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FIRES-RC II
A COMPUTER PROGRAM FOR THE FIRE RESPONSE OF STRUCTURES-REINFORCED CONCRETE FRAMES (REVISED VERSION)

JULY 1977

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WASHINGTON, DC 20550

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FIRE RESEARCH GROUP
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(REVISED VERSION)

by

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and
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F I R E S - R C I I

A Computer Program for the
FIre REsponse of Structures -
Reinforced Concrete Frames
Second (Revised) Version

by
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ABSTRACT

FIRES-RC II is a computer program used to evaluate the structural response of reinforced concrete frames in fire environments. The report describes the analytical and material behavior models upon which FIRES-RC II is based. The thermal response associated with fire environments used for the analysis of reinforced concrete frames in FIRES-RC II is predicted by a companion computer program, FIRES-T.

A nonlinear, direct stiffness formulation coupled with time step integration is the analytical technique used in FIRES-RC II. Within a given time step, an iterative approach is used to find a deformed shape which results in equilibrium between internal stresses and external forces.

The material behavior models for concrete and steel account for dimensional changes caused by temperature differentials, changes in mechanical properties of materials with changes in temperature, degradation of sections by cracking and/or crushing, and increased rates of shrinkage and creep with an increase in temperature. Nonlinear stress-strain laws, in which inelastic deformation associated with unloading is accounted for, are used in FIRES-RC II to model concrete and steel behavior.

The report includes a user's manual for FIRES-RC II, a sample problem, and a listing of the program.

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1. INTRODUCTION

This report presents the current version of the computer program FIRES-RC II, FIre REsponse of Structures - Reinforced Concrete Frames, Second (revised) version. The program is used to evaluate the structural response of reinforced concrete framed structures in fire environments.

FIRES-RC II is a revision and extension of an earlier program, FIRES-RC [5], which was based on still earlier work on time-dependent response in reinforced concrete frames carried out at the University of California during recent years [6, 8, 27]. The most significant revisions in FIRES-RC II are the following:

1. The basic equations to be solved during each time step have been reformulated in terms of equilibrium between internal and external forces. Previous work was based on correction forces due to nonlinearity.
2. A tangent stiffness solution approach has replaced the secant stiffness approach of earlier work.
3. Frame members are discretized by beam elements in which moment varies linearly along the axis of an element. Previously, lower-order, constant moment elements were used.
4. In the redesigned storage scheme, all variables are dynamically dimensioned, eliminating the need for external storage files for all but the largest problems. These changes make FIRES-RC II two or three times less expensive to use than FIRES-RC.
5. Input data organization has been simplified and a new fully annotated Input Manual written.

Predictions of thermal response associated with fire environments from the companion program FIRES-T [4] are used directly as thermal data input for program FIRES-RC II.

The structural response analysis of reinforced concrete frames in fire environments in FIRES-RC II accounts for: (a) dimensional changes caused by temperature differentials, (b) changes in mechanical properties of materials with changes in temperature, (c) degradation of sections by cracking and/or crushing, and (d) acceleration of shrinkage and creep with

an increase in temperature. Determining the fire response of reinforced concrete structures is thus a complex nonlinear analysis problem in which the strength and stiffness of a structure as well as internal forces continually change due to restraints imposed by the structural system on free thermal expansion, shrinkage, or creep to maintain compatibility among all structural elements.

Because fire response problems are complex and the behavior associated with time-dependent thermal gradients is incremental in nature, the solution method chosen for use in FIRES-RC II is a nonlinear direct stiffness procedure coupled with time step integration. Within a given time step, an iterative approach is used to find a deformed shape resulting in equilibrium between forces associated with external loads and internal stresses.

When reinforced concrete frames are exposed to fire, concrete may crack and crush locally, and steel reinforcement may yield, resulting in degradation of strength and stiffness of members. Under some conditions, spalling of concrete exposes reinforcement to higher temperatures, further degrading strength and stiffness. Spalling is not modeled in FIRES-RC II since calculation of temperature distribution histories in FIRES-T is based on the assumption that cross-sections remain intact. Although modifications in FIRES-T and FIRES-RC II could account for spalling, it has not been explicitly included in the present version of the program since it is a special rather than general condition. Geometric nonlinearities are not considered in FIRES-RC II since the analysis is concerned with structural response history prior to development of large deformations and failure.

The main text of the report is divided into three sections dealing with (1) the analytical solution technique, (2) models of material behavior, and (3) the nature of the computer program, followed by a commentary on use of the program. The three appendices to the report include a user's manual for FIRES-RC II, a sample problem, and a listing of the program.

2. STRUCTURAL ANALYSIS MODEL

2.1 General Approach for Nonlinear Structures

FIRES-RC II was designed to determine the structural response of reinforced concrete frames to particular loading and thermal histories*. Because frames are modeled as an assemblage of members connected to joints, the basic analytical problem is to find the deformation history of the joints, $\underset{\sim}{U}(t)$, when external loading at the joints, $\underset{\sim}{R}(t)$, and temperature history within the members, $T(t)$, are specified. Since only two-dimensional frames are considered, each joint has three degrees of freedom -- two translational and one rotational. Likewise, there are two forces and a moment at each joint.

The basic equilibrium equations defining this structural system are:

$$\underset{\sim}{F}(\underset{\sim}{U}(t)) = \underset{\sim}{R}(t) \tag{2.1}$$

i.e., internal forces acting at joints, $\underset{\sim}{F}$, must equal external forces at these joints, $\underset{\sim}{R}$, at all times t. The internal forces (horizontal force, vertical force, and moment) at each joint represent the resistance to deformation contributed by each member attached to that joint, and depend on member geometry and material composition. The approach for determining internal forces within members is developed in detail in Sections 2.2 and 2.3.

The time-dependent behavior of a structure is approximated by time step integration. That is, Eq. 2.1 is solved for conditions existing at $t = 0$ $(\underset{\sim}{R}(0), T(0))$ to obtain $\underset{\sim}{U}(0) = \underset{\sim}{U}_0$. Time is then incremented by an amount Δt, and the equations resolved to obtain $\underset{\sim}{U}_1$ for loading and temperature at time t_1. The process is repeated, gradually generating a sequence of deformation states $\{\underset{\sim}{U}_0, \underset{\sim}{U}_1, \underset{\sim}{U}_2, \underset{\sim}{U}_3, \ldots\}$ approximating the response history of the frame, $\underset{\sim}{U}(t)$.

The equation to be solved for each time step i is:

---

*FIRES-RC II is currently programmed for plain or reinforced concrete structures. However, the methods are suitable for analyzing frames of any nonlinear material (structural steel, plastic, etc.) and only minor modifications would be needed to incorporate other materials into the program.

$$\underset{\sim}{F}_i(\underset{\sim}{U}_i) = \underset{\sim}{R}_i \tag{2.2}$$

If the structural behavior is linear, this equation can be solved directly since internal forces are proportional to deformation, i.e.,

$$\underset{\sim}{F}_i(\underset{\sim}{U}_i) = [\underset{\sim}{K}]\underset{\sim}{U}_i = \underset{\sim}{R}_i \tag{2.3}$$

or, solving,

$$\underset{\sim}{U}_i = [\underset{\sim}{K}]^{-1}\underset{\sim}{R}_i \tag{2.4}$$

where $[\underset{\sim}{K}]$ is the linear stiffness matrix for the frame. However, the response of reinforced concrete frames is highly nonlinear because the stress-strain laws for steel and concrete are nonlinear, and because concrete tends to crack or crush. Also, internal forces are influenced by temperature- and history-dependent factors such as creep and shrinkage. The nonlinear equations governing behavior of a structural system (Eq. 2.1) are temperature- and history-dependent, as follows:

$$\underset{\sim}{F}_i(\underset{\sim}{U}_i, T_i, H_{i-1}) = \underset{\sim}{R}_i \tag{2.5}$$

where

$\underset{\sim}{F}_i$ - internal forces at current time t_i

$\underset{\sim}{U}_i$ - current deformed shape

T_i - current temperature distribution within structure

H_{i-1} - prior response and thermal history of structure

$\underset{\sim}{R}_i$ - external loading at current time t_i

Given loading $\underset{\sim}{R}_i$, and temperature T_i, and previous response H_{i-1}, the deformed configuration $\underset{\sim}{U}_i$ satisfying Eq. 2.5 is sought. This equation is nonlinear and can be solved using any number of iterative techniques, such as the secant stiffness method used in the previous version of FIRES-RC [5]. FIRES-RC II uses a Newton-Raphsen equation-solving iterative approach, defined by the equation:

$$\underset{\sim}{U}_i^{j+1} = \underset{\sim}{U}_i^j + [\nabla\underset{\sim}{F}_i^j(\underset{\sim}{U}_i^j, T_i, H_{i-1})]^{-1}\{\underset{\sim}{R}_i - \underset{\sim}{F}_i^j(\underset{\sim}{U}_i^j, T_i, H_{i-1})\} \tag{2.6}$$

where $j = 0, 1, 2, 3, \ldots$ signifies the number of iterations. The term $\nabla \underset{\sim}{F}_i^j$ is the gradient of internal forces, $\underset{\sim}{F}_i^j$, or, in structural engineering terms, the tangent stiffness matrix for the frame in its deformed configuration $\underset{\sim}{U}_i^j$. The displacement assumed at the start of iteration, $\underset{\sim}{U}_i^0$, is taken to be $\underset{\sim}{U}_{i-1}$, the configuration of the structure at the end of the previous time step. This iteration method may be regarded as a sequence of corrections to obtain a convergent solution (i.e., one which satisfies Eq. 2.5). That is, Eq. 2.6 can be rewritten in the more convenient form:

$$\delta \underset{\sim}{U}_i^j = [\underset{\sim}{K}_i^j]^{-1} \delta \underset{\sim}{R}_i^j \tag{2.7}$$

where

$\delta \underset{\sim}{U}_i^j$ = displacement correction for time step i and iteration j

$= (\underset{\sim}{U}_i^{j+1} - \underset{\sim}{U}_i^j)$

$\underset{\sim}{K}_i^j$ = tangent stiffness for time step i and iteration j

$= \nabla \underset{\sim}{F}_i^j(\underset{\sim}{U}_i^j, T_i, H_{i-1})$

$\delta \underset{\sim}{R}_i^j$ = out-of-balance forces for time step i and iteration j

$= (\underset{\sim}{R}_i - \underset{\sim}{F}_i^j(\underset{\sim}{U}_i^j, T_i, H_{i-1}))$

The tangent stiffness iteration method is illustrated in Fig. 2.1 for time step i. Thus a complex nonlinear analysis is carried out through time step integration in the temporal domain and an iterative solution procedure using a sequence of linear analyses in the geometric domain. The overall procedure of FIRES-RC II is described below and illustrated in a flow chart (Fig. 2.2).

A time step begins with the reading of the time increment, Δt_i, and external load increment, $\Delta \underset{\sim}{R}_i$, which are added to the previous time and load values to obtain the current time, t_i, and the current load vector, $\underset{\sim}{R}_i$. The first iteration is initiated with the assumption that $\underset{\sim}{U}_i^0$, the current deformation used to calculate tangent stiffness and internal forces, is $\underset{\sim}{U}_{i-1}$, the state of the system at the end of the previous time step (see Fig. 2.1). The current tangent stiffness of the structure

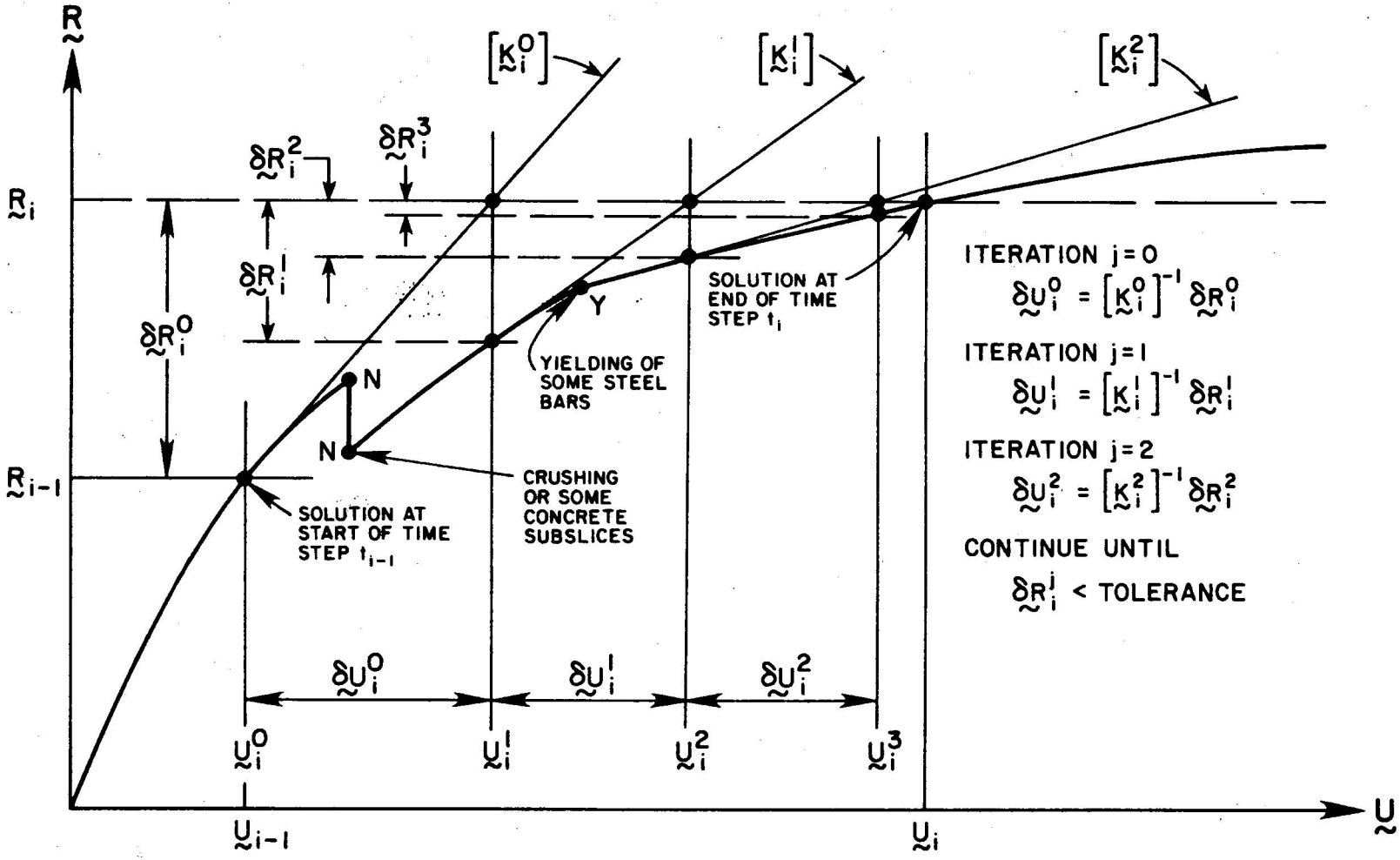


FIGURE 2.1 SOLUTION OF TIME-DEPENDENT NONLINEAR EQUILIBRIUM EQUATIONS

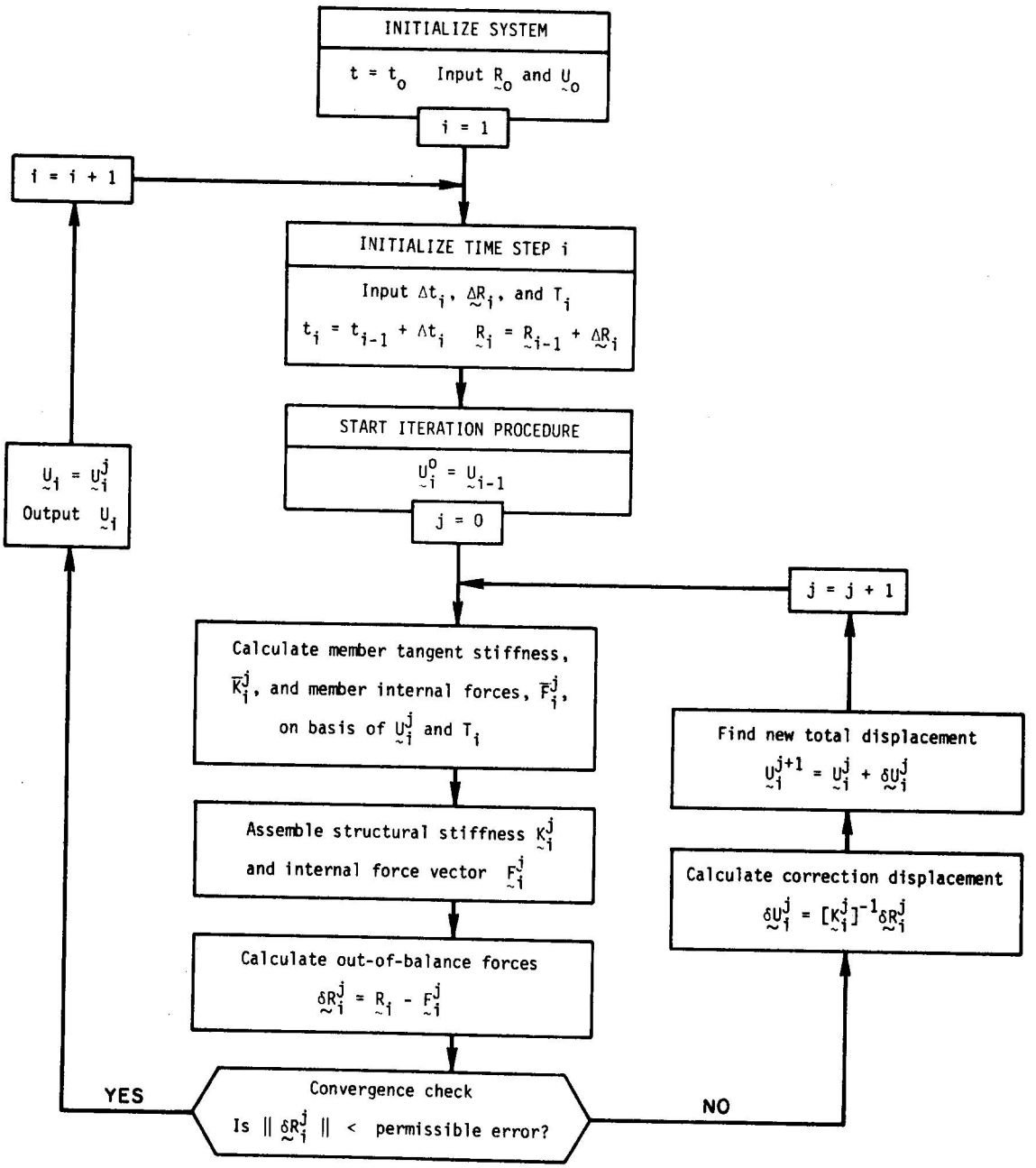


FIGURE 2.2 FLOW CHART - GENERAL SOLUTION PROCEDURE

is obtained by first extracting the deformed shape of each member, $\overline{U}_i^j$, from $\underset{\sim}{U}_i^j$, calculating each member's stiffness from its current deformed shape, $\overline{K}_i^j$, and finally by assembling member stiffnesses into the structural stiffness matrix, $\underset{\sim}{K}_i^j$. The contribution of each member to internal forces in the structure, $\overline{F}_i^j$, is calculated along with member stiffnesses and assembled into the system's internal force vector, $\underset{\sim}{F}_i^j$. At this point, out-of-balance forces are calculated:

$$\underset{\sim}{\delta R}_i^j = \underset{\sim}{R}_i - \underset{\sim}{F}_i^j \tag{2.8}$$

which is equivalent to determining if the basic equilibrium equations governing the system are satisfied (Eq. 2.5). If equilibrium is not satisfied, the current tangent stiffness and out-of-balance forces are used to calculate a correction, $\underset{\sim}{\delta U}_i^j$, to the current solution:

$$\underset{\sim}{\delta U}_i^j = [\underset{\sim}{K}_i^j]^{-1} \underset{\sim}{\delta R}_i^j \tag{2.9}$$

thereby obtaining a more accurate deformed shape:

$$\underset{\sim}{U}_i^{j+1} = \underset{\sim}{U}_i^j + \underset{\sim}{\delta U}_i^j \tag{2.10}$$

The iterative cycle is repeated, a new tangent stiffness and internal force vector based on the new deformed shape $\underset{\sim}{U}_i^{j+1}$ calculated, and the resulting out-of-balance forces rechecked. Iteration continues until equilibrium is satisfied to within a specified tolerance, i.e. until

$$|| \underset{\sim}{\delta R}_i^j || < \text{permissible error} \tag{2.11}$$

at which point the solution for the time step is considered to be complete ($\underset{\sim}{U}_i = \underset{\sim}{U}_i^j$) and calculations for the next time step begin (Fig. 2.2).

The force-deflection curve for reinforced concrete structures is discontinuous as well as nonlinear (Fig. 2.1). For example, when some steel bars yield, the slope of the curve changes abruptly (point Y on the curve in Fig. 2.1). Similarly, when some concrete subslices crush, the internal force vector (which is the resultant of internal stresses) drops

suddenly (line NN on the curve in Fig. 2.1). The simultaneous crushing of several concrete subslices results in large unbalanced forces which may delay convergence of the solution or create numerical instabilities. This problem could be mitigated by using smaller time steps.

2.2 Discretization of Frame Members

The overall system stiffness matrix of a framed structure is assembled by incorporating the stiffness contribution of each member in the frame. For a simple linear frame in which each member is modeled as a linear beam element, the member stiffness matrix is:

$$\bar{K}_{lin} = \begin{bmatrix} \frac{AE}{L} & 0 & 0 & -\frac{AE}{L} & 0 & 0 \\ & \frac{12EI}{L^3} & \frac{6EI}{L^2} & 0 & -\frac{12EI}{L^3} & \frac{6EI}{L^2} \\ & & \frac{4EI}{L} & 0 & -\frac{6EI}{L^2} & \frac{2EI}{L} \\ & & & \frac{AE}{L} & 0 & 0 \\ & & & & \frac{12EI}{L^3} & -\frac{6EI}{L^2} \\ & & & & & \frac{4EI}{L} \end{bmatrix} \qquad (2.12)$$

$$6 \times 6$$

However, this stiffness matrix is correct only for members which (1) can be modeled by simple beam theory, and (2) are composed of a linear elastic material. In a reinforced concrete frame, the first condition holds if members are of usual proportions, but the second condition is violated for virtually all loading conditions. The materials in a reinforced concrete frame are nonlinear, and detailed knowledge of the strain states existing within members is necessary in order to obtain the 6 x 6 matrix defining member stiffness. Hence, the member must be further discretized.

The basic discretization scheme used in FIRES-RC II to determine stiffness properties and internal forces is shown in Fig. 2.3. Frame

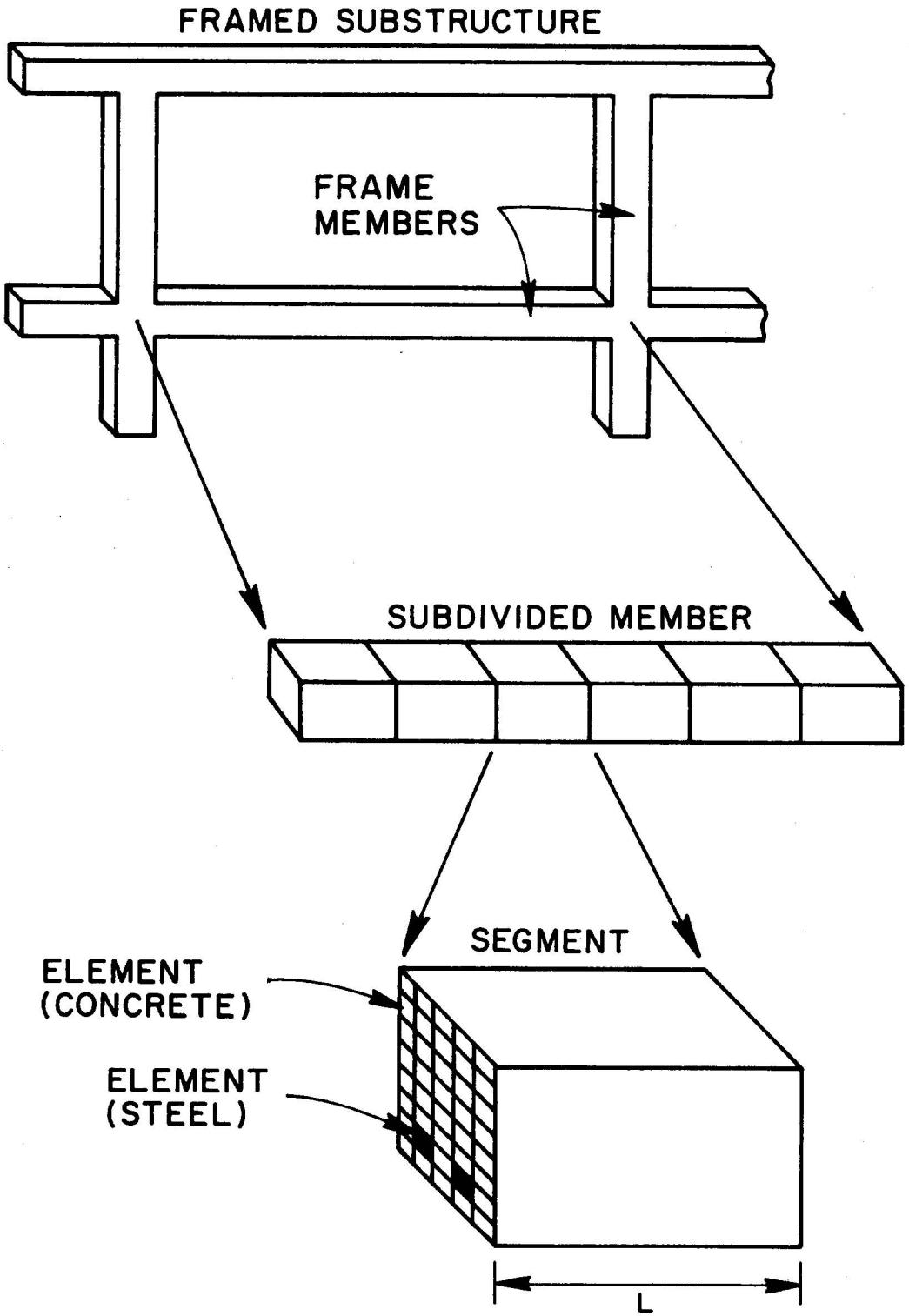


FIGURE 2.3 GEOMETRIC IDEALIZATION OF A FRAME

members are substructured into a number of segments such that by calculating segment properties, it is possible to determine overall member properties. Each segment is treated as a standard beam element in which axial force is assumed to be constant and bending moment to vary linearly along the length of a segment. However, in order to calculate section properties and internal forces and moments within a segment, it is necessary to discretize cross sections further into subslices as shown in Fig. 2.3.

The general computational procedure (covered in detail in Section 2.3) transforms member end displacements to segment end displacements and segment end displacements to strains in individual subslices. On the basis of subslice strains, the contribution from each subslice to current stiffness and internal forces and moments can be computed and integrated over a segment's cross-section to obtain average segment properties. Average segment stiffness and internal forces are then assembled for an entire substructured member and statically condensed into member properties -- i.e., the 6 x 6 stiffness matrix, $\overline{K}$, and the 6 x 1 internal force vector, $\overline{F}$.

Various levels of discretization and substructuring are necessary to form the stiffness matrix of a frame. The notation used in this report directly reflects this discretization hierarchy. For example, deformation state and stiffness in each level are expressed as follows:

$\underset{\sim}{U}$, $\underset{\sim}{K}$ - system displacement and stiffness (at joints of frame)

$\overline{U}$, $\overline{K}$ - member displacement and stiffness (at member ends)

U, K - substructured member displacement and stiffness (at intersegmental nodes)

u, k - segment displacement and stiffness (at segment ends)

ε, E - subslice strain and modulus

Notation used in the analysis for other quantities is consistent with the above.

The subslices associated with each segment can be envisioned as uniaxially loaded prisms. Therefore, only uniaxial stress states are considered, equivalent to assuming that the effect of multiaxial stress components is negligible. This type of prismatic model allows only

the effects of axial and flexural stiffness to be considered in modeling structural behavior, neglecting the effect of shear in member idealization. Local effects near member ends are not considered. However, in most structural frames, these effects are of secondary importance and principal structural action is due to flexure and axial deformation.

2.3 Computational Algorithm for Substructured Members

The computational procedure used in FIRES-RC II to form member stiffness $\overline{K}$ and internal forces $\overline{F}$ is described in this subsection. The procedure is also presented in summary form in Fig. 2.4.

In the first part of the analysis, the current deformation state of all discretized units within a member is determined for the particular time step (i) and iteration (j) under consideration. Member end deformations $\overline{U}_i^j$ are taken directly from system deformations $\underset{\sim}{U}_i^j$. Substructured member deformations U_i^j can be found from $\overline{U}_i^j$ and the substructured member stiffness matrix and load vector. However, tangent stiffness changes as deformation progresses so that U_i^j must be calculated incrementally. That is, the substructured member deformation U_i^j is updated at the beginning of each iteration using the system displacement increment from the previous iteration $\delta \underset{\sim}{U}_i^{j-1}$ (or in terms of member ends $\overline{\delta U}_i^{j-1}$), and the substructured member tangent stiffness and out-of-balance load vector K_i^{j-1} and δR_i^{j-1}. The correction displacement δU_i^{j-1} needed to update U_i^j is found by establishing the following relation within a substructured member:

$$[K_i^{j-1}]\, \delta U_i^{j-1} = \delta R_i^{j-1} \tag{2.13}$$

The matrix for the deformed shape of a substructured member is divided into three parts:

$$\delta U_i^{j-1} = \begin{bmatrix} \overline{\delta U}(I) \\ \delta U^{\text{interior}} \\ \overline{\delta U}(J) \end{bmatrix} \tag{2.14}$$

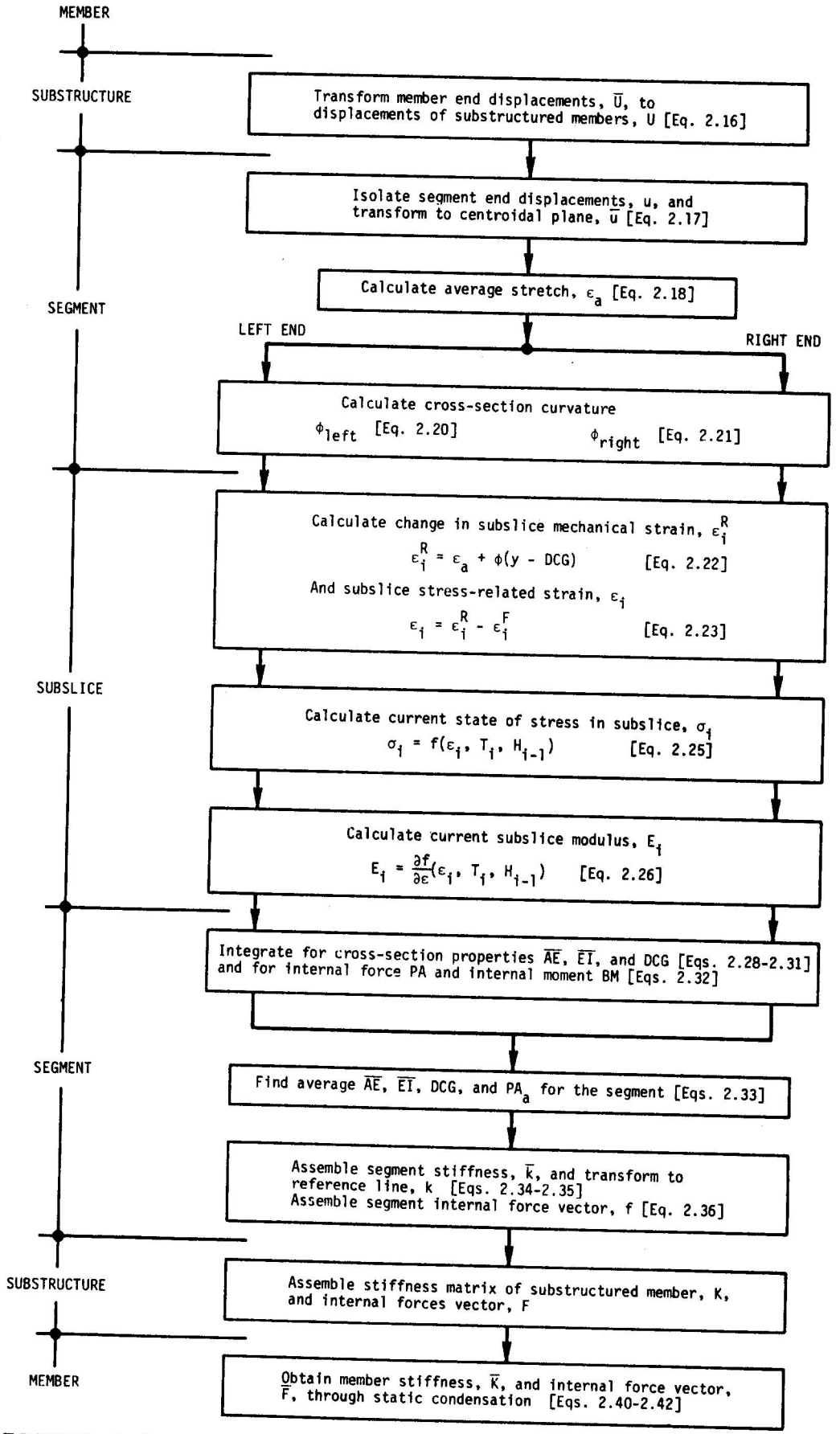


FIGURE 2.4 FLOW CHART - COMPUTATIONAL PROCEDURE FOR SUBSTRUCTURED MEMBER

where

$\overline{\delta U}(I)$ - member end deformations at node I
$\overline{\delta U}(J)$ - member end deformations at node J
} $\overline{\delta U}_i^{j-1}$

$\delta U^{interior}$ - intersegmental node deformations for interior of member

By partitioning in this manner, it is possible to rewrite Eq. 2.13 as follows:

$$\begin{bmatrix} K_{II} & K_{IS} & 0 \\ K_{SI} & K_{SS} & K_{SJ} \\ 0 & K_{JS} & K_{JJ} \end{bmatrix} \begin{bmatrix} \overline{\delta U}(I) \\ \delta U^{interior} \\ \overline{\delta U}(J) \end{bmatrix} = \begin{bmatrix} \delta R(I) \\ \delta R^{interior} \\ \delta R(J) \end{bmatrix} \tag{2.15}$$

Equation 2.15 leads to the following expression for $\delta U^{interior}$:

$$\delta U^{interior} = [K_{SS}]^{-1}(\delta R^{interior} - K_{SI}\overline{\delta U}(I) - K_{SJ}\overline{\delta U}(J)) \tag{2.16}$$

The total current substructured member deformation, U_i^j, is found by adding the correction terms $\delta U^{interior}$, $\overline{\delta U}(I)$, and $\overline{\delta U}(J)$ to U_i^{j-1}, the deformed shape during the previous iteration.

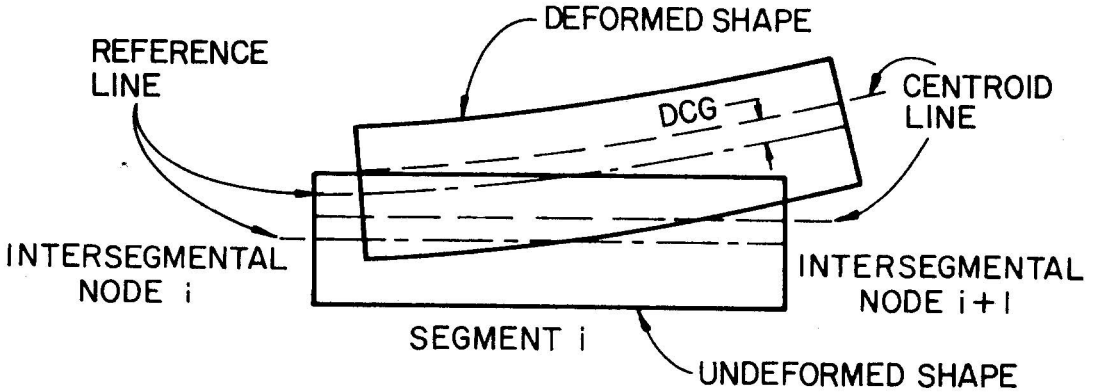
Deformations for each segment, u_i^j, are then extracted from the deformation vector of the substructured member, U_i^j. These segment deformations are measured at the reference line of the member and must be transformed to the centroid of the segment cross section in order to uncouple axial and bending effects. This transformation is illustrated in Fig. 2.5 and given by the formula:

$$\overline{u}_i^j = [e]\, u_i^j \tag{2.17}$$

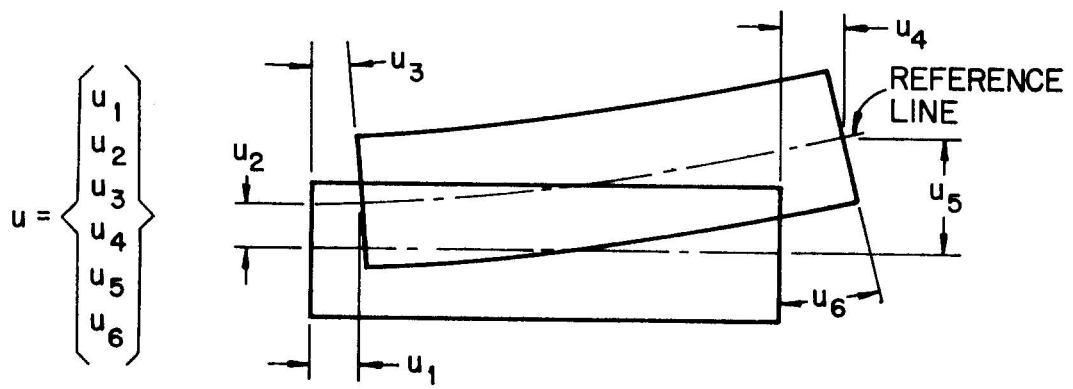
where

$\overline{u}_i^j$ - centroidal segment deformation vector {6 x 1}

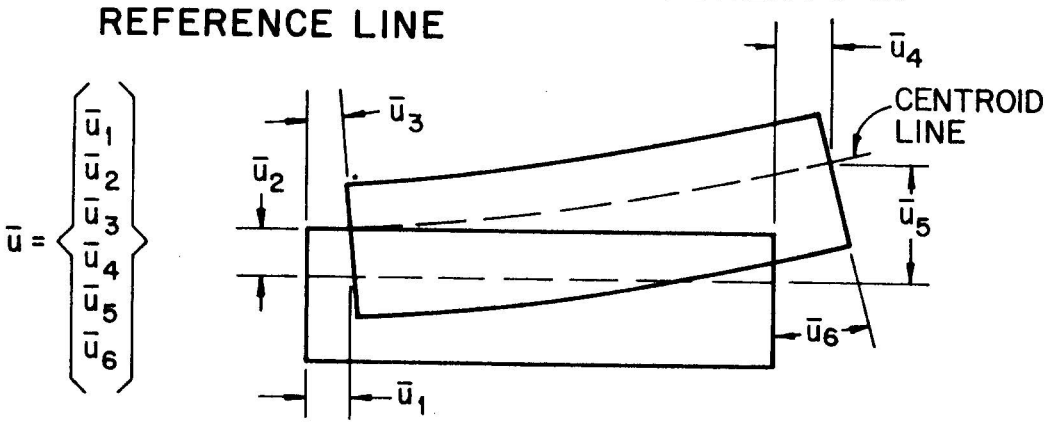
u_i^j - reference line segment deformation vector {6 x 1}



a. DEFORMATION MODE OF SEGMENT



b. DISPLACEMENT VECTOR COMPONENTS OF REFERENCE LINE



c. DISPLACEMENT VECTOR COMPONENTS OF CENTROID LINE

FIGURE 2.5 SEGMENT END DISPLACEMENTS

[e] - transformation matrix {6 x 6}

all $e_{k,j} = 0$

except

$$e_{k,k} = 1 \quad , \quad k = 1, 6$$

$$e_{1,3} = -DCG_i^{j-1}$$

$$e_{4,6} = -DCG_i^{j-1}$$

DCG_i^{j-1} - distance from reference plane to centroidal plane from previous iteration

Segment end displacements $\bar{u}_i^j$ must then be used to find axial strain and curvature within a segment. Segments are idealized as standard beam elements which assumes that the kinematic behavior of segments is governed by simple beam theory (plane sections remain plane), that cross sections are uniform over segment length, and that the material is linear. Therefore, average axial strain (i.e., strain at the centroid), ε_a, is constant along segment length, L, and curvature, ϕ, varies linearly as shown in Fig. 2.6. Using elementary beam theory, average axial strain and curvature are expressed in terms of beam end deformations as follows:

$$\varepsilon_a = \frac{\bar{u}_4 - \bar{u}_1}{L} \tag{2.18}$$

$$\begin{aligned} \phi(X) = & \left(\frac{12X}{L^3} - \frac{6}{L^2}\right) \bar{u}_2 + \left(\frac{6X}{L^2} - \frac{4}{L}\right) \bar{u}_3 \\ & + \left(\frac{6}{L^2} - \frac{12X}{L^3}\right) \bar{u}_5 + \left(\frac{6X}{L^2} - \frac{2}{L}\right) \bar{u}_6 \end{aligned} \tag{2.19}$$

The expressions for curvature at segment ends are:

$$\phi_{left} = -\frac{6}{L^2} \bar{u}_2 - \frac{4}{L} \bar{u}_3 + \frac{6}{L^2} \bar{u}_5 - \frac{2}{L} \bar{u}_6 \tag{2.20}$$

$$\phi_{right} = \frac{6}{L^2} \bar{u}_2 + \frac{2}{L} \bar{u}_3 - \frac{6}{L^2} \bar{u}_5 + \frac{4}{L} \bar{u}_6 \tag{2.21}$$

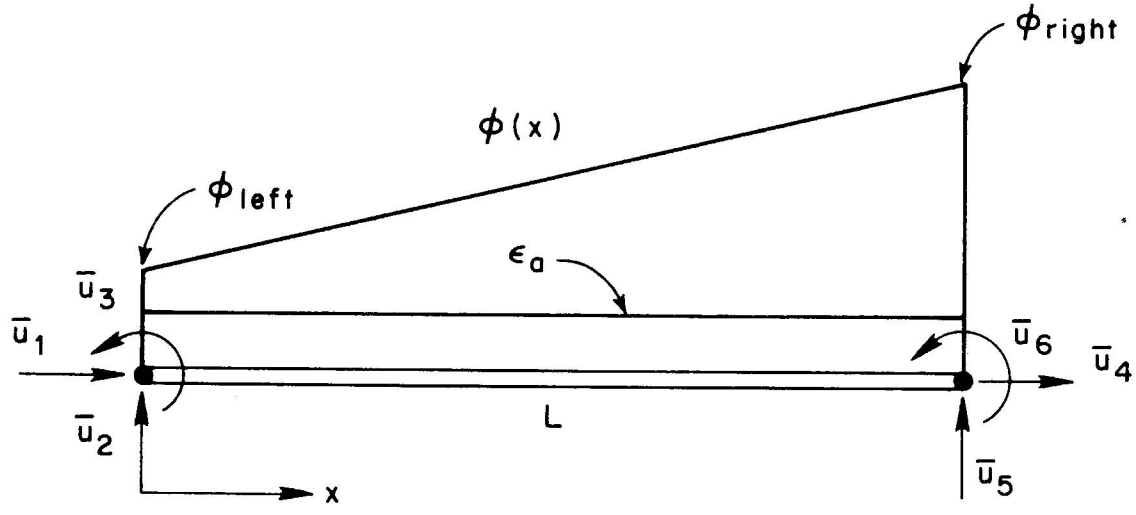


FIGURE 2.6 STRAIN AND CURVATURE IN BEAM ELEMENT

Note that in the beam elements (segments) of a reinforced concrete frame the stress-strain relationship is nonlinear and hence the moment-curvature and axial force-axial strain relationships are also nonlinear. Thus, the assumptions of linear curvature and constant axial strain over the length of the segment do not yield an exactly linear moment field or a constant axial force field (Fig. 2.7). Similarly, neither bending stiffness $(EI)_{tang}$ nor axial stiffness $(EA)_{tang}$ of a cross-section will be uniform over the length of a segment. An approximate moment field in the segment is obtained by calculating the interal moments at each end (based on $(\varepsilon_a, \phi_{right})$ and $(\varepsilon_a, \phi_{left})$) and assuming a linear distribution at interior points, as shown in Fig. 2.7. Likewise, approximate axial force, bending stiffness, and axial stiffness are obtained by averaging the internal force and stiffness states at the two ends of the segment. The error introduced by these approximations becomes negligible as the number of segments in each member increases, as shown in Fig. 2.8.

Internal axial force and bending moment at each end of a segment are found by summing the force and moment contributions of subslices discretizing the cross-section. Since strain state (ε_a, ϕ) is different at each end of the segment, subslice stresses and section forces will also differ, and the following procedure must be repeated for two cross-sections.

The mechanical strain in each subslice can be found directly from the stretch and curvature of a cross-section:

$$\varepsilon_i^{R,j} = \varepsilon_a + \phi(y - DCG) \tag{2.22}$$

where

y - distance from subslice to reference line

In order to find current stress in each subslice, ε_i^j, that part of current mechanical strain $\varepsilon_i^{R,j}$ which gives rise to stress must be determined:

$$\varepsilon_i^j = \varepsilon_i^{R,j} - \varepsilon_i^F \tag{2.23}$$

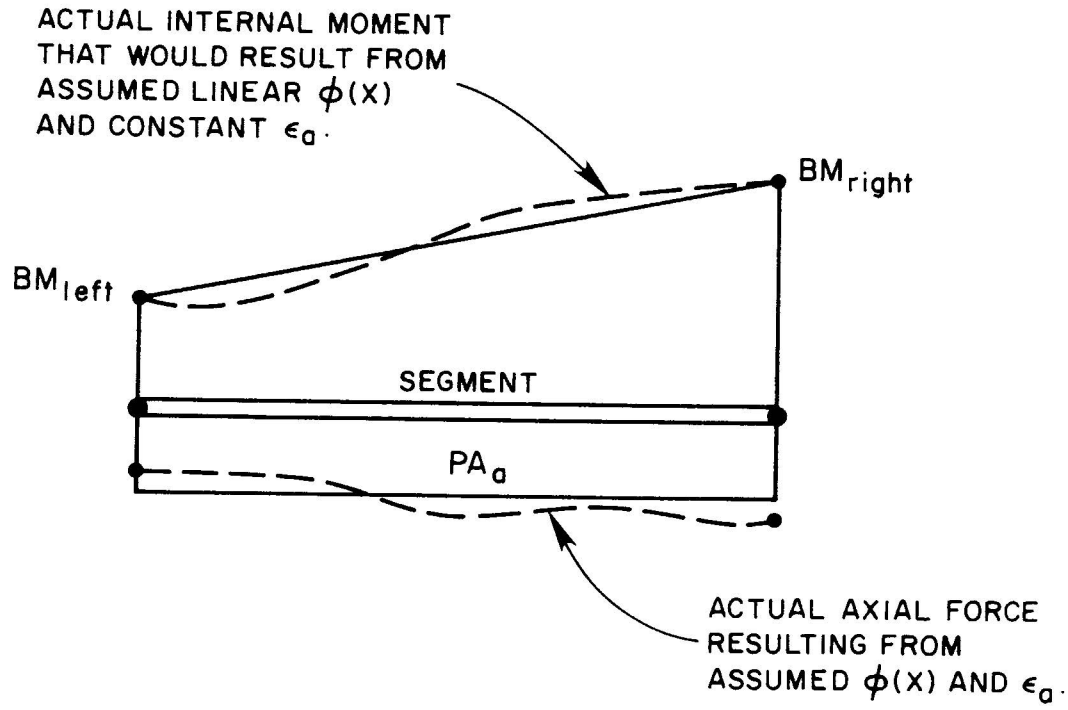


FIGURE 2.7 LINEAR-MOMENT ELEMENT

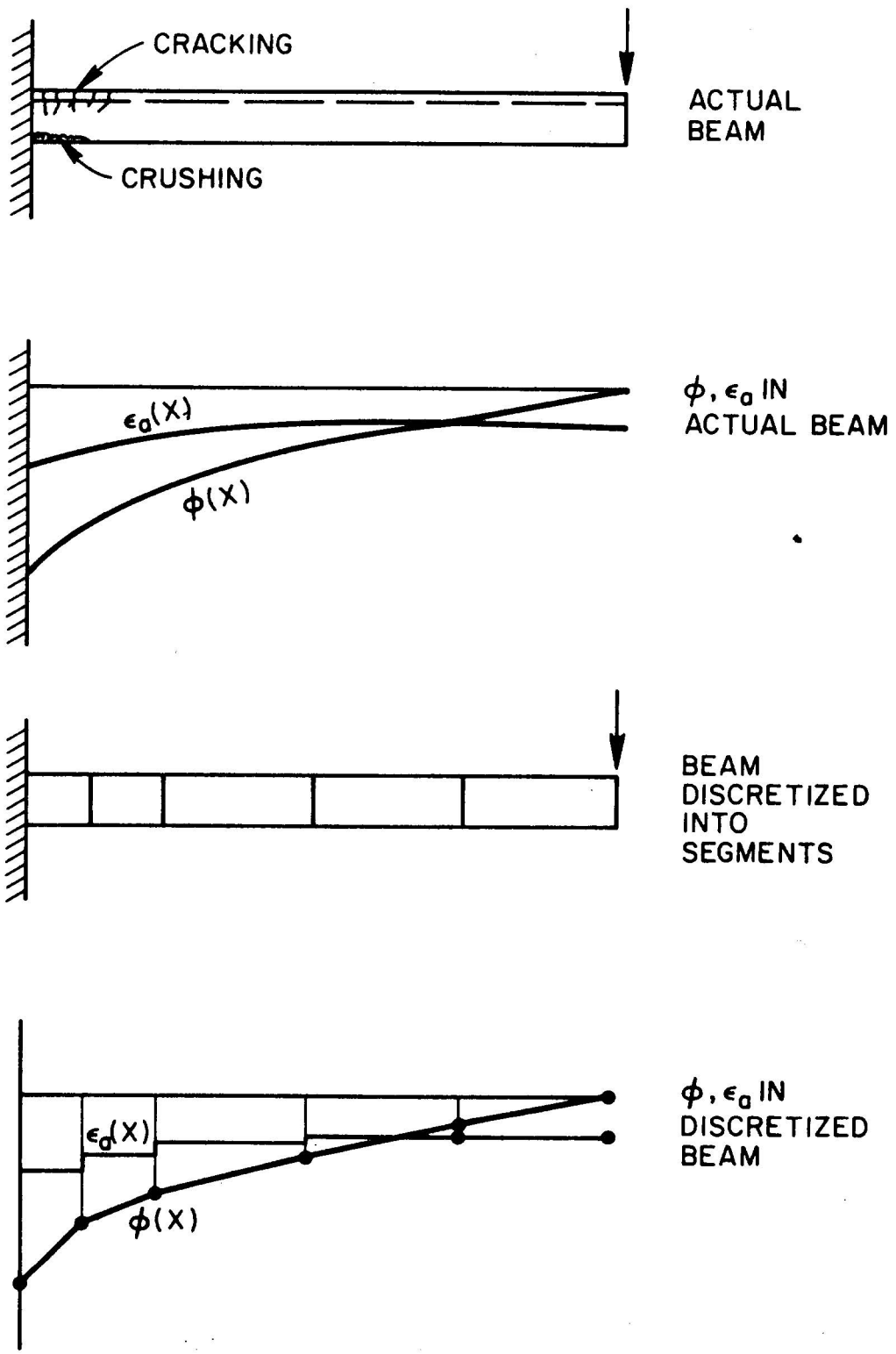


FIGURE 2.8 DEFORMATION WITHIN NONLINEAR BEAM

where

ε_i^j - stress-related strain for time step i and iteration j

$\varepsilon^{R,j}$ - total mechanical subslice strain for time step i and iteration j

ε_i^F - free strain in subslice for time step i

Free strain is defined as the strain that would occur in a subslice if it were totally free to deform when exposed to changes in temperature, to loss of moisture (shrinkage), and/or to total creep due to sustained stress. This deformation does not give rise to stress and hence is subtracted from total mechanical strain to find stress-related strain (Eq. 2.23). Free strains are determined for each subslice at the beginning of a time step and do not vary during iteration within a time step. They are calculated according to the following formulae:

$$\varepsilon_i^{F,c} = \varepsilon_{i-1}^{F,c} + \Delta\varepsilon_i^{creep,c} + \Delta\varepsilon_i^{shrinkage,c} + \Delta\varepsilon_i^{temp,c} \tag{2.24a}$$

$$\varepsilon_i^{F,s} = \varepsilon_i^{F,s} + \Delta\varepsilon_i^{creep,s} + \Delta\varepsilon_i^{temp,s} \tag{2.24b}$$

where

$\varepsilon_i^{F,c}$ - free strain for concrete subslice for time step i

$\varepsilon_i^{F,s}$ - free strain for steel subslice for time step i

$\varepsilon_{i-1}^{F,c}$ - free strain for concrete subslice for previous time step, i-1

$\varepsilon_{i-1}^{F,s}$ - free strain for steel subslice for previous time step, i-1

$\Delta\varepsilon_i^{creep}$ - free creep strain accumulated over current time step i

$\Delta\varepsilon_i^{shrink}$ - free shrinkage strain accumulated over current time step i

$\Delta\varepsilon_i^{temp}$ - free thermal expansion accumulated over current time step i

Concrete and steel creep are approximated using temperature-compensated time models. An incremental creep strain is calculated over each time step by maintaining history functions indicative of cumulative creep response. Incremental shrinkage strains are estimated assuming that they occur at a temperature-dependent rate until cumulative shrinkage equals total possible shrinkage. It is also assumed that shrinkage above 212°F is incorporated into the coefficient of expansion. The models of material behavior used in FIRES-RC II are described in Section 3 of this report.

The current level of stress in a subslice can be determined from the stress-strain law for that material:

$$\sigma_i^{c,j} = f_c(\varepsilon_i^j, T_i, H_{i-1}) \tag{2.25a}$$

$$\sigma_i^{s,j} = f_s(\varepsilon_i^j, T_i, H_{i-1}) \tag{2.25b}$$

A typical stress-strain curve (for concrete) is shown in Fig. 2.9. This curve is temperature-dependent and also models concrete cracking and crushing. Stress in a subslice is zero if a specified crushing limit has been exceeded. The argument H_{i-1} is included since subslice stress also depends on loading history; a different stress-strain curve for unloading or for crack closing is included in the functions f_c and f_s. Material models are discussed in more detail in Section 3.

Once the current state of strain is known, the current tangent modulus for each subslice can be determined, corresponding to the tangent of the stress-strain curve f at the point ε_i^j (see Fig. 2.9):

$$E_i^j = \frac{\partial f}{\partial \varepsilon}(\varepsilon_i^j, T_i, H_{i-1}) \tag{2.26}$$

If a subslice has crushed or cracked, the modulus is set equal to zero. This derivative is calculated by finite differences:

$$E_i^j = \frac{f((\varepsilon_i^j+0.00005), T_i, H_{i-1}) - f((\varepsilon_i^j-0.00005), T_i, H_{i-1})}{0.0001} \tag{2.27}$$

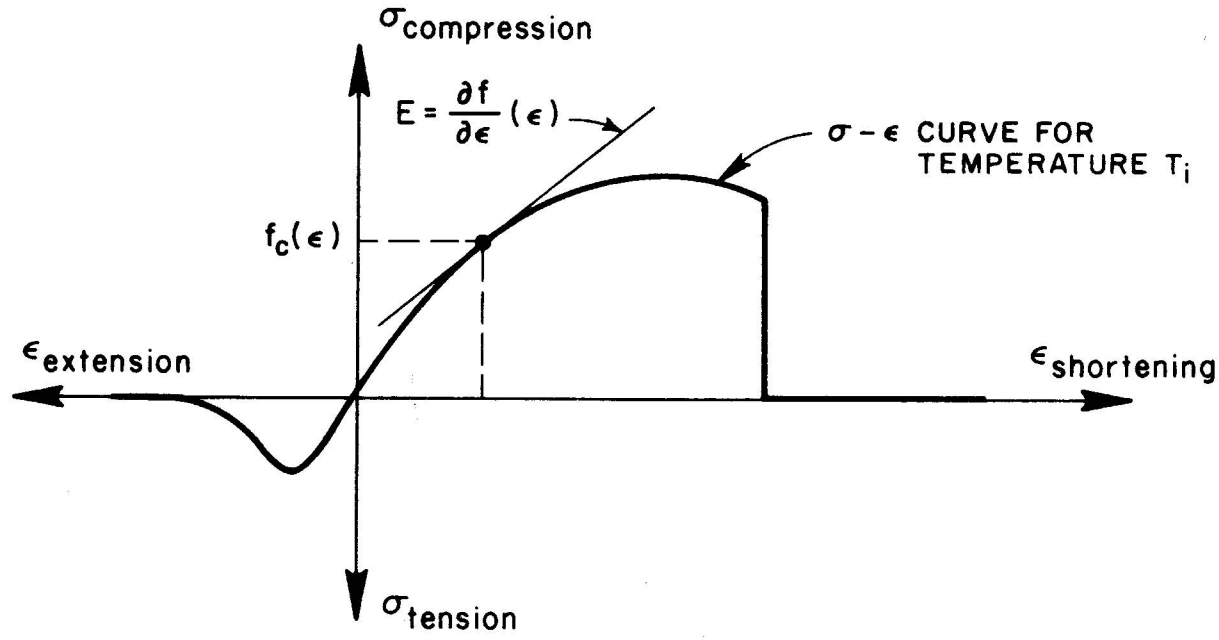


FIGURE 2.9 TYPICAL STRESS-STRAIN CURVE

The overall properties of a cross section are found by summing over all k subslices, i.e.,

$$AE = \sum_k A_k E_k \tag{2.28a}$$

$$EI = \sum_k A_k E_k Y_k^2 \tag{2.28b}$$

$$EQ = \sum_k A_k E_k Y_k \tag{2.28c}$$

where

AE - effective axial stiffness

EI - effective bending stiffness about reference line

EQ - effective first moment about reference line

A_k - area of subslice k

E_k - tangent modulus of subslice k

Y_k - distance from subslice k to reference line

The centroid location, DCG_i^j, is then

$$DCG_i^j = \frac{EQ}{AE} \tag{2.29}$$

Bending stiffness about the centroidal plane is found by the transformation:

$$\overline{EI} = EI - AE \cdot DCG^2 \tag{2.30}$$

and the axial stiffness is simply

$$\overline{AE} = AE \tag{2.31}$$

Likewise, total force and moment in each cross section are found by summing the contribution of each subslice k:

$$PA = \sum_k \sigma_k A_k \tag{2.32a}$$

$$BM = \sum_k \sigma_k Y_k A_k \tag{2.32b}$$

As discussed previously, the beam segment model used to discretize members assumes averaged section properties and axial force. These are found by:

$$\overline{AE} = (\overline{AE}_{left} + \overline{AE}_{right})/2 \tag{2.33a}$$

$$\overline{EI} = (\overline{EI}_{left} + \overline{EI}_{right})/2 \tag{2.33b}$$

$$DCG = (DCG_{left} + DCG_{right})/2 \tag{2.33c}$$

$$PA_a = (PA_{left} + PA_{right})/2 \tag{2.33d}$$

Internal bending moment is linear in segments and is not averaged.

From the averaged segment properties (Eqs. 2.33a-d), the segment stiffness matrix is formed:

$$\bar{k}_i^j = \begin{bmatrix} \frac{\overline{AE}}{L} & 0 & 0 & -\frac{\overline{AE}}{L} & 0 & 0 \\ & \frac{12\overline{EI}}{L^3} & \frac{6\overline{EI}}{L^2} & 0 & -\frac{12\overline{EI}}{L^3} & \frac{6\overline{EI}}{L^2} \\ & & \frac{4\overline{EI}}{L} & 0 & -\frac{6\overline{EI}}{L^2} & \frac{2\overline{EI}}{L} \\ & & & \frac{\overline{AE}}{L} & 0 & 0 \\ & & & & \frac{12\overline{EI}}{L^3} & -\frac{6\overline{EI}}{L^2} \\ & & & & & \frac{4\overline{EI}}{L} \end{bmatrix} \tag{2.34}$$

where L is segment length. This stiffness matrix is formulated about the centroidal plane (to uncouple axial and bending stiffness) and must now be transformed back to the reference plane of the substructured member. The transformation matrix $[e]$ (see Eq. 2.17) is reformed with the new DCG (Eq. 2.29) and the transformation effected by the formula:

$$k_i^j = [e]^T \bar{k}_i^j [e] \tag{2.35}$$

The internal force vector for a segment is formed as follows:

$$f_i^j = \begin{Bmatrix} -PA_a \\ V_a \\ -BM_{left} \\ PA_a \\ V_a \\ BM_{right} \end{Bmatrix} \tag{2.36}$$

where average segment shear, V_a, is derived from statics

$$V_a = \frac{BM_{left} - BM_{right}}{L} \tag{2.37}$$

This force f_i^j represents the internal force contributed by a segment to its adjacent intersegmental nodes. These segment forces can be assembled into the current internal force vector of the substructured member, F_i^j. Likewise, the segment stiffness matrices (Eq. 2.35) can be assembled into the current stiffness matrix for the substructured member, K_i^j. Both K_i^j and F_i^j must then be statically condensed to member terms. That is, the matrices and forces for the substructured member,

$$K_i^j = \begin{bmatrix} K_{II} & K_{IS} & \\ K_{SI} & K_{SS} & K_{SJ} \\ & K_{JS} & K_{JJ} \end{bmatrix} \tag{2.38}$$

$$F_i^j = \begin{Bmatrix} F_I \\ F_S \\ F_j \end{Bmatrix} \tag{2.39}$$

are condensed to member stiffness,

$$\overline{K}_i^j = \begin{bmatrix} \overline{K}_{II} & \overline{K}_{IJ} \\ \overline{K}_{JI} & \overline{K}_{JJ} \end{bmatrix} \tag{2.40}$$

and member internal force vector

$$\overline{F}_i^j = \begin{Bmatrix} \overline{F}_I \\ \overline{F}_J \end{Bmatrix} \tag{2.41}$$

by the following expressions:

$$\begin{aligned}
\overline{K}_{II} &= K_{II} - K_{IS}[K_{SS}]^{-1} K_{SI} \\
\overline{K}_{IJ} &= K_{IS}[K_{SS}]^{-1} K_{SJ} \\
\overline{K}_{JJ} &= K_{JJ} - K_{JS}[K_{SS}]^{-1} K_{SJ} \\
\overline{K}_{JI} &= [\overline{K}_{IJ}]^T \\
\overline{F}_I &= F_I - K_{IS}[K_{SS}]^{-1} F_S \\
\overline{F}_J &= F_J - K_{JS}[K_{SS}]^{-1} F_S
\end{aligned} \tag{2.42}$$

This static condensation of the properties of the substructured member into effective member stiffness $\overline{K}_i^j$ and internal forces $\overline{F}_i^j$ completes the formation of necessary member properties.

3. MATERIAL BEHAVIOR MODELS

The models of material behavior used in FIRES-RC II have, whenever possible, been based on experimental data. However, these data are generally insufficient for precisely formulating or verifying these models. Therefore, models of material behavior used here provide only a first order approximation of the relationships between strain, stress, temperature, and time. All models assume a uniaxial state of stress which is, except when noted, positive for extension and negative for contraction. It is believed that the assumed models of material behavior can provide a reasonably accurate basis for evaluating structural response. Analyses based on these models were compared to experimental data [20] and good correspondence between computed and measured behavior was obtained.

3.1 Temperature Dependence of Material Parameters

Many parameters used to describe material behavior in FIRES-RC II are temperature-dependent. These temperature-dependent functions are represented in FIRES-RC II as linearly segmented curves (see Fig. 3.1). A temperature-dependent material parameter is represented by a series of points and connecting lines in a space in which the y-axis is the material property value and the x-axis temperature. The value of a material property f for a given temperature T_i is calculated by the following expression:

$$f(T_i) = f(T_n) + (T_i - T_n)S_n \tag{3.1}$$

where

$T_n \leq T_i \leq T_{n+1}$

S_n - slope between points n and $n + 1$

The value of a temperature-dependent material property is calculated in the computer program by the function VMATL, such that

$$f_J(T) = \text{VMATL}(J,T)$$

where

J - material property number

T - temperature of subslice

3.2 Stress-Strain Laws

The instantaneous, nonlinear, inelastic (path-dependent), and temperature-dependent stress-strain relationships for concrete and steel used in FIRES-RC II are discussed in this section. These relationships contain history functions which account for instantaneous inelastic deformation. The history functions are based on a continual reconstruction of the stress-strain diagram on the basis of permanent inelastic strain, ε_0, in a subslice at the end of the previous time step.

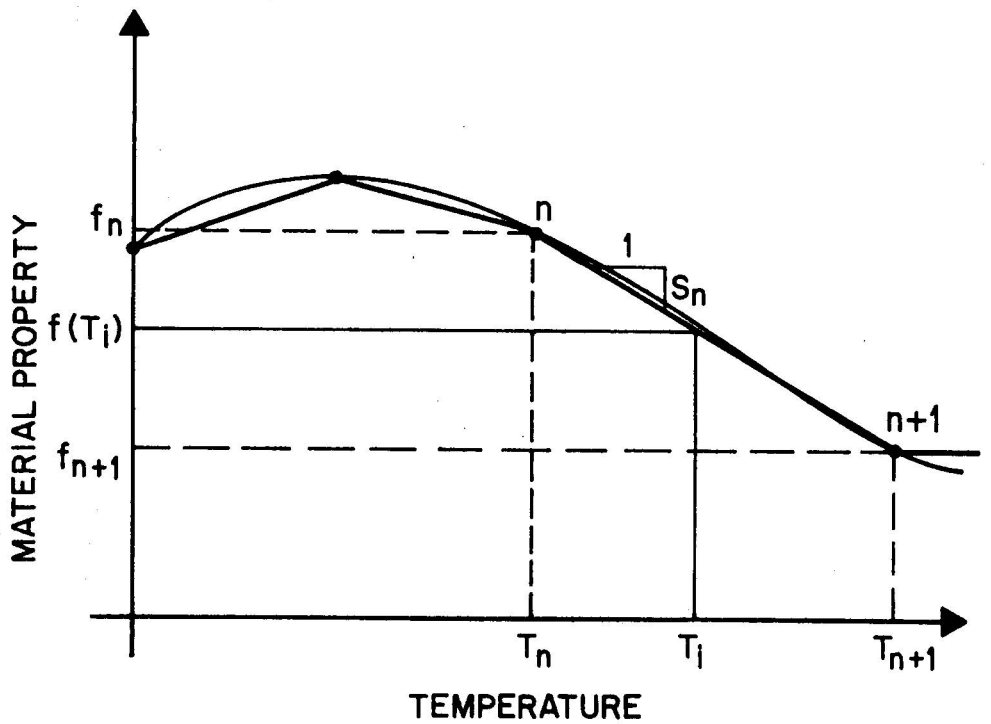


FIGURE 3.1 LINEAR SEGMENTED IDEALIZATION OF A TEMPERATURE-DEPENDENT MATERIAL PROPERTY

3.2.1 Stress-Strain Law for Concrete

A typical stress-strain curve for concrete under uniaxial loading is shown in Fig. 3.2. The curve consists of two parts: a compressive part and a tensile part. The models used for these two parts are discussed below.

3.2.1.1 Compression - Because internal microcracks develop at the interface between cement paste and aggregate, the stress-strain curve for concrete in compression is nonlinear. The theory of internal microcracking [18, 19, 20] qualitatively describes the stress-strain relationship. Only approximate empirical formulae are available to describe the relationship quantitatively. In general, the parameters characterizing such formulae are determined by curve-fitting, so that a given formula fits experimental results.

Most standard mathematical curves for the stress-strain relationship -- including, directly or indirectly, the more important parameters -- have been investigated for this study, e.g. a parabola, hyperbola, ellipse, cubic parabola, and sine and exponential curves. However, the formula chosen for this study is the one proposed by Saenz [25] which is easy to apply and fits experimental data well for both ascending and descending branches of concrete stress-strain curve. Saenz's formula incorporates several parameters -- modulus of elasticity, E_c; maximum compressive strength, f'_c, and strain at compressive strength, ε_f; ultimate stress, σ_u, and ultimate crushing strain, ε_u -- and takes the following form:

$$\sigma = \frac{E_c \varepsilon}{A + B\varepsilon + C\varepsilon^2 + D^3}$$

where A, B, C, and D are coefficients to be found.

The conditions to be satisfied are (see Fig. 3.2):

1. For $\varepsilon = 0$, $\sigma = 0$, or point of origin. This condition is satisfied trivially.
2. For $\varepsilon = 0$, $\frac{d\sigma}{d\varepsilon} = E_c$, or value of Young's modulus.

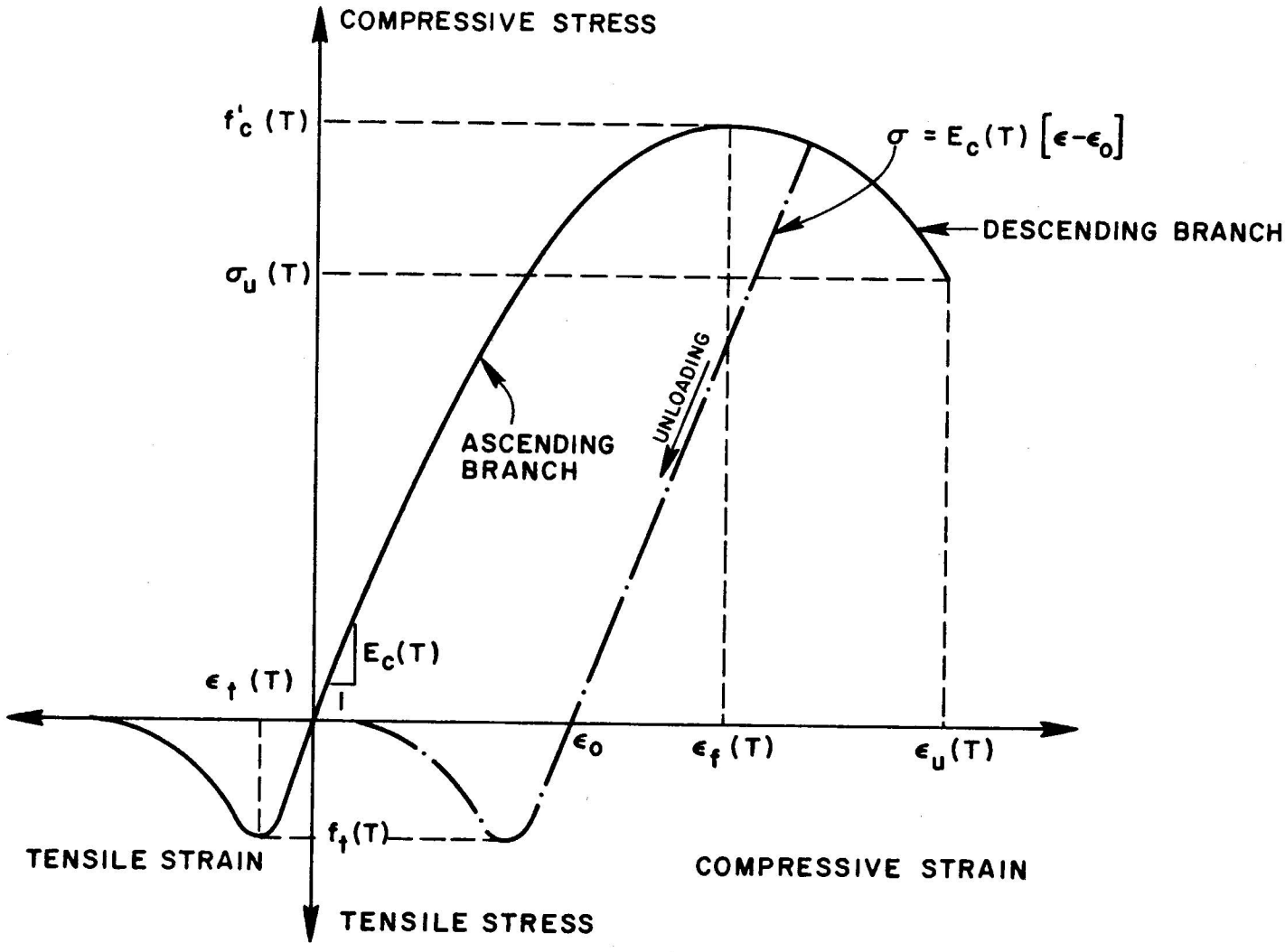


FIGURE 3.2 TYPICAL STRESS-STRAIN CURVE FOR CONCRETE AT TEMPERATURE T

3. For $\varepsilon = \varepsilon_f$, $\sigma = f'_c$, or point of maximum stress.

4. For $\varepsilon = \varepsilon_f$, $\frac{d\sigma}{d\varepsilon} = 0$, or maximum of the curve.

5. For $\varepsilon = \varepsilon_u$, $\sigma = \sigma_u$, or point of maximum strain.

The following values for these coefficients are easily obtained:

$$A = 1$$

$$B = \left(\frac{R_E + R - 2}{R_E\ f'_c}\right)E_c$$

$$C = -\frac{(2R - 1)E_c}{R_E\ f'_c\ \varepsilon_f}$$

$$D = \frac{R\ E_c}{R_E\ f'_c\ \varepsilon_f^2}$$

where

$R_E = \frac{E_c}{E_f}$ is the modular ratio

$E_f = \frac{f'_c}{\varepsilon_f}$ is the secant modulus at f'_c

$$R = \left[\frac{R_E(R_\sigma - 1)}{(R_\varepsilon - 1)^2} - \frac{1}{R_\varepsilon}\right]$$

$R_\sigma = \frac{f'_c}{\sigma_u}$ is the stress ratio

$R_\varepsilon = \frac{\varepsilon_u}{\varepsilon_f}$ is the strain ratio

Differentiation of Eq. 3.2 with respect to strain ε results in the following expression for the tangent modulus at strain ε for uniaxial compression:

$$E = \frac{(A - C\varepsilon^2 - 2D\varepsilon^2) \cdot E_c}{(A + B + C\varepsilon^2 + D\varepsilon^3)^2} \tag{3.3}$$

Equation 3.2 fits the descending branch of experimentally obtained curves, but deviates slightly from the ascending branch. However, by setting R equal to zero, Eq. 3.2 reduces to the quadratic form of Saenz's equation, given by:

$$\sigma = \frac{E_c \varepsilon}{A + B\varepsilon + C\varepsilon^2} \tag{3.4}$$

Equation 3.4 fits the ascending branch very well, but not the descending branch. Therefore, R will be used in Eq. 3.2 with the following values:

$$R = 0 \quad , \quad \text{for } \varepsilon < \varepsilon_f \quad \text{(ascending branch)}$$

$$R = \left[\frac{R_E(R_\sigma - 1)}{(R_\varepsilon - 1)^2} - \frac{1}{R_\varepsilon} \right] \quad , \quad \text{for } \varepsilon < \varepsilon \quad \text{(descending branch)}$$

The concept of using two values for R in Saenz's equation (Eq. 3.2) was proposed by Bresler [7].

The permanent inelastic strain, ε_0, during time step i is calculated on the basis of the stress and strain at the end of the previous time step i-1.

$$\varepsilon_0 = \varepsilon_{i-1} - \frac{\sigma_{i-1}}{E_c} \tag{3.5}$$

The computational algorithm within the iteration then proceeds by calculating two stresses, one based on the stress-strain relationship (Eq. 3.2) and the other on Eq. 3.6, given below:

$$\sigma = E_c(\varepsilon - \varepsilon_0) \tag{3.6}$$

The algebraically greater of these stresses is then assumed as the current state of stress.

The computer function implementing the model for the stress-strain relationship of concrete in compression is STR such that:

$$\sigma^c = \text{STR(E, EC, FC, EFC, FU, EFU, EO)}$$

where

σ^c - stress in concrete

E - strain in concrete

EC - modulus of elasticity, E_c; temperature-dependent

FC - compressive strength, f'_c; temperature-dependent

EFC - strain at compressive strength, ε_f; temperature-dependent

FU - ultimate stress, σ_u; temperature-dependent

EFU - ultimate (crushing) strain, ε_u; temperature-dependent

EO - permanent plastic deformation, ε_0

3.2.1.2 Tension - Figure 3.3 shows a reinforced concrete element under uniaxial tension. When concrete reaches ultimate tensile strain, primary cracks form at finite intervals along the length of an element. Total load is transferred across these cracks by reinforcement. However, concrete between cracks is still capable of carrying stress due to bond between concrete and steel. This phenomenon is called the tensioning-stiffening effect. Thus, although concrete stress at cracks is zero, it is not zero if averaged over the length of a member. As load increases, more cracks form and the amount of tension carried by concrete progressively decreases. Therefore, the average concrete stress-strain curve for reinforced concrete elements may be considered to have a descending branch extending beyond ultimate tensile strength for plain concrete (Fig. 3.4). The concept of working with average stress and strain over a relatively long gauge length to account for the tensioning-stiffening effect was used by Scanlon in Ref. 26.

The literature indicates that in general the stress-strain curve for concrete in tension at room temperature follows more or less a straight line with a slope equal to Young's modulus of elasticity for concrete (Young's modulus for concrete is identical in tension and compression) up to tensile strength f_t. After that, the curve has a descending branch whose length and slope depend on material characteristics of concrete.

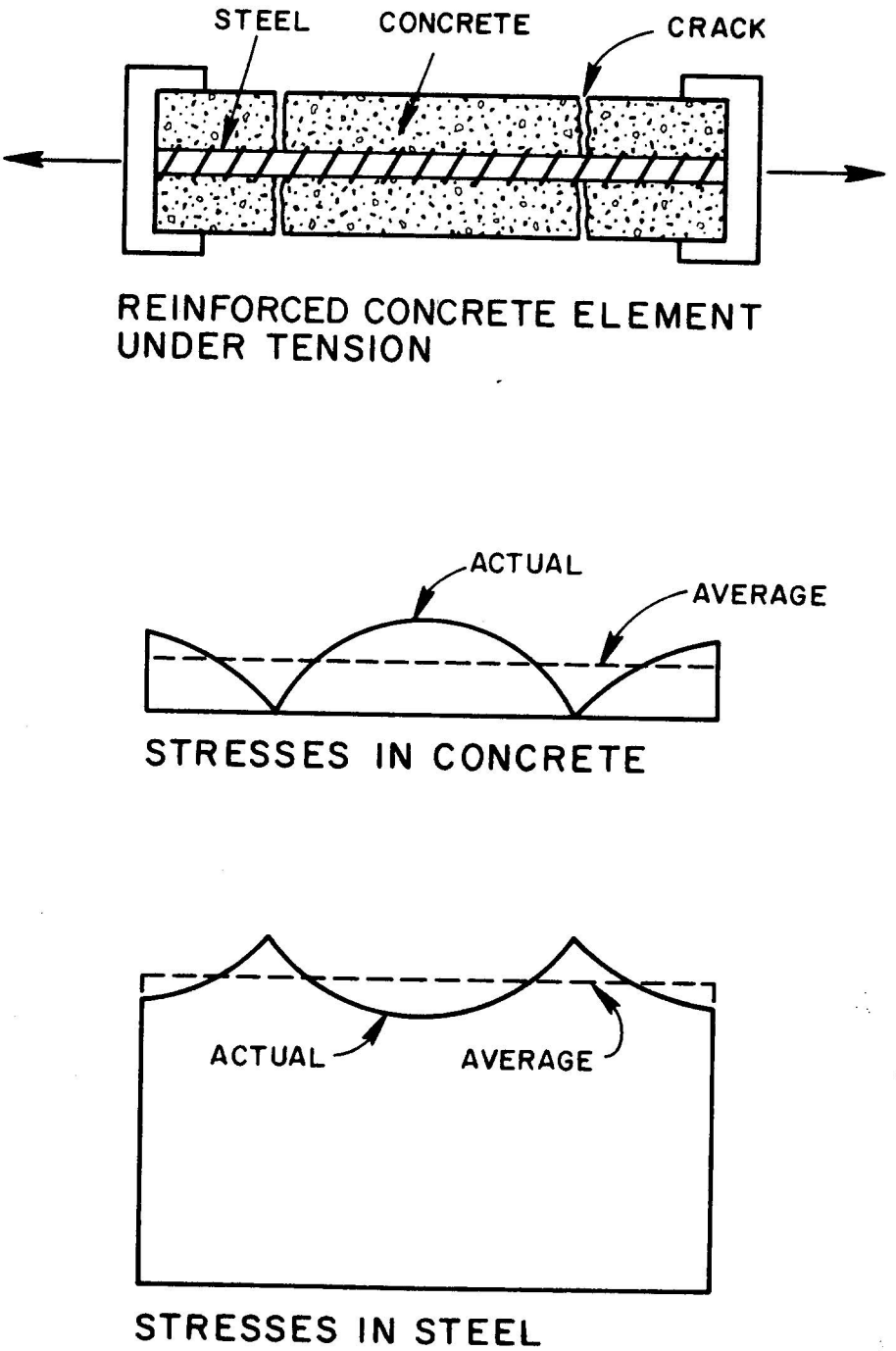


FIGURE 3.3 ACTUAL AND AVERAGE STRESS DISTRIBUTIONS IN A CRACKED REINFORCED CONCRETE ELEMENT

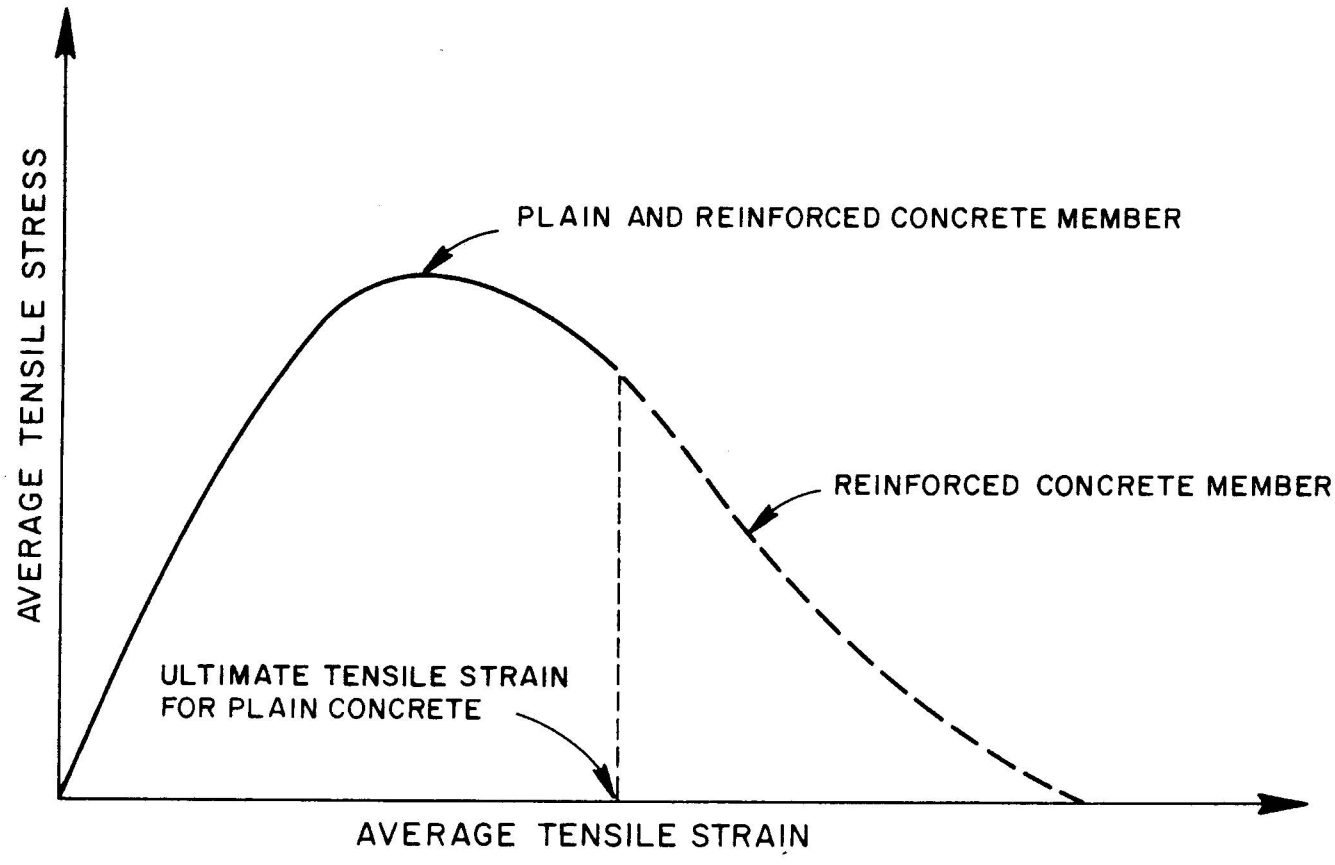


FIGURE 3.4 AVERAGE STRESS - AVERAGE STRAIN RELATIONSHIP FOR CONCRETE UNDER UNIAXIAL TENSION

Due to a lack of data on the shape of the stress-strain curve for concrete in tension at high temperatures, a first order approximation is used. Thus, it will be assumed that the shape of the curve at high temperatures is similar to that at room temperature. A general model for this curve as a function of temperature T is proposed as shown in Fig. 3.5(a).

The curve shown in Fig. 3.5(a) consists of two parts. The first part is a straight line with a slope equal to $E_c(T)$ up to tensile strength $f_t(T)$. The second part is a nonlinear curve defined by specifying pairs of stress ratios, $\sigma_i/f_t(T)$, and strain ratios, $\varepsilon_i/\varepsilon_t(T)$, to fit a polynomial of the form:

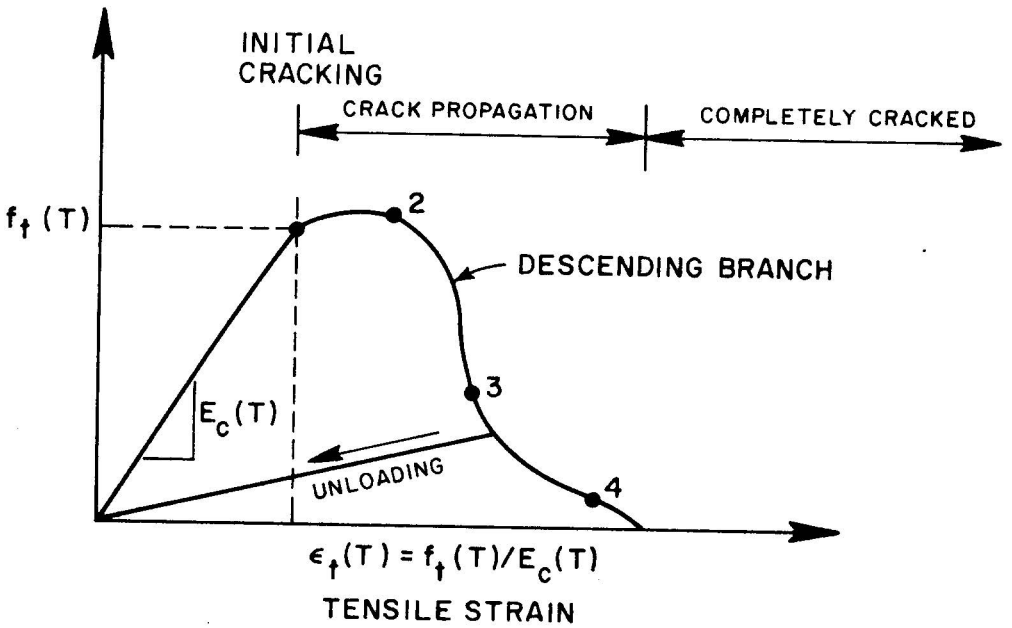
$$\frac{\sigma}{f_t(T)} = a_1 + a_2 \frac{\varepsilon}{\varepsilon_t(T)} + a_3\left(\frac{\varepsilon}{\varepsilon_t(T)}\right)^2 + a_4\left(\frac{\varepsilon}{\varepsilon_t(T)}\right)^3 + \cdots \tag{3.7}$$

In FIRES-RC II, up to four points (four pairs of stress and strain ratios) can be specified for this polynomial. With two specified data points, the polynomial defines a straight line, with three points a parabola, and with four a cubic curve.

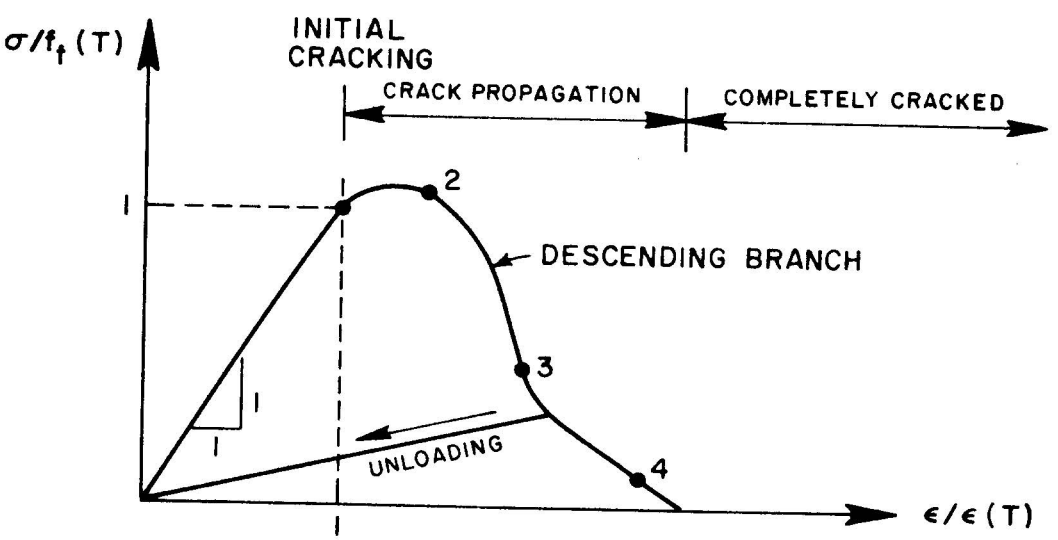
Furthermore, it is assumed that the stress and strain ratios are identical at all temperatures, simplifying input to the computer and reducing computational effort. The shape of the stress-strain curve in tension thus remains the same at all temperatures as illustrated by the curve plotted in nondimensional form in Fig. 3.5(b).

A mathematical procedure is used to pass the polynomial curve through given stress-strain points. The coefficients $a_1 \ldots, a_n$ (n = 2 to 4) are determined as follows:

$$\begin{Bmatrix} \frac{\sigma_1}{f_t(T)} \\ \cdot \\ \cdot \\ \frac{\sigma_n}{f_t(T)} \end{Bmatrix} = \begin{bmatrix} 1 & \frac{\varepsilon_1}{\varepsilon_t(T)} & \cdot & \cdot & \left(\frac{\varepsilon_1}{\varepsilon_t(T)}\right)^n \\ \cdot & & & & \\ \cdot & & & & \\ 1 & \frac{\varepsilon_n}{\varepsilon_t(T)} & \cdot & \cdot & \left(\frac{\varepsilon_n}{\varepsilon_t(T)}\right)^n \end{bmatrix} \begin{Bmatrix} a_1 \\ \cdot \\ \cdot \\ a_n \end{Bmatrix} \tag{3.8a}$$



(a) STRESS-STRAIN CURVE FOR CONCRETE IN TENSION AS A FUNCTION OF TEMPERATURE



(b) STRESS-STRAIN CURVE FOR CONCRETE IN TENSION IN NONDIMENSIONAL FROM

FIGURE 3.5 GENERAL MODEL FOR STRESS-STRAIN CURVE OF CONCRETE IN TENSION

or symbolically

$$\underset{n \times 1}{\{\sigma_i\}} = \underset{n \times n}{[\varepsilon_i]} \; \underset{n \times 1}{\{a_i\}} \tag{3.8b}$$

This matrix equation is solved for the coefficients $\{a_i\}$:

$$\underset{n \times 1}{\{a_i\}} = \underset{n \times n}{[\varepsilon_i]^{-1}} \; \underset{n \times 1}{\{\sigma_i\}} \tag{3.8c}$$

where $[\varepsilon_i]^{-1}$ is the inverse of matrix $[\varepsilon_i]$. The coefficients $\{a_i\}$ are evaluated once and then used in Eq. 3.7 for all temperatures.

Finally, there are no data in the literature on the behavior of concrete in tension upon loading. Therefore, a simple model for unloading is proposed as shown in Fig. 3.5.

3.2.2 Stress-Strain Law for Reinforcing Steel

The stress-strain law for reinforcing steel is based on a stress-strain envelope determined by the modulus of elasticity, yield stress, and strain-hardening modulus. The envelope is shown in Fig. 3.6 and can be constructed from three parameters: $E_s(T)$ (modulus of elasticity of steel), $f_y(T)$ (yield strength), or $\varepsilon_y(T)$ (yield strain), and E^* (strain-hardening modulus).

By extending yield plateaus throughout the strain range, an envelope is bounded by the two resulting parallel lines. The equations for these lines are:

a. upper bound - $\sigma_u = f_y + E^*(\varepsilon - \varepsilon_y)$ (3.9)

b. lower bound - $\sigma_\ell = -f_y + E^*(\varepsilon + \varepsilon_y)$ (3.10)

A third line (Eq. 3.11) is defined as intercepting the strain axis at the point of permanent inelastic strain, ε_0, with a slope equal to the modulus of elasticity.

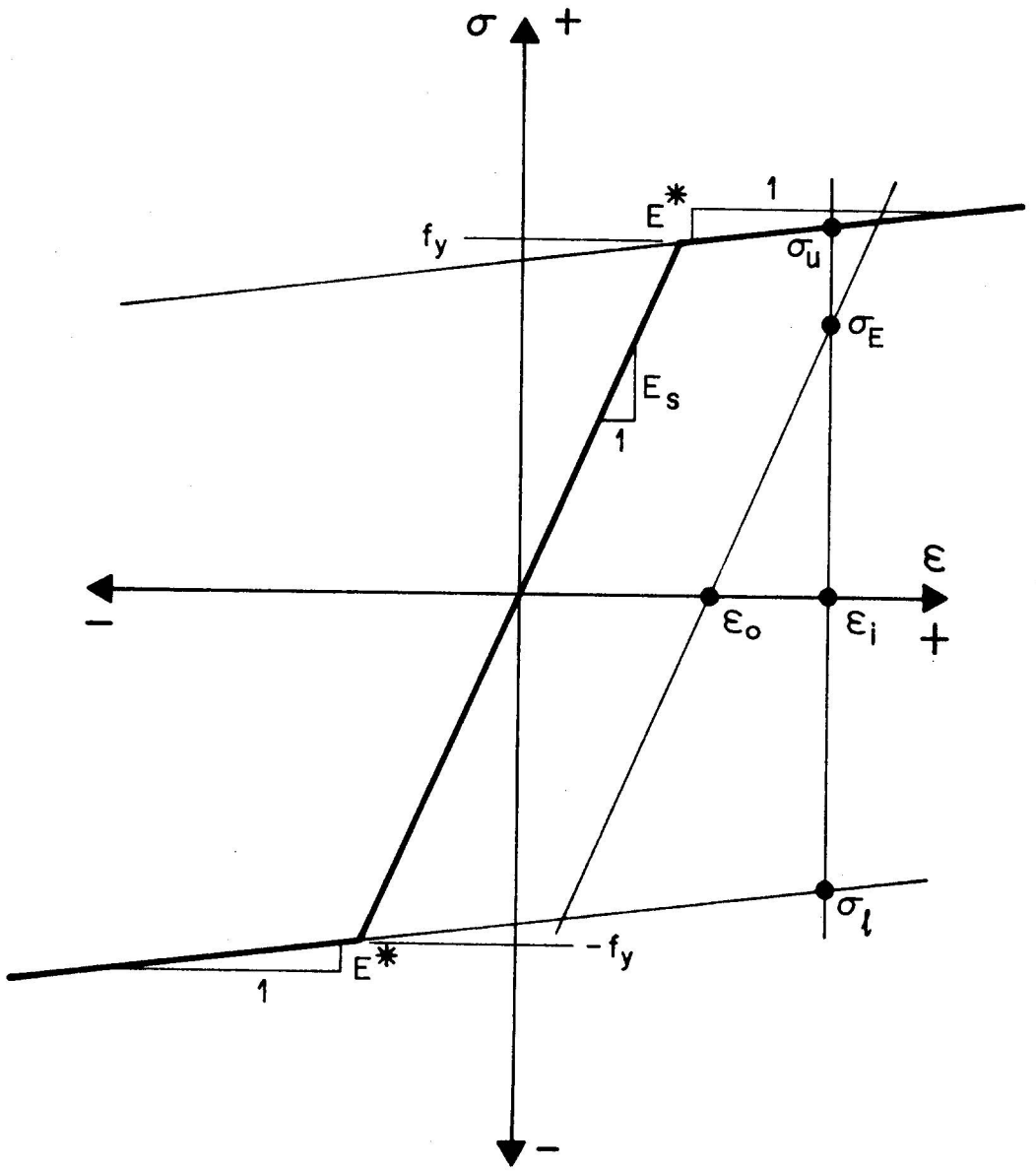


FIGURE 3.6 STRESS-STRAIN LAW FOR STEEL

$$\sigma_E = E_s(\varepsilon - \varepsilon_0) \tag{3.11}$$

Permanent inelastic strain, ε_0, during time step i is calculated on the basis of stress and strain at the end of the previous time step, i-1.

$$\varepsilon_0 = \varepsilon_{i-1} - \frac{\sigma_{i-1}}{E_s} \tag{3.12}$$

The computational algorithm within the iterative procedure of a time step in which ε_0 remains constant, calculates three stresses - σ_u, σ_ℓ, and σ_E - for the current state of strain ε_i. The actual state of stress is then determined as follows:

$$\text{if } \sigma_E > \sigma_u \text{ , then } \sigma = \sigma_u \tag{3.13a}$$

else

$$\text{if } \sigma_E < \sigma_\ell \text{ , then } \sigma = \sigma_\ell \tag{3.13b}$$

else

$$\sigma = \sigma_E \tag{3.13c}$$

The computer function is SS, such that

$$\sigma^s = SS(E, EY, ES, FY, EO)$$

where

E - strain in steel

EY - yield strain (ε_y); temperature-dependent

ES - modulus of elasticity (E_s); temperature-dependent

FY - yield stress (f_y); temperature-dependent

EO - permanent deformation (ε_0)

note: E* is set by a DATA statement and is considered to be temperature-independent

3.3 Thermal Model

Changes in thermal strain for both concrete and steel subslices are determined by multiplying the temperature-dependent coefficient of expansion by the change in temperature. The free thermal strain increment during time step i is thus calculated as shown below:

for concrete:

$$\Delta\varepsilon^{temp,c}(i) = \alpha_c(\overline{T}_i)(T_i - T_{i-1}) \tag{3.14a}$$

for steel:

$$\Delta\varepsilon^{temp,s}(i) = \alpha_s(\overline{T}_i)(T_i - T_{i-1}) \tag{3.14b}$$

where

α - coefficient of expansion

$\overline{T}_i$ - average temperature during time step i $= \dfrac{T_i + T_{i-1}}{2}$

and in the computer program

$$\alpha_c(\overline{T}_i) = \text{VMATL}(1, \overline{T}_i)$$

$$\alpha_s(\overline{T}_i) = \text{VMATL}(6, \overline{T}_i)$$

Total free thermal strain at time step n is then calculated as follows:

for concrete:

$$\varepsilon^{temp,c}(n) = \sum_{i=1}^{n} \Delta\varepsilon^{temp,c}(i) \tag{3.15a}$$

for steel:

$$\varepsilon^{temp,s}(n) = \sum_{i=1}^{n} \Delta\varepsilon^{temp,s}(i) \tag{3.15b}$$

3.4 Concrete Shrinkage Model

Shrinkage in concrete due to moisture loss is highly temperature-dependent, reflected both in total shrinkage and the rate at which it occurs. The basic shrinkage model is given below:

$$\frac{d\varepsilon_s}{dt} = a(T)\,[\varepsilon_\infty(T) - \varepsilon_s] \tag{3.16}$$

where

ε_s - current cumulative shrinkage strain (note: in this case, contraction is positive)

$\varepsilon_\infty(T)$ - total potential shrinkage

$a(T)$ - rate constant

It is assumed that shrinkage continues until a temperature of 212°F is reached, whereupon all remaining shrinkage is considered to occur within the current time step. In addition, the total amount of shrinkage occurring within any time step cannot cause cumulative shrinkage to exceed total potential shrinkage for the temperature at that time step. Lastly, shrinkage is considered to be an irreversible process.

Incremented shrinkage strain within a time step is calculated using the following sequence of equations:

$$a(\overline{T}_i) = (0.001 + \left[\frac{T_i - 68}{144}\right]^2) \tag{3.17}$$

$$\varepsilon_\infty(\overline{T}_i) = 0.0005(1 + \frac{T_i - 68}{144}) \tag{3.18}$$

$$\Delta\varepsilon_i^{shrink} = a(\overline{T}_i)\{\varepsilon_\infty(\overline{T}_i) - \varepsilon_s\}\Delta t_i \tag{3.19}$$

where

$\Delta\varepsilon_i^{shrink}$ - incremental shrinkage strain

Δt - time step

Equations 3.17 and 3.18 are valid for a temperature range of 68°F to 212°F. Maximum total shrinkage at the upper range, 212°F, is 0.001 in/in. The computer function for calculating incremental shrinkage strain is SHRINK and takes the following form:

$$\Delta\varepsilon^{shrink} = \text{SHRINK(DT, T, S)}$$

where

DT - time step

T - average temperature during time step

S - cumulative shrinkage strain

Total free shrinkage strain at time step n is then calculated as follows:

$$\varepsilon^{shrink}(n) = \sum_{i=1}^{n} \Delta\varepsilon_i^{shrink} \tag{3.20}$$

3.5 Creep Models

High-temperature creep is modeled using a temperature-modified time that reflects the thermal acceleration of creep. Both steel and concrete creep models take the same basic form in that they predict a change in free creep strain $\Delta\varepsilon_i^{creep}$ for a given subslice over a time Δt_i. These models require that the state of stress σ_{i-1} at the end of the time step t_{i-1}, the average temperature during the time step $\overline{T}_i$, and the history of the subslice to the beginning of the time step H_{i-1} already be determined (see Fig. 3.7). The general form of these creep models is:

$$\Delta\varepsilon_i^{creep} = f_{creep}(\sigma_{i-1}, \Delta t_i, \overline{T}_i, H_{i-1}) \tag{3.21}$$

3.5.1 Creep Model for Concrete

In the concrete creep model, the superposition principle is combined with an effective stress concept that accounts for nonlinear effects at higher stress levels. The model was developed for this study by M. Mukaddam and is based on previously developed temperature-compensated time models [21, 22, 23]. The following temperature-compensated compliance function was suggested by M. Mukaddam:

$$C(t) = \sum_{i=1}^{m} J_i[1 - e^{-\lambda_i \phi(T) t}] \tag{3.22}$$

where

C(t) - compliance in millionths/ksi

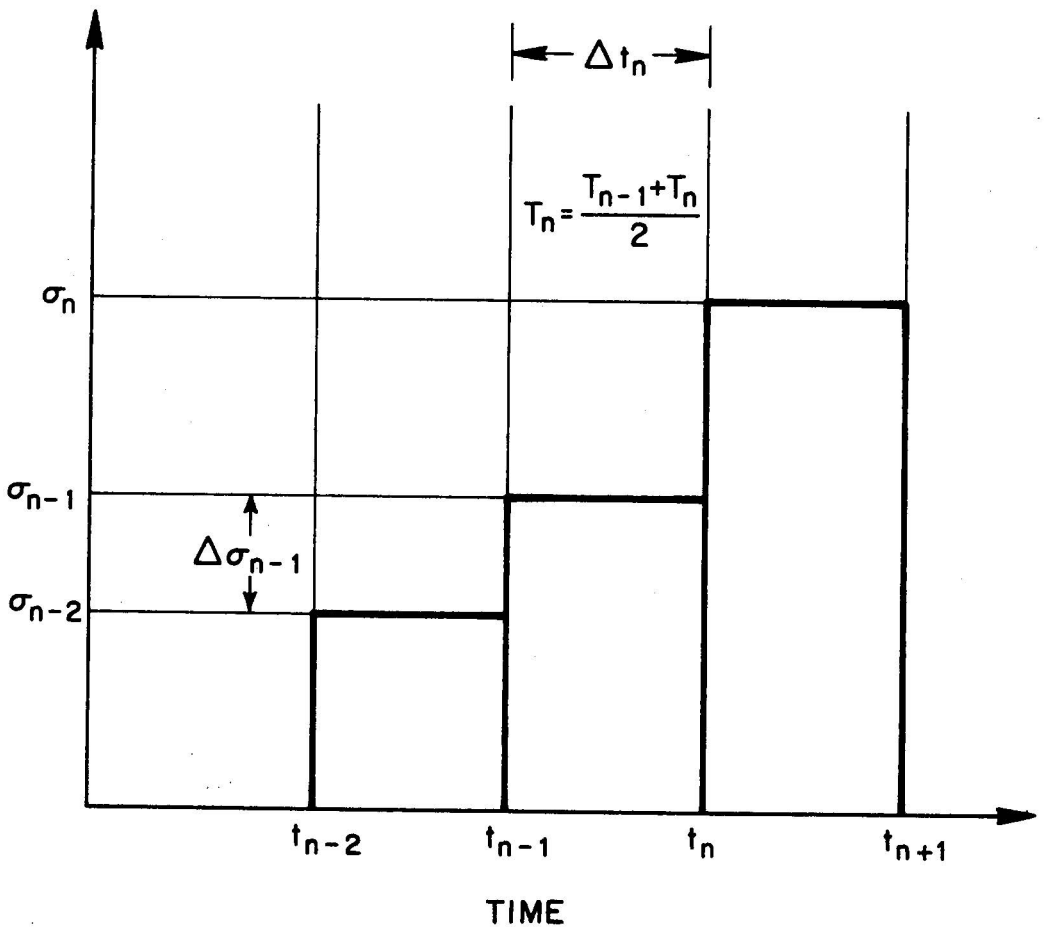


FIGURE 3.7 STRESS HISTORY CONSIDERED IN DETERMINATION OF CREEP STRAIN

J_i - linear constants

λ_i - exponential constants

$\phi(T)$ - temperature shift function

t - time

Using experimental data of Cruz [10], the following coefficients were derived for the first four terms of Eq. 3.22:

i	1	2	3	4
J_i	142.716	169.464	70.563	2737.7
λ_i	0.1	0.01	0.001	0.0001

The temperature shift function given below is also based on Cruz's data:

$$\phi(T) = e^{\Psi(T)} \tag{3.23}$$

where

		Temperature in °F	
$\Psi(T) = 0$		$T \leq 75$	(3.24a)
$= 0.767(\frac{T}{75}) - 0.767$		$75 < T \leq 300$	(3.24b)
$= 0.520(\frac{T}{75}) + 0.220$		$300 < T \leq 900$	(3.24c)
$= 0.297(\frac{T}{75}) + 2.900$		$900 < T$	(3.24d)

The compliance model compares favorably with Cruz's experimental data (see Figs. 3.8 and 3.9).

The effective stress function for nonlinear creep is based on the work of Roll [13, 24] and takes the following form:

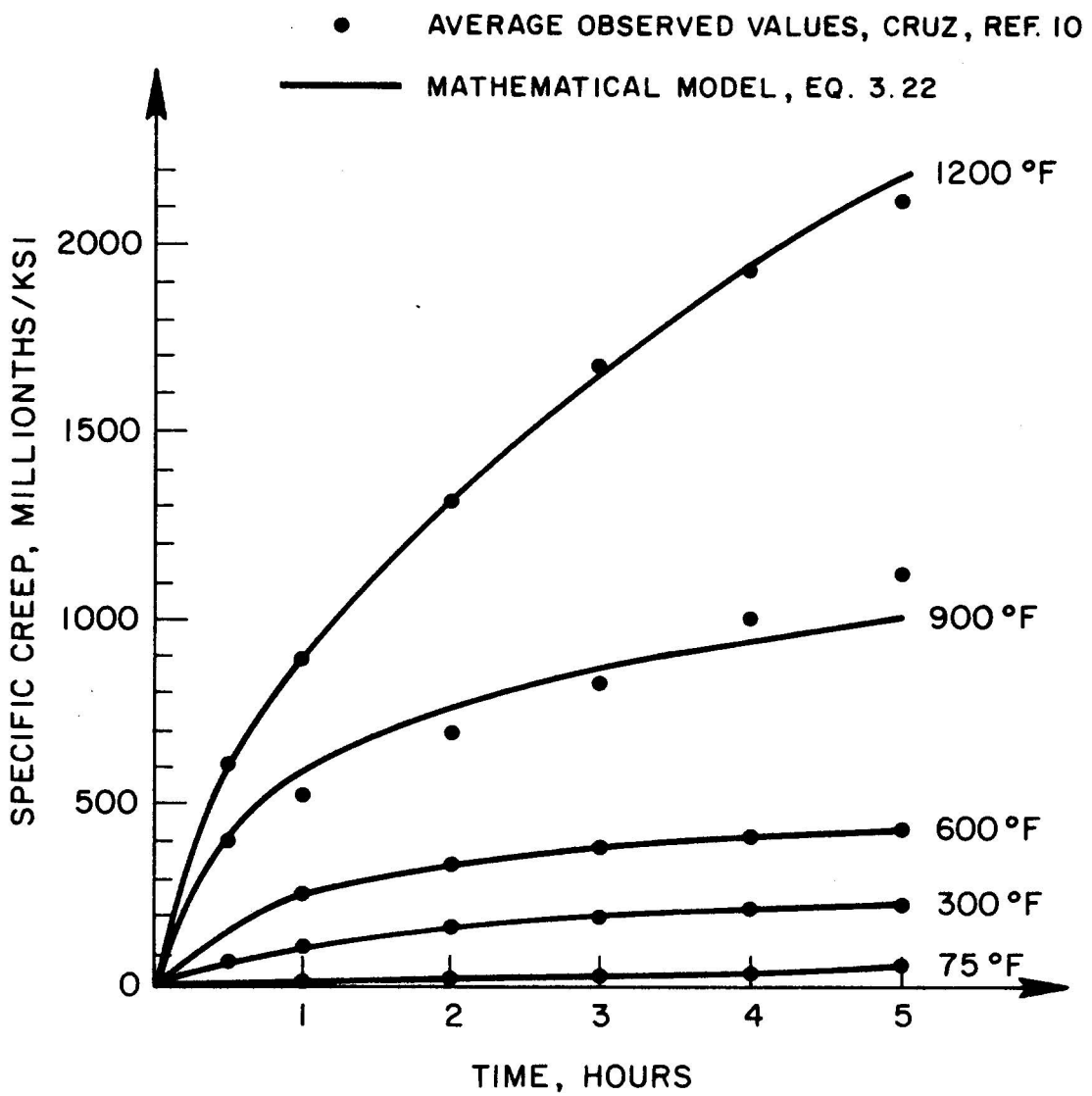


FIGURE 3.8 COMPARISON OF OBSERVED AND PREDICTED CONCRETE CREEP VS. TIME

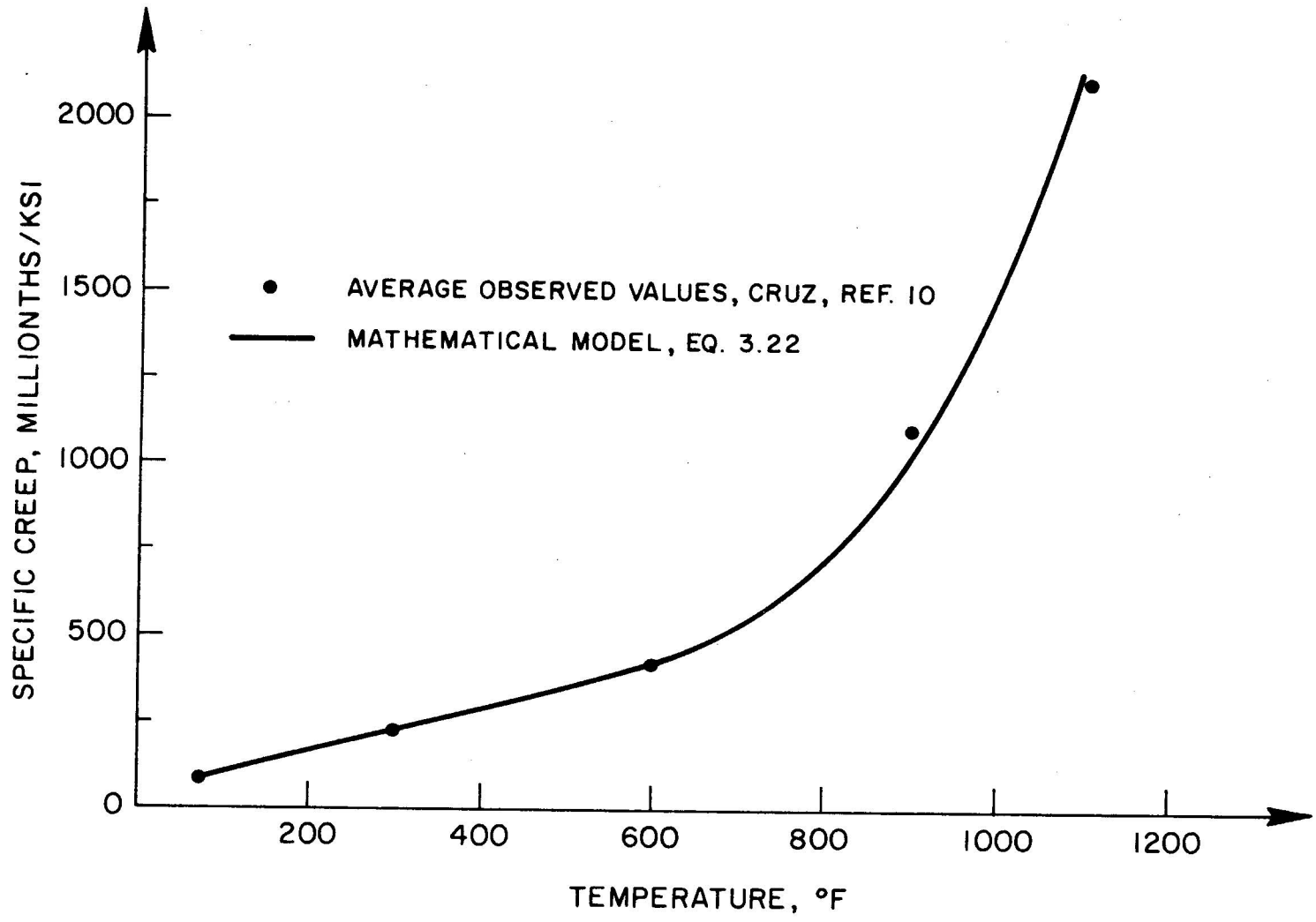


FIGURE 3.9 FIVE HOURS' CREEP VS. TEMPERATURE

$$\sigma_{eff} = \begin{cases} \sigma & \frac{\sigma}{f'_c} \leq 0.35 \\ 2.330\sigma - .465f'_c & 1 \geq \frac{\sigma}{f'_c} > 0.35 \end{cases} \tag{3.25}$$

The upper bound of the effective stress equation (Eq. 3.25) is taken as f'_c; this bound is, however, only a current best estimate, and further investigation is necessary.

A general expression for the overall creep strain of a concrete subslice (Eq. 3.26) can be obtained by assuming stresses to be constant throughout each time step (average temperature, $\overline{T}_n$), and all time steps to be equal.

$$\varepsilon^{creep}(t_n) = 10^{-6} \cdot \sum_{i=0}^{m} a_i(n) \tag{3.26}$$

where

$$t_n = \sum_{i=0}^{n} \Delta t_i \tag{3.27}$$

$$a_0(n) = a_0(n-1) + \Delta\sigma_{eff}(n-1)[\sum_{i=1}^{m} J_i] \tag{3.28}$$

$$a_i(n) = [a_i(n-1) - J_i\Delta\sigma_{eff}(n-1)]e^{-\lambda_i\phi(\overline{T}_n)\Delta t_n} \tag{3.29}$$

and

$$a_0(0) = 0 \tag{3.30}$$

$$a_i(0) = 0 \tag{3.31}$$

The algorithm for calculating $\Delta\varepsilon_n^{creep}$ then proceeds as follows:

1. calculate $\Delta\sigma_{eff}(n-1)$
2. calculate $\Delta\sigma_{eff}(n-1)[\sum_{i=1}^{4} J_i]$
3. sum $a_i(n-1)$ terms for $i = 1, 2, 3, 4$

4. calculate $a_i(n)$ terms for $i = 1, 2, 3, 4$

5. sum $a_i(n)$ terms for $i = 1, 2, 3, 4$

6. calculate $\Delta\varepsilon_n^{creep}$ from the following equation:

$$\Delta\varepsilon_n^{creep} = \Delta\sigma_{eff}(n-1)[\sum_{i=1}^{4} J_i] + \sum_{i=1}^{4} a_i(n) - \sum_{i=1}^{4} a_i(n-1) \qquad (3.32)$$

Since available research data on tensile creep are limited, it is assumed that creep of concrete in tension and compression is the same for equal stresses (in absolute values). The results of a study on tensile creep in concrete at room temperature conducted at the University of California, Berkeley, by Akatsuka, Chang, and Polivka [1] indicated that the difference between the magnitude of tensile creep and compressive creep for equal stresses is very small, tensile creep being slightly higher than compressive creep. Therefore, the error introduced by the assumption that tensile creep and compressive creep are equal will be negligible.

The computer function for calculating incremental creep in concrete is CRPC and takes the following form:

$$\Delta\varepsilon^{creep,c} = \text{CRPC(DT, S1G1, S1G2, T, B, C, D, E, FC)}$$

where

DT - time interval (Δt)

S1G1 - stress at beginning of previous time step $(\sigma(n-2)$

S1G2 - stress at beginning of current time step $(\sigma(n-1)$

T - average temperature during current time step $(\overline{T}_n)$

B, C, D, E - $a_i(n-1)$ as input

$a_i(n)$ as output

FC - compressive strength of concrete (f'_c)

Total free creep strain in concrete at time step n is then calculated as follows:

$$\varepsilon^{creep,c}(t_n) = \sum_{i=1}^{n} \Delta\varepsilon_i^{creep,c} \tag{3.33}$$

3.5.2 Creep Model for Reinforcing Steel

The model used in FIRES-RC II for creep in reinforcing steel considers primary and secondary creep, neglecting tertiary creep (see Fig. 3.10(a)). Creep in steel is considered to be a function of the current state of strain; the path to that state thus negligibly influences the current rate of creep. In addition, creep rate in steel is primarily a function of shear strain and is therefore assumed to be identical in tension and compression except for the possibility of tensile creep rupture.

A creep model for constant temperature and stress can be extended to variable temperature using Dorn's θ - Method [11, 28, 30] and to variable stress by a strain-hardening rule [12]. It is known that the creep rate for secondary creep is a constant in the domain of temperature-compensated time; thus,

$$\frac{d\varepsilon_t}{d\theta} = Z \tag{3.34}$$

where

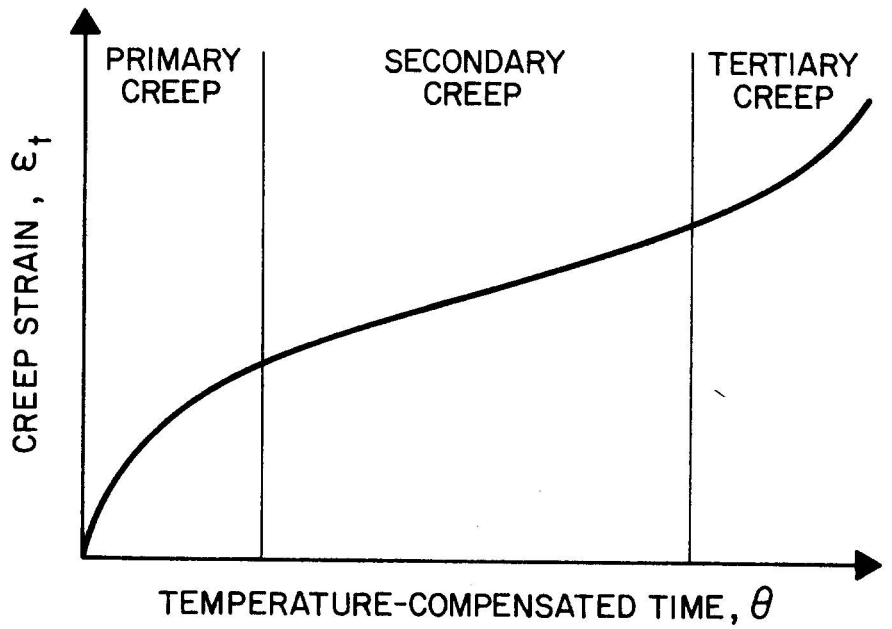
ε_t - creep strain

θ - temperature-compensated time

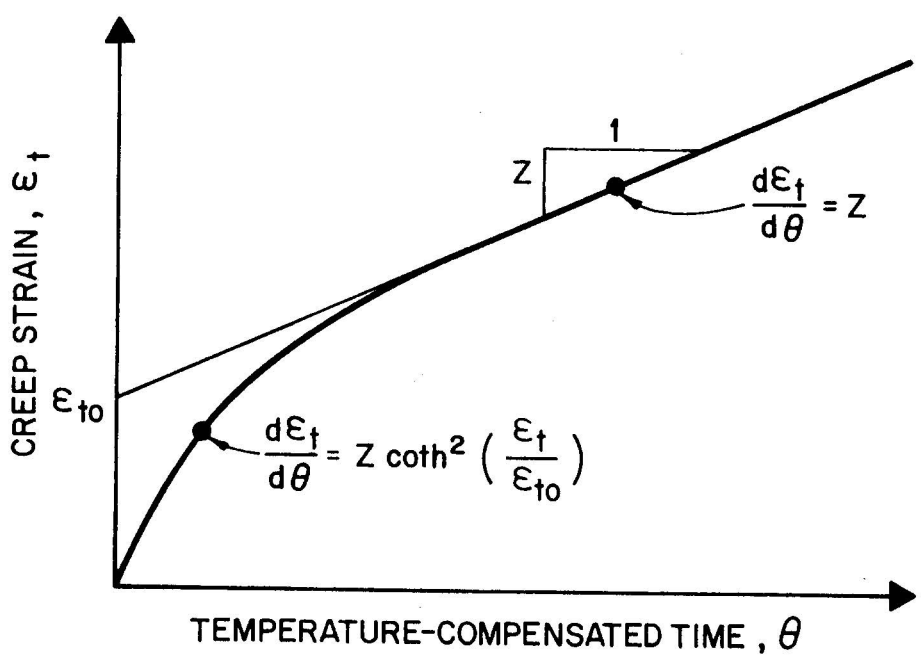
Z - Zener-Hollomon Constant

Harmathy [14, 15, 17] has suggested that this basic relationship can be used to determine both primary and secondary creep with the following modification:

$$\frac{d\varepsilon_t}{d\theta} = Z \, \mathrm{COTH}^2 \left\{ \frac{\varepsilon_t}{\varepsilon_{to}} \right\} \tag{3.35}$$



a. PHASES OF STEEL CREEP



b. HARMATHY'S FORMULATION OF CREEP MODEL

FIGURE 3.10 STEEL CREEP MODEL

where

ε_{to} - y-axis intercept of secondary creep phase

Temperature-compensated time, θ, can be calculated by the following equation:

$$\theta = \int_0^t [e^{-\frac{\Delta H}{R}\frac{1}{(T+460)}}]\, dt \tag{3.36a}$$

or

$$d\theta = dt \cdot e^{-\frac{\Delta H}{R}\frac{1}{(T+460)}} \tag{3.36b}$$

where

ΔH - activation energy of creep

R - gas constant

Harmathy's suggested creep relationship is shown in Fig. 3.10(b).

Harmathy has suggested a computational algorithm that combines his creep model with Dorn's θ - Method and a strain-hardening rule [16]. This method, with minor modifications, is used in FIRES-RC II. Incremental creep strain is given by Eq. 3.37.

$$\Delta\varepsilon_t = Z(\sigma) \cdot \Delta\theta(T,\Delta t)\ \mathrm{COTH}^2 \left\{ \frac{\bar{\varepsilon}_t}{\varepsilon_{to}(\sigma)} \right\} \tag{3.37}$$

where (note: the following coefficients were derived for A-36 steel)

$$Z(\sigma) = 3.2734 \times 10^{12}\ |\sigma|^{4.7}\ \mathrm{sgn}\ \sigma \quad |\sigma| \leq 15 \tag{3.38a}$$

$$Z(\sigma) = 1.23 \times 10^{(16+.1392\sigma)}\ \mathrm{sgn}\ \sigma \quad |\sigma| > 15 \tag{3.38b}$$

$\Delta\theta$ - temperature-compensated time

$$\Delta\theta(T,t) = \Delta t \cdot 10^{-\frac{30400}{T+460}} \tag{3.39}$$

ε_{to} - y-axis intercept

$$\varepsilon_{to}(\sigma) = 3.02 \times 10^{-5} |\sigma|^{1.75} \tag{3.40}$$

$\bar{\varepsilon}_t$ - cumulative absolute creep strain

$$\bar{\varepsilon}_t = \sum_{i=0}^{t} |\Delta\varepsilon_i| \tag{3.41}$$

σ - stress in ksi

Results obtained using this creep model can be very sensitive to experimental coefficients. If steel having a higher yield strength than that intended for the set of coefficients used in the analysis is evaluated, excessive creep will be predicted. Likewise, if steel with lower yield strength is analyzed, the creep effect may be underestimated. Because of this sensitivity to experimental coefficients, the steel creep model should be substantiated by experimental data whenever possible. Cylic loading and creep recovery are not modeled.

In the first time step where $\bar{\varepsilon}_t = 0$, the hyperbolic cotangent term goes to infinity (∞). Creep strain for the first time step is calculated by the following approximate equation:

$$\Delta\varepsilon_t = \varepsilon_t = [3 \cdot Z \cdot \theta \cdot \varepsilon_{to}^2]^{1/3} + Z \cdot \theta \tag{3.42}$$

This expression was first suggested by Harmathy in 1967 [15], and approximates creep strain well for values of ε_t to $0.5\varepsilon_{to}$.

The computer function for calculating incremental creep in reinforcing steel is CRPS and takes the following form:

$$\Delta\varepsilon^{creep,s} = \text{CRPS}(T, DT, S, ET)$$

where

T - average time step temperature

DT - time step

S - stress at beginning of current time step

ET - cumulative absolute creep

Total free creep strain in steel reinforcement at time step n is then calculated as follows:

$$\varepsilon^{creep,s}(t_n) = \sum_{i=1}^{n} \Delta\varepsilon_i^{creep,s} \tag{3.43}$$

4. DESCRIPTION OF COMPUTER PROGRAM

4.1 Overall Organization

FIRES-RC II is a hierarchically structured computer program, a natural consequence of the discretization methods chosen to model a reinforced concrete frame. That is, overall joint forces and stiffnesses are assembled by considering the contribution of each member, segment, and subslice in a structure. Hence, for each basic calculation in the solution process (stiffness formation, output, etc.) there are two or three levels in the hierarchy of subroutines as shown in Fig. 4.1. The lowest level is called into use each time a subslice quantity is calculated and higher levels control calculations for an entire member or, in the case of the main program, an entire frame.

Figure 4.1 shows that the program is organized to reflect not only the geometric substructuring idealizations used in the analysis, but also the three distinct phases of the analytical process. The first three subsidiary subroutines (INPT, SEGIN, MATLIN) perform operations needed to input the data describing the problem to be solved. The next block of subroutines (time-step solution phase) determines overall structural response at the end of each time step. This phase is divided into (1) an initialization process at the beginning of each time step (subroutine INITIAL or INSTEP) and (2) a stiffness formation (subroutine MEMBERS) and displacement solution (subroutine BANDEC) for each iteration within the time step. And the last block (output phase) prints and punches results of the analysis when requested. These three phases are described in more detail later in this section.

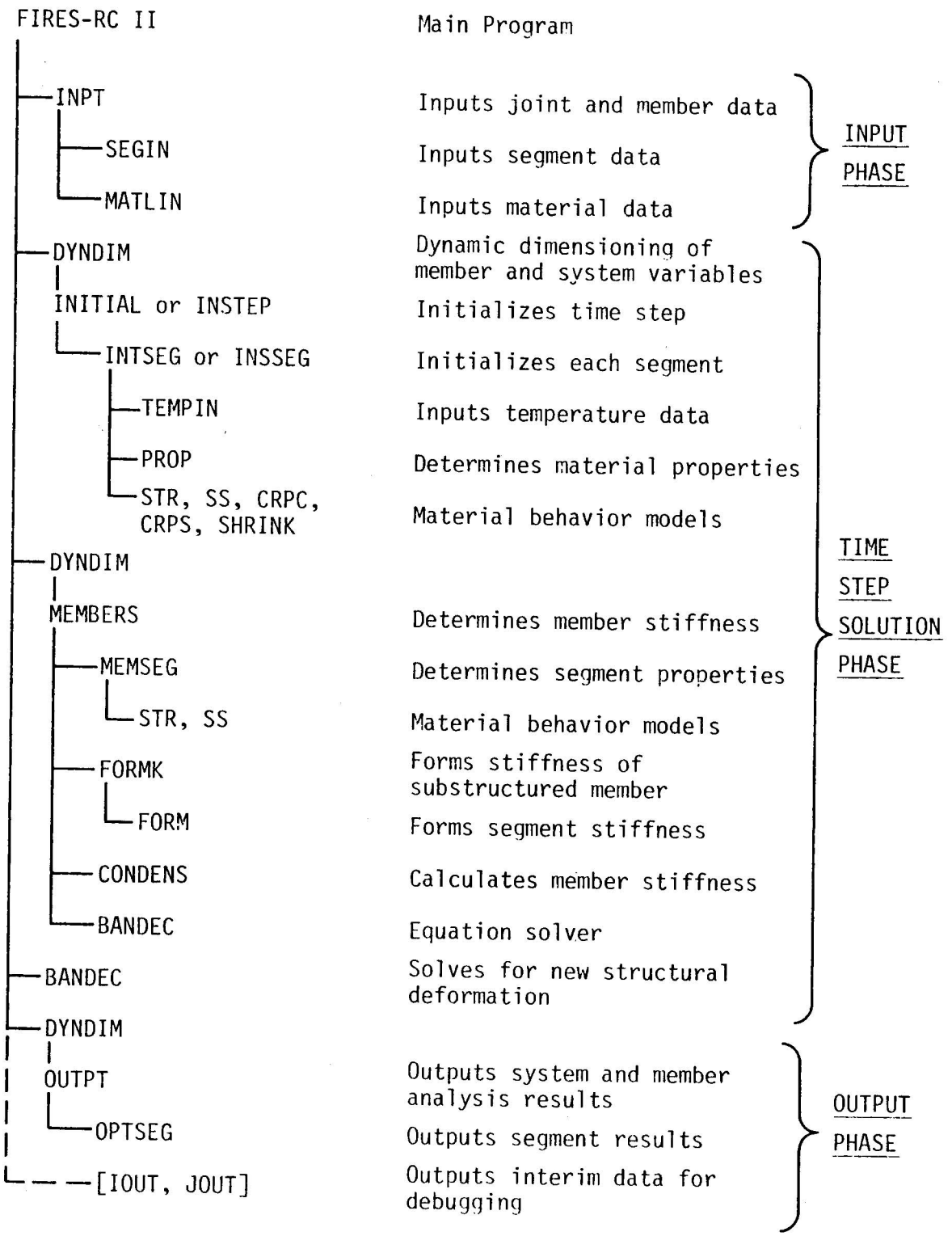


FIGURE 4.1 STRUCTURE OF PROGRAM FIRES-RC II

4.2 Storage Allocation by Dynamic Dimensioning

Because several levels of discretization are necessary to model the behavior of a concrete frame, a great many variables must be referred to during the solution process. The way in which these variables are organized and stored within the computer is critical in designing an efficient programming technique. In a large problem, the manipulation of data files can be far more costly than the actual numerical calculations, and every effort must be made to use storage in the high-speed central memory of the computer as efficiently as possible.

In FIRES-RC II, the most important information that must be stored during the solution process is divided into four files. Note that these files correspond exactly to the discretization hierarchy of the analysis (system, member, and segment).

1. /ISYSTEM/ - This file contains all system variables used in the analysis, such as joint deflections and rotations, support reactions, or system stiffness matrix. These variables are listed in Table 4.1. The storage needed for this file is

$$NJ \times (28 + MAXBAN)$$

   where NJ is the number of joints in a frame and MAXBAN is the maximum half-bandwidth of the system stiffness matrix.

2. /IMEMB/ - This file contains the variables for each substructured member in a frame, such as member end and intersegmental displacements, segment lengths, etc. Table 4.2 lists these variables for a typical member. Note that the storage needed for each member depends on NSEG, the number of segments into which a member is divided, and is equal to

$$NSEG \times 33 + 4$$

   Storage needed for the entire file /IMEMB/ (i.e. for all members in a structure) is obtained by summation. Members are stored sequentially on the file.

3. /ITEMP/ - This file contains all quantities needed at the beginning of each time step in order to initialize each segment cross-section. These variables include subslice temperature, creep history variables,

TABLE 4.1 STRUCTURAL SYSTEM INFORMATION /ISYSTEM/

Address in Blank Common	Variable and Dimension*	Description
N1 = 1	X(NJ)	X-coordinate
N2	Y(NJ)	Y-coordinate
N3	IBC(NJ)	Support code
N4	JS(NJ)	Restrained joints
N5	FJ(NJ3)	Total external load, $\underset{\sim}{R}_i$
N6	U(NJ3)	Total displacement, $\underset{\sim}{U}_i^j$
N7	DV(NJ3)	Increment in load vector, $\Delta\underset{\sim}{R}_i$, then out-of-balance force vector, $\delta\underset{\sim}{R}_i^j$
N8	DPL(NJ3)	Fixed boundary condition displacements
N9	SP(2,NJ3)	Spring stiffness boundary conditions
N10	AAW(NJ3)	Support reactions
N11	DELR(NJ3)	Out-of-balance forces, $\delta\underset{\sim}{R}_i^j$, then correction displacement, $\delta\underset{\sim}{U}_i^j = [\underset{\sim}{K}_i^j]^{-1}\delta\underset{\sim}{R}_i^j$
N12	SYSTIF(MAXBAN,NJ3)	Current tangent stiffness matrix, $\underset{\sim}{K}_i^j$

*Note:

NJ = Number of joints
NJ3 = 3 x NJ
MAXBAN = Maximum half-bandwidth
ISYSTM = Total storage need for system information
= N12 + MAXBAN x NJ3

TABLE 4.2 MEMBER INFORMATION /IMEMB/

Address in Blank Common	Variable and Dimension*	Description
N20 = ISYSTM	MI	Node at left (I) end of member
N21	MJ	Node at right (J) end of member
N22	SEGL(NSEG)	Length of each segment in member
N23	AE(NSEG)	Current axial stiffness of each segment
N24	AEI(NSEG)	Initial axial stiffness of each segment
N25	EI(NSEG)	Current bending stiffness of each segment
N26	EII(NSEG)	Initial bending stiffness of each segment
N27	DCG(NSEG)	Current distance from reference plane to center of gravity (average for each segment)
N28	W(NODS)	Current deformation of substructured member, U_i^j (in member coordinate system)
N29	F(NINTER)	External load increment, ΔR_i, for intersegmental nodes of substructured member
N30	DELF(NINTER)	Out-of-balance forces for substructured member, δR_i^j
N31	FA(NINTER)	Total intersegmental external load, R_i
N32	PA(2,NSEG)	Cross-section axial force (at left and right ends of each segment)
N33	BM(2,NSEG)	Cross-section bending moment about reference line (at left and right ends of each segment)

TABLE 4.2 MEMBER INFORMATION (cont.)

Address in Blank Common	Variable and Dimension*	Description
N34	ASTRAIN(2,NSEG)	Average axial strain in each segment, ε_a
N35	ACURV(2,NSEG)	Segment curvature ϕ (at left and right ends of each segment)
N36	AREA(NSEG)	Area of cross-section of each segment
N37	CRUSH(2,NSEG)	Area of cross-section crushed (at left and right ends of each segment)
N38	CRACK(2,NSEG)	Area of cross-section cracked (at left and right ends of each segment)
N39	NCONCR(NSEG)	Number of concrete subslices in each segment
N40	NSTEEL(NSEG)	Number of steel subslices in each segment

*Note:

NSEG = Number of segments in member

NSEG2 = 2 x NSEG

NODS = Number of nodes in substructured member
= 3 x (NSEG + 1)

NINTER = Number of intersegmental nodes
= 3 x (NSEG - 1)

The above storage scheme is for the first member in the structure. Information for the second member is stored in the same way except that N20 for member No. 2 is set to N40 (of member No. 1) + NSEG (see Fig. 4.2)

and current subslice shrinkage. Table 4.3 shows the contents of this file for a single segment. A segment with NC concrete subslices and NS steel subslices requires

$$NC \times 7 + NS \times 2 + 1$$

storage locations. Information for each segment is stored sequentially, i.e., all quantities for segment 1 of member 1, then all quantities for segment 2 of member 1, up to the quantities for the last segment of the last member in the structure.

4. /ISEG/ - This file contains segment variables that are needed for every iteration within a time step. Note that variables which are needed only during initialization of a time step are allocated to file /ITEMP/ to minimize data manipulation. These quantities are tabulated in Table 4.4. The size of this file for a single segment is

$$NC \times 25 + NS \times 13 + 10$$

Segment data is stored sequentially as described above for /ITEMP/.

The basic idea of the dynamic dimensioning technique is to allot these four files to available high-speed central memory storage in the most efficient way possible. In FIRES-RC II, this is carried out as follows:

1. File /ISYSTEM/ is permanently stored in the first portion of blank common (see Fig. 4.2). During the input of joint and member data, the space needed for this file is determined and the address of each variable in blank common is set (N1, N2, . . . N12), as shown in Table 4.1.

2. File /IMEMB/ is permanently stored in the next portion of blank common (Fig. 4.2). The starting point within blank common of this file is labelled ISYSTM, and is equal to the size of file /ISYSTEM/. As before, it is possible to fix the address of each member variable within blank common (N20, N21, . . . N40) during the input of member data. Note that information for each member is stored sequentially. Hence, for example, the value of N20 (address of variable MI) for member 2 is different than that for member 1. A special subroutine (DYNDIM) adjusts the values of N20, N21, . . . whenever the program must execute calculations that require looping over all members of

TABLE 4.3 SEGMENT INFORMATION REQUIRED FOR INITIALIZATION OF EACH TIME STEP /ITEMP/

Address in Blank Common	Variable and Dimension*	Description
M45	TEMPC(NC)	Concrete subslice temperature for current time step i
M46	TEMPS(NS)	Steel subslice temperature for current time step i
M47	SST(NC)	Total concrete subslice shrinkage
M48	BCRP(NC)	a_1 — history function for concrete creep
M49	CCRP(NC)	a_2 — history function for concrete creep
M50	DCRP(NC)	a_3 — history function for concrete creep
M51	ECRP(NC)	a_4 — history function for concrete creep
M52	ET(NS)	Sum of absolute changes in steel creep strain
M53	SAVG(NC)	Average stress in each concrete subslice at the start of the previous time step (i - 1) (for creep calculations)
M54	ISYM	Flag to indicate if input temperatures are for a symmetric cross-section (i.e., for a quadrant)

*Note:

NC = number of concrete subslices in segment

NS = number of steel subslices in segment

TABLE 4.4 SEGMENT INFORMATION REQUIRED FOR EACH ITERATION /ISEG/

Address in Blank Common	Variable and Dimension*	Description
M20 = MINIT	AC(NC)	Area of each concrete subslice
M21	YC(NC)	Distance from each concrete subslice to reference plane
M22	AS(NS)	Area of each steel subslice
M23	YS(NS)	Distance from each steel subslice to reference plane
M24	AMOD(NC)	Elastic modulus of concrete, $E_c(T)$ (for each concrete subslice)
M25	STRE(NC)	Compressive strength of concrete, $f'_c(T)$
M26	EPU(NC)	Ultimate strain for concrete, $\varepsilon_u(T)$
M27	TES(NC)	Tensile strength of concrete, $f_t(T)$
M28	AMOS(NS)	Elastic modulus of steel, $E_s(T)$ (for each steel subslice)
M29	YIE(NS)	Yield strength of steel, $f_y(T)$
M30	AR(2,NC)**	Current modulus of each concrete subslice, $E_i^{c,j}$
M31	ARS(2,NS)	Current modulus of each steel subslice, $E_i^{s,j}$
M32	KRAT(2,NC)	Permanent flag for subslice cracking
M33	KRAF(2,NC)	Interim flag for subslice cracking
M34	AKAK(2,NC)	Permanent flag for subslice cracking
M35	AKK(2,NC)	Interim flag for subslice crushing
M36	STRC(NC)	Free strain, ε^F, in each concrete subslice
M37	EHC(2,NC)	Current value of stress-related strain, ε_i^j, in each concrete subslice

TABLE 4.4 SEGMENT INFORMATION REQUIRED FOR EACH ITERATION /ISEG/ (cont.)

Address in Blank Common	Variable and Dimension*	Description
M38	SIC(2,NC)	Current stress, $\sigma^c(\varepsilon_i^j, T_i)$, in each concrete subslice
M39	STRS(NS)	Free strain, ε^F, in each steel subslice
M40	EHS(2,NS)	Current value of stress-related strain, ε_i^j, in each steel subslice
M41	SIS(2,NS)	Current stress, $\sigma^s(\varepsilon_i^j, T_i)$, in each steel subslice
M42	ESHIFTC(2,NC)	Permanent concrete subslice deformation, ε_0^c
M43	ESHIFTS(2,NS)	Permanent steel subslice deformation, ε_0^s
MEFC	EFC(NC)	Strain at compressive strength, ε_f (for each concrete subslice)
MFU	FU(NC)	Ultimate crushing stress of concrete, σ_u
M44	NSTR(10)	Template for selected subslice output (punched)

*Note: NC = number of concrete subslices in segment
NS = number of steel subslices in segment

**Note: Singly-subscripted variables refer to quantities which are constant or averaged over segment length, such as subslice area or subslice free strain. Doubly-subscripted variables refer to quantities which have one value at the left segment end cross-section and perhaps another value at the right end cross-section, such as subslice stress or cracking and crushing patterns.

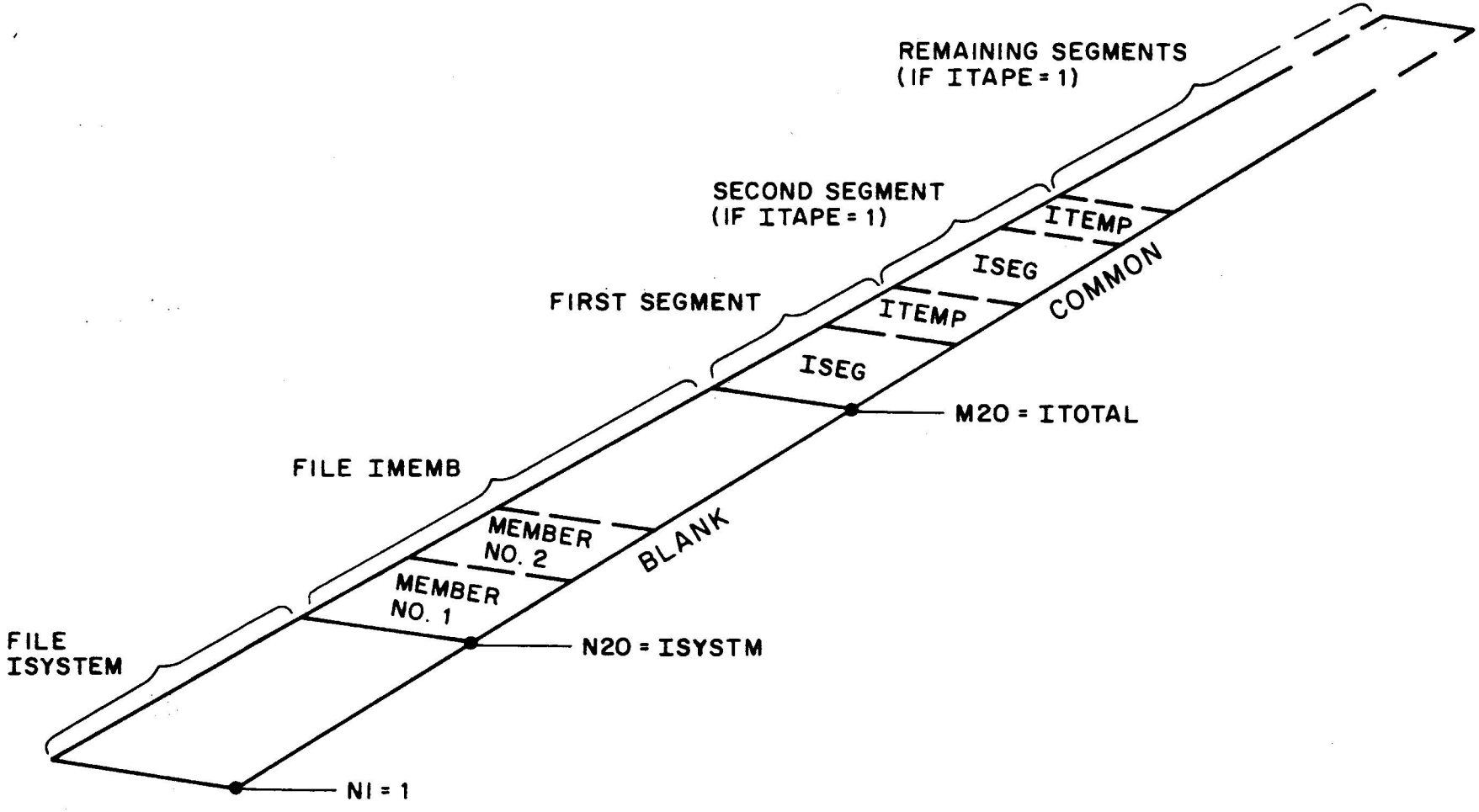


FIGURE 4.2 STORAGE ALLOCATION IN BLANK COMMON BY DYNAMIC DIMENSIONING

the structure.

3. Files /ITEMP/ and /ISEG/ must be treated differently from the previous two files. Two approaches can be used:

   A. IN-CORE SOLUTION: If the problem is sufficiently small to permit information from all subslices and segments to be fit into the blank common size specified in the program dimension statement, permanent addresses are given to each segment variable in /ITEMP/ and /ISEG/. The information is stored sequentially in blank common, starting with segment 1 of member 1 and ending with the final segment of the last member as shown in Fig. 4.2. Segment storage starts at point ITOTAL, directly after member data (which ends at point IMEMB) and a small storage block allocated to working variables.

   The program automatically determines whether all segment information will simultaneously fit into blank common during initialization of the first time step (STEP 0) in subroutine INITIAL. If it will fit, the flag variable ITAPE is set to "1". If not, ITAPE is set to "0" and method B must be used.

   B. EXTERNAL STORAGE METHOD: If the problem is so large that files /ITEMP/ and /ISEG/ do not entirely fit into central memory storage it is necessary that these files be put in external low-speed storage. One external file (tape) is used for /ITEMP/ and another for /ISEG/. Blank common then need hold information only for the segment being analyzed at any particular moment, i.e., only the first two blocks of segment data in Fig. 4.2 are used. Data for each segment are read into these locations as needed.

   In actuality, two storage tapes are used for each file, since data from each segment must be stored externally before data from the next segment erases it. It would be possible to backspace and use just one tape for each file, but this procedure is very expensive.

Method A is preferable to method B since problem solution time can triple or quadruple whenever external file manipulation is necessary. The amount of blank common needed for an in-core solution is printed along with output for the first time step (STEP 0); if at all possible, the dimension of blank common (in the main program) should be set high enough to accommodate the entire problem.

Once the dynamic dimensioning method has been chosen, the program knows the location of each variable within blank common. During calculations that require looping over all members and segments in the structure, variable addresses are adjusted for the member or segment under consideration. That is, N20 - N40 are reset before calling INITIAL, INSTEP, MEMBERS, OUTPT, or IOUT, and M20 - M54 are reset before calling INTSEG, INSSEG, MEMSEG, OPTSEG, or IOTSEG.

4.3 Input Phase

The first parts of the program input the data defining the problem. The data are divided into blocks, each block headed by an alphanumeric control card with a key word (to assist the user in assembling the data deck) and a control parameter (to guide the program in inputting the remaining data in the block) as shown in Fig. A.1, Appendix A.

The first item of input is the problem heading to be used in labeling output. The next item is a group of control cards which specify whether creep and shrinkage are to be considered in the analysis, followed by a description of the concrete frame -- location and end conditions of each joint, and location and segmentation of each member (INPT). Each segment in the frame is assigned a cross-section type which is sequentially input as the next data block. Each cross-section discretization (SEGIN) is effected through use of a finite element mesh composed of concrete elements and steel elements. The mesh used in FIRES-T to obtain temperature data can be used directly here. The program converts these elements into uniaxial subslices and stores their areas and moment arms for use in later calculations.

Material properties (cf. Section 3) are input next (MATLIN), either as temperature-dependent quantities or as constants. Finally,

convergence criteria are defined to control the iterative solution within each time step: (1) the maximum number of iterations, and (2) the maximum permissible out-of-balance forces and moments.

4.4 Time Step Solution Phase

When data defining the problem have been input, the program begins time step integration. This phase basically consists of assembling and solving Eq. 2.5 at the end of each time step. A flow chart showing how FIRES-RC II is organized around this solution process is shown in Fig. 4.3. This flow chart is the programming equivalent of Fig. 2.2, a schematic representation of the general solution procedure discussed in Section 2. Note that both figures clearly illustrate the two repetitive loops that dominate the logic of the program: a loop for each time step and a loop for each iterative solution within the time step.

The first step of the procedure for each time step is to input a control card for that particular time step. This control card specifies the time step number (as a check in sequencing data cards), time step size, printing and punching options, and whether additional input is needed for this time step. Then subroutine INSTEP is called in order to initialize the structure for this time step. For the first time step (STEP 0) a slightly different initialization process is required and a different subroutine (INITIAL) must be called instead of INSTEP. The most important functions performed by INSTEP and its subsidiary subroutines (see Fig. 4.4) are:

1. Input and print any changes in system loading or boundary conditions.

2. Input and print any change in loading within substructured members.

3. Input new temperature distributions (TEMPIN) and calculate new temperature-dependent material properties (PROP).

4. For each subslice of each segment (INSSEG) calculate current total free strain ε^F due to creep, shrinkage, and thermal expansion.

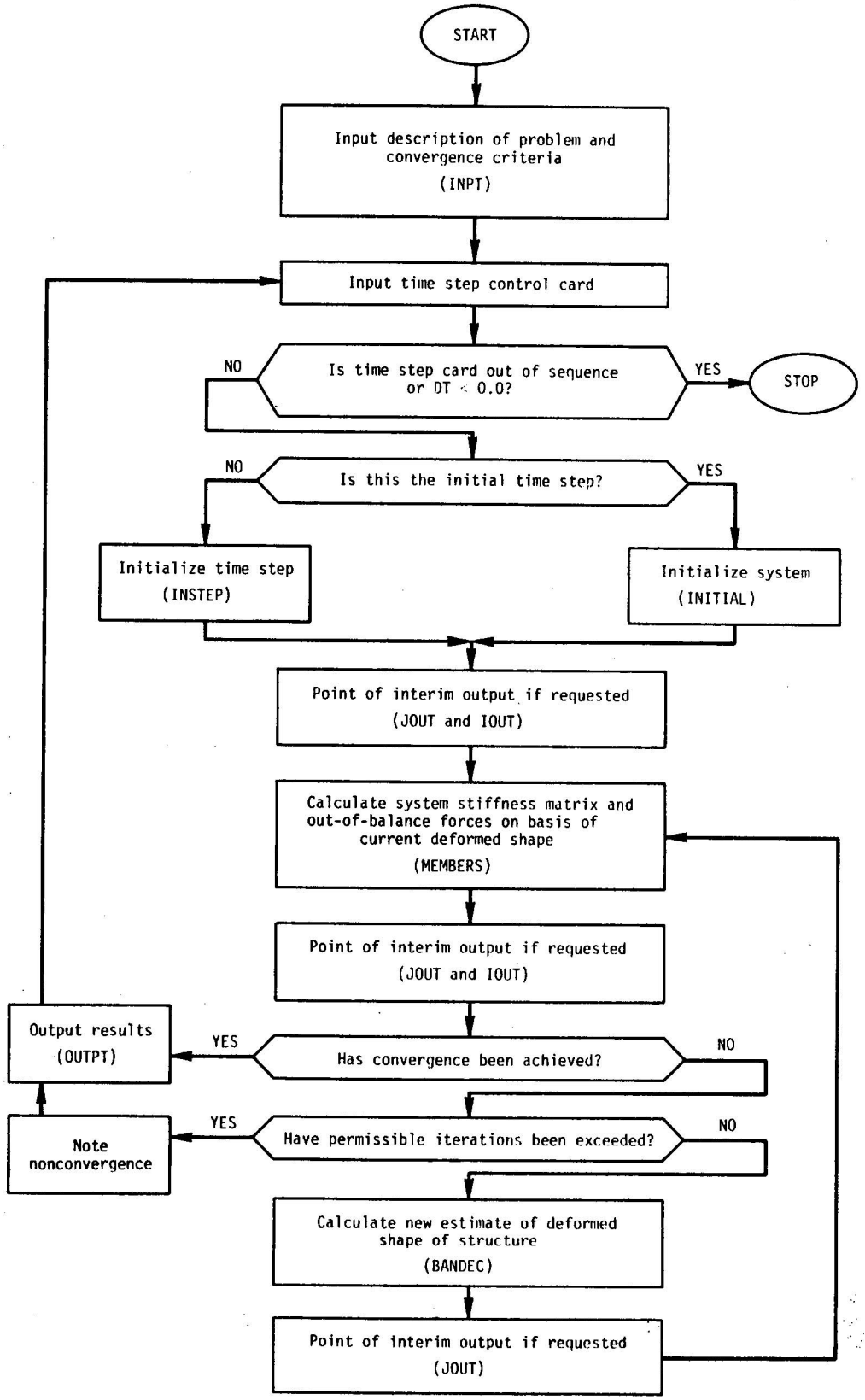


FIGURE 4.3 FLOW CHART FOR PROGRAM FIRES-RC II
(TITLES IN PARENTHESES ARE NAMES OF PROGRAM SUBROUTINES)

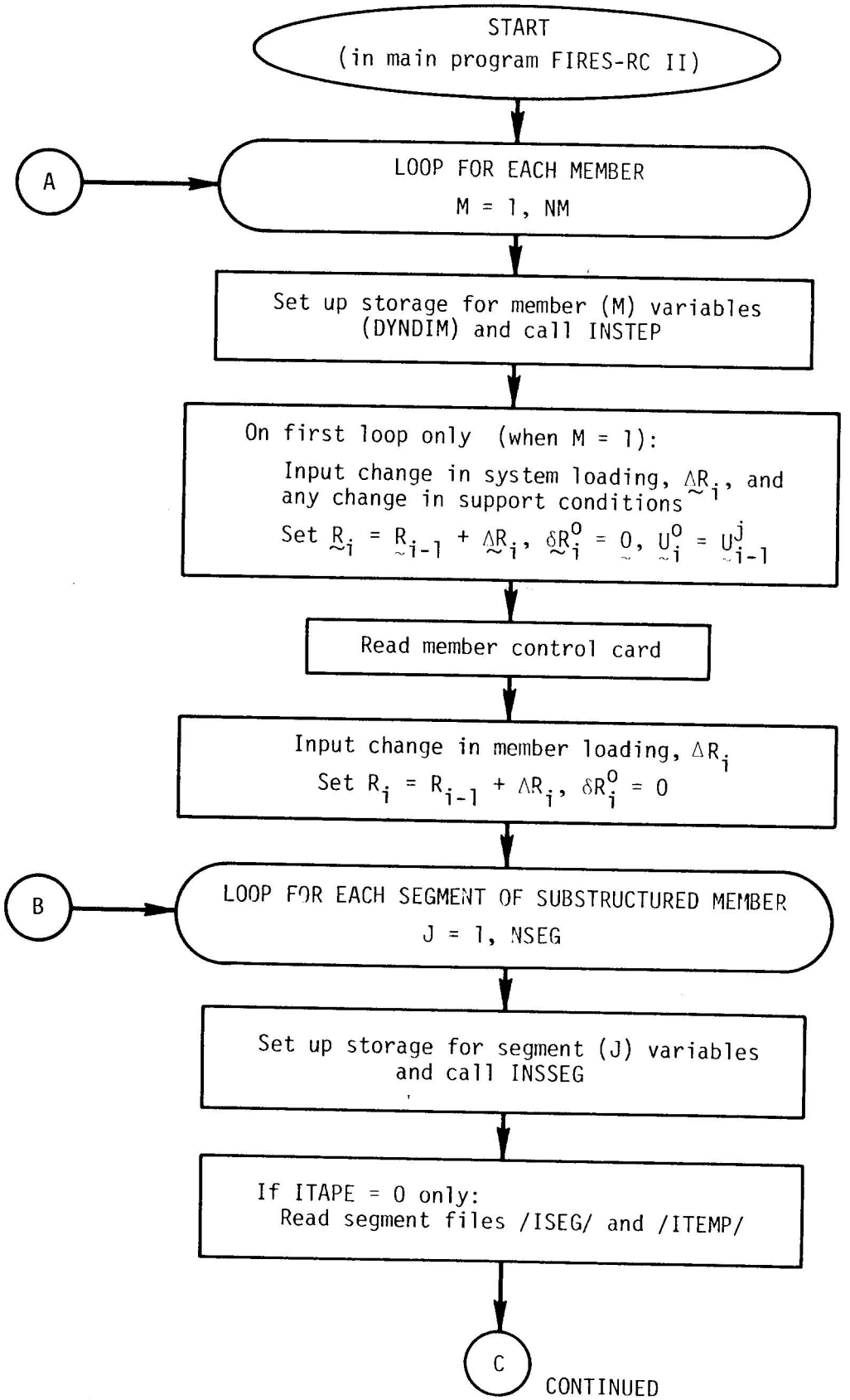


FIGURE 4.4 FLOW CHART FOR TIME STEP INITIALIZATION (INSTEP & INSSEG)

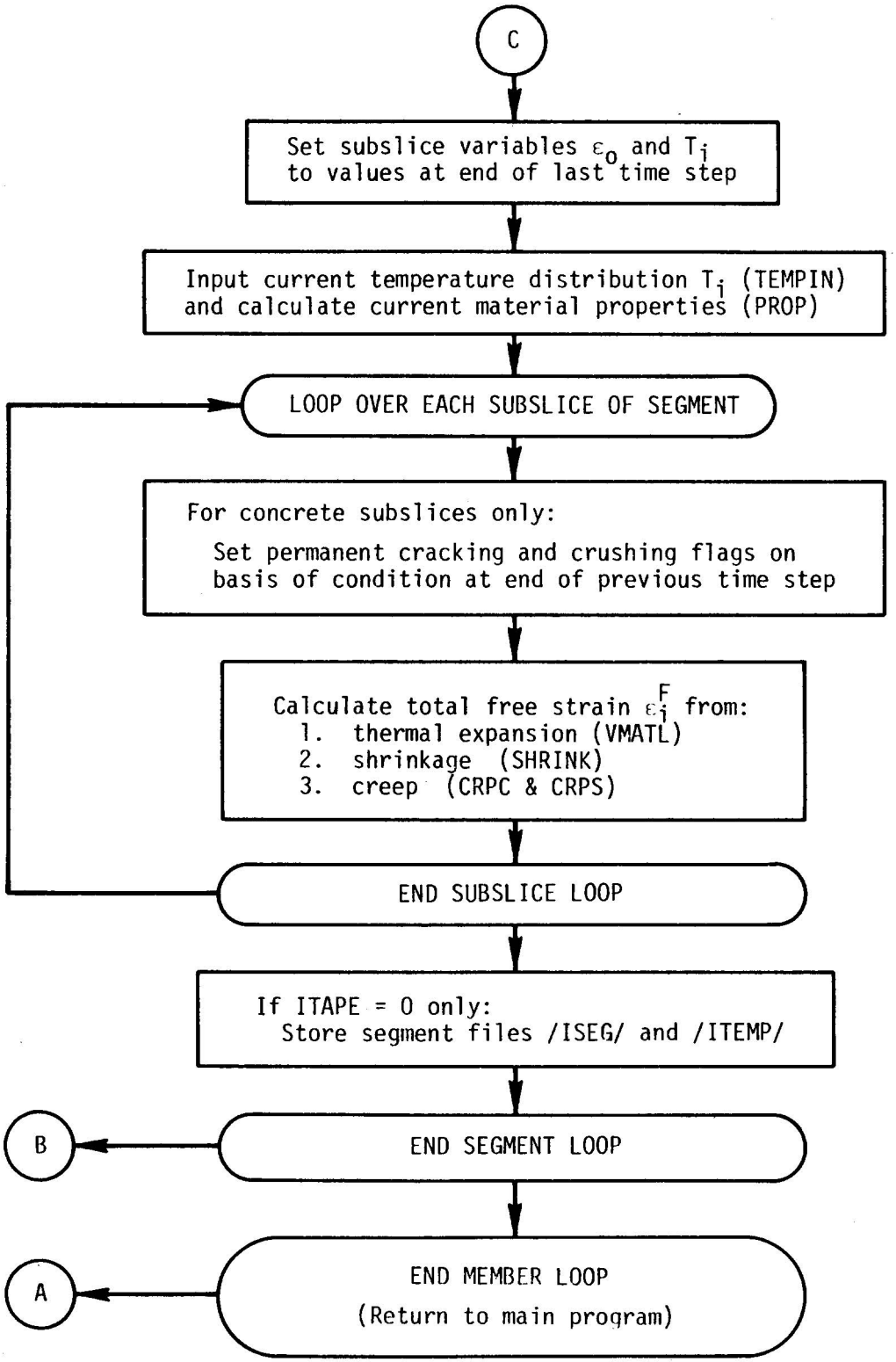


FIGURE 4.4 (CONT.)

After the system has been initialized, the program enters the first iterative loop by calling subroutine MEMBERS (Fig. 4.5) which calculates and assembles member stiffnesses for the current deformed shape into the overall structural tangent stiffness matrix $\underset{\sim}{K}_i^j$. This subroutine also calculates internal forces in each member and compares them with external loads to assemble the out-of-balance forces $\underset{\sim}{\delta R}_i^j$ for the current deformed shape of the structure. For each element in the system, MEMBERS initially transforms end displacements to a local coordinate system, forms the current tangent stiffness matrix of the substructured member (FORMK), and solves for displacements of the substructured member (BANDEC). Subroutine MEMSEG (see Fig. 4.6) is then called to calculate current segment properties on the basis of the deformed shape of the substructured member. With these new data, MEMBERS reforms the stiffness, K_i^j, of the substructured member (FORMK), recalculates the out-of-balance forces, δR_i^j, and checks for convergence within the substructured member. These substructured member quantities are then statically condensed (CONDENS) to member terms, $\overline{K}_i^j$ and $\delta\overline{R}_i^j$, which are then assembled into the structural stiffness matrix and out-of-balance force vector. Each term in the out-of-balance force vector $\underset{\sim}{\delta R}_i^j$ is then checked to ascertain if convergence tolerances are satisfied.

At this point, the program checks the convergence flag NCONV and ceases iteration if its value is zero. The convergence flag is actually a counter of the total number of times that individual convergence checks have failed during this iteration. If this flag is nonzero when the maximum permissible number of iterations is reached, the value of the flag along with the system and member out-of-balance force vectors are printed as part of the time step output. If convergence has not been obtained, a correction displacement is calculated (BANDEC) by solving the equation

$$[\underset{\sim}{K}_i^j]\ \underset{\sim}{\delta U}_i^j = \underset{\sim}{\delta R}_i^j \tag{4.1}$$

and this correction is used to update the current displacement, $\underset{\sim}{U}_i^j$. Another cycle of iteration then begins by returning to subroutine MEMBERS as shown in Fig. 4.3. Once convergence has been obtained, the results of the analysis are printed (OUTPT) and the program begins with the reading of the next time step control card (Fig. 4.3).

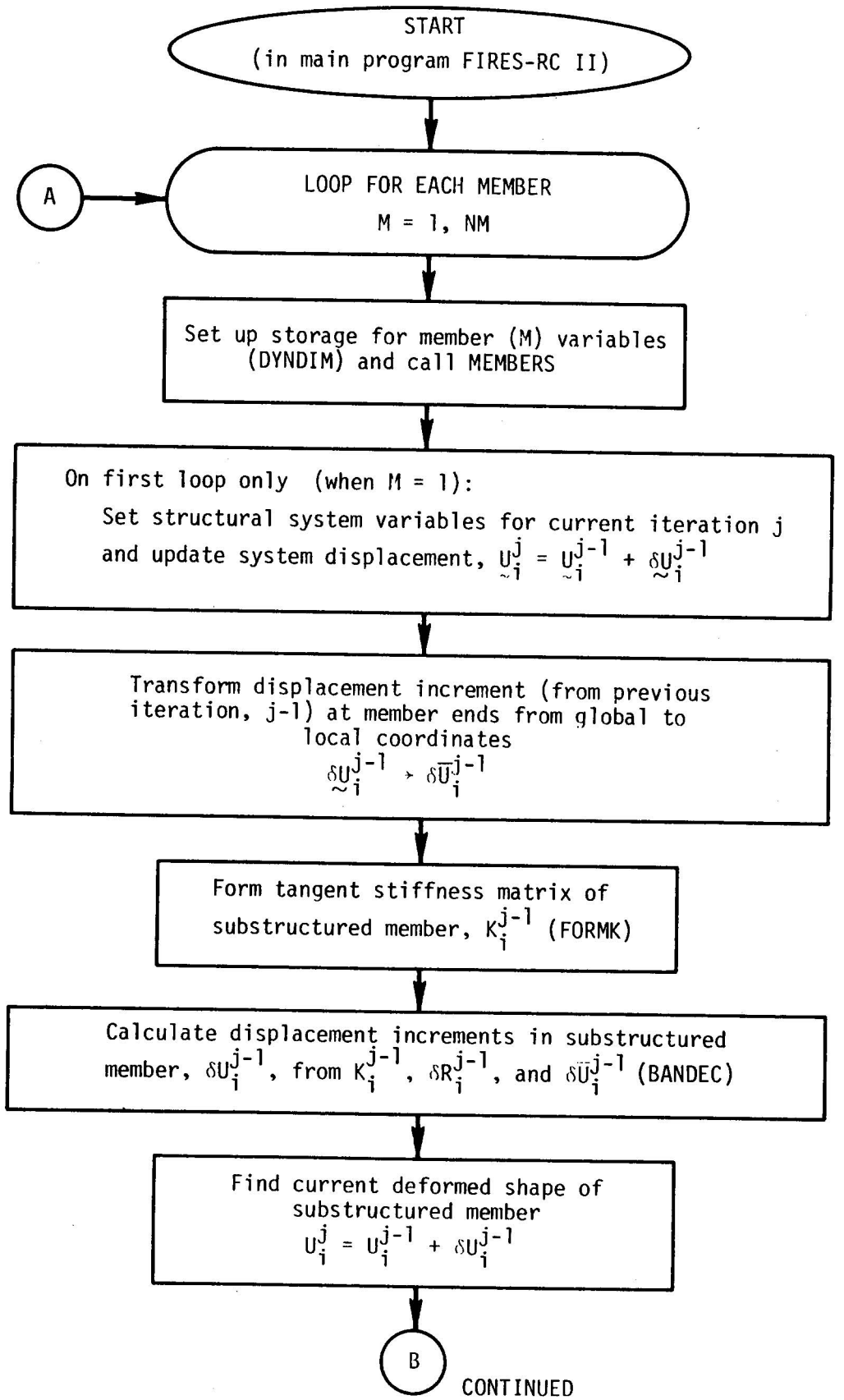


FIGURE 4.5 FLOW CHART FOR MEMBER STIFFNESS CALCULATION (MEMBERS)

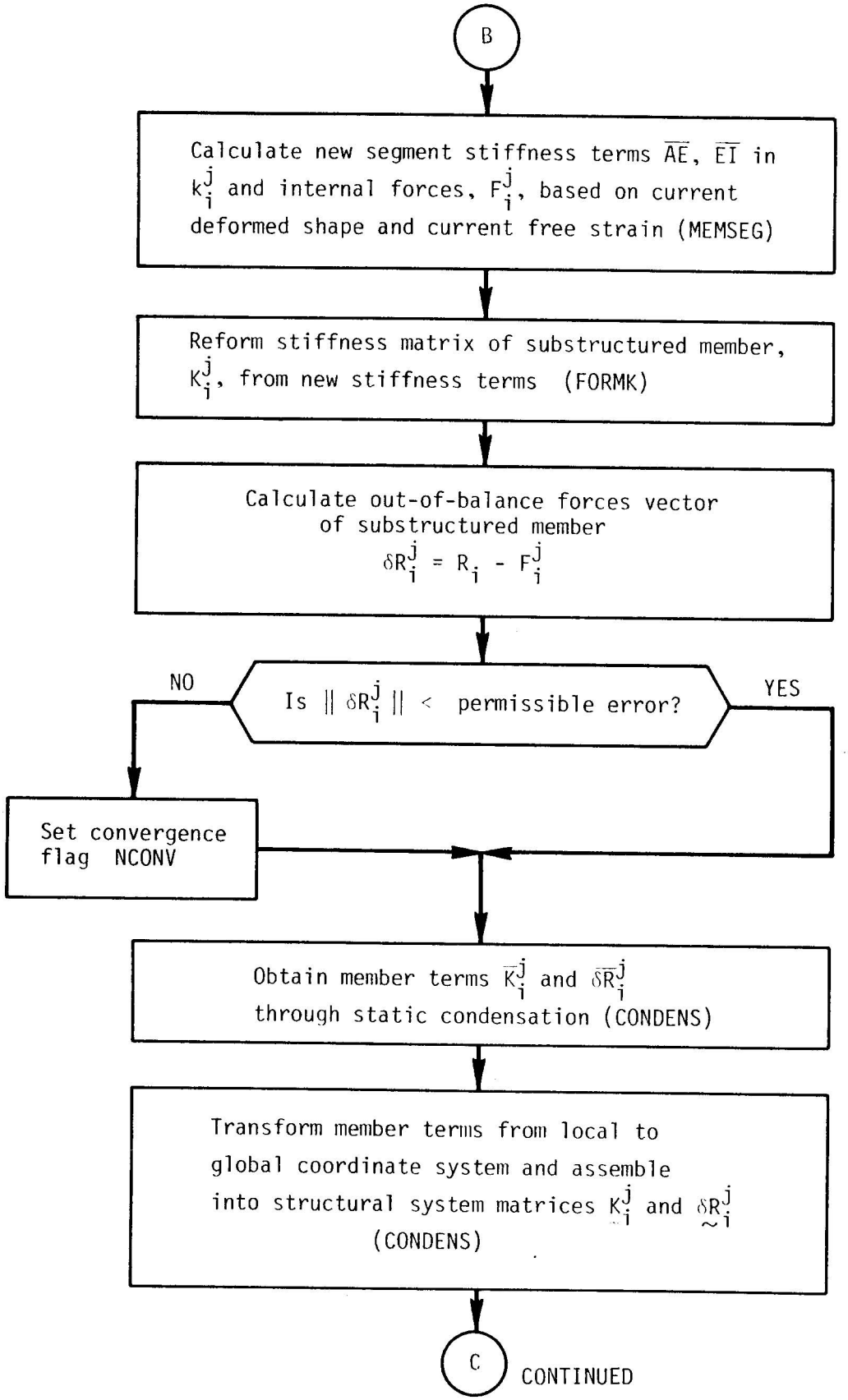


FIGURE 4.5 (CONT.)

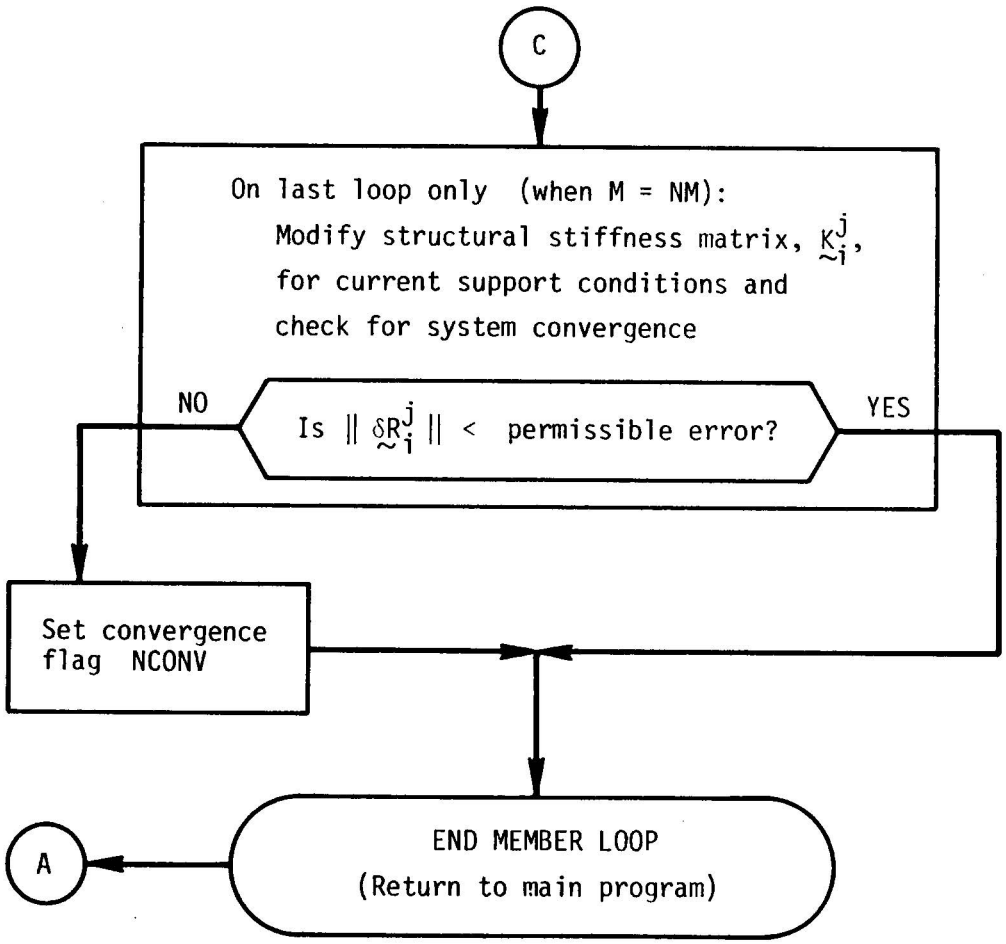


FIGURE 4.5 (CONT.)

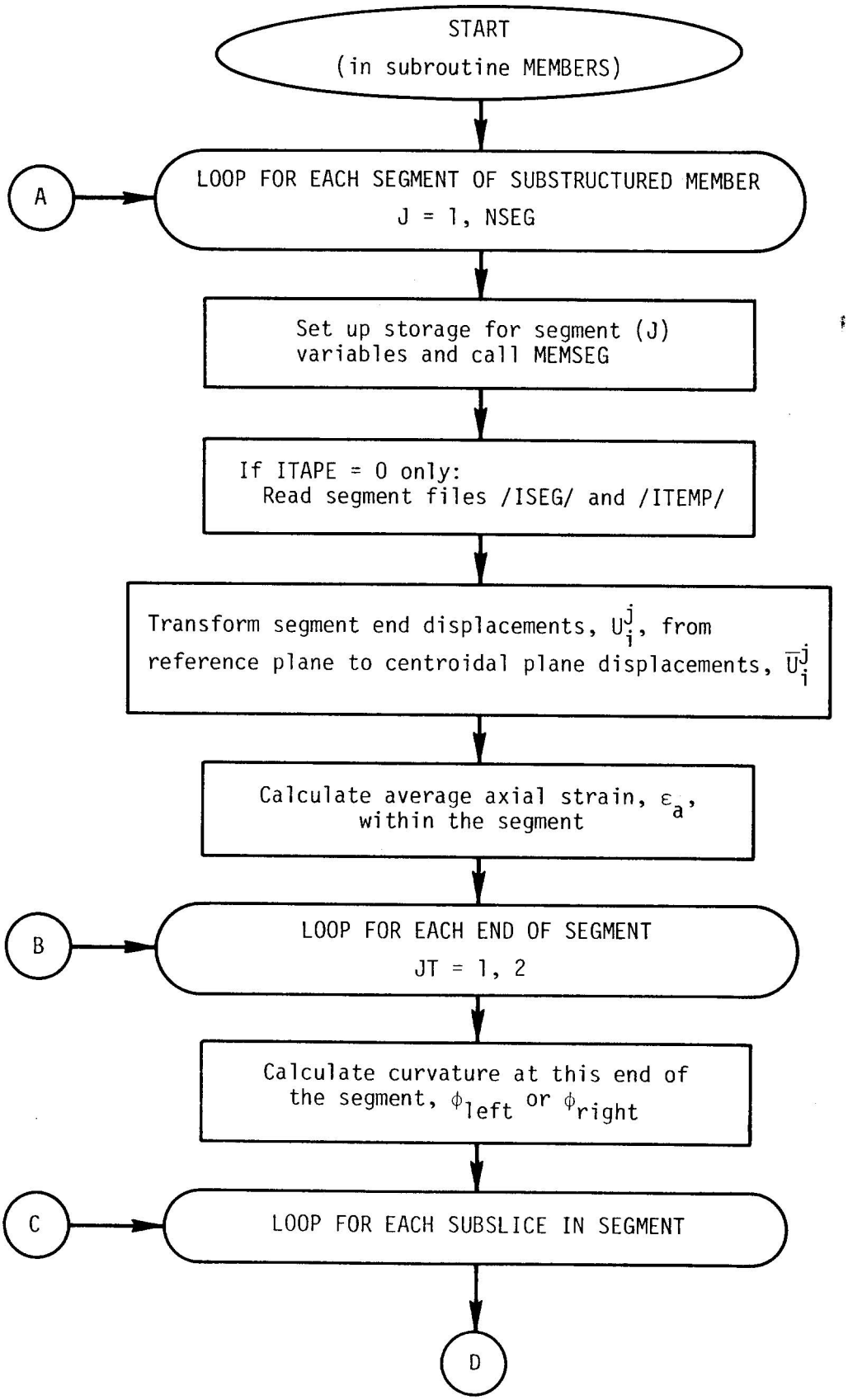


FIGURE 4.6 FLOW CHART FOR SEGMENT STIFFNESS CALCULATIONS (MEMSEG)

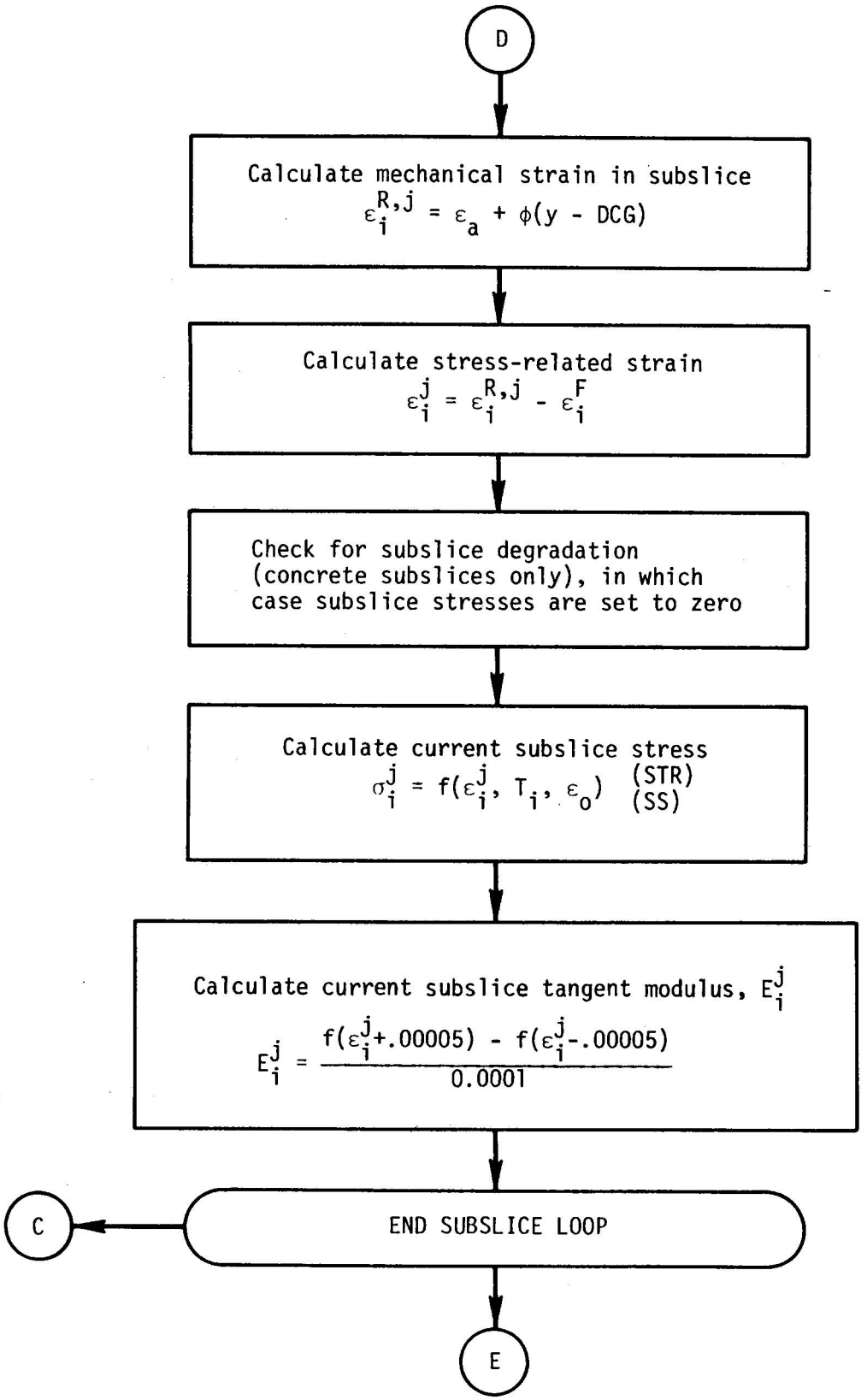


FIGURE 4.6 (CONT.)

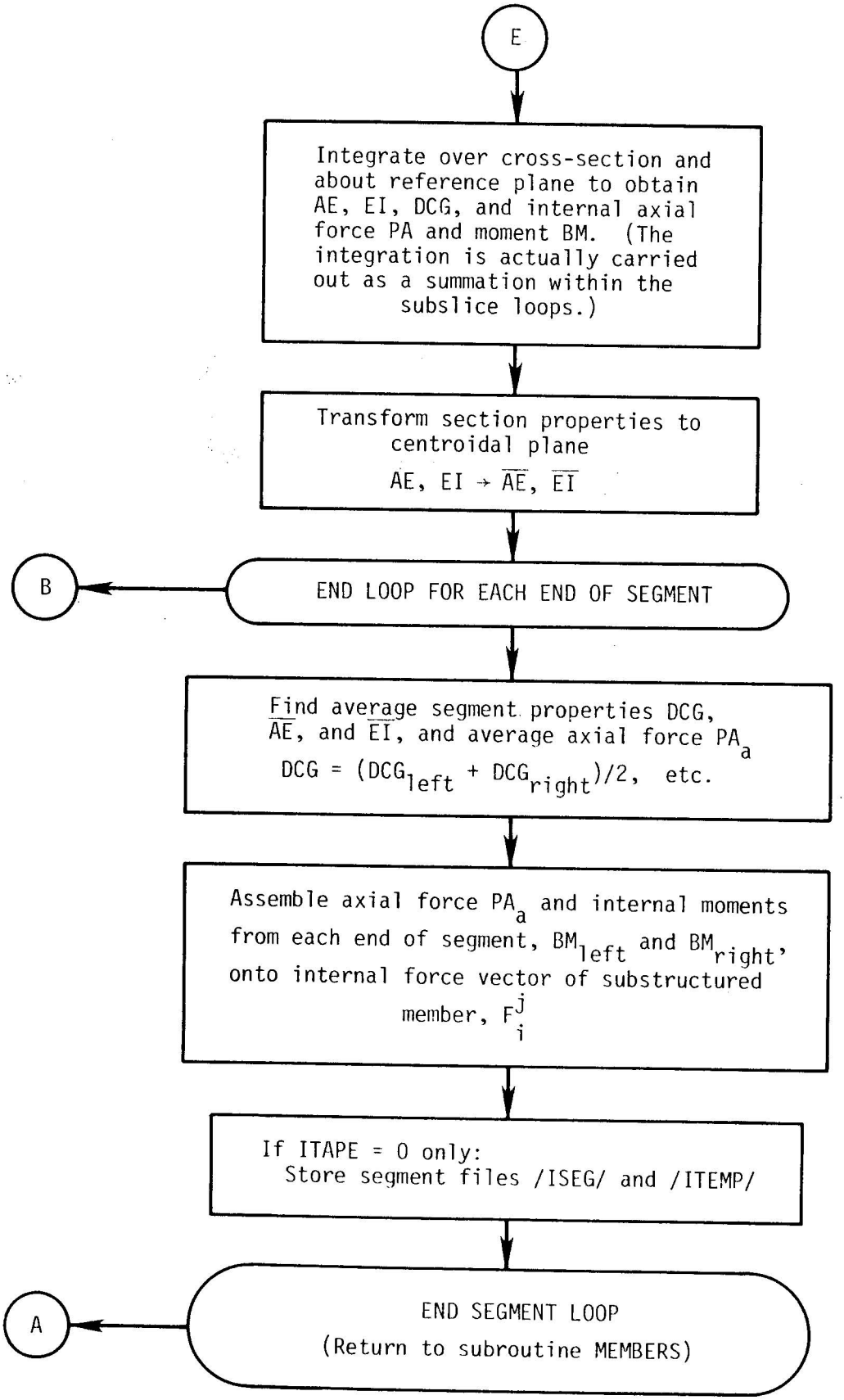


FIGURE 4.6 (CONT.)

The step-by-step solution process outlined above continues until a time step control card with a negative step size is encountered. The solution is then considered complete and the program begins consideration of the next data case in the input deck.

4.5 Output Phase

A printing subroutine (OUTPT) is called when iteration is complete at the end of each time step (see Fig. 4.3). The time step control card specifies which levels of results will be printed for that time step -- joint data, member data, or segment cross-section data. Printing of segment results is quite expensive for large problems and should not be requested for every time step. Another option permits printing of the subslice temperatures provided for input by FIRES-T. Any changes in loading or support conditions and the total number of iterations needed to effect convergence are always printed. See Appendix B for examples of printed output.

A more detailed output during any time step may be specified (IOUT and JOUT) in order to follow the solution process iteration-by-iteration. This interim printout occurs at the points indicated in Fig. 4.3 and can be helpful should a user encounter convergence difficulties. This option is also quite expensive (especially when segment subslice quantities are printed) and should not be used in routine runs.

Two output formats are built into the program: (1) an option for routine runs that efficiently uses the entire page of computer output, and (2) a special option that uses only 61 columns of the output page so that computer results need not be reduced when published on 8-1/2" × 11" pages. The results shown in Appendix B were produced using the second option.

All control variables for the various output options are defined in Appendix A - the User's Manual.

5. COMMENTARY ON USE OF PROGRAM FIRES-RC II

5.1 Discretizing into Segments and Subslices

Considerable engineering judgement is needed to discretize a structure economically. The discretization must be fine enough to model the nonlinearities that will arise in the structure's behavior, and yet be as coarse as is feasible since solution cost increases rapidly with the number of segments and subslices. Some factors to be considered when designing such a discretization will be discussed below.

Member segmentation is necessary to represent nonuniformity of temperature, cracking pattern, etc., along the length of a member. For linearly elastic beams with uniform cross-sections, one segment suffices, which is equivalent to using a single standard beam element to model a member. However, one segment is seldom appropriate when cracking occurs. For example, consider the beam shown below in Fig. 5.1. Average segment properties are based on conditions at the segment ends (cracked and highly stressed in this example), which will greatly underestimate the stiffness of the beam as a whole. At least two segments are needed in this case.

In general, 3 or 4 segments suffice to discretize frame members under moderate loading conditions. More segments are necessary for more complicated loading states or for members where highly accurate analysis is desired.

Insufficient segmentation can lead to convergence difficulties since a member will not have sufficient flexibility and degrees of freedom to deform easily into a shape and degradation pattern satisfying equilibrium. It is sometimes necessary to redesign a discretization scheme where convergence is disproportionately slow.

Columns subjected only to axial loading can be modeled by a single segment if cross-section temperature distribution does not vary along the length of the column. More than six segments may be used if a frame element is modeled as two members, e.g., if a 'joint' is added at the center of a beam or column.

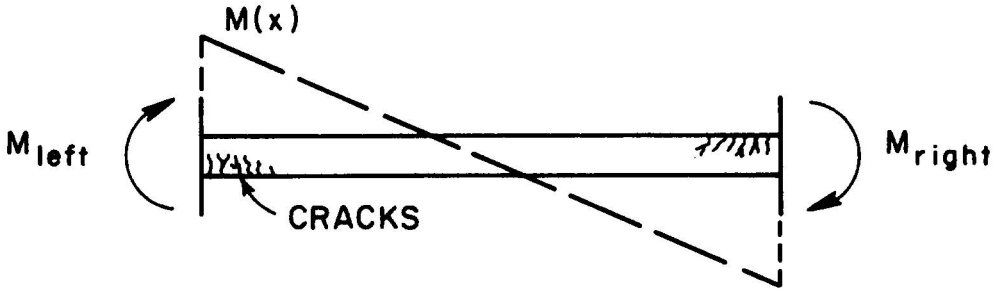


FIGURE 5.1 NONUNIFORM BEAM

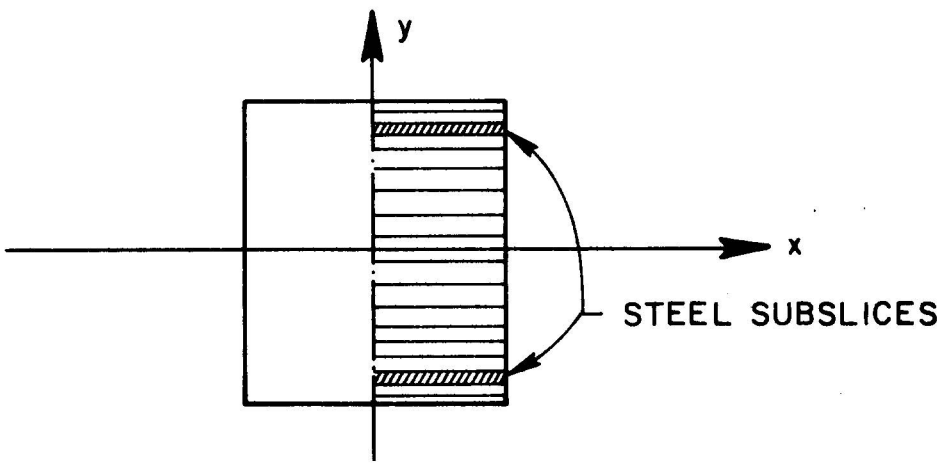


FIGURE 5.2 CROSS-SECTION DISCRETIZED INTO SUBSLICES

Segment cross-sections must be further discretized into subslices to account for nonuniformity of stresses, cracking, crushing, temperature, creep, and shrinkage effects. For segments in which temperature varies in the y-direction only (see Fig. 5.2), cross-sections can be discretized by division into subslices as shown in Fig. 5.2. Steel bars can be represented by subslices with an equivalent area as shown in Fig. 5.2. The mesh should be designed such that the smallest subslices lie where temperature, cracking crushing, and other nonlinear effects are most complex, usually at the outer fibers of members. Only the righthand half of a cross-section need be divided into subslices, since the program automatically extends the pattern to the lefthand half.

For problems in which temperature input varies in the x-direction (see Fig. 5.2) as well as in the y-direction, a two-dimensional cross-sectional mesh is necessary. Such a mesh is normally used when temperature input is provided by FIRES-T. In this case, subslices should be smallest where temperature gradients are greatest, usually by cross-section surfaces. See Fig. B.3 of Appendix B for an example of such a mesh.

5.2 Time Step Size

Users must exercise good judgment in choosing time step length. Two basic types of situations exist:

1. Nonlinear Static Problems - i.e., when the problem is not time dependent. In such cases, time steps are actually load steps and size is not relevant. Only the size of the load increment applied during each time step is relevant. For most nonlinear problems, several load steps must be used to calculate the final deformed shape of the structure since applying the entire load at once might lead to divergence (see Section 2.1), especially if there is severe cracking in concrete or yielding in reinforcing steel. Creep and shrinkage options should not be used in static analyses.

2. Time-Dependent Problems - i.e., where temperature, loading, creep response, or other factors vary with time. The basic analytical techniques underlying FIRES-RC II assume all these factors to be constant during a time step, so that time step size should be smallest where these factors can be expected to vary most. For fire response calculations, a time step size of 0.05 hours has been used with apparently satisfactory results. Time steps as small as 0.01 hours and as large as 0.10 hours have been used resulting in prediction of essentially similar response. For large frames, a smaller time step ($\leq$ 0.05 hours) may be necessary since convergence is slower and more sensitive.

For the sake of economy, time steps should be as large as accuracy and ease of convergence permit. Time step size should vary throughout the analysis to reflect heating and cooling rates.

5.3 Substructuring and Boundary Conditions

In applying FIRES-RC II to large structures, the number of structural elements often exceeds the capacity of available computer storage, and some form of structural partitioning must be employed. Structural partitioning corresponds to dividing a structure into a number of substructures with specified boundaries. Once the stiffness properties of each substructure have been determined, substructures can be treated as complex structural elements, and a matrix displacement method of structural analysis can be formulated for the partitioned structure.

Consider, for example, the thirteen-story, five-bay frame shown in Fig. 5.3. This frame is assumed to be subjected to fire on the seventh floor in the second compartment. The frame can be partitioned in several ways. One manner of partitioning is shown in Fig. 5.4, where the complete frame is partitioned into three substructures. Substructure II is analyzed separately for fire exposure using program FIRES-RC II. The effect of substructures I and III on substructure II can be accounted for by attaching springs to substructure II at the 12 boundary joints as shown in Fig. 5.5. The values of spring stiffnesses can be determined from simple frame analysis, from a standard linear structural analysis [3], or from a separate analysis

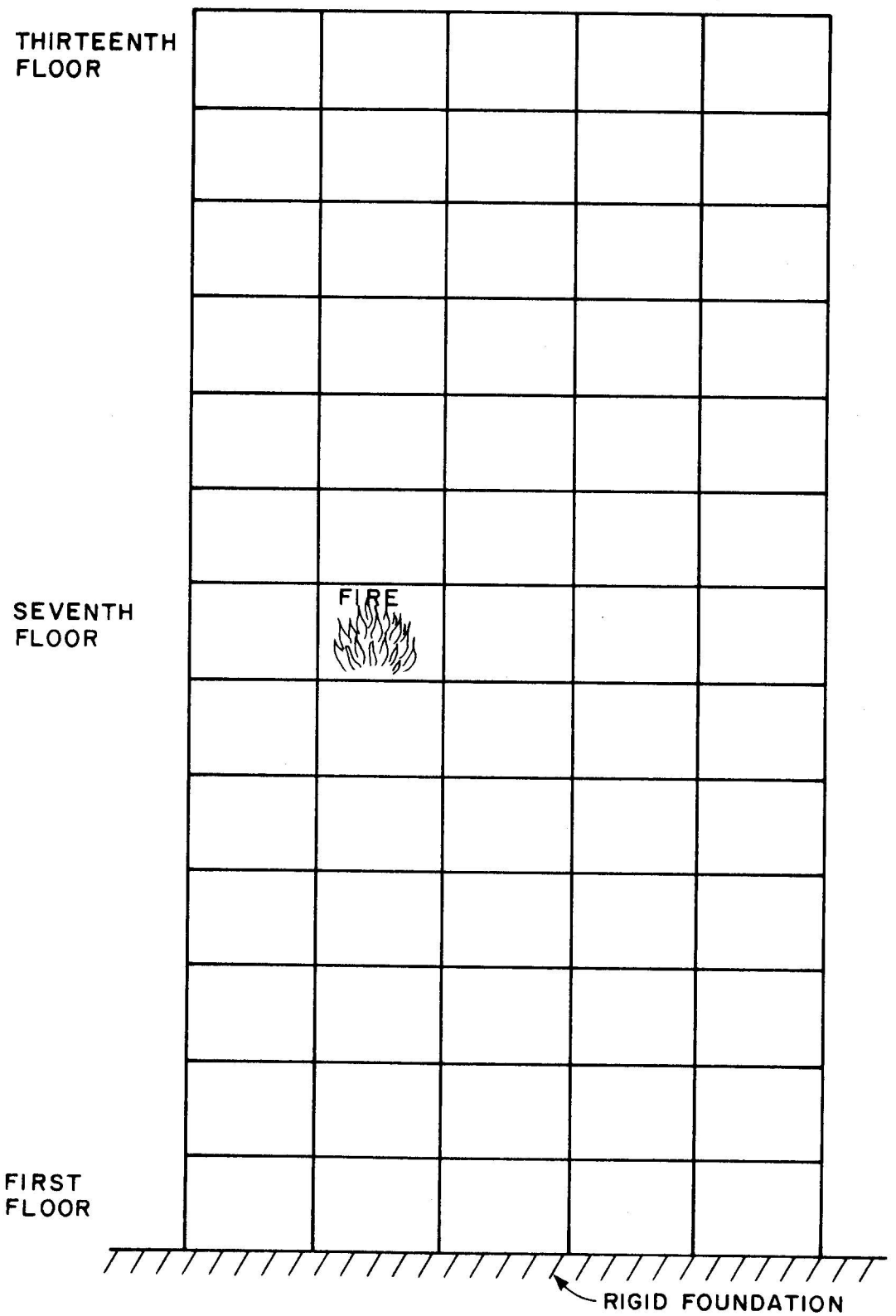


FIGURE 5.3 PROTOTYPE FRAME

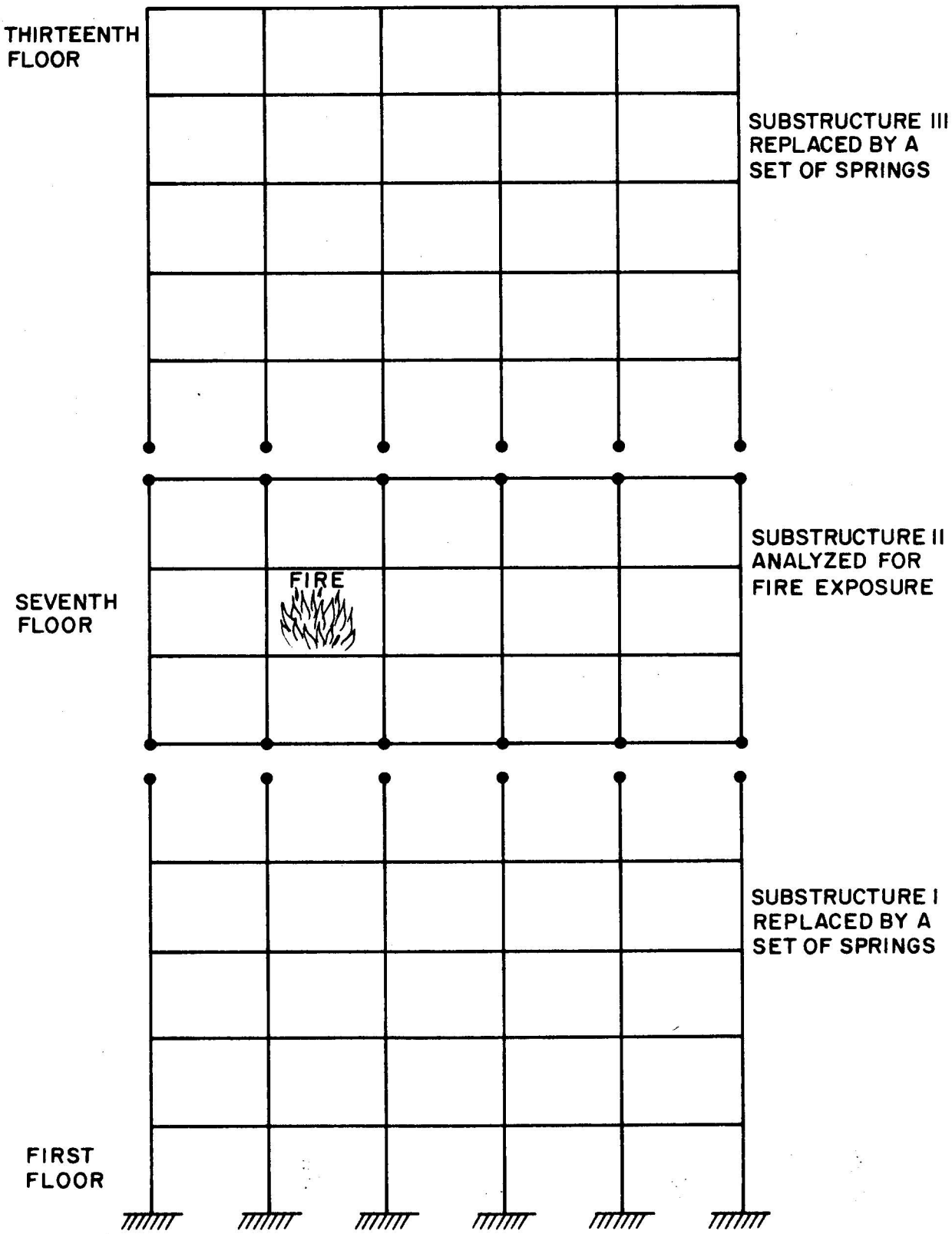


FIGURE 5.4 SUBSTRUCTURING OF MAIN FRAME

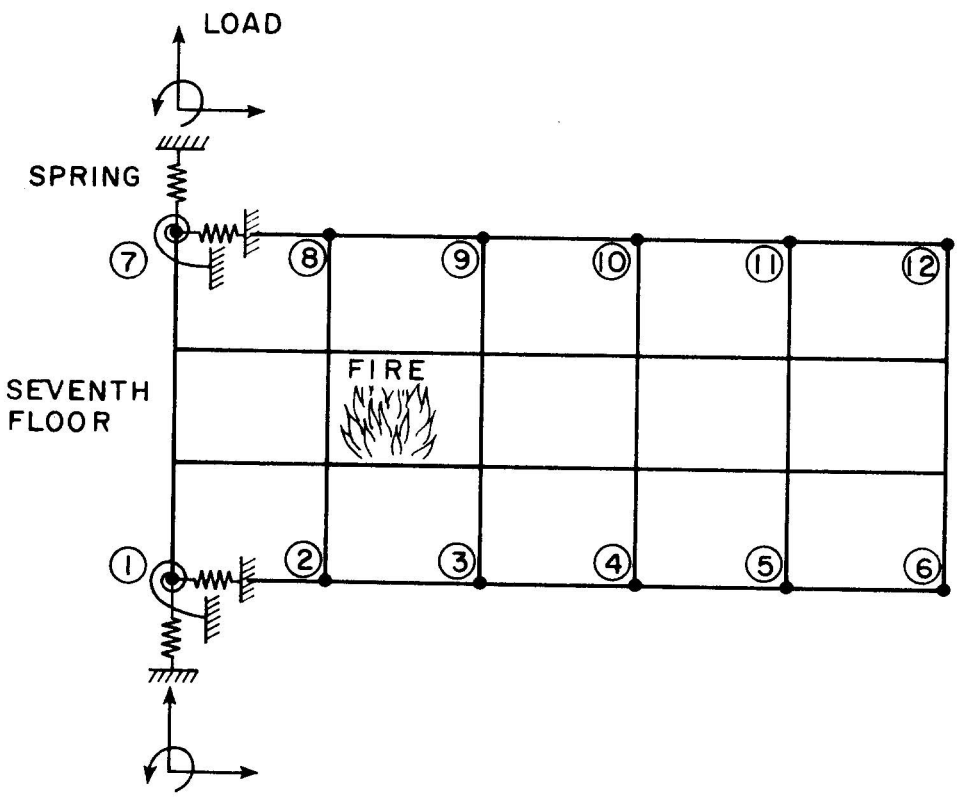


FIGURE 5.5 IDEALIZATION OF SUBSTRUCTURE II

using FIRES-RC II. The basic idea of the analysis is to determine the force exerted on substructure II by substructure I or III when a unit displacement is imposed at a boundary degree of freedom in substructure I or III while maintaining all other degrees of freedom as fixed. In the example considered here, there are 12 common boundary joints each with 3 degrees of freedom (2 translational and 1 rotational), resulting in 36 boundary degrees of freedom in substructure II. Spring stiffness calculation when a unit displacement is imposed at the first boundary degree of freedom in substructure II. Spring stiffness calculation when a unit displacement is imposed at the first boundary degree of freedom in substructure I is shown in Fig. 5.6. The above procedure is repeated for the remaining 35 boundary degrees of freedom from which a 36 × 36 boundary spring stiffness matrix $[k_B]$ is obtained (see below).

The above procedure is equivalent to finding the complete stiffness matrix for substructures I and III, including all joints, and then statically condensing this complete stiffness matrix to one involving only the desired boundary joints.

When analyzing large problems, a large number of spring constants must be input to the program if all coupling terms of the spring stiffness matrix ($k_{i,j}$, $i \neq j$) are considered. Due to symmetry of the spring stiffness matrix, only 342 terms need be input for the above example.

$$[k_B] = \begin{bmatrix} k_{11} & k_{1,2} \cdots & k_{1,18} & 0 & 0 \cdots & 0 \\ & & & & & \vdots \\ & & k_{13,18} & 0 & 0 & 0 \\ & \text{SYM} & & & & \\ & & & k_{19,19} & k_{19,20} & k_{19,36} \\ & & & & & \vdots \\ & & & & & k_{36,36} \end{bmatrix}$$

36 × 36

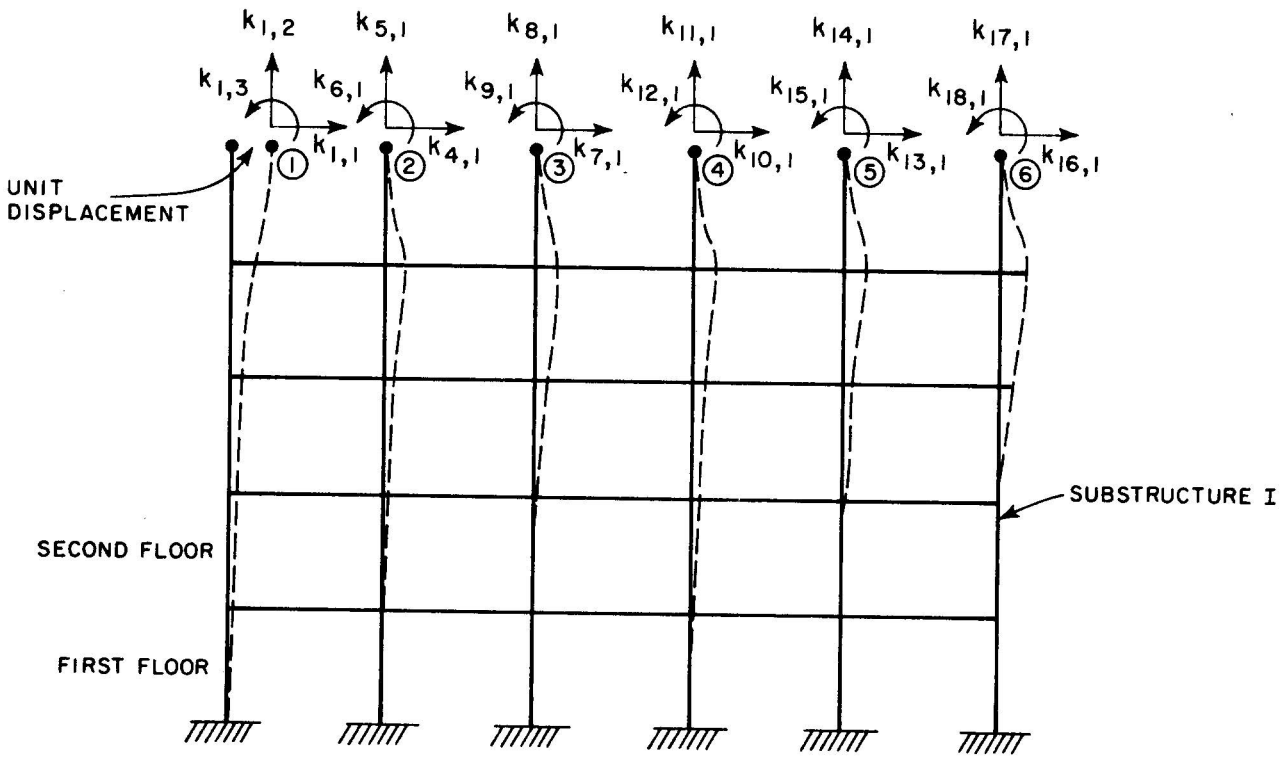


FIGURE 5.6 CALCULATION OF SPRING STIFFNESS

In order to reduce computational time and effort, a simpler procedure is followed in the present version of FIRES-RC II. Coupling terms in the spring stiffness matrix are considered only at the joint level; all remaining coupling terms are neglected. That is, each boundary joint is considered to have a 3 × 3 spring stiffness matrix $[k_{BJ}]$ of the form:

$$[k_{BJ}] = \begin{bmatrix} k_{11} & k_{12} & k_{13} \\ & k_{22} & k_{23} \\ \text{SYM} & & k_{33} \end{bmatrix}$$

$$3 \times 3$$

Hence, only 6 spring stiffness terms are required for each boundary joint, and for the example shown in Fig. 5.5, only $12 \times 6 = 72$ terms are required since there are 12 boundary joints.

Specifying spring constants can further be simplified by inputting only diagonal terms of the spring stiffness matrix (i.e., by assuming that boundary springs are completely uncoupled). In this case, only 36 spring constants need be input for the example shown in Fig. 5.5. In some cases, spring constants are naturally uncoupled, as when modeling flexible or rigid foundations.

Similarly, loads on boundary joints can be approximated by a simple analysis or more accurately by using a static condensation procedure on a complete substructure and condensing the complete load vector to one involving only boundary joints.

Substructure II (Fig. 5.5) can be modeled simply as shown in Fig. 5.7. The lower boundary joints are assumed to rest on infinitely (10^{30} kip/in) rigid springs. All other springs are omitted with the exception of one horizontal stiff spring to prevent rigid body motion. External vertical joint loads can be calculated from loads on upper floors. In this case, only 7 stiff springs need be specified in the input.

Rigid supports are modeled in FIRES-RC II by specifying certain displacement or rotational joint degrees of freedom to be fixed. Within

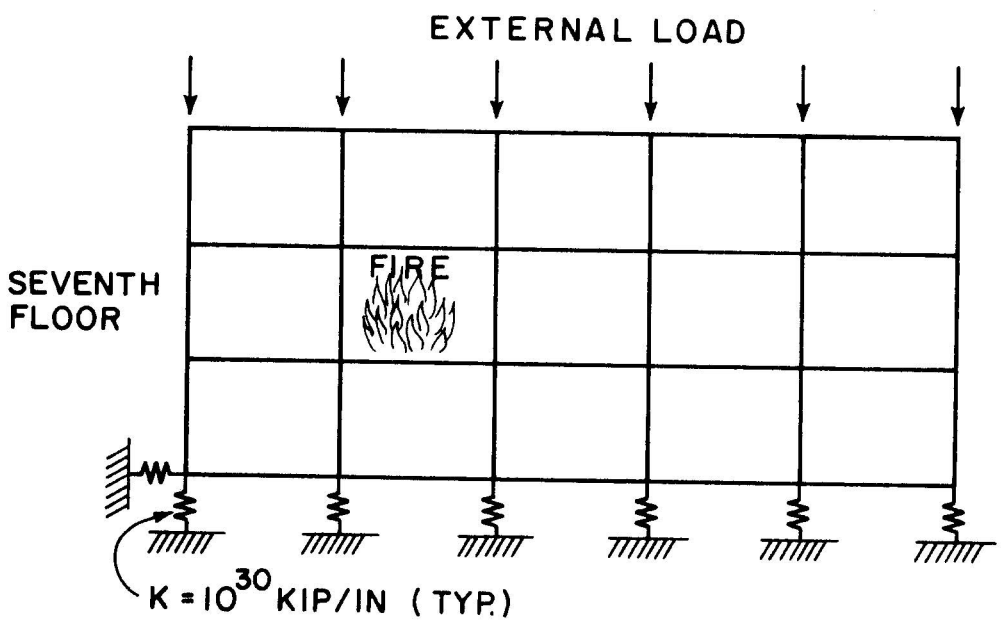


FIGURE 5.7 SIMPLE MODEL FOR SUBSTRUCTURE II

the program, this fixity is accomplished by attaching an extremely high spring stiffness (10^{30} kip/in) to any fixed degree of freedom, thereby preventing any significant motion of that degree of freedom. This method of imposing boundary conditions greatly simplifies the solution algorithm and calculation of support reactions at fixed joints.

5.4 Minimizing Solution Cost

Discretization of a large reinforced concrete frame into many segments and subslices can lead to an expensive analysis, especially if the solution is carried out through many time steps. However, cost is usually not prohibitive if the problem is carefully set up, giving special consideration to the following:

1. File manipulation can be extremely expensive if external storage tapes are used. Solution costs can double or triple if all subslice data are moved in and out of high-speed storage during each iteration. For very large problems, there is no choice but to use external files. But for other problems, care should be taken to minimize discretization size so that subslice data from all segments fit into blank common simultaneously. For example, only those members under close analytical scrutiny need have fine cross-sectional meshes; other less essential members should be assigned coarser meshes preferably using a simple layering of subslices (Fig. 5.2) rather than a fully two-dimensional mesh.

   In addition, the dimensioning of blank common should be increased if necessary in order to fit the entire problem into high-speed storage. A blank common size of 10000 is specified in the listing of FIRES-RC in Appendix C, but the capacity of most computers permits a much greater size. It is much cheaper to use the full storage capacity of a computer than to use external data files during the iterative solution process.

2. Number of iterations should be minimized. Solution cost is roughly proportional to the total number of iterations during the entire solution period (all time steps). However, accuracy is

not directly proportional to number of iterations, especially if it is only the last time step (or load step) or certain selected time steps where the solution is of importance. High accuracy is not necessary in other time steps, since equilibrium is independently satisfied at the end of each time step. The previous solution is merely a starting point ($\underset{\sim}{U}_i^0$) for Newton-Raphsen iteration and does not affect the accuracy of the final convergent solution. However, divergence may result if time steps are too large or segments are too coarse of if the solution from the previous step is so inaccurate that it forms an unrealistic starting point for the iterative process.

Generally, it is most efficient to specify a rough accuracy in the input data (data block CONVERGENCE, page A-14) to be used with most time steps and then a higher accuracy for time steps where the solution is of most interest (data block STEP for given steps, page A-15). Such a procedure can reduce computer costs by half.

Accuracy and number of iterations within each time step are controlled by specifying a tolerance for out-of-balance forces $\delta\underset{\sim}{R}_i^j$. A value of 0.1 kips (or 1.00 kip-in for moments) gives very high and usually unnecessary accuracy; a value of 2.0 kips (or 20.0 kip-in) gives reasonable accuracy for most practical frame problems. Solution cost is sensitive to the tolerance chosen, so tolerances smaller than necessary are to be avoided. In addition, an iteration limit is set to avoid excessive costs when divergence is encountered (e.g. at failure of a structure), or when a particularly sensitive time step is encountered and should be circumvented by proceeding to the next time step. Thirty is a reasonable value for most problems.

The number of iterations needed to effect convergence to within a specified tolerance tends to increase with problem size, as is to be expected with any solution technique for systems of nonlinear equations. Hence, choice of tolerance limits

becomes especially critical when solving very large problems. Experience with analyzing large framed structures [9] has shown that convergence rate differs greatly in different parts of a structure. The specified tolerance limit will affect the size of out-of-balance error only in that part of a frame where convergence is 'slowest;' in other parts of a structure, the error in satisfying equilibrium will usually be several orders of magnitude less than the specified tolerance.

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REFERENCES

1. Akatsuka, Y., Chang, S., and Polivka, M., "Methods of Evaluating Tensile Creep and Stress-Relaxation of Concrete Loads," Transactions of the Japan Society of Civil Engineers, No. 97, September 1963.

2. Anderberg, Y. and Thelandersson, S., "Stress and Deformation Characteristics of Concrete at High Temperatures," Bulletin 34, Lund Institute of Technology, Lund, Sweden, 1973.

3. Bathe, K. J., Wilson, E. L., and Peterson, F. E., "SAP IV - A Structural Analysis Program for Static and Dynamic Response of Linear Systems," Report No. EERC 73-11, Earthquake Engineering Research Center, College of Engineering, University of California, Berkeley, 1973 (revised, April 1974).

4. Becker, J. M., Bizri, H., and Bresler, B., "FIRES-T - A Computer Program for the FIre REsponse of Structures - Thermal," Report No. UCB FRG 74-1, Fire Research Group, Structural Engineering and Structural Mechanics, Department of Civil Engineering, University of California, Berkeley, 1974.

5. Becker, J. M. and Bresler, B., "FIRES-RC - A Computer Program for the FIre REsponse of Structures - Reinforced Concrete Frames," Report No. UCB FRG 74-3, Fire Research Group, Structural Engineering and Structural Mechanics, Department of Civil Engineering, University of California, Berkeley, 1974.

6. Bizri, H., "Structural Capacity of Reinforced Concrete Columns Subjected to Fire Induced Thermal Gradients," Report No. UC SESM 73-1, Structural Engineering Laboratory, University of California, Berkeley, 1973.

7. Bresler, B., "Lightweight Aggregate Reinforced Concrete Columns," Paper SP 29-7, ACI Special Publication SP 29, 'Lightweight Concrete,' 1971.

8. Bresler, B., "Some Factors in the Investigation of Long Term Behavior of Reinforced Concrete Structures," Laboratory Note No. LN/150/BB, Road Research Laboratory, DSIR, England, August 1962.

9. Bresler, B., et al., "Limit State Behavior of Reinforced Concrete Frames in Fire Environments," Proceedings of the Regional Conference on Tall Buildings, Hong Kong, September 20-22, 1976, pp. 310-325.

10. Cruz, C., "Apparatus for Measuring Creep of Concrete at High Temperatures," Journal of Portland Cement Association, Vol. 10, No. 3, September 1968.

11. Dorn, J. E., "Some Fundamental Experiments on High Temperature Creep," Journal Mech. and Phys. Solids, Vol. 3, 1954, p. 85.

12. Dorn, J. E., ed., Mechanical Behavior of Materials at Elevated Temperatures, McGraw-Hill, 1961, Chapter 14, Manson, S. Stanford, "Creep Under Nonsteady Temperatures and Stresses," pp. 419-476.

13. Freudenthal, A. M. and Roll, F., "Creep and Creep Recovery of Concrete under High Compressive Stress," Proceedings of the ACI, Vol. 54, 1957-58, pp. 1111-1142.

14. Harmathy, T., "Deflection and Failure of Steel-Supported Floors and Beams in Fire," ASTM STP 422, Symposium on Fire Test Methods - Restraint and Smoke, July 1966.

15. Harmathy, T. Z., "A Comprehensive Creep Model," Transactions of the ASME, September 1967, pp. 496-502.

16. Harmathy, T. Z. "Creep Deflection of Beams," ASCE Nat'l. Structural Engineering Meeting Preprint 2216, April 1974, 25 pp.

17. Harmathy, T. and Stanzak, W., "Elevated Temperature Tensile and Creep Properties of Some Structural and Prestressing Steels," ASTM STP 464, Symposium on Fire Test Performance, Feb. 1969.

18. Hsu, T. T., et. al., "Microcracking of Plain Concrete and the Shape of the Stress-Strain Curve," ACI Journal, Vol. 60, No. 2, Feb. 1963, pp. 209-224.

19. Hsu, T. T. and Slate, F. O., "Tensile Bond Strength Between Aggregate and Cement Paste or Mortar," ACI Journal, Vol. 60, No. 4, April 1963, pp. 465-486.

20. Iding, R., Lee, J., and Bresler, B., "Behavior of Reinforced Concrete under Variable Elevated Temperatures," Report No. UCB FRG 75-8, Fire Research Group, Structural Engineering and Structural Mechanics, Department of Civil Engineering, University of California, Berkeley, 1975.

21. Mukaddam, M., "Behavior of Concrete under Variable Temperature and Loading," Final Report, Symposium, Design of Concrete Structures for Creep, Shrinkage and Temperature Changes, Madrid, 1970, pp. 301-310.

22. Mukaddam, M., "Creep Analysis of Concrete at Elevated Temperature," ACI Journal, Vol. 71, No. 2, February 1974, pp. 72-79.

23. Mukaddam, M. A. and Bresler, B., "Behavior of Concrete under Variable Temperature and Loading," ACI SP-34, Paper No. 37, 1972, pp. 771-797.

24. Roll, F., "Long-Time Creep-Recovery of Highly Stressed Concrete Cylinders, ACI SP-9, Paper No. 4, 1964, pp. 95-114.

25. Saenz, L. P., "Discussion of 'Equation for the Stress-Strain Curve for Concrete,' by Desayi, P. and Krishnan, S., " ACI Journal, Vol. 61, No. 9, September 1964, pp. 1229-1235.

26. Scanlon, A., "Time-Dependent Deflections of Reinforced Concrete Slabs," Ph.D. Dissertation, Department of Civil Engineering, University of Alberta, Edmonton, Canada, December 1971.

27. Selna, L., "Creep, Cracking, and Shrinkage in Concrete Frame Structures," Journal of the Structural Division, ASCE, Vol. 95, No. ST12, Proceedings Paper 6949, December 1969, pp. 2743-2761.

28. Sherby, O. and Dorn, J. E., "An Analysis of the Phenomenon of High Temperature Creep," Proceedings of the Society for Experimental Stress Analysis, Vol. 12, 1953, p. 139.

29. Slate, F. O. and Olsefski, S., "X-Rays for Study of Internal Structure and Microcracking of Concrete," ACI Journal, Vol. 5, No. 5, May 1963, pp. 575-588.

30. Symposium on Naval and Structural Mechanics, Third, 1963, Proceedings: High Temperatures in Structures and Materials, "Physical Aspects of Creep," Dorn, J. E. and Mote, J., p. 95.

APPENDIX A - INPUT INSTRUCTIONS FOR FIRES-RC II

Contents

I. Heading Card

II. Material Model Control Cards

III. Joint Data

IV. Member Data

V. Segment Data

For each segment cross-section type:

1. Control Card
2. Nodal Data Cards
3. Concrete Element Data Cards
4. Steel Element Data Cards

VI. Material Property Data

VII. Convergence Criteria

VIII. Time Step (or Load Step) Data

For each time step:

A. Control Card

B. Joint Loading Data

C. Joint Boundary Conditions Data

D. Member Data

I. HEADING CARD (10A6)

NOTE/ Begin each new data case with a new heading card. To halt the program insert two blank cards instead of a heading card.

II. MATERIAL MODEL CONTROL CARDS

A. Shrinkage Card (80A1)

note	columns	entry
(1)	1-9	Enter the word "SHRINKAGE"

NOTE/ Insert this card if concrete shrinkage is to be considered in the analysis

B. Concrete Creep Card (80A1)

note	columns	entry
(1)	1-14	Enter the words "CONCRETE CREEP"

NOTE/ Insert this card if creep in concrete is to be considered in the analysis

C. Steel Creep Card (80A1)

note	columns	entry
(1)	1-11	Enter the words "STEEL CREEP"

NOTE/ Insert this card if creep in steel is to be considered in the analysis

III. JOINT DATA

A. Control Card (Alphanumeric)

JOINTS, N1

note	field	variable	entry
(1)	JOINTS	--	Enter the word "JOINTS"
(2)	N1	NJ	Number of joints

NOTES/

(1) This is an alphanumeric control card containing both a key word (JOINTS) to identify the block of input data to follow and a control parameter (N1) for that block of data. Alphanumeric control cards are left-justified with no blanks in the list. Note the examples in Fig. A.1.

(2) Enter the total number of joints in the structure.

B. <u>Joint Data Cards</u> (I5,2F10.0,A5)

note	field	variable	entry
(1)	1- 5	N	Joint number GE.1 and LE. NJ
(2)	6-15	X(N)	X-coordinate
(2)	16-25	Y(N)	Y-coordinate
(3)	28	IX	Restraint on X-degree of freedom EQ. 0, unrestrained EQ. 1, fixed
(3)	29	IY	Restraint on Y-degree of freedom EQ. 0, unrestrained EQ. 1, fixed
(3)	30	IR	Restraint on Θ-degree of freedom EQ. 0, unrestrained EQ. 1, fixed

NOTES/

(1) Joint data must be defined for all (NJ) joints in the frame.

(2) Joint coordinates can be input using any system of units. However, this same system must be used to define all other input quantities.

(3) If a degree of freedom for a joint is to act as a boundary condition (i.e., be restrained), it is so indicated on this card.

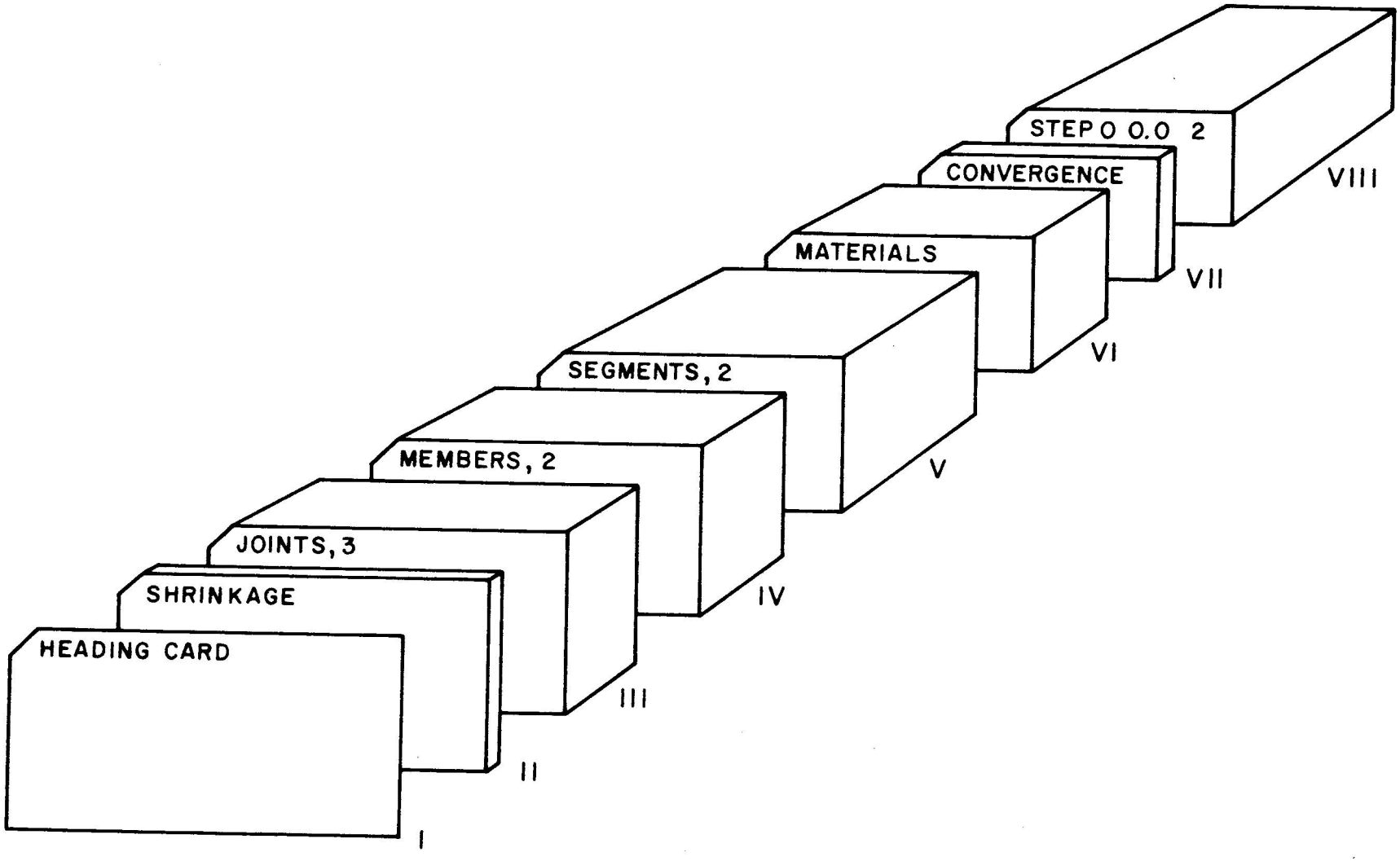

FIGURE A.1 TYPICAL INPUT DECK FOR FIRES-RC II

IV. MEMBER DATA

A. Control Card (Alphanumeric)

MEMBERS, N1

note	field	variable	entry
(1)	MEMBERS	--	Enter the word "MEMBERS"
(2)	N1	NM	Number of members in frame

NOTES/

(1) This is an alphanumeric control card with key word (MEMBERS) and control parameter (N1) as in Fig. A.1.

(2) Enter the total number of members in the frame.

B. Member Data Cards (3I5,6(I3,F7.0))

note	field	variable	entry
(1)	1- 5	N	Member number
(2)	6-10	MI	Joint I
(2)	11-15	MJ	Joint J
(3)	16-18	MSEG(1)	Segment type number for segment 1
(3)	19-25	SEGL(1)	Proportional length of segment 1
	.		
	.		continued for segments 2 to 6
	.		

NOTES/

(1) One card is required for each of the (NM) members in the frame. Member cards must be input in ascending member number order.

(2) The member's location is defined by the bounding joints, as in Fig. A.2. The number of joint I must be the lower of the two.

(3) Each member may be divided into from 1 to 6 segments (see Fig. A.2). Segments are represented by both a segment type number and a proportional length which is taken with other segment lengths against overall member length. The program counts segments until the first zero segment length is encountered.

V. SEGMENT DATA

A. Control Card (Alphanumeric)

SEGMENTS, N1

note	field	variable	entry
(1)	SEGMENTS	--	Enter the word "SEGMENTS"
(2)	N1	MGTY	Number of segment cross section types

NOTES/

(1) This is an alphanumeric control card with key word (SEGMENTS) and control parameter (N1) as in Fig. A.1.

(2) Enter the number of different cross section types that occur in the structure. Note that each segment defined on the Member Data Cards (page A-5) must refer to one of these segment cross-section types.

B. Segment Type Data

Input the following set of cards for each segment cross section type:

1. Control Card (A1,6X,I3,5I5,F10.0)

note	field	variable	entry
	1- 7	--	Enter the word "SEGMENT"
	8-10	ISEGTY	Segment cross-section type number GE.1 and LE. MGTY
(1)	11-15	ISYM	Symmetry indicator EQ. 0, section nonsymmetrical EQ. 1, section symmetrical about x-axis
(2)	16-20	NUMNP	Number of nodal points in input cross section.
(3)	21-25	NELCON	Number of concrete elements in input cross section. GT.0
(3)	26-30	NELSTL	Number of steel elements in input cross section. GE.0
(4)	31-35	ICG	Reference plane shift indicator EQ. 0, x-axis is on reference plane EQ. 1, read in shift, y_{ref} EQ. 2, shift cross section so that center of gravity of uncracked transformed section is on reference plane.

(4)	36-45	YREF	Data for reference plane shift If ICG EQ. 0, leave blank If ICG EQ. 1, enter y_{ref} If ICG EQ. 2, enter the modulus ratio $n = E_s/E_c$ EQ. 0, default value of "1" used

NOTES/

(1) Segment cross sections are always assumed to be symmetric about the y-axis (see Fig. A.2). It is also possible to specify that the cross section is also symmetric about the x-axis in which case only the upper right (x and y positive) quadrant is input. The program will rotate this quadrant mesh about the x-axis to generate a full mesh.

(2) Each segment cross section is idealized as a collection of steel and concrete elements. Enter the total number of nodal points that define the corners of these elements for this segment type. Note that only half the cross section is divided into elements due to symmetry about the vertical y-axis. If ISYM .EQ. 1 above, then only a quadrant is discretized into elements.

(3) Each element in the mesh can be specified as being composed of concrete or steel (reinforcing bars). Enter the total number of each type of element.

(4) The sign convention for the coordinates of the segment cross section is based on the orientation of the substructured member. Joint I of the member is considered an origin from which the X-axis extends to Joint J. The Y-axis then extends to the left as one would traverse from I to J (see Fig. A.2). The X-Y plane is the plane of analysis for the frame and therefore provides a plane of symmetry for the cross-section. The X-axis extended perpendicularly to the X-Y plane defines a reference plane. The cross section data that are input are based on a x-y coordinate system (see Fig. A.2). The y-axis of this system is coincident with the member Y-axis, but the x-axis need not be on the reference plane that connects joints I and J. FIRES-RC II allows the user to input a shift for the x-axis or will calculate the shift required for the center of gravity of the cross section to be on the reference plane.

2. <u>Nodal Data Cards</u> (I5,2F10.0)

note	columns	variable	entry
(1)	1- 5	N	Nodal point number
(2)	6-15	X(N)	x-coordinate
(2)	16-25	Y(N)	y-coordinate

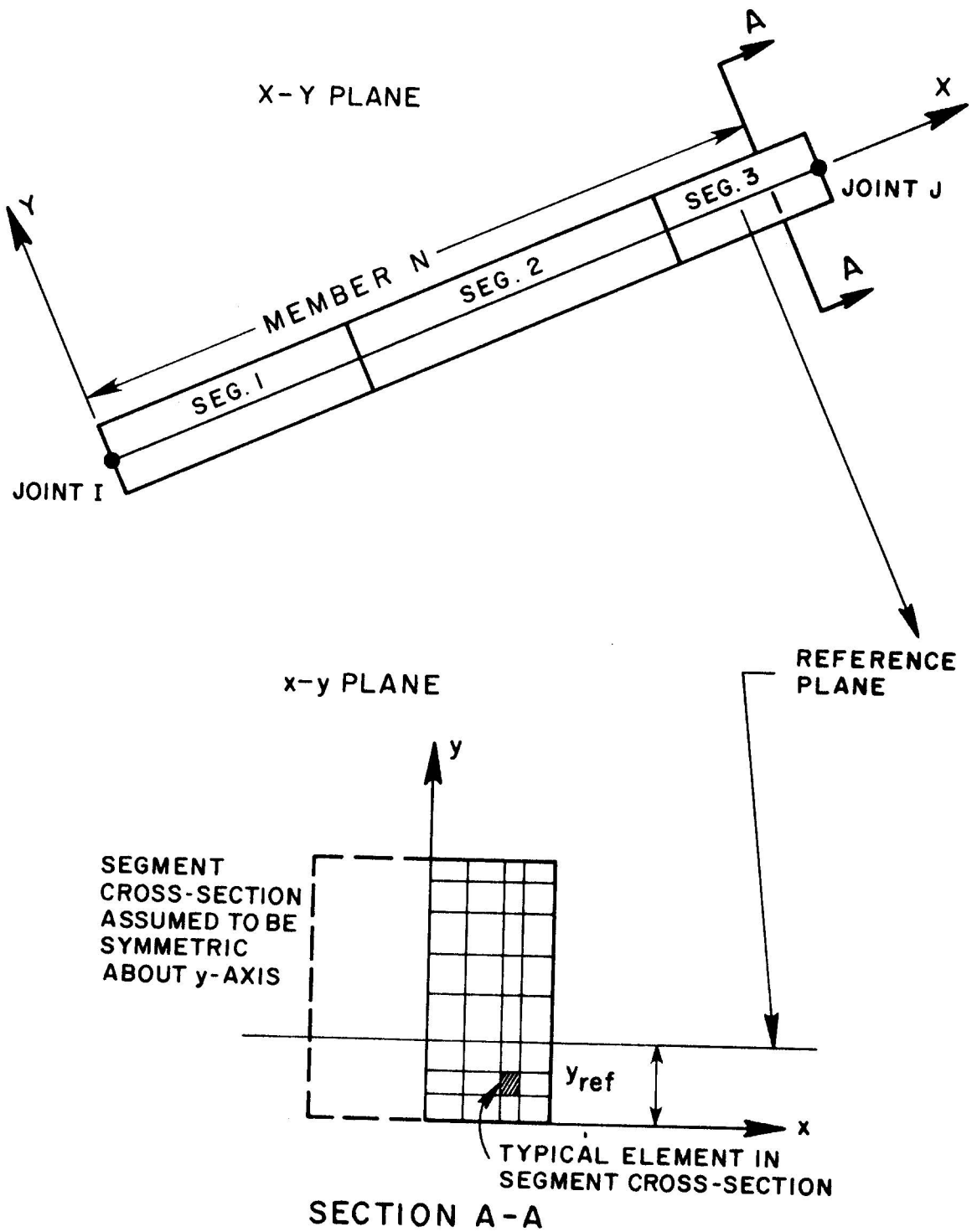

FIGURE A.2 MEMBER DISCRETIZED INTO SEGMENTS AND SEGMENT DISCRETIZED INTO ELEMENTS

NOTES/

(1) Nodal point data cards must be in numerical sequence. If cards are omitted, the missing nodes are generated at equal intervals along a straight line between the bounding nodal points.

(2) Nodal coordinates must be in the same system of units as frame dimensions, material properties, etc.

3. Concrete Element Data Cards (5I5)

note	columns	variable	entry
(1)	1- 5	N	element number
(2)	6-10	LM(1,N)	nodal point I
(2)	11-15	LM(2,N)	nodal point J
(2)	16-20	LM(3,N)	nodal point K
(2)	21-25	LM(4,N)	nodal point L

NOTES/

(1) Concrete elements must be input in ascending element number order. If element cards are missing, the program generates the missing elements by incrementing N and nodal points I, J, K, and L. The last concrete element in the mesh cannot be generated.

(2) The program uses quadrilateral elements defined by their corner nodes (I, J, K, L). Enter the cross section node number of each of these four corner nodes in counterclockwise order as shown in Fig. A.3. Triangular elements can be formed by specifying a degenerate quadrilateral, i.e. by letting K and L be defined by the same node (see Fig. A.3).

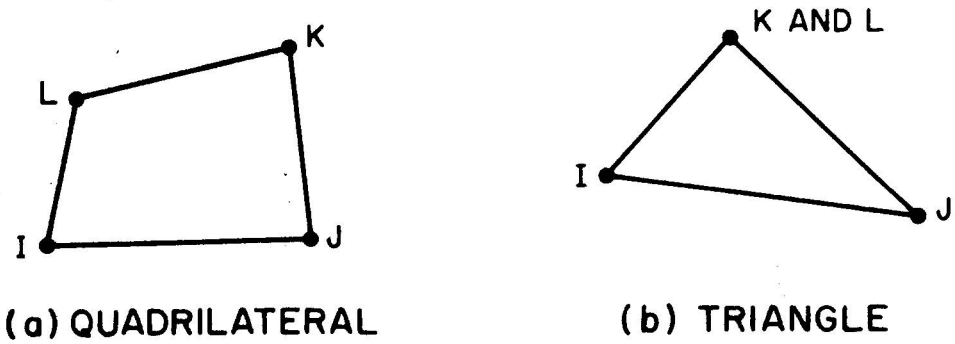

FIGURE A.3 FOUR-NODE ELEMENTS

4. Steel Element Data Cards (5I5)

note	columns	variable	entry
(1)	1- 5	N	steel element number
	6-10	LM(1,N)	nodal point I
	11-15	LM(2,N)	nodal point J
	16-20	LM(3,N)	nodal point K
	21-25	LM(4,N)	nodal point L

NOTE/

(1) Input steel elements in the same way as concrete elements.

VI. MATERIAL PROPERTY DATA

A. Control Card (Alphanumeric)

MATERIALS

note	field	variable	entry
(1)	MATERIALS --		Enter the word "MATERIALS"

NOTE/

(1) This is an alphanumeric control card with key word (MATERIALS)

B. Concrete Parameters

1. Concrete Control Card (7I5)

note	columns	variable	entry
(1)	1- 5	KCEC	coefficient of expansion control
(1)	6-10	KEC	modulus of elasticity control
(1)	11-15	KFC	compressive strength control
(1)	16-20	KEFC	strain at compressive strength control
(1)	21-25	KFU	ultimate (crushing) stress control
(1)	26-30	KEFU	ultimate (crushing) strain control
(1)	31-35	KFT	tensile strength control

NOTE/

(1) A zero (0) control variable indicates a temperature-independent material property. A nonzero value from 2 through 10 indicates the number of points required to define the material property as a piecewise linearized function of temperature. All material parameters are input as positive quantities.

2. Coefficient of Expansion (8E10.0)

note	columns	variable	entry
(1)	1-10	X(1)	temperature at point 1
(1)	11-20	Y(1)	coefficient of expansion at point 1
(1)	21-30	X(2)	temperature at point 2
	.	.	.
	.	.	.
	.	.	.

NOTES/

(1) If the control variable KCEC on the Control Card V1.B.1 is zero (0), then the coefficient of expansion is a constant and is input in cols 1 - 10 with format E10.0. If KCEC is nonzero, then input function points as ordered pairs (temperature, coefficient of expansion) at four pairs to a card.

3. Modulus of Elasticity (8E10.0)

(same as above)

4. Compressive Strength (8E10.0)

(same as above)

5. Strain at Compressive Strength (8E10.0)

(same as above)

6. Ultimate (Crushing) Stress (8E10.0)

(same as above)

7. Crushing Strain (8E10.0)

(same as above)

8. Tensile Strength (8E10.0)

(same as above)

C. Steel Parameters

1. Steel Control Card (3I5)

note	columns	variable	entry
(1)	1- 5	KCES	coefficient of expansion control
(1)	6-10	KES	modulus of elasticity control
(1)	11-15	KEY	yield strain control

NOTE/

(1) Same as control variables for concrete properties.

2. Coefficient of Expansion (8E10.0)

note	columns	variable	entry
(1)	1-10	X(1)	temperature at point 1
	11-20	Y(1)	coefficient of expansion at point 1
	21-30	X(2)	temperature at point 2
	.	.	.
	.	.	.

NOTE/

(1) Same as for concrete properties.

3. Modulus of Elasticity (8E10.0)

(same as above)

4. Yield Strain (8E10.0)

(same as above)

D. Cracking Unloading Curve

1. Cracking Curve Control Card (I5)

note	columns	variable	entry
(1)	1- 5	NSP	number of input stress-strain points defining cracked unloading curve

NOTE/

(1) Maximum number of points permitted is 4.

2. Stress-Strain Points Defining Cracking Curve (8F10.0)

note	columns	variable	entry
(1)	1-10	SN(1)	normalized strain of first point
(1)	11-20	AP(1)	normalized stress of first point
(1)	21-30	SN(2)	normalized strain of second point
(1)	31-40	AP(2)	normalized stress of second point
(1)	41-50	SN(3)	normalized strain of third point
(1)	51-60	AP(3)	normalized stress of third point
(1)	61-70	SN(4)	normalized strain of fourth point
(1)	71-80	AP(4)	normalized stress of fourth point

NOTE/

(1) Input as many points as are specified in the preceding card (NSP). Each point is defined by a normalized strain, $SN(i) = \varepsilon_i/\varepsilon_t(T)$, and a normalized stress, $AP(i) = \sigma_i/f_t(T)$. A normalized cracking unloading curve will be defined by a polynomial curve passing through these points. See Sec. 3.2.1.2., page 35.

VII. CONVERGENCE CRITERIA

A. Control Card (Alphanumeric)

CONVERGENCE

note	field	variable	entry
(1)	CONVERGENCE	--	Enter the word "CONVERGENCE"

NOTE/

(1) This is an alphanumeric control card with key word (CONVERGENCE) as in Fig. A.1.

B. Convergence Criteria Card (I5,3E10.0)

note	columns	variable	entry
(1)	1- 5	LOOMX	Maximum number of iterations permitted in each time step EQ. 0, no iteration
(1)	6-15	ERP(1)	Permissible out-of-balance force - X-direction EQ. 0, default value of 0.01 used
(1)	16-25	ERP(2)	Permissible out-of-balance force - Y-direction EQ. 0, default value of 0.01 used
(1)	26-35	ERP(3)	Permissible out-of-balance moment EQ. 0, default value of 0.01 used

NOTES/

(1) Iteration within any time step will continue until either (1) the out-of-balance forces and moments at all joints and intersegmental nodes are less than the specified tolerances ERP, or (2) the number of iterations exceeds LOOMX. If the iteration limit is reached, a warning message is printed and the program proceeds to the next time step using the nonconvergent solution as an approximation to the initial conditions for the next time step.

IX. TIME STEP (OR LOAD STEP) DATA

For each time step input the following set of cards:

A. Time Step Control Card (A4,I6,F10.0,4I5,2X,A3,2I5,3F5.3)

note	columns	variable	entry
	1-4	ISTEP	Enter the control word "STEP"
(1)	5-10	NDT	Time step number GE. 0
(2)	11-20	DT	Time step length LT. 0, stop solution
(3)	21-25	I0	Number of joints at which an incremental load is applied during this time step
(4)	26-30	I1	Number of joints at which boundary conditions are reset during this time step
(5)	31-35	I2	Printed output option EQ. 0, system and member data EQ. 1, system, member, and segment data EQ. 2, system, member, and segment data, including input temperature distributions.
(6)	36-40	I3	Punch output option EQ. 0, no punched output EQ. 1, system and member data EQ. 2, system, member, and selected segment data
	41-42	--	Blank
	43-45	LABEL	Three-letter label for punched output EQ. blank, FRC is used
(7)	46-50	I4	Intermediate printout option (for debugging purposes) EQ. 0, no printout EQ. 1, system data EQ. 2, system and member data EQ. 3, system, member, and segment data
(8)	51-55	I5	Special publishable output option EQ. 0, standard output EQ. 1, special output
(9)	56-60	ERP(1)	Convergence limit for X-direction out-of-balance forces

(9)	61-65	ERP(2)	Convergence limit for Y-direction out-of-balance forces
(9)	66-70	ERP(3)	Convergence limit for out-of-balance moments

NOTES/

(1) The first time step control card input must be for initialization and NDT is specified as zero (0) in this case. Subsequent time steps must be sequential with no time step cards omitted.

(2) Time step length in hours. For STEP 0, this entry indicates starting time. A negative time step will conclude the step-by-step solution of this problem and begin consideration of the next problem in the input deck.

(3) Joint loads may be increased or decreased during any time step. Enter the total number of joints in the frame at which a load increment is applied during this particular time step.

(4) Boundary conditions (fixed or spring) may also be changed during any time step. Enter the total number of joints at which a boundary condition is changed during this time step.

(5) Select the amount of printed output desired for this time step. Note that the printing of segment cross-section data can be quite expensive for large problems and should not be requested for all time steps unless necessary.

(6) Refer to note for Card IX.D.3.a (page A-20) if punched output is desired for segment cross sections.

(7) If convergence difficulties are encountered in solving a certain problem, this option may be specified to print numerous problem variables during each iteration. Do not use this option for normal runs.

(8) Normal output format (I5.EQ.0) makes efficient use of the entire page of computer output. Special output format (I5.EQ.1) uses only 61 columns of the output page so that computer results need not be reduced when published on 8-1/2" x 11" pages. Do not use this option for normal runs.

(9) If these variables are left blank, the convergence tolerances specified on Card VII.B are used. If new tolerances are specified here, they will be used for this time step only. See Section 5.4 for comments on this option.

B. Joint Loading Data (I5,3E10.0)

Omit this card if (IO) in columns 21 - 25 of the preceding card is zero.

note	columns	variable	entry
(1)	1- 5	JT	Joint number
	6-15	DV(1)	Load change in X-direction
	16-25	DV(2)	Load change in Y-direction
	26-35	DV(3)	Change in moment

NOTE/

(1) There must be one joint loading card for each of the (IO) joints indicated on the Time Step Control Card. The sign convention for positive loads coincides with the X-Y axes and for positive moments is counterclockwise. The quantities on this card are load increments which are added to the joint loads existing previous to this time step.

C. Joint Boundary Conditions Data (I5,9E8.0)

Omit this card if (I1) in columns 26 - 30 of the Time Step Control Card is zero.

note	columns	variable	entry
(1)	1- 5	JT	Joint number
(2)	6-13	SP(1)	K_{11} (X-direction spring constant)
	14-21	SP(2)	K_{22} (Y-direction spring constant)
	22-29	SP(3)	K_{33} (rotational spring constant)
	30-37	SP(4)	K_{12} (X-Y coupling term) EQ. 0.0, no spring coupling
	38-45	SP(5)	K_{13} (X-θ coupling term) EQ. 0.0, no spring coupling
	46-53	SP(6)	K_{23} (Y-θ coupling term) EQ. 0.0, no spring coupling

(2)	54-61	DPL(1)	Known displacement, X-direction
	62-69	DPL(2)	Known displacement, Y-direction
	70-77	DPL(3)	Known rotation (in radians)

NOTES/

(1) There must be one joint boundary condition card for each of the (I1) joints indicated on the Time Step Control Card.

(2) Either spring stiffness boundary conditions or fixed displacement boundary conditions may be specified. Stiffness is defined by the 3 x 3 matrix

$$K = \begin{bmatrix} K_{11} & K_{12} & K_{13} \\ K_{12} & K_{22} & K_{23} \\ K_{13} & K_{23} & K_{33} \end{bmatrix}$$

where K_{11} and K_{22} are translational spring stiffnesses, K_{33} is the rotational spring stiffness, and K_{12}, K_{13}, and K_{23} are optional coupling terms. A fixed boundary condition is specified by setting the appropriate term (K_{11}, K_{22}, or K_{33}) to 1.0E+30. Use of this card affects all 6 values of K for this joint, so that degrees of freedom fixed in the Joint Data Cards III.B must be reset to 1.0E+30 if they are to remain fixed.

D. Member Data

For each member insert the following set of cards:

1. Member Control Card (A1,A5,I4,I5,F10.0,I5)

note	columns	variable	entry
	1- 6	--	Enter the control word "MEMBER"
	7-10	M	Member number
	11-15	M1	Temperature input indicator EQ. 0, temperature nonuniform and input on separate data cards (see Section IX.D.3.b) EQ. 1, temperature uniform throughout member and input as TCONST on this card.
(1)	16-25	TCONST	Temperature of member If M1 EQ. 0, leave blank

(2)	26-30	M2	Indicator for interior loads on substructured member. EQ. 0, no change in load during this time step. EQ. 1, change in interior loading.

NOTES/

(1) If temperature is uniform throughout the member during this time step, set (M1) to "1" and enter this temperature as (TCONST) in columns 16 - 25. If a nonuniform temperature distribution is to be input along with the segment data cards which follow this control card, enter "0" in column 15 and leave columns 16 - 25 blank.

(2) If during this time step external load increments are to be applied at the intersegmental nodes within the member, enter (M2) equal to "1".

2. <u>Member Load Cards</u> (6E10.0)

Omit this card if (M2) in columns 26 - 30 of the Member Control Card is zero.

note	columns	variable	entry
(1)	1-10	F(1)	Load change in X-direction (first intersegmental node)
	11-20	F(2)	Load change in Y-direction (first intersegmental node)
	21-30	F(3)	Change in moment load (first intersegmental node)
	31-40	F(4)	Load change in X-direction (second intersegmental node)
	.		
	.		
	.		continue until all intersegmental nodes are input

NOTES/

(1) Load increments are applied using the member coordinate system (Fig. A.4), not the global frame coordinate system. Only interior intersegmental nodes may be loaded as shown for the case of a 3-segment member in Fig. A.4. Input two (2) nodes (6 entries) maximum per card.

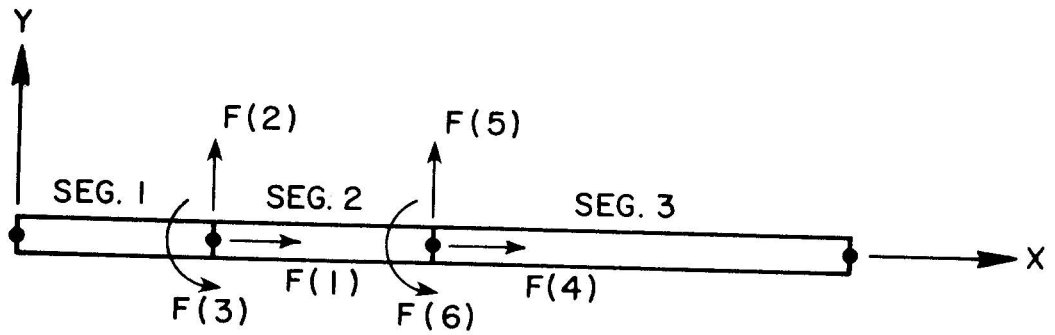

FIGURE A.4 INTERIOR LOADING ON SUBSTRUCTURED MEMBER

3. Segment Data

For each segment in this member insert the following cards:

a. Selected Stress Data for Punching (9(A1,I7))

Omit this card if (I3) in columns 36 - 40 of the Time Step Control Card is less than "2" for all time steps.

note	columns	variable	entry	
(1)	1	IELTYPE	Type of element EQ. C, concrete EQ. S, steel	First Element to be Punched
	2-8	NSTR(1)	Element number	
	9	IELTYPE	Type of element	Second Element to be Punched
	.	.	.	
	.	.	.	
	.	.	.	

NOTES/

(1) If selected stress and strain data are desired, as indicated by I3 .EQ. 2 in the Time Step Control Card VIII.A, this card must appear for each segment in the structure during the initial time step only. Data for up to nine elements can be punched. This consists of subslice stress, and stress-related strain x 1000 for concrete subslices or stress ratio to yield for steel subslices.

b. Segment Temperature Data Control Card (2A10,18X,F6.3,2X,I4)

Omit this card if (M1) in columns 11 - 15 of Member Control Card is "1".

note	columns	variable	entry
(1)	1- 8	J1	Enter the word "CONSTANT" if temperature is constant throughout cross-section; otherwise leave blank
(1)	11-20	TM	If temperature is constant, place value here; otherwise leave blank
	21-46	--	blank
(2)	47-50	NELS	Total number of elements (steel plus concrete) in this segment

NOTES/

(1) If the temperature distribution within this segment cross-section is uniform during this time step, enter the word "CONSTANT" in columns 1 - 8 and input the temperature in columns 11 - 20. If a nonuniform distribution is to be input, leave columns 1 - 20 blank.

(2) Enter the total number of elements in the mesh for this segment, i.e., (NELCON + NELSTL) from Segment Type Control Card V.B. Leave blank if (J1) equals "CONSTANT".

This header card is consistent with the punched output from program FIRES-T.

c. Segment Temperature Data (7(4X,F6.1))

Omit these cards if (M1) in columns 11 - 15 of Member Control Card is zero or if (J1) in columns 1 - 10 of Segment Temperature Data Control Card is the word "CONSTANT".

note	columns	variable	entry
	1- 4	--	not used
(1)	5-10	T(1)	Temperature of first concrete element
	11-14	--	not used
	15-20	T(2)	Temperature of second concrete element
	.	.	.
	.	.	.
	.	.	.
		T(NELS)	Temperature of last steel element

NOTES/

(1) The current temperature of each element is input on these cards. All elements must be in sequential order with all concrete elements preceding the steel elements. Seven (7) element temperatures are input on each card. This format is compatible with the punched output of program FIRES-T.

Note that these are current temperatures and not temperature increments. Also note that the input temperatures must be in the same system of units as the coefficients of thermal expansion input in Sections VI.B.2 and VI.C.2.

APPENDIX B

SAMPLE PROBLEM

The sample problem illustrates the capabilities of FIRES-T and FIRES-RC II in predicting thermal and structural response of reinforced concrete frames exposed to fire. For this purpose, a single-bay, one-story frame (30 ft. wide, 15 ft. high) was selected for analysis. This frame was assumed to be fixed at the base and exposed to an interior symmetric fire. The dimensions of frame members and details of reinforcement are shown in Fig. B.1. The total gravity load uniformly distributed on the frame girder was 2 kips/foot.

Thermal properties of concrete and steel were modeled for use in FIRES-T and are given in Table B.1. Mechanical properties were based on concrete with a compressive strength, f'_c, of 4 ksi, and steel reinforcement with a yield strength, f_y, of 40 ksi. These mechanical properties are temperature-dependent and can be found in the sample output given in Table B.4.

The pseudo-fire is represented by the first hour of the ASTM E119-73 fire curve (see Fig. B.4). The thermal response of the frame was modeled by dividing the interior of the frame into four fire zones (see Fig. B.2). The coefficients used to describe convective and radiative characteristics of the four fire zones for the fire and surfaces of frame members are given in Table B.2.

It was assumed that the insulating effect of both the roof and exterior walls could be modeled in the thermal analysis by adding 4 inches of concrete to the top of the beam and the exterior of the column. This 'concrete' insulation was then considered to be exposed to an ambient environment at a constant temperature of 68°f, with coefficients for boundary conditions as shown in Table B.2. The thermal analysis was carried out using computer program FIRES-T with the finite element idealization shown in Figs. B.2 and B.3. Typical subslice temperatures for the beam cross-section in fire zone 1 are shown in Fig. B.4; the isotherms for this cross-section at 1.0 hour are shown in Fig. B.5. In Fig. B.6, temperature in the same subslice for the four fire zones is compared.

For the structural analysis using FIRES-RC II, the frame was idealized by taking advantage of conditions of symmetry (see Fig. B.2). The column was then divided into five segments while the beam (actually one-half of the beam) was divided into four segments. The cross-section finite element idealizations in FIRES-RC II are similar to those used in FIRES-T with the exception that the 'concrete' insulation layers are omitted as they are presumed to have no structural strength or stiffness. An abbreviated form of the input used for this problem is given in Table B.3.

The output from FIRES-RC II, abbreviated to include only one time step in addition to the initial condition, is presented in Table B.4. In Fig. B.7, the deformed shape of the frame at quarter-hour increments throughout the hour-long fire is shown. The moment diagram for the frame is given for each quarter hour in Fig. B.8. The reactions at the supports of the frame are shown in Fig. B.9. The sharp transitions in behavior seen in Fig. B.9. are attributable to degradation of the cross-section due to cracking and crushing of concrete. This degradation may be expressed as the ratio of the area that is either cracked or crushed to the total area of the cross-section. Figure B.10 shows this degradation ratio for the right end of beam segment B4 along with the bending moment at that cross section. A comparison of these data helps to establish the relationship between degradation and the redistribution of internal forces. In Fig. B.11, cracking and crushing profiles for the right end of beam segment B4 are shown to help clarify the nature of cross-section degradation. Only a portion of data available for each cross section is presented in Figs. B.10 and B.11; a more complete example of available data is presented for two typical cross sections, the top of C5 and the right end of B4, in Tables B.5 and B.6. In addition, stress and strain data are available. See, for example, the sample output from FIRES-RC II given in Table B.4.

This frame problem was run on the CDC 6400 Computer at the University of California, Berkeley. The thermal histories developed by FIRES-T required approximately 55 seconds of central processing time for each fire zone, using 40 time steps at intervals of 0.025 seconds. The structural analysis provided by FIRES-RC II required 245 seconds of central processing

time and 35 seconds of peripheral processing time, using 20 time steps at intervals of 0.050 hours. When this example was solved using the earlier program FIRES-RC (results are tabulated in Reference 5) with a slightly coarser substructuring (11 cross sections rather than 18 cross sections as above), 360 seconds of central processing time and 1043 seconds of peripheral processing time were required. Improved methods of manipulation and dimensioning of data files are responsible for this increase in efficiency.

TABLE B.1 THERMAL PROPERTIES

CONCRETE					
Thermal Properties	Units	Node	Temperature	Value	Slope
Conductivity	$\frac{BTU}{ft\text{-}hr\text{-}^{o}F}$	1	0	1.010	0
		2	390.0	1.010	-.0004
		3	1650.0	.506	0
		4	3000.0	.506	
Specific Heat	$\frac{BTU}{lb\text{-}^{o}F}$		constant	.272	
Density	lbs/ft^3		constant	150	

STEEL					
Thermal Properties	Units	Node	Temperature	Value	Slope
Conductivity	$\frac{BTU}{ft\text{-}hr\text{-}^{o}F}$	1	0	30.0	-.00918
		2	1100	19.9	0
		3	3000	19.0	
Specific Heat	$\frac{BTU}{lb\text{-}^{o}F}$	1	0	.107	.00005
		2	750	.144	.00008
		3	1100	.172	0
		4	3000	.172	
Density	lbs/ft^3		constant	480	

TABLE B.2 FIRE BOUNDARY CONDITIONS USED IN FIRES-T THERMAL ANALYSES

Fire Zone	Surface	Fire Exposure	Convection Factor A	Convection Power N	View Factor V	Surface Absorption a	Flame Emissivity ε_f	Surface Emissivity ε_s
1	1	ASTM	.38	1.25	1.0	0.9	0.9	0.9
	2	ASTM	.27	1.25	0.8	0.9	0.9	0.9
	3	Ambient	.38	1.25	1.0	1.0	0.9	0.9
2	1	ASTM	.38	1.25	0.8	0.9	0.9	0.9
	2	ASTM	.27	1.25	0.5	0.9	0.9	0.9
	3	Ambient	.38	1.25	1.0	1.0	0.9	0.9
3	1	ASTM	.27	1.25	0.8	0.9	0.9	0.9
	2	ASTM	.27	1.25	0.5	0.9	0.9	0.9
	3	Ambient	.27	1.25	1.0	1.0	0.9	0.9
4	1	ASTM	.135	1.25	0.5	0.9	0.9	0.9
	2	ASTM	.135	1.25	0.3	0.9	0.9	0.9
	3	Ambient	.270	1.25	1.0	1.0	0.9	0.9

```
   * * *  FRAME STUDY  *  ASTM FIRE  *  LOAD = 2 K/FT  * * *
SHRINKAGE
CONCRETE CREEP
STEEL CREEP
JOINTS,3
    1       0.0        0.0   111
    2       0.0      180.0   000
    3     180.0      180.0   101
MEMBERS,2
    1    1    2  1    2  1    3  1    5  1    3  1    2
    2    2    3  2    2  2    4  2    4  2    5
SEGMENTS,2
SEGMENT  1     0  118   90    6    2    0.
    1  0.          0.
    2  2.000400    0.
    3  3.675600    0.
    4  4.924800    0.
    5  6.000000    0.
    6  6.999600    0.
    7  0.           .999600
    8  2.000400     .999600
    9  3.675600     .999600
   10  4.924800     .999600
   11  6.000000     .999600
   12  6.999600     .999600
   13  0.          2.074800
   14   .625200    2.074800
   15  2.000400    2.074800
   16  3.675600    2.074800
   17  4.924800    2.074800
   18  6.000000    2.074800
   19  6.999600    2.074800
   20  0.          3.325200
   21   .625200    3.325200
   22  2.000400    3.325200
   23  3.675600    3.325200
   24  4.924800    3.325200
   25  6.000000    3.325200
   26  6.999600    3.325200
   27  0.          5.000400
   28  2.000400    5.000400
   29  3.675600    5.000400
   30  4.924800    5.000400
   31  6.000000    5.000400
   32  6.999600    5.000400
   33  0.          6.999600
   34  2.000400    6.999600
   35  3.675600    6.999600
   36  4.924800    6.999600
   37  6.000000    6.999600
   38  6.999600    6.999600
   39  0.          9.000000
   40  2.000400    9.000000
   41  3.675600    9.000000
   42  4.924800    9.000000
```

TABLE B.3 INPUT FOR FRAME PROBLEM

43	6.000000	9.000000
44	6.999600	9.000000
45	0.	10.250400
46	2.000400	10.250400
47	3.675600	10.250400
48	4.924800	10.250400
49	6.000000	10.250400
50	6.999600	10.250400
51	0.	12.000000
52	2.000400	12.000000
53	3.675600	12.000000
54	4.924800	12.000000
55	6.000000	12.000000
56	6.999600	12.000000
57	0.	14.000400
58	2.000400	14.000400
59	3.675600	14.000400
60	4.924800	14.000400
61	6.000000	14.000400
62	6.999600	14.000400
63	0.	15.999600
64	2.000400	15.999600
65	3.675600	15.999600
66	4.924800	15.999600
67	6.000000	15.999600
68	6.999600	15.999600
69	0.	17.750400
70	2.000400	17.750400
71	3.675600	17.750400
72	4.924800	17.750400
73	6.000000	17.750400
74	6.999600	17.750400
75	0.	18.999600
76	2.000400	18.999600
77	3.675600	18.999600
78	4.924800	18.999600
79	6.000000	18.999600
80	6.999600	18.999600
81	0.	21.000000
82	2.000400	21.000000
83	3.675600	21.000000
84	4.924800	21.000000
85	6.000000	21.000000
86	6.999600	21.000000
87	0.	23.000400
88	2.000400	23.000400
89	3.675600	23.000400
90	4.924800	23.000400
91	6.000000	23.000400
92	6.999600	23.000400
93	0.	24.675600
94	.625200	24.675600
95	2.000400	24.675600
96	3.675600	24.675600
97	4.924800	24.675600
98	6.000000	24.675600

TABLE B.3 (cont.)

99	6.999600	24.675600
100	0.	25.924800
101	.625200	25.924800
102	2.000400	25.924800
103	3.675600	25.924800
104	4.924800	25.924800
105	6.000000	25.924800
106	6.999600	25.924800
107	0.	27.000000
108	2.000400	27.000000
109	3.675600	27.000000
110	4.924800	27.000000
111	6.000000	27.000000
112	6.999600	27.000000
113	0.	27.999600
114	2.000400	27.999600
115	3.675600	27.999600
116	4.924800	27.999600
117	6.000000	27.999600
118	6.999600	27.999600

1	1	2	8	7
6	7	8	14	13
7	8	15	14	14
8	8	9	16	15
12	14	15	22	21
14	17	18	25	24
16	20	21	28	27
17	21	22	28	28
19	22	23	29	28
22	27	28	34	33
27	33	34	40	39
32	39	40	46	45
34	42	43	49	48
36	45	46	52	51
41	51	52	58	57
46	57	58	64	63
51	63	64	70	69
56	69	70	76	75
58	72	73	79	78
60	75	76	82	81
65	81	82	88	87
70	87	88	94	93
71	88	95	94	94
72	88	89	96	95
76	94	95	102	101
78	97	98	105	104
80	100	101	108	107
81	101	102	108	108
82	102	103	109	108
86	107	108	114	113
90	111	112	118	117
1	13	14	21	20
2	16	17	24	23
3	41	42	48	47
4	71	72	78	77
5	93	94	101	100

TABLE B.3 (cont.)

```
         10        20        30        40        50        60        70        80
     6   96    97  104   103
SEGMENT  2     0  118    92   4     2         0.
     1   0.        0.
     2   2.000400  0.
     3   3.675600  0.
     4   4.924800  0.
     5   6.000000  0.
     6   6.999600  0.
     7   0.          .999600
     8   2.000400    .999600
     9   3.675600    .999600
    10   4.924800    .999600
    11   6.000000    .999600
    12   6.999600    .999600
    13   0.        2.074800
    14    .625200  2.074800
    15   2.000400  2.074800
    16   3.675600  2.074800
    17   4.924800  2.074800
    18   6.000000  2.074800
    19   6.999600  2.074800
    20   0.        3.325200
    21    .625200  3.325200
    22   2.000400  3.325200
    23   3.675600  3.325200
    24   4.924800  3.325200
    25   6.000000  3.325200
    26   6.999600  3.325200
    27   0.        5.000400
    28   2.000400  5.000400
    29   3.675600  5.000400
    30   4.924800  5.000400
    31   6.000000  5.000400
    32   6.999600  5.000400
    33   0.        6.999600
    34   2.000400  6.999600
    35   3.675600  6.999600
    36   4.924800  6.999600
    37   6.000000  6.999600
    38   6.999600  6.999600
    39   0.        9.000000
    40   2.000400  9.000000
    41   3.675600  9.000000
    42   4.924800  9.000000
    43   6.000000  9.000000
    44   6.999600  9.000000
    45   0.       10.250400
    46   2.000400 10.250400
    47   3.675600 10.250400
    48   4.924800 10.250400
    49   6.000000 10.250400
    50   6.999600 10.250400
    51   0.       12.000000
    52   2.000400 12.000000
    53   3.675600 12.000000
    54   4.924800 12.000000
         10        20        30        40        50        60        70        80
```

TABLE B.3 (cont.)

55	6.000000	12.000000
56	6.999600	12.000000
57	0.	14.000400
58	2.000400	14.000400
59	3.675600	14.000400
60	4.924800	14.000400
61	6.000000	14.000400
62	6.999600	14.000400
63	0.	15.999600
64	2.000400	15.999600
65	3.675600	15.999600
66	4.924800	15.999600
67	6.000000	15.999600
68	6.999600	15.999600
69	0.	17.750400
70	2.000400	17.750400
71	3.675600	17.750400
72	4.924800	17.750400
73	6.000000	17.750400
74	6.999600	17.750400
75	0.	18.999600
76	2.000400	18.999600
77	3.675600	18.999600
78	4.924800	18.999600
79	6.000000	18.999600
80	6.999600	18.999600
81	0.	21.000000
82	2.000400	21.000000
83	3.675600	21.000000
84	4.924800	21.000000
85	6.000000	21.000000
86	6.999600	21.000000
87	0.	23.000400
88	2.000400	23.000400
89	3.675600	23.000400
90	4.924800	23.000400
91	6.000000	23.000400
92	6.999600	23.000400
93	0.	24.675600
94	.625200	24.675600
95	2.000400	24.675600
96	3.675600	24.675600
97	4.924800	24.675600
98	6.000000	24.675600
99	6.999600	24.675600
100	0.	25.924800
101	.625200	25.924800
102	2.000400	25.924800
103	3.675600	25.924800
104	4.924800	25.924800
105	6.000000	25.924800
106	6.999600	25.924800
107	0.	27.000000
108	2.000400	27.000000
109	3.675600	27.000000
110	4.924800	27.000000

TABLE B.3 (cont.)

```
         10        20        30        40        50        60        70        80
111  6.000000 27.000000
112  6.999600 27.000000
113  0.       27.999600
114  2.000400 27.999600
115  3.675600 27.999600
116  4.924800 27.999600
117  6.000000 27.999600
118  6.999600 27.999600
  1    1    2    8    7
  6    7    8   14   13
  7    8   15   14   14
  8    8    9   16   15
 12   14   15   22   21
 14   17   18   25   24
 16   20   21   28   27
 17   21   22   28   28
 18   22   23   29   28
 22   27   28   34   33
 27   33   34   40   39
 32   39   40   46   45
 34   41   42   48   47
 35   42   43   49   48
 37   45   46   52   51
 42   51   52   58   57
 47   57   58   64   63
 52   63   64   70   69
 57   69   70   76   75
 59   71   72   78   77
 60   72   73   79   78
 62   75   76   82   81
 67   81   82   88   87
 72   87   88   94   93
 73   88   95   94   94
 74   88   89   96   95
 78   94   95  102  101
 80   97   98  105  104
 82  100  101  108  107
 83  101  102  108  108
 84  102  103  109  108
 88  107  108  114  113
 92  111  112  118  117
  1   13   14   21   20
  2   16   17   24   23
  3   93   94  101  100
  4   96   97  104  103
MATERIAL
  4    4    4    3    0
     0.0   6.0E-6    400.0   12.0E-6    600.0   20.0E-6   2000.0   20.0E-6
     0.0 4000.0      600.0    2500.0   1200.0    1900.0   2000.0    1900.0
     0.0    4.00     600.0      4.42   1200.0      2.25   2000.0      2.25
     0.0    0.30    1200.0      0.06   2000.0      0.06
   0.004
  3    3    0
     0.0   6.0E-6   1500.0   12.0E-6   2000.0   12.0E-6
     0.0 30000.0    1600.0   17200.0   2000.0   17200.0
0.00132333
         10        20        30        40        50        60        70        80
```

TABLE B.3 (cont.)

```
CONVERGENCE
   15        0.100        0.100        1.000        1.000
STEP      0          0.0      2      0      1                  1
    2                        -2.0
    3                        -5.0
MEMBER    1      1           68.0
MEMBER    2      1           68.0      1
                     -6.0                          -8.0
                     -9.0
STEP      1          0.050                1                  1
MEMBER    1
  ----ELEMENT TEMPERATURES AT TIME =      .050 -  96 ELEMENTS                                  1
   1  78.8   2  78.8   3  78.9   4  79.5   5  86.6   6  68.9   7  68.6
   8  68.9   9  69.0  10  69.6  11  76.8  12  68.1  13  68.1  14  68.7
  15  75.9  16  68.0  17  68.0  18  68.0  19  68.1  20  68.7  21  75.9
  22  68.0  23  68.0  24  68.1  25  68.7  26  75.9  27  68.0  28  68.0
  29  68.0  30  68.7  31  75.9  32  68.0  33  68.0  34  68.7  35  75.9
  36  68.0  37  68.0  38  68.0  39  68.7  40  75.9  41  68.0  42  68.0
  43  68.1  44  68.7  45  75.9  46  68.0  47  68.0  48  68.1  49  68.7
  50  75.9  51  68.0  52  68.0  53  68.0  54  68.7  55  75.9  56  68.0
  57  68.0  58  68.7  59  75.9  60  68.0  61  68.0  62  68.0  63  68.7
  64  75.9  65  68.0  66  68.0  67  68.1  68  68.7  69  75.9  70  68.0
  71  68.0  72  68.0  73  68.0  74  68.7  75  75.9  76  68.0  77  68.0
  78  68.7  79  75.9  80  68.0  81  68.0  82  68.0  83  68.0  84  68.6
  85  75.7  86  68.0  87  68.0  88  68.0  89  68.4  90  73.2  91  68.1
  92  68.1  93  68.0  94  68.0  95  68.0  96  68.0
  ----ELEMENT TEMPERATURES AT TIME =      .050 -  96 ELEMENTS                                  2
   1  78.8   2  78.8   3  78.9   4  79.5   5  86.6   6  68.9   7  68.6
   8  68.9   9  69.0  10  69.6  11  76.8  12  68.1  13  68.1  14  68.7
  15  75.9  16  68.0  17  68.0  18  68.0  19  68.1  20  68.7  21  75.9
  22  68.0  23  68.0  24  68.1  25  68.7  26  75.9  27  68.0  28  68.0
  29  68.0  30  68.7  31  75.9  32  68.0  33  68.0  34  68.7  35  75.9
  36  68.0  37  68.0  38  68.0  39  68.7  40  75.9  41  68.0  42  68.0
  43  68.1  44  68.7  45  75.9  46  68.0  47  68.0  48  68.1  49  68.7
  50  75.9  51  68.0  52  68.0  53  68.0  54  68.7  55  75.9  56  68.0
  57  68.0  58  68.7  59  75.9  60  68.0  61  68.0  62  68.0  63  68.7
  64  75.9  65  68.0  66  68.0  67  68.1  68  68.7  69  75.9  70  68.0
  71  68.0  72  68.0  73  68.0  74  68.7  75  75.9  76  68.0  77  68.0
  78  68.7  79  75.9  80  68.0  81  68.0  82  68.0  83  68.0  84  68.6
  85  75.7  86  68.0  87  68.0  88  68.0  89  68.4  90  73.2  91  68.1
  92  68.1  93  68.0  94  68.0  95  68.0  96  68.0
  ----ELEMENT TEMPERATURES AT TIME =      .050 -  96 ELEMENTS                                  3
   1  78.8   2  78.8   3  78.9   4  79.5   5  86.6   6  68.9   7  68.6
   8  68.9   9  69.0  10  69.6  11  76.8  12  68.1  13  68.1  14  68.7
  15  75.9  16  68.0  17  68.0  18  68.0  19  68.1  20  68.7  21  75.9
  22  68.0  23  68.0  24  68.1  25  68.7  26  75.9  27  68.0  28  68.0
  29  68.0  30  68.7  31  75.9  32  68.0  33  68.0  34  68.7  35  75.9
  36  68.0  37  68.0  38  68.0  39  68.7  40  75.9  41  68.0  42  68.0
  43  68.1  44  68.7  45  75.9  46  68.0  47  68.0  48  68.1  49  68.7
  50  75.9  51  68.0  52  68.0  53  68.0  54  68.7  55  75.9  56  68.0
  57  68.0  58  68.7  59  75.9  60  68.0  61  68.0  62  68.0  63  68.7
  64  75.9  65  68.0  66  68.0  67  68.1  68  68.7  69  75.9  70  68.0
  71  68.0  72  68.0  73  68.0  74  68.7  75  75.9  76  68.0  77  68.0
  78  68.7  79  75.9  80  68.0  81  68.0  82  68.0  83  68.0  84  68.6
  85  75.7  86  68.0  87  68.0  88  68.0  89  68.4  90  73.2  91  68.1
  92  68.1  93  68.0  94  68.0  95  68.0  96  68.0
```

TABLE B.3 (cont.)

```
                                                                                                                                  4
----ELEMENT TEMPERATURES AT TIME =      .050 - 106 ELEMENTS
  1  86.4   2  86.3   3  86.5   4  87.6   5 100.0   6  69.6   7  69.1
  8  69.6   9  69.7  10  70.8  11  83.6  12  68.1  13  68.1  14  69.3
 15  82.2  16  68.0  17  68.0  18  68.0  19  68.1  20  69.3  21  82.1
 22  68.0  23  68.0  24  68.1  25  69.3  26  82.1  27  68.0  28  68.0
 29  68.1  30  69.2  31  82.1  32  68.0  33  68.0  34  69.2  35  82.1
 36  68.0  37  68.0  38  68.1  39  69.2  40  82.1  41  68.0  42  68.0
 43  68.1  44  69.3  45  82.1  46  68.0  47  68.0  48  68.1  49  69.3
 50  82.1  51  68.0  52  68.0  53  68.1  54  69.2  55  82.1  56  68.0
 57  68.0  58  69.2  59  82.1  60  68.0  61  68.0  62  68.1  63  69.2
 64  82.1  65  68.0  66  68.0  67  68.1  68  69.3  69  82.1  70  69.0
 71  68.0  72  68.0  73  68.1  74  69.2  75  82.1  76  68.0  77  68.0
 78  69.2  79  82.0  80  68.0  81  68.0  82  68.0  83  68.1  84  69.1
 85  81.8  86  68.0  87  68.0  88  68.1  89  68.8  90  77.3  91  68.1
 92  68.2  93  68.1  94  68.1  95  68.0  96  68.1
                                                                                                                                  5
----ELEMENT TEMPERATURES AT TIME =      .050 -  96 ELEMENTS
  1  86.4   2  86.3   3  86.5   4  87.6   5 100.0   6  69.6   7  69.1
  8  69.6   9  69.7  10  70.8  11  83.6  12  68.1  13  68.1  14  69.3
 15  82.2  16  68.0  17  68.0  18  68.0  19  68.1  20  69.3  21  82.1
 22  68.0  23  68.0  24  68.1  25  69.3  26  82.1  27  68.0  28  68.0
 29  68.1  30  69.2  31  82.1  32  68.0  33  68.0  34  69.2  35  82.1
 36  68.0  37  68.0  38  68.1  39  69.2  40  82.1  41  68.0  42  68.0
 43  68.1  44  69.3  45  82.1  46  68.0  47  68.0  48  68.1  49  69.3
 50  82.1  51  68.0  52  68.0  53  68.1  54  69.2  55  82.1  56  68.0
 57  68.0  58  69.2  59  82.1  60  68.0  61  68.0  62  68.1  63  69.2
 64  82.1  65  68.0  66  68.0  67  68.1  68  69.3  69  82.1  70  68.0
 71  68.0  72  68.0  73  68.1  74  69.2  75  82.1  76  68.0  77  68.0
 78  69.2  79  82.0  80  68.0  81  68.0  82  68.0  83  68.1  84  69.1
 85  81.8  86  68.0  87  68.0  88  68.1  89  68.8  90  77.3  91  68.1
 92  68.2  93  68.1  94  68.1  95  68.0  96  68.1
MEMBER    2
                                                                                                                                  6
----ELEMENT TEMPERATURES AT TIME =      .050 -  96 ELEMENTS
  1  88.9   2  88.9   3  89.0   4  90.1   5 102.5   6  69.8   7  69.2
  8  69.8   9  69.9  10  71.1  11  83.8  12  68.1  13  68.2  14  69.4
 15  82.2  16  68.0  17  68.0  18  68.0  19  68.1  20  69.3  21  82.1
 22  68.0  23  68.0  24  68.1  25  69.3  26  82.1  27  68.0  28  68.0
 29  68.1  30  69.3  31  82.1  32  68.0  33  68.0  34  68.1  35  69.3
 36  82.1  37  68.0  38  68.0  39  68.1  40  69.3  41  82.1  42  68.0
 43  68.0  44  68.1  45  69.3  46  82.1  47  68.0  48  68.0  49  68.1
 50  69.3  51  82.1  52  68.0  53  68.0  54  68.1  55  69.3  56  82.1
 57  68.0  58  68.0  59  68.1  60  69.3  61  82.1  62  68.0  63  68.0
 64  68.1  65  69.3  66  82.1  67  68.0  68  68.0  69  68.1  70  69.3
 71  82.1  72  68.0  73  68.0  74  68.0  75  68.1  76  69.2  77  82.1
 78  68.0  79  68.0  80  69.2  81  82.0  82  68.0  83  68.0  84  68.0
 85  68.1  86  69.1  87  81.8  88  68.0  89  68.0  90  68.1  91  68.8
 92  77.3  93  68.1  94  68.2  95  68.0  96  68.1
                                                                                                                                  7
----ELEMENT TEMPERATURES AT TIME =      .050 -  96 ELEMENTS
  1  88.9   2  88.9   3  89.0   4  90.1   5 102.5   6  69.8   7  69.2
  8  69.8   9  69.9  10  71.1  11  83.8  12  68.1  13  68.2  14  69.4
 15  82.2  16  68.0  17  68.0  18  68.0  19  68.1  20  69.3  21  82.1
 22  68.0  23  68.0  24  68.1  25  69.3  26  82.1  27  68.0  28  68.0
 29  68.1  30  69.3  31  82.1  32  68.0  33  68.0  34  68.1  35  69.3
 36  82.1  37  68.0  38  68.0  39  68.1  40  69.3  41  82.1  42  68.0
 43  68.0  44  68.1  45  69.3  46  82.1  47  68.0  48  68.0  49  68.1
 50  69.3  51  82.1  52  68.0  53  68.0  54  68.1  55  69.3  56  82.1
 57  68.0  58  68.0  59  68.1  60  69.3  61  82.1  62  68.0  63  68.0
```

TABLE B.3 (cont.)

```
                10        20        30        40        50        60        70        80
 64   68.1  65   69.3  66   82.1  67   68.0  68   68.0  69   68.1  70   69.3
 71   82.1  72   68.0  73   68.0  74   68.0  75   68.1  76   69.2  77   82.1
 78   68.0  79   68.0  80   69.2  81   82.0  82   68.0  83   68.0  84   68.0
 85   68.1  86   69.1  87   81.8  88   68.0  89   68.0  90   68.1  91   68.8
 92   77.3  93   68.1  94   68.2  95   68.0  96   68.1
----ELEMENT TEMPERATURES AT TIME =      .050 -  96 ELEMENTS                    9
  1   91.8   2   91.7   3   91.8   4   93.2   5  109.5   6   70.1   7   69.4
  8   70.0   9   70.2  10   71.7  11   88.3  12   68.1  13   68.2  14   69.7
 15   86.5  16   68.0  17   68.0  18   68.0  19   68.2  20   69.6  21   86.4
 22   68.0  23   68.0  24   68.1  25   69.6  26   86.4  27   68.0  28   68.0
 29   68.1  30   69.6  31   86.4  32   68.0  33   68.0  34   68.1  35   69.6
 36   86.4  37   68.0  38   68.0  39   68.1  40   69.6  41   86.4  42   68.0
 43   68.0  44   68.1  45   69.6  46   86.4  47   68.0  48   68.0  49   68.1
 50   69.6  51   86.4  52   68.0  53   68.0  54   68.1  55   69.6  56   86.4
 57   68.0  58   68.0  59   68.1  60   69.6  61   86.4  62   68.0  63   68.0
 64   68.1  65   69.6  66   86.4  67   68.0  68   68.0  69   68.1  70   69.6
 71   86.4  72   68.0  73   68.0  74   68.0  75   68.1  76   69.6  77   86.4
 78   68.0  79   68.0  80   69.6  81   86.4  82   68.0  83   68.0  84   68.0
 85   68.1  86   69.4  87   86.0  88   68.0  89   68.0  90   68.1  91   69.0
 92   80.2  93   68.1  94   68.2  95   68.0  96   68.1
----ELEMENT TEMPERATURES AT TIME =      .050 -  96 ELEMENTS                   10
  1   91.8   2   91.7   3   91.8   4   93.2   5  109.5   6   70.1   7   69.4
  8   70.0   9   70.2  10   71.7  11   88.3  12   68.1  13   68.2  14   69.7
 15   86.5  16   68.0  17   68.0  18   68.0  19   68.2  20   69.6  21   86.4
 22   68.0  23   68.0  24   68.1  25   69.6  26   86.4  27   68.0  28   68.0
 29   68.1  30   69.6  31   86.4  32   68.0  33   68.0  34   68.1  35   69.6
 36   86.4  37   68.0  38   68.0  39   68.1  40   69.6  41   86.4  42   68.0
 43   68.0  44   68.1  45   69.6  46   86.4  47   68.0  48   68.0  49   68.1
 50   69.6  51   86.4  52   68.0  53   68.0  54   68.1  55   69.6  56   86.4
 57   68.0  58   68.0  59   68.1  60   69.6  61   86.4  62   68.0  63   68.0
 64   68.1  65   69.6  66   86.4  67   68.0  68   68.0  69   68.1  70   69.6
 71   86.4  72   68.0  73   68.0  74   68.0  75   68.1  76   69.6  77   86.4
 78   68.0  79   68.0  80   69.6  81   86.4  82   68.0  83   68.0  84   68.0
 85   68.1  86   69.4  87   86.0  88   68.0  89   68.0  90   68.1  91   69.0
 92   80.2  93   68.1  94   68.2  95   68.0  96   68.1
                10        20        30        40        50        60        70        80
```

TABLE B.3 (cont.)

```
*****************************************************************

FFFFF I RRRRR EEEEE SSSSS    RRRRR CCCCC   IIIII
F     I R   R E     S        R   R C   C    I I
F     I R   R E     S        R   R C        I I
FFF   I RRRRR EEE   SSSSS == RRRRR C        I I
F     I R R   E         S    R R   C        I I
F     I R  R  E         S    R  R  C   C    I I
F     I R   R EEEEE SSSSS    R   R CCCCC   IIIII
```

A STRUCTURAL ANALYSIS PROGRAM FOR REINFORCED CONCRETE MEMBERS AND FRAMES SUBJECTED TO A FIRE ENVIRONMENT

F E B R U A R Y 1 9 7 6

```
*****************************************************************

          • • • • •  TITLE OF RUN  • • • • •

  * * *  FRAME STUDY  *  ASTM FIRE  *  LOAD = 2 K/FT  * * *

*****************************************************************

          • • •  ANALYSIS CONSIDERATIONS  • • •

CONCRETE STRESS-STRAIN LAW   -  PARABOLIC MODEL WITH
                                UNLOADING
                                ESTAR =  -125.0 KSI

STEEL STRESS-STRAIN LAW      -  BILINEAR MODEL WITH UNLOADING
                                ESTAR =   100.0 KSI

CONCRETE CREEP MODEL         -  MUKADDAMS TEMPERATURE-
                                COMPENSATED-TIME MODEL

STEEL CREEP MODEL            -  HARMATHY VARIATION OF DORNS
                                THETA METHOD
                                COEFFICIENTS - HARMATHY(1969)
                                ASTM STP 464, TEST SERIES 1C

CONCRETE SHRINKAGE MODEL     -  SHRINKAGE CALCULATED ON BASIS
                                OF TEMPERATURE-DEPENDENT RATE
                                MAX SHRINKAGE - 0.0010 IN/IN
```

TABLE B.4 OUTPUT FOR FRAME PROBLEM

```
*************************************************************

              GEOMETRIC DESCRIPTION OF PROBLEM

*************************************************************


 . . . . .  JOINT DATA  -   3 JOINTS  . . . . .

 JOINT      COORDINATES          BOUNDARY CONDITIONS
NUMBER       X          Y    X-DIRECTION Y-DIRECTION    ROTATION

  1         0.         0.     RESTRAINED  RESTRAINED   RESTRAINED

  2         0.       180.0

  3       180.0      180.0    RESTRAINED               RESTRAINED


 . . . . .  MEMBER DATA  -   2 MEMBERS  . . . . .

MEMB   JOINT              SEGMENT TYPE AND LENGTH
 NO.   I TO J   TP LGTH TP LGTH TP LGTH TP LGTH TP LGTH TP LGTH

  1     1  2    1  24.0 1  36.0 1  60.0 1  36.0 1  24.0

  2     2  3    2  24.0 2  48.0 2  48.0 2  60.0

 THE BANDWIDTH OF THE STIFFNESS MATRIX IS      6

 . . . . . .  SYSTEM REQUIREMENT FOR BLANK COMMON . . . . .

          SIZE BLANK COMMON =        139 (DECIMAL)
                            =    0000213 (OCTAL)

 . . . . . .  SYSTEM AND MEMBER TOTAL REQUIREMENT . . . . .

          SIZE BLANK COMMON =        428 (DECIMAL)
                            =    0000654 (OCTAL)
```

****

CROSS-SECTIONAL DATA - 2 SEGMENT TYPES

****

- - - - - - - - - - -SEGMENT TYPE NO. 1 - - - - - - - - - - -

FINITE ELEMENT IDEALIZATION

-NODAL POINTS-

NODE	X	Y	NODE	X	Y	NODE	X	Y
1	0.	0.	2	2.000	0.	3	3.676	0.
4	4.925	0.	5	6.000	0.	6	7.000	0.
7	0.	1.000	8	2.000	1.000	9	3.676	1.000
10	4.925	1.000	11	6.000	1.000	12	7.000	1.000
13	0.	2.075	14	.625	2.075	15	2.000	2.075
16	3.676	2.075	17	4.925	2.075	18	6.000	2.075
19	7.000	2.075	20	0.	3.325	21	.625	3.325
22	2.000	3.325	23	3.676	3.325	24	4.925	3.325
25	6.000	3.325	26	7.000	3.325	27	0.	5.000
28	2.000	5.000	29	3.676	5.000	30	4.925	5.000
31	6.000	5.000	32	7.000	5.000	33	0.	7.000
34	2.000	7.000	35	3.676	7.000	36	4.925	7.000
37	6.000	7.000	38	7.000	7.000	39	0.	9.000
40	2.000	9.000	41	3.676	9.000	42	4.925	9.000
43	6.000	9.000	44	7.000	9.000	45	0.	10.250
46	2.000	10.250	47	3.676	10.250	48	4.925	10.250
49	6.000	10.250	50	7.000	10.250	51	0.	12.000
52	2.000	12.000	53	3.676	12.000	54	4.925	12.000
55	6.000	12.000	56	7.000	12.000	57	0.	14.000
58	2.000	14.000	59	3.676	14.000	60	4.925	14.000
61	6.000	14.000	62	7.000	14.000	63	0.	16.000
64	2.000	16.000	65	3.676	16.000	66	4.925	16.000
67	6.000	16.000	68	7.000	16.000	69	0.	17.750
70	2.000	17.750	71	3.676	17.750	72	4.925	17.750
73	6.000	17.750	74	7.000	17.750	75	0.	19.000
76	2.000	19.000	77	3.676	19.000	78	4.925	19.000
79	6.000	19.000	80	7.000	19.000	81	0.	21.000
82	2.000	21.000	83	3.676	21.000	84	4.925	21.000
85	6.000	21.000	86	7.000	21.000	87	0.	23.000
88	2.000	23.000	89	3.676	23.000	90	4.925	23.000
91	6.000	23.000	92	7.000	23.000	93	0.	24.676
94	.625	24.676	95	2.000	24.676	96	3.676	24.676
97	4.925	24.676	98	6.000	24.676	99	7.000	24.676
100	0.	25.925	101	.625	25.925	102	2.000	25.925
103	3.676	25.925	104	4.925	25.925	105	6.000	25.925

106	7.000	25.925	107	0.	27.000	108	2.000	27.000
109	3.676	27.000	110	4.925	27.000	111	6.000	27.000
112	7.000	27.000	113	0.	28.000	114	2.000	28.000
115	3.676	28.000	116	4.925	28.000	117	6.000	28.000
118	7.000	28.000						

-CONCRETE ELEMENTS-

ELEM	I	J	K	L	ELEM	I	J	K	L	ELEM	I	J	K	L
1	1	2	8	7	2	2	3	9	8	3	3	4	10	9
4	4	5	11	10	5	5	6	12	11	6	7	8	14	13
7	8	15	14	14	8	8	9	16	15	9	9	10	17	16
10	10	11	18	17	11	11	12	19	18	12	14	15	22	21
13	15	16	23	22	14	17	18	25	24	15	18	19	26	25
16	20	21	28	27	17	21	22	28	28	18	22	23	29	28
19	23	24	30	29	20	24	25	31	30	21	25	26	32	31
22	27	28	34	33	23	28	29	35	34	24	29	30	36	35
25	30	31	37	36	26	31	32	38	37	27	33	34	40	39
28	34	35	41	40	29	35	36	42	41	30	36	37	43	42
31	37	38	44	43	32	39	40	46	45	33	40	41	47	46
34	42	43	49	48	35	43	44	50	49	36	45	46	52	51
37	46	47	53	52	38	47	48	54	53	39	48	49	55	54
40	49	50	56	55	41	51	52	58	57	42	52	53	59	58
43	53	54	60	59	44	54	55	61	60	45	55	56	62	61
46	57	58	64	63	47	58	59	65	64	48	59	60	66	65
49	60	61	67	66	50	61	62	68	67	51	63	64	70	69
52	64	65	71	70	53	65	66	72	71	54	66	67	73	72
55	67	68	74	73	56	69	70	76	75	57	70	71	77	76
58	72	73	79	78	59	73	74	80	79	60	75	76	82	81
61	76	77	83	82	62	77	78	84	83	63	78	79	85	84
64	79	80	86	85	65	81	82	88	87	66	82	83	89	88
67	83	84	90	89	68	84	85	91	90	69	85	86	92	91
70	87	88	94	93	71	88	95	94	94	72	88	89	96	95
73	89	90	97	96	74	90	91	98	97	75	91	92	99	98
76	94	95	102	101	77	95	96	103	102	78	97	98	105	104
79	98	99	106	105	80	100	101	108	107	81	101	102	108	108
82	102	103	109	108	83	103	104	110	109	84	104	105	111	110
85	105	106	112	111	86	107	108	114	113	87	108	109	115	114
88	109	110	116	115	89	110	111	117	116	90	111	112	118	117

-STEEL ELEMENTS-

ELEM	I	J	K	L	ELEM	I	J	K	L	ELEM	I	J	K	L
91	13	14	21	20	92	16	17	24	23	93	41	42	48	47
94	71	72	78	77	95	93	94	101	100	96	96	97	104	103

CROSS-SECTION IDEALIZATION

AREA AND CENTROID OF EACH CONCRETE SUBSLICE

ELEM	AREA	YC	ELEM	AREA	YC	ELEM	AREA	YC
1	4.00	-13.50	2	3.35	-13.50	3	2.50	-13.50
4	2.15	-13.50	5	2.00	-13.50	6	2.82	-12.56
7	1.48	-12.28	8	3.60	-12.46	9	2.69	-12.46
10	2.31	-12.46	11	2.15	-12.46	12	3.44	-11.30
13	4.19	-11.30	14	2.69	-11.30	15	2.50	-11.30
16	4.40	-9.69	17	2.30	-10.12	18	5.61	-9.84
19	4.19	-9.84	20	3.60	-9.84	21	3.35	-9.84
22	8.00	-8.00	23	6.70	-8.00	24	4.99	-8.00
25	4.30	-8.00	26	4.00	-8.00	27	8.00	-6.00
28	6.70	-6.00	29	5.00	-6.00	30	4.30	-6.00
31	4.00	-6.00	32	5.00	-4.37	33	4.19	-4.37
34	2.69	-4.37	35	2.50	-4.37	36	7.00	-2.87
37	5.86	-2.87	38	4.37	-2.87	39	3.76	-2.87
40	3.50	-2.87	41	8.00	-1.00	42	6.70	-1.00
43	5.00	-1.00	44	4.30	-1.00	45	4.00	-1.00
46	8.00	1.00	47	6.70	1.00	48	4.99	1.00
49	4.30	1.00	50	4.00	1.00	51	7.00	2.88
52	5.87	2.88	53	4.37	2.88	54	3.76	2.88
55	3.50	2.88	56	5.00	4.38	57	4.19	4.38
58	2.69	4.38	59	2.50	4.38	60	8.00	6.00
61	6.70	6.00	62	5.00	6.00	63	4.30	6.00
64	4.00	6.00	65	8.00	8.00	66	6.70	8.00
67	5.00	8.00	68	4.30	8.00	69	4.00	8.00
70	4.40	9.69	71	2.30	10.12	72	5.61	9.84
73	4.19	9.84	74	3.60	9.84	75	3.35	9.84
76	3.44	11.30	77	4.19	11.30	78	2.69	11.30
79	2.50	11.30	80	2.82	12.56	81	1.48	12.28
82	3.60	12.46	83	2.69	12.46	84	2.31	12.46
85	2.15	12.46	86	4.00	13.50	87	3.35	13.50
88	2.50	13.50	89	2.15	13.50	90	2.00	13.50

AREA AND CENTROID OF EACH STEEL SUBSLICE

ELEM	AREA	YC	ELEM	AREA	YC	ELEM	AREA	YC
1	1.56	-11.30	2	3.12	-11.30	3	3.12	-4.37
4	3.12	4.38	5	1.56	11.30	6	3.12	11.30

CROSS SECTIONAL PROPERTIES

	AREA	MOMENT OF INERTIA
CONCRETE	376.4	24198.9
STEEL	15.6	1316.1
TOTAL	392.0	25515.0

- - - - - - - - - - - -SEGMENT TYPE NO. 2 - - - - - - - - - - - -

FINITE ELEMENT IDEALIZATION

-NODAL POINTS-

NODE	X	Y	NODE	X	Y	NODE	X	Y
1	0.	0.	2	2.000	0.	3	3.676	0.
4	4.925	0.	5	6.000	0.	6	7.000	0.
7	0.	1.000	8	2.000	1.000	9	3.676	1.000
10	4.925	1.000	11	6.000	1.000	12	7.000	1.000
13	0.	2.075	14	.625	2.075	15	2.000	2.075
16	3.676	2.075	17	4.925	2.075	18	6.000	2.075
19	7.000	2.075	20	0.	3.325	21	.625	3.325
22	2.000	3.325	23	3.676	3.325	24	4.925	3.325
25	6.000	3.325	26	7.000	3.325	27	0.	5.000
28	2.000	5.000	29	3.676	5.000	30	4.925	5.000
31	6.000	5.000	32	7.000	5.000	33	0.	7.000
34	2.000	7.000	35	3.676	7.000	36	4.925	7.000
37	6.000	7.000	38	7.000	7.000	39	0.	9.000
40	2.000	9.000	41	3.676	9.000	42	4.925	9.000
43	6.000	9.000	44	7.000	9.000	45	0.	10.250
46	2.000	10.250	47	3.676	10.250	48	4.925	10.250
49	6.000	10.250	50	7.000	10.250	51	0.	12.000
52	2.000	12.000	53	3.676	12.000	54	4.925	12.000
55	6.000	12.000	56	7.000	12.000	57	0.	14.000
58	2.000	14.000	59	3.676	14.000	60	4.925	14.000
61	6.000	14.000	62	7.000	14.000	63	0.	16.000
64	2.000	16.000	65	3.676	16.000	66	4.925	16.000
67	6.000	16.000	68	7.000	16.000	69	0.	17.750
70	2.000	17.750	71	3.676	17.750	72	4.925	17.750
73	6.000	17.750	74	7.000	17.750	75	0.	19.000
76	2.000	19.000	77	3.676	19.000	78	4.925	19.000
79	6.000	19.000	80	7.000	19.000	81	0.	21.000
82	2.000	21.000	83	3.676	21.000	84	4.925	21.000
85	6.000	21.000	86	7.000	21.000	87	0.	23.000
88	2.000	23.000	89	3.676	23.000	90	4.925	23.000
91	6.000	23.000	92	7.000	23.000	93	0.	24.676
94	.625	24.676	95	2.000	24.676	96	3.676	24.676
97	4.925	24.676	98	6.000	24.676	99	7.000	24.676
100	0.	25.925	101	.625	25.925	102	2.000	25.925
103	3.676	25.925	104	4.925	25.925	105	6.000	25.925
106	7.000	25.925	107	0.	27.000	108	2.000	27.000
109	3.676	27.000	110	4.925	27.000	111	6.000	27.000
112	7.000	27.000	113	0.	28.000	114	2.000	28.000
115	3.676	28.000	116	4.925	28.000	117	6.000	28.000
118	7.000	28.000						

-CONCRETE ELEMENTS-

ELEM	I	J	K	L	ELEM	I	J	K	L	ELEM	I	J	K	L

1	1	2	8	7	2	2	3	9	8	3	3	4	10	9
4	4	5	11	10	5	5	6	12	11	6	7	8	14	13
7	8	15	14	14	8	8	9	16	15	9	9	10	17	16
10	10	11	18	17	11	11	12	19	18	12	14	15	22	21
13	15	16	23	22	14	17	18	25	24	15	18	19	26	25
16	20	21	28	27	17	21	22	28	28	18	22	23	29	28
19	23	24	30	29	20	24	25	31	30	21	25	26	32	31
22	27	28	34	33	23	28	29	35	34	24	29	30	36	35
25	30	31	37	36	26	31	32	38	37	27	33	34	40	39
28	34	35	41	40	29	35	36	42	41	30	36	37	43	42
31	37	38	44	43	32	39	40	46	45	33	40	41	47	46
34	41	42	48	47	35	42	43	49	48	36	43	44	50	49
37	45	46	52	51	38	46	47	53	52	39	47	48	54	53
40	48	49	55	54	41	49	50	56	55	42	51	52	58	57
43	52	53	59	58	44	53	54	60	59	45	54	55	61	60
46	55	56	62	61	47	57	58	64	63	48	58	59	65	64
49	59	60	66	65	50	60	61	67	66	51	61	62	68	67
52	63	64	70	69	53	64	65	71	70	54	65	66	72	71
55	66	67	73	72	56	67	68	74	73	57	69	70	76	75
58	70	71	77	76	59	71	72	78	77	60	72	73	79	78
61	73	74	80	79	62	75	76	82	81	63	76	77	83	82
64	77	78	84	83	65	78	79	85	84	66	79	80	86	85
67	81	82	88	87	68	82	83	89	88	69	83	84	90	89
70	84	85	91	90	71	85	86	92	91	72	87	88	94	93
73	88	95	94	94	74	88	89	96	95	75	89	90	97	96
76	90	91	98	97	77	91	92	99	98	78	94	95	102	101
79	95	96	103	102	80	97	98	105	104	81	98	99	106	105
82	100	101	108	107	83	101	102	108	108	84	102	103	109	108
85	103	104	110	109	86	104	105	111	110	87	105	106	112	111
88	107	108	114	113	89	108	109	115	114	90	109	110	116	115
91	110	111	117	116	92	111	112	118	117					

-STEEL ELEMENTS-

ELEM	I	J	K	L	ELEM	I	J	K	L	ELEM	I	J	K	L
93	13	14	21	20	94	16	17	24	23	95	93	94	101	100
96	96	97	104	103										

CROSS-SECTION IDEALIZATION

AREA AND CENTROID OF EACH CONCRETE SUBSLICE

ELEM	AREA	YC	ELEM	AREA	YC	ELEM	AREA	YC
1	4.00	-13.50	2	3.35	-13.50	3	2.50	-13.50
4	2.15	-13.50	5	2.00	-13.50	6	2.82	-12.56
7	1.48	-12.28	8	3.60	-12.46	9	2.69	-12.46

10	2.31	-12.46	11	2.15	-12.46	12	3.44	-11.30
13	4.19	-11.30	14	2.69	-11.30	15	2.50	-11.30
16	4.40	-9.69	17	2.30	-10.12	18	5.61	-9.84
19	4.19	-9.84	20	3.60	-9.84	21	3.35	-9.84
22	8.00	-8.00	23	6.70	-8.00	24	4.99	-8.00
25	4.30	-8.00	26	4.00	-8.00	27	8.00	-6.00
28	6.70	-6.00	29	5.00	-6.00	30	4.30	-6.00
31	4.00	-6.00	32	5.00	-4.37	33	4.19	-4.37
34	3.12	-4.37	35	2.69	-4.37	36	2.50	-4.37
37	7.00	-2.87	38	5.86	-2.87	39	4.37	-2.87
40	3.76	-2.87	41	3.50	-2.87	42	8.00	-1.00
43	6.70	-1.00	44	5.00	-1.00	45	4.30	-1.00
46	4.00	-1.00	47	8.00	1.00	48	6.70	1.00
49	4.99	1.00	50	4.30	1.00	51	4.00	1.00
52	7.00	2.88	53	5.87	2.88	54	4.37	2.88
55	3.76	2.88	56	3.50	2.88	57	5.00	4.38
58	4.19	4.38	59	3.12	4.38	60	2.69	4.38
61	2.50	4.38	62	8.00	6.00	63	6.70	6.00
64	5.00	6.00	65	4.30	6.00	66	4.00	6.00
67	8.00	8.00	68	6.70	8.00	69	5.00	8.00
70	4.30	8.00	71	4.00	8.00	72	4.40	9.69
73	2.30	10.12	74	5.61	9.84	75	4.19	9.84
76	3.60	9.84	77	3.35	9.84	78	3.44	11.30
79	4.19	11.30	80	2.69	11.30	81	2.50	11.30
82	2.82	12.56	83	1.48	12.28	84	3.60	12.46
85	2.69	12.46	86	2.31	12.46	87	2.15	12.46
88	4.00	13.50	89	3.35	13.50	90	2.50	13.50
91	2.15	13.50	92	2.00	13.50			

AREA AND CENTROID OF EACH STEEL SUBSLICE

ELEM	AREA	YC	ELEM	AREA	YC	ELEM	AREA	YC
1	1.56	-11.30	2	3.12	-11.30	3	1.56	11.30
4	3.12	11.30						

CROSS SECTIONAL PROPERTIES

	AREA	MOMENT OF INERTIA
CONCRETE	382.6	24318.4
STEEL	9.4	1196.5
TOTAL	392.0	25515.0

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MATERIAL DATA

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• • • • CONCRETE • • • •

- - COEFFICENT OF EXPANSION - -

NODE	TEMPERATURE	VALUE	SLOPE
1	0.	.600E-05	
			.150E-07
2	400.0	.120E-04	
			.400E-07
3	600.0	.200E-04	
			0.
4	2000.0	.200E-04	

- - MODULUS OF ELASTICITY - -

NODE	TEMPERATURE	VALUE	SLOPE
1	0.	.400E+04	
			-2.500
2	600.0	.250E+04	
			-1.000
3	1200.0	.190E+04	
			0.
4	2000.0	.190E+04	

- - COMPRESSIVE STRENGTH - -

NODE	TEMPERATURE	VALUE	SLOPE
1	0.	4.000	
			.700E-03
2	600.0	4.420	
			-.362E-02
3	1200.0	2.250	
			0.
4	2000.0	2.250	

- - TENSILE STRENGTH - -

NODE	TEMPERATURE	VALUE	SLOPE
1	0.	.300	
			-.200E-03
2	1200.0	.600E-01	
			0.
3	2000.0	.600E-01	

- - CRUSHING STRAIN - -

MATERIAL PARAMETER OF CONSTANT VALUE .400E-02

. . . . STEEL . . . .

- - COEFFICENT OF EXPANSION - -

NODE	TEMPERATURE	VALUE	SLOPE
1	0.	.600E-05	
			.400E-08
2	1500.0	.120E-04	
			0.
3	2000.0	.120E-04	

- - MODULUS OF ELASTICITY - -

NODE	TEMPERATURE	VALUE	SLOPE
1	0.	.300E+05	
			-8.000
2	1600.0	.172E+05	
			0.
3	2000.0	.172E+05	

- - YIELD STRAIN - -

MATERIAL PARAMETER OF CONSTANT VALUE .133E-02

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*****************************************************************

                    CONVERGENCE DATA

*****************************************************************

          PERMISSIBLE ERROR FOR OUT-OF-BALANCE FORCES
            AXIAL FORCE =          .10000
            SHEAR FORCE =          .10000
            MOMENT      =         1.00000

    MAXIMUM NUMBER OF ITERATIONS FOR A TIME STEP =       15
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*****************************************************************

  * * *  FRAME STUDY  *  ASTM FIRE  *  LOAD = 2 K/FT  * * *

          PROBLEM INITIALIZED AT TIME        .0000

*****************************************************************

  . . .  STRUCTURAL LOADS AND BOUNDARY CONDITIONS  . . .

JOINT     SYSTEM        SUPPORT STIFFNESS MATRIX        PRESCRIBED
          LOADS                                          DISPLS.
                          X           Y           R

 1  X    0.            .100E+30  0.          0.          0.
    Y    0.            0.        .100E+30    0.          0.
    R    0.            0.        0.          .100E+30    0.

 2  X   -0.            0.        0.          0.          0.
    Y   -2.000         0.        0.          0.          0.
    R   -0.            0.        0.          0.          0.

 3  X   -0.            .100E+30  0.          0.          0.
    Y   -5.000         0.        0.          0.          0.
    R   -0.            0.        0.          .100E+30    0.

      . . .  INTERSEGMENTAL FORCES FOR MEMBER    2 . . .

      1          2          3          4

 F-X      -0.        -0.        -0.

 F-Y      -6.00      -8.00      -9.00

 F-M      -0.        -0.        -0.


      BLANK COMMON REQUIRED TO SOLVE THIS PROBLEM
      USING HIGHSPEED STORAGE ONLY                    =    26051

      BLANK COMMON AVAILABLE IN DIMENSION STATEMENT =    10000

      READ/WRITE ON TAPE FOR EACH ITERATION
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• • • • • ANALYSIS RESULTS FOR STRUCTURAL SYSTEM • • • • • •

JOINT	JOINT DISPLACEMENTS (GLOBAL COORDINATE SYSTEM) X-G (INCHES)	Y-G (INCHES)	R-G (RADIANS)	SUPPORT REACTIONS F-X (KIPS) F-Y (KIPS) M-R (IN-K)
1	-.00000	-.00000	.00000	13.11 30.00 -870.92
2	-.00678	-.00063	-.00071	NONE
3	.00000	-.17994	-.00000	-13.11 -0. 1210.70

• • • • • • • • ANALYSIS RESULTS FOR MEMBER 1 • • • • • • •

-DISPLACEMENTS AND STRAINS-

NODE	SEG	SEGMENT END DISPLACEMENTS (MEMBER COORDINATE SYSTEM) X-M (INCHES)	Y-M (INCHES)	R-M (RADS)	SECTION STRAINS ELONGATION	CURV.
1		-.00000	.00000	.00000		
	LEFT					7.64E-06
	1 AVG.				-1.55E-05	
	RIGHT					4.26E-06
2		-.00033	.00188	.00014		
	LEFT					4.26E-06
	2 AVG.				-1.58E-05	
	RIGHT					6.44E-07
3		-.00090	.00900	.00023		
	LEFT					6.44E-07
	3 AVG.				-1.59E-05	
	RIGHT					-5.39E-06
4		-.00186	.02040	.00009		
	LEFT					-5.38E-06
	4 AVG.				-1.32E-05	
	RIGHT					-1.41E-05
5		-.00183	.01824	-.00026		
	LEFT					-1.63E-05
	5 AVG.				-2.28E-05	
	RIGHT					-2.13E-05

6 -.00063 .00678 -.00071

-FORCES AND SECTION PROPERTIES-

SEGMENT		SEGMENT FORCES			SEGMENT STIFFNESS		AREA REDUCTION		CENTER OF GRAVITY
		AXIAL (KIPS)	SHEAR (KIPS)	MOMENT (IN-K)	-AE- (PERCENT OF INITIAL)	-EI- (PERCENT OF INITIAL)	CRUSHED (PERCENT)	CRACKED (PERCENT)	(IN)
	LEFT			870.9			0.	8.	
1	AVG.	-30.0	-13.1		96.	91.			.32
	RIGHT			556.2			0.	0.	
	LEFT			556.2			0.	0.	
2	AVG.	-30.0	-13.1		99.	99.			-.04
	RIGHT			84.2			0.	0.	
	LEFT			84.2			0.	0.	
3	AVG.	-30.0	-13.1		99.	99.			.03
	RIGHT			-702.6			0.	0.	
	LEFT			-702.6			0.	0.	
4	AVG.	-30.0	-13.1		87.	77.			-1.42
	RIGHT			-1174.6			0.	32.	
	LEFT			-1174.6			0.	43.	
5	AVG.	-30.0	-13.1		63.	49.			-3.87
	RIGHT			-1489.3			0.	50.	

* * * * ANALYSIS RESULTS FOR SEGMENT CROSS-SECTION * * * *

MEMBER 1 - LEFT END OF SEGMENT 1

- - - - - - - - - - - C O N C R E T E - - - - - - - - - - -

FOR EACH SUBSLICE, STRESS (KSI) IS GIVEN OVER
STRESS-RELATED STRAIN X 1000 OVER TEMPERATURE (DEG F)

```
     I
     I        1        2        3        4        5
----I-------------------------------------------------
     I
 0   I  CRACK    CRACK    CRACK    CRACK    CRACK
```

	.09	.09	.09	.09	.09
5	CRACK	CRACK	CRACK	CRACK	CRACK
	.08	.08	.08	.08	.08
10	CRACK	.28	.28	.28	.28
	.08	.07	.07	.07	.07
15	.23	.25	.24	.24	.24
	.06	.06	.06	.06	.06
20	.24	.18	.18	.18	.18
	.06	.05	.05	.05	.05
25	.18	.13	.13	.13	.13
	.05	.03	.03	.03	.03
30	.13	.08	.08	.08	.08
	.03	.02	.02	.02	.02
35	.03	.03	.03	.03	.03
	.01	.01	.01	.01	.01
40	-.02	-.02	-.02	-.02	-.02
	-.01	-.01	-.01	-.01	-.01
45	-.08	-.08	-.08	-.08	-.08
	-.02	-.02	-.02	-.02	-.02
50	-.13	-.13	-.13	-.13	-.13
	-.04	-.04	-.04	-.04	-.04
55	-.18	-.18	-.18	-.18	-.22
	-.05	-.05	-.05	-.05	-.06
60	-.22	-.22	-.22	-.22	-.28
	-.06	-.06	-.06	-.06	-.07
65	-.28	-.28	-.28	-.28	-.33
	-.07	-.07	-.07	-.07	-.09
70	-.34	-.33	-.33	-.33	-.33
	-.09	-.09	-.09	-.09	-.09
75	-.37	-.37	-.37	-.37	-.41
	-.10	-.10	-.10	-.10	-.11
80	-.40	-.40	-.40	-.40	-.40
	-.11	-.11	-.11	-.11	-.11
85	-.43	-.43	-.43	-.43	-.43
	-.12	-.12	-.12	-.12	-.12

- - - - - - - - - - - - STEEL - - - - - - - - - - - -

SUBSLICE	STRESS (KSI)	RATIO TO YIELD	STRESS-REL STRAIN (X 1000)	TEMPERATURE (IF REQUESTED) (DEG F)
1	2.2	.05	.07	
2	2.2	.05	.07	
3	.6	.02	.02	
4	-1.4	.03	-.05	
5	-2.9	.07	-.10	
6	-2.9	.07	-.10	

* * * * ANALYSIS RESULTS FOR SEGMENT CROSS-SECTION * * * *

MEMBER 1 - RIGHT END OF SEGMENT 1

- - - - - - - - - - - C O N C R E T E - - - - - - - - - - -

FOR EACH SUBSLICE, STRESS (KSI) IS GIVEN OVER
STRESS-RELATED STRAIN X 1000 OVER TEMPERATURE (DEG F)

	1	2	3	4	5
0	.17	.17	.17	.17	.17
	.04	.04	.04	.04	.04
5	.15	.15	.15	.15	.15
	.04	.04	.04	.04	.04
10	.15	.13	.13	.13	.13
	.04	.03	.03	.03	.03
15	.10	.11	.11	.11	.11
	.03	.03	.03	.03	.03
20	.11	.08	.08	.08	.08
	.03	.02	.02	.02	.02
25	.08	.04	.04	.04	.04
	.02	.01	.01	.01	.01
30	.04	.02	.02	.02	.02
	.01	.00	.00	.00	.00
35	-.01	-.01	-.01	-.01	-.01
	-.00	-.00	-.00	-.00	-.00

40	I	-.04	-.04	-.04	-.04	-.04
	I	-.01	-.01	-.01	-.01	-.01
	I					
45	I	-.07	-.07	-.07	-.07	-.07
	I	-.02	-.02	-.02	-.02	-.02
	I					
50	I	-.10	-.10	-.10	-.10	-.10
	I	-.03	-.03	-.03	-.03	-.03
	I					
55	I	-.12	-.12	-.12	-.12	-.15
	I	-.03	-.03	-.03	-.03	-.04
	I					
60	I	-.15	-.15	-.15	-.15	-.18
	I	-.04	-.04	-.04	-.04	-.05
	I					
65	I	-.18	-.18	-.18	-.18	-.21
	I	-.05	-.05	-.05	-.05	-.06
	I					
70	I	-.22	-.21	-.21	-.21	-.21
	I	-.06	-.06	-.06	-.06	-.06
	I					
75	I	-.24	-.24	-.24	-.24	-.25
	I	-.06	-.06	-.06	-.06	-.07
	I					
80	I	-.25	-.25	-.25	-.25	-.25
	I	-.07	-.07	-.07	-.07	-.07
	I					
85	I	-.27	-.27	-.27	-.27	-.27
	I	-.07	-.07	-.07	-.07	-.07

- - - - - - - - - - - - - S T E E L - - - - - - - - - - - -

SUBSLICE	STRESS (KSI)	RATIO TO YIELD	STRESS-REL STRAIN (X 100C)	TEMPERATURE (IF REQUESTED) (DEG F)
1	1.0	.03	.03	
2	1.0	.03	.03	
3	.1	.00	.00	
4	-1.0	.02	-.03	
5	-1.8	.05	-.06	
6	-1.8	.05	-.06	

• • • • • • • • ANALYSIS RESULTS FOR MEMBER 2 • • • • • • • •

-DISPLACEMENTS AND STRAINS-

NODE	SEG	SEGMENT END DISPLACEMENTS (MEMBER COORDINATE SYSTEM) X-M (INCHES)	Y-M (INCHES)	R-M (RADS)	SECTION STRAINS ELONGATION	CURV.
1		-.00678	-.00063	-.00071		
	LEFT					-2.54E-05
	1 AVG.				-9.97E-06	
	RIGHT					-1.34E-05
2		-.00478	-.02390	-.00118		
	LEFT					-9.90E-06
	2 AVG.				-1.24E-06	
	RIGHT					1.86E-06
3		-.00458	-.08733	-.00137		
	LEFT					1.86E-06
	3 AVG.				-1.86E-06	
	RIGHT					1.19E-05
4		-.00413	-.14712	-.00104		
	LEFT					1.46E-05
	4 AVG.				-1.09E-05	
	RIGHT					2.00E-05
5		.00000	-.17994	-.00000		

-FORCES AND SECTION PROPERTIES-

SEGMENT		SEGMENT FORCES AXIAL (KIPS)	SHEAR (KIPS)	MOMENT (IN-K)	SEGMENT STIFFNESS -AE- (PERCENT OF INITIAL)	-EI-	AREA REDUCTION CRUSHED (PERCENT)	CRACKED	CENTER OF GRAVITY (IN)
	LEFT			-1489.3			0.	57.	
1	AVG.	-13.1	28.0		57.	44.			-4.83
	RIGHT			-817.3			0.	43.	
	LEFT			-816.9			0.	24.	
2	AVG.	-13.1	22.0		89.	80.			-1.31
	RIGHT			238.7			0.	0.	
	LEFT			238.7			0.	0.	
3	AVG.	-13.1	14.0		86.	76.			1.65
	RIGHT			910.4			0.	32.	
	LEFT			910.7			0.	43.	
4	AVG.	-13.1	5.0		60.	45.			4.60
	RIGHT			1210.7			0.	50.	

```
*****************************************************************
   * * *  FRAME STUDY  *  ASTM FIRE  *  LOAD = 2 K/FT  * * *
   TIME STEP NUMBER      1     AT A TIME OF      .0500 HOURS
*****************************************************************
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. . . . . ANALYSIS RESULTS FOR STRUCTURAL SYSTEM . . . . . .

JOINT	JOINT DISPLACEMENTS (GLOBAL COORDINATE SYSTEM) X-G (INCHES)	Y-G (INCHES)	R-G (RADIANS)	SUPPORT REACTIONS F-X (KIPS) F-Y (KIPS) M-R (IN-K)
1	-.00000	-.00000	.00000	13.29 30.00 -846.86
2	-.01067	.00157	-.00068	NONE
3	.00000	-.17296	-.00000	-13.29 -0. 1154.12

. . . . . ANALYSIS RESULTS FOR MEMBER 1 . . . . . .

-DISPLACEMENTS AND STRAINS-

NODE	SEG	SEGMENT END DISPLACEMENTS (MEMBER COORDINATE SYSTEM) X-M (INCHES)	Y-M (INCHES)	R-M (RADS)	SECTION STRAINS ELONGATION	CURV.
1		-.00000	.00000	.00000		
	LEFT					8.44E-06
	1 AVG.				-7.27E-06	
	RIGHT					4.56E-06
2		-.00006	.00206	.00016		
	LEFT					4.55E-06
	2 AVG.				-6.76E-06	
	RIGHT					8.66E-07
3		-.00031	.00982	.00025		

	LEFT					8.55E-07
3	AVG.				-6.83E-06	
	RIGHT					-5.29E-06
4		-.00072	.02288	.00012		
	LEFT					-6.04E-06
4	AVG.				1.43E-06	
	RIGHT					-1.42E-05
5		.00005	.02154	-.00024		
	LEFT					-1.57E-05
5	AVG.				-6.38E-06	
	RIGHT					-2.08E-05
6		.00157	.01067	-.00068		

-FORCES AND SECTION PROPERTIES-

SEGMENT		SEGMENT FORCES			SEGMENT STIFFNESS		AREA REDUCTION		CENTER OF GRAVITY
		AXIAL (KIPS)	SHEAR (KIPS)	MOMENT (IN-K)	-AE- (PERCENT OF INITIAL)	-EI- (PERCENT OF INITIAL)	CRUSHED (PERCENT)	CRACKED (PERCENT)	(IN)
	LEFT			844.7			0.	15.	
1	AVG.	-30.1	-13.2		93.	86.			.70
	RIGHT			527.9			0.	0.	
	LEFT			527.8			0.	0.	
2	AVG.	-30.0	-13.3		99.	99.			-.02
	RIGHT			49.3			0.	0.	
	LEFT			49.3			0.	0.	
3	AVG.	-30.0	-13.3		99.	99.			.04
	RIGHT			-748.3			0.	0.	
	LEFT			-748.4			0.	9.	
4	AVG.	-30.0	-13.3		82.	68.			-1.99
	RIGHT			-1226.8			0.	35.	
	LEFT			-1226.9			0.	42.	
5	AVG.	-30.0	-13.3		64.	49.			-3.82
	RIGHT			-1545.9			0.	49.	

. . . . . ANALYSIS RESULTS FOR MEMBER 2 . . . . . .

-DISPLACEMENTS AND STRAINS-

NODE	SEG	SEGMENT END DISPLACEMENTS (MEMBER COORDINATE SYSTEM) X-M (INCHES)	Y-M (INCHES)	R-M (RADS)	SECTION STRAINS ELONGATION	CURV.
1		-.01067	.00157	-.00068		
	LEFT					-2.54E-05
1	AVG.				8.65E-06	

2 RIGHT	-.00812	-.02094	-.00114		-1.31E-05
2 LEFT AVG.				2.10E-05	-1.07E-05
3 RIGHT	-.00675	-.08320	-.00134		2.38E-06
3 LEFT AVG.				1.91E-05	2.53E-06
4 RIGHT	-.00525	-.14128	-.00100		1.18E-05
4 LEFT AVG.				5.67E-06	1.41E-05
5 RIGHT	.00000	-.17286	-.00000		1.93E-05

-FORCES AND SECTION PROPERTIES-

SEGMENT	SEGMENT FORCES			SEGMENT STIFFNESS		AREA REDUCTION		CENTER OF GRAVITY
	AXIAL (KIPS)	SHEAR (KIPS)	MOMENT (IN-K)	-AE- (PERCENT OF INITIAL)	-EI- (PERCENT OF INITIAL)	CRUSHED (PERCENT)	CRACKED (PERCENT)	(IN)
1 LEFT			-1545.9			0.	57.	
1 AVG.	-13.3	28.0		54.	43.			-5.08
1 RIGHT			-873.9			0.	49.	
2 LEFT			-873.5			0.	35.	
2 AVG.	-13.3	22.0		84.	75.			-1.79
2 RIGHT			181.8			0.	0.	
3 LEFT			182.4			0.	0.	
3 AVG.	-13.3	14.0		85.	77.			1.70
3 RIGHT			853.9			0.	33.	
4 LEFT			854.1			0.	48.	
4 AVG.	-13.3	5.0		56.	45.			4.90
4 RIGHT			1154.1			0.	54.	

TABLE B.5 TYPICAL COLUMN SEGMENT DATA - C5

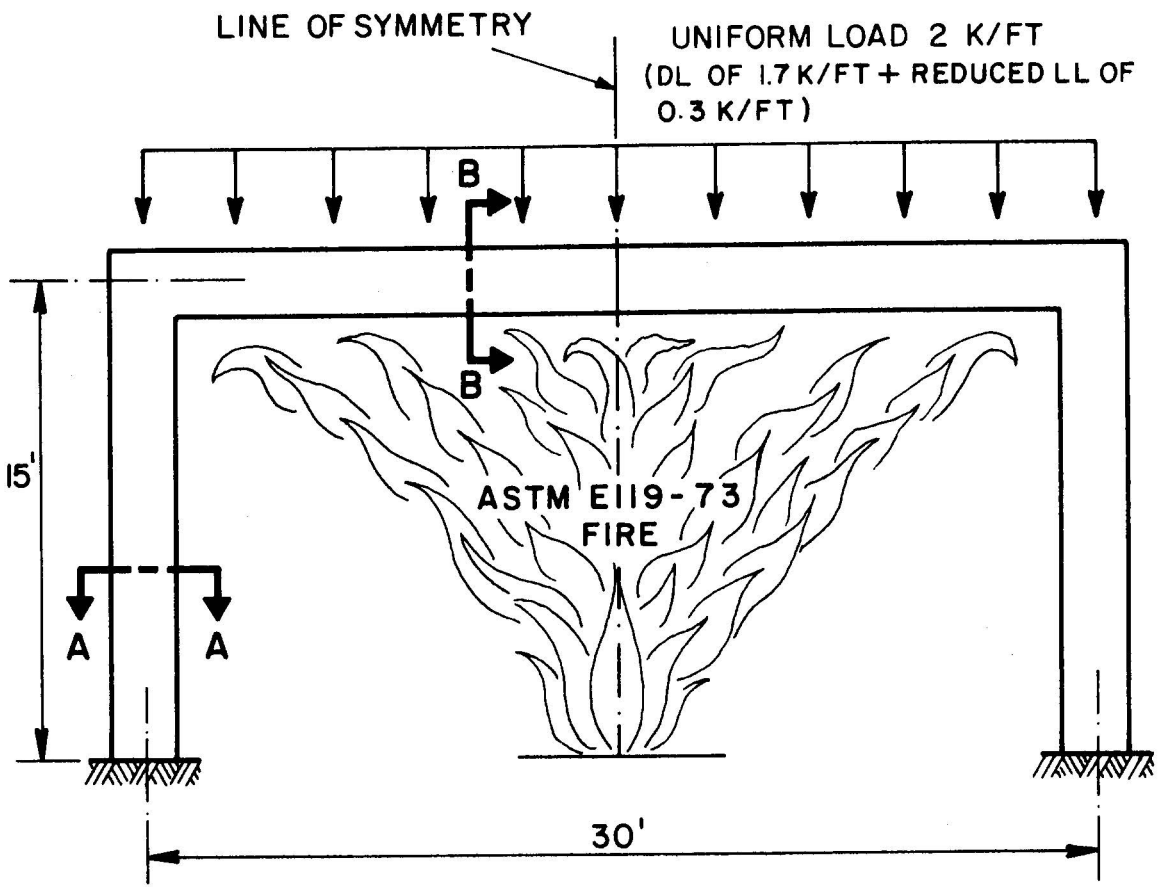
Time	Axial Strain ε_a	Curvature ϕ	Axial Force (kips)	Shear Force (kips)	Bending Moment (k-in)	AE Ratio	EI Ratio	DCG (inches)	Crush'g Ratio	Crack'g Ratio
.00	-2.28 E-05	-2.13 E-05	-30.0	-13.1	1489.3	.63	.49	-3.87	-	.50
.05	-6.68 E-06	-2.08 E-05	-30.0	-13.3	1545.4	.64	.49	-3.82	-	.49
.10	1.00 E-04	-2.57 E-05	-30.0	-16.9	1998.7	.53	.53	-3.42	-	.57
.15	2.67 E-04	-2.94 E-05	-30.0	-17.7	2263.9	.41	.48	-2.26	-	.68
.20	3.30 E-04	-3.15 E-05	-30.0	-19.7	2523.3	.41	.47	-1.95	.01	.66
.25	5.16 E-04	-2.58 E-05	-30.0	-15.9	2159.0	.34	.40	-1.39	.01	.74
.30	5.71 E-04	-3.32 E-05	-30.0	-11.0	1837.2	.32	.38	-1.26	.04	.72
.35	5.82 E-04	-3.92 E-05	-30.0	-11.7	1873.0	.31	.39	-2.12	.06	.70
.40	3.55 E-04	-3.16 E-05	-30.0	-18.3	2458.3	.36	.39	-2.42	.18	.61
.45	5.10 E-04	-3.44 E-05	-30.0	-21.8	2789.8	.34	.39	-1.62	.18	.62
.50	6.93 E-04	-3.75 E-05	-30.0	-23.5	3075.3	.32	.36	-0.65	.18	.63
.55	8.53 E-04	-4.05 E-05	-30.0	-24.6	3244.2	.30	.33	-0.24	.18	.66
.60	1.01 E-03	-4.42 E-05	-30.0	-24.2	3494.1	.28	.30	-0.71	.18	.66
.65	1.17 E-03	-4.68 E-05	-30.0	-24.6	3693.7	.27	.29	-0.97	.18	.64
.70	1.35 E-03	-4.42 E-05	-30.0	-24.8	3811.3	.26	.28	-0.84	.19	.64
.75	1.52 E-03	-4.34 E-05	-30.0	-25.2	3866.4	.26	.28	-0.95	.19	.64
.80	1.70 E-03	-4.20 E-05	-30.0	-24.9	3901.3	.26	.29	-0.96	.19	.62
.85	1.85 E-03	-4.37 E-05	-30.0	-24.4	3912.8	.26	.28	-1.02	.19	.62
.90	1.97 E-03	-4.78 E-05	-30.0	-23.2	3830.4	.24	.27	-1.21	.21	.62
.95	2.13 E-03	-4.44 E-05	-30.0	-22.2	3786.5	.23	.25	-0.88	.21	.62
1.00	2.30 E-03	-4.02 E-05	-30.0	-20.5	3705.3	.23	.25	-0.86	.21	.62

NOTE: Quantities that vary linearly across a segment (curvature, moment, crushing and cracking ratios) are given the value that they take at the top (right end) of the segment.

TABLE B.6 TYPICAL BEAM SEGMENT DATA - B4

Time	Axial Strain ε_a	Curvature ϕ	Axial Force (kips)	Shear Force (kips)	Bending Moment (k-in)	AE Ratio	EI Ratio	DCG (inches)	Crush'g Ratio	Crack'g Ratio
.00	-1.09 E-05	2.00 E-05	-13.1	5.0	-1210.7	.60	.45	4.60	-	.50
.05	5.33 E-06	1.93 E-05	-13.3	5.0	-1154.6	.56	.45	4.90	-	.54
.10	2.49 E-04	2.29 E-05	-16.9	5.0	-701.3	.36	.56	2.17	-	.69
.15	5.92 E-04	2.29 E-05	-17.7	5.0	-436.1	.24	.36	-0.77	-	.82
.20	7.96 E-04	2.36 E-05	-19.7	5.0	-176.7	.21	.33	-0.11	.01	.82
.25	8.78 E-04	1.57 E-05	-15.9	5.0	-541.0	.17	.29	0.01	.04	.82
.30	4.15 E-04	2.47 E-05	-11.1	5.0	-862.6	.28	.39	0.15	.17	.65
.35	4.29 E-04	2.93 E-05	-11.7	5.0	-827.0	.29	.40	1.52	.17	.65
.40	6.70 E-04	2.74 E-05	-18.3	5.0	-241.7	.26	.38	-0.27	.18	.65
.45	9.03 E-04	2.65 E-05	-21.8	5.0	89.8	.24	.35	-0.38	.18	.65
.50	1.13 E-03	2.59 E-05	-23.5	5.0	375.3	.23	.34	-0.35	.18	.65
.55	1.33 E-03	2.52 E-05	-24.6	5.0	544.2	.23	.34	-0.22	.18	.64
.60	1.55 E-03	2.52 E-05	-24.4	5.0	794.1	.21	.33	-0.21	.18	.64
.65	1.81 E-03	2.45 E-05	-24.6	5.0	993.7	.19	.28	-1.42	.18	.64
.70	2.05 E-03	2.42 E-05	-24.8	5.0	1111.3	.18	.27	-1.38	.18	.64
.75	2.28 E-03	2.56 E-05	-25.2	5.0	1166.4	.17	.26	-1.35	.18	.64
.80	2.50 E-03	2.73 E-05	-24.9	5.0	1201.3	.17	.26	-1.30	.18	.64
.85	2.69 E-03	2.98 E-05	-24.4	5.0	1212.6	.15	.24	-0.59	.18	.64
.90	2.87 E-03	3.69 E-05	-23.2	5.0	1130.4	.13	.21	0.53	.18	.64
.95	3.07 E-03	4.25 E-05	-22.2	5.0	1086.7	.12	.20	0.67	.18	.64
1.00	3.24 E-03	4.06 E-05	-20.5	5.0	1004.2	.14	.23	-1.30	.20	.64

NOTE: Quantities that vary linearly across a segment (curvature, moment, crushing and cracking ratios) are given the value that they take at the right end of the segment (frame centerline).



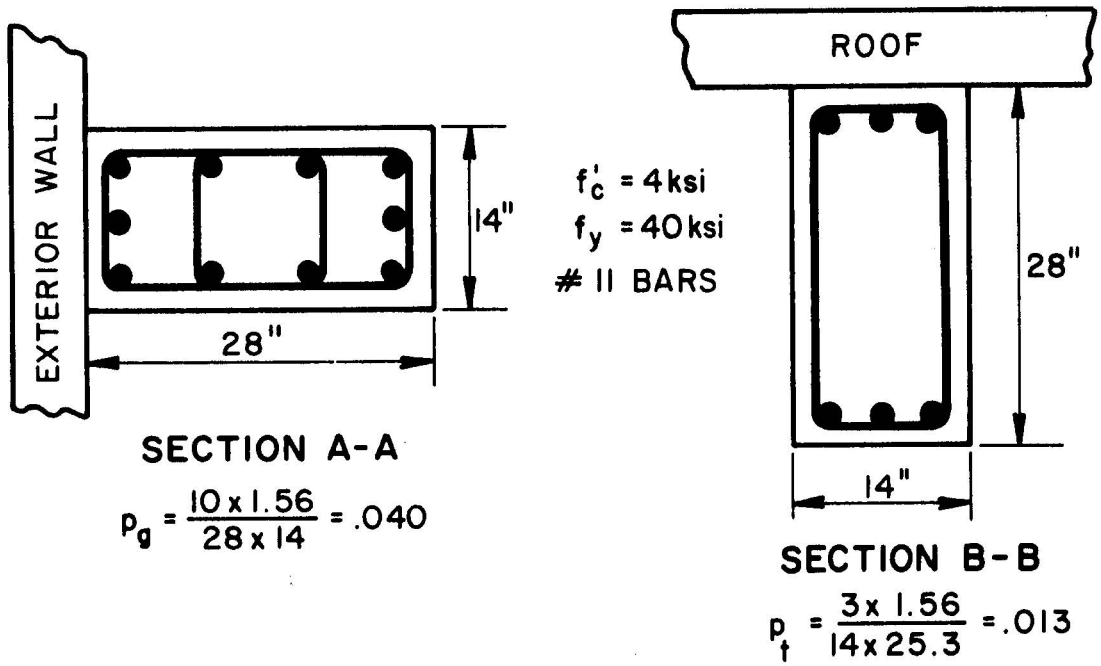


FIGURE B.1 TYPICAL REINFORCED CONCRETE FRAME

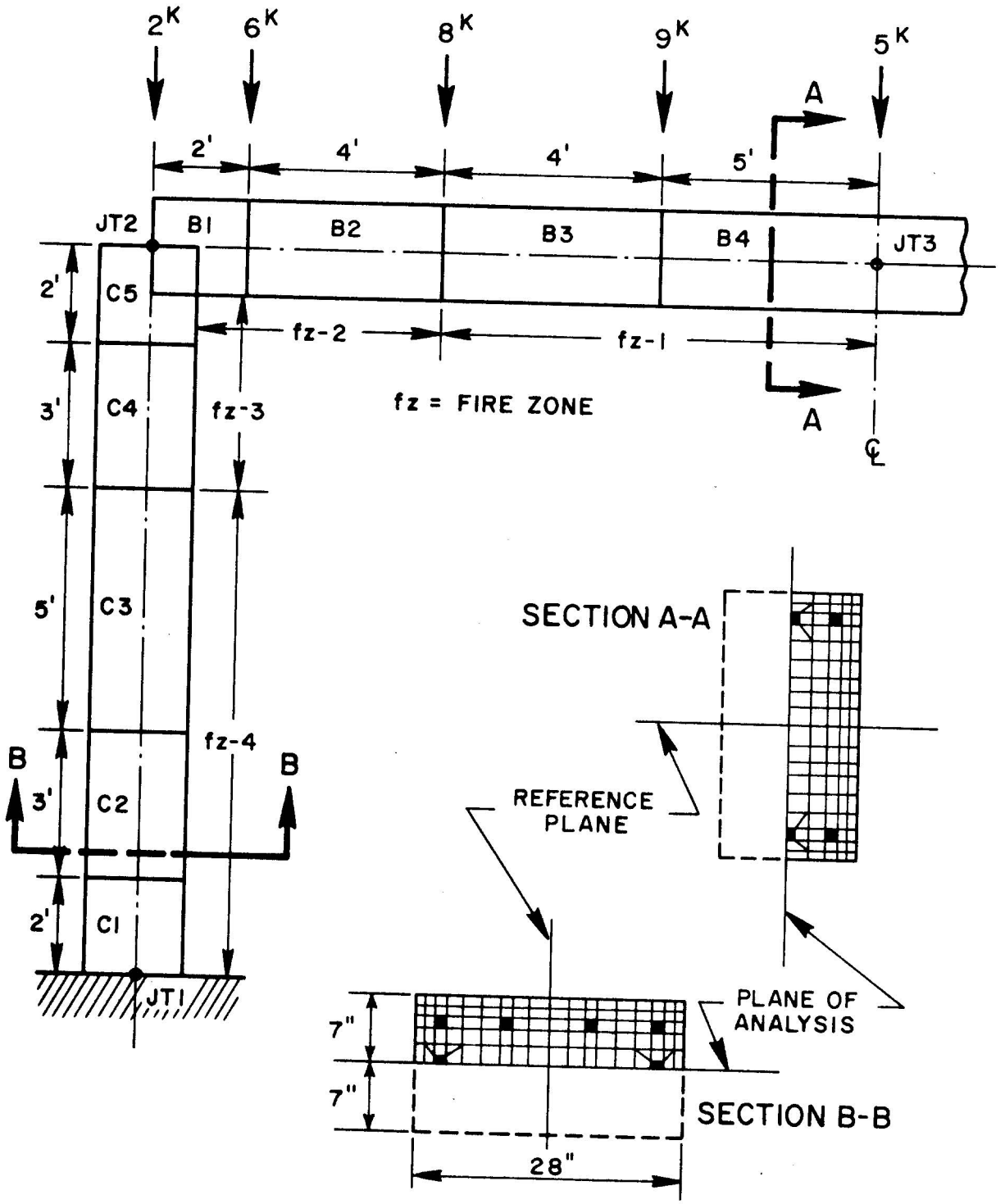


FIGURE B.2 FRAME IDEALIZATION FOR FIRES-T AND FIRES-RC II

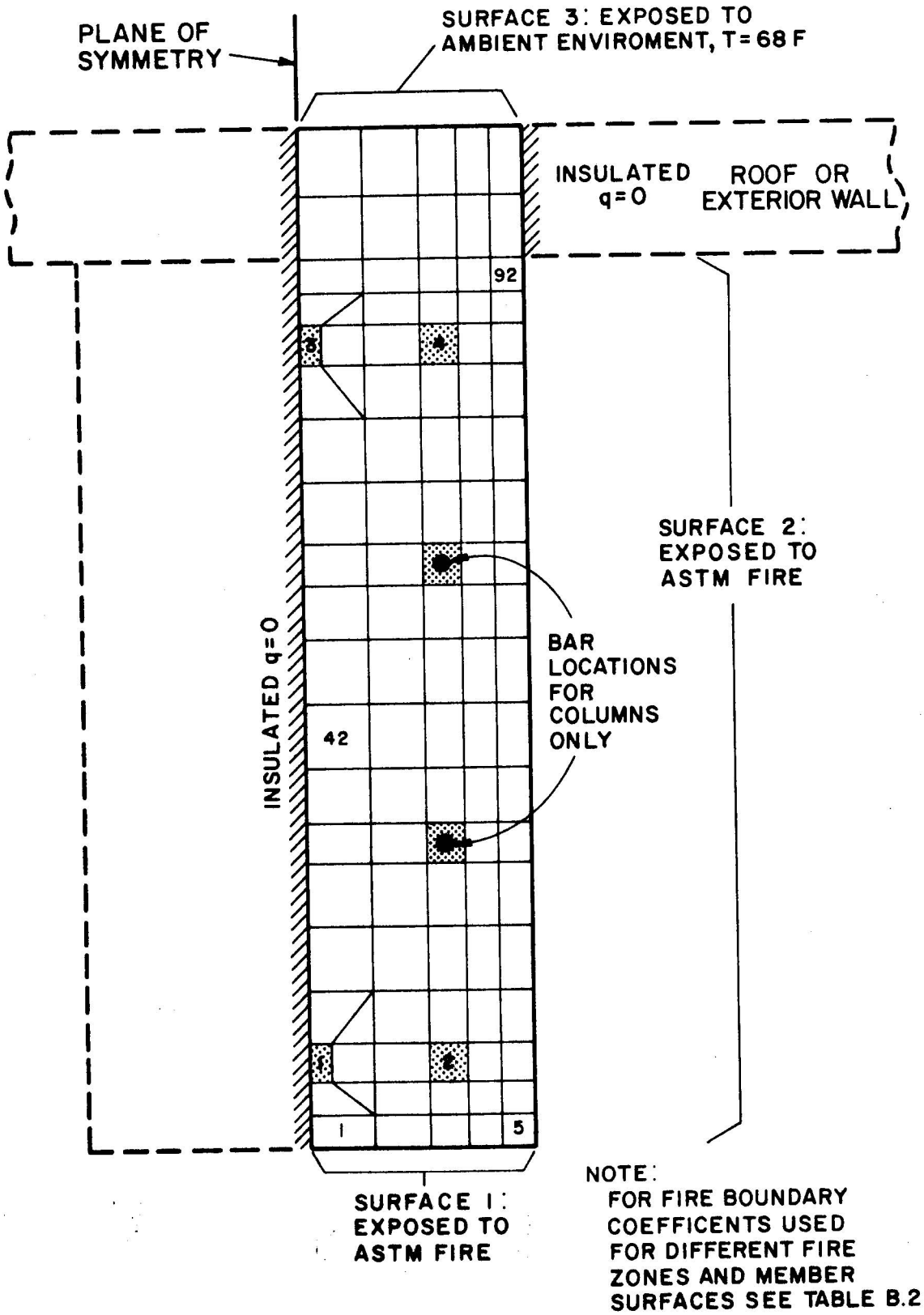


FIGURE B.3 FINITE ELEMENT MESH FOR TYPICAL SEGMENT

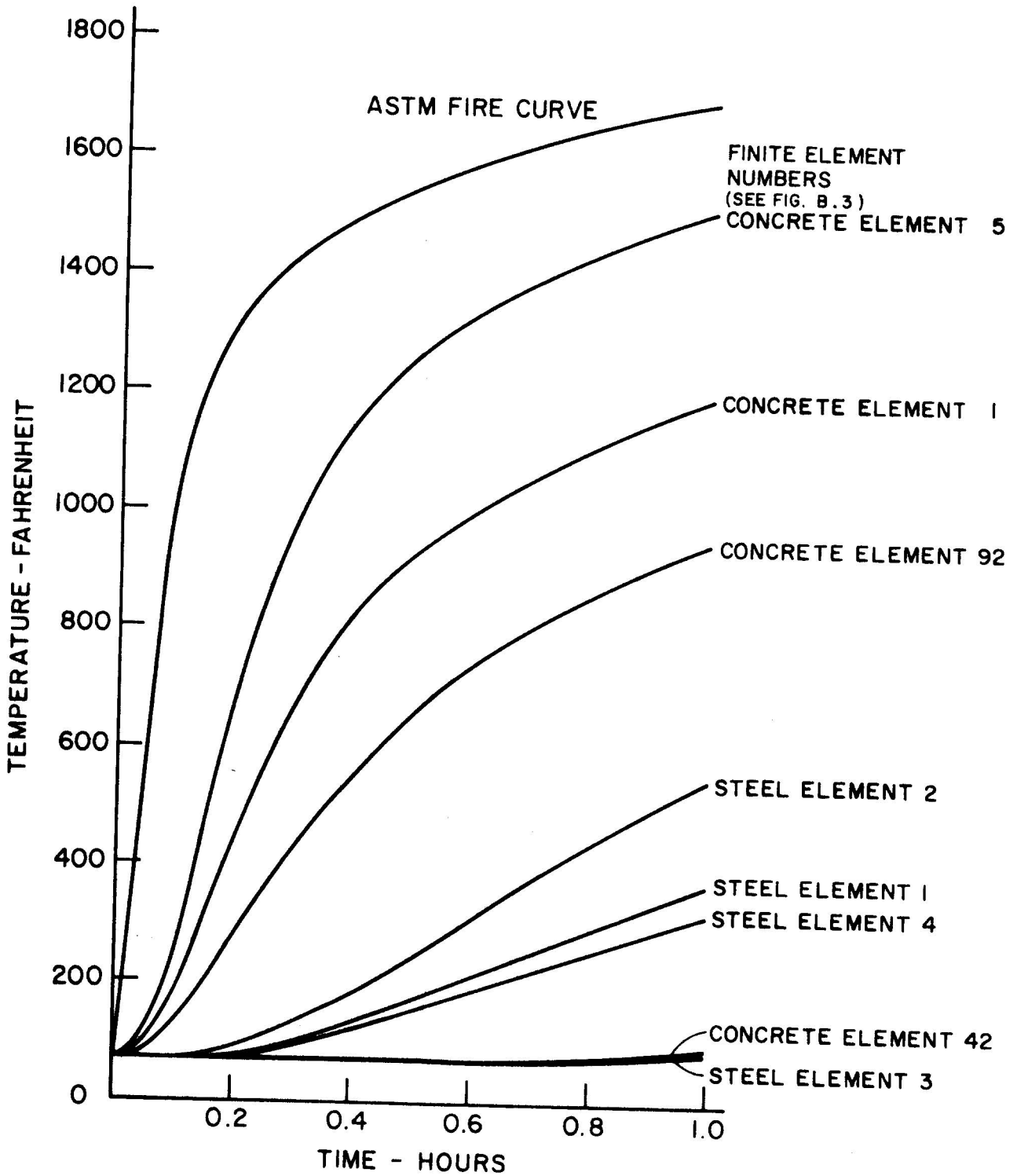


FIGURE B.4 TEMPERATURE HISTORIES FOR TYPICAL BEAM SEGMENT IN FIRE ZONE 1

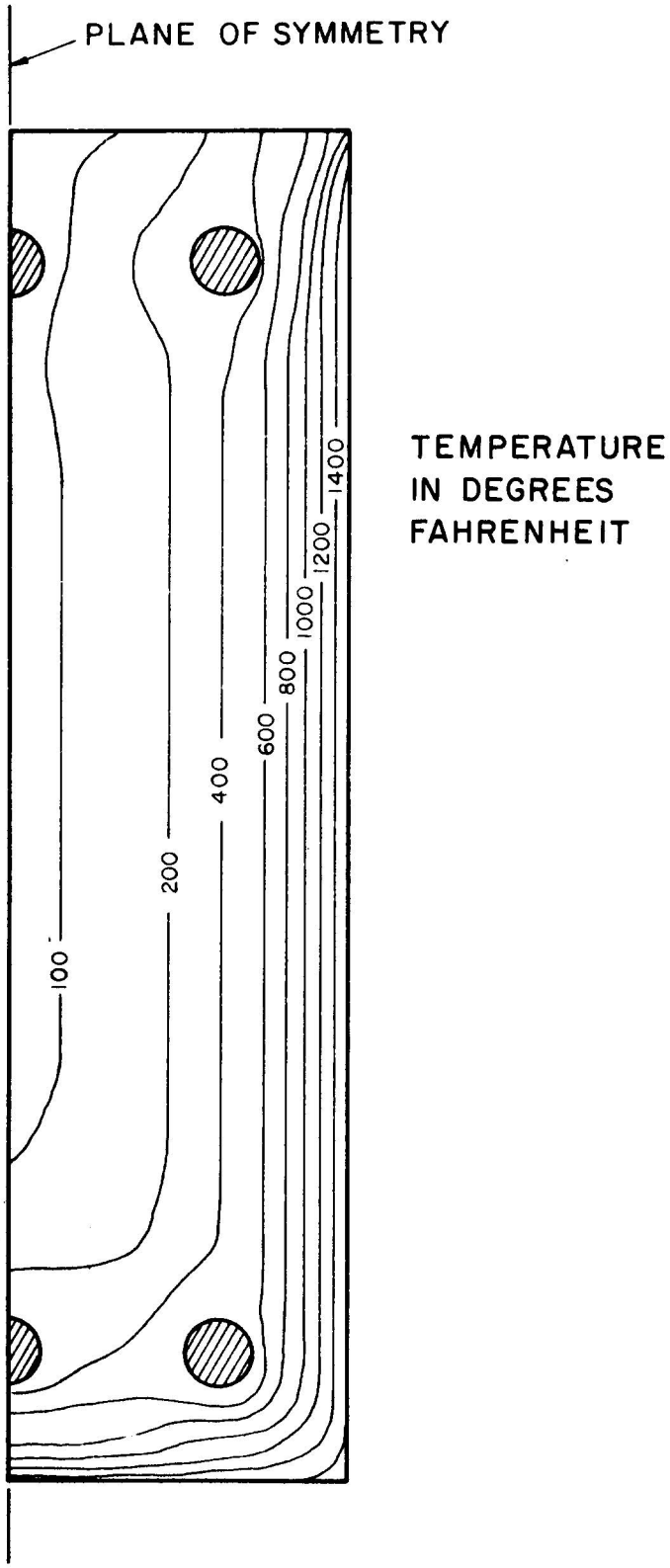


FIGURE B.5 ISOTHERM FOR BEAM SEGMENTS IN FIRE ZONE 1
(T = 1.0 HOUR)

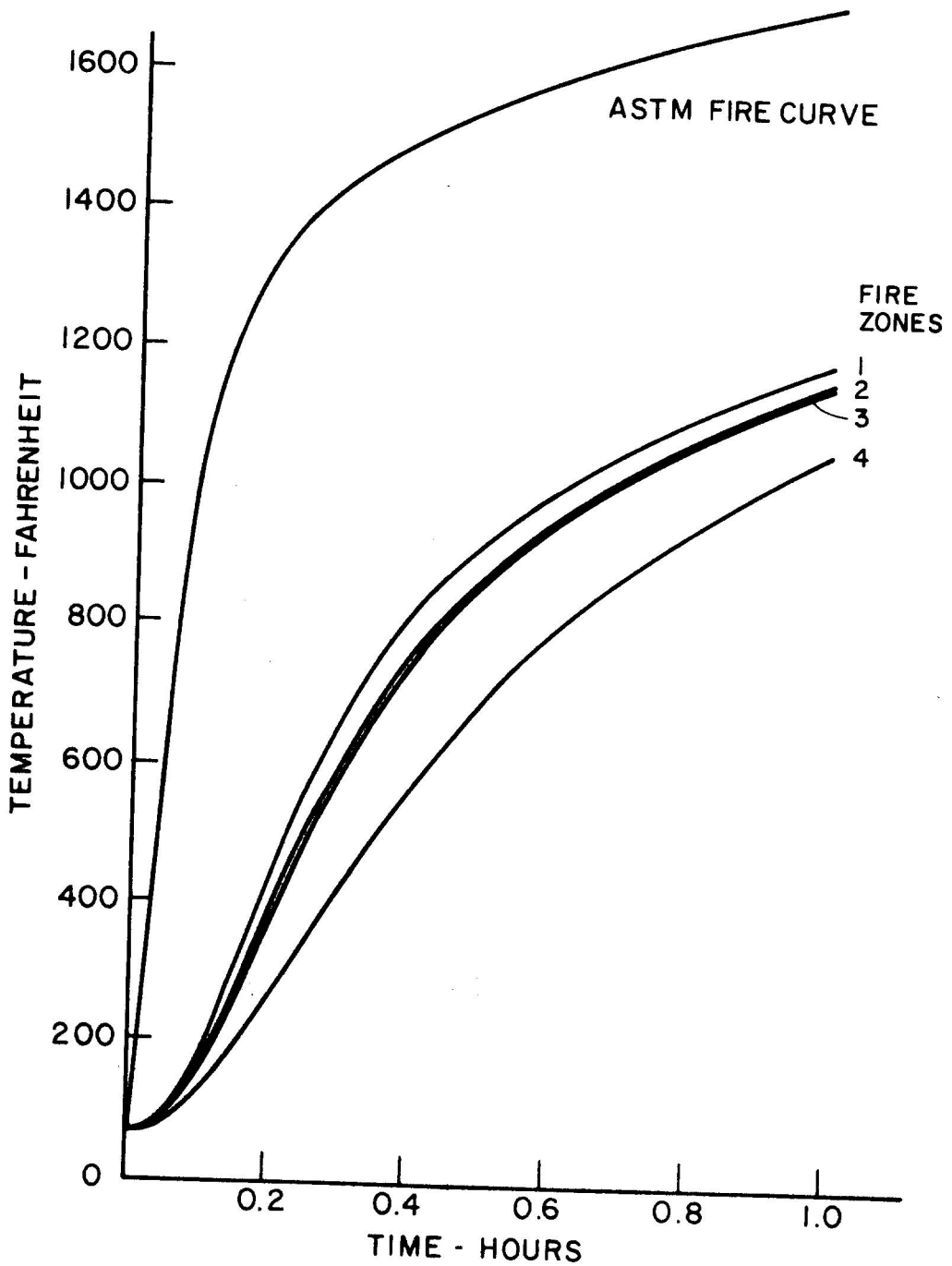


FIGURE B.6 TEMPERATURE HISTORY FOR BEAM AND COLUMN SEGMENT SUBSLICE 1 FOR THE FOUR FIRE ZONES

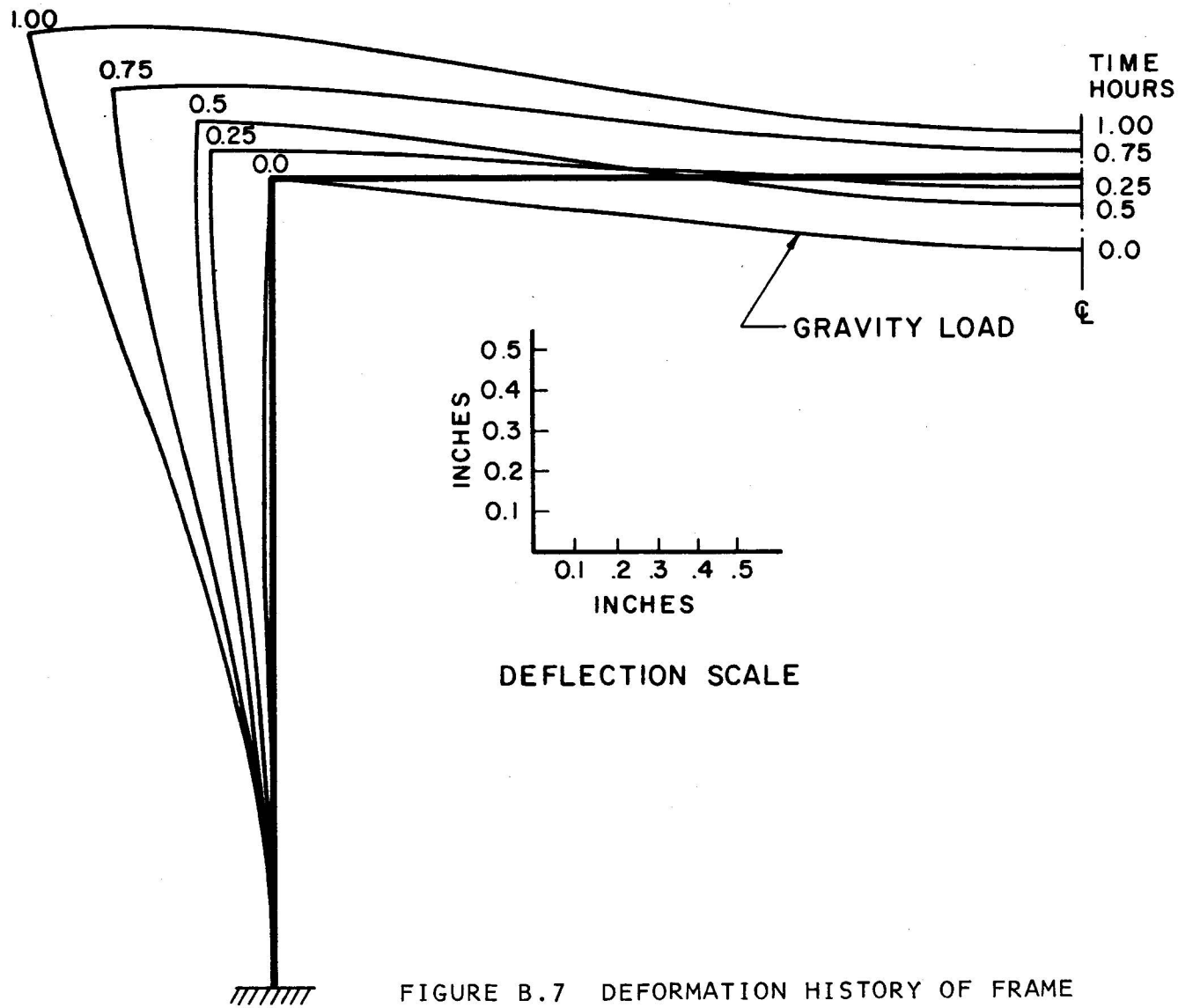


FIGURE B.7 DEFORMATION HISTORY OF FRAME

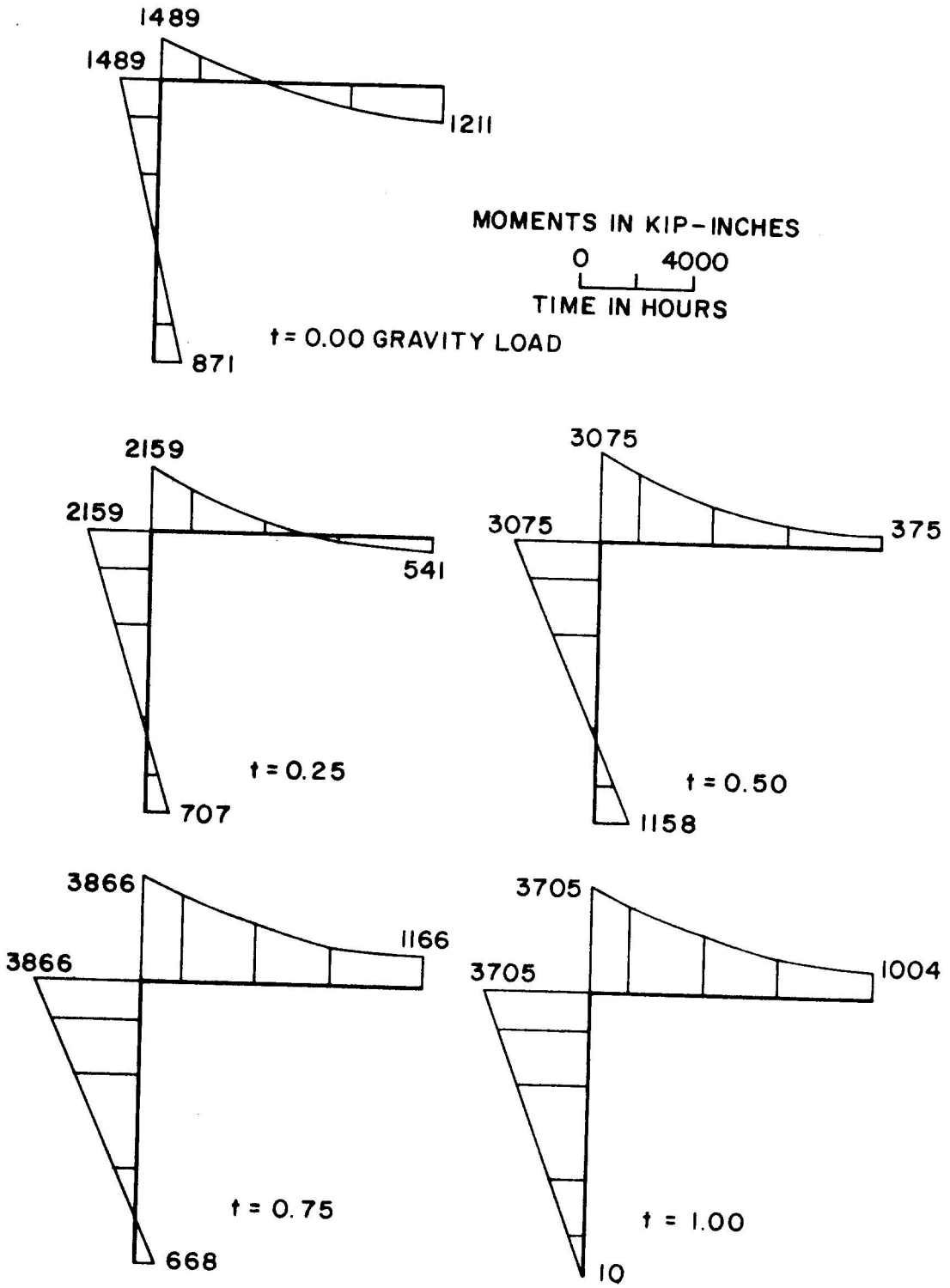


FIGURE B.8 BENDING MOMENT DIAGRAMS FOR FRAME

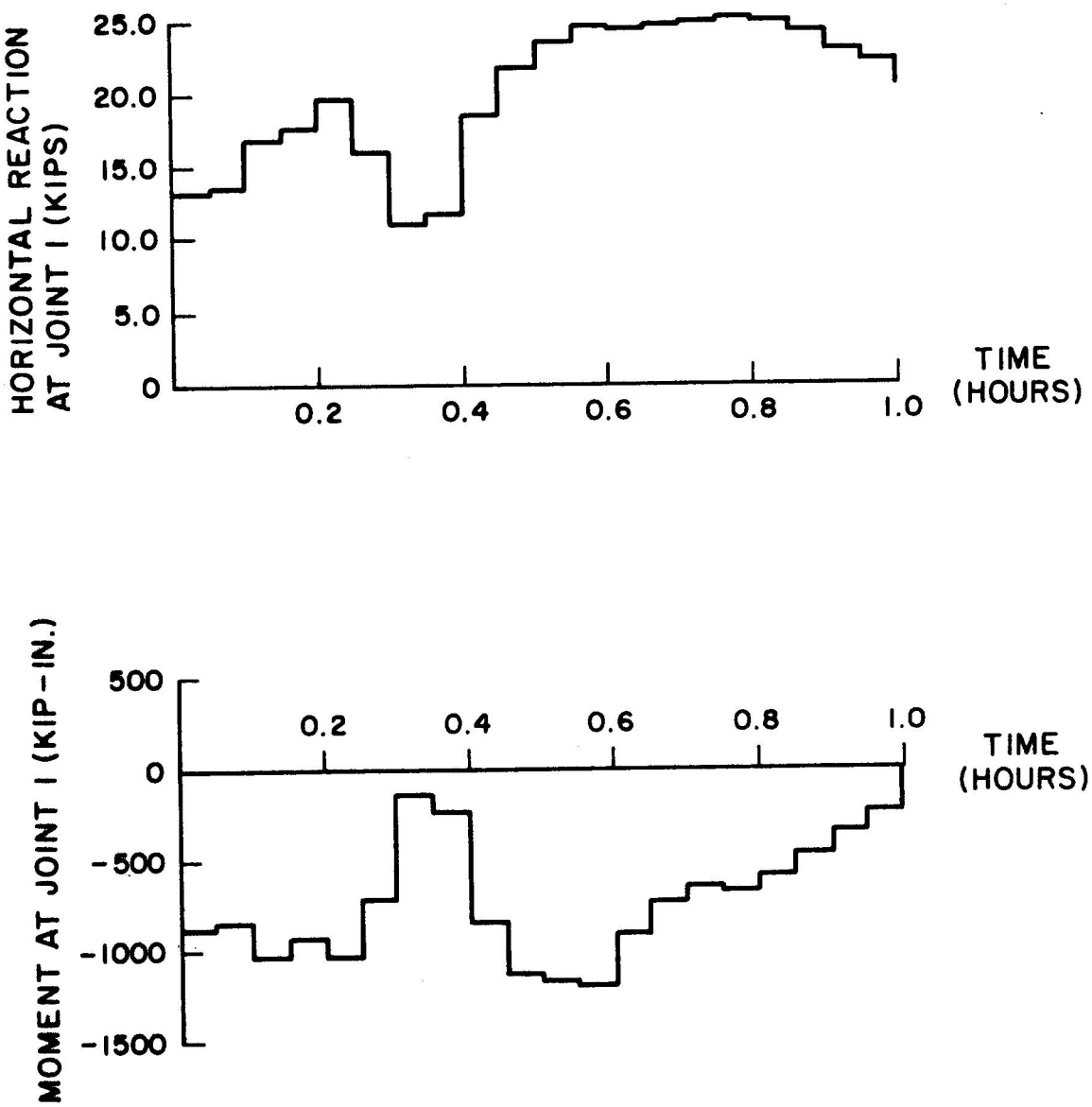


FIGURE B.9 SUPPORT REACTIONS

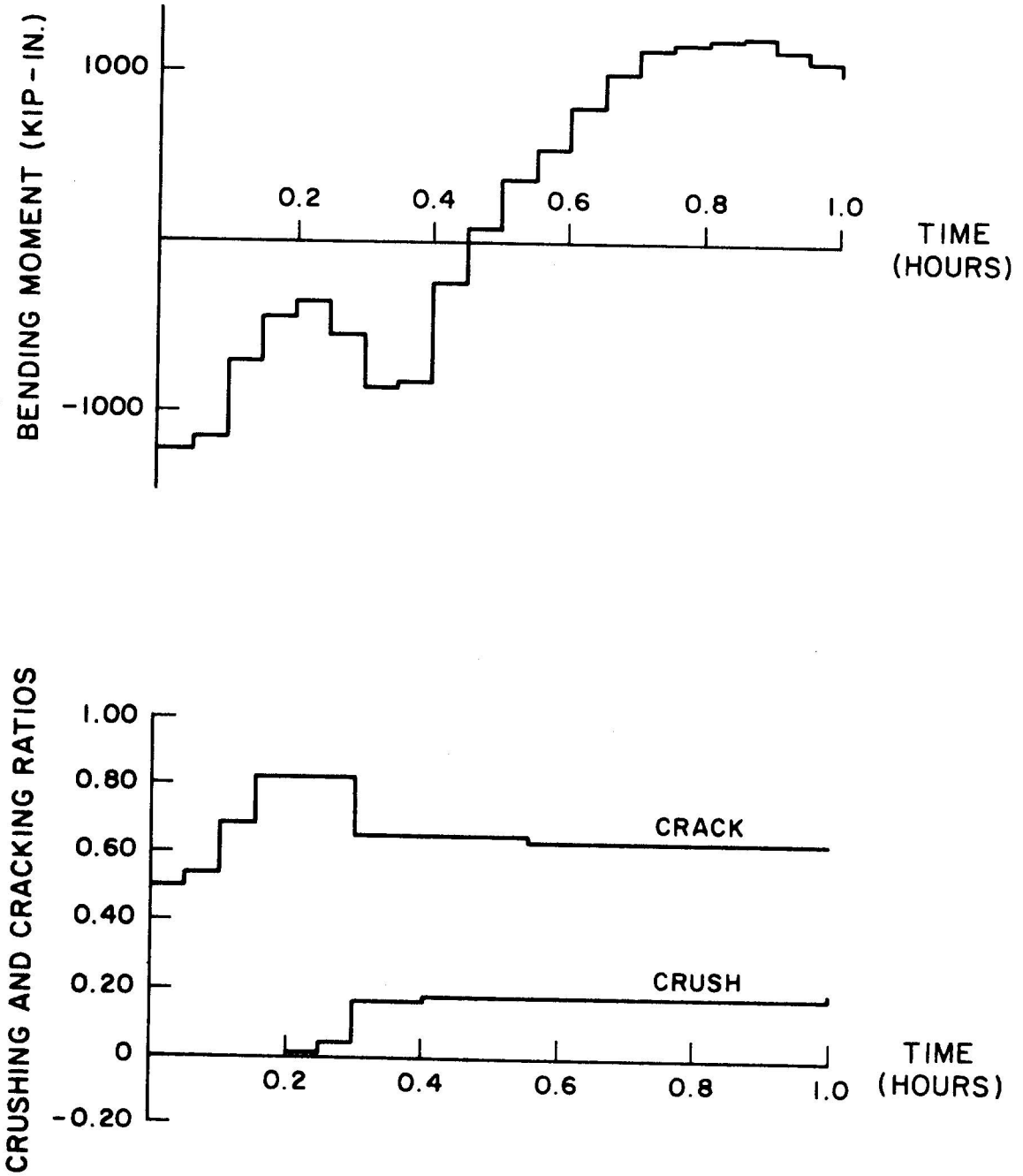


FIGURE B.10 BENDING MOMENT AND DEGRADATION RATIOS FOR RIGHT END OF BEAM SEGMENT B4

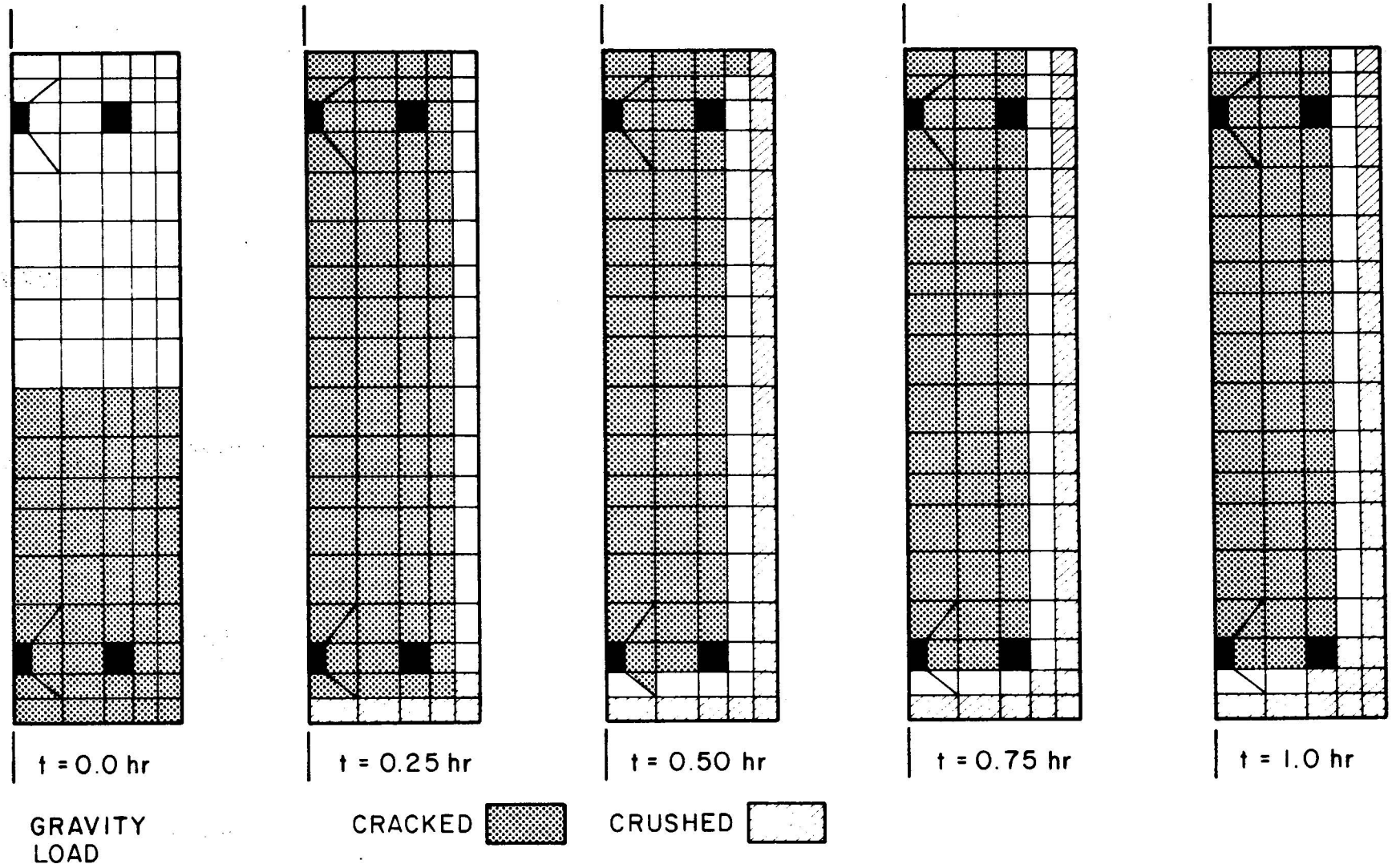


FIGURE B.11 DEGRADATION PROFILES FOR RIGHT END OF BEAM SEGMENT B4

APPENDIX C - LISTING OF FIRES-RC II

```
* * * * * * * * * * * * * * * * * * * * * * * * * * * *
*                                                     *
*  The following listing is the operational version   *
*  of the computer program FIRES-RC II as of July,    *
*  1977.  Although the program has been tested, no    *
*  warranty is made regarding its accuracy or relia-  *
*  bility, and no responsibility is assumed in this   *
*                    respect.                         *
*                                                     *
* * * * * * * * * * * * * * * * * * * * * * * * * * * *
```

```
      PROGRAM FIRERC2(INPUT,OUTPUT,PUNCH,TAPE1,TAPE2,TAPE3,TAPE4,TAPE11=
     1INPUT,TAPE12=OUTPUT,TAPE13=PUNCH)
C
C                    F I R E S - R C    I I
C
C                      AUGUST  1976
C
C                 UNIVERSITY OF CALIFORNIA - BERKELEY
C
C                       PROGRAMMED BY
C                         R. IDING
C                         B. BRESLER
C                         Z. NIZAMODDIN
C
C     PROGRAM  *FIRERC2*  DETERMINES THE STRUCTURAL RESPONSE OF PLANAR
C     REINFORCED CONCRETE FRAMES TO FIRE CONDITIONS.  IT IS BASED ON A
C     NON-LINEAR METHOD OF ANALYSIS WHICH USES A STEP BY STEP TIME-LOAD
C     INCREMENTAL TECHNIQUE. NONLINEAR MATERIALS WITH TEMPERATURE-
C     DEPENDENT STRESS-STRAIN LAWS, AND TEMPERATURE-DEPENDENT CREEP,
C     SHRINKAGE AND THERMAL EXPANSION MODELS AS WELL AS CRACKING
C     AND CRUSHING OF CONCRETE ARE CONSIDERED IN THE ANALYSIS
C
C
      COMMON /TAP/ HED(10),ITEMP1,ITEMP2,ISEG1,ISEG2,NIN,NOUT,NPUNCH
      COMMON /DYN/ NDT,NSTORE,NCMAX,NSMAX,NCONTL,NSTLTL,ISYSTM,IMEMB,ITO
     1TAL,ITAPE
      COMMON /BLK1/ NJ,NM,NBC,NJ3,MAXBAN,NCRPS,NCRPC,NSHRINK,NCONV
      COMMON /DIM1/ N1,N2,N3,N4,N5,N6,N7,N8,N9,N10,N11,N12
      COMMON /DIM2/ I0,I1,I2,I3,I4,I5,LCARD,NCARD,ISTART,LCOP,TIME,ERR(3
     1),IX(3),DT
      COMMON /CARD/ IREAD(80)
      COMMON C(10000)
      INTEGER OPT
C
C
C     DEFINE AND REWIND STORAGE FILES
C
   10 ITEMP1=1
      REWIND ITEMP1
      ITEMP2=2
      REWIND ITEMP2
      ISEG1=3
      REWIND ISEG1
      ISEG2=4
      REWIND ISEG2
C
C     DEFINE INPUT/OUTPUT FILES
C
      NIN=11
      NOUT=12
      NPUNCH=13
C
C     INITIALIZE ANALYSIS INDICATORS TO DEFAULT CONDITIONS
C
      NSTORE=10000
      ITAPE=0
      INT=1
      INS=2
      MBS=3
```

```
FIRES-RC2      OPT=4
FIRES-RC2      IOT=5
FIRES-RC2      NCMAX=1
FIRES-RC2      NSMAX=0
FIRES-RC2      NCRPS=0
FIRES-RC2      NCRPC=0
FIRES-RC2      NSHRINK=0
FIRES-RC2  C
FIRES-RC2  C   READ PROBLEM HEADING
FIRES-RC2  C
FIRES-RC2      READ (NIN,380) HED
FIRES-RC2  C
FIRES-RC2  C   WRITE PROGRAM NAME
FIRES-RC2  C
FIRES-RC2      WRITE (NOUT,360)
FIRES-RC2      WRITE (NOUT,370)
FIRES-RC2      WRITE (NOUT,390)
FIRES-RC2      WRITE (NOUT,400)
FIRES-RC2      WRITE (NOUT,410)
FIRES-RC2      WRITE (NOUT,420)
FIRES-RC2      WRITE (NOUT,430)
FIRES-RC2      WRITE (NOUT,440)
FIRES-RC2      WRITE (NOUT,450)
FIRES-RC2      WRITE (NOUT,460)
FIRES-RC2      WRITE (NOUT,370)
FIRES-RC2      WRITE (NOUT,470) HED
FIRES-RC2      WRITE (NOUT,370)
FIRES-RC2      WRITE (NOUT,480)
FIRES-RC2  C
FIRES-RC2  C   ANALYSIS CONTROL - DEFAULT CONDITIONS - NO CREEP OR SHRINKAGE
FIRES-RC2  C   TO MAKE USE OF NON-DEFAULT CONSIDERATIONS USE FOLLOWING CARDS
FIRES-RC2  C      SHRINK - FOR SHRINKAGE IN CONCRETE
FIRES-RC2  C      CONCRETE CREEP - FOR CREEP IN CONCRETE
FIRES-RC2  C      STEEL CREEP - FOR CREEP IN STEEL
FIRES-RC2  C
FIRES-RC2   20 READ (NIN,490) IREAD
FIRES-RC2      J=IREAD(1)
FIRES-RC2      K=IREAD(2)
FIRES-RC2  C
FIRES-RC2  C   CHECK FOR ANALYSIS CONTROL CARD OR, IF NONE, JOINT CONTROL CARD
FIRES-RC2  C
FIRES-RC2      IF (J.EQ.12B) GO TO 70
FIRES-RC2      IF (J.EQ.23B.AND.K.EQ.10B) GO TO 40
FIRES-RC2      IF (J.EQ.3B) GO TO 50
FIRES-RC2      IF (J.EQ.23B.AND.K.EQ.24B) GO TO 60
FIRES-RC2      IF (J.NE.55B) GO TO 30
FIRES-RC2      WRITE (NOUT,580)
FIRES-RC2      STOP
FIRES-RC2  C
FIRES-RC2  C   ERFOR IN INPUT OF CONTROL CARDS
FIRES-RC2  C
FIRES-RC2   30 WRITE (NOUT,500) IREAD
FIRES-RC2      STOP
FIRES-RC2  C
FIRES-RC2  C   SET SHRINKAGE FLAG
FIRES-RC2  C
FIRES-RC2   40 NSHRINK=1
FIRES-RC2      GO TO 20
FIRES-RC2  C
FIRES-RC2  C   SET CREEP IN CONCRETE FLAG
FIRES-RC2  C
FIRES-RC2   50 NCRPC=1
```

```
FIRES-RC2  125          GO TO 20
FIRES-RC2  126   C
FIRES-RC2  127   C      SET CREEP IN STEEL FLAG
FIRES-RC2  128   C
FIRES-RC2  129       60 NCRPS=1
FIRES-RC2  130          GO TO 20
FIRES-RC2  131   C
FIRES-RC2  132       70 CONTINUE
FIRES-RC2  133   C
FIRES-RC2  134   C      LABELING OF MATERIAL MODEL FUNCTIONS
FIRES-RC2  135   C
FIRES-RC2  136          WRITE (NOUT,510)
FIRES-RC2  137          A=STRL(0)
FIRES-RC2  138          WRITE (NOUT,520)
FIRES-RC2  139          A=SSL(0)
FIRES-RC2  140          WRITE (NOUT,530)
FIRES-RC2  141          IF (NCRPC.EQ.0) 80,90
FIRES-RC2  142       80 WRITE (NOUT,540)
FIRES-RC2  143          GO TO 100
FIRES-RC2  144       90 A=CRPCL(0)
FIRES-RC2  145      100 WRITE (NOUT,550)
FIRES-RC2  146          IF (NCRPS.EQ.0) 110,120
FIRES-RC2  147      110 WRITE (NOUT,540)
FIRES-RC2  148          GO TO 130
FIRES-RC2  149      120 A=CRPSL(0)
FIRES-RC2  150      130 WRITE (NOUT,560)
FIRES-RC2  151          IF (NSHRINK.EQ.0) 140,150
FIRES-RC2  152      140 WRITE (NOUT,540)
FIRES-RC2  153          GO TO 160
FIRES-RC2  154      150 A=SHRINKL(0)
FIRES-RC2  155      160 WRITE (NOUT,570)
FIRES-RC2  156   C
FIRES-RC2  157   C      DETERMINE THE NUMBER OF JOINTS
FIRES-RC2  158   C
FIRES-RC2  159          N=1
FIRES-RC2  160          NJ=NUMBER(N,IREAD,NOUT)
FIRES-RC2  161          IF (NJ.EQ.0) GO TO 30
FIRES-RC2  162          WRITE (NOUT,370)
FIRES-RC2  163   C
FIRES-RC2  164   C      DYNAMIC ALLOCATION OF SYSTEM STORAGE
FIRES-RC2  165   C
FIRES-RC2  166          NJ3=NJ*3
FIRES-RC2  167          N1=1
FIRES-RC2  168          N2=N1+NJ
FIRES-RC2  169          N3=N2+NJ
FIRES-RC2  170          N4=N3+NJ
FIRES-RC2  171          N5=N4+NJ
FIRES-RC2  172          N6=N5+NJ3
FIRES-RC2  173          N7=N6+NJ3
FIRES-RC2  174          N8=N7+NJ3
FIRES-RC2  175          N9=N8+NJ3
FIRES-RC2  176          N10=N9+2*NJ3
FIRES-RC2  177          N11=N10+NJ3
FIRES-RC2  178          N12=N11+NJ3
FIRES-RC2  179   C
FIRES-RC2  180   C      -INPUT- READS IN THE INPUT DATA THAT DEFINES THE PROBLEM
FIRES-RC2  181   C
FIRES-RC2  182          CALL INPT (N12,C(N1),C(N2),C(N3),C(N4))
FIRES-RC2  183   C
FIRES-RC2  184   C      INPUT CONVERGENCE CRITERIA
FIRES-RC2  185   C
FIRES-RC2  186   C        LOOMX - MAXIMUM NUMBER OF ITERATIONS
```

```
FIRES-RC2  187  C      ERP - CONVERGENCE LIMIT FOR OUT-OF-BALANCE FORCES
FIRES-RC2  188  C
FIRES-RC2  189        NCARD=0
FIRES-RC2  190        WRITE (NOUT,630)
FIRES-RC2  191        WRITE (NOUT,370)
FIRES-RC2  192        WRITE (NOUT,590)
FIRES-RC2  193        WRITE (NOUT,370)
FIRES-RC2  194        READ (NIN,600) LOOMX,ERP(1),ERP(2),ERP(3)
FIRES-RC2  195        IF (LOOMX.EQ.0) LOOMX=1
FIRES-RC2  196        IF (ERP(1).LT.0.0000001) ERP(1)=0.01
FIRES-RC2  197        IF (ERP(2).LT.0.0000001) ERP(2)=0.01
FIRES-RC2  198        IF (ERP(3).LT.0.0000001) ERP(3)=0.01
FIRES-RC2  199        ERRX=ERP(1)
FIRES-RC2  200        ERRY=ERP(2)
FIRES-RC2  201        ERRM=ERP(3)
FIRES-RC2  202        DO 170 I=1,3
FIRES-RC2  203    170 IF (ERP(I).LT.0.00000001) ERP(I)=0.01
FIRES-RC2  204        WRITE (NOUT,610) ERP(1),ERP(2),ERP(3)
FIRES-RC2  205        WRITE (NOUT,620) LOOMX
FIRES-RC2  206        MDT=-1
FIRES-RC2  207  C
FIRES-RC2  208  C     BEGINNING OF LOOP FOR EACH TIME STEP
FIRES-RC2  209  C
FIRES-RC2  210    180 CONTINUE
FIRES-RC2  211        MDT=MDT+1
FIRES-RC2  212  C
FIRES-RC2  213  C     LABEL PAGE FOR BEGINNING OF TIME STEP
FIRES-RC2  214  C
FIRES-RC2  215        WRITE (NOUT,630)
FIRES-RC2  216        WRITE (NOUT,370)
FIRES-RC2  217        WRITE (NOUT,640) HED
FIRES-RC2  218  C
FIRES-RC2  219  C     STEP CONTROL PARAMETERS
FIRES-RC2  220  C
FIRES-RC2  221  C     NDT - STEP SEQUENCE NUMBER MUST START WITH A ZERO
FIRES-RC2  222  C     DT - TIME STEP INTERVAL, FOR NDT=0 DT IS THE RELATIVE
FIRES-RC2  223  C     INITIALIZATION TIME
FIRES-RC2  224  C     I0 - INDICATES THE NUMBER OF JOINTS AT WHICH AN INCREMENTAL LOAD
FIRES-RC2  225  C          IS APPLIED DURING THIS TIME STEP
FIRES-RC2  226  C     I1 - INDICATES THE NUMBER OF JOINTS AT WHICH BOUNDARY CONDITIONS
FIRES-RC2  227  C          ARE RESET DURING THIS TIME STEP
FIRES-RC2  228  C     I2 - INDICATES OUTPUT OPTIONS FOR PRINTING
FIRES-RC2  229  C          0 - SYSTEM AND MEMBER DATA
FIRES-RC2  230  C          1 - SAME AS 0 WITH THE ADDITION OF SEGMENT STRESS
FIRES-RC2  231  C              DISTRIBUTIONS AND CRACKING AND CRUSHING PATTERNS
FIRES-RC2  232  C          2 - SUBSLICE TEMPERATURES ARE ALSO PRINTED
FIRES-RC2  233  C     I3 - INDICATES THE OUTPUT OPTIONS FOR PUNCHING
FIRES-RC2  234  C          0 - NO PUNCHED OUTPUT
FIRES-RC2  235  C          1 - SYSTEM AND MEMBER DATA TO BE PUNCHED
FIRES-RC2  236  C          2 - SAME AS 1 WITH THE ADDITION OF SPECIFIED STRESSES
FIRES-RC2  237  C     LABEL - 3 CHARACTER ALPHA-NUMERIC LABEL FOR PUNCHED DATA
FIRES-RC2  238  C             READ ONLY AT INITIAL STEP AND THEN SET TO LCARD
FIRES-RC2  239  C     I4 - INDICATES THE DESIRE FOR INTERMEDIATE OUTPUT
FIRES-RC2  240  C          0 - NO INTERIMEDIATE OUTPUT
FIRES-RC2  241  C          1 - SYSTEM DATA
FIRES-RC2  242  C          2 - SYSTEM DATA AND MEMBER DATA
FIRES-RC2  243  C          3 - SYSTEM DATA, MEMBER DATA, AND SEGMENT DATA
FIRES-RC2  244  C     I5 - INDICATES THE DESIRE FOR SPECIAL PUBLISHABLE FORMAT
FIRES-RC2  245  C          0 - NORMAL OUTPUT
FIRES-RC2  246  C          1 - SPECIAL FORMAT OUTPUT
FIRES-RC2  247  C     ERP(I) - INDICATES A CHANGE IN CONVERGENCE LIMITS FOR
FIRES-RC2  248  C              THIS TIME STEP
```

```
FIRES-RC2  249  C                 0.0 - NO CHANGE FROM LIMITS SPECIFIED IN INPUT DATA
FIRES-RC2  250  C
FIRES-RC2  251        READ (NIN,650) ISTEP,NDT,DT,I0,I1,I2,I3,LABEL,I4,I5,ERP(1),ERP(2),
FIRES-RC2  252       1ERP(3)
FIRES-RC2  253        IF (ISTEP.NE.4HSTEP) GO TO 220
FIRES-RC2  254  C
FIRES-RC2  255        LCOP=0
FIRES-RC2  256        IF (ERP(1).LT.0.0000001.AND.ERP(2).LT.0.0000001.AND.ERP(3).LT.0.00
FIRES-RC2  257       100001) GO TO 190
FIRES-RC2  258        WRITE (NOUT,660) ERP(1),ERP(2),ERP(3)
FIRES-RC2  259        GO TO 200
FIRES-RC2  260    190 ERP(1)=ERRX
FIRES-RC2  261        ERP(2)=ERRY
FIRES-RC2  262        ERP(3)=ERRM
FIRES-RC2  263    200 IF (MDT.NE.0) GO TO 230
FIRES-RC2  264        IF (NDT.NE.0) GO TO 220
FIRES-RC2  265        LCARD=LABEL
FIRES-RC2  266        IF (LCARD.EQ.3H    ) LCARD=3HFRC
FIRES-RC2  267  C
FIRES-RC2  268        TIME=DT+1.0E-10
FIRES-RC2  269        WRITE (NOUT,670) TIME
FIRES-RC2  270        WRITE (NOUT,370)
FIRES-RC2  271  C
FIRES-RC2  272  C     -INITIAL- INTIALIZES THE SYSTEM FOR TIME=DT AT NDT=0
FIRES-RC2  273  C
FIRES-RC2  274        ISTART=ISYSTM
FIRES-RC2  275        DO 210 M=1,NM
FIRES-RC2  276        CALL DYNDIM (INT,M)
FIRES-RC2  277    210 CONTINUE
FIRES-RC2  278        GO TO 270
FIRES-RC2  279  C
FIRES-RC2  280  C     ERFOR FOUND IN INPUT - PROGRAM RUN TERMINATED
FIRES-RC2  281  C
FIRES-RC2  282    220 WRITE (NOUT,680)
FIRES-RC2  283        WRITE (NOUT,690) MDT,ISTEP,NDT,DT,I0,I1,I2,I3,LABEL,I4,I5
FIRES-RC2  284        STOP
FIRES-RC2  285  C
FIRES-RC2  286  C     DETERMINE TIME STEP AND CALCULATE CURRENT TIME
FIRES-RC2  287  C
FIRES-RC2  288  C     IF TIME STEP LENGTH IS NEGATIVE END STEP-BY-STEP SOLUTION
FIRES-RC2  289  C     AND GO TO THE NEXT DATA CASE
FIRES-RC2  290  C
FIRES-RC2  291    230 IF (MDT.NE.NDT) GO TO 220
FIRES-RC2  292        IF (NDT.NE.1) GO TO 240
FIRES-RC2  293        IF (DT.LE.0.0) GO TO 10
FIRES-RC2  294        SDT=DT
FIRES-RC2  295        GO TO 250
FIRES-RC2  296    240 IF (DT.LT.0.0) GO TO 10
FIRES-RC2  297        IF (DT.EQ.0.0) DT=SDT
FIRES-RC2  298        SDT=DT
FIRES-RC2  299    250 TIME=TIME+DT
FIRES-RC2  300  C
FIRES-RC2  301        WRITE (NOUT,700) NDT,TIME
FIRES-RC2  302        WRITE (NOUT,370)
FIRES-RC2  303  C
FIRES-RC2  304  C     -INSTEP- INITIALIZES TIME STEP AND PROCESSES NECESSARY INPUT
FIRES-RC2  305  C
FIRES-RC2  306        ISTART=ISYSTM
FIRES-RC2  307        DO 260 M=1,NM
FIRES-RC2  308        CALL DYNDIM (INS,M)
FIRES-RC2  309    260 CONTINUE
FIRES-RC2  310  C
```

```
FIRES-RC2  311  C     REVERSE FILE ASSIGNMENTS FOR FILES ISEG AND ITEMP
FIRES-RC2  312  C
FIRES-RC2  313    270 M=ITEMP1
FIRES-RC2  314        ITEMP1=ITEMP2
FIRES-RC2  315        ITEMP2=M
FIRES-RC2  316        M=ISEG1
FIRES-RC2  317        ISEG1=ISEG2
FIRES-RC2  318        ISEG2=M
FIRES-RC2  319  C
FIRES-RC2  320  C     -JOUT AND IOUT- PRINT INTERMEDIATE JOINT, MEMBER, AND SEGMENT DATA
FIRES-RC2  321  C
FIRES-RC2  322        IF (I4.GE.1) CALL JOUT (C(N5),C(N6),C(N7),C(N8),C(N9),C(N10),C(N11
FIRES-RC2  323       1),C(N12),NJ3,LOOP,TIME,NDT,1)
FIRES-RC2  324        IF (I4.LT.2) GO TO 290
FIRES-RC2  325        ISTART=ISYSTM
FIRES-RC2  326        DO 280 M=1,NM
FIRES-RC2  327        CALL DYNDIM (IOT,M)
FIRES-RC2  328    280 CONTINUE
FIRES-RC2  329  C
FIRES-RC2  330  C     BEGINNING OF LOOP FOR EACH ITERATION
FIRES-RC2  331  C
FIRES-RC2  332    290 CONTINUE
FIRES-RC2  333        LOOP=LOOP+1
FIRES-RC2  334  C
FIRES-RC2  335        NCONV=0
FIRES-RC2  336  C
FIRES-RC2  337        REWIND ISEG1
FIRES-RC2  338        REWIND ISEG2
FIRES-RC2  339  C
FIRES-RC2  340  C     -MEMBERS- CALCULATES TANGENT STIFFNESS AND INTERNAL FORCES FOR THE
FIRES-RC2  341  C               PRESENT CONFIGURATION AND TEMPERATURE DISTRIBUTION
FIRES-RC2  342  C
FIRES-RC2  343        ISTART=ISYSTM
FIRES-RC2  344        DO 300 M=1,NM
FIRES-RC2  345        CALL DYNDIM (MBS,M)
FIRES-RC2  346    300 CONTINUE
FIRES-RC2  347  C
FIRES-RC2  348  C     REVERSE FILE ASSIGNMENTS FOR ISEG
FIRES-RC2  349  C
FIRES-RC2  350        M=ISEG1
FIRES-RC2  351        ISEG1=ISEG2
FIRES-RC2  352        ISEG2=M
FIRES-RC2  353  C
FIRES-RC2  354  C     -JOUT AND IOUT- PRINT INTERMEDIATE JOINT, MEMBER, AND SEGMENT DATA
FIRES-RC2  355  C
FIRES-RC2  356        IF (I4.GE.1) CALL JOUT (C(N5),C(N6),C(N7),C(N8),C(N9),C(N10),C(N11
FIRES-RC2  357       1),C(N12),NJ3,LOOP,TIME,NDT,2)
FIRES-RC2  358        IF (I4.LT.2) GO TO 320
FIRES-RC2  359        ISTART=ISYSTM
FIRES-RC2  360        DO 310 M=1,NM
FIRES-RC2  361        CALL DYNDIM (IOT,M)
FIRES-RC2  362    310 CONTINUE
FIRES-RC2  363  C
FIRES-RC2  364  C     CHECK FOR CONVERGENCE
FIRES-RC2  365  C
FIRES-RC2  366    320 IF (NCONV.EQ.0.AND.LOOP.NE.1) GO TO 340
FIRES-RC2  367        IF (LOOP.LE.LOOMX) GO TO 330
FIRES-RC2  368  C
FIRES-RC2  369        WRITE (NOUT,710) NCONV
FIRES-RC2  370        GO TO 340
FIRES-RC2  371    330 CONTINUE
FIRES-RC2  372  C
```

```
FIRES-RC2  373  C      SOLVE FOR STRUCTURAL JOINT DISPLACEMENTS AND GO TO NEXT LOOP
FIRES-RC2  374  C
FIRES-RC2  375         CALL BANDEC (C(N12),C(N11),NJ3,MAXBAN,1,NJ3,MAXBAN,1)
FIRES-RC2  376  C
FIRES-RC2  377  C      -JOUT- PRINTS INTERMEDIATE JOINT DATA
FIRES-RC2  378  C
FIRES-RC2  379         IF (I4.GE.1) CALL JOUT (C(N5),C(N6),C(N7),C(N8),C(N9),C(N10),C(N11
FIRES-RC2  380        1),C(N12),NJ3,LOOP,TIME,NOT,3)
FIRES-RC2  381  C
FIRES-RC2  382  C      RETURN FOR NEXT EQUILIBRIUM ITERATION
FIRES-RC2  383  C
FIRES-RC2  384         GO TO 290
FIRES-RC2  385  C
FIRES-RC2  386    340 REWIND ITEMP1
FIRES-RC2  387        REWIND ITEMP2
FIRES-RC2  388        REWIND ISEG1
FIRES-RC2  389        REWIND ISEG2
FIRES-RC2  390  C
FIRES-RC2  391  C      -OUTPUT- PRINTS THE SOLUTION FOR THIS TIME STEP
FIRES-RC2  392  C
FIRES-RC2  393        ISTART=ISYSTM
FIRES-RC2  394        DO 350 M=1,NM
FIRES-RC2  395        CALL DYNDIM (OPT,M)
FIRES-RC2  396    350 CONTINUE
FIRES-RC2  397  C
FIRES-RC2  398  C      PRINT NUMBER OF ITERATIONS NEEDED FOR CONVERGENCE
FIRES-RC2  399  C
FIRES-RC2  400        LOOP=LOOP-1
FIRES-RC2  401        WRITE (NOUT,720) LOOP
FIRES-RC2  402  C
FIRES-RC2  403  C      RETURN FOR NEXT TIME STEP
FIRES-RC2  404  C
FIRES-RC2  405        GO TO 180
FIRES-RC2  406  C
FIRES-RC2  407  C
FIRES-RC2  408  C
FIRES-RC2  409  C
FIRES-RC2  410    360 FORMAT (1H6,3(/))
FIRES-RC2  411    370 FORMAT (1X,61(1H*))
FIRES-RC2  412    380 FORMAT (10A6)
FIRES-RC2  413    390 FORMAT (///7X,48HFFFFF I RRRRR EEEEE SSSSS    RRRRR CCCCC    IIIII)
FIRES-RC2  414    400 FORMAT (7X,48HF      I R   R E     S        R   R C   C     I I )
FIRES-RC2  415    410 FORMAT (7X,48HF      I R   R E     S        R   R C         I I )
FIRES-RC2  416    420 FORMAT (7X,48HFFFF   I RRRRR EEE   SSSSS == RRRRR C         I I )
FIRES-RC2  417    430 FORMAT (7X,48HF      I R R   E         S    R R   C         I I )
FIRES-RC2  418    440 FORMAT (7X,48HF      I R  R  E         S    R  R  C   C     I I )
FIRES-RC2  419    450 FORMAT (7X,48HF      I R   R EEEEE SSSSS    R   R CCCCC    IIIII///)
FIRES-RC2  420    460 FORMAT (4X,53HA STRUCTURAL ANALYSIS PROGRAM FOR REINFORCED CONCRET
FIRES-RC2  421       1E/4X,50HMEMBERS AND FRAMES SUBJECTED TO A FIRE ENVIRONMENT///18X,2
FIRES-RC2  422       25HF E B R U A R Y   1 9 7 6///)
FIRES-RC2  423    470 FORMAT (//9X,44H  .  .  .  .  .  TITLE OF RUN  .  .  .  .  .//1X,1
FIRES-RC2  424       10A6//)
FIRES-RC2  425    480 FORMAT (//9X,44H  .  .  .  ANALYSIS CONSIDERATIONS  .  .  .)
FIRES-RC2  426    490 FORMAT (80R1)
FIRES-RC2  427    500 FORMAT (///34H  INPUT ERROR - PROGRAM TERMINATED//1X,80R1)
FIRES-RC2  428    510 FORMAT (/33H  CONCRETE STRESS-STRAIN LAW  -  )
FIRES-RC2  429    520 FORMAT (/33H  STEEL STRESS-STRAIN LAW     -  )
FIRES-RC2  430    530 FORMAT (/33H  CONCRETE CREEP MODEL        -  )
FIRES-RC2  431    540 FORMAT (1H+,32X,14HNOT CONSIDERED)
FIRES-RC2  432    550 FORMAT (/33H  STEEL CREEP MODEL           -  )
FIRES-RC2  433    560 FORMAT (/33H  CONCRETE SHRINKAGE MODEL    -  )
FIRES-RC2  434    570 FORMAT (//)
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FIRES-RC2   580 FORMAT (//6X,10HEND OF RUN)
FIRES-RC2   590 FORMAT (///23X,16HCONVERGENCE DATA///)
FIRES-RC2   600 FORMAT (I5,3E10.0)
FIRES-RC2   610 FORMAT (//8X,46H   PERMISSIBLE ERROR FOR OUT-OF-BALANCE FORCES/8X,
FIRES-RC2      119H     AXIAL FORCE = F13.5/8X,19H     SHEAR FORCE = ,F13.5/8X,19H
FIRES-RC2      2     MOMENT       = ,F13.5)
FIRES-RC2   620 FORMAT (//2X,51H   MAXIMUM NUMBER OF ITERATIONS FOR A TIME STEP =
FIRES-RC2      1 ,I6)
FIRES-RC2   630 FORMAT (1H6,6(/))
FIRES-RC2   640 FORMAT (/1X,10A6)
FIRES-RC2   650 FORMAT (A4,I6,F10.0,4I5,2X,A3,2I5,3F5.3)
FIRES-RC2   660 FORMAT (/56H  FOR THIS TIME STEP ONLY, CONVERGENCE LIMITS CHANGED
FIRES-RC2      1TO/2X,7HERP(1)=,F10.5,10H,  ERP(2)=,F10.5,10H,  ERP(3)=,F10.5/)
FIRES-RC2   670 FORMAT (/10X,31H  PROBLEM INITIALIZED AT TIME  F10.4/)
FIRES-RC2   680 FORMAT (6(/)48H  -------INPUT ERROR - PROGRAM TERMINATED-------)
FIRES-RC2   690 FORMAT (//32H  ERROR IN TIME STEP CARD NUMBER,I6//1X,A4,I6,F10.5,4
FIRES-RC2      1I5,2X,A3,2I5)
FIRES-RC2   700 FORMAT (/3X,19H  TIME STEP NUMBER ,I6,3X,13H AT A TIME OF,F10.4,6H
FIRES-RC2      1 HOURS/)
FIRES-RC2   710 FORMAT (//1X,10(1H*),36H ANALYSIS HAS NOT CONVERGED, NCONV =,I4,1X
FIRES-RC2      1,9(1H*)//)
FIRES-RC2   720 FORMAT (//I10,50H ITERATIONS PERFORMED IN ORDER TO FIND EQUILIBRIU
FIRES-RC2      1M/20X,21HWITHIN THIS TIME STEP)
FIRES-RC2       END


FIRES-RC2       SUBROUTINE INPT (NTOTAL,X,Y,IBC,JS)
FIRES-RC2   C
FIRES-RC2   C
FIRES-RC2   C   SUBROUTINE  *INPT*  ORGANIZES INPUT DATA - ESPECIALLY THE
FIRES-RC2   C   GEOMETRIC DESCRIPTION OF THE REINFORCED CONCRETE FRAME AND THE
FIRES-RC2   C   SUBSTRUCTURING OF THE MEMBERS
FIRES-RC2   C
FIRES-RC2   C
FIRES-RC2       DIMENSION PLM(4,4), SN(4)
FIRES-RC2       COMMON /KRAKP/ AP(4)
FIRES-RC2       COMMON /TAP/ HED(10),ITEMP1,ITEMP2,ISEG1,ISEG2,NIN,NOUT,NPUNCH
FIRES-RC2       COMMON /DYN/ NDT,NSTORE,NCMAX,NSMAX,NCONTL,NSTLTL,ISYSTM,IMEMB,ITO
FIRES-RC2      1TAL,ITAPE
FIRES-RC2       COMMON /BLK1/ NJ,NM,NBC,NJ3,MAXBAN,NCRPS,NCRPC,NSHRINK,NCONV
FIRES-RC2       COMMON /CARD/ IREAD(80)
FIRES-RC2       COMMON /MEMB/ NNSEG(75)
FIRES-RC2       COMMON C(1)
FIRES-RC2       DIMENSION X(1), Y(1), IBC(1), JS(1), MSEG(6), SEGL(6)
FIRES-RC2   C
FIRES-RC2   C
FIRES-RC2   C   WRITE TITLE TO PAGE
FIRES-RC2   C
FIRES-RC2       WRITE (NOUT,220)
FIRES-RC2       WRITE (NOUT,230)
FIRES-RC2       WRITE (NOUT,240)
FIRES-RC2       WRITE (NOUT,230)
FIRES-RC2       WRITE (NOUT,250) NJ
FIRES-RC2       WRITE (NOUT,260)
FIRES-RC2   C
FIRES-RC2   C   READ IN JOINT DATA  - X AND Y COORDINATES  -  IBC BOUNDARY DATA
FIRES-RC2   C
FIRES-RC2       NBC=0
FIRES-RC2       DO 50 I=1,NJ
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FIRES-RC2  492          READ (NIN,270) J,X(I),Y(I),IBC(I)
FIRES-RC2  493   C
FIRES-RC2  494   C      CHECK FOR PROPER SEQUENCING OF THE JOINT DATA
FIRES-RC2  495   C
FIRES-RC2  496          IF (I.EQ.J) 20,10
FIRES-RC2  497       10 WRITE (NOUT,280)
FIRES-RC2  498          WRITE (NOUT,290) I,J,X(I),Y(J),IBC(I)
FIRES-RC2  499          STOP
FIRES-RC2  500   C
FIRES-RC2  501       20 CONTINUE
FIRES-RC2  502          NX=10H
FIRES-RC2  503          NY=10H
FIRES-RC2  504          NR=10H
FIRES-RC2  505   C
FIRES-RC2  506   C      DETERMINE SUPPORT CONDITIONS AND SET INDICATORS
FIRES-RC2  507   C
FIRES-RC2  508          DECODE (10,300,IBC(I) )IX,IY,IR
FIRES-RC2  509          IF (IX.EQ.1) NX=10HRESTRAINED
FIRES-RC2  510          IF (IY.EQ.1) NY=10HRESTRAINED
FIRES-RC2  511          IF (IR.EQ.1) NR=10HRESTRAINED
FIRES-RC2  512          IF (IX+IY+IR) 40,40,30
FIRES-RC2  513       30 NBC=NBC+1
FIRES-RC2  514          JS(NBC)=I
FIRES-RC2  515   C
FIRES-RC2  516       40 CONTINUE
FIRES-RC2  517          WRITE (NOUT,310) I,X(I),Y(I),NX,NY,NR
FIRES-RC2  518       50 CONTINUE
FIRES-RC2  519   C
FIRES-RC2  520   C      READ MEMBER CONTROL CARD AND DETERMINE NUMBER OF MEMBERS
FIRES-RC2  521   C
FIRES-RC2  522          READ (NIN,410) IREAD
FIRES-RC2  523          IF (IREAD(1).NE.15B) GO TO 60
FIRES-RC2  524          N=1
FIRES-RC2  525          NM=NUMBER(N,IREAD,NOUT)
FIRES-RC2  526   C
FIRES-RC2  527          IF (NM.EQ.0) GO TO 60
FIRES-RC2  528          GO TO 70
FIRES-RC2  529       60 WRITE (NOUT,320) IREAD
FIRES-RC2  530          STOP
FIRES-RC2  531   C
FIRES-RC2  532       70 CONTINUE
FIRES-RC2  533          LSEG=0
FIRES-RC2  534          WRITE (NOUT,330) NM
FIRES-RC2  535          WRITE (NOUT,340)
FIRES-RC2  536   C
FIRES-RC2  537   C      INPUT DATA FOR EACH MEMBER  -  JOINTS MI AND MJ
FIRES-RC2  538   C      AND MEMBER SEGMENTATION TYPE AND LENGTH  MSEG AND SEGL
FIRES-RC2  539   C
FIRES-RC2  540          NSEGTL=0
FIRES-RC2  541          MAXBAN=0
FIRES-RC2  542          ISTORE=ITEMP1
FIRES-RC2  543          REWIND ISTORE
FIRES-RC2  544          DO 160 M=1,NM
FIRES-RC2  545          READ (NIN,350) N,I,J,(MSEG(K),SEGL(K),K=1,6)
FIRES-RC2  546          IF (N.EQ.M) GO TO 90
FIRES-RC2  547       80 WRITE (NOUT,280)
FIRES-RC2  548          WRITE (NOUT,360) M,N,I,J,(MSEG(K),SEGL(K),K=1,6)
FIRES-RC2  549          STOP
FIRES-RC2  550       90 CONTINUE
FIRES-RC2  551          IF (I.GT.NJ.OR. J.GT.NJ.OR.I.EQ.J) GO TO 80
FIRES-RC2  552          MI=I
FIRES-RC2  553          MJ=J
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FIRES-RC2  554          MB=IABS(I-J)
FIRES-RC2  555          MB=3*(MB+1)
FIRES-RC2  556          IF (MB.GT.MAXBAN) MAXBAN=MB
FIRES-RC2  557          SUM=0.0
FIRES-RC2  558          XY=SQRT((X(I)-X(J))**2+(Y(I)-Y(J))**2)
FIRES-RC2  559   C
FIRES-RC2  560   C      DETERMINE LENGTH OF SEGMENTS IN SUBSTRUCTURED MEMBER
FIRES-RC2  561   C
FIRES-RC2  562          L=0
FIRES-RC2  563      100 L=L+1
FIRES-RC2  564          IF (L.GT.6) GO TO 110
FIRES-RC2  565          IF (SEGL(L).LE.0.0) GO TO 110
FIRES-RC2  566          SUM=SUM+SEGL(L)
FIRES-RC2  567          GO TO 100
FIRES-RC2  568      110 IF (SUM.LE.0) GO TO 130
FIRES-RC2  569          L=L-1
FIRES-RC2  570          NSEG=L
FIRES-RC2  571          DO 120 K=1,L
FIRES-RC2  572      120 SEGL(K)=SEGL(K)*(XY/SUM)
FIRES-RC2  573          GO TO 140
FIRES-RC2  574      130 NSEG=1
FIRES-RC2  575          SEGL(1)=XY
FIRES-RC2  576      140 L=NSEG
FIRES-RC2  577          DO 150 K=1,L
FIRES-RC2  578          IF (MSEG(K).GT.LSEG) LSEG=MSEG(K)
FIRES-RC2  579      150 CONTINUE
FIRES-RC2  580   C
FIRES-RC2  581   C      WRITE AND STORE MEMBER DATA
FIRES-RC2  582   C
FIRES-RC2  583          WRITE (NOUT,370) M,I,J,(MSEG(K),SEGL(K),K=1,L)
FIRES-RC2  584          WRITE (ISTORE) MI,MJ,(MSEG(K),SEGL(K),K=1,L)
FIRES-RC2  585          NNSEG(M)=NSEG
FIRES-RC2  586          NSEGTL=NSEGTL+NSEG
FIRES-RC2  587      160 CONTINUE
FIRES-RC2  588          WRITE (NOUT,380) MAXBAN
FIRES-RC2  589   C
FIRES-RC2  590   C      NOTE STORAGE REQUIREMENTS FOR SYSTEM AND MEMBER VARIABLES
FIRES-RC2  591   C
FIRES-RC2  592          ISYSTM=NTOTAL+MAXBAN*NJ3
FIRES-RC2  593          IMEMB=ISYSTM+33*NSEGTL-4*NM
FIRES-RC2  594          WRITE (NOUT,390) ISYSTM,ISYSTM
FIRES-RC2  595          WRITE (NOUT,400) IMEMB,IMEMB
FIRES-RC2  596          WRITE (NOUT,220)
FIRES-RC2  597          WRITE (NOUT,230)
FIRES-RC2  598   C
FIRES-RC2  599   C      READ SEGMENT CONTROL CARD AND DETERMINE THE NUMBER OF SEGMENTS
FIRES-RC2  600   C
FIRES-RC2  601          READ (NIN,410) IREAD
FIRES-RC2  602          IF (IREAD(1).NE.23B) GO TO 60
FIRES-RC2  603          N=1
FIRES-RC2  604          METY=NUMBER(N,IREAD,NOUT)
FIRES-RC2  605          IF (METY.LT.LSEG) 170,180
FIRES-RC2  606   C
FIRES-RC2  607      170 WRITE (NOUT,420) METY,LSEG
FIRES-RC2  608          STOP
FIRES-RC2  609   C
FIRES-RC2  610      180 WRITE (NOUT,430) METY
FIRES-RC2  611          WRITE (NOUT,230)
FIRES-RC2  612   C
FIRES-RC2  613   C      SET UP TEMPORARY STORAGE IN BLANK COMMON FOR THE INPUT OF
FIRES-RC2  614   C      SEGMENT TYPE DATA
FIRES-RC2  615   C       ( THE MAXIMUM MESH THAT MAY BE INPUT IS AS FOLLOWS )
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FIRES-RC2  616  C                CONCRETE SUBSLICES                400
FIRES-RC2  617  C                STEEL SUBSLICES                   100
FIRES-RC2  618  C                NODES IN FEM MESH                 300
FIRES-RC2  619  C                ELEMENTS IN FEM MESH              300
FIRES-RC2  620  C                 (TOTAL,STEEL+CONCRETE)
FIRES-RC2  621  C
FIRES-RC2  622          M20=ISYSTM
FIRES-RC2  623          M21=M20+300
FIRES-RC2  624          M22=M21+300
FIRES-RC2  625          M23=M22+400
FIRES-RC2  626          M24=M23+400
FIRES-RC2  627          M25=M24+100
FIRES-RC2  628          M26=M25+100
FIRES-RC2  629          M27=M26+4*300
FIRES-RC2  630          IF (M27.LE.NSTORE) GO TO 190
FIRES-RC2  631          WRITE (NOUT,450) M27
FIRES-RC2  632          STOP
FIRES-RC2  633  C
FIRES-RC2  634  C       CALL SUBROUTINE SEGIN FOR INPUT OF SEGMENT DATA
FIRES-RC2  635  C
FIRES-RC2  636    190 CALL SEGIN (METY,C(M20),C(M21),C(M22),C(M23),C(M24),C(M25),C(M26))
FIRES-RC2  637  C
FIRES-RC2  638  C       READ MATERIAL CONTROL CARD
FIRES-RC2  639  C
FIRES-RC2  640          READ (NIN,410) IREAD
FIRES-RC2  641          IF (IREAD(1).NE.15B) GO TO 60
FIRES-RC2  642          WRITE (NOUT,220)
FIRES-RC2  643          WRITE (NOUT,230)
FIRES-RC2  644          WRITE (NOUT,440)
FIRES-RC2  645          WRITE (NOUT,230)
FIRES-RC2  646  C
FIRES-RC2  647  C       READ PARAMETERS DEFINING MATERIAL PROPERTIES
FIRES-RC2  648  C
FIRES-RC2  649          CALL MATLIN
FIRES-RC2  650          READ 460, NSP
FIRES-RC2  651          READ 470, (SN(I),AP(I),I=1,4)
FIRES-RC2  652          IF (NSP.LE.1) GO TO 210
FIRES-RC2  653          PRINT 480, (SN(I),AP(I),I=1,NSP)
FIRES-RC2  654  C       -----INTERPOLATE TENSILE STRAIN SOFTENING CURVE
FIRES-RC2  655          DO 200 I=1,NSP
FIRES-RC2  656          PLM(I,1)=1.
FIRES-RC2  657          DO 200 J=2,NSP
FIRES-RC2  658    200 PLM(I,J)=PLM(I,J-1)*SN(I)
FIRES-RC2  659          CALL SOLEQ (PLM,AP,NSP,4)
FIRES-RC2  660    210 CONTINUE
FIRES-RC2  661  C
FIRES-RC2  662  C       READ CONVERGENCE DATA CONTROL CARD (DATA ACTUALLY READ IN SOLV)
FIRES-RC2  663  C
FIRES-RC2  664          READ (NIN,410) IREAD
FIRES-RC2  665          IF (IREAD(1).NE.3B) GO TO 60
FIRES-RC2  666  C
FIRES-RC2  667          RETURN
FIRES-RC2  668  C
FIRES-RC2  669  C
FIRES-RC2  670  C
FIRES-RC2  671    220 FORMAT (1H6,6(/))
FIRES-RC2  672    230 FORMAT (1X,61(1H*))
FIRES-RC2  673    240 FORMAT (//14X,32HGEOMETRIC DESCRIPTION OF PROBLEM//)
FIRES-RC2  674    250 FORMAT (////30H  .  .  .  .  .  JOINT DATA  -,I4,22H JOINTS  .  .
FIRES-RC2  675       1 .  .  .//)
FIRES-RC2  676    260 FORMAT (52H  JOINT      COORDINATES            BOUNDARY CONDITIONS/(1
FIRES-RC2  677       1H NUMBER      X          Y    X-DIRECTION Y-DIRECTION    ROTATION)
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FIRES-RC2   678     270 FORMAT (I5,2F10.0,A5)
FIRES-RC2   679     280 FORMAT (6(/)52H  -------INPUT ERROR - PROGRAM TERMINATED----------
FIRES-RC2   680        1-)
FIRES-RC2   681     290 FORMAT (//48H  ERROR IN JOINT INPUT - READING DATA FOR JOINT,I5/19
FIRES-RC2   682        1H  DATA ON CARD WAS ,I5,2G10.0,A5)
FIRES-RC2   683     300 FORMAT (2X,3I1)
FIRES-RC2   684     310 FORMAT (/I4,2X,F8.1,2X,F8.1,1X,3A12)
FIRES-RC2   685     320 FORMAT (///34H  INPUT ERROR - PROGRAM TERMINATED//1X,80R1)
FIRES-RC2   686     330 FORMAT (6(/),31H  .  .  .  .  .  MEMBER DATA  -,I4,23H MEMBERS  .
FIRES-RC2   687        1 .  .  .  .)
FIRES-RC2   688     340 FORMAT (//13H MEMB   JOINT,12X,23HSEGMENT TYPE AND LENGTH/62H  NO.
FIRES-RC2   689        1  I TO J  TP LGTH TP LGTH TP LGTH TP LGTH TP LGTH TP LGTH)
FIRES-RC2   690     350 FORMAT (3I5,6(I3,F7.0))
FIRES-RC2   691     360 FORMAT (//16H  MEMBER NUMBER ,I5,14H    INPUT WAS ,3I5,6(I3,F7.2))
FIRES-RC2   692     370 FORMAT (/I4,2X,2I3,2X,6(I2,F6.1)).
FIRES-RC2   693     380 FORMAT (//43H  THE BANDWIDTH OF THE STIFFNESS MATRIX IS I5)
FIRES-RC2   694     390 FORMAT (//60H  .  .  .  .  .  .  SYSTEM REQUIREMENT FOR BLANK COMMON .
FIRES-RC2   695        1.  .  .  .//12X,20HSIZE BLANK COMMON = ,I10,10H (DECIMAL)/30X,5H=
FIRES-RC2   696        2,O7,8H (OCTAL))
FIRES-RC2   697     400 FORMAT (//2X,6(2H. ),46H SYSTEM AND MEMBER TOTAL REQUIREMENT . . .
FIRES-RC2   698        1 . .//12X,20HSIZE BLANK COMMON = ,I10,10H (DECIMAL)/30X,5H=     ,O7
FIRES-RC2   699        2,8H (OCTAL))
FIRES-RC2   700     410 FORMAT (80R1)
FIRES-RC2   701     420 FORMAT (//20H  PROGRAM TERMINATED/1X,I5,34H SEGMENTS SPECIFIED FOR
FIRES-RC2   702        1 INPUT AND,I4,18H SEGMENTS REQUIRED)
FIRES-RC2   703     430 FORMAT (//8X,29H        CROSS-SECTIONAL DATA -,I4,14H SEGMENT TYPES
FIRES-RC2   704        1//)
FIRES-RC2   705     440 FORMAT (//24X,13HMATERIAL DATA//)
FIRES-RC2   706     450 FORMAT (//31H INCREASE BLANK COMMON SIZE TO ,I5)
FIRES-RC2   707     460 FORMAT (I5)
FIRES-RC2   708     470 FORMAT (8F10.0)
FIRES-RC2   709     480 FORMAT (*TENSILESTRAINSOFTENINGCURVE*/8X6HSTRAIN,8X6HSTRESS//(2E14
FIRES-RC2   710        1.5))
FIRES-RC2   711         END
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FIRES-RC2   712         SUBROUTINE SEGIN (NSEGTY,X,Y,AC,YC,AS,YS,LM)
FIRES-RC2   713   C
FIRES-RC2   714   C
FIRES-RC2   715   C     SUBROUTINE  *SEGIN*  INPUTS DATA FOR EACH SEGMENT TYPE
FIRES-RC2   716   C
FIRES-RC2   717   C
FIRES-RC2   718   C     -X,Y- NODAL COORDINATES
FIRES-RC2   719   C     -AC,YC- CONCRETE SUBSLICE AREA AND DISTANCE FROM REFERENCE PLANE
FIRES-RC2   720   C     -AS,YS- STEEL SUBSLICES AREA AND DISTANCE FROM REFERENCE PLANE
FIRES-RC2   721   C     -NSEGTY- NO. OF SEGMENT TYPES
FIRES-RC2   722   C     -ISYM- INDICATES SYMMETRY OF INPUT MESH ABOUT X-AXIS
FIRES-RC2   723   C     -ISEGTY- SEGMENT TYPE NUMBER
FIRES-RC2   724   C
FIRES-RC2   725   C
FIRES-RC2   726         COMMON /TAP/ HED(10),ITEMP1,ITEMP2,ISEG1,ISEG2,NIN,NOUT,NPUNCH
FIRES-RC2   727         COMMON /DYN/ NDT,NSTORE,NCMAX,NSMAX,NCONTL,NSTLTL,ISYSTM,IMEMB,ITO
FIRES-RC2   728        1TAL,ITAPE
FIRES-RC2   729         DIMENSION X(1), Y(1), AC(1), YC(1), AS(1), YS(1), LM(4,1)
FIRES-RC2   730   C
FIRES-RC2   731   C
FIRES-RC2   732         ISTORE=ISEG1
FIRES-RC2   733         REWIND ISTORE
FIRES-RC2   734   C
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FIRES-RC2  735  C      LOOP OVER ALL SEGMENT TYPES
FIRES-RC2  736  C
FIRES-RC2  737         DO 360 NSG=1,NSEGTY
FIRES-RC2  738         READ (NIN,370) IS,ISEGTY,ISYM,NUMNP,NELCON,NELSTL,ICG,YREF
FIRES-RC2  739         IF (IS.EQ.1HS.AND.ISEGTY.EQ.NSG) GO TO 20
FIRES-RC2  740      10 WRITE (NOUT,380) NSG
FIRES-RC2  741         STOP
FIRES-RC2  742  C
FIRES-RC2  743      20 CONTINUE
FIRES-RC2  744         ARCONC=0.
FIRES-RC2  745         ARSTL=0.
FIRES-RC2  746         AIYC=0.
FIRES-RC2  747         AIYS=0.
FIRES-RC2  748         L=1
FIRES-RC2  749         IF (NUMNP.LE.0) GO TO 10
FIRES-RC2  750  C
FIRES-RC2  751  C      INPUT NODAL COORDINATES
FIRES-RC2  752  C
FIRES-RC2  753      30 READ (NIN,390) N,X(N),Y(N)
FIRES-RC2  754         IF (N.GE.L) GO TO 50
FIRES-RC2  755      40 WRITE (NOUT,400) N,X(N),Y(N)
FIRES-RC2  756         STOP
FIRES-RC2  757      50 IF (N.EQ.L) GO TO 70
FIRES-RC2  758         IF (L.EQ.1) GO TO 40
FIRES-RC2  759  C
FIRES-RC2  760  C      WHEN N.GE.L THE PROGRAM GENERATES INTERMEDIATE NODES AT INTERVALS
FIRES-RC2  761  C      OF DX AND DY
FIRES-RC2  762  C
FIRES-RC2  763         DIFF=N+1-L
FIRES-RC2  764         DX=(X(N)-X(L-1))/DIFF
FIRES-RC2  765         DY=(Y(N)-Y(L-1))/DIFF
FIRES-RC2  766      60 X(L)=X(L-1)+DX
FIRES-RC2  767         Y(L)=Y(L-1)+DY
FIRES-RC2  768         L=L+1
FIRES-RC2  769         IF (N.GT.L) GO TO 60
FIRES-RC2  770      70 L=L+1
FIRES-RC2  771         IF (N.LT.NUMNP) GO TO 30
FIRES-RC2  772         IF (N.NE.NUMNP) GO TO 40
FIRES-RC2  773  C
FIRES-RC2  774  C      INPUT DATA DESCRIBING THE ELEMENTS IN THE SYSTEM
FIRES-RC2  775  C
FIRES-RC2  776         NC=0
FIRES-RC2  777         NS=0
FIRES-RC2  778         NUMTOT=0
FIRES-RC2  779         NELTOT=NELCON+NELSTL
FIRES-RC2  780         DO 180 N=1,NELTOT
FIRES-RC2  781         IF (NUMTOT-N) 80,90,90
FIRES-RC2  782  C
FIRES-RC2  783  C      READ IN ELEMENT CARD
FIRES-RC2  784  C
FIRES-RC2  785      80 READ (NIN,410) NUM,K1,K2,K3,K4
FIRES-RC2  786         NUMTOT=NUM
FIRES-RC2  787         IF (N.GT.NELCON) NUMTOT=NUM+NELCON
FIRES-RC2  788         IF (NUMTOT.GT.NELTOT) GO TO 120
FIRES-RC2  789         IF (N.EQ.1) GO TO 110
FIRES-RC2  790  C
FIRES-RC2  791  C      SHIFT ELEMENT DESCRIPTION ONE LOCATION
FIRES-RC2  792  C
FIRES-RC2  793      90 DO 100 I=1,4
FIRES-RC2  794     100 LM(I,N)=LM(I,N-1)+1
FIRES-RC2  795     110 IF (NUMTOT-N) 120,130,140
FIRES-RC2  796     120 CONTINUE
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FIRES-RC2  797          WRITE (NOUT,420) NUM,K1,K2,K3,K4
FIRES-RC2  798          STOP
FIRES-RC2  799      130 CONTINUE
FIRES-RC2  800          LM(1,N)=K1
FIRES-RC2  801          LM(2,N)=K2
FIRES-RC2  802          LM(3,N)=K3
FIRES-RC2  803          LM(4,N)=K4
FIRES-RC2  804      140 CONTINUE
FIRES-RC2  805  C
FIRES-RC2  806  C       CALCULATE THE LOCATION OF THE ELEMENTS CENTER OF GRAVITY
FIRES-RC2  807  C       C. G. COORDINATES ARE XX AND YY
FIRES-RC2  808  C
FIRES-RC2  809          I=LM(1,N)
FIRES-RC2  810          J=L4(2,N)
FIRES-RC2  811          K=LM(3,N)
FIRES-RC2  812          L=LM(4,N)
FIRES-RC2  813          IF (K.EQ.L) GO TO 150
FIRES-RC2  814          AR1=(X(L)-X(J))*(Y(I)-Y(J))-(X(J)-X(I))*(Y(J)-Y(L))
FIRES-RC2  815          Y1=(Y(I)+Y(J)+Y(L))/3.
FIRES-RC2  816          AR2=(X(J)-X(L))*(Y(K)-Y(L))-(X(L)-X(K))*(Y(L)-Y(J))
FIRES-RC2  817          Y2=(Y(J)+Y(K)+Y(L))/3.
FIRES-RC2  818          AR=AR1+AR2
FIRES-RC2  819          YY=(Y1*AR1+Y2*AR2)/AR
FIRES-RC2  820          GO TO 160
FIRES-RC2  821      150 YY=(Y(I)+Y(J)+Y(K))/3.0
FIRES-RC2  822          AR=(X(K)-X(J))*(Y(I)-Y(J))-(X(J)-X(I))*(Y(J)-Y(K))
FIRES-RC2  823      160 CONTINUE
FIRES-RC2  824          IF (N.GT.NELCON) GO TO 170
FIRES-RC2  825          NC=N
FIRES-RC2  826          YC(NC)=YY
FIRES-RC2  827          AC(NC)=AR
FIRES-RC2  828          ARCONC=ARCONC+AR
FIRES-RC2  829          AIYC=AIYC+AR*YY*YY
FIRES-RC2  830          GO TO 180
FIRES-RC2  831      170 NS=N-NELCON
FIRES-RC2  832          YS(NS)=YY
FIRES-RC2  833          AS(NS)=AR
FIRES-RC2  834          ARSTL=ARSTL+AR
FIRES-RC2  835          AIYS=AIYS+AR*YY*YY
FIRES-RC2  836      180 CONTINUE
FIRES-RC2  837  C
FIRES-RC2  838  C       FORM VECTORS OF SYMMETRICAL PART OF CROSS-SECTION
FIRES-RC2  839  C
FIRES-RC2  840          IF (ISYM) 220,220,190
FIRES-RC2  841      190 DO 200 I=1,NC
FIRES-RC2  842          YC(NC+I)=-YC(I)
FIRES-RC2  843      200 AC(NC+I)=AC(I)
FIRES-RC2  844          NC=2*NC
FIRES-RC2  845          AIYC=2.*AIYC
FIRES-RC2  846          ARCONC=2.*ARCONC
FIRES-RC2  847          IF (NS.EQ.0) GO TO 220
FIRES-RC2  848          DO 210 I=1,NS
FIRES-RC2  849          YS(NS+I)=-YS(I)
FIRES-RC2  850      210 AS(NS+I)=AS(I)
FIRES-RC2  851          NS=2*NS
FIRES-RC2  852          AIYS=2.*AIYS
FIRES-RC2  853          ARSTL=2.*ARSTL
FIRES-RC2  854      220 CONTINUE
FIRES-RC2  855  C
FIRES-RC2  856  C       SHIFT REFERENCE PLANE IF SO SPECIFIED
FIRES-RC2  857  C
FIRES-RC2  858          IF (ICG-1) 300,270,230
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FIRES-RC2   859      230 XN=YREF
FIRES-RC2   860          YCG=0.
FIRES-RC2   861          IF (XN.LE.0.0) XN=1.0
FIRES-RC2   862          DO 240 I=1,NC
FIRES-RC2   863      240 YCG=YCG+AC(I)*YC(I)
FIRES-RC2   864          IF (NS.EQ.0) GO TO 260
FIRES-RC2   865          DO 250 I=1,NS
FIRES-RC2   866      250 YCG=YCG+XN*AS(I)*YS(I)
FIRES-RC2   867      260 YREF=YCG/(ARCONC+XN*ARSTL)
FIRES-RC2   868      270 AIYC=0.0
FIRES-RC2   869          DO 280 I=1,NC
FIRES-RC2   870          YC(I)=YC(I)-YREF
FIRES-RC2   871      280 AIYC=AIYC+AC(I)*YC(I)*YC(I)
FIRES-RC2   872          AIYS=0.0
FIRES-RC2   873          IF (NS.EQ.0) GO TO 300
FIRES-RC2   874          DO 290 I=1,NS
FIRES-RC2   875          YS(I)=YS(I)-YREF
FIRES-RC2   876      290 AIYS=AIYS+AS(I)*YS(I)*YS(I)
FIRES-RC2   877      300 CONTINUE
FIRES-RC2   878    C
FIRES-RC2   879    C     OUTPUT
FIRES-RC2   880    C
FIRES-RC2   881          IF (NSG-1) 310,310,320
FIRES-RC2   882      310 WRITE (NOUT,430)
FIRES-RC2   883          GO TO 330
FIRES-RC2   884      320 WRITE (NOUT,440) NSG
FIRES-RC2   885      330 WRITE (NOUT,450)
FIRES-RC2   886          WRITE (NOUT,470)
FIRES-RC2   887          WRITE (NOUT,460) (I,X(I),Y(I),I=1,NUMNP)
FIRES-RC2   888          WRITE (NOUT,480)
FIRES-RC2   889          WRITE (NOUT,500) (I,LM(1,I),LM(2,I),LM(3,I),LM(4,I),I=1,NELCON)
FIRES-RC2   890          IF (NELSTL.EQ.0) GO TO 340
FIRES-RC2   891          WRITE (NOUT,490)
FIRES-RC2   892          NN=NELCON+1
FIRES-RC2   893          WRITE (NOUT,500) (I,LM(1,I),LM(2,I),LM(3,I),LM(4,I),I=NN,NELTOT)
FIRES-RC2   894      340 CONTINUE
FIRES-RC2   895          WRITE (NOUT,510)
FIRES-RC2   896          WRITE (NOUT,520)
FIRES-RC2   897          WRITE (NOUT,530)
FIRES-RC2   898          WRITE (NOUT,540) (I,AC(I),YC(I),I=1,NC)
FIRES-RC2   899          IF (NS.EQ.0) GO TO 350
FIRES-RC2   900          WRITE (NOUT,550)
FIRES-RC2   901          WRITE (NOUT,530)
FIRES-RC2   902          WRITE (NOUT,540) (I,AS(I),YS(I),I=1,NS)
FIRES-RC2   903      350 ARTOT=ARCONC+ARSTL
FIRES-RC2   904          AIY=AIYC+AIYS
FIRES-RC2   905          WRITE (NOUT,560)
FIRES-RC2   906          WRITE (NOUT,570) ARCONC,AIYC
FIRES-RC2   907          WRITE (NOUT,580) ARSTL,AIYS
FIRES-RC2   908          WRITE (NOUT,590) ARTOT,AIY
FIRES-RC2   909          IF (NC.GT.NCMAX) NCMAX=NC
FIRES-RC2   910          IF (NS.GT.NSMAX) NSMAX=NS
FIRES-RC2   911          WRITE (ISTORE) NC,NS
FIRES-RC2   912          WRITE (ISTORE) (AC(I),I=1,NC),(YC(I),I=1,NC),(AS(I),I=1,NS),(YS(I)
FIRES-RC2   913         1,I=1,NS),ISYM
FIRES-RC2   914      360 CONTINUE
FIRES-RC2   915          RETURN
FIRES-RC2   916    C
FIRES-RC2   917    C
FIRES-RC2   918    C
FIRES-RC2   919      370 FORMAT (A1,6X,I3,5I5,F10.0)
FIRES-RC2   920      380 FORMAT (30H CONTROL CARD ERROR IN SEGMENT,I3)
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FIRES-RC2  921     390 FORMAT (I5,2E10.0)
FIRES-RC2  922     400 FORMAT (5(/),51H  - - - PROGRAM TERMINATED - NODE INPUT ERROR - -
FIRES-RC2  923        1-,//1X,I5,2F10.4)
FIRES-RC2  924     410 FORMAT (6I5)
FIRES-RC2  925     420 FORMAT (5(/),50H  - - - - PROGRAM TERMINATED - ELEMENT INPUT ERROR
FIRES-RC2  926        1,/1X,5I5)
FIRES-RC2  927     430 FORMAT (//11(2H -),18HSEGMENT TYPE NO. 1,11(2H -)////)
FIRES-RC2  928     440 FORMAT (1H1,11(2H -),16HSEGMENT TYPE NO.I2,11(2H -)////)
FIRES-RC2  929     450 FORMAT (18X27HFINITE ELEMENT IDEALIZATION,//5X,14H-NODAL POINTS-/)
FIRES-RC2  930     460 FORMAT (3(I4,2F8.3,1X))
FIRES-RC2  931     470 FORMAT (1X4HNODE3X1HX7X1HY,2(5X4HNODE3X1HX7X1HY)/)
FIRES-RC2  932     480 FORMAT (///,5X19H-CONCRETE ELEMENTS-,//3(21H ELEM  I    J    K    L )
FIRES-RC2  933        1/)
FIRES-RC2  934     490 FORMAT (///,5X19H-STEEL ELEMENTS-    ,//3(21H ELEM  I    J    K    L )
FIRES-RC2  935        1/)
FIRES-RC2  936     500 FORMAT (3(5I4,1X))
FIRES-RC2  937     510 FORMAT (///18X,26HCROSS-SECTION IDEALIZATION//)
FIRES-RC2  938     520 FORMAT (//,10X,43HAREA AND CENTROID OF EACH CONCRETE SUBSLICE/)
FIRES-RC2  939     530 FORMAT (3(21H ELEM   AREA       YC )/)
FIRES-RC2  940     540 FORMAT (3(I4,2F8.2,1X))
FIRES-RC2  941     550 FORMAT (//10X,43HAREA AND CENTROID OF EACH STEEL SUBSLICE    /)
FIRES-RC2  942     560 FORMAT (////18X26HCROSS SECTIONAL PROPERTIES,//,25X4HAREA3X17HMOME
FIRES-RC2  943        1NT OF INERTIA/)
FIRES-RC2  944     570 FORMAT (5X,9H CONCRETE,9X,F6.1,6X,F8.1)
FIRES-RC2  945     580 FORMAT (5X,6H STEEL,12X,F6.1,6X,F8.1)
FIRES-RC2  946     590 FORMAT (5X,6H TOTAL,12X,F6.1,6X,F8.1)
FIRES-RC2  947         END
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FIRES-RC2  948         SUBROUTINE DYNDIM (NCODE,M)
FIRES-RC2  949   C
FIRES-RC2  950   C     SUBROUTINE  * DYNDIM *  ALLOCATES STORAGE IN BLANK COMMON
FIRES-RC2  951   C     FOR THE SYSTEM VARIABLES AND FOR THE VARIABLES PERTAINING TO
FIRES-RC2  952   C     MEMBER (M)
FIRES-RC2  953   C
FIRES-RC2  954         COMMON /TAP/ HED(10),ITEMP1,ITEMP2,ISEG1,ISEG2,NIN,NOUT,NPUNCH
FIRES-RC2  955         COMMON /DYN/ NDT,NSTORE,NCMAX,NSMAX,NCONTL,NSTLTL,ISYSTM,IMEMB,ITO
FIRES-RC2  956        1TAL,ITAPE
FIRES-RC2  957         COMMON /BLK1/ NJ,NM,NBC,NJ3,MAXBAN,NCRPS,NCRPC,NSHRINK,NCONV
FIRES-RC2  958         COMMON /DIM1/ N1,N2,N3,N4,N5,N6,N7,N8,N9,N10,N11,N12
FIRES-RC2  959         COMMON /DIM2/ I0,I1,I2,I3,I4,I5,LCARD,NCARD,ISTART,LOOP,TIME,ERR(3
FIRES-RC2  960        1),IX(3),DT
FIRES-RC2  961         COMMON /MEMB/ NNSEG(75)
FIRES-RC2  962         COMMON C(1)
FIRES-RC2  963   C
FIRES-RC2  964   C
FIRES-RC2  965   C     ALLOCATE SPACE IN THE SECOND MAJOR BLOCK OF BLANK COMMON FOR ALL
FIRES-RC2  966   C     VARIABLES PERTAINING TO MEMBER (M)
FIRES-RC2  967   C
FIRES-RC2  968         IF (NM.EQ.1.AND.NCODE.GT.1) GO TO 10
FIRES-RC2  969         NSG=NNSEG(M)
FIRES-RC2  970         NSG2=2*NSG
FIRES-RC2  971         NSUBST=3*(NSG+1)
FIRES-RC2  972         NINTER=3*(NSG-1)
FIRES-RC2  973         N20=ISTART
FIRES-RC2  974         N21=N20+1
FIRES-RC2  975         N22=N21+1
FIRES-RC2  976         N23=N22+NSG
FIRES-RC2  977         N24=N23+NSG
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FIRES-RC2   978          N25=N24+NSG
FIRES-RC2   979          N26=N25+NSG
FIRES-RC2   980          N27=N26+NSG
FIRES-RC2   981          N28=N27+NSG
FIRES-RC2   982          N29=N28+NSUBST
FIRES-RC2   983          N30=N29+NINTER
FIRES-RC2   984          N31=N30+NINTER
FIRES-RC2   985          N32=N31+NINTER
FIRES-RC2   986          N33=N32+NSG2
FIRES-RC2   987          N34=N33+NSG2
FIRES-RC2   988          N35=N34+NSG2
FIRES-RC2   989          N36=N35+NSG2
FIRES-RC2   990          N37=N36+NSG
FIRES-RC2   991          N38=N37+NSG2
FIRES-RC2   992          N39=N38+NSG2
FIRES-RC2   993          N40=N39+NSG
FIRES-RC2   994          N41=N40+NSG
FIRES-RC2   995          ISTART=N41
FIRES-RC2   996          IF (ISTART.LE.NSTORE) GO TO 10
FIRES-RC2   997          WRITE (NOUT,70) N41
FIRES-RC2   998          STOP
FIRES-RC2   999   C
FIRES-RC2  1000   C      CALL THE SUBROUTINE SPECIFIED IN THE MAIN PROGRAM
FIRES-RC2  1001   C
FIRES-RC2  1002       10 GO TO (20,30,40,50,60), NCODE
FIRES-RC2  1003   C
FIRES-RC2  1004       20 CALL INITIAL (C(N1),C(N2),C(N3),C(N4),C(N5),C(N6),C(N7),C(N8),C(N9
FIRES-RC2  1005         1),C(N10),C(N11),C(N12),C(N20),C(N21),C(N22),C(N23),C(N24),C(N25),C
FIRES-RC2  1006         2(N26),C(N27),C(N28),C(N29),C(N30),C(N31),C(N32),C(N33),C(N36),C(N3
FIRES-RC2  1007         39),C(N40),I0,I1,I2,I3,LCARD,NJ3,M)
FIRES-RC2  1008          RETURN
FIRES-RC2  1009   C
FIRES-RC2  1010       30 CALL INSTEP (C(N1),C(N2),C(N3),C(N4),C(N5),C(N6),C(N7),C(N8),C(N9)
FIRES-RC2  1011         1,C(N10),C(N11),C(N12),C(N29),C(N30),C(N31),C(N39),C(N40),DT,I0,I1,
FIRES-RC2  1012         2I2,I3,LCARD,NJ3,M)
FIRES-RC2  1013          RETURN
FIRES-RC2  1014   C
FIRES-RC2  1015       40 CALL MEMBERS (C(N1),C(N2),C(N3),C(N4),C(N5),C(N6),C(N7),C(N8),C(N9
FIRES-RC2  1016         1),C(N10),C(N11),C(N12),C(N20),C(N21),C(N22),C(N23),C(N25),C(N27),C
FIRES-RC2  1017         2(N28),C(N30),C(N31),C(N32),C(N33),C(N34),C(N35),C(N37),C(N38),C(N3
FIRES-RC2  1018         39),C(N40),NJ3,ERP(1),LOOP,M)
FIRES-RC2  1019          RETURN
FIRES-RC2  1020   C
FIRES-RC2  1021       50 CALL OUTPT (C(N3),C(N4),C(N6),C(N10),C(N11),C(N22),C(N23),C(N24),C
FIRES-RC2  1022         1(N25),C(N26),C(N27),C(N28),C(N30),C(N32),C(N33),C(N34),C(N35),C(N3
FIRES-RC2  1023         26),C(N37),C(N38),C(N39),C(N40),I2,I3,I5,LCARD,NCARD,TIME,M)
FIRES-RC2  1024          RETURN
FIRES-RC2  1025   C
FIRES-RC2  1026       60 CALL IOUT (C(N20),C(N21),C(N22),C(N23),C(N24),C(N25),C(N26),C(N27)
FIRES-RC2  1027         1,C(N28),C(N29),C(N30),C(N31),C(N32),C(N33),C(N34),C(N35),C(N36),C(
FIRES-RC2  1028         2N37),C(N38),C(N39),C(N40),I4,LOOP,TIME,M)
FIRES-RC2  1029          RETURN
FIRES-RC2  1030   C
FIRES-RC2  1031   C
FIRES-RC2  1032   C
FIRES-RC2  1033   C
FIRES-RC2  1034       70 FORMAT (//31H INCREASE BLANK COMMON TO        ,I10)
FIRES-RC2  1035          END
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FIRES-RC2 1036          SUBROUTINE INITIAL (X,Y,IBC,JS,FJ,U,DV,DPL,SP,AAW,DELR,SYSTIF,MI,M
FIRES-RC2 1037         1J,SEGL,AE,AEI,EI,EII,DCG,W,F,DELF,FA,PA,BM,AREA,NCONCR,NSTEEL,IO,I
FIRES-RC2 1038         21,I2,I3,LCARD,NJ3,M)
FIRES-RC2 1039   C
FIRES-RC2 1040   C
FIRES-RC2 1041   C       SUBROUTINE  *INITIAL*  INITIALIZES ALL VARIABLES
FIRES-RC2 1042   C
FIRES-RC2 1043   C         (  USED FOR FIRST TIME STEP ONLY  )
FIRES-RC2 1044   C
FIRES-RC2 1045   C
FIRES-RC2 1046          COMMON /TAP/ HED(10),ITEMP1,ITEMP2,ISEG1,ISEG2,NIN,NOUT,NPUNCH
FIRES-RC2 1047          COMMON /DYN/ NDT,NSTORE,NCMAX,NSMAX,NCONTL,NSTLTL,ISYSTM,IMEMB,ITO
FIRES-RC2 1048         1TAL,ITAPE
FIRES-RC2 1049          COMMON /BLK1/ NJ,NM,NBC,NXX,MAXBAN,NCRPS,NCRPC,NSHRINK,NCONV
FIRES-RC2 1050          COMMON /BLK2/ A(6,6),E(6,6)
FIRES-RC2 1051          COMMON /MEMB/ NNSEG(75)
FIRES-RC2 1052          COMMON C(1)
FIRES-RC2 1053          DIMENSION X(1), Y(1), IBC(1), JS(1), FJ(1), U(1), DV(1), DPL(1), S
FIRES-RC2 1054         1P(2,1), AAW(1), SYSTIF(NJ3,1), DELR(1), SEGL(1), AE(1), AEI(1), EI
FIRES-RC2 1055         2(1), EII(1), DCG(1), W(1), F(1), DELF(1), FA(1), PA(2,1), BM(2,1),
FIRES-RC2 1056         3 AREA(1), NCONCR(1), NSTEEL(1)
FIRES-RC2 1057          DIMENSION IX(10), TF(10), ISTR(9), MSEG(6)
FIRES-RC2 1058   C
FIRES-RC2 1059   C
FIRES-RC2 1060   C       INITIALIZATION OF THE OVERALL STRUCTURAL SYSTEM
FIRES-RC2 1061   C          ( ON FIRST CALL OF SUBROUTINE ONLY - WHEN M .EQ. 1)
FIRES-RC2 1062   C
FIRES-RC2 1063   C       VARIABLES DESCRIBING THE SYSTEM CONFIGURATION
FIRES-RC2 1064   C
FIRES-RC2 1065   C       FJ - JOINT FORCES(LOADS) - FJ((I-1)*3+J) = FJ(I,J)
FIRES-RC2 1066   C                                  I = JOINT NUMBER
FIRES-RC2 1067   C                                  J = DIRECTION  1,X/2,Y/3,R
FIRES-RC2 1068   C       U - SYSTEM DISPLACEMENTS
FIRES-RC2 1069   C       SP - BOUNDARY CONDITION STIFFNESS MATRIX
FIRES-RC2 1070   C              SP(1,J)  -  DIAGONALS (SPRING STIFFNESSES)
FIRES-RC2 1071   C              SP(2,J)  -  OFF-DIAGONALS (COUPLING STIFFNESSES)
FIRES-RC2 1072   C           DEFAULT VALUE FOR RESTRAINED JOINTS IS 1.0E29
FIRES-RC2 1073   C       DPL - PRESCRIBED BOUNDARY CONDITION DISPLACEMENTS
FIRES-RC2 1074   C
FIRES-RC2 1075          IF (M.GT.1) GO TO 80
FIRES-RC2 1076          IF (I3.NE.0) WRITE (NOUT,210) I3,LCARD
FIRES-RC2 1077          NJJ=NJ3*8
FIRES-RC2 1078          DO 10 J=1,NJJ
FIRES-RC2 1079       10 FJ(J)=0.0
FIRES-RC2 1080          DO 20 J=1,NBC
FIRES-RC2 1081          I=JS(J)
FIRES-RC2 1082          DECODE (10,220,IBC(I) )IX(1),IX(2),IX(3)
FIRES-RC2 1083          K=(I-1)*3+1
FIRES-RC2 1084          IF (IX(1).EQ.1) SP(1,K)=1.0E29
FIRES-RC2 1085          IF (IX(2).EQ.1) SP(1,K+1)=1.0E29
FIRES-RC2 1086          IF (IX(3).EQ.1) SP(1,K+2)=1.0E29
FIRES-RC2 1087       20 CONTINUE
FIRES-RC2 1088          IF (IO.EQ.0) GO TO 40
FIRES-RC2 1089   C
FIRES-RC2 1090   C       INPUT JOINT LOADS
FIRES-RC2 1091   C
FIRES-RC2 1092          DO 30 I=1,IO
FIRES-RC2 1093          READ (NIN,230) JT,(TF(J),J=1,3)
FIRES-RC2 1094          K=(JT-1)*3
FIRES-RC2 1095          DO 30 J=1,3
FIRES-RC2 1096       30 FJ(K+J)=TF(J)
FIRES-RC2 1097       40 CONTINUE
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FIRES-RC2 1098  C
FIRES-RC2 1099  C      INPUT NON-DEFAULT BOUNDARY CONDITIONS FOR JOINTS
FIRES-RC2 1100  C
FIRES-RC2 1101         IF (I1.EQ.0) GO TO 60
FIRES-RC2 1102         DO 50 I=1,I1
FIRES-RC2 1103         READ (NIN,240) JT,(TF(J),J=1,9)
FIRES-RC2 1104         K=(JT-1)*3
FIRES-RC2 1105         DO 50 J=1,3
FIRES-RC2 1106         SP(I,K+J)=TF(J)
FIRES-RC2 1107         SP(2,K+J)=TF(J+3)
FIRES-RC2 1108         IF (TF(J+3).EQ.0.0) GO TO 50
FIRES-RC2 1109         WRITE (NOUT,200)
FIRES-RC2 1110         STOP
FIRES-RC2 1111      50 DPL(K+J)=TF(J+6)
FIRES-RC2 1112      60 CONTINUE
FIRES-RC2 1113  C
FIRES-RC2 1114  C      OUTPUT CHANGES IN STATUS OF SYSTEM INPUT VARIABLES
FIRES-RC2 1115  C
FIRES-RC2 1116         WRITE (NOUT,250)
FIRES-RC2 1117         DO 70 J=1,NJ
FIRES-RC2 1118         J1=(J-1)*3+1
FIRES-RC2 1119         J2=J1+1
FIRES-RC2 1120         J3=J1+2
FIRES-RC2 1121         WRITE (NOUT,260) J,FJ(J1),SP(1,J1),SP(2,J1),SP(2,J2),DPL(J1),FJ(J2
FIRES-RC2 1122        1),SP(2,J1),SP(1,J2),SP(2,J3),DPL(J2),FJ(J3),SP(2,J2),SP(2,J3),SP(1
FIRES-RC2 1123        2,J3),DPL(J3)
FIRES-RC2 1124      70 CONTINUE
FIRES-RC2 1125  C
FIRES-RC2 1126         REWIND ITEMP1
FIRES-RC2 1127         REWIND ISEG1
FIRES-RC2 1128         NFILE=0
FIRES-RC2 1129         NSEGTL=0
FIRES-RC2 1130         NCONTL=0
FIRES-RC2 1131         NSTLTL=0
FIRES-RC2 1132  C
FIRES-RC2 1133  C      INITIALIZATION OF SUBSTRUCTURED MEMBERS
FIRES-RC2 1134  C      ( LOOP OVER ALL MEMBERS, WITH THE DO-LOOP IN THE MAIN PROGRAM )
FIRES-RC2 1135  C
FIRES-RC2 1136      80 CONTINUE
FIRES-RC2 1137  C
FIRES-RC2 1138  C      READ MEMBER CONTROL CARD
FIRES-RC2 1139  C
FIRES-RC2 1140  C        MB - MEMBER NUMBER
FIRES-RC2 1141  C        M1 - IF NON-ZERO, THEN THE INITIAL TEMPERATURE IS UNIFORM
FIRES-RC2 1142  C             FOR ALL SEGMENTS OF THE MEMBER
FIRES-RC2 1143  C             IF ZERO, THEN READ TEMPERATURE DATA FOR EACH SEGMENT
FIRES-RC2 1144  C        TCONST - UNIFORM TEMPERATURE (IF M1.NE.0)
FIRES-RC2 1145  C        M2 - INDICATES NON-ZERO LOADS AT INTERIOR SEGMENT NODES
FIRES-RC2 1146  C
FIRES-RC2 1147         READ (NIN,270) MB1,MB2,MB,M1,TCONST,M2
FIRES-RC2 1148  C
FIRES-RC2 1149         IF (M.EQ.MB.AND.MB1.EQ.IHM) GO TO 90
FIRES-RC2 1150  C
FIRES-RC2 1151         WRITE (NOUT,280)
FIRES-RC2 1152         WRITE (NOUT,290) M,MB1,MB2,MB,M1,TCONST,M2
FIRES-RC2 1153         STOP
FIRES-RC2 1154  C
FIRES-RC2 1155  C      READ MEMBER DATA FROM THE FILE ITEMP1 CREATED IN SUBROUTINE INPT
FIRES-RC2 1156  C
FIRES-RC2 1157      90 NSEG=NNSEG(M)
FIRES-RC2 1158         NSL=(NSEG-1)*3
FIRES-RC2 1159         READ (ITEMP1) MI,MJ,(MSEG(K),SEGL(K),K=1,NSEG)
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FIRES-RC2 1160  C
FIRES-RC2 1161  C       INITIALIZE TO 0.0 THE FOLLOWING VARIABLES
FIRES-RC2 1162  C         W, F, DELF, FA, PA, BM
FIRES-RC2 1163  C
FIRES-RC2 1164          IMAX=(NSEG-1)*9+(NSEG+1)*3+NSEG*4
FIRES-RC2 1165          DO 100 I=1,IMAX
FIRES-RC2 1166      100 W(I)=0.0
FIRES-RC2 1167  C
FIRES-RC2 1168  C       INITIALIZE TO 0.0 THE FOLLOWING VARIABLES
FIRES-RC2 1169  C       WHICH ARE STORED IN BLANK COMMON AFTER THE MEMBER VARIABLES
FIRES-RC2 1170  C         SIGC, EPC, SIGS, EPS, TC, TS
FIRES-RC2 1171  C       ALSO INITIALIZE TRANSFOMATION MATRICES E AND A
FIRES-RC2 1172  C
FIRES-RC2 1173          DO 110 I=1,72
FIRES-RC2 1174      110 A(I)=0.0
FIRES-RC2 1175          ITOTAL=IMEMB+3*NCMAX+3*NSMAX
FIRES-RC2 1176          IMAX=ITOTAL-1
FIRES-RC2 1177          DO 120 I=IMEMB,IMAX
FIRES-RC2 1178      120 C(I)=0.0
FIRES-RC2 1179          DO 130 I=1,6
FIRES-RC2 1180      130 E(I,I)=1.0
FIRES-RC2 1181          A(3,3)=1.0
FIRES-RC2 1182          A(6,6)=1.0
FIRES-RC2 1183          IF (M2.EQ.0) GO TO 150
FIRES-RC2 1184  C
FIRES-RC2 1185  C       INPUT NON-ZERO LOAD CONDITIONS FOR SUBSTRUCTURED MEMBER
FIRES-RC2 1186  C
FIRES-RC2 1187          READ (NIN,300) (F(I),I=1,NSL)
FIRES-RC2 1188          WRITE (NOUT,310) M,(I,I=1,NSEG)
FIRES-RC2 1189          II=6H  F-X
FIRES-RC2 1190          WRITE (NOUT,320) II,(F(I),I=1,NSL,3)
FIRES-RC2 1191          II=6H  F-Y
FIRES-RC2 1192          WRITE (NOUT,320) II,(F(I),I=2,NSL,3)
FIRES-RC2 1193          II=6H  F-M
FIRES-RC2 1194          WRITE (NOUT,320) II,(F(I),I=3,NSL,3)
FIRES-RC2 1195          DO 140 I=1,NSL
FIRES-RC2 1196          FA(I)=F(I)
FIRES-RC2 1197      140 CONTINUE
FIRES-RC2 1198      150 CONTINUE
FIRES-RC2 1199  C
FIRES-RC2 1200  C       SEGMENT INITIALIZATION
FIRES-RC2 1201  C       ( LOOP OVER ALL SEGMENTS IN THIS MEMBER )
FIRES-RC2 1202  C
FIRES-RC2 1203          DO 190 JSEG=1,NSEG
FIRES-RC2 1204          NSTYP=MSEG(JSEG)
FIRES-RC2 1205  C
FIRES-RC2 1206  C       READ SEGMENT DATA FROM FILE ISEG1 THAT WAS CREATED IN SEGIN
FIRES-RC2 1207  C
FIRES-RC2 1208          IFLWR=0
FIRES-RC2 1209          IF (NSTYP.EQ.NFILE) GO TO 180
FIRES-RC2 1210          IF (NSTYP.GT.NFILE) GO TO 160
FIRES-RC2 1211          REWIND ISEG1
FIRES-RC2 1212          NFILE=0
FIRES-RC2 1213      160 READ (ISEG1) NCONC,NSTL
FIRES-RC2 1214          NFILE=NFILE+1
FIRES-RC2 1215          IF (NFILE.NE.NSTYP) READ (ISEG1)
FIRES-RC2 1216          IFLWR=1
FIRES-RC2 1217          IF (NFILE.EQ.NSTYP) 170,160
FIRES-RC2 1218      170 CONTINUE
FIRES-RC2 1219  C
FIRES-RC2 1220  C       SET UP DYNAMIC STORAGE FOR THIS SEGMENT
FIRES-RC2 1221  C         ( FOR FILES ITEMP AND ISEG )
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FIRES-RC2 1222  C
FIRES-RC2 1223          M20=ITOTAL
FIRES-RC2 1224          M21=M20+NCONC
FIRES-RC2 1225          M22=M21+NCONC
FIRES-RC2 1226          M23=M22+NSTL
FIRES-RC2 1227          M24=M23+NSTL
FIRES-RC2 1228          M25=M24+NCONC
FIRES-RC2 1229          M26=M25+NCONC
FIRES-RC2 1230          M27=M26+NCONC
FIRES-RC2 1231          M28=M27+NCONC
FIRES-RC2 1232          M29=M28+NSTL
FIRES-RC2 1233          M30=M29+NSTL
FIRES-RC2 1234          M31=M30+2*NCONC
FIRES-RC2 1235          M32=M31+2*NSTL
FIRES-RC2 1236          M33=M32+2*NCONC
FIRES-RC2 1237          M34=M33+2*NCONC
FIRES-RC2 1238          M35=M34+2*NCONC
FIRES-RC2 1239          M36=M35+2*NCONC
FIRES-RC2 1240          M37=M36+NCONC
FIRES-RC2 1241          M38=M37+2*NCONC
FIRES-RC2 1242          M39=M38+2*NCONC
FIRES-RC2 1243          M40=M39+NSTL
FIRES-RC2 1244          M41=M40+2*NSTL
FIRES-RC2 1245          M42=M41+2*NSTL
FIRES-RC2 1246          M43=M42+2*NCONC
FIRES-RC2 1247          MEFC=M43+2*NSTL
FIRES-RC2 1248          MFU=MEFC+NCONC
FIRES-RC2 1249          M44=MFU+NCONC
FIRES-RC2 1250          M45=M44+10
FIRES-RC2 1251          M46=M45+NCONC
FIRES-RC2 1252          M47=M46+NSTL
FIRES-RC2 1253          M48=M47+NCONC
FIRES-RC2 1254          M49=M48+NCONC
FIRES-RC2 1255          M50=M49+NCONC
FIRES-RC2 1256          M51=M50+NCONC
FIRES-RC2 1257          M52=M51+NCONC
FIRES-RC2 1258          M53=M52+NSTL
FIRES-RC2 1259          M54=M53+NCONC
FIRES-RC2 1260          M55=M54+1
FIRES-RC2 1261          IF (M55.LE.NSTORE) GO TO 180
FIRES-RC2 1262          WRITE (NOUT,330) M55
FIRES-RC2 1263          STOP
FIRES-RC2 1264  C
FIRES-RC2 1265  C       INITIALIZE SEGMENT VARIABLES
FIRES-RC2 1266  C
FIRES-RC2 1267    180 CALL INTSEG (IFLWR,NCONC,NSTL,C(M20),C(M21),C(M22),C(M23),C(M24),C
FIRES-RC2 1268       1(M25),C(M26),C(M27),C(M28),C(M29),C(M30),C(M31),C(M32),C(M33),C(M3
FIRES-RC2 1269       24),C(M35),C(M36),C(M37),C(M38),C(M39),C(M40),C(M41),C(M42),C(M43),
FIRES-RC2 1270       3C(M44),C(M45),C(M46),C(M47),C(M48),C(M49),C(M50),C(M51),C(M52),C(M
FIRES-RC2 1271       453),C(M54),AE,AEI,EI,EII,DCG,AREA,I3,JSEG,M,M1,M2,TCONST,C(MEFC),C
FIRES-RC2 1272       5(MFU))
FIRES-RC2 1273        NCONCR(JSEG)=NCONC
FIRES-RC2 1274        NSTEEL(JSEG)=NSTL
FIRES-RC2 1275        NSEGTL=NSEGTL+1
FIRES-RC2 1276        NCONTL=NCONTL+NCONC
FIRES-RC2 1277        NSTLTL=NSTLTL+NSTL
FIRES-RC2 1278    190 CONTINUE
FIRES-RC2 1279        IF (M.NE.NM) RETURN
FIRES-RC2 1280  C
FIRES-RC2 1281  C       SET DYNAMIC SEGMENT DATA STORAGE FLAG
FIRES-RC2 1282  C
FIRES-RC2 1283  C         ITAPE .EQ. 0    BLANK COMMON CAN HOLD ONLY ONE SEGMENT OF
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FIRES-RC2 1284  C                          FILE ISEG1 AND ITEMP1
FIRES-RC2 1285  C
FIRES-RC2 1286  C        ITAPE .EQ. 1      BLANK COMMON CAN HOLD ALL SEGMENTS OF
FIRES-RC2 1287  C                          FILES ISEG1 AND ITEMP1 TOGETHER ( I.E., ENTIRE
FIRES-RC2 1288  C                          PROBLEM CAN BE SOLVED IN HIGH SPEED STORAGE )
FIRES-RC2 1289  C
FIRES-RC2 1290        NSIZE=ITOTAL+32*NCONTL+15*NSTLTL+11*NSEGTL
FIRES-RC2 1291        IF (NSIZE.LT.NSTORE) ITAPE=1
FIRES-RC2 1292        WRITE (NOUT,340) NSIZE,NSTORE
FIRES-RC2 1293        IF (ITAPE.EQ.0) WRITE (NOUT,350)
FIRES-RC2 1294        IF (ITAPE.EQ.1) WRITE (NOUT,360)
FIRES-RC2 1295  C
FIRES-RC2 1296        RETURN
FIRES-RC2 1297  C
FIRES-RC2 1298  C
FIRES-RC2 1299  C
FIRES-RC2 1300    200 FORMAT (///52H STOP  -  NO OFF-DIAGONAL TERMS PERMITTED IN THIS VE
FIRES-RC2 1301       1,20HRSION OF FIRES-RC II)
FIRES-RC2 1302    210 FORMAT (//34H   .  .  .  PUNCHED DATA OF LEVEL ,I2,26H HAS BEEN RE
FIRES-RC2 1303       1QUESTED  .  . /20X,24HCARDS WILL BE LABELED   ,A3)
FIRES-RC2 1304    220 FORMAT (2X,3I1)
FIRES-RC2 1305    230 FORMAT (I5,3E10.0)
FIRES-RC2 1306    240 FORMAT (I4,9E8.0)
FIRES-RC2 1307    250 FORMAT (//61H   .  .  .  STRUCTURAL LOADS AND BOUNDARY CONDITIONS
FIRES-RC2 1308       1 .  .  .///62H JOINT    SYSTEM       SUPPORT STIFFNESS MATRIX
FIRES-RC2 1309       2PRESCRIBED/62H          LOADS
FIRES-RC2 1310       3  DISPLS. /62H                        X          Y          R
FIRES-RC2 1311       4          )
FIRES-RC2 1312    260 FORMAT (/I3,1X,4H X  ,G10.3,2X,3G10.3,2X,G10.3/4X,4H Y  ,G10.3,2X,
FIRES-RC2 1313       13G10.3,2X,G10.3/4X,4H R  ,G10.3,2X,3G10.3,2X,G10.3/)
FIRES-RC2 1314    270 FORMAT (A1,A5,I4,I5,F10.0,I5)
FIRES-RC2 1315    280 FORMAT (6(/)48H  -------INPUT ERROR - PROGRAM TERMINATED-------)
FIRES-RC2 1316    290 FORMAT (//32H  INPUT ERROR FOR MEMBER NUMBER ,I5/1X,A1,A5,I4,I5,F1
FIRES-RC2 1317       10.0,I5)
FIRES-RC2 1318    300 FORMAT (6E10.0)
FIRES-RC2 1319    310 FORMAT (//7X,39H. . . INTERSEGMENTAL FORCES FOR MEMBER ,I4,6H . .
FIRES-RC2 1320       1.//7X,I1,1X,5I9)
FIRES-RC2 1321    320 FORMAT (/A6,F10.2,5F9.2)
FIRES-RC2 1322    330 FORMAT (//31H INCREASE BLANK COMMON TO      ,I10)
FIRES-RC2 1323    340 FORMAT (///50H        BLANK COMMON REQUIRED TO SOLVE THIS PROBLEM/7
FIRES-RC2 1324       1X,28HUSING HIGHSPEED STORAGE ONLY,18X,1H=,I8//54H        BLANK COMM
FIRES-RC2 1325       2ON AVAILABLE IN DIMENSION STATEMENT =,I8/)
FIRES-RC2 1326    350 FORMAT (6X,50H READ/WRITE ON TAPE FOR EACH ITERATION              //
FIRES-RC2 1327       1)
FIRES-RC2 1328    360 FORMAT (6X,50H ALL DATA STORED IN CORE - NO EXTERNAL READ/WRITE //
FIRES-RC2 1329       1)
FIRES-RC2 1330        END


FIRES-RC2 1331        SUBROUTINE INTSEG (IFLWR,NCONC,NSTL,AC,YC,AS,YS,AMOD,STRE,EPU,TE
FIRES-RC2 1332       1AMOS,YIE,AR,ARS,KRAT,KRAF,AKAK,AKK,STRC,EHC,SIC,STRS,EHS,SIS,ESHIF
FIRES-RC2 1333       2TC,ESHIFTS,NSTR,TEMPC,TEMPS,SST,BCRP,CCRP,DCRP,ECRP,ET,SAVG,ISYM,A
FIRES-RC2 1334       3E,AEI,EI,EII,DCG,AREA,I3,JSEG,M,M1,M2,TCONST,EFC,FU)
FIRES-RC2 1335  C
FIRES-RC2 1336  C
FIRES-RC2 1337       .COMMON /TAP/ HED(10),ITEMP1,ITEMP2,ISEG1,ISEG2,NIN,NOUT,NPUNCH
FIRES-RC2 1338        DIMENSION AC(1), YC(1), AS(1), YS(1), AMOD(1), STRE(1), EPU(1), TE
FIRES-RC2 1339       1S(1), AMOS(1), YIE(1), AR(2,1), ARS(2,1), KRAT(2,1), KRAF(2,1), AK
FIRES-RC2 1340       2AK(2,1), AKK(2,1), STRC(1), EHC(2,1), SIC(2,1), STRS(1), EHS(2,1),
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FIRES-RC2 1341          3 SIS(2,1), ESHIFTC(2,1), ESHIFTS(2,1), NSTR(1), TEMPC(1), TEMPS(1)
FIRES-RC2 1342          4, SST(1), BCRP(1), CCRP(1), DCRP(1), ECRP(1), ET(1), SAVG(1), AREA
FIRES-RC2 1343          5(1), DCG(1), AE(1), AEI(1), EI(1), EII(1), EFC(1), FU(1)
FIRES-RC2 1344           DIMENSION ISTR(9)
FIRES-RC2 1345           INTEGER AKAK,AKK,TPLC,TPLS
FIRES-RC2 1346    C
FIRES-RC2 1347    C
FIRES-RC2 1348    C      READ IN SEGMENT DATA CALCULATED IN SUBROUTINE SEGIN
FIRES-RC2 1349    C
FIRES-RC2 1350           IF (IFLWR.EQ.0) GO TO 10
FIRES-RC2 1351           READ (ISEG1) (AC(I),I=1,NCONC),(YC(I),I=1,NCONC),(AS(I),I=1,NSTL),
FIRES-RC2 1352          1(YS(I),I=1,NSTL),ISYM
FIRES-RC2 1353        10 CONTINUE
FIRES-RC2 1354    C
FIRES-RC2 1355    C      INITIALIZE TO 0.0 THE FOLLOWING VARIABLES (CONSTANT IN SEGMENT)
FIRES-RC2 1356    C        STRC,STRS,BCRP,CCRP,DCRP,ECRP,ET,SAVG
FIRES-RC2 1357    C
FIRES-RC2 1358    C        KRAT,KRAF,AKAK,AKK,EHC,SIC,EHS,SIS,ESHIFTC,ESHIFTS (LINEAR IN SEGMENT)
FIRES-RC2 1359    C
FIRES-RC2 1360           DO 30 I=1,NCONC
FIRES-RC2 1361           DO 20 J=1,2
FIRES-RC2 1362           KRAT(J,I)=0.0
FIRES-RC2 1363           KRAF(J,I)=0.0
FIRES-RC2 1364           AKAK(J,I)=0.0
FIRES-RC2 1365           AKK(J,I)=0.0
FIRES-RC2 1366           EHC(J,I)=0.0
FIRES-RC2 1367           SIC(J,I)=0.0
FIRES-RC2 1368        20 ESHIFTC(J,I)=0.0
FIRES-RC2 1369           STRC(I)=0.0
FIRES-RC2 1370           SAVG(I)=0.0
FIRES-RC2 1371           BCRP(I)=0.0
FIRES-RC2 1372           CCRP(I)=0.0
FIRES-RC2 1373           DCRP(I)=0.0
FIRES-RC2 1374        30 ECRP(I)=0.0
FIRES-RC2 1375           IF (NSTL.EQ.0) GO TO 60
FIRES-RC2 1376           DO 50 I=1,NSTL
FIRES-RC2 1377           DO 40 J=1,2
FIRES-RC2 1378           EHS(J,I)=0.0
FIRES-RC2 1379           SIS(J,I)=0.0
FIRES-RC2 1380        40 ESHIFTS(J,I)=0.0
FIRES-RC2 1381           STRS(I)=0.0
FIRES-RC2 1382        50 ET(I)=0.0
FIRES-RC2 1383    C
FIRES-RC2 1384    C      IF PUNCHED OUTPUT OF STRESSES IS DESIRED THEN NSTR IS INITIALIZED
FIRES-RC2 1385    C
FIRES-RC2 1386        60 NSTR(10)=0
FIRES-RC2 1387           IF (I3.EQ.0) GO TO 120
FIRES-RC2 1388           READ (NIN,200) ISTR
FIRES-RC2 1389           IC=1
FIRES-RC2 1390        70 IF (ISTR(IC).EQ.9H          ) GO TO 100
FIRES-RC2 1391           DECODE (8,210,ISTR(IC) )NS,MS
FIRES-RC2 1392           IF (MS.EQ.1HS) GO TO 80
FIRES-RC2 1393           IF (MS.NE.1HC.OR.NS.GT.NCONC) GO TO 110
FIRES-RC2 1394           NSTR(IC)=NS
FIRES-RC2 1395           GO TO 90
FIRES-RC2 1396        80 IF (NS.GT.NSTL) GO TO 110
FIRES-RC2 1397           NSTR(IC)=NS-1000
FIRES-RC2 1398        90 IC=IC+1
FIRES-RC2 1399           IF (IC.GE.10) 100,70
FIRES-RC2 1400       100 NSTR(10)=IC-1
FIRES-RC2 1401           GO TO 120
FIRES-RC2 1402    C
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FIRES-RC2 1403  C     INPUT ERROR IN STRESS INDICATOR CARDS
FIRES-RC2 1404  C
FIRES-RC2 1405    110 CONTINUE
FIRES-RC2 1406        WRITE (NOUT,190)
FIRES-RC2 1407        WRITE (NOUT,220) M,JSEG,ISTR
FIRES-RC2 1408        STOP
FIRES-RC2 1409  C
FIRES-RC2 1410    120 CONTINUE
FIRES-RC2 1411  C
FIRES-RC2 1412  C     INPUT TEMPERATURES FOR SEGMENT CROSS-SECTION
FIRES-RC2 1413  C
FIRES-RC2 1414        CALL TEMPIN (M1,TCONST,TEMPC,TEMPS,NCONC,NSTL,M,JSEG,ISYM,AMOD)
FIRES-RC2 1415  C
FIRES-RC2 1416  C     CALCULATE CROSS-SECTION MATERIAL PROPERTIES
FIRES-RC2 1417  C
FIRES-RC2 1418        CALL PROP (M1,TCONST,TEMPC,TEMPS,NCONC,NSTL,AMOD,STRE,EPU,TES,AMOS
FIRES-RC2 1419       1,YIE,EFC,FU)
FIRES-RC2 1420  C
FIRES-RC2 1421        DO 130 I=1,NCONC
FIRES-RC2 1422        SST(I)=0.0
FIRES-RC2 1423        AA=AMOD(I)
FIRES-RC2 1424        AR(1,I)=AA
FIRES-RC2 1425    130 AR(2,I)=AA
FIRES-RC2 1426        IF (NSTL.EQ.0) GO TO 150
FIRES-RC2 1427        DO 140 I=1,NSTL
FIRES-RC2 1428        AA=AMOS(I)
FIRES-RC2 1429        ARS(1,I)=AA
FIRES-RC2 1430    140 ARS(2,I)=AA
FIRES-RC2 1431  C
FIRES-RC2 1432    150 BE=0.0
FIRES-RC2 1433        BI=0.0
FIRES-RC2 1434        DC=0.0
FIRES-RC2 1435        SA=0.0
FIRES-RC2 1436  C
FIRES-RC2 1437  C     CROSS-SECTIONAL PROPERTIES ARE NOW CALCULATED
FIRES-RC2 1438  C      ( BASED ON AVERAGE OF STRESS STATE AT THE TWO SEGMENT ENDS )
FIRES-RC2 1439  C
FIRES-RC2 1440        DO 160 I=1,NCONC
FIRES-RC2 1441        SA=SA+AC(I)
FIRES-RC2 1442        AA=AC(I)*AMOD(I)
FIRES-RC2 1443        BE=BE+AA
FIRES-RC2 1444        YY=YC(I)
FIRES-RC2 1445        AA=AA*YY
FIRES-RC2 1446        DC=DC+AA
FIRES-RC2 1447        BI=BI+AA*YY
FIRES-RC2 1448    160 CONTINUE
FIRES-RC2 1449  C
FIRES-RC2 1450        IF (NSTL.EQ.0) GO TO 180
FIRES-RC2 1451        DO 170 I=1,NSTL
FIRES-RC2 1452        AA=AS(I)*AMOS(I)
FIRES-RC2 1453        BE=BE+AA
FIRES-RC2 1454        YY=YS(I)
FIRES-RC2 1455        AA=AA*YY
FIRES-RC2 1456        DC=DC+AA
FIRES-RC2 1457        BI=BI+AA*YY
FIRES-RC2 1458    170 CONTINUE
FIRES-RC2 1459  C
FIRES-RC2 1460    180 AREA(JSEG)=SA
FIRES-RC2 1461        DCG(JSEG)=DC/BE
FIRES-RC2 1462        AE(JSEG)=BE
FIRES-RC2 1463        AEI(JSEG)=BE
FIRES-RC2 1464        BI=BI-BE*DCG(JSEG)**2
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FIRES-RC2 1465          EI(JSEG)=BI
FIRES-RC2 1466          EII(JSEG)=BI
FIRES-RC2 1467   C
FIRES-RC2 1468   C      STORE ALL SEGMENT DATA ON FILES ISEG2 AND ITEMP2
FIRES-RC2 1469   C
FIRES-RC2 1470          ISIZE=7*NCONC+2*NSTL+1
FIRES-RC2 1471          WRITE (ITEMP2) (TEMPC(I),I=1,ISIZE)
FIRES-RC2 1472          ISIZE=25*NCONC+13*NSTL+10
FIRES-RC2 1473          WRITE (ISEG2) (AC(I),I=1,ISIZE)
FIRES-RC2 1474   C
FIRES-RC2 1475          RETURN
FIRES-RC2 1476   C
FIRES-RC2 1477   C
FIRES-RC2 1478   C
FIRES-RC2 1479      190 FORMAT (6(/)48H  -------INPUT ERROR - PROGRAM TERMINATED-------)
FIRES-RC2 1480      200 FORMAT (9A8)
FIRES-RC2 1481      210 FORMAT (I7,A1)
FIRES-RC2 1482      220 FORMAT (63H  ERROR HAS OCCURRED IN STRESS INDICATOR INPUT FOR PUNC
FIRES-RC2 1483         1HED DATA/9H  MEMBER ,I5,10H  SEGMENT ,I5/1X,9A8)
FIRES-RC2 1484          END
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FIRES-RC2 1485          SUBROUTINE INSTEP (X,Y,IBC,JS,FJ,U,DV,DPL,SP,AAW,DELR,SYSTIF,F,DEL
FIRES-RC2 1486         1F,FA,NCONCR,NSTEEL,DT,I0,I1,I2,I3,LCARD,NJ3,M)
FIRES-RC2 1487   C
FIRES-RC2 1488   C
FIRES-RC2 1489   C      SUBROUTINE  *INSTEP*  INITIALIZES THE SYSTEM AT THE
FIRES-RC2 1490   C      BEGINNING OF EACH TIME STEP
FIRES-RC2 1491   C
FIRES-RC2 1492   C
FIRES-RC2 1493          COMMON /TAP/ HED(10),ITEMP1,ITEMP2,ISEG1,ISEG2,NIN,NOUT,NPUNCH
FIRES-RC2 1494          COMMON /DYN/ NDT,NSTORE,NCMAX,NSMAX,NCONTL,NSTLTL,ISYSTM,IMEMB,ITO
FIRES-RC2 1495         1TAL,ITAPE
FIRES-RC2 1496          COMMON /BLK1/ NJ,NM,NBC,NXX,MAXBAN,NCRPS,NCRPC,NSHRINK,NCONV
FIRES-RC2 1497          COMMON /BLK2/ A(6,6),E(6,6)
FIRES-RC2 1498          COMMON /BLK3/ DIS(6),DISP(6),FX(21,7),SIJ(6,6),S(21,6),AF(15),FF(2
FIRES-RC2 1499         1,18),T(6,6),TSF(6,6)
FIRES-RC2 1500          COMMON /MEMB/ NNSEG(75)
FIRES-RC2 1501          COMMON C(1)
FIRES-RC2 1502          DIMENSION X(1), Y(1), IBC(1), JS(1), FJ(1), U(1), DV(1), DPL(1), S
FIRES-RC2 1503         1P(2,1), AAW(1), DELR(1), SYSTIF(NJ3,1), F(1), DELF(1), FA(1), NCON
FIRES-RC2 1504         2CR(1), NSTEEL(1)
FIRES-RC2 1505          DIMENSION IX(10), TF(10)
FIRES-RC2 1506   C
FIRES-RC2 1507   C      INITIALIZATION OF THE OVERALL STRUCTURAL SYSTEM
FIRES-RC2 1508   C         ( ON FIRST CALL OF SUBROUTINE ONLY - WHEN M .EQ. 1 )
FIRES-RC2 1509   C
FIRES-RC2 1510          IF (M.GT.1) GO TO 100
FIRES-RC2 1511   C
FIRES-RC2 1512   C      INITIALIZE SYSTEM VARIABLES
FIRES-RC2 1513   C
FIRES-RC2 1514          IF (I3.NE.0) WRITE (NOUT,170) I3,LCARD
FIRES-RC2 1515          DO 10 I=1,NJ3
FIRES-RC2 1516          DELR(I)=0.
FIRES-RC2 1517       10 DV(I)=0.0
FIRES-RC2 1518   C
FIRES-RC2 1519   C      INPUT NONZERO CONDITIONS AT JOINTS
FIRES-RC2 1520   C
FIRES-RC2 1521          JTT=0
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FIRES-RC2 1522          IF (I0.EQ.0) GO TO 40
FIRES-RC2 1523          WRITE (NOUT,180)
FIRES-RC2 1524          DO 30 KK=1,I0
FIRES-RC2 1525          JTT=1
FIRES-RC2 1526          READ (NIN,200) JT,(TF(J),J=1,3)
FIRES-RC2 1527          K=(JT-1)*3
FIRES-RC2 1528          DO 20 J=1,3
FIRES-RC2 1529       20 DV(K+J)=TF(J)
FIRES-RC2 1530       30 CONTINUE
FIRES-RC2 1531       40 IF (I1.EQ.0) GO TO 60
FIRES-RC2 1532          DO 50 KK=1,I1
FIRES-RC2 1533          JTT=1
FIRES-RC2 1534          READ (NIN,190) JT,(TF(J),J=1,9)
FIRES-RC2 1535          K=(JT-1)*3
FIRES-RC2 1536          DO 50 J=1,3
FIRES-RC2 1537          SP(1,K+J)=TF(J)
FIRES-RC2 1538          SP(2,K+J)=TF(J+3)
FIRES-RC2 1539          IF (TF(J+3).EQ.0.0) GO TO 50
FIRES-RC2 1540          WRITE (NOUT,160)
FIRES-RC2 1541          STOP
FIRES-RC2 1542       50 DPL(K+J)=TF(J+6)
FIRES-RC2 1543       60 CONTINUE
FIRES-RC2 1544    C
FIRES-RC2 1545    C     ADD LOAD INCREMENT FROM THIS TIME/LOAD STEP TO FORM
FIRES-RC2 1546    C     TOTAL SYSTEM LOAD VECTOR (EXCLUDING INTERSEGMENTAL CONTRIBUTIONS)
FIRES-RC2 1547    C
FIRES-RC2 1548          DO 70 I=1,NJ3
FIRES-RC2 1549       70 FJ(I)=FJ(I)+DV(I)
FIRES-RC2 1550    C
FIRES-RC2 1551    C     IF NONZERO JOINT LOADS OR BOUNDARY CONDITIONS WERE JUST INPUT,
FIRES-RC2 1552    C     PRINT THE NEW JOINT LOADING AND BOUNDARY CONDITIONS
FIRES-RC2 1553    C
FIRES-RC2 1554          IF (JTT.EQ.0) GO TO 90
FIRES-RC2 1555          DO 80 J=1,NJ
FIRES-RC2 1556          J1=(J-1)*3+1
FIRES-RC2 1557          J2=J1+1
FIRES-RC2 1558          J3=J1+2
FIRES-RC2 1559          WRITE (NOUT,210) J,FJ(J1),SP(1,J1),SP(2,J1),SP(2,J2),DPL(J1),FJ(J2
FIRES-RC2 1560         1),SP(2,J1),SP(1,J2),SP(2,J3),DPL(J2),FJ(J3),SP(2,J2),SP(2,J3),SP(1
FIRES-RC2 1561         2,J3),DPL(J3)
FIRES-RC2 1562       80 CONTINUE
FIRES-RC2 1563       90 MINIT=ITOTAL
FIRES-RC2 1564          IBLOCK=0
FIRES-RC2 1565    C
FIRES-RC2 1566    C     INITIALIZATION OF SUBSTRUCTURED MEMBERS
FIRES-RC2 1567    C     ( LOOP OVER ALL MEMBERS, WITH THE DO-LOOP IN THE MAIN PROGRAM )
FIRES-RC2 1568    C
FIRES-RC2 1569      100 CONTINUE
FIRES-RC2 1570    C
FIRES-RC2 1571    C     READ MEMBER CONTROL CARD (SEE SUBROUTINE INITIAL FOR EXPLANATION)
FIRES-RC2 1572    C
FIRES-RC2 1573          READ (NIN,220) MB1,MB2,MB,M1,TCONST,M2
FIRES-RC2 1574          IF (M.EQ.MB.AND.MB1.EQ.1HM) GO TO 110
FIRES-RC2 1575    C
FIRES-RC2 1576          WRITE (NOUT,230)
FIRES-RC2 1577          WRITE (NOUT,240) M,MB1,MB2,MB,M1,TCONST,M2
FIRES-RC2 1578          STOP
FIRES-RC2 1579    C
FIRES-RC2 1580      110 NSEG=NNSEG(M)
FIRES-RC2 1581          NM1=NSEG-1
FIRES-RC2 1582          NM31=3*NM1
FIRES-RC2 1583          NM32=NM31-3
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FIRES-RC2 1584          NM3=3*NSEG
FIRES-RC2 1585          NM3P1=(NSEG+1)*3
FIRES-RC2 1586    C
FIRES-RC2 1587          IF (NSEG.EQ.1) GO TO 140
FIRES-RC2 1588          DO 120 I=1,NM31
FIRES-RC2 1589          DELF(I)=0.0
FIRES-RC2 1590      120 F(I)=0.0
FIRES-RC2 1591          IF (M2.EQ.0) GO TO 140
FIRES-RC2 1592    C
FIRES-RC2 1593    C     INPUT NON-ZERO VALUES OF SUBSTRUCTURED MEMBERS LOAD VECTOR
FIRES-RC2 1594    C
FIRES-RC2 1595          READ (NIN,250) (F(I),I=1,NM31)
FIRES-RC2 1596          WRITE (NOUT,260) M,(I,I=1,NSEG)
FIRES-RC2 1597          II=6H  F-X
FIRES-RC2 1598          WRITE (NOUT,270) II,(F(I),I=1,NM31,3)
FIRES-RC2 1599          II=6H  F-Y
FIRES-RC2 1600          WRITE (NOUT,270) II,(F(I),I=2,NM31,3)
FIRES-RC2 1601          II=6H  F-M
FIRES-RC2 1602          WRITE (NOUT,270) II,(F(I),I=3,NM31,3)
FIRES-RC2 1603          DO 130 I=1,NM31
FIRES-RC2 1604          FA(I)=FA(I)+F(I)
FIRES-RC2 1605      130 CONTINUE
FIRES-RC2 1606      140 CONTINUE
FIRES-RC2 1607    C
FIRES-RC2 1608    C     SEGMENT INITIALIZATION
FIRES-RC2 1609    C     ( LOOP OVER ALL SEGMENTS IN THIS MEMBER )
FIRES-RC2 1610    C
FIRES-RC2 1611          DO 150 JSEG=1,NSEG
FIRES-RC2 1612    C
FIRES-RC2 1613    C     SET UP DYNAMIC STORAGE FOR THIS SEGMENT
FIRES-RC2 1614    C
FIRES-RC2 1615          NCONC=NCONCR(JSEG)
FIRES-RC2 1616          NSTL=NSTEEL(JSEG)
FIRES-RC2 1617          MINIT=MINIT+IBLOCK
FIRES-RC2 1618          IBLOCK=32*NCONC+15*NSTL+11
FIRES-RC2 1619          IF (ITAPE.EQ.0) IBLOCK=0
FIRES-RC2 1620          M14=IMEMB
FIRES-RC2 1621          M15=M14+NCMAX
FIRES-RC2 1622          M16=M15+NCMAX
FIRES-RC2 1623          M17=M16+NSMAX
FIRES-RC2 1624          M18=M17+NSMAX
FIRES-RC2 1625          M19=M18+NCMAX
FIRES-RC2 1626          M20=MINIT
FIRES-RC2 1627          M24=M20+2*NCONC+2*NSTL
FIRES-RC2 1628          M25=M24+NCONC
FIRES-RC2 1629          M26=M25+NCONC
FIRES-RC2 1630          M27=M26+NCONC
FIRES-RC2 1631          M28=M27+NCONC
FIRES-RC2 1632          M29=M28+NSTL
FIRES-RC2 1633          M32=M29+3*NSTL+2*NCONC
FIRES-RC2 1634          M33=M32+2*NCONC
FIRES-RC2 1635          M34=M33+2*NCONC
FIRES-RC2 1636          M35=M34+2*NCONC
FIRES-RC2 1637          M36=M35+2*NCONC
FIRES-RC2 1638          M37=M36+NCONC
FIRES-RC2 1639          M38=M37+2*NCONC
FIRES-RC2 1640          M39=M38+2*NCONC
FIRES-RC2 1641          M40=M39+NSTL
FIRES-RC2 1642          M41=M40+2*NSTL
FIRES-RC2 1643          M42=M41+2*NSTL
FIRES-RC2 1644          M43=M42+2*NCONC
FIRES-RC2 1645          MEFC=M43+2*NSTL
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FIRES-RC2 1646          MFU=MEFC+NCONC
FIRES-RC2 1647          M44=MFU+NCONC
FIRES-RC2 1648          M45=M44+10
FIRES-RC2 1649          M46=M45+NCONC
FIRES-RC2 1650          M47=M46+NSTL
FIRES-RC2 1651          M48=M47+NCONC
FIRES-RC2 1652          M49=M48+NCONC
FIRES-RC2 1653          M50=M49+NCONC
FIRES-RC2 1654          M51=M50+NCONC
FIRES-RC2 1655          M52=M51+NCONC
FIRES-RC2 1656          M53=M52+NSTL
FIRES-RC2 1657          M54=M53+NCONC
FIRES-RC2 1658   C
FIRES-RC2 1659   C      INITIALIZE SEGMENT VARIABLES
FIRES-RC2 1660   C
FIRES-RC2 1661          CALL INSSEG (NCONC,NSTL,C(M14),C(M15),C(M16),C(M17),C(M18),C(M19),
FIRES-RC2 1662         1C(M20),C(M24),C(M25),C(M26),C(M27),C(M28),C(M29),C(M32),C(M33),C(M
FIRES-RC2 1663         234),C(M35),C(M36),C(M37),C(M38),C(M39),C(M40),C(M41),C(M42),C(M43)
FIRES-RC2 1664         3,C(M45),C(M46),C(M47),C(M48),C(M49),C(M50),C(M51),C(M52),C(M53),C(
FIRES-RC2 1665         4M54),JSEG,M,M1,TCONST,DT,C(MEFC),C(MFU))
FIRES-RC2 1666   C
FIRES-RC2 1667     150 CONTINUE
FIRES-RC2 1668   C
FIRES-RC2 1669          RETURN
FIRES-RC2 1670   C
FIRES-RC2 1671   C
FIRES-RC2 1672   C
FIRES-RC2 1673     160 FORMAT (///52H STOP  -  NO OFF-DIAGONAL TERMS PERMITTED IN THIS VE
FIRES-RC2 1674         1,20HRSION OF FIRES-RC II)
FIRES-RC2 1675     170 FORMAT (//34H   .  .  .  PUNCHED DATA OF LEVEL ,I2,26H HAS BEEN RE
FIRES-RC2 1676         1QUESTED  .  . /20X,24HCARDS WILL BE LABELED   ,A3)
FIRES-RC2 1677     180 FORMAT (//61H   .  CHANGES IN STRUCTURAL LOADS AND BOUNDARY CONDIT
FIRES-RC2 1678         1IONS   .//62H JOINT     SYSTEM        SUPPORT STIFFNESS MATRIX     P
FIRES-RC2 1679         2RESCRIBED/62H           LOADS
FIRES-RC2 1680         3 DISPLS. /62H                          X          Y          R
FIRES-RC2 1681         4          )
FIRES-RC2 1682     190 FORMAT (I4,9E8.0)
FIRES-RC2 1683     200 FORMAT (I5,3E10.0)
FIRES-RC2 1684     210 FORMAT (/I3,1X,4H X  ,G10.3,2X,3G10.3,2X,G10.3/4X,4H Y  ,G10.3,2X,
FIRES-RC2 1685         13G10.3,2X,G10.3/4X,4H R  ,G10.3,2X,3G10.3,2X,G10.3/)
FIRES-RC2 1686     220 FORMAT (A1,A5,I4,I5,F10.0,I5)
FIRES-RC2 1687     230 FORMAT (6(/)48H  -------INPUT ERROR - PROGRAM TERMINATED-------)
FIRES-RC2 1688     240 FORMAT (//32H  INPUT ERROR FOR MEMBER NUMBER ,I5/1X,A1,A5,I4,I5,F1
FIRES-RC2 1689         10.0,I5)
FIRES-RC2 1690     250 FORMAT (6E10.0)
FIRES-RC2 1691     260 FORMAT (//7X,39H. . . INTERSEGMENTAL FORCES FOR MEMBER ,I4,6H . .
FIRES-RC2 1692         1.//7X,I1,1X,5I9)
FIRES-RC2 1693     270 FORMAT (/A6,F10.2,5F9.2)
FIRES-RC2 1694          END
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FIRES-RC2 1695          SUBROUTINE INSSEG (NCONC,NSTL,SIGC,EPC,SIGS,EPS,TC,TS,AC,AMOD,STRE
FIRES-RC2 1696         1,EPU,TES,AMOS,YIE,KRAT,KRAF,AKAK,AKK,STRC,EHC,SIC,STRS,EHS,SIS,ESH
FIRES-RC2 1697         2IFTC,ESHIFTS,TEMPC,TEMPS,SST,BCRP,CCRP,DCRP,ECRP,ET,SAVG,ISYM,JSEG
FIRES-RC2 1698         3,M,M1,TCONST,DT,EFC,FU)
FIRES-RC2 1699   C
FIRES-RC2 1700   C
FIRES-RC2 1701          COMMON /TAP/ HED(10),ITEMP1,ITEMP2,ISEG1,ISEG2,NIN,NOUT,NPUNCH
FIRES-RC2 1702          COMMON /DYN/ NDT,NSTORE,NCMAX,NSMAX,NCONTL,NSTLTL,ISYSTM,IMEMB,ITO
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FIRES-RC2 1703          ITAL,ITAPE
FIRES-RC2 1704           COMMON /BLK1/ NJ,NM,NBC,NXX,MAXBAN,NCRPS,NCRPC,NSHRINK,NCONV
FIRES-RC2 1705           COMMON /BLK3/ DIS(6),DISP(6),FX(21,7),SIJ(6,6),S(21,6),AF(15),FF(2
FIRES-RC2 1706          1,18),T(6,6),TSF(6,6)
FIRES-RC2 1707           DIMENSION SIGC(1), EPC(1), SIGS(1), EPS(1), TC(1), TS(1)
FIRES-RC2 1708           DIMENSION AMOD(1), STRE(1), EPU(1), TES(1), AMOS(1), YIE(1), AC(1)
FIRES-RC2 1709          1, KRAT(2,1), KRAF(2,1), AKAK(2,1), AKK(2,1), STRC(1), EHC(2,1), SI
FIRES-RC2 1710          2C(2,1), STRS(1), EHS(2,1), SIS(2,1), ESHIFTC(2,1), ESHIFTS(2,1), T
FIRES-RC2 1711          3EMPC(1), TEMPS(1), SST(1), BCRP(1), CCRP(1), DCRP(1), ECRP(1), ET(
FIRES-RC2 1712          41), SAVG(1), EFC(1), FU(1)
FIRES-RC2 1713           INTEGER AKK,AKAK
FIRES-RC2 1714    C
FIRES-RC2 1715    C
FIRES-RC2 1716    C      READ ALL SEGMENT DATA FROM FILES ISEG1 AND ITEMP1
FIRES-RC2 1717    C
FIRES-RC2 1718           IF (NDT.GT.1.AND.ITAPE.EQ.1) GO TO 10
FIRES-RC2 1719    C
FIRES-RC2 1720           IF (M.EQ.1.AND.JSEG.EQ.1) REWIND ITEMP1
FIRES-RC2 1721           ISIZE=7*NCONC+2*NSTL+1
FIRES-RC2 1722           READ (ITEMP1) (TEMPC(I),I=1,ISIZE)
FIRES-RC2 1723           IF (ITAPE.EQ.1) GO TO 10
FIRES-RC2 1724           ISIZE=25*NCONC+13*NSTL+10
FIRES-RC2 1725           READ (ISEG1) (AC(I),I=1,ISIZE)
FIRES-RC2 1726    C
FIRES-RC2 1727    C      DETERMINE INELASTIC DEFORMATION ASSOCIATED WITH EACH SUBSLICE AT
FIRES-RC2 1728    C      END OF LAST TIME STEP AND STORE TEMPERATURE AT END OF LAST TIME
FIRES-RC2 1729    C      STEP
FIRES-RC2 1730    C
FIRES-RC2 1731       10 DO 40 I=1,NCONC
FIRES-RC2 1732          DO 40 J=1,2
FIRES-RC2 1733          IF (AKK(J,I)+AKAK(J,I)+KRAF(J,I)) 20,20,30
FIRES-RC2 1734       20 XXX=STRI(EHC(J,I),AMOD(I),SIC(J,I),EFC(I),FU(I),EPU(I),ESHIFTC(J,I
FIRES-RC2 1735         1))
FIRES-RC2 1736       30 CONTINUE
FIRES-RC2 1737          TC(I)=TEMPC(I)
FIRES-RC2 1738       40 CONTINUE
FIRES-RC2 1739          IF (NSTL.EQ.0) GO TO 60
FIRES-RC2 1740          DO 50 I=1,NSTL
FIRES-RC2 1741          DO 50 J=1,2
FIRES-RC2 1742          EPSY=YIE(I)/AMOS(I)
FIRES-RC2 1743          XXX=SSI(EHS(J,I),EPSY,AMOS(I),SIS(J,I),ESHIFTS(J,I))
FIRES-RC2 1744          TS(I)=TEMPS(I)
FIRES-RC2 1745       50 CONTINUE
FIRES-RC2 1746    C
FIRES-RC2 1747    C      INPUT CURRENT TEMPERATURE DISTRIBUTION FOR SEGMENT CROSS-SECTION
FIRES-RC2 1748    C
FIRES-RC2 1749       60 CALL TEMPIN (M1,TCONST,TEMPC,TEMPS,NCONC,NSTL,M,JSEG,ISYM,AMOD)
FIRES-RC2 1750    C
FIRES-RC2 1751    C      DETERMINE MATERIAL PROPERTIES FOR SEGMENT CROSS-SECTION
FIRES-RC2 1752    C
FIRES-RC2 1753           CALL PROP (M1,TCONST,TEMPC,TEMPS,NCONC,NSTL,AMOD,STRE,EPU,TES,AMOS
FIRES-RC2 1754          1,YIE,EFC,FU)
FIRES-RC2 1755    C
FIRES-RC2 1756    C      LOOP FOR CONCRETE SUBSLICES TO CALCULATE FREE STRAINS
FIRES-RC2 1757    C
FIRES-RC2 1758           DO 110 I=1,NCONC
FIRES-RC2 1759    C
FIRES-RC2 1760    C      SET PERMANENT CRACKING AND CRUSHING FLAGS ON BASIS OF SUBSLICE
FIRES-RC2 1761    C      STATUS AT END OF LAST TIME STEP
FIRES-RC2 1762    C
FIRES-RC2 1763           DO 70 J=1,2
FIRES-RC2 1764           IF (AKK(J,I).EQ.1) AKAK(J,I)=1
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FIRES-RC2 1765      70 IF (KRAF(J,I).EQ.1) KRAT(J,I)=1
FIRES-RC2 1766   C
FIRES-RC2 1767         TT=TEMPC(I)
FIRES-RC2 1768         TTT=(TT+TC(I))/2.
FIRES-RC2 1769   C
FIRES-RC2 1770   C     CALCULATE FREE THERMAL STRAIN
FIRES-RC2 1771   C
FIRES-RC2 1772         STRC(I)=VMATL(1,TTT)*(TT-TC(I))+STRC(I)
FIRES-RC2 1773   C
FIRES-RC2 1774   C     CALCULATE FREE SHRINKAGE STRAIN
FIRES-RC2 1775   C
FIRES-RC2 1776         IF (NSHRINK.NE.0) STRC(I)=STRC(I)-SHRINK(DT,TC(I),SST(I))
FIRES-RC2 1777   C
FIRES-RC2 1778         SIG1=SAVG(I)
FIRES-RC2 1779         IF (AKAK(1,I).EQ.1.OR.KRAF(1,I).EQ.1) GO TO 80
FIRES-RC2 1780         IF (AKAK(2,I).EQ.1.OR.KRAF(2,I).EQ.1) GO TO 80
FIRES-RC2 1781   C
FIRES-RC2 1782   C     CALCULATE NEW AVERAGE STRESS RESULTING FROM THERMAL SHIFT IN THE
FIRES-RC2 1783   C     STRESS STRAIN DIAGRAM
FIRES-RC2 1784   C
FIRES-RC2 1785         S1=STR(EHC(1,I),AMOD(I),STRE(I),EFC(I),FU(I),EPU(I),ESHIFTC(1,I))
FIRES-RC2 1786         S2=STR(EHC(2,I),AMOD(I),STRE(I),EFC(I),FU(I),EPU(I),ESHIFTC(2,I))
FIRES-RC2 1787         SAVG(I)=(S1+S2)/2.
FIRES-RC2 1788         GO TO 90
FIRES-RC2 1789   C
FIRES-RC2 1790   C     THERE IS NO TEMPERATURE SHIFT CORRECTION FOR A SUBSLICE
FIRES-RC2 1791   C     THAT HAS BEEN PREVIOUSLY CRACKED OR CRUSHED
FIRES-RC2 1792   C
FIRES-RC2 1793      80 SAVG(I)=(SIC(1,I)+SIC(2,I))/2.
FIRES-RC2 1794   C
FIRES-RC2 1795      90 CONTINUE
FIRES-RC2 1796         IF (NCRPC.EQ.0) GO TO 100
FIRES-RC2 1797   C
FIRES-RC2 1798   C     CALCULATE FREE CREEP STRAIN
FIRES-RC2 1799   C
FIRES-RC2 1800         TT=0.5*(TC(I)+TEMPC(I))
FIRES-RC2 1801         DSTRC=CRPC(DT,SIG1,SAVG(I),TT,BCRP(I),CCRP(I),DCRP(I),ECRP(I),STRE
FIRES-RC2 1802        1(I))
FIRES-RC2 1803         STRC(I)=STRC(I)+DSTRC
FIRES-RC2 1804     100 CONTINUE
FIRES-RC2 1805     110 CONTINUE
FIRES-RC2 1806   C
FIRES-RC2 1807   C     LOOP FOR EACH STEEL SUBSLICE TO CALCULATE FREE STRAINS
FIRES-RC2 1808   C
FIRES-RC2 1809         IF (NSTL.EQ.0) GO TO 130
FIRES-RC2 1810         DO 120 I=1,NSTL
FIRES-RC2 1811         TT=TEMPS(I)
FIRES-RC2 1812         TTT=(TT+TS(I))/2.
FIRES-RC2 1813   C
FIRES-RC2 1814   C     CALCULATE FREE THERMAL STRAIN
FIRES-RC2 1815   C
FIRES-RC2 1816         STRS(I)=VMATL(8,TTT)*(TT-TS(I))+STRS(I)
FIRES-RC2 1817   C
FIRES-RC2 1818   C     CALCULATE  NEW        STRESS RESULTING FROM THERMAL SHIFT IN THE
FIRES-RC2 1819   C     STRESS STRAIN DIAGRAM
FIRES-RC2 1820   C
FIRES-RC2 1821         EPSY=YIE(I)/AMOS(I)
FIRES-RC2 1822         S1=SS(EHS(1,I),EPSY,AMOS(I),YIE(I),ESHIFTS(1,I))
FIRES-RC2 1823         S2=SS(EHS(2,I),EPSY,AMOS(I),YIE(I),ESHIFTS(2,I))
FIRES-RC2 1824         SIG1=(S1+S2)/2.
FIRES-RC2 1825         IF (NCRPS.EQ.0) GO TO 120
FIRES-RC2 1826   C
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FIRES-RC2 1827  C      CALCULATE FREE CREEP STRAIN
FIRES-RC2 1828  C
FIRES-RC2 1829         TT=0.5*(TS(I)+TEMPS(I))
FIRES-RC2 1830  C
FIRES-RC2 1831         DDD=CRPS(TT,DT,SIGI,ET(I))
FIRES-RC2 1832         STRS(I)=STRS(I)+DDD
FIRES-RC2 1833  C
FIRES-RC2 1834     120 CONTINUE
FIRES-RC2 1835  C
FIRES-RC2 1836  C      STORE SEGMENT DATA ON FILES ISEG2 AND ITEMP2
FIRES-RC2 1837  C
FIRES-RC2 1838     130 IF (ITAPE.EQ.1) RETURN
FIRES-RC2 1839         ISIZE=7*NCONC+2*NSTL+1
FIRES-RC2 1840         WRITE (ITEMP2) (TEMPC(I),I=1,ISIZE)
FIRES-RC2 1841         ISIZE=25*NCONC+13*NSTL+10
FIRES-RC2 1842         WRITE (ISEG2) (AC(I),I=1,ISIZE)
FIRES-RC2 1843  C
FIRES-RC2 1844         RETURN
FIRES-RC2 1845  C
FIRES-RC2 1846         END
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FIRES-RC2 1847         SUBROUTINE MEMBERS (X,Y,IBC,JS,FJ,U,DV,DPL,SP,AAW,DELR,SYSTIF,MI,M
FIRES-RC2 1848        1J,SEGL,AE,EI,DCG,W,DELF,FA,PA,BM,ASTRAIN,ACURV,CRUSH,CRACK,NCONCP,
FIRES-RC2 1849        2NSTEEL,NJ3,ERP,LOOP,M)
FIRES-RC2 1850  C
FIRES-RC2 1851  C
FIRES-RC2 1852  C      SUBROUTINE  *MEMBERS*  CALCULATES THE SUBSTRUCTURED MEMBER TANGENT
FIRES-RC2 1853  C      STIFFNESS AND INTERNAL FORCES ON THE BASIS OF THE CURRENT
FIRES-RC2 1854  C      DEFORMED SHAPE OF THE STRUCTURE
FIRES-RC2 1855  C
FIRES-RC2 1856  C
FIRES-RC2 1857  C                        ***   N O T E   ***
FIRES-RC2 1858  C
FIRES-RC2 1859  C      THROUGHOUT THE ENTIRE PROGRAM THE SAME SIGN CONVENTION IS USED
FIRES-RC2 1860  C      FOR BOTH INTERNAL FORCES AND EXTERNAL FORCES, SUCH THAT
FIRES-RC2 1861  C                        F (EXTERNAL)  -  F (INTERNAL)  =  0
FIRES-RC2 1862  C
FIRES-RC2 1863  C      THE SIGN CONVENTION FOR JOINT, MEMBER END, AND SEGMENT END FORCES
FIRES-RC2 1864  C      AND MOMENTS IS
FIRES-RC2 1865  C
FIRES-RC2 1866  C         FX    -    POSITIVE WITH X-AXIS
FIRES-RC2 1867  C                    (GLOBAL X-AXIS FOR JOINTS
FIRES-RC2 1868  C                    AND MEMBER X-AXIS (I TO J)
FIRES-RC2 1869  C                    FOR MEMBERS AND SEGMENTS)
FIRES-RC2 1870  C         FY    -    POSITIVE WITH Y-AXIS
FIRES-RC2 1871  C         M     -    POSITIVE COUNTERCLOCKWISE
FIRES-RC2 1872  C
FIRES-RC2 1873  C      SIGN CONVENTION FOR INTERNAL FORCES WITHIN CROSS-SECTION IS
FIRES-RC2 1874  C
FIRES-RC2 1875  C         F     -    POSITIVE IF TENSION
FIRES-RC2 1876  C         M     -    POSITIVE FOR BENDING DEFLECTION IN THE
FIRES-RC2 1877  C                    -Y DIRECTION (DOWNWARDS)
FIRES-RC2 1878  C
FIRES-RC2 1879  C
FIRES-RC2 1880         COMMON /TAP/ HED(10),ITEMP1,ITEMP2,ISEG1,ISEG2,NIN,NOUT,NPUNCH
FIRES-RC2 1881         COMMON /DYN/ NDT,NSTORE,NCMAX,NSMAX,NCONTL,NSTLTL,ISYSTM,INEMA,ITO
FIRES-RC2 1882        1TAL,ITAPE
FIRES-RC2 1883         COMMON /BLK1/ NJ,NM,NBC,NXX,MAXBAN,NCRPS,NCRPC,NSHRINK,NCONV
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FIRES-RC2 1884          COMMON /BLK2/ A(6,6),E(6,6)
FIRES-RC2 1885          COMMON /BLK3/ DIS(6),DISP(6),FX(21,7),SIJ(6,6),S(21,6),AF(15),FF(2
FIRES-RC2 1886         1,18),T(6,6),TSF(6,6)
FIRES-RC2 1887          COMMON /MEMB/ NNSEG(75)
FIRES-RC2 1888          COMMON C(1)
FIRES-RC2 1889          DIMENSION X(1), Y(1), IBC(1), JS(1), FJ(1), U(1), DV(1), DPL(1), S
FIRES-RC2 1890         1P(2,1), AAW(1), DELR(1), SYSTIF(NJ3,1), ERP(1), IX(3), SEGL(1), AE
FIRES-RC2 1891         2(1), EI(1), DCG(1), W(1), DELF(1), FA(1), PA(2,1), BM(2,1), ASTRAI
FIRES-RC2 1892         3N(2,1), ACURV(2,1), CRUSH(2,1), CRACK(2,1), NCONCR(1), NSTEEL(1)
FIRES-RC2 1893   C
FIRES-RC2 1894   C
FIRES-RC2 1895   C      INITIALIZE STRUCTURAL SYSTEM FOR THIS ITERATION
FIRES-RC2 1896   C         ( ON FIRST CALL OF SUBROUTINE ONLY - WHEN M .EQ. 1 )
FIRES-RC2 1897   C
FIRES-RC2 1898          IF (M.GT.1) GO TO 20
FIRES-RC2 1899   C
FIRES-RC2 1900   C         U  -  JOINT DISPLACEMENTS AT START OF THIS ITERATION
FIRES-RC2 1901   C         DV -  OUT-OF-BALANCE FORCES AT JOINTS
FIRES-RC2 1902   C         DELR- DISPLACEMENT INCREMENT FROM PREVIOUS ITERATION
FIRES-RC2 1903   C
FIRES-RC2 1904          DO 10 I=1,NJ3
FIRES-RC2 1905          U(I)=U(I)+DELR(I)
FIRES-RC2 1906          DV(I)=FJ(I)
FIRES-RC2 1907          SYSTIF(I,1)=1.0
FIRES-RC2 1908          DO 10 J=2,MAXBAN
FIRES-RC2 1909       10 SYSTIF(I,J)=0.0
FIRES-RC2 1910          MINIT=ITOTAL
FIRES-RC2 1911          IBLOCK=0
FIRES-RC2 1912   C
FIRES-RC2 1913   C      CALCULATIONS FOR EACH SUBSTRUCTURED MEMBER
FIRES-RC2 1914   C      ( LOOP OVER ALL MEMBERS, WITH THE DO-LOOP IN THE MAIN PROGRAM )
FIRES-RC2 1915   C
FIRES-RC2 1916       20 CONTINUE
FIRES-RC2 1917   C
FIRES-RC2 1918          NSEG=NNSEG(M)
FIRES-RC2 1919          NM3=3*NSEG
FIRES-RC2 1920          NM31=3*(NSEG-1)
FIRES-RC2 1921          NM32=NM31-3
FIRES-RC2 1922          NM3P1=NM3+3
FIRES-RC2 1923          NM1=NSEG-1
FIRES-RC2 1924   C
FIRES-RC2 1925   C      CALCULATE DIRECTION COSINES AND THE TRANSFORMATION MATRIX ( A )
FIRES-RC2 1926   C
FIRES-RC2 1927          DX=X(MJ)-X(MI)
FIRES-RC2 1928          DY=Y(MJ)-Y(MI)
FIRES-RC2 1929          D=SQRT(DX*DX+DY*DY)
FIRES-RC2 1930          A(1,1)=DX/D
FIRES-RC2 1931          A(2,2)=A(1,1)
FIRES-RC2 1932          A(1,2)=DY/D
FIRES-RC2 1933          A(2,1)=-A(1,2)
FIRES-RC2 1934          DO 30 J=1,2
FIRES-RC2 1935          DO 30 K=1,2
FIRES-RC2 1936       30 A(J+3,K+3)=A(J,K)
FIRES-RC2 1937   C
FIRES-RC2 1938   C      FOR FIRST LOOP OF TIME STEP ITERATION, GO DIRECTLY TO STIFFNESS
FIRES-RC2 1939   C      AND INTERNAL FORCES CALCULATIONS, SINCE THE DEFORMED CONFIGURATION
FIRES-RC2 1940   C      OF THE SUBSTRUCTURED MEMBER IS ALREADY KNOWN
FIRES-RC2 1941   C
FIRES-RC2 1942          IF (LOOP.EQ.1) GO TO 140
FIRES-RC2 1943   C
FIRES-RC2 1944   C      TRANSFORM JOINT DISPLACEMENT INCREMENT TO MEMBER REFERENCE AXES
FIRES-RC2 1945   C
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FIRES-RC2 1946          DO 40 J=1,3
FIRES-RC2 1947          J1=(MI-1)*3+J
FIRES-RC2 1948          J2=(MJ-1)*3+J
FIRES-RC2 1949          DIS(J)=DELR(J1)
FIRES-RC2 1950       40 DIS(J+3)=DELR(J2)
FIRES-RC2 1951          DO 60 J=1,6
FIRES-RC2 1952          D=0.0
FIRES-RC2 1953          DO 50 K=1,6
FIRES-RC2 1954       50 D=D+A(J,K)*DIS(K)
FIRES-RC2 1955       60 DISP(J)=D
FIRES-RC2 1956   C
FIRES-RC2 1957   C      CHECK FOR A ONE SEGMENT MEMBER
FIRES-RC2 1958   C
FIRES-RC2 1959          IF (NSEG.NE.1) GO TO 80
FIRES-RC2 1960   C
FIRES-RC2 1961          DO 70 J=1,6
FIRES-RC2 1962       70 W(J)=DISP(J)+W(J)
FIRES-RC2 1963          GO TO 140
FIRES-RC2 1964       80 CONTINUE
FIRES-RC2 1965   C
FIRES-RC2 1966   C      FORM STIFFNESS MATRIX OF SUBSTRUCTURED MEMBER
FIRES-RC2 1967   C
FIRES-RC2 1968          CALL FORMK (SEGL,AE,EI,DCG,M)
FIRES-RC2 1969   C
FIRES-RC2 1970   C      FORM LOAD VECTOR FOR SUBSTRUCTURED MEMBER
FIRES-RC2 1971   C
FIRES-RC2 1972          DO 90 J=1,NM31
FIRES-RC2 1973       90 FX(J,1)=DELF(J)
FIRES-RC2 1974          DO 100 J=1,3
FIRES-RC2 1975          L=J+NM32
FIRES-RC2 1976          DO 100 K=1,3
FIRES-RC2 1977          KI=K+3
FIRES-RC2 1978          FX(J,1)=FX(J,1)-SIJ(K,J+3)*DISP(K)
FIRES-RC2 1979      100 FX(L,1)=FX(L,1)-SIJ(KI,J)*DISP(KI)
FIRES-RC2 1980          DO 110 J=1,NM31
FIRES-RC2 1981          DO 110 K=1,6
FIRES-RC2 1982      110 S(J,K)=S(J+3,K)
FIRES-RC2 1983   C
FIRES-RC2 1984   C      SOLVE FOR CURRENT DEFORMED SHAPE OF SUBSTRUCTURED MEMBER
FIRES-RC2 1985   C
FIRES-RC2 1986          CALL BANDEC (S,FX,NM31,6,1,21,6,7)
FIRES-RC2 1987   C
FIRES-RC2 1988          DO 120 J=1,3
FIRES-RC2 1989          L=J+NM3
FIRES-RC2 1990          W(J)=DISP(J)+W(J)
FIRES-RC2 1991      120 W(L)=DISP(J+3)+W(L)
FIRES-RC2 1992          DO 130 J=4,NM3
FIRES-RC2 1993      130 W(J)=FX(J-3,1)+W(J)
FIRES-RC2 1994      140 CONTINUE
FIRES-RC2 1995   C
FIRES-RC2 1996   C      LOOP OVER EACH SEGMENT IN SUBSTRUCTURED MEMBER
FIRES-RC2 1997   C      TO FIND STIFFNESS AND INTERNAL FORCES BASED ON
FIRES-RC2 1998   C      THE CURRENT DEFORMED SHAPE OF THE MEMBER ( W )
FIRES-RC2 1999   C
FIRES-RC2 2000          DO 150 J=1,NSEG
FIRES-RC2 2001   C
FIRES-RC2 2002   C      SET UP DYNAMIC STORAGE FOR THIS SEGMENT
FIRES-RC2 2003   C
FIRES-RC2 2004          NCONC=NCONCR(J)
FIRES-RC2 2005          NSTL=NSTEEL(J)
FIRES-RC2 2006          MINIT=MINIT+IBLOCK
FIRES-RC2 2007          IBLOCK=32*NCONC+15*NSTL+11
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FIRES-RC2 2008          IF (ITAPE.EQ.0) IBLOCK=0
FIRES-RC2 2009          M14=IMEMB
FIRES-RC2 2010          M15=M14+NCMAX
FIRES-RC2 2011          M16=M15+NCMAX
FIRES-RC2 2012          M17=M16+NSMAX
FIRES-RC2 2013          M20=MINIT
FIRES-RC2 2014          M21=M20+NCONC
FIRES-RC2 2015          M22=M21+NCONC
FIRES-RC2 2016          M23=M22+NSTL
FIRES-RC2 2017          M24=M23+NSTL
FIRES-RC2 2018          M25=M24+NCONC
FIRES-RC2 2019          M26=M25+NCONC
FIRES-RC2 2020          M27=M26+NCONC
FIRES-RC2 2021          M28=M27+NCONC
FIRES-RC2 2022          M29=M28+NSTL
FIRES-RC2 2023          M30=M29+NSTL
FIRES-RC2 2024          M31=M30+2*NCONC
FIRES-RC2 2025          M32=M31+2*NSTL
FIRES-RC2 2026          M33=M32+2*NCONC
FIRES-RC2 2027          M34=M33+2*NCONC
FIRES-RC2 2028          M35=M34+2*NCONC
FIRES-RC2 2029          M36=M35+2*NCONC
FIRES-RC2 2030          M37=M36+NCONC
FIRES-RC2 2031          M38=M37+2*NCONC
FIRES-RC2 2032          M39=M38+2*NCONC
FIRES-RC2 2033          M40=M39+NSTL
FIRES-RC2 2034          M41=M40+2*NSTL
FIRES-RC2 2035          M42=M41+2*NSTL
FIRES-RC2 2036          M43=M42+2*NCONC
FIRES-RC2 2037          MEFC=M43+2*NSTL
FIRES-RC2 2038          MFU=MEFC+NCONC
FIRES-RC2 2039    C
FIRES-RC2 2040          CALL MEMSEG (NCONC,NSTL,C(M14),C(M15),C(M16),C(M17),C(M20),C(M21),
FIRES-RC2 2041         1C(M22),C(M23),C(M24),C(M25),C(M26),C(M27),C(M28),C(M29),C(M30),C(M
FIRES-RC2 2042         231),C(M32),C(M33),C(M34),C(M35),C(M36),C(M37),C(M38),C(M39),C(M40)
FIRES-RC2 2043         3,C(M41),C(M42),C(M43),SEGL,AE,EI,DCG,W,PA,BM,ASTRAIN,ACURV,CRUSH,C
FIRES-RC2 2044         4RACK,NCONCR,NSTEEL,J,LOOP,C(MEFC),C(MFU))
FIRES-RC2 2045    C
FIRES-RC2 2046      150 CONTINUE
FIRES-RC2 2047    C
FIRES-RC2 2048    C     REFORM MEMBER STIFFNESS MATRIX
FIRES-RC2 2049    C
FIRES-RC2 2050          CALL FORMK (SEGL,AE,EI,DCG,M)
FIRES-RC2 2051    C
FIRES-RC2 2052          IF (NSEG.NE.1) GO TO 170
FIRES-RC2 2053    C
FIRES-RC2 2054    C     FOR ONE SEGMENT MEMBERS ADD INTERNAL FORCE TO JOINTS
FIRES-RC2 2055    C
FIRES-RC2 2056          DO 160 J=1,3
FIRES-RC2 2057          DIS(J)=FF(1,J)
FIRES-RC2 2058      160 DIS(J+3)=FF(2,J)
FIRES-RC2 2059    C
FIRES-RC2 2060          CALL STIFF (NM31,NM32,NJ3,MI,MJ,DELF,DV,SYSTIF,FJ)
FIRES-RC2 2061          GO TO 200
FIRES-RC2 2062    C
FIRES-RC2 2063    C     FOR MEMBERS WITH MORE THAN ONE SEGMENT
FIRES-RC2 2064    C     COMPUTE TOTAL ACTIONS ON SEGMENTS ENDS BY ADDING EXTERNALY
FIRES-RC2 2065    C     APPLIED LOADS
FIRES-RC2 2066    C
FIRES-RC2 2067      170 CONTINUE
FIRES-RC2 2068          DO 180 L=1,NM31
FIRES-RC2 2069      180 AF(L)=FF(2,L)+FF(1,L+3)
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FIRES-RC2 2070  C
FIRES-RC2 2071  C
FIRES-RC2 2072  C      CALCULATE OUT-OF-BALANCE FORCES FOR SUBSTRUCTURED MEMBER AND
FIRES-RC2 2073  C      AND CHECK AGAINST PERMISSIBLE ERROR LEVELS
FIRES-RC2 2074  C
FIRES-RC2 2075         DO 190 J=1,NM1
FIRES-RC2 2076         DO 190 K=1,3
FIRES-RC2 2077         L=3*(J-1)+K
FIRES-RC2 2078         AA=FA(L)-AF(L)
FIRES-RC2 2079         DELF(L)=AA
FIRES-RC2 2080         IF (ABS(AA).GT.ERP(K)) NCONV=NCONV+1
FIRES-RC2 2081     190 CONTINUE
FIRES-RC2 2082  C
FIRES-RC2 2083  C      CALL SUBROUTINE CONDENS TO OBTAIN MEMBER STIFFNESS AND LOAD
FIRES-RC2 2084  C      VECTOR THROUGH PROCESS OF STATIC CONDENSATION
FIRES-RC2 2085  C
FIRES-RC2 2086         CALL CONDENS (NM31,NM32,NJ3,MI,MJ,DELF,DV,SYSTIF,FJ)
FIRES-RC2 2087  C
FIRES-RC2 2088     200 CONTINUE
FIRES-RC2 2089         IF (M.LT.NM) RETURN
FIRES-RC2 2090  C
FIRES-RC2 2091  C      FORM GLOBAL OUT-OF-BALANCE LOAD VECTOR  ( DELR )
FIRES-RC2 2092  C
FIRES-RC2 2093         DO 210 I=1,NJ3
FIRES-RC2 2094     210 DELR(I)=DV(I)
FIRES-RC2 2095  C
FIRES-RC2 2096  C      MODIFY STRUCTURAL STIFFNESS MATRIX FOR SUPPORT SPRING STIFFNESSES
FIRES-RC2 2097  C      AND FOR SUPPORT DISPLACEMENTS IF ANY
FIRES-RC2 2098  C
FIRES-RC2 2099         DO 220 KK=1,NJ
FIRES-RC2 2100         JJ=(KK-1)*3+1
FIRES-RC2 2101         II=JJ+2
FIRES-RC2 2102         J=0
FIRES-RC2 2103         DO 220 I=JJ,II
FIRES-RC2 2104         J=J+1
FIRES-RC2 2105         AAW(I)=-U(I)*SP(1,I)
FIRES-RC2 2106         DELR(I)=DELR(I)+AAW(I)
FIRES-RC2 2107         SYSTIF(I,I)=SYSTIF(I,I)+SP(I,I)
FIRES-RC2 2108         IF (DPL(I).NE.0.0) DELR(I)=DELR(I)-SP(I)*DPL(I)
FIRES-RC2 2109     220 CONTINUE
FIRES-RC2 2110         DO 240 I=1,NJ3
FIRES-RC2 2111         IF (SYSTIF(I,I).NE.1.0) GO TO 230
FIRES-RC2 2112         DELR(I)=0.
FIRES-RC2 2113         GO TO 240
FIRES-RC2 2114     230 SYSTIF(I,I)=SYSTIF(I,I)-1.0
FIRES-RC2 2115     240 CONTINUE
FIRES-RC2 2116  C
FIRES-RC2 2117  C      CALCULATE THE OUT-OF-BALANCE FORCES FOR THE OVERALL STRUCTURAL
FIRES-RC2 2118  C      SYSTEM AND COMPARE AGAINST PERMISSIBLE ERROR
FIRES-RC2 2119  C
FIRES-RC2 2120         I=0
FIRES-RC2 2121         DO 250 II=1,NJ
FIRES-RC2 2122         DO 250 JJ=1,3
FIRES-RC2 2123         I=I+1
FIRES-RC2 2124         ERROR=DELR(I)
FIRES-RC2 2125         ERROR=ABS(ERROR)
FIRES-RC2 2126         IF (ERROR.GT.ERP(JJ)) NCONV=NCONV+1
FIRES-RC2 2127     250 CONTINUE
FIRES-RC2 2128  C
FIRES-RC2 2129  C
FIRES-RC2 2130         RETURN
FIRES-RC2 2131  C
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FIRES-RC2 2132  C
FIRES-RC2 2133        END


FIRES-RC2 2134        SUBROUTINE MEMSEG (NCONC,NSTL,SIGC,EPC,SIGS,EPS,AC,YC,AS,YS,AMOD,S
FIRES-RC2 2135       1TRE,EPU,TES,AMOS,YIE,AR,ARS,KRAT,KRAF,AKAK,AKK,STRC,EHC,SIC,STRS,E
FIRES-RC2 2136       2HS,SIS,ESHIFTC,ESHIFTS,SEGL,AE,EI,DCG,W,PA,BM,ASTRAIN,ACURV,CRUSH,
FIRES-RC2 2137       3CRACK,NCONCR,NSTEEL,J,LOOP,EFC,FU)
FIRES-RC2 2138  C
FIRES-RC2 2139  C
FIRES-RC2 2140        COMMON /TAP/ HED(10),ITEMP1,ITEMP2,ISEG1,ISEG2,NIN,NOUT,NPUNCH
FIRES-RC2 2141        COMMON /BLK1/ NJ,NM,NBC,NXX,MAXBAN,NCFPS,NCRPC,NSHRINK,NCONV
FIRES-RC2 2142        COMMON /BLK2/ A(6,6),E(6,6)
FIRES-RC2 2143        COMMON /BLK3/ DIS(6),DISP(6),FX(21,7),SIJ(6,6),S(21,6),AF(15),FF(2
FIRES-RC2 2144       1,18),T(6,6),TSF(6,6)
FIRES-RC2 2145        COMMON /DYN/ NDT,NSTORE,NCMAX,NSMAX,NCONTL,NSTLTL,ISYSTM,IMEMB,ITO
FIRES-RC2 2146       1TAL,ITAPE
FIRES-RC2 2147        DIMENSION SIGC(1), EPC(1), SIGS(1), EPS(1), AC(1), YC(1), AS(1), Y
FIRES-RC2 2148       1S(1), AMOD(1), STRE(1), EPU(1), TES(1), AMOS(1), YIE(1), AR(2,1),
FIRES-RC2 2149       2ARS(2,1), KRAT(2,1), KRAF(2,1), AKAK(2,1), AKK(2,1), STRC(1), EHC(
FIRES-RC2 2150       32,1), SIC(2,1), STRS(1), EHS(2,1), SIS(2,1), ESHIFTC(2,1), ESHIFTS
FIRES-RC2 2151       4(2,1), SEGL(1), AE(1), EI(1), DCG(1), W(1), PA(2,1), BM(2,1), ASTR
FIRES-RC2 2152       5AIN(2,1), ACURV(2,1), CRUSH(2,1), CRACK(2,1), NCONCR(1), NSTEEL(1)
FIRES-RC2 2153       6, EFC(1), FU(1)
FIRES-RC2 2154        INTEGER AKAK,AKK
FIRES-RC2 2155  C
FIRES-RC2 2156  C     READ IN SEGMENT DATA FROM STORAGE FILE ISEG1
FIRES-RC2 2157  C
FIRES-RC2 2158        IF (ITAPE.EQ.1.AND.NDT.NE.0) GO TO 10
FIRES-RC2 2159        IF (ITAPE.EQ.1.AND.LOOP.GT.1) GO TO 10
FIRES-RC2 2160        ISIZE=25*NCONC+13*NSTL+10
FIRES-RC2 2161        READ (ISEG1) (AC(I),I=1,ISIZE)
FIRES-RC2 2162  C
FIRES-RC2 2163  C     TRANSFORM SEGMENT DISPLACEMENTS FROM REFERENCE LINE TO CENTER
FIRES-RC2 2164  C     OF GRAVITY OF CROSS-SECTION
FIRES-RC2 2165  C
FIRES-RC2 2166     10 E(1,3)=-DCG(J)
FIRES-RC2 2167        E(4,6)=E(1,3)
FIRES-RC2 2168        L=3*(J-1)+1
FIRES-RC2 2169        M=L+5
FIRES-RC2 2170        DO 20 NR=1,6
FIRES-RC2 2171        DIS(NR)=0.
FIRES-RC2 2172        DO 20 K=L,M
FIRES-RC2 2173        N=K-L+1
FIRES-RC2 2174     20 DIS(NR)=DIS(NR)+E(NR,N)*W(K)
FIRES-RC2 2175  C
FIRES-RC2 2176  C     BEGINNING OF LOOP TO FIND STRESSES AND FORCES
FIRES-RC2 2177  C     AT EACH END OF SEGMENT
FIRES-RC2 2178  C
FIRES-RC2 2179        DO 140 JT=1,2
FIRES-RC2 2180  C
FIRES-RC2 2181  C     CALCULATE AVERAGE STRETCH AND CURVATURE
FIRES-RC2 2182  C     AT LEFT END ( JT = 1 ) OR RIGHT END ( JT = 2 ) OF SEGMENT
FIRES-RC2 2183  C
FIRES-RC2 2184        DL=SEGL(J)
FIRES-RC2 2185        DL2=DL*DL
FIRES-RC2 2186        ST=(DIS(4)-DIS(1))/DL
FIRES-RC2 2187        ASTRAIN(JT,J)=ST
FIRES-RC2 2188        IF (JT.EQ.1) FEE=-(DIS(2)*6./DL2)-(DIS(3)*4./DL)+(DIS(5)*6./DL2)-(
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FIRES-RC2 2189          1DIS(6)*2./DL)
FIRES-RC2 2190           IF (JT.EQ.2) FEE=+(DIS(2)*6./DL2)+(DIS(3)*2./DL)-(DIS(5)*6./DL2)+(
FIRES-RC2 2191          1DIS(6)*4./DL)
FIRES-RC2 2192           ACURV(JT,J)=FEE
FIRES-RC2 2193   C
FIRES-RC2 2194   C       SET SUMMATION VARIABLES TO ZERO (0.0)
FIRES-RC2 2195   C
FIRES-RC2 2196           SAE=0.0
FIRES-RC2 2197           SEI=0.0
FIRES-RC2 2198           SDCG=0.0
FIRES-RC2 2199           SBM=0.0
FIRES-RC2 2200           SPA=0.0
FIRES-RC2 2201           SPAS=0.0
FIRES-RC2 2202           ACRUSH=0.0
FIRES-RC2 2203           ACRACK=0.0
FIRES-RC2 2204   C
FIRES-RC2 2205   C       CALCULATE CURRENT STATE OF STRAIN, STRESS AND MODULUS FOR
FIRES-RC2 2206   C       CONCRETE SUBLICES
FIRES-RC2 2207   C
FIRES-RC2 2208           DO 110 K=1,NCONC
FIRES-RC2 2209   C
FIRES-RC2 2210   C       STRAIN CALCULATIONS
FIRES-RC2 2211   C
FIRES-RC2 2212           EPC(K)=ST+FEE*(DCG(J)-YC(K))
FIRES-RC2 2213           EPC(K)=EPC(K)-STRC(K)
FIRES-RC2 2214           EHC(JT,K)=EPC(K)
FIRES-RC2 2215   C
FIRES-RC2 2216   C       CHECK FOR CONCRETE SUBSLICE DEGRADATION (IE. CRACKING OR CRUSHING)
FIRES-RC2 2217   C
FIRES-RC2 2218           IF (AKAK(JT,K).EQ.1) GO TO 70
FIRES-RC2 2219           EE=EHC(JT,K)-ESHIFTC(JT,K)
FIRES-RC2 2220           IF (EE) 30,40,40
FIRES-RC2 2221        30 IF (ABS(EHC(JT,K)).GT.EPU(K)) GO TO 60
FIRES-RC2 2222        40 AKK(JT,K)=0
FIRES-RC2 2223           IF (EE.LT.0) GO TO 80
FIRES-RC2 2224   C
FIRES-RC2 2225   C       IF SLICE IS CRACKED THE TENSION IS ZERO
FIRES-RC2 2226   C
FIRES-RC2 2227           IF (KRAT(JT,K).EQ.1) GO TO 50
FIRES-RC2 2228           SIGC(K)=STR(EHC(JT,K),AMOD(K),STRE(K),EFC(K),FU(K),EPU(K),ESHIFTC(
FIRES-RC2 2229          1JT,K))
FIRES-RC2 2230           IF (SIGC(K).LE.TES(K)) GO TO 90
FIRES-RC2 2231   C
FIRES-RC2 2232   C       CONSIDER SLICE WHICH IS JUST CRACKED OR SLICE CRACKED
FIRES-RC2 2233   C       AT EARLIER STEP THEN COMPRESSED NOW IN TENSION AGAIN
FIRES-RC2 2234   C
FIRES-RC2 2235        50 KRAF(JT,K)=1
FIRES-RC2 2236           ACRACK=ACRACK+AC(K)
FIRES-RC2 2237           AR(JT,K)=0.
FIRES-RC2 2238           EE=EE*AMOD(K)/TES(K)
FIRES-RC2 2239           SIGC(K)=STCRAK(EE)
FIRES-RC2 2240           SIGC(K)=SIGC(K)*TES(K)
FIRES-RC2 2241           IF (SIGC(K).GT.SIC(JT,K)) SIGC(K)=2.*SIC(JT,K)-SIGC(K)
FIRES-RC2 2242           IF (SIGC(K).LT.0.) SIGC(K)=0.
FIRES-RC2 2243           GO TO 100
FIRES-RC2 2244        60 CONTINUE
FIRES-RC2 2245   C
FIRES-RC2 2246   C       CONSIDER CRUSHED SLICE
FIRES-RC2 2247   C
FIRES-RC2 2248           AKK(JT,K)=1
FIRES-RC2 2249        70 CONTINUE
FIRES-RC2 2250           ACRUSH=ACRUSH+AC(K)
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FIRES-RC2 2251          AR(JT,K)=0.0
FIRES-RC2 2252          SIGC(K)=0.0
FIRES-RC2 2253          EPC(K)=0.0
FIRES-RC2 2254          GO TO 100
FIRES-RC2 2255   C
FIRES-RC2 2256   C      STRESS CALCULATION
FIRES-RC2 2257   C
FIRES-RC2 2258       80 SIGC(K)=STR(EHC(JT,K),AMOD(K),STRE(K),EFC(K),FU(K),EPU(K),ESHIFTC(
FIRES-RC2 2259         1JT,K))
FIRES-RC2 2260       90 KRAF(JT,K)=0
FIRES-RC2 2261   C
FIRES-RC2 2262   C      MODULUS CALCULATIONS
FIRES-RC2 2263   C
FIRES-RC2 2264          X1=EHC(JT,K)+0.00005
FIRES-RC2 2265          X3=STR(X1,AMOD(K),STRE(K),EFC(K),FU(K),EPU(K),ESHIFTC(JT,K))
FIRES-RC2 2266          X2=EHC(JT,K)-0.00005
FIRES-RC2 2267          X4=STR(X2,AMOD(K),STRE(K),EFC(K),FU(K),EPU(K),ESHIFTC(JT,K))
FIRES-RC2 2268          AR(JT,K)=10000.0*(X3-X4)
FIRES-RC2 2269      100 CONTINUE
FIRES-RC2 2270          SIC(JT,K)=SIGC(K)
FIRES-RC2 2271   C
FIRES-RC2 2272   C      SUMMATION FOR SEGMENT CROSS-SECTION PROPERTIES
FIRES-RC2 2273   C
FIRES-RC2 2274          AA=AC(K)*AR(JT,K)
FIRES-RC2 2275          SAE=SAE+AA
FIRES-RC2 2276          YY=YC(K)
FIRES-RC2 2277          AA=AA*YY
FIRES-RC2 2278          SDCG=SDCG+AA
FIRES-RC2 2279          SEI=SEI+AA*YY
FIRES-RC2 2280          C=AC(K)*SIGC(K)
FIRES-RC2 2281          SPA=SPA+C
FIRES-RC2 2282      110 SBM=SBM-C*YC(K)
FIRES-RC2 2283   C
FIRES-RC2 2284   C      CALCULATE CURRENT STATE OF STRAIN, STRESS AND MODULUS FOR
FIRES-RC2 2285   C      STEEL SUBSLICES
FIRES-RC2 2286   C
FIRES-RC2 2287          IF (NSTL.EQ.0) GO TO 130
FIRES-RC2 2288          DO 120 K=1,NSTL
FIRES-RC2 2289   C
FIRES-RC2 2290   C      STRAIN CALCULATIONS
FIRES-RC2 2291   C
FIRES-RC2 2292          EPS(K)=ST+FEE*(DCG(J)-YS(K))
FIRES-RC2 2293          EPS(K)=EPS(K)-STRS(K)
FIRES-RC2 2294          EHS(JT,K)=EPS(K)
FIRES-RC2 2295   C
FIRES-RC2 2296   C      STRESS CALCULATION
FIRES-RC2 2297   C
FIRES-RC2 2298          EPSY=YIE(K)/AMOS(K)
FIRES-RC2 2299          SIGS(K)=SS(EHS(JT,K),EPSY,AMOS(K),YIE(K),ESHIFTS(JT,K))
FIRES-RC2 2300   C
FIRES-RC2 2301   C      MODULUS CALCULATIONS
FIRES-RC2 2302   C
FIRES-RC2 2303          X1=EHS(JT,K)+0.00005
FIRES-RC2 2304          X3=SS(X1,EPSY,AMOS(K),YIE(K),ESHIFTS(JT,K))
FIRES-RC2 2305          X2=EHS(JT,K)-0.00005
FIRES-RC2 2306          X4=SS(X2,EPSY,AMOS(K),YIE(K),ESHIFTS(JT,K))
FIRES-RC2 2307          ARS(JT,K)=10000.0*(X3-X4)
FIRES-RC2 2308          SIS(JT,K)=SIGS(K)
FIRES-RC2 2309   C
FIRES-RC2 2310   C      SUMMATION FOR SEGMENT CROSS-SECTION PROPERTIES
FIRES-RC2 2311   C
FIRES-RC2 2312          AA=AS(K)*SIGS(K)
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FIRES-RC2 2313          SPAS=SPAS+AA
FIRES-RC2 2314          YY=YS(K)
FIRES-RC2 2315          SBM=SBM-YY*AA
FIRES-RC2 2316          AA=AS(K)*ARS(JT,K)
FIRES-RC2 2317          SAE=SAE+AA
FIRES-RC2 2318          AA=AA*YY
FIRES-RC2 2319          SDCG=SDCG+AA
FIRES-RC2 2320      120 SEI=SEI+AA*YY
FIRES-RC2 2321    C
FIRES-RC2 2322    C     STORE CROSS-SECTION DATA
FIRES-RC2 2323    C
FIRES-RC2 2324      130 PA(JT,J)=SPA+SPAS
FIRES-RC2 2325          BM(JT,J)=SBM
FIRES-RC2 2326          IF (JT.EQ.1) DCGTEMP=SDCG/SAE
FIRES-RC2 2327          IF (JT.EQ.2) DCG(J)=(DCGTEMP+SDCG/SAE)/2.
FIRES-RC2 2328          IF (JT.EQ.1) AETEMP=SAE
FIRES-RC2 2329          IF (JT.EQ.2) AE(J)=(AETEMP+SAE)/2.
FIRES-RC2 2330          S1=SEI-SAE*((SDCG/SAE)**2)
FIRES-RC2 2331          IF (JT.EQ.1) EITEMP=S1
FIRES-RC2 2332          IF (JT.EQ.2) EI(J)=(EITEMP+S1)/2.
FIRES-RC2 2333          CRUSH(JT,J)=ACRUSH
FIRES-RC2 2334          CRACK(JT,J)=ACRACK
FIRES-RC2 2335    C
FIRES-RC2 2336      140 CONTINUE
FIRES-RC2 2337    C
FIRES-RC2 2338    C     FIND INTERNAL FORCES VECTOR FOR THIS SEGMENT
FIRES-RC2 2339    C
FIRES-RC2 2340          JJ=(J-1)*3+1
FIRES-RC2 2341          PSEGMNT=(PA(1,J)+PA(2,J))/2.
FIRES-RC2 2342          FF(1,JJ)=-PSEGMNT
FIRES-RC2 2343          FF(2,JJ)=+PSEGMNT
FIRES-RC2 2344          FF(1,JJ+2)=-BM(1,J)
FIRES-RC2 2345          FF(2,JJ+2)=+BM(2,J)
FIRES-RC2 2346          SHEAR=(FF(1,JJ+2)+FF(2,JJ+2))/SEGL(J)
FIRES-RC2 2347          FF(1,JJ+1)=SHEAR
FIRES-RC2 2348          FF(2,JJ+1)=-SHEAR
FIRES-RC2 2349    C
FIRES-RC2 2350    C
FIRES-RC2 2351    C     WRITE SEGMENT DATA ON ISEG1
FIRES-RC2 2352    C
FIRES-RC2 2353          IF (ITAPE.NE.0) RETURN
FIRES-RC2 2354          ISIZE=25*NCONC+13*NSTL+10
FIRES-RC2 2355          WRITE (ISEG2) (AC(I),I=1,ISIZE)
FIRES-RC2 2356    C
FIRES-RC2 2357          RETURN
FIRES-RC2 2358    C
FIRES-RC2 2359          END
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FIRES-RC2 2360          SUBROUTINE OUTPT (IBC,JS,U,AAW,DELR,SEGL,AE,AEI,EI,EII,DCG,W,DELF,
FIRES-RC2 2361         1PA,BM,ASTRAIN,ACURV,AREA,CRUSH,CRACK,NCONCR,NSTEFL,I2,I3,I5,LCARD,
FIRES-RC2 2362         2NCARD,TIME,M)
FIRES-RC2 2363    C
FIRES-RC2 2364    C
FIRES-RC2 2365    C     SUBROUTINE  *OUTPT*  PRINTS AND PUNCHES ANALYSIS RESULTS
FIRES-RC2 2366    C
FIRES-RC2 2367    C
FIRES-RC2 2368          COMMON /TAP/ HED(10),ITEMP1,ITEMP2,ISEG1,ISEG2,NIN,NOUT,NPUNCH
FIRES-RC2 2369          COMMON /DYN/ NDT,NSTORE,NCMAX,NSMAX,NCONTL,NSTLTL,ISYSTM,IMEMB,ITC
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FIRES-RC2 2370        ITAL,ITAPE
FIRES-RC2 2371         COMMON /BLK1/ NJ,NM,NBC,NJ3,MAXBAN,NCRPS,NCRPC,NSHRINK,NCONV
FIRES-RC2 2372         COMMON /MEMB/ NNSEG(75)
FIRES-RC2 2373         COMMON C(1)
FIRES-RC2 2374         DIMENSION IBC(1), JS(1), U(1), AAW(1), DELR(1), SEGL(1), AE(1), AE
FIRES-RC2 2375        1I(1), EI(1), EII(1), DCG(1), W(1), DELF(1), PA(2,1), BM(2,1), ASTR
FIRES-RC2 2376        2AIN(2,1), ACURV(2,1), AREA(1), CRUSH(2,1), CRACK(2,1), NCONCR(1),
FIRES-RC2 2377        3NSTEEL(1)
FIRES-RC2 2378  C
FIRES-RC2 2379  C      OUTPUT FOR SYSTEM (ON FIRST CALL OF SUBROUTINE ONLY, WHEN M.EQ.1)
FIRES-RC2 2380  C
FIRES-RC2 2381         IF (M.GT.1) GO TO 60
FIRES-RC2 2382         IF (I5.EQ.0) WRITE (NOUT,160)
FIRES-RC2 2383         IF (I5.EQ.1) WRITE (NOUT,180)
FIRES-RC2 2384         IF (NCONV.EQ.0) GO TO 10
FIRES-RC2 2385         WRITE (NOUT,190)
FIRES-RC2 2386         WRITE (NOUT,200) (DELR(I),I=1,NJ3)
FIRES-RC2 2387      10 CONTINUE
FIRES-RC2 2388         IF (I5.EQ.0) WRITE (NOUT,210)
FIRES-RC2 2389         IF (I5.EQ.1) WRITE (NOUT,220)
FIRES-RC2 2390  C
FIRES-RC2 2391         IF (I3.EQ.0) GO TO 30
FIRES-RC2 2392  C
FIRES-RC2 2393  C      PUNCH HEADER CARD
FIRES-RC2 2394  C
FIRES-RC2 2395         IF (NCARD.NE.0) GO TO 20
FIRES-RC2 2396         NCARD=NCARD+1
FIRES-RC2 2397         WRITE (NPUNCH,230) HED,LCARD,NCARD
FIRES-RC2 2398         NCARD=NCARD+1
FIRES-RC2 2399      20 WRITE (NPUNCH,240) NDT,TIME,NM,NJ,LCARD,NCARD
FIRES-RC2 2400         NCARD=NCARD+1
FIRES-RC2 2401  C
FIRES-RC2 2402  C      PRINT AND/OR PUNCH SYSTEM INFORMATION
FIRES-RC2 2403  C
FIRES-RC2 2404      30 CONTINUE
FIRES-RC2 2405         DO 50 J=1,NJ
FIRES-RC2 2406         DECODE (10,250,IBC(J) )IX,IY,IR
FIRES-RC2 2407         J1=(J-1)*3+1
FIRES-RC2 2408         J2=J1+2
FIRES-RC2 2409         IF ((IX+IY+IR).GT.0) GO TO 40
FIRES-RC2 2410  C
FIRES-RC2 2411  C      UNRESTRAINED JOINTS
FIRES-RC2 2412  C
FIRES-RC2 2413         IF (I5.EQ.0) WRITE (NOUT,260) J,(U(I),I=J1,J2)
FIRES-RC2 2414         IF (I5.EQ.1) WRITE (NOUT,270) J,(U(I),I=J1,J2)
FIRES-RC2 2415         IF (I3.EQ.0) GO TO 50
FIRES-RC2 2416  C
FIRES-RC2 2417         WRITE (NPUNCH,300) J,(U(I),I=J1,J2),LCARD,NCARD
FIRES-RC2 2418         NCARD=NCARD+1
FIRES-RC2 2419         GO TO 50
FIRES-RC2 2420  C
FIRES-RC2 2421  C      RESTRAINED JOINTS
FIRES-RC2 2422  C
FIRES-RC2 2423      40 CONTINUE
FIRES-RC2 2424         IF (I5.EQ.0) WRITE (NOUT,260) J,(U(I),I=J1,J2),(AAW(I),I=J1,J2)
FIRES-RC2 2425         IF (I5.EQ.1) WRITE (NOUT,260) J,(U(I),I=J1,J2),AAW(J1)
FIRES-RC2 2426         IF (I5.EQ.1) WRITE (NOUT,280) AAW(J1+1)
FIRES-RC2 2427         IF (I5.EQ.1) WRITE (NOUT,290) AAW(J2)
FIRES-RC2 2428         IF (I3.EQ.0) GO TO 50
FIRES-RC2 2429  C
FIRES-RC2 2430         WRITE (NPUNCH,310) J,(U(I),I=J1,J2),(AAW(I),I=J1,J2),LCARD,NCARD
FIRES-RC2 2431         NCARD=NCARD+1
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FIRES-RC2 2432      50. CONTINUE
FIRES-RC2 2433          MINIT=ITOTAL
FIRES-RC2 2434          IBLOCK=0
FIRES-RC2 2435  C
FIRES-RC2 2436  C       PRINT AND/OR PUNCH RESULTS FOR SUBSTRUCTURED MEMBERS
FIRES-RC2 2437  C       ( LOOP OVER ALL MEMBERS, WITH THE DO-LOOP IN THE MAIN PROGRAM )
FIRES-RC2 2438  C
FIRES-RC2 2439      60 CONTINUE
FIRES-RC2 2440  C
FIRES-RC2 2441  C       PRINT HEADINGS FOR MEMBER DATA
FIRES-RC2 2442  C
FIRES-RC2 2443          NSEG=NNSEG(M)
FIRES-RC2 2444          IF (I5.EQ.0) WRITE (NOUT,320) M
FIRES-RC2 2445          IF (I5.EQ.1) WRITE (NOUT,330) M
FIRES-RC2 2446          IF (NCONV.EQ.0) GO TO 70
FIRES-RC2 2447          IF (NSEG.EQ.1) GO TO 70
FIRES-RC2 2448          WRITE (NOUT,340)
FIRES-RC2 2449          NS=(NSEG-1)*3
FIRES-RC2 2450          WRITE (NOUT,200) (DELF(I),I=1,NS)
FIRES-RC2 2451      70 CONTINUE
FIRES-RC2 2452          IF (I5.EQ.0) WRITE (NOUT,350)
FIRES-RC2 2453          IF (I5.EQ.1) WRITE (NOUT,360)
FIRES-RC2 2454          IF (I3.EQ.0) GO TO 100
FIRES-RC2 2455          NM3P1=3*NSEG+3
FIRES-RC2 2456  C
FIRES-RC2 2457  C       PUNCH NODE DISPLACEMENT DATA HERE IF DESIRED
FIRES-RC2 2458  C
FIRES-RC2 2459          J1=1
FIRES-RC2 2460          K1=1
FIRES-RC2 2461          NSG1=NSEG+1
FIRES-RC2 2462      80 IF (J1.GT.NSG1) GO TO 100
FIRES-RC2 2463          J2=J1+1
FIRES-RC2 2464          K2=K1+1
FIRES-RC2 2465          K3=K2+1
FIRES-RC2 2466          IF (J2.GT.NSG1) GO TO 90
FIRES-RC2 2467          K4=K3+1
FIRES-RC2 2468          K5=K4+1
FIRES-RC2 2469          K6=K5+1
FIRES-RC2 2470          WRITE (NPUNCH,370) M,J1,W(K1),W(K2),W(K3),J2,W(K4),W(K5),W(K6),LCA
FIRES-RC2 2471         1RD,NCARD
FIRES-RC2 2472          NCARD=NCARD+1
FIRES-RC2 2473          J1=J2+1
FIRES-RC2 2474          K1=K6+1
FIRES-RC2 2475          GO TO 80
FIRES-RC2 2476      90 CONTINUE
FIRES-RC2 2477          WRITE (NPUNCH,380) M,J1,W(K1),W(K2),W(K3),LCARD,NCARD
FIRES-RC2 2478          NCARD=NCARD+1
FIRES-RC2 2479  C
FIRES-RC2 2480  C       PRINT MEMBER DATA
FIRES-RC2 2481  C
FIRES-RC2 2482     100 CONTINUE
FIRES-RC2 2483  C
FIRES-RC2 2484          IF (I5.EQ.0) GO TO 120
FIRES-RC2 2485          DO 110 I=1,NSEG
FIRES-RC2 2486          J1=(I-1)*3+1
FIRES-RC2 2487          J2=J1+2
FIRES-RC2 2488          WRITE (NOUT,390) I,(W(J),J=J1,J2)
FIRES-RC2 2489          WRITE (NOUT,460) ACURV(1,I)
FIRES-RC2 2490          WRITE (NOUT,470) I,ASTRAIN(1,I)
FIRES-RC2 2491          WRITE (NOUT,480) ACURV(2,I)
FIRES-RC2 2492     110 CONTINUE
FIRES-RC2 2493          J1=J1+3
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FIRES-RC2 2494          J2=J1+2
FIRES-RC2 2495          I=NSEG+1
FIRES-RC2 2496          WRITE (NOUT,390) I,(W(J),J=J1,J2)
FIRES-RC2 2497      120 CONTINUE
FIRES-RC2 2498    C
FIRES-RC2 2499          IF (I5.EQ.1) WRITE (NOUT,170)
FIRES-RC2 2500          DO 130 I=1,NSEG
FIRES-RC2 2501          J1=(I-1)*3+1
FIRES-RC2 2502          J2=J1+2
FIRES-RC2 2503          IF (I5.EQ.0) WRITE (NOUT,390) I,(W(J),J=J1,J2)
FIRES-RC2 2504          SHEAR=(BM(2,I)-BM(1,I))/SEGL(I)
FIRES-RC2 2505          AXIAL=(PA(2,I)+PA(1,I))/2.
FIRES-RC2 2506          DO 130 JT=1,2
FIRES-RC2 2507          RAE=100.*AE(I)/AEI(I)
FIRES-RC2 2508          REI=100.*EI(I)/EII(I)
FIRES-RC2 2509          RCRACK=100.*CRACK(JT,I)/AREA(I)
FIRES-RC2 2510          RCRUSH=100.*CRUSH(JT,I)/AREA(I)
FIRES-RC2 2511          IF (JT.EQ.1.AND.I5.EQ.0) WRITE (NOUT,400) ACURV(JT,I),BM(JT,I),RCR
FIRES-RC2 2512         1USH,RCRACK
FIRES-RC2 2513          IF (JT.EQ.1.AND.I5.EQ.1) WRITE (NOUT,410) BM(JT,I),RCRUSH,RCRACK
FIRES-RC2 2514          IF (JT.EQ.1.AND.I5.EQ.0) WRITE (NOUT,420) I,ASTRAIN(JT,I),AXIAL,SH
FIRES-RC2 2515         1EAR,AE(I),EI(I),DCG(I)
FIRES-RC2 2516          IF (JT.EQ.1.AND.I5.EQ.1) WRITE (NOUT,430) I,AXIAL,SHEAR,RAE,REI,DC
FIRES-RC2 2517         1G(I)
FIRES-RC2 2518          IF (JT.EQ.2.AND.I5.EQ.0) WRITE (NOUT,440) ACURV(JT,I),BM(JT,I),RAE
FIRES-RC2 2519         1,REI,RCRUSH,RCRACK
FIRES-RC2 2520          IF (JT.EQ.2.AND.I5.EQ.1) WRITE (NOUT,450) BM(JT,I),RCRUSH,RCRACK
FIRES-RC2 2521          IF (I3.EQ.0) GO TO 130
FIRES-RC2 2522    C
FIRES-RC2 2523    C     PUNCH MEMBER DATA
FIRES-RC2 2524    C
FIRES-RC2 2525          WRITE (NPUNCH,490) M,I,ASTRAIN(JT,I),ACURV(JT,I),AXIAL,BM(JT,I),SH
FIRES-RC2 2526         1EAR,RAE,REI,RCRUSH,RCRACK,DCG(I),LCARD,NCARD
FIRES-RC2 2527          NCARD=NCARD+1
FIRES-RC2 2528      130 CONTINUE
FIRES-RC2 2529          J1=J1+3
FIRES-RC2 2530          J2=J1+2
FIRES-RC2 2531          I=NSEG+1
FIRES-RC2 2532          IF (I5.EQ.0) WRITE (NOUT,390) I,(W(J),J=J1,J2)
FIRES-RC2 2533    C
FIRES-RC2 2534          IF (I2.EQ.0.AND.I3.NE.2) GO TO 150
FIRES-RC2 2535    C
FIRES-RC2 2536          DO 140 JSEG=1,NSEG
FIRES-RC2 2537    C
FIRES-RC2 2538    C     SET UP DYNAMIC STORAGE FOR THIS SEGMENT
FIRES-RC2 2539    C
FIRES-RC2 2540          NCONC=NCONCR(JSEG)
FIRES-RC2 2541          NSTL=NSTEEL(JSEG)
FIRES-RC2 2542          MINIT=MINIT+IBLOCK
FIRES-RC2 2543          IBLOCK=32*NCONC+15*NSTL+11
FIRES-RC2 2544          IF (ITAPE.EQ.0) IBLOCK=0
FIRES-RC2 2545          M14=IMEMB
FIRES-RC2 2546          M15=M14+NCMAX
FIRES-RC2 2547          M20=MINIT
FIRES-RC2 2548          M29=M20+6*NCONC+3*NSTL
FIRES-RC2 2549          M32=M29+3*NSTL+2*NCONC
FIRES-RC2 2550          M33=M32+2*NCONC
FIRES-RC2 2551          M34=M33+2*NCONC
FIRES-RC2 2552          M35=M34+2*NCONC
FIRES-RC2 2553          M37=M35+3*NCONC
FIRES-RC2 2554          M38=M37+2*NCONC
FIRES-RC2 2555          M40=M38+2*NCONC+NSTL
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FIRES-RC2 2556          M41=M40+2*NSTL
FIRES-RC2 2557          M42=M41+2*NSTL
FIRES-RC2 2558          M44=M42+2*NSTL+6*NCONC
FIRES-RC2 2559          M45=M44+10
FIRES-RC2 2560          M47=M45+2*NCONC
FIRES-RC2 2561   C
FIRES-RC2 2562   C      OUTPUT SEGMENT DATA
FIRES-RC2 2563   C
FIRES-RC2 2564          CALL OPTSEG (NCONC,NSTL,C(M14),C(M15),C(M20),C(M29),C(M32),C(M33),
FIRES-RC2 2565         1C(M34),C(M35),C(M37),C(M38),C(M40),C(M41),C(M42),C(M44),C(M45),C(M
FIRES-RC2 2566         247),JSEG,M,I2,I3,I5,NCARD,LCARD)
FIRES-RC2 2567   C
FIRES-RC2 2568     140 CONTINUE
FIRES-RC2 2569     150 CONTINUE
FIRES-RC2 2570          IF (M.NE.NM) RETURN
FIRES-RC2 2571   C
FIRES-RC2 2572   C      REWIND STORAGE FILES THAT HAVE BEEN USED IN OUTPUT
FIRES-RC2 2573   C
FIRES-RC2 2574          IF (ITAPE.EQ.1) RETURN
FIRES-RC2 2575          REWIND ISEG1
FIRES-RC2 2576          REWIND ITEMP1
FIRES-RC2 2577   C
FIRES-RC2 2578          RETURN
FIRES-RC2 2579   C
FIRES-RC2 2580   C
FIRES-RC2 2581   C
FIRES-RC2 2582     160 FORMAT (///15(2H .),39H ANALYSIS RESULTS FOR STRUCTURAL SYSTEM,20(
FIRES-RC2 2583         12H .))
FIRES-RC2 2584     170 FORMAT (//15X,31H-FORCES AND SECTION PROPERTIES-///63H SEGMENT
FIRES-RC2 2585         1   SEGMENT FORCES        SEGMENT        AREA     CENTER /34X,29HSTIFFNE
FIRES-RC2 2586         2SS   REDUCTION     OF  /56X,7HGRAVITY/62H                AXIAL    SHEAR
FIRES-RC2 2587         3 MOMENT -AE-  -EI- CRUSHED              /62H              (KIPS)  (KIPS)
FIRES-RC2 2588         4 (IN-K) (PERCENT       CRACKED  (IN) /60H
FIRES-RC2 2589         5          OF INITIAL) (PERCENT)      //)
FIRES-RC2 2590     180 FORMAT (///5(2H .),39H ANALYSIS RESULTS FOR STRUCTURAL SYSTEM,6(2H
FIRES-RC2 2591         1 .))
FIRES-RC2 2592     190 FORMAT (/2X,10(1H*),39H OUT-OF-BALANCE FORCES - SYSTEM - DELR 10(1
FIRES-RC2 2593         1H*)/)
FIRES-RC2 2594     200 FORMAT (1P,12X,3E12.4)
FIRES-RC2 2595     210 FORMAT (//3X,5HJOINT,9X,19HJOINT DISPLACEMENTS,22X,17HSUPPORT REAC
FIRES-RC2 2596         1TIONS/15X,24HGLOBAL COORDINATE SYSTEM/17X,3HX-G,9X,3HY-G,9X,3HR-G,
FIRES-RC2 2597         213X,3HF-X,9X,3HF-Y,7X,6HMOMENT/12X,8H(INCHES),4X,3H(INCHES),3X,9H(
FIRES-RC2 2598         3RADIANS),11X,6H(KIPS),6X,6H(KIPS),6X,6H(IN-K)/)
FIRES-RC2 2599     220 FORMAT (//3X,5HJOINT,9X,19HJOINT DISPLACEMENTS,18X,7HSUPPORT/14X,2
FIRES-RC2 2600         16H(GLOBAL COORDINATE SYSTEM),13X,9HREACTIONS//17X,3HX-G,9X,3HY-G,9
FIRES-RC2 2601         2X,3HR-G,8X,10HF-X (KIPS)/12X,8H(INCHES),4X,8H(INCHES),3X,9H(RADIAN
FIRES-RC2 2602         3S),8X,10HF-Y (KIPS)/52X,10HM-R (IN-K)/)
FIRES-RC2 2603     230 FORMAT (12A6,A3,I5)
FIRES-RC2 2604     240 FORMAT (4HSTEP,I3,9H * TIME =,F6.2,12H * MEMBERS =,I3,11H * JOINTS
FIRES-RC2 2605         1 =,I3,2H *,19X,A3,I5)
FIRES-RC2 2606     250 FORMAT (2X,3I1)
FIRES-RC2 2607     260 FORMAT (/I8,3F12.5,5X,3F12.2)
FIRES-RC2 2608     270 FORMAT (I8,3F12.5,13X,4HNONE)
FIRES-RC2 2609     280 FORMAT (49X,F12.2)
FIRES-RC2 2610     290 FORMAT (49X,F12.2/)
FIRES-RC2 2611     300 FORMAT (2HJT,I3,2F10.5,F10.7,37X,A3,I5)
FIRES-RC2 2612     310 FORMAT (2HJT,I3,2F10.5,F10.7,3F10.1,7X,A3,I5)
FIRES-RC2 2613     320 FORMAT (////20(2H .),28H ANALYSIS RESULTS FOR MEMBER,I4,25(2H .))
FIRES-RC2 2614     330 FORMAT (////8(2H .),28H ANALYSIS RESULTS FOR MEMBER,I4,7(2H .)//17
FIRES-RC2 2615         1X,28H-DISPLACEMENTS AND STRAINS- /)
FIRES-RC2 2616     340 FORMAT (/1X,10(1H*),40H OUT-OF-BALANCE FORCES - MEMBER - DELF  10(
FIRES-RC2 2617         11H*)/)
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FIRES-RC2 2618     350 FORMAT (/63H NODE SEG       SEGMENT END DISPLACEMENTS       SECTION
FIRES-RC2 2619        1STRAINS  ,69H     SEGMENT FORCES        SEGMENT STIFFNESS     AREA R
FIRES-RC2 2620        2EDUCTION  CENTER,/40H                 (MEMBER COORDINATE SYSTEM),86X,
FIRES-RC2 2621        32HOF,/63H                        X-M        Y-M        R-M    ELONGATION
FIRES-RC2 2622        4 CURV.,69H   AXIAL  SHEAR  MOMENT    AXIAL ROTATIONAL  CRUSHED  CR
FIRES-RC2 2623        5ACKED GRAVITY,/42H                 (INCHES)  (INCHES)    (RADS),23X,6
FIRES-RC2 2624        67H(KIPS)  (KIPS)  (IN-K)      -AE-    -EI-         (PERCENT)
FIRES-RC2 2625        7   /)
FIRES-RC2 2626     360 FORMAT (/63H NODE SEG       SEGMENT END DISPLACEMENTS       SECTION
FIRES-RC2 2627        1STRAINS  ,/40H                 (MEMBER COORDINATE SYSTEM),/63H
FIRES-RC2 2628        2          X-M        Y-M        R-M    ELONGATION    CURV.,/42H
FIRES-RC2 2629        3         (INCHES)  (INCHES)    (RADS),/)
FIRES-RC2 2630     370 FORMAT (2HMB,I2,2(2HND,I2,2F10.5,F10.7),A3,I5)
FIRES-RC2 2631     380 FORMAT (2HMB,I2,2HND,I2,2F10.5,F10.7,34X,A3,I5)
FIRES-RC2 2632     390 FORMAT (I3,10X,3F10.5)
FIRES-RC2 2633     400 FORMAT (6X,4HLEFT,43X,1P,E10.2,16X,0P,F8.1,23X,2F7.2)
FIRES-RC2 2634     410 FORMAT (3X,4HLEFT,18X,F8.1,12X,2F5.0)
FIRES-RC2 2635     420 FORMAT (I5,1X,4HAVG.,33X,1P,E10.2,10X,0P,2F8.1,8X,1P,2E10.2,16X,0P
FIRES-RC2 2636        1,F8.2)
FIRES-RC2 2637     430 FORMAT (I2,1X,4HAVG.,2X,2F8.1,8X,2F6.0,10X,F8.2)
FIRES-RC2 2638     440 FORMAT (6X,5HRIGHT,42X,1P,E10.2,0P,16X,F8.1,4H   (,F5.2,1H),4H   (
FIRES-RC2 2639        1,F5.2,1H),3X,2F7.2)
FIRES-RC2 2640     450 FORMAT (3X,5HRIGHT,17X,F8.1,12X,2F5.0/)
FIRES-RC2 2641     460 FORMAT (6X,4HLEFT,43X,1P,E10.2)
FIRES-RC2 2642     470 FORMAT (I5,1X,4HAVG.,33X,1P,E10.2)
FIRES-RC2 2643     480 FORMAT (6X,5HRIGHT,42X,1P,E10.2)
FIRES-RC2 2644     490 FORMAT (2HMB,I2,3HSEG,I2,2E9.2,3F8.1,4F4.2,F5.1,A3,I5)
FIRES-RC2 2645         END
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FIRES-RC2 2646         SUBROUTINE OPTSEG (NCONC,NSTL,IPR,PR,AC,YIE,KRAT,KRAF,AKAK,AKK,EHC
FIRES-RC2 2647        1,SIC,EHS,SIS,ESHIFTC,NSTR,TEMPC,TEMPS,JSEG,M,I2,I3,I5,NCARD,LCARD)
FIRES-RC2 2648   C
FIRES-RC2 2649   C
FIRES-RC2 2650         COMMON /TAP/ HED(10),ITEMP1,ITEMP2,ISEG1,ISEG2,NIN,NOUT,NPUNCH
FIRES-RC2 2651         COMMON /DYN/ NDT,NSTORE,NCMAX,NSMAX,NCONTL,NSTLTL,ISYSTM,IMEMB,ITO
FIRES-RC2 2652        1TAL,ITAPE
FIRES-RC2 2653         COMMON /BLK1/ NJ,NM,NBC,NXX,MAXBAN,NCRPS,NCRPC,NSHRINK,NCONV
FIRES-RC2 2654         DIMENSION IPR(1), PR(1), AC(1), YIE(1), KRAT(2,1), KRAF(2,1), AKAK
FIRES-RC2 2655        1(2,1), AKK(2,1), EHC(2,1), SIC(2,1), EHS(2,1), SIS(2,1), ESHIFTC(2
FIRES-RC2 2656        2,1), NSTR(1), TEMPC(1), TEMPS(1)
FIRES-RC2 2657         DIMENSION IP(9), PI(9)
FIRES-RC2 2658         INTEGER AKAK,AKK
FIRES-RC2 2659   C
FIRES-RC2 2660   C     READ SEGMENT DATA FROM FILES ISEG1 AND ITEMP1
FIRES-RC2 2661   C
FIRES-RC2 2662         IF (ITAPE.NE.0) GO TO 10
FIRES-RC2 2663         ISIZE=25*NCONC+13*NSTL+10
FIRES-RC2 2664         READ (ISEG1) (AC(I),I=1,ISIZE)
FIRES-RC2 2665         IF (I2.NE.2) GO TO 10
FIRES-RC2 2666         ISIZE=7*NCONC+2*NSTL+1
FIRES-RC2 2667         READ (ITEMP1) (TEMPC(I),I=1,ISIZE)
FIRES-RC2 2668   C
FIRES-RC2 2669      10 CONTINUE
FIRES-RC2 2670   C
FIRES-RC2 2671         IF (I2.NE.1) GO TO 80
FIRES-RC2 2672   C
FIRES-RC2 2673   C     LOOP OVER BOTH ENDS OF SEGMENT
FIRES-RC2 2674   C
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FIRES-RC2 2675          DO 70 JT=1,2
FIRES-RC2 2676   C
FIRES-RC2 2677   C      PRINT STRAINS AND STRESSES FOR SEGMENT CROSS-SECTION
FIRES-RC2 2678   C
FIRES-RC2 2679          IF (JT.EQ.1) WRITE (NOUT,160) M,JSEG
FIRES-RC2 2680          IF (JT.EQ.2) WRITE (NOUT,170) M,JSEG
FIRES-RC2 2681          WRITE (NOUT,180)
FIRES-RC2 2682   C
FIRES-RC2 2683   C      CONCRETE STRAINS AND STRESSES
FIRES-RC2 2684   C
FIRES-RC2 2685          DO 40 I=1,NCONC
FIRES-RC2 2686          IF (AKK(JT,I).NE.0.OR.AKAK(JT,I).NE.0) GO TO 20
FIRES-RC2 2687          EE=EHC(JT,I)-ESHIFTC(JT,I)
FIRES-RC2 2688          IF (KRAF(JT,I).NE.0.AND.EE.GE.0.0) GO TO 30
FIRES-RC2 2689          ENCODE (10,190,IPR(I) )SIC(JT,I)
FIRES-RC2 2690          GO TO 40
FIRES-RC2 2691       20 IPR(I)=9H  CRUSH
FIRES-RC2 2692          GO TO 40
FIRES-RC2 2693       30 IPR(I)=9H  CRACK
FIRES-RC2 2694       40 CONTINUE
FIRES-RC2 2695          IF (I5.EQ.0) NCOL=10
FIRES-RC2 2696          IF (I5.EQ.1) NCOL=5
FIRES-RC2 2697          IF (I5.EQ.0) WRITE (NOUT,200) (I,I=1,10)
FIRES-RC2 2698          IF (I5.EQ.1) WRITE (NOUT,210) (I,I=1,5)
FIRES-RC2 2699          J3=-NCOL
FIRES-RC2 2700          J1=1-NCOL
FIRES-RC2 2701          J2=0
FIRES-RC2 2702       50 J3=J3+NCOL
FIRES-RC2 2703          J1=J1+NCOL
FIRES-RC2 2704          J2=J2+NCOL
FIRES-RC2 2705          IF (J2.GE.NCONC) J2=NCONC
FIRES-RC2 2706          WRITE (NOUT,220) J3,(IPR(J),J=J1,J2)
FIRES-RC2 2707          WRITE (NOUT,230) (EHC(JT,J),J=J1,J2)
FIRES-RC2 2708          IF (I2.EQ.2) WRITE (NOUT,240) (TEMPC(J),J=J1,J2)
FIRES-RC2 2709          IF (J2.LT.NCONC) GO TO 50
FIRES-RC2 2710   C
FIRES-RC2 2711   C      STEEL STRAINS AND STRESSES
FIRES-RC2 2712   C
FIRES-RC2 2713          IF (NSTL.EQ.0) GO TO 70
FIRES-RC2 2714          WRITE (NOUT,250)
FIRES-RC2 2715          DO 60 I=1,NSTL
FIRES-RC2 2716          PR(I)=ABS(SIS(JT,I)/YIE(I))
FIRES-RC2 2717       60 CONTINUE
FIRES-RC2 2718          IF (I2.NE.2) WRITE (NOUT,270) (I,SIS(JT,I),PR(I),EHS(JT,I),I=1,NST
FIRES-RC2 2719         1L)
FIRES-RC2 2720          IF (I2.EQ.2) WRITE (NOUT,260) (I,SIS(JT,I),PR(I),EHS(JT,I),TEMPS(I
FIRES-RC2 2721         1),I=1,NSTL)
FIRES-RC2 2722       70 CONTINUE
FIRES-RC2 2723       80 CONTINUE
FIRES-RC2 2724   C
FIRES-RC2 2725          IF (I3.NE.2) GO TO 150
FIRES-RC2 2726   C
FIRES-RC2 2727   C      PUNCH SELECTED STRESS DATA
FIRES-RC2 2728   C
FIRES-RC2 2729          N=NSTR(10)
FIRES-RC2 2730          IF (N.EQ.0) GO TO 150
FIRES-RC2 2731          DO 140 JT=1,2
FIRES-RC2 2732          DO 90 I=1,9
FIRES-RC2 2733          IP(I)=10H
FIRES-RC2 2734       90 PI(I)=0.000001
FIRES-RC2 2735          DO 130 I=1,N
FIRES-RC2 2736          IF (NSTR(I).GT.0) GO TO 100
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FIRES-RC2 2737  C
FIRES-RC2 2738  C      STEEL STRESS
FIRES-RC2 2739  C
FIRES-RC2 2740         J=1000+NSTR(I)
FIRES-RC2 2741         ENCODE (10,190,IP(I) )SIS(JT,J)
FIRES-RC2 2742         PI(I)=ABS(SIS(JT,J)/YIE(J))
FIRES-RC2 2743         GO TO 130
FIRES-RC2 2744  C
FIRES-RC2 2745  C      CONCRETE STRESS
FIRES-RC2 2746  C
FIRES-RC2 2747    100 CONTINUE
FIRES-RC2 2748         J=NSTR(I)
FIRES-RC2 2749         PI(I)=EHC(JT,J)*1000.0
FIRES-RC2 2750         IF (AKK(JT,I).NE.0.OR.AKAK(JT,I).NE.0) GO TO 110
FIRES-RC2 2751         EE=EHC(JT,I)-ESHIFTC(JT,I)
FIRES-RC2 2752         IF (KRAF(JT,I).NE.0.AND.EE.GE.0.0) GO TO 120
FIRES-RC2 2753         ENCODE (10,190,IP(I) )SIC(JT,J)
FIRES-RC2 2754         GO TO 130
FIRES-RC2 2755    110 IP(I)=7H  CRUSH
FIRES-RC2 2756         GO TO 130
FIRES-RC2 2757    120 IP(I)=7H  CRACK
FIRES-RC2 2758    130 CONTINUE
FIRES-RC2 2759         WRITE (NPUNCH,280) M,JSEG,(IP(I),I=1,9),LCARD,NCARD
FIRES-RC2 2760         NCARD=NCARD+1
FIRES-RC2 2761         WRITE (NPUNCH,290) M,JSEG,(PI(I),I=1,9),LCARD,NCARD
FIRES-RC2 2762         NCARD=NCARD+1
FIRES-RC2 2763    140 CONTINUE
FIRES-RC2 2764    150 CONTINUE
FIRES-RC2 2765  C
FIRES-RC2 2766         RETURN
FIRES-RC2 2767  C
FIRES-RC2 2768  C
FIRES-RC2 2769  C
FIRES-RC2 2770    160 FORMAT (////62H * * * *  ANALYSIS RESULTS FOR SEGMENT CROSS-SECTIO
FIRES-RC2 2771       1N  * * * * //20H              MEMBER,I3,22H - LEFT END OF SEGMENT,
FIRES-RC2 2772       2I2///)
FIRES-RC2 2773    170 FORMAT (////62H * * * *  ANALYSIS RESULTS FOR SEGMENT CROSS-SECTIO
FIRES-RC2 2774       1N  * * * * //20H              MEMBER,I3,23H - RIGHT END OF SEGMENT
FIRES-RC2 2775       2,I2///)
FIRES-RC2 2776    180 FORMAT (62H   - - - - - - - - - - - C O N C R E T E  - - - - - - -
FIRES-RC2 2777       1- - -  //61H          FOR EACH SUBSLICE, STRESS (KSI) IS GIVEN OVE
FIRES-RC2 2778       2R      /62H      STRESS-RELATED STRAIN X 1000 OVER TEMPERATURE (DE
FIRES-RC2 2779       3G F)   )
FIRES-RC2 2780    190 FORMAT (F9.2)
FIRES-RC2 2781    200 FORMAT (///9X,1HI/9X,1HI,10I9/5X,5H----I,105(1H-))
FIRES-RC2 2782    210 FORMAT (///9X,1HI/9X,1HI,5I9/5X,5H----I,48(1H-))
FIRES-RC2 2783    220 FORMAT (9X,1HI/I7,3H  I,10A9)
FIRES-RC2 2784    230 FORMAT (9X,1HI,3P,10F9.2)
FIRES-RC2 2785    240 FORMAT (9X,1HI,10F9.2)
FIRES-RC2 2786    250 FORMAT (//61H   - - - - - - - - - - - -   S T E E L   - - - - - - -
FIRES-RC2 2787       1- - - - //62H    SUBSLICE        STRESS  RATIO TO  STRESS-REL TEMPE
FIRES-RC2 2788       2RATURE   /62H                     (KSI)    YIELD     STRAIN  (IF RE
FIRES-RC2 2789       3QUESTED) /60H                                       (X 1000)     (D
FIRES-RC2 2790       4EG F)  //)
FIRES-RC2 2791    260 FORMAT (I12,F13.1,F10.2,3P,F12.2,0P,F12.2)
FIRES-RC2 2792    270 FORMAT (I12,0P,F13.1,F10.2,3P,F12.2)
FIRES-RC2 2793    280 FORMAT (4HSTRS,2I2,9A7,1X,A3,I5)
FIRES-RC2 2794    290 FORMAT (4HSTRN,2I2,9F7.2,1X,A3,I5)
FIRES-RC2 2795        END
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FIRES-RC2 2796          SUBROUTINE JOUT (FJ,U,DV,DPL,SP,AAW,DELR,SYSTIF,NJ3,LOOP,TIME,NDT,
FIRES-RC2 2797         1K)
FIRES-RC2 2798   C
FIRES-RC2 2799   C
FIRES-RC2 2800   C      SUBROUTINE  *JOUT*  IS AN OUTPUT SUBROUTINE USED FOR PROVIDING
FIRES-RC2 2801   C      SYSTEM RESULTS DURING ITERATIVE PROCEDURE
FIRES-RC2 2802   C
FIRES-RC2 2803   C
FIRES-RC2 2804          COMMON /TAP/ HED(10),ITEMP1,ITEMP2,ISEG1,ISEG2,NIN,NOUT,NPUNCH
FIRES-RC2 2805          COMMON /BLK1/ NJ,NM,NBC,NXX,MAXBAN,NCRPS,NCRPC,NSHRINK,NCONV
FIRES-RC2 2806          DIMENSION FJ(1), U(1), DELR(1), DPL(1), SP(2,1), AAW(1), SYSTIF(NJ
FIRES-RC2 2807         13,1), IX(3), DV(1)
FIRES-RC2 2808   C
FIRES-RC2 2809   C
FIRES-RC2 2810          IF (K-2) 10,20,30
FIRES-RC2 2811       10 IP1=10HAFTER INIT
FIRES-RC2 2812          IP2=10HIALIZATION
FIRES-RC2 2813          WRITE (NOUT,90) TIME,NDT,LOOP,IP1,IP2
FIRES-RC2 2814          GO TO 40
FIRES-RC2 2815       20 IP1=10HAFTER MEMB
FIRES-RC2 2816          IP2=10HERS
FIRES-RC2 2817          WRITE (NOUT,90) TIME,NDT,LOOP,IP1,IP2
FIRES-RC2 2818          GO TO 40
FIRES-RC2 2819       30 IP1=10HAFTER BAND
FIRES-RC2 2820          IP2=10HEC
FIRES-RC2 2821          WRITE (NOUT,90) TIME,NDT,LOOP,IP1,IP2
FIRES-RC2 2822          GO TO 70
FIRES-RC2 2823       40 CONTINUE
FIRES-RC2 2824          WRITE (NOUT,100)
FIRES-RC2 2825          DO 50 J=1,NJ
FIRES-RC2 2826          JR=J*3
FIRES-RC2 2827          JY=JR-1
FIRES-RC2 2828          JX=JY-1
FIRES-RC2 2829          WRITE (NOUT,110) J,U(JX),U(JY),U(JR),DV(JX),DV(JY),DV(JR),FJ(JX),F
FIRES-RC2 2830         1J(JY),FJ(JR),DELR(JX),DELR(JY),DELR(JR)
FIRES-RC2 2831       50 CONTINUE
FIRES-RC2 2832   C
FIRES-RC2 2833          WRITE (NOUT,120)
FIRES-RC2 2834          DO 60 J=1,NJ
FIRES-RC2 2835          JR=J*3
FIRES-RC2 2836          JY=JR-1
FIRES-RC2 2837          JX=JY-1
FIRES-RC2 2838          WRITE (NOUT,110) J,SP(1,JX),SP(1,JY),SP(1,JR),SP(2,JX),SP(2,JY),SP
FIRES-RC2 2839         1(2,JR),DPL(JX),DPL(JY),DPL(JR),AAW(JX),AAW(JY),AAW(JR)
FIRES-RC2 2840       60 CONTINUE
FIRES-RC2 2841   C
FIRES-RC2 2842          IF (K.EQ.1) RETURN
FIRES-RC2 2843   C
FIRES-RC2 2844       70 CONTINUE
FIRES-RC2 2845          IX(1)=3H-X
FIRES-RC2 2846          IX(2)=3H-Y
FIRES-RC2 2847          IX(3)=3H-R
FIRES-RC2 2848          WRITE (NOUT,130)
FIRES-RC2 2849          DO 80 J=1,NJ
FIRES-RC2 2850          WRITE (NOUT,140)
FIRES-RC2 2851          II=3*(J-1)
FIRES-RC2 2852          DO 80 IJ=1,3
FIRES-RC2 2853          I=IJ+II
FIRES-RC2 2854          L=10
FIRES-RC2 2855          IF (MAXBAN.LT.10) L=MAXBAN
FIRES-RC2 2856          WRITE (NOUT,150) J,IX(IJ),DELR(I),(SYSTIF(I,M),M=1,L)
FIRES-RC2 2857          IF (MAXBAN.LE.10) GO TO 80
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FIRES-RC2 2858          WRITE (NOUT,160) (SYSTIF(I,M),M=11,MAXBAN)
FIRES-RC2 2859       80 CONTINUE
FIRES-RC2 2860   C
FIRES-RC2 2861          RETURN
FIRES-RC2 2862   C
FIRES-RC2 2863   C
FIRES-RC2 2864   C
FIRES-RC2 2865       90 FORMAT (4(/),1X,10(2H* ),28HSYSTEM INFORMATION * TIME = F7.4,10H *
FIRES-RC2 2866         1 STEP = I3,10H * LOOP = I3,3H * 2A10,10(2H *))
FIRES-RC2 2867      100 FORMAT (//3X,5HJOINT6X,3HU-X7X,3HU-Y7X,3HU-R6X,4HDV-X6X,4HDV-Y6X,4
FIRES-RC2 2868        1HDV-R6X,4HFJ-X6X,4HFJ-Y6X,4HFJ-R5X,6HDELR-X4X,6HDELR-Y4X,6HDELR-R)
FIRES-RC2 2869      110 FORMAT (/1X,I7,2X,1P,12E10.0)
FIRES-RC2 2870      120 FORMAT (//3X,5HJOINT5X,5HSP-XX5X,5HSP-YY5X,5HSP-RR5X,5HSP-XY5X,5HS
FIRES-RC2 2871         1P-XR5X,5HSP-YR5X,5HDPL-X5X,5HDPL-Y,5X,5HDPL-R5X,5HAAW-X5X,5HAAW-Y5
FIRES-RC2 2872         2X,5HAAW-R)
FIRES-RC2 2873      130 FORMAT (//2X,5HJOINT,4X,4HDELR6X,6HSYSTIF)
FIRES-RC2 2874      140 FORMAT (1X)
FIRES-RC2 2875      150 FORMAT (1X,I4,A3,1P,E10.2,1X,10E10.2)
FIRES-RC2 2876      160 FORMAT (20X,1P,10E10.2)
FIRES-RC2 2877          END
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FIRES-RC2 2878          SUBROUTINE IOUT (MI,MJ,SEGL,AE,AEI,EI,EII,DCG,W,F,DELF,FA,PA,BM,AS
FIRES-RC2 2879         1TRAIN,ACURV,AREA,CRUSH,CRACK,NCONCR,NSTEEL,I4,LOOP,TIME,M)
FIRES-RC2 2880   C
FIRES-RC2 2881   C
FIRES-RC2 2882   C      SUBROUTINE  *IOUT*  IS AN OUTPUT SUBROUTINE USED IN PROVIDING
FIRES-RC2 2883   C      MEMBER AND SEGMENT RESULTS DURING THE ITERATIVE PROCEDURE
FIRES-RC2 2884   C
FIRES-RC2 2885   C
FIRES-RC2 2886          COMMON /TAP/ HED(10),ITEMP1,ITEMP2,ISEG1,ISEG2,NIN,NOUT,NPUNCH
FIRES-RC2 2887          COMMON /DYN/ NDT,NSTORE,NCMAX,NSMAX,NCCNTL,NSTLTL,ISYSTM,IMEMB,ITO
FIRES-RC2 2888         1TAL,ITAPE
FIRES-RC2 2889          COMMON /BLK1/ NJ,NM,NBC,NXX,MAXBAN,NCRPS,NCRPC,NSHRINK,NCONV
FIRES-RC2 2890          COMMON /BLK3/ DIS(6),DISP(6),FX(21,7),SIJ(6,6),S(21,6),AF(15),FF(2
FIRES-RC2 2891         1,18),T(6,6),TSF(6,6)
FIRES-RC2 2892          COMMON /MEMB/ NNSEG(75)
FIRES-RC2 2893          COMMON C(1)
FIRES-RC2 2894          DIMENSION SEGL(1), AE(1), AEI(1), EI(1), EII(1), DCG(1), W(1), F(1
FIRES-RC2 2895         1), DELF(1), FA(1), PA(2,1), BM(2,1), ASTRAIN(2,1), ACURV(2,1), ARE
FIRES-RC2 2896         2A(1), CRUSH(2,1), CRACK(2,1), NCONCR(1), NSTEEL(1)
FIRES-RC2 2897   C
FIRES-RC2 2898   C
FIRES-RC2 2899   C      REWIND TAPES AND INITIALIZE STORAGE
FIRES-RC2 2900   C         ( ON FIRST CALL OF SUBROUTINE ONLY - WHEN M .EQ. 1 )
FIRES-RC2 2901   C
FIRES-RC2 2902          IF (M.GT.1) GO TO 10
FIRES-RC2 2903          IF (ITAPE.EQ.1.AND.NDT.NE.0) GO TO 10
FIRES-RC2 2904          IF (I4.GE.3) REWIND ISEG1
FIRES-RC2 2905          IF (I4.GE.3.AND.LOOP.EQ.0) REWIND ITEMP1
FIRES-RC2 2906          MINIT=ITOTAL
FIRES-RC2 2907          IBLOCK=0
FIRES-RC2 2908   C
FIRES-RC2 2909   C      PRINT OUT THE MEMBER DATA
FIRES-RC2 2910   C      ( LOOP OVER ALL MEMBERS, WITH THE DO-LOOP IN THE MAIN PROGRAM )
FIRES-RC2 2911   C
FIRES-RC2 2912       10 CONTINUE
FIRES-RC2 2913   C
FIRES-RC2 2914          NSEG=NNSEG(M)
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FIRES-RC2 2915          WRITE (NOUT,70) M,MI,MJ,NSEG,TIME,NDT,LOOP
FIRES-RC2 2916    C
FIRES-RC2 2917          WRITE (NOUT,80)
FIRES-RC2 2918    C
FIRES-RC2 2919          DO 20 J=1,NSEG
FIRES-RC2 2920          J3=3*J
FIRES-RC2 2921          J2=J3-1
FIRES-RC2 2922          J1=J2-1
FIRES-RC2 2923          DO 20 JT=1,2
FIRES-RC2 2924    C
FIRES-RC2 2925          IF (JT.EQ.1) WRITE (NOUT,90)
FIRES-RC2 2926          IF (JT.EQ.2) WRITE (NOUT,100)
FIRES-RC2 2927          WRITE (NOUT,110) J,SEGL(J),AE(J),EI(J),AEI(J),EII(J),DCG(J),ASTRAI
FIRES-RC2 2928         1N(JT,J),ACURV(JT,J),PA(JT,J),BM(JT,J),CRUSH(JT,J),CRACK(JT,J),AREA
FIRES-RC2 2929         2(J),NCONCR(J),NSTEEL(J)
FIRES-RC2 2930       20 CONTINUE
FIRES-RC2 2931    C
FIRES-RC2 2932          WRITE (NOUT,120)
FIRES-RC2 2933          L=1
FIRES-RC2 2934          WRITE (NOUT,130) L,W(1),W(2),W(3)
FIRES-RC2 2935    C
FIRES-RC2 2936          IF (NSEG.EQ.1) GO TO 40
FIRES-RC2 2937    C
FIRES-RC2 2938          DO 30 J=2,NSEG
FIRES-RC2 2939          J3=3*J
FIRES-RC2 2940          J2=J3-1
FIRES-RC2 2941          J1=J2-1
FIRES-RC2 2942          K3=J3-3
FIRES-RC2 2943          K2=K3-1
FIRES-RC2 2944          K1=K2-1
FIRES-RC2 2945          WRITE (NOUT,130) J,W(J1),W(J2),W(J3),F(K1),F(K2),F(K3),FA(K1),FA(K
FIRES-RC2 2946         12),FA(K3),DELF(K1),DELF(K2),DELF(K3)
FIRES-RC2 2947       30 CONTINUE
FIRES-RC2 2948    C
FIRES-RC2 2949       40 CONTINUE
FIRES-RC2 2950          K1=NSEG+1
FIRES-RC2 2951          J3=K1*3
FIRES-RC2 2952          J2=J3-1
FIRES-RC2 2953          J1=J2-1
FIRES-RC2 2954          WRITE (NOUT,130) K1,W(J1),W(J2),W(J3)
FIRES-RC2 2955    C
FIRES-RC2 2956          IF (I4.EQ.2) GO TO 60
FIRES-RC2 2957    C
FIRES-RC2 2958          DO 50 J=1,NSEG
FIRES-RC2 2959    C
FIRES-RC2 2960    C
FIRES-RC2 2961    C     SET UP DYNAMIC STORAGE FOR SEGMENT DATA
FIRES-RC2 2962    C
FIRES-RC2 2963          NCONC=NCONCR(J)
FIRES-RC2 2964          NSTL=NSTEEL(J)
FIRES-RC2 2965          MINIT=MINIT+IBLOCK
FIRES-RC2 2966          IBLOCK=32*NCONC+15*NSTL+11
FIRES-RC2 2967          IF (ITAPE.EQ.0) IBLOCK=0
FIRES-RC2 2968          IF (ITAPE.EQ.1.AND.NDT.EQ.0.AND.LOOP.EQ.0) IBLOCK=0
FIRES-RC2 2969          M20=MINIT
FIRES-RC2 2970          M21=M20+NCONC
FIRES-RC2 2971          M22=M21+NCONC
FIRES-RC2 2972          M23=M22+NSTL
FIRES-RC2 2973          M24=M23+NSTL
FIRES-RC2 2974          M25=M24+NCONC
FIRES-RC2 2975          M26=M25+NCONC
FIRES-RC2 2976          M27=M26+NCONC
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FIRES-RC2 2977          M28=M27+NCONC
FIRES-RC2 2978          M29=M28+NSTL
FIRES-RC2 2979          M30=M29+NSTL
FIRES-RC2 2980          M31=M30+2*NCONC
FIRES-RC2 2981          M32=M31+2*NSTL
FIRES-RC2 2982          M33=M32+2*NCONC
FIRES-RC2 2983          M34=M33+2*NCONC
FIRES-RC2 2984          M35=M34+2*NCONC
FIRES-RC2 2985          M36=M35+2*NCONC
FIRES-RC2 2986          M37=M36+NCONC
FIRES-RC2 2987          M38=M37+2*NCONC
FIRES-RC2 2988          M39=M38+2*NCONC
FIRES-RC2 2989          M40=M39+NSTL
FIRES-RC2 2990          M41=M40+2*NSTL
FIRES-RC2 2991          M42=M41+2*NSTL
FIRES-RC2 2992          M43=M42+2*NCONC
FIRES-RC2 2993          MEFC=M43+2*NSTL
FIRES-RC2 2994          MFU=MEFC+NCONC
FIRES-RC2 2995          M44=MFU+NCONC
FIRES-RC2 2996          M45=M44+10
FIRES-RC2 2997          M46=M45+NCONC
FIRES-RC2 2998          M47=M46+NSTL
FIRES-RC2 2999          M48=M47+NCONC
FIRES-RC2 3000          M49=M48+NCONC
FIRES-RC2 3001          M50=M49+NCONC
FIRES-RC2 3002          M51=M50+NCONC
FIRES-RC2 3003          M52=M51+NCONC
FIRES-RC2 3004          M53=M52+NSTL
FIRES-RC2 3005          M54=M53+NCONC
FIRES-RC2 3006  C
FIRES-RC2 3007          CALL IOTSEG (NCONC,NSTL,C(M20),C(M21),C(M22),C(M23),C(M24),C(M25),
FIRES-RC2 3008         1C(M26),C(M27),C(M28),C(M29),C(M30),C(M31),C(M32),C(M33),C(M34),C(M
FIRES-RC2 3009         235),C(M36),C(M37),C(M38),C(M39),C(M40),C(M41),C(M42),C(M43),C(M44)
FIRES-RC2 3010         3,C(M45),C(M46),C(M47),C(M48),C(M49),C(M50),C(M51),C(M52),C(M53),C(
FIRES-RC2 3011         4M54),LOOP,J,TIME,M,C(MEFC),C(MFU))
FIRES-RC2 3012  C
FIRES-RC2 3013       50 CONTINUE
FIRES-RC2 3014  C
FIRES-RC2 3015       60 CONTINUE
FIRES-RC2 3016  C
FIRES-RC2 3017          RETURN
FIRES-RC2 3018  C
FIRES-RC2 3019  C
FIRES-RC2 3020  C
FIRES-RC2 3021       70 FORMAT (///1X,3(3H  *),26H   INTERIM DATA MEMBER NO.I4,5H * JTI3,6
FIRES-RC2 3022         1H TO JTI3,10H * NSEG = I2,10H * TIME = F7.4,10H * STEP = I3,10H *
FIRES-RC2 3023         2LOOP = I3,3(3H  *))
FIRES-RC2 3024       80 FORMAT (//27H  SEGMENT DATA FROM  /MEMB//128H  SEG    SEGL          A
FIRES-RC2 3025         1E          EI          AEI          EII       DCG    ASTRAIN       ACURV       PA
FIRES-RC2 3026         2          BM     CRUSH CRACK   AREA NCON NSTL)
FIRES-RC2 3027       90 FORMAT (10H LEFT END )
FIRES-RC2 3028      100 FORMAT (10H RIGHT END)
FIRES-RC2 3029      110 FORMAT (1X,I4,F7.1,1P,4E10.2,0P,F8.2,1P,4E10.2,0P,3F6.1,2I5)
FIRES-RC2 3030      120 FORMAT (//39H  INTERSEGMENTAL NODE DATA FROM  /MEMB//27H NODE     W-
FIRES-RC2 3031         1X       W-Y       W-R,7X,83HF-X         F-Y         F-R         FA-X        FA-
FIRES-RC2 3032         2Y       FA-R      DELF-X      DELF-Y      DELF-R)
FIRES-RC2 3033      130 FORMAT (/1X,I4,1P,4(3E10.1))
FIRES-RC2 3034          END
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FIRES-RC2 3035          SUBROUTINE IOTSEG (NCONC,NSTL,AC,YC,AS,YS,AMOD,STRE,EPU,TES,AMOS,Y
FIRES-RC2 3036         1IE,AR,ARS,KRAT,KRAF,AKAK,AKK,STRC,EHC,SIC,STRS,EHS,SIS,ESHIFTC,ESH
FIRES-RC2 3037         2IFTS,NSTR,TEMPC,TEMPS,SST,BCRP,CCRP,DCRP,ECRP,ET,SAVG,ISYM,LOOP,J,
FIRES-RC2 3038         3TIME,M,EFC,FU)
FIRES-RC2 3039   C
FIRES-RC2 3040   C
FIRES-RC2 3041          COMMON /TAP/ HED(10),ITEMP1,ITEMP2,ISEG1,ISEG2,NIN,NOUT,NPUNCH
FIRES-RC2 3042          COMMON /DYN/ NDT,NSTORE,NCMAX,NSMAX,NCONTL,NSTLTL,ISYSTM,IMEMB,ITO
FIRES-RC2 3043         1TAL,ITAPE
FIRES-RC2 3044          DIMENSION AC(1), YC(1), AS(1), YS(1), AMOD(1), STRE(1), EPU(1), TE
FIRES-RC2 3045         1S(1), AMOS(1), YIE(1), AR(2,1), ARS(2,1), KRAT(2,1), KRAF(2,1), AK
FIRES-RC2 3046         2AK(2,1), AKK(2,1), STRC(1), EHC(2,1), SIC(2,1), STRS(1), EHS(2,1),
FIRES-RC2 3047         3 SIS(2,1), ESHIFTC(2,1), ESHIFTS(2,1), NSTR(1), TEMPC(1), TEMPS(1)
FIRES-RC2 3048         4, SST(1), BCRP(1), CCRP(1), DCRP(1), ECRP(1), ET(1), SAVG(1), EFC(
FIRES-RC2 3049         51), FU(1)
FIRES-RC2 3050          INTEGER AKK,AKAK
FIRES-RC2 3051   C
FIRES-RC2 3052   C      READ IN SEGMENT DATA (IF NOT ALREADY IN CORE)
FIRES-RC2 3053   C
FIRES-RC2 3054          IF (ITAPE.EQ.1.AND.NDT.GT.0) GO TO 10
FIRES-RC2 3055          IF (ITAPE.EQ.1.AND.LOOP.GT.0) GO TO 10
FIRES-RC2 3056          ISIZE=25*NCONC+13*NSTL+10
FIRES-RC2 3057          READ (ISEG1) (AC(I),I=1,ISIZE)
FIRES-RC2 3058          IF (LOOP.NE.0) GO TO 10
FIRES-RC2 3059          ISIZE=7*NCONC+2*NSTL+1
FIRES-RC2 3060          READ (ITEMP1) (TEMPC(I),I=1,ISIZE)
FIRES-RC2 3061   C
FIRES-RC2 3062       10 WRITE (NOUT,50) J,M,NCONC,NSTL,TIME,NDT,LOOP
FIRES-RC2 3063   C
FIRES-RC2 3064          IF (LOOP.NE.0) GO TO 30
FIRES-RC2 3065   C
FIRES-RC2 3066          WRITE (NOUT,60)
FIRES-RC2 3067          WRITE (NOUT,70) (I,TEMPC(I),SST(I),BCRP(I),CCRP(I),DCRP(I),ECRP(I)
FIRES-RC2 3068         1,I=1,NCONC)
FIRES-RC2 3069   C
FIRES-RC2 3070          IF (NSTL.EQ.0) GO TO 30
FIRES-RC2 3071          WRITE (NOUT,80)
FIRES-RC2 3072          DO 20 I=1,NSTL
FIRES-RC2 3073       20 WRITE (NOUT,90) I,TEMPS(I)
FIRES-RC2 3074   C
FIRES-RC2 3075       30 CONTINUE
FIRES-RC2 3076   C
FIRES-RC2 3077   C      PRINT SEGMENT DATA  (FOR BOTH ENDS OF THE SEGMENT)
FIRES-RC2 3078   C
FIRES-RC2 3079          WRITE (NOUT,100)
FIRES-RC2 3080          WRITE (NOUT,110) (I,AC(I),YC(I),AMOD(I),STRE(I),EPU(I),TES(I),STRC
FIRES-RC2 3081         1(I),AR(1,I),KRAT(1,I),KRAF(1,I),AKAK(1,I),AKK(1,I),EHC(1,I),SIC(1,
FIRES-RC2 3082         2I),ESHIFTC(1,I),AR(2,I),KRAT(2,I),KRAF(2,I),AKAK(2,I),AKK(2,I),EHC
FIRES-RC2 3083         3(2,I),SIC(2,I),ESHIFTC(2,I),I=1,NCONC)
FIRES-RC2 3084   C
FIRES-RC2 3085          IF (NSTL.EQ.0) GO TO 40
FIRES-RC2 3086          WRITE (NOUT,120)
FIRES-RC2 3087          WRITE (NOUT,130) (I,AS(I),YS(I),AMOS(I),YIE(I),STRS(I),ARS(1,I),EH
FIRES-RC2 3088         1S(1,I),SIS(1,I),ESHIFTS(1,I),ARS(2,I),EHS(2,I),SIS(2,I),ESHIFTS(2,
FIRES-RC2 3089         2I),I=1,NSTL)
FIRES-RC2 3090       40 CONTINUE
FIRES-RC2 3091   C
FIRES-RC2 3092          RETURN
FIRES-RC2 3093   C
FIRES-RC2 3094   C
FIRES-RC2 3095   C
FIRES-RC2 3096       50 FORMAT (//4X,2(4H*    ),28HINTERIM DATA FOR SEGMENT NO.I3,14H OF ME
```

```
FIRES-RC2 3097        1MBER NO.I3,11H * NCONC = I3,10H * NSTL = I3,10H * TIME = F7.4,10H
FIRES-RC2 3098        2* STEP = I3,10H * LOOP = I3)
FIRES-RC2 3099     60 FORMAT (//39H  CONCRETE SUBSLICE DATA FROM  /ITEMP//74H  SUBSLICE
FIRES-RC2 3100        1      TEMPC          SST       BCRP       CCRP       DCRP       ECRP /)
FIRES-RC2 3101     70 FORMAT (1X,I9,F11.1,5X,1P,5E10.2,0P)
FIRES-RC2 3102     80 FORMAT (//35H  STEEL SUBSLICE DATA FROM  /ITEMP//31H  SUBSLICE
FIRES-RC2 3103        1  TEMPS          /)
FIRES-RC2 3104     90 FORMAT (1X,I9,F11.1)
FIRES-RC2 3105    100 FORMAT (//37H  CONCRETE SUBSLICE DATA FROM  /ISEG//128H  SUBS    AC
FIRES-RC2 3106        1     YC     AMOD     STRE     EPU      TES       ASTRC
FIRES-RC2 3107        2              AR     K K A A      EHC     SIC    ESHIFTC/95X7HR R K K/9
FIRES-RC2 3108        35X,7HA A A K/95X,7HT F K  )
FIRES-RC2 3109    110 FORMAT (1X,I5,2F6.1,F9.1,F7.2,F8.4,F7.2,1P,E10.2,18X,8HLEFT     ,0P
FIRES-RC2 3110        1,F9.1,4I2,1P,E10.2,0P,F7.2,1P,E10.2,0P/77X,8HRIGHT    ,F9.1,4I2,1P,
FIRES-RC2 3111        2E10.2,0P,F7.2,1P,E10.2,0P)
FIRES-RC2 3112    120 FORMAT (//34H  STEEL SUBSLICE DATA FROM  /ISEG//32H  SUBS    AS
FIRES-RC2 3113        1YS     AMOS     YIE,12H          STRS,26X,36H     ARS        EHS      SIS
FIRES-RC2 3114        2   ESHIFTS /)
FIRES-RC2 3115    130 FORMAT (1X,I5,2F6.1,F9.1,F7.2,1P,E10.2,18X,8HLEFT     ,0P,F9.1,1P,E
FIRES-RC2 3116        110.2,0P,F7.2,1P,E10.2/62X,8HRIGHT    ,0P,F9.1,1P,E10.2,0P,F7.2,1P,E
FIRES-RC2 3117        210.2,0P)
FIRES-RC2 3118         END
```

```
FIRES-RC2 3119         FUNCTION NUMBER (I,IREAD,NOUT)
FIRES-RC2 3120   C
FIRES-RC2 3121   C
FIRES-RC2 3122   C     NUMBER IS A FUNCTION THAT OBTAINS AN INTEGER CONSTANT CONTAINED
FIRES-RC2 3123   C     ON AN ALPHA-NUMERIC CONTROL CARD.  THE INTEGER CONSTANT MUST
FIRES-RC2 3124   C     BE CONTAINED BETWEEN COMMAS OR BETWEEN A COMMA AND A BLANK
FIRES-RC2 3125   C
FIRES-RC2 3126   C
FIRES-RC2 3127         DIMENSION IREAD(80)
FIRES-RC2 3128   C
FIRES-RC2 3129         K=0
FIRES-RC2 3130      10 J=IREAD(I)
FIRES-RC2 3131         IF (J.EQ.56B) GO TO 20
FIRES-RC2 3132         IF (J.GT.32B) GO TO 40
FIRES-RC2 3133         I=I+1
FIRES-RC2 3134         IF (I.EQ.81) GO TO 30
FIRES-RC2 3135         GO TO 10
FIRES-RC2 3136      20 I=I+1
FIRES-RC2 3137         J=IREAD(I)
FIRES-RC2 3138         IF (J.EQ.55B.OR.J.EQ.56B) GO TO 30
FIRES-RC2 3139         IF (J.LT.33B.OR.J.GT.44B) GO TO 40
FIRES-RC2 3140         J=J-33B
FIRES-RC2 3141         K=K*10+J
FIRES-RC2 3142         GO TO 20
FIRES-RC2 3143      30 NUMBER=K
FIRES-RC2 3144         RETURN
FIRES-RC2 3145   C
FIRES-RC2 3146      40 CONTINUE
FIRES-RC2 3147         WRITE (NOUT,50) IREAD
FIRES-RC2 3148         STOP
FIRES-RC2 3149   C
FIRES-RC2 3150   C
FIRES-RC2 3151   C
FIRES-RC2 3152      50 FORMAT (///,33H - - - PROGRAM TERMINATED - - - -,//,13H  INPUT ERR
FIRES-RC2 3153        1OR,/1X,80R1)
```

```
FIRES-RC2 3154          END


FIRES-RC2 3155          SUBROUTINE TEMPIN (M1,TCONST,TEMPC,TEMPS,NCONC,NSTL,IM,IS,ISYM,T)
FIRES-RC2 3156    C
FIRES-RC2 3157    C
FIRES-RC2 3158    C     SUBROUTINE  * TEMPIN *  READS IN TEMPERATURE DATA
FIRES-RC2 3159    C
FIRES-RC2 3160    C
FIRES-RC2 3161          COMMON /TAP/ HED(10),ITEMP1,ITEMP2,ISEG1,ISEG2,NIN,NOUT,NPUNCH
FIRES-RC2 3162          DIMENSION TEMPC(1), TEMPS(1), T(1)
FIRES-RC2 3163    C
FIRES-RC2 3164    C     TEMPERATURE CONSTANT THROUGHOUT SEGMENT CROSS-SECTION
FIRES-RC2 3165    C
FIRES-RC2 3166          IF (M1.EQ.0) GO TO 40
FIRES-RC2 3167       10 DO 20 I=1,NCONC
FIRES-RC2 3168       20 TEMPC(I)=TCONST
FIRES-RC2 3169          DO 30 I=1,NSTL
FIRES-RC2 3170       30 TEMPS(I)=TCONST
FIRES-RC2 3171          RETURN
FIRES-RC2 3172    C
FIRES-RC2 3173    C     READ SEGMENT TEMPERATURE CONTROL CARD
FIRES-RC2 3174    C
FIRES-RC2 3175       40 READ (NIN,80) J1,J2,T1,J3
FIRES-RC2 3176          NELC=NCONC
FIRES-RC2 3177          NELS=NSTL
FIRES-RC2 3178          IF (ISYM.EQ.1) NELC=NCONC/2
FIRES-RC2 3179          IF (ISYM.EQ.1) NELS=NSTL/2
FIRES-RC2 3180          NEL=NELC+NELS
FIRES-RC2 3181    C
FIRES-RC2 3182    C     CHECK FOR CONSTANT CROSS-SECTION TEMPERATURE
FIRES-RC2 3183    C
FIRES-RC2 3184          IF (J1.NE.10HCONSTANT  ) GO TO 50
FIRES-RC2 3185          DECODE (10,90,J2) TCONST
FIRES-RC2 3186          GO TO 10
FIRES-RC2 3187       50 READ (NIN,100) (T(I),I=1,NEL)
FIRES-RC2 3188    C
FIRES-RC2 3189    C     TRANSFORM TEMPERATURE VECTOR TO CONCRETE SUBSLICE TEMPERATURES
FIRES-RC2 3190    C
FIRES-RC2 3191          DO 60 I=1,NCONC
FIRES-RC2 3192          J=I
FIRES-RC2 3193          IF (I.GT.NELC) J=I-NELC
FIRES-RC2 3194       60 TEMPC(I)=T(J)
FIRES-RC2 3195    C
FIRES-RC2 3196    C     TRANSFORM TEMPERATURE VECTOR TO STEEL SUBSLICE TEMPERATURES
FIRES-RC2 3197    C
FIRES-RC2 3198          IF (NSTL.EQ.0) RETURN
FIRES-RC2 3199          DO 70 I=1,NSTL
FIRES-RC2 3200          J=I+NELC
FIRES-RC2 3201          IF (I.GT.NELS) J=I-NELS+NELC
FIRES-RC2 3202       70 TEMPS(I)=T(J)
FIRES-RC2 3203          RETURN
FIRES-RC2 3204    C
FIRES-RC2 3205    C
FIRES-RC2 3206    C
FIRES-RC2 3207       80 FORMAT (2A10,18X,F6.3,2X,I4)
FIRES-RC2 3208       90 FORMAT (F10.0)
FIRES-RC2 3209      100 FORMAT (7(4X,F6.1))
FIRES-RC2 3210          END
```

```
FIRES-RC2 3211          SUBROUTINE PROP (M1,TCONST,TEMPC,TEMPS,NCONC,NSTL,AMOD,STRE,EPU,TE
FIRES-RC2 3212         1S,AMOS,YIE,EFC,FU)
FIRES-RC2 3213   C
FIRES-RC2 3214   C
FIRES-RC2 3215   C      SUBROUTINE PROP DETERMINES THE SUBSLICE MATERIAL PROPERTIES FOR
FIRES-RC2 3216   C      A SEGMENT CROSS-SECTION
FIRES-RC2 3217   C
FIRES-RC2 3218   C
FIRES-RC2 3219          DIMENSION TEMPC(1), TEMPS(1), AMOD(1), STRE(1), EPU(1), TES(1), AM
FIRES-RC2 3220         1OS(1), YIE(1), EFC(1), FU(1)
FIRES-RC2 3221   C
FIRES-RC2 3222          IF (M1.EQ.0) GO TO 30
FIRES-RC2 3223   C
FIRES-RC2 3224   C      MATERIAL PROPERTIES CONSTANT THROUGHOUT THE ENTIRE CROSS-SECTION
FIRES-RC2 3225   C
FIRES-RC2 3226          T=TCONST
FIRES-RC2 3227          AM=VMATL(2,T)
FIRES-RC2 3228          ST=VMATL(3,T)
FIRES-RC2 3229          EEFC=VMATL(4,T)
FIRES-RC2 3230          FFU=VMATL(5,T)
FIRES-RC2 3231          EP=VMATL(6,T)
FIRES-RC2 3232          TE=VMATL(7,T)
FIRES-RC2 3233   C
FIRES-RC2 3234          DO 10 I=1,NCONC
FIRES-RC2 3235          AMOD(I)=AM
FIRES-RC2 3236          STRE(I)=ST
FIRES-RC2 3237          EFC(I)=EEFC
FIRES-RC2 3238          FU(I)=FFU
FIRES-RC2 3239          EPU(I)=EP
FIRES-RC2 3240       10 TES(I)=TE
FIRES-RC2 3241          AM=VMATL(9,T)
FIRES-RC2 3242          ST=VMATL(11,T)
FIRES-RC2 3243   C
FIRES-RC2 3244          DO 20 I=1,NSTL
FIRES-RC2 3245          AMOS(I)=AM
FIRES-RC2 3246       20 YIE(I)=ST
FIRES-RC2 3247          RETURN
FIRES-RC2 3248   C
FIRES-RC2 3249   C      MATERIAL PROPERTIES VARY WITH EACH SUBSLICE IN THE CROSS-SECTION
FIRES-RC2 3250   C
FIRES-RC2 3251       30 CONTINUE
FIRES-RC2 3252          DO 40 I=1,NCONC
FIRES-RC2 3253          T=TEMPC(I)
FIRES-RC2 3254          AMOD(I)=VMATL(2,T)
FIRES-RC2 3255          STRE(I)=VMATL(3,T)
FIRES-RC2 3256          EFC(I)=VMATL(4,T)
FIRES-RC2 3257          FU(I)=VMATL(5,T)
FIRES-RC2 3258          EPU(I)=VMATL(6,T)
FIRES-RC2 3259       40 TES(I)=VMATL(7,T)
FIRES-RC2 3260   C
FIRES-RC2 3261          DO 50 I=1,NSTL
FIRES-RC2 3262          T=TEMPS(I)
FIRES-RC2 3263          AMOS(I)=VMATL(9,T)
FIRES-RC2 3264       50 YIE(I)=VMATL(11,T)
FIRES-RC2 3265   C
FIRES-RC2 3266          RETURN
FIRES-RC2 3267          END
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```
FIRES-RC2 3268          SUBROUTINE FORMK (SEGL,AE,EI,DCG,MM)
FIRES-RC2 3269    C
FIRES-RC2 3270    C
FIRES-RC2 3271    C     SUBROUTINE  * FORMK *  CONSTRUCTS THE SUBSTRUCTURED MEMBER
FIRES-RC2 3272    C     STIFFNESS MATRIX
FIRES-RC2 3273    C
FIRES-RC2 3274    C
FIRES-RC2 3275          COMMON /MEMB/ NNSEG(75)
FIRES-RC2 3276          COMMON /BLK2/ A(6,6),E(6,6)
FIRES-RC2 3277          COMMON /BLK3/ DIS(6),DISP(6),FX(21,7),SIJ(6,6),S(21,6),AF(15),FF(2
FIRES-RC2 3278         1,18),T(6,6),TSF(6,6)
FIRES-RC2 3279          DIMENSION SEGL(1), AE(1), EI(1), DCG(1)
FIRES-RC2 3280    C
FIRES-RC2 3281    C     INITIALIZE THE MEMBER STIFFNESS MATRIX
FIRES-RC2 3282    C
FIRES-RC2 3283          NSEG=NNSEG(MM)
FIRES-RC2 3284          NM3P1=(NSEG+1)*3
FIRES-RC2 3285          DO 10 J=1,NM3P1
FIRES-RC2 3286          DO 10 K=1,6
FIRES-RC2 3287       10 S(J,K)=0.
FIRES-RC2 3288    C
FIRES-RC2 3289    C     FORM SEGMENT STIFFNESS MATRIX WITH RESPECT TO SEGMENT CENTROID
FIRES-RC2 3290    C
FIRES-RC2 3291          DO 100 J=1,NSEG
FIRES-RC2 3292    C
FIRES-RC2 3293          CALL FORM (AE(J),EI(J),SEGL(J),TSF)
FIRES-RC2 3294    C
FIRES-RC2 3295    C     FORM TRANSFORMATION MATRIX AND TRANSFORM SEGMENT STIFFNESS MATRIX
FIRES-RC2 3296    C     FROM CENTROID TO MEMBER REFERENCE LINE
FIRES-RC2 3297    C
FIRES-RC2 3298          E(1,3)=-DCG(J)
FIRES-RC2 3299          E(4,6)=E(1,3)
FIRES-RC2 3300    C
FIRES-RC2 3301          DO 20 K=1,6
FIRES-RC2 3302          DO 20 L=1,6
FIRES-RC2 3303          T(K,L)=0.
FIRES-RC2 3304          DO 20 M=1,6
FIRES-RC2 3305       20 T(K,L)=T(K,L)+TSF(K,M)*E(M,L)
FIRES-RC2 3306    C
FIRES-RC2 3307          DO 30 K=1,6
FIRES-RC2 3308          DO 30 L=1,6
FIRES-RC2 3309          TSF(K,L)=0.
FIRES-RC2 3310          DO 30 M=1,6
FIRES-RC2 3311       30 TSF(K,L)=TSF(K,L)+E(M,K)*T(M,L)
FIRES-RC2 3312    C
FIRES-RC2 3313    C     SUPERPOSE SEGMENTS STIFFNESS MATRICES TO FORM MEMBER STIFFNESS
FIRES-RC2 3314    C     MATRIX
FIRES-RC2 3315    C
FIRES-RC2 3316          DO 40 K=1,6
FIRES-RC2 3317          NR=K
FIRES-RC2 3318          M=3*(J-1)+K
FIRES-RC2 3319          DO 40 L=NR,6
FIRES-RC2 3320          N=L-NR+1
FIRES-RC2 3321       40 S(M,N)=S(M,N)+TSF(K,L)
FIRES-RC2 3322    C
FIRES-RC2 3323          IF (J-1) 100,50,60
FIRES-RC2 3324       50 L=1
FIRES-RC2 3325          GO TO 80
FIRES-RC2 3326       60 IF (J-NSEG) 100,70,100
FIRES-RC2 3327       70 L=4
FIRES-RC2 3328    C
FIRES-RC2 3329       80 M=L+2
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FIRES-RC2 3330  C
FIRES-RC2 3331  C       FORM STIFFNESS MATRIX PERTAINING TO DEGREES OF FREEDOM OF
FIRES-RC2 3332  C       CONNECTING MEMBERS JOINTS
FIRES-RC2 3333  C
FIRES-RC2 3334          DO 90 K=L,M
FIRES-RC2 3335          DO 90 N=1,6
FIRES-RC2 3336       90 SIJ(K,N)=TSF(K,N)
FIRES-RC2 3337      100 CONTINUE
FIRES-RC2 3338  C
FIRES-RC2 3339          RETURN
FIRES-RC2 3340          END
```

```
FIRES-RC2 3341          SUBROUTINE FORM (A,I,L,K)
FIRES-RC2 3342  C
FIRES-RC2 3343  C
FIRES-RC2 3344  C       THIS SUBROUTINE FORMS THE 6*6 SEGMENT STIFFNESS MATRIX ABOUT
FIRES-RC2 3345  C       THE CENTROID
FIRES-RC2 3346  C
FIRES-RC2 3347  C
FIRES-RC2 3348          REAL K(6,6),L,I
FIRES-RC2 3349          REAL L2,L3
FIRES-RC2 3350  C
FIRES-RC2 3351          L2=L*L
FIRES-RC2 3352          L3=L2*L
FIRES-RC2 3353          DO 10 J=1,36
FIRES-RC2 3354       10 K(J)=0.0
FIRES-RC2 3355          K(1,1)=A/L
FIRES-RC2 3356          K(1,4)=-K(1,1)
FIRES-RC2 3357          K(4,4)=K(1,1)
FIRES-RC2 3358          K(2,2)=12.0*I/L3
FIRES-RC2 3359          K(2,5)=-K(2,2)
FIRES-RC2 3360          K(5,5)=K(2,2)
FIRES-RC2 3361          K(3,3)=4.0*I/L
FIRES-RC2 3362          K(6,6)=K(3,3)
FIRES-RC2 3363          K(3,6)=K(3,3)/2.0
FIRES-RC2 3364          K(2,3)=6.0*I/L2
FIRES-RC2 3365          K(2,6)=K(2,3)
FIRES-RC2 3366          K(3,5)=-K(2,3)
FIRES-RC2 3367          K(5,6)=K(3,5)
FIRES-RC2 3368          DO 20 J=1,6
FIRES-RC2 3369          M=J
FIRES-RC2 3370          DO 20 N=M,6
FIRES-RC2 3371       20 K(N,J)=K(J,N)
FIRES-RC2 3372          RETURN
FIRES-RC2 3373  C
FIRES-RC2 3374          END
```

```
FIRES-RC2 3375          SUBROUTINE BANDEC (A,F,NEQ,MAXB,NVEC,NROW,NBAN,NBEC)
FIRES-RC2 3376  C
FIRES-RC2 3377  C
FIRES-RC2 3378  C       EQUATION SOLVER, WHICH SERVES FOR STATIC CONDENSATION AS WELL
FIRES-RC2 3379  C       AS FOR SOLVING FOR DISPLACEMENTS
FIRES-RC2 3380  C
FIRES-RC2 3381  C
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FIRES-RC2 3382          DIMENSION A(NROW,NBAN), F(NROW,NBEC)
FIRES-RC2 3383    C
FIRES-RC2 3384          LOOP=NEQ-1
FIRES-RC2 3385          DO 30 I=1,LOOP
FIRES-RC2 3386          IF (ABS(A(I,1))-1.E-30) 70,70,10
FIRES-RC2 3387       10 M=I+1
FIRES-RC2 3388          N=MIN0(I+MAXB-1,NEQ)
FIRES-RC2 3389          DO 30 J=M,N
FIRES-RC2 3390          L=J+2-M
FIRES-RC2 3391          D=A(I,L)/A(I,1)
FIRES-RC2 3392          DO 20 MM=1,NVEC
FIRES-RC2 3393       20 F(J,MM)=F(J,MM)-D*F(I,MM)
FIRES-RC2 3394          MM=MIN0(MAXB-L+1,NEQ-J+1)
FIRES-RC2 3395          DO 30 K=1,MM
FIRES-RC2 3396          NN=L+K-1
FIRES-RC2 3397       30 A(J,K)=A(J,K)-D*A(I,NN)
FIRES-RC2 3398          DO 40 I=1,NVEC
FIRES-RC2 3399       40 F(NEQ,I)=F(NEQ,I)/A(NEQ,1)
FIRES-RC2 3400          DO 60 I=2,NEQ
FIRES-RC2 3401          J=NEQ-I+1
FIRES-RC2 3402          K=MIN0(NEQ-J+1,MAXB)
FIRES-RC2 3403          DO 60 MM=1,NVEC
FIRES-RC2 3404          DO 50 L=2,K
FIRES-RC2 3405          M=J+L-1
FIRES-RC2 3406       50 F(J,MM)=F(J,MM)-A(J,L)*F(M,MM)
FIRES-RC2 3407       60 F(J,MM)=F(J,MM)/A(J,1)
FIRES-RC2 3408          RETURN
FIRES-RC2 3409    C
FIRES-RC2 3410       70 PRINT 80, I
FIRES-RC2 3411          STOP
FIRES-RC2 3412    C
FIRES-RC2 3413    C
FIRES-RC2 3414    C
FIRES-RC2 3415       80 FORMAT (29H1 ZERO DIAGONAL ELEMENT, ROW I4)
FIRES-RC2 3416          END
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FIRES-RC2 3417          SUBROUTINE CONDENS (NM31,NM32,NJ3,MI,MJ,DELF,DV,SYSTIF,FJ)
FIRES-RC2 3418    C
FIRES-RC2 3419    C
FIRES-RC2 3420    C     SUBROUTINE CONDENS STATICALLY CONDENSES THE SUBSTRUCTURED MEMBERS
FIRES-RC2 3421    C     STIFFNESS MATRIX AND LOAD VECTOR INTO MEMBER TERMS AND THEN
FIRES-RC2 3422    C     ADDS THESE TO THE OVERALL STRUCTURAL STIFFNESS MATRIX AND LOAD
FIRES-RC2 3423    C     VECTOR
FIRES-RC2 3424    C
FIRES-RC2 3425    C
FIRES-RC2 3426          COMMON /BLK2/ A(6,6),E(6,6)
FIRES-RC2 3427          COMMON /BLK3/ DIS(6),DISP(6),FX(21,7),SIJ(6,6),S(21,6),AF(15),FF(2
FIRES-RC2 3428         1,18),T(6,6),TSF(6,6)
FIRES-RC2 3429          DIMENSION DELF(15), SYSTIF(NJ3,1), FJ(1), DV(1)
FIRES-RC2 3430    C
FIRES-RC2 3431    C     START CONDENSATION TO OBTAIN EQUIVALENT MEMBER END STIFFNESSES
FIRES-RC2 3432    C     AND ACTIONS
FIRES-RC2 3433    C
FIRES-RC2 3434          DO 20 J=1,NM31
FIRES-RC2 3435          DO 10 K=1,6
FIRES-RC2 3436       10 FX(J,K)=0.
FIRES-RC2 3437    C
FIRES-RC2 3438    C     STORE NEGATIVE OF INTERSEGMENTAL OUT-OF-BALANCE LOADS
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```
FIRES-RC2 3439  C
FIRES-RC2 3440     20 FX(J,7)=-DELF(J)
FIRES-RC2 3441        DO 30 J=1,3
FIRES-RC2 3442        JI=J+3
FIRES-RC2 3443        DO 30 K=1,3
FIRES-RC2 3444        L=NM32+K
FIRES-RC2 3445        FX(K,J)=-SIJ(J,K+3)
FIRES-RC2 3446        FX(L,JI)=-SIJ(JI,K)
FIRES-RC2 3447     30 CONTINUE
FIRES-RC2 3448        DO 40 J=1,NM31
FIRES-RC2 3449        DO 40 K=1,6
FIRES-RC2 3450     40 S(J,K)=S(J+3,K)
FIRES-RC2 3451        CALL BANDEC (S,FX,NM31,6,7,21,6,7)
FIRES-RC2 3452  C
FIRES-RC2 3453  C     STORE NEGATIVE OF MEMBER END INTERNAL FORCES IN ( DIS )
FIRES-RC2 3454  C
FIRES-RC2 3455        DO 50 J=1,3
FIRES-RC2 3456        DIS(J)=-FF(1,J)
FIRES-RC2 3457        JJ=J+NM31
FIRES-RC2 3458        JK=J+3
FIRES-RC2 3459        DIS(JK)=-FF(2,JJ)
FIRES-RC2 3460        DO 50 K=1,3
FIRES-RC2 3461        KL=K+3
FIRES-RC2 3462        TSF(JK,KL)=SIJ(JK,KL)
FIRES-RC2 3463        TSF(JK,K)=0.
FIRES-RC2 3464        TSF(J,KL)=0.
FIRES-RC2 3465        TSF(J,K)=SIJ(J,K)
FIRES-RC2 3466        MM=K+NM32
FIRES-RC2 3467        DIS(JK)=DIS(JK)+SIJ(JK,K)*FX(MM,7)
FIRES-RC2 3468        DIS(J)=DIS(J)+SIJ(J,KL)*FX(K,7)
FIRES-RC2 3469        DO 50 L=1,3
FIRES-RC2 3470        LM=L+3
FIRES-RC2 3471        MM=L+NM32
FIRES-RC2 3472        TSF(JK,KL)=TSF(JK,KL)+SIJ(JK,L)*FX(MM,KL)
FIRES-RC2 3473        TSF(JK,K)=TSF(JK,K)+SIJ(JK,L)*FX(MM,K)
FIRES-RC2 3474        TSF(J,KL)=TSF(J,KL)+SIJ(J,LM)*FX(L,KL)
FIRES-RC2 3475     50 TSF(J,K)=TSF(J,K)+SIJ(J,LM)*FX(L,K)
FIRES-RC2 3476        GO TO 70
FIRES-RC2 3477  C
FIRES-RC2 3478        ENTRY STIFF
FIRES-RC2 3479  C
FIRES-RC2 3480  C     FOR ONE-SEGMENT MEMBER, STORE NEGATIVE OF JOINT INTERNAL FORCES
FIRES-RC2 3481  C     IN ( DIS )
FIRES-RC2 3482  C
FIRES-RC2 3483        DO 60 I=1,6
FIRES-RC2 3484     60 DIS(I)=-DIS(I)
FIRES-RC2 3485  C
FIRES-RC2 3486  C     TRANSFORM MEMBER TERMS INTO THE GLOBAL COORDINATES
FIRES-RC2 3487  C
FIRES-RC2 3488     70 DO 80 J=1,6
FIRES-RC2 3489        DISP(J)=0.
FIRES-RC2 3490        DO 80 K=1,6
FIRES-RC2 3491        T(J,K)=0.
FIRES-RC2 3492        DISP(J)=DISP(J)+A(K,J)*DIS(K)
FIRES-RC2 3493        DO 80 L=1,6
FIRES-RC2 3494     80 T(J,K)=T(J,K)+A(L,J)*TSF(L,K)
FIRES-RC2 3495        DO 90 J=1,6
FIRES-RC2 3496        DO 90 K=1,6
FIRES-RC2 3497        TSF(J,K)=0.
FIRES-RC2 3498        DO 90 L=1,6
FIRES-RC2 3499     90 TSF(J,K)=TSF(J,K)+T(J,L)*A(L,K)
FIRES-RC2 3500  C
```

```
FIRES-RC2 3501  C      ADD TRANSFORMED TERMS TO STRUCTURAL SYSTEM MATRICES
FIRES-RC2 3502  C
FIRES-RC2 3503         NR=(MI-1)*3
FIRES-RC2 3504         NC=(MJ-MI)*3
FIRES-RC2 3505         II=(MJ-1)*3
FIRES-RC2 3506         DO 110 J=1,3
FIRES-RC2 3507         MM=J
FIRES-RC2 3508         N=J
FIRES-RC2 3509         JJ=NR+J
FIRES-RC2 3510         LL=II+J
FIRES-RC2 3511  C
FIRES-RC2 3512  C      LOAD VECTOR  (OUT-OF-BALANCE FORCES)
FIRES-RC2 3513  C
FIRES-RC2 3514         DV(JJ)=DV(JJ)+DISP(J)
FIRES-RC2 3515         DV(LL)=DV(LL)+DISP(J+3)
FIRES-RC2 3516  C
FIRES-RC2 3517  C      STIFFNESS MATRIX
FIRES-RC2 3518  C
FIRES-RC2 3519         DO 100 K=N,3
FIRES-RC2 3520         KK=K-MM+1
FIRES-RC2 3521         SYSTIF(JJ,KK)=SYSTIF(JJ,KK)+TSF(J,K)
FIRES-RC2 3522     100 SYSTIF(LL,KK)=SYSTIF(LL,KK)+TSF(J+3,K+3)
FIRES-RC2 3523         DO 110 K=1,3
FIRES-RC2 3524         KK=K+NC-N+1
FIRES-RC2 3525     110 SYSTIF(JJ,KK)=SYSTIF(JJ,KK)+TSF(J,K+3)
FIRES-RC2 3526  C
FIRES-RC2 3527         RETURN
FIRES-RC2 3528         END
```

```
FIRES-RC2 3529         SUBROUTINE MATLIN
FIRES-RC2 3530  C
FIRES-RC2 3531  C
FIRES-RC2 3532  C      SUBROUTINE MATLIN CONTROLS THE INPUT OF TEMPERATURE-DEPENDENT
FIRES-RC2 3533  C      MATERIAL PROPERTIES
FIRES-RC2 3534  C
FIRES-RC2 3535  C
FIRES-RC2 3536         COMMON /TAP/ HED(10),ITEMP1,ITEMP2,ISEG1,ISEG2,NIN,NOUT,NPUNCH
FIRES-RC2 3537         COMMON /MATL/ XCEC(10),YCEC(10),SCEC(10),KCEC,XEC(10),YEC(10),SEC(
FIRES-RC2 3538        110),KEC,XFC(10),YFC(10),SFC(10),KFC,XFT(10),YFT(10),SFT(10),KFT,XC
FIRES-RC2 3539        2S(10),YCS(10),SCS(10),KCS,XCES(10),YCES(10),SCES(10),KCES,XES(10),
FIRES-RC2 3540        3YES(10),SES(10),KES,XEY(10),YEY(10),SEY(10),KEY,XFY(10),YFY(10),SF
FIRES-RC2 3541        4Y(10),KFY,XEFC(10),YEFC(10),SEFC(10),KEFC,XFU(10),YFU(10),SFU(10),
FIRES-RC2 3542        5KFU
FIRES-RC2 3543  C
FIRES-RC2 3544         WRITE (NOUT,10)
FIRES-RC2 3545         READ (NIN,20) KCEC,KEC,KFC,KEFC,KFU,KCS,KFT
FIRES-RC2 3546         IB=10H
FIRES-RC2 3547         CALL MATIN (10HCOEFFICENT,10H OF EXPANS,10HION          ,XCEC,YCEC,SC
FIRES-RC2 3548        1EC,KCEC)
FIRES-RC2 3549         CALL MATIN (10HMODULUS OF,10H ELASTICIT,10HY            ,XEC,YEC,SEC,
FIRES-RC2 3550        1KEC)
FIRES-RC2 3551         CALL MATIN (10HCOMPRESSIV,10HE STRENGTH,IB,XFC,YFC,SFC,KFC)
FIRES-RC2 3552         CALL MATIN (10HCOMPRESSIV,10HE STRAIN  ,IB,XEFC,YEFC,SEFC,KEFC)
FIRES-RC2 3553         CALL MATIN (10HULTIMATE S,10HTRESS     ,IB,XFU,YFU,SFU,KFU)
FIRES-RC2 3554         CALL MATIN (10HCRUSHING S,10HTRAIN     ,IB,XCS,YCS,SCS,KCS)
FIRES-RC2 3555         CALL MATIN (10HTENSILE ST,10HRENGTH    ,IB,XFT,YFT,SFT,KFT)
FIRES-RC2 3556  C
FIRES-RC2 3557         WRITE (NOUT,30)
```

```
FIRES-RC2 3558          READ (NIN,20) KCES,KES,KEY
FIRES-RC2 3559          CALL MATIN (10HCOEFFICENT,10H OF EXPANS,10HION        ,XCES,YCES,SC
FIRES-RC2 3560         1ES,KCES)
FIRES-RC2 3561          CALL MATIN (10HMODULUS OF,10H ELASTICIT,10HY          ,XES,YES,SES,
FIRES-RC2 3562         1KES)
FIRES-RC2 3563          CALL MATIN (10HYIELD STRA,10HIN         ,IB,XEY,YEY,SEY,KEY)
FIRES-RC2 3564   C
FIRES-RC2 3565          RETURN
FIRES-RC2 3566   C
FIRES-RC2 3567   C
FIRES-RC2 3568   C
FIRES-RC2 3569       10 FORMAT (///25H . . . . CONCRETE . . . .)
FIRES-RC2 3570       20 FORMAT (7I5)
FIRES-RC2 3571       30 FORMAT (5(/)22H . . . . STEEL . . . .)
FIRES-RC2 3572          END
```

```
FIRES-RC2 3573          SUBROUTINE MATIN (I1,I2,I3,X,Y,S,K)
FIRES-RC2 3574   C
FIRES-RC2 3575   C
FIRES-RC2 3576   C      SUBROUTINE MATIN INPUTS A GIVEN MATERIALS TEMPERATURE-DEPENDENT
FIRES-RC2 3577   C      PROPERTIES, CALCULATES THEIR SLOPES, AND DISPLAYS RESULTS.
FIRES-RC2 3578   C
FIRES-RC2 3579   C
FIRES-RC2 3580          COMMON /TAP/ HED(10),ITEMP1,ITEMP2,ISEG1,ISEG2,NIN,NOUT,NPUNCH
FIRES-RC2 3581          DIMENSION X(10), Y(10), S(10)
FIRES-RC2 3582   C
FIRES-RC2 3583          WRITE (NOUT,50) I1,I2,I3
FIRES-RC2 3584          IF (K.NE.0) GO TO 10
FIRES-RC2 3585   C
FIRES-RC2 3586   C      MATERIAL PARAMETER IS CONSTANT WITH TEMPERATURE
FIRES-RC2 3587   C
FIRES-RC2 3588          READ (NIN,60) X(1)
FIRES-RC2 3589          WRITE (NOUT,70) X(1)
FIRES-RC2 3590          RETURN
FIRES-RC2 3591   C
FIRES-RC2 3592   C      CHECK NUMBER OF NODES AGAINST PERMISSIBLE BOUNDS
FIRES-RC2 3593   C
FIRES-RC2 3594       10 IF (K.LE.1.OR.K.GT.10) GO TO 40
FIRES-RC2 3595   C
FIRES-RC2 3596   C      INPUT LINEARIZED FUNCTION OF MATERIAL PARAMETER
FIRES-RC2 3597   C      AS A FUNCTION OF TEMPERATURE
FIRES-RC2 3598   C
FIRES-RC2 3599          READ (NIN,60) (X(I),Y(I),I=1,K)
FIRES-RC2 3600          M=K-1
FIRES-RC2 3601          DO 20 I=1,M
FIRES-RC2 3602       20 S(I)=(Y(I+1)-Y(I))/(X(I+1)-X(I))
FIRES-RC2 3603          WRITE (NOUT,80)
FIRES-RC2 3604          DO 30 I=1,M
FIRES-RC2 3605          WRITE (NOUT,90) I,X(I),Y(I)
FIRES-RC2 3606          WRITE (NOUT,100) S(I)
FIRES-RC2 3607       30 CONTINUE
FIRES-RC2 3608          WRITE (NOUT,90) K,X(K),Y(K)
FIRES-RC2 3609          RETURN
FIRES-RC2 3610   C
FIRES-RC2 3611       40 WRITE (NOUT,110) K
FIRES-RC2 3612          STOP
FIRES-RC2 3613   C
FIRES-RC2 3614   C
```

```
FIRES-RC2 3615  C
FIRES-RC2 3616      50 FORMAT (//8H     - - ,3A10,4H - -)
FIRES-RC2 3617      60 FORMAT (8E10.0)
FIRES-RC2 3618      70 FORMAT (/39H  MATERIAL PARAMETER OF CONSTANT VALUE ,G11.3)
FIRES-RC2 3619      80 FORMAT (/5X,4HNODE,4X,11HTEMPERATURE,8X,5HVALUE,8X,5HSLOPE/)
FIRES-RC2 3620      90 FORMAT (I9,F13.1,6X,G11.3)
FIRES-RC2 3621     100 FORMAT (39X,G11.3)
FIRES-RC2 3622     110 FORMAT (6(/)44H  ------------PROGRAM TERMINATED------------/14H
FIRES-RC2 3623        1INPUT ERROR/57H   MATERIAL CURVE IS A CONSTANT OR HAS FROM 2 TO 10
FIRES-RC2 3624        2 NODES/31H   NUMBER OF NODES INDICATED IS,I6)
FIRES-RC2 3625        END
```

```
FIRES-RC2 3626        FUNCTION VMATL (MAT,TEMP)
FIRES-RC2 3627  C
FIRES-RC2 3628  C
FIRES-RC2 3629  C     FUNCTION FOR CALCULATING TEMPERATURE-DEPENDENT MATERIAL PARAMETERS
FIRES-RC2 3630  C
FIRES-RC2 3631  C     . . . . . . . . . . . . . CONCRETE . . . . . . . . . . .
FIRES-RC2 3632  C
FIRES-RC2 3633  C        1 - COEF. OF EXPANSION          2 - MODULUS OF ELASTICITY
FIRES-RC2 3634  C        3 - COMPRESSIVE STRENGTH        4 - COMPRESSIVE STRAIN
FIRES-RC2 3635  C        5 - CRUSHING STRESS             6 - CRUSHING STRAIN
FIRES-RC2 3636  C        7 - TENSILE STRENGTH
FIRES-RC2 3637  C
FIRES-RC2 3638  C     . . . . . . . . . . . . . STEEL . . . . . . . . . .
FIRES-RC2 3639  C
FIRES-RC2 3640  C        8 - COEF. OF EXPANSION          9 - MODULUS OF ELASTICITY
FIRES-RC2 3641  C        10- YIELD STRAIN                11- YIELD STRENGTH
FIRES-RC2 3642  C
FIRES-RC2 3643  C
FIRES-RC2 3644        COMMON /MATL/ XCEC(10),YCEC(10),SCEC(10),KCEC,XEC(10),YEC(10),SEC(
FIRES-RC2 3645       110),KEC,XFC(10),YFC(10),SFC(10),KFC,XFT(10),YFT(10),SFT(10),KFT,XC
FIRES-RC2 3646       2S(10),YCS(10),SCS(10),KCS,XCES(10),YCES(10),SCES(10),KCES,XES(10),
FIRES-RC2 3647       3YES(10),SES(10),KES,XEY(10),YEY(10),SEY(10),KEY,XFY(10),YFY(10),SF
FIRES-RC2 3648       4Y(10),KFY,XEFC(10),YEFC(10),SEFC(10),KEFC,XFU(10),YFU(10),SFU(10),
FIRES-RC2 3649       5KFU
FIRES-RC2 3650  C
FIRES-RC2 3651        GO TO (10,20,30,40,50,60,70,80,90,100,110), MAT
FIRES-RC2 3652  C
FIRES-RC2 3653     10 CALL MATOUT (XCEC,YCEC,SCEC,KCEC,TEMP,VALUE,10HC.EXP.CON )
FIRES-RC2 3654        GO TO 120
FIRES-RC2 3655     20 CALL MATOUT (XEC,YEC,SEC,KEC,TEMP,VALUE,10HE OF CONC )
FIRES-RC2 3656        GO TO 120
FIRES-RC2 3657     30 CALL MATOUT (XFC,YFC,SFC,KFC,TEMP,VALUE,10HFC OF CONC)
FIRES-RC2 3658        GO TO 120
FIRES-RC2 3659     40 CALL MATOUT (XEFC,YEFC,SEFC,KEFC,TEMP,VALUE,10HEFC CONC  )
FIRES-RC2 3660        GO TO 120
FIRES-RC2 3661     50 CALL MATOUT (XFU,YFU,SFU,KFU,TEMP,VALUE,10HFU CONC   )
FIRES-RC2 3662        GO TO 120
FIRES-RC2 3663     60 CALL MATOUT (XCS,YCS,SCS,KCS,TEMP,VALUE,10HCRUSHING  )
FIRES-RC2 3664        GO TO 120
FIRES-RC2 3665     70 CALL MATOUT (XFT,YFT,SFT,KFT,TEMP,VALUE,10HFT OF CONC)
FIRES-RC2 3666        GO TO 120
FIRES-RC2 3667     80 CALL MATOUT (XCES,YCES,SCES,KCES,TEMP,VALUE,10HC.EXP.STL )
FIRES-RC2 3668        GO TO 120
FIRES-RC2 3669     90 CALL MATOUT (XES,YES,SES,KES,TEMP,VALUE,10HE OF STEEL)
FIRES-RC2 3670        GO TO 120
FIRES-RC2 3671    100 CALL MATOUT (XEY,YEY,SEY,KEY,TEMP,VALUE,10HEY OF STL )
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```
FIRES-RC2 3672          GO TO 120
FIRES-RC2 3673      110 CALL MATOUT (XES,YES,SES,KES,TEMP,VALUE,10HE OF STEEL)
FIRES-RC2 3674          CALL MATOUT (XEY,YEY,SEY,KEY,TEMP,V,10HEY OF STL )
FIRES-RC2 3675          VALUE=VALUE*V
FIRES-RC2 3676      120 VMATL=VALUE
FIRES-RC2 3677    C
FIRES-RC2 3678          RETURN
FIRES-RC2 3679          END
```

```
FIRES-RC2 3680          SUBROUTINE MATOUT (X,Y,S,K,T,V,NAME)
FIRES-RC2 3681    C
FIRES-RC2 3682    C
FIRES-RC2 3683    C     SUBROUTINE MATOUT CALCULATES THE VALUE OF A GIVEN MATERIAL
FIRES-RC2 3684    C     PARAMETER REQUIRED BY FUNCTION VMATL
FIRES-RC2 3685    C
FIRES-RC2 3686          COMMON /TAP/ HED(10),ITEMP1,ITEMP2,ISEG1,ISEG2,NIN,NOUT,NPUNCH
FIRES-RC2 3687          DIMENSION X(10), Y(10), S(10)
FIRES-RC2 3688    C
FIRES-RC2 3689          IF (K.NE.0) GO TO 10
FIRES-RC2 3690    C
FIRES-RC2 3691    C     MATERIAL PARAMETER IS OF CONSTANT VALUE
FIRES-RC2 3692    C
FIRES-RC2 3693          V=X(1)
FIRES-RC2 3694          RETURN
FIRES-RC2 3695    C
FIRES-RC2 3696    C     MATERIAL VALUE IS TEMPERATURE DEPENDENT
FIRES-RC2 3697    C
FIRES-RC2 3698       10 I=0
FIRES-RC2 3699       20 I=I+1
FIRES-RC2 3700          IF (I.GT.K) GO TO 50
FIRES-RC2 3701          IF (T-X(I)) 40,30,20
FIRES-RC2 3702       30 V=Y(I)
FIRES-RC2 3703          RETURN
FIRES-RC2 3704    C
FIRES-RC2 3705       40 IF (I.EQ.1) GO TO 50
FIRES-RC2 3706          V=Y(I-1)+S(I-1)*(T-X(I-1))
FIRES-RC2 3707          RETURN
FIRES-RC2 3708    C
FIRES-RC2 3709       50 WRITE (NOUT,60) NAME,T,X(1),X(K)
FIRES-RC2 3710          STOP
FIRES-RC2 3711    C
FIRES-RC2 3712    C
FIRES-RC2 3713    C
FIRES-RC2 3714       60 FORMAT (6(/)48H  -------------PROGRAM TERMINATED --------------/50
FIRES-RC2 3715         1H    BOUNDS OF CURVE DESCRIBING MATERIAL PARAMETER ,A10,19H HAVE B
FIRES-RC2 3716         2EEN EXCEEDED/23H   THE TEMPERATURE WAS ,F10.3,20H THE LOWER BOUND
FIRES-RC2 3717         3IS ,F10.3,24H AND THE UPPER BOUND IS ,F10.3)
FIRES-RC2 3718          END
```

```
FIRES-RC2 3719          SUBROUTINE SOLEQ (A,B,NN,MM)
FIRES-RC2 3720    C
FIRES-RC2 3721    C     SOLVE SIMULTANEOUS EQUATIONS
FIRES-RC2 3722    C
FIRES-RC2 3723          DIMENSION A(MM,1), B(1)
```

```
FIRES-RC2 3724  C
FIRES-RC2 3725        NN1=NN-1
FIRES-RC2 3726        DO 20 N=1,NN1
FIRES-RC2 3727        N1=N+1
FIRES-RC2 3728        B(N)=B(N)/A(N,N)
FIRES-RC2 3729        DO 20 J=N1,NN
FIRES-RC2 3730        A(N,J)=A(N,J)/A(N,N)
FIRES-RC2 3731        DO 10 I=N1,NN
FIRES-RC2 3732     10 A(I,J)=A(I,J)-A(I,N)*A(N,J)
FIRES-RC2 3733     20 B(J)=B(J)-A(J,N)*B(N)
FIRES-RC2 3734  C
FIRES-RC2 3735        B(NN)=B(NN)/A(NN,NN)
FIRES-RC2 3736        DO 30 K=1,NN1
FIRES-RC2 3737        I=NN-K
FIRES-RC2 3738        II=I+1
FIRES-RC2 3739        DO 30 J=II,NN
FIRES-RC2 3740     30 B(I)=B(I)-A(I,J)*B(J)
FIRES-RC2 3741  C
FIRES-RC2 3742        RETURN
FIRES-RC2 3743        END
```

```
FIRES-RC2 3744        FUNCTION STCRAK (E)
FIRES-RC2 3745        COMMON /KRAKP/ AP(4)
FIRES-RC2 3746        STCRAK=AP(1)+E*(AP(2)+E*(AP(3)+E*AP(4)))
FIRES-RC2 3747        RETURN
FIRES-RC2 3748        END
```

```
FIRES-RC2 3749        FUNCTION STR (E,EC,FC,EFC,FU,EFU,EO)
FIRES-RC2 3750  C
FIRES-RC2 3751  C
FIRES-RC2 3752  C     PARABOLIC STRESS-STRAIN LAW FOR CONCRETE WITH UNLOADING.
FIRES-RC2 3753  C     STRESSES UPON UNLOADING ARE COMPUTED ON THE BASIS OF PERMANENT
FIRES-RC2 3754  C     INELASTIC DEFORMATION (EO)
FIRES-RC2 3755  C
FIRES-RC2 3756  C
FIRES-RC2 3757        COMMON /TAP/ HED(10),ITEMP1,ITEMP2,ISEG1,ISEG2,NIN,NOUT,NPUNCH
FIRES-RC2 3758  C
FIRES-RC2 3759  C     EC - INITIAL MODULUS OF ELASTICITY
FIRES-RC2 3760  C     FC - MAXIMUM COMPRESSIVE STRENGTH
FIRES-RC2 3761  C     E - STRAIN
FIRES-RC2 3762  C     EO - CUMULATIVE INELASTIC STRAIN
FIRES-RC2 3763  C
FIRES-RC2 3764        IF (E) 30,10,20
FIRES-RC2 3765     10 STR=0.0
FIRES-RC2 3766        GO TO 60
FIRES-RC2 3767  C
FIRES-RC2 3768  C     TENSILE STRESS IS LINEAR ELASTIC
FIRES-RC2 3769  C
FIRES-RC2 3770     20 STR=E*EC
FIRES-RC2 3771        GO TO 60
FIRES-RC2 3772  C
FIRES-RC2 3773  C     COMPRESSIVE STRESS
FIRES-RC2 3774  C
FIRES-RC2 3775     30 ES=FC/EFC
```

```
FIRES-RC2 3776          RE=EC/ES
FIRES-RC2 3777          RSIG=FC/FU
FIRES-RC2 3778          REPS=EFU/EFC
FIRES-RC2 3779          IF (E.GE.-EFC) GO TO 40
FIRES-RC2 3780   C      CUBIC PORTION OF CURVE
FIRES-RC2 3781          R=RE*(RSIG-1.)/((REPS-1.)*(REPS-1.))
FIRES-RC2 3782          R=R-1./REPS
FIRES-RC2 3783          GO TO 50
FIRES-RC2 3784   C      PARABOLIC PORTION OF CURVE
FIRES-RC2 3785       40 R=0.
FIRES-RC2 3786       50 A=1./EC
FIRES-RC2 3787          B=RE+R-2.
FIRES-RC2 3788          B=-B/(RE*FC)
FIRES-RC2 3789          C=1.-2.*R
FIRES-RC2 3790          C=C/(RE*FC*EFC)
FIRES-RC2 3791          D=-R/(RE*FC*EFC*EFC)
FIRES-RC2 3792          STR=E/(A+B*E+C*E*E+D*E*E*E)
FIRES-RC2 3793   C
FIRES-RC2 3794   C      CALCULATE LINEAR ELASTIC STRESS WITH ORIGIN AT EO
FIRES-RC2 3795   C
FIRES-RC2 3796       60 S=EC*(E-EO)
FIRES-RC2 3797   C
FIRES-RC2 3798   C      CHOOSE LARGER STRESS
FIRES-RC2 3799   C
FIRES-RC2 3800          IF (S.GT.STR) STR=S
FIRES-RC2 3801          RETURN
FIRES-RC2 3802   C
FIRES-RC2 3803   C      LABELING OF FUNCTION
FIRES-RC2 3804   C
FIRES-RC2 3805          ENTRY STRL
FIRES-RC2 3806   C
FIRES-RC2 3807          WRITE (NOUT,70)
FIRES-RC2 3808          RETURN
FIRES-RC2 3809   C
FIRES-RC2 3810   C      CALCULATE EO AT END OF PREVIOUS TIME STEP
FIRES-RC2 3811   C
FIRES-RC2 3812          ENTRY STRI
FIRES-RC2 3813   C
FIRES-RC2 3814   C      E - STRAIN AT END OF PREVIOUS TIME STEP
FIRES-RC2 3815   C      FC - STRESS AT END OF PREVIOUS TIME STEP
FIRES-RC2 3816   C
FIRES-RC2 3817          EO=E-FC/EC
FIRES-RC2 3818          RETURN
FIRES-RC2 3819   C
FIRES-RC2 3820   C
FIRES-RC2 3821   C
FIRES-RC2 3822       70 FORMAT (1H+,32X,32HSAENZ MODEL WITH UNLOADING       )
FIRES-RC2 3823          END


FIRES-RC2 3824          FUNCTION SS (E,EY,ES,FY,EO)
FIRES-RC2 3825   C
FIRES-RC2 3826   C
FIRES-RC2 3827   C      STRESS-STRAIN LAW FOR STEEL
FIRES-RC2 3828   C
FIRES-RC2 3829   C
FIRES-RC2 3830          COMMON /TAP/ HED(10),ITEMP1,ITEMP2,ISEG1,ISEG2,NIN,NOUT,NPUNCH
FIRES-RC2 3831   C
FIRES-RC2 3832          DATA ESTAR/100.0/
```

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FIRES-RC2 3833  C
FIRES-RC2 3834  C      BILINEAR STRESS-STRAIN LAW WITH UNLOADING.
FIRES-RC2 3835  C      STRESSES ARE COMPUTED ON THE BASIS OF THE PERMENANT INELASTIC
FIRES-RC2 3836  C      STRAIN ( EO )
FIRES-RC2 3837  C
FIRES-RC2 3838  C      E - STRAIN IN STEEL
FIRES-RC2 3839  C      PERMANENT INELASTIC STRAIN
FIRES-RC2 3840  C      ES - MODULUS OF ELASTICITY
FIRES-RC2 3841  C      ESTAR - STRAIN HARDENING MODULUS
FIRES-RC2 3842  C      FY - YIELD STRESS
FIRES-RC2 3843  C      EY - YIELD STRAIN
FIRES-RC2 3844  C
FIRES-RC2 3845  C      CALCULATE STRAIN FROM SHIFTED ORIGIN (EO)
FIRES-RC2 3846  C
FIRES-RC2 3847         SS=ES*(E-EO)
FIRES-RC2 3848  C
FIRES-RC2 3849  C      CALCULATE UPPER BOUND OF STRESS-STRAIN ENVELOPE
FIRES-RC2 3850  C
FIRES-RC2 3851         F=FY+ESTAR*(E-EY)
FIRES-RC2 3852  C
FIRES-RC2 3853  C      CHECK FOR VIOLATION OF UPPER BOUND
FIRES-RC2 3854  C
FIRES-RC2 3855         IF (SS-F) 10,30,20
FIRES-RC2 3856  C
FIRES-RC2 3857  C      CALCULATE LOWER BOUND OF STRESS-STRAIN ENVELOPE
FIRES-RC2 3858  C
FIRES-RC2 3859      10 F=-FY+ESTAR*(E+EY)
FIRES-RC2 3860  C
FIRES-RC2 3861  C      CHECK FOR VIOLATION OF LOWER BOUND
FIRES-RC2 3862  C
FIRES-RC2 3863         IF (SS-F) 20,30,30
FIRES-RC2 3864  C
FIRES-RC2 3865  C      SET THE STEEL STRESS
FIRES-RC2 3866  C
FIRES-RC2 3867      20 SS=F
FIRES-RC2 3868      30 RETURN
FIRES-RC2 3869  C
FIRES-RC2 3870  C      LABEL FUNCTION
FIRES-RC2 3871  C
FIRES-RC2 3872         ENTRY SSL
FIRES-RC2 3873  C
FIRES-RC2 3874         WRITE (NOUT,40) ESTAR
FIRES-RC2 3875         RETURN
FIRES-RC2 3876  C
FIRES-RC2 3877  C      CALCULATE INELASTIC DEFORMATION AT END OF PREVIOUS TIME STEP
FIRES-RC2 3878  C
FIRES-RC2 3879  C      E - STRAIN AT END OF PREVIOUS TIME STEP
FIRES-RC2 3880  C      FY - STRESS AT END OF PREVIOUS TIME STEP
FIRES-RC2 3881  C
FIRES-RC2 3882         ENTRY SSI
FIRES-RC2 3883  C
FIRES-RC2 3884         EO=E-FY/ES
FIRES-RC2 3885         RETURN
FIRES-RC2 3886  C
FIRES-RC2 3887  C
FIRES-RC2 3888  C
FIRES-RC2 3889  C
FIRES-RC2 3890      40 FOFMAT (1H+,32X,29HBILINEAR MODEL WITH UNLOADING/33X,8HESTAR = ,F7
FIRES-RC2 3891        1.1,4H KSI)
FIRES-RC2 3892         END
```

```
FIRES-RC2 3893          FUNCTION SHRINK (DT,T,S)
FIRES-RC2 3894    C
FIRES-RC2 3895    C
FIRES-RC2 3896    C     FUNCTION SHRINK CALCULATES THE CHANGE IN SHRINKAGE STRAIN
FIRES-RC2 3897    C     DURING A TIME STEP.  SHRINKAGE STRAIN IS CONSIDERED TO BE
FIRES-RC2 3898    C     IRRECOVERABLE.  THE INCREMENTAL SHRINKAGE STRAIN IS CALCULATED
FIRES-RC2 3899    C     BY THE FOLLOWING FORMULA
FIRES-RC2 3900    C
FIRES-RC2 3901    C     INCREMENTAL  STRAIN = SHRINK = A(T)*(SMAX(T)-S)
FIRES-RC2 3902    C
FIRES-RC2 3903    C     WHERE
FIRES-RC2 3904    C        A - IS THE SHRINKAGE RATE CONSTANT
FIRES-RC2 3905    C        SMAX - IS THE MAXIMUM POSSIBLE SHRINKAGE
FIRES-RC2 3906    C        S - CURRENT CUMULATIVE SHRINKAGE
FIRES-RC2 3907    C
FIRES-RC2 3908    C
FIRES-RC2 3909          COMMON /TAP/ HED(10),ITEMP1,ITEMP2,ISEG1,ISEG2,NIN,NOUT,NPUNCH
FIRES-RC2 3910    C
FIRES-RC2 3911    C     CHECK TO SEE IF MAXIMUM SHRINKAGE HAS ALREADY OCCURRED
FIRES-RC2 3912    C
FIRES-RC2 3913          SULT=0.001
FIRES-RC2 3914          IF (S-SULT) 20,10,10
FIRES-RC2 3915    C
FIRES-RC2 3916       10 SHRINK=0.0
FIRES-RC2 3917          RETURN
FIRES-RC2 3918    C
FIRES-RC2 3919    C     CHECK TO SEE IF SUBSLICE TEMPERATURE HAS EXCEEDED 212.0 F
FIRES-RC2 3920    C
FIRES-RC2 3921       20 IF (T-212.0) 40,40,30
FIRES-RC2 3922    C
FIRES-RC2 3923    C     IF TEMPERATURE HAS EXCEEDED 212.0 F THEN ALL SHRINKAGE MUST OCCUR
FIRES-RC2 3924    C
FIRES-RC2 3925       30 SHRINK=SULT-S
FIRES-RC2 3926          S=SULT
FIRES-RC2 3927          RETURN
FIRES-RC2 3928    C
FIRES-RC2 3929    C     CALCULATE A AND SMAX
FIRES-RC2 3930    C
FIRES-RC2 3931       40 SMAX=T-68.0
FIRES-RC2 3932          SMAX=0.006944*SMAX
FIRES-RC2 3933          A=SMAX*SMAX
FIRES-RC2 3934          A=A+0.001
FIRES-RC2 3935          SMAX=SMAX+1.0
FIRES-RC2 3936          SMAX=0.0005*SMAX
FIRES-RC2 3937    C
FIRES-RC2 3938    C     CHECK TO SEE IF S HAS ALREADY EXCEEDED SMAX
FIRES-RC2 3939    C
FIRES-RC2 3940          IF (S-SMAX) 50,70,70
FIRES-RC2 3941    C
FIRES-RC2 3942    C     CALCULATE INCREMENTAL SHRINKAGE STRAIN
FIRES-RC2 3943    C
FIRES-RC2 3944       50 SHRINK=A*(SMAX-S)*DT
FIRES-RC2 3945          S=S+SHRINK
FIRES-RC2 3946    C
FIRES-RC2 3947    C     CHECK TO SEE THAT S DOES NOT EXCEED SMAX
FIRES-RC2 3948    C
FIRES-RC2 3949          IF (S-SMAX) 70,70,60
FIRES-RC2 3950    C
FIRES-RC2 3951    C     CORRECT SHRINK IF S HAS EXCEEDED SMAX
FIRES-RC2 3952    C
FIRES-RC2 3953       60 SHRINK=SMAX-(S-SHRINK)
FIRES-RC2 3954          S=SMAX
```

```
FIRES-RC2 3955   C
FIRES-RC2 3956      70 RETURN
FIRES-RC2 3957   C
FIRES-RC2 3958   C     LABELING OF FUNCTION
FIRES-RC2 3959   C
FIRES-RC2 3960         ENTRY SHRINKL
FIRES-RC2 3961         WRITE (NOUT,80)
FIRES-RC2 3962         RETURN
FIRES-RC2 3963   C
FIRES-RC2 3964   C
FIRES-RC2 3965   C
FIRES-RC2 3966      80 FORMAT (1H+,32X,29HSHRINKAGE CALCULATED ON BASIS/33X,29HOF TEMPERA
FIRES-RC2 3967        1TURE-DEPENDENT RATE/33X,28HMAX SHRINKAGE - 0.0010 IN/IN)
FIRES-RC2 3968         END
```

```
FIRES-RC2 3969         FUNCTION CRPC (DT,SIG1,SIG2,T,B,C,D,E,FC)
FIRES-RC2 3970   C
FIRES-RC2 3971   C
FIRES-RC2 3972   C     THIS FUNCTION CALCULATES THE CREEP INCREMENT, CRPC, IN A CONCRETE
FIRES-RC2 3973   C     SUBSLICE DUE TO STRESS INCREMENT DISG
FIRES-RC2 3974   C
FIRES-RC2 3975   C        DT - TIME STEP
FIRES-RC2 3976   C        SIG1 - STRESS AT BEGINNING OF PREVIOUS TIME STEP
FIRES-RC2 3977   C        SIG2 - STRESS AT END OF PREVIOUS TIME STEP
FIRES-RC2 3978   C        T - SUBLICE TEMPERATURE, AVERAGE DURING PREVIOUS TIME STEP
FIRES-RC2 3979   C        B, C, D, E - HISTORY COEFFICENTS FOR CREEP MODEL
FIRES-RC2 3980   C        FC - COMPRESSIVE STRENGTH OF CONCRETE
FIRES-RC2 3981   C
FIRES-RC2 3982   C
FIRES-RC2 3983         COMMON /TAP/ HED(10),ITEMP1,ITEMP2,ISEG1,ISEG2,NIN,NOUT,NPUNCH
FIRES-RC2 3984   C
FIRES-RC2 3985   C     1 - CALCULATION OF EFFECTIVE STRESS INCREMENT
FIRES-RC2 3986   C
FIRES-RC2 3987         S1=SIG1
FIRES-RC2 3988         S2=SIG2
FIRES-RC2 3989         IF (S1/FC-.35) 20,20,10
FIRES-RC2 3990      10 S1=2.33*S1-.465*FC
FIRES-RC2 3991      20 IF (S2/FC-.35) 40,40,30
FIRES-RC2 3992      30 S2=2.33*S2-.465*FC
FIRES-RC2 3993      40 DSIG=S2-S1
FIRES-RC2 3994   C
FIRES-RC2 3995   C     2- CALCULATION OF SHIFT FUNCTION PHIT=EXP(SIT)
FIRES-RC2 3996   C        SIT=AMOUNT OF SHIFT
FIRES-RC2 3997   C
FIRES-RC2 3998         PHIT=DT
FIRES-RC2 3999         IF (T-75.) 110,110,50
FIRES-RC2 4000      50 IF (T-300.) 60,60,70
FIRES-RC2 4001      60 SIT=.01023*T-.767
FIRES-RC2 4002         GO TO 100
FIRES-RC2 4003      70 IF (T-900.) 80,80,90
FIRES-RC2 4004      80 SIT=.006933*T+.22
FIRES-RC2 4005         GO TO 100
FIRES-RC2 4006      90 SIT=.00396*T+2.9
FIRES-RC2 4007     100 PHIT=DT*EXP(SIT)
FIRES-RC2 4008   C
FIRES-RC2 4009   C     3- CALCULATION OF CREEP INCREMENT ( CRPC )
FIRES-RC2 4010   C
FIRES-RC2 4011     110 CRPC=DSIG*3120.443-B-C-D-E
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```
FIRES-RC2 4012          B=(B-DSIG*142.716)*EXP(-.1*PHIT)
FIRES-RC2 4013          C=(C-DSIG*169.464)*EXP(-.01*PHIT)
FIRES-RC2 4014          D=(D-DSIG*70.563)*EXP(-.001*PHIT)
FIRES-RC2 4015          E=(E-DSIG*2737.7)*EXP(-.0001*PHIT)
FIRES-RC2 4016          CRPC=(CRPC+B+C+D+E)*.000001
FIRES-RC2 4017   C
FIRES-RC2 4018          RETURN
FIRES-RC2 4019   C
FIRES-RC2 4020   C      LABELING OF FUNCTION
FIRES-RC2 4021   C
FIRES-RC2 4022          ENTRY CRPCL
FIRES-RC2 4023          WRITE (NOUT,120)
FIRES-RC2 4024          RETURN
FIRES-RC2 4025   C
FIRES-RC2 4026   C
FIRES-RC2 4027   C
FIRES-RC2 4028      120 FORMAT (1H+,32X,22HMUKADDAMS TEMPERATURE-/33X,22HCOMPENSATED-TIME
FIRES-RC2 4029         1MODEL)
FIRES-RC2 4030          END
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FIRES-RC2 4031          FUNCTION CRPS (TEMP,DT,STRESS,ET)
FIRES-RC2 4032   C
FIRES-RC2 4033   C
FIRES-RC2 4034   C      FUNCTION CRPS CALCULATES THE INCREMENTAL CREEP STRAIN IN STEEL.
FIRES-RC2 4035   C      THIS FUNCTION COMBINES DORNS THETA METHOD FOR TEMPERATURE
FIRES-RC2 4036   C      VARIATION WITH A STRAIN HARDENING APPROACH WHICH ACCOUNTS FOR
FIRES-RC2 4037   C      STRESS VARIATION.  THE FORM OF THE BASIC CREEP CURVE IS THAT
FIRES-RC2 4038   C      SUGGESTED BY HARMATHY
FIRES-RC2 4039   C
FIRES-RC2 4040   C      INCREMENTAL CREEP STRAIN = CRPS = Z*DTHETA*(CTNH(ET/ETO))**2
FIRES-RC2 4041   C
FIRES-RC2 4042   C      WHERE Z - ZENER-HOLLOMON CONSTANT-A FUNCTION OF STRESS
FIRES-RC2 4043   C            DTHETA - CHANGE IN TEMPERATURE COMPENSATED TIME
FIRES-RC2 4044   C            ET - CUMULATIVE ABSOLUTE CREEP STRAIN
FIRES-RC2 4045   C            ETO - INTERCEPT OF LINEAR PORTION OF CREEP CURVE
FIRES-RC2 4046   C      IN ADDITION
FIRES-RC2 4047   C            TEMP - AVERAGE TIME STEP TEMPERATURE
FIRES-RC2 4048   C            STRESS - INITIAL TIME STEP STRESS (KSI)
FIRES-RC2 4049   C            DT - TIME STEP (HOURS)
FIRES-RC2 4050   C
FIRES-RC2 4051   C
FIRES-RC2 4052   C      COEFFICENTS FOR CALCULATION FROM HARMATHY (1969), ASTM STP 464
FIRES-RC2 4053   C      FROM TEST SERIES 1C FOR ASTM A36 STEEL
FIRES-RC2 4054   C
FIRES-RC2 4055   C
FIRES-RC2 4056          COMMON /TAP/ HED(10),ITEMP1,ITEMP2,ISEG1,ISEG2,NIN,NOUT,NPUNCH
FIRES-RC2 4057   C
FIRES-RC2 4058          CRPS=0.0
FIRES-RC2 4059   C
FIRES-RC2 4060   C      NO CREEP IS CONSIDERED TO OCCUR BELOW 400 F
FIRES-RC2 4061   C
FIRES-RC2 4062          IF (TEMP.LE.400.0) RETURN
FIRES-RC2 4063   C
FIRES-RC2 4064   C      DETERMINE SIGN AND NORMALIZE STRESS TO POSITIVE NUMBER
FIRES-RC2 4065   C
FIRES-RC2 4066          SIGN=1.0
FIRES-RC2 4067          S=STRESS
FIRES-RC2 4068          IF (S) 20,10,30
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FIRES-RC2 4069      10 RETURN
FIRES-RC2 4070      20 SIGN=-1.0
FIRES-RC2 4071         S=SIGN*S
FIRES-RC2 4072      30 CONTINUE
FIRES-RC2 4073  C
FIRES-RC2 4074  C      CREEP STRAIN IS CALCULATED FOR ALL TEMPERATURES ABOVE 700 F
FIRES-RC2 4075  C
FIRES-RC2 4076         SP=TEMP-700.0
FIRES-RC2 4077         IF (SP) 40,40,50
FIRES-RC2 4078  C
FIRES-RC2 4079  C      CHECK TO SEE IF STRESS IS LESS THAN 0.1167*(700-TEMP)
FIRES-RC2 4080  C
FIRES-RC2 4081      40 SP=-SP*0.11666667
FIRES-RC2 4082         IF (S.LE.SP) RETURN
FIRES-RC2 4083  C
FIRES-RC2 4084      50 CONTINUE
FIRES-RC2 4085  C
FIRES-RC2 4086  C      CALCULATE INTERCEPT ETO
FIRES-RC2 4087  C
FIRES-RC2 4088         ETO=S**1.75
FIRES-RC2 4089         ETO=0.000030231*ETO
FIRES-RC2 4090  C
FIRES-RC2 4091  C      CALCULATE EXPONENT OF DTHETA TERM
FIRES-RC2 4092  C
FIRES-RC2 4093         A=TEMP+460.0
FIRES-RC2 4094         A=30400.0/A
FIRES-RC2 4095  C
FIRES-RC2 4096         IF (S-15.0) 60,60,70
FIRES-RC2 4097  C
FIRES-RC2 4098  C      CALCULATE Z*DTHETA TERM (ZT) FOR STRESSES LESS THAN 15 KSI
FIRES-RC2 4099  C
FIRES-RC2 4100      60 S=S**4.7
FIRES-RC2 4101         A=12.0-A
FIRES-RC2 4102         A=10.0**A
FIRES-RC2 4103         ZT=3.2734*S*A*DT
FIRES-RC2 4104         GO TO 80
FIRES-RC2 4105  C
FIRES-RC2 4106  C      CALCULATE Z*DTHETA TERM (ZT) FOR STRESSES GREATER THAN 15 KSI
FIRES-RC2 4107  C
FIRES-RC2 4108      70 S=0.130287*S
FIRES-RC2 4109         A=16.0+S-A
FIRES-RC2 4110         A=10.0**A
FIRES-RC2 4111         ZT=1.23*A*DT
FIRES-RC2 4112  C
FIRES-RC2 4113      80 CONTINUE
FIRES-RC2 4114         IF (ET) 90,90,100
FIRES-RC2 4115  C
FIRES-RC2 4116  C      IF ET IS 0.0 THAN START CREEP CALCULATIONS WITH
FIRES-RC2 4117  C      ET =(3*ZT*ETO*ETO)**0.333333+ZT
FIRES-RC2 4118  C
FIRES-RC2 4119      90 CONTINUE
FIRES-RC2 4120         CRPS=3.0*ZT*ETO*ETO
FIRES-RC2 4121         CRPS=CRPS**0.33333333333
FIRES-RC2 4122         CRPS=CRPS+ZT
FIRES-RC2 4123         GO TO 110
FIRES-RC2 4124  C
FIRES-RC2 4125     100 CONTINUE
FIRES-RC2 4126  C
FIRES-RC2 4127  C      CALCULATE INCREMENTAL CREEP STRAIN
FIRES-RC2 4128  C
FIRES-RC2 4129         A=ET/ETO
FIRES-RC2 4130         A=CTNH(A)
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FIRES-RC2 4131          CRPS=ZT*A*A
FIRES-RC2 4132   C
FIRES-RC2 4133     110 CONTINUE
FIRES-RC2 4134   C
FIRES-RC2 4135   C      ACCUMULATE THE ABSOLUTE INCREMENTAL CREEP STRAIN
FIRES-RC2 4136   C
FIRES-RC2 4137          ET=ET+CRPS
FIRES-RC2 4138   C
FIRES-RC2 4139   C      CHANGE INCREMENTAL CREEP STRAIN TO PROPER SIGN
FIRES-RC2 4140   C
FIRES-RC2 4141          CRPS=SIGN*CRPS
FIRES-RC2 4142   C
FIRES-RC2 4143          RETURN
FIRES-RC2 4144   C
FIRES-RC2 4145   C      LABEL FUNCTICN
FIRES-RC2 4146   C
FIRES-RC2 4147          ENTRY CRPSL
FIRES-RC2 4148   C
FIRES-RC2 4149          WRITE (NOUT,120)
FIRES-RC2 4150          RETURN
FIRES-RC2 4151   C
FIRES-RC2 4152   C
FIRES-RC2 4153   C
FIRES-RC2 4154     120 FORMAT (1H+,32X,27HHARMATHY VARIATION OF DORNS/33X,12HTHETA METHOD
FIRES-RC2 4155        1/33X,29HCOEFFICIENTS - HARMATHY(1969),/33X,28HASTM STP 464, TEST S
FIRES-RC2 4156        2ERIES 1C/)
FIRES-RC2 4157          END
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FIRES-RC2 4158          FUNCTION CTNH (X)
FIRES-RC2 4159   C
FIRES-RC2 4160   C
FIRES-RC2 4161   C      FUNCTION CTNH(X) CALCULATES AN APPROXIMATE VALUE OF THE
FIRES-RC2 4162   C      HYPERBOLIC COTANGENT OF X
FIRES-RC2 4163   C
FIRES-RC2 4164   C
FIRES-RC2 4165          IF (X-0.2) 10,10,20
FIRES-RC2 4166   C
FIRES-RC2 4167   C      IF X IS LESS THAN 0.2 THEN CTNH IS EQUAL TO 1/X
FIRES-RC2 4168   C
FIRES-RC2 4169      10 CTNH=1.0/X
FIRES-RC2 4170          RETURN
FIRES-RC2 4171   C
FIRES-RC2 4172      20 IF (X-2.0) 30,40,40
FIRES-RC2 4173   C
FIRES-RC2 4174   C      IF X IS GREATER THAN 0.2 AND LESS THAN 2.0 A SERIES EXPANSION
FIRES-RC2 4175   C      IS USED IN APPROXIMATING CTNH
FIRES-RC2 4176   C
FIRES-RC2 4177      30 ST=1.0
FIRES-RC2 4178          SB=X
FIRES-RC2 4179          A=X
FIRES-RC2 4180          A=A*X
FIRES-RC2 4181          ST=0.5*A+ST
FIRES-RC2 4182          A=A*X
FIRES-RC2 4183          SB=0.1667*A+SB
FIRES-RC2 4184          A=A*X
FIRES-RC2 4185          ST=0.0417*A+ST
FIRES-RC2 4186          A=A*X
FIRES-RC2 4187          SB=0.00834*A+SB
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FIRES-RC2 4188          A=A*X
FIRES-RC2 4189          ST=0.00139*A+ST
FIRES-RC2 4190          A=A*X
FIRES-RC2 4191          SB=0.000185*A+SB
FIRES-RC2 4192          CTNH=ST/SB
FIRES-RC2 4193          RETURN
FIRES-RC2 4194   C
FIRES-RC2 4195   C      IF X IS GREATER THAN 2.0 THEN CTHN = 1.0
FIRES-RC2 4196   C
FIRES-RC2 4197       40 CTNH=1.0
FIRES-RC2 4198   C
FIRES-RC2 4199          RETURN
```

RECENT REPORTS OF THE FIRE RESEARCH GROUP, UNIVERSITY OF CALIFORNIA, BERKELEY

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76-13 Crossman, E. R. F. W., *Cost Effective Techniques for Improving Return Rate in Fire Oriented Mail Survey.*

76-14 Zachary, W. B., Crossman, E. R. F. W., and Quan, E. C., *The San Francisco Residential High-Rise Fire Safety Investigation.*

76-15 Sahota, M. S., *Heat and Mass Transfer in Porous Concrete Structures Subject to Fires*, PhD Dissertation, September 1976.

76-16 Babrauskas, V., *Fire Endurance in Buildings*, PhD Dissertation, October 1976.

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77-1 Becker, J. M., and Bresler, B., "Reinforced Concrete Frames in Fire Environments," January 1977. Published in *ASCE Journal of the Structural Division*, 103, 211-224 (1977)

77-2 Pagni, P. J., Tien, C. L., Shih, T. M., and Yuen, W. W.,"Excess Pyrolyzate Production by Cellular Plastics," *Final Report to the Products Research Committee*, February 1977.

77-3 Shih, T. M., and Pagni, P. J., "Analytic Incorporation of Probability Density Functions in Turbulent Flames," April 1977. Submitted to the *International Journal of Heat and Mass Transfer.*

77-4 Shih, T. M., and Pagni, P. J., "Wake Turbulent Flames," April 1977. To be presented at the *National Heat Transfer Conference, August 15, 1977, Salt Lake City.*

77-5 Pitz, W. J., and Sawyer, R. F., "Deflection Mapping in the Study of Polymer Burning," April 1977. Presented at the *1977 Spring Meeting, Western States Section/The Combustion Institute, Seattle, Paper*, No. 77-21.

77-6 Shih, T. M., and Pagni, P. J., *Excess Pyrolyzate from Diffusion Flames*, June 1977.

77-7 Shih, T. M., and Pagni, P. J., Laminar Mixed Mode Forced and Free Diffusion Flames, June 1977. Submitted to the *Journal of Heat Transfer.*

77-8 Iding, R., Bresler, B., and Nizamuddin Z., *FIRES-RC II a Computer Program for the FIre REsponse of Structures -Reinforced Concrete Frames*, Revised Version, July 1977.

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16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

FIRES-RC II is a computer program used to evaluate the structural response of reinforced concrete frames in fire environments. The report describes the analytical and material behavior models upon which FIRES-RC II is based. The thermal response associated with fire environments used for the analysis of reinforced concrete frames in FIRES-RC II is predicted by a companion computer program, FIRES-T. A nonlinear, direct stiffness formulation coupled with time step integration is the analytical technique used in FIRES-RC II. Within a given time step, an iterative approach is used to find a deformed shape which results in equilibrium between internal stresses and external forces. The material behavior models for concrete and steel account for dimensional changes caused by temperature differentials, changes in mechanical properties of materials with changes in temperature, degradation of sections by cracking and/or crushing, and increased rates of shrinkage and creep with an increase in temperature. Nonlinear stress-strain laws, in which inelastic deformation associated with unloading is accounted for, are used in FIRES-RC II to model concrete and steel behavior. The report includes a user's manual for FIRES-RC II, a sample problem, and a listing of the program.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)* Building fires; computer programs; concretes; creeps; failure analysis; fire models; steels; structural failure; structural materials; thermal degradation

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