last station and enter only one card

DTN - Depth of centroid of top reinforcement from top

ATN - cross section area of top reinforcement

DBN - Depth of centroid of bottom reinforcement from top

ABN - cross section area of bottom reinforcement

D) Prestressed Steel Description

1) Steel Control Card

Only one card required

NSLEV
I5
6 10

where:

NSLEV - Number of steel layers; maximum of ten layers
If prestressed steel is not present leave card blank

2) Steel Data

One card for each steel layer. No card if NSLEV = 0

NSLV	IOP	ARS	PSTRNN	NPT2
I5	I5	E10.3	E10.3	I5
6 10	15	21 30	40	46 50

where:

NSLV - Number of the steel layer

IOP - Geometry of steel layer NSLV
=1, Layer at same depth from top of section throughout
=2, Layer depth variation linear
=3, Layer depth variation parabolic

ARS - Area of steel layer NSLV

PSTRNN - Effective steel strain of NSLV after all losses except change in strain due to bending of member

NPT2 - Number of points to define the geometry of layer NSLV. NPT2 equals the number of points at which the depths of layer NSLV given in the next set of data

3) Geometry of Prestressed Steel

Maximum of three cards for each steel layer

IPN(1)	YST(1)	IPN(2)	YST(2)	...	...
I5	E10.3	I5	E10.3	I5	E10.3
6 10	20	26 30	40	46 50	60

where:

IPN(K) - station number at which the depth of steel layer NSLV is defined. Enter last station if depth of layer remains constant

YST(K) - Depth of centroid of layer NSLV from top at station IPN(K)

Remarks - All cards in TABLE 2 must be in ascending order of station numbers

Values for omitted stations are interpolated between input stations

Omitted segments are assumed to be equally spaced within the zone

For steel layer at same depth throughout the beam, data needed only for the last station

Provide data at the ends and at the center for a parabolic or V-shaped segment of the layer

TABLE 3. STRESS-STRAIN CURVES

Minimum of five cards; maximum of 13 cards
No card, if TABLE 3 is retained from previous problem
Specification according to Figure 3

A) Control Card

Only one card required

NSSC
I5
6 – 10

where:

NSSC - Number of stress-strain curves to be input. Maximum of three curves are allowed. Last curve input is used for prestressed steel

B) Specific Weight and Stress Values

Two cards for each curve

SIGMUL	GAMMA
E10.3	E10.3
11 – 20	– 30

SIGN(1) SIGN(2) ... ... SIGN(J), J=1, 10 (10F8.0)

1 – 8	– 16	– 24	– 32	– 40	– 48	– 56	– 64	– 72	– 80

where:

SIGMUL - Stress multiplier; may not be zero or blank

GAMMA - Specific weight of the material, necessary for calculation of self-weight of the structure and concentrated point masses

SIGN(J) - factor to be internally multiplied by the stress multiplier, in order to obtain the stress at the jth point of the stress-strain curve. Input must proceed from most negative to most positive value. Ten values must be supplied.

C) Strain Values

Two cards for each curve.

	EPSMUL	EPSU
Format	E10.3	E10.3
Columns	11–20	30

EPSN(1)	EPSN(2)			EPSN(J), J=1, 10					(10F8.0)
1–8	16	24	32	40	48	56	64	72	80

where:

EPSMUL Strain multiplier; may not be zero or blank

EPSU - Ultimate strain for the material
Compressive strain for concrete and tensile strain for steel
=EPSN(1) or EPSN(10) multiplied by EPSMUL

EPSN(J) - Factor to be internally multiplied by the strain multiplier, in order to obtain the strain at the jth point of the stress-strain curve. Input must proceed from most negative to most positive value.
Ten values must be supplied

Remarks - At least one stress-strain curve must be given

Input zero (or very small) values for SIGN(9) and SIGN(10) if tension in concrete is allowed

TABLE 4. SPECIFIED DEFLECTIONS

Minimum of two cards for each problem.
No card if TABLE 4 is retained from previous problem

	JSDN	VSN	IENDN
Format	I5	E10.3	A3
Columns	6–10	20	26–28

where:

JSDN - Station number where a displacement is to be specified

VSN - Value of specified vertical displacement

IENDN - Enter "END" if last card in TABLE 4

TABLE 5. STATIC LOADS

Minimum of one card for each problem; maximum of ten cards per run. Data in TABLE 5 are cumulative. If TABLE 5 is retained, present specification is added to previous table; if no additional load is added to previous table, or no static solution is to be performed, enter one blank card

JI5	JL5	KONT5	QN
I5	I5	I1	E10.3
6 10	15	20	31 40

where:

JI5 - Station number at which load begins

JL5 - Station number at which load ends

KONT5 - Code for load distribution
=0, Last card in TABLE 5
=1, Data varies linearly between values at JI5 on this card and values at JL5 on next card
=2, End of distribution sequence
=3, Data uniformly distributed between JI5 and JL5

QN - Value of lateral load

Remarks - If JI5 = JL5 and KONT5 = 0 or 3, values are assumed to be concentrated; otherwise all values are assumed to be given per unit length of beam
Overlapping distributions and concentrated values are cumulative
Values for omitted stations are linearly interpolated between input stations
Values are lumped at each station according to station X-coordinates

Downward loads are considered negative

TABLE 6. DYNAMIC LOADS

Minimum of one card; maximum of twenty load sets per run. TABLE 6 may be retained from the previous problem and additional data sets may be added to the existing table.
No card is necessary if number of additional loadings (NDL in TABLE 1) is zero.
Data in TABLE 6 is arranged in sets. A set may contain any number of cards, provided that the limit of the run is observed

A) Control Card

Only one card per run is necessary

IDTP	ILTP	TR	TD
A2	A2	E10.3	E10.3
6 7	11 12	16 25	31 40

where:

IDTP - Load distribution
= SI, Load distributed sinusoidally
= UN, Load distributed uniformly

ILTP - Dynamic load type
= IM, Impulse
= PR, Forcing pulse

TR - Time of rise
Not required for load type IM

TD - Time of pulse duration
Not required for load type IM

B) Load Sets

One card for each dynamic load specified in TABLE 1 (NDL)

ITYPE	PEAK
A3	E10.3
6 8	21 30

where:

ITYPE - Symmetry of load distribution
= SYM, Symmetric load distribution
=USM, Unsymmetric load distribution
Not required for load distribution UN

PEAK - Peak Value

Remarks - Dynamic loads are assumed to be distributed over the full length of the beam. Values are lumped at each station according to station X-coordinates

Only one distribution type, sinusoidal or uniform, and one load type, impulse or forcing pulse, are permitted for any problem. Load systems added to previous TABLE 6 must have same distribution and type as existing TABLE 6 loads

Symmetric sinusoidal distributions have peak value at beam centerline. Unsymmetric sinusoidal distributions have peak value at right hand quarter point

Uniform impulse loadings are not permitted.

Dynamic loading effects are superimposed on the static loading specified in TABLE 5

Data are cumulative for each data set

Downward loads are considered negative

TABLE 7. COLLAPSE PARAMETERS

Required only for dynamic solution
No card if dynamic solution is not required or TABLE 7 is retained from previous problem

A) Maximum Displacements

One card is required

VMAX
E10.3
11 – 20

where:

VMAX - Maximum allowable vertical displacement

B) Maximum Shear

Minimum of one card; maximum of ten cards

JS7N	SMAX
I5	E10.3
6 – 10	16 – 25

where:

JS7N - Number of station where a change in allowable shear occurs. For uniform maximum allowable shear throughout the structure, set JS7N equal to the last station and enter only one card

SMAX - Ultimate shear at station JS7N

Remarks - Ultimate shear is linearly interpolated between input stations

All cards must be in ascending order of station numbers

Last card must contain the last station number of the structure

APPENDIX C

PROGRAM DYNPCB: CODING LISTINGS AND

SELECTED PRINTOUT SHEETS

```
00000000011111111112222222222333333333344444444445555555555666666666677777777778
12345678901234567890123456789012345678901234567890123456789012345678901234567890

DYNPCB EXAMPLE PROBLEM
WIDE FLANGE BEAM
P1        STATIC LOADS ONLY

     YES      2
        20     0  386.4       2    1
        20+4.800E+02          11.502    0.504     11.502         END
              2+0.318E+00         5+0.795E+00         6+0.795E+00
             11+4.795E+00        19+11.365           24+15.365
             25+15.365           28+15.842           30+16.16
        20

         1
          +1.000E+04  0.28618
-4.74   -4.73   -4.72   -4.71   -4.70   4.70    4.71    4.72    4.73    4.74
          +1.000E-03+15.70E-03
-15.7   -12.2   -8.64   -5.1    -1.57    1.57    5.1     8.64    12.2    15.7
         0
        20                END
         0   20    0               -83.333
P1        SINUSOIDAL IMPULSE
     KEEP KEEP KEEP
      NO          1    2   40+3.000E-026.6345E-05
        20     0  386.4       2    1

     SI   IM
     SYM              -2.000E+00
          +10.00E+00
        20    +1.000E+10
          TERMINATE
```

```
00000000011111111112222222222333333333344444444445555555555666666666677777777778
12345678901234567890123456789012345678901234567890123456789012345678901234567890

DYNPCB EXAMPLE PROBLEM
REINFORCED CONCRETE BEAM
P2        STATIC AND IMPULSE LOADING

     YES      2    1    2    5+1.000E-024.7874E-05
        20     0+3.864E+02    2    1
        20+1.800E+02                +8.000E+00+8.000E+00+8.000E+00     END
              2+0.300E+00         6+2.200E+00         7+2.200E+00
             11+4.100E+00        19+7.900E+00        23+9.800E+00
             24+9.800E+00        28+11.70E+00        30+12.00E+00
        20                            +1.000E+01+1.000E+00

         2
          +1.000E+030.08484
 0.0    -2.0    -4.0    -4.01   -4.0     0.001   0.002   0.003    0.004  0.005
          +1.000E-03-10.00E-03
-10.0   -6.25   -2.5    -2.0    -1.5     6.0     12.0    18.0     24.0   30.0
          +1.000E+040.28612
-4.74   -4.73   -4.72   -4.71   -4.7     4.7     4.71    4.72     4.73   4.74
          +1.000E-03+15.70E-03
-15.7   -12.2   -8.64   -5.1    -1.57    1.57    5.1     8.64     12.2   15.7
         0 0.0
        20 0.0            END
         0   20    0               -4.167E+01
     SI   IM
     SYM              -25.0
           3.0
        20    +3.000E+04
P2        FORCE PULSE LOADING
     KEEP KEEP KEEP KEEP      KEEP
     YES      2    1    2    5+1.000E-024.7874E-05
        20     0+3.864E+02    2    1

     UN   PR    +6.000E-02     +12.00E-02
                      -5.000E+02
          TERMINATE
```

```
00000000011111111112222222222333333333344444444445555555555666666666677777777778
12345678901234567890123456789012345678901234567890123456789012345678901234567890

DYNPCB EXAMPLE PROBLEM
PRESTRESSED CONCRETE BEAM
P3          STATIC AND IMPULSE LOADING

     YES       2     1     2      5+6.000E-04
        24     0 396.4           4    2
        24   288.0                20.0       20.0       20.0             END
                2 1.0              6 4.0                 7 4.0
               11 10.0            19 20.0               23 26.0
               24 26.0            28  29.0              30  30.0
         1
         1     3      2.4      +5.600E-03           3
         0 15.0            12 21.0              24 15.0
         2
           +1.000E+03+8.484E-02
 0.0     -4.0     -4.7    -5.0     -4.2      0.111   0.222    0.555    0.005     0.005
           +1.000E-03-5.000E-03
 -5.0    -3.5     -3.0     -2.25    -1.25    0.033   0.066    0.099    15.0      40.0
           +1.000E+04+2.861E-01
-25.87   -25.50  -23.62   -21.75   -18.75    18.75   21.75    23.62    25.50     25.87
           +1.000E-03+64.00E-03
-64.0    -45.0   -20.0    -10.0    -7.0      7.0     10.0     20.0     45.0      64.0
         0  0.0
        24  0.0              END
         0   24     0              -300.0
     SI   IM
     SYM               -10.0
           6.0
        24      +2.000E+05
          TERMINATE
```

```
00000000011111111112222222222333333333344444444445555555555666666666677777777778
12345678901234567890123456789012345678901234567890123456789012345678901234567890

DYNPCB EXAMPLE PROBLEM
PRESTRESSED CONCRETE I BEAM
P4          STATIC AND IMPULSE LOADING

     YES       2     1     2     10+1.000E-02
        30     1 386.4          3    1
        30 360.0                13.0       6.0       17.0            END
              2 2.0               4 4.0                5 5.0
              8 8.0              12 13.0              16 18.0
             19 21.0             25 27.0              30 32.0
        30     2.0        0.62
         7
         1     1      0.085      +4.800E-03          1
         2     1      0.085      +4.800E-03          1
         3     1      0.085      +4.800E-03          1
         4     1       0.170     +4.800E-03          1
         5     1       0.170     +4.800E-03          1
         6     1       0.170     +4.800E-03          1
         7     1        0.425    +4.800E-03          1
        30 4.0
        30 20.0
        30 22.0
        30 24.0
        30 26.0
        30 28.0
        30 30.0
         3
           +1.000E+03+8.484E-02
0.0      -4.0     -4.7     -5.0     -4.2     0.111   0.222    0.555    0.005     0.005
           +1.000E-03-5.000E-03
 -5.0    -3.5     -3.0     -2.25    -1.22    0.033   0.066    0.099     15.0      30.0
           +1.000E+04+2.861E-01
-4.74    -4.73    -4.72    -4.71    -4.7     4.7     4.71     4.72     4.73      4.74
           +1.000E-03+15.70E-03
-15.7    -12.2    -8.64    -5.1     -1.57    1.57    5.1      8.64     12.2      15.7
           +1.000E+04+2.887E-01
 -25.87  -25.5   -23.62   -21.75   -18.75    18.75   21.75    23.62    25.5      25.87
           +1.000E-03+64.00E-03
-64.0    -45.0   -20.0    -10.0    -7.0      7.0     10.0     20.0     45.0      64.0
         0 0.0
        30 0.0               END
         0   30     0              -83.3333
     SI   IM
     SYM               -40.0
           8.0
        30      +10.00E+04
          TERMINATE
```

PROGRAM DYNPCB
ANALYSIS AND PREDICTION OF COLLAPSE OF PRESTRESSED CONCRETE BEAMS UNDER STATIC AND DYNAMIC LOADING

DYNPCB EXAMPLE PROBLEM
WIDE FLANGE BEAM

PROBLEM P1

STATIC LOADS ONLY

TABLE 1. PROGRAM CONTROL DATA

NC KEEP OPTIONS EXERCISED

STATIC SOLUTION REQUIRED	YES
STATIC OUTPUT OPTION	2
SELF WEIGHT OPTION	0
STRUCTURE TYPE	2
STRUCTURE SIMPLICITY	1
NUMBER OF BARS	20
ACCEL. DUE TO GRAVITY	3.864D 02

TABLE 2. CROSS SECTION DESCRIPTION

CONTROL DATA

STA	X-COORD	TOP FLANGE WIDTH	WEB THICKNESS	BOT FLANGE WIDTH
20	4.800D 02	1.150D 01	5.040D-01	1.150D 01

SEGMENT, DEPTH DATA

SEG	DEPTH	SEG	DEPTH	SEG	DEPTH
2	0.318D 00	5	0.795D 00	6	0.795D 00
11	0.480D 01	19	0.114D 02	24	0.154D 02
25	0.154D 02	28	0.158D 02	30	0.162D 02

REINFORCEMENT DESCRIPTION

STA	TOP REINF DEPTH	TOP REINF AREA	BOTTOM REINF DEPTH	BOTTOM REINF AREA
20	0.0	0.0	0.0	0.0

PRESTRESSING STEEL DESCRIPTION

NON-PRESTRESSED BEAM

TABLE 3. STRESS-STRAIN CURVES

CURVE NO 1

MATERIAL SPECIFIC WEIGHT	2.862D-01
ULTIMATE STRAIN	1.570D-02
STRESS VALUE SCALE FACTOR	1.000D 04
STRAIN VALUE SCALE FACTOR	1.000D-03

STRESS INPUT VALUES
-4.740 -4.730 -4.720 -4.710 -4.700 4.700 4.710 4.720 4.730 4.740

STRAIN INPUT VALUES
-15.700-12.200 -8.640 -5.100 -1.570 1.570 5.100 8.640 12.200 15.700

TABLE 4. SPECIFIED DEFLECTIONS

STA	DEFL
0	0.0
20	0.0

TABLE 5. STATIC LOADS

FROM STA	TO STA	CONT CODE	LATERAL LOAD
0	20	0	-8.333D 01

TABLE 6. DYNAMIC LOADING

NONE

TABLE 7. COLLAPSE PARAMETERS

NONE

COMPLETE RESPONSE, TIME = 0.0

STA	X COORD	MOMENT	SHEAR	Y DISP
0	0.0	0.0		0.0
			0.1900D 05	
1	2.4000D 01	4.5600D 05		-2.5383D-01
			0.1700D 05	
2	4.8000D 01	8.6400D 05		-5.0040D-01
			0.1500D 05	
3	7.2000D 01	1.2240D 06		-7.3323D-01
			0.1300D 05	
4	9.6000D 01	1.5360D 06		-9.4660D-01
			0.1100D 05	
5	1.2000D 02	1.8000D 06		-1.1355D 00
			0.9000D 04	
6	1.4400D 02	2.0160D 06		-1.2959D 00
			0.7000D 04	
7	1.6800D 02	2.1840D 06		-1.4241D 00
			0.5000D 04	
8	1.9200D 02	2.3040D 06		-1.5176D 00
			0.3000D 04	
9	2.1600D 02	2.3760D 06		-1.5745D 00
			0.1000D 04	
10	2.4000D 02	2.4000D 06		-1.5936D 00
			-0.1000D 04	
11	2.6400D 02	2.3760D 06		-1.5745D 00
			-0.3000D 04	
12	2.8800D 02	2.3040D 06		-1.5176D 00
			-0.5000D 04	
13	3.1200D 02	2.1840D 06		-1.4241D 00
			-0.7000D 04	
14	3.3600D 02	2.0160D 06		-1.2959D 00
			-0.9000D 04	
15	3.6000D 02	1.8000D 06		-1.1355D 00
			-0.1100D 05	
16	3.8400D 02	1.5360D 06		-9.4660D-01
			-0.1300D 05	
17	4.0800D 02	1.2240D 06		-7.3323D-01
			-0.1500D 05	
18	4.3200D 02	8.6400D 05		-5.0040D-01
			-0.1700D 05	
19	4.5600D 02	4.5600D 05		-2.5383D-01
			-0.1900D 05	
20	4.8000D 02	0.0		0.0

PROGRAM DYNPCB
ANALYSIS AND PREDICTION OF COLLAPSE OF PRESTRESSED CONCRETE
BEAMS UNDER STATIC AND DYNAMIC LOADING

DYNPCB EXAMPLE PROBLEM
WIDE FLANGE BEAM

PROBLEM P1

SINUSOIDAL IMPULSE

TABLE 1. PROGRAM CONTROL DATA

RETAIN PRIOR DATA TABLES	2 ,3 ,4 ,
STATIC SOLUTION REQUIRED	NO
SELF WEIGHT OPTION	0
STRUCTURE TYPE	2
STRUCTURE SIMPLICITY	1
NUMBER OF BARS	20
ACCEL. DUE TO GRAVITY	3.864D 02
NUMBER OF DYNAMIC LOADINGS	1
DYNAMIC OUTPUT OPTION	2
OUTPUT INTERVAL	40
TIME LIMIT	3.000D-02
TIME INTERVAL	6.634D-05

TABLE 5. STATIC LOADS

FROM STA	TO STA	CONT CODE	LATERAL LOAD
0	0	0	0.0

TABLE 6. DYNAMIC LOADING

IMPULSE, SINUSOIDAL DISTRIBUTION

LOAD NO.	TYPE	PEAK
1	SYMMETRIC	-2.0000 00

TABLE 7. COLLAPSE PARAMETERS

DISPLACEMENT LIMIT = 1.000D 01

SHEAR LIMITS

TERM STA	SHEAR VALUE
20	1.000D 10

COMPLETE RESPONSE, TIME = 2.3884D-02

STA	X COORD	MOMENT	SHEAR	Y DISP
0	0.0	0.0		0.0
			0.1774D 05	
1	2.4000D 01	4.2572D 05		-2.7497D-01
			0.1730D 05	
2	4.8000D 01	8.4095D 05		-5.4316D-01
			0.1644D 05	
3	7.2000D 01	1.2355D 06		-7.9798D-01
			0.1517D 05	
4	9.6000D 01	1.5996D 06		-1.0332D 00
			0.1353D 05	
5	1.2000D 02	1.9243D 06		-1.2429D 00
			0.1156D 05	
6	1.4400D 02	2.2016D 06		-1.4220D 00
			0.9297D 04	
7	1.6800D 02	2.4248D 06		-1.5661D 00
			0.6809D 04	
8	1.9200D 02	2.5882D 06		-1.6717D 00
			0.4154D 04	
9	2.1600D 02	2.6879D 06		-1.7361D 00
			0.1396D 04	
10	2.4000D 02	2.7214D 06		-1.7577D 00
			-0.1396D 04	
11	2.6400D 02	2.6879D 06		-1.7361D 00
			-0.4154D 04	
12	2.8800D 02	2.5882D 06		-1.6717D 00
			-0.6809D 04	
13	3.1200D 02	2.4248D 06		-1.5661D 00
			-0.9297D 04	
14	3.3600D 02	2.2016D 06		-1.4220D 00
			-0.1156D 05	
15	3.6000D 02	1.9243D 06		-1.2429D 00
			-0.1353D 05	
16	3.8400D 02	1.5996D 06		-1.0332D 00
			-0.1517D 05	
17	4.0800D 02	1.2355D 06		-7.9798D-01
			-0.1644D 05	
18	4.3200D 02	8.4095D 05		-5.4316D-01
			-0.1730D 05	
19	4.5600D 02	4.2572D 05		-2.7497D-01
			-0.1774D 05	
20	4.8000D 02	0.0		0.0

COMPLETE RESPONSE, TIME = 2.6538D-02

STA	X COORD	MOMENT	SHEAR	Y DISP
0	0.0	0.0		0.0
			0.1797D 05	
1	2.4000D 01	4.3126D 05		-2.7855D-01
			0.1753D 05	
2	4.8000D 01	8.5190D 05		-5.5023D-01
			0.1665D 05	
3	7.2000D 01	1.2516D 06		-8.0837D-01
			0.1537D 05	
4	9.6000D 01	1.6204D 06		-1.0466D 00
			0.1371D 05	
5	1.2000D 02	1.9493D 06		-1.2591D 00
			0.1171D 05	
6	1.4400D 02	2.2303D 06		-1.4405D 00
			0.9418D 04	
7	1.6800D 02	2.4563D 06		-1.5865D 00
			0.6898D 04	
8	1.9200D 02	2.6219D 06		-1.6934D 00
			0.4208D 04	
9	2.1600D 02	2.7229D 06		-1.7587D 00
			0.1414D 04	
10	2.4000D 02	2.7568D 06		-1.7806D 00
			-0.1414D 04	
11	2.6400D 02	2.7229D 06		-1.7587D 00
			-0.4208D 04	
12	2.8800D 02	2.6219D 06		-1.6934D 00
			-0.6898D 04	
13	3.1200D 02	2.4563D 06		-1.5865D 00
			-0.9418D 04	
14	3.3600D 02	2.2303D 06		-1.4405D 00
			-0.1171D 05	
15	3.6000D 02	1.9493D 06		-1.2591D 00
			-0.1371D 05	
16	3.8400D 02	1.6204D 06		-1.0466D 00
			-0.1537D 05	
17	4.0800D 02	1.2516D 06		-8.0837D-01
			-0.1665D 05	
18	4.3200D 02	8.5190D 05		-5.5023D-01
			-0.1753D 05	
19	4.5600D 02	4.3126D 05		-2.7855D-01
			-0.1797D 05	
20	4.8000D 02	0.0		0.0

COMPLETE RESPONSE, TIME = 2.9192D-02

STA	X COORD	MOMENT	SHEAR	Y DISP
0	0.0	0.0		0.0
			0.1776D 05	
1	2.4000D 01	4.2623D 05		-2.7530D-01
			0.1732D 05	
2	4.8000D 01	8.4197D 05		-5.4382D-01
			0.1646D 05	
3	7.2000D 01	1.2370D 06		-7.9895D-01
			0.1519D 05	
4	9.6000D 01	1.6015D 06		-1.0344D 00
			0.1355D 05	
5	1.2000D 02	1.9266D 06		-1.2444D 00
			0.1157D 05	
6	1.4400D 02	2.2043D 06		-1.4237D 00
			0.9308D 04	
7	1.6800D 02	2.4277D 06		-1.5680D 00
			0.6817D 04	
8	1.9200D 02	2.5913D 06		-1.6737D 00
			0.4159D 04	
9	2.1600D 02	2.6911D 06		-1.7382D 00
			0.1398D 04	
10	2.4000D 02	2.7247D 06		-1.7598D 00
			-0.1398D 04	
11	2.6400D 02	2.6911D 06		-1.7382D 00
			-0.4159D 04	
12	2.8800D 02	2.5913D 06		-1.6737D 00
			-0.6817D 04	
13	3.1200D 02	2.4277D 06		-1.5680D 00
			-0.9308D 04	
14	3.3600D 02	2.2043D 06		-1.4237D 00
			-0.1157D 05	
15	3.6000D 02	1.9266D 06		-1.2444D 00
			-0.1355D 05	
16	3.8400D 02	1.6015D 06		-1.0344D 00
			-0.1519D 05	
17	4.0800D 02	1.2370D 06		-7.9895D-01
			-0.1646D 05	
18	4.3200D 02	8.4197D 05		-5.4382D-01
			-0.1732D 05	
19	4.5600D 02	4.2623D 05		-2.7530D-01
			-0.1776D 05	
20	4.8000D 02	0.0		0.0

BEAM DID NOT FAIL IN SPECIFIED TIME LIMIT

PROGRAM DYNPCB
ANALYSIS AND PREDICTION OF COLLAPSE OF PRESTRESSED CONCRETE
BEAMS UNDER STATIC AND DYNAMIC LOADING

DYNPCB EXAMPLE PROBLEM
REINFORCED CONCRETE BEAM

PROBLEM P2

STATIC AND IMPULSE LOADING

TABLE 1. PROGRAM CONTROL DATA

NO KEEP OPTIONS EXERCISED

STATIC SOLUTION REQUIRED	YES
STATIC OUTPUT OPTION	2
SELF WEIGHT OPTION	0
STRUCTURE TYPE	2
STRUCTURE SIMPLICITY	1
NUMBER OF BARS	20
ACCEL. DUE TO GRAVITY	3.864D 02
NUMBER OF DYNAMIC LOADINGS	1
DYNAMIC OUTPUT OPTION	2
OUTPUT INTERVAL	5
TIME LIMIT	1.0000D-02
TIME INTERVAL	4.787D-05

TABLE 2. CROSS SECTION DESCRIPTION

CONTROL DATA

STA	X-COORD	TOP FLANGE WIDTH	WEB THICKNESS	BOT FLANGE WIDTH
20	1.800D 02	8.000D 00	8.000D 00	8.000D 00

SEGMENT, DEPTH DATA

SEG	DEPTH	SEG	DEPTH	SEG	DEPTH
2	0.300D 00	6	0.220D 01	7	0.220D 01
11	0.410D 01	19	0.790D 01	23	0.980D 01
24	0.980D 01	28	0.117D 02	30	0.120D 02

REINFORCEMENT DESCRIPTION

STA	TOP REINF DEPTH	TOP REINF AREA	BOTTOM REINF DEPTH	BOTTOM REINF AREA
20	0.0	0.0	1.0000D 01	1.0000D 00

PRESTRESSING STEEL DESCRIPTION

NON-PRESTRESSED BEAM

TABLE 3. STRESS-STRAIN CURVES

CURVE NO 1

MATERIAL SPECIFIC WEIGHT	8.484D-02
ULTIMATE STRAIN	-1.0000D-02
STRESS VALUE SCALE FACTOR	1.0000D 03
STRAIN VALUE SCALE FACTOR	1.0000D-03

STRESS INPUT VALUES
0.0 -2.000 -4.000 -4.010 -4.000 0.001 0.002 0.003 0.004 0.005

STRAIN INPUT VALUES
-10.000 -6.250 -2.500 -2.000 -1.500 6.000 12.000 18.000 24.000 30.000

CURVE NO 2

MATERIAL SPECIFIC WEIGHT	2.861D-01
ULTIMATE STRAIN	1.570D-02
STRESS VALUE SCALE FACTOR	1.0000D 04
STRAIN VALUE SCALE FACTOR	1.0000D-03

STRESS INPUT VALUES
-4.740 -4.730 -4.720 -4.710 -4.700 4.700 4.710 4.720 4.730 4.740

STRAIN INPUT VALUES
-15.700-12.200 -8.640 -5.100 -1.570 1.570 5.100 8.640 12.200 15.700

TABLE 4. SPECIFIED DEFLECTIONS

STA	DEFL
0	0.0
20	0.0

TABLE 5. STATIC LOADS

FROM STA	TO STA	CONT. CODE	LATERAL LOAD
0	20	0	-4.167D 01

TABLE 6. DYNAMIC LOADING

IMPULSE, SINUSOIDAL DISTRIBUTION

LOAD NO.	TYPE	PEAK
1	SYMMETRIC	-2.500D 01

TABLE 7. COLLAPSE PARAMETERS

DISPLACEMENT LIMIT = 3.000D 00

SHEAR LIMITS

TERM STA	SHEAR VALUE
20	3.000D 04

COMPLETE RESPONSE, TIME = 0.0

STA	X COORD	MOMENT	SHEAR	Y DISP
0	0.0	0.0		0.0
			0.3563D 04	
1	9.0000D 00	3.2065D 04		-5.9383D-02
			0.3188D 04	
2	1.8000D 01	6.0755D 04		-1.1707D-01
			0.2813D 04	
3	2.7000D 01	8.6069D 04		-1.7154D-01
			0.2438D 04	
4	3.6000D 01	1.0801D 05		-2.2146D-01
			0.2063D 04	
5	4.5000D 01	1.2657D 05		-2.6566D-01
			0.1688D 04	
6	5.4000D 01	1.4176D 05		-3.0317D-01
			0.1313D 04	
7	6.3000D 01	1.5357D 05		-3.3317D-01
			0.9376D 03	
8	7.2000D 01	1.6201D 05		-3.5505D-01
			0.5625D 03	
9	8.1000D 01	1.6708D 05		-3.6835D-01
			0.1875D 03	
10	9.0000D 01	1.6876D 05		-3.7282D-01
			-0.1875D 03	
11	9.9000D 01	1.6708D 05		-3.6835D-01
			-0.5625D 03	
12	1.0800D 02	1.6201D 05		-3.5505D-01
			-0.9376D 03	
13	1.1700D 02	1.5357D 05		-3.3317D-01
			-0.1313D 04	
14	1.2600D 02	1.4176D 05		-3.0317D-01
			-0.1688D 04	
15	1.3500D 02	1.2657D 05		-2.6566D-01
			-0.2063D 04	
16	1.4400D 02	1.0801D 05		-2.2146D-01
			-0.2438D 04	
17	1.5300D 02	8.6069D 04		-1.7154D-01
			-0.2813D 04	
18	1.6200D 02	6.0755D 04		-1.1707D-01
			-0.3188D 04	
19	1.7100D 02	3.2065D 04		-5.9383D-02
			-0.3563D 04	
20	1.8000D 02	0.0		0.0

COMPLETE RESPONSE, TIME = 1.1969D-03

STA	X COORD	MOMENT	SHEAR	Y DISP
0	0.0	0.0		C.0
			0.1643D 05	
1	9.0000D 00	1.4790D 05		-2.7559D-01
			0.1517D 05	
2	1.8000D 01	2.8446D 05		-5.4335D-01
			0.7128D 04	
3	2.7000D 01	3.4860D 05		-7.9606D-01
			0.2812D 04	
4	3.6000D 01	3.7391D 05		-1.0303D 00
			0.2709D 04	
5	4.5000D 01	3.9829D 05		-1.2406D 00
			0.1718D 04	
6	5.4000D 01	4.1375D 05		-1.4200D 00
			0.9372D 03	
7	6.3000D 01	4.2219D 05		-1.5640D 00
			0.8905D 02	
8	7.2000D 01	4.2299D 05		-1.6693D 00
			0.5255D 02	
9	8.1000D 01	4.2346D 05		-1.7335D 00
			0.2145D 02	
10	9.0000D 01	4.2365D 05		-1.7551D 00
			-0.2145D 02	
11	9.9000D 01	4.2346D 05		-1.7335D 00
			-0.5255D 02	
12	1.0800D 02	4.2299D 05		-1.6693D 00
			-0.8905D 02	
13	1.1700D 02	4.2219D 05		-1.5640D 00
			-0.9372D 03	
14	1.2600D 02	4.1375D 05		-1.4200D 00
			-0.1718D 04	
15	1.3500D 02	3.9829D 05		-1.2406D 00
			-0.2709D 04	
16	1.4400D 02	3.7391D 05		-1.0303D 00
			-0.2812D 04	
17	1.5300D 02	3.4860D 05		-7.9606D-01
			-0.7128D 04	
18	1.6200D 02	2.8446D 05		-5.4335D-01
			-0.1517D 05	
19	1.7100D 02	1.4790D 05		-2.7559D-01
			-0.1643D 05	
20	1.8000D 02	0.0		C.0

COMPLETE RESPONSE, TIME = 2.2980D-03

STA	X COORD	MOMENT	SHEAR	Y DISP
C	C.0	0.0		0.0
			0.1108D 05	
1	9.0000D 00	9.9742D 04		-4.5816D-01
			0.1669D 05	
2	1.8000D 01	2.4997D 05		-9.1105D-01
			0.1352D C5	
3	2.7000D 01	3.7166D 05		-1.3507D 00
			0.5779D C4	
4	3.6000D 01	4.2368D 05		-1.7632D 00
			0.4519D 03	
5	4.5000D 01	4.2774D 05		-2.1325D 00
			0.2583D 03	
6	5.4000D 01	4.3007D 05		-2.4460D 00
			0.1764D 03	
7	6.3000D 01	4.3166D 05		-2.6966D 00
			0.1390D 03	
8	7.2000D 01	4.3291D 05		-2.8795D 00
			0.8391D 02	
9	8.1000D 01	4.3366D 05		-2.9909D 00
			0.3424D 02	
1C	9.0000D 01	4.3397D 05		-3.0283D 00
			-0.3424D 02	
11	9.9000D 01	4.3366D 05		-2.9909D 00
			-0.8391D 02	
12	1.0800D 02	4.3291D 05		-2.8795D 00
			-0.1390D 03	
13	1.1700D 02	4.3166D 05		-2.6966D 00
			-0.1764D 03	
14	1.2600D 02	4.3007D 05		-2.4460D 00
			-0.2583D C3	
15	1.3500D 02	4.2774D 05		-2.1325D 00
			-0.4519D 03	
16	1.4400D 02	4.2368D 05		-1.7632D 00
			-0.5779D 04	
17	1.5300D 02	3.7166D 05		-1.3507D 00
			-0.1352D 05	
18	1.6200D 02	2.4997D 05		-9.1105D-01
			-0.1669D 05	
19	1.7100D 02	9.9742D 04		-4.5816D-01
			-0.1108D 05	
2C	1.8000D 02	0.0		0.0

FAILURE DUE TO LATERAL DEFLECTION AT X = 9.0000D 01

FAILURE AT TIME = 2.2980D-03

PROGRAM DYNPCB
ANALYSIS AND PREDICTION OF COLLAPSE OF PRESTRESSED CONCRETE BEAMS UNDER STATIC AND DYNAMIC LOADING

DYNPCB EXAMPLE PROBLEM
REINFORCED CONCRETE BEAM

PROBLEM P2

FORCE PULSE LOADING

TABLE 1. PROGRAM CONTROL DATA

RETAIN PRIOR DATA TABLES	2 ,3 ,4 ,5 ,7 ,
STATIC SOLUTION REQUIRED	YES
STATIC OUTPUT OPTION	2
SELF WEIGHT OPTION	0
STRUCTURE TYPE	2
STRUCTURE SIMPLICITY	1
NUMBER OF BARS	20
ACCEL. DUE TO GRAVITY	3.864D 02
NUMBER OF DYNAMIC LOADINGS	1
DYNAMIC OUTPUT OPTION	2
OUTPUT INTERVAL	5
TIME LIMIT	1.000D-02
TIME INTERVAL	4.787D-05

TABLE 5. STATIC LOADS

FROM STA	TO STA	CONT CODE	LATERAL LOAD
USING DATA FROM PREVIOUS PROBLEM			
0	20	0	-4.167D 01
ADDITIONAL DATA FOR THIS PROBLEM			
0	0	0	0.0

TABLE 6. DYNAMIC LOADING

PRESSURE, UNIFORM DISTRIBUTION
RISE TIME 6.000D-02
PULSE DURATION . . 1.200D-01

LOAD NO.	TYPE	PEAK
1	UNIFORM	-5.000D 02

COMPLETE RESPONSE, TIME = 1.6756D-03

STA	X COORD	MOMENT	SHEAR	Y DISP
0	0.0	0.0		0.0
			0.3662D 04	
1	9.0000D 00	3.2960D 04		-5.9539D-02
			0.3204D 04	
2	1.8000D 01	6.1793D 04		-1.1733D-01
			0.2784D 04	
3	2.7000D 01	8.6846D 04		-1.7186D-01
			0.2395D 04	
4	3.6000D 01	1.0840D 05		-2.2179D-01
			0.2027D 04	
5	4.5000D 01	1.2664D 05		-2.6598D-01
			0.1669D 04	
6	5.4000D 01	1.4166D 05		-3.0347D-01
			0.1310D 04	
7	6.3000D 01	1.5346D 05		-3.3347D-01
			0.9445D 03	
8	7.2000D 01	1.6196D 05		-3.5535D-01
			0.5708D 03	
9	8.1000D 01	1.6709D 05		-3.6866D-01
			0.1909D 03	
10	9.0000D 01	1.6881D 05		-3.7312D-01
			-0.1909D 03	
11	9.9000D 01	1.6709D 05		-3.6866D-01
			-0.5708D 03	
12	1.0800D 02	1.6196D 05		-3.5535D-01
			-0.9445D 03	
13	1.1700D 02	1.5346D 05		-3.3347D-01
			-0.1310D 04	
14	1.2600D 02	1.4166D 05		-3.0347D-01
			-0.1669D 04	
15	1.3500D 02	1.2664D 05		-2.6598D-01
			-0.2027D 04	
16	1.4400D 02	1.0840D 05		-2.2179D-01
			-0.2395D 04	
17	1.5300D 02	8.6846D 04		-1.7186D-01
			-0.2784D 04	
18	1.6200D 02	6.1793D 04		-1.1733D-01
			-0.3204D 04	
19	1.7100D 02	3.2960D 04		-5.9539D-02
			-0.3662D 04	
20	1.8000D 02	0.0		0.0

COMPLETE RESPONSE, TIME = 7.4205D-03

STA	X COORD	MOMENT	SHEAR	Y DISP
0	0.0	0.0		0.0
			0.4683D 04	
1	9.0000D 00	4.2151D 04		-6.5902D-02
			0.3849D 04	
2	1.8000D 01	7.6793D 04		-1.2957D-01
			0.3106D 04	
3	2.7000D 01	1.0474D 05		-1.8918D-01
			0.2447D 04	
4	3.6000D 01	1.2677D 05		-2.4325D-01
			0.1870D 04	
5	4.5000D 01	1.4360D 05		-2.9060D-01
			0.1374D 04	
6	5.4000D 01	1.5596D 05		-3.3036D-01
			0.9611D 03	
7	6.3000D 01	1.6461D 05		-3.6187D-01
			0.6255D 03	
8	7.2000D 01	1.7024D 05		-3.8467D-01
			0.3495D 03	
9	8.1000D 01	1.7339D 05		-3.9846D-01
			0.1120D 03	
10	9.0000D 01	1.7440D 05		-4.0307D-01
			-0.1120D 03	
11	9.9000D 01	1.7339D 05		-3.9846D-01
			-0.3495D 03	
12	1.0800D 02	1.7024D 05		-3.8467D-01
			-0.6255D 03	
13	1.1700D 02	1.6461D 05		-3.6187D-01
			-0.9611D 03	
14	1.2600D 02	1.5596D 05		-3.3036D-01
			-0.1374D 04	
15	1.3500D 02	1.4360D 05		-2.9060D-01
			-0.1870D 04	
16	1.4400D 02	1.2677D 05		-2.4325D-01
			-0.2447D 04	
17	1.5300D 02	1.0474D 05		-1.8918D-01
			-0.3106D 04	
18	1.6200D 02	7.6793D 04		-1.2957D-01
			-0.3849D 04	
19	1.7100D 02	4.2151D 04		-6.5902D-02
			-0.4683D 04	
20	1.8000D 02	0.0		0.0

COMPLETE RESPONSE, TIME = 1.0006D-02

STA	X COORD	MOMENT	SHEAR	Y DISP
0	0.0	0.0		0.0
			0.5203D 04	
1	9.0000D 00	4.6831D 04		-7.3284D-02
			0.4225D 04	
2	1.8000D 01	8.4857D 04		-1.4409D-01
			0.3391D 04	
3	2.7000D 01	1.1538D 05		-2.1041D-01
			0.2690D 04	
4	3.6000D 01	1.3959D 05		-2.7062D-01
			0.2102D 04	
5	4.5000D 01	1.5851D 05		-3.2344D-01
			0.1602D 04	
6	5.4000D 01	1.7293D 05		-3.6788D-01
			0.1171D 04	
7	6.3000D 01	1.8347D 05		-4.0317D-01
			0.7949D 03	
8	7.2000D 01	1.9062D 05		-4.2875D-01
			0.4601D 03	
9	8.1000D 01	1.9476D 05		-4.4425D-01
			0.1504D 03	
10	9.0000D 01	1.9611D 05		-4.4943D-01
			-0.1504D 03	
11	9.9000D 01	1.9476D 05		-4.4425D-01
			-0.4601D 03	
12	1.0800D 02	1.9062D 05		-4.2875D-01
			-0.7949D 03	
13	1.1700D 02	1.8347D 05		-4.0317D-01
			-0.1171D 04	
14	1.2600D 02	1.7293D 05		-3.6788D-01
			-0.1602D 04	
15	1.3500D 02	1.5851D 05		-3.2344D-01
			-0.2102D 04	
16	1.4400D 02	1.3959D 05		-2.7062D-01
			-0.2690D 04	
17	1.5300D 02	1.1538D 05		-2.1041D-01
			-0.3391D 04	
18	1.6200D 02	8.4857D 04		-1.4409D-01
			-0.4225D 04	
19	1.7100D 02	4.6831D 04		-7.3284D-02
			-0.5203D 04	
20	1.8000D 02	0.0		0.0

TERMINATE

PROGRAM DYNPCB
ANALYSIS AND PREDICTION OF COLLAPSE OF PRESTRESSED CONCRETE
BEAMS UNDER STATIC AND DYNAMIC LOADING

DYNPCB EXAMPLE PROBLEM
PRESTRESSED CONCRETE BEAM

PROBLEM P3

STATIC AND IMPULSE LOADING

TABLE 1. PROGRAM CONTROL DATA

NO KEEP OPTIONS EXERCISED

STATIC SOLUTION REQUIRED	YES
STATIC OUTPUT OPTION	2
SELF WEIGHT OPTION	0
STRUCTURE TYPE	4
STRUCTURE SIMPLICITY	2
NUMBER OF BARS	24
ACCEL. DUE TO GRAVITY	3.864D 02
NUMBER OF DYNAMIC LOADINGS	1
DYNAMIC OUTPUT OPTION	2
OUTPUT INTERVAL	5
TIME LIMIT	6.0000D-04
TIME INTERVAL	INTERNAL

TABLE 2. CROSS SECTION DESCRIPTION

USING DATA FROM PREVIOUS PROBLEM

CONTROL DATA

STA	X-COORD	TOP FLANGE WIDTH	WEB THICKNESS	BOT FLANGE WIDTH
24	2.880D 02	2.000D 01	2.000D 01	2.000D 01

SEGMENT, DEPTH DATA

SEG	DEPTH	SEG	DEPTH	SEG	DEPTH
2	0.100D 01	6	0.400D 01	7	0.400D 01
11	0.100D 02	19	0.200D 02	23	C.260D 02
24	0.260D 02	28	0.290D 02	30	0.300D 02

REINFORCEMENT DESCRIPTION
NON-PRESTRESSED STEEL ABSENT

PRESTRESSING STEEL DESCRIPTION

NUMBER OF STEEL LAYERS 1

LAYER	GEOMETRY	AREA	STRAIN	SEGMENTS
1	3	2.400D 00	5.600D-03	3

LAYER	STA	DEPTH
1	0	1.500D 01
1	12	2.100D 01
1	24	1.500D 01

TABLE 3. STRESS-STRAIN CURVES

CURVE NO 1

MATERIAL SPECIFIC WEIGHT	8.484D-02
ULTIMATE STRAIN	-5.000D-03
STRESS VALUE SCALE FACTOR	1.000D 03
STRAIN VALUE SCALE FACTOR	1.000D-03

STRESS INPUT VALUES
0.0 -4.000 -4.700 -5.000 -4.200 0.111 0.222 0.555 0.005 0.005

STRAIN INPUT VALUES
-5.000 -3.500 -3.000 -2.250 -1.250 0.033 0.066 0.099 15.000 40.000

CURVE NO 2

MATERIAL SPECIFIC WEIGHT	2.861D-01
ULTIMATE STRAIN	6.400D-02
STRESS VALUE SCALE FACTOR	1.000D 04
STRAIN VALUE SCALE FACTOR	1.000D-03

STRESS INPUT VALUES
-25.870-25.500-23.620-21.750-18.750 18.750 21.750 23.620 25.500 25.870

STRAIN INPUT VALUES
-64.000-45.000-20.000-10.000 -7.000 7.000 10.000 20.000 45.000 64.000

TABLE 4. SPECIFIED DEFLECTIONS

STA	DEFL
0	0.0
24	0.0

TABLE 5. STATIC LOADS

FROM STA	TO STA	CONT CODE	LATERAL LOAD
0	24	0	-3.000D 02

TABLE 6. DYNAMIC LOADING

IMPULSE, SINUSOIDAL DISTRIBUTION

LOAD NO.	TYPE	PEAK
1	SYMMETRIC	-1.000D 01

TABLE 7. COLLAPSE PARAMETERS

DISPLACEMENT LIMIT = 6.000D 00

SHEAR LIMITS

TERM STA	SHEAR VALUE
24	2.000D 05

MOMENT - CURVATURE VALUES

MOMENT L	MOMENT T	MOMENT P	CURVATURE
-3.49217D 06	-5.79325D 06	-2.30108D 06	-6.14682D-04
-5.13925D 06	-7.25042D 06	2.11117D 06	-2.45873D-04
-4.69005D 06	-6.66237D 06	-1.97232D 06	-9.83490D-05
-3.04363D 06	-5.00623D 06	-1.96260D 06	-3.93396D-05
-3.17351D 05	-2.31939D 06	-2.00204D 06	-1.57358D-05
3.96597D 06	1.90284D 06	-2.06313D 06	1.22254D-05
6.63694D 06	4.53261D 06	-2.10434D 06	3.05635D-05
9.09346D 06	6.80967D 06	-2.28379D 06	7.64087D-05
1.09434D 07	8.23653D 06	-2.70690D 06	1.91022D-04
1.01920D 07	7.12853D 06	-3.06349D 06	4.77555D-04

COMPLETE RESPONSE, TIME = 0.0

STA	X COORD	MOMENT	SHEAR	Y DISP
0	0.0	0.0		0.0
			0.4140D 05	
1	1.2000D 01	4.9680D 05		-7.9082D-03
			0.3780D 05	
2	2.4000D 01	9.5040D 05		-1.5654D-02
			0.3420D 05	
3	3.6000D 01	1.3608D 06		-2.3089D-02
			0.3060D 05	
4	4.8000D 01	1.7280D 06		-3.0084D-02
			0.2700D 05	
5	6.0000D 01	2.0520D 06		-3.6521D-02
			0.2340D 05	
6	7.2000D 01	2.3328D 06		-4.2299D-02
			0.1980D 05	
7	8.4000D 01	2.5704D 06		-4.7333D-02
			0.1620D 05	
8	9.6000D 01	2.7648D 06		-5.1549D-02
			0.1260D 05	
9	1.0800D 02	2.9160D 06		-5.4888D-02
			0.9000D 04	
10	1.2000D 02	3.0240D 06		-5.7306D-02
			0.5400D 04	
11	1.3200D 02	3.0888D 06		-5.8769D-02
			0.1800D 04	
12	1.4400D 02	3.1104D 06		-5.9259D-02
			-0.1800D 04	
13	1.5600D 02	3.0888D 06		-5.8769D-02
			-0.5400D 04	
14	1.6800D 02	3.0240D 06		-5.7306D-02
			-0.9000D 04	
15	1.8000D 02	2.9160D 06		-5.4888D-02
			-0.1260D 05	
16	1.9200D 02	2.7648D 06		-5.1549D-02
			-0.1620D 05	
17	2.0400D 02	2.5704D 06		-4.7333D-02
			-0.1980D 05	
18	2.1600D 02	2.3328D 06		-4.2299D-02
			-0.2340D 05	
19	2.2800D 02	2.0520D 06		-3.6521D-02
			-0.2700D 05	
20	2.4000D 02	1.7280D 06		-3.0084D-02
			-0.3060D 05	
21	2.5200D 02	1.3608D 06		-2.3085D-02
			-0.3420D 05	
22	2.6400D 02	9.5040D 05		-1.5654D-02
			-0.3780D 05	
23	2.7600D 02	4.9680D 05		-7.9082D-03
			-0.4140D 05	
24	2.8800D 02	0.0		0.0

COMPLETE RESPONSE, TIME = 4.2050D-04

STA	X COORD	MOMENT	SHEAR	Y DISP
0	0.0	0.0		0.0
			0.4762D 05	
1	1.2000D 01	5.7150D 05		-1.2028D-02
			0.4395D 05	
2	2.4000D 01	1.0989D 06		-2.3823D-02
			0.4019D 05	
3	3.6000D 01	1.5811D 06		-3.5168D-02
			0.3634D 05	
4	4.8000D 01	2.0172D 06		-4.5864D-02
			0.3238D 05	
5	6.0000D 01	2.4058D 06		-5.5733D-02
			0.2832D 05	
6	7.2000D 01	2.7456D 06		-6.4615D-02
			0.2415D 05	
7	8.4000D 01	3.0354D 06		-7.2370D-02
			0.1989D 05	
8	9.6000D 01	3.2741D 06		-7.8879D-02
			0.1556D 05	
9	1.0800D 02	3.4608D 06		-8.4044D-02
			0.1116D 05	
10	1.2000D 02	3.5947D 06		-8.7788D-02
			0.6714D 04	
11	1.3200D 02	3.6752D 06		-9.0057D-02
			0.2241D 04	
12	1.4400D 02	3.7021D 06		-9.0817D-02
			-0.2241D 04	
13	1.5600D 02	3.6752D 06		-9.0057D-02
			-0.6714D 04	
14	1.6800D 02	3.5947D 06		-8.7788D-02
			-0.1116D 05	
15	1.8000D 02	3.4608D 06		-8.4044D-02
			-0.1556D 05	
16	1.9200D 02	3.2741D 06		-7.8879D-02
			-0.1989D 05	
17	2.0400D 02	3.0354D 06		-7.2370D-02
			-0.2415D 05	
18	2.1600D 02	2.7456D 06		-6.4615D-02
			-0.2832D 05	
19	2.2800D 02	2.4058D 06		-5.5733D-02
			-0.3238D 05	
20	2.4000D 02	2.0172D 06		-4.5864D-02
			-0.3634D 05	
21	2.5200D 02	1.5811D 06		-3.5168D-02
			-0.4019D 05	
22	2.6400D 02	1.0989D 06		-2.3823D-02
			-0.4395D 05	
23	2.7600D 02	5.7150D 05		-1.2028D-02
			-0.4762D 05	
24	2.8800D 02	0.0		0.0

COMPLETE RESPONSE, TIME = 5.2563D-04

STA	X COORD	MOMENT	SHEAR	Y DISP
0	0.0	0.0		0.0
			0.4919D 05	
1	1.2000D 01	5.9029D 05		-1.3057D-02
			0.4549D 05	
2	2.4000D 01	1.1362D 06		-2.5863D-02
			0.4168D 05	
3	3.6000D 01	1.6364D 06		-3.8184D-02
			0.3776D 05	
4	4.8000D 01	2.0895D 06		-4.9805D-02
			0.3372D 05	
5	6.0000D 01	2.4941D 06		-6.0530D-02
			0.2954D 05	
6	7.2000D 01	2.8486D 06		-7.0187D-02
			0.2524D 05	
7	8.4000D 01	3.1515D 06		-7.8621D-02
			0.2081D 05	
8	9.6000D 01	3.4012D 06		-8.5702D-02
			0.1629D 05	
9	1.0800D 02	3.5967D 06		-9.1323D-02
			0.1170D 05	
10	1.2000D 02	3.7371D 06		-9.5398D-02
			0.7041D 04	
11	1.3200D 02	3.8216D 06		-9.7868D-02
			0.2351D 04	
12	1.4400D 02	3.8498D 06		-9.8695D-02
			-0.2351D 04	
13	1.5600D 02	3.8216D 06		-9.7868D-02
			-0.7041D 04	
14	1.6800D 02	3.7371D 06		-9.5398D-02
			-0.1170D 05	
15	1.8000D 02	3.5967D 06		-9.1323D-02
			-0.1629D 05	
16	1.9200D 02	3.4012D 06		-8.5702D-02
			-0.2081D 05	
17	2.0400D 02	3.1515D 06		-7.8621D-02
			-0.2524D 05	
18	2.1600D 02	2.8486D 06		-7.0187D-02
			-0.2954D 05	
19	2.2800D 02	2.4941D 06		-6.0530D-02
			-0.3372D 05	
20	2.4000D 02	2.0895D 06		-4.9805D-02
			-0.3776D 05	
21	2.5200D 02	1.6364D 06		-3.8184D-02
			-0.4168D 05	
22	2.6400D 02	1.1362D 06		-2.5863D-02
			-0.4549D 05	
23	2.7600D 02	5.9029D 05		-1.3057D-02
			-0.4919D 05	
24	2.8800D 02	0.0		0.0

BEAM DID NOT FAIL IN SPECIFIED TIME LIMIT

PROGRAM CYNPCB
ANALYSIS AND PREDICTION OF COLLAPSE OF PRESTRESSED CONCRETE BEAMS UNDER STATIC AND DYNAMIC LOADING

DYNPCB EXAMPLE PROBLEM
PRESTRESSED CONCRETE I BEAM

PRCBLEM P4

STATIC AND IMPULSE LOADING

TABLE 1. PROGRAM CONTROL DATA

NO KEEP OPTIONS EXERCISED

STATIC SOLUTION REQUIRED	YES
STATIC OUTPUT OPTION	2
SELF WEIGHT OPTION	1
STRUCTURE TYPE	3
STRUCTURE SIMPLICITY	1
NUMBER OF BARS	30
ACCEL. DUE TO GRAVITY	3.864D 02
NUMBER OF DYNAMIC LOADINGS	1
DYNAMIC OUTPUT OPTION	2
OUTPUT INTERVAL	10
TIME LIMIT	1.0000-02
TIME INTERVAL	INTERNAL

TABLE 2. CROSS SECTION DESCRIPTION

USING DATA FROM PREVIOUS PROBLEM

CONTROL DATA

STA	X-COORD	TOP FLANGE WIDTH	WEB THICKNESS	BOT FLANGE WIDTH
30	3.600D 02	1.300D 01	6.000D 00	1.700D 01

SEGMENT, DEPTH DATA

SEG	DEPTH	SEG	DEPTH	SEG	DEPTH
2	0.200D 01	4	0.400D 01	5	C.500D 01
8	0.800D 01	12	0.130D 02	16	C.180D 02
19	0.210D 02	25	0.270D 02	30	0.320C 02

REINFORCEMENT DESCRIPTION

STA	TOP REINF DEPTH	TOP REINF AREA	BOTTOM REINF DEPTH	BOTTOM REINF AREA
30	2.0000 00	6.200D-01	0.0	0.0

PRESTRESSING STEEL DESCRIPTION

NUMBER OF STEEL LAYERS 7

LAYER	GEOMETRY	AREA	STRAIN	SEGMENTS
1	1	8.500D-02	4.800D-03	1
2	1	8.500D-02	4.800D-C3	1
3	1	8.500D-02	4.800D-03	1
4	1	1.700D-01	4.800D-03	1
5	1	1.700D-01	4.800D-C3	1
6	1	1.700D-01	4.800D-03	1
7	1	4.250D-01	4.800C-03	1

LAYER	STA	DEPTH
1	30	4.000D 00
2	30	2.000D 01
3	30	2.200D 01
4	30	2.400D 01
5	30	2.600D 01
6	30	2.800D 01
7	30	3.000D 01

TABLE 3. STRESS-STRAIN CURVES

CURVE NO 1

MATERIAL SPECIFIC WEIGHT	8.484D-02
ULTIMATE STRAIN	-5.000D-03
STRESS VALUE SCALE FACTOR	1.000C 03
STRAIN VALUE SCALE FACTOR	1.000D-03

STRESS INPUT VALUES
0.0 -4.000 -4.700 -5.000 -4.200 0.111 0.222 0.555 0.005 0.005

STRAIN INPUT VALUES
-5.000 -3.500 -3.000 -2.250 -1.220 0.033 0.066 0.099 15.000 30.000

CURVE NO 2

MATERIAL SPECIFIC WEIGHT	2.861D-01
ULTIMATE STRAIN	1.570D-02
STRESS VALUE SCALE FACTOR	1.000D 04
STRAIN VALUE SCALE FACTOR	1.000D-03

STRESS INPUT VALUES
-4.740 -4.730 -4.720 -4.710 -4.700 4.700 4.710 4.720 4.730 4.740

STRAIN INPUT VALUES
-15.700-12.200 -8.640 -5.100 -1.570 1.570 5.100 8.640 12.200 15.700

CURVE NO 3

MATERIAL SPECIFIC WEIGHT 2.887D-01
ULTIMATE STRAIN 6.400D-02
STRESS VALUE SCALE FACTOR 1.000D 04
STRAIN VALUE SCALE FACTOR 1.000D-03

STRESS INPUT VALUES
-25.870-25.500-23.620-21.750-18.750 18.750 21.750 23.620 25.500 25.870

STRAIN INPUT VALUES
-64.000-45.000-20.000-10.000 -7.000 7.000 10.000 20.000 45.000 64.000

TABLE 4. SPECIFIED DEFLECTIONS

STA	DEFL
0	0.0
30	0.0

TABLE 5. STATIC LOADS

FROM STA	TO STA	CONT CODE	LATERAL LOAD
0	30	0	-8.333D 01

TABLE 6. DYNAMIC LOADING

IMPULSE, SINUSOIDAL DISTRIBUTION

LOAD NO.	TYPE	PEAK
1	SYMMETRIC	-4.000D 01

TABLE 7. COLLAPSE PARAMETERS

DISPLACEMENT LIMIT = 8.000D 00

SHEAR LIMITS

TERM STA	SHEAR VALUE
30	1.000D 05

COMPLETE RESPONSE, TIME = 0.0

STA	X COORD	MOMENT	SHEAR	Y DISP
0	0.0	0.0		0.0
			0.1989D 05	
1	1.2000D 01	2.3872D 05		-3.7213D-03
			0.1852D 05	
2	2.4000D 01	4.6097D 05		-8.5641D-03
			0.1715D 05	
3	3.6000D 01	6.6676D 05		-1.4202D-02
			0.1578D 05	
4	4.8000D 01	8.5609D 05		-2.0334D-02
			0.1441D 05	
5	6.0000D 01	1.0290D 06		-2.6682D-02
			0.1303D 05	
6	7.2000D 01	1.1854D 06		-3.3004D-02
			0.1166D 05	
7	8.4000D 01	1.3253D 06		-3.9125D-02
			0.1029D 05	
8	9.6000D 01	1.4488D 06		-4.4890D-02
			0.8918D 04	
9	1.0800D 02	1.5558D 06		-5.0162D-02
			0.7546D 04	
10	1.2000D 02	1.6463D 06		-5.4824D-02
			0.6174D 04	
11	1.3200D 02	1.7204D 06		-5.8774D-02
			0.4802D 04	
12	1.4400D 02	1.7780D 06		-6.1931D-02
			0.3430D 04	
13	1.5600D 02	1.8192D 06		-6.4232D-02
			0.2058D 04	
14	1.6800D 02	1.8439D 06		-6.5631D-02
			0.6860D 03	
15	1.8000D 02	1.8521D 06		-6.6100D-02
			-0.6860D 03	
16	1.9200D 02	1.8439D 06		-6.5631D-02
			-0.2058D 04	
17	2.0400D 02	1.8192D 06		-6.4232D-02
			-0.3430D 04	
18	2.1600D 02	1.7780D 06		-6.1931D-02
			-0.4802D 04	
19	2.2800D 02	1.7204D 06		-5.8774D-02
			-0.6174D 04	
20	2.4000D 02	1.6463D 06		-5.4824D-02
			-0.7546D 04	
21	2.5200D 02	1.5558D 06		-5.0162D-02
			-0.8918D 04	
22	2.6400D 02	1.4488D 06		-4.4890D-02
			-0.1029D 05	
23	2.7600D 02	1.3253D 06		-3.9125D-02
			-0.1166D 05	
24	2.8800D 02	1.1854D 06		-3.3004D-02
			-0.1303D 05	
25	3.0000D 02	1.0290D 06		-2.6682D-02
			-0.1441D 05	
26	3.1200D 02	8.5609D 05		-2.0334D-02
			-0.1578D 05	
27	3.2400D 02	6.6676D 05		-1.4202D-02
			-0.1715D 05	
28	3.3600D 02	4.6097D 05		-8.5641D-03
			-0.1852D 05	
29	3.4800D 02	2.3872D 05		-3.7213D-03
			-0.1989D 05	
30	3.6000D 02	0.0		0.0

COMPLETE RESPONSE, TIME = 1.1225D-03

STA	X COORD	MOMENT	SHEAR	Y DISP
0	0.0	0.0		0.0
			0.6688D 05	
1	1.2000D 01	8.0257D 05		-6.2395D-02
			0.6178D 05	
2	2.4000D 01	1.5439D 06		-1.2509D-01
			0.6900D 05	
3	3.6000D 01	2.3719D 06		-1.8718D-01
			0.7362D 05	
4	4.8000D 01	3.2553D 06		-2.4776D-01
			0.5081D 05	
5	6.0000D 01	3.8650D 06		-3.0581D-01
			0.3001D 05	
6	7.2000D 01	4.2252D 06		-3.6064D-01
			0.1949D 05	
7	8.4000D 01	4.4591D 06		-4.1184D-01
			0.2385D 05	
8	9.6000D 01	4.7452D 06		-4.5901D-01
			0.1552D 05	
9	1.0800D 02	4.9314D 06		-5.0129D-01
			0.1750D 05	
10	1.2000D 02	5.1414D 06		-5.3812D-01
			0.1116D 05	
11	1.3200D 02	5.2754D 06		-5.6888D-01
			0.6505D 04	
12	1.4400D 02	5.3535D 06		-5.9314D-01
			0.6019D 04	
13	1.5600D 02	5.4257D 06		-6.1069D-01
			0.3518D 04	
14	1.6800D 02	5.4679D 06		-6.2129D-01
			0.2839D 03	
15	1.8000D 02	5.4713D 06		-6.2483D-01
			-0.2839D 03	
16	1.9200D 02	5.4679D 06		-6.2129D-01
			-0.3518D 04	
17	2.0400D 02	5.4257D 06		-6.1069D-01
			-0.6019D 04	
18	2.1600D 02	5.3535D 06		-5.9314D-01
			-0.6505D 04	
19	2.2800D 02	5.2754D 06		-5.6888D-01
			-0.1116D 05	
20	2.4000D 02	5.1414D 06		-5.3812D-01
			-0.1750D 05	
21	2.5200D 02	4.9314D 06		-5.0129D-01
			-0.1552D 05	
22	2.6400D 02	4.7452D 06		-4.5901D-01
			-0.2385D 05	
23	2.7600D 02	4.4591D 06		-4.1184D-01
			-0.1949D 05	
24	2.8800D 02	4.2252D 06		-3.6064D-01
			-0.3001D 05	
25	3.0000D 02	3.8650D 06		-3.0581D-01
			-0.5081D 05	
26	3.1200D 02	3.2553D 06		-2.4776D-01
			-0.7362D 05	
27	3.2400D 02	2.3719D 06		-1.8718D-01
			-0.6900D 05	
28	3.3600D 02	1.5439D 06		-1.2509D-01
			-0.6178D 05	
29	3.4800D 02	8.0257D 05		-6.2395D-02
			-0.6688D 05	
30	3.6000D 02	0.0		0.0

COMPLETE RESPONSE, TIME = 2.0580D-03

STA	X COORD	MOMENT	SHEAR	Y DISP
0	0.0	0.0		0.0
			0.9140D 05	
1	1.2000D 01	1.0968D 06		-1.0886D-01
			0.8599D 05	
2	2.4000D 01	2.1288D 06		-2.1762D-01
			0.8205D 05	
3	3.6000D 01	3.1134D 06		-3.2514D-01
			0.7416D 05	
4	4.8000D 01	4.0033D 06		-4.3028D-01
			0.6603D 05	
5	6.0000D 01	4.7957D 06		-5.3203D-01
			0.4491D 05	
6	7.2000D 01	5.3346D 06		-6.2874D-01
			0.3060D 05	
7	8.4000D 01	5.7018D 06		-7.1879D-01
			0.2651D 05	
8	9.6000D 01	6.0200D 06		-8.0106D-01
			0.1982D 05	
9	1.0800D 02	6.2579D 06		-8.7461D-01
			0.1088D 05	
10	1.2000D 02	6.3884D 06		-9.3854D-01
			0.3724D 04	
11	1.3200D 02	6.4331D 06		-9.9191D-01
			0.3504D 04	
12	1.4400D 02	6.4752D 06		-1.0342D 00
			0.3440D 04	
13	1.5600D 02	6.5164D 06		-1.0650D 00
			0.3634D 04	
14	1.6800D 02	6.5601D 06		-1.0837D 00
			0.2136D 03	
15	1.8000D 02	6.5626D 06		-1.0900D 00
			-0.2136D 03	
16	1.9200D 02	6.5601D 06		-1.0837D 00
			-0.3634D 04	
17	2.0400D 02	6.5164D 06		-1.0650D 00
			-0.3440D 04	
18	2.1600D 02	6.4752D 06		-1.0342D 00
			-0.3504D 04	
19	2.2800D 02	6.4331D 06		-9.9191D-01
			-0.3724D 04	
20	2.4000D 02	6.3884D 06		-9.3854D-01
			-0.1088D 05	
21	2.5200D 02	6.2579D 06		-8.7461D-01
			-0.1982D 05	
22	2.6400D 02	6.0200D 06		-8.0106D-01
			-0.2651D 05	
23	2.7600D 02	5.7018D 06		-7.1879D-01
			-0.3060D 05	
24	2.8800D 02	5.3346D 06		-6.2874D-01
			-0.4491D 05	
25	3.0000D 02	4.7957D 06		-5.3203D-01
			-0.6603D 05	
26	3.1200D 02	4.0033D 06		-4.3028D-01
			-0.7416D 05	
27	3.2400D 02	3.1134D 06		-3.2514D-01
			-0.8205D 05	
28	3.3600D 02	2.1288D 06		-2.1762D-01
			-0.8599D 05	
29	3.4800D 02	1.0968D 06		-1.0886D-01
			-0.9140D 05	
30	3.6000D 02	0.0		0.0

FAILURE DUE TO SHEAR AT X = 1.8000D 01

FAILURE DUE TO SHEAR AT X = 3.4200D 02

FAILURE AT TIME = 3.0496D-03

COMPLETE RESPONSE, TIME = 3.0496D-03

STA	X COORD	MOMENT	SHEAR	Y DISP
0	0.0	0.0		0.0
			0.1139D 06	
1	1.2000D 01	1.3664D 06		-1.5541D-01
			0.1031D 06	
2	2.4000D 01	2.6038D 06		-3.1042D-01
			0.7923D 05	
3	3.6000D 01	3.5546D 06		-4.6365D-01
			0.5941D 05	
4	4.8000D 01	4.2675D 06		-6.1399D-01
			0.6001D 05	
5	6.0000D 01	4.9876D 06		-7.6063D-01
			0.5767D 05	
6	7.2000D 01	5.6756D 06		-9.0139D-01
			0.4742D 05	
7	8.4000D 01	6.2486D 06		-1.0340D 00
			0.2980D 05	
8	9.6000D 01	6.6062D 06		-1.1572D 00
			0.2010D 05	
9	1.0800D 02	6.8474D 06		-1.2673D 00
			0.3670D 04	
10	1.2000D 02	6.8915D 06		-1.3615D 00
			0.6923D 03	
11	1.3200D 02	6.8998D 06		-1.4395D 00
			0.1805D 04	
12	1.4400D 02	6.9214D 06		-1.5012D 00
			0.1018D 05	
13	1.5600D 02	7.0436D 06		-1.5464D 00
			0.2705D 04	
14	1.6800D 02	7.0761D 06		-1.5736D 00
			-0.2130D 04	
15	1.8000D 02	7.0505D 06		-1.5826D 00
			0.2130D 04	
16	1.9200D 02	7.0761D 06		-1.5736D 00
			-0.2705D 04	
17	2.0400D 02	7.0436D 06		-1.5464D 00
			-0.1018D 05	
18	2.1600D 02	6.9214D 06		-1.5012D 00
			-0.1805D 04	
19	2.2800D 02	6.8998D 06		-1.4395D 00
			-0.6923D 03	
20	2.4000D 02	6.8915D 06		-1.3615D 00
			-0.3670D 04	
21	2.5200D 02	6.8474D 06		-1.2673D 00
			-0.2010D 05	
22	2.6400D 02	6.6062D 06		-1.1572D 00
			-0.2980D 05	
23	2.7600D 02	6.2486D 06		-1.0340D 00
			-0.4742D 05	
24	2.8800D 02	5.6756D 06		-9.0139D-01
			-0.5767D 05	
25	3.0000D 02	4.9876D 06		-7.6063D-01
			-0.6001D 05	
26	3.1200D 02	4.2675D 06		-6.1399D-01
			-0.5941D 05	
27	3.2400D 02	3.5546D 06		-4.6365D-01
			-0.7923D 05	
28	3.3600D 02	2.6038D 06		-3.1042D-01
			-0.1031D 06	
29	3.4800D 02	1.3664D 06		-1.5541D-01
			-0.1139D 06	
30	3.6000D 02	0.0		0.0

TERMINATE

VITA

Ramachandran Lakshmikanthan

Candidate for the Degree of

Doctor of Philosophy

Thesis: A METHOD OF ANALYSIS FOR NONLINEAR DYNAMIC RESPONSE OF PRESTRESSED CONCRETE BEAMS

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