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LA THÈSE A ÉTÉ MICROFILMÉE TELLE QUE NOUS L'AVONS RŒUE.
A COMPUTER PROGRAM FOR

THREE DIMENSIONAL ANALYSIS OF BUILDINGS

by

JALAL UDDIN KHANDOKER

B.Sc.Engg.

A THESIS
Presented to the
Faculty of Graduate Studies
of Carleton University
in partial fulfillment of
the degree of

MASTER OF ENGINEERING IN CIVIL ENGINEERING

Carleton University
Ottawa, Canada
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ABSTRACT

A set of computer programs are developed for a linear three-dimensional analysis of building structures consisting of frames and shearwalls for gravity, earthquake and lateral loads. The building is resolved into an orthogonal set of frame or frame-shearwall substructures connected by the floor diaphragms which are considered rigid in their own planes. A frame substructure is composed of horizontal beams and vertical columns or shearwalls. Beams must be prismatic. A column may be prismatic or circular. Flexural and shear deformations are accounted for in all members; for columns, axial deformations are also included. Joints of finite sizes having infinite rigidity are considered in the formulation. The mass of the building is assumed to be lumped at floor levels. The columns and shearwalls are considered to rest on rigid foundations located at the same level.

Two different computer programs are developed for the purpose. The first program, called AIDS, is a conversational computer program designed to act as a 'front end' processor to the main analysis program and reads all necessary input data. The data can be input in 'free format' mode with a high speed input option. The program then rearranges the data and stores it in disc files to be used finally by the second program.

The second program, called ANGELS, is designed to perform the analysis. A maximum of four independent gravity load cases, three differ-
ent lateral load cases and a design response spectrum loading may be considered in the analysis. The above loads can be weighted and combined at the user's option for the purpose of analysis. Any number of such combinations are possible. Also, at the user's option, the structural mode shapes and frequencies are evaluated and printed out. Design story shears for spectrum loading may also be obtained.

The programs are written in standard FORTRAN IV language and designed to run on any computer accepting FORTRAN IV. During the process of development, the program AIDS was tested on an IM-70 minicomputer and the created data files were electronically transferred to a HONEYWELL Sigma-9 computer. The program ANGELS designed to run in a batch mode was tested on a Sigma-9 computer using the input data generated by the program AIDS.
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LIST OF SYMBOLS

a  length of rigid zone at the left end of a beam or at the bottom of a column
(a)  eigenvector
A  area of cross-section of a member
[A]  coefficient matrix
A_i  value of the largest element of the ith trial vector in the iteration of a mode shape
[A^m]  transformation matrix for the mth frame
b  length of rigid zone at the right end of a beam or at the top of a column
(b)  vector of known components (forces)
[B]  matrix of mode shapes
[C]  damping matrix
C_n  multiplicative constants in the expansion of trial vector
    d^m_n  perpendicular distance to the mth frame from global origin at level n
[D]  dynamic matrix
[D]_i  dynamic matrix modified so that the iteration converges in the ith mode shape
[D]  dynamic matrix formed when origin is shifted
DX_n  x-distance of point of action of lateral load at level n from global reference point
DY_n  y-distance of point of action of lateral load at level n from global reference point
E  modulus of elasticity
[f] member flexibility matrix

F member end actions due to joint displacement only

F_k^1 moment at joint k due to gravity load

F_k^2 vertical load at joint k due to gravity load

FM final end actions of a member

FX fixed end forces on a beam due to gravity load

{F} frame joint load vector

{F_B} vector of frame story forces

{F_g} global load vector for lateral loads

{F_H_n} lateral load vector at level n in global origin

G modulus of rigidity

H_x n x-component of lateral load at level n

H_y n y-component of lateral load at level n

I moment of inertia

[I] identity matrix

k_{AA} submatrix of the frame stiffness matrix with elements not corresponding to sidesway

k_{BB} submatrix of the frame stiffness matrix with elements corresponding to sidesway

[k_b] beam stiffness matrix considering bending degrees of freedom only

[k_c] column stiffness matrix considering bending and axial distortions

[k_m^\text{m}] condensed stiffness matrix of mth frame in the local coordinates

[k_m^\text{g}] condensed stiffness matrix of mth frame in global coordinate system
\[
\begin{align*}
[k_{i,j}] & \quad \text{a submatrix of } [k]^n \\
[K] & \quad \text{stiffness matrix} \\
[K_B] & \quad \text{beam stiffness matrix} \\
[K_C] & \quad \text{column stiffness matrix} \\
[K_F] & \quad \text{frame stiffness matrix} \\
[K_g] & \quad \text{global stiffness matrix} \\
L & \quad \text{clear length of a member between rigid zone ends} \\
L_b & \quad \text{row number of first non-zero entry in the load vector} \\
L_j & \quad \text{row number of first non-zero entry in column } j \text{ of the coefficient matrix} \\
[M] & \quad \text{global mass matrix} \\
N & \quad \text{number of stories in the building} \\
NC & \quad \text{number of columns in a frame} \\
NE & \quad \text{number of elements of a frame stiffness matrix required to be stored} \\
NF & \quad \text{number of frames in the building} \\
NM & \quad \text{number of modes to be considered} \\
NP & \quad \text{number of period coordinates required to define the response spectrum} \\
NT & \quad \text{number of towers in the building} \\
NB_i & \quad \text{number of bays in tower } i \\
NS_i & \quad \text{number of stories in tower } i \\
P & \quad \text{concentrated load acting on beam} \\
P(t) & \quad \text{time dependent forcing function}
\end{align*}
\]
\( Q_i \)  
modal participation factor for ith mode

\( \{r\} \)  
vector of pseudostatic displacements along the global coordinates due to a unit displacement of the base in the direction of the earthquake motion

\( S_a \)  
spectral acceleration

\( S_D \)  
spectral displacement

\( S_v \)  
spectral velocity

\( [S]_i \)  
matrix for sweeping mode shapes up to the ith mode shape from a trial vector

\( T \)  
period

\( [T_B] \)  
beam transformation matrix

\( [T_C] \)  
column transformation matrix

\( T_D \)  
period defining the boundary between the velocity bound and the acceleration bound on the design response spectrum

\( \{u\} \)  
mode shape

\( \ddot{v}_g \)  
time dependent acceleration of the ground motion

\( v_n \)  
displacement vector at nth floor in global coordinates

\( v^m_n \)  
displacement in local coordinates of the mth frame at level n

\( \{v\} \)  
displacement vector

\( \{v_a\} \)  
vector of absolute displacement along global coordinates with reference to a fixed frame in space

\( \{\dot{v}\} \)  
velocity vector

\( \{\ddot{v}\} \)  
acceleration vector

\( \{v_g\} \)  
vector of pseudostatic displacements along the global coordinates resulting from displacement of the base due to the earthquake motion

\( w \)  
load distributed uniformly on a beam
\( \{x\} \) vector of unknown displacements

\( X_n \) displacement of floor at level \( n \) in global \( x \)-direction

\( \bar{X}_n \) \( x \)-distance of global origin or center of mass from reference axis at level \( n \)

\( Y_n \) displacement of floor at level \( n \) in global \( y \)-direction

\( \bar{Y}_n \) \( y \)-distance of global origin or center of mass at level \( n \) from reference axis

\( z_i \) \( i \)th normal mode coordinate

\( \{z\} \) normal displacement vector

\( \mathbf{\beta} \) angle of incidence of earthquake with global \( x \)-axis

\( \$ \) member deformation

\( \{\phi_i\} \) \( i \)th mode shape

\( \xi_i \) damping ratio in the \( i \)th mode

\( \lambda_o \) shifted origin in the extradiction of eigenvalue

\( \lambda \) inverse of the square of frequency

\( \mu \) ductility factor

\( \mu_i \) square of the \( i \)th residual eigenvalue measured from a shifted origin

\( \omega_i \) \( i \)th natural frequency

\( \psi \) phase angle

\( \theta \) joint deformation

\( \theta_n \) rotation about the global origin at level \( n \)

\( \theta_A \) displacement vector not corresponding to sidesway

\( \theta_B \) displacement vector corresponding to sidesway

\( \{\theta\} \) frame displacement vector

\( \{\theta_g\} \) global displacement vector
CHAPTER 1

INTRODUCTION

1.1 GENERAL

A real building is a three-dimensional continuous system with complex structural components and distribution of loading. However, for the purpose of analysis, it is a common practice to resolve the building into a series of plane frames so that the problem is reduced to one in two dimensions. These approximations may give satisfactory results only in cases where the building is symmetrical in nature and has uniform distributions of mass and stiffnesses. For practical reasons, real buildings are very often unsymmetrical and have some irregularities in their structural shapes and uneven distributions of loads and structural properties. Analysis of such buildings by the plane frame approach is likely to give inaccurate results, which may lead to irrational design. Therefore, for many practical buildings, a three-dimensional analysis in which the structure as a whole is considered to take part in resisting the forces is essential.

On the other hand, a very rigorous approach to three-dimensional analysis would involve a large number of unknown variables and thus would necessitate the solution of a great many number of equations. Only a few buildings, which are very irregular and have an extremely complex distribution of loading, may need such a sophisticated analysis. Most
buildings, even when they are complex, usually have a comparatively simple geometry and consist of right angle frames or frame-shearwall systems. With the aid of some basic reasonable assumptions, it is possible to reduce the number of unknowns considerably, still considering the building as a whole for the analysis. The results obtained by such an approach are quite accurate for most practical purposes. This makes the analysis simpler and suitable for normal design office use. The task is however still too formidable for manual computations and suitable computer programs must be developed for the analysis.

1.2 COMPUTER PROGRAMS FOR STRUCTURAL ANALYSIS

There are several general purpose computer programs that can carry out two and three-dimensional linear analysis of complex structures. Most of these programs can be used for the analysis of buildings. However, there are several disadvantages in the use of a general structural analysis program for a building system. Some of the major difficulties are as follows:

1. Most buildings are of simple geometry with horizontal and vertical members. Also, many frames and shearwalls are typical and repeated in the structural layout. Most general purpose programs do not recognize these facts. Therefore, on one hand they are inefficient for the purpose and on the other they need an input data which is often unnecessarily complex and voluminous.
2. The general purpose analysis programs will also not recognize that the floor diaphragms are very rigid in their own planes (this is true of most well designed buildings). If this assumption is not made, the resulting number of equilibrium equations may be very large. This may lead to a very large increase in the computational effort. Also, numerical errors may be introduced because the inplane floor stiffnesses are several orders of magnitude greater than the story to story stiffnesses. Since these two stiffnesses are added in a direct stiffness approach, double precision may be required in the solution, and even then the numerical difficulties may not be completely eliminated.

3. In the dynamic analysis of buildings, a reasonable approximation can be made whereby the mass of the structure is lumped at the floor levels. With this assumption, the eigenvalue problem is reduced to a reasonable size and results obtained are sufficiently accurate for all practical purposes. A general purpose analysis program, not specifically designed to solve a building structure, may not utilize the above approximation.

4. In a building, the loading is of a regular form and certain loads are applied only at a limited number of locations. The simplifications resulting from this may not be exploited in a general purpose program. Also, in many programs, there may be no simple and direct method of satisfying various loading
requirements such as, for example, the various combinations of gravity, wind and earthquake loadings and such requirements may be satisfied only at the cost of increased computational effort.

5. It is desirable to have the computer output categorized as pertaining to a frame, story, column, or a beam and presented accordingly. Most general purpose programs can not supply the output in a convenient format.

The above drawbacks cause difficulty for the user. Also, general purpose programs usually entail a high running cost. To overcome these difficulties, programs which are specially dedicated to the analysis of building structures need to be designed. There are, of course, some special purpose programs available for analysis of only building structures. However, the majority of them are problem oriented; for example, some may be able to analyze the structure for static loads only, some others may be, able to perform only a dynamic analysis of the building and so on. Some programs have other limitations. Many of them can not directly handle setback frames; they usually put zero properties for members above the setback levels, increasing computation cost and computer storage requirements. Also, many such programs do not take into account shear deformations in structural members which may be significant in some cases. Thus, the need for a more sophisticated special building analysis program is apparent.

† Numbers in round parentheses refer to the references listed at the end of this thesis.
A few special purpose programs which can effectively perform a three-dimensional analysis of buildings for various loading conditions have been developed in recent past. Notable among them is TABS\(^{(20)}\). Program TABS performs a three-dimensional analysis of buildings on the basis of assumptions similar to those discussed above and hence is not beset by many of the difficulties experienced in the use of general purpose programs.

The program reported in this thesis has more or less the same capabilities as TABS. In its internal organization, however, it is completely different. This program uses computational techniques based on the up-to-date state-of-the-art. The techniques will be detailed in the subsequent sections of this thesis; they relate mainly to the storage of stiffness matrix, solution of equations, static condensation of matrices and the solution of eigenvalue problems. To the user, however, the major difference is in data input. Unlike TABS, the present program affords the facility of completely free format data input through an interactive conversational 'front-end' processor.
1.3 CONVERSATIONAL COMPUTER PROGRAMS

To date, most computer programs that handle civil engineering problems have been designed for processing in the batch mode. Most of them are written in FORTRAN IV and in some of them (e.g. ICES STRUDL, AMECO, etc.), the communication between the user and the program is in a special problem-oriented language. In order to work with them, the user must put substantial effort in learning the language of communication or in mastering the data input format. Also, one of the troublesome features of standard FORTRAN is the rigid nature of input format. If numbers or 'alphanumeric' variables are positioned incorrectly on data cards or in the input data files, the computer interprets the information incorrectly. The user is thus forced to spend time to make certain that the data on his punched cards are exactly in the specified position. If the structure to be solved is big, the number of such data cards are equally large and the time spent on scrutinizing them may be considerable. After preparation of the data, the user submits it to the data center for 'batch execution' and has to wait for several minutes to several hours before he receives the printed output.

The difficulties just cited in using engineering programs are obviously a cause of frustration to the user-engineer and of reluctance in using these programs frequently.

Computer programs have been developed which overcome at least some of the above difficulties. These programs have one or more of the following attributes:
1. Data input is made in a 'free format' mode.

2. A remote 'time sharing' terminal is used to run the programs instead of resorting to batch execution.

3. An interactive conversational mode of communication is established between the user and the computer during the execution of a program.

The above points are discussed below in some detail.

1.3.1 Free Format Data Input

It is possible to devise an interfacing FORTRAN subroutine which will accept data in essentially 'free format', and convert it into integers, real numbers, or alphanumeric variables as appropriate. This makes it possible to avoid punching data in the correct position on data cards or on input data files. Instead, one only needs to separate individual data items by one or more blanks. One such general purpose subroutine, called 'REED' has been developed by Wright(18) and is in extensive use. The subroutine operates in the following steps:

1. A line (or card) of data input is read in AL format and stored in an array.

2. The array of data just read is processed character by character. Strings of consecutive non-blank alphanumeric characters are recognized as discrete data items, that is, a group of one or more consecutive blanks is recognized as a data item separator.
3. If a particular discrete data item, so defined, contains only digits and possibly plus, minus, or decimal signs in appropriate locations, it is recognized as a potential numeric data item and its value as a real number is computed. If it contains any other character, it is considered as not being a numeric data item.

4. From the unprocessed alphanumeric input array, the subroutine constructs the real numeric input array, the integer input array, and the processed alphanumeric input array. The program then selects the desired data items from the desired array. The program can accept numeric data in a very easy and natural way. The input is truly free format; no decimal is required for an integer; also, when real numbers are whole numbers, as is often the case, they can be supplied as just the numbers, the decimal being optional. By contrast, if the user by mistake follows an integer by a decimal, the program is not disturbed thereby. Also, if by mistake, a user types in the letter O as the digit zero and the letter I as the digit one, the subroutine can automatically process them as the desired numerals.

A more detailed description of the subroutine is available in References (18) and (19).

Since the subroutine is written in standard FORTRAN, it is machine independent and can be used on any computer accepting FORTRAN.
1.3.2 Time-Sharing on a Computer

To paraphrase Wright (17), the idea of time-sharing on a computer is to commute computer resources in time (time-sharing) from one user to another. In contrast, a batch mode of operation forces a user to commute from one computing activity to another between computer runs. The concept of time-sharing arises from the fact that the human thinking process and responses are rather slow relative to the logical and arithmetic capability of the computer creating a time lag between the two systems (the human and the computer). This time lag has been properly utilized to switch the computing resources from one user to another in such a way that the user can interact from a terminal on line to the computer and think he has the sole access.

The intention of time-sharing, however, is not the reduction of the programmer's frustration but a new mode of machine-aided problem solving. Of course, in this mode, a user can sit down at a console and in one or more continuous sessions write, debug, and run his programs interactively. In this way, one feels more imaginative and can usually maintain a better contact with his problem during its execution. Also, using the system file storage facilities, information can be updated and retrieved on demand.

The very common features of time-sharing are as follows:

1. The creation, editing and accessing of data files.
2. The development, editing and debugging of programs.
3. The execution of small and medium jobs.
A more detailed account of time-sharing mode of operation can be found in References (21) and (17).

With the development of time-sharing systems, new types of computer programs which utilize this facility provided by the computer have been written and are in successful use.

1.3.3 Development of Conversational Programs

With the development of a time-sharing system in computers, one of the areas that has received considerable attention has been that of conversational computer programs. The role of such a program may be described as follows.

With a conversational computer program, the user in effect carries on a dialogue (a conversation) with a host computer via an appropriate time-sharing terminal. To accomplish this, the user at first establishes contact with the computer and requests it to execute a desired program to solve a particular problem. The computer replies via the terminal first by announcing that the desired program is about to be executed. Then it starts asking a series of auto-explanatory questions one by one, via the terminal and invites the user to supply an immediate answer at the terminal. Finally, when all relevant information (i.e. the input data) has been supplied, the computer provides a solution to the problem on the user's terminal.

The important features of a conversational program are at once obvious. First, it requires from the user only a rudimentary knowledge
of computer use. Second, the user does not have the need to go through a program user's manual or to learn a complicated set of instructions for the execution of the program. Again, since the conversation takes place via a time-sharing terminal, an essential aspect of a conversational program is a free-format data input. For a structural problem of some size, a large volume of data input is required by the program. However, for a real building, many members are typical and repetitive over the whole structure, and may carry loads that are similar. Also, many of the dimensions are repetitive. It is possible to write an efficient conversational program which takes advantage of the above features and makes it possible for the user to supply data at a high speed using the free-format facility of the program.

In addition to providing engineers and users with a range of computer-based tools for quick and direct problem solving, conversational programs can be usefully employed to prepare the input data for many of the larger compute-bound programs which must be run in a remote batch mode.

For many other applications, conversational programs can offer improved effectiveness and very substantial savings in time even to the engineer experienced in computer use. The above advantages of the conversational computer programs appear to be immediately obvious and make them very effective for use in the engineering offices.
The role of conversational programs is described in more detail in Reference (19).

1.4 EARTHQUAKE ANALYSIS OF BUILDINGS

At the present time, most buildings in regions of Canada with a possible seismic hazard are designed based on the equivalent static lateral loads specified in the National Building Code (14). In this approach, the magnitude of the design base shear depends on two basic parameters: the fundamental period of the building and the seismic zone in which it is located. An approximate formula may be used to estimate the fundamental period. The suggested distribution of the lateral loads over the height of the building is based on the assumption that the predominant response is in the fundamental mode, though an approximate adjustment is made to account for the effect of higher modes. While this approach may be satisfactory for buildings that are regular in distribution of mass and stiffness, it has serious limitations when applied to the design of buildings with complex structural configurations. Thus, for buildings that may have unusual mass or stiffness distributions, major setbacks, or large torsional eccentricities, a more comprehensive dynamic analysis should be carried out to obtain reasonable estimates of the earthquake induced forces. The commentary to the National Building Code (3) recommends a dynamic analysis approach to the design of such buildings. In the recommended procedure, the structure is analyzed for a design earthquake base motion represented by an average response spectrum,
which is appropriate to the estimated peak ground acceleration at the site and the damping in the structure. The calculated response is then modified for plastic behaviour in a manner which takes into account the capability of the structure for inelastic deformation.

The computer program described in this report has the ability to perform a dynamic analysis of the building following the approach given in the commentary to the code.

1.5 OBJECTIVES AND SCOPE OF PRESENT WORK

The work reported in this thesis involves the development of computer programs for linear three-dimensional analysis of building systems for the effect of gravity, earthquake and lateral loads. Effort has been made to incorporate into these programs many of the desirable attributes described earlier in this Chapter. The following two computer programs have been developed:

1. The first program called AIDS has been developed to read all relevant information and the input data required for the analysis of the building in a conversational mode and with a 'high speed' data input option.

2. The second program called ANGELS is designed to accept the input data prepared by AIDS and to carry out a linear three-dimensional analysis of the building structure for gravity, earthquake and lateral load systems.
The scope and limitations of the programs mentioned above are summarized here. More detailed descriptions of some of these appear in the subsequent sections.

1.5.1 The Input Data Program - AIDS

This program written in standard FORTRAN IV is essentially a 'front end' processor for the other program ANGELS. It is designed to read all input data in a conversational mode and to prepare it for use by ANGELS. The important features of this program are as follows:

1. With the aid of general purpose subroutine 'REED'\(^{(18)}\), the program reads all data in a true free-format mode.

2. For a big building, the volume of the actual input data is large. However, in most cases, various dimensions, member properties and sizes and loadings etc. are typical and repeated over the structure. The program has a rapid data input facility which makes it possible to greatly speed up the process of reading repetitive data.

3. While the data is being read from the terminal in a conversational mode, a copy of the input supplied by the user is written on a disc file for possible subsequent corrections of input data.

4. The data read with a rapid input option is interpreted by the program rearranged and written on three separate disc files - the first containing the general data and the seismic...
loading data, if any, the second containing the member and frame properties data, and the third containing the loading data frame by frame.

As stated earlier, the program acts only as a 'front end' processor for reading in data and does not carry out any other computations.

1.5.2 The Analysis Program - ANGELS

This program is designed to read input data from the three disc data files generated by program AIDS, perform a linear three-dimensional analysis of the building and print the results in terms of member forces. The program is written in standard FORTRAN IV and runs in a remote batch mode. The scope and limitations of this program are as follows:

1. The building to be analyzed should consist of right angle frame or frame-shearwall substructures, each containing horizontal beams and vertical columns or shearwalls. Frames with identical properties are grouped together, each group being called a 'Frame Group'.

2. The joints in a frame are considered rigid and the base columns and shearwalls are considered to be attached to rigid foundations at the same level.

3. The beams are considered axially rigid and the floor diaphragms infinitely rigid in their own planes. Bending distortions are accounted for in both beams and columns. In addition, for
columns, the axial deformations are also included. Shearing distortions and finite joint regions of infinite rigidity may be included at the user's option.

4. For three-dimensional analysis, since the floor diaphragms are considered infinitely rigid in their planes, there are only three degrees of freedom - two translations in the x and y directions and a rotation at each floor of the building. However, for symmetric buildings with symmetric distribution of mass and lateral loads, the analysis can be accomplished by a superposition of a couple of two-dimensional analyses, one in each principal direction. In appropriate cases, if the user so wishes, the program will carry out such two-dimensional analyses.

5. The mass of the building is assumed to be lumped at the floor levels and only translational inertia forces are considered.

6. The program performs a dynamic analysis using an earthquake design response spectrum according to the method discussed in Section 1.4. The three-dimensional mode shapes, frequencies and story forces are evaluated and printed out at the option of the user. Also, if required, the root-sum-square forces are computed at the member level.

7. The program can carry out an analysis for a maximum of four different gravity load cases, three different lateral load cases and a seismic load case for a specified design response.
spectrum. The individual load cases can be weighted and superimposed in any number of load combinations and the member forces can be obtained for each such combination. A load combination is referred to as a 'Load System'. For each load system, the multipliers for individual component load cases must be specified by the user.

8. Any of the gravity, lateral or seismic load cases may be suppressed from analysis. The three-dimensional mode shapes and frequencies can be evaluated at the user's option, even when the seismic load case is not considered.

Briefly, the following steps are taken to improve the efficiency of the program as a whole:

1. The frame stiffness matrices are stored in a compacted column string storage to minimize storage space requirements.

2. An efficient algorithm is used\(^{(22)}\) to solve the stiffness equations. It works on a stiffness matrix stored as described in step one above and uses the Crout reduction technique. An adaptation of the same technique is used in the static condensation of the stiffness matrix, required for obtaining the frame sideways stiffness matrix.

3. Because of the lumped mass idealization, the mass matrix obtained is diagonal. An efficient eigenvalue solution algorithm, which takes into account the special character of the mass matrix, is used.
4. A dynamic storage allocation scheme is used for major variable arrays. In this method, storage is allocated at run time and because many arrays can share a common storage, the minimum amount of computer storage is used.

During program development, the input data program AIDS was run on a dedicated DM-70 minicomputer with a terminal capable of communicating with the computer at the rate of 960 characters per second. The three disc data files produced by program AIDS were transferred to a HONEYWELL Sigma-9 computer as three 'unkeyed' disc files. These files formed the input data files for program ANGELS which was run in remote batch mode.

1.6 THE FORMAT OF THE THESIS

Details of the present work are reported in this thesis according to the following format.

Chapter 1 of the thesis has presented a brief discussion of the concepts related to the work and has specified the objectives of the project.

The assumptions made and the limitations inherent in the method of analysis used here are presented in Chapter 2. The theoretical background to the method of analysis and the mathematical modelling of the structure are also presented there.

The theory used in the dynamic analysis of the structure is developed in Chapter 3.
Chapter 4 presents a description of the computer programs developed for this project. The logic and the organization of the programs are briefly discussed and outline flow diagrams are given.

Chapter 5 presents a summary of the work done and discusses the various findings. Possible further developments on the subject are also outlined.

The program user's manual is contained in Appendix A.

The FORTRAN listings of the computer programs are presented in Appendix B.
CHAPTER 2

STRUCTURAL IDEALIZATION

2.1 BASIC ASSUMPTIONS

An exact three-dimensional structural analysis, that is, a space frame analysis, is required for only a limited number of buildings. For a majority of buildings, the following two basic assumptions can be made in formulating the mathematical model of the structure. These assumptions significantly reduce the computational effort and greatly simplify the preparation of input data.

1. It is assumed that the floor diaphragms are rigid in their own planes. This is a realistic approximation for a large number of common buildings. As a result, the structure has three degrees of freedom at each floor level — two translational in the x and y directions and a rotational about the vertical axis of the floor.

The other degrees of freedom include: the bending deformations in the horizontal beams and floor slabs, and a vertical displacement and a rotation at each column or shearwall at each floor level.

2. It is further assumed that the horizontal lateral loads act at the floor levels and are transferred to the columns through rigid floor diaphragms. Also, the mass of the building is
assumed to be lumped at the floor levels. As a consequence, the active dynamic degrees of freedom at each floor are three, corresponding to the three displacement degrees of freedom as mentioned in 1 above.

2.2 STRUCTURAL MODELLING

The elevation and plan views of a typical building are shown in Fig. 2.1. The complete building structure is modelled as consisting of two sets of planar frames or frame-shearwall systems which are orthogonal to each other in plan view. Isolated shearwalls within a set are considered to be frames consisting of a single continuous column line. Each frame is treated as an independent substructure. A substructure is permitted to have two degrees of freedom per joint (vertical displacement and in-plane rotation) and one lateral translation per story. However, of all the above degrees of freedom, the only active dynamic degrees of freedom are those associated with lateral displacements at the floor levels. It is possible to eliminate the inactive joint degrees of freedom by a static condensation of the stiffness matrix before the Global stiffness matrix is assembled. Thus, a typical constituent frame-wall system of story N will bring forth a condensed or sideways stiffness matrix of size N by N. The substructure stiffness matrix is assembled into the global matrix on the assumption that the structure has three active degrees of freedom per floor: two translational, and one rotational.
(a) PLAN

(b) ELEVATION

FIG. 2.1 TYPICAL FRAME AND SHEARWALL BUILDING
The increase in the stiffness of a shearwall due to the presence of an intersecting shearwall can be accounted for in any reasonable manner. However, in the present structural modelling, it is assumed that a frame-wall substructure does not have any stiffness in a direction perpendicular to its own plane, nor does it have any torsional stiffness about its own axis.

The following additional approximations are also inherent in the present approach:

1. Complete compatibility with regard to joint displacements is not enforced at joints which are common to two intersecting frames. Thus, in a column which is common to two intersecting frames, the axial deformations will not be the same. However, for design purposes, a reasonable approximation to the axial load in such a column can be obtained by adding those calculated for the component frames. As for joint rotations, since the intersecting frames are assumed to be perpendicular in plan view, the in-plane joint rotations of the frames are orthogonal to each other and are hence uncoupled.

2. As the floor diaphragms are assumed to be rigid in their respective planes, it is apparent that the axial deformation is not permitted in the beams. However, bending stiffness of the floors may be included approximately in modelling of individual frames. All beam center lines in a floor are assumed to be coincident with the central plane of the floor-diaphragm.
Similarly, columns for all stories, located in one vertical stack must have the same center line.

3. The torsional resistance of any member section is neglected.

2.3 FRAME SUBSTRUCTURE

A frame substructure may be a beam and column system, a frame-shearwall system or an isolated shearwall. Any of the above substructures may be regular or setback. The cross-section of a typical setback frame-wall substructure is shown in Fig. 2.2. A frame in which the number of bays in the base floor is larger than those in some upper floors is called a setback frame. The part of the frame height having the same number of bays is defined as a tower; the lowest being called the base tower. In modelling the frame, it is assumed that the center lines of all columns in a stack lie in the same vertical. The assumption will, however, result in some errors when an upper column center line is offset with respect to the center line of the column below it, but such errors will be reasonably small and can be neglected. The above assumption also implies that the bay widths are constant throughout the height of the building and are measured between the center lines of the adjacent column stacks.

It is further assumed that the center lines of all beams at a floor lie in one horizontal plane. This assumption will result in errors in the analysis when the beams in a floor are of different depths, but such errors are likely to be small. The story height is measured from the common center line of beams in one floor to the same in the next floor.
Tower: part of frame height with same no. of bays
NST: no. of stories in a tower
NBA: no. of bays in a tower
NBS: no. of bay-setback between two towers at left

FIG. 2.2 ELEVATION OF A SETBACK FRAME
Fig. 2.3 compares a real frame and its mathematical model on the basis of the assumption stated above.

Deformations within the joint may be neglected by specifying finite beam and column widths. When finite joint sizes are used, the effective length of a beam is reduced at either end by half the width of the columns below. Also, the effective height of a column is reduced by half the maximum depth of girders on either side, at both ends of the column.

Beams and columns may be prismatic or circular. However, when finite joint sizes are taken into account, a rigid zone of very large moment of inertia is assumed at each end of such members. Shear deformation is included and for columns, axial distortions are also considered.

In general, each frame is thought of as a setback frame. Hence, the number of towers (blocks with the same number of bays) must be specified. A regular frame is treated as one having a single tower. Members may be omitted from any position simply by specifying zero properties. However, if two adjacent beams are omitted, the lateral displacement of the common joint is still constrained to be the same as that of other joints at that level. Also, at least one of the members framing into a joint must have non-zero properties.

It is assumed that the foundations of all columns and shearwalls are rigid and lie at the same level.
FIG. 2.3 MATHEMATICAL MODEL OF A FRAME
2.4 MEMBER STIFFNESS

2.4.1 Beam Stiffness

A beam member, being a part of the frame, can be modelled as shown in Fig. 2.4. The total length of a beam is defined as the distance between the two end column center lines. When finite joint sizes are considered, the effective length of the beam is its total length less the lengths of the two rigid end stubs. A rigid end stub is taken as half the width of the column below the beam end. The beams are considered to have two degrees of freedom at each end and in developing their stiffness both flexure and shear deformations are taken into account.

For a prismatic beam (Fig. 2.4), the member-flexibility matrix corresponding to the rotational degrees of freedom and including shear and bending distortions can be written as\(^{13,20}\):

\[
[f] = \frac{L}{6EI} \begin{bmatrix}
2 + a & a - 1 \\
a - 1 & 2 + a
\end{bmatrix}
\]  \hspace{1cm} (2.1)

where

\[
a = \frac{6EI}{k'AGL^2} \hspace{1cm} (2.1a)
\]

\[A = \text{area of cross-section}\]
\[k' = \text{effective shear coefficient} < 1\]  \hspace{1cm} (2.1b)
\[L = \text{length of beam}\]
\[I = \text{moment of inertia}\]
FIG. 2.4 BEAM MODAL WITH RIGID END STUBS

FIG. 2.5 FLEXURAL BEAM DEFORMATIONS

FIG. 2.6 TRANSFORMATION RELATION BETWEEN BEAM DEFORMATIONS AND FRAME DISPLACEMENTS
E = modulus of elasticity
G = modulus of rigidity

By inverting the above flexibility matrix, the basic stiffness matrix for end rotations is obtained as:

\[
\begin{bmatrix}
    k_d \\
\end{bmatrix} = \frac{2EI}{L^2(1+2\alpha)} \begin{bmatrix}
    2+\alpha & 1-\alpha \\
    1-\alpha & 2+\alpha \\
\end{bmatrix}
\]  
(2.2)

In line with the direct stiffness technique, two rigid end stubs are now attached to the effective beam length of Fig. 2.5 and a transformation relation developed between the member deformations and frame displacements. Referring to Fig. 2.6, the transformation relationship is derived as follows.

\[Y = a\theta_1 + b\theta_2 + \theta_3 - \theta_4 \]  
(2.3a)

Since \(\theta_1\) and \(\theta_2\) are small

\[\beta = \frac{Y}{L} \]  
(2.3b)

\[\phi_1 = \theta_1 + \beta \]  
(2.3c)

and

\[\phi_2 = \theta_2 + \beta \]  
(2.3d)

where \(L\) is the effective length and \(a\) and \(b\) are lengths of rigid end stubs.

Expressing Eqs. (2.3a) through (2.3d) in a matrix form:
\[
\begin{bmatrix}
\phi_1 \\
\phi_2 \\
\phi_3 \\
\phi_4
\end{bmatrix} = \begin{bmatrix}
1+a/L & b/L & 1/L & -1/L \\
a/L & 1+b/L & 1/L & -1/L \\
a/L & 1+b/L & 1/L & -1/L \\
1/L & 1/L & -1/L & -1/L
\end{bmatrix}
\begin{bmatrix}
\theta_1 \\
\theta_2 \\
\theta_3 \\
\theta_4
\end{bmatrix}
\] (2.4)

Equations (2.4) can be symbolically written as:

\[
[\phi_B] = [T_B][\theta_B]
\] (2.4a)

where \([T_B]\) represents a transformation matrix and \([\phi_B]\) and \([\theta_B]\) denote member deformation and frame displacement vectors respectively.

Now, following standard theory, the stiffness matrix, \(K_B\), of a beam in the frame coordinates, is given by:

\[
[K_B] = [T_B]^T[K_B][T_B]
\] (2.5)

Substitution of Eqs. (2.2) and (2.4) into Eq. (2.5) gives:

\[
K_B = \frac{2EI}{L(1+2\alpha)} \begin{bmatrix}
1+a/L & a/L & 2+\alpha & 1-a \\
b/L & 1+b/L & 1+2\alpha & 1-a \\
a/L & 1+b/L & 1/L & -1/L \\
1/L & 1/L & -1/L & -1/L
\end{bmatrix}
\] (2.6)

Equation (2.6) then gives the following stiffness matrix for an individual beam, when finite rigid joints are considered and shearing deformation is included:
\[
\begin{bmatrix}
(2+\alpha + \frac{6a}{L} + \frac{6a^2}{L^2}) & (1-\alpha + \frac{3}{L} (a+b)) + \frac{6ab}{L^2} & \frac{3}{L} + \frac{6a}{L^2} & -\frac{3}{L} + \frac{6a}{L^2} \\
\frac{1-\alpha + \frac{3}{L} (a+b) + \frac{6ab}{L^2}}{L^2} & (2+\alpha + \frac{6b}{L} + \frac{6b^2}{L^2}) & \frac{3}{L} + \frac{6b}{L^2} & -\frac{3}{L} + \frac{6b}{L^2} \\
\frac{1-\alpha + \frac{3}{L} (a+b) + \frac{6ab}{L^2}}{L^2} & \frac{3}{L} + \frac{6b}{L^2} & \frac{6}{L^2} & -\frac{6}{L^2} \\
\frac{1-\alpha + \frac{3}{L} (a+b) + \frac{6ab}{L^2}}{L^2} & -\frac{3}{L} + \frac{6b}{L^2} & -\frac{6}{L^2} & \frac{6}{L^2}
\end{bmatrix}
\]

(2.7)

where

\[
\gamma = \frac{2EI}{L(1+2\alpha)}
\]  

(2.8)

2.4.2 Column Stiffness

Column stiffness matrix is developed in a very similar manner except that here the axial deformation is also taken into account.

Thus, in terms of the basic deformation coordinates shown in Fig. 2.7, the column stiffness inclusive of shear distortion can be written as:

\[
\begin{bmatrix}
\mathbf{k}_c
\end{bmatrix} = \gamma \times \begin{bmatrix}
2+\alpha & 1-\alpha & 0 \\
1-\alpha & 2+\alpha & 0 \\
0 & 0 & \frac{AE}{\gamma L}
\end{bmatrix}
\]  

(2.9)

Referring to Fig. 2.8, the transformation relation is derived as follows:

\[
x = a\theta_1 + b\theta_2 - \theta_3 + \theta_4
\]  

(2.10a)

Since \(\phi_1\) and \(\phi_2\) are small,
FIG. 2.7 FLEXURAL COLUMN DEFORMATIONS

FIG. 2.8 TRANSFORMATION RELATION BETWEEN COLUMN DEFORMATIONS AND FRAME DISPLACEMENTS
\[ \theta = \frac{x}{L} \quad (2.10b) \]
\[ \phi_1 = \theta_1 + \beta \quad (2.10c) \]
\[ \phi_2 = \theta_2 + \beta \quad (2.10d) \]
\[ \phi_3 = \theta_6 - \theta_5 \quad (2.10e) \]

Expressing Eqs. (2.10a) through (2.10e) in a matrix form:

\[
\begin{bmatrix}
\phi_1 \\
\phi_2 \\
\phi_3
\end{bmatrix} =
\begin{bmatrix}
1 + a/L & b/L & -l/L & 1/L & 0 & 0 \\
a/L & 1 + b/L & -l/L & 1/L & 0 & 0 \\
0 & 0 & 0 & 0 & -1 & 1
\end{bmatrix}
\begin{bmatrix}
\theta_1 \\
\theta_2 \\
\theta_3 \\
\theta_4 \\
\theta_5 \\
\theta_6
\end{bmatrix} \quad (2.11)
\]

or

\[
[\phi_c] = [T_c][\theta_c] \quad (2.12)
\]

where \([T_c]\) denotes the column transformation matrix.

From Eqs. (2.9) and (2.12), the column stiffness matrix \([K_c]\) is given by:

\[
[K_c] = [T_c]^T[K_c][T_c] \quad (2.13)
\]

which leads to the following final form:
\[
[K_C] = \gamma \begin{bmatrix}
(2+a+ \frac{6a}{L^2} + \frac{6a^2}{L^2}) & (1-a+ \frac{3}{L}(a+b)+ \frac{6ab}{L^2}) & -\left(\frac{3}{L} + \frac{6a}{L^2}\right) & \left(\frac{3}{L} + \frac{6a}{L^2}\right) & 0 & 0 \\
(1-a+ \frac{3}{L}(a+b)+ \frac{6ab}{L^2}) & (2+a+ \frac{6b}{L^2} + \frac{6b^2}{L^2}) & -\left(\frac{3}{L} + \frac{6b}{L^2}\right) & \left(\frac{3}{L} + \frac{6b}{L^2}\right) & 0 & 0 \\
-\left(\frac{3}{L} + \frac{6a}{L^2}\right) & -\left(\frac{3}{L} + \frac{6b}{L^2}\right) & \left(\frac{6}{L^2}\right) & -\left(\frac{6}{L^2}\right) & 0 & 0 \\
\left(\frac{3}{L} + \frac{6a}{L^2}\right) & \left(\frac{3}{L} + \frac{6b}{L^2}\right) & -\left(\frac{6}{L^2}\right) & \left(\frac{6}{L^2}\right) & 0 & 0 \\
0 & 0 & 0 & 0 & \frac{AE}{\gamma L} & -\frac{AE}{\gamma L} \\
0 & 0 & 0 & 0 & -\frac{AE}{\gamma L} & \frac{AE}{\gamma L}
\end{bmatrix}
\] (2.14)

The definition of member stiffness matrices in this form makes it a simple matter to model a shearwall. Thus, a shearwall is treated like any other column, except that the former has a large width. The beams framing into the shearwall will therefore have wide rigid end stubs.

2.5 FRAME STIFFNESS

The complete stiffness matrix for each frame is assembled using the direct stiffness technique. In this approach, the frame degrees of freedom must be numbered first. An efficient scheme is used as illustrated in Fig. 2.9 in which the frame degrees of freedom are numbered in such a manner that all non-zero elements of the stiffness matrix lie in a minimum bandwidth around the leading diagonal. Starting from the
FIG. 2.9 FRAME DEGREES OF FREEDOM

FIG. 2.10 FRAME STIFFNESS MATRIX
lowest floor, the rotational degrees of freedom at a floor are numbered first; the story sideways degree of freedom is numbered next, being followed by the vertical joint displacement degrees of freedom. With this sequence of numbering, the maximum half-bandwidth of the stiffness matrix works out to \(3\times(NBA+1)+2\), where \(NBA\) is the number of bays in the base story.

The stiffness matrix is always symmetric. It is necessary to make the best use of this symmetry and bandedness of the stiffness matrix to conserve computer storage space and to avoid repetition of computations. In assembling the stiffness matrix, the method of direct joint stiffness is employed. In this method, a unit value is assigned to one joint displacement, the other displacement values being held to zero, and the forces generated at all affected degrees of freedom are calculated. Because only one symmetric half of the stiffness matrix need be generated, when a unit displacement is assigned to a particular degree of freedom, joint stiffness forces need be determined only in the affected degrees of freedom with a lower number. Of course, the joint force along the degree of freedom to which the displacement is assigned must also be determined. The stiffness matrix for the frame of Fig. 2.9 is shown schematically in Fig. 2.10.

The details of the technique employed are described in Section 4.5.1.
2.6 FRAME SIDESWAY STIFFNESS

The approximations described in Section 2 allow each frame to be treated as a separate substructure. The only connection is through the common displacements at the floor levels. Hence, the first step in the development of the stiffness matrix for the complete structure is to develop the sidesway stiffness matrices of the individual frames. A sidesway stiffness matrix contains only the degrees of freedom corresponding to the story sidesways. Since there is no straightforward method of determining the sidesway stiffness matrix directly, the complete frame stiffness matrix is developed first, as described in Section 2.5. Static condensation of the stiffness matrix is then used to obtain the sidesway stiffness matrix as follows.

A general frame stiffness equation for a given set of loads can be written as:

\[
[K_F]\{\theta\} = \{F\} \tag{2.15}
\]

where

\[
[K_F] = \text{frame stiffness matrix}
\]

\[
\{\theta\} = \text{frame displacement vector}
\]

\[
\{F\} = \text{frame joint force vector}
\]

Let the displacement vector be rearranged and partitioned into two sub-vectors such that vector $\theta_B$ represents displacements along sidesway degrees of freedom and $\theta_A$ denotes displacements along the remaining degrees of freedom. If the stiffness matrix and the load vector are also
rearranged and partitioned correspondingly, Eq. (2.15) can be rewritten as:

\[
\begin{bmatrix}
  k_{AA} & k_{AB} \\
  k_{BA} & k_{BB}
\end{bmatrix}
\begin{bmatrix}
  \theta_A \\
  \theta_B
\end{bmatrix}
= 
\begin{bmatrix}
  F_A \\
  F_B
\end{bmatrix}
\]  
(2.16)

or as

\[
k_{AA}\theta_A + k_{AB}\theta_B = F_A
\]  
(2.17)

\[
k_{BA}\theta_A + k_{BB}\theta_B = F_B
\]  
(2.18)

If the only loads acting on the frame are horizontal loads at floor levels, vector \( F_A \) is zero, and Eq. (2.17) gives:

\[
\theta_A = - \left( k_{AA}^{-1} k_{AB} \right) \theta_B
\]  
(2.19)

Substitution of Eq. (2.19) into Eq. (2.18) gives:

\[
\left( k_{BB} - k_{BA} k_{AA}^{-1} k_{AB} \right) \theta_B = F_B
\]  
(2.20)

or

\[
K_* \theta_B = F_B
\]  
(2.21)

where

\[
K_* = k_{BB} - k_{BA} k_{AA}^{-1} k_{AB}
\]  
(2.22)

The stiffness matrix \( K_* \) defined in Eq. (2.22) relates the story sidesway forces, \( F_B \), to the story displacements degrees of freedom \( \theta_B \) and is known as the condensed stiffness matrix or the Frame sidesway stiffness matrix.
It is important to note that in Eq. (2.21) the lateral loads $F_B$ are not known until the complete building is solved. Thus, the individual frame sidesway stiffness matrices are essential for assembling the complete structure stiffness matrix or the global stiffness matrix and in distributing the in-plane lateral story forces, acting on the building, to its component frames (i.e. to obtain the force vector $F_B$ in Eq. (2.21)).

The sidesway stiffness matrix can be obtained directly from Eq. (2.22). An alternative approach is to use the Gaussian elimination and back substitution method with a suitable adjustment technique as described in Section 4.5.3.

2.7 ASSEMBLY OF BUILDING STIFFNESS MATRIX

In order to assemble the complete building stiffness matrix from the component frame sidesway stiffness matrices, the latter should be transformed from the local coordinates of the frame to a common displacement coordinate system, which will be referred to as the global system. The local coordinates correspond to the lateral displacement of the frame at each floor level. The global coordinate system comprises three coordinates at each floor – two translations and one rotation. The location of these coordinates is taken at the centers of mass of different floors. To specify the positions of these centers of mass, a system of global reference axes are used. The coordinates of the centers of mass as measured from the global reference axes may vary from floor to floor.
With structure coordinates centered at the mass centers, the mass matrix required for the dynamic analysis will be a diagonal matrix, thus simplifying the eigenvalue solution. However, in cases where an analysis is required for lateral loads other than due to earthquake, the position of the global origin at each floor is arbitrary and can be set on the reference point.

The first step in the global stiffness matrix assembly is to develop a transformation relation between the local and global coordinate systems mentioned above. Fig. 2.11 shows the coordinate systems, at say, the nth floor level. For a frame oriented in the global Y-direction,

\[ v_n^m = y_n + d_n^m \theta_n \quad (2.23) \]

where \( d_n^m \) is the perpendicular distance from the global origin to the frame axis, positive in the positive direction of global x-axis.

In matrix form:

\[ v_n^m = \begin{bmatrix} 0 & 1 & d_n^m \end{bmatrix} \begin{bmatrix} x_n \\ y_n \\ \theta_n \end{bmatrix} \quad (2.24) \]

or

\[ v_n^m = [a_n^m] (v_n) \quad (2.25) \]

where \([a_n^m]\) is the transformation matrix for floor \( n \). For a frame oriented in the global X-direction, it can be shown that...
\[
\begin{bmatrix}
\bar{d}_m^n \\
0 \\
-d_n^n
\end{bmatrix}
\]  
(2.26)

where \( \bar{d}_m^n \) is the perpendicular distance measured parallel to the global Y-axis and is positive in the positive Y-direction. The complete transformation matrix for frame \( m \) is given by:

\[
\begin{bmatrix}
a_1^m \\
a_2^m \\
\vdots \\
a_n^m \\
a_N^m
\end{bmatrix}
\]  
(2.27)

where \( N \) is the number of stories in the frame.

If the lateral stiffness of the frame in the local coordinate system is represented by \( [k_m^m] \) and in global system by \( [k_m^n] \), then

\[
[k_m^n] = [A_m^m]^T [k_m^m] [A_m^m]
\]  
(2.28)

The transformation matrix \( A_m^m \) is very sparse; the matrix operations in Eq. (2.28) are therefore greatly simplified, and it can be shown that

\[
[k_{ij}] = [a_i^m]^T k_{ij} [a_j^m]
\]  
(2.29)

in which \( [k_{ij}] \) is a 3x3 submatrix.

The global stiffness matrix \( K_g \) is now obtained by the direct summation of the transformed frame lateral stiffness matrices. Thus

\[
[K_g] = \sum_m [k_m^n]
\]  
(2.30)
It may be noted that the global stiffness $[K_g]$ is a full matrix but its size is relatively small compared to the total number of degrees of freedom associated with all the frames in the structure. In buildings with a symmetric distribution of mass and stiffness, the translational and rotational modes of vibration are uncoupled, and a lateral motion at the base of the building does not excite its torsional modes of vibration. In such a situation, the total response (or displacements) of the building can be obtained by the superposition of its responses (or displacements) along the two mutually perpendicular principal directions. A similar situation arises when the lateral loads on the building act through the centers of rigidity. The analysis is thus reduced from a single three-dimensional problem to a couple of two-dimensional ones resulting in a considerable saving in computing time. To analyze the building for its response in any one principal direction, the global stiffness matrix of the building for motion in that direction must be obtained. This is achieved in a simple manner by a direct superposition of the lateral stiffness matrices of all the frames oriented in the direction being considered. Thus,

$$[K_g] = \sum_m [K^m]$$

(2.30a)

where summation extends over all the frames in the direction considered.
FIG. 2.11 GLOBAL AND LOCAL COORDINATES OF A TYPICAL FLOOR
2.8 SOLUTION FOR STATIC LOADS

2.8.1 Gravity Loads

Gravity loads are supplied as uniformly distributed loads and/or concentrated loads on individual beams. For these loads, the joint load vector is prepared for each frame substructure and the system is analyzed frame by frame by the usual methods of two dimensional analysis. The general frame stiffness, Eqs. (2.15), are used and solved by one of the elimination methods which give the unknown joint displacements vector \( \mathbf{\theta} \). These joint displacements along with the member fixed end forces, which were derived earlier during preparation of the joint load vector, are applied to the individual frame members giving the member forces at the face of the joints in a standard fashion.

a) Beam Fixed End Forces

For a prismatic beam, the fixed end force vector for concentrated load including shear effect can be expressed as

\[
\begin{bmatrix}
FX_1 \\
FX_2 \\
FX_3 \\
FX_4
\end{bmatrix} = \frac{P}{1+2\alpha} \begin{bmatrix}
\frac{c \alpha^2}{L^2} (1 + \frac{aL}{d}) \\
-\frac{c^2d}{L^2} (1 + \frac{dL}{c}) \\
\frac{c^2}{L^2} (3c + d + \frac{2aL^2}{d}) \\
\frac{c^2}{L^3} (c + 3d + \frac{2aL}{c})
\end{bmatrix}
\]  

(2.31)

where \(FX_1, FX_2, FX_3, FX_4\) are the fixed end actions and the other notations are explained in Fig. 2.12.
FIG. 2.12 FIXED END ACTIONS FOR GRAVITY LOADS

FIG. 2.13 JOINT FORCES FOR GRAVITY LOADS
For a load distributed uniformly over the entire length of the beam, the shear deformation has no effect on the fixed end force vector and referring to Fig. 2.12(b), the fixed end force vector is given by:

\[
\begin{bmatrix}
FX_1 \\
FX_2 \\
FX_3 \\
FX_4
\end{bmatrix} = \begin{bmatrix}
wL^2/12 \\
-wL^2/12 \\
wL/2 \\
wL/2
\end{bmatrix}
\]  

(2.32)

where \( w \) = intensity of load per unit length of the beam.

b) Frame Joint Load Vector

Since the columns do not carry any loads along their length, the joint loads are obtained as follows. The expressions derived below include the effect of finite joint sizes.

Let \( k \) be a typical joint where two beams \( i \) and \( j \) meet as shown in Fig. 2.13a. Using the free body diagram of Fig. 2.13b, the joint forces \( F_1^k \) and \( F_2^k \) are given by:

\[
F_1^k = -FX_2 + FX_1 + (-FX_4)a_j + \frac{w_i(b_i)^2}{2} - \frac{w_j(a_j)^2}{2}
\]

or

\[
F_1^k = -\left[FX_2 + FX_1 + a_jFX_3 - b_iFX_4\right] + \left[\frac{w_i(b_i)^2}{2} - \frac{w_j(a_j)^2}{2}\right]
\]  

(2.33)

and

\[
F_2^k = -\left[FX_4 + FX_3 + w_i b_i + w_j b_j\right]
\]  

(2.34)
where $F_x$ represents the sum of fixed end actions for concentrated and distributed loads, and other notations are described in Fig. 2.13(b).

Finally, the frame joint force vector $\{F\}$ is obtained by computing $F_1^k$ and $F_2^k$ for all joints in a frame and putting them in appropriate slots corresponding to the degrees of freedom in the frame.

2.8.2 Lateral Loads

In this case, the global X and Y components of lateral forces and their points of action are supplied for each floor of the structure. The global load vector $\{F_g\}$ is obtained as follows:

Referring to Fig. 2.14,

$$F_{h1}^1 = HX_n$$  \hspace{1cm} (2.36)
$$F_{h1}^2 = HY_n$$  \hspace{1cm} (2.37)
$$F_{h1}^3 = -HX_n(DY_n - \bar{V}_n) + HY_n(DX_n - \bar{V}_n)$$  \hspace{1cm} (2.38)

and

$$\{F_{h1}\} = \begin{bmatrix} F_{h1}^1 \\ F_{h1}^2 \\ F_{h1}^3 \end{bmatrix}$$  \hspace{1cm} (2.39)

For a building where stiffness and lateral loads are symmetrically distributed, $F_{h1}^3$ may be taken as zero and the translational and rotational displacements are uncoupled which greatly simplifies the computations as discussed in Section 2.7. The global load vector $\{F_g\}$ is given by:
FIG. 2.14 PLAN OF n^{th} FLOOR OF A BUILDING WITH LATERAL LOADS

FIG. 2.15 BEAM END FORCES FOR JOINT DEFORMATIONS
\[ \{F_g\} = \begin{bmatrix} F_{H_1} \\ F_{H_2} \\ \vdots \\ F_{H_n} \\ \vdots \\ F_{H_N} \end{bmatrix} \]  

(2.40)

The above derivation is based on the assumption that the global origin is coincident with the center of mass. As stated earlier, when analysis for earthquake forces is not required, global origin can be moved to the reference origin. In that case, \( \bar{X}_n \), \( \bar{Y}_n \) will each be equal to zero and the global stiffness equations can be written as:

\[ [K_j] \{\theta_g\} = \{F_g\} \]  

(2.41)

Equations (2.41) are solved by the method of matrix inversion to give the global displacements \( \{\theta_g\} \). The global displacements can be transformed to individual frame story displacements using the transformation matrix given by Eq. (2.27). Substitution of these story displacements in Eq. (2.21) gives the frame story forces \( \{F_B\} \). A frame load vector is prepared from these story forces and the frame analyzed by the general method of Section 2.8.1 to obtain the member forces. It should be noted that the frame load vector in this case has zero values in all positions other than those corresponding to the sideway degrees of freedom and that there are no fixed end forces acting on the members.
2.8.3 Evaluation of Member Forces

After the frame stiffness Eqn. (2.15) is solved for any load vector, the frame displacement vector \( \theta \) can be obtained. The transformation relation (2.4) then gives:

\[
\phi_1 = (1 + \frac{a}{L} \theta_1 + \frac{b}{L} \theta_2 + \frac{1}{L} (\theta_3 - \theta_4))
\]

or

\[
\phi_1 = \theta_1 + \frac{(a \theta_1 + b \theta_2 + \theta_3 - \theta_4)}{L} = \theta_1 + \frac{\delta}{L} \tag{2.42}
\]

Similarly,

\[
\phi_2 = \theta_2 + \frac{(a \theta_1 + b \theta_2 + \theta_3 - \theta_4)}{L} = \theta_2 + \frac{\delta}{L} \tag{2.43}
\]

where \( \phi \) and \( \theta \) are member deformations and the corresponding frame displacements respectively as shown in Fig. 2.6 and \( \delta = (a \theta_1 + b \theta_2 + \theta_3 - \theta_4) \).

Using beam stiffness matrix of Eq. (2.2), the member stiffness relation for the clear length of the beam can be expressed as:

\[
\begin{bmatrix}
2+\alpha & 1-\alpha \\
1-\alpha & 2+\alpha
\end{bmatrix}
\begin{bmatrix}
\phi_1 \\
\phi_2
\end{bmatrix}
+ 
\begin{bmatrix}
FX_1 \\
FX_2
\end{bmatrix} = 
\begin{bmatrix}
FM_1 \\
FM_2
\end{bmatrix} \tag{2.44}
\]

where

\[
FX_1 = \text{fixed end moment at the left end of a beam}
\]

\[
FX_2 = \text{fixed end moment at the right end of a beam}
\]

\[
FM_1 = \text{final member end moment at the left end}
\]

\[
FM_2 = \text{final member end moment at the right end}
\]
Eqs. (2.44) give:

\[ \begin{align*}
F_{M_1} &= \gamma [(2+\alpha)\phi_1 + (1-\alpha)\phi_2] + FX_1 = F_1 + FX_1 \\
F_{M_2} &= \gamma [(1-\alpha)\phi_1 + (2+\alpha)\phi_2] + FX_2 = F_2 + FX_2
\end{align*} \tag{2.45} \]

where \( F_1 \) and \( F_2 \) are the beam end moments caused by the corresponding end rotation \( \phi_1 \) and \( \phi_2 \) only.

Let \( F_3 \) and \( F_4 \) be the beam end reactions associated with the end moments \( F_1 \) and \( F_2 \) as shown in Fig. 2.15. Reactions \( F_3 \) and \( F_4 \) are then given by:

\[ F_3 = (F_1 + F_2) / L \tag{2.47} \]

and

\[ F_4 = -(F_1 + F_2) / L = -F_3 \tag{2.48} \]

If \( FX_3 \) and \( FX_4 \) are the fixed end reactions due to the applied loads, the final beam end reactions may be obtained as:

\[ F_{M_3} = F_3 + FX_3 \tag{2.49} \]

and

\[ F_{M_4} = F_4 + FX_4 = -F_3 + FX_4 \tag{2.50} \]

Substitutions of Eq. (2.42) into Eq. (2.45) and Eq. (2.43) into Eq. (2.46) give:

\[ F_{M_1} = \gamma [(2+\alpha)(\theta_1 + \delta/L) + (1-\alpha)(\theta_2 + \delta/L)] + FX_1 \]

or

\[ F_{M_1} = \gamma [(2+\alpha)\theta_1 + (1-\alpha)\theta_2 + 3\delta/L] + FX_1 \tag{2.51} \]
Similarly,

$$FM_2 = \gamma \left[ (1-\theta_1) \theta_1 + (2+\alpha) \theta_2 + 3\delta/L \right] + FX_2$$  \hspace{1cm} (2.52)

Thus, Eqs. (2.49) and (2.50) with the aid of Eqs. (2.42) through (2.48) give:

$$FM_3 = \gamma \left[ 3(\theta_1 + \theta_2)/L + 6\delta/L^2 \right] + FX_3$$  \hspace{1cm} (2.53)

and

$$FM_4 = -\gamma \left[ 3(\theta_1 + \theta_2)/L + 6\delta/L^2 \right] + FX_4$$  \hspace{1cm} (2.54)

Thus, using the computed values of frame displacements, final beam end forces at the face of joints can be obtained by using Eqs. (2.51) through (2.54). A similar set of expressions can be derived for column end forces; however, the fixed end forces for columns are all zero.
CHAPTER 3

ANALYSIS FOR EARTHQUAKE MOTION

3.1 FORMULATION OF EQUATIONS OF MOTION

An actual building is a continuous system with a complex distribution of mass and stiffness. The exact formulation of the dynamic response of such a structure involves an infinite number of degrees of freedom. For most structures, however, a reasonable approximation to the true dynamic response may be obtained by defining the motion along a limited number of degrees of freedom within the system. In the buildings considered here, the response may be described by the lateral motions of each floor level, as described earlier in Section 2.7. Correspondingly, the mass of the building is lumped at each floor level, so that the system response is completely defined by specifying three displacements at each floor which has an assigned-mass: two orthogonal translations in the plane of the floor and a rotation about the center of mass at the floor. With this lumped mass idealization, the dynamic equilibrium of the building in the above coordinate system is described as:

\[
[M]\ddot{v} + [C]\dot{v} + [K]v = \{P(t)\}
\]

(3.1)
in which \(M\) is the mass matrix, \(C\) the damping matrix, \(K\) the global stiffness matrix and \(P(t)\) the time dependent forcing function; \(v\) being the displacement vector.
A structure subjected to a general base motion can be schematically represented by Fig. 3.1(a). In this case, as there is no externally applied load on the system, i.e. P(t) = 0, Eq. (3.1) becomes:

\[
[M][\ddot{v}] + [C][\dot{v}] + [K][v] = 0 \tag{3.2}
\]

in which \(v\) is the vector of absolute displacements along the structure degrees of freedom measured with reference to a fixed frame in space and \(v\) is the vector of displacements relative to the base. Since

\[
\{v\} = \{v\} + \{v\}_g \tag{3.3}
\]

where \(v\) (Fig. 3.1(b)) is the vector of pseudo-static displacements due to support movement, it follows that

\[
\{\ddot{v}\} = \{\ddot{v}\} + \{\ddot{v}\}_g \tag{3.4}
\]

For the nth floor of a building with the displacement coordinates as shown in Fig. 3.1, relations (3.3) and (3.4) take the form:

\[
\begin{bmatrix}
\dot{v}_{aX} \\
\dot{v}_{aY} \\
\dot{v}_{a\theta}
\end{bmatrix}_n =
\begin{bmatrix}
\dot{v}_{X} \\
\dot{v}_{Y} \\
\dot{v}_{\theta}
\end{bmatrix}_n +
\begin{bmatrix}
\dot{v}_{gX} \\
\dot{v}_{gY} \\
\dot{v}_{g\theta}
\end{bmatrix}_n =
\begin{bmatrix}
\dot{v}_{X} \\
\dot{v}_{Y} \\
\dot{v}_{\theta}
\end{bmatrix}_n +
\begin{bmatrix}
\cos\beta \\
\sin\beta \\
0
\end{bmatrix}_n \ddot{v}_g \tag{3.4a}
\]

and

\[
\begin{bmatrix}
\ddot{v}_{aX} \\
\ddot{v}_{aY} \\
\ddot{v}_{a\theta}
\end{bmatrix}_n =
\begin{bmatrix}
\ddot{v}_{X} \\
\ddot{v}_{Y} \\
\ddot{v}_{\theta}
\end{bmatrix}_n +
\begin{bmatrix}
\cos\beta \\
\sin\beta \\
0
\end{bmatrix}_n \ddot{v}_g \tag{3.4b}
\]
FIG. 3.1 GROUND AND STRUCTURE DISPLACEMENTS
\[ \{ \ddot{v}_n \} = \{ \ddot{v} \}_n + \{ r \} \ddot{g} \]  

Hence, for all the floors,

\[ \{ \ddot{v}_a \} = \{ \ddot{v} \} + \{ r \} \ddot{g} \]  

where

\[
\{ r \} = \begin{bmatrix} r_1 \\ r_2 \\ \vdots \\ r_n \\ r_N \end{bmatrix} ; \quad r_1 = r_2 = \ldots = r_n = \begin{bmatrix} \cos \beta \\ \sin \beta \\ 0 \end{bmatrix} \quad \text{etc.}
\]  

and

\[ \beta = \text{angle of incidence of earthquake with the global x-axis} \]

\[ N = \text{total number of stories in the building} \]

With the aid of Eq. (3.4), Eq. (3.2) can be rearranged as:

\[ [M] \{ \ddot{v} \} + \{ r \} \ddot{g} + [C] \{ \ddot{v} \} + [K] \{ v \} = 0 \]  

or

\[ [M] \{ \ddot{v} \} + [C] \{ \ddot{v} \} + [K] \{ v \} = -\ddot{g} [M] \{ r \} \]  

The equations in (3.6) are coupled because, although \([M]\) is a diagonal matrix, \([K]\) and \([C]\) are not. These equations must normally be solved as \(3N\) simultaneous differential equations. However, it is possible to develop a transformation which uncouples these equations so that they may be solved as a set of \(3N\) independent equations. The transformation
matrix which consists of 3N columns is generated via the mode shapes or eigenvectors of the system as described in the following sections.

3.2 MODE SHAPES AND FREQUENCIES

The mode shapes and frequencies of the building are obtained by solving the undamped free vibration equations given by:

\[
[M]{v} + [K]{v} = 0
\]  
(3.7)

Eqs. (3.7) have a solution of the form:

\[
{v} = (a)\sin(\omega t + \psi)
\]  
(3.8)

so that

\[
{\ddot{v}} = -\omega^2(a)\sin(\omega t + \psi)
\]  
(3.9)

where \(\omega\) = frequency of vibration and \(\psi\) = phase angle.

Substitution of Eqs. (3.8) and (3.9) into Eqs. (3.7) gives:

\[-\omega^2[M]{a} + [K]{a} = 0\]  
(3.10)

or

\[([I] - \omega^2[K]^{-1}[M]){a} = 0\]

or

\[([I] - \omega^2[D]){a} = 0\]  
(3.11)

in which \([I]\) is an identity matrix and \([D]\) called the dynamic matrix is equal to \([K]^{-1}[M]\). Equations (3.11) have a non-trivial solution only when the determinant of the matrix \([I] - \omega^2[D]\) is zero. This condition leads to a polynomial equation of order 3N in \(\omega^2\) and gives 3N different
values of the frequency $\omega$. Substitution of these values of $\omega$ into Eqs. (3.11) gives $3N$ different solutions for the vector $(a)$. These solution vectors are not, however, unique. One of the elements of such a vector can be assigned any arbitrary value; the rest are then uniquely determined. The $3N$ solution vectors are called the mode shapes, and it is usual to normalize them so that if $(\phi_i)$ represents the $ith$ mode shape

$$(\phi_i)^T[M](\phi_i) = 1 \quad (3.12)$$

In the dynamic analysis of a structure, it is usual to calculate only the first few modes, since contribution of the higher modes to the response of the system is negligible. The method for determining mode shapes and frequencies, which is most suitable in these cases, is the so-called matrix iteration method or the method of inverse power. A brief description of the method is given below.

3.2.1 The Matrix Iteration Method

An alternative form of Eq. (3.11) is:

$$\frac{1}{\omega^2}[(I)-(D)](a) = 0$$

or

$$\frac{1}{\omega^2}(a) = [D](a) \quad (3.13)$$

This implies that if a vector $(a)$ representing any one of the mode shapes is multiplied by the dynamic matrix the resulting vector is equal to $(a)$ multiplied by a certain constant. In general, if an arbitrary vector
\( \{u_1\} \) is multiplied by \([D]\), the resulting vector \( \{u_{i+1}\} \) will not be
similar to \( \{u_i\} \). However, it can be shown that if the multiplication
by \([D]\) is repeated several times the resulting vector will converge to
the mode shape with the lowest frequency, that is, the fundamental mode
shape. This can be expressed as follows.

If \( u_i \) and \( u_{i+1} \) represent two successive trial vectors so that

\[
\frac{1}{\lambda_{i+1}} (u)_{i+1} = [D](u)_i
\]  
(3.14)

where \( \lambda_{i+1} \) is that element of \( u_{i+1} \) which has the largest absolute value,
then \( u_{i+1} \) will converge to the first mode shape and \( \lambda_{i+1} \) will converge
to the square of the fundamental frequency. This can be proved as
follows.

Let \( \omega_1, \omega_2, \omega_3, \ldots, \omega_N \) represent the \( N \) frequencies of an \( N \) degree
of freedom system so that

\[
\omega_1 < \omega_2 < \omega_3 < \ldots < \omega_N
\]

and let the corresponding mode shapes be denoted by the vectors \( \phi_1, \phi_2, \ldots, \phi_N \). Then any arbitrary trial vector, say \( \{u\} \) can be represented as:

\[
\{u\} = c_1(\phi_1) + c_2(\phi_2) + \ldots + c_N(\phi_N)
\]  
(3.15)

where \( c_1, c_2, \ldots, c_N \) are constants. Premultiplication of \( \{u\} \) by \([D]\) gives:

\[
\{u\}_2 = [D]\{u\}_1 = c_1[D](\phi_1) + c_2[D](\phi_2) + \ldots + c_N[D](\phi_N)
\]

\[
= c_1 \frac{1}{\omega_1^2} (\phi_1) + c_2 \frac{1}{\omega_2^2} (\phi_2) + \ldots + c_N \frac{1}{\omega_N^2} (\phi_N)
\]

\[
= \frac{1}{\omega_1} \left[ c_1(\phi_1) + c_2 \frac{1}{\omega_2} (\phi_2) + \ldots + c_N \frac{1}{\omega_N} (\phi_N) \right]
\]  
(3.16a)
Repeated multiplication by \([D]\) will give:

\[
{\{u\}}_3 = [D]{\{u\}}_2 = \frac{1}{\omega_1} \left[ c_1 \phi_1 + c_2 \frac{\omega_1^4}{\omega_2^4} \phi_2 + \cdots + c_N \frac{\omega_1^4}{\omega_N} \phi_N \right] \tag{3.16b}
\]

\[
{\{u\}}_p = [D]{\{u\}}_{p-1} = \frac{1}{\omega_1} \left[ c_1 \phi_1 + c_2 \frac{\omega_1^2(p-1)}{\omega_2^2(p-1)} \phi_2 + \cdots + \omega_1^2(p-1) \cdots + c_N \frac{\omega_1^2(p-1)}{\omega_N^2(p-1)} \phi_N \right] \tag{3.16c}
\]

\[
{\{u\}}_{p+1} = [D]{\{u\}}_p = \frac{1}{\omega_1} \left[ c_1 \phi_1 + c_2 \frac{\omega_1^{2p}}{\omega_2^{2p}} \phi_2 + \cdots + \omega_1^{2p} \cdots + c_N \frac{\omega_1^{2p}}{\omega_N^{2p}} \phi_N \right] \tag{3.16d}
\]

Since \(\omega_1 < \omega_2 < \omega_3 \cdots < \omega_N\), then if \(p\) is sufficiently large,

\[
\frac{1}{\omega_1^{2p}} \gg \frac{1}{\omega_2^{2p}} \gg \cdots \gg \frac{1}{\omega_N^{2p}} \tag{3.17}
\]

Therefore, in the limit,

\[
\lim_{p \to \infty} \{u\}_p = \frac{1}{\omega_1} \left[ c_1 \phi_1 \right] \tag{3.18a}
\]

\[
\lim_{p \to \infty} \{u\}_{p+1} = \frac{1}{\omega_1} c_1 \phi_1 \tag{3.18b}
\]

The ratio of any two corresponding elements of \({\{u\}_p}\) and \({\{u\}_{p+1}}\) will approach the value

\[
\frac{u_{j,p+1}}{u_{j,p}} = \frac{1}{\omega_1^2} \tag{3.19}
\]
and the vector \( [u] \) will approach \( \{\phi_1\} \).

To obtain the higher modes by the inverse power method, the trial vector must be independent of the previous modes. If it is possible to make \( c_1 \) zero in Eq. (3.15), then after iteration, vector \( [u] \) will converge to the second mode, \( \{\phi_2\} \). This gives the condition:

\[
c_1 = \frac{[u]^T[M]\{\phi_1\}}{\{\phi_1\}^T[M]\{\phi_1\}} = 0
\]

or

\[
[u]^T[M]\{\phi_1\} = 0 \tag{3.21}
\]

On expanding,

\[
u_1^1 + u_2^1 + u_3^1 + \ldots + u_N^1 = 0 \tag{3.22}
\]

where

\[
(m^1)^T = [M]\{\phi_1\} \tag{3.23}
\]

In Eq. (3.22), elements \( u_2, u_3, \ldots, u_N \) can be chosen arbitrarily and a new value of \( u_1 \) determined as follows:

\[
u_1 = -\frac{1}{m^1} \left( u_2^1 + u_3^1 + \ldots + u_N^1 \right) \tag{3.24}
\]

Also,

\[
\bar{u}_2 = u_2 \tag{3.25}
\]

\[
\bar{u}_3 = u_3
\]

\[
\bar{u}_N = u_N
\]
In matrix form, these relationships can be expressed as:

\[
(\overline{u}) = \begin{bmatrix}
0 & -\frac{m_2}{m_1} & -\frac{m_3}{m_1} & \ldots & -\frac{m_N}{m_1} \\
0 & 1 & 0 & \ldots & 0 \\
0 & 0 & 1 & \ldots & 0 \\
0 & 0 & 0 & \ldots & 1 \\
\end{bmatrix}
\begin{bmatrix}
u_1 \\
u_2 \\
u_3 \\
u_N \\
\end{bmatrix}
\]

or

\[
\{\overline{u}\} = [s]_1 \{u\}
\]

(3.27)

Matrix $[s]$ is called the sweeping matrix because it sweeps out the previous mode and $\{\overline{u}\}$ is called a purified trial vector. Since the process of iteration may introduce contributions of the swept mode in the new trial vector, the process of sweeping should be repeated at each step. Recognizing that

\[
(\overline{u})_p = [p](\overline{u})_{p-1}
\]

\[
= [p][s]_1 \{u\}_{p-1}
\]

\[
= [p]_2 \{u\}_{p-1}
\]

(3.28)

the sweeping process will be automatically accomplished if $[D]$ is replaced by $[D]_2$ in the iteration process. Matrix $[D]_2 = [D][s]_1$ is called the modified dynamic matrix.
A similar process is used to obtain the higher modes. Thus, for the third mode, the trial vector should be independent of the first and the second modes and the following orthogonality relationships should be satisfied:

\[(u)^T[M](\phi_1) = 0\]  
\[(u)^T[M](\phi_2) = 0\]

Expansion of Eqs. (3.29) and (3.30) leads to

\[u_1m_1 + u_2m_2 + \ldots + u_Nm_N = 0\]  
\[u_1m_1^2 + u_2m_2^2 + \ldots + u_Nm_N^2 = 0\]

When Eqs. (3.31) and (3.32) are used to define new elements \(\bar{u}_1\) and \(\bar{u}_2\), these two elements of the trial vector are constrained. The remaining elements may be chosen arbitrarily; thus,

\[
\begin{align*}
\bar{u}_3 &= u_3 \\
\vdots \\
\bar{u}_4 &= u_4 \\
&\quad \vdots \\
\bar{u}_N &= u_N
\end{align*}
\]

Equations (3.31), (3.32) and (3.33) may be combined to form a new sweeping matrix \([S]_2\) which sweeps out the first and second modes. The new sweeping matrix is similar to \([S]_1\) defined in Eq. (3.26), except that here the first two rows are determined by Eqs. (3.31) and (3.32). The second
sweeping is used, as was the first, to modify the dynamic matrix as:

$$[D]_3 = [D]_2 [S]_2$$  \hspace{1cm} (3.34)

The modified dynamic matrix $[D]_3$ is such as to cause convergence to the third mode when used in Eq. (3.14).

The process of sweeping the modes may be very conveniently accomplished on the computer if the following procedure is used.

Supposing that $\{\phi_1\}$ has been obtained by the iteration process, the dynamic matrix must then be revised to obtain the second mode. It can be shown that the modified dynamic matrix, $[D]_2$, is given by:

$$[D]_2 = [D] - \frac{1}{\omega_1^2} \{\phi_1\} [M] \{\phi_1\}^T$$  \hspace{1cm} (3.35)

provided $\{\phi_1\}$ has been properly normalized so that

$$\{\phi_1\}^T [M] \{\phi_1\} = 1$$  \hspace{1cm} (3.36)

To show this, let the arbitrary trial vector be expressed as:

$$\{u\} = c_1 \{\phi_1\} + c_2 \{\phi_2\} + \ldots + c_N \{\phi_N\}$$

Then

$$[D]_2 \{u\} = c_1 [D] \{\phi_1\} + c_2 [D] \{\phi_2\} + \ldots + c_N [D] \{\phi_N\}$$

$$- \frac{c_1}{\omega_1^2} \{\phi_1\} [M] \{\phi_1\}$$

$$\ldots \ldots \ldots \ldots \ldots$$

$$- \frac{c_N}{\omega_1^2} \{\phi_1\} [M] \{\phi_N\}$$  \hspace{1cm} (3.37)
Because of the orthogonality relationships,

\( \{ \phi_i \}^T \{ M \} \{ \phi_j \} = 0 \), \( i \neq j \) \hfill (3.38)

and Eq. (3.37) reduces to

\[
[D]_2 (u) = \frac{c_1}{\omega_1} \{ \phi_1 \} + \frac{c_2}{\omega_2} \{ \phi_2 \} + \ldots + \frac{c_N}{\omega_N} \{ \phi_N \} - \frac{c_1}{\omega_1} \{ \phi_1 \}
\]

\[
= \frac{c_2}{\omega_2} \{ \phi_2 \} + \ldots + \frac{c_N}{\omega_N} \{ \phi_N \} \tag{3.39}
\]

Obviously, the first mode has been swept off and the iteration process will therefore converge to the second mode.

3.2.2 Inverse Power Method with Shifts

The method of sweeping, used with the iteration process to obtain the higher modes, may introduce cumulatively increasing numerical inaccuracies in those mode shapes. After a certain number of modes have been obtained, the loss in accuracies may become significant. The inverse power method can be slightly modified\(^{(5)}\) to overcome this drawback.

Consider again the eigenvalue Eq. (3.10) which can be rewritten as:

\[
K - \lambda M (u) = 0 \tag{3.40}
\]

where \( \lambda = \omega^2 \) and let a shift be introduced in the origin from where the eigenvalues are measured so that

\[
\lambda = \lambda_0 + \mu \tag{3.41}
\]

Then
\[
[K - (\lambda_o + \mu)M] (u) = 0
\]
or
\[
\frac{1}{\mu} (u) = [K - \lambda_o M]^{-1} [M] (u)
\]
(3.42)

It is obvious that if a revised dynamic matrix \( \overline{D} = [K - \lambda_o M]^{-1} [M] \) is used, the iteration will converge to the smallest value of \( \mu \) or to the mode whose frequency is closest to the shift point.

Fig. 3.2 shows a schematic representation of the shift of origin.

Supposing that the first four mode shapes and frequencies have been obtained with \( \lambda_o = 0 \). At this stage, it is decided that the origin be shifted to a point close to the fifth mode frequency.

In order to estimate a value of the new shift, the iteration process is continued beyond \( \lambda_4 \) with the previous origin but terminated after only a few cycles giving a new value of \( \lambda \) which will be close to \( \lambda_5 \) and may be used as \( \lambda_o \) for the new dynamic matrix. However, numerical instability may arise if \( \lambda_o \) is too close to \( \lambda_5 \). The shifted origin is therefore located so that \( \lambda_o \) is the average of \( \lambda_4 \) and the estimated value of \( \lambda_5 \). The following new dynamic matrix is now formed:

\[
\overline{D} = [K - \lambda_o M]^{-1} [M]
\]
(3.43)

If the fifth mode frequency is closer to the shifted origin than any other frequency, an iteration using \( [\overline{D}] \) will converge to the fifth mode. However, because only an approximate estimate of the fifth mode frequency can be made at this stage in the iteration and also because the
FIG. 3.2 MEASUREMENT OF EIGENVALUES FROM SHIFTED ORIGIN (ref. 8)

FIG. 3.3 ELASTIC AVERAGE RESPONSE SPECTRUM FOR 1.09 MAX GROUND ACCELERATION (ref. 8)
shifted origin will probably be used to find the sixth and a few more
modes, the dynamic matrix is revised so that the mode shapes previously
determined are swept off giving:

\[
[D]_2 = [\bar{D}] - \sum_{i=1}^{4} \frac{1}{\mu_i} (\phi_i^T \phi_i) [M]
\]  

(3.44)

The iteration carried out with \([\bar{D}]_2\) will converge to the fifth mode. In
general, about six modes can be extracted from each origin without a
significant loss of accuracy. Each time the origin is shifted, a new
matrix inversion is required. However, in exchange, not only the accuracy
of the subsequent modes is improved, but also the iteration process is
speeded up.

3.3 TRANSFORMATION OF THE EQUATIONS OF MOTION

The mode shapes of any structural system satisfy the orthogonality
relationships:

\[
\phi_i^T [M] \phi_j = 0, \quad i \neq j
\]  

(3.45)

\[
\phi_i^T [K] \phi_j = 0, \quad i \neq j
\]  

(3.46)

Further, if the mode shapes have been properly normalized, the following
relationships hold:

\[
\phi_i^T [M] \phi_i = 1
\]  

(3.47)

and

\[
\phi_i^T [K] \phi_i = \omega_i^2
\]  

(3.48)
Now, let the following transformation of coordinates be introduced in Eqs. (3.6).

\[ (v) = \begin{bmatrix} \phi_1 & \phi_2 & \cdots & \phi_i & \cdots & \phi_{3N} \end{bmatrix} \begin{bmatrix} z_1 \\ z_2 \\ z_i \\ \vdots \\ z_{3N} \end{bmatrix} \]  \hspace{1cm} (3.49)

or \[ (v) = [B](z) \]  \hspace{1cm} (3.50)

so that Eq. (3.6) reduces to:

\[ [M][B](\ddot{z}) + [C][B](\dot{z}) + [K][B](z) = -\ddot{v}_g[M](x) \]  \hspace{1cm} (3.51)

Premultiplication of Eqs. (3.51) by \([B]^T\) yields:

\[ [B]^T[M][B](\ddot{z}) + [B]^T[C][B](\dot{z}) + [B]^T[K][B](z) = -\ddot{v}_g[B]^T[M](x) \]  \hspace{1cm} (3.52)

Now because of orthogonality relationships, Eqs. (3.45) and (3.46), matrices \([B]^T[M][B]\) and \([B]^T[K][B]\) will be diagonal. This is not in general true of \([B]^T[C][B]\). However, let it be assumed that the damping matrix is specially chosen so that the transformation diagonalizes it and let

\[ [\phi_i]^T[C]\phi_i = 2\omega_i\xi_i \]  \hspace{1cm} (3.53)

where \(\xi_i\) represents damping in the ith mode. Then Eqs. (3.52) will give 3N uncoupled single degree of freedom equations; the ith equation being

\[ \ddot{z}_i + 2\omega_i\xi_i \dot{z}_i + \omega_i^2 z_i = -Q_i\ddot{v}_g \]  \hspace{1cm} (3.54)
where $Q_i$ is called the modal participation factor for the $i$th mode and is given by:

$$Q_i = (\phi_i)^T[M](\phi_i)$$  \hspace{1cm} (3.55)

The $3N$ single degrees of freedom equations can be solved to obtain the vector $\{z\}$, which on substitution into transformation Eq. (3.50) will give the displacement vector $\{v\}$.

### 3.4 Spectrum Analysis

For earthquake analysis of a structure, when the maximum values of the displacements and forces are of interest, a realistic approach is via the response spectrum. The response of a single degree of freedom system subjected to a ground motion is defined by the equation:

$$m\ddot{v} + c\dot{v} + kv = -m\ddot{v}_g$$

or

$$\ddot{v} + 2\xi\dot{v} + \omega^2v = -\ddot{v}_g$$ \hspace{1cm} (3.56)

The maximum absolute value that $v$ attains relative to the ground during the entire history is called the spectral displacement and is denoted by $S_D$, so that

$$S_D = v_{\text{max}}$$ \hspace{1cm} (3.57)

Spectral velocity and spectral acceleration are two other quantities of interest, and it is customary to define them as follows:
Spectral velocity, \( S_v = \omega v_{\text{max}} \) \hspace{1cm} (3.58)  

Spectral acceleration, \( S_a = \omega^2 v_{\text{max}} \) \hspace{1cm} (3.59)  

Any one of the three spectral quantities may be evaluated for certain values of damping and plotted against frequency or period. Such a plot is called a response spectrum.

In terms of the spectral acceleration, the maximum response of a structure in its \( i \)th mode is given by:

\[
z_i^{(\text{max})} = \frac{Q_i S_a (\omega_i, \xi_i)}{\omega_i^2} \hspace{1cm} (3.60)
\]

If it is assumed that the maximum response in each mode occurs at the same instance of time, the above implies a set of actual displacements.

\[
\{v_i\} = \{\phi_i\}z_i^{(\text{max})} \hspace{1cm} (3.61)
\]

and a corresponding set of member forces.

The maximum of different modes will generally occur at different times. The response is therefore less than the direct sum of the absolute values in different modes. A reasonable estimate of the maximum displacements and member forces may be made by calculating the root-sum-square of the modal values. However, since this may sometimes underestimate the true maxima, the National Building Code of Canada recommends that a second estimate of true response be obtained by taking the sum of the two absolute modal values and that the greater of the values so obtained and the one obtained by root-sum-square be taken as the true response.
3.5 DESIGN RESPONSE SPECTRUM

The dynamic analysis procedure specified in the commentary to the National Building Code recommends the use of design response spectra to evaluate the maximum response of a structure. The code provides design response spectra for several values of damping and a design acceleration of $g$. Response spectra for other values of ground acceleration are obtained by a simple linear scaling. Also, spectra for the values of damping other than those given in the code can be obtained by linear interpolation. The design spectra given in the commentary consist of line segments on a double log graph as shown in Fig. 3.3. The damping in the structure is automatically provided for by selecting an appropriate response spectrum. The effect of inelasticity can be accounted for by a procedure given in the Code (14). The commentary to the Code recommends that the elastic spectral values be adjusted for the inelasticity in the following manner.

The spectral acceleration should be divided by the ductility factor $\mu$, that can be realized in the structure, for modal periods falling in the range of the velocity and displacement bounds on the response spectrum (i.e. for periods greater than $T_D$ shown in Fig. 3.3) and by $\sqrt{2\mu-1}$ for modal periods along the acceleration bound (i.e. for periods less than $T_D$).

The spectral displacement should be left unchanged for periods greater than $T_D$, but should be multiplied by $\mu/\sqrt{2\mu-1}$ for periods less than $T_D$. 
Appropriate values of $\mu$ are given in the commentary for different structural layouts and materials.
CHAPTER 4

DESCRIPTION OF PROGRAMS

4.1 GENERAL

This Chapter presents a description of the program developed for the three-dimensional analysis of building structures. The program is written in standard FORTRAN IV language and is designed to run on any computer installation which accepts FORTRAN IV.

The program is divided into two sections. The first section named AIDS+ reads all necessary input data in a conversational mode with rapid input options. This program section then translates the data, rearranges it and writes it in rigid format on disc files so that it is in a form compatible with the main program of the second part. The program has been tested on an IM-70 minicomputer and should run on other minicomputers with similar attributes.

The second section named ANGELS* is designed to carry out a complete elastic analysis of the building based on the assumptions described in Chapter 2 and using the data supplied by program AIDS. The program has been tested on a HONEYWELL Sigma-9 computer and can be adapted to run on a minicomputer. This program can also work independently of program AIDS. In that case, however, data has to be supplied through cards or

---

+AIDS - Automatic Input Data Supplier

*ANGELS - Analysis of building for Gravity, Earthquake and Lateral loads
data files in rigid format described in Appendix A. Program ANGELS finally produces all necessary output requested through user options. The programs are designed to accept any set of consistent units for length, force and displacements. Appropriate set of units must be selected by the user while supplying input data.

4.2 MATHEMATICAL DESCRIPTION OF THE BUILDING

For the purpose of preparing the numerical input data, the building to be analyzed is at first resolved into two orthogonal sets of planar frame or frame-shearwall systems. Each frame or frame-wall system must be assigned two identifier numbers. The first identifier is a frame group number; frames with similar geometric and structural properties being collected into one group. A typical building, such as the one shown in Fig. 4.1, may have several frame groups. Each group is assigned a number starting from one and increasing sequentially. The second identifier is a unique number assigned to each frame, called the frame number. This number also starts from one and increases sequentially. It is, however, a requirement that the frames in Group I are numbered first, those in Group II are numbered next and so on, till all the frame groups are exhausted. Also, within a group, frames carrying exactly the same gravity loads must be numbered so that they form a cluster uninterrupted by frames with different loading patterns.

Gravity loads are to be specified in terms of uniformly distributed loads and concentrated loads on each beam in a frame. A maximum of four
concentrated loads can be specified on any one beam. Lateral loads are applied at the floor levels and act on the complete structure. The values of their X and Y components along with the coordinates of their points of action with reference to the global reference point should be supplied to the program.

The program also needs the orientations and locations of the frames to assemble the global stiffness matrix. Further, it requires the location of mass center and the translational and rotational masses at each floor level to assemble the global mass matrix. The frame locations and mass centers must be specified with respect to the global reference points at each floor level. The choice of a reference point is arbitrary, but all reference points must lie on the same vertical line. Also, it is to be noted that the line of action of the earthquake force resultant acts through the center of mass at each floor level.

Each frame or shearwall element is assumed to have stiffness only in the in-plane direction. Elements which have stiffness in another direction too must be defined by an additional element. For example, the properties of columns which are common to two different frames must be supplied twice. As stated earlier, the axial deformations in these doubly defined columns will not be the same. However, this incompatibility should not cause any serious error in the analysis.

The properties of a frame or shearwall are specified with respect to its local stiffness direction. Floor beam center lines and column center lines are the basic reference lines used in the frame description.
The height from one floor beam center line to the next is assumed to be the same for all frames and is equal to the story height. A member may be omitted from any position by specifying zero properties. However, a shearwall must be continuous all through to the base of the frame. Beams must be prismatic and columns may be prismatic or circular. Both flexural and shearing deformations are considered in the analysis. Beams are considered axially rigid but axial deformation of columns are accounted for. Also, finite joint sizes of infinite rigidity may be considered. A frame, in general, is considered as a setback one. A part of the frame height containing the same number of bays is named a tower; a frame containing more than one tower is called a setback frame as illustrated in Fig. 2.2. A regular frame is considered as one consisting of a single tower.

4.3 INPUT DATA PROGRAM - AIDS

The program is designed to act as a front end program to the main analysis program - ANGELS. It reads all input data required for the main program in a conversational mode. The conversational program is designed to accept a machine independent free-format input. To achieve this, a special subroutine called REED has been used in this program. The input of data is supplied via a time sharing terminal and is truly free format. One or more data items can be read from a line of input, consecutive data items being separated by one or more blanks. The data
can be numeric or alphanumerical. For numeric data, no decimal is required for an integer; also, a real whole number can be supplied as an integer, the decimal being optional.

If the building to be analyzed is large in size with a great many frames, a large amount of data will be required by the program ANGELS. However, very often, several dimensions, sizes and loads in a structure are repetitive. For example, most story heights may be equal; also, member sizes may be the same over a number of stories and bays. It is possible to speed up the data input considerably by taking advantage of these repetitions. In program AIDS, a very careful attention has been given to this aspect and ways have been devised for speeding up the input process without making it too complex.

The essential features of data input for the program AIDS are illustrated with reference to the building of Fig. 4.1. The conversational data input to a minicomputer is shown in Appendix A. Those portions of the dialogue which are keyed in by the user are underlined; the remaining portions are prompted by the computer.

The first question that the program asks the user is whether he wishes to make a copy of the input data on a disc file. If the data is currently being supplied through a terminal, it is a good practice to make a copy. The copy can be later used to make any corrections that may be required in the data supplied during the current session on the terminal. The user can express his wish to create such a file by typing a Y. With this option, the program will make a copy of the currently
FIG. 4.1  REINFORCED CONCRETE BUILDING UNDER GRAVITY, EARTHQUAKE AND LATERAL LOADS.
FIG. 4.1 (cont'd) Gravity Loads On The Building

(e) Frames 1 & 2

(f) Frames 3 & 4

(g) Frame 5

FIG. 4.1 (cont'd) Lateral Loads on The Building

(h) Story 1

(i) Story 2

(j) Story 3

FIG. 4.1 (cont'd) Centers of Masses

(k) Story 1

(l) Story 2

(m) Story 3
supplied input data on a disc file on unit 6; the name of the file being predetermined during assignment of units.

The option to read the data from a previously created disc file instead of from a terminal, is exercised at the question immediately following.

The next few questions which are self explanatory, deal with structure and frame description. A subsequent question prompts the user to supply the story heights. The story heights are supplied starting from the lowest story and proceeding upwards. For the present example, the user types in 120, in reply to a request for story height between levels 0 and 1. Because the height of the next story is also 120, the user can speed up the data input at this stage by typing in 120 TO 2. If he does so, the program automatically assigns a value of 120 to both of the first and second stories and then prompts the user to supply the story height between levels 2 and 3; the user then types in 100.

The next question asked by the computer relates to the frame information and left identification. The left identification is a symbol as put on the drawing to identify the left side of a frame in a building.

The program then asks for frame group properties starting from Group I. The program first prompts the user to supply the lengths of bays for frame Group I, starting from the left, and proceeding to the right. A procedure similar to the one described for the story heights can be used in supplying this data.

Beam cross-section properties for frame Group I are input next. The computer asks whether all beams at Story No. 1 are of rectangular concrete sections or other (i.e. steel sections, etc.). If they are all concrete, the user types in C. The program then asks for the width and the depth of the
beam in Bay No. 1 (the leftmost bay). To speed up the input, the user

types in 10 20 TO 2. With this, the program automatically assigns a size

of 10 by 20 to the first and second beams of Story No. 1. Since all the

beams at Story No. 1 have been input, the computer asks whether the

beams in the next story are exactly like those in any preceding story

(here the first story only). In fact, the beams in Story No. 2 are exactly

of the same size as those in Story No. 1. The user can, therefore, speed

up the input by typing in I(KE) 1. The computer automatically assigns

appropriate sizes to beams in story 2 so that these beams are exactly

the same as the corresponding beams in story 1.

It is to be noted that when asked for the type of section, the

user has the option to type in C or 0. For type C, the program asks for

the beam width and depth. Program ANGELS uses these properties to cal-
culate the area and moment of inertia for the gross section. The

computed values are then used in the analysis. For cross-sections other

than rectangular or for the case where the user does not want to use the

gross section properties, he should type in 0. In that case, the user

would be asked to supply the moment of inertia and depth in lieu of

width and depth of the beams. Again, the speed of input can be enhanced

by using the procedure described above.

Column cross-section properties are supplied in a manner similar
to that followed for the beam cross-section properties.

Very often, several frames in a structure carry exactly the same

gravity loads. When frames carrying similar gravity loads also belong
to the same frame group, program AIDS can enhance the speed of data

input. For example, with reference to the building of Fig. 4.1, in which
frames 1 and 2 belong to the frame Group I, the beams in frames 1 and 2 carry exactly the same gravity loads (in each of the gravity load cases). After the gravity load data has been supplied for frame 1, the computer asks whether the next frame (i.e. frame 2) carries exactly the same gravity load as frame 1. The user now types in Y. The program makes a note of this on the disc file and asks for the load data for frame 3. If frame 3 were also in frame Group I and the gravity loads on it were similar to those in frame 1, the user could further speed up input by typing in Y TO 3.

The dialogue between the computer and the user is self-explanatory and the data can be readily input in the usual manner.

An outline flow diagram of program AIDS is shown in Fig. 4.2. It is clear from the flow diagram that the program reads all input data in conversational mode, rearranges it and writes it on three disc files on units 3, 4 and 5 respectively. Also, the program is designed to keep a duplicate copy of all the user's input on a disc file assigned to unit 6.
Fig. 4.2. Outline flow diagram for Program AIDS.
Program AIDS also provides the facility for correcting errors in the input data. This is achieved by creating a duplicate input file on unit 6. For major errors, the user can edit this file using the conventional edit system of the computer. He can then rerun program AIDS, this time specifying that the input data be read from the disc file instead of from the terminal. However, for minor numerical errors made during the conversational input, the user can appropriately edit the file written on units 3, 4 or 5. For example, suppose that when asked for modulus of elasticity in Story No. 5 and Bay No. 3, the user has input a value of 2500 instead of 3000. After program AIDS has been run, the user can edit the file on unit 4 (file for member properties) substituting the correct value of modulus of elasticity for the wrong value.

The files written on units 3, 4 and 5 are used to supply the input data to the main analysis program ANGELS. During the development of programs reported here, the front end program AIDS was run on an IM-70 minicomputer using a 9600 bauds-terminal, and the data files created by the program were transferred to a HONEYWELL Sigma-9 computer as 'unkeyed' input data files. The main program ANGELS was run in a batch mode on Sigma-9 which read the data from the unkeyed input data files.

4.4 ANALYSIS PROGRAM - ANGELS

4.4.1 Basic Function

The program is designed to perform a complete three-dimensional analysis of multistoried buildings consisting of rigid frame and/or
frame-shearwall systems based on the assumptions described in Chapter 2. Any substructure within the building may be a regular or a setback frame or frame-wall. The analysis is based on the assumption that beams are axially rigid but columns can deform axially. Flexural deformations are, of course, considered. In addition, the following options are available:

i) Shear deformations in the beams and columns may be accounted for provided the modulus of rigidity and the shear coefficients are specified. Such deformations will be disregarded if any of these items is assigned a value of zero. In fact, program AIDS asks the user whether he wishes to consider shear deformations and if he replies with an N, the computer will automatically set the shear coefficient to zero.

ii) Finite joint sizes may be considered in the analysis.

Program ANGELS can analyze a building for:

i) a maximum of 4 gravity load cases (GL1, GL2, GL3 and GL4)

ii) a maximum of 3 lateral load cases (WL1, WL2, WL3)

iii) one lateral earthquake load case supplied through a design spectrum (EL).

The above-stated load cases can be combined to form any number of load combinations. A load combination is defined by specifying the multiplication factors applicable to its component loads. One such load combination is called a 'Load System'. It may be formed, for example, from the expression aGL2 + bWL1 + cEL, where a, b and c are called load case multipliers.
In addition, if required, the program can evaluate three-dimensional mode shapes and frequencies of the building. Also, at the user's option, the modal story forces and displacements of the building (adjusted for ductility) for a specified design elastic spectrum may be calculated and printed out.

4.4.2 Organization of the Program

An outline flow diagram showing the program organization is shown in Fig. 4.3. The basic operations can be divided into the following major steps.

1. The first operation performed by the main program is to read and print out the basic control information and the global data associated with the building. This data is read from the disc file on unit 1.

2. The program next reads the properties of all substructures of the building from the disc file on unit 2. This data is then adapted for use in the calculations of stiffnesses and member forces. The program produces an echo print of the input data and writes its adapted version on a file on unit 4. The operations on this step are performed by subroutine PROP.

3. The next operation involves the formation of the frame stiffness matrices for each different frame or frame-shearwall in the building using frame property data written on unit 4. The program keeps a record of the diagonal addresses of the stiffness matrices and assigns suitable indices to the sidesway
degrees of freedom. The stiffness matrices and the associated records are stored sequentially on a disc file or a tape on unit 5. The operations are performed by subroutine STIFF.

4. The above stiffness matrices are then reduced one by one using Crout reduction method\(^{(6)}\) and stored sequentially on a disc file (or a tape) on unit 6 (subroutine REDUCE).

5. The gravity load data is then read from the disc file on unit 3, load vectors are prepared and an echo print of the input load data is produced (subroutine LOAD). Gravity load analysis is then carried out for each frame for all gravity load cases. The operations are performed by subroutine GRAVT which calls subroutine BSUB. The resulting joint displacement vectors are sequentially written on a disc file on unit 8 for use in Step 15.

6. The next operation involves the formation of a sidesway stiffness matrix for each individual frame and shearwall in the building by static condensation of the frame stiffness matrix which is retrieved from unit 5. The sidesway stiffness matrices are then sequentially written on the disc file on unit 2. The operation is performed by subroutine COND which calls subroutines CONDEN, REDUCE and BSUB.

7. Story mass data is then read from the disc file on unit 1 and printed out. This data includes the location of mass center at each floor and the story translation and rotational masses.
The operations are carried out by subroutine STORY which also assembles the global mass matrix.

8. The program next assembles the global stiffness matrix using frame sideways stiffness matrices retrieved from unit 2, and the frame locations data read in step 1. Subroutine FRAME performs these operations. The global stiffness matrix is written on a file on unit 5 for use in step 10.

9. The program next reads the lateral load data for the building from the file at unit 3, for a maximum of 3 different lateral load cases and prints it out. The structure is then analyzed for these lateral loads. Frame lateral story forces are calculated and written on a file on unit 1 for use in step 13. These operations are accomplished by subroutine HLOAD which calls subroutines RECIP and SFORCE.

10. The mode shapes and frequencies of the building are then evaluated by subroutine EIGVAL, which is called through subroutine SPECTRM. The procedure described in Section 3.2 is followed in the evaluation.

11. The modal response is next calculated using the specifications of the design elastic spectrum read by the main program in step 1. The seismic design forces and displacements along the global coordinates are worked out and the values obtained are adjusted for ductility before being printed out at the user's
option. The operations are performed by the subroutine SPCTR which calls subroutine RESP.

12. From the adjusted elastic modal displacements worked out in Step 11 and the frame location data read earlier, the modal floor story forces are worked out for each frame and stored sequentially on a disc file on unit 1 for subsequent use. The operations described in this step are carried out by subroutine SFORCE.

13. The program next retrieves from unit 1 the frame lateral story forces calculated in step 9, forms joint load vectors and solves for joint displacements (subroutine ROOT) for each lateral load case. The joint displacements are written sequentially on a file on unit 3 for use in step 15.

14. Using the modal frame story forces evaluated in step 12, the program then computes the root-sum-square forces for the members in each frame of the building and writes them down on a tape or disc file on unit 5 for use in step 15. These operations also are performed by subroutine ROOT which calls subroutines BSUB and FORCE.

15. Finally, the program reads for each frame the displacement vectors for gravity load cases from unit 8 and for lateral load cases from unit 3. The following steps are carried out for each load system. The displacement vectors for gravity and lateral load cases are multiplied by appropriate multiplying
factors defined earlier by the user (read in step 1) to form a final displacement vector. The member forces are then determined from this displacement vector. If the load system also includes earthquake loads, the root-sum-square forces are read from unit 5, multiplied by the proper factor and superimposed on the member forces calculated above to evaluate the final member forces which are then printed out. When combining earthquake forces with other loads, two sets of values are calculated to give both maximum and minimum member forces. In one set, the earthquake forces are added to other forces, while in the second set, they are subtracted from the combination of other forces. The entire procedure as described above is repeated for each frame of the building. The above operations are performed by subroutine SYSTEM which calls subroutine FORCE.

The program organization and file management for the program ANGELS is shown in Fig. 4.4.

4.5 **Efficiency of Algorithms**

In the development of program ANGELS, effort has been made to achieve optimum efficiency in computer storage, solution of equations, condensation of frame stiffness matrices and the solution of eigenvalue problems. Various subroutine algorithms which effectively handle the above problems are discussed below.
START

Read and print basic control data and load system data for the building.

Read and print frame properties, data, prepare an adapted version of the data and write it on a disc file.

Assemble frame stiffness matrices.

Reduce frame stiffness matrices by Crout method.

Read gravity load data and evaluate the joint displacement vectors for each frame.

Form frame sideways stiffness matrices by static condensation of the frame stiffnesses.

Read and print story mass data and assemble global mass matrix.

Assemble global stiffness matrix from frame lateral stiffness matrices.

Read and print lateral load data and for each frame find story lateral loads for each lateral load case.

Evaluate mode shapes and frequencies of the building. Also print them out.

A

Perform spectral analysis and print modal story forces and displacements for the building.

Calculate modal story forces and displacements for each frame.

Calculate joint displacements for each lateral load case.

Find member forces due to spectral story forces for each mode and calculate root-sum-square forces for each frame of the building.

For each frame, retrieve the displacement vectors for all gravity load cases (maximum 4) and for all lateral load cases (maximum 3). Multiply them by appropriate factors to find a new displacement vector for each load system.

If the above load system includes earthquake loads, multiply the frame root-sum-square forces by the proper factor and add to the above member forces to evaluate the final member forces.

For each frame, print the final member forces for each load system.

STOP

FIG. 4.3. Outline flow diagram for operation of the program ANGELS.
FIG. 4.4 PROGRAM ORGANIZATION AND FILE MANAGEMENT FOR PROGRAM-ANGELS
4.5.1 Generation of Frame Stiffness Matrices, Subroutine STIFF

This subroutine is designed to formulate the frame stiffness matrices exploiting their symmetry and bandedness. With the algorithm used, only the non-zero elements within the upper half of the diagonal of a matrix are computed and stored. The subroutine internally generates an efficient numbering scheme as described in Section 2.5, which gives a very compact bandwidth for the matrix.

The stiffness matrix for the frame of Fig. 2.9 is schematically shown in Fig. 2.10 where only the non-zero elements and embedded zeros have been identified. It is obvious that because of symmetry and sparsity of the stiffness matrix it is not necessary to store all the elements of the matrix, and with special storage schemes, a great economy can be exercised in the storage requirement. Two such schemes have been in general use. They are:

1) Skew banded rectangular storage and

2) Compacted column storage with the non-zero part of each column above the diagonal of the matrix, strung compactly into a vector.

Thus, for the frame of Fig. 2.9, the storage of the entire stiffness matrix requires a 19x19 array, i.e.: 361 storage spaces. A skew banded storage scheme, in which only the upper half band of the matrix is stored, with the diagonal elements positioned in the first column, will require a 19x11 array, i.e. 209 storage spaces. The compacted column storage will
require only 120 storage spaces. Obviously, the last scheme which omits the storage of almost all zero elements is the most efficient. It should be noted that the embedded zeros must still be stored; their storage is, in any case, essential because they are modified to non-zero quantities during a subsequent Gaussian elimination.

Subroutine STIFF assembles the frame stiffness matrices from the known values of member stiffness elements generated by the function routines CST and BST. The assembly of a stiffness matrix begins at the lowest story and proceeds upwards. During one pass of a DO-loop, the column vectors of the matrix pertaining to all degrees of freedom at a particular story are generated and stored in compacted column strings. It should be noted that because of the symmetry of the stiffness matrix, only those elements of a column including and above the diagonal need be generated. Concurrently with the assembly of the matrix, the program also generates the addresses of the diagonal positions in the storage string and assigns appropriate indices to the columns for identifying those degrees of freedom which will have to be eliminated subsequently during the static condensation of the matrix. The array that stores the stiffness matrix of Fig. 2.10 by the compacted column storage scheme is shown in Fig. 4.5. Fig. 4.5 also shows the diagonal address array and the array containing the indices assigned to various degrees of freedom.
(a) String Storage of Stiffness Matrix

1 2 3 4 5 6 7 110 111 112 113 114 115 116 117 118 119 120

(b) Diagonal Address Array

1 3 5 9 14 20 26 34 42 50 61 69 77 25 92 99 103 114 120

(c) Array of Indices to Identify Sidesway Degrees of Freedom

0 0 0 0 1 0 0 0 0 0 0 1 0 0 0 0 0 1 0 0

FIG. 4.5 STORAGE OF STIFFNESS MATRIX OF A MULTISTORY FRAME
4.5.2 **Solution of Simultaneous Equations**

Any structural analysis problem eventually reduces to the solution of a set of simultaneous equations. For a fairly large building, the number of such equations can be very large. The efficiency of an analysis program is therefore greatly dependent on the efficiency of the equation solving routine that it uses. Researchers have therefore devoted considerable attention to this aspect and solution algorithms of almost optimal efficiency have been developed. Most of them use some variation of the Gaussian elimination technique. For sparsely populated coefficient matrices, the Crout reduction procedure, which is a modified form of Gauss elimination scheme, has been found to be ideally suitable for computer application.

An algorithm based on the Crout reduction method has been developed\(^{(22)}\) which omits all unnecessary computations and may be briefly described as follows.

Consider the solution of a symmetrical set of equations:

\[
[A][x] = [b] \tag{4.1}
\]

where

\[
[A] = [a_{ij}] = N \times N \text{ non-singular symmetric matrix}
\]

\[
[x] = [x_i] = N \times 1 \text{ vector of unknown, and}
\]

\[
[b] = [b_i] = N \times 1 \text{ vector of known elements.}
\]

The required solution formulations may then be expressed as follows.
i) Reduction of coefficient matrix \( \mathbf{A} \)

\[
 a_{ij}^{(i-1)} = a_{ij} - \sum_{k=k_0}^{i-1} \frac{a_{ki}^{(k-1)}}{a_{kj}^{(k-1)}} a_{kj}^{(k-1)}
\]

and

\[
 a_{jj}^{(j-1)} = a_{jj} - \sum_{k=L_j}^{j-1} \frac{a_{kj}^{(k-1)}}{a_{kj}^{(k-1)}} a_{kj}^{(k-1)}
\]

in which

\[
 j = 2, \ldots, N
\]

\[
i = L_j + 1, \ldots, j-1
\]

\[
k_0 = \max(L_i, L_j)
\]

\[
\alpha_{ki}^{(k-1)} = a_{ki}^{(k-1)}/a_{kj}^{(k-1)}
\]

\( L_j \) = row number of the first non-zero entry in column \( j \) of the matrix \( \mathbf{A} \).

Superscript \((k-1)\) indicates the value after elimination of the \((k-1)\)th equation.

ii) Reduction of load vector \( \mathbf{b} \)

\[
 b_i^{(i-1)} = b_i - \sum_{k=k_0}^{i-1} \frac{a_{ki}^{(k-1)}}{a_{kj}^{(k-1)}} b_k^{(k-1)}
\]

in which

\[
i = L_b + 1, \ldots, N
\]

\[
k_0 = \max(L_i, L_b)
\]

\( L_b \) = row number of the first non-zero entry in vector \( \mathbf{b} \).
and

\[ b_i^{(i-1)} = \frac{b_i^{(i-1)}}{a_{ii}^{(i-1)}} \] (4.3b)

where

\[ i = L_b^i, \ldots, N \]

Equation (4.3b) is applied after completing the operations in Eq. (4.3a).

iii) Back substitution

\[ x_k = b_k^{(k-1)}, \quad k = 1, \ldots, N \] (4.4)

and

\[ x_k = x_k^{(k-1)} - \frac{a_{ki}^{(k-1)}}{a_{ii}^{(k-1)}} x_i^{(k-1)} \]

in which

\[ i = N, N-1, \ldots, 2 \]

\[ k = L_i^1, L_i+1, \ldots, i-1 \]

The solution vector is generally overwritten on \( \{b\} \). It should be noted that \( a_{kj}^{(k-1)} \) is replaced by \( \bar{a}_{kj}^{(k-1)} = a_{kj}^{(k-1)} / a_{kk}^{(k-1)} \) when the operations in Eqs. (4.2) are performed. Equations (4.3) and (4.4) may be repeated for any number of load cases.

Subroutine REDUCE is designed to reduce the frame stiffness matrices using the procedure of Eqs. (4.2). Subroutine BSUB carries out the reduction of load vectors and back substitution based on Eqs. (4.3) and (4.4). After subroutines REDUCE and BSUB have been called, vector \( \{b\} \) contains the solution vector of joint displacements.
4.5.3 Condensation of Frame Stiffness Matrices

The frame stiffness matrix is required to be condensed to obtain the frame sideway matrix which consists of elements relating to the story sideway degrees of freedom only.

For a symmetric matrix like the one shown in Fig. 4.6a which has been suitably rearranged and partitioned so that all sideway degrees of freedom are grouped together, the condensed stiffness matrix can be expressed as:

$$\mathbf{K}_e = \mathbf{K}_{BB} - \mathbf{K}_{BA}\mathbf{K}_{AA}^{-1}\mathbf{K}_{AB}$$  \hspace{1cm} (2.22)

where $\mathbf{K}_{AA}$ is the submatrix which relates to themselves the degrees of freedom other than those corresponding to sideway. $\mathbf{K}_{BB}$ is a submatrix which relates the sideway degrees of freedom to each other, and $\mathbf{K}_{AB}$ and $\mathbf{K}_{BA}$ are submatrices which describe the cross-relation between the sideway degrees of freedom and the others. Condensed matrix $\mathbf{K}_e$ is of the same size as the submatrix $\mathbf{K}_{BB}$.

The condensation can thus be performed by inverting the submatrix $\mathbf{K}_{AA}$ and solving Eqs. (2.22). However, when the degrees of freedom are numbered in such a manner as to give the minimum bandwidth, the columns associated with the sideway degrees of freedom are scattered within the matrix (as indicated in Fig. 4.6(b), rather than being grouped together. In such a case, Eqs. (2.22) can be applied only if the matrix of Fig. 4.6(b) is rearranged to attain the form shown in Fig. 4.6(a). But any such rearrangement will greatly enlarge the bandwidth of the matrix causing a large increase in the required storage space.
(a) Regular Matrix With Sidesway Degrees of Freedom Partitioned

(b) Banded Matrix With Sidesway Degrees of Freedom in Between

FIG. 4.6 CONDENSATION OF STIFFNESS MATRIX
An alternative method which uses the Gaussian elimination or the Crout reduction technique can be conveniently employed to remedy the above situation. The method, as used in this program (subroutine CONDEN), is described below.

Referring to Fig. 4.6(a), let the submatrix $k_{AB}$ be of size $n$ by $m$, and the $i$th common vector be referred to as $k_{AB}^i$. Submatrix $k_{BA}$ will contain $m$ row vectors of length $n$, so that

$$\begin{bmatrix} k_{BA}^i \end{bmatrix} = (k_{AB}^i)^T \quad (4.5)$$

Now introduce a fictitious unknown displacement vector $(x^i)$ of length $n$ so that, by treating the vector $(k_{AB}^i)$ as a load vector, a stiffness equation may be written as

$$\begin{bmatrix} k_{AA} \end{bmatrix}(x^i) = (k_{AB}^i) \quad (4.6)$$

Eq. (4.6) can be solved for $(x^i)$ as

$$(x^i) = (k_{AA})^{-1}(k_{AB}^i) \quad (4.7)$$

However, Eqs. (4.6) contain a set of simultaneous equations which can be solved by Gaussian elimination or the Crout reduction technique to obtain $(x^i)$. In fact, once $[k_{AA}]$ has been reduced, only a load vector reduction and a back substitution are required to find $(x^i)$ for any particular value of $i$. The process can be repeated $m$ times to find all $(x^i)$s. Now

$$k_{ij}^* = k_{ij}^B - [k_{BA}^i](x^i)$$

or

$$k_{ij}^* = k_{ij}^B - (k_{AB}^i)^T(x^i) \quad (4.8)$$
Because \([K_d]\) can overwrite \([k_{BB}]\), Eq. (4.3) can be written as

\[
k_{ij}^{BB} \leftarrow k_{ij}^{BB} - (k_{AB}^T \chi^j)
\] (4.9)

Equation (4.9) is solved for all values of \(i\) and \(j\), finally giving rise to the condensed stiffness matrix \(K_\star\).

This method can still be used when the sidesway vectors are scattered in the stiffness matrix and not grouped together. If the rows and columns corresponding to the sidesway degrees of freedom, shown shaded in Fig. 4.6(b) are deleted, the remaining matrix is \(k_{AA}\). During forward reduction of the stiffness matrix therefore, rows and columns corresponding to the sidesway degrees are skipped. The resulting matrix contains a reduced \(k_{AA}\) matrix. To continue the operations described in Eqs. (4.7) through (4.9), the vectors contained in the L-shaped shaded areas of Fig. 4.6(b) are taken one at a time and treated as the load vectors. It should be noted that the portions shaded solid are elements of matrix \(k_{BB}\); they should therefore be omitted from the load vectors. These omitted elements are finally used in Eq. (4.9) to give the elements of the condensed matrix. The operations do involve some bookkeeping but are otherwise straightforward.

Subroutine CONDEN effectively uses the above approach with the aid of subroutines REDUCE and BSUB as described earlier. Provision is made within the subroutines to recognize the sidesway vectors and their rows in the matrix and skip or carry out operations on them as required in the procedure described above.
4.5.4 Solution of Eigenvalue Problem

The determination of mode shapes and frequencies is important for the dynamic analysis of a building, for several reasons. One of these is to develop a transformation relation by which it is possible to reduce a large number of coupled equations of motion into an equivalent set of uncoupled single degree of freedom equations.

Subroutine EIGVAL is designed to evaluate the mode shapes and frequencies of the building based on the inverse power method with shifts as described in Section 3.2. The subroutine uses the method of partitioning\(^{(12)}\) to invert a matrix. The algorithm takes advantage of the symmetry and sparsity of the matrix to be inverted and treats it as a one-dimensional array to reduce the address arithmetic (subroutine RECIP). The inverted matrix occupies the same space as the original stiffness matrix. Also, the latter is transferred to the auxiliary storage before inversion is carried out. The method as a whole is iterative and the iteration for evaluating a mode shape is continued till a convergence has been achieved\(^{(7)}\). This is supposed to happen when the ratio of the maximum difference between the absolute values of the corresponding elements of two successive trial vectors to the current value of that element is less than a preset allowable value which is 0.000001 in the standard version of the program. This method of testing for convergence is likely to create trouble when one of the elements is zero or close to zero. In such a case, the difference between the successive trial values of the zero
(very small) element may only be a random noise of very small magnitude. It will, however, be greatly magnified when divided by the current value of the element, creating an erroneous impression that the iteration has not converged, even though the convergence criterion may be satisfied for other elements of the vector. This problem is overcome by skipping the convergence test for an element which is very small as compared to the other elements of the vector. In the standard version of the program, an element with a value less than or equal to $10^{-6}$ in a vector normalized so that the largest element is equal to 1 is considered very small. The iteration process is also terminated if the number of iterations has reached a preset maximum, even though the convergence might not have been achieved. When this occurs, the program prints a warning message, giving the mode number being calculated and the maximum difference between the corresponding elements of the last two trial vectors. If this difference is too large and therefore unacceptable, either of the following two corrective actions can be taken and the job run again:

A smaller number may be specified in the input data for the number of modes to be extracted from one origin. Alternatively, the limit on the number of iterations may be increased. This can be achieved by changing the number in the following FORTRAN statement of the main program:

$$MI = 300$$

It should be noted here that the inverse power method is very efficient when only the first few modes are to be extracted. However, using the algorithm of the subroutine EIGVAL, the accuracy and the
computational efficiency is further improved by periodically shifting the origin on the eigenvalue axis.

4.5.5 Optimization of Computer In-Core Storage Space

Since program ANGELS is a fairly large analysis program, a considerable amount of computer storage is required to accommodate the instructions. Also, the analysis of a large building requires a fair amount of core space. To minimize the core-space requirement, therefore, a dynamic storage allocation scheme is devised within the program for major variable arrays by storing them in a blank COMMON block. Because dynamic allocation of storage requires that the variables sharing the COMMON space be transferred between subroutines and between subroutines and the main program as arguments in the calling statements, this results in some loss of efficiency. To optimize the situation, one major array (of frame properties), which is repeatedly required by the program, is kept in labelled COMMON block called/COM1/ instead of being placed in the blank COMMON.

In the blank COMMON block, the amount of high speed storage required for a particular problem may be changed by altering the following two FORTRAN statements at the beginning of the main program:

COMMON SK(n)
MOORE = n

where n is the storage requirement for the major arrays.
For a given building, the value of \( n \) is computed as follows:

Let

\[ N = \text{total number of stories in the building} \]
\[ NF = \text{total number of frames in the building} \]
\[ NQ = \text{size of the global stiffness matrix} \]
\[ = 3 \times N \text{ when a three-dimensional analysis is required} \]
\[ = N \text{ when two-dimensional analysis is required, as would be the case, for example, symmetrical buildings.} \]
\[ NM = \text{number of modes to be considered.} \]

For the complete building, check

1. \[ N_1 = NQ(NQ+1) + (N-1)(N+2) + NF. \]

If dynamic analysis is required, check

2. \[ N_2 = NQ(NQ+2NM+1) + NF(N+2) + NM + MP \]

where

\[ MP = NQ \times NM/N \]

but not less than \( NQ \).

Also, for the largest frame,

\[ NC = \text{total number of columns in the frame} \]

and

3. \[ N_3 = 14 \times NC + NE \]

where

\[ NE = \text{total number of elements in the frame stiffness matrix, that are required to be stored.} \]

\( NEL \) can be obtained by running the 'front end' program AIDS, or can be
approximately calculated as follows.

If \( NT = \) number of towers in the frame, for a setback frame (for a regular frame \( NT=1 \))

\( NB_i = \) number of bays in tower \( i \)

\( NS_i = \) number of stories in tower \( i \)

and if

\[ NY_i = 4(NB_i)^2 + 15 * NB_i + 13 \]

then NEL can be approximately obtained (within 10% above) by the integer value of

\[ NE = \left\{ (NS_i-0.5)NY_i + \sum_{i=2}^{NT} (NS_i+0.5)NY_i \right\} \]

The frame which leads to the largest value of \( N_j \) may not be readily recognized. In that case, two or three frames may have to be checked out.

The value of \( n \) is then the maximum of \( N_1, N_2 \) and \( N_3 \).
CHAPTER 5

SUMMARY AND CONCLUSIONS

5.1 SUMMARY

This work was concerned primarily with the development of a set of two computer programs for the three-dimensional linear analysis of multistoried building structures.

The first package in this set called AIDS is written in FORTRAN IV and is an interactive program designed to serve as a 'Front-End' processor to the second part. It reads all input data, required for the three-dimensional analysis of a building, in a conversational mode with a rapid data input option. The program then rearranges the supplied data in proper format to be compatible with the main analysis program and writes it into three disc files or tapes. The first of these files contains the general control and information data and the data required for the seismic analysis, if any; the second file contains the frame and member properties data stored sequentially and member by member within a frame group. Data is stored for only one frame in a group of frames having similar properties (called a frame group). The third file contains the gravity load data for each frame and for each gravity load case followed by the data for the lateral load cases. The program keeps a duplicate version of user's input and stores it sequentially along with appropriate identifying comments in a fourth file. This copy is used
for any correction to the user supplied input which may be required when the user makes one or more mistakes in typing in the data during execution of the program. This can be achieved by editing the duplicate file after the program has run and then rerunning the program, this time specifying the option that the data will be read from the duplicate file instead of from the terminal. During execution of the program, the user can correct only those errors in a line of supplied data which he detects before hitting the return key at the end of that line. The questions asked for by the computer are designed to be self-explanatory so that the user has to put in only a minimum of effort in learning to use the conversational data input facility. During execution, the program prompts the user to type in the required data, which is accepted in a free format, relieving the user of the rather inconvenient task of learning the rigid data input formats of standard FORTRAN.

The second program, called ANGELS, also is written in FORTRAN IV language and is designed to perform a three-dimensional linear analysis of buildings.

For the purpose of analysis, the program assumes that the floor diaphragms of the building are infinitely rigid in their own planes and the building rests on a foundation which is axially and flexurally rigid and lies in one horizontal plane. Assumption of rigid diaphragm implies that the beams are axially rigid. However, columns are considered axially deformable. Flexural deformations are taken into account
for all beams and columns. At the user's option, shear deformations and finite joint sizes can also be accounted for.

Since the floor diaphragms are axially rigid and the columns are interconnected through these floors, there are only three displacement coordinates at each floor level - two translations and one rotation about the vertical axis. The mass of the building is also assumed to be lumped at the floor levels.

The program can analyze a building for a maximum of four different gravity load cases, three different lateral load cases and for one design earthquake response spectrum. If desired, the earthquake forces can be modified to take account of the ductility in the structure. Individual load cases can be weighted and superimposed to obtain any number of load combinations. Member forces are worked out for each such load case. The results of the analysis are printed out in the form of member end actions at the faces of the joints, or at the center of joints when finite joint sizes are not considered. Also, at the option of the user, the program evaluates and prints out the three-dimensional mode shapes and frequencies of the building and 'Absolute Sum' and 'Root-Sum-Square' values of story earthquake forces and displacements. The program also provides an echoprint of all input data.

Because of the lengthy computations and the large volume of output, the program is designed to run in a remote batch mode, taking in all data from the three disc files generated by the 'front end' program.
AIDS. However, program ANGELS can also work independently of program AIDS. In that case, the input data must be prepared on data cards in appropriate format and then copied to three unkeyed disc files.

5.2 CONCLUSIONS

1. With the aid of an interactive conversational program, which is executed in a time-sharing mode, data can be read at the user's terminal in a free format. Such an interactive program can also be designed to speed up the data input considerably when advantage is taken of the repetitive nature of building dimensions, member properties, and loading. By making use of a duplicate file, corrections can be efficiently made in the input data supplied through the conversational input data program. These advantages can be realized by writing a front-end processor to the main analysis program. Such a processor written in the conversational mode is thus a very convenient means for the preparation and correction of input data for a fairly large or very large analysis program. It can save a substantial amount of engineer's time which he would otherwise have to devote in learning a complex set of instructions for the use, requirements and data input formats of a program. An additional advantage of the front-end processor is that it can be run on an in-house mini-computer. Data preparation and checking thus becomes simpler and more economical. The present study confirmed the above advantages of a front-end processor written in conversational mode.
2. For linear three-dimensional analysis of a building, consideration of floors as rigid diaphragms, an assumption which is reasonable for most well designed buildings, reduces the number of unknown variables considerably. The resulting structural (global) stiffness matrix is comparatively small in size and leads to substantial savings in the computational effort. However, the results obtained on the basis of this assumption are sufficiently accurate for all practical purposes. Similarly, the assumption that the mass of the building is lumped at the floor levels is also quite reasonable. With this assumption, the mass matrix generated by the program is diagonal and of the same size as the global stiffness matrix. This greatly simplifies the eigenvalue problem, leading to saving the computational effort in the iterative solution for the mode shapes and frequencies of the building.

3. The use of compacted column storage scheme for the frame stiffness matrices is most economical in terms of computer storage requirements. Also, dynamic storage allocation in which major variable arrays are assigned storage space during run time is an effective means of reducing computer core space requirements.

5.3 RECOMMENDATIONS FOR FURTHER DEVELOPMENTS

The study has indicated the need for further development in the following areas related to computer programming for linear three-dimensional analysis of building structures.
1. Study of the Presence of Shear Panels and Infilled Shearwalls in a Building

Shear panels (a shearwall divided at the base into two supporting columns) and infilled shearwalls are sometimes used in multistory buildings. At the present stage, the program does not have the ability to take account of substructures of the above type. Inclusion of some members in analysis by modifying the subroutines for the assembly of frame stiffness matrices and calculation of member forces will make the program more general.

2. Study of the Effect of Cantilever Spans Beyond the Exterior Spans

In a practical design situation, the building structures might have cantilever spans beyond the exterior spans. The programs developed for this project can not handle exterior cantilever spans. The generality of the present program can be extended by accounting for cantilever spans in the three-dimensional analysis of the buildings.

3. Study of the Effect of Non-Prismatic Beams and Columns

For practical reasons, a building may sometimes have beams with haunches at their ends or columns with capitals as in flat slab structures. The program, in its present form, is not able to handle such practical situations. The program may be extended to include the presence of such non-prismatic members.
4. Modification of Reference Axes for Beams and Columns

The program described in this thesis considers the floor beam center lines and column center lines as basic reference axes for the frames. It assumes that all beam center lines lie in a common plane and that all columns in the vertical stack have a common center line. But, in practical buildings, the top surfaces of beams rather than their center lines lie in one plane. Also, for architectural reasons, the exterior columns are generally flush on their outer faces; some interior columns also may not have their center lines coincident. An analysis based on the assumption of coplanar center lines may therefore lead to some errors. The magnitude of these errors needs some study.

The program can be suitably modified to take into account the actual rather than the idealized locations of the beam-column center lines.

5. Study of the Inclusion of Semi-Rigid and Hinged Joints and Foundations

The present study is concerned with the analysis of buildings which have rigid beam-column joints and are attached to a flexurally rigid foundation. But, a practical building, particularly one in steel, may have hinged or semi-rigid joints. Also, the foundation of the building may not be essentially rigid. Inclusion of semi-rigid and hinged joints and supports in the present analysis program will increase its generality.
6. Study of Effect of Actual Earthquake Acceleration in the Analysis
   In the present study, the seismic analysis of buildings is based
   on a design earthquake response spectrum. The present work may be
   extended by incorporating into it the ability to carry out a time
   history analysis for a given earthquake acceleration record.

7. Study of the Presence of Braced Frames in the Building
   Some buildings particularly those of steel may contain frames with
   inclined bracings. The present program may be extended to take
   into account the effect of bracings in the building frames.

8. Study to Run the Present Program in a Minicomputer
   The present program is designed to run in batch mode on a computer
   with a fair size of memory. Since in-house minicomputers are
   finding increasing use in engineering design offices, it will be
   worthwhile adapting this program to run on a minicomputer. It
   should be possible to accomplish this without too much effort.
REFERENCES


APPENDIX A

LINEAR THREE-DIMENSIONAL ANALYSIS
OF BUILDING STRUCTURES

PROGRAM USER'S MANUAL

August 1978

DEPARTMENT OF CIVIL ENGINEERING
CARLETON UNIVERSITY
OTTAWA, CANADA
DISCLAIMER

The program package described here consists of a set of computer programs designed to perform a three dimensional linear analysis of building structures with rigid frames and shearwalls for gravity, earthquake and lateral load cases. While every effort has been made to ensure the accuracy of the information presented in this manual, and the reliability of the programs described therein, use of this material can be made only with the understanding that neither the programmer nor the manual writer will assume any liability of any kind arising from such use.
DISCLAIMER

The National Library of Canada also does not assume any liability of any kind arising from the use of information presented in this manual.
CHAPTER A1

INTRODUCTION

A1.1 GENERAL

The programs described in this user's manual constitute a part of a thesis submitted by the author to Carleton University, Ottawa, Canada, in partial fulfillment of the requirements of an M.Eng. degree in Civil Engineering. The programs were developed for a linear three-dimensional analysis of building structures.

The first program is a conversational program, called AIDS\(^+\), designed to read the input data required by the second program which is the main analysis program. The analysis program named ANGELS\(^*\) is designed to perform a linear three-dimensional analysis of building structures for gravity, earthquake and lateral loads. The program calculates and prints out the member forces for different load cases. At the user's option, it can also calculate and output the mode shapes and frequencies of the building. The building to be analyzed should consist of two orthogonal sets of rectangular frame or frame-shearwall substructures. The joints and the foundations are considered rigid and the stiffness method of analysis is used.

\[+\] AIDS - Automatic Input Data Supplier

\[\ast\] ANGELS - Analysis of buildings for Gravity, Earthquake and Lateral loads
To make this manual self-contained, a brief description of the algorithms and program operations is included. For a more detailed presentation of these topics, the original thesis may be referred to. This manual also presents outline flow charts, a list of FORTRAN variables used, instructions for the use of the programs, the FORTRAN source listings and an example of a three-dimensional analysis of a building.

1.2 ASSUMPTIONS AND LIMITATIONS

An exact three-dimensional analysis is required for only a limited number of buildings. For a majority of buildings, the following two basic approximations can be made which greatly simplify the preparation of input data and significantly reduce the computational effort.

1. It is assumed that the floor diaphragms are rigid in their own planes. This is a realistic approximation for a large number of common buildings. As a result, the structure has three degrees of freedom at each floor level - two translational, in the X and Y directions, and a rotational about the vertical axis of the floor.

The other degrees of freedom include: the bending deformation in the horizontal beams and floor slabs, and a vertical displacement and a rotation at each column or shearwall at each floor level.

2. It is further assumed that the horizontal lateral loads act at the floor levels and are transferred to the columns
through the rigid floor diaphragms. Also, the mass of the building is assumed to be lumped at the floor levels. As a consequence, the active dynamic degrees of freedom at each floor are three, corresponding to the three displacement degrees of freedom mentioned in 1 above.

Also, in modelling the complete structure, the building is assumed to consist of two sets of planar frames or frame-shearwall systems which are orthogonal to each other in plan view. Isolated shearwalls within a set are considered to be frames consisting of a single continuous column line. Each frame is treated as an independent substructure. A substructure is permitted to have two degrees of freedom per joint (vertical displacement and inplane rotation) and one lateral translation per story. However, of all the above degrees of freedom, the only active dynamic degrees of freedom are those associated with the frame lateral displacements at the floor levels. The substructure stiffness matrix is assembled into the structural (global) stiffness matrix on the assumption that the structure has three active degrees of freedom per floor: two translational and one rotational.

The following additional approximations are also inherent in the present approach:

1. Complete compatibility with regard to joint displacements is not enforced at joints which are common to two intersecting frames. Thus, in a column which is common to two intersecting frames, the axial deformations will not be the same (compatible).
However, for design purposes, a reasonable approximation to the axial load in such a column may be obtained by adding those calculated for the component frames. As for joint rotations, since the intersecting frames are assumed to be perpendicular in plan view, the in-plane joint rotations of the frames are orthogonal to each other and are hence uncoupled.

2. As the floor diaphragms are assumed to be rigid in their respective planes, it is apparent that the axial deformation is not permitted in the beams. However, bending stiffness of the floor slabs may be included approximately in modelling of the individual frames. All beam centerlines in a floor are assumed to be coincident with the central plane of the floor diaphragm. Similarly, columns for all stories, located in one vertical stack are assumed to have the same center line.

3. The torsional resistance of any member section is neglected.

Al. 3 IDENTIFICATION OF STRUCTURE GEOMETRY AND LOADING

For the purpose of preparing the numerical input data, the building to be analyzed is at first resolved into two orthogonal sets, of planar frame or frame-shearwall systems. Each frame or frame-wall system must be assigned two identifier numbers. The first identifier is a frame group number; frames with similar geometric and structural properties being collected into one group. A typical building, such as
FIG. A.1 TYPICAL FRAME AND SHEARWALL BUILDING
the one shown in Fig. A.1, may have several frame groups. Each group is assigned a number starting from one and increasing sequentially. The second identifier is a unique number assigned to each frame, called the frame number. This number also starts from one and increases sequentially. It is, however, a requirement that the frames in Group I are numbered first, those in Group II are numbered next, and so on, till all the frame groups are exhausted. Also, within a group, frames carrying exactly the same gravity loads must be numbered so that they form a cluster uninterrupted by frames with different loading patterns.

Gravity loads are to be specified in terms of uniformly distributed loads and concentrated loads on each beam in a frame. A maximum of four concentrated loads can be specified on any one beam. Lateral loads are applied at the floor levels and act on the complete structure. The values of their X and Y components along with the coordinates of their points of action with reference to the global reference point should be supplied to the program.

The program also needs the orientations and locations of the frames to assemble the global stiffness matrix. Further, it requires the location of mass center and the translational and rotational masses at each floor level to assemble the global mass matrix. The frame locations and mass centers must be specified with respect to the global reference points at each floor level. The choice of a reference point is arbitrary, but all reference points must lie on the same vertical line. Also, it is to be noted that the line of action of the earthquake force resultant acts through the center of mass at each floor level.
Each frame or shearwall element is assumed to have stiffness only in the in-plane direction. Elements which have stiffness in another direction too must be defined by an additional element. For example, the properties of columns which are common to two different frames must be supplied twice. As stated earlier, the axial deformations in these doubly defined columns will not be the same. However, this incompatibility should not cause any serious error in the analysis.

The properties of a frame or shearwall are specified with respect to its local stiffness direction. Floor beam center lines and column center lines are the basic reference lines used in the frame description. The height from one floor beam center line to the next is assumed to be the same for all frames and is equal to the story height. A member may be omitted by specifying zero properties. However, a shearwall must be continuous all through to the base of the frame. Beams must be prismatic and columns may be prismatic or circular. Both flexural and shearing deformations are considered in the analysis. Beams are considered axially rigid but axial deformations of columns are accounted for. Also, finite joint sizes of infinite rigidity may be considered. In general, each frame is considered a setback frame. A part of the frame height containing the same number of bays is named a tower; a frame containing more than one tower is called a setback frame as illustrated in Fig. A.2. A uniform frame is considered as a setback frame with a single tower.
FIG. A.2  ELEVATION OF A SETBACK FRAME

Tower : part of frame height with same no. of bays
NST : no. of stories in a tower
NBA : no. of bays in a tower
NBS : no. of bay-setback between two towers at left
In the analysis, a maximum of four different gravity load cases, a maximum of three different lateral load cases and a seismic design spectrum case may be considered. Any or all of the above load cases can be combined to form load combinations. There is no limit on the number of combinations. Each such combination, called a 'load system' is fully specified once the multiplying factors for its component load cases have been supplied.

A1.4 SIGN CONVENTIONS AND UNITS

The positive directions of global axes are indicated in Fig. A.3a. The local axis of a frame will be in the plane of the frame and will be parallel to the global X-axis or global Y-axis. The positive direction of a local axis is the same as the positive direction of the global axis to which it is parallel. Also, for forces and displacements, the following set of conventions is used:

1. Forces and Displacements
   - They are positive when directed upwards or to the right.

2. Moments and Rotations
   - They are positive when counter clockwise.

3. Column Shears
   - A column shear is considered positive when produced by a top reaction directed to the right.

4. Column Axial Force
   - A tensile force is positive.
FIG. A.3a Global and Local Coordinates

(a) Forces and Displacements

(b) Moments and Rotations

(c) Loads

(d) Column Shears

(e) Column Axial Loads

FIG. A.3b Sign Convention For Forces And Displacements
5. Gravity Loads on Beams

- They are positive when downward.

The sign conventions are illustrated in Fig. A.3b.

The program accepts any consistent set of units; no transformation of units is carried out within the program. A typical set of consistent units is shown below.

<table>
<thead>
<tr>
<th>Physical Quantity</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length, displacement</td>
<td>feet</td>
</tr>
<tr>
<td>Force, weight</td>
<td>kips</td>
</tr>
<tr>
<td>Time</td>
<td>seconds</td>
</tr>
<tr>
<td>Mass</td>
<td>kip-sec^2/ft</td>
</tr>
<tr>
<td>Moment</td>
<td>kip-ft</td>
</tr>
<tr>
<td>Acceleration due to</td>
<td>ft/sec^2</td>
</tr>
<tr>
<td>gravity (g)</td>
<td></td>
</tr>
<tr>
<td>Spectral acceleration</td>
<td>in units of g</td>
</tr>
<tr>
<td>Frequency</td>
<td>rad/sec</td>
</tr>
<tr>
<td>Period</td>
<td>seconds</td>
</tr>
</tbody>
</table>

A1.5 JOB CONTROL COMMANDS

During development of the programs, the input data program AIDS was compiled and run on an IM-70 minicomputer. The main analysis program - ANGELS was compiled and run on a HONEYWELL Sigma-9 computer. The job control statements (or cards) required to compile and run the programs are indicated below.
Al.5.1 Compilation and Running of Program AIDS

In an IM-70 minicomputer, the System Utility Codes are as follows:

- **LØ**: means the list output file
- **LI**: means the list input file
- **SI**: means the source input file
- **SØ**: means the source output file
- **BI**: means the binary input file
- **BØ**: means the binary output file

The physical units are:

- **AØ**: console terminal
- **A1**: line printer
- **F0**: floppy drive 0
- **F1**: floppy drive 1
- **F2**: floppy drive 2
- **F3**: floppy drive 3

The meaning of some essential commands are:

- **ØS**: operating system
- **AS**: assign
- **SF**: system file
- **SS**: scratch source
- **FORTRAN IV compilation**: FORTRAN IV compilation
- **LINK**: link
- **LDR**: load and run
EL       error listing only
LL
UL       unconditional link
TE       terminate operations
EX       execute

Let the program AIDS (source program) be on a floppy disc in
drive F1 and the system file be on a disc in drive 0. Suppose the pro-
gram is to be compiled and the object module (the binary output after
compilation) is to be stored on a disc in drive F2 on a file named BAIDS.
The commands necessary for compilation are:

>AS  LØ = A1   (CR)
>AS  SI = F1.AIDS (CR)
>AS  BØ = F2.BAIDS (CR)
>AS  SS = F3   (CR)
>EX  FORT:4,EL (CR)

where (CR) means press 'carriage return'.

After the above commands have been issued, the minicomputer will
start compiling the program AIDS; the binary object module will be
created and stored in file BAIDS on disc in drive F2.

A free format read subroutine REED is also required to compile
and link with BAIDS during creation of the load module in the next step.
Supposing that the object code of REED is on file REEDB, the load module
of the program can be obtained as follows.
Let the object file BAIDS be in disc F1 and the object file REEDB in F2. Suppose that the load module is to be directed to file *AIDS on disc F3. Then the following control commands will be required to obtain the load module:

```plaintext
>AS  L@ = A1  (CR)
>AS  B1 = F1.BAIDS  (CR)
>AS  B@ = F3.*AIDS  (CR)
>AS  L1 = F2.REEDB  (CR)
>EX  @S:LNK,LL  (CR)
```

When these commands have been issued, the computer will display on the terminal an informative summary and will prompt the user with a set of questions to which the user should respond as follows:

```plaintext
?AS LI = F0.F:BSLB  (CR).
? LL,TE  (CR)
```

The load module will then be created and stored on file *AIDS on disc F3. This load module can be run whenever input data is to be supplied in a conversational mode. The commands necessary to run a job are as follows:

```plaintext
>AS  1 = A0  (CR)
>AS  2 = A0  (CR)
>AS  3 = F1.RID1  (CR)
>AS  4 = F1.RID2  (CR)
>AS  5 = F1.RID3  (CR)
```
After these commands are typed in, the computer will display on the terminal a message stating that program AIDS is ready to read the input data for program ANGELS. The computer will then prompt the user with a series of questions and will invite immediate answers to them. After the program has run the input data will be stored on three files RID1, RID2 and RID3 on the disc in drive F1. Also, a duplicate version of the user's input will be written on file DUPLI on the disc in drive F2.

1.5.2 Compilation and Running of Program ANGELS

As a first step in running a job, files RID1, RID2 and RID3 obtained from program AIDS are transferred from the minicomputer to the HONEYWELL computer using appropriate commands. These data files are stored in the user's account on HONEYWELL on three unkeyed files. The following job commands may then be used to run program ANGELS, a source of which exists in the user's account:

1. Compilation and running:

```plaintext
!JOB ACCOUNT NO, ACCOUNT NAME, 5,
!LIMIT (TIME,4), (CORE,40), (L,100)
! ASSIGN F:1, (FILE,RID1), (INOUT), (REL)
! ASSIGN F:2, (FILE,RID2), (INOUT), (REL)
! ASSIGN F:3, (FILE,RID3), (INOUT), (REL)
! ASSIGN F:4, (FILE,RID4), (OUTIN), (REL)
! ASSIGN F:5, (FILE,RID5), (OUTIN), (REL)
! ASSIGN F:6, (FILE,RID6), (OUTIN), (REL)
! ASSIGN F:7, (DEVICE,LP)
! ASSIGN F:8, (FILE,RID8), (OUTIN), (REL)
! ASSIGN M:61, (FILE,ANGELS), (IN), (SAVE)
! FORTRAN BC,GO
!LOAD (GO)
!RUN
```
2. Compilation and making a load module

!JOB ACCOUNT :X, ACCOUNT NAME, 5,
!LIMIT (TIME, 5), (CORE, 40),
!ASSIGN F:1, (FILE, RDL1), (INOUT), (REL)
!ASSIGN F:2, (FILE, RDL2), (INOUT), (REL)
!ASSIGN F:3, (FILE, RDL3), (INOUT), (REL)
!ASSIGN F:4, (FILE, RDL4), (OUTIN), (REL)
!ASSIGN F:5, (FILE, RDL5), (OUTIN), (REL)
!ASSIGN F:6, (FILE, RDL6), (OUTIN), (REL)
!ASSIGN F:7, (DEVICE, LP)
!ASSIGN F:8, (FILE, RDL8), (OUTIN), (REL)
!ASSIGN M:SI, (FILE, ANGELS), (IN), (SAVE)
!FORTRAN BC, GO
!LOAD (GO), (LAN, *ANGELS), (PERM)

If the user wants to run the load module *ANGELS at the same time, he
should add the following command to the above run:

!RUN (LAN, *ANGELS)

This command will initiate a run and the results will be printed
out on the line printer. Also, the load module will be saved in the
user's account on file named *ANGELS.

3. Running a job with a previously created load module

!JOB ACCOUNT NO, ACCOUNT NAME, 5,
!LIMIT (TIME, 5), (CORE, 40)
!ASSIGN F:1, (FILE, RDL1), (INOUT), (REL)
!ASSIGN F:2, (FILE, RDL2), (INOUT), (REL)
!ASSIGN F:3, (FILE, RDL3), (INOUT), (REL)
!ASSIGN F:4, (FILE, RDL4), (OUTIN), (REL)
!ASSIGN F:5, (FILE, RDL5), (OUTIN), (REL)
!ASSIGN F:6, (FILE, RDL6), (OUTIN), (REL)
!ASSIGN F:7, (DEVICE, LP)
!ASSIGN F:8, (FILE, RDL8), (OUTIN), (REL)
!RUN (LAN, *ANGELS)

4. For small size problems, the program can be run on line and
the result directed to the user's terminal. The following
on-line commands should be used:
!SET F:1/RID1; INOUT; REL (CR)
!SET F:2/RID2; INOUT; REL (CR)
!SET F:3/RID3; INOUT; REL (CR)
!SET F:4/RID4; OUTIN; REL (CR)
!SET F:5/RID5; OUTIN; REL (CR)
!SET F:6/RID6; OUTIN; REL (CR)
!SET F:7 ME (CR)
!SET F:8/RID8; OUTIN; REL (CR)
!* ANGELS.
CHAPTER A2

PROGRAM FOR INPUT DATA - AIDS

A2.1 DESCRIPTION OF PROGRAM

Program AIDS, written in standard FORTRAN IV, is designed to act as a 'front end' processor to the main analysis program ANGELS. It reads all input data required for the analysis, in a conversational mode. The data input is in free format. To achieve free format inputs, a special subroutine, called REED†, has been used in this program. The input is supplied via a time-sharing terminal. One or more data items can be read from a line, consecutive data items being separated by one or more blanks. The data can be numeric or alphanumeric. For numeric data, no decimal is required for an integer, also a real whole number can be supplied as an integer, the decimal being optional.

If the building to be analyzed is large in size, with a great number of frames, a large amount of data will be required by the program ANGELS. However, very often, several dimensions, sizes and loads in a structure are repetitive. For example, most story heights may be equal; also, member sizes may be the same over a number of bays and stories. It is possible to speed up the data input considerably by taking advantage

† The general purpose 'free format' subroutine has been developed by Dr. W. Wright of Public Works, Canada.
of these repetitions. In program AIDS, a very careful attention has been
given to this aspect and ways have been devised for speeding up the
input process without making it too complex.

An outline flow diagram of program AIDS is shown in Fig. A.4. It
is clear from the flow diagram that the program reads all input data in
a conversational mode, rearranges it and writes it on three disc files
on units 3, 4 and 5 respectively. Also, the program is designed to keep
a copy of the user's input on a disc file assigned to unit 6.

The program also provides the facility for correcting errors in
the input data. This is achieved by creating a duplicate input file on
unit 6. For major errors, the user can edit this file after the program
has been run, using the conventional edit system of the computer. He can
then rerun program AIDS, this time specifying that the input data be
read from the disc file instead of from the terminal. However, for minor
numerical errors made during the conversational input, the user can
appropriately edit the files written on unit 3, 4 or 5. For example,
suppose that when asked for modulus of elasticity for beam in Story No. 2
and Bay No. 2, of the frame in Fig. A.1, the user has input a value of
2500 instead of 3000. After program AIDS has been run, the user can
edit the file on unit 4 (file for member properties) substituting the
correct value of modulus of elasticity for the wrong value.
START

Read general data that is number of frames, frame groups, frame locations, stories, etc. Read user's options. Write on a disc file on unit 3. Write a copy of the supplied input on a disc file on unit 6.

Read frame and member properties (e.g. number of bays, towers and stories, beam and column sizes, modulus of elasticity, shear coefficients, etc.) for all frame groups of the building. Rearrange and write the data in appropriate rigid format on a disc file on unit 4. Write a copy of the supplied input on the file on unit 6.

Read gravity load data for all gravity load cases (up to a maximum of four) for all frames; read lateral load data for the building and rearrange. Write in a rigid format on a disc file on unit 5. Read seismic load data and write on the file on unit 3. Write a copy of the supplied input on the file on unit 6.

STOP

Fig. A.4. Outline flow diagram for program AIDS.
FIG. A.5 REINFORCED CONCRETE BUILDING UNDER GRAVITY, EARTHQUAKE AND LATERAL LOADS.
(e) Frames 1 & 2
(f) Frames 3 & 4
(g) Frame 5

FIG. A.5(contd) Gravity Loads On The Building

(h) Story 1
(i) Story 2
(j) Story 3

Reference Point

FIG. A.5(contd) Lateral Loads on The Building

(k) Story 1
(l) Story 2
(m) Story 3

Reference Point

FIG. A.5(contd) Centers of Masses
A2.2 INSTRUCTIONS FOR DATA INPUT

For the purpose of analysis, the building must first be modelled in a manner described in Section A1.3. The building is resolved into two orthogonal sets of frames. Each frame must be given an individual number and also a frame group number. In preparing the input data, the following points must also be noted:

1. A fixed reference point must be selected (usually a corner of the building) from which the distances of the frames and their X- or Y-orientations are to be specified.

2. Member sizes must be specified as follows: for rectangular sections, the section dimensions; and for standard steel sections, moment of inertia, area, and width (or depth) in the plane of the frame to which the member belongs.

3. The gravity loads must be specified in terms of a uniformly distributed load and concentrated loads if any on each beam. A maximum of four concentrated loads can be specified on a beam. A maximum of four independent sets of gravity load cases may be considered.

4. For lateral loads, the x- and y-components of loads and the distances of their lines of action from the reference axes must be computed and specified for each floor of the building. A maximum of three different lateral load cases may be considered.
5. For dynamic analysis, the mass of the building assigned to each floor level must be input. For an unsymmetrical building where the lateral and torsional vibrations are coupled, the mass moment of inertia should also be specified. The centers of these masses as measured from the reference point are also to be supplied. When a spectral analysis is required, the period and acceleration coordinates of the spectrum should be specified. In addition, ductility factor, a scale factor for the design acceleration and acceleration due to gravity must also be supplied.

The essential features of data input for the program AIDS are illustrated with reference to the building of Fig. A.5. The conversational data input to a minicomputer is shown in Section A2.5. Those portions of the dialogue which are keyed in by the user are underlined; the remaining portions are prompted by the computer.

The first question that the program asks the user is whether he wishes to make a copy of the input data on a disc file. If the data is currently being supplied through a terminal, it is a good practice to make a copy. The copy can be later used to make any corrections that may be required in the data supplied during the current session on the terminal. The user can express his wish to create such a file by typing a Y. With this option, the program will make a copy of the currently supplied input data on a disc file on unit 6; the name of the file being predetermined during assignment of units.
The option to read the data from a previously created disc file instead of from a terminal, is exercised at the question immediately following.

The next few questions which are self explanatory, deal with structure and frame description. A subsequent question prompts the user to supply the story heights. The story heights are supplied starting from the lowest story and proceeding upwards. For the present example, the user types in 120, in reply to a request for story height between levels 0 and 1. Because the height of the next story is also 120, the user can speed up the data input at this stage by typing in 120 TO 2. If he does so, the program automatically assigns a value of 120 to both of the first and the second stories and then prompts the user to supply the story height between levels 2 and 3; the user then types in 100.

The next question asked by the computer relates to the frame information and left identification. The left identification is a symbol as put on the drawing to identify the left side of a frame in a building.

The program then asks for frame group properties starting from Group I. The program first prompts the user to supply the lengths of bays for frame Group I, starting from the left, and proceeding to the right. A procedure similar to the one described for the story heights can be used in supplying this data.

Beam cross-section properties for frame Group I are input next. The computer asks whether all beams at Story No. 1 are of rectangular concrete sections or other (i.e. steel sections, etc.). If they are all concrete, the user types in C. The program then asks for the width and the depth of the
beam in Bay No. 1 (the leftmost bay). To speed up the input, the user
types in 10 20 TO 2. With this, the program automatically assigns a size
of 10 by 20 to the first and second beams of Story No. 1. Since all the
beams at Story No. 1 have been input, the computer asks whether the
beams in the next story are exactly like those in any preceding story
(here the first story only). In fact, the beams in Story No. 2 are exactly
of the same size as those in Story No. 1. The user can, therefore, speed
up the input by typing in L(IKE) 1. The computer automatically assigns
appropriate sizes to beams in story 2 so that these beams are exactly
the same as the corresponding beams in story 1.

It is to be noted that when asked for the type of section, the
user has the option to type in C or O. For type C, the program asks for
the beam width and depth. Program ANGELS uses these properties to cal-
culate the area and moment of inertia for the gross section. The
computed values are then used in the analysis. For cross-sections other
than rectangular or for the case where the user does not want to use the
gross section properties, he should type in O. In that case, the user
would be asked to supply the moment of inertia and depth in lieu of
width and depth of the beams. Again, the speed of input can be enhanced
by using the procedure described above.

Column cross-section properties are supplied in a manner similar
to that followed for the beam cross-section properties.

Very often, several frames in a structure carry exactly the same
gravity loads. When frames carrying similar gravity loads also belong
to the same frame group, program AIDS can enhance the speed of data
input. For example, with reference to the building of Fig. A.5, in which
frames 1 and 2 belong to the frame Group I, the beams in frames 1 and 2 carry exactly the same gravity loads (in each of the gravity load cases). After the gravity load data has been supplied for frame 1, the computer asks whether the next frame (i.e. frame 2) carries exactly the same gravity load as frame 1. The user now types in Y. The program makes a note of this on the disc file and asks for the load data for frame 3. If frame 3 were also in frame Group I and the gravity loads on it were similar to those in frame 1, the user could further speed up input by typing in Y to 3.

A2.3 DEFINITION OF FORTRAN SYMBOLS

Variables appearing in program AIDS are listed here. The local variables within subroutine REED are not listed. Indices, counters, and variables providing temporary locations have been grouped together. In the following, type A stands for an array and type S for a scalar.

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>TYPE</th>
<th>DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>AB</td>
<td>A</td>
<td>areas of cross-section for beams</td>
</tr>
<tr>
<td>AC</td>
<td>A</td>
<td>areas of cross-section for columns</td>
</tr>
<tr>
<td>AFLX</td>
<td>A</td>
<td>array to store the floating point numbers read by subroutine REED</td>
</tr>
<tr>
<td>AG</td>
<td>S</td>
<td>acceleration due to gravity</td>
</tr>
<tr>
<td>B</td>
<td>A</td>
<td>bay lengths for a frame group</td>
</tr>
<tr>
<td>SYMBOL</td>
<td>TYPE</td>
<td>DEFINITION</td>
</tr>
<tr>
<td>--------</td>
<td>------</td>
<td>------------</td>
</tr>
<tr>
<td>BETA</td>
<td>S</td>
<td>angle of incidence of earthquake with respect to the global x-axis</td>
</tr>
<tr>
<td>BI</td>
<td>A</td>
<td>moments of inertia for beams</td>
</tr>
<tr>
<td>BK</td>
<td>A</td>
<td>shear coefficients for beam sections</td>
</tr>
<tr>
<td>CI</td>
<td>A</td>
<td>moments of inertia of columns in a frame group</td>
</tr>
<tr>
<td>CK</td>
<td>A</td>
<td>shear coefficients of column cross-sections in a frame group</td>
</tr>
<tr>
<td>CNL</td>
<td>A</td>
<td>array containing concentrated loads on different beams in a frame</td>
</tr>
<tr>
<td>DB</td>
<td>A</td>
<td>depths of beams in a frame group</td>
</tr>
<tr>
<td>DBX</td>
<td>A</td>
<td>widths of beams in a frame group</td>
</tr>
<tr>
<td>DC</td>
<td>A</td>
<td>widths of columns in the plane of the frame</td>
</tr>
<tr>
<td>DCX</td>
<td>A</td>
<td>widths of columns perpendicular to the plane of the frame</td>
</tr>
<tr>
<td>DDN</td>
<td>S</td>
<td>perpendicular distance of a frame from the reference point</td>
</tr>
<tr>
<td>DHX</td>
<td>A</td>
<td>x-coordinates of the points of action of story lateral loads</td>
</tr>
<tr>
<td>DHY</td>
<td>A</td>
<td>y-coordinates of the points of action of story lateral loads</td>
</tr>
<tr>
<td>DIS</td>
<td>A</td>
<td>distances of the concentrated loads on beams from the respective left column center lines</td>
</tr>
<tr>
<td>EB</td>
<td>A</td>
<td>modulii of elasticity of beams</td>
</tr>
<tr>
<td>EC</td>
<td>A</td>
<td>modulii of elasticity of columns</td>
</tr>
<tr>
<td>FBND</td>
<td>A</td>
<td>array containing real input data bounds</td>
</tr>
<tr>
<td>GB</td>
<td>A</td>
<td>modulii of rigidity of beams</td>
</tr>
<tr>
<td>SYMBOL</td>
<td>TYPE</td>
<td>DEFINITION</td>
</tr>
<tr>
<td>--------</td>
<td>------</td>
<td>------------</td>
</tr>
<tr>
<td>H</td>
<td>A</td>
<td>story heights</td>
</tr>
<tr>
<td>HLX</td>
<td>A</td>
<td>x-components of story lateral loads</td>
</tr>
<tr>
<td>HLY</td>
<td>A</td>
<td>y-components of story lateral loads</td>
</tr>
<tr>
<td>IAL</td>
<td>A</td>
<td>array of single character alphanumeric variables read and processed by subroutine REED</td>
</tr>
<tr>
<td>IAX</td>
<td>A</td>
<td>array containing the name of the project</td>
</tr>
<tr>
<td>IBC</td>
<td>A</td>
<td>indices for the type of beam cross-sections at different stories</td>
</tr>
<tr>
<td>IBND</td>
<td>A</td>
<td>array containing integer input data bounds</td>
</tr>
<tr>
<td>ICC</td>
<td>A</td>
<td>array of indices indicating the type of column cross-sections in a column line in a frame group</td>
</tr>
<tr>
<td>IDW</td>
<td>S</td>
<td>flag to indicate whether or not an input data file is to be built</td>
</tr>
<tr>
<td>IDR</td>
<td>S</td>
<td>flag to indicate whether the data is to be supplied from a disc file or terminal</td>
</tr>
<tr>
<td>IFD</td>
<td>S</td>
<td>index to define whether a frame is parallel to global x-axis or y-axis</td>
</tr>
<tr>
<td>IFIX</td>
<td>A</td>
<td>array to store the fixed point numbers read by subroutine REED</td>
</tr>
<tr>
<td>II</td>
<td>S</td>
<td>frame number; also acts as a counter</td>
</tr>
<tr>
<td>ILFT</td>
<td>A</td>
<td>array of symbol to identify the left side of a frame</td>
</tr>
<tr>
<td>INDL</td>
<td>S</td>
<td>index to check whether or not the gravity loads in a frame are the same as those in the preceding frame</td>
</tr>
<tr>
<td>INDX</td>
<td>A</td>
<td>numeric indicator array to indicate whether or not a discrete data item read by subroutine REED is a number</td>
</tr>
<tr>
<td>SYMBOL</td>
<td>TYPE</td>
<td>DEFINITION</td>
</tr>
<tr>
<td>--------</td>
<td>------</td>
<td>------------</td>
</tr>
<tr>
<td>INST</td>
<td>S</td>
<td>flag to indicate whether or not instruction is required by the program AIDS</td>
</tr>
<tr>
<td>INX</td>
<td>S</td>
<td>variable indicating the number of characters to be processed by subroutine REED from one line of data input</td>
</tr>
<tr>
<td>IOUT</td>
<td>S</td>
<td>index for special output i.e. mode shapes, frequencies and story shears for seismic loading</td>
</tr>
<tr>
<td>IR</td>
<td>S</td>
<td>unit number from which input data is read</td>
</tr>
<tr>
<td>ISTB</td>
<td>S</td>
<td>flag to indicate whether or not finite joint sizes are to be considered in the analysis</td>
</tr>
<tr>
<td>ITOT</td>
<td>S</td>
<td>maximum number of discrete data items expected to be read at each subsequent call to subroutine REED</td>
</tr>
<tr>
<td>IW</td>
<td>S</td>
<td>unit number to which output is directed</td>
</tr>
<tr>
<td>IW1</td>
<td>S</td>
<td>unit number on which general data and seismic load data is to be written</td>
</tr>
<tr>
<td>IW2</td>
<td>S</td>
<td>unit number on which the frame properties data is to be written</td>
</tr>
<tr>
<td>IW3</td>
<td>S</td>
<td>unit number on which the gravity and lateral load data are to be written</td>
</tr>
<tr>
<td>IWF</td>
<td>S</td>
<td>unit number on which the user's input data is to be copied</td>
</tr>
<tr>
<td>IYD</td>
<td>S</td>
<td>flag to indicate whether or not all beams in a frame group have the same modulus of elasticity</td>
</tr>
<tr>
<td>IYDN</td>
<td>S</td>
<td>flag to indicate whether or not dynamic analysis is to be carried out</td>
</tr>
<tr>
<td>IYS</td>
<td>S</td>
<td>flag to indicate whether or not shear deformations are to be considered</td>
</tr>
<tr>
<td>SYMBOL</td>
<td>TYPE</td>
<td>DEFINITION</td>
</tr>
<tr>
<td>--------</td>
<td>------</td>
<td>------------</td>
</tr>
<tr>
<td>JAX</td>
<td>A</td>
<td>array of unprocessed alphanumerical data read by subroutine REED</td>
</tr>
<tr>
<td>JEND</td>
<td>A</td>
<td>check array to indicate whether or not the input data is to be checked for validity</td>
</tr>
<tr>
<td>IM</td>
<td>S</td>
<td>number of modes to be extracted from one origin</td>
</tr>
<tr>
<td>M</td>
<td>S</td>
<td>group number to which frame belongs</td>
</tr>
<tr>
<td>NBAY</td>
<td>A</td>
<td>number of bays in a tower of a frame group</td>
</tr>
<tr>
<td>NBS</td>
<td>A</td>
<td>number of bays - setback at left between two adjacent towers of a frame group</td>
</tr>
<tr>
<td>NCL</td>
<td>A</td>
<td>number of concentrated loads on a beam in a frame</td>
</tr>
<tr>
<td>NDYN</td>
<td>S</td>
<td>index to define whether or not seismic load is to be considered in the analysis</td>
</tr>
<tr>
<td>NPG</td>
<td></td>
<td>total number of frame groups in the building</td>
</tr>
<tr>
<td>NFIG</td>
<td>A</td>
<td>number of frames in a frame group</td>
</tr>
<tr>
<td>NFT</td>
<td>S</td>
<td>total number of frames in the building</td>
</tr>
<tr>
<td>NGR</td>
<td>S</td>
<td>number of different gravity load cases</td>
</tr>
<tr>
<td>NM</td>
<td>S</td>
<td>number of modes to be considered</td>
</tr>
<tr>
<td>NNS</td>
<td>S</td>
<td>total number of stories in the building</td>
</tr>
<tr>
<td>NOPT</td>
<td>S</td>
<td>story translation code, indicating whether the story displacements for lateral loads are only translational (x- or y-translations) or coupled with rotations (for unsymmetric building)</td>
</tr>
<tr>
<td>NP</td>
<td>S</td>
<td>number of period coordinates defining the design spectrum</td>
</tr>
<tr>
<td>SYMBOL</td>
<td>TYPE</td>
<td>DEFINITION</td>
</tr>
<tr>
<td>--------</td>
<td>------</td>
<td>------------</td>
</tr>
<tr>
<td>NSS</td>
<td>S</td>
<td>number of stories in a frame group</td>
</tr>
<tr>
<td>NST</td>
<td>A</td>
<td>number of stories in a tower of a frame group</td>
</tr>
<tr>
<td>NSTB</td>
<td>S</td>
<td>index to check whether or not finite joint sizes are considered</td>
</tr>
<tr>
<td>NSYS</td>
<td>S</td>
<td>number of load systems (load combinations) to be considered</td>
</tr>
<tr>
<td>NTF</td>
<td>A</td>
<td>number of towers in different frame groups</td>
</tr>
<tr>
<td>NWL</td>
<td>S</td>
<td>number of different lateral load cases</td>
</tr>
<tr>
<td>SAC</td>
<td>S</td>
<td>acceleration coordinates of the design spectrum</td>
</tr>
<tr>
<td>SF</td>
<td>S</td>
<td>scale factor to be applied to the design spectrum</td>
</tr>
<tr>
<td>SMULP</td>
<td>A</td>
<td>multipliers for different load cases in a load system</td>
</tr>
<tr>
<td>TC</td>
<td>S</td>
<td>period coordinates on the design response spectrum</td>
</tr>
<tr>
<td>UDL</td>
<td>A</td>
<td>values of uniformly distributed loads on the beams in a frame</td>
</tr>
<tr>
<td>XB</td>
<td>A</td>
<td>x-coordinates of story mass centers from the reference point</td>
</tr>
<tr>
<td>XM</td>
<td>A</td>
<td>story masses of the building</td>
</tr>
<tr>
<td>XMI</td>
<td>A</td>
<td>story mass moments of inertia of the building</td>
</tr>
<tr>
<td>XMU</td>
<td>S</td>
<td>ductility factor</td>
</tr>
<tr>
<td>YB</td>
<td>A</td>
<td>Y-coordinates of story mass centers from the reference points</td>
</tr>
<tr>
<td>IFR, IMB, INC</td>
<td>S</td>
<td>indices, counters, and temporary integer locations</td>
</tr>
<tr>
<td>SYMBOL</td>
<td>TYPE</td>
<td>DEFINITION</td>
</tr>
<tr>
<td>--------</td>
<td>------</td>
<td>----------------------------------</td>
</tr>
<tr>
<td>I1O, IIT, IOF, IOO, ITP, ITI, IYP</td>
<td>S</td>
<td>alphanumeric variables, temporary</td>
</tr>
<tr>
<td>EG, EY</td>
<td>S</td>
<td>temporary real locations</td>
</tr>
<tr>
<td>IB, IBL, IC, IL, IN, IO, IT, IY</td>
<td>S</td>
<td>literal constants</td>
</tr>
</tbody>
</table>

A2.4 **EXAMPLE OF DATA INPUT**

For the building shown in Fig. A.5, the data is prepared in a manner as discussed in Section A2.3. Any consistent sets of units may be used. In this example, a "in-kip-sec" units are used. The conversational data input is shown below. The output from program AIDS as stored in four disc files is shown in Section A2.5.
READS DATA BY CONVERSATIONAL MODE WITH RAPID INPUT OPTION AND WRITES IN THREE FILES FOR THE THREE DIMENSIONAL BUILDING ANALYSIS PROGRAM.

DO YOU WISH TO CREATE A NEW DATA FILE CONTAINING A COPY OF THE PRESENT INPUT DATA FOR FUTURE USE? Y/N

THE INPUT DATA WILL BE SAVED ON A FILE NAMED - DUPLI DO YOU WISH TO INPUT DATA BY MEANS OF THE TERMINAL OR BY MEANS OF AN EXISTING DATA FILE? I/F

DO YOU WANT INSTRUCTION FOR THIS RAPID DATA INPUT SYSTEM? Y/N

RAPID DATA INPUT EXAMPLE:

----------------------------------
BEAM CROSS SECTION PROPERTIES:

...... ..... ..... ..... ...
STORY LEVEL 41
ARE ALL THE BEAMS IN THIS STORY LEVEL OF CONCRETE RECTANGULAR OR OTHER? C/O
?C (CR)

BAY NO. 1:
PUT BEAM WIDTH AND THEN BEAM DEPTH, SEPARATED BY A BLANK
?15 20 TO 6 (CR) THIS DATA SUPPLIED BY THE USER WILL SET A SIZE OF 15 BY 20 TO BEAM 1 TO BEAM 6 AT STORY 4

BAY NO. 71
?15 24 (CR)

THIS SET OF DATA IS COMPLETE UPTO STORY LEVEL 4 NOW, ARE THE BEAMS IN THE NEXT STORY EXACTLY LIKE THOSE IN ANY PRECEDING STORY? IF NOT—PUT NO IF YES—LIKE WHICH?
?LIKE 2 TO 8 (CR)
WITH THIS DATA THE PROGRAM WILL SET ALL BEAM SIZES IN STORIES 5 TO 8, EXACTLY SAME AS THE CORRESPONDING ONES IN STORY 2

A SIMILAR RAPID DATA INPUT PROCEDURE CAN BE USED FOR STORY HEIGHTS, BAY LENGTHS, COLUMN CROSS SECTIONS, LOAD DATA ETC.

DURING THE DATA INPUT FOR GRAVITY LOADS, WHEN DATA FOR ONE FRAME (SAY FRAME NO. 3) IS COMPLETE, THE COMPUTER PROMPTS WITH —

GRAVITY LOAD DATA IS COMPLETE UPTO FRAME NO. 3 NOW, ARE THESE DATA IN THE NEXT FRAME EXACTLY SAME (FOR ALL OTHER LOAD CASES) AS THOSE IN FRAME NO. 3? Y/N

? Y TO 6 (CR)

WITH THIS THE COMPUTER WILL PUT GRAVITY LOADS IN FRAMES 4 TO 6 SAME AS THOSE IN FRAME 3.

ALL OTHER DIALOGUES ARE SELF EXPLANATORY

PUT A CASE TITLE FOR THIS PROJECT

EXAMPLE BUILDING

DO YOU WANT FINITE JOINT SIZES TO BE TO BE CONSIDERED FOR THIS ANALYSIS? Y/N

? Y

DO YOU WANT SHEAR DEFORMATIONS TO BE TO BE CONSIDERED FOR THIS ANALYSIS? Y/N

? Y

** THE UNITS TO BE USED IN THIS PROGRAM MAY BE OF ANY TYPE, BUT THEY MUST BE CONSISTENT **

STRUCTURE HISTORY:

TOTAL NO. OF FRAMES IN THE BUILDING

? 5

NO. OF FRAME GROUPS IN THE BUILDING

? 3

TOTAL NO. OF STORIES IN THE BUILDING

? 3

NO. OF BAYS IN THE WIDEST FRAME OF THE BUILDING?

? 2

STORY HEIGHTS, C/C INTERSECTING FLOOR BEAMS

BETWEEN STORY LEVELS 0 AND 1

? 1.20 TO 2

BETWEEN STORY LEVELS 2 AND 3

? 1.00
FRAME INFORMATION:

FOR FRAME NO. 1:

FRAME GROUP NO. 1

PARALLEL TO GLOBAL X-DIRECTION OR Y-DIRECTION? X/Y?

PERPENDICULAR DISTANCE FROM THE REFERENCE POINT TO THE FRAME ?

SYMBOL (MAX. 10 CHARACTERS) TO IDENTIFY LEFT SIDE OF THE FRAME ?WEST-S

FOR FRAME NO. 2:

FRAME GROUP NO. 2

PARALLEL TO GLOBAL X-DIRECTION OR Y-DIRECTION? X/Y?

PERPENDICULAR DISTANCE FROM THE REFERENCE POINT TO THE FRAME ?

SYMBOL (MAX. 10 CHARACTERS) TO IDENTIFY LEFT SIDE OF THE FRAME ?WEST-N

FOR FRAME NO. 3:

FRAME GROUP NO. 3

PARALLEL TO GLOBAL X-DIRECTION OR Y-DIRECTION? X/Y?

PERPENDICULAR DISTANCE FROM THE REFERENCE POINT TO THE FRAME ?

SYMBOL (MAX. 10 CHARACTERS) TO IDENTIFY LEFT SIDE OF THE FRAME ?SOUTH-MID

FOR FRAME NO. 4:

FRAME GROUP NO. 4

PARALLEL TO GLOBAL X-DIRECTION OR Y-DIRECTION? X/Y?
PERPENDICULAR DISTANCE FROM
THE REFERENCE POINT TO THE FRAME
?360

SYMBOL (MAX. 10 CHARACTERS) TO IDENTIFY
LEFT SIDE OF THE FRAME
?SOUTH-E

FOR FRAME NO. 5
FRAME GROUP NO.
?3

PARALLEL TO GLOBAL X-DIRECTION OR Y-DIRECTION? X/Y
?Y

PERPENDICULAR DISTANCE FROM
THE REFERENCE POINT TO THE FRAME
?

SYMBOL (MAX. 10 CHARACTERS) TO IDENTIFY
LEFT SIDE OF THE FRAME
?SOUTH-W

FRAME GROUP NO. 1

HOW MANY TOWER DOES THIS FRAME HAVE
INCLUDING THE BASE TOWER
?2

IN TOWER 1 (BASE TOWER), NO. OF STORIES
?2

NO. OF BAYS
?2

LENGTHS OF BAYS, C/C OF COLUMNS
STARTING FROM LEFT

BAY NO. 1
?240

BAY NO. 2
?120

IN TOWER 2, NO. OF STORIES
?1

NO. OF BAYS
?1

NO. OF BAY-SLIPS BETWEEN
TOWERS 1 AND 2 AT LEFT
?1
BEAM CROSS SECTION PROPERTIES:

THIS SET OF DATA IS TO BE INPUT BEAM BY BEAM IN EACH FLOOR AND THIS WAY FLOOR BY FLOOR STORY LEVEL 1:
ARE ALL THE BEAMS IN THIS STORY LEVEL OF CONCRETE RECTANGULAR SECTIONS OR OTHER? C/O?

BAY NO. 1:
PUT BEAM WIDTH AND THEN BEAM DEPTH, SEPARATED BY A BLANK
10 20

THIS SET OF DATA IS COMPLETE UPTO STORY LEVEL 1 NOW, ARE THE BEAMS IN THE NEXT STORY (AND MAX. UPTO STORY 2) EXACTLY LIKE THOSE IN ANY PRECEDING STORY?
IF NOT——PUT NO, IF YES——LIKE WHICH?
EXAMPLE: LIKE M TO N, THIS MEANS THE BEAMS IN THE NEXT STORY AND TO THE NTH STORY, EXACTLY LIKE THOSE IN THE MTH STORY.
LIKE 1

STORY LEVEL 3:
ARE ALL THE BEAMS IN THIS STORY LEVEL OF CONCRETE RECTANGULAR SECTIONS OR OTHER? C/O?
C

BAY NO. 2:
PUT BEAM WIDTH AND THEN BEAM DEPTH, SEPARATED BY A BLANK
10 15

BEAM MOD. OF ELASTICITY AND MOD. OF RIGIDITY:
ARE THE MODULI OF ELASTICITY SAME FOR ALL THE BEAMS IN THIS FRAME GROUP? Y/N
Y

PUT THE MOD. OF ELASTICITY AND THEN THE MOD. OF RIGIDITY, SEPARATED BY A BLANK
3000 1200

SHEAR COEFFICIENTS FOR BEAMS:

STORY LEVEL 1:

FOR BEAM AT BAY NO. 1
8.833 TO 2

THIS SET OF DATA IS COMPLETE UPTO STORY LEVEL 1 NOW, ARE THE SHEAR COEFFICIENTS FOR THE NEXT FLOOR BEAMS (AND MAX. UPTO STORY LEVEL 2) EXACTLY LIKE THOSE IN ANY PRECEDING STORY? IF NOT——PUT NO, IF YES——LIKE WHICH?
LIKE 1
STORY LEVEL 3:
FOR BEAM AT BAY NO. 2
?.833

COLUMN CROSS SECTION PROPERTIES:

THIS SET OF DATA IS TO BE PUT VERTICALLY COLUMN BY COLUMN IN EACH COL. LINE AND THIS WAY COL. LINE BY COL. LINE, FROM LEFT COLUMN LINE 1:

ARE ALL THE COLUMNS IN THIS COLUMN LINE OF CONCRETE RECTANGULAR SECTIONS OR OTHER? C/O
?

STORY NO. 1:
PUT THE COLUMN WIDTH ACROSS THE PLANE OF FRAME AND THEN, THE WIDTH IN THE PLANE OF FRAME, SEPARATED BY A BLANK
?12.16

STORY NO. 2:
PUT THE COLUMN WIDTH ACROSS THE PLANE OF FRAME AND THEN THE WIDTH IN THE PLANE OF FRAME, SEPARATED BY A BLANK
?12.14

COLUMN LINE 2:
ARE ALL THE COLUMNS IN THIS COLUMN LINE OF CONCRETE RECTANGULAR SECTIONS OR OTHER? C/O
?

STORY NO. 1:
PUT THE COLUMN WIDTH ACROSS THE PLANE OF FRAME AND THEN THE WIDTH IN THE PLANE OF FRAME, SEPARATED BY A BLANK
?16.18

STORY NO. 2:
PUT THE COLUMN WIDTH ACROSS THE PLANE OF FRAME AND THEN THE WIDTH IN THE PLANE OF FRAME, SEPARATED BY A BLANK
?12.16

STORY NO. 3:
PUT THE COLUMN WIDTH ACROSS THE PLANE OF FRAME AND THEN THE WIDTH IN THE PLANE OF FRAME, SEPARATED BY A BLANK
?12.12

THIS SET OF DATA IS COMPLETE UPTO COL. LINE 2
NOW, ARE THE COLUMNS IN THE NEXT COL. LINE EXACTLY LIKE THOSE IN ANY PRECEDING COLUMN LINE?
IF NOT---PUT NO, IF YES---LIKE WHICH?
?LIKE 2

COLUMN MOD. OF ELASTICITY AND MOD. OF ROGIDITY:
ARE THE MODULII OF ELASTICITY SAME FOR ALL THE COLUMNS IN THIS FRAME GROUP? Y/N
?Y
PUT THE MOD. OF ELASTICITY AND THEN
THE MOD. OF RIGIDITY, SEPARATED BY A BLANK
?3000 1150

SHEAR COEFFICIENTS FOR COLUMNS:

COLUMN LINE 1

FOR COLUMN AT STORY NO. 1
? .833 TO 2

COLUMN LINE 2

FOR COLUMN AT STORY NO. 1
? .833 TO 3

THIS SET OF DATA IS COMPLETE UPTO COL. LINE 2.
NOW, ARE THE SHEAR COEFFICIENTS OF THE COLUMNS IN THE
NEXT COL. LINE EXACTLY LIKE THOSE IN ANY PRECEDING COL. LINE?
IF NOT——PUT NO, IF YES——LIKE WHICH?
? L 2

---------------------
FRAME GROUP NO. 2
---------------------

HOW MANY TOWER DOES THIS FRAME HAVE
INCLUDING THE BASE TOWER
?

IN TOWER 1 (BASE TOWER), NO. OF STORIES
?

NO. OF BAYS
?

LENGTHS OF BAYS, C/C OF COLUMNS
STARTING FROM LEFT

BAY NO. 1
?240

BEAM CROSS SECTION PROPERTIES:
THIS SET OF DATA IS TO BE INPUT BEAM BY BEAM
IN EACH FLOOR AND THIS MAY FLOOR BY FLOOR
STORY LEVEL 1;
ARE ALL THE BEAMS IN THIS STORY LEVEL OF
CONCRETE RECTANGULAR SECTIONS OR OTHER?
? C/0
BAY NO. 1:
PUT BEAM WIDTH AND THEN BEAM DEPTH, SEPARATED BY A BLANK.

?10 18

THIS SET OF DATA IS COMPLETE UPTO STORY LEVEL 1
NOW, ARE THE BEAMS IN THE NEXT STORY (AND MAX. UPTO STORY 3)
EXACTLY LIKE THOSE IN ANY PRECEDING STORY?
IF NOT—PUT NO, IF YES—LIKE WHICH?
EXAMPLE: LIKE N TO N, THIS MEANS THE BEAMS IN
THE NEXT STORY AND TO THE NTH STORY, EXACTLY
LIKE THOSE IN THE MTH STORY.

?L 1

THIS SET OF DATA IS COMPLETE UPTO STORY LEVEL 2
NOW, ARE THE BEAMS IN THE NEXT STORY (AND MAX. UPTO STORY 3)
EXACTLY LIKE THOSE IN ANY PRECEDING STORY?
IF NOT—PUT NO, IF YES—LIKE WHICH?
EXAMPLE: LIKE N TO N, THIS MEANS THE BEAMS IN
THE NEXT STORY AND TO THE NTH STORY, EXACTLY
LIKE THOSE IN THE MTH STORY.

?N

STORY LEVEL 3:
ARE ALL THE BEAMS IN THIS STORY LEVEL OF
CONCRETE RECTANGULAR SECTIONS OR OTHER? C/O

?C

BAY NO. 1:
PUT BEAM WIDTH AND THEN BEAM DEPTH, SEPARATED BY A BLANK

?10 15

BEAM MOD. OF ELASTICITY AND MOD. OF RIGIDITY:
ARE THE MODULI OF ELASTICITY SAME FOR ALL THE BEAMS
IN THIS FRAME GROUP? Y/N

?Y

PUT THE MOD. OF ELASTICITY AND THEN
THE MOD. OF RIGIDITY, SEPARATED BY A BLANK

?3000 1200

SHEAR COEFFICIENTS FOR BEAMS:

STORY LEVEL 1:
FOR BEAM AT BAY NO. 1

?0.833

THIS SET OF DATA IS COMPLETE UPTO STORY LEVEL 1
NOW, ARE THE SHEAR COEFFICIENTS FOR THE NEXT FLOOR BEAMS
(AND MAX. UPTO STORY LEVEL 3) EXACTLY LIKE THOSE
IN ANY PRECEDING STORY? IF NOT—PUT NO, IF YES—LIKE WHICH?

?L 1, TO 2
COLUMN CROSS SECTION PROPERTIES:
THIS SET OF DATA IS TO BE PUT VERTICALLY COLUMN BY COLUMN IN EACH COL.LINE AND THIS WAY COL.LINE BY COL.LINE, FROM LEFT

COLUMN LINE 1:

ARE ALL THE COLUMNS IN THIS COLUMN LINE OF CONCRETE RECTANGULAR SECTIONS OR OTHER? C/0

?C

STORY NO. 1:
PUT THE COLUMN WIDTH ACCROSS THE PLANE OF FRAME AND THEN THE WIDTH IN THE PLANE OF FRAME, SEPARATED BY A BLANK
?18 16

STORY NO. 2:
PUT THE COLUMN WIDTH ACCROSS THE PLANE OF FRAME AND THEN THE WIDTH IN THE PLANE OF FRAME, SEPARATED BY A BLANK
?16 12

STORY NO. 3:
PUT THE COLUMN WIDTH ACCROSS THE PLANE OF FRAME AND THEN THE WIDTH IN THE PLANE OF FRAME, SEPARATED BY A BLANK
?12 12

THIS SET OF DATA IS COMPLETE UPTO COL.LINE 1
NOW, ARE THE COLUMNS IN THE NEXT COL.LINE EXACTLY LIKE THOSE IN ANY PRECEDING COLUMN LINE?
IF NOT---PUT NO, IF YES---LIKE WHICH?
?L 1

COLUMN MOD. OF ELASTICITY AND MOD. OF ROGIDITY:
ARE THE MODULI OF ELASTICITY SAME FOR ALL THE COLUMNS IN THIS FRAME GROUP? Y/N
?Y

PUT THE MOD. OF ELASTICITY AND THEN THE MOD. OF RIGIDITY, SEPARATED BY A BLANK
?3000 1150

SHEAR COEFFICIENTS FOR COLUMNS:

COLUMN LINE 1:

FOR COLUMN AT STORY NO. 1
?0.833 TO 3

THIS SET OF DATA IS COMPLETE UPTO COL.LINE 1, NOW, ARE THE SHEAR COEFFICIENTS OF THE COLUMNS IN THE NEXT COL.LINE EXACTLY LIKE THOSE IN ANY PRECEDING COL.LINE?
IF NOT---PUT NO, IF YES---LIKE WHICH?
?L 1
FRAME GROUP NO. 3

HOW MANY TOWERS DOES THIS FRAME HAVE
INCLUDING THE BASE TOWER

IN TOWER 1 (BASE TOWER), NO. OF STORIES

NO. OF BAYS

LENGTHS OF BAYS, C/C OF COLUMNS
STARTING FROM LEFT:

BAY NO. 1:

BEAM CROSS SECTION PROPERTIES:
THIS SET OF DATA IS TO BE INPUT BEAM BY BEAM
IN EACH FLOOR AND THIS WAY FLOOR BY FLOOR
STORY LEVEL:
ARE ALL THE BEAMS IN THIS STORY LEVEL OF
CONCRETE RECTANGULAR SECTIONS OR OTHER? C/O

BAY NO. 1:
PUT BEAM WIDTH AND THEN BEAM DEPTH, SEPARATED BY A BLANK

THIS SET OF DATA IS COMPLETE UPTO STORY LEVEL 1
NOW, ARE THE BEAMS IN THE NEXT STORY (AND MAX. UPTO STORY 2)
EXACTLY LIKE THOSE IN ANY PRECEEDING STORY?
IF NOT—PUT NO, IF YES——LIKE WHICH?

EXAMPLE: LIKE M TO N, THIS MEANS THE BEAMS IN
THE NEXT STORY AND TO THE NTH STORY, EXACTLY
LIKE THOSE IN THE MTH STORY.

BEAM MOD. OF ELASTICITY AND MOD. OF RIGIDITY:

ARE THE MODULII OF ELASTICITY SAME FOR ALL THE BEAMS
IN THIS FRAME GROUP? Y/N

PUT THE MOD. OF ELASTICITY AND THEN
THE MOD. OF RIGIDITY, SEPARATED BY A BLANK

3000 1200
SHEAR COEFFICIENTS FOR BEAMS:

STORY LEVEL 1:
FOR BEAM AT BAY NO. 1
2.833

THIS SET OF DATA IS COMPLETE UPTO STORY LEVEL 1
NOW, ARE THE SHEAR COEFFICIENTS FOR THE NEXT FLOOR BEAMS
(AND MAX. UPTO STORY LEVEL 2) EXACTLY LIKE THOSE
IN ANY PRECEDING STORY? IF NOT--PUT NO, IF YES--LIKE WHICH?
L 1

COLUMN CROSS SECTION PROPERTIES:
THIS SET OF DATA IS TO BE PUT VERTICALLY COLUMN BY COLUMN IN
EACH COL.LINE AND THIS WAY COL.LINE BY COL.LINE, FROM LEFT

COLUMN LINE 1:
ARE ALL THE COLUMNS IN THIS COLUMN LINE OF
CONCRETE RECTANGULAR SECTIONS OR OTHER? C/0
C

STORY NO. 1:
PUT THE COLUMN WIDTH ACROSS THE PLANE OF FRAME AND THEN
THE WIDTH IN THE PLANE OF FRAME, SEPARATED BY A BLANK
16 12

STORY NO. 2:
PUT THE COLUMN WIDTH ACROSS THE PLANE OF FRAME AND THEN
THE WIDTH IN THE PLANE OF FRAME, SEPARATED BY A BLANK
14 12

THIS SET OF DATA IS COMPLETE UPTO COL.LINE 1
NOW, ARE THE COLUMNS IN THE NEXT COL.LINE EXACTLY
LIKE THOSE IN ANY PRECEDING COLUMN LINE?
IF NOT--PUT NO, IF YES--LIKE WHICH?
L 1

COLUMN MOD. OF ELASTICITY AND MOD. OF ROGIDITY:
ARE THE MODULI OF ELASTICITY SAME FOR ALL THE COLUMNS
IN THIS FRAME GROUP? Y/N
Y

PUT THE MOD. OF ELASTICITY AND THEN
THE MOD. OF RIGIDITY, SEPARATED BY A BLANK
3000 1150
SHEAR COEFFICIENTS FOR COLUMNS

COLUMN LINE 1:

FOR COLUMN AT STORY NO. 1
7.833 TO 2

THIS SET OF DATA IS COMPLETE UPTO COLUMN 1.
NOW, ARE THE SHEAR COEFFICIENTS OF THE COLUMNS IN THE NEXT COLUMN EXACTLY LIKE THOSE IN ANY PRECEDING COLUMN?
IF NOT---PUT NO, IF YES---LIKE WHICH?
?L 1

LOAD CASE INFORMATION DATA:
HOW MANY GRAVITY LOAD CASES (MAX. 4) YOU WANT TO INCLUDE IN YOUR ANALYSIS?
?4

HOW MANY LATERAL LOAD CASES (MAX. 3) YOU WANT TO INCLUDE IN YOUR ANALYSIS?
?3

DO YOU WANT TO INCLUDE EARTHQUAKE LOADS IN ANALYSIS? Y/N
?Y

HOW MANY LOAD SYSTEMS (LOAD COMBINATIONS) DO YOU WANT FOR THE ABOVE LOAD CASES?
?

DO YOU WANT OUTPUT FOR THE STRUCTURAL MODE SHAPES AND FREQUENCIES? Y/N?
?Y

DO YOU WANT OUTPUT FOR STORY SHEARS AND OTHER FORCES AND MOMENTS FOR DYNAMIC ANALYSIS? Y/N?
?Y

FOR THREE DIMENSIONAL ANALYSIS:
NO. OF DEGREES OF FREEDOM PER STORY? 1/2/3

1 FOR X-TRANSLATION ONLY
2 FOR Y-TRANSLATION ONLY
3 FOR X, Y-TRANSLATION AND ROTATION
?3
LOAD SYSTEMS INFORMATION DATA:
LOAD SYSTEMS MUST BE ARRANGED (NUMBERED) SEQUENTIALLY
ACCORDING TO THE FOLLOWING PREFERENCE LIST:
LOAD SYSTEMS CONTAINING —
1. GRAVITY LOAD CASES ONLY
2. GRAVITY LOAD, AND/OR LATERAL LOAD CASES
3. GRAVITY LOAD, AND/OR LATERAL LOAD, AND/OR SEISMIC LOADS

FOR LOAD SYSTEM 1:

PUT MULT. FACTOR FOR THE GRAVITY LOAD CASE?

PUT MULT. FACTOR FOR THE LATERAL LOAD CASE?

PUT THE MULT. FACTOR FOR THE EARTHQUAKE LOAD (IF ANY)?

FOR LOAD SYSTEM 2:

PUT MULT. FACTOR FOR THE GRAVITY LOAD CASE?

PUT MULT. FACTOR FOR THE LATERAL LOAD CASE?

PUT THE MULT. FACTOR FOR THE EARTHQUAKE LOAD (IF ANY)?

FOR LOAD SYSTEM 3:

PUT MULT. FACTOR FOR THE GRAVITY LOAD CASE?

PUT MULT. FACTOR FOR THE LATERAL LOAD CASE?

PUT THE MULT. FACTOR FOR THE EARTHQUAKE LOAD (IF ANY)?

FOR LOAD SYSTEM 4:

PUT MULT. FACTOR FOR THE GRAVITY LOAD CASE?

PUT MULT. FACTOR FOR THE LATERAL LOAD CASE 2.75?

PUT THE MULT. FACTOR FOR THE EARTHQUAKE LOAD (IF ANY)? 2.8
DATA FOR GRAVITY LOAD CASES:

----------
FOR FRAME NO. 1
----------

GRAVITY LOAD CASE 1:

DATA FOR UDL GRAVITY LOADS:

PUT THE DISTRIBUTED LOAD VALUE
PER LINEAR UNIT IN EACH BEAM

STORY LEVEL 1:
FOR BEAM AT BAY NO. 1

? .07 TO 2

UDL DATA IS COMPLETE UPTO STORY LEVEL 1:
NOW, ARE THE UDL IN THE NEXT STORY BEAMS (AND MAX. UPTO)
STORY 2) EXACTLY LIKE THOSE IN ANY PRECEDING STORY?
IF NOT---PUT NO, IF YES---LIKE WHICH?

? L L

STORY LEVEL 3:

FOR BEAM AT BAY NO. 2

? .03

DATA FOR CONCENTRATED GRAVITY LOADS:
(MAX. 4 LOADS PER BEAM)

STORY LEVEL 1:
NO. OF CONC. LOADS ON THE BEAM AT BAY NO. 1
?

NO. OF CONC. LOADS ON THE BEAM AT BAY NO. 2
?

LOAD NO. 1:
PUT THE LOAD VALUE AND THEN ITS DISTANCE FROM
THE LEFT COLUMN CENTRE, SEPARATED BY A BLANK
? 4.60

CONC. LOAD DATA IS COMPLETE UPTO STORY LEVEL 1:
NOW, ARE THE LOADS AND THEIR POSITIONS IN THE NEXT STORY
(AND MAX. UPTO STORY LEVEL 2) EXACTLY LIKE THOSE
IN ANY PRECEDING STORY? IF NOT---PUT NO, IF YES---LIKE WHICH?

? L L

STORY LEVEL 3:

NO. OF CONC. LOADS ON THE BEAM AT BAY NO. 2
?

GRAVITY LOAD DATA IS COMPLETE UPTO FRAME NO. 1
NOW, ARE THESE DATA IN THE NEXT FRAME ( AND UPTO FRAME NO. 2 )
EXACTLY SAME ( FOR ALL GR. LOAD CASES ) AS THOSE IN
FRAME NO. 1 ? Y/N
?

----------
FOR FRAME NO. 3
----------

GRAVITY LOAD CASE 1 :

DATA FOR UDL GRAVITY LOADS :
PUT THE DISTRIBUTED LOAD VALUE PER LINEAR UNIT IN EACH BEAM
STORY LEVEL 1 :

FOR BEAM AT BAY NO. 1
?

UDL DATA IS COMPLETE UPTO STORY LEVEL 1 :
NOW, ARE THE UDL IN THE NEXT STORY BEAMS ( AND MAX. UPTO STORY 3 ) EXACTLY LIKE THOSE IN ANY PRECEDING STORY ? IF NOT——PUT NO, IF YES——LIKE WHICH ?
?

UDL DATA IS COMPLETE UPTO STORY LEVEL 2 :
NOW, ARE THE UDL IN THE NEXT STORY BEAMS ( AND MAX. UPTO STORY 3 ) EXACTLY LIKE THOSE IN ANY PRECEDING STORY ? IF NOT——PUT NO, IF YES——LIKE WHICH ?
?

STORY LEVEL 3 :

FOR BEAM AT BAY NO. 1
?

DATA FOR CONCENTRATED GRAVITY LOADS :
(MAX. 4 LOADS PER BEAM)
STORY LEVEL 1 :

NO. OF CONC. LOADS ON THE BEAM AT BAY NO. 1
?

LOAD NO. 1 :
PUT THE LOAD VALUE AND THEN ITS DISTANCE FROM THE LEFT COLUMN CENTRE, SEPARATED BY A BLANK
?

CONC. LOAD DATA IS COMPLETE UPTO STORY LEVEL 1 :
NOW, ARE THE LOADS AND THEIR POSITIONS IN THE NEXT STORY ( AND MAX. UPTO STORY LEVEL 3 ) EXACTLY LIKE THOSE IN ANY PRECEDING STORY ? IF NOT——PUT NO, IF YES——LIKE WHICH ?
?
CONC. LOAD DATA IS COMPLETE UPTO STORY LEVEL 2
NOW, ARE THE LOADS AND THEIR POSITIONS IN THE NEXT STORY
( AND MAX. UPTO STORY LEVEL 3 ) EXACTLY LIKE THOSE
IN ANY PRECEDING STORY? IF NOT---PUT NO, IF YES---LIKE WHICH?

STORY LEVEL 3 :
NO. OF CONC. LOADS ON THE BEAM AT BAY NO. 1

GRAVITY LOAD DATA IS COMPLETE UPTO FRAME NO. 3
NOW, ARE THESE DATA IN THE NEXT FRAME ( AND UPTO FRAME NO. 4)
EXACTLY SAME ( FOR ALL GR. LOAD CASES ) AS THOSE IN
FRAME NO. 3 ? Y/N

Y

---------------
FOR FRAME NO. 5
---------------

GRAVITY LOAD CASE 1 :

DATA FOR UDL GRAVITY LOADS :

PUT THE DISTRIBUTED LOAD VALUE
PER LINEAR UNIT IN EACH BEAM
STORY LEVEL 1 :
FOR BEAM AT BAY NO. 1

UDL DATA IS COMPLETE UPTO STORY LEVEL 1 :
NOW, ARE THE UDL IN THE NEXT STORY BEAMS ( AND MAX. UPTO
STORY 2 ) EXACTLY LIKE THOSE IN ANY PRECEDING STORY?
IF NOT---PUT NO, IF YES---LIKE WHICH?

L I

DATA FOR CONCENTRATED GRAVITY LOADS :
(MAX. LOADS PER BEAM)
STORY LEVEL 1 :

NO. OF CONC. LOADS ON THE BEAM AT BAY NO. 1

CONC. LOAD DATA IS COMPLETE UPTO STORY LEVEL 1 :
NOW, ARE THE LOADS AND THEIR POSITIONS IN THE NEXT STORY
( AND MAX. UPTO STORY LEVEL 2 ) EXACTLY LIKE THOSE
IN ANY PRECEDING STORY? IF NOT---PUT NO, IF YES---LIKE WHICH?
LIKE I
DATA FOR LATERAL LOAD CASES

LATERAL LOAD CASE 1

STORY NO. 1
PUT HORIZONTAL LOAD COMPONENT IN GLOBAL X-DIRECTION AND THEN COMPONENT IN THE Y-DIRECTION, SEPARATED BY A BLANK

PUT THE X-DISTANCE AND THEN THE Y-DISTANCE OF THE POINT OF ACTION FROM GLOBAL ORIGIN

LOAD AND DISTANCE DATA IS COMPLETE UPTO STORY 1
NOW, ARE THESE DATA IN THE NEXT STORY EXACTLY LIKE THOSE IN ANY PRECEDING STORY? IF NOT—PUT NO, IF YES—LIKE WHICH?

STORY NO. 2
PUT HORIZONTAL LOAD COMPONENT IN GLOBAL X-DIRECTION AND THEN COMPONENT IN THE Y-DIRECTION, SEPARATED BY A BLANK

PUT THE X-DISTANCE AND THEN THE Y-DISTANCE OF THE POINT OF ACTION FROM GLOBAL ORIGIN

LOAD AND DISTANCE DATA IS COMPLETE UPTO STORY 2
NOW, ARE THESE DATA IN THE NEXT STORY EXACTLY LIKE THOSE IN ANY PRECEDING STORY? IF NOT—PUT NO, IF YES—LIKE WHICH?

STORY NO. 3
PUT HORIZONTAL LOAD COMPONENT IN GLOBAL X-DIRECTION AND THEN COMPONENT IN THE Y-DIRECTION, SEPARATED BY A BLANK

PUT THE X-DISTANCE AND THEN THE Y-DISTANCE OF THE POINT OF ACTION FROM GLOBAL ORIGIN

DYNAMIC ANALYSIS

NO. OF MODES TO BE CONSIDERED

NO. OF MODES TO BE EXTRACTED FROM ONE ORIGIN

DUCTILITY FACTOR

SCALE FACTOR FOR DESIGN SPECTRUM
ANGLE OF INCIDENCE OF EARTHQUAKE
WITH THE GLOBAL X-AXIS, DEGREES

?30

NO. OF PERIOD COORDINATES FOR RESPONSE SPECTRUM

?4

FOR PERIOD COORD. NO. 1:
PUT THE PERIOD VALUE AND THEN THE CORRESPONDING
SPECTRAL ACCELERATION, SEPARATED BY A BLANK

?1 3

FOR PERIOD COORD. NO. 2:
PUT THE PERIOD VALUE AND THEN THE CORRESPONDING
SPECTRAL ACCELERATION, SEPARATED BY A BLANK

?42 3

FOR PERIOD COORD. NO. 3:
PUT THE PERIOD VALUE AND THEN THE CORRESPONDING
SPECTRAL ACCELERATION, SEPARATED BY A BLANK

?5 26

FOR PERIOD COORD. NO. 4:
PUT THE PERIOD VALUE AND THEN THE CORRESPONDING
SPECTRAL ACCELERATION, SEPARATED BY A BLANK

?!5 .029

PERIOD WHICH SEPARATES THE ACCL. BOUND FROM
THE VEL. BOUND ON THE RESPONSE SPECTRUM

?5

ACCELERATION DUE TO GRAVITY

?386.4

· MASS DATA ·

AT STORY LEVEL 1, TRANSLATIONAL FLOOR MASS

?2

ROTATIONAL MASS MOM. OF INERTIA

?2900.

PUT X-DISTANCE AND THEN Y-DISTANCE OF THE CENTRE OF
MASS FROM THE REFERENCE POINT, SEPARATED BY A BLANK

?180 120

THE MASS AND DISTANCE DATA IS COMPLETE UPTO STORY 1
NOW, ARE THESE DATA IN THE NEXT STORY EXACTLY LIKE THOSE
IN ANY PRECEDING STORY? IF NOT—PUT NO, IF YES—LIKE WHICH?

?L 1

THE MASS AND DISTANCE DATA IS COMPLETE UPTO STORY 2
NOW, ARE THESE DATA IN THE NEXT STORY EXACTLY LIKE THOSE
IN ANY PRECEDING STORY? IF NOT—PUT NO, IF YES—LIKE WHICH?

?W
AT STORY LEVEL 3, TRANSLATIONAL FLOOR MASS
7.06

ROTATIONAL MASS MOM. OF INERTIA
7400

PUT X-DISTANCE AND THEN Y-DISTANCE OF THE CENTRE OF
MASS FROM THE REFERENCE POINT, SEPARATED BY A BLANK
7300   120

** MAX. NO. OF FRAME STIFFNESS ELEMENTS
** REQUIRED TO BE STORED IS, NEL = 120
*STOP* 0
A2.5 DATA OUTPUT

As mentioned earlier, program AIDS rearranges the user's input and writes in three disc files on units 3, 4 and 5, the names of the files being RID1, RID2 and RID3. File RID1 contains the general structure data and earthquake spectrum loading data. File RID2 contains the frame properties data stored sequentially. File RID3 carries the static load data. Also a copy of the user's input is kept in the file named 'DUPLI' on unit 6. A printout of the data files and the input copy file is given below.
1. General Data File - RID1

**EXAMPLE BUILDING**

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| C | .30000E 04 | .12000E 04 | .83300E 00 | .10000E 02 | .15000E 02 |
| C | .30000E 04 | .11500E 04 | .83300E 00 | .12000E 02 | .16000E 02 |
| C | .30000E 04 | .11500E 04 | .83300E 00 | .12000E 02 | .12000E 02 |
| C | .30000E 04 | .11500E 04 | .83300E 00 | .12000E 02 | .12000E 02 |
| 1 | 2 | 1 |
| 2 | 1 |
| 240.000 |

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| C | .30000E 04 | .12000E 04 | .83300E 00 | .10000E 02 | .15000E 02 |
| C | .30000E 04 | .11500E 04 | .83300E 00 | .16000E 02 | .12000E 02 |
| C | .30000E 04 | .11500E 04 | .83300E 00 | .14000E 02 | .12000E 02 |
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4. Copy of User's Input, File - Dupli

EXAMPLE BUILDING

Y

5
3
2
120 TO 2
100

1

X

0
WEST-S
1
X
240
WEST-N
2
Y
240
SOUTH-MID
2
Y
360
SOUTH-E
3
Y
0
SOUTH-W
2
2
2
240
120
1
1

BEAM CROSS SECTION PROPERTIES

C
10 20 TO 2
LIKE 1
C
10 15
3000 1200
SHURE COEFFICIENTS FOR BEAMS
.833 TO 2
LIKE 1

- FINITE JOINT SIZES CONSIDERED?
- SHEAR DEFORMATIONS CONSIDERED?
- NO. OF FRAMES
- NO. OF FRAMES GROUPS
- NO. OF STORIES
- NO. OF BAYS IN THE WIDEST FRAME
- STORY HT. BETWN. LEVELS 0 AND 1
- STORY HT. BETWN. LEVELS 2 AND 3
- FOR FRAME 1, FRAME GR. NO.
- ORIENTATION OF THE FRAME
- DIST. FROM REF. POINT
- LEFT IDENTIFICATION
- FOR FRAME 2, FRAME GR. NO.
- ORIENTATION OF THE FRAME
- DIST. FROM REF. POINT
- LEFT IDENTIFICATION
- FOR FRAME 3, FRAME GR. NO.
- ORIENTATION OF THE FRAME
- DIST. FROM REF. POINT
- LEFT IDENTIFICATION
- FOR FRAME 4, FRAME GR. NO.
- ORIENTATION OF THE FRAME
- DIST. FROM REF. POINT
- LEFT IDENTIFICATION
- FOR FRAME 5, FRAME GR. NO.
- ORIENTATION OF THE FRAME
- DIST. FROM REF. POINT
- LEFT IDENTIFICATION
- NO. OF TOWERS IN FRAME GR. 1
- IN TOWER 1, NO. OF STORIES
- NO. OF BAYS
- BAY LENGTH FOR BAY NO. 1
- BAY LENGTH FOR BAY NO. 2
- IN TOWER 2, NO. OF STORIES
- NO. OF BAYS
- BAY-SETBACK AT LEFT BETWN TOWR 1 & 2

- SECTION TYPE, STORY 1
- BEAM AT BAY 1
- COMPLETE UPTO STORY 1, NEXT?
- SECTION TYPE, STORY 3
- BEAM AT BAY 2
- ARE MOD. OF ELAST. SAME FOR ALL BEAMS?
- VALUES OF MOD. OF ELAST & RIGIDITY
- BEAM AT BAY 1
- COMPLETE UPTO STORY 1, NEXT?
- BEAM AT BAY 2
COLUMN CROSS SECTION PROPERTIES

C
12 16
12 14
C
16 18
12 16
12 12
LIKE 2
Y - ARE MOD. OF ELAST. SAME FOR ALL COLUMNS?
Y

3000 1150
SHEAR COEFFICIENTS FOR COLUMNS
.833 TO 2
.833 TO 3

L 2
1
3
1

240
BEAM CROSS SECTION PROPERTIES

C
10 18
L 1
N
C
10-15
Y - ARE MOD. OF ELAST. SAME FOR ALL BEAMS?
Y

3000 1200
SHEAR COEFFICIENTS FOR BEAMS
.833
L 1 TO 3

COLUMN CROSS SECTION PROPERTIES

C
18 16
16 12
12 12
L 1
Y - ARE MOD. OF ELAST. SAME FOR ALL COLUMNS?

3000 1150
SHEAR COEFFICIENTS FOR COLUMNS
.833 TO 3

L 1
2
1

240
BEAM CROSS SECTION PROPERTIES

C
10 15
L 1
Y - ARE MOD. OF ELAST. SAME FOR ALL BEAMS?

3000 1200
SHEAR COEFFICIENTS FOR BEAMS
.833
SHEAR COEFFICIENTS FOR BEAMS

- BEAM AT BAY 1
  - COMPLETE UPTO STORY 1, NEXT?
  - COLUMN AT STORY 1
  - COLUMN AT STORY 2

- X-SECTION TYPE AT COL. LINE 1
  - COLUMN AT STORY 1
  - COLUMN AT STORY 2

- COMPLETE UPTO COL. LINE 1, NEXT?
  - VALUES OF MOD. OF ELAST & RIGIDITY

- COLUMN AT STORY 1
  - COMPLETE UPTO COL. LINE 1, NEXT?
  - NO. OF CAVITY LOAD CASES
  - NO. OF LATERAL LOAD CASES
  - SEISMIC LOADS CONSIDERED?
  - NO. OF LOAD SYSTEMS CONSIDERED
  - OUTPUT FOR MODE SHAPES REQD?
  - OUTPUT FOR DYN. STORY FORCES REQD?
  - CODE FOR STORY DEGREES OF FREEDOM
  - IN LOAD SYS1, FACTRS FOR GRVT LOADS
  - IN LOAD SYS1, FACTRS FOR LATH LOADS
  - FACTR FOR BIOSEISMIC LOADS, LOAD SYS1
  - IN LOAD SYS1, FACTRS FOR GRVT LOADS
  - IN LOAD SYS1, FACTRS FOR LATH LOADS
  - FACTR FOR SEISMIC LOADS, LOAD SYSM 1
  - IN LOAD SYS1, FACTRS FOR GRVT LOADS
  - IN LOAD SYS1, FACTRS FOR LATH LOADS
  - FACTR FOR SEISMIC LOADS, LOAD SYSM 1
  - IN LOAD SYS1, FACTRS FOR GRVT LOADS
  - IN LOAD SYS1, FACTRS FOR LATH LOADS
  - FACTR FOR SEISMIC LOADS, LOAD SYSM 1
  - IN LOAD SYS1, FACTRS FOR GRVT LOADS
  - IN LOAD SYS1, FACTRS FOR LATH LOADS
  - FACTR FOR SEISMIC LOADS, LOAD SYSM 1

GRAVITY LOAD CASE DATA

UDL - FRAME 1, GRVT LOAD CASE 1

- BEAM AT BAY 1
  - COMPLETE UPTO STORY 1, NEXT?
  - BEAM AT BAY 2

- NO. OF CONCTD. LOADS, BEAM 1, STORY 1
  - NO. OF CONCTD. LOADS, BEAM 2, STORY 1
  - LOAD - "1 & DIST.

- COMPLETE UPTO STORY 1, NEXT?
  - NO. OF CONCTD. LOADS, BEAM 2, STORY 1
  - COMPLETE UPTO FRAME 1, NEXT-SAME?

UDL - FRAME 2, GRVT LOAD CASE 1

- BEAM AT BAY 1
  - COMPLETE UPTO STORY 1, NEXT?

- COMPLETE UPTO STORY 2, NEXT?
  - BEAM AT BAY 1

- NO. OF CONCTD. LOADS, BEAM 1, STORY 1
  - LOAD - 1 & DIST.

- COMPLETE UPTO STORY 1, NEXT?
  - COMPLETE UPTO STORY 2, NEXT?
  - NO. OF CONCTD. LOADS, BEAM 1, STORY 2

- COMPLETE UPTO FRAME 3, NEXT-SAME?
UDL - FRAME 5, GRVT LOAD CASE 1

0.07
L 1
0
LIKE 1
4 6
180 120
N
4 4
204 120
N
1.6 1
300 120

DYNAMIC ANALYSIS:
9
5.
4
0.08
30
4
1.3
.42 3
5 .26
15 .029
.5
386.4

MASS DATA:
2
2900
180 120
L 1
N
.06
400
300 120

- BEAM AT BAY 1
- COMPLETE UPTO STORY 1, NEXT?
- NO. OF CONC'D. LOADS, BEAM 1, STORY 1
- COMPLETE UPTO STORY 1, NEXT?
- LAT. LOAD X-, Y-COMPTS FOR CASE 1
- X-DIST & Y-DIST
- COMPLETE UPTO STORY 1, NEXT?
- LAT. LOAD X-, Y-COMPTS FOR CASE 1
- X-DIST & Y-DIST
- COMPLETE UPTO STORY 2, NEXT?
- LAT. LOAD X-, Y-COMPTS FOR CASE 1
- X-DIST & Y-DIST
- NO. OF MODES CONSIDERED
- MODES EXTRACTED FROM ONE ORIGIN
- DUCTILITY FACTOR
- SCALE FACTOR
- ANGLE OF INCIDENCE
- NO. OF PERIOD COORDS.
- PERIOD & ACCLN. OF COORD. 1
- PERIOD & ACCLN. OF COORD. 2
- PERIOD & ACCLN. OF COORD. 3
- PERIOD & ACCLN. OF COORD. 4
- PERIOD BOUND
- ACCLN. DUE TO GRAVT.

- MASS AT STORY 1
- MASS MOM. OF INERTIA
- X-DIST & Y-DIST FROM REF POINT
- COMPLETE UPTO STORY 1, NEXT?
- COMPLETE UPTO STORY 2, NEXT?
- MASS AT STORY 3
- MASS MOM. OF INERTIA
- X-DIST & Y-DIST FROM REF POINT.
CHAPTER A3

ANALYSIS PROGRAM ANGELS

A3.1 FUNCTION

The program is designed to perform a complete three-dimensional analysis of multistoried buildings consisting of rigid frame and/or frame-shearwall systems based on the assumptions described in Chapter A1. Any substructure within the building may be a regular or a setback frame or frame-wall. The analysis is based on the assumption that beams are axially rigid but columns can deform axially. Flexural deformations are, of course, considered. In addition, the following options are available:

i) Shear deformations in the beams and columns may be accounted for provided the modulus of rigidity and the shear coefficients are specified. Such deformations will be disregarded if any of these items is assigned a value of zero. In fact, program AIDS asks the user whether he wishes to consider shear deformations and if he replies with an N, the computer will automatically set the shear coefficients to zero.

ii) Finite joint sizes may be considered in the analysis.

Program ANGELS can analyze a building for:

1) a maximum of 4 gravity load cases (GL1, GL2, GL3, GL4)
2) a maximum of 3 lateral load cases (WL1, WL2, WL3)
3) one lateral earthquake load case supplied through a design spectrum (EL)
The above-stated load cases can be combined to form any number of load combinations. A load combination is defined by specifying the multiplication factors applicable to its component loads. One such load combination is called a 'load system'. It may be formed, for example, from the expression $aGL_2+bWl+cEL$, where $a$, $b$ and $c$ are called load case multipliers.

In addition, if required, the program can evaluate three-dimensional mode shapes and frequencies of the building. Also, at the user's option, the modal story forces and displacements of the building (adjusted for ductility) for a specified design elastic spectrum may be calculated and printed out.

A3.2 BASIC OPERATION

An outline flow diagram showing the program operation is shown in Fig. A.6. The basic operations can be divided into the following major steps:

1. The first operation performed by the main program is to read and print out the basic control information and the global data associated with the building. This data is read from the disc file on unit 1.

2. The program next reads the properties of all substructures of the building from the disc file on unit 2. This data is then adapted for use in the calculations of stiffnesses and member forces. The program produces an echo print of the input data.
and writes its adapted version on a file on unit 4. The operations in this step are performed by subroutine PROP.

3. The next operation involves the formation of the frame stiffness matrices for each different frame or frame-shearwall in the building using frame property data written on unit 4. The program keeps a record of the diagonal addresses of the stiffness matrices and assigns suitable indices to the side sway degrees of freedom. The stiffness matrices and the associated records are stored sequentially on a disc file or a tape on unit 5. The operations are performed by subroutine STIFF.

4. The above stiffness matrices are then reduced one by one using Crout reduction method and stored sequentially on a disc file (or a tape) on unit 6 (subroutine REDUCE).

5. The gravity load data is then read from the disc file on unit 3, load vectors are prepared and an echo print of the input load data is produced (subroutine LOAD). Gravity load analysis is then carried out for each frame for all gravity load cases. The operations are performed by subroutine GRAVIT which calls subroutine RSUB. The resulting joint displacement vectors are sequentially written on a disc file on unit 8 for use in step 15.

6. The next operation involves the formation of a side sway stiffness matrix for each individual frame and shearwall in the building by static condensation of the frame stiffness matrix which is retrieved from unit 5. The side sway stiffness matrices
are then sequentially written on the disc file on unit 2. The
operation is performed by subroutine COND which calls sub-
routine CONDEN, REDUCE and BSUB.

7. Story mass data is then read from the disc file on unit 1 and
printed out. This data includes the location of mass centers,
at each floor and the story translation and rotational masses.
The operations are carried out by subroutine STORY which also
assembles the global mass matrix.

8. The program next assembles the global stiffness matrix using
frame sidesway stiffness matrix retrieved from unit 2, and the
frame location data read in step 1. Subroutine FRAME performs
these operations. The global stiffness matrix is written on a
file on unit 5 for use in step 10.

9. The program next reads the lateral load data for the building
from the file at unit 3, for a maximum of 3 different lateral
load cases and prints it out. The structure is then analyzed
for these lateral loads. Frame lateral story forces are cal-
culated and written on a file on unit 1 for use in step 13.
These operations are accomplished by subroutine HLOAD which
calls subroutines RECIP and SFORCE.

10. The mode shapes and frequencies of the building are then
evaluated by subroutine EIGVAL, which is called through sub-
routine SPCTRZ.
11. The modal response is next calculated using the specifications of the design elastic spectrum read by the main program in step 1. The seismic design forces and displacements along the global coordinates are worked out and the values obtained are adjusted for ductility before being printed out at the user's option. The operations are performed by the subroutine SPCTRM which calls subroutine RESP.

12. From the adjusted elastic modal displacements worked out in step 11 and the frame location data read earlier, the modal floor story forces are worked out for each frame and stored sequentially on a disc file on unit 1 for subsequent use. The operations described in this step are carried out by subroutine SFORCE.

13. The program next retrieves from unit 1 the frame lateral story forces calculated in step 9, forms joint load vectors and solves for joint displacements (subroutine ROOT) for each lateral load case. The joint displacements are written sequentially on a file on unit 3 for use in step 15.

14. Using the modal frame story forces evaluated in step 12, the program then computes the root-sum-square forces for the members in each frame of the building and writes them down on a tape or disc file on unit 5 for use in step 15. These operations also are performed by subroutine ROOT which calls subroutines BSUB and FORCE.
LEAF 65 OMITTED IN PAGE NUMBERING.
START

Read and print basic control data and load system data for the building.

Read and print frame properties, data, prepare an adapted version of the data and write it on a disc file.

Assemble frame stiffness matrices.

Reduce frame stiffness matrices by Crout method.

Read gravity load data and evaluate the joint displacement vectors for each frame.

Form frame sidesway stiffness matrices by static condensation of the frame stiffnesses.

Read and print story mass data and assemble global mass matrix.

Assemble global stiffness matrix from frame lateral stiffness matrices.

Read and print lateral load data and for each frame find story lateral loads for each lateral load case.

Evaluate mode shapes and frequencies of the building. Also print them out.

STOP

A

A

Perform spectral analysis and print modal story forces and displacements for the building.

Calculate modal story forces and displacements for each frame.

Calculate joint displacements for each lateral load case.

Find member forces due to spectral story forces for each mode and calculate root-sum-square forces for each frame of the building.

For each frame, retrieve the displacement vectors for all gravity load cases (maximum 4) and for all lateral load cases (maximum 3). Multiply them by appropriate factors to find a new displacement vector for each load system.

If the above load system includes earthquake loads, multiply the frame root-sum-square forces by the proper factor and add to the above member forces to evaluate the final member forces.

For each frame, print the final member forces for each load system.

FIG A.6 Outline flow diagram for operation of the program ANGELS.
FIG. A.7  PROGRAM ORGANIZATION AND FILE MANAGEMENT FOR PROGRAM-ANGELS
15. Finally, the program reads for each frame the displacement vectors for gravity load cases from unit 8 and for lateral load cases from unit 3. The following steps are carried out for each load system. The displacement vectors for gravity and lateral load cases are multiplied by appropriately multiplying factors defined earlier by the user (read in step 1) to form a final displacement vector. The member forces are then determined from this displacement vector. If the load system also includes earthquake loads, the root-sum-square forces are read from unit 5, multiplied by the proper factor and added to (and subtracted from) the member forces calculated above to evaluate the final member forces which are then printed out. The entire procedure described above is repeated for each frame of the building. The above operations are performed by subroutine SYSTEM which calls subroutine FORCE.

The program organization and file management for program ANGELS is shown in Fig. A.7.

A3.3 DEFINITION OF FORTRAN SYMBOLS

The FORTRAN symbols for variables have been listed here main program or subprogram wise. Variables appearing more than once in the main program and one or more subprograms have been listed only once at the time of their first appearance. Also, indices, counters and variables providing temporary locations have been omitted. Type A stands for array and type S for a scalar.
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<th>Definition</th>
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<td>S</td>
<td>acceleration due to gravity</td>
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<td>AI</td>
<td>A</td>
<td>transformation matrix required in formulating global stiffness matrix</td>
</tr>
<tr>
<td>AJ</td>
<td>A</td>
<td>transformation matrix required in formulating global stiffness matrix</td>
</tr>
<tr>
<td>ALLOW</td>
<td>S</td>
<td>value used in convergence test for extraction of mode shapes</td>
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<td>S</td>
<td>angle of incidence of earthquake with respect to the global x-axis</td>
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<td>A</td>
<td>story heights</td>
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<td>flag for the frame orientation (x or y) as read from input data file</td>
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<td>index for special output</td>
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<tr>
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<td>S</td>
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<tr>
<td>IM</td>
<td>S</td>
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<tr>
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<tr>
<td>MI</td>
<td>S</td>
<td>maximum number of iterations to be used in extracting the eigenvalue</td>
</tr>
<tr>
<td>MINCR</td>
<td>S</td>
<td>array increment in the blank common</td>
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<td>SYMBOL</td>
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<td>DEFINITION</td>
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<td>------------</td>
</tr>
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<td>A</td>
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<td>number of frames in different towers of a frame</td>
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<tr>
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<td>number of bays setback between adjacent towers of a frame</td>
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<td>orientation of the frame (x or y)</td>
</tr>
<tr>
<td>NDYN</td>
<td>S</td>
<td>number of seismic load cases (0 or 1)</td>
</tr>
<tr>
<td>NE</td>
<td>S</td>
<td>total number of stiffness elements to be stored for a frame</td>
</tr>
<tr>
<td>NEQ</td>
<td>S</td>
<td>number of degrees of freedom in a frame</td>
</tr>
<tr>
<td>NFG</td>
<td>S</td>
<td>number of frame groups in the building</td>
</tr>
<tr>
<td>NFT</td>
<td>S</td>
<td>number of frames in the building</td>
</tr>
<tr>
<td>NGR</td>
<td>S</td>
<td>number of different gravity load cases</td>
</tr>
<tr>
<td>NH</td>
<td>S</td>
<td>temporary index</td>
</tr>
<tr>
<td>NM</td>
<td>S</td>
<td>number of modes to be considered</td>
</tr>
<tr>
<td>NMLLP</td>
<td>S</td>
<td>ratio of the number of global degrees of freedom to the total number of stories in the building</td>
</tr>
<tr>
<td>NN</td>
<td>S</td>
<td>number of stories in a frame</td>
</tr>
<tr>
<td>NNS</td>
<td>S</td>
<td>total number of stories in the building</td>
</tr>
<tr>
<td>NOPT</td>
<td>S</td>
<td>story translation code to specify whether pure translation (x or y) or coupled (x, y, θ)</td>
</tr>
<tr>
<td>NP</td>
<td>S</td>
<td>number of period coordinates defining the design response spectrum</td>
</tr>
<tr>
<td>NQ</td>
<td>S</td>
<td>total global degrees of freedom</td>
</tr>
<tr>
<td>SYMBOL</td>
<td>TYPE</td>
<td>DEFINITION</td>
</tr>
<tr>
<td>--------</td>
<td>------</td>
<td>------------</td>
</tr>
<tr>
<td>NR</td>
<td>A</td>
<td>array of indices to identify frame sidesway degrees of freedom</td>
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<tr>
<td>NSS</td>
<td>A</td>
<td>number of stories in the tower of a frame</td>
</tr>
<tr>
<td>NSYS</td>
<td>S</td>
<td>number of load combinations to be considered</td>
</tr>
<tr>
<td>NT</td>
<td>S</td>
<td>number of towers in a frame</td>
</tr>
<tr>
<td>NWL</td>
<td>S'</td>
<td>number of different lateral load cases</td>
</tr>
<tr>
<td>SAC</td>
<td>A</td>
<td>acceleration coordinates in the response spectrum</td>
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<tr>
<td>SF</td>
<td>S</td>
<td>scale factor for design spectrum</td>
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<tr>
<td>SK</td>
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<td>array in blank common containing the major variables referred to in the program</td>
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<td>SLD</td>
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<td>load vector for a frame</td>
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<td>weight factors for different load cases to be used for the load combinations</td>
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<td>A</td>
<td>period coordinates in the response spectrum</td>
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<td>TD</td>
<td>S</td>
<td>period defining the boundary between the acceleration bound and velocity bound in the spectrum</td>
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<tr>
<td>XMU</td>
<td>S</td>
<td>ductility factor</td>
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Subroutine PROP

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<td>AB</td>
<td>A</td>
<td>beams cross-section area</td>
</tr>
<tr>
<td>AC</td>
<td>A</td>
<td>columns cross-section area</td>
</tr>
<tr>
<td>B</td>
<td>A</td>
<td>bay lengths</td>
</tr>
<tr>
<td>SYMBOL</td>
<td>TYPE</td>
<td>DEFINITION</td>
</tr>
<tr>
<td>--------</td>
<td>------</td>
<td>------------</td>
</tr>
<tr>
<td>BA</td>
<td>A</td>
<td>length of rigid end stub at left end of a beam</td>
</tr>
<tr>
<td>BB</td>
<td>A</td>
<td>length of rigid end stub at right end of a beam</td>
</tr>
<tr>
<td>BE</td>
<td>A</td>
<td>moduli of elasticity of beams</td>
</tr>
<tr>
<td>BEF</td>
<td>A</td>
<td>$\gamma = 2EI/L(1+2\alpha)$ for beams</td>
</tr>
<tr>
<td>BG</td>
<td>A</td>
<td>$\alpha = 6EI/K'AGL^2$ for beams</td>
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<tr>
<td>BI</td>
<td>A</td>
<td>beams moment of inertia</td>
</tr>
<tr>
<td>BK</td>
<td>A</td>
<td>shear coefficient for beams</td>
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<tr>
<td>BL</td>
<td>A</td>
<td>clear beam length</td>
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<td>BMCL</td>
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<td>dummy array</td>
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<td>BMG</td>
<td>A</td>
<td>beams modulus of rigidity</td>
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<td>CA</td>
<td>A</td>
<td>length of rigid end stub at lower end of a column</td>
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<td>a column $E/L$ for columns</td>
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<td>$\gamma = 2EI/L(1+2\alpha)$ for columns</td>
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<td>$\alpha = 6EI/K'AGL^2$ for columns</td>
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<td>column shear coefficients</td>
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<td>beam widths</td>
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<td>column widths in plane of frame</td>
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<td>A</td>
<td>column widths perpendicular to plane of frame</td>
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<td>index for cross-section type for columns in a column line</td>
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<td>S</td>
<td>output unit number</td>
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<td>unit number on which the modified frame properties are written</td>
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<tr>
<td>NCL</td>
<td>S</td>
<td>number of columns in a frame</td>
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<td>NFR</td>
<td>S</td>
<td>number of frames in a frame group</td>
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<tr>
<td>NQQ</td>
<td>S</td>
<td>number of degrees of freedom in a frame</td>
</tr>
<tr>
<td>NSC</td>
<td>A</td>
<td>number of stories in different column lines</td>
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<tr>
<td>OSTB</td>
<td>S</td>
<td>index to check whether or not finite joint sizes are considered</td>
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**Subroutine STIFF**

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<td>AK</td>
<td>A</td>
<td>frame stiffness elements within the upper half band in a compacted column string storage</td>
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<tr>
<td>ICD</td>
<td>A</td>
<td>indices to identify the sideways degree of freedom</td>
</tr>
<tr>
<td>IR</td>
<td>S</td>
<td>unit from which modified frame properties are read</td>
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<tr>
<td>SYMBOL</td>
<td>TYPE</td>
<td>DEFINITION</td>
</tr>
<tr>
<td>--------</td>
<td>------</td>
<td>------------</td>
</tr>
<tr>
<td>IW</td>
<td>S</td>
<td>unit on which stiffness matrix is written for subsequent uses</td>
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<td>total number of beams in the frame</td>
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<td>NDA</td>
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<td>diagonal addresses for the frame stiffness in a string storage</td>
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<tr>
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<td>total number of stories in the frame</td>
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<tr>
<td><strong>Subroutine GRAVT</strong></td>
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<td>A</td>
<td>A</td>
<td>reduced stiffness matrix of a frame</td>
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<td>B</td>
<td>A</td>
<td>load or displacement vector for a frame</td>
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<tr>
<td>FC</td>
<td>A</td>
<td>dummy array</td>
</tr>
<tr>
<td>FX1</td>
<td>A</td>
<td>fixed end moments at left end of beams</td>
</tr>
<tr>
<td>FX2</td>
<td>A</td>
<td>fixed end moments at right end of beams</td>
</tr>
<tr>
<td>FX3</td>
<td>A</td>
<td>fixed end reactions at left end of beams</td>
</tr>
<tr>
<td>FX4</td>
<td>A</td>
<td>fixed end reaction at right end of beams</td>
</tr>
<tr>
<td>IFL</td>
<td>S</td>
<td>index to check whether the gravity loads on a frame are the same as those in the preceding frames</td>
</tr>
<tr>
<td>IR</td>
<td>S</td>
<td>unit from which gravity load data is read</td>
</tr>
<tr>
<td>NEL</td>
<td>S</td>
<td>total number of elements required to be stored in a string for the frame stiffness matrix</td>
</tr>
<tr>
<td>SYSTEM</td>
<td>TYPE</td>
<td>DEFINITION</td>
</tr>
<tr>
<td>--------</td>
<td>------</td>
<td>------------</td>
</tr>
<tr>
<td>A</td>
<td>S</td>
<td>distance of concentrated load from left column face</td>
</tr>
<tr>
<td>B</td>
<td>S</td>
<td>distance of concentrated load from right column face</td>
</tr>
<tr>
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<td>A</td>
<td>concentrated loads on a beam</td>
</tr>
<tr>
<td>DIS</td>
<td>A</td>
<td>distance of concentrated load from left column center line</td>
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<tr>
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<td>S</td>
<td>left end beam fixed end moments for gravity loads</td>
</tr>
<tr>
<td>FL2</td>
<td>S</td>
<td>left end beam fixed end reaction for gravity loads</td>
</tr>
<tr>
<td>FR1</td>
<td>S</td>
<td>right end beam fixed end moments for gravity loads</td>
</tr>
<tr>
<td>FR2</td>
<td>S</td>
<td>right end beam fixed end reactions for gravity loads</td>
</tr>
<tr>
<td>FUD1</td>
<td>S</td>
<td>fixed end moments for UDL</td>
</tr>
<tr>
<td>FUD2</td>
<td>S</td>
<td>fixed end reactions for UDL</td>
</tr>
<tr>
<td>IS</td>
<td>S</td>
<td>story number</td>
</tr>
<tr>
<td>NI</td>
<td>S</td>
<td>bay number</td>
</tr>
<tr>
<td>UDL</td>
<td>A</td>
<td>uniformly distributed loads on beams</td>
</tr>
</tbody>
</table>

<p>| Subroutine FORCE |
| BETA | A | displacement vector of a frame |
| FA   | S | final column axial load |
| FL   | S | final beam left end moment for static loads |</p>
<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>TYPE</th>
<th>DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>F2</td>
<td>S</td>
<td>final beam right end moment for static loads</td>
</tr>
<tr>
<td>F3</td>
<td>S</td>
<td>final beam left end reaction for static loads</td>
</tr>
<tr>
<td>F4</td>
<td>S</td>
<td>final beam right end reaction for static loads</td>
</tr>
<tr>
<td>FC1</td>
<td>A</td>
<td>root-sum-square value of column top moment from dynamic analysis</td>
</tr>
<tr>
<td>FC2</td>
<td>A</td>
<td>root-sum-square value of column bottom moment from dynamic analysis</td>
</tr>
<tr>
<td>FC3</td>
<td>A</td>
<td>root-sum-square value of column axial load</td>
</tr>
<tr>
<td>FC4</td>
<td>A</td>
<td>root-sum-square value of column shear force from dynamic analysis</td>
</tr>
<tr>
<td>FMB</td>
<td>S</td>
<td>final column bottom moment</td>
</tr>
<tr>
<td>FMT</td>
<td>S</td>
<td>final column top moment</td>
</tr>
<tr>
<td>FS</td>
<td>S</td>
<td>final column shear</td>
</tr>
<tr>
<td>FXL</td>
<td>S</td>
<td>beam left end moment</td>
</tr>
<tr>
<td>FX2</td>
<td>S</td>
<td>beam right end moment</td>
</tr>
<tr>
<td>FX3</td>
<td>A</td>
<td>beam left end reaction</td>
</tr>
<tr>
<td>FX4</td>
<td>A</td>
<td>beam right end reaction</td>
</tr>
<tr>
<td>NBA</td>
<td>A</td>
<td>number of bays in the different towers of a frame</td>
</tr>
<tr>
<td>OPT</td>
<td>S</td>
<td>a control index</td>
</tr>
<tr>
<td>SQB1</td>
<td>A</td>
<td>root-sum-square value of beam left end moment in a frame</td>
</tr>
<tr>
<td>SQB2</td>
<td>A</td>
<td>root-sum-square value of beam right end moment in a frame</td>
</tr>
<tr>
<td>SYMBOL</td>
<td>TYPE</td>
<td>DEFINITION</td>
</tr>
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<td>------</td>
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</tr>
<tr>
<td>SQB3</td>
<td>A</td>
<td>root-sum-square value of beam left end reaction in a frame</td>
</tr>
<tr>
<td>SQB4</td>
<td>A</td>
<td>root-sum-square value of beam right end reaction in a frame</td>
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**Subroutine COND**

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<tr>
<td>IR</td>
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<td>input unit number</td>
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<tr>
<td>IW</td>
<td>S</td>
<td>output unit number</td>
</tr>
<tr>
<td>MM</td>
<td>S</td>
<td>size of the condensed stiffness matrix</td>
</tr>
<tr>
<td>NL</td>
<td>S</td>
<td>number of elements to be stored for frame stiffness</td>
</tr>
<tr>
<td>SC</td>
<td>A</td>
<td>frame sidesway stiffness matrix</td>
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<tr>
<td>TA</td>
<td>A</td>
<td>temporary storage array used in condensation</td>
</tr>
<tr>
<td>TX</td>
<td>A</td>
<td>temporary storage array</td>
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**Subroutine CONDEN**

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<td>A</td>
<td>number of degrees of freedom other than sidesway degrees of freedom</td>
</tr>
<tr>
<td>NC</td>
<td>A</td>
<td>number of sidesway degrees of freedom</td>
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**Subroutine DOTPRD**

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<tr>
<td>C,D</td>
<td>S</td>
<td>temporary array to perform matrix multiplication</td>
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<tr>
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### Subroutine REDUCE

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<td>output unit number</td>
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<tr>
<td>LI</td>
<td>S</td>
<td>integer indicating the row number of the first non-zero element in column I of the matrix</td>
</tr>
<tr>
<td>LJ</td>
<td>S</td>
<td>integer indicating the row number of the first non-zero element in column J of a matrix</td>
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### Subroutine BSUB

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<tr>
<td>B</td>
<td>A</td>
<td>load/displacement vector</td>
</tr>
<tr>
<td>LI</td>
<td>S</td>
<td>integer indicating the row number of the first non-zero element in column I of the matrix</td>
</tr>
<tr>
<td>NB</td>
<td>S</td>
<td>row number of the first non-zero element in the load vector</td>
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### Subroutine ROOT

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<td>root-sum-square forces for beams</td>
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<tr>
<td>FB3,FB4</td>
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<tr>
<td>FC1,FC2</td>
<td>A</td>
<td>root-sum-square forces for columns</td>
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<tr>
<td>FC3,FC4</td>
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<td></td>
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<tr>
<td>IR,IRR,IRI</td>
<td>S</td>
<td>input unit numbers</td>
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<tr>
<td>IW</td>
<td>S</td>
<td>output unit number</td>
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<tr>
<td>NFG</td>
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<td>total number of frame groups in a building</td>
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<tr>
<td>SYMBOL</td>
<td>TYPE</td>
<td>DEFINITION</td>
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<tr>
<td>SM</td>
<td>A</td>
<td>global mass vector</td>
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<td>XBAR</td>
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<td>X distance of the story mass centre from the reference point</td>
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<tr>
<td>XM</td>
<td>S</td>
<td>story mass</td>
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<tr>
<td>XM1</td>
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<td>story mass moment of inertia</td>
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<tr>
<td>YBAR</td>
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<td>y distance of the story mass centre from the reference point</td>
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<table>
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<tr>
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<tr>
<td>DD</td>
</tr>
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</tr>
<tr>
<td>FORCE2</td>
</tr>
<tr>
<td>G</td>
</tr>
<tr>
<td>NA</td>
</tr>
<tr>
<td>NP</td>
</tr>
<tr>
<td>SAC</td>
</tr>
<tr>
<td>SHEAR1</td>
</tr>
<tr>
<td>SHEAR2</td>
</tr>
<tr>
<td>T</td>
</tr>
<tr>
<td>TC</td>
</tr>
<tr>
<td>TD</td>
</tr>
<tr>
<td>VAL</td>
</tr>
<tr>
<td>VEC</td>
</tr>
<tr>
<td>XMULD</td>
</tr>
<tr>
<td>XMULP</td>
</tr>
<tr>
<td>SYMBOL</td>
</tr>
<tr>
<td>--------</td>
</tr>
<tr>
<td>Subroutine EIGVAL</td>
</tr>
<tr>
<td>ALFA</td>
</tr>
<tr>
<td>BETAA</td>
</tr>
<tr>
<td>CMAX</td>
</tr>
<tr>
<td>ERMAX</td>
</tr>
<tr>
<td>ERR</td>
</tr>
<tr>
<td>NT</td>
</tr>
<tr>
<td>NVT</td>
</tr>
<tr>
<td>R1</td>
</tr>
<tr>
<td>SH</td>
</tr>
<tr>
<td>VT</td>
</tr>
<tr>
<td>VVT</td>
</tr>
</tbody>
</table>

| Subroutine RESP |      |            |
| SI    | S    | modal participation factor |
| F     | A    | seismic story force in a frame |
| X     | A    | seismic story displacement in a frame |
### Subroutine HLOAD

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>TYPE</th>
<th>DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>DA</td>
<td>A</td>
<td>global displacement vectors for lateral loads</td>
</tr>
<tr>
<td>DN</td>
<td>S</td>
<td>frame story lateral displacements</td>
</tr>
<tr>
<td>DX</td>
<td>A</td>
<td>x-coordinates of the point of action of the story lateral forces from the reference point</td>
</tr>
<tr>
<td>DY</td>
<td>A</td>
<td>y-coordinates of the point of action of the story lateral forces from the reference point</td>
</tr>
<tr>
<td>F</td>
<td>A</td>
<td>frame story lateral forces</td>
</tr>
<tr>
<td>FH</td>
<td>A</td>
<td>lateral load vector in global coordinates</td>
</tr>
<tr>
<td>HX</td>
<td>A</td>
<td>x-components of story lateral loads</td>
</tr>
<tr>
<td>HY</td>
<td>A</td>
<td>y-components of story lateral loads</td>
</tr>
<tr>
<td>IR</td>
<td>S</td>
<td>input unit number</td>
</tr>
<tr>
<td>NST</td>
<td>S</td>
<td>total number of stories in the building</td>
</tr>
<tr>
<td>S</td>
<td>A</td>
<td>condensed stiffness matrix</td>
</tr>
<tr>
<td>X</td>
<td>A</td>
<td>array size equal to the number of stories</td>
</tr>
</tbody>
</table>

### Subroutine SYSTEM

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>TYPE</th>
<th>DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>A</td>
<td>final frame displacement vector</td>
</tr>
<tr>
<td>BTA</td>
<td>A</td>
<td>unmodified frame displacement vector for different load cases</td>
</tr>
<tr>
<td>FS1,FS2</td>
<td>A</td>
<td>final fixed end load vectors</td>
</tr>
<tr>
<td>FS3,FS4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FX1,FX2</td>
<td>A</td>
<td>fixed end load vectors for different gravity load cases</td>
</tr>
<tr>
<td>FX3,FX4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
A3.4 INPUT DATA AND FORMATS

The input data required for the program ANGELS is obtained from those generated by program AIDS and stored in three data files as discussed in Section A2.5. However, the program ANGELS is designed to run also independent of program AIDS. In that case, the data is to be prepared by the user in rigid formats and kept in three unkeyed files in a manner as stored by the program AIDS. To achieve this, the necessary formats required for data input are described below.
### 1. MAIN FILE-RID1

<table>
<thead>
<tr>
<th>CARD GROUP</th>
<th>NO. OF CARDS</th>
<th>FORTRAN VARIABLES</th>
<th>FORMAT</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
<td>NAME - case title</td>
<td>40Al</td>
<td>title used to identify the problem</td>
</tr>
<tr>
<td>B</td>
<td>1</td>
<td>NFT - total no. of frames</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>NFG - no. of frame groups</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>NNS - no. of stories</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>NBA - max. no. of bays in the widest frame</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>NNS/8</td>
<td>(H(I), - story height I=1,NNS) c/c of floor beams</td>
<td>8F10.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>increased to the next higher integer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>NFT</td>
<td>II - frame no.</td>
<td>15</td>
<td>parallel to global X or Y direction (X or Y)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M - frame group no.</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>IFD - frame origination</td>
<td>4X,Al</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>DDA - perp. distance from reference point</td>
<td>F15.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>ILFT - left identification</td>
<td>3X,10Al</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>1</td>
<td>NGR - no. of gravity load cases</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>NWL - no. of lateral load cases</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>NDYN - no. of seismic load cases (=0, or 1 only)</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>NSYS - no. of load systems considered</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>IOUT - index for special output</td>
<td>15</td>
<td></td>
</tr>
</tbody>
</table>

=0, if output for mode shapes and frequencies is not required

=1, if output for mode shapes and frequencies is required

=2, if story shears are required in addition to mode shapes
<table>
<thead>
<tr>
<th>CARD</th>
<th>NO. OF CARDS</th>
<th>FORTRAN VARIABLES</th>
<th>FORMAT</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>1</td>
<td>NOPT - no. of degrees of freedom per story</td>
<td>I5</td>
<td>- a value of 1 or 2 may be used for symmetrical buildings only and will result in a substantial reduction in the computation time. - omit this card if all of NWL, NDYN and IOUT are equal to zero</td>
</tr>
<tr>
<td>G</td>
<td>NSYS</td>
<td>SMULP(I,J) * multipliers for load cases J=1,NK, NK=NGR+NW+NDYN I=1,NSYS</td>
<td>BF10.3</td>
<td>- for each load system put first the multiplier for gravity load cases, then those for the lateral load cases and then for spectrum cases. - omit this card if NSYS=0</td>
</tr>
<tr>
<td>H</td>
<td>1</td>
<td>N9M - no. of modes considered</td>
<td>I5</td>
<td>- omit this card if both IOUT and NDYN are equal to zero</td>
</tr>
<tr>
<td>I</td>
<td></td>
<td>NP - no. of period coordinates</td>
<td>I5</td>
<td>- omit if NDYN=0</td>
</tr>
<tr>
<td>J</td>
<td>NP</td>
<td>TC - period value</td>
<td>F10.3</td>
<td>- start from the first period coordinate. - spectral acceleration values are to be specified in units of g, the acceleration due to gravity. - omit these if NDYN=0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SAC - corresponding spectral acceleration</td>
<td>F10.3</td>
<td></td>
</tr>
<tr>
<td>K</td>
<td>1</td>
<td>XMU - ductility factor</td>
<td>F10.3</td>
<td>- omit this card if NDYN=0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SF - scale factor for design acceleration</td>
<td>F10.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>BETA - angle of incidence of earthquake with global X-axis, degrees</td>
<td>F10.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>TD - period which separates the acceleration bound and velocity bound</td>
<td>F10.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>AG - acceleration due to gravity (g)</td>
<td>F10.3</td>
<td></td>
</tr>
<tr>
<td>CARD GROUP</td>
<td>NO. OF CARDS</td>
<td>FORTRAN VARIABLES</td>
<td>FORMAT</td>
<td>REMARKS</td>
</tr>
<tr>
<td>------------</td>
<td>-------------</td>
<td>-------------------</td>
<td>--------</td>
<td>---------</td>
</tr>
<tr>
<td>L</td>
<td>NNS</td>
<td>XM - translational floor mass</td>
<td>F10.0</td>
<td>- include one card per story</td>
</tr>
<tr>
<td></td>
<td></td>
<td>XMI - rotational mass moment of inertia of the floor</td>
<td>F10.0</td>
<td>- omit these cards if both NDYN and IOUT are zero</td>
</tr>
<tr>
<td></td>
<td></td>
<td>XB - X-distance of the center of mass from the reference point</td>
<td>F10.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>YB - Y-distance of the center of mass from the reference point</td>
<td>F10.0</td>
<td></td>
</tr>
</tbody>
</table>
### DATA FILE FOR FRAME PROPERTIES - RID2

<table>
<thead>
<tr>
<th>CARD GROUP</th>
<th>NO. OF CARDS</th>
<th>FORTRAN VARIABLES</th>
<th>FORMAT</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
<td>NT - no. of towers in frame group</td>
<td>I5</td>
<td>- for a regular frame (not setback) NT=1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NNS - no. of stories in the frame group</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>NFR - no. of frames in the frame group</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>NT/5</td>
<td>NSS(J), - no. of stories increased J=1,NT in each tower to the next integral value</td>
<td>5I5</td>
<td>- part of the frame height containing the same number of bays is called a tower</td>
</tr>
<tr>
<td></td>
<td></td>
<td>starting from the lowest tower</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>NT/5</td>
<td>NBAY(J), - no. of bays in increased J=1,NT each tower to next integer</td>
<td>5I5</td>
<td>- start from the base tower</td>
</tr>
<tr>
<td>D</td>
<td>(NT-1)/5</td>
<td>NBS(J), - no. of bay-set-increased J=1,(NT-1) back at left, to next integer between two towers starting from the lowest</td>
<td>5I5</td>
<td>- for a regular frame (i.e. if NT=1), omit this card</td>
</tr>
<tr>
<td>E</td>
<td>1</td>
<td>B(K) - lengths of bays in K=1,NBAY(J) the base tower, starting from left,</td>
<td>8F10.3</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>1</td>
<td>OSTB - index to identify whether or not the finite joint sizes are considered</td>
<td>I5</td>
<td>OSTB=0 if finite joint sizes are not considered OSTB=1 if finite joint sizes are considered in the analysis</td>
</tr>
<tr>
<td>G</td>
<td>1</td>
<td>IBC - index for beam cross-section type</td>
<td>1X,A1</td>
<td>- include one card per story followed by the card group H or I</td>
</tr>
<tr>
<td></td>
<td></td>
<td>= C, if the cross-section is rectangular</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>= B, if the section is other than rectangular</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CARD GROUP</td>
<td>NO. OF CARDS</td>
<td>FORTRAN VARIABLES</td>
<td>FORMAT</td>
<td>REMARKS</td>
</tr>
<tr>
<td>------------</td>
<td>-------------</td>
<td>------------------</td>
<td>--------</td>
<td>---------</td>
</tr>
<tr>
<td>H</td>
<td></td>
<td>BE - beam modulus of elasticity</td>
<td>E12.6</td>
<td>if IBC=0, include one card per beam, starting from left and complete for all beams in the story - omit this group of cards if IBC=0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BMG - modulus of rigidity of beam (put zero if shear deformation is not considered)</td>
<td>E12.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>BK - shear coefficient (&lt;1) of beam (put zero if shear deformation is not considered)</td>
<td>E12.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>DBX - width of the beam</td>
<td>E12.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>DB - depth of beam</td>
<td>E12.6</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td></td>
<td>BE - same as H</td>
<td>E12.6</td>
<td>- omit this group of cards if IBC=C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BMG - same as H</td>
<td>E12.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>BK - same as H</td>
<td>E12.6</td>
<td>- if IBC=Ø, include one card per beam starting from left; complete for all beams in the story</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DB - same as H</td>
<td>E12.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>AB - area of cross section of the beam</td>
<td>E12.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>BI - moment of inertia of the beam</td>
<td>E12.6</td>
<td></td>
</tr>
<tr>
<td>J</td>
<td>1</td>
<td>ICC - index for column cross-section type</td>
<td>LX,AL</td>
<td>- include one card per column line followed by the card group K or L</td>
</tr>
<tr>
<td></td>
<td></td>
<td>=C if the cross-section is rectangular</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>=Ø if the cross-section is other than rectangular</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>NSC - no. of columns in the column line</td>
<td>I5</td>
<td></td>
</tr>
<tr>
<td>K</td>
<td></td>
<td>CE - column modulus of elasticity</td>
<td>E12.5</td>
<td>- omit this group of cards if ICC=Ø</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CLG - modulus of rigidity for the column (put zero if shear deformation is not considered)</td>
<td>E12.5</td>
<td>- if ICC=C, include one card per column, starting from the lowest and complete for all columns in the column line</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CK - coefficient of shear (&lt;1) for the column (put zero if shear deformation is not considered)</td>
<td>E12.5</td>
<td></td>
</tr>
<tr>
<td>CARD GROUP</td>
<td>NO. OF CARDS</td>
<td>FORTRAN VARIABLES</td>
<td>FORMAT</td>
<td>REMARKS</td>
</tr>
<tr>
<td>------------</td>
<td>--------------</td>
<td>--------------------</td>
<td>--------</td>
<td>---------</td>
</tr>
<tr>
<td>K (cont)</td>
<td></td>
<td>DCX - width of column across E12.5</td>
<td>E12.5</td>
<td>- width of column across E12.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>the plane of frame</td>
<td></td>
<td>the plane of frame</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DC - width of column in the E12.5</td>
<td>E12.5</td>
<td>- width of column in the E12.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>plane of frame</td>
<td></td>
<td>plane of frame</td>
</tr>
<tr>
<td>L</td>
<td>no. of columns</td>
<td>CE - same as K</td>
<td>E12.5</td>
<td>- omit this group of cards if ICC=C</td>
</tr>
<tr>
<td></td>
<td>in a column</td>
<td>CLG - same as K</td>
<td>E12.5</td>
<td>- if ICC=∅ include one card per column starting</td>
</tr>
<tr>
<td></td>
<td>line</td>
<td>CK - same as K</td>
<td>E12.5</td>
<td>from the lowest and complete for all columns</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DC - same as K</td>
<td>E12.5</td>
<td>in the column line</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AC - area of cross-section of the column</td>
<td>E12.5</td>
<td>repeat the card groups J through L for all the column lines in the frame group</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CI - moment of inertia of the column</td>
<td>E12.5</td>
<td></td>
</tr>
</tbody>
</table>
3. DATA FILE FOR STATIC LOADS - RID3

<table>
<thead>
<tr>
<th>CARD GROUP</th>
<th>NO. OF CARDS</th>
<th>FORTRAN VARIABLES</th>
<th>FORMAT</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
<td>NFR - no. of frames in a group</td>
<td>I5</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>1</td>
<td>IFL - index for gravity loads repetitive over different frames =0 if the gravity load in the present frame is not similar to that of the preceding frame =1 if the load in the present frame is similar to that of the preceding frame for all gravity load cases</td>
<td>I5</td>
<td>if IFL=1, omit card groups C through E</td>
</tr>
<tr>
<td>C</td>
<td>no. of stories</td>
<td>UDL(I,J) - value of load distributed in the frame uniformly over the beam</td>
<td>8F10.3</td>
<td>include one card per story for beams in that story starting from the lowest story</td>
</tr>
<tr>
<td>D</td>
<td>1</td>
<td>NC - no. of concentrated loads on a beam, starting from the left of a story</td>
<td></td>
<td>put one card per beam followed by the card group E</td>
</tr>
<tr>
<td>E</td>
<td>1</td>
<td>CNL(I) - value of concentrated load DIS(I) - distance of the I=1,NC load from left column center line</td>
<td>F10.3</td>
<td>omit this card if NC=0 if NC&gt;0, include one card per beam and put the load value followed by its distance; continue this way for all the concentrated loads on the beam</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>repeat card groups D and E for all beams in a story and this way for all the stories in the frame</td>
</tr>
<tr>
<td>CARD GROUP</td>
<td>NO. OF CARDS</td>
<td>FORTRAN VARIABLES</td>
<td>FORMAT</td>
<td>REMARKS</td>
</tr>
<tr>
<td>------------</td>
<td>-------------</td>
<td>--------------------</td>
<td>--------</td>
<td>---------</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- then repeat card groups C through E for all gravity load cases (only if IFL=0)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- then repeat card groups B through E for all frames in a frame group; then this way continue for all frame groups in the building</td>
</tr>
<tr>
<td>F</td>
<td>no. of stories in the building</td>
<td>HX - global x-components of the story lateral load</td>
<td>F15.5</td>
<td>- omit this group of cards if NWL=0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>HY - global y-components of the story lateral load</td>
<td>F15.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>DX - x-coordinate of the point application</td>
<td>F15.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>DY - y-coordinate of the point application</td>
<td>F15.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- repeat card group F for all lateral load cases</td>
</tr>
</tbody>
</table>
A3.5 OUTPUT FROM THE PROGRAM

The program echo prints all input data and options as supplied by the user. In addition, the following outputs may be obtained:

1. Member forces in terms of end moments and shears and column axial loads may be obtained for any number of weighted combinations of a maximum of four gravity load cases, a maximum of three lateral load cases and a design response spectrum case. If finite joint sizes are specified, the above forces will be computed at the faces of the joints; otherwise, at the center's

2. Structural mode shapes and frequencies (optional).

3. For seismic response spectrum, the design values of story shears and cumulative torsional moments, story forces and torsional moments, story displacements and rotations for the structure as a whole. The design values are obtained by two different methods, one by taking the root-sum-square of the modal values, and the other by taking the sum of two absolute maximum modal values. The modal values are themselves adjusted to account for ductility. These items will be evaluated and printed out at the user's options.

A3.6 EXAMPLE OF ANALYSIS

The building shown in Fig. A.5 is analyzed. The data generated by program AIDS (as shown in Section A2.5) is input through three 'unkeyed' disc files. The previously created 'load module' of the program ANGELS is then run and the output given below is obtained.
**** ANALYSIS OF BUILDINGS FOR GRAVITY, EARTHQUAKE AND LATERAL LOADS ****

AAAAAAAA NNN  NNN  GGGGGGG  FEEEFEFEFEFE LLL  SSSSSS
AAAAAAAAAAA NNNN  NNN  GGGGGGGGG  FEEEFEFEFEFE LLL  SSSSSS
AA A A NNNNNN  NNN  GGG  GGG  FEE  LLL  SSS  SSS
AAA A AA NNNNNN  NNN  GGG  GGG  FEE  LLL  SSS  SSS
AAAAAAAAAAAA NNN  NNNN  NNN  GGGGGG  FEEEFEFEFEFE LLL  SSSSSS
AAAAAAAAAAAAA NNN  NNNN  NNN  GGGGGG  FEEEFEFEFEFE LLL  SSSSSS
AAA A A A NNNN  NNN  GGGGGGGG  FEEEFEFEFEFE LLL  SSSSSS
AAA A A A NNNN  NNN  GGGGGGGGG  FEEEFEFEFEFE LLLLLLLLLLL  SSSSSS
AAA A A A NNN  NNNN  GGGGGGGG  FEEEFEFEFEFE LLL  SSSSSS
AAA A A A NNN  NNNN  GGGGGGGGG  FEEEFEFEFEFE LLLLLLLLLLL  SSSSSS

**** ANALYSIS OF BUILDINGS FOR GRAVITY, EARTHQUAKE AND LATERAL LOADS ****

----------------------- PROGRAMMED BY -- J. U. KHANDKER -----------------------
--- DEPARTMENT OF CIVIL ENGINEERING, CARLETON UNIVERSITY, OTTAWA, CANADA ---

NAME OF PROJECT :: EXAMPLE BUILDING

TOTAL NO. OF FRAMES IN THIS BUILDING ......... = 5
TOTAL NO. OF FRAME GROUPS ......... = 3
TOTAL NO. OF STORIES IN THE BUILDING ......... = 3
NO. OF BAYS IN THE WIDEST FRAME ......... = 2

*** UNITS ARE CONSISTENT

-----------------------
FRAME POSITION DATA
-----------------------

<table>
<thead>
<tr>
<th>FRAME</th>
<th>FRAME GROUP</th>
<th>DIRECTION</th>
<th>DIST FROM ORIGIN</th>
<th>LEFT SYMBOL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>X</td>
<td>.40</td>
<td>WEST-S</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>X</td>
<td>-240.36</td>
<td>WEST-N</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>Y</td>
<td>-240.36</td>
<td>SOUTH-MID</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>Y</td>
<td>2000.56</td>
<td>SOUTH-L</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
<td>Y</td>
<td>.56</td>
<td>SOUTH-N</td>
</tr>
</tbody>
</table>
NO. OF GRAVITY LOAD CASES = 1
NO. OF LATERAL LOAD CASES = 1
NO. OF SEISMIC LOAD CASES = 1
NO. OF LOAD SYSTEMS (LOAD COMBINATIONS) = 4

STORY TRANSLATION CODE = 3
NUMBER OF MODES TO BE CONSIDERED = 9
NUMBER OF MODES TO BE EXTRACTED FROM ONE ORIGIN = 5
DUCTILITY FACTOR = 4.00
SCALE FACTOR FOR DESIGN GROUND ACCELERATION = 0.08
ANGLE OF INCIDENCE OF EARTHQUAKE = 30.00

ACCELERATION SPECTRUM

NUMBER OF PERIOD COORDS = 4
PERIOD BOUND = 0.50
ACCELERATION DUE TO GRAVITY = 386.40

<table>
<thead>
<tr>
<th>PERIOD</th>
<th>ACCELERATION</th>
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<tbody>
<tr>
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<td>3.000</td>
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<tr>
<td>0.420</td>
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</tr>
<tr>
<td>5.000</td>
<td>0.260</td>
</tr>
<tr>
<td>15.000</td>
<td>0.029</td>
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</tbody>
</table>

STORY HEIGHTS, C/C OF INTERSECTING FLOOR BEAMS

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<thead>
<tr>
<th>BETWEEN 0 AND 1</th>
<th>STORY HEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
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<td>120.030</td>
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<tr>
<td>1 AND 2</td>
<td>120.000</td>
</tr>
<tr>
<td>2 AND 3</td>
<td>130.230</td>
</tr>
</tbody>
</table>
FRAME PROPERTIES

FRAME GROUP NO. 1

NO. OF TOWERS = 2
NO. OF STORIES = 3

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<tr>
<th>TOWER</th>
<th>NO. OF BAYS</th>
<th>NO. OF STORIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

NO. OF BAYS-SETBACK AT LEFT

BETWEEN TOWERS 1 AND 2 = 1

LENGTHS OF BAYS C/C OF COLS. STARTING AT LEFT

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<tr>
<th>BAY NO.</th>
<th>LENGTH</th>
</tr>
</thead>
<tbody>
<tr>
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<tr>
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BEAM PROPERTIES

<table>
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<th>DEPTH</th>
<th>AREA</th>
<th>INERTIA</th>
<th>ELASTICITY</th>
<th>RIGIDITY</th>
<th>SH. COEF</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>C 10.00</td>
<td>20.00</td>
<td></td>
<td>3.000E+04</td>
<td>1.200E+04</td>
<td>0.833</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>C</td>
<td>10.00</td>
<td>20.00</td>
<td></td>
<td>3.000E+04</td>
<td>1.200E+04</td>
<td>0.833</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>C 10.00</td>
<td>20.00</td>
<td></td>
<td>3.000E+04</td>
<td>1.200E+04</td>
<td>0.833</td>
<td></td>
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<tr>
<td>2</td>
<td>C</td>
<td>10.00</td>
<td>20.00</td>
<td></td>
<td>3.000E+04</td>
<td>1.200E+04</td>
<td>0.833</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>C 10.00</td>
<td>15.00</td>
<td></td>
<td>3.000E+04</td>
<td>1.200E+04</td>
<td>0.833</td>
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</tbody>
</table>
### COLUMN PROPERTIES

<table>
<thead>
<tr>
<th>COLM LINE</th>
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<th>INERTIA</th>
<th>ELASTICITY</th>
<th>RIGIDITY</th>
<th>SH. COEF</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
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<td>16.00</td>
<td>.30000E 04</td>
<td>.11500E 04</td>
<td>.833</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>C</td>
<td>17.00</td>
<td>14.00</td>
<td>.30000E 04</td>
<td>.11500E 04</td>
<td>.833</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>C</td>
<td>16.00</td>
<td>18.00</td>
<td>.30000E 04</td>
<td>.11500E 04</td>
<td>.833</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>C</td>
<td>12.00</td>
<td>16.00</td>
<td>.30000E 04</td>
<td>.11500E 04</td>
<td>.833</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>3</td>
<td>C</td>
<td>12.00</td>
<td>12.00</td>
<td>.30000E 04</td>
<td>.11500E 04</td>
<td>.833</td>
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<td></td>
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<tr>
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<td>16.00</td>
<td>18.00</td>
<td>.30000E 04</td>
<td>.11500E 04</td>
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<tr>
<td></td>
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<td>C</td>
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<td>16.00</td>
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<td></td>
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<tr>
<td></td>
<td>3</td>
<td>C</td>
<td>12.00</td>
<td>12.00</td>
<td>.30000E 04</td>
<td>.11500E 04</td>
<td>.833</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**FINITE JOINT SIZES ARE CONSIDERED**

**SHEAR DEFORMATIONS ARE CONSIDERED**

---

### FRAME GROUP NO. 2

<table>
<thead>
<tr>
<th>NO. OF TOWERS</th>
<th>NO. OF STORIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TOWER</th>
<th>NO. OF BAYS</th>
<th>NO. OF STORIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>

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### LENGTHS OF BAYS C/C OF COLS. STARTING AT LEFT

<table>
<thead>
<tr>
<th>BAY NO.</th>
<th>LENGTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>240.00</td>
</tr>
</tbody>
</table>
### Beam Properties

<table>
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<tr>
<th>STORY BAY TYPE</th>
<th>WIDTH</th>
<th>DEPTH</th>
<th>AREA</th>
<th>INERTIA</th>
<th>ELASTICITY</th>
<th>RIGIDITY</th>
<th>SH.COEF</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 1 C</td>
<td>10.00</td>
<td>18.00</td>
<td></td>
<td></td>
<td>.30000E 04</td>
<td>.12000E 04</td>
<td>.833</td>
</tr>
<tr>
<td>2 1 C</td>
<td>10.00</td>
<td>18.00</td>
<td></td>
<td></td>
<td>.30000E 04</td>
<td>.12000E 04</td>
<td>.833</td>
</tr>
<tr>
<td>3 1 C</td>
<td>10.00</td>
<td>15.00</td>
<td></td>
<td></td>
<td>.30000E 04</td>
<td>.12000E 04</td>
<td>.833</td>
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</table>

### Column Properties

<table>
<thead>
<tr>
<th>COLMN LINE STORY TYPE</th>
<th>CROSS WIDTH</th>
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<th>AREA</th>
<th>INERTIA</th>
<th>ELASTICITY</th>
<th>RIGIDITY</th>
<th>SH.COEF</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 1 C</td>
<td>18.00</td>
<td>16.00</td>
<td></td>
<td></td>
<td>.30000E 04</td>
<td>.11500E 04</td>
<td>.833</td>
</tr>
<tr>
<td>2 C</td>
<td>16.00</td>
<td>12.00</td>
<td></td>
<td></td>
<td>.30000E 04</td>
<td>.11500E 04</td>
<td>.833</td>
</tr>
<tr>
<td>3 C</td>
<td>12.00</td>
<td>12.00</td>
<td></td>
<td></td>
<td>.30000E 04</td>
<td>.11500E 04</td>
<td>.833</td>
</tr>
<tr>
<td>2 1 C</td>
<td>18.00</td>
<td>16.00</td>
<td></td>
<td></td>
<td>.30000E 04</td>
<td>.11500E 04</td>
<td>.833</td>
</tr>
<tr>
<td>2 C</td>
<td>16.00</td>
<td>12.00</td>
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<td></td>
<td>.30000E 04</td>
<td>.11500E 04</td>
<td>.833</td>
</tr>
<tr>
<td>3 C</td>
<td>12.00</td>
<td>12.00</td>
<td></td>
<td></td>
<td>.30000E 04</td>
<td>.11500E 04</td>
<td>.833</td>
</tr>
</tbody>
</table>

** Finite joint sizes are considered **

** Shear deformations are considered **

---

** FRAME GROUP NO. 3 **

** NO. OF TOWERS = 1 **
** NO. OF STORIES = 2 **

<table>
<thead>
<tr>
<th>TOWER NO.</th>
<th>NO. OF BAYS</th>
<th>NO. OF STORIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>
LENGTHS OF BAYS C/C OF COLS. STARTING AT LEFT

<table>
<thead>
<tr>
<th>BAY NO.</th>
<th>LENGTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>240.00</td>
</tr>
</tbody>
</table>

BEAM PROPERTIES

<table>
<thead>
<tr>
<th>STORY</th>
<th>BAY TYPE</th>
<th>WIDTH</th>
<th>DEPTH</th>
<th>AREA</th>
<th>INERTIA</th>
<th>ELASTICITY</th>
<th>RIGIDITY</th>
<th>SH. COEF</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>C</td>
<td>10.00</td>
<td>15.00</td>
<td></td>
<td>.30000E+04</td>
<td>.12000E+04</td>
<td>.833</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>C</td>
<td>10.00</td>
<td>15.00</td>
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<td>.30000E+04</td>
<td>.12000E+04</td>
<td>.833</td>
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COLUMN PROPERTIES

<table>
<thead>
<tr>
<th>COLM LINE</th>
<th>STORY</th>
<th>TYPE</th>
<th>CROSS WIDTH</th>
<th>WIDTH</th>
<th>AREA</th>
<th>INERTIA</th>
<th>ELASTICITY</th>
<th>RIGIDITY</th>
<th>SH. COEF</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>C</td>
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<td>12.00</td>
<td></td>
<td>.30000E+04</td>
<td>.11500E+04</td>
<td>.833</td>
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<tr>
<td></td>
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<td>12.00</td>
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<td>.30000E+04</td>
<td>.11500E+04</td>
<td>.833</td>
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<td>2</td>
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<td>C</td>
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<td>12.00</td>
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<td>.30000E+04</td>
<td>.11500E+04</td>
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<td>.30000E+04</td>
<td>.11500E+04</td>
<td>.833</td>
<td></td>
</tr>
</tbody>
</table>

** FINITE JOINT SIZES ARE CONSIDERED **

** SHEAR DEFORMATIONS ARE CONSIDERED **

NOTE: - BEAM/COL TYPE: C=CONC. SECTION, 0=NOT A CONC. RECT. SECTION
DATA FOR GRAVITY LOAD CASES

FRAME NO. 1

GRAVITY LOAD CASE 1:

SUPPLIED LOAD DATA

CONCENTRATED LOAD DATA

<table>
<thead>
<tr>
<th>STORY</th>
<th>BAY</th>
<th>UDL</th>
<th>LOAD-1 DIST-1</th>
<th>LOAD-2 DIST-2</th>
<th>LOAD-3 DIST-3</th>
<th>LOAD-4 DIST-4</th>
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<tr>
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<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
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<td></td>
<td></td>
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<tr>
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<td>4.00 60.00</td>
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<tr>
<td>3</td>
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</tr>
</tbody>
</table>

***

GRAVITY LOADS (FOR ALL LOAD CASES) IN FRAME 2 ARE EXACTLY SAME AS THOSE IN FRAME 1
***
FRAME NO. 3

GRAVITY LOAD CASE 1:

SUPPLIED LOAD DATA

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<th>STORY</th>
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<th>LOAD-1 DIST-1</th>
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<tr>
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</tbody>
</table>

CONCENTRATED LOAD DATA

GRAVITY LOADS (FOR ALL LOAD CASES) IN FRAME 4 ARE EXACTLY SAME AS THOSE IN FRAME 3

FRAME NO. 5

GRAVITY LOAD CASE 1:
### Supplied Load Data

<table>
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<tr>
<th>STORY</th>
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<th>UDL</th>
<th>LOAD-1</th>
<th>DIST-1</th>
<th>LOAD-2</th>
<th>DIST-2</th>
<th>LOAD-3</th>
<th>DIST-3</th>
<th>LOAD-4</th>
<th>DIST-4</th>
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</thead>
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<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>0.070</td>
<td></td>
<td></td>
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**CODE 1 - ROOT SUM SQUARE**

**CODE 2 - SUM OF TWO MAXIMUM ABSOLUTE MODAL VALUES**
**ANALYSIS FOR LOAD SYSTEMS**

LOAD CASE MULTIPLYING FACTORS:

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FRAME NO. 1

FOR LOAD SYSTEM 1

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FOR LOAD SYSTEM 2

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FOR LOAD SYSTEM 3

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FOR LOAD SYSTEM 1

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### FRAME NO. 3

### FOR LOAD SYSTEM 1

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FOR LOAD SYSTEM 2

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FOR LOAD SYSTEM 3

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FOR LOAD SYSTEM 2

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### FRAME NO. 5

FOR LOAD SYSTEM 1

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For Load System 3

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FOR LOAD SYSTEM 4

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*** SIGN USED ***

HUM/TORN: CNTR.CLK +VE ; FORCE/DISP: UP +VE, RHT +VE

*** NOTE :***

MAX = OTHER FORCES + SEISMIC ROOT SUM SQR. FORCES
MIN = OTHER FORCES - SEISMIC ROOT SUM SQR. FORCES
CHAPTER B1

FORTRAN LISTING OF PROGRAM - AIDS
ASSIGNMENT OF LOGICAL INPUT AND OUTPUT DEVICES

CONVERSATIONAL INPUT

CONVERSATIONAL OUTPUT

RID1 OUTPUT OF GENERAL STRUCTURE DATA

AND DATA FOR DYNAMIC ANALYSIS

RID2 OUTPUT OF FRAME PROPERTIES DATA

RID3 OUTPUT OF GRAVITY AND LATERAL LOAD DATA

DUPW NEW FILE CREATING COPY OF INPUT DATA

DUPR PREVIOUSLY CREATED INPUT DATA FILE

SCRA SCRATCH FILE REQD. FOR SECOND PART

COMMON/BLOKL/IR, IWX, INX, ITOT, JAX(80), IAL(48), IFIX(6), AFLX(6),
+INDX(6), JBIND(8,6), IBIND(4,6), FBIND(4,6)
COMMON/Main/NTF(10), NSI(10,5), NBAY(10,5), NBS(10,5), NSC(8),
+NFIG(10), NFG, NFT, NNS, MBA, H(30), M(30), IDF(30), DDN(30), IAX(40),
+IWI, IWX, IWS, IY, IT, IL, IBL, IO, IDR, IDW, JTOT
DIMENSION B(d), EB(30,8), ARB(30,8), GB(30,8), BK(30,8), BI(30,8),
+DB(30,8), DBX(30,8), IBC(30), ICC(9)
DIMENSION EC(30,8), AC(30,8), GC(30,8), CK(30,8), CI(30,8), DC(30,8),
+DCX(30,8)
EQUIVALENCE (EB(1,1), EC(1,1)), (AB(1,1), AC(1,1)), (GB(1,1), GC(1,1)),
+(BK(1,1), CK(1,1)), (BI(1,1), CI(1,1)), (DB(1,1), DC(1,1)),
+(DBX(1,1), DCX(1,1))
DATA IB, IC, IN, IT, IY, IL, IHB, IHC, IHN, IHT, IHY, IHL
DATA IBL, IO, JR/1H, IH0, IHR/

C
INITIALIZE READ AND WRITE PARAMETERS

IR=1
IW=2
IW1=3
IW2=4
IW3=5
IWS=6
IWF=8
INX=40
ITOT=1
JIOT=0

C
INITIALIZE DATA BOUND PARAMETERS

DO 50 I=1,4
DO 50 J=1,6
JBND(I,J)=0
JBND(I+4,J)=0
FBND(I,J)=0
50 CONTINUE

C
START RAPID DATA INPUT SYSTEM

C
INITIATE AN INPUT DATA FILE FOR FUTURE USE

WRITE(IW,1000)
CALL REED
IDW=IAL(1)
IF(IDW.EQ.IY) WRITE(IW,1100)

C
ESTABLISH MANNER OF DATA INPUT

WRITE(IW,1200)
CALL REED
IDR=IAL(1)
IF(IDR.NE.IT) IR=7
READ NAME OF PROJECT

IF(IDR.EQ.II) WRITE(IW,1405)
READ(IR,7050) (IAX(KK),KK=1,40)
IF(IDM.EQ.IY) WRITE(IWF,7050) (IAX(KK),KK=1,40)
JTOT=JTOT+1
ISIB=IBL
IYS=IBL
IF(IDR.EQ.II) WRITE(IW,1440)
CALL REED
ISIB=IAL(1)
IF(IDM.EQ.IY) WRITE(IWF,8000) ISTB
JTOT=JTOT+1
IF(IDR.EQ.II) WRITE(IW,1450)
CALL REED
IYS=IAL(1)
IF(IDM.EQ.IY) WRITE(IWF,8010) IYS
JTOT=JTOT+1
IF(IDR.EQ.II .AND. IYS NE IY) WRITE(IW,1460)

STRUCTURE HISTORY:

IF(IDR.EQ.II) WRITE(IW,1500)
CALL REED
NFT=IFIX(1)
IF(IDM.EQ.IY) WRITE(IWF,8020) NFT
JTOT=JTOT+1
IF(IDR.EQ.II) WRITE(IW,1600)
CALL REED
NFG=IFIX(1)
IF(IDM.EQ.IY) WRITE(IWF,8030) NFG
JTOT=JTOT+1
IF(IDR.EQ.II) WRITE(IW,1700)
CALL REED
NNS=IFIX(1)
IF(IDM.EQ.IY) WRITE(IWF,8040) NNS
JTOT=JTOT+1
IF(IDR.EQ.II) WRITE(IW,1750)
CALL REED
MBA=IFIX(1)
IF(IDM.EQ.IY) WRITE(IWF,8045) MBA
JTOT=JTOT+1
READ STORY HEIGHTS
IF(IDR.EQ.IT) WRITE(IW,2900)
IIT=IBL
IIO=IBL
INC=0
DO 70 I=1,NNS
IF(IIT.NE.II.OR.IIO.NE.IO) GO TO 60
IF(I.I.GT.INC) GO TO 60
H(I)=H(I-1)
GO TO 70
JJ=I-1
IF(IDR.EQ.IT) WRITE(IW,2950) JJ,I
ITOT=3
CALL REED
IF(IDM.EQ.IY) WRITE(IWF,8050) (JAX(KK),KK=1,24),JJ,I
JTOT=JTOT+1
H(I)=AFLX(1)
IIT=IAL(9)
IIO=IAL(10)
INC=IFIX(3)
CONTINUE
FRAME INFORMATIONS
IF(IDR.EQ.IT) WRITE(IW,1900)
K=1
MP=1
DO 80 II=1,NFF
IF(IDR.EQ.IT) WRITE(IW,1950) II
CALL REED
MM=IFIX(1)
M(II)=MM
IF(IDC.EQ.IY) WRITE(IWF,8060) MM,II
JTOT=JTOT+1
IF(IDC.EQ.IT) WRITE(IW,2100)
CALL REED
IFD(I1)=IAL(1)
IF(IDW.EQ.IY) WRITE(IWF,8070) IFD(I1)
JTOI=JTOI+1
IF(IDR.EQ.IY) WRITE(IW,2200)
CALL REED
DDN(I1)=AFLX(1)
IF(IDM.EQ.IY) WRITE(IWF,8080) (JAX(KK),KK=1,20)
JTOI=JTOI+1
IF(MM.LE.MP) GO TO 80
NFIG(MP)=II-K
K=II
MP=MM
80 CONTINUE
NFIG(MM)=NFT-K+1
C
IF(IDL.EQ.IY) WRITE(IWF,2400)
DO 400 IJ=1,NFG
IF(IDR.EQ.IY) WRITE(IW,2500) IJ
400 IT0I=IT0I+1
CALL REED
NT=IFIX(1)
NIF(IJ)=NT
IF(IDW.EQ.IY) WRITE(IWF,8100) NT,IJ
JTOI=JTOI+1
D0 80 IK=1,NT
IF(IK.NE.1) GO TO 110
IF(IDR.EQ.IY) WRITE(IW,2600)
GO TO 120
110 IF(IDL.EQ.IY) WRITE(IWF,2650) IK
120 CALL REED
NST(IJ,IK)=IFIX(1)
IF(IDW.EQ.IY) WRITE(IWF,8110) NST(IJ,IK),IK
JTOI=JTOI+1
IF(IDR.EQ.IY) WRITE(IW,2700)
CALL REED
NBAY(IJ,IK)=IFIX(1)
IF(IDM.EQ.IY) WRITE(IWF,8120) NBAY(IJ,IK)
JTOI=JTOI+1
IF(IK.EQ.1) GO TO 122
KK=IK-1
IF(IDR.EQ.1) WRITE(IW,2750) KK,IK
CALL REED
NBS(IJ,KK)=IFIX(1)
IF(IDW.EQ.1) WRITE(IWF,8130) NBS(IJ,KK),KK,IK
JT0T=JT0T+1
READ BEAM SPANS
IF(IK.NE.1) GO TO 140
122 IF(IDR.EQ.1) WRITE(IW,2800)
NB=NBAY(IJ,1)
II=IBL
II0=IBL
INC=0
IF(NB.EQ.0) GO TO 130
DO 130 I=1,NB
IF(I.IE.10.OR.II0.IE.10) GO TO 125
IF(I.GT.INC) GO TO 125
B(I)=B(I-1)
GO TO 130
125 IF(IDR.EQ.1) WRITE(IW,2850)
JT0T=3
CALL REED
IF(IDW.EQ.1) WRITE(IWF,8140) (JAX(KK),KK=1,24),I
JT0T=JT0T+1
B(I)=AFLX(I)
II=IAL(9)
II0=IAL(10)
INC=IFIX(3)
130 CONTINUE
140 NSS=NSS+NST(IJ,IK)
160 CONTINUE
WRITE(IWZ,7000) NT,NSS,NFIG(IJ)
WRITE(IW2,7000) (NST(IJ,IK),IK=1,NT)
WRITE(IW2,7000) (NBAY(IJ,IK),IK=1,NT)
IF(NT.EQ.1) GO TO 161
NT1 = NT - 1
WRITE(IW2,7000) (NBS(IJ,IK), IK=1,NT1)
WRITE(IW2,7030) (B(IK), IK=1,NB)

READ BEAM CROSS-SECTION PROPERTIES
IF(IDR.EQ.I1) WRITE(IW,3000)
IF(IDW.EQ.IY) WRITE(IWF,8150)
JT0T = JT0T + 1
IF(IDR.NE.I1) READ(IR,7040)
IS = 0
NN = 0
DO 190 I = 1,NT
NSS = NST(IJ,I)
NB = NBAY(IJ,I)
IF(I.IE.1) GO TO 162
NSB = 0
GO TO 163
162 NSB = NSB + NBS(IJ,I-1)
163 NBS1 = NSB + 1
NBS2 = NSB + NB
NN = NN + NSS
ILL = IBL
100 = IBL
IMB = 0
IND = 0
DO 180 J = 1, NSS
IS = [IS+1
IIT = IBL
IIO = IBL
INC = 0
IF(ILL.NE.I1) GO TO 170
IBC(IS) = IBC(IMB)
IF(IBC(IS).NE.JR) GO TO 165
DO 164 II = NBS1,NBS2
DB(IS,II) = DB(IMB,II)
DBX(IS,II) = DBX(IMB,II)
164 CONTINUE
GO TO 166
DO 166 II = NBS1,NBS2
0283 BI(IS,II)=BI(IMB,II)
0284 AB(IS,II)=AB(IMB,II)
0285 DB(IS,II)=DB(IMB,II)
0286 168 CONTINUE
0287 IF(IT,NE,IT,OR,IK,NE,IO) GO TO 178
0288 IF(IS,EQ,IND) GO TO 178
0289 GO TO 180
0290 170 IF(IDR,EQ,IT) WRITE(IW,3050) IS
0291 CALL REED
0292 IIC=IAL(I)
0293 IBC(IS)=IIC
0294 IF(IDM,EQ,ITY) WRITE(IWF,5155) IIC,IS
0295 JTOI=JTOI+1
0296 IF(IIC,NE,JR) GO TO 175
0297 IF(IDR,EQ,IT) WRITE(IW,3070)
0298 DO 174 JK=NBS1,NBS2
0299 IF(IT,NE,IT,OR,II0,NE,IO) GO TO 172
0300 IF(JK,GT,INC) GO TO 172
0301 DB(IS,JK)=DB(IS,JK-1)
0302 DBX(IS,JK)=DBX(IS,JK-1)
0303 GO TO 174
0304 172 IF(IDR,EQ,IT) WRITE(IW,2850) JK
0305 JTOI=4
0306 CALL REED
0307 IF(IDM,EQ,ITY) WRITE(IWF,8160) (JAX(KK),KK=1,40),JK
0308 JTOI=JTOI+1
0309 DBX(IS,JK)=AFLX(I)
0310 DB(IS,JK)=AFLX(2)
0311 IIT=IAL(17)
0312 II0=IAL(18)
0313 INC=IFIX(4)
0314 174 CONTINUE
0315 GO TO 178
0316 175 IF(IDR,EQ,IT) WRITE(IW,3080)
0317 DO 177 JK=NBS1,NBS2
0318 IF(IT,NE,IT,OR,II0,NE,IO) GO TO 176
0319 IF(JK,GT,INC) GO TO 176
0320 BI(IS,JK)=BI(IS,JK-1)
0321 AB(IS,JK)=AB(IS,JK-1)
0322 DB(IS,JK)=DB(IS,JK-1)
GO TO 177
176 IF(IDR.EQ.IT) WRITE(IW,2850) JK
IT0T=5
CALL REED
IF(IDW.EQ.IY) WRITE(IWF,8160) (JAX(KK),KK=1,40),JK
JTOI=JTOI+1
BI(ISJK)=AFLX(1)
AB(ISJK)=AFLX(2)
DB(ISJK)=AFLX(3)
ITI=IAL(25)
IIO=IAL(26)
INC=IFIX(5)
177 CONTINUE
178 IF(IS.GE.NN) GO TO 180
179 IF(IDR.EQ.IT) WRITE(IW,3200) IS,NN
ITOT=4
CALL REED
IF(IDW.EQ.IY) WRITE(IWF,8170) (JAX(KK),KK=1,32),IS
JTOT=JTOT+1
ILL=IAL(1)
IMB=IFIX(2)
ITI=IAL(17)
I(X)=IAL(18)
IND=IFIX(4)
180 CONTINUE
190 CONTINUE
NSI=0
NI=0
DO 200 J=1,NT
NB=NBay(IJ,J)+1
NSI=NSI+NST(IJ,J)
NJ=NI
IF(J.EQ.NT) GO TO 192
NI=NI+NBS(IJ,J)
NIL=NI+NBay(IJ,J+1)+1
DO 196 I=1,NB
IK=I+NJ
IF(J.EQ.NT) GO TO 194
200 CONTINUE
192 CONTINUE
0363 IF(KT.NI.AND.KL.NI) GO TO 196
0364 NSC(K)=NSI
0365 GO TO 196
0366 NSC(K)=NSI
0367 196 CONTINUE
0368 200 CONTINUE
0369 C
0370 C READ MODULII OF ELASTICITY AND MODULII OF RIGIDITY OF BEAMS
0371 C
0372 IYD=IBL
0373 IF(1DR.EQ.1T) WRITE(IW,3600)
0374 CALL REED
0375 IYD=IYD+1
0376 IF(1D1.EQ.1Y) WRITE(IWF,8190) IYD
0377 JTO1=JTO1+1
0378 IF(IYD.NE.IY) GO TO 210
0379 IF(1DR.EQ.1T) WRITE(IW,3650)
0380 JTO1=2
0381 CALL REED
0382 IF(1D1.EQ.1Y) WRITE(IWF,8200) (JAX(KK),KK=1,20)
0383 JTO1=JTO1+1
0384 EY=AFLX(1)
0385 EG=AFLX(2)
0386 IS=0
0387 NJ=0
0388 DO 206 I=1,NT
0389 NSS=NST(IJ,I)
0390 NB=NBAY(IJ,I)
0391 DO 204 J=1,NSS
0392 IS=IS+1
0393 DO 203 K=1,NB
0394 NI=NJ+K
0395 E(B(IS,NI))=EY
0396 GB(IS,NI)=EG
0397 203 CONTINUE
0398 204 CONTINUE
0399 IF(I.EQ.NT) GO TO 208
0400 NJ=NJ+NBS(IJ,I)
0401 206 CONTINUE
GO TO 230
210 IF(IDR.EQ.IT) WRITE(IW,3650)
       NN=0
       IS=0
       DO 228 I=1,NT
       NSS=NSL(IJ,I)
       NN=NN+NNS
       NB=NBAY(IJ,I)
       IF(I.NE.1) GO TO 212
       NSB=0
       GO TO 214
212 NSB=NSB+NBS(IJ,I-1)
214 NBS1=NSB+1
       NBS2=NSB+NB
       ILL=IBL
       IIT=IBL
       IIO=IBL
       IMB=0
       IND=0
       DO 226 J=1,NSS
       IS=IS+1
       IIT=IBL
       IIO=IBL
       INC=0
       IF(ILL.NE.IL) GO TO 218
       DO 216 II=NBS1,NBS2
       EB(IS,II)=EB(IMB,II)
       GB(IS,II)=GB(IMB,II)
       CONTINUE
216 IF(IIT.NE.IIT.OR.IIO.NE.II) GO TO 224
       IF(IS.EQ.IND) GO TO 224
       GO TO 226
218 IF(IDR.EQ.IT) WRITE(IW,4050) IS
       DO 223 K=NBS1,NBS2
       IF(IIT.NE.IIT.OR.IIO.NE.II) GO TO 220
       IF(K.GT.INC) GO TO 22Q
       EB(IS,K)=EB(IS,K-1)
       GB(IS,K)=GB(IS,K-1)
       GO TO 223
220 IF(IDR.EQ.IT) WRITE(IW,2850) K
       ITOT=4
0483  GO TO 234
0484  233 NSB=NSB+NBS(IJ, I-1)
0485  234 NBS1=NSB+1
0486   NBS2=NSB+NB
0487   ILL=IBL
0488   IIT=IBL
0489   IIX=IBL
0490   IMB=0
0491   IND=0
0492   DO 246 J=1, NSS
0493   IS=IS+1
0494   IIT=IBL
0495   IIX=IBL
0496   INC=0
0497   IF(IIL NE. IL) GO TO 238
0498   DO 236 II=NBS1, NBS2
0499   BK(IS, II)=BK(IMB, II)
0500  236 CONTINUE
0501   IF(IIT NE. IT. OR. (IIX NE. I0) GO TO 244
0502   IF(IS. EQ. IND) GO TO 244
0503   GO TO 246
0504  238 IF(IDR. EQ. IT) WRITE(IW, 4050) IS
0505       DO 243 K=NBS1, NBS2
0506       IF(IIT NE. IT. OR. I10, NE. I0) GO TO 240
0507       IF(K GT. INC) GO TO 240
0508       BK(IS, K)=BK(IS, K-1)
0509       GO TO 243
0510  240 IF(IDR. EQ. IT) WRITE(IW, 4100) K
0511   ITO=3
0512   CALL REED
0513   IF(IDW. EQ. IY) WRITE(IMW, 8160) (JAX(KK), KK=1, 40), K
0514       JT0=IT0T+1
0515       BK(IS, K)=FLX(1)
0516   IIT=IAL(9)
0517   IIX=IAL(10)
0518   INC=IFIX(3)
0519  243 CONTINUE
0520  244 IF(IS. GE. NN) GO TO 246
0521  245 IF(IDR. EQ. IT) WRITE(IW, 4200) IS, NN
0522   ITO=4
CALL REED
0524 IF(IDM.EQ.IY) WRITE(IWF,8170) (JAX(KK),KK=1,32),IS
0525 JI0T=JI0T+1
0526 ILL=IAL(J)
0527 IMB=IFIX(2)
0528 I11=IAL(17)
0529 I00=IAL(18)
0530 IND=IFIX(4)
0531 246 CONTINUE
0532 248 CONTINUE
0533 250 CONTINUE
0534 C WRITE BEAM PROPERTIES
0535 C IS=0
0536 NJS=0
0537 NSB=1
0540 IF(ISB.NE.IY) NSB=0
0541 WRITE(IW2,7000) NSB
0542 C DO 254 I=1,NT
0543 D0 254 J=1,NSS
0547 IS=IS+1
0548 WRITE(IW2,7040) ISB(IS)
0549 D0 252 K=1,NB
0550 NI=NJ+K
0551 IF(ISY.NE.IY) BK(IS,NI)=0,0
0552 IF(ISB(IS),NE.JR) GO TO 251
0553 WRITE(IW2,7010) EB(IS,NI),GB(IS,NI),BK(IS,NI),DBX(IS,NI),DB(IS,NI)
0554 GO TO 252
0555 251 WRITE(IW2,7010) EB(IS,NI),GB(IS,NI),BK(IS,NI),DB(IS,NI),AB(IS,NI),
0556 +BI(IS,NI)
0557 252 CONTINUE
0558 253 CONTINUE
0559 NJ=NJ+NBS(IJ,I)
0560 254 CONTINUE
0561 C READ COLUMN CROSS SECTION PROPERTIES
0563 C
0564 IF(IDR.EQ.IT) WRITE(IW,3300)
0565 IF(IDW.EQ.IY) WRITE(IWF,8210)
0566 JTOT=JTOT+1
0567 IF(IDR.NE.IT) READ(IR,7040)
0568 Nb=NBAY(IJ,1)+1
0569 ILL=IBL
0570 I00=IBL
0571 IMB=0
0572 IND=0
0573 NN=NSC(I)
0574 DO 280 I=1,NB
0575 I1T=IBL
0576 I00=IBL
0577 INC=0
0578 NNF=NNF
0579 IF(I1T.NE.II) GO TO 259
0580 ICC(I)=ICC(IMB)
0581 IF(ICC(I).NE.JR) GO TO 256
0582 DO 255 II=1,NN
0583 DC(II,I)=DC(II,IMB)
0584 DCX(II,I)=DCX(II,IMB)
0585 255 CONTINUE
0586 GO TO 258
0587 256 DO 257 II=1,NN
0588 CI(II,I)=CI(II,IMB)
0589 AC(II,I)=AC(II,IMB)
0590 DC(II,I)=DC(II,IMB)
0591 257 CONTINUE
0592 258 CONTINUE
0593 IF(I1T.NE.IT.OR.I00.NE.I0) GO TO 278
0594 IF(I.EQ.IND) GO TO 278
0595 GO TO 280
0596 259 IF(IDR.EQ.IT) WRITE(IW,3350) I
0597 CALL REED
0598 IIIC=IAL(I)
0599 ICC(I)=IIIC
0600 IF(IDW.EQ.IY) WRITE(IWF,8220) IIIC,I
0601 JTOT=JTOT+1
0602 IF(IIIC.NE.JR) GO TO 270
0603 IF(IDR.EQ.IT) WRITE(IW,3360)
0604 DO 265 J=1,NN
0605 IF(IIT.NE.IT.OR.II0.NE.IO) GO TO 260
0606 IF(J.GT.INC) GO TO 260
0607 DC(J,I)=DC(J-1,I)
0608 DCX(J,I)=DCX(J-1,I)
0609 GO TO 265
0610 260 IF(IDR.EQ.IT) WRITE(IW,3400) J
0611 ITOT=4
0612 CALL REED
0613 IF(IDM.EQ.IY) WRITE(IWF,8230) (JAX(KK),KK=1,40),J
0614 JTOT=JTOT+1
0615 DCX(J,I)=AFLX(1)
0616 DC(J,I)=AFLX(2)
0617 IIT=IAL(17)
0618 II0=IAL(18)
0619 INC=IFIX(4)
0620 265 CONTINUE
0621 GO TO 278
0622 270 IF(IDR.EQ.IT) WRITE(IW,3370)
0623 DO 277 J=1,NN
0624 IF(IIT.NE.IT.OR.II0.NE.IO) GO TO 275
0625 IF(J.GT.INC) GO TO 275
0626 CI(J,I)=CI(J-1,I)
0627 AC(J,I)=AC(J-1,I)
0628 DC(J,I)=DC(J-1,I)
0629 GO TO 277
0630 275 IF(IDR.EQ.IT) WRITE(IW,3400) J
0631 ITOT=5
0632 CALL REED
0633 IF(IDM.EQ.IY) WRITE(IWF,8230) (JAX(KK),KK=1,40),J
0634 JTOT=JTOT+1
0635 CI(J,I)=AFLX(1)
0636 AC(J,I)=AFLX(2)
0637 DC(J,I)=AFLX(3)
0638 IIT=IAL(25)
0639 II0=IAL(26)
0640 INC=IFIX(5)
0641 277 CONTINUE
0642 278 IF(I.GE.NB) GO TO 280
0643  NNF=NSC(I+1)
0644  IF(NNF,LE.NN) GO TO 279
0645  ILL=IBL
0646  GO TO 280
0647  279 IF(IDR.EQ.IT) WRITE(IW,3500) I
0648  ITOT=4
0649  CALL REED
0650  IF(IDM.EQ.IY) WRITE(IWF,8240) (JAX(KK),KK=1,32),I
0651  JTOT=JTOT+1
0652  ILL=IAL(1)
0653  IMB=IFIX(2)
0654  IIT=IAL(17)
0655  IXX=IAL(18)
0656  IND=IFIX(4)
0657  280 CONTINUE
0658 C READ MODULII OF ELASTICITY & MODULII OF RIGIDITY OF COLUMNS
0659 C
0660 C IYD=IBL
0661  IF(IDR.EQ.IT) WRITE(IW,4300)
0662  CALL REED
0663  IYD=IAL(1)
0664  IF(IDM.EQ.IY) WRITE(IWF,8260) IYD
0665  JTOT=JTOT+1
0666  IF(IYD.NE.IY) GO TO 290
0667  IF(IDR.EQ.IT) WRITE(IW,3650)
0668  ITOT=2
0669  CALL REED
0670  IF(IDM.EQ.IY) WRITE(IWF,8200) (JAX(KK),KK=1,20)
0671  JTOT=JTOT+1
0672  EY=AFLX(1)
0673  EG=AFLX(2)
0674  NB=NWAY(IJ,1)+1
0675  DO 284 I=1,NB
0676  NN=NSC(I)
0677  DO 282 J=1,NN
0678  EC(J,I)=EY
0679  GC(J,I)=EG
0680  282 CONTINUE
0681  284 CONTINUE
0683 GO TO 310
0684 290 IF(IDR.EQ.IT) WRITE(IW,3650)
0685 NB=NBAY(IJ,1)+1
0686 ILL=IBL
0687 I00=IBL
0688 IMB=0
0689 IND=0
0690 NNF=NSC(I)
0691 DO 308 I=1,NB
0692 IIT=IBL
0693 I00=IBL
0694 INC=0
0695 NN=NNF
0696 IF(I00.NE.I0) GO TO 294
0697 DO 292 J=1,NN
0698 EC(J,I)=EC(J,IMB)
0699 GC(J,I)=GC(J,IMB)
0700 CONTINUE
0701 IF(IIT.NE.IT.OR.I00.NE.I0) GO TO 306
0702 IF(I.EQ.IND) GO TO 306
0703 GO TO 308
0704 294 IF(IDR.EQ.IT) WRITE(IW,4750) I
0705 DO 305 J=1,NN
0706 IF(IIT.NE.IT.OR.I00.NE.I0) GO TO 296
0707 IF(J.GT.IND) GO TO 296
0708 EC(J,I)=EC(J-1,I)
0709 GC(J,I)=GC(J-1,I)
0710 GO TO 305
0711 296 IF(IDR.EQ.IT) WRITE(IW,4050) J
0712 ITOI=4
0713 CALL REED
0714 IF(IDW.EQ.IY) WRITE(IWF,8230) (JAX(KK),KK=1,40),J
0715 JTOI=JTOI+1
0716 EC(J,I)=AFLX(1)
0717 GC(J,I)=AFLX(2)
0718 IIT=IAL(17)
0719 I00=IAL(18)
0720 INC=IFIX(4)
0721 CONTINUE
0722 306 IF(I.GE.NB) GO TO 308
0723 NNF=NSC(I+1)
0724 IF(NNF.LE.NN) GO TO 307
0725 ILL=IBL
0726 GO TO 308
0727 307 IF(IDR.EQ.IT) WRITE(IW,4600) I
0728 JTOT=JTOT+1
0729 CALL REED
0730 IF(IDW.EQ.IY) WRITE(IWF,8240) (JAX(KK),KK=1,32),I
0731 JTOT=JTOT+1
0732 ILL=IAL(1)
0733 IMB=IFIX(2)
0734 IIT=IAL(17)
0735 I0X=IAL(18)
0736 IND=IFIX(4)
0737 308 CONTINUE
0738 C READ SHEAR COEFFICIENTS FOR COLUMNS
0739 C
0740 C
0741 310 IF(IYS.NE.IY) GO TO 340
0742 IF(IDR.NE.II) GO TO 311
0743 WRITE(IW,4700)
0744 GO TO 312
0745 311 READ(IR,7040)
0746 312 IF(IDW.EQ.IY) WRITE(IWF,8265)
0747 JTOT=JTOT+1
0748 ILL=IBL
0749 IIT=IBL
0750 I0X=IBL
0751 IMB=0
0752 IND=0
0753 NNF=NSC(1)
0754 DO 330 I=1,NB
0755 IIT=IBL
0756 I0X=IBL
0757 INC=0
0758 NN=NNF
0759 IF(ILL.NE.IIL) GO TO 314
0760 DO 313 J=1,NN
0761 CK(J,I)=CK(J,IMB)
0762 313 CONTINUE
0763 IF(I1T.NE.I1T.OR.l00.NE.I0) GO TO 327
0764 IF(I.EQ.IND) GO TO 327
0765 GO TO 330
0766 314 IF(IDR.EQ.I1T) WRITE(IW,4750) I
0767 DO 326 J=1,NN
0768 IF(I1T.NE.I1T.OR.I10.NE.I0) GO TO 329
0769 IF(J.GT.IND) GO TO 320
0770 CK(J,I)= CK(J-1,I)
0771 GO TO 326
0772 320 IF(IDR.EQ.I1T) WRITE(IW,4800) J
0773 ITOT=3
0774 CALL REED
0775 IF(IDW.EQ.IY) WRITE(IWF,8230) (JAX(KK),KK=1,40),J
0776 JT0T=JT0T+1
0777 CK(J,I)=AFIX(1)
0778 I1T=IAL(9)
0779 I10=IAL(10)
0780 INC=IFIX(3)
0781 326 CONTINUE
0782 327 IF(I.GE.NB) GO TO 330
0783 NNF=NSC(I+1)
0784 IF(NNF.LE.NN) GO TO 328
0785 ILL=IBL
0786 GO TO 330
0787 328 IF(IDR.EQ.I1T) WRITE(IW,4900) I
0788 ITOT=4
0789 CALL REED
0790 IF(IDW.EQ.IY) WRITE(IWF,8240) (JAX(KK),KK=1,32),1
0791 JT0T=JT0T+1
0792 ILL=IAL(1)
0793 IMB=IFIX(2)
0794 I1T=IAL(17)
0795 I10=IAL(18)
0796 IND=IFIX(4)
0797 330 CONTINUE
0798 340 CONTINUE
0799 C    WRITE COLUMN PROPERTIES DATA
0800 C    NB=NBAY(IJ,1)+1
DO 390 I=1,NB
NN=NSC(I)
WRITE(IW2,7045) ICC(I),NN
DO 380 J=1,NN
IF(IYS.NE.IY) CK(J,I)=0.0
IF(ICC(I).NE.JR) GO TO 375
WRITE(IW2,7010) EC(J,I),GC(J,I),CK(J,I),DCX(J,I),DC(J,I)
GO TO 380
375 WRITE(IW2,7010) EC(J,I),GC(J,I),CK(J,I),DC(J,I),AC(J,I),CI(J,I)
380 CONTINUE
390 CONTINUE
400 CONTINUE
STOP
C
C
C
C
1000 FORMAT(/&
* * * * * * * * * * * * * * * * * * &*
* &
* &
* & A I D S &
* &
* &
* & READS DATA BY CONVERSATIONAL
* &
* & MODE WITH RAPID INPUT OPTION
* &
* & AND WRITES IN THREE FILES
* &
* & FOR THE THREE DIMENSIONAL
* &
* & BUILDING ANALYSIS PROGRAM.
* &
* &
* & DO YOU WISH TO CREATE A NEW DATA FILE CONTAINING
* &
* & A COPY OF THE PRESENT INPUT DATA FOR FUTURE USE ? Y/N
* &
1100 FORMAT(/& THE INPUT DATA WILL BE SAVED ON
* &
* & A FILE NAMED - DUPLI/
* &
1200 FORMAT(/& DO YOU WISH TO INPUT DATA BY MEANS OF THE
* &
* & TERMINAL OR BY MEANS OF AN EXISTING DATA FILE ? T/F
* &
1405 FORMAT(/& CASE TITLE (MAX. 40 CHARACTERS) /
* &
1440 FORMAT(/& DO YOU WANT FINITE JOINT SIZES TO BE CONSIDERED ? Y/N
* &
1450 FORMAT(/& DO YOU WANT SHEAR DEFORMATIONS TO BE CONSIDERED ? Y/N
* &
1460 FORMAT(/& WHEN ASKED FOR, PUT VALUES OF
BEAM/COLUMN MOD. OF RIGIDITY EQUAL TO 0.0*

1500 FORMAT(//
++ *** USE CONSISTENT UNITS ***/"
++ STRUCTURE HISTORY */
++ TOTAL NO. OF FRAMES IN THE BUILDING*/
1600 FORMAT(// NO. OF FRAME GROUPS IN THE BUILDING*/
1700 FORMAT(// TOTAL NO. OF STORIES IN THE BUILDING*/
1750 FORMAT(// MAX. NO. OF BAYS IN THE WIDEST FRAME OF THE BUILDING*/
1900 FORMAT(// FRAME INFORMATION */
1950 FORMAT(// FRAME NO.,I3,; */
++ FRAME GROUP NO.*/
2100 FORMAT(// PARALLEL TO GLOBAL X-DIRECTION OR Y-DIRECTION ? X/Y*/
2200 FORMAT(// PERPENDICULAR DISTANCE FROM*/
++ THE REFERENCE POINT TO THE FRAME*/
2400 FORMAT(// FRAME GROUP PROPERTIES */
2500 FORMAT(//
++ -----------------------/
2600 FORMAT(// FRAME GROUP NO.,I3,;
++ -----------------------/
2650 FORMAT(// NO. OF TOWERS, INCLUDING THE BASE TOWER*/
2600 FORMAT(// IN TOWER 1 (BASE TOWER), NO. OF STORIES*/
2650 FORMAT(// IN TOWER',I3,', NO. OF STORIES*/
2700 FORMAT(// NO. OF BAYS*/
2750 FORMAT(// NO. OF BAYS-SETBACK AT LEFT*/
++ BETWEEN TOWERS',I3,' AND',I3)
2800 FORMAT(// LENGTHS OF BAYS, C/C OF COLUMNS*/
++ STARTING FROM LEFT */
2850 FORMAT(// BAY NO.,I3,;
2900 FORMAT(// STORY HEIGHTS, C/C FLOOR BEAMS */
2950 FORMAT(// BETWEEN STORY LEVELS',I3,' AND',I3)
3000 FORMAT(// BEAM CROSS SECTION PROPERTIES */
3050 FORMAT(// STORY LEVEL',I3,; */
++ THIS SET OF DATA IS TO BE INPUT BEAM BY BEAM*/
++ STARTING AT LEFT AT EACH FLOOR AND THUS FLOOR BY FLOOR*/
3070 FORMAT(// STORY LEVEL',I3,; */
++ ARE ALL THE BEAMS IN THIS STORY OF*/
++ RECTANGULAR SECTION OR OTHER ? R/O*/
3070 FORMAT(// INPUT BEAM WIDTH AND THEN DEPTH SEPARATED BY A BLANK*/
3080 FORMAT(// INPUT : BEAM MOMENT OF INERTIA, AREA AND DEPTH*/
++ SEPARATED BY BLANKS*/
3200 FORMAT(// THIS SET OF DATA IS COMPLETE UPTO STORY ',I3,'*/
0883< ARE THE BEAMS IN THE NEXT STORY (AND POSSIBLY MAX.)?
0884< UPTO STORY",I3," EXACTLY LIKE THOSE IN ANY PRECEDING STORY ?
0885< IF NOT--PUT NO, IF YES--LIKE WHICH ?
08863300 FORMAT(" COLUMN CROSS SECTION PROPERTIES :"
0887< THIS SET OF DATA IS TO BE INPUT VERTICALLY COLUMN BY COLUMN IN"
0888< EACH COL. LINE AND THUS COL. LINE BY COL. LINE, FROM LEFT")
08893350 FORMAT(" COLUMN LINE",I3," :"
0890< ARE ALL THE COLUMNS IN THIS COLUMN LINE OF"
0891< RECTANGULAR SECTION, OR OTHER ? R/0")
08923360 FORMAT(" INPUT COLUMN WIDTH ACROSS THE PLANE OF FRAME AND"
0893< THEN WIDTH IN THE PLANE OF FRAME, SEPARATED BY A BLANK")
08943370 FORMAT(" INPUT COLUUMN MOM. OF INERTIA, AREA AND THEN"
0895< COLUMN WIDTH IN PLANE OF FRAME, SEPARATED BY BLANKS")
08963400 FORMAT(" STORY NO."",I3," :"
08973500 FORMAT(" THIS SET OF DATA IS COMPLETE UPTO COL. LINE",I3,""
0898< ARE THE COLUMNS IN THE NEXT COL. LINE EXACTLY"
0899< LIKE THOSE IN ANY PRECEDING COLUMN LINE ?"
0900< IF NOT--PUT NO, IF YES--LIKE WHICH ?")
09013600 FORMAT(" BEAM MOD. OF ELASTICITY AND MOD. OF RIGIDITY :"
0902< ARE THE MOD. OF ELASTICITY AND MOD. OF RIGIDITY SAME"
0903< FOR ALL THE BEAMS IN THIS FRAME GROUP ? Y/N")
09043650 FORMAT(" INPUT THE MOD. OF ELASTICITY AND THEN"
0905< THE MOD. OF RIGIDITY, SEPARATED BY A BLANK")
09063900 FORMAT(" THIS SET OF DATA IS COMPLETE UPTO STORY",I3,""
0907< ARE THE MODULII FOR BEAMS IN THE NEXT STORY (AND MAX.)"
0908< UPTO STORY",I3," ) EXACTLY LIKE THOSE IN ANY PRECEDING STORY ?"
0909< IF NOT--PUT NO, IF YES--LIKE WHICH ?")
09104000 FORMAT(" SHEAR COEFFICIENTS FOR BEAMS :"
09114050 FORMAT(" STORY NO."",I3," :"
09124100 FORMAT(" FOR BEAM IN BAY NO."",I3"
09134200 FORMAT(" THIS SET OF DATA IS COMPLETE UPTO STORY",I3,""
0914< ARE THE SHEAR COEFFICIENTS FOR THE BEAMS IN THE NEXT STORY"
0915< (AND MAX. UPTO STORY",I3," ) EXACTLY LIKE THOSE"
0916< IN ANY PRECEDING STORY ? IF NOT--PUT NO, IF YES--LIKE WHICH?")
09174300 FORMAT(" COLUMN MOD. OF ELASTICITY AND MOD. OF RIGIDITY :"
0918< ARE THE MOD. OF ELASTICITY AND MOD. OF RIGIDITY SAME"
0919< FOR ALL THE COLUMNS IN THIS FRAME GROUP ? Y/N")
09204600 FORMAT(" THIS SET OF DATA IS COMPLETE UPTO COL. LINE",I3,""
0921< NOW, ARE THE MOD. OF ELASTICITY OF THE COLUMNS IN THE"
0922< NEXT COL. LINE EXACTLY LIKE THOSE IN ANY PRECEDING COL. LINE?"
0923  ← IF NOT—PUT NO. IF YES—LIKE WHICH?
0924  4700 FORMAT(/** SHEAR COEFFICIENTS FOR COLUMNS **/)
0925  4750 FORMAT(/** COLUMN LINE, I3, **/)
0926  4800 FORMAT(/** FOR COLUMN IN STORY NO., I3 **/)
0927  4900 FORMAT(/** THIS SET OF DATA IS COMPLETE UPTO COL, LINE, I3, **/)
0928  ← ARE THE SHEAR COEFFICIENTS FOR COLUMNS IN THE NEXT
0929  ← COL. LINE EXACTLY LIKE THOSE IN ANY PRECEDING COL. LINE ?
0930  ← IF NOT—PUT NO, IF YES—LIKE WHICH ?
0931  7000 FORMAT(5I5)
0932  7010 FORMAT(6E12.5)
0933  7020 FORMAT(5F15.5)
0934  7030 FORMAT(8F10.3)
0935  7040 FORMAT(1X,1A1)
0936  7045 FORMAT(1X,1A1,1I)
0937  7050 FORMAT(40A1)
0938  7060 FORMAT(1X,40A1)
0939  7080 FORMAT(215,4X,1A1,F15.5)
0940  C
0941  8000 FORMAT(A1,31X, ← FINITE JOINT SIZES CONSIDERED ?)
0942  8010 FORMAT(A1,31X, ← SHEAR DEFORMATIONS CONSIDERED ?)
0943  8020 FORMAT(I3,29X, ← NO. OF FRAMES ?)
0944  8030 FORMAT(I3,29X, ← NO. OF FRAMES GROUPS ?)
0945  8040 FORMAT(I3,29X, ← NO. OF STORIES ?)
0946  8045 FORMAT(I3,29X, ← NO. OF BAYS IN THE WIDEST FRAME ?)
0947  8050 FORMAT(24A1,8X, ← STORY HT. BETWN. LEVELS, I3 , AND , I3)
0948  8060 FORMAT(I3,29X, ← FOR FRAME , I3 , FRAME GR. NO. ?)
0949  8070 FORMAT(A1,31X, ← ORIENTATION OF THE FRAME ?)
0950  8080 FORMAT(20A1,12X, ← DIST. FROM REF. POINT ?)
0951  8100 FORMAT(I3,29X, ← NO. OF TOWERS IN FRAME GR. , I3 ?)
0952  8110 FORMAT(I3,29X, ← IN TOWER , I3 , NO. OF STORIES ?)
0953  8120 FORMAT(I3,29X, ← NO. OF BAYS ?)
0954  8130 FORMAT(I3,21X, ← BAY-SETBACK AT LEFT BETWN TOWR , I2 , & , I2)
0955  8140 FORMAT(24A1,8X, ← BAY LENGTH FOR BAY NO. , I3 ?)
0956  8150 FORMAT( ← BEAM CROSS SECTION PROPERTIES ?)
0957  8155 FORMAT(A1,31X, ← SECTION TYPE, STORY , I3 ?)
0958  8160 FORMAT(40A1, ← BEAM AT BAY , I3 ?)
0959  8170 FORMAT(32A1, ← COMPLETE UPTO STORY , I3 , NEXT ?)
0960  8190 FORMAT(A1,23X, ← ARE MOD. OF ELAST. SAME FOR ALL BEAMS ?)
0961  8200 FORMAT(20A1,12X, ← VALUES OF MOD. OF ELAST & RIGIDITY ?)
0962  8205 FORMAT( ← SHEAR COEFFICIENTS FOR BEAMS ?)
0963  8210 FORMAT("COLUMN CROSS SECTION PROPERTIES")
0964  8220 FORMAT(A1,31X,"- X-SECTION TYPE AT 'COL. LINE', I3)
0965  8230 FORMAT(40A1,"- COLUMN AT STORY', I3)
0966  8240 FORMAT(32A1,"- COMPLETE UPTO COL. LINE', I3, ', NEXT?")
0967  8260 FORMAT(A1,23X,"- ARE MOD. OF ELAST SAME FOR ALL COLMNS?")
0968  8265 FORMAT(" SHEAR COEFFICIENTS FOR COLUMNS")
0969 C
0970   END
SECOND PART OF PROGRAM - AIDS

COMMON/BLOK1/IR, IM, INX, ITOT, JAX(80), IAL(48), IFIX(6), AFLX(6),
+INDX(6), JBND(8, 6), IBND(4, 6), FBND(4, 6)
+COMMON/MAIN/NT(10), NST(10, 5), NBAY(10, 5), NBS(10, 5), NSC(8),
+NFG(10), NFG, NFT, NNS, MBA, H(30), M(30), IFD(30), DDN(30), IAX(40),
+IM1, IM3, IMW, IY, IT, IL, IBL, I0, IDR, IDW, JT0T
DIMENSION UDL(30, 7), CNL(30, 7, 4), DIS(30, 7, 4), SMULP(15, 8)
DIMENSION NCL(30, 7), HLX(30), HLY(30), XM(30), XM1(30), XB(30), YB(30)
+, DHX(30), DHY(30)
EQUIVALENCE (UDL(1, 1), HLX(1)), (UDL(1, 2), HLY(1)), (UDL(1, 3), DHX(1))
+, (UDL(1, 4), DHY(1)), (UDL(1, 5), XM(1)), (UDL(1, 6), XM1(1))
+, (UDL(1, 7), XB(1)), (UDL(1, 1), YB(1))
WRITE(IW1, 7060) (IAK(KK), KK=1, 40)
WRITE(IW1, 7000) NFT, NFG, NNS, MBA
WRITE(IW1, 7030) (H(I), I=1, NNS)
DO 10 I=1, NFT
10 WRITE(IW1, 7080) I, M(I), IFD(I), DDN(I)
IF(IDW .NE. IY) GO TO 30
DO 20 I=1, JT0T
READ(IMS, 7070) (JAX(KK), KK=1, 70)
WRITE(IW1, 7070) (JAX(KK), KK=1, 70)
CONTINUE
30 IF(IDR.EQ.IT) GO TO 50
DO 40 I=1, JT0T
40 READ(IR, 7040)
CONTINUE
READ LOAD SYSTEMS INFORMATION
NGR=0
NWL=0
NDYN=0
NSYS=0
IMS=IBL
0043  ISS=IBL
0044  ITOI=1
0045  IDYN=IBL
0046  IF(IDR.EQ.IT) WRITE(IW,1410)
0047  CALL REED
0048  NGR=IFIX(1)
0049  IF(IDW.EQ.IY) WRITE(IWF,8270) NGR
0050  IF(IDR.EQ.IT) WRITE(IW,1420)
0051  CALL REED
0052  NWL=IFIX(1)
0053  IF(IDW.EQ.IY) WRITE(IWF,8280) NWL
0054  IF(IDR.EQ.IT) WRITE(IW,1430)
0055  CALL REED
0056  IYDN=IAL(1)
0057  IF(IDW.EQ.IY) WRITE(IWF,8290) IYDN
0058  IF(IDR.EQ.IT) WRITE(IW,1435)
0059  CALL REED
0060  NSYS=IFIX(1)
0061  IF(IDW.EQ.IY) WRITE(IWF,8300) NSYS
0062  IF(IYDN.EQ.IY) NDYN=1
0063  IOUT=0
0064  IF(IDR.EQ.IT) WRITE(IW,1436)
0065  CALL REED
0066  IMS=IAL(1)
0067  IF(IMS.EQ.IY) IOUT=1
0068  IF(IDW.EQ.IY) WRITE(IWF,8310) IMS
0069  IF(NDYN.EQ.0) GO TO 401
0070  IF(IDR.EQ.IT) WRITE(IW,1438)
0071  CALL REED
0072  ISS=IAL(1)
0073  IF(IDW.EQ.IY) WRITE(IWF,8320) ISS
0074  IF(ISS.EQ.IY) IOUT=2
0075  401 NK=NWL+NDYN
0076  WRITE(IW,7000) NGR,NWL,NDYN,NSYS,IOUT
0077  IF(NK.EQ.0.AND.IOUT.EQ.0) GO TO 402
0078  IF(IDR.EQ.IT) WRITE(IW,5700)
0079  CALL REED
0080  NOPT=IFIX(1)
0081  IF(IDW.EQ.IY) WRITE(IWF,8325) NOPT
0082  WRITE(IW,7000) NOPT
402 IF(NSYS.EQ.0) GO TO 426
408 C  NCASE=NK+NGR
0086 IF(IDR.EQ.IT) WRITE(IW,4910)
0087 DO 403 I=1,NSYS
0088 DO 403 J=1,NCASE
0089 403 SMULP(I,J)=0.0
0090 C  DO 425 I=1,NSYS
0092 J=0
0093 IF(IDR.EQ.IT) WRITE(IW,4920) I
0094 IF(NGR-1) 408,404,405
0095 404 ITOT=1
0096 IF(IDR.EQ.IT) WRITE(IW,4925)
0097 CALL REED
0098 J=J+1
0099 SMULP(I,J)=AFLX(1)
0100 GO TO 407
0101 405 ITOT=NGR
0102 IF(IDR.EQ.IT) WRITE(IW,4930) NGR
0103 CALL REED
0104 DO 406 K=1,NGR
0105 J=J+1
0106 406 SMULP(I,J)=AFLX(K)
0107 407 IF(IDW.EQ.IY) WRITE(IWF,8330) (JAX(KK),KK=1,32),I
0108 408 IF(NWL-1) 416,410,412
0109 410 ITOT=1
0110 J=J+1
0111 IF(IDR.EQ.IT) WRITE(IW,4935)
0112 CALL REED
0113 SMULP(I,J)=AFLX(1)
0114 GO TO 415
0115 412 ITOT=NWL
0116 IF(IDR.EQ.IT) WRITE(IW,4940) NWL
0117 CALL REED
0118 DO 414 K=1,NWL
0119 J=J+1
0120 414 SMULP(I,J)=AFLX(K)
0121 415 IF(IDW.EQ.IY) WRITE(IWF,8340) (JAX(KK),KK=1,32),I
0122 416 IF(NDYN.EQ.0) GO TO 418
ITOT=1
IF(IDR.EQ.IT) WRITE(IW,4945)
CALL REED
IF(IDW.EQ.IY) WRITE(IWF,8350) (JAX(KK),KK=1,8),I
J=J+1
SMULP(I,J)=AFLX(1)
WRITE(IW,7030) (SMULP(I,K),K=1,NCASE)
CONTINUE

426 IF(NGR.EQ.0.AND.NWL.EQ.0) GO TO 560
C
READ DATA FOR GRAVITY LOAD CASES
DATA FOR DISTRIBUTED LOADS :

IF(NGR.EQ.0) GO TO 510
IFR=0
NFR=0
IF(IDR.NE.IT) GO TO 427
WRITE(IW,4950)
GO TO 428
READ(IR,7040)

427 IF(IDW.EQ.IY) WRITE(IWF,8360)
DO 500 IJ=1,NFG
NNG=NFIG(IJ)
WRITE(IWF,7000) NNG
IYF=1BL
ITY=1BL
IOF=1BL
INF=0
NFR=NFR+NNG
DO .490 JJ=1,NNG.
IFR=IFR+1
IF(IYF.NE.IY) GO TO 431
INDL=1
WRITE(IWF,7000) INDL
IF(ITF.NE.IT.OR.IOF.NE.IO) IYF=1BL
IF(IFR.EQ.INF) IYF=1BL
GO TO 490
INDL=0
WRITE(IWF,7000) INDL
0163 IF(IDR.EQ.II) WRITE(IW,4980) IFR
0164 C
0165 NT=NTF(IJ)
0166 DO 475 IK=1,NGR
0167 IF(IDR.NE.II) GO TO 432
0168 WRITE(IW,4990) IK
0169 WRITE(IW,5000)
0170 GO TO 433
0171 432 READ(IR,7040)
0172 433 IF(IDM.EQ.IY) WRITE(IWF,8370) IFR,IK
0173 IS=0
0174 NN=0
0175 DO 450 I=1,NT
0176 NSS=NST(IJ,I)
0177 NB=NBAY(IJ,I)
0178 NN=NN+NSS
0179 IF(I.NE.I) GO TO 434
0180 NSB=0
0181 GO TO 435
0182 434 NSB=NSB+NBS(IJ,I-1)
0183 435 NBS1=NSB+1
0184 NBS2=NSB+NB
0185 ILL=IBL
0186 II=IBL
0187 I00=IBL
0188 IMB=0
0189 IND=0
0190 DO 448 J=1,NSS
0191 IS=IS+1
0192 II=IBL
0193 I0=IBL
0194 INC=0
0195 IF(ILL.NE.IL) GO TO 438
0196 DO 436 II=NBS1,NBS2
0197 UDL(IS,II)=UDL(IMB,II)
0198 436 CONTINUE
0199 WRITE(IW3,7030) (UDL(IS,II),II=NBS1,NBS2)
0200 IF(I.TT.NE.I1.OR.I00.NE.10) GO TO 445
0201 IF(IS.EQ.IND) GO TO 445
0202 GO TO 448
438 IF(IDR.EQ.IT) WRITE(IW,4050) IS
440 WRITE(IW,4100) K
454 CONTINUE
456 CONTINUE
0203 DO 444 K=NB1,NB2
0204 IF(IIT.NE.IT.OR.IIO.NE.IO) GO TO 440
0205 IF(I.GT.1NC) GO TO 440
0206 UDL(IS,K)=UDL(IS,K-1)
0207 UDL(IS,K)=UDL(IS,K-1)
0208 GO TO 444
0209 IF(IDR.EQ.IT) WRITE(IW,4100) K
0210 IIT=3
0211 CALL REED
0212 IF(IDW.EQ.IY) WRITE(IWF,8160) (JAX(KK),KK=1,40),K
0213 UDL(IS,K)=AFLX(1)
0214 IIT=IAL(9)
0215 IIO=IAL(10)
0216 INC=IFIX(3)
0217 WRITE(IW,7030) (UDL(IS,K),K=NB1,NB2)
0218 WRITE(IW,7030) (UDL(IS,K),K=NB1,NB2)
0219 IF(IS.GE.NN) GO TO 448
0220 IF(IDR.EQ.IT) WRITE(IW,5200) IS,NN
0221 IIT=4
0222 CALL REED
0223 IF(IDW.EQ.IY) WRITE(IWF,8170) (JAX(KK),KK=1,32),IS
0224 IIL=IAL(1)
0225 IMB=IFIX(2)
0226 IIT=IAL(17)
0227 IIO=IAL(8)
0228 INC=IFIX(4)
0229 WRITE(IW,5300)
0230 CONTINUE
0231 IF(IDR.EQ.IT) WRITE(IW,5300)
0232 C
0233 C
0234 C
0235 READ FORCE DATA FOR CONCENTRATED LOADS
0236 IS=0
0237 DO 470 I=1,NT
0238 NSS=NST(IJ,I)
0239 NN=NN+NSS
0240 NB=NBAY(IJ,I)
0241 IF(I.NE.1) GO TO 452
0242 NSB=0
GO TO 454
NSB=NSB+NBS(IJ,I-1)
NBS1=NSB+1
NBS2=NSB+NB
ILL=IBL
ITT=IBL
I00=IBL
IMB=0
IND=0
DO 468 J=1,NSS
IS=IS+1
IIT=IBL
IIO=IBL
INC=0
IF(ILL.NE.IL) GO TO 460
DO 458 II=NBS1,NBS2
NC=NCL(IMB,II)
NCL(IS,II)=NC
WRITE(IW3,7000) NC
IF(NC.EQ.0) GO TO 458
DO 455 JK=1,NC
CNL(IS,II,JK)=CNL(IMB,II,JK)
DIS(IS,II,JK)=DIS(IMB,II,JK)
455 CONTINUE
WRITE(IW3,7030) (CNL(IS,II,JK),DIS(IS,II,JK),JK=1,NC)
458 CONTINUE
IF(ITT.NE.IT.0R.I00.NE.I0) GO TO 465
IF(IS.EQ.IND) GO TO 465
GO TO 468
IF(IDR.EQ.IT) WRITE(IW,4050) IS
DO 464 K=NBS1,NBS2
IF(ITT.NE.IT.0R.IIO.NE.I0) GO TO 461
IF(K.GT.INC) GO TO 461
NCL(IS,K)=NCL(IS,K-1)
WRITE(IW3,7000) NCL(IS,K)
GO TO 464
IF(IDR.EQ.IT) WRITE(IW,5350) K
ITOT=3
CALL REED
NCL(IS,K)=IFIX(1)
0283  IIT=IAL(9)
0284  IIO=IAL(10)
0285  INC=IFIX(3)
0286  NC=NCL(IS,K)
0287  IF(NC.LE.4) GO TO 462
0288  IF(IDR.EQ.IT).WRITE(IWF,5370)
0289  GO TO 461
0290  462 WRITE(IWF,7000) NC
0291  IF(IDW.EQ.IY) WRITE(IWF,8380) (JAX(KK),KK=1,24),K,IS
0292  IF(NC.EQ.0) GO TO 464
0293  IF(IDR.EQ.IT) WRITE(IWF,5380)
0294  DO 463 JK=1,NC
0295  IF(IDR.EQ.IT) WRITE(IWF,5400) JK
0296  ITOT=2
0297  CALL REED
0298  IF(IDW.EQ.IY) WRITE(IWF,8390) (JAX(KK),KK=1,16),JK
0299  CNL(IS,K,JK)=AFLX(1)
0300  DIS(IS,K,JK)=AFLX(2)
0301  463 CONTINUE
0302  WRITE(IWF,7030) (CNL(IS,K,JK),DIS(IS,K,JK),JK=1,NC)
0303  464 CONTINUE
0304  465 IF(IS.GE.NN) GO TO 468
0305  466 IF(IDR.EQ.IT) WRITE(IWF,5450) IS,NN
0306  ITOT=4
0307  CALL REED
0308  IF(IDW.EQ.IY) WRITE(IWF,8170) (JAX(KK),KK=1,32),IS
0309  ILL=IAL(1)
0310  IMB=IFIX(2)
0311  IIT=IAL(17)
0312  IOK=IAL(18)
0313  IND=IFIX(4)
0314  468 CONTINUE
0315  470 CONTINUE
0316  475 CONTINUE
0317  IF(JJ.EQ.NNG) GO TO 490
0318  IF(IDR.EQ.IT) WRITE(IWF,5480) IFR,NFR
0319  ITOT=3
0320  CALL REED
0321  IF(IDW.EQ.IY) WRITE(IWF,8400) (JAX(KK),KK=1,24),IFR
0322  IYF=IAL(1)
0323 ITF=IAL(9)
0324 I0F=IAL(10)
0325 INF=IFIX(3)
0326 490 CONTINUE
0327 500 CONTINUE
0328 C
0329 C    READ DATA FOR LATERAL LOADS
0330 C
0331 510 IF(NWL.EQ.0) RETURN
0332 IF(IDR.EQ.IT) WRITE(IW,5500)
0333 DO 555 J=1,NWL
0334 IF(IDR.EQ.IT) WRITE(IW,5520) J
0335 ILL=IBL
0336 ITT=IBL
0337 I00=IBL
0338 IMB=0
0339 IND=0
0340 DO 550 I=1,NNS
0341 IF(I.LT.NS) GO TO 520
0342 HLX(I)=HLX(IMB)
0343 HLY(I)=HLY(IMB)
0344 DHX(I)=DHX(IMB)
0345 DHY(I)=DHY(IMB)
0346 WRITE(IW3,7020) HLX(I),HLY(I),DHX(I),DHY(I)
0347 IF(ITT.NE.100.OR.I00.NE.10) GO TO 530
0348 IF(I.EQ.IND) GO TO 530
0349 GO TO 550
0350 520 IF(IDR.EQ.IT) WRITE(IW,5550) I
0351 I10T=2
0352 CALL REED
0353 IF(IDW.EQ.IY) WRITE(IWF,8410) (JAX(KK),KK=1,16),J
0354 HLX(I)=AFLX(1)
0355 HLY(I)=AFLX(2)
0356 IF(IDR.EQ.IT) WRITE(IW,5600)
0357 CALL_REED
0358 IF(IDW.EQ.IY) WRITE(IWF,8420) (JAX(KK),KK=1,16)
0359 DHX(I)=AFLX(1)
0360 DHY(I)=AFLX(2)
0361 WRITE(IW3,7020) HLX(I),HLY(I),DHX(I),DHY(I)
0362 530 IF(I.EQ.NNS) GO TO 550
0403 IF(IDW.EQ.IY) WRITE(IWF,8480) (JAX(KK),KK=1,10)
0404 IF(IDR.EQ.IT) WRITE(IWF,8100)
0405 CALL REED
0406 NP=IPIX(1)
0407 IF(IDW.EQ.IY) WRITE(IWF,8490) NP
0408 WRITE(IWF,7000) NP
0409 IF(IDR.EQ.IT) WRITE(IWF,6110)
0410 DO 565 IP=1,NP
0411 IF(IDR.EQ.IT) WRITE(IWF,6120) IP
0412 CALL REED
0413 TC=AFLX(1)
0414 SAC=AFLX(2)
0415 IF(IDW.EQ.IY) WRITE(IWF,8500) (JAX(KK),KK=1,16),IP
0416 WRITE(IWF,7030) TC,SAC
0417 565 CONTINUE
0418 IF(IDR.EQ.IT) WRITE(IWF,6150)
0419 CALL REED
0420 TD=AFLX(1)
0421 IF(IDW.EQ.IY) WRITE(IWF,8510) (JAX(KK),KK=1,10)
0422 IF(IDR.EQ.IT) WRITE(IWF,6200)
0423 CALL REED
0424 AG=AFLX(1)
0425 IF(IDW.EQ.IY) WRITE(IWF,8520) (JAX(KK),KK=1,10)
0426 WRITE(IWF,7030) XMU,SD,BETA,TD,AG
0427 566 CONTINUE
0428 IF(IDR.NE.IT) GO TO 567
0429 WRITE(IWF,6300)
0430 GO TO 568
0431 567 READ(IR,7040)
0432 568 IF(IDW.EQ.IY) WRITE(IWF,8530)
0433 ILL=IBL
0434 ITT=IBL
0435 I(0)=IBL
0436 IMB=0
0437 IND=0
0438 DO 600 I=1,NNS
0439 IF(ILL.NE.IL) GO TO 570
0440 XM(I)=XM(IMB)
0441 XMI(I)=XMI(IMB)
0442 XB(I)=XB(IMB)
0443  YB(I)=YB(IMB)
0444  WRITE(IW,7030) XM(I),XMI(I),XB(I),YB(I)
0445  IF(ITT,NE,IT,0R,100,NE,IT,0) GO TO 580
0446  IF(I.EQ.IND) GO TO 580
0447  GO TO 600
0448  570 IF(IDR,EQ,IT) WRITE(IW,6350) I
0449  CALL REED
0450  XM(I)=AFLX(1)
0451  IF(IDW,EQ,ITY) WRITE(IWF,8540) (JAX(KK),KK=1,10),I
0452  IF(NOPT,EQ,3) GO TO 575
0453  XMI(I)=0.0
0454  GO TO 576
0455  575 IF(IDR,EQ,IT) WRITE(IW,6400)
0456  CALL REED
0457  XMI(I)=AFLX(1)
0458  IF(IDW,EQ,ITY) WRITE(IWF,8550) (JAX(KK),KK=1,10)
0459  576 IF(IDR,EQ,IT) WRITE(IW,6450)
0460  ITOI=2
0461  CALL REED
0462  XB(I)=AFLX(1)
0463  YB(I)=AFLX(2)
0464  IF(IDW,EQ,ITY) WRITE(IWF,8560) (JAX(KK),KK=1,16)
0465  WRITE(IW,7030) XM(I),XMI(I),XB(I),YB(I)
0466  580 IF(I,GE,NNS) GO TO 600
0467  590 IF(IDR,EQ,IT) WRITE(IW,6500) I
0468  ITOI=4
0469  CALL REED
0470  IF(IDW,EQ,ITY) WRITE(IWF,8170) (JAX(KK),KK=1,32),I
0471  ILL=IAL(1)
0472  IMB=IFIX(2)
0473  IIT=IAL(17)
0474  IOO=IAL(18)
0475  IND=IFIX(4)
0476  600 CONTINUE
0477  C
0478  C  FIND NO.OF ELEMENTS OF STIFFNESS MATRIX REQD TO STORE
0479  C
0480  650,NE1=0
0481  DO 700 IJ=1,NFG
0482  NT=NTF(IJ)
JTN=0
JTR=0
DO 695 I=1,NT
NB=NBAY(I,J,I)
NSS=NST(I,J,I)
JA=2*NB+4
JB=3*NB+5
JC=NB+1
JY=2*JA*JC+JB
JTN=JTN+JY*(NSS-1)
IF(I.EQ.1) GO TO 692
NSB=NBS(I,J,I-1)
JP=JA1-NSB
JQ=JP+JC
JR=NB+NB1-NSB+4
JT=JC*(JP+JR)+JQ
JTR=JTR+JT
GO TO 694
692 JX=(JA-NB)*NB+2*(JA-1)
694 JA1=JA
NB1=NB
CONTINUE
NEL=JX+JTN+JTR
IF(NEL.GT.NEL) NEL=NEL
NEL=NEL
C
CONTINUE
WRITE(IW,7090) NEL
C
STOP
C
1410 FORMAT(1' LOAD CASE INFORMATION DATA :'/)
1420 FORMAT(1' NUMBER OF GRAVITY LOAD CASES (MAX. 4)/)
1430 FORMAT(1' DO YOU WANT TO INCLUDE EARTHQUAKE LOADS?'/)
1435 FORMAT(1' NUMBER OF LOAD SYSTEMS (LOAD COMBINATIONS)'/)
1436 FORMAT(1' DO YOU WANT THE STRUCTURAL'/)
1438 FORMAT(1' DO YOU WANT EARTHQUAKE STORY SHEAR'/)
4050 FORMAT(/ STORY NO., I3, /)
4100 FORMAT(/ FOR BEAM IN BAY NO., I3)
4910 FORMAT(/ LOAD SYSTEMS INFORMATION DATA: /)
+ LOAD SYSTEMS MUST BE ARRANGED(NUMBERED) SEQUENTIALLY
+ ACCORDING TO THE FOLLOWING PREFERENCE LIST ....
+ LOAD SYSTEMS CONTAINING
+ 1 GRAVITY LOAD CASES ONLY
+ 2 GRAVITY LOAD, AND/OR LATERAL LOAD CASES
+ 3 GRAVITY LOAD, AND/OR LATERAL LOAD, AND/OR SEISMIC LOADS
4920 FORMAT(/ LOAD SYSTEM, I3, /)
4925 FORMAT(/ INPUT MULT. FACTOR FOR THE GRAVITY LOAD CASE)
4930 FORMAT(/ INPUT MULT. FACTORS FOR GRAVITY LOAD CASES 1 THRU I3,
+ SEPARATED BY BLANKS)
4935 FORMAT(/ INPUT MULT. FACTOR FOR THE LATERAL LOAD CASE)
4940 FORMAT(/ INPUT MULT. FACTORS FOR LATERAL LOAD CASES 1 THRU I3,
+ SEPARATED BY BLANKS)
4945 FORMAT(/ INPUT MULT. FACTOR FOR THE EARTHQUAKE LOAD(IF ANY))
4950 FORMAT(/ DATA FOR GRAVITY LOAD CASES: /)
4980 FORMAT(/)
+ FRAME NO., I3,
+ --------------/
4990 FORMAT(/ GRAVITY LOAD CASE, I3, /)
5000 FORMAT(/ UNIFORMLY DISTRIBUTED LOADS(UDL); /)
5048 + INPUT THE DISTRIBUTED LOAD PER LINEAR UNIT FOR EACH BEAM
5200 FORMAT(/ UDL DATA IS COMPLETE UPTO STORY, I3,
+ ARE THE UDL'S ON THE BEAMS IN THE NEXT STORY(AND MAX. UPTO/
+ STORY, I3, ) EXACTLY LIKE THOSE IN ANY PRECEDING STORY ?
+ IF NOT-----PUT NO, IF YES-----LIKE WHICH ?
5300 FORMAT(/ DATA FOR CONCENTRATED LOADS: /)
5344 (+ MAX. 4 LOADS PER BEAM)
5350 FORMAT(/ NO. OF CONC. LOADS ON THE BEAM AT BAY NO., I3)
5370 FORMAT(/ THE NO. OF CONC. LOADS JUST SUPPLIED
+ IS MORE THAN 4, TRY AGAIN....
5380 FORMAT(/ INPUT THE LOAD VALUE AND THEN ITS DISTANCE FROM/
+ THE LEFT COLUMN CENTER, SEPARATED BY A BLANK)
5400 FORMAT(/ LOAD NO., I3, /)
5450 FORMAT(/ CONC. LOAD DATA IS COMPLETE UPTO STORY, I3, /)
+ ARE THE LOADS AND THEIR POSITIONS IN THE NEXT STORY.
(AND MAX. UPTO STORY, I3, ) EXACTLY LIKE THOSE

IN ANY PRECEDING STORY? IF NOT—PUT NO, IF YES—LIKE WHICH?"

5480 FORMAT(//' GRAVITY LOAD DATA IS COMPLETE FOR FRAME NO., I3,' //

IS THIS DATA EXACTLY THE SAME( FOR ALL GR. LOAD CASES)?'

IN THE NEXT FRAME( AND POSSIBLY UPTO FRAME NO., I3, ) ? Y/N')

5500 FORMAT(//' DATA FOR LATERAL LOAD CASES ' //)

5520 FORMAT(//' LATERAL LOAD CASE, I3, ' //)

5550 FORMAT(//' STORY NO., I3, ' //)

INPUT HOR. LOAD COMPONENT IN GLOBAL X-DIRECTION AND THEN ' //

IN THE Y-DIRECTION, SEPARATED BY A BLANK')

5600 FORMAT(//' INPUT THE X-DISTANCE AND THEN THE Y-DISTANCE OF ' //

THE POINT OF ACTION FROM GLOBAL ORIGIN')

5650 FORMAT(//' LOAD AND DISTANCE DATA IS COMPLETE UPTO STORY, I3,' //

IS THIS DATA FOR THE NEXT STORY EXACTLY LIKE THAT?'

IN ANY PRECEDING STORY? IF NOT—PUT NO, IF YES—LIKE WHICH?"

5700 FORMAT(//' FOR THREE DIMENSIONAL ANALYSIS ' //)

CODE FOR NO. OF DEGREES OF FREEDOM AT EACH STORY ? 1/2/3//' //

1 FOR X-TRANSLATION ONLY'

2 FOR Y-TRANSLATION ONLY'

3 FOR X, Y-TRANSLATION AND ROTATION/

5800 FORMAT(//' DYNAMIC ANALYSIS ' //)

NO. OF MODES TO BE CONSIDERED'

5850 FORMAT(//' NO. OF MODES TO BE EXTRACTED FROM ONE ORIGIN'

(USUALLY NOT MORE THAN 5)')

5900 FORMAT(//' DUCTILITY FACTOR')

6000 FORMAT(//' SCALE FACTOR FOR DESIGN SPECTRUM')

6050 FORMAT(//' ANGLE OF INCIDENCE OF EARTHQUAKE')

WITH THE GLOBAL X-AXIS, DEGREES'

6100 FORMAT(//' NO. OF PERIOD COORDINATES FOR RESPONSE SPECTRUM')

FOR EACH PERIOD COORDINATE, INPUT THE PERIOD VALUE'

AND THEN THE CORRESPONDING SPECTRAL ACCELERATION',

SEPARATED BY A BLANK')

6120 FORMAT(//' PERIOD COORD. NO., I3, ' ')

6150 FORMAT(//' PERIOD WHICH SEPARATES THE ACCL. BOUND FROM'

THE VEL. BOUND ON THE RESPONSE SPECTRUM')

6200 FORMAT(//' ACCELERATION DUE TO GRAVITY')

6300 FORMAT(//' MASS DATA ' //)

AT STORY LEVEL, I3, , TRANSLATIONAL FLOOR MASS'

6400 FORMAT(//' ROTATIONAL MASS MOM. OF INERTIA')

6450 FORMAT(//' PUT X-DISTANCE AND THEN Y-DISTANCE OF THE CENTRE OF//
MASS FROM THE REFERENCE POINT, SEPARATED BY A BLANK

THE MASS AND DISTANCE DATA IS COMPLETE UPTO STORY I3.

IS THIS DATA IN THE NEXT STORY EXACTLY LIKE THAT?

IN ANY PRECEDING STORY? IF NOT--PUT NO, IF YES—LIKE WHICH?

7000 FORMAT(5I5)
7020 FORMAT(5F15.5)
7030 FORMAT(8F10.3)
7040 FORMAT(1X,1A1)
7050 FORMAT(40A1)
7060 FORMAT(1X,40A1)
7070 FORMAT(70A1)
7080 FORMAT(215,4X,A1,F15.5)
7090 FORMAT(/** MAX. NO. OF FRAME STIFFNESS ELEMENTS**/

** REQUIRED TO BE STORED IS, NEL = ',16)

C

8160 FORMAT(40A1,/-- BEAM AT BAY ',I3)
8170 FORMAT(32A1,/- COMPLETE UPTO STORY ',I3,/, NEXT?')
8270 FORMAT(I3,29X,/- NO. OF GRAVT LOAD CASES')
8280 FORMAT(I3,29X,/- NO. OF LATERAL LOAD CASES')
8290 FORMAT(A1,31X,/- SEISMIC LOADS CONSIDERED?)
8300 FORMAT(I3,29X,/- NO. OF LOAD SYSTEMS CONSIDERED?)
8310 FORMAT(A1,31X,/- OUTPUT FOR MODE SHAPES REQD.?)
8320 FORMAT(A1,31X,/- OUTPUT FOR DYN. STORY FORCES REQD.?)
8325 FORMAT(I3,29X,/- CODE FOR STORY DEGREES OF FREEDOM)
8330 FORMAT(32A1,/- IN LOAD SYSTM',I3,/,FACTRS FOR GRVT LOADS')
8340 FORMAT(32A1,/- IN LOAD SYSTM',I3,/,FACTRS FOR LATR LOADS')
8350 FORMAT(8A1,24X,/- FACTR FOR SEISMIC LOADS,LOAD SYSTM',I3)
8360 FORMAT( 'GRAVITY LOAD CASE DATA')
8370 FORMAT( 'UDL - FRAME',I3,/, GRVT LOAD CASE',I3)
8380 FORMAT(24A1,6X,/- NO. OF CONC'TD. LOADS,BEAM',I2,/,STORY',I3)
8390 FORMAT(16A1,16X,/- LOAD ',I3, ' & DIST.')
8400 FORMAT(24A1,/- COMPLETE UPTO FRAME',I3,/,NEXT-SAME?)
8000 FORMAT(16A1,16X,/- LAT. LOAD X-,Y-COMPNTS FOR CASE',I2)
8200 FORMAT(16A1,16X,/- X-DIST & Y-DIST')
840 FORMAT( 'DYNAMIC ANALYSIS')
8440 FORMAT(I3,29X,/- NO. OF MODES CONSIDERED')
8450 FORMAT(I3,29X,/- MODES EXTRACTED FROM ONE ORIGIN')
8460 FORMAT(10A1,22X,/- DUCTILITY FACTOR')
8470 FORMAT(10A1,22X,/- SCALE FACTOR')
8480 FORMAT(10A1,22X,/- ANGLE OF INCIDENCE')
END
SUBROUTINE REED

SUBROUTINE FOR FREE FORMAT READ

VERSION OF UTILITY SUBROUTINE REED: MAY 4, 1978

COMMON/BLOKI/IR, IWK, IN, ITOT, JA(80), IA(48), IFI(6), AFL(6), IND(6),
     *JBNBD(6, 6), JBND(4, 6), FBND(4, 6)

DIMENSION JBNTT(6)

DATA 10, 1, 12, 13, 14, 15, 16, 17, 18, 19/
     +1H0, 1H1, 1H2, 1H3, 1H4, 1H5, 1H6, 1H7, 1H8, 1H9/

DATA IBLANK, IPLUS, IMINUS, IDU1/1H-1H+, 1H-, 1H1/1H0,
DATA ITL, ITU, IY/I1H1, 1H0, 1HT, 1HU, 1HY/

DATA IF, IINN/I1HF, 1HN/

C INITIALIZE INPUT DATA ARRAYS TO BLANK OR ZERO

DO 100 I = 1, 48
100 IA(I) = IBLANK

DO 101 I = 1, 6
101 IFI(I) = 0

DO 230 IND(I) = 0

DO 240 JBNTT(I) = 0

AFL(I) = 0.

DO 260 J = 1, 6
260 DO 270 K = 1, 4
270 JBNTT(J) = JBNTT(J) + JBND(K, J) + JBND(K + 4, J)

READ UNPROCESSED ALPHANUMERIC INPUT

READ(IR, I, END=108)(JA(I), I = 1, IN)

GO TO 109

MALS

READ(IR, I)(JA(I), I = 1, IN)

MALS

IF(ENDIF, IR) GO TO 109

WRITE(IW, 3)

GO TO 110
41.000 C
42.000 C SET COUNTS ETC TO INITIAL VALUES
43.000 109 KOUNT=1
44.000 1OOUNT=1
45.000 INUMB=1
46.000 NUMB=0
47.000 ISIGN=1
48.000 IDES=0
49.000 IDEF=1
50.000 IWORD=0
51.000 ISIZE=0
52.000 IBIG=0
53.000 IZERO=0
54.000 C
55.000 C PROCESS AS MUCH AS REQUESTED OF INPUT ARRAY UNLESS TERMINATED
56.000 C BY UPPER LIMITS ON NO. OF DATA UNITS TO BE GENERATED
57.000 DO 102 I=1,IN
58.000 C RECOGNIZE BLANK AND TRANSFER CONTROL FOR PROCESSING OF BLANK
59.000 IF(JA(I).NE.IBLEANK)GOTO 103
60.000 IF(IWORD.EQ.0)GOTO 102
61.000 IF(INUMB.EQ.0)GOTO 107
62.000 GOTO 113
63.000 C
64.000 103 IWORD=1
65.000 IF(ISIZE.GT.8)GOTO 106
66.000 C LOAD A1 DATA INTO ALPHANUMERIC ARRAY IF DATA UNIT LENGTH DOES NOT
67.000 C EXCEED EIGHT
68.000 IA(I0OUNT)=JA(I)
69.000 I0OUNT=I0UNT+1
70.000 ISIZE=ISIZE+1
71.000 106 IF(INUMB.EQ.0)GOTO 102
72.000 C
73.000 C CONVERT ALPHANUMERIC DIGIT TO NUMERICAL EQUIVALENT
74.000 IF(JA(I).EQ.10.OR.JA(I).EQ.10)GOTO 500
75.000 IF(JA(I).EQ.11.OR.JA(I).EQ.11)GOTO 501
76.000 IF(JA(I).EQ.12)GOTO 502
77.000 IF(JA(I).EQ.13)GOF0 503
78.000 IF(JA(I).EQ.14)GOTO 504
79.000 IF(JA(I).EQ.15)GOTO 505
80.000 IF(JA(I).EQ.16)GOTO 506
81.000 IF(JA(I).EQ.17)GOTO 507
82.000 IF(JA(I).EQ.18)GOTO 508
83.000 IF(JA(I).EQ.19)GOTO 509
84.000 IF(JA(I).EQ.IDOT)GOTO 150
85.000 IF(JA(I).EQ.IMINUS)GOTO 122
86.000 INUMB=0
87.000 ISIGN=1
88.000 IDES=0
89.000 IBIG=0
90.000 IFI(KOUNT)=0
91.000 AFL(KOUNT)=0.
92.000 ING(KOUNT)=0
93.000 GOTO 102
94.000 C
95.000 150 IF(IDES.EQ.1)INUMB=0
96.000 IDES=1
97.000 C IDES=1 MEANS THAT A DECIMAL POINT HAS BEEN ENCOUNTERED
98.000 GOTO 102
99.000 C
100.000 122 IF((ISIGN.EQ.-1).OR.(NUMB.NE.0).OR.(IZER0.NE.0)
101.000 +.OR.(IDES.NE.0))INUMB=0
102.000 ISIGN=-1
103.000 GOTO 102
104.000 C
105.000 500 NUM=0.
106.000 IF(NUMB.EQ.0)IZER0=1
107.000 GOTO 104
108.000 501 NUM=1
109.000 GOTO 104
110.000 502 NUM=2
111.000 GOTO 104
112.000 503 NUM=3
113.000 GOTO 104
114.000 504 NUM=4
115.000 GOTO 104
116.000 505 NUM=5
117.000 GOTO 104
118.000 506 NUM=6
119.000 GOTO 104
120.000 507 NUM=7
121.000  GO TO 104
122.000  508 NUM=8
123.000  GO TO 104
124.000  509 NUM=9
125.000  104 CONTINUE
126.000  IF (NUM.B.GT.3275) GO TO 105
127.000  114 IF (IDET.EQ.10000) GO TO 119
128.000  NUMB=10*NUMB+NUM
129.000  IF (IDES.EQ.1) IDET=10*IDET
130.000  GO TO 102
131.000  C
132.000  119 ANUM=NUM
133.000  IF (IBIG.EQ.2) GO TO 117
134.000  ANUMB=NUMB
135.000  GO TO 115
136.000  C
137.000  105 ANUM=NUM
138.000  IF (IBIG.EQ.1) GO TO 116
139.000  IF (IBIG.EQ.2) GO TO 117
140.000  IF (NUMB.EQ.3276. AND. NUM.LE.7) GO TO 114
141.000  ANUMB=NUMB
142.000  116 IF (IDES.EQ.1) GO TO 115
143.000  ANUMB=10.*ANUMB+ANUM
144.000  IBIG=1
145.000  GO TO 102
146.000  C
147.000  115 ADET=IDET
148.000  IBIG=2
149.000  ANUMB=ANUMB/ADET
150.000  117 ADET=10.*ADET
151.000  ANUMB=ANUMB+ANUM/ADET
152.000  GO TO 102
153.000  C
154.000  118 IND(KOUNT)=1
155.000  IF (ISIGN.LT.1) ANUMB=-ANUMB
156.000  AFL(KOUNT)=ANUMB
157.000  GO TO 121
158.000  C
159.000  C CARRY OUT FINAL COMPUTATION AND STORAGE OF NUMERICAL DATA
160.000  113 IF (IBIG.GE.1) GO TO 119
C DO FINAL COMPUTATION AND STORAGE OF FIXED POINT NUMERICAL DATA

IFI(KOUNT)=NUMB/IDET
AIDET=IDET
ANUMB=NUMB

C DO FINAL COMPUTATION AND STORAGE OF FLOATING POINT NUMERICAL DATA

AFL(KOUNT)=ANUMB/AIDET
IND(KOUNT)=2

C PERFORM RANGE CHECKS IF REQUIRED

121 JBNT=JNBD(1,KOUNT)+JNBD(2,KOUNT)+JNBD(3,KOUNT)+JNBD(4,KOUNT)
172 IF(JBNT.EQ.0)GO TO 524
173 IF(JNBD(1,KOUNT).EQ.0)GO TO 521
174 IF(IFK(KOUNT).LE.IBND(1,KOUNT))GO TO 521
175 WRITE(IW,5)IFI(KOUNT)
176 GO TO 112
177 IF(JNBD(2,KOUNT).EQ.0)GO TO 522
178 IF(IFK(KOUNT).GE.IBND(2,KOUNT))GO TO 522
179 WRITE(IW,6)IFI(KOUNT)
180 GO TO 112
181 IF(JNBD(3,KOUNT).EQ.0)GO TO 523
182 IF(IFK(KOUNT).LE.IBND(3,KOUNT))GO TO 523
183 WRITE(IW,7)IFI(KOUNT)
184 READ(IR,1)IYN
185 IF((IYN.NE.IY).AND.(IYN.NE.IO).AND.(IYN.NE.IO))GOTO 112
186 IF(JNBD(4,KOUNT).EQ.0)GO TO 524
187 IF(IFK(KOUNT).GE.IBND(4,KOUNT))GO TO 524
188 WRITE(IW,8)IFI(KOUNT)
189 READ(IR,1)IYN
190 IF((IYN.NE.IY).AND.(IYN.NE.IO).AND.(IYN.NE.IO))GOTO 112
191 JBNT=JNBD(5,KOUNT)+JNBD(6,KOUNT)+JNBD(7,KOUNT)+JNBD(8,KOUNT)
192 IF(JBNT.EQ.0)GO TO 528
193 IF(JNBD(5,KOUNT).EQ.0)GO TO 525
194 IF(AFL(KOUNT).LE.FNBD(1,KOUNT))GO TO 525
195 WRITE(IW,9)AFL(KOUNT)
196 GO TO 112
197 IF(JNBD(6,KOUNT).EQ.0)GO TO 526
198 IF(AFL(KOUNT).GE.FNBD(2,KOUNT))GO TO 526
199 WRITE(IW,10)AFL(KOUNT)
200 GO TO 112
201.000 526 IF(JBND(7,KOUNT).EQ.0)GO TO 527
202.000 IF(AFL(KOUNT).LE.FBND(3,KOUNT))GO TO 527
203.000 WRITE(IW,11)AFL(KOUNT)
204.000 READ(IR,1)IYN
205.000 IF((IYN.NE.IY).AND.(IYN.NE.IO).AND.(IYN.NE.IO))GO TO 112
206.000 527 IF(JBND(8,KOUNT).EQ.0)GO TO 528
207.000 IF(AFL(KOUNT).GE.FBND(4,KOUNT))GO TO 528
208.000 WRITE(IW,12)AFL(KOUNT)
209.000 READ(IR,1)IYN
210.000 IF((IYN.NE.IY).AND.(IYN.NE.IO).AND.(IYN.NE.IO))GO TO 112
211.000 528 CONTINUE
212.000 C
213.000 NUMB=0
214.000 ISIGN=1
215.000 IDES=0
216.000 IDET=1
217.000 IBIG=0
218.000 C
219.000 C DATA ITEM COUNT FOR BOTH NUMERIC AND ALPHANUMERIC DATA
220.000 107 KOUNT=KOUNT+1
221.000 IF(KOUNT.GT.10)GO TO 510
222.000 IOUTN=8*KOUNT-7
223.000 ISIZE=0
224.000 IWORD=0
225.000 INUMB=1
226.000 IDES=0
227.000 NUMB=0
228.000 ISIGN=1
229.000 IBIG=0
230.000 IDET=1
231.000 IZERO=0
232.000 102 CONTINUE
233.000 C
234.000 510 CONTINUE
235.000 IF(IA(1).EQ.IA(2).EQ.IA(3).EQ.IA(4).EQ.IA(5))GO TO 333
236.000 + GO TO 333
237.000 IF(IA(1).EQ.IF.AND.IA(2).EQ.II.AND.IA(3).EQ.INN)GO TO 333
238.000 GO TO 111
239.000 333 WRITE(IW,4)
240.000 STOP
241.000 C
242.000 601 WRITE(IN,13)KKKK
243.000  GOTO 112
244.000 C
245.000 111 CONTINUE
246.000  DO 602 J=1,ITOT
247.000  KKKK=J
248.000  IF(IND(J).EQ.0.AND.JBNT(J).GT.0)GOTO 601
249.000 602 CONTINUE
250.000  DO 120 I=1,8
251.000  DO 120 J=1,ITOT
252.000 120 JBDI(I,J)=0
253.000 831 CONTINUE
254.000  RETURN
255.000 C
256.000 1 FORMAT(130A1)
257.000 3 FORMAT(’NO DATA SUPPLIED. TRY AGAIN’)
258.000 4 FORMAT(’PROGRAM HAS BEEN INTERRUPTED BY USER’)
259.000 5 FORMAT(’DATA VALUE JUST SUPPLIED (*.17,*) IS TOO LARGE.’)
260.000  + ’TRY AGAIN’)
261.000 6 FORMAT(’DATA VALUE JUST SUPPLIED (*.17,*) IS TOO SMALL.’)
262.000  + ’TRY AGAIN’)
263.000 7 FORMAT(’DATA VALUE JUST SUPPLIED (*.17,*) IS UNUSUALLY LARGE.’)
264.000  + ’DO YOU WISH TO USE IT? Y/N’)
265.000 8 FORMAT(’DATA VALUE JUST SUPPLIED (*.17,*) IS UNUSUALLY SMALL.’)
266.000  + ’DO YOU WISH TO USE IT? Y/N’)
267.000 9 FORMAT(’DATA VALUE JUST SUPPLIED (*.12.4,*) IS TOO LARGE.’)
268.000  + ’TRY AGAIN’)
269.000 10 FORMAT(’DATA VALUE JUST SUPPLIED (*.12.4,*) IS TOO SMALL.’)
270.000  + ’TRY AGAIN’)
271.000 11 FORMAT(’DATA VALUE JUST SUPPLIED (*.12.4,*) IS UNUSUALLY.’)
272.000  + ’LARGE.’, ’DO YOU WISH TO USE IT? Y/N’)
273.000 12 FORMAT(’DATA VALUE JUST SUPPLIED (*.12.4,*) IS UNUSUALLY.’)
274.000  + ’SMALL.’, ’DO YOU WISH TO USE IT? Y/N’)
275.000 13 FORMAT(’THERE IS AN ERROR IN TERM NO. *.13, OF INPUT DATA JUST SUPPLIED.’)
276.000  + ’PLEASE TRY AGAIN’)
277.000  END
CHAPTER 82

FORTRAN LISTING OF PROGRAM - ANGELS
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1.000 C
2.000 C
3.000 C
4.000 C
5.000 C
6.000 C
7.000 C
8.000 C
9.000 C
10.000 C
11.000 C
12.000 C
13.000 C
14.000 C
15.000 C
16.000 C
17.000 C
18.000 COMMON/COM1/BI2MCL(2490),NT,NN,NSS(10),NBAY(9),NBS(9),H(30)
19.000 COMMON/COM/NNS,NFT,NOP,T,Q,NMULP
20.000 COMMON/SPEC/NM,LM,XMU,SK,BETA,MI,ALLOW,TD,AG,NP,TC(10),SAC(10)
21.000 COMMON/COMSY/NOR,NML,NDYN,NSYS10,INUT,SMULP(12,8)
22.000 COMMON/MISC/IR,IV,AT(3),AJ(3),IDN,NH
23.000 COMMON,SK(12000)
24.000 DIMENSION M(D20),NDIR(20),DDA(20),NAME(40)
25.000 DATA IX,IY,IXH,ITY/
26.000 C
27.000 IR=1
28.000 IW=7
29.000 MGORE=12000
30.000 MI=300
31.000 ALLOW=0.000001
32.000 CALL NAM(IW)
33.000 READ(IR,600) (NAME(I),I=1,40)
34.000 WRITE(IW,650) (NAME(I),I=1,40)
35.000 READ(IR,100) NFT,NFG,NNS,NBA
36.000 WRITE(IW,520) NFT,NFG,NNS,NBA
37.000 WRITE(IW,335)
38.000 READ(IR,300) (H(IK),IK=1,NNS)
39.000 WRITE(IW,301)
40.000 WRITE(IW,302)
41.000 C READ AND PRINT FRAME LOCATIONS
42.000 C
43.000 C
44.000 DO 10 K=1,NFT
45.000 READ(IR,110) II,M(K),IFD,DDA(K)
46.000 ND=1
47.000 IF(IFD.EQ.IY) ND=2
48.000 NDIR(K)=ND
49.000 WRITE(IW,303) II,M(K),IFD,DDA(K)
50.000 CONTINUE
51.000 READ(IR,100) NGR,NWL,NDYN,NSYS,IOUT
52.000 WRITE(IW,652) NGR,NWL,NDYN,NSYS
53.000 NJ=NWL+NDYN
54.000 IF(IOUT.EQ.0.AND.NJ.EQ.0) GO TO 11
55.000 READ(IR,100) NOPT
56.000 WRITE(IW,307) NOPT
57.000 NK=NJ+NGR
58.000 IF(NSYS.EQ.0) GO TO 13
59.000 DO 12 I=1,NSYS
60.000 READ(IR,130) (SMULP(I,J),J=1,NK)
61.000 IF(NDYN.EQ.0.AND.IOUT.EQ.0) GO TO 15
62.000 READ(IR,100) NM,LM
63.000 WRITE(IW,312) NM
64.000 WRITE(IW,314) LM
65.000 IF(NDYN.EQ.0) GO TO 15
66.000 READ(IR,100) NP
67.000 DO 14 IP=1,NP
68.000 READ(IR,130) TG(IP),SAC(IP)
69.000 READ(IR,130) XMU,SF,BETA,ID,AG
70.000 WRITE(IW,304) XMU
71.000 WRITE(IW,315) SF
72.000 WRITE(IW,316) BETA
73.000 BETA=BETA*3.14159262/180.
74.000 CALL SP(IW,2)
75.000 WRITE(IW,331)
76.000 WRITE(IW,318)
77.000 WRITE(IW,331)
78.000 CALL SP(IW,2)
79.000 WRITE(IW,319) NP
80.000 WRITE(IW,332) TD
81.000  WRITE(IW,333) AG
82.000  CALL SP(IW,1)
83.000  WRITE(IW,321)
84.000  WRITE(IW,322) (TC(I),SAC(I),I=1,NP)
85.000  15 WRITE(IW,140)
86.000  DO 16 IK=1,NNS
87.000       IJ=IK-1
88.000  16 WRITE(IW,150) IJ,IK,H(IK)
89.000  C
90.000  NBA1=NBA+1
91.000  M1=NNS*NBA
92.000  M2=M1+NNS
93.000  N1=NBA+2
94.000  N2=N1+NNS
95.000  N3=N2+NBA1
96.000  N4=N3+NBA
97.000  N5=N4+M1
98.000  N6=N5+M1
99.000  N7=N6+M1
100.000  N8=N7+M1
101.000  N9=N8+M1
102.000  N10=N9+M1
103.000  N11=N10+M1
104.000  N12=N11+M2
105.000  N13=N12+M2
106.000  N14=N13+M2
107.000  N15=N14+M2
108.000  N16=N15+M2
109.000  N17=N16+M2
110.000  N18=N17+M2-1
111.000  MINCR=N18-MCORE
112.000  IF(N18.GT.MCORE) CALL CORE(MINCR)
113.000  C
114.000  CALL PRO(NGF,NBA,NBA1,NNS,NGQ,NEL,MBM,MCL,SK(1),
115.000   +SK(N1),SK(N2),SK(N3),SK(N4),SK(N5),SK(N6),SK(N7),
116.000   +SK(N8),SK(N9),SK(N10),SK(N11),SK(N12),SK(N13),SK(N14),
117.000   +SK(N15),SK(N16),SK(N17))
118.000  C
119.000  IF(NGR.NE.0) WRITE(IW,200)
120.000  C
M1=1+NEL
M2=M1+NQQ
M3=M2+NQQ
M4=M3+NQQ
M5=M4+MBM
M6=M5+MBM
M7=M6+MBM
M8=M7+MBM
M9=M8+NNS*NBA-1
MINCR=M9-MCORE
IF(M9.GT.MCORE) CALL CORE(MINCR)

DIMENSION SK(1:8), NQQ(1:8)

IJ=0
DO 17 I=1,NFG
CALL STIFF(NEL,NQQ,SK(1),SK(M1),SK(M2),NEQ,NE)
JPT=0
CALL REDUCE(JOPT,NEL,NQQ,SK(1),SK(M1),SK(M2),NEQ,NE)
IF(NGR.EQ.0) GO TO 17
CALL GRAVIT(IJ,NGR,NEL,NQQ,NEQ,MBM,NBA,NNS,SK(1),SK(M1),
+SK(M2),SK(M3),SK(M4),SK(M5),SK(M6),SK(M7),SK(M8))
17 CONTINUE
IF(NJ.EQ.0.AND.NUT.EQ.0) GO TO 90
CALL COND(NFG,SK(1),SK(M1),SK(M2),SK(M3),NQQ,NEL,NEQ,NE)
IF(NOPT.EQ.3) GO TO 18
18 NQ=NNS
G0 TO 20
19 NQ=3*NNS
20 N1=NQ*NQ+1
N2=N1+NNS*NFT
N3=N2+NQ
N4=N3+NNS
N5=N4+NNS
N6=N5+NNS*NNS-1
MINCR=N6-MCORE
IF(N6.GT.MCORE) CALL CORE(MINCR)
IDN=1
CALL STORY(SK(N2),SK(N3),SK(N4))
CALL FRAME(SK(1), SK(N1), M, NDIR, SK(N3), SK(N4), SK(N5), DDA)

RECORD

IF(NWL .NE. 0) CALL HLOAD(SK(1), SK(N1), M, NDIR,
+ SK(N3), SK(N4))

C

IF(NDYN .EQ. 0 .AND. IOUT .EQ. 0) GO TO 80

WRITE(IW, 300)

NMULP = 1

C

IF(NOPT .EQ. 3) NMULP = 3

C

N4 = N3 + NQ * NM

C

N5 = N4 + NM

C

N6 = N5 + NQ * NM

C

N71 = N6 + NM * NMULP

C

N72 = N6 + NQ

C

N7 = MAXO(N71, N72)

C

MINCR = N7 - MCORE + 1

C

IF(N7 .GT. MCORE) CALL CORE(MINCR)

C

NH = NM

C

CALL SPCTRM(SK(1), SK(N2), SK(N3), SK(N4), SK(N5), SK(N3), SK(N3),
+ SK(N6), SK(N6))

C

N5 = N4 + NNS

C

CALL SFORCE(SK(1), SK(N1), M, NDIR, SK(N3), SK(N4), SK(N5))

C

80 REWIND 1

M9 = M8 + MCL

M10 = M9 + MCL

M11 = M10 + MCL

M12 = M11 + MCL

MINCR = M12 + NNS - 1 - MCORE

IF(NWL .EQ. 0) GO TO 85

C

IF(MINCR .GT. 0) CALL CORE(MINCR)

RECORD

CALL R0UT(NFG, NDIR, NEL, NQQ, MCL, MBM, O, 1, SK(1), SK(M1),
+ SK(M2), SK(M3), SK(M4), SK(M5), SK(M6), SK(M7),
+ SK(M8), SK(M9), SK(M10), SK(M11), SK(M12))

IF(NDYN .EQ. 0) GO TO 90

IF(MINCR .GT. 0) CALL CORE(MINCR)
201.000       REWIND 5
202.000       CALL ROOT(NFG,NDIR,NEL,NOQ,MCL,MBM,1,1,SK(1),SK(M1),
203.000         +SK(M2),SK(M3),SK(M4),SK(M5),SK(M6),SK(M7),
204.000         +SK(M8),SK(M9),SK(M10),SK(M11),SK(M12))
205.000       C
206.000       90 IF(NSYS.EQ.0) GO TO 99
207.000       M1=4*MBM
208.000       N1=NOQ+1
209.000       N2=N1+MBM
210.000       N3=N2+MBM
211.000       N4=N3+MBM
212.000       N5=N4+MBM
213.000       N6=N5+MBM
214.000       N7=N6+MBM
215.000       N8=N7+MBM
216.000       N9=N8+MBM
217.000       N10=N9+MCL
218.000       N11=N10+MCL
219.000       N12=N11+MCL
220.000       N13=N12+MCL
221.000       N14=N13+1
222.000       N15=N14+1
223.000       N16=N15+1
224.000       N17=N16+1
225.000       N18=N17+7*NOQ
226.000       N19=N18+NNS-1
227.000       MNCR=N19-MCORE
228.000       IF(MNCR.GT.0) CALL CORE(MNCR)
229.000       C
230.000       CALL SYSTEM(NFG,NOQ,MBM,MCL,NNS,SK(1),SK(N1),SK(N2),
231.000         +SK(N3),SK(N4),SK(N5),SK(N6),SK(N7),SK(N8),SK(N9),
232.000         +SK(N10),SK(N11),SK(N12),SK(N13),SK(N14),SK(N15),SK(N16),
233.000         +SK(N17),SK(N18))
234.000       C
235.000       99 STOP
236.000       C
237.000       100 FORMAT(5I5)
238.000       110 FORMAT(215,4X,A1,F15.5)
239.000       120 FORMAT(5F15.5)
240.000       130 FORMAT(8F10.3)
241.000 135 FORMAT(///  *** UNITS ARE CONSISTENT///)
242.000 140 FORMAT(///  -------------------///)
243.000 4* STORY HEIGHTS, C/C OF///
244.000 4* INTERSECTING FLOOR BEAMS///
245.000 4* --------------------------///
246.000 4* BETWEEN STORY///
247.000 4* STORY LEVELS HEIGTHS///
248.000 150 FORMAT(2X,I3,\ AND\,I3,F12.3)
249.000 200 FORMAT(I1,///
250.000 4* --------------------------///
251.000 4* DATA FOR GRAVITY LOAD CASES///
252.000 4* --------------------------///
253.000 300 FORMAT(I1,///
254.000 4* --------------------------///
255.000 4* DYNAMIC ANALYSIS///
256.000 4* --------------------------///
257.000 301 FORMAT(/2X,---------------------///
258.000 4* +2X,'FRAME POSITION DATA',///
259.000 4* +2X,-------------------///
260.000 302 FORMAT(2X,'FRAME',4X,'FRAME GROUP',4X,'DIRECTION',4X,
261.000 4* 'DIST FROM ORIGIN')///
262.000 303 FORMAT(1X,I4,112,13X,A1,F18.2)
263.000 304 FORMAT(2X,'DUCTILITY FACTOR ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... ... 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281.000  333 FORMAT(1X, 'ACCELERATION DUE TO GRAVITY...='','F10.2)
282.000  520 FORMAT(2X, 'TOTAL NO. OF FRAMES IN THE BUILDING...'),
283.000  +-- ---. = ',I3,'/
284.000  +2X, 'TOTAL NO. OF FRAME GROUPS... ... ... ... ',
285.000  +-- ---. = ',I3,'/
286.000  +2X, 'TOTAL NO. OF STORIES IN THE BUILDING... ',
287.000  +-- ---. = ',I3,'/
288.000  +2X, 'MAX. NO. OF BAYS IN THE WIDEST FRAME... ',
289.000  +-- ---. = ',I3,'/
290.000  600 FORMAT(40A1)
291.000  650 FORMAT(//19X, 'NAME OF PROJECT : = ',40A1//)
292.000  652 FORMAT(/)
293.000  + 'NO. OF GRAVITY LOAD CASES... ... ... ... = ',I3,'
294.000  + 'NO. OF LATERAL LOAD CASES... ... ... ... = ',I3,'
295.000  + 'NO. OF SEISMIC LOAD CASES ... ... ... ... = ',I3,'
296.000  + 'NO. OF LOAD SYSTEMS (LOAD COMBINATIONS)... = ',I3//)
297.000  END
298.000  C
299.000  SUBROUTINE NAM(IW)
300.000  C
301.000  C
302.000  C
303.000  WRITE(IW,50)
304.000  WRITE(IW,100)
305.000  WRITE(IW,200)
306.000  WRITE(IW,60)
307.000  WRITE(IW,300)
308.000  RETURN
309.000  C
310.000  50 FORMAT(1H1// '79(1H=),/ '7(1H*), 'ANALYSIS OF BUILDINGS',
311.000  + 'FOR GRAVITY, EARTHQUAKE AND LATERAL LOADS ',7(1H*),/)
312.000  + '79(1H=))
313.000  60 FORMAT(1H1// '79(1H=),/ '7(1H*), 'ANALYSIS OF BUILDINGS',
314.000  + 'FOR GRAVITY AND LATERAL LOADS ',7(1H*),/)
315.000  + '79(1H=))
316.000  100 FORMAT(4X6(1HA)4X,3(1HN)6X3(1HN)5X6(1HG)5X12(1HE),
317.000  +1X3(1HL)13X6(1HS)/3X8(1HA)3X4(1HN)5X3(1HN)3X
318.000  +1X8(1HG)3X12(1HE)1X3(1HL)11X10(1HS)1X2X3(1HA),
319.000  +4X3(1HA)2X5(1HN)4X3(1HN)2X3(1HG)1X4X1X3(1HG)2X
320.000  +3(1HE)10X3(1HL)10X3(1HS)6X3(1HS)/1X3(1HA)6X3(1HA),
321.000  +1X6(1HN)3X3(1HN)1X3(1HG)8A(1HG)1X3(1HE)10X3(1HL)10X3(1HS)1X
322.000  200 FORMAT(1X3(1HA)6X3(1HA)2(1X3(1HN))2X3(1HN)1X3(1HG)12X9(1HE),
323.000  +4X3(1HL)11X8(1HS)1X1X2(1HA)1X3(1HN)1X2(1X3(1HN))1X
324.000  +3(1HG)4X7(1HE)4X3(1HL)3X8(1HS)1X1X2(1HA),
325.000  +1X3(1HN)3X6(1HN)1X3(1HG)4X7(1HG)1X3(1HE)10X3(1HL)19X
326.000  +3(1HS)1X3(1HA)6X3(1HA)1X3(1HN)4X5(1HN)2X3(1HG)
327.000  +6X3(1HG)1IX3(1HE)10X3(1HL)10X3(1HS)1X4X1X3T1 HS/=,
328.000  +1X3(1HA)6X3(1HA)1X3(1HN)5X4(1HN)3X10(1HG)3X12(1HE),
329.000  +1X12(1HL)2X10(1HS)1X1X3(1HA)6X3(1HA)1X3(1HN)6X3(1HN),
330.000  +5X6(1HG)1IX4X12(1HE)1X12(1HL)4X6(1HS)=/.}
331.000  300 FORMAT(/' ---------------- PROGRAMMED 'BY --- J. U. KHANDOKER',
332.000  +' AND J. L. HUMAR ---------------'/,
333.000  +' ---- DEPARTMENT OF CIVIL ENGINEERING, CARLETON',
334.000  +' UNIVERSITY, OTTAWA, CANADA ----/'
335.000  END
336.000  C
337.000  SUBROUTINE PROP(NFG,NBA,NBAI,NNN,NQQ,NEL,MBM,
338.000  +MCL,NSC,IBC,ICC,B,AB,EB,BMG,BK,BI,DE,DBX,AC,CE,CLG,
339.000  +CK,CI,DC,DCX)
340.000  C
341.000  READ AND WRITE FRAME PROPERTIES
342.000  C
343.000  COMMON/COM1/BL(210),BA(210),BB(210),BG(210),BEF(210),
344.000  +CL(240),CA(240),CB(240),CG(240),CEF(240),CAL(240),NT,
345.000  +NNS,NSS(10),NBS(9),NBS(9),H(30)
346.000  C
347.000  DIMENSION NSC(NBAI),IBC(NNN),ICC(NBAI),B(NBA),AB(NNN,NBA),
348.000  +BE(NNN,NBA),BMG(NNN,NBA),BK(NNN,NBA),BI(NNN,NBA),
349.000  +DB(NNN,NBA),DBX(NNN,NBA),AC(NNN,NBA1),CE(NNN,NBA1),
350.000  +CLG(NNN,NBA1),CK(NNN,NBA1),CI(NNN,NBA1),DC(NNN,NBA1),
351.000  +DCX(NNN,NBA1)
352.000  C
353.000  DATA IH1/IHR/
354.000  IH1=2
355.000  IH1=2
356.000  IH1=2
357.000  WRITE(IW,501)
358.000  IBI=0
359.000  NEI=0
360.000  DO 200 II=1,NFG
361.000 WRITE(IW,502) II
362.000 READ(IR1,503) NT,NNS,NFR
363.000 WRITE(IW,503) NT,NNS,NFR
364.000 READ(IR1,503) (NSS(J),J=1,NT)
365.000 WRITE(IW,503) (NSS(J),J=1,NT)
366.000 READ(IR1,503) (NBY(J),J=1,NT)
367.000 WRITE(IW,503) (NBY(J),J=1,NT)
368.000 WRITE(IW,505) NT,NNS
369.000 WRITE(IW,506)
370.000 WRITE(IW,507) (I,NBY(I),NSS(I),I=1,NT)
371.000 IF(NT.EQ.1) GO TO 8
372.000 NT=NT-1
373.000 READ(IR1,503) (NBS(J),J=1,NT)
374.000 WRITE(IW,503) (NBS(J),J=1,NT)
375.000 WRITE(IW,508)
376.000 DO 5 I=1,NT
377.000 J=1+1
378.000 WRITE(IW,509) I,J,NBS(J)
379.000 NB=NBS(J)
380.000 READ(IR1,504) (B(K),K=1,NB)
381.000 WRITE(IW,510)
382.000 WRITE(IW,511) (J,B(J),J=1,NB)
383.000 READ(IR1,503) OSTB
384.000 WRITE(IW,512)
385.000 IS=0
386.000 IB=0
387.000 NJ=0
388.000 DO 50 I=1,NT
389.000 NN=NSS(I)
390.000 NB=NBS(I)
391.000 DO 40 J=1,NN
392.000 IS=IS+1
393.000 READ(IR1,513) IBC(IS)
394.000 DO 30 K=1,NB
395.000 IB=IB+1
396.000 NI=NI+K
397.000 IF(IBC(IS),NE,NRR) GO TO 20
398.000 READ(IR1,514) BE(IS,NI),BMG(IS,NI),BK(IS,NI),DBX(IS,NI),DB(IS,NI)
399.000 IF(K,NE,1) GO TO 18
400.000 WRITE(IW,515) IS,NI,IBC(IS),DBX(IS,NI),DB(IS,NI),BE(IS,NI),
401.000  +BMG(IS,NI),BK(IS,NI)
402.000  GO TO 30
403.000  WRITE(IW,522) NI,IBC(IS),DBX(IS,NI),DB(IS,NI),BE(IS,NI),
404.000  +BMG(IS,NI),BK(IS,NI)
405.000  GO TO 30
406.000  READ(IR1,514) BE(IS,NI),BMG(IS,NI),BK(IS,NI),DB(IS,NI),
407.000  +AB(IS,NI),BI(IS,NI)
408.000  IF(K.NE.1) GO TO 25
409.000  WRITE(IW,516) IS,NI,IBC(IS),DB(IS,NI),AB(IS,NI),BI(IS,NI),
410.000  +BE(IS,NI),BMG(IS,NI),BK(IS,NI)
411.000  GO TO 30
412.000  WRITE(IW,523) NI,IBC(IS),DB(IS,NI),AB(IS,NI),BI(IS,NI),
413.000  +BE(IS,NI),BMG(IS,NI),BK(IS,NI)
414.000  30 CONTINUE
415.000  40 CONTINUE
416.000  NJ=NJ+NBS(I)
417.000  50 CONTINUE
418.000  NBM=IB
419.000  NCL=IB+NNS
420.000  WRITE(IW,517)
421.000  NB=NBAY(I)+1
422.000  DO 75 I=1,NB
423.000  READ(IR1,518) ICC(I),NSC(I)
424.000  NN=NSC(I)
425.000  DO 70 J=1,NN
426.000  IF(ICC(I).NE.IRR) GO TO 60
427.000  READ(IR1,514) CE(J,I),CLG(J,I),CK(J,I),DCX(J,I),DC(J,I)
428.000  IF(J.NE.1) GO TO 55
429.000  WRITE(IW,515) I,J,ICC(I),DCX(J,I),DC(J,I),CE(J,I),CLG(J,I),CK(J,I)
430.000  GO TO 70
431.000  55 WRITE(IW,522) J,ICC(I),DCX(J,I),DC(J,I),CE(J,I),
432.000  +CLG(J,I),CK(J,I)
433.000  GO TO 70
434.000  60 READ(IR1,514) CE(J,I),CLG(J,I),CK(J,I),DC(J,I),AC(J,I),CI(J,I)
435.000  IF(J.NE.1) GO TO 65
436.000  WRITE(IW,516) I,J,ICC(I),DC(J,I),AC(J,I),CI(J,I),CE(J,I),
437.000  +CLG(J,I),CK(J,I)
438.000  GO TO 70
439.000  65 WRITE(IW,523) J,ICC(J),DC(J,I),AC(J,I),CI(J,I),CE(J,I),
440.000  +CLG(J,I),CK(J,I)
441.000   70 CONTINUE
442.000   75 CONTINUE
443.000   NEO=2*NCL+NNS
444.000   WRITE(IW,503) NBM,NCL,NEO
445.000   IF(OSTB.EQ.0) GO TO 76
446.000   WRITE(IW,600)
447.000   GO TO 77
448.000   76 WRITE(IW,610)
449.000Q   77 IF(BMG(1,1).EQ.0.0.OR.BK(1,1).EQ.0.0) GO TO 78
450.000   WRITE(IW,620)
451.000   GO TO 79
452.000   78 WRITE(IW,630)
453.000   79 CONTINUE
454.000 C
455.000 C   CALCULATE BEAM AND COLUMN LENGTHS AND END STUBS
456.000 C   OSTB=0 MEANS FINITE JOINT SIZES ARE NOT CONSIDERED
457.000 C
458.000   IF(OSTB.EQ.0) GO TO 100
459.000   IB=0
460.000   IC=0
461.000   NJ=0
462.000   JS=1
463.000   NB=NBAY(I)+1
464.000   DO 80 I=1,NB
465.000   80 CA(I)=0.0
466.000   DO 98 I=1,NT
467.000   NS=NSS(I)
468.000   NB=NBAY(I)+1
469.000   NJ1=NBS(I)
470.000   NJ2=NJ1+NBAY(I+1)+1
471.000   IF(I.EQ.NT) NJ1=NB
472.000   DO 95 J=1,NS
473.000   D2=0.0
474.000   JS=JS
475.000   JS=JS+1
476.000   JC=IC+NB
477.000   IF(J.EQ.NS) JC=JC-NJ1
478.000   DO 90 K=1,NB
479.000   NI=NJ+K
480.000   NK=NI-1
481.000 JB=IB
482.000 IB=IB+1
483.000 IC=IC+1
484.000 JC=JC+1
485.000 IF(K.NE.NB) GO TO 81
486.000 BB(JB)=DC(IS,NI)/2.
487.000 CB(IC)=DB(IS,NK)/2.
488.000 GO TO 85
489.000 81 BA(IB)=DC(IS,NI)/2.
490.000 DI=DB(IS,NI)/2.
491.000 IF(K.EQ.1) GO TO 82
492.000 D2=DB(IS,NK)/2.
493.000 BB(JB)=BA(IB)
494.000 82 CB(IC)=MAX1(D1,D2)
495.000 85 IF(J.NE.NS) GO TO 86
496.000 IF(K.LE.NJ1.0R.K.GT.NJ2) GO TO 87
497.000 86 CA(JC)=CB(IC)
498.000 87 IF(K.EQ.1) GO TO 88
499.000 BL(JB)=BNK-BA(JB)-BB(JB)
500.000 88 CL(IC)=H(IS)-CA(IC)-CB(IC)
501.000 90 CONTINUE
502.000 IB=JB
503.000 95 CONTINUE
504.000 NJ=NJ+NJ
505.000 98 CONTINUE
506.000 PREPARE DATA FOR PROGRAMS STIFF AND LOAD
507.000 100 IS=0
508.000 IB=0
509.000 NJ=0
510.000 DO 120 I=1,NI
511.000 NS=NSS(I)
512.000 NB=NBAY(I)
513.000 DO 110 J=1,NS
514.000 IS=IS+1
515.000 DO 105 K=1,NB
516.000 NI=NJ+K
517.000 IB=IB+1
518.000 IF(OSTB.NE.0) GO TO 101
521.000  BA(IB)=0.
522.000  BB(IB)=0.
523.000  BL(IB)=B(NI).
524.000  101 IF(IBC(IS).NE.IRR) GO TO 102
525.000  AB(IS,NI)=DB(IS,NI)*DBX(IS,NI)
526.000  BI(IS,NI)=DBX(IS,NI)*(DBC(IS,NI))**3/12.0
527.000  102 IF(BMG(IS,NI).EQ.0.0.OR.BK(IS,NI).EQ.0.) GO TO 103
528.000  BG(IB)=6.*BE(IS,NI)*BI(IS,NI)/(BK(IS,NI)**AB(IS,NI)*
529.000  +BMG(IS,NI)**(BL(IB))**2)
530.000  BEF(IB)=2.*BE(IS,NI)*BI(IS,NI)/(BL(IB)**(1.+2.*BG(IB)))
531.000  GO TO 104
532.000  103 BG(IB)=0.0
533.000  BEF(IB)=2.*BE(IS,NI)*BI(IS,NI)/BL(IB)
534.000  104 WRITE(IW1,520) BL(IB),BA(IB),BB(IB),BG(IB),BEF(IB)
535.000  105 CONTINUE
536.000  110 CONTINUE
537.000  NJ=NJ+NBS(I)
538.000  120 CONTINUE
539.000  C
540.000  IS=0
541.000  IC=0
542.000  NJ=0
543.000  DO 150 I=1,NT
544.000  NS=NSS(I)
545.000  NB=NBY(I)+1
546.000  DO 140 J=1,NS
547.000  IS=IS+1
548.000  DO 130 K=1,NB
549.000  NI=NJ+K
550.000  IC=IC+1
551.000  IF(OSTB,NE.0) GO TO 122
552.000  CA(IC)=0.
553.000  CB(IC)=0.
554.000  CL(IC)=H(IS)
555.000  122 IF(ICC(NI).NE.IRR) GO TO 125
556.000  AC(IS,NI)=DC(IS,NI)*DCX(IS,NI)
557.000  CI(IS,NI)=DCX(IS,NI)**(DC(IS,NI))**3/12.0
558.000  125 CAL(IC)=AC(IS,NI)*CE(IS,NI)/CL(IC)
559.000  IF(CLG(IS,NI).EQ.0.0.OR.CK(IS,NI).EQ.0.) GO TO 127
560.000  CG(IC)=6.*CE(IS,NI)*CI(IS,NI)/
+(CK(IS,NI)*AC(IS,NI)*CLG(IS,NI)*(CL(IC)**2)
CEF(IC)=2.*CE(IS,NI)*CI(IS,NI)/(CL(IC)**(1.+2.*CG(IC)))
GO TO 128
127 CG(IC)=0.0
CEF(IC)=2.*CE(IS,NI)*CI(IS,NI)/CL(IC)
128 WRITE(IW,520) CL(IC),CA(IC),CB(IC),CG(IC),CEF(IC),CAL(IC)
130 CONTINUE
140 CONTINUE
NJ=NJ+NBS(I)
150 CONTINUE
C
FIND MAX. NO. OF BEAMS(MBM), MAX. NO. OF COLUMNS(MCL),
MAX NO. OF EQNS.(NQQ) AND MAX NO. OF STIFFNESS ELEMENTS(NEL)
IF(NBM,GT,IB1) GO TO 155
NBM=IB1
160 CONTINUE
MBM=NBM
MCL=NCL
NQQ=NEQ
IB1=NBM
155 CONTINUE
C
160 JTN=0
JTR=0
DO 180 I=1,NT
NB=NBAY(I)
NN=NSSY(I)
JA=2*NB+4
JB=3*NB+5
JC=NB+1
JY=2*JA*JC+JB
JTN=JTN+JY*(NN-1)
165 IF(I.EQ.1) GO TO 165
NSB=NBS(I-1)
JP=JA1-NSB
JQ=JP+JC
JR=NB+NB1-NSB+4
JT=JC*(JP+JR)+JQ
JTR=JTR+JT
170 CONTINUE
GO TO 170
601.000 165  JX=(JA-NB)*NB+2*(JA-1)
602.000 170  JA1=JA
603.000  NBI=NB
604.000 180  CONTINUE
605.000  NEL=JX+JIN+JTR
606.000  IF(NE1.GT.NEL)  NEL=NE1
607.000  NE1=NEL
608.000  C
609.000  200  CONTINUE
610.000  WRITE(IW,525)
611.000  REWIND IW1
612.000  RETURN
613.000  C
614.000  501 FORMAT(/'-----------------',/)
615.000  +,'2X,'FRAME PROPERTIES',/)
616.000  +,'-----------------',/)
617.000  502 FORMAT(/)
618.000  +'------------------'/
619.000  +' FRAME GROUP NO.',I3,'/
620.000  +'------------------'
621.000  503 FORMAT(515)
622.000  504 FORMAT(8F10.3)
623.000  505 FORMAT(/'2X,'NO. OF TOWERS =',I3,'
624.000  +2X,'NO. OF STORIES =',I3)
625.000  506 FORMAT(/'2X,'TOWER NO. OF BAYS SETBACK AT LEFT'/)
626.000  +3X,'NO. BAYS STORIES')
627.000  507 FORMAT(3X,I2,8X,I2,10X,I2)
628.000  508 FORMAT(/'2X,'NO. OF BAYS=SETBACK AT LEFT'/)
629.000  +'------------------'/)
630.000  509 FORMAT(2X,'BETWN TOWERS',I3,' AND',I3,'=',I3)
631.000  510 FORMAT(/'2X,'LENGTHS OF BAYS C/C OF',/)
632.000  +2X,'COLS. STARTING AT LEFT',/
633.000  +2X,'------------------',/
634.000  +4X,'BAY NO.',5X,'LENGTH'/)
635.000  511 FORMAT(I8,4X,F10.2)
636.000  512 FORMAT(/'2X,'BEAM PROPERTIES',/)
637.000  +2X,'------------------'/
638.000  +' STORY BAY TYPE WIDTH DEPTH AREA INERTIA',
639.000  +' ELASTICITY RIGIDITY SH.COEFF')
640.000  513 FORMAT(1X,A1)
641.000  514 FORMAT(6E12.5)
642.000  515 FORMAT(/15X,A1,F9.2,F8.2,18X,2E11.5,F8.3)
644.000  517 FORMAT(/2X,'COLUMN PROPERTIES',/)
645.000  518 FORMAT('COLM',13X,'CROSS',/)
646.000  519 FORMAT('LINE STORRY TYPE WIDTH WIDTH AREA INERTIA',/)
647.000  520 FORMAT('ELASTICITY RIGIDITY SH.COE',/)
648.000  521 FORMAT(1X,A1,'5)
649.000  522 FORMAT(6E12.5)
650.000  523 FORMAT(/10,4X,A1,F9.2,F8.2,18X,2E11.5,F8.3)
651.000  524 FORMAT(/5X,A1,F9.2,8X,F8.2,F10.2,2E11.5,F8.3)
652.000  525 FORMAT(/'NOTE:- BEAM/COL TypY: R=RECT. SECTION',/)
653.000  526 FORMAT(+0= NOT A RECT. SECTION'/)
654.000  527 FORMAT(/'** FINITE JOINT SIZES ARE CONSIDERED **/)
655.000  528 FORMAT(/'** FINITE JOINT SIZES ARE NOT CONSIDERED **/)
656.000  529 FORMAT(/'** SHEAR DEFORMATIONS ARE CONSIDERED **/)
657.000  530 FORMAT(/'** SHEAR DEFORMATIONS ARE NOT CONSIDERED **/)
658.000  531 FORMAT(END)
659.000  532 FORMAT(SUBROUTINE STIFF(NEL,NQQ,AK,NDA,ICD,NED,NE')
660.000  533 FORMAT(C THIS PROGRAM ASSEMBLES THE FRAME STIFFNESS MATRICES)
661.000  534 FORMAT(C)
662.000  535 FORMAT(1C9/ COMMON/COMI/BL(210),BA(210),BB(210),BG(210),BEF(210),
663.000  536 FORMAT(1C9/ +CL(240),CA(240),CB(240),CG(240),CEF(240),CAL(240),NT,NS,
664.000  537 FORMAT(1C9/ +NST(10),NBAY(9),NBS(9),H(30)
665.000  538 FORMAT(DIMENSION AK(NEL),NDA(NQQ),ICD(NQQ)
666.000  539 FORMAT(C)
667.000  540 FORMAT(C)
668.000  541 FORMAT(C)
669.000  542 FORMAT(C)
670.000  543 FORMAT(C)
671.000  544 FORMAT(C)
672.000  545 FORMAT(IR=4)
673.000  546 FORMAT(IN=5)
674.000  547 FORMAT(READ(IR,520) NT,NS)
675.000  548 FORMAT(READ(IR,520) (NST(I),I=1,NT)
676.000  549 FORMAT(READ(IR,520) (NBAY(I),I=1,NT)
677.000  550 FORMAT(NT2=NT-1
678.000  551 FORMAT(IF(N1,GT,1) READ(IR,520) (NBS(I),I=1,NT2)
679.000  552 FORMAT(READ(IR,520) NBM,NCL
680.000  553 FORMAT(READ(IR,518) (BL(I),BA(I),BB(I),BG(I),BEF(I),I=1,NBM)
READ(IR,510) (CL(I),CA(I),CB(I),CG(I),CEF(I),CAL(I),I=1,NCL)
C
INITIALIZES STIFFNESS ELEMENTS.
DO 6 I=1,NEL
AK(I)=0.
6 CONTINUE
C
ASSEMBLES STIFFNESS FOR THE FIRST FLOOR
IB=0
ID=0
K=0.
IC=0
NB=NBAY(1)
NB2=NB+1
NBS1=NBS(1)
NB1=NBAY(2)
NB3=NB1+1
NBS2=NBS1+NB3
JC=NB2
IF(NST(1).EQ.1) JC=JC-NBS1
KH=2*NB2-1
KV=KH+NB2+1
IDV=NB2+1
SUM=0.
DO 50 IN=1,NB2
JB=IB
IB=IB+1
IC=IC+1
JC=JC+1
K=K+1
KH=KH+1
KV=KV+1
KV1=KV+NB+3
IF(IN.EQ.1) KV1=KV1-1
KV2=KV1-1
X2=0.
X3=0.
X4=0.
721.000  X5=0.
722.000  Y=0.
723.000  Y1=0.
724.000  Z1=0.
725.000  Z2=0.
726.000  Z3=0.
727.000  Z4=0.
728.000  Z5=0.
729.000  Z6=0.
730.000  Z8=0.
731.000  X1=CST(IC,3)
732.000  Y2=CST(IC,5)
733.000  Y3=CST(IC,6)
734.000  Z7=CAL(IC)
735.000  IF(NS.EQ.1) GO TO 20
736.000  IF(NST(1).NE.1) GO TO 10
737.000  IF(IN.LE.NBS1.OR.IN.GT.NBS2) GO TO 20
738.000   10 X2=CST(JC,1)
739.000   Y=CST(JC,4)
740.000   Y1=CST(JC,6)
741.000   Z8=CAL(JC)
742.000   20 IF(IN.EQ.1) GO TO 30
743.000   X3=BST(JB,2)
744.000   X4=BST(JB,3)
745.000   AK(K)=X3
746.000   K=K+1
747.000   Z1=BST(JB,4)
748.000   Z2=BST(JB,6)
749.000   Z3=BST(JB,5)
750.000   AK(KV)=-Z1
751.000   KV=KV+1
752.000   IF(IN.EQ.NB2) GO TO 40
753.000   30 X5=BST(IB,1)
754.000   Z4=BST(IB,4)
755.000   Z5=BST(IB,6)
756.000   Z6=BST(IB,5)
757.000   40 AK(K)=X1+X2+X4+X5
758.000   AK(KH)=Y2-Y
759.000   SUM=SUM+Y1+Y3
760.000   AK(KV)=-Z3+Z4
761.000  KV=KV+1
762.000  AK(KV)=Z6
763.000  AK(KV2)=-Z2
764.000  AK(KV1)=Z2+Z5+Z7+Z8
765.000  ID=ID+1
766.000  IDV=IDV+1
767.000  NDA(ID)=K
768.000  NDA(IDV)=KV1
769.000  ICD(ID)=0
770.000  ICD(IDV)=0
771.000  KV=KV1
772.000  50 CONTINUE
773.000  KH=KH+1
774.000  AK(KH)=SUM
775.000  ID=ID+1
776.000  NDA(ID)=KH
777.000  ICD(ID)=1
778.000  ID=IDV
779.000  K=KV1
780.000  IF(NS.EQ.1) G0 TO 499
781.000  IB=JB
782.000  NS1=2
783.000  Q
784.000  DO 200 IT=1,NT
785.000  NS1=NST(IT)
786.000  NB2=NB+1
787.000  NK=2*NB+3
788.000  IF(IT.NE.1) G0 TO 104
789.000  IF(NST(1).EQ.1) G0 TO 160
790.000   104 IF(IT.EQ.NT) G0 TO 105
791.000   105 NB1=NBAY(IT+1)
792.000   106 NB3=NB1+1
793.000   107 NBS1=NBS(IT)
794.000   108 NBS2=NBS1+NB3
795.000     109 GO TO 106
796.000   105 NBS1=NB2
797.000   106 NN=NK+1
798.000   107 NNH=NN*NB2
799.000   108 NNV=NNH+NN+NB2
ASSEMBLES STIFFNESSES FOR TYPICAL FLOORS

DO 155 J=NS1,NST1
IF(J.NE.2) GO TO 110
N1=NK
N2=NB+2
N3=NK
N4=NB2
NH=NNH
NV=NNV
IH=0
JC=IC+NB2
IF(J.EQ.NST1) JC=JC-NBS1
IDV=ID+NB2+1
KH=K+NH
KV=K+NV
KH1=KH+N1
SUM=0
SUM1=0

DO 150 IN=1,NB2
NI=NI+1
JB=IB
IB=IB+1
IC=IC+1
JC=JC+1
K=K+1
KH=KH+1
KH1=KH1+1
KV=KV+1
KI=K+N1
K2=K+N2-IN
KV1=KV+N3
KV2=KV+N4
K3=K1-1
KV3=KV2-1
KV4=KV2+1
KV5=KV1-1
X4=0
X5=0
841.000  X6=0.
842.000  X7=0.
843.000  Y3=0.
844.000  Y4=0.
845.000  Z2=0.
846.000  Z3=0.
847.000  Z4=0.
848.000  Z5=0.
849.000  Z6=0.
850.000  Z7=0.
351.000  Z8=0.
852.000  X1=CST(IC,2)
853.000  X2=CST(IC,3)
854.000  X3=CST(IC,5)
855.000  Y1=CST(IC,4)
856.000  Y2=CST(IC,6)
857.000  Z1=CAL(IC)
858.000  IF(J.NE.NST1) GO TO 115
859.000  IF(IN.LE.NBS1.OR.IN.GT.NBS2) GO TO 120
860.000   115 X4=CST(JC,1)
861.000  Y3=CST(JC,4)
862.000  Y4=CST(JC,6)
863.000  Z2=CAL(JC)
864.000   120 IF(IN.EQ.1) GO TO 130
865.000  X5=BST(JB,2)
866.000  X6=BST(JB,3)
867.000  Z3=BST(JB,4)
868.000  Z4=BST(JB,6)
869.000  Z5=BST(JB,5)
870.000  IF(IN.EQ.NB2) GO TO 140
871.000   130 X7=BST(IB,1)
872.000  Z6=BST(IB,4)
873.000  Z7=BST(IB,6)
874.000  Z8=BST(IB,5)
875.000   140 AK(K)=X1
876.000  AK(K2)=-X3
877.000  AK(K3)=X5
878.000  AK(K1)=X2+X4+X6+X7
879.000  AK(KH)=Y1.
880.000  AK(KHI)=X3-Y3
881.000  SUM=SUM+Y2
882.000  SUM1=SUM1+Y2+Y4
883.000  AK(KV)=-Z1
884.000  AK(KV2)=-Z5+Z6
885.000  AK(KV3)=-Z3
886.000  AK(KV4)=Z8
887.000  AK(KV5)=-Z4
888.000  AK(KV1)=Z1+Z2+Z4+Z7
889.000  ID=ID+1
890.000  IDV=IDV+1
891.000  NDA(ID)=K1
892.000  NDA(IDV)=KVI
893.000  ICD(ID)=0
894.000  ICD(IDV)=0
895.000  K=K1
896.000  KV=KVI
897.000  150 CONTINUE
898.000  KH=KH+IH+1
899.000  KH1=KH1+1
900.000  AK(KH)=SUM
901.000  AK(KH1)=SUM1
902.000  ID=ID+1
903.000  NDA(ID)=KH1
904.000  ICD(ID)=1
905.000  ID=IDV
906.000  K=KVI
907.000  IB=JB
908.000  155 CONTINUE
909.000  IF(IT.EQ.NT) GO TO 200
910.000  C
911.000  160 NI=NK-NBS1
912.000  N2=NB-NBS1+2
913.000  N3=NB+NB1+3-NBS1
914.000  N4=NB2-NBS1
915.000  NN=NK-NBS1+1
916.000  NH=NN*NB3
917.000  NV=NH+NN+NB3
918.000  IH=NB-NB1-NBS1
919.000  NSJ=1
920.000  NB=NB1
921.000 200 CONTINUE
922.000 C
923.000 499 NEO=ID
924.000 NE=K
925.000 WRITE(IW,500) NEO,NE
926.000 WRITE(IW,500) (NDA(I),ICD(I),II=1,NEQ)
927.000 WRITE(IW,510) (AK(IK),IK=1,NE)
928.000 RETURN
929.000 C
930.000 500 FORMAT(2I8)
931.000 510 FORMAT(6E12.5)
932.000 515 FORMAT(5E12.5)
933.000 520 FORMAT(5I5)
934.000 END
935.000 C
936.000 FUNCTION CST(I,IND)
937.000 COMMON/COM1/BEAM(1050),CL(240),CA(240),CB(240),CG(240),
938.000 +CEF(240),CAL(240),NT,NS,NST(10),NBAY(9),NBS(9),H(30)
939.000 FG=CG(I)
940.000 CO=CEF(I),
941.000 GO TO (3,4,5,6,7,8), IND
942.000 3 CST=CO*(2.*FG+6.*CA(I)/CL(I)+6.*(CA(I)/CL(I))**2)
943.000 RETURN
944.000 4 CST=CO*(1.-FG+3.*(CA(I)+CB(I))/CL(I)+6.*CA(I)*CB(I)/CL(I)**2)
945.000 RETURN
946.000 5 CST=CO*(2.*FG+6.*CB(I)/CL(I)+6.*CB(I)/CL(I)**2)
947.000 RETURN
948.000 6 CST=CO*(3./CL(I)+6.*CA(I)/CL(I)**2)
949.000 RETURN
950.000 7 CST=CO*(3./CL(I)+6.*CA(I)/CL(I)**2)
951.000 RETURN
952.000 8 CST=CO*6./CL(I)**2
953.000 RETURN
954.000 END
955.000 C
956.000 FUNCTION BST(I,IMB)
957.000 COMMON/COM1/BL(210),BA(210),BB(210),BG(210),BEF(210),
958.000 +CLM(1440),NT,NS,NST(10),NBAY(9),NBS(9),H(30)
959.000 FG=BG(I)
960.000 CO=BEF(I)
GO TO(1, 2, 3, 4, 5, 6), IMB
1 BST=CO*(2.+FG+6.*BA(I)/BL(I)+6.*(BA(I)/BL(I))**2)
2 BST=CO*(1.-FG+3.*(BA(I)*BB(I))/BL(I)+6.*BA(I)*BB(I)/BL(I)**2)
3 BST=CO*(2.+FG+6.*BB(I)/BL(I)+6.**(BB(I)/BL(I))**2)
4 BST=CO*(3./BL(I)+6.*BA(I)/BL(I)**2)
5 BST=CO*(3./BL(I)+6.*BB(I)/BL(I)**2)
6 BST=CO*6./BL(I)**2
RETURN
END

SUBROUTINE GRAVIT(IJ, NGR, NE, NQQ, NEL, NEQ, MBM, MBA, NNN, +A, NA, NR, SLD, FX1, FX2, FX3, FX4, UDL)

SOLVES FOR GRAVITY LOAD

COMMON/COM1,BMCL(2490),NT,NSS,NSS(10),NBAY(9),NBS(9),H(30)
DIMENSION A(NQ),NA(NQQ),NR(NQQ),SLD(NQQ),FX1(MBM),FX2(MBM), +FX3(MBM),FX4(MBM),UDL(NNN,MBA)
IR=3
IN=7
READ(IR,500) NFR
DO 100 I=1,NFR
100 IJ=IJ+1
READ(IR,500) IFL
WRITE(8) IFL
IF(IFL.NE.0) GO TO 50
WRITE(IN,600) IJ
DO 40 J=1,NGR
40 WRITE(IN,630) J
CALL LOAD(NQQ,MBA,NNN,SLD,MBM,NBM,FX1,FX2,FX3,FX4,UDL)
JOPT=0
CALL BSUB(JOPT,NE,NQQ,A,NA,NR,SLD,NEQ,NEL)
WRITE(8) (SLD(JJ),JJ=1,NEQ)
WRITE(8) (FXX(JJ),JJ=1,NBM)
CONTINUE
1001.000 K=IJ
1002.000 GO TO 100
1003.000 50 WRITE(1W,620) IJ,K
1004.000 100 CONTINUE
1005.000 RETURN
1006.000 C
1007.000 500 FORMAT(5I5)
1008.000 600 FORMAT(/**-----------------------/
1009.000 +** FRAME NO.,I3,/
1010.000 +** ----------------------)
1011.000 +**
1012.000 620 FORMAT(/** ***/**)
1013.000 +** GRAVITY LOADS(FOR ALL LOAD CASES) IN FRAME',I3,/
1014.000 +** ARE EXACTLY SAME AS THOSE IN FRAME',I3,/
1015.000 +** ***/**)
1016.000 630 FORMAT(/**
1017.000 +** GRAVITY LOAD CASE',I3,*/
1018.000 +** -----------------------)
1019.000 END
1020.000 C
1021.000 SUBROUTINE LOAD(NOQ,MBA,NNN,SLD,MBM,NBM,FX1,FX2,FX3,FX4,UDL)
1022.000 C
1023.000 PREPARE THE LOAD MATRIX
1024.000 C
1025.000 COMMON/COM1/BL(210),BA(210),BB(210),BG(210),BEF(210),
1026.000 +CL(240),CA(240),CB(240),CG(240),CEF(240),CAL(240),
1027.000 +NT,NNS,NSS(10),NBA(9),NBS(9),CNL(15),DIS(15)
1028.000 DIMENSION SLD(NOQ),FX1(MBM),FX2(MBM),FX3(MBM),FX4(MBM),
1029.000 +UDL(NNN,MBA)
1030.000 C
1031.000 IR=3
1032.000 IW=7
1033.000 IK=0
1034.000 IH=0
1035.000 IS=0
1036.000 NJ=0.
1037.000 IB=0
1038.000 60 DO 6 I=1,NT
1039.000 NN=NSS(I)
1040.000 NB=NBA(I)
1041.000 DO 5 J=1,NN
1042.000 IH=IH+1
1043.000 READ(IR,2000) (UDL(IH,K),K=1,NB)
1044.000 5 CONTINUE
1045.000 CONTINUE
1046.000 WRITE(IW,4500)
1047.000 DO 40 I=1,NT
1048.000 NN=NSS(I)
1049.000 NB=NBA(I)
1050.000 DX=30 J=1,NN
1051.000 IS=IS+1
1052.000 FNI=0.0
1053.000 FN2=0.0
1054.000 DO 25 K=1,NB
1055.000 IB=IB+1
1056.000 IK=IK+1
1057.000 IK1=IK+NB+2
1058.000 NI=NJ+K
1059.000 UD=UDL(IS,K)
1060.000 FUD2=UD*BL(IB)/2.
1061.000 FUD1=FUD2*BL(IB)/6.
1062.000 FST2=UD*BA(IB)
1063.000 FST1=FST2*BA(IB)/2.
1064.000 FST4=UD*B8(IB)
1065.000 FST3=-FST4*B8(IB)/2.
1066.000 READ(IR,1000) NC
1067.000 FC1=0.0
1068.000 FC2=0.0
1069.000 FC3=0.0
1070.000 FC4=0.0
1071.000 BGX=BG(IB)
1072.000 IF(NC.EQ.0) GO TO 21
1073.000 READ(IR,2000) (CNL(KK),DIS(KK),KK=1,NC)
1074.000 LX) 20 KK=1,NC
1075.000 CN=CNL(KK)
1076.000 A=DIS(KK)-BA(IB)
1077.000 B=BL(IB)-A
1078.000 PG=CN/(1.2*BGX)
1079.000 FL1=(1.+BX*BL(IB)/B)*PG*A*B/BL(IB)**2
1080.000 F2=(3.*A*B+2.*BGX*BL(IB)**2/B)*PG*B/BL(IB)**3
F3 = (1 + BOX*BL(IB)/A)*PG*B*A*A/B(LIB)**2
F4 = CN - F2
FC1 = FC1 + F1
FC2 = FC2 + F2
FC3 = FC3 + F3
FC4 = FC4 + F4
20 CONTINUE
21 FL1 = FUD1 + FC1
FL2 = FUD2 + FC2
SLD(IK) = -(FL1 + FN1 + FST1 + FL2 + BA(IB))
SLD(IK1) = -(FL2 + FN2 + FST2)
FR1 = FUD1 + FC3
FR2 = FUD2 + FC4
FN1 = FR1 + FST3 - FR2 + BB(IB)
FN2 = FR2 + FST4
FX1(IB) = FL1
FX2(IB) = FR1
FX3(IB) = FL2
FX4(IB) = FR2
1100.000 IF(NC, NE, 0) GO TO 23
1101.000 IF(K, NE, 1) GO TO 22
1102.000 WRITE(IW, 5000) (IS, NI, UD)
1103.000 GO TO 25
1104.000 22 WRITE(IW, 5100) NI, UD
1105.000 GO TO 25
1106.000 23 IF(K, NE, 1) GO TO 24
1107.000 WRITE(IW, 5000) IS, NI, UD, (CNL(KK), DIS(KK), KK=1, NC)
1108.000 GO TO 25
1109.000 24 WRITE(IW, 5100) NI, UD, (CNL(KK), DIS(KK), KK=1, NC)
1110.000 25 CONTINUE
1111.000 IK = IK + 1
1112.000 IK1 = IK1 + 1
1113.000 IK2 = IK + 1
1114.000 SLD(IK) = -FN1
1115.000 SLD(IK1) = -FN2
1116.000 SLD(IK2) = 0.0
1117.000 IK = IK1
1118.000 30 CONTINUE
1119.000 IF(I, EQ, NT) GO TO 40
1120.000 NJ = NJ + NBS(I)
1121.000  40 CONTINUE
1122.000  NBM=IB
1123.000  RETURN
1124.000  C
1125.000  1000 FORMAT(5I5)
1126.000  2000 FORMAT(8F10.3)
1127.000  4500 FORMAT(//2X,'SUPPLIED LOAD DATA',/
1128.000   +2X,'------------------',/
1129.000   +38X,'CONCENTRATED LOAD DATA',/
1130.000   +2X,'STORY BAY UDL LOAD-1 DIST-1 LOAD-2 DIST-2',/
1131.000   +2X,'LOAD-3 DIST-3 LOAD-4 DIST-4',/
1132.000  5000 FORMAT(215,F7.3,2X,4(F8.2,F7.2))
1133.000  5100 FORMAT(110,F7.3,2X,4(F8.2,F7.2))
1134.000  END
1135.000  C
1136.000  SUBROUTINE FORCE(OPT,MBM,MCL,NOQ,NNN,FX1,FX2,FX3,FX4,
1137.000    +FC1,FC2,FC3,FC4,SBQ1,SBQ2,SBQ3,SBQ4,BETA,DSP)
1138.000  C
1139.000  C
1140.000  COMMON/COM1/BL(210),BA(210),B8(210),BG(210),BEF(210),
1141.000  +CL(240),CA(240),CB(240),CG(240),CEF(240),CAL(240),NT,NNS,
1142.000  +NSS(10),NBA(9),NBS(9),DISQ(30)
1143.000  DIMENSION FX1(MBM),FX2(MBM),FX3(MBM),FX4(MBM),FC1(MCL),
1144.000  +FC2(MCL),FC3(MCL),FC4(MCL),SBQ1(MBM),SBQ2(MBM),
1145.000  +SBQ3(MBM),SBQ4(MBM),BETA(NQQ),DSP(NNN)
1146.000  C
1147.000  C
1148.000  OPT=0 MEANS THERE IS NO GRAVITY LOAD ON THE BEAMS
1149.000  OPT=1 MEANS BEAMS HAVE GRAVITY LOADS
1150.000  OPT=2 MEANS CALCULATE ROOT SUM SQRT OF FORCES
1151.000  OPT=3 MEANS OPT=0 & OPT=2 ; OPT=4 MEANS OPT=1 & OPT=2
1152.000  C
1153.000  IN=7
1154.000  IF(OPT.NE.2) WRITE(IN,600)
1155.000  IS=0
1156.000  IK=1
1157.000  NJ=0
1158.000  IB=0
1159.000  IX 30 I=1,NT
1160.000  NN=NSS(1)
1161.000  NB=NBA(I)
1162.000  DO 25 J=1,NB
1163.000  IS=IS+1
1164.000  IJ1=IK1+NB+2
1165.000  DO 20 K=1,NB
1166.000  IB=IB+1
1167.000  NI=NJ+K
1168.000  IK=IK1
1169.000  IK1=IK1+1
1170.000  IJ=IJ1
1171.000  IJ1=IJ1+1
1172.000  DL1=BETA(IK)
1173.000  DL2=BETA(IK1)
1174.000  DEL=BA(IB)*BETA(IK)+BB(IB)*BETA(IK1)+BETA(IJ)-BETA(IJ1)
1175.000  DBL=3.*DEL/BL(IB)
1176.000  AA=HEF(IB)
1177.000  B=(1.-BG(IB))
1178.000  C=(2.+BG(IB))
1179.000  F1=AA*(C*DL1+B*DL2+DBL)
1180.000  F2=AA*(B*DL1+C*DL2+DBL)
1181.000  F3=AA*3.*(DL1+DL2)+2.*DBL)/BL(IB)
1182.000  F4=-F3
1183.000  KOPT=OPT+1
1184.000  GO TO(16,10,19,12,10), KOPT
1185.000    10 F1=F1+FX1(IB)
1186.000    10  F2=F2+FX2(IB)
1187.000    10  F3=F3+FX3(IB)
1188.000    10  F4=F4+FX4(IB)
1189.000    12 IF(OPT.EQ.1) GO TO 16
1190.000  12 FS1=F1+SQB1(IB)
1191.000  12 FS2=F2+SQB2(IB)
1192.000  12 FS3=F3+SQB3(IB)
1193.000  12 FS4=F4+SQB4(IB)
1194.000  F1=F1-SQB1(IB)
1195.000  F2=F2-SQB2(IB)
1196.000  F3=F3-SQB3(IB)
1197.000  F4=F4-SQB4(IB)
1198.000  IF(K.NE.1) GO TO 14
1199.000 WRITE(IW,530) IS,NI,FS1,FS2,FS3,FS4,F1,F2,F3,F4
1200.000 GO TO 20
1201.000 14 WRITE(IW,535) NI,FS1,FS2,FS3,FS4,F1,F2,F3,F4
1202.000 GO TO 20
1203.000 16 IF(K.NE.1) GO TO 17
1204.000 WRITE(IW,520) IS,NI,F1,F2,F3,F4
1205.000 GO TO 20
1206.000 17 WRITE(IW,525) NI,F1,F2,F3,F4
1207.000 GO TO 20
1208.000 19 FX1(IB)=FX1(IB)+F1+F1
1209.000 FX2(IB)=FX2(IB)+F2+F2
1210.000 FX3(IB)=FX3(IB)+F3+F3
1211.000 FX4(IB)=FX4(IB)
1212.000 20 CONTINUE
1213.000 IK1=IJ1+1
1214.000 25 CONTINUE
1215.000 IF(I.EQ.NT) GO TO 30
1216.000 NJ=NJ+NBS(I)
1217.000 30 CONTINUE
1218.000 C
1219.000 IS=0
1220.000 IK=0
1221.000 NJ=0
1222.000 IC=0
1223.000 IF(OPT.NE.2) WRITE(IW,620)
1224.000 DO 90 I=1,NT
1225.000 NN=NSS(I)
1226.000 NB=NBA(I)+1
1227.000 DO 80 J=1,NN
1228.000 IS=IS+1
1229.000 IJ=IK+NB+1
1230.000 IV=IJ
1231.000 DP=BETA(IJ)
1232.000 IF(OPT.NE.2) GO TO 35
1233.000 DSP(IJ)=DSP(IJ)+DP*DP
1234.000 GO TO 38
1235.000 35 DSP(IJ)=DP
1236.000 38 CONTINUE
1237.000 DO 60 K=1,NB
1238.000 IC=IC+1
1239.000 NI=NJ+K
1240.000 IK=IK+1
28
1281.000  55 FC1(IC)=FC1(IC)+FMT*FMT
1282.000  FC2(IC)=FC2(IC)+FMB*FMB
1283.000  FC3(IC)=FC3(IC)+FA*FA
1284.000  FC4(IC)=FC4(IC)+FS*FS
1285.000  60 CONTINUE.
1286.000  IJI=I-J.
1287.000  IK=IV
1288.000  IV1=IJ
1289.000  80 CONTINUE.
1290.000  IF(I.EQ.NI) GO TO 90
1291.000  NJ=NJ+NBS(I)
1292.000  IK=IK1+NBS(I)
1293.000  IV1=IV+NBS(I)
1294.000  90 CONTINUE.
1295.000  IF(OPT2<2) 92,99.94
1296.000  WRITE(IN,640)
1297.000  WRITE(IN,650) (IS,DSP(IS),IS=1,NNS)
1298.000  GO TO 99
1299.000  WRITE(IN,640)
1300.000  DO 96 IS=1,NNS
1301.000  DP=DSP(IS)+DISQ(IS)
1302.000  DPI=DSP(IS)-DISQ(IS)
1303.000  WRITE(IN,540) IS,DP,DP1
1304.000  96 WRITE(IN,540)
1305.000  99 RETURN
1306.000  C
1307.000  520 FORMAT(/I5,I6,4(3X,E12.5))
1308.000  525 FORMAT(111,4(3X,E12.5))
1309.000  530 FORMAT(15,16,4(3X,E12.5),MAX',/)
1310.000  +11X,4(3X,E12.5),MIN')
1311.000  535 FORMAT(111,4(3X,E12.5),MAX',/11X,4(3X,E12.5),MIN')
1312.000  540 FORMAT(17,15.5,MAX',/7X,E15.5,MIN')
1313.000  600 FORMAT(/2X,'BEAM END ACTIONS',/)
1314.000  +2X,--------------------------',/
1315.000  +2X,'STORY BAY-NO',2X,'LFT-MOMENT',6X,'RT-MOMENT',6X,'LFT-FORCE',
1316.000  +7X,'RT-FORCE',)
1317.000  620 FORMAT(/2X,'COLUMN END ACTIONS',/)
1318.000  +2X,--------------------------',/
1319.000  +2X,'STORY COL.IN TOP-MOMENT BOT-MOMENT AXIAL-FORCE',
1320.000  +2X,'SHEAR-FORCE',)
1321.000 640 FORMAT(/" STORY LATERAL DISPLT/"
1322.000 +-----------------------/
1323.000 + ST.LEVEL DISPLT/"
1324.000 650 FORMAT(I7,E15.5)
1325.000 END
1326.000 C
1327.000 C SUBROUTINE COND(NFG,A,NA,NR,TX,NQQ,NEL,NEQ,NL)
1328.000 C
1329.000 C THIS READS THE FRAME STIFFNESS AND CONDENSES TO
1330.000 C THE STORY DEGREES OF FREEDOM AND WRITES
1331.000 C
1332.000 COMMON/COM1/SC(35,35),TA(660),NF(625),NC(40)
1333.000 DIMENSION A(NEL),NA(NQQ),NR(NQQ),TX(NQQ)
1334.000 IR=5
1335.000 IN=2
1336.000 REWIND IR
1337.000 REWIND IR
1338.000 DO 20 I=1,NFG
1339.000 READ(IR,302) NEQ,NL
1340.000 READ(IR,302) (NA(I),NR(I),I=1,NEQ)
1341.000 READ(IR,303) (A(I),I=1,NL)
1342.000 CALL CONDEN(MM,A,NA,NR,NQQ,NEL,NEQ,NL,TX)
1343.000 WRITE(IN,302) II,MM
1344.000 DO 10 I=1,MM
1345.000 WRITE(IN,303) (SC(I,J),J=1,MM)
1346.000 10 CONTINUE
1347.000 20 CONTINUE
1348.000 RETURN
1349.000 302 FORMAT(2I8)
1350.000 303 FORMAT(5E12.5)
1351.000 END
1352.000 C SUBROUTINE CONDEN(MM,A,NA,NR,NQQ,NEL,NEQ,NL,TX)
1353.000 C
1354.000 COMMON/COM1/SC(35,35),TA(660),NF(625),NC(40)
1355.000 DIMENSION A(NEL),NA(NQQ),NR(NQQ),TX(NQQ)
1356.000 JOPT=1
1357.000 CALL REDUCE(JOPT,NEL,NQQ,A,NA,NR,NEQ,NL)
1358.000 LL=0
1359.000 MM=0
DO 50 I=1,NEQ
NN=NR(I)+1
GO TO (30, 40, 50), NN
30 LL=LL+1
NF(LL)=I
GO TO 50
40 MM=MM+1
NC(MM)=I
50 CONTINUE
DO 55 I=1,MM
DO 55 J=1,MM
55 SC(I,J)=0.
DO 60 J=2,MM
KJ=NC(J-1)
NAJ=NA(KJ)
JJ=KJ-1
NAPJ=NA(JJ)
IJ=NAJ-KJ
IL=J-1
DO 60 I=1,IL
60 CONTINUE
KI=NC(I)
NADR=IJ+KI
IF(NADR.LE.NAPJ) GO TO 60
SC(I,J)=A(NADR)
SC(J,I)=A(NADR)
60 CONTINUE
DO 70 I=1,MM
70 CONTINUE
KI=NC(I)
NAI=NA(KI)
SC(I,I)=A(NAI)
70 CONTINUE
LO 130 J=1,MM
DO 75 I=1,NEQ
75 TX(I)=0.
NT=I-0
JADR=NC(J-1)
DO 90 I=1,LL
IADR=NF(I)
IF(IADR.LT.JADR) GO TO 80
80 IA=JADR.
JA=IADR
NADR=NA(JA)-JA+IA
JJ=JA-1.
GO TO 85
NADR=NA(JADR)-JADR+IADR
JJ=JADR-1
85 NAJP=NA(JJ)
IF(NADR.LE.NAJP) GO TO 90
NTEST=1
TX(IADR)=A(NADR)
CONTINUE
90 CONTINUE
IF(NTEST.EQ.0) GO TO 130
DO 100 I=1,NEQ
100 CONTINUE
CALL BSUB(JOPT,NEL,NQQ,A,NA,NR,TX,NEQ)
CALL DOTPDX(TX,NEQ,S,NQQ)
SC(J,J)=SC(J,J)-S
IF(J.EQ.1) GO TO 130
DO 105 I=1,NEQ
105 TA(I)=0.
IL=J-1
DO 130 I=1,IL
130 N2T=0
IADR=NC(I)
DO 120 K=1,LL
120 KADR=NF(K)
IF(KADR.LT.IADR) GO TO 110
KA=IADR
IA=KADR
NADR=NA(IA)-IA+KA
II=IA-1
GO TO 115
110 NADR=NA(IADR)-IADR+KADR
II=IADR-1
115 NAIP=NA(II)
IF(NADR.LE.NAIP) GO TO 120
N2T=1
TA(KADR)=A(NADR)
CONTINUE
120 CONTINUE
1441.000 IF(N2I.EQ.0) GO TO 130
1442.000 CALL DOTPRD(TX,NEQ,S,NQQ)
1443.000 SC(I,J)=SC(I,J)-S
1444.000 SC(J,I)=SC(I,J)
1445.000 130 CONTINUE
1446.000 RETURN
1447.000 END
1448.000 C
1449.000 SUBROUTINE DOTPRD(U,L,S,NQQ)
1450.000 COMMON/COM1/SC(35,35),C(660),NF(625),NC(40)
1451.000 DIMENSION D(NQQ)
1452.000 S=0.
1453.000 DO 10 I=1,L
1454.000 S=S+C(I)*D(I)
1455.000 10 CONTINUE
1456.000 RETURN
1457.000 END
1458.000 C
1459.000 SUBROUTINE REDUCE(JOPT,NEL,NQQ,A,NA,NR,NEQ,NL)
1460.000 DIMENSION A(NEL),NA(NQQ),NR(NQQ)
1461.000 IM=6
1462.000 NAJP=1
1463.000 DO 90 J=2,NEQ
1464.000 NAJ=NA(J)
1465.000 IF(JOPT.EQ.1.AND.NR(J).NE.0) GO TO 90
1466.000 IL=J-1
1467.000 LJ=J+NAJP-NAJ+1
1468.000 IF(LJ.GT.IL) GO TO 90
1469.000 IN=IJ+1
1470.000 JK=NAJ-J
1471.000 IF(IN.GT.IL) GO TO 90
1472.000 NAJP=NA(JL)
1473.000 DO 50 I=IN,IL
1474.000 NAI=NA(I)
1475.000 IF(JOPT.EQ.1.AND.NR(I).NE.0) GO TO 50
1476.000 KL=I-1
1477.000 LI=I+NAJP-NAI+1
1478.000 KI=MAX0(LI,LJ)
1479.000 IF(KI.GT.KL) GO TO 50
1480.000 IK=NAI-I
1481. 000  SUM=0.
1482. 000  DO 30 K=KI,KL
1483. 000  IF(JOPT.EQ.1.AND.NR(K).NE.0) GO TO 30
1484. 000  IKA=IK+K
1485. 000  JKA=JK+K
1486. 000  SUM=SUM+A(IKA)*A(JKA)
1487. 30  CONTINUE
1488. 000  IJ=JK+I
1489. 000  A(IJ)=A(IJ)-SUM
1490. 000  50 NAIP=NAI
1491. 000  60 SUM=0.
1492. 000  DO 70 K=LJ,IL
1493. 000  IF(JOPT.EQ.1.AND.NR(K).NE.0) GO TO 70
1494. 000  JKA=JK+K
1495. 000  KKA=NA(K)
1496. 000  CC=A(JKA)*A(KKA)
1497. 000  SUM=SUM+CC*A(JKA)
1498. 000  A(JKA)=CC
1499. 000  70 CONTINUE
1500. 000  A(NAJ)=A(NAJ)-SUM
1501. 000  90 NAJP=NAJ
1502. 000  IF(JOPT.EQ.1) GO TO 99
1503. 000  WRITE(IW,540) NEQ,NL
1504. 000  WRITE(IW,540) (NA(I),NR(I),I=1,NEQ)
1505. 000  WRITE(IW,550) (A(I),I=1,NL)
1506. 000  99 RETURN
1507. 000  540 FORMAT(2I8)
1508. 000  550 FORMAT(6E12.5)
1509. 000  END
1510. 000  C
1511. 000  SUBROUTINE BSUB(JOPT,NEL,NQQ,A,NA,NR,B,NEQ)
1512. 000  DIMENSION A(NEL),NA(NQQ),NR(NQQ),B(NQQ)
1513. 000  110 CONTINUE
1514. 000  I=N1
1515. 000  IF(B(I).NE.0.) GO TO 110
1516. 000  DO 100 I=1,N1
1517. 000  I=NI
1518. 000  110 NB=I
1519. 000  IN=NB+1
1520. 000  NAIP=NA(NB)
I=IN,NEQ
NAI=NA(I)
IF(JOPT.EQ.1.AND.NR(I).NE.0) GO TO 150
LI=I-NAI+NAIP+1
KI=MISO(LI,NB)
KL=I-1
IF(KI.GT.KL) GO TO 150
IK=NAI-I
SUM=0.
DO 120 K=KI,KL
IF(JOPT.EQ.1.AND.NR(K).NE.0) GO TO 120
IKA=IK+K
SUM=SUM+A(IKA)*B(K)
120 CONTINUE
B(I)=B(I)-SUM
NAIP=NAI
DO 160 I=NB,NEQ
IF(JOPT.EQ.1.AND.NR(I).NE.0) GO TO 160
NAI=NA(I)
B(I)=B(I)/A(NAI)
160 CONTINUE
I=NEQ
NAN=NA(I)
KL=(I-I)
NAI=NA(KL)
IF(JOPT.EQ.1.AND.NR(I).NE.0) GO TO 175
KI=I-NAN+NAI+1
IF(KI.GT.KL) GO TO 175
IK=NAN-I
DO 170 K=KI,KL
IF(JOPT.EQ.1.AND.NR(K).NE.0) GO TO 170
IKA=IK+K
B(K)=B(K)-A(IKA)*B(I)
170 CONTINUE
I=I-1
IF(I.EQ.1) GO TO 180
NAN=NAI
GO TO 165
RETURN
END
SUBROUTINE STORY(SM, XBAR, YBAR)

READS AND PRINTS STORY DATA

COMMON/CON/NS1, NF, NOPT, NEQ, NMULP
COMMON/COMPSYS/NGK, NWL, NDYN, NSYS, IOUT, SMULP(12, 8)
COMMON/MISC/IW, AI(3), AJ(3), IDN, NH
DIMENSION SM(NEQ), XBAR(NST), YBAR(NST)

IF(NDYN.NE.0.OR.IOUT.NE.0) GO TO 5

DO 3 I=1, NST

XBAR(I)=0.0

YBAR(I)=0.0

3 CONTINUE

RETURN

5 CALL SP(IW, 2)

WRITE(IW, 301)

WRITE(IW, 302)

WRITE(IW, 301)

CALL SP(IW, 1)

WRITE(IW, 303)

DO 20 I=1, NST

READ(IR, 304) XM, XM1, XBAR(I), YBAR(I)

WRITE(IW, 305) 1, XM, XM1, XBAR(I), YBAR(I)

IF(400.NE.0) GO TO 10

20 CONTINUE

10 L=3*I

SM(L)=XM1

L=L-1

SM(L)=XM

L=L-1

SM(L)=XM

20 CONTINUE

RETURN

301 FORMAT(1X, '--------------')

302 FORMAT(1X, 'STORY MASS DATA')

303 FORMAT(1X, 'LEVEL', 6X, 'MASS', 6X, 'MASS INERTIA', 6X,

1X, 'XBAR', 6X, 'YBAR')

304 FORMAT(9F10.0)
305 FORMAT(I9, I4, F13.3, F15.3, F13.2, F10.2)
END

SUBROUTINE CORE(M)
COMMON/MISC/IR, IM, AI(3), AJ(3), IDN, NH
WRITE(IW, 301) M
STOP

301 FORMAT($X, "$ INCREASE MCODE BY $I, "$ **
END

SUBROUTINE FRAME(A, DN, M, NDIR, XBAR, YBAR, S, DDA)

C REALS FRAME LOCATIONS AND FRAME STIFFNESS MATRICES AND
C ASSEMBLES BUILDING STIFFNESS MATRIX

COMMON/CON/NST, NFT, NOPT, NEQ, NMULP
COMMON/MISC/IR, IM, AI(3), AJ(3), IDN, NH
DIMENSION A(NEQ, NEQ), S(NST, NST), XBAR(NST), YBAR(NST)
DIMENSION DN(NST, NFT), M(NFT), NDIR(NFT), DDA(NFT)

IP = 0
DO 5 I = 1, NEQ
      DO 5 J = 1, NEQ
        5 A(I, J) = 0.0
      END
      REWIND 2
      GO TO 10(10, 30, 0), NOP1

C HERE WHEN NOP1 = 1

10 DO 30 NF = 1, NF
      IF(M(NF), EQ, IFP) GO TO 10 20

C READ CONDENSED FRAME STIFFNESS FROM UNI12, TRANSFORM INTO
C TO GLOBAL COORDINATES AND ADD TO BUILDING STIFFNESS MATRIX

READ(2, 306) NFG, MST
DO 12 LL = 1, MST
      READ(2, 307)(S(LL, J), J = 1, MST)
12 CONTINUE

IP = M(NF)
20 IF(NDIR(NF), EQ, 2) GO TO 30

DO 30 I = 1, MST
      DO 30 J = 1, MST

30 CONTINUE
A(I,J)=A(I,J)+S(I,J)
30 CONTINUE
GO TO 155
HERE WHEN NQ1=2
DO 60 NF=1,NF
IF(M(NF),EQ.,IFP)GO TO 50
READ CONDENSED FRAME STIFFNESS FROM UNIT 2, TRANSFORM II
TO GLOBAL COORDINATES AND ADD TO BUILDING STIFFNESS MATRIX
DO 42 LL=1,MST
READ(2,307)(S(LL,J),J=1,MST)
42 CONTINUE
IFP=M(NF)
50 IF(NDIR(NF),EQ.,1)GO TO 60
DO 60 I=1,MST
DO 60 J=1,MST
A(I,J)=A(I,J)+S(I,J)
60 CONTINUE
GO TO 155
HERE WHEN NQ1=3
DO 140 I=1,NF
UDN=UDA(I)
IF(M(I),EQ.,IFP) GO TO 80
READ CONDENSED FRAME STIFFNESS FROM UNIT 2, TRANSFORM II
TO GLOBAL COORDINATES AND ADD TO BUILDING STIFFNESS MATRIX
DO 72 LL=1,MST
READ(2,307)(S(LL,J),J=1,MST)
72 CONTINUE
IFP=M(I)
80 IF(NDIR(I),EQ.,2) GO TO 100
DO 90 K=1,MST
1681.000  DN(K,I)=-DDN+YBAR(K)
1682.000  90 CONTINUE
1683.000  Ai(1)=1.
1684.000  Ai(2)=0.
1685.000  Aj(1)=1.
1686.000  Aj(2)=0.
1687.000  GO TO 120
1688.000  100 DO 110 K=1,MST
1689.000  DN(K,I)=DDN-XBAR(K)
1690.000  110 CONTINUE
1691.000  Ai(1)=0.
1692.000  Ai(2)=1.
1693.000  Aj(i)=0.
1694.000  Aj(2)=1.
1695.000  120 DO 130 II=1,MST.
1696.000  IAD=(II-1)*3
1697.000  Ai(3)=DN(II,I)
1698.000  DO 130 JJ=II,MST
1699.000  JAD=(JJ-1)*3
1700.000  Aj(3)=DN(JJ,I)
1701.000  DO 130 KK=1,3
1702.000  DO 130 XM=1,3
1703.000  NI=IAD+KK
1704.000  NJ=JAD+MM
1705.000  A(NI,NJ)=A(NI,NJ)+S(II,JJ)*AI(KK)*AJ(MM)
1706.000  130 CONTINUE
1707.000  140 CONTINUE
1708.000  DO 150 I=2,NEQ
1709.000  II=I-1
1710.000  DO 150 J=1,II
1711.000  A(I,J)=A(J,I)
1712.000  150 CONTINUE
1713.000  C
1714.000  C  WRITE GLOBAL STIFFNESS MATRIX ON UNIT 5
1715.000  C
1716.000  155 REWIND 5
1717.000  WRITE(5)((A(I,J),I=1,NEQ),J=1,NEQ)
1718.000  RETURN
1719.000  300 FORMAT(315,6F10.0)
1720.000  306 FORMAT(218)
FORMAT(6E12.5)
END
SUBROUTINE SPCIRM(A,SM,DA,VAL,VEC,CO,BB,TEMP,NA)

CALCULATES AND PRINTS MODE SHAPES AND FREQUENCIES
CALCULATES DESIGN STORY SHEARS AND FORCES

COMMON/CON/NST,NOPT,NEQ,NMULP
COMMON/SPEC/NM,LM,XMU,SH,BETA,MI,ALLOW,ID,G,NP,TC(10),SAC(10)
COMMON/COMSYS/NGR,NNL,NDYN,NSYS,INOUT,SMULP(12,9)
COMMON/MISC/IR,IN,AL(3),AJ(3),IDN,NH
EQUIVALENCE (SHIP,AI),(SHP2,AJ)
DIMENSION A(NEQ,NEQ),SM(NEQ),DA(NEQ,NM),VAL(NM)
DIMENSION VEC(NEQ,NM),CO(NEQ),NA(NEQ),BB(NEQ)
DIMENSION TEMP(NM,NMULP)
DIMENSION SHIP(3),SHP2(3)

CALCULATE MODE SHAPES AND FREQUENCIES

CALL EIGVAL(A,SM,VAL,VEC,CO,NA,BB)
IF(INOUT.EQ.0) GO TO 41
WRITE(IN,307)
DO 10 I = 1,NM
WRITE(IN,308) I,VAL(I)
10 CALL SP(IN,2)
WRITE(IN,330)
WRITE(IN,309)
CALL SP(IN,2)
WRITE(IN,330)
XNM=FLOAT(NM)/4.
NM1=NM/4
XNM=FLOAT(NM1)
IF(XNM.GT.XNM1) NM1=NM1+1
DO 40 INM=1,NM1
40 KI=(INM-1)*4+1
I=M(IK)
LAST=INM*4
IF(LAST.GT.NM) LAST=NM
CALL SP(IN,2)
WRITE(IN,310) I,I=KI,LAST
CALL SP(IN,2)
GO TO(20,30,12),NOPT
1761.000 12 DO 4.5 IKK=1,NST 
1762.000 I=NST-I KK+1 
1763.000 II=(I-1)*3+1 
1764.000 WRITE(IW,317) I,(VEC(II,KK),KK=K1,LAST) 
1765.000 II=II+1 
1766.000 WRITE(IW,323) (VEC(II,KK),KK=K1,LAST) 
1767.000 II=II+1 
1768.000 WRITE(IW,324) (VEC(II,KK),KK=K1,LAST) 
1769.000 CALL SPIW,2 
1770.000 15 CONTINUE 
1771.000 GO TO 40 
1772.000 20 DO 25 I=1,NST 
1773.000 WRITE(IW,317) I,(VEC(I,J),J=K1,LAST) 
1774.000 CALL SPIW,1 
1775.000 25 CONTINUE 
1776.000 GO TO 40 
1777.000 30 DO 35 I=1,NS1 
1778.000 WRITE(IW,326) I,(VEC(I,J),J=K1,LAST) 
1779.000 CALL SPIW,1 
1780.000 35 CONTINUE 
1781.000 40 CONTINUE 
1782.000 41 IF(NDYN.EQ.0) RETURN 
1783.000 C FOR EACH MODE, CALCULATE DESIGN SPECIFIED ACCELERATION 
1784.000 C 
1785.000 DO 90 I=1,NM 
1786.000 T=2.*3.14159/VAL(I) 
1787.000 IF(T.GT.1C(I)) GO TO 45 
1788.000 J=1 
1789.000 JJ=2 
1790.000 GO TO 60 
1791.000 45 NPP=NPP-1 
1792.000 DO 50 J=1,NPP 
1793.000 JJ=J+1 
1794.000 IF(T.GT.1C(J)) ANU.1L1C(JJ) GO TO 60 
1795.000 IF(T.EQ.1C(J)) GO TO 70 
1796.000 50 CONTINUE 
1797.000 70 J=NPP 
1798.000 JJ=NP 
1799.000 60 CT=ALOG10(SAC(JJ)/SAC(J))/ALOG10(1C(JJ)/1C(J))
SA=SAC(J)*(T/TC(J))*CT*G*SF
1802.000  GO TO 80
1803.000  70 SA=SAC(J)*G*SF
1804.000  C
1805.000  C  CALCULATE MODAL STORY DISPLACEMENT
1806.000  C
1807.000  80 CALL RESP(SM,DA,VEC,SA,I)
1808.000  90 CONTINUE
1809.000  CALL SF(IW,3)
1810.000  WRITE(IW,334)
1811.000  WRITE(IW,335)
1812.000  WRITE(IW,334)
1813.000  CALL SP(IW,3)
1814.000  WRITE(IW,313)
1815.000  DO 95 J=1,NM
1816.000  DO 95 J=1,NMULP
1817.000  95 IMXP(I,J)=0.0
1818.000  DO 97 J=1,NMULP
1819.000  SH1P(J)=0.0
1820.000  97 SH2P(J)=0.0
1821.000  DO 160 JJ=1,NST
1822.000  J=NST+I-JJ
1823.000  JX=(J-1)*3
1824.000  DO 150 K1=1,NMULP
1825.000  JY=J
1826.000  IF(NOPT.EQ.3) JY=JX+K1
1827.000  SUMA=0.
1828.000  SUMB=0.
1829.000  XMULP=1.
1830.000  XMULD=1.
1831.000  XMAXA=0.
1832.000  XMAXB=0.
1833.000  C
1834.000  C  MODIFY DISPLACEMENTS AND FORCES FOR THE DESIGN DUCTILITY
1835.000  C  SUPERIMPOSE MODAL STORY FORCES AND DISPLACEMENTS AND
1836.000  C  PRINT OUT DESIGN VALUES
1837.000  C
1838.000  DO 140 I=1,NM
1839.000  I=2.*3.14159/VAL(I)
1840.000  IF(I.GE.10) GO TO 100
1841.000 XMULP=1./SQRT(2.*XMU-1.)
1842.000 XMULD=XMU/SQRT(2.*XMU-1.)
1843.000 GO TO 110
1844.000 100 XMULP=1./XMU
1845.000 110 IF(IOUT.NE.2) GO TO 135
1846.000 TEMP(I,K1)=TEMP(I,K1)+DA(JY,I)*SM(JY)*XMULP
1847.000 IF(XMAXA.LT.ABS(TEMP(I,K1))) GO TO 120
1848.000 IF(XMAXB.LT.ABS(TEMP(I,K1))) XMAXB=ABS(TEMP(I,K1))
1849.000 GO TO 130
1850.000 120 XMAXB=XMAXA
1851.000 XMAXA=ABS(TEMP(I,K1))
1852.000 130 SUMA=SUMA+TEMP(I,K1)**2
1853.000 DA(JY,I)=DA(JY,I)/VAL(I)**2
1854.000 SUMB=SUMB+(DA(JY,I)**XMULP)**2
1855.000 135 DA(JY,I)=DA(JY,I)*XMULP
1856.000 140 CONTINUE
1857.000 IF(IOUT.NE.2) GO TO 150
1858.000 SHEAR1=SQRT(SUMA)
1859.000 SHEAR2=XMAXA+XMAXB
1860.000 FORCE1=SHEAR1-SHP(K1)
1861.000 FORCE2=SHEAR2-SHP(K1)
1862.000 SHP(K1)=SHEAR1
1863.000 SHP(K1)=SHEAR2
1864.000 DU=SQRT(SUMB)
1865.000 GO TO (142, 144, 146, K1)
1866.000 142 IF(NOP1.LT.2) GO TO 148
1867.000 CALL SPIW(1)
1868.000 WRITE(IW,328) J,SHEAR1,SHEAR2,FORCE1,FORCE2,DU
1869.000 GO TO 150
1870.000 144 WRITE(IW,327) SHEAR1,SHEAR2,FORCE1,FORCE2,DU
1871.000 GO TO 150
1872.000 146 WRITE(IW,314) SHEAR1,SHEAR2,FORCE1,FORCE2,DU
1873.000 GO TO 150
1874.000 148 CALL SPIW(1)
1875.000 WRITE(IW,329) J,SHEAR1,SHEAR2,FORCE1,FORCE2,DU
1876.000 150 CONTINUE
1877.000 160 CONTINUE
1878.000 CALL SPIW(3)
1879.000 WRITE(IW,315)
1880.000 WRITE(IW,316)
RETURN

307 FORMAT(IX, 'MODE NUMBER', II, 'FREQUENCY')
308 FORMAT(IX, I7, E25.5)
309 FORMAT(IX, 'MODE SHAPE')
310 FORMAT(IX, 'LEVEL', 3X, 'DIRN', I8, 3I12)
311 FORMAT(IS, 7F10.0)
312 FORMAT(4F10.0)
313 FORMAT(21X, 'SHEAR OR', 12X, 'FORCE OR', '/20X, 'CUMULATIVE',
     11X, 'TORSIONAL', 1X, 'STORY', 2X, 'DIRN', 8X, 'TOR. MOMENT',
     21X, 'MOMENT', 10X, 'DISP', '/4X, 'LEVEL', 11X, 'CODE 1', 4X,
     3*CODE 2', 4X, 'CODE 1', 4X, 'CODE 2')
314 FORMAT(8X, 'THETA', 4F10.3, E11.4)
315 FORMAT(7X, '*CODE 1 - ROOT SUM SQUARE')
316 FORMAT(7X, '*CODE 2 - SUM OF TWO MAXIMUM ABSOLUTE')
317 FORMAT(1X, I4, 2X, 'X TRAN', 4E12.5)
323 FORMAT(7X, 'Y TRAN', 4E12.5)
324 FORMAT(9X, 'ROTH', 4E12.5)
326 FORMAT(1X, I4, 2X, 'Y TRAN', 4E12.5)
327 FORMAT(8X, 'Y', 4F10.3, E11.4)
328 FORMAT(14, 4X, 'X', 4F10.3, E11.4)
329 FORMAT(14, 4X, 'Y', 4F10.3, E11.4)
330 FORMAT(1X, '---')
334 FORMAT(1X, 'GLOBAL SEISMIC STORY FORCES AND DISPLACEMENTS')
335 FORMAT(1X, '---')
END

SUBROUTINE EIGVAL(A, SM, VAL, VEC, CO, NA, BB)
CALCULATES MODE SHAPES AND FREQUENCIES
COMMON/CON/NST, NFT, NOPT, NEO, NMULP,
COMMON/SPEC/NM, LM, XM, SF, BETA, WI, ALLOW, TD, G, NP, TC(10), SAC(10),
COMMON/MISC/IR, IW, AI(3), AJ(3), IDN, NH
DIMENSION ANEO, NEO, SM(NEQ), VEC(NEQ, NM), VAL(NM)
DIMENSION CO(NEQ), NA(NEQ), BB(NEQ)
FORM DYNAMIC MATRIX
CALL DYNO(A, SM, NA, BB)
1921.000  SH=0.
1922.000  K=1
1923.000  LL=0
1924.000  RI=1.E-06
1925.000  NVT=0
1926.000 C
1927.000 C  SET INITIAL VALUE OF THE TRIAL VECTORS
1928.000 C
1929.000  10 DO 20 I=1,NEQ
1930.000  CO(I)=1.
1931.000  20 CONTINUE
1932.000  NI=1
1933.000 C
1934.000 C  OBTAIN NEW TRIAL VECTORS
1935.000 C
1936.000  30 DO 40 I=1,NEQ
1937.000  VEC(I,K)=0.
1938.000  DO 40 J=1,NEQ
1939.000  VEC(I,K)=VEC(I,K)+A(I,J)*CO(J)
1940.000  40 CONTINUE
1941.000 C
1942.000 C  INITIALIZE NEW TRIAL VECTOR BY DIVIDING IT BY THE
1943.000 C  LARGEST ELEMENT
1944.000 C
1945.000  NT=1
1946.000  CMAX=ABS(VEC(I,K))
1947.000  DO 50 I=2,NEQ
1948.000  IF(ABS(VEC(I,K)).LT.CMAX) GO TO 50
1949.000  CMAX=ABS(VEC(I,K))
1950.000  NT=1
1951.000  50 CONTINUE
1952.000  TT=CO(NI)/VEC(NI,K)
1953.000  TTS=TT/ABS(TT)
1954.000  CMAX=CMAX*TTS
1955.000  DO 60 I=1,NEQ
1956.000  VEC(I,K)=VEC(I,K)/CMAX
1957.000  60 CONTINUE
1958.000 C
1959.000 C  TEST IF THE ORIGIN REQUIRES SHIFTING
1960.000 C
1961.000 C
1962.000 IF(LL.LT.LM) GO TO 65
1963.000 IF(NVT.EQ.1) GO TO 65
1964.000 IF(NI.LT.10) GO TO 65
1965.000 VT=SH+ABS(1./CMAV)
1966.000 KT=K-1
1967.000 VVT=SQRVT(VT)
1968.000 IF(ABS(VVT-VAL(KT)).GT..05*VAL(KT)) GO TO 100
1969.000 NVT=1
1970.000 C
1971.000 C TEST FOR CONVERGENCE
1972.000 C
1973.000 65 ERMAX=0.
1974.000 DO 70 I=1,NEQ
1975.000 IF(ABS(VEG(I,K)).LT.R1)GO TO 70
1976.000 ERR=(CO(I)-VEG(I,K))/VEG(I,K)
1977.000 ERR=ABS(ERR)
1978.000 IF(ERR.GT.ERMAX) ERMAX=ERR
1979.000 70 CONTINUE
1980.000 IF(ERMAX.LE.ALLOW) GO TO 120
1981.000 IF(NI.GT.MI) GO TO 118
1982.000 DO 80 I=1,NEQ
1983.000 CO(I)=VEG(I,K)
1984.000 80 CONTINUE
1985.000 NI=NI+1
1986.000 GO TO 30
1987.000 C
1988.000 C HERE TO CALCULATE THE NEW ORIGIN
1989.000 C
1990.000 100 SH=(VT+VAL(KT)*VAL(KT))/2.
1991.000 REWIND 5
1992.000 C
1993.000 C RETRIEVE BUILDING STIFFNESS MATRIX FROM UNIT 5
1994.000 C
1995.000 READ(5)((A(I,J),I=1,NEQ),J=1,NEQ)
1996.000 DO 110 I=1,NEQ
1997.000 A(I,I)=A(I,I)-SH*SM(I)
1998.000 110 CONTINUE
1999.000 C
2000.000 C FORM DYNAMIC MATRIX AND MODIFY IT TO SWEEP THE MODE
2001.000 C SHAPES ALREADY FOUND
2002.000 C
2003.000 IDN=1
2004.000 CALL DYNO(A,SM,NA,BB)
2005.000 DO 112 I=1,NEQ
2006.000 CO(I)=VEC(I,K)
2007.000 112 CONTINUE
2008.000 KK=K-1
2009.000 DO 115 N=1,KK
2010.000 HAT=1./(VAL(N)*VAL(N)-SH)
2011.000 DO 115 I=1,NEQ
2012.000 DO 115 J=1,NEQ
2013.000 A(I,J)=A(I,J)-HAT*VEC(J,N)*VEC(I,N)*SM(J)
2014.000 115 CONTINUE
2015.000 LL=0
2016.000 NI=NI+1
2017.000 GO TO 30
2018.000 C PRINT OUT WARNING MESSAGE
2019.000 C
2020.000 C
2021.000 118 WRITE(IW,301)
2022.000 WRITE(IW,302) K
2023.000 WRITE(IW,303) NI
2024.000 WRITE(IW,304) ERMAX
2025.000 C CALCULATE DIMENSIONLESS FREQUENCY
2026.000 C AND NORMALISED MODE SHAPE
2027.000 C
2028.000 C
2029.000 120 VAL(K)=SQRT(SH+1./CMAX)
2030.000 ALFA=0.
2031.000 DO 130 I=1,NEQ
2032.000 ALFA=ALFA+VEC(I,K)*VEC(I,K)*SM(I)
2033.000 130 CONTINUE
2034.000 BETA=SQR(ALFA)
2035.000 DO 140 I=1,NEQ
2036.000 VEC(I,K)=VEC(I,K)/BETA
2037.000 140 CONTINUE
2038.000 IF(K-NM) 150,200,200
2039.000 150 CONTINUE
2040.000 C
MODIFY DYNAMIC MATRIX TO SWEEP THE MODE SHAPE LAST FOUND

DO 160 I=1,NEQ
DO 160 J=1,NEQ
A(I,J)=A(I,J)-CMAX*VEC(I,K)*VEC(J,K)*SM(J)
160 CONTINUE
K=K+1
LL=LL+1
NVT=0
GO TO 10
RETURN

301 FORMAT(//6X, ** WARNING - ITERATION COUNTER LIMIT REACHED **)
302 FORMAT(5X, 'MODE NUMBER ..............................................=', I4)
303 FORMAT(5X, 'NUMBER OF ITERATION ....................................=', I4)
304 FORMAT(5X, 'MAXIMUM DIFFERENCE BETWEEN SUCCESSIVE TRIAL VECTORS ...=', F12.8)
END

SUBROUTINE DYN0(A,SM,NA,BB)
FORMS DYNAMIC MATRIX: D=INV(A)*SM

COMMON/CON/NST,NFT,NOPT,NEQ,NMULP
COMMON/MISC/IR,IN,AL(I),AJ(J),IDN,NH
DIMENSION A(I),NA(I),SM(I),BB(I)

INVERT MATRIX A

IF(IDN,EQ,1) CALL RECIP(A,NA,BB)
DO 10 I=2,NEQ
10 IAD=(I-1)*NEQ
JADR=I
DO 10 J=1,I
10 IADR=IADR+J
A(JADR)=A(IADR)
JADR=JADR+NEQ
CONTINUE

FORM THE PRODUCT OF A INVERSE AND THE MASS MATRIX SM
2081.000 C
2082.000 DO 20 J=1,NEQ
2083.000 JAD=(J-1)*NEQ
2084.000 DO 20 I=1,NEQ
2085.000 JADR=JAD+I
2086.000 A(JADR)=A(JADR)*SM(J)
2087.000 CONTINUE
2088.000 RETURN
2089.000 END
2090.000 SUBROUTINE RECIP(A,NA,BB)
2091.000 C
2092.000 C INVERTS SYMMETRIC MATRIX A AND STORES INVERTED SYMMETRIC
2093.000 C HALF IN THE DIAGONAL AND UPPER TRIANGLE OF A
2094.000 C
2095.000 COMMON/CON/NST,NFT,NOPT,NEQ,NMULP
2096.000 DIMENSION A(1),BB(1),NA(1)
2097.000 NN=NEQ-1
2098.000 NADR=1
2099.000 DO 40 J=2,NEQ
2100.000 NADR=NADR+NEQ
2101.000 LIMIT=NADR+J-1
2102.000 N1=1
2103.000 DO 30 I=NADR,LIMIT
2104.000 IF(A(I).NE.0) GO TO 40
2105.000 N1=N1+1
2106.000 CONTINUE
2107.000 NA(J)=N1
2108.000 A(1)=1./A(1)
2109.000 DO 80 M=1,NN
2110.000 O M=1,NN
2111.000 K=M+1
2112.000 KAD=(K-1)*NEQ
2113.000 KADK=KAD+K
2114.000 IN=NA(K)
2115.000 IF(IN.LE.M) GO TO 45
2116.000 A(KADK)=1./A(KADK)
2117.000 GO TO 80
2118.000 DO 60 I=1,M
2119.000 IAD=(I-1)*NEQ
2120.000 BB(I)=0.
IF (IN.GT.I) GO TO 55
DO 50 J=IN,I
IADR=IAD+J
KADR=KAD+J
BB(I)=BB(I)+A(IADR)*A(KADR)
50 CONTINUE
IF (I.EQ.M) GO TO 65
II=I+1
JJ=MAXO(I,IN)
JADR=(JJ-1)*NEQ+I
DO 60 J=JJ,M
KADR=KAD+J
BB(I)=BB(I)+A(JADR)*A(KADR)
JADR=JADR+NEQ
60 CONTINUE
D=0.
DO 70 I=IN,M
KADR=KAD+I
70 D=D+A(KADR)*BB(I)
D=A(KADK)-D
A(KADK)=I./D
DO 75 I=1,M
IADR=KAD+I
75 A(IADR)=-BB(I)*A(KADK)
DO 80 I=1,M
JADR=(I-1)*NEQ+I
80 CONTINUE
RETURN
END
SUBROUTINE SP(IW,ISP)
C SKIPS A LINE IN THE OUTPUT
C
DO 10 I=1,ISP
10 WRITE(IW,I)
FORMAT("")
RETURN
END
SUBROUTINE RESPM,DA,VEC,SA,I

CALCULATES MODAL STORY DISPLACEMENTS

COMMON/NST,NFT,NOPT,NEQ,NMULP
COMMON/SPC/NM,LM,XMU,SM,F,BETA,MI,ALLOW,TD,G,MP,TC(10),SAC(10)
DIMENSION VEC(NEQ,NM),SM(NEQ),DA(NEQ,NM)
SUM=0.
IF(NOPT.EQ.3) GO TO 20

HERE WHEN NOPT=1 OR 2, CALCULATE MODAL PARTICIPATION FACTOR

DO 10 J=1,NEQ
SUM=SUM+VEC(J,I)*SM(J)
10 CONTINUE
SI=SUM
GO TO 40

HERE WHEN NOPT=3, CALCULATE MODAL PARTICIPATION FACTOR

LAST=NEQ-2
DO 30 J=1,LAST,3
SUM=SUM+VEC(J,I)*SM(J)*COS(BETA)
30 CONTINUE
-LAST=NEQ-1
DO 35 J=2,LAST,3
SUM=SUM+VEC(J,I)*SM(J)*SIN(BETA)
35 CONTINUE
SI=SUM
DA(J,I)=VEC(J,I)*SI*SA

RETURN
END
SUBROUTINE SFORCE(S,DN,M,NDIR,DA,F,X)

CALCULATES AND PRINTS MODAL STORY DISPLACEMENTS AND FORCES IN INDIVIDUAL FRAME
COMMON/CON/NST,NFT,NOPT,NEQ,NMULP
COMMON/MISC/IW1,IW,AI(3),AJ(3),IDN,NH
DIMENSION S(NST,NST),DN(NST,NFT),M(NFT),NDIR(NFT)
DIMENSION DA(NEQ,NH),F(NST),X(NST)
IFP=0
IW1=1
REWIND 2
NM=NH
CALL SP(IW1,3)
GO TO(10,60,110),NOPT
HERE FOR NOPT=1
10 DO 50 NF=1,NFT
IF(M(NF).EQ.IFP) GO TO 20
READ CONDENSED FRAME STIFFNESS MATRIX FROM UNIT 2
READ(2,306)NFG,MST
DO 12 LL=1,MST
READ(2,307)(S(LL,J),J=1,MST)
CONTINUE
IFP=M(NF)
20 IF(NDIR(NF).EQ.2) GO TO 50
WRITE(IW1) NF,MST,NM
CALL SP(IW1,3)
DO 40 K=1,NM
DO 30 I=1,MST
F(I)=0.
DO 30 J=1,MST
F(I)=F(I)+S(I,J)*DA(J,K)
CONTINUE
WRITE MODAL STORY FORCES ON UNIT IW1
WRITE(IW1) (F(I),I=1,MST)
CONTINUE
RETURN
HERE FOR NOPT=2

DO 100 NF=1,NFT
IF(M(NF).EQ.IFP) GO TO 70

READ CONDENSED FRAME STIFFNESS MATRIX FROM UNIT 2

READ(2,306)NFG,MST
DO 62 LL=1,MST
READ(2,307)(S(LL,J),J=1,MST)
CONTINUE

IF(NDIR(NF).EQ.1) GO TO 100
WRITE(IW1) NF,MST,NM
CALL SP(IW,3)
LX 90 K=1,NM
DX 80 I=1,MST
F(I)=0.
DO 80 J=1,MST
F(I)=F(I)+S(I,J)*DA(J,K)
CONTINUE

WRITE STORY FORCES ON UNIT IW1

WRITE(IW1) (F(I),I=1,MST)
CONTINUE

CONTINUE

RETURN

HERE FOR NOPT=3

DO 180 NF=1,NFT
IF(M(NF).EQ.IFP) GO TO 120

READ CONDENSED FRAME STIFFNESS MATRIX FROM UNIT 2

READ(2,306)NFG,MST
DO 112 LL=1,MST
READ(2,307)(S(LL,J),J=1,MST)
2281.000  112 CONTINUE
2282.000  IFP=M(NF)
2283.000  120 CALL SP(IM,3)
2284.000  WRITE(111,*,NF,NST,NM
2285.000  IF(NDIR(NF).EQ.2) GO TO 130
2286.000  AI(I)=1.
2287.000  AI(2)=0.
2288.000  GO TO 140
2289.000  130 AI(I)=0;
2290.000  AI(2)=1.
2291.000  140 DO 180 K=1,NM
2292.000  DO 150 I=1,MST
2293.000  X(I)=0.
2294.000  II=(I-1)*3
2295.000  AI(3)=DN(I,NF)
2296.000  DO 150 J=1,3
2297.000  ID=II+J
2298.000  X(I)*=X(I)+AI(J)*DA(ID,K)
2299.000  150 CONTINUE
2300.000  180 CONTINUE
2301.000  F(I)=0.
2302.000  DO 160 J=1,MST
2303.000  F(I)=F(I)+3(I,J)*X(J)
2304.000  160 CONTINUE
2305.000  WRITE STORY FORCES ON WNIT IN!
2306.000  WRITE(111,*) (F(I),I=1,MST)
2307.000  180 CONTINUE
2308.000  RETURN
2309.000  C
2310.000  C
2311.000  306 FORMAT(218)
2312.000  307 FORMAT(6E12.5)
2313.000  ENU
2314.000  C
2315.000  SUBROUTINE ROOT(NF,NST,NDIR,NQO,MC,M,HN,IRR,
2316.000  +A,NA,SD,SLD,FH1,FH2,FH3,FH4,FC1,FC2,FC3,FC4,DS)
2317.000  COMMON/COM/BL(210),BA(210),BB(210),BG(210),BE(210),
2318.000  +CL(240),CA(240),CB(240),CG(240),CEF(240),CAL(240),N1,NS,
2319.000  +NST(10),NBAY(9),NBS(9),DISQ(30)
COMMON/CUN/NNS,NFT,NOPT,NO,NMULP
DIMENSION A(NNEL),NQA(NNQ),S0(NNQ),SDL(NNQ),FB1(MBM),
+FB2(MBM),FB3(MBM),FB4(MBM),FC1(NCL),FC2(NCL),FC3(NCL),
+FC4(NCL),DSP(NNS),NDIR(NFT)

C
REWIND 4
REWIND 6
IR=4
IR1=6
IW=7
J0PT=0
IFR=0
OPT=2

20 DO 100 II=1,NFG
READ(IR,500) NT,NS,NFR
READ(IR,500) (NST(I),I=1,NT)
READ(IR,500) (NBAY(I),I=1,NT)
NT2=NT-1
IF(NT,GT,1) READ(IR,500) (NBS(I),I=1,NT2)
READ(IR,500) NBM,NCL
READ(IR,525) (BL(I),BA(I),BB(I),BG(I),BEF(I),I=1,NBM)
READ(IR,520) (CL(I),CA(I),CB(I),CG(I),CEF(I),CAL(I),I=1,NCL)
READ(IR,510) NEQ,NL
READ(IR,515) (NA(I),I=1,NEQ)
READ(IR,520) (A(I),I=1,NL)
DO 90 I=1,NFR
IFR=IFR+1
IF(NOPT.LE.2.AND.NOPT.NE.NDIR(IFR)) GO TO 90
READ(IRR) NF,MST,NM

DO 28 IL=1,NBM
FB1(IL)=0.
FB2(IL)=0.
FB3(IL)=0.
FB4(IL)=0.
28 CONTINUE
DO 30 IL=1,NCL
FC1(IL)=0.
FC2(IL)=0.
FC3(IL)=0.
FC4(IL)=0.
2361.000  30 CONTINUE
2362.000    DO 35 IL=1,NST
2363.000  35 DSP(IL)=0.0
2364.000    DO 70 J=1,NM
2365.000    READ(IHP) (SD(JJ),JJ=1,MST)
2366.000    DO 40 KK=1,NEQ
2367.000  40 SLD(KK)=0.
2368.000    K=0
2369.000    IS=0
2370.000    DO 60 IJ=1,NT
2371.000    NN=NST(IJ)
2372.000    NB=NBAY(IJ)+1
2373.000    NB1=NB+1
2374.000    DO 50 IK=1,NN
2375.000    IS=IS+1
2376.000    K=K+NB1
2377.000    SLD(K)=SD(IS)
2378.000    K=K+NB
2379.000  50 CONTINUE
2380.000  60 CONTINUE
2381.000    CALL BSUB(JOPT,NEL,NOQ,A,NA,SD,SLD,NEQ)
2382.000    IF(IDN.NE.0) GO TO 65
2383.000    WRITE(3) (SLD(J),J=1,NEQ)
2384.000    GO TO 70
2385.000  65 MB=MBA+1
2386.000    CALL FORCE(OPT,MBM,MCL,NOQ,NNS,FB1,FB2,FB3,FB4,FC1,FC2,
2387.000      +FC3,FC4,NA(1),NA(MB),SD(1),SD(MB),SLD,DSP)
2388.000  70 CONTINUE
2389.000    IF(IDN.EQ.0) GO TO 90
2390.000  C
2391.000    DO 75 IB=1,NBM
2392.000    FB1(IB)=SQR(FB1(IB))
2393.000    FB2(IB)=SQR(FB2(IB))
2394.000    FB3(IB)=SQR(FB3(IB))
2395.000    FB4(IB)=SQR(FB4(IB))
2396.000  75 CONTINUE
2397.000    DO 80 IC=1,NCL
2398.000    FC1(IC)=SQR(FC1(IC))
2399.000    FC2(IC)=SQR(FC2(IC))
2400.000    FC3(IC)=SQR(FC3(IC))
2401.000  FC4(IC)=SORT(FC4(IC))
2402.000  80 CONTINUE
2403.000  DO 85 IL=1,NS
2404.000  85 DSP(IL)=SORT(DSP(IL))
2405.000  WRITE(5) (FB1(IB),FB2(IB),FB3(IB),FB4(IB),IB=1,NBM)
2406.000  WRITE(5) (FC1(IC),FC2(IC),FC3(IC),FC4(IC),IC=1,NCL)
2407.000  WRITE(5) (DSP(IL),IL=1,NS)
2408.000  90 CONTINUE
2409.000  100 CONTINUE
2410.000  RETURN
2411.000  C
2412.000  500 FORMAT(5I5)
2413.000  510 FORMAT(2I8)
2414.000  515 FORMAT(I8)
2415.000  520 FORMAT(6E12.5)
2416.000  525 FORMAT(5E12.5)
2417.000  END
2418.000  C
2419.000  SUBROUTINE HLOAD(A,DN,M,NDIR,XBAR,YBAR)
2420.000  C
2421.000  C PREPARE LATERAL LOAD VECTOR
2422.000  C AND FIND FRAME STORY FORCES.
2423.000  C
2424.000  COMMON/CON/NST,NFT,NOPT,NEQ,NMULP
2425.000  COMMON/CON/1HX(40),HY(40),DX(40),DY(40),NA(120),FH(120),
2426.000  F(120,3),X(40),S(1710)
2427.000  COMMON/CO/NGB/NGR,NWL,NDYN,NSYS,IOUT,SMULP(12,8)
2428.000  COMMON/MISC/IW,IN,AL(3),AJ(3),IDN,NH
2429.000  DIMENSION A(NEQ,NEQ),XBAR(NST),YBAR(NST),M(NFT),
2430.000  NDIR(NFT),DN(NST,NFT)
2431.000  IR=3
2432.000  IW=7
2433.000  WRITE(IW,110)
2434.000  CALL RECIPE(A,NA,FH)
2435.000  IDN=0
2436.000  DO 99 IH=1,NW
2437.000  WRITE(IW,150) IH
2438.000  DO 60 I=1,NST.
2439.000  READ(IR,100) HX(I),HY(I),DX(I),DY(I)
2440.000  GO TO (30,40,50),NOPT
2441.000  30  FH(I)=HX(I)
2442.000  GO TO 60
2443.000  40  FH(I)=HY(I)
2444.000  GO TO 60
2445.000  50  XB=XBAR(I)
2446.000  YB=YBAR(I)
2447.000  K=3*I
2448.000  FH(K)=HY(T)*DX(I)-XB)-HX(I)*DY(I)-YB
2449.000  FH(K-2)=HX(I)
2450.000  FH(K-1)=HY(I)
2451.000  60  CONTINUE
2452.000  WRITE(IW,200) (I,HX(I),HY(I),DX(I),DY(I),I=1,NST)
2453.000  DO 90 I=1,NEQ
2455.000  SB=0.
2456.000  DO 70 J=1,I
2457.000  70  SB=SB+A(J,I)*FH(J)
2458.000  IF(II.EQ.NEQ) GO TO 90
2459.000  II=II+1
2460.000  DO 80 K=II,NEQ
2461.000  80  SB=SB+A(I,K)*FH(K)
2462.000  90  DA(I,II)=SB
2463.000  CONTINUE
2464.000  99  CONTINUE
2465.000  NH=NWL
2466.000  CALL SFORCE(S,DN,M,NDIR,DA,F,X)
2467.000  RETURN
2468.000  100  FORMAT(5F15.5)
2469.000  110  FORMAT(/)
2470.000  ++  ---------------/
2471.000  ++  LATERAL LOAD DATA/
2472.000  ++  ---------------/
2473.000  150  FORMAT(// LATERAL LOAD CASE,13,"
2474.000  ++  ---------------/
2475.000  ++  LEVEL X-FORCE Y-FORCE X-DIST Y-DIST"
2476.000  200  FORMAT(15,2X,4F10.3)
2477.000  END
2478.000  C
2479.000  SUBROUTINE SYSTEM(NFG,NQQ,MBM,MCL,NNS,B,FS1,FS2,FS3,
2480.000  +FS4,SB1,SB2,SB3,SB4,SC1,SC2,SC3,SC4,FX1,FX2,
+FX3,FX4,UIA,DSP)
FINDS AND WRITES MEMBER FORCES FOR LOAD SYSTEMS
COMMON.COM1,COM2,COM3,COM4,COM5,COM6,COM7,COM8,COM9,
+CL(C40),CA(C40),CB(C40),CG(C40),CEF(C40),CAL(C40),NT,NS,
+NSTC10,NBAY9,NND(9),NISO(30)
DIMENSION B(NQO),FS1(MBM),FS2(MBM),FS3(MBM),FS4(MBM),
+SQB1(MBM),SQB2(MBM),SQB3(MBM),SQB4(MBM),SQC1(MCL),
+SQC2(MCL),SQC3(MCL),SQC4(MCL),FX1(4,MBM),FX2(4,MBM),
+FX3(4,MBM),FX4(4,MBM),HIA(7,NOO),DSP(INS)
COMMON/COMSYS,NGR,NWL,NDYN,NSYS,IOUT,SMULP(12,8)
RE’WR’’ND 4
IR=4
I’’W=7
K=NGR
WRITE(IW,600)
N1=NGR+1
N2=NGR+NWL
NCASE=N2+NDYN
WRITE(IW,100) (I,I=1,NSYS)
IF(NGR,NE,0) GO TO 2
WRITE(IW,150)
GO TO 4
2 DO 3 J=1,NGR
WRITE(IW,200) J,(SMULP(I,J),I=1,NSYS)
3 CONTINUE
RE’WR’’ND 8
4 IF(NWL,NE,0) GO TO 5
WRITE(IW,250)
GO TO 7
5 CONTINUE
RE’WR’’ND 3
6 DO 6 J=1,NWL
K=K+1
7 IF(NDYN,NE,0) GO TO 8
WRITE(IW,350)
2521.000       GO TO 9
2522.000       K=K+1
2523.000       REMIND 5
2524.000       WRITE(1W,400) (SMULP(I,K),I=1,NSYS)
2525.000       9   IFR=0
2526.000       DO 60 II=1,NFG
2527.000       READ(IR,500) NT,NS,NFR
2528.000       READ(IR,500) (NST(I),I=1,NT)
2529.000       READ(IR,500) (NBAY(I),I=1,NT)
2530.000       NT2=NT-1
2531.000       IF(NT2.GT.1) READ(IR,500) (NBS(I),I=1,NT2)
2532.000       READ(IR,500) NBM,NCL,NEQ
2533.000       READ(IR,525) (BL(I),BA(I),BB(I),BG(I),BIF(I),I=1,NBM)
2534.000       READ(IR,520) (CL(I),CA(I),CB(I),CG(I),CEF(I),CAL(I),I=1,NCL)
2535.000       DO 55 IJ=1,NFR
2536.000       IFR=IFR+1
2537.000       NK=NCA
2538.000       WRITE(1W,550) IFR
2539.000       IF(NGR.EQ.0) GO TO 15
2540.000       READ(8) INDL
2541.000       IF(INDL.NE.0) GO TO 15
2542.000       DO 10 I=1,NGR
2543.000       READ(8) (BTA(I,J),J=1,NEQ)
2544.000       READ(8) (FX1(I,J),FX2(I,J),FX3(I,J),FX4(I,J),J=1,NBM)
2545.000       10   CONTINUE
2546.000       IF(NWL.EQ.0) GO TO 20
2547.000       DO 18 I=N1,N2
2548.000       18   READ(3) (BTA(I,J),J=1,NEO)
2549.000       20   IF(NDFYN.EQ.0) GO TO 25
2550.000       READ(5) (SQB1(K),SQB2(K),SQB3(K),SQB4(K),K=1,NBM)
2551.000       READ(5) (SOC1(K),SOC2(K),SOC3(K),SOC4(K),K=1,NCL)
2552.000       READ(5) (DISO(K),K=1,NS)
2553.000       NK=NK-1
2554.000       SML=1
2555.000       25   DO 50 I=1,NSYS
2556.000       WRITE(1W,560) I
2557.000       DO 26 IB=1,NEQ
2558.000       26   B(IB)=0.0
2559.000       DO 28 IK=1,NBM
2560.000       PSI(IK)=0.0
2561.000  FS2(IK)=0.0
2562.000  FS3(IK)=0.0
2563.000  FS4(IK)=0.0
2564.000  28 CONTINUE
2565.000   L=0
2566.000   DO 40 J=1,NK
2567.000   XMUL=SMULP(I,J)
2568.000   IF(XMUL.EQ.0) GO TO 40
2569.000   DO 30 K=1,NEQ
2570.000   30 B(K)=B(K)+XMUL*BTA(J,K)
2571.000   IF(J.GT.NGR) GO TO 40
2572.000   L=L+1
2573.000   DO 35 K=1,NBM
2574.000   FS1(K)=FS1(K)+XMUL*FX1(J,K)
2575.000   FS2(K)=FS2(K)+XMUL*FX2(J,K)
2576.000   FS3(K)=FS3(K)+XMUL*FX3(J,K)
2577.000   FS4(K)=FS4(K)+XMUL*FX4(J,K)
2578.000  35 CONTINUE
2579.000  40 CONTINUE
2580.000   OPT=0
2581.000   IF(L.GT.0) OPT=1
2582.000   IF(NDYN.EQ.0) GO TO 45
2583.000   XMUL=SMULP(I,NCASE)
2584.000   IF(XMUL.EQ.0) GO TO 45
2585.000   OPT=OPT+3
2586.000   SMLT=XMUL/SMLT
2587.000   DO 42 K=1,NBM
2588.000   SQB1(K)=SMLT*SQB1(K)
2589.000   SQB2(K)=SMLT*SQB2(K)
2590.000   SQB3(K)=SMLT*SQB3(K)
2591.000   SQB4(K)=SMLT*SQB4(K)
2592.000  42 CONTINUE
2593.000   DO 43 K=1,NCL
2594.000   SQC1(K)=SMLT*SQC1(K)
2595.000   SQC2(K)=SMLT*SQC2(K)
2596.000   SQC3(K)=SMLT*SQC3(K)
2597.000   SQC4(K)=SMLT*SQC4(K)
2598.000  43 CONTINUE
2599.000   DO 44 K=1,NS
2600.000  44 DISQ(K)=SMLT*DISQ(K)
SMUL=XMUL
CALL FORCOS(OPT, MBM, MCL, NOO, NNS, FS1, FS2, FS3, FS4, SQC1,
+SQC2, SQC3, SQC4, SQB1, SQB2, SQB3, SQB4, B, DSP)
50 CONTINUE
55 CONTINUE
60 CONTINUE
WRITE(IW,700)
IF(NDYN.EQ.0) WRITE(IW,675)
RETURN
100 FORMAT('///20X, LOAD CASE MULTIPLYING FACTORS ///')
101 FORMAT('///20X, LOAD SYSTEM',6X,12I7)
150 FORMAT('///20X, *** GRAVITY LOAD CASES ARE NOT CONSIDERED ***')
200 FORMAT('/// GRAVITY LOAD CASE',6X,12F7.3)
250 FORMAT('///20X, *** LATERAL LOAD CASES ARE NOT CONSIDERED ***')
300 FORMAT('/// LATERAL LOAD CASE',6X,12F7.3)
350 FORMAT('///20X, *** SEISMIC LOAD CASE IS NOT CONSIDERED ***')
400 FORMAT('/// SEISMIC LOAD CASE',6X,12F7.3)
500 FORMAT(5I5)
520 FORMAT(6E12.5)
525 FORMAT(5E12.5)
550 FORMAT(/)
560 FORMAT(/)
570 FORMAT('/// FOR LOAD SYSTEM',6X,13)
580 FORMAT('///')
600 FORMAT(11H1, '//
602 FORMAT('/// MAX = STATIC FORCES OR DISPLACEMENTS + SEISMIC///
604 FORMAT('/// ROOT SUM SQUARE FORCES OR DISPLACEMENTS///
606 FORMAT('/// MIN = STATIC FORCES OR DISPLACEMENTS - SEISMIC///
608 FORMAT('/// ROOT SUM SQUARE FORCES OR DISPLACEMENTS///
610 FORMAT('/// *** SIGN USED ***///
612 FORMAT('/// ** MOM/TURN: CNTR.CLK +VE ; FORCE/DISP: UP +VE, RTH +VE ///
614 END