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DESIGN AND BEHAVIOR
OF
COMPOSITE SPACE TRUSSS

by
Juan Pedro Martin Navarro Cota

A thesis submitted to the Faculty of the
DEPARTMENT OF CIVIL ENGINEERING
AND
ENGINEERING MECHANICS
In partial fulfillment of the requirements
For the degree of
MASTER OF SCIENCE
WITH A MAJOR IN CIVIL ENGINEERING
In the Graduate College
THE UNIVERSITY OF ARIZONA

1987
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This thesis has been approved on the date shown below:

_____________________________ 9 May 1987
Dr. Reidar Bjorhovde
Professor of Civil Engineering and Engineering Mechanics
ACKNOWLEDGMENTS

This work has been dedicated to all of the members of my family, without their support it would not have been possible.

To my mother, whom the Lord took from our side but whose memory is always with me.

To my father, whose example has been guidance and reason for the greatest proudness I want to express. To him my deepest love and gratitude.

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ABSTRACT

A fully automated computer program is developed for the optimum design of steel space trusses acting compositely with a concrete slab placed on top. The program sizes the truss members to meet the requirements of the load and resistance factor design specification of the American Institute of Steel Construction using the load combinations of ANSI. However, earthquake loading is not considered. The optimum size is based on minimum cost, regarding the amount of welding required at the joints and of the member itself. The joint plates are sized to meet the welding requirements and to ensure the proper location of the connecting elements. The total cost is based on all steel work in the truss.

Once the truss configuration has been defined, and it has been ensured that the concrete stresses are such that linear elastic behavior exists, the structure is analyzed for the construction process, to make sure that no over stressing will take place in any structural element at any time during construction and service.

The analysis and design principles are presented and an actual design case is solved.
CHAPTER 1
INTRODUCTION

Current structural analysis and design approaches are based on two-dimensional idealizations of members and structures. The primary reasons for this simplification are rooted in the needs for having rational and relatively simple design approaches, as well as the necessity for minimizing the computational work.

It is very useful in many buildings to have areas free of interior columns because of the spaciousness and the versatility that this allows for many building uses. To make this type of construction economical, three-dimensional behavior should be taken into account. This is the aim of utilizing the composite space truss, where advantage can be taken of a concrete slab which is required to act compositely with an assemblage of members that possess stiffness and strength in all of the directions of the three-dimensional environment.

One of the main drawbacks of the analysis of three-dimensional structures is their high degree of static indeterminacy. This results in a time-consuming process of evaluating the member forces and the structural deflections. The only way to make the analysis feasible is
through the application of a computer-oriented solution, using structural analysis techniques such as the stiffness method.

In current construction of composite frames, the spacing between adjacent frames is in the range of 10 to 16 ft., and formed steel deck which is designed as formwork to carry the wet concrete will require a much larger member than what is needed in the case of a composite space truss. In the actual design of composite frames the member sections are sized on the basis of the maximum moments and other stress resultants. This means that other parts along the member length are understressed. On the other hand, the use of composite trusses is likely to produce structures where the members are more effectively utilized.

It has been recognized that utilizing the large amount of material in floor systems more efficiently will reduce the level of stress and deflection (7,13). However, no work has been presented on composite space trusses where a concrete slab is integrated with the assemblage of bar type members.

Composite space trusses is a novel idea, and for that reason no analysis and design procedures have been developed that can be used to size their components. It is the objective of this work, through the use of strength and analysis models and the computer program, to introduce the
concepts of this type of structure and to demonstrate its advantages and practical applications.
CHAPTER 2
BACKGROUND STUDIES

2.1 Composite construction

The purpose of this type of construction is to make two materials with different properties interact so that full utilization of the different components can be achieved. This requires that they must be placed where they perform the best and that they must be adequately connected to each other.

The most commonly used materials for composite construction are currently steel and concrete. It is possible that other materials eventually may be utilized in building construction, but for the time being no changes are considered.

Steel is a material whose behavior is well defined and understood. Although the material itself performs equally well whether it is loaded in tension or compression (see Fig. 2.1), in a structural member the behavior in compression is influenced significantly by the occurrence of buckling. For this and other several reasons, it is generally preferable to place the steel where it will be primarily subjected to tension.

Concrete is a non-homogeneous material and its
Fig. 2.1
Steel stress strain curve

Fig. 2.2
Concrete stress strain curve
response characteristics are also well understood. A typical stress-strain curve is shown in Fig. 2.2, which illustrates the linearly elastic response for low stresses. Also, the tensile strength is low, whereas the compressive strength is relatively high. It is therefore preferable to use concrete where it will be subjected to compression.

Composite members have been in use since the end of 1940's, but formalized standards for their design and construction evolved relatively slowly, compared to those for structural steel of the American Institute of Steel Construction (AISC), and reinforced and prestressed concrete of the American Concrete Institute (ACI).

Composite behavior was first modeled through elastic theory using the concept of the equivalent cross section along with the appropriate allowable stress, this permitted the elastic design of composite members. In the past several years, however, the development of the concepts of limit states design have provided improved criteria that are based on ultimate strength considerations. These concepts have been utilized in the development of the strength models for the composite space truss; they will be detailed in chapter 4.

The philosophy of designing a member to the point where is no longer useful in a probabilistic context has been developed in the LRFD criteria. This is the most
scientific approach for design, for this reason generalized acceptance is being gained and similarly to the evolution of plastic analysis in reinforced concrete design, LRFD will be considered as the basic design approach instead of the current AISC specification which is based in allowable stresses. LRFD is explained in further detail later in this chapter.

The LRFD considerations for members currently in use will be shown next, they are beams, columns, beam-columns, planar trusses. The presence of shear connectors is fundamental for the achievement of the composite action in any given member, its strength model will be presented in chapter 3.

2.1.1. Beam

It is the typical composite member, actually research on composite behavior was initiated when it was realized that advantage could be taken from the fact that the stress distribution exhibits compressive stresses at top where a concrete slab is to be placed to supply the needed surface for the use of the floor. A typical floor system is shown in Fig. 2.3, in it a formed steel deck is used to provide temporary support to the wet concrete. The presence of reinforcing steel was initially intended to fulfill temperature requirements however taking advantage of developments in evaluating negative moment capacities
Fig. 2.3 Typical composite floor system.
of composite sections, design of continuous floor systems is feasible and economically attractive.

One of the main areas of study is the determination of the effective slab width that acts compositely with the steel beam, it can be determined as the smallest of the following:

a) One-eighth of the beam span, center-to-center of supports;

b) One-half the distance to the centerline of the adjacent beam; or the distance from the beam centerline to the edge of the slab.

Figure 2.4 shows the typical composite cross sections that are considered in analysis and design of composite beams. The resulting stress distributions under positive and negative moment are shown in Fig. 2.5, these correspond to an ultimate limit state which corresponds to yielding of steel and crushing of concrete at a stress level of 0.85 f'c. The value hr refers to the rib height of the formed steel deck, this value is different depending on the deck orientation with respect to the beam. Regardless of the type of moment, the cross section must be in equilibrium which exists when the resultant of all compressive stresses equals the resultant of all the tensile ones. For the evaluation of the compressive force C the smallest of the values in the presented expressions is
Fig. 2.4 Typical composite beam cross sections.
Fig. 2.5 Stress distribution at ultimate load in a composite beam.
used:

For positive moment:

\[ C = A_{SW} F_{yw} + 2A_{sf} F_{yf} \]  \hspace{1cm} (1)
\[ C = 0.85 f'_c A_c \]  \hspace{1cm} (2)
\[ C = Q_n \]  \hspace{1cm} (3)

For negative moment:

\[ C = A_r F_{yr} \]  \hspace{1cm} (4)
\[ C = \sum Q_n \]  \hspace{1cm} (5)

where

- \( f'_c \) = specified compressive strength of concrete
- \( A_c \) = area of concrete slab within effective width
- \( A_s \) = area of steel cross section
- \( A_{SW} \) = area of steel web
- \( A_{sf} \) = area of steel flange
- \( F_y \) = minimum specified yield stress of steel
- \( F_{yw} \) = minimum yield stress of web steel
- \( F_{yf} \) = minimum specified yield stress of flange steel
- \( \sum Q_n \) = Sum of nominal strengths of shear connectors between the point of maximum positive moment and the point of zero moment to either side

Equations 3 and 5 correspond to the case where there is no full interaction between steel and concrete and therefore some slip takes place, such slip can be taken into account in revising for service conditions, the equivalent section moment of inertia \( I_{eff} \) can be computed
by:

\[ I_{\text{eff}} = I_s + \left( \sum \frac{Q_n}{C_f} \right) (I_{tr} - I_s) \]  

(6)

where

- \( I_s \) = moment of inertia for the structural steel section
- \( I_{tr} \) = moment of inertia for the fully composite uncracked transformed section
- \( C_f \) = compression force in concrete slab for fully composite beam; smaller of formulas 1 and 2.

The type of construction must be considered in the selection of the steel beam cross section since it must take all loads to be applied before concrete has gained strength. Its unbraced length may control its flexural strength depending on lateral bracing provided at that stage. Detailed considerations for composite flexural members can be found in references 3, 11, 12, 15.

2.1.2. Column

Typical cross sections are shown in Fig. 2.6. It can be seen that there are two types: encased and concrete filled tubing. For a member to be considered as composite column the following requirements must be met:

a) There must be at least a 4% steel area, otherwise member is considered as a reinforced concrete member.

b) In encased columns there must be a minimum amount of transverse and longitudinal reinforcement to prevent
a) Composite Column

b) Concrete Encased Steel Column

c) Concrete Filled Tubes

Fig. 2.6 Composite Column Cross Sections.
spalling during fire.

c) Minimum normal weight Concrete strength of 3 ksi and 4 ksi for lightweight, maximum strength for both concrete types is 8 ksi.

d) There is a limit strain value of .0018 to warranty concrete soundness and thus prevent steel buckling in encased columns.

e) Specified minimum wall thickness are identical to those in the ACI code to prevent buckling of steel shape before yielding.

Design strength is based on the formulas for compression members which are presented in chapter 3 applying the following modifications:

a) Replace $A_g$ for $A_s$ and use $r$ as the radius of gyration of the steel shape.

b) Replace $F_y$ with modified yield stress $F_{my}$ and $E$ with $E_m$.

\[
F_{my} = F_y + C_1F_{yr}(A_r/A_s) + C_2F'c(A_c/A_s) \tag{7}
\]

\[
E_m = E + C_3E_c(A_c/A_s) \tag{8}
\]

where

$A_c$ = area of concrete

$A_r$ = area of longitudinal reinforcing bars

$A_s$ = area of steel

$E$ = modulus of elasticity of steel

$E_c$ = modulus of elasticity of concrete
Fy = specified minimum yield stress of steel shape, pipe or tubing

Fyr = specified minimum yield stress of longitudinal reinforcing bars

f'c = specified compressive strength of concrete

C1 = numerical coefficients. For concrete-filled pipe and tubing: C1 = 1.0, C2 = 0.85, C3 = 0.4; for concrete encased shapes C1 = 0.7, C2 = 0.6 and C3 = 0.2

2.1.3. Beam-column

This member is quite common in moment-resisting frames where at the ends of the columns high moments may act to warranty the frame stability. It is subjected simultaneously to the actions of axial force and bending moment, thus the determination of its capacity requires the use of an interaction formula. The expression to be used is the same as that used for a bare steel member, the difference resides in the evaluation of the nominal individual resistances for axial load and bending moment that have been presented in sections 2.1.1 and 2.1.2, the mentioned expressions are:

For \( \frac{Pu}{Py} \geq 0.2 \)
\[
\frac{Pu}{\phi Pn} + \frac{8 \cdot Mu}{9 \phi bMn} \leq 1.0
\]

For \( \frac{Pu}{Py} < 0.2 \)
\[
\frac{Pu}{2\phi Pn} + \frac{Mu}{\phi bMn} \leq 1.0
\]

Pu and Mu are the required strength values which
are obtained from structural analysis and local and overall buckling considerations which are well defined in the LRFD criteria. The axial load term is evaluated considering member buckling about both section principal axis, load sharing or p-delta effect must be accounted for since story buckling is the limit state for in plane behavior. In the evaluation of $\mu_u$, amplification factors play a role accounting for cross section and frame stability; the former one is essentially the same as in the current AISC allowable stress specification, while the second one takes into consideration second order effects along with setting a specified drift value that makes no longer necessary to be checked under working conditions in meeting serviceability requirements.

2.1.4. Planar-truss

Typical configurations are presented in Fig. 2.7. The study of this type of members is relatively new and there is no formalized specifications for them, its analysis is based upon the considerations that have been presented for beams. Thus ultimate strength, i.e. ultimate moment is evaluated from equilibrium in the equivalent cross section composed by truss upper chord along with the connected concrete slab and truss lower chord, diagonal members are sized according to shear requirements and joint equilibrium as presented in reference 5.
CONCRETE SLAB

a) Commercial Joist

TEMPERATURE REINFORCING STEEL

b) Gable truss

Fig. 2.7 Composite Planar Truss
An alternate approach is to solve the structure on a finite element basis considering the members with the appropriate elastic and sectional properties, this implies to consider certain effective width from existing specifications and evaluate and equivalent cross section for the upper chord members, detailed explanation is beyond the scope of this work, however the author has performed the design of industrial type structures obtaining economically advantageous solutions compared to the usual type consisting of sheet metal, specially in hurricane prompt regions.

2.2 LRFD philosophy

The general format of the LRFD specification is given by the formula:

$$\sum \gamma Q_i < \phi R_n$$

(11)

\[ \sum = \text{summation} \]
\[ i = \text{type of load, i.e dead load, live load, wind, etc} \]
\[ Q = \text{nominal load effect} \]
\[ \gamma = \text{load factor corresponding to } Q \]
\[ Q = \text{required resistance} \]
\[ R_n = \text{nominal resistance} \]
\[ \phi = \text{resistance factor corresponding to } R_n \]
\[ \phi R_n = \text{design strength} \]

The left side of equation 11 represents the
required resistance computed from structural analysis based on assumed loads. The right side represents a limiting structural capacity provided by the selected member. The load and resistance factors reflect the fact that loads, and therefore their effects (forces and moments), as well as the resistances can be computed only to imperfect degrees of accuracy. These factors account for unavoidable inaccuracies in the theory, variations in material properties and dimensions and uncertainties in the determination of the loads.

The LRFD specification is based on a probabilistic model, a calibration of the new criteria to the 1978 AISC specification, and the evaluation of the resulting criteria by judgement and past experience aided by comparative design office studies of representative structures. In Fig. 2.8, frequency distributions for load effects, Q and resistance R, which are assumed to be statistically independent random variables, are represented by separate curves on a common plot. As long as R is greater than Q, a margin of safety exists for the particular limit state. However, because Q and R are random variables, there is some probability that R may be less than Q. This indicates the probability of failure, and is graphically pictured as the shaded area in Fig. 2.8.

An equivalent situation is presented in Fig 2.9 where a
Fig. 2.8 Frequency distributions of load effect $Q$ and resistance $R$.

Fig. 2.9 Definition of reliability index.

$D$: Distance representing the feasibility of failure

$B$: $\ln \left( \frac{R}{Q} \right)$

$\sigma_{\ln \left( \frac{R}{Q} \right)}$: Standard deviation of function $\ln \left( \frac{R}{Q} \right)$

$\beta$: Reliability index.
single frequency distribution curve represents the combined uncertainties of \( R \) and \( Q \). For improved mathematical treatment, the result is expressed logarithmically. The probability of failure is equal to the probability that \( \ln(R/Q) \leq 0 \), and is represented by the shaded area in the diagram.

The number of standard deviations that defines the distance from the origin to the distribution mean \( [\ln(R/Q)]_m \) is named the reliability index, \( \theta \). The shaded area may be reduced and thus reliability increased by moving the mean of \( \ln(R/Q) \) to the right or by reducing the spread of the curve.

In defining appropriate values for the reliability index, the calibration process plays a significant role. The index is usually set to be the same for similar members and loading conditions. Detailed discussions of these aspects of LRFD are given in Refs. (3, 10).

2.3 Double layer grids

Double layer grids are a logical extension of single-layer grid frameworks, consisting of two or more sets of parallel beams intersecting each other at right or oblique angles, and loaded mainly by forces perpendicular to the plane of the framework. Due to the interconnection, concentrated loads acting upon a part of the structure are resisted not only by the directly loaded members, but also
by other members which may be at a considerable distance from the point of application of the load. In fact, the efficiency of any structure is usually judged by its ability to distribute the applied loading as widely as possible. The high stresses in the directly loaded members are then decreased and the stresses in the more distant members increased, thus achieving a more uniform stress distribution over the whole structure.

There are various types of single-layer grid structures used in civil engineering. The most common is a rectangular grid in which the intersecting elements are perpendicular to each other and the supporting walls. A diagonal grid consists of beams forming an oblique angles with the walls. This will have a greater rigidity than the rectangular ones, due to the fact that the beams follow roughly the trajectories of the principal stresses.

Whereas the single-layer grid is mainly subjected to bending, the component members of double-layer grids are almost exclusively under the action of axial forces. The elimination of bending moments leads to an improved utilization of the capacity of all of the elements.

Figure 2.10 gives the most common types of double-layer grids, as follows:

(a) Lattice: This consists of intersecting vertical lattices, and forms a regular grid. Both top and bottom
Fig. 2.10 Main types of double-layer grids.
grids are directionally the same.

(b) Differential Space Grid: The two parallel grids are of a different layout but are chosen to coordinate and form a regular pattern.

(c) Offset Space Grid: This consists of two parallel grids that have an identical layout. One grid is offset from the other in plan, but remains directionally the same.

The increasing use of double layer grids is due to a number of advantages:

(a) External loads are distributed omnidirectionally.

(b) Due to high degree of static indeterminacy, buckling of any compression member will not lead to the collapse of the whole structure.

(c) The large rigidity of double layer grids leads to relatively small deflections.

(d) Analysis and tests show a larger fire resistance than conventional systems.

(e) The space between the top and bottom grids can be used for the installation and maintenance of mechanical and electric services, such as heating, cooling and ventilating.

(g) The regular pattern of double-layer grids provides an attractive appearance. This can be a valuable feature in many architectural applications.
2.4 Finite element method

This is a computer-oriented solution-method which involves the solution of a large number of linear simultaneous equations. The details of this technique is very well known; References (8, 9, 17) give detailed description of the philosophy, concepts, and applications. This method has been utilized in the development of the design approach for the composite space truss. Further details are given in Chapters 3 and 4.
CHAPTER 3
MODEL DEVELOPMENT

3.1 General considerations

The type of grid under consideration is the offset space grid which was discussed in Chapter 2. The node numbering sequence is done such that the banded stiffness matrix will require the smallest possible computer memory. Specifically, proceeding along the direction of the short span, going from the upper grid layer to the lower grid layer, the numbers start at the left corner. It is noted that the origin of the coordinate system is located at the upper level.

Figure 3.1 shows a composite space truss system in which the following features are noted:

a) The concrete slab is reinforced with steel bars, this is done to satisfy strength, temperature and shrinkage requirements. This gives the slab the necessary homogeneous diaphragm characteristics, by avoiding common types of cracking which would contradict the model considerations.

b) Shear connectors at the joints ensure full composite action of the structure.

c) A formed steel deck is used as formwork. However, it is not a prerequisite for the design criteria that are
Fig. 3.1 Composite space truss floor system.
developed. Other construction methods can be used, as will be discussed later.

d) The bar members of the truss are welded to steel plates at the joints. The optimum sizes are selected such that the least cost truss configuration results. Least cost is defined as that associated with the smallest amount from combining steel and welding material used in the structure.

The grid member spacing has been selected as twice the truss depth. The object of this choice was to obtain a better more uniform distribution of the load effects throughout the space truss.

The structure is regarded as a truss because the joints or nodes act as pins for the following reasons:

(a) The member flexural stiffness is quite low, since only bar-type members with a maximum diameter of 1.5 in are considered.

(b) The plates which are provided at the joints are designed to develop axial loads through fillet welds. The plates are thin, and therefore govern the magnitude of the moment that can be generated at the node.

(c) All loads are placed at nodes.

(d) Although members have different sizes, all centerlines (which are considered as the lines of action of the member forces) of oblique elements intersect at a point on the plate. This point is regarded as the node, for the
purposes of the analysis. The small eccentricity that is introduced can be ignored.

The nodes are located in the intersection of members in the upper and lower layer grid. All nodes, except those on the periphery of the upper grid, connect four additional oblique or diagonal members to the layer grid members. The ones on the periphery connect only two additional oblique members. There is full compatibility between the bar and membrane elements at the nodes. This implies that the nodal displacements will serve as the basis for defining the states of strain and therefore of stress for both types of members.

The analysis is based on an elastic, first-order response of the structure.

3.2 Bar elements

These elements model the steel members whose cross-sectional and material properties are to be determined in the design process. There are basically three types of members, as follows: upper grid members are mainly subjected to compression. They are restrained by the concrete slab, which increases their buckling capacity. The lower grid members are subjected primarily to tensile forces. Finally, the diagonal members can be subjected to either compression or tension depending on their orientation and specific loading case for the truss.
3.2.1. Considerations.

The bare members can carry only axial loads which are assumed to act along the centroidal axis. The ultimate limit states for each requirement are different, as discussed in the following.

(a) **Tensile forces**: The member will fail through yielding of the gross cross section. Fracture of the net cross section is not a feasible limit state, since welded connections are being used. Residual stresses in the section have no effect on the capacity of the member.

(b) **Compressive forces**: Column theory is used, considering the member ends as pins. This is a conservative consideration since the members are welded at the ends, thus restraining member end rotations. However, this compensates for the eccentricity which may exist at the nodes. The presence of residual stresses and an initial out-of-straightness are accounted for, since the column design rules of the AISC LRFD Specification (3) are used.

3.2.2. Contribution to structure stiffness matrix.

All members located in the grids are assumed to contribute to the structure stiffness only along the direction they are oriented (X or Y), whereas the contribution of the diagonal members is the same with respect to all degrees of freedom. Their contribution in the gravity load direction is the only one provided in the
Fig. 3.2 Diagonal bar member
whole structure. Figure 3.2 shows the member in the three-dimensional environment, as well as the local and global stiffness matrix. It is noted that each diagonal bar has six degrees of freedom, while the other ones only two.

### 3.3 Membrane elements

These elements are located in the upper layer grid only, since they model the concrete slab. The reinforcing steel provided and the formed steel deck are neglected in evaluating the membrane stiffness. Any bending stiffness is neglected, due to the small thickness of the slab. This provides for a considerable reduction in the necessary size of computer memory.

#### 3.3.1. Considerations

The element can be subjected to three type of stresses acting on the different faces. As shown in Fig 3.3 (a), on the vertical sides normal and shear stresses act in the x and y directions. The modulus of elasticity is evaluated from the expression:

\[
Ec = 33 w^{1.5} (f'c)^{0.5} \tag{12}
\]

where

- \( w \) : concrete unit weight (pcf)
- \( f'c \) : ultimate concrete strength (psi)

Accounting for the phenomena of creep, the value of \( Ec \) is reduced by one half.
3.3.2. Contribution to structure stiffness matrix.

These members contribute to the structural stiffness only in the horizontal (x-y) plane. Figure 3.3 (b) shows the resulting stiffness matrix. It is noted that the actual coefficients are evaluated by Gauss quadrature, considering only one sampling point regarding the regularity of the shape. This technique is especially useful for isoparametric elements where the sides of the elements are not parallel. It is utilized in this work due to its improved computer-oriented format.

The B matrix which is the derivative of the interpolation matrix, is evaluated in this procedure. In addition to being fundamental for the evaluation of the stiffness values, this is the approach to transforming nodal displacements into strains; multiplying by the elasticity matrix the element stresses can be evaluated.

The transformation matrix translates the local member coordinates into global coordinates (Fig. 3.3 (c)) by inserting four rows and four columns of zeros, according to the degrees of freedom in the perpendicular direction. The presence of zeros in the diagonal of the stiffness matrix indicates instability, which means that the slab alone could not work unless flexural stiffness also was incorporated.
\[ \mathbf{K} = \mathbf{E} \mathbf{I} \mathbf{E}^T \]

\( \mathbf{F} \) = STRESS VECTOR

\( \mathbf{E} \) = ELASTIC PROPERTIES MATRIX

\( \mathbf{E} \) = STRAIN VECTOR

**a) Element model**

```
\[
\begin{bmatrix}
K_1 & K_2 & -K_2 & -K_3 & K_1 & -K_2 & K_2 & K_3 \\
K_2 & K_1 & K_3 & K_2 & -K_2 & K_1 & -K_3 & -K_2 \\
-K_2 & K_3 & K_1 & -K_2 & K_2 & -K_3 & K_1 & K_2 \\
-K_3 & K_2 & K_1 & K_3 & K_2 & -K_1 & -K_2 & K_1 \\
-K_1 & -K_2 & K_3 & K_1 & K_2 & -K_3 & K_1 & K_2 \\
-K_2 & -K_1 & K_3 & K_1 & K_2 & -K_3 & K_1 & K_2 \\
K_2 & -K_3 & K_1 & K_2 & -K_1 & K_3 & K_1 & K_2 \\
K_3 & K_2 & -K_1 & K_3 & K_1 & K_2 & -K_1 & K_3 \\
\end{bmatrix}
\]
```

\( K_1, K_2, K_3 \) : VALUES FROM NUMERICAL INTEGRATION

**b) Local stiffness matrix**

**c) Global stiffness matrix**

**Fig. 3.3 Quadrilateral element**
3.4 Shear connection

The types of shear connectors that can be used are shown in Fig 3.4 (a). The ultimate limit states on which their strength models have been developed are illustrated in Fig 3.4 (b). The most common type which will be considered for its use in the composite space truss is the stud type. The connector is to be welded on the plates at the upper grid joint locations.

Since no provisions have been made for the design of shear connectors in two way slabs, the model for the space truss will be based on that of one way action, as currently used for composite beams.

The governing force for the design of shear connectors in beams is given by the smallest value of the ultimate capacity of the concrete slab and the steel beam. Based on this approach, the shear connectors will be designed to provide a force equal to that which can be developed by the maximum size bars placed in the lower and upper grid instead of that developed by concrete in the slab in one half of the shorter of the truss spans. The latter would be excessively conservative due to the fact that it would yield a much larger force than that of the steel at ultimate condition. Using a basic span/depth ratio of 20, the design force $F_d$ becomes:

$$F_d = N_m A_s F_y$$  \( (13) \)
Fig. 3.4 Types and failure modes of shear connectors.
where:

\( N_m \) : number of members that are assumed to supply the tensile force in the effective slab width (1 is used here)

\( A_s \) : Maximum member cross sectional area ( \( A_s = 1.77 \text{ in}^2 \), for a diameter of 1.5 in)

\( F_y \) : maximum yield stress of 55 ksi

Also

\( N_c = G_s / 2 \) \hspace{1cm} (14)

where

\( N_c \) : Number of supplied studs (= 5.5)

\( G_s \) : Number of grid interspaces, computed as

(\( \text{span/ratio} \))/2.

Substituting for these terms and evaluating the required strength per connector, \( Q_{req} \) gives:

\[ Q_{req} = 1 \left( 1.77 \right) \left( 55 \right) / 5.5 = 17.70 \text{ kips} \]

A common stud of 5/8 diameter with a minimum height of 2.5 in has an ultimate capacity, \( Q_u \), of 18.4 kips, considering a concrete with a lower strength of 4ksi. This is computed using the ultimate strength model of the LRFD specification (3). A resistance factor of one is used in order to account for the improved behavior of the connector under the two-way slab action:

\[ Q_u = 0.5 A_{sc} \left( f'_c E_c \right)^{0.5} \] \hspace{1cm} (15)

where
\[ A_{sc} = \text{cross-sectional area of the stud} \]

Since \( Qu > Q_{req} \) the use of 5/8 in shear connectors is acceptable.

Although the size of the shear connector has been based on a depth of one twentieth of the shorter span, this value may be useful for other span/depth ratios, for the following reasons:

(a) For larger span/depth ratios, the force that is developed by the concrete will be smaller, because the slab width is smaller, besides the number of shear connectors will be greater, regarding the regular square grid which is used. On the other hand regarding the actual configuration, the number of bars that provide the tensile force is proportional to the number of joints where the shear connectors are supplied.

(b) For larger span/depth ratios the concrete force will be greater as will be the spacing between the connectors. However, bearing in mind that the behavior of the composite space truss is similar to that of a slab that is simply supported along the edges, any cross section will require smaller tensile and compressive forces to develop a certain moment because of the increase the moment arm. This implies that considering the force that is developed by the concrete is too conservative. Besides regarding the truss configuration, the number of steel bars that supply the
tensile force are proportional to the number of connectors provided.

The preceding procedure is likely to lead to too many connectors. However, it will assure full interaction between the slab and the truss, and the cost differential is relatively minor. Improvements can be made once additional research work has been done on two-way action of composite floor systems.
CHAPTER 4
ANALYSIS AND DESIGN CRITERIA

4.1 General considerations

A first-order elastic analysis is performed assuming that the response in compression and tension are the same. As a result of the collapse of the roof space truss in the Connecticut Coliseum, Smith (16) has suggested that any inelastic response should be incorporated into the structural analysis. However, instead of updating the stiffness matrix as the loading increases which is the classical and excessively time-consuming, he suggests an alternate procedure which makes use of certain fictitious loads that are applied to the structure. The evaluation of these loads is based on considerations of member imperfections and stability. In a composite space truss the presence of the slab improves the buckling response of upper layer members and the phenomenon of chord snap-through is not likely to occur.

The strength models for the steel members are based on the LRFD criteria of AISC (3). With regard to the slab elements some limiting stress values will be set to ensure that the response is elastic.

At the joints, diagonal members are connected through a
Evaluation of ellipse major axis $H$:

$$H = \frac{D}{\cos 54.74°} \cdot \frac{H/2}{H}$$

$H = 1.73 D$

Fig. 4.1 Diagonal Member Projected Area at the Joints
Fig. 4.2 Definition of truss geometric characteristics in the plane of the diagonals
Fig. 4.3 Member connection and related eccentricities at a typical joint
Fig. 4.4 Determination of a diagonal member construction characteristics
weld fillet that is located in the projected ellipse perimeter of the circular member cross section on the plate. In Figure 4.1, the ellipse is defined by considering the angle of intersection of the member in the plate. Regarding the plane of the diagonals, the truss geometric characteristics are defined in Fig 4.2, where the interior circle of 1.5 in diameter on the plate provides space to locate the maximum size bars. It is noted that the maximum bar size directly affects the eccentricities of the members (for that reason they have been limited), as well as the thickness of the joint plates for which a standard and minimum value of .25 in has been considered for the typical joint.

The eccentricities of the different axial loads that intersect at a typical node are defined and shown in Fig. 4.3. The centerlines of the diagonal members always intersect at the nodes and the different size bars are located such that the intersection is achieved. The determination of the real length for a diagonal member is illustrated in Fig 4.4 (a). It is based on the vertical and horizontal projections of the bar in its plane. The vertical projection is influenced by the plate thickness at the end joints, K1 is a constant value for the whole space truss due to construction and fabrication considerations. The variables that influence in the determination of the
size of the joint plates considering the diagonal members are presented in Fig 4.4 (b).

4.2 Load combinations

The load factors and load combinations recognize that when several loads act in combination with the dead load, only one of these takes on its maximum lifetime value, while the others are at their arbitrary point in time value (2, 3 , 4).

According to ANSI (4), the design of structures must be based on the most unfavorable combination of loads, taking into account their relative frequency of occurrence. The following load combinations are used for steel structures (it is noted that seismic loads are not incorporated in the design of the composite space truss):

1) $1.4 \ D$
2) $1.2 \ D + 1.6 \ L + 0.5 \ R$
3) $1.2 \ D + 1.6 \ R + 0.5 \ L$
4) $1.2 \ D + 1.6 \ L + 1.6 \ R + 0.8 \ W1$
5) $1.2 \ D + 1.6 \ L + 1.6 \ R + 0.8 \ W2$
6) $1.2 \ D + 1.6 \ L + 1.6 \ R + 0.8 \ W3$
7) $1.2 \ D + 1.6 \ L + 1.6 \ R + 0.8 \ W4$
8) $1.2 \ D + 0.5 \ L + 0.5 \ R + 1.3 \ W1$
9) $1.2 \ D + 0.5 \ L + 0.5 \ R + 1.3 \ W2$
10) $1.2 \ D + 0.5 \ L + 0.5 \ R + 1.3 \ W3$
11) $1.2 \ D + 0.5 \ L + 0.5 \ R + 1.3 \ W4$
12) 0.9 D + 1.3 W1
13) 0.9 D + 1.3 W2
14) 0.9 D + 1.3 W3
15) 0.9 D + 1.3 W4

However, the design of concrete members is made according to the requirements of the ACI code (1), which uses the following combinations and load factors:

1) 1.4 D + 1.7 L + 1.7 R
2) 1.05 D + 1.3 L + 1.3 R + 1.3 W1
3) 1.05 D + 1.3 L + 1.3 R + 1.3 W2
4) 1.05 D + 1.3 L + 1.3 R + 1.3 W3
5) 1.05 D + 1.3 L + 1.3 R + 1.3 W4
6) 0.9 D + 1.3 L + 1.3 R + 1.3 W1
7) 0.9 D + 1.3 L + 1.3 R + 1.3 W2
8) 0.9 D + 1.3 L + 1.3 R + 1.3 W3
9) 0.9 D + 1.3 L + 1.3 R + 1.3 W4

In the above expressions, the following symbols are used:

D = Dead load
L = Live load, defined according to service purposes
R = Roof load, it is a function of the area, and a value of 12 psf for large space trusses is common
W1 = Wind load generated by wind acting in the positive X direction
W2 = Wind load generated by wind acting in the negative X direction
4.3 Evaluation of wind loads

The analytical procedure that has been used to evaluate the wind pressures according to ANSI provides data corresponding to constant wind speed durations of 1 to 10 seconds (4). The design wind speed is converted to a velocity pressure $q_z$ in psf at a height $z$ by the equation:

$$q_z = 0.00256 K_z (IV)^2$$

where

- $V$ = Basic wind speed in miles per hour
- $I$ = Importance factor as defined by Table 4.2

The importance factor is a function of the type of structure as defined in Table 4.1

- $K_z =$ pressure coefficient, given as
  
  For $z > 15$ ft then $K_z = 2.58 \left( \frac{z}{z_g} \right)^{2/\alpha}$ (16)
  
  For $z < 15$ ft then $K_z = 2.58 \left( \frac{15}{z_g} \right)^{2/\alpha}$ (17)

and $z_g$ and $\alpha$ are given in Table 4.3

- $z_g$ : gradient height in ft
- $\alpha$ : power law coefficient

In fig 4.5 the different pressures acting on the
Fig. 4.5 Pressure distribution on building caused by wind.
Table 4.1 Classification of Buildings.

<table>
<thead>
<tr>
<th>NATURE OF OCCUPANCY</th>
<th>CATEGORY</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALL EXCEPT THOSE LISTED BELOW</td>
<td>I</td>
</tr>
<tr>
<td>THOSE WHERE MORE THAN 300 PEOPLE CONGREGATE IN ONE AREA</td>
<td>II</td>
</tr>
<tr>
<td>THOSE DESIGNATED AS ESSENTIAL FACILITIES</td>
<td>III</td>
</tr>
<tr>
<td>THOSE REPRESENTING LOW HAZARD TO HUMAN LIFE IN THE EVENT OF FAILURE</td>
<td>IV</td>
</tr>
</tbody>
</table>

Table 4.2 Building Importance Factors

<table>
<thead>
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<th>CATEGORY</th>
<th>LOCATION WITH RESPECT TO HURRICANE OCEANLINE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MORE THAN 100 MILES</td>
</tr>
<tr>
<td>I</td>
<td>1.00</td>
</tr>
<tr>
<td>II</td>
<td>1.07</td>
</tr>
<tr>
<td>III</td>
<td>1.07</td>
</tr>
<tr>
<td>IV</td>
<td>0.95</td>
</tr>
</tbody>
</table>
Table 4.3 Exposure Category Constants

<table>
<thead>
<tr>
<th>EXPOSURE CATEGORY</th>
<th>$\alpha$</th>
<th>Zg</th>
<th>$D_0$</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>3.0</td>
<td>1500</td>
<td>0.025</td>
</tr>
<tr>
<td>B</td>
<td>4.5</td>
<td>1200</td>
<td>0.010</td>
</tr>
<tr>
<td>C</td>
<td>7.0</td>
<td>900</td>
<td>0.005</td>
</tr>
<tr>
<td>D</td>
<td>10.0</td>
<td>700</td>
<td>0.003</td>
</tr>
</tbody>
</table>

Table 4.4 Coefficients to evaluate Leeward Pressures

<table>
<thead>
<tr>
<th>L/B</th>
<th>$C_p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 2</td>
<td>0.5</td>
</tr>
<tr>
<td>2 - 4</td>
<td>0.3</td>
</tr>
<tr>
<td>&gt; 4</td>
<td>0.2</td>
</tr>
</tbody>
</table>
building are shown. They are defined by:

\[ P_w = q_z \, G_h \, C_p \]  
where \( C_p = 0.8 \)

\[ P_l = q_h \, G_h \, C_p \]  
where \( C_p \) is defined in Table 4.3

\[ P_s = q_h \, G_h \, C_p \]  
where \( C_p = 0.7 \)

\[ P_r = q_h \, G_h \, C_p \]  
where \( C_p = 0.7 \)

where

\( P_w, P_l, P_s, P_r = \) Windward, leeward, side and roof pressures, respectively. All except the windward pressures are negative (suction type) pressures.

\( G_h : \) Gust response factor at height \( h \), accounts for additional loading effects due to turbulence

\[ G_h = 0.65 + 3.65 \, T_h \]

where

\[ T_h = (2.35) \sqrt{\left(\frac{D_o}{h/30}\right)^{0.4}} \]

and \( D_o = \) coefficient that accounts for the surface drag effect as defined in Table 4.3

\( q_h = \) velocity pressure at a height of \( z=h \)

All coefficients in Table 4.4 are a function of the type of building exposure. Details are given by the ANSI code (4).
4.4 Bar elements

The limit states of the bar elements are either buckling under compression or yielding in tension. In selecting the cross section the slenderness ratio of the member must be considered. It should be limited to 275, to avoid vibration problems in the structure, as well as to avoid local bending of the members during construction, in the event that a concentrated load is placed by accident somewhere other than at the joints. However, when the slab is cast on the ground, and there will be no accidental construction load to consider, and the limit for the slenderness ratio is increased by 25\% for this case.

4.4.1. Strength Models.

Tension: The design strength of tension members is governed by the limit state of yielding of the gross cross section. Fracture of the net cross section is not feasible, since the ultimate stress is greater than 1.33 times the yield stress, and welded connections are used. Equation (18) gives the design criteria according to the AISC LRFD Specification.

\[
\text{Design Strength} = \phi P_n
\]  

(18)

where

\[
P_n = F_y A_g
\]  

(19)

\[
\phi = 0.90 = \text{resistance factor for the limit state of gross area yielding}
\]
$A_g =$ gross cross-sectional area

$F_y =$ specified minimum yield stress

**Compression:** The design strength of compression members is $\phi P_n$, where

$\phi = 0.85 =$ resistance factor for the limit state of column buckling

$$P_n = A_g F_{cr} \quad (20)$$

where $F_{cr} =$ critical compressive stress, given as:

for $\lambda_c \leq 1.5$ $F_{cr} = (0.658 \lambda_c^2) F_y \quad (21)$

for $\lambda_c > 1.5$ $F_{cr} = \left( \frac{0.877}{\lambda_c} \right) F_y \quad (22)$

where

$$\lambda_c = \frac{K l}{r F_y E} \quad (23)$$

$E =$ modulus of elasticity

$K =$ effective length factor

$l =$ unbraced length of member

$r =$ governing radius of gyration

In the design of the space truss, the unbraced length is set equal to the full length between the nodes for all members. However, the upper grid members when the slab is cast on ground are designed considering a value reduced to one fourth accounting for the effect of the slab, which will be present at all times for this construction procedure. This implies that the reinforcing bars are attached to the upper grid through welding (if permitted) or some other procedure, to ensure the lateral restraint of
the members.

4.4.2. Welding Requirements

The welded joints for the grid members and the diagonal members are designed differently. The design force $P_w$ is the maximum that can be developed by the member in either compression or tension. Since the tensile one will always govern, this is the one that will be considered, except for the upper-layer grid members when the slab is cast on ground. In this case the compressive force is used since the presence of the slab will prevent larger forces from developing. Slab cracking may occur under tensile stresses, preventing the larger forces from developing. Under the other procedure, since the slab does not exist during certain times of the life of the structure, provisions must be made in order to ensure that the member will fail before the weldment does.

The weld area $A_w$ must provide a design strength $P_{w_d}$ that is greater than or equal to the required strength $P_w$. $P_{w_d}$ is the smallest of the values for the following limit states:

(a) Fracture of weldment.

$$P_{w_d} = \phi \ 0.60F_{exx} \ A_w$$  \hspace{1cm} (24)

where

$\phi = 0.75$ = Resistance factor for weld failure

$F_{exx} =$ Nominal weld metal ultimate stress
(b) Material yielding.

\[ P_{wd} = \phi F_y A_w \]  \hspace{1cm} (25)

where

\[ \phi = 0.75 = \text{Resistance factor for base metal yielding} \]

\[ F_y = \text{Specified minimum yield stress of the base metal} \]

Setting \( P_{wd} = P_w \), \( A_w \) can be evaluated, since \( A_w = L_w r \). By defining one of the two variables \( L_w \) and \( r \), the other can then be found.

In the above expressions,

\[ L_w = \text{length of weldment} \]

\[ r = \text{fillet weld throat dimension} \]

The volume of the fillet is computed by considering a quarter of a circle area, and the weight is found by using a unit weight of 380 pcf.

**Diagonal members.** A typical weldment is shown in Fig. 4.6. The length of the weldment is the variable which is defined by the perimeter of the projected ellipse onto the joint plate. For the evaluation of the perimeter the following approximate expression can be used:

\[ P_e = \sqrt{2(H^2 + B^2)} \]  \hspace{1cm} (26)

where

\[ H \text{ and } B \text{ correspond to the major and minor semi-axes of the ellipse and according to Fig. 4.1, these are 0.87D and 0.50D respectively. D is the bar diameter.} \]

**Grid member.** A typical weldment is shown in Fig
Plate size

Plate thickness

View-(A)

Weld fillet location

View-(B)

Plate thickness

$r = \text{greatest of}$

1) $Pu/(0.45 \times F_{exx})$

2) $Pu/(0.9 \times F_y)$

Pu: Ultimate force in diagonal member

$F_{exx}$: Fracture weld stress

$F_y$: Bar yield stress

Fig. 4.6 Welding considerations in diagonal members.
Plan View

- r = Weld fillet size = Plate thickness
- l = Weld fillet length greatest of:
  1) $Pu/0.45 \times F_{exx}(r)$
  2) $Pu/0.9 \times F_{y}(r)$

Pu = ULTIMATE FORCE IN GRID MEMBER
$F_{exx}$ = FRACTURE WELD STRESS
$F_{y}$ = BAR YIELD STRESS

Fig. 4.7 Welding considerations in grid layer layer members
4.7. For this members the fillet weld size is defined by the related plate thickness.

4.5 Joint plates

The minimum size requirements for the joint plates are defined in Figs. 4.4, 4.6 and 4.7 since the size of the plates is intended to fulfill the welding requirements. The thickness is defined to be greater than or equal to the weld fillet size \( r \) in diagonal members.

The minimum plan dimension \( PL_{\text{min}} \) is defined by both types of members. Thus, in the case of grid members:

\[
PL_{\text{min}} = L_w + 1.5\text{in} \quad (27)
\]

and in the case of diagonal members:

\[
PL_{\text{min}} = 2\left(\frac{.75\text{in} + \text{EXTSP} + 1.3\text{in} + 0.87\text{D} + 1\text{in}}{2}\right) \quad (28)
\]

where \( \text{EXTSP} \) = Extra spacing required when plate thickness is greater than 0.25 in, \( X_1 \) in Fig. 4.4.

The constant values of .75, 1.30, and .87 have been defined in previous figures.

Some edge distance is provided to insure proper heat dissipation during welding and ease of work. The plate yield stress must be at least equal to the maximum of any of the connecting members.

4.6 Membrane elements

In reality, bending stresses are generated in the concrete slab when forces are transmitted to the nodes.
However, due to the small span/thickness ratios, these moments are small, and can be taken by the temperature reinforcement, and the shear forces by the concrete.

Referring to the behavior of concrete discussed in chapter 2 (Fig 2.2), the limit states for the membrane element are given by the limits of the linearly elastic range. The maximum compressive stress that can be taken is 0.45 f'c and the maximum tensile stress is 6 f'c, according to the ACI code (1).

The principal planes in the elements are defined to evaluate the maximum and minimum normal stresses, although critical magnitudes may be found in different planes in the members, depending on the loading.

Plate buckling is not a feasible limit state for the membrane elements, due to the low compressive stresses and the bond to the steel framework and the shear connectors.

4.7 Construction procedures

The steel member assemblage is independent of how the concrete slab is cast. The suggested procedure envisions the fabrication of the layer grids and the subsequent connection to them by the diagonal members. This can be carried out in modules, as one piece in place, or as one piece somewhere else for later installation.

Two construction procedures will be defined in the
following, depending on whether the concrete slab is cast on the ground in a nearby location or whether it is cast in place, using a formed steel deck or other type of formwork. These will affect the design of the upper layer grid members and their welded connections. A revision must be carried out to ensure the proper performance of all of the elements, according to the same limit states that were used in their design.

4.7.1. Slab cast on ground.

The revision must be made for both types of elements, but taking into account the early strength of the concrete elements. Similarly, in assessing the structure stiffness matrix for this stage, the reduced stiffness of the slab is taken into account.

The construction procedure can be divided into three phases. These are illustrated in Fig. 4.8. The structure has the same stiffness in each of the phases, although the support conditions and the loads are different. The locations where the forces are to be applied are specified by the engineer for each phase. The first two phases are the rotations that must take place considering the shortest span; the third phase is the lift-up of the structure from the ground to the proper location.

Phase 1 consists of bringing the structure to an upright position. The critical condition is represented by
Phase (1)  First 90 degrees rotation

Phase (2)  Second 90 degrees rotation

Phase (3)  Lift up and location on place

Fig. 4.8 Installation process for slab cast on ground
the point where the structure is just leaving the ground, since the span is then at maximum. The span then decreases to zero when the truss is vertical. It is noted that the self-weight loads act in the opposite direction to what was considered in the design, and thus it is a condition that must be carefully evaluated.

Phase 2 brings the space truss from the upright to a horizontal position, similar to that when it is located in its final position, i.e. the slab is on upper layer of the structure. The passive support points are those where the rotation takes place, which are the same for phases 1 and 2. The active locations, which are those where the lifting forces are applied can be different for the two phases, but are normally on the slab. Suitable local reinforcement must be made in the slab to allow the application of these forces.

Phase 3 consists of the lift-up of the structure by a crane or similar equipment. The number of locations where the lifting forces are applied is decided by the designer. The supporting points in all phases are considered to restrain all related degrees of freedom.

4.7.2. Slab cast in place.

Through the use of a formed steel deck or other sort of formwork, the concrete will be placed on top of the steel assemblage when this is in its final position in the
building. Since there is no concrete contribution to the structural stiffness, the space truss may need temporary shores at certain locations to ensure the adequate behavior of all steel members. The shoring devices used are considered to restrain only in the vertical direction. No strain is supposed to take place in the shores.

4.8 Serviceability criteria

The service conditions of the structure are usually set by the designer so that particular building criteria are met. Setting deflection limits is similar to the drift limitations of frame design, and are intended to satisfy human comfort and other environmental requirements. It is important to distinguish between the deflections due to dead load and those due to service loads.
CHAPTER 5
COMPUTER PROGRAM DESCRIPTION

5.1 General

This chapter describes the organization of the computer program, and how the basis for the model development along with the applicable design criteria were assembled into a computer code in BASIC language. It is its purpose to serve as a guide for other pieces of software that deal with the structural analysis and the design with optimization features. Furthermore, the information provided here, along with that given in chapter 8, where an actual design is performed, will serve as a User's Guide to the interested engineer. The texts of the several modules that constitute the computer program are given in Appendix A through G, they are supplied with comments to ease the understanding of its methodology in all subroutines. The user may want to refer to it every time an explanation is given.

The variable names are as similar as possible to those of practice, to ease the tracing of the code. The code has been written for use with personal computers. Good programming practice dictates that only those values of the variables are used which are required for the computation
process of the program, but it is a strict necessity in machines with limited memory.

Several files are used for storage of information, and all of them will reside in the default directory. With the exception of file stiff.dat, which saves the stiffness matrix coefficients for use in the evaluation of reactions, all files are of the random type, to speed storage and retrieval of values.

The program is composed of several individual modules in order to have rapid execution and minimum use of computer memory. A program flow chart is given in Appendix \textit{H}.

It must be mentioned that the most time consuming process in the execution is the process of solving for the displacements in the structure. The number of coefficients in the stiffness matrix is in the range of 50000 to 150000, even when advantage is taken of its symmetry. Since it is not possible to store all of these values in a single vector, eight vectors are declared where values are stored, modified, and retrieved. This is done through subroutines \texttt{AUXSTO}, \texttt{AUXADD}, \texttt{AUXREP}, respectively.

The program consists of the following basic portions:

(a) Structure information

(b) Available cross section information
(c) Available joint plate information
(d) Structural design
(e) Revision during construction phase
(f) Printout of results

5.2 Structure information

In this portion the files containing the information that pertains to the building are handled; they may be created, revised in the screen, and modified in any way. All information except that regarding support conditions is kept in file BUILDING.DAT, where there is a record for every story in the building. It is noted that every story represents a composite space truss which is to be designed and / or revised. Support conditions are stored in individual files for each level, using file name SUPP + level number + .DAT. For instance, the characteristics of level three will be in a file named SUPP3.DAT, which will contain as many records as support nodes. Support locations will be discussed further later in this chapter.

Each record in the file BUILDING.DAT will contain information regarding floor geometry, loads, construction procedure, and concrete characteristics. No information is given with respect to bar members since that is the task of the design portion, which selects the most adequate cross section for each member from a given file.

Floor geometry variables are the following:
HEIGHT : Elevation of slab level

The value is checked so that it is greater than the one in the level below, and smaller than the one in the level above. If the level under consideration is the roof, then it is checked only against the one below; if it is the first floor, it is checked to be greater than zero.

L1 : Least floor dimension ;
L2 : Other floor dimension

These values define a rectangle, and are checked so that the least value pertains to L1. The input data are given in feet although the computations are based on feet converted to inches.

DEPTH : Dimension from lower grid to upper grid layer

A default value can be used, equal to L1/20, as suggested by Makowski (7, 13). Otherwise a value in the range of L1/4 to L1/40 is utilized, and L1 and L2 are updated if they are not a multiple of 2*DEPTH, which is the spacing between adjacent members in the grid layers.

THICK : Concrete slab thickness (in)

An equivalent value must be computed and input to account for the voids if a formed steel deck is used.

ND1, ND2, ND3, ND4 : Corner nodes defining service area

The service area is defined as the portion of the floor structure that is to be used for access to and exit from the given level. It may be a stairway or an elevator,
and can be located anywhere on the floor. The sides must be parallel to those of the structure periphery. Its location is mainly and architectural decision.

**BRA : Definition of structural role of service area**

A value of 1 means that the service area offers support to the structure, and 0 means that no support is offered. Actually, some concentrated loads may be applied to the periphery due to the accommodation of the stairway.

Acting load variables are the following:

**DEAD : Additional dead load, not including self-weight**

It refers to the effect of any material that will be placed on the slab on a permanent basis, such as tile, leveling material and adhesive, carpeting, etc. The self-weight of the structure is accounted for in the analysis and design processes, as will be shown.

**LIVE : Live load to be considered in design**

The value must be unreduced, to compensate for inelastic response in some members. The load may exist in all levels, except for the roof.

**ROOF : Load acting on the uppermost level of the building**

A distinction has been made in the LRFD specification (1, 2) for non-permanent loads acting on the roof level.

All areal loads must be input in psf.
CDL : Concentrated dead load (lb) ; and
CLL : Concentrated live load (lb)

There may be some locations where concentrated loads may act. These can be applied only in the direction perpendicular to the slab (Z-direction), which is defined as gravity positive. There can be up to 23 loads of each type.

LODL : Node identification for application of dead load
LOLL : Location of live load application

Concentrated loads are applied only at nodes. If a load is acting over certain area, tributary areas must be found to evaluate the loads at the affected nodes.

Construction procedure variable :
CONTYP : Flag variable defining the type of construction

A value of 1 corresponds to the procedure of casting the slab on the ground, and 2 represents the casting of the slab in the structure. It is important to include this as part of the building information, because it affects the structural design, as discussed in chapter 4.

Concrete characteristics variables :
FC3 : Three-day ultimate strength (ksi)

This value is needed when the slab is cast on ground, to analyze the structural performance during erection. It defines the available stiffness of the slab at
that age and its limit state.

**FC28 : Twenty eight-day ultimate strength (ksi)**

This value is used in the design of the structure, i.e. to define the characteristics under service conditions.

**GAMMA : Unit weight (pcf)**

This value is used to evaluate the weight of the slab when considering the structural self-weight and the modulus of elasticity in the design and construction analysis.

**P : Poisson's ratio**

In files regarding the support conditions there will be as many records as there are perimetral nodes, plus the number of nodes defining the service area if this is considered to offer support to the structure. It should be noted that one of the traits of the composite space truss is to have large unobstructed interior areas. Each record will have a zero or a one that is associated with each degree of freedom. Since all related nodes will be generated through the same subroutines there is no need to save the node number in each record. In defining degrees of freedom conditions, a zero denotes that the displacement is free to occur, and a one that it is restrained from taking place, and that therefore there needs to exist certain external action to enforce that condition. A discussion on external reactions is presented later in this chapter.
There are three subroutines that define nodes that play a key role in the structure. Although they will be explained in this section, they are used extensively in the program. These subroutines are PERINODE, PERIVECTORS, and SERAVECTORS.

Subroutine PERINODE: All nodes in the structure periphery are generated and stored in array BN. This subroutine is fundamental for the other two because nodes will now be sorted.

Subroutine PERIVECTORS: Periphery nodes are classified and stored in two arrays. In BCN those corresponding to the corners are saved, the remaining ones are saved in array BPN.

Subroutine SERAVECTORS: This is called only in those levels having a service area, i.e. all levels except the roof one. In it three arrays are generated, as follows: ICN defines the service area corner nodes, IPN the remaining nodes which correspond to the service area, and ULN contains those nodes which do not exist due to one of the following reasons:

(a) They are inside the region designated for service purposes.

(b) They belong simultaneously to one of the corners of the structure and one of the corners of the service area.
(c) They are present in both vectors IPN and BPN, meaning that they are on the periphery, but not at the corners of the structure and the service area. ULN is an array used to check that a non-existing node is ignored.

When a service area is used to help support the structure, it is considered to restrain all degrees of freedom associated with each node. This is a realistic consideration because elevator cores are generally designed as shear walls which have significant stiffness in all degrees of freedom.

5.2.1. Creation of files.

In this option all files related to structure definition are created. Since all previous information residing in the current directory is deleted, it is advisable to use different directories for the individual projects that may be in progress.

5.2.2. Revision of files.

The program has the capability of displaying on the screen all information regarding a given building. In this way the designer can check the stored information and identify if any changes need to be made.

5.2.3. Modification of files.

This option provides the capacity to modify any specific feature of the building which are already stored in the files. Maximum advantage can be taken of available
existing information so that any modification in the project will not require the creation of a new set of files. When changed, some of the features when changed require some additional modifications to be made, as can be seen in the following description of changes:

**L1, L2, and/or DEPTH**: These three variables define the number of nodes in the structure (NMAX) through the evaluation of A(1), A(2), NPN, GAP. NPN is the number of perimetral nodes, if the number of nodes on any side (A(1) and/or A(2)) is altered, then the support conditions of the periphery nodes will have to be reinput. The rest of the geometric characteristics will not cause any further modifications in the files.

Any existing area load can be changed. With respect to concentrated loads, it is possible to add more loads up to the limit of 23 in each type and also to modify the existing ones not only in magnitude and direction but also as to the aspect of point of application.

Modification of support conditions is carried out on a node by node basis. The node of interest is given and the actual conditions are displayed, the degree of freedom to modify is chosen, and since only two conditions may exist, the other one is assigned. The other degrees of freedom can then be considered as well as another node. If it is decided to change nothing, there is an option to do
so. When no other node is to be considered, then the change in the structural role of the service area is done similarly.

Any modification of concrete characteristics is carried out by inputting the new value next to the former one.

5.3 Available cross sections information

The file storing this information is AVSECT.DAT. Each record corresponds to a cross section. From this file, the program that defines the structural configuration in the design process will select the most suitable one, considering all related costs. Sections are limited to bars due to two reasons: a low moment of inertia is needed to provide low flexural capacity, and the relatively low cost of members that are not rolled shapes. The maximum diameter size that can be used is 1.5 in., with the purpose of keeping low eccentricity values at the joints.

Cross section characteristics to input are given below. The realistic ranges are given in parentheses:

DIAM : Bar diameter (in) (0 - 1.5)

From this value the cross-sectional area (AREA), moment of inertia (INERTIA), and weight in pounds per linear foot (WEIGHT) are evaluated and saved in the file.

FY : Yield stress (ksi) (25 - 60)

MELAST : Modulus of elasticity (ksi) ( >20000)
The type is defined according to the American Welding Institute (14).

All information which is introduced to the file is stored in a sequential fashion, and there is no internal sorting of any form. The reason behind this is the way in which the results that involve the cross sections are presented, as explained later in this chapter.

If any modification is to be made to any of the characteristics of a given cross section, a new record needs to be created and the former one deleted. The limited versatility in this respect is due to the reduced number of characteristics that needs to be handled regarding each record, and the need to keep the computer memory requirement as small as possible.

There may be a need for inputting new cross section information in the process of design if none of the existing ones are suitable. This is an important advantage, since the design process is not halted, but only interrupted until at least one suitable section becomes available.

5.4 Available joint plate information

Plates are used at the joints of the structure to
provide a surface for the welding of the members that intersect at the nodal location. The information is stored in the file AVPLATE.DAT, which maintains a record for each individual plate, and contains each of the following relevant characteristics (the adequate range appears in parentheses):

- **PLATHICK**: Plate thickness (in) (0.25 - 1)
- **PLADIM**: Plate plan dimension (in) (> 3.5)

Since the plates are square, one side dimension is sufficient to define its plane geometry.

- **PLAFY**: Plate yield stress (ksi) (25 - 60)
- **PLAPRI**: Steel cost in dollars per pound

The form of handling information is similar to that used in considering the cross sections with respect to the following: modification of any plate characteristic, the format of record creation and deletion, and what occurs when there is no suitable plate for a given joint. As in working with file AVSECT.DAT, file AVPLATE.DAT can be displayed on the screen in a record by record basis for proper revision by the designer.

### 5.5 Structural design

Based on the available plate and cross sections, the configuration of the steel assemblage is defined, aiming to obtain the least cost structure.

The design is based on the considerations presented
in chapter 3 and 4.

The process consists of assuming a given configuration, and solving this structure to obtain the loads in the members. The critical actions are then evaluated by applying the adequate load combinations and load factors, and then revising each member to make sure that the least cost one has been selected. Every time a member cross section is modified, due to the change in relative stiffness of the members, a force redistribution takes place. This originates an iterative process which ends for a given level when the optimum design is attained. The execution may then proceed to the design of the remaining levels, if any.

For the process to take place the following basic conditions are required:

(a) All files regarding building information and support conditions must be present in the default directory.

(b) There must be at least three records in file AVSECT.DAT, i.e. three available cross sections.

(c) At least two records must be present in the file containing the available plates information.

Taking advantage of the fact that the building geometry is defined and that it is a box type one, for which the ANSI criteria with regard to lateral loads are
applicable, the pressures on all of the walls are evaluated considering the four possible wind directions. The pressure values are independent of the truss configuration. The windward and leeward values depend on the story height, while the side and roof pressures are a constant for the whole building.

The following information is to be input at the time of execution: building category, type of exposure, location with respect to hurricane zones, and the value of the basic wind speed. The pressure value is translated into a distributed load that acts on the level periphery using the story tributary height. This is evaluated as follows: If H1 is the distance between the floor in consideration to the one below, and H2 is to the one above, the tributary height is \((H1 + H2)/2\). When considering the roof level, \(H2\) is zero. There are five files to store the different information generated by the process, as follows:

1. **(1) SPTR + level number + .DAT**: Each record corresponds to a bar member in the truss. It contains information regarding the cross section reference number that is selected for it, and seven values of axial loads, which correspond to the individual loading conditions. These values are combined and multiplied by load factors to obtain the critical loads for analysis and design.

2. **(2) SLAB + level number + .DAT**: Each record
corresponds to each one of the membrane elements. A reference value is given to identify whether the element is part of the service area or not, the rest of the information are the maximum compressive and tensile stresses occurring in the element for each one of the individual loading conditions.

(3) DISP + level number + .DAT: Each record corresponds to each one of the nodes in the structure. Every record is composed of 42 values, 21 correspond to the values of loads and the others to the values of displacements for the seven conditions in the three degrees of freedom associated to each node. There is a reference value stored in each record which is used to identify the node existence when defining joint plates in the output of results.

(4) REAC + level number + .DAT: Each record corresponds to each one of the nodes in the structure periphery and, if the service area provides support, each one of the nodes in its periphery. Every record is composed of 21 values that correspond to the external forces generated in each degree of freedom for the individual loading conditions.

(5) STIFF + level number + .DAT: This is the only file that is a not random access type. Instead, it is sequential for input or output. In it the original
stiffness coefficients (i.e., no accounting for boundary conditions) are stored for their use in the computation of external reactions.

Since all elements are generated through the same subroutine and thus the same sequence, there is no need to save the element identification as part of the record.

The high amount of time that execution requires in the iterative process is taking place and optimum design is attained would prevent the computer from any other use which may not be desirable to the user. To overcome this disadvantage, the program has a feature that allows the user to stop execution at any point. All information that has been generated up to this point is stored in the respective files. Besides, the designer may be interested in the design of a specific level, and the execution is therefore focused only on that story. In fact, when it is desired to use information generated in the previous run, a specific level must be selected, and then accept to work starting with the already generated available information. If no level is specified, the process starts with level one, deleting all generated type information that may exist in the current directory. It ends when the last building level is designed, unless the interruption feature is used.

The configuration of the truss is independent of certain types of information, which needs to be defined for
the iterative process to take place:

(a) Width of the band in the stiffness matrix which defines a set of coefficients which are enough to define the entire matrix.

(b) Number of degrees of freedom from the total number of joints. Along with (a), this defines the size of the vector to handle the stiffness coefficients, such a vector whose size is larger than what is feasible to be handled by personal computers. It is broken into eight individual ones of the same size.

(c) Definition of lateral distributed loads based on considerations of tributary height.

The iterative process begins with the formation of the stiffness matrix, which depends on whether it is the first iteration, i.e. no information has been generated and stored in file SPTR + level number + .DAT, or there is some information available from previous runs. In the case of the first iteration, all members will be assigned the properties of section reference number one, otherwise the actual value in the member record is used to define the cross section by referring to file AVSECT.DAT.

It is noted that a service area exists for all levels except the roof one. In such an area there are neither concrete elements nor steel members; however, in order to have a numerical solution, negligible but non-zero
values are assigned to the axial stiffness of the bar members and no contribution is provided by quadrilateral elements. Elements which do not exist are identified through a subroutine that checks the related nodes. If at least one of the nodes does not exist, then the element is classified in this category and thus treated differently.

CONNECTIVITY is the subroutine that generates the whole structural assemblage by defining for each member the nodal identifications. Subroutine GETCOR will define the X, Y, and Z coordinates of each node. Based on the nodal coordinates the following can be generated by using the adequate subroutine (either BARSTIFFNESS or QUADRILATERAL), depending on the type of element:

(a) The bar element length and the transformation matrix for bars which serves to translate local stiffness values to the global environment. For the process of force evaluation, the axial deformations and therefore strains are obtained from the displacements in global coordinates.

b) The interpolation function matrix for quadrilateral elements which through numerical integration (gauss quadrature solution) and multiplication by the matrix of elastic properties yields the stiffness coefficients in global coordinates. Considering the nodal displacements in the X-Y plane, strains are evaluated, and by considering the elastic properties the three different
generated stresses can be evaluated.

Since all quadrilateral elements have the same stiffness features, the values are generated once, and retrieved every time the global stiffness matrix is to be updated. The process of updating the stiffness matrix is explained in chapter 3 and is carried out in subroutine STORE.

Subroutines GETCOR and CONNECTIVITY are multifunctional, and the definition of certain flags decides the action to take: NPASS having a value of 1 generates stiffness matrix, a value of 2 is for any other action. WONLY being "Y" considers the structure self-weight on a member by member basis and incorporates it to the load vector. DESIG being "Y" checks the member behavior to decide if a better section can be used. Once the generation of the stiffness matrix is completed, it is stored in file STIFF_.DAT and then modified to for the displacement solving process. The modification consists of the consideration of the support conditions since all those degrees of freedom which are restricted must have a related displacement of zero, for this purpose all coefficients in the row and column of the degree of freedom are set to zero and the value of the diagonal to one.

The process of solving for the displacements is carried out through a Gauss-elimination equation solver,
which can be divided into two parts: forward reduction and backward substitution. Forward reduction is performed once for a given configuration, which essentially consists of setting the matrix in an upper triangular fashion. Nevertheless, this process takes more than two-thirds of execution time. Backward substitution consists of solving for the unknowns starting with the last one; it is performed for each load condition by considering the respective load vector.

For each load condition the load vector is saved in file DISP_.DAT before performing backward substitution because the same vector variable is used to store the displacements which are also saved in the same file. Having evaluated the displacements, every bar will be considered evaluating the resultant axial load and storing the value in the appropriate location of SPTR_.DAT, every quadrilateral will be considered by evaluating the principal stresses and storing them in file SLAB_.DAT.

For the generation of the load vectors two subroutines are fundamental: VLONO and LLONO.

**Subroutine VLONO**: It transforms all areal loads and places the resulting concentrated forces in the proper locations of the load vector considering the tributary area for each node and hence each degree of freedom affected. Areal loads are those of gravitational type or the suction
generated on the roof level under the action of wind. The determination of tributary area is based on whether the nodes are in the corners, on the periphery, or defining the perimeter of the service area. This subroutine is used when placing dead, live, and roof type loads which correspond to load conditions 1 to 3, the selection of the appropriate load to use is made in subroutine LOADSTR. In dealing with dead load besides the areal load, the weight of the different elements is considered and then translated into equivalent nodal loads. Any concentrated load that may be applied is considered by adding its effect to the load vector. At the roof level no live load is considered, thus loads, displacements, axial loads, and slab stresses are all zero. Similarly for the other levels when considering roof load, provision has been made so that no evaluation of any type takes place but only storage of the values in the respective files.

Subroutine LLONO : It places the equivalent nodal loads which arise from wind action on the periphery. Based on the tributary width for each node and the pressure effect as a equivalent distributed load evaluated from tributary story height considerations, the loads are generated and placed in the corresponding location of the load vector. If the service area is on the periphery, the loads are no longer acting on interior peripheral nodes of
it. Instead, they are transferred to the corners of the area, if one corner coincides with the floor corner, since that node will be a non-existing one, the application of the load will moved to the closest existing node in the direction of the load. Note that this assumes a service area rigid enough to perform the considered load transference. Load conditions 4 to 7 correspond to the different directions in which wind may act. The directions are positive and negative X direction and positive and negative Y direction, in the mentioned order. Referring to section 4.3, it can be seen that depending on the direction of the wind the walls on which the different types of pressures act vary, it is the task of the subroutine to identify the right load and place it in the right location of the load vector for a given node when wind is acting in a given direction.

Having all resulting axial loads stored, subroutine DESIGN will come into play where every member will be considered with the purpose of choosing the optimum cross section.

The algorithm behind the optimization subroutine can be described as follows: Each member is related to the seven axial loads from the different individual loading conditions and the cross section reference, the load combinations are performed and critical actions evaluated,
i.e. maximum compression and tension force. Design forces (i.e. nominal resistances reduced by an adequate factor) and corresponding slenderness ratio for each of the available sections are evaluated, those which fulfill the three requirements are considered as suitable and from the design forces the required amount of welding is computed. The cost of the member is added to the cost of the welding material which is required to be placed at each end to ensure adequate connection. The section representing the least cost is selected, if it is different from the one assigned before then another iteration will be required.

The joint plates are defined from the connecting members as stated in section 4.6. A similar procedure of least cost is used to define the most adequate option from the suitable ones.

After each iteration the total cost of the structure is displayed on the screen, considering bar members and joint plates separately. This may be useful for the engineer, for the purpose of having an idea of the cost of the structure, since no appreciable difference in cost will develop after the second iteration.

If no section was changed for any member, the process has been completed. The program continues to the next level if so indicated or returns to the main menu.
5.6 Revision during the construction phase

The structural configuration is defined for service conditions. However, the available stiffness during the construction phase must be analyzed separately since it may be different from what is expected in design. The purpose of this revision is to set those degrees of freedom which need to be restricted not only to compensate for the reduced structural strength of the structure at this stage, but also to account for the different types of loading to which the structure may be subjected. Having set them, all structural elements are revised, and if any one fails or excessive deformation occurs, then new temporary support locations are considered. The process is repeated until an adequate result has been obtained. In other words, the revision of the structural performance during the construction phase is a trial and error procedure.

5.6.1. Slab cast on ground

The structure is composed of bar members and a low strength concrete slab (due to its early age).

As presented in Chapter 4, there are three stages that must be considered separately. The support conditions are indicated during execution, and only active or passive types will support the structure at this stage. The support conditions in final service do not affect the construction stage characteristics. The designer determines the support
locations and all of the concrete and steel elements are then revised. The next stage is subsequently considered, once the first analysis is satisfactory; otherwise a new set of locations must be tried. If in any of the following stages the proposed locations are not adequate, then the process will be repeated for that specific stage. In other words, when a given stage has been completed, there is no need to focus on it any longer. Instead, attention must be transferred to the remaining individual stages. When the considered stage is solved with respect to the support locations, the forces are displayed for the proper design of the passive and active devices. The vertical component forces for the proper manipulation of the structure while it is being lifted and placed in the structure are also found at this point.

5.6.2. Slab Cast On Site

The stiffness matrix is defined only by the bar members, and the loads will be those of the self-weight and any construction load. The load factor for the revision of the bar members is defined during execution; it should be within the range of 1.2 and 1.6, as defined by the LRFD load combination. It is noted that the shoring locations that are specified will restrict the degrees of freedom at these nodes, in addition to those that are already defined by the service support conditions. If it is concluded that
construction is feasible then the maximum deflection and the forces at the shoring locations are displayed. Otherwise the failing members are displayed along with the related maximum and design forces.

5.7 Printout of results

Since the values of the stiffness matrix before any manipulation where stored in files which identify the level number as well as the rest of the needed files, the user can have the results for any specific floor as long as the optimum design has been attained, and the information resides in the default directory. If the optimum design has not been attained, then the file DISP_.DAT is null. In this way the printout of a level whose optimum design has not been reached is prevented. The results are categorized as follows:

a) Bar member definition
b) Joint plates
c) Concrete stresses
d) Serviceability revision
e) External Reactions

Bar member definition: For each type of member the information is organized so that the different available cross sections are related to the elements using them. The information is separated in three categories of members: diagonal, upper, and lower grid layer, in that sequence.
The number of members of a given category may need more than one page of listing, and even the number of members of a given category using a given cross section may do so, thus a proper page numbering is required. When the total of members have been defined for a given cross section, then the related cost is printed, and a subtotal is also printed when a given category is finished. After all lower grid layers have been defined, then the total cost for the steel bar members is printed.

The actual printout format for diagonal and grid layer member has the headings, (i) page number for the total of pages for that category, and (ii) the page number for the cross section under consideration. All information for the section is contained in record in the file AVSECT.DAT. However, the information for each of the members using the related cross section is different, depending on whether the member corresponds to the diagonal or grid layer member category. For the diagonal category, the size of the fillet weld is part of the heading, and the connecting nodes and the actual construction length are given. For the grid layer members, the intergrid spacing is part of the heading, while for each member the connecting joints are given, along with the required weldment length and throat size.
Joint plates: For each structural node there is an associated plate. For each one of the available plates, the related node numbers are printed sequentially, and the total number of the nodes using it will be identified as well as the related price. After all plates have been considered, the total cost regarding all of the plates is printed.

The actual format of the output pages has as heading the page number related to that plate and all of the corresponding characteristics. The information is contained in each record of the file AVPLATE.DAT.

Concrete stresses: For each of the quadrilateral elements, the maximum compressive and tensile stress are presented, along with the nodes which identify the element. The stresses are evaluated by performing the appropriate ACI code (1) load combinations. These are evaluated in the principal planes of the elements as explained in chapter 4. The limiting values are presented in each page of the printout, and in case any stress exceeds the limiting value, a warning message is printed along with the corresponding value. The limiting values are shown as part of the page heading.

Serviceability revision: The maximum deflection values are given presented in the printout. It is also shown where these occur, by identifying the corresponding
The designer may enforce the required limitations:

(1) Vertical displacement due to dead load alone.
(2) Upward displacement produced by the combination of all acting service loads.
(3) Downward displacement due to all service loads.

The load combinations are presented in chapter 4.

External reactions: The reactions which act on the composite space truss serve as the actions for the design of the supporting structures. These can be a combination of braced or moment resisting frames and shear walls. The supporting structure(s) can be either made out of concrete or steel, but since the applicable load factors are different, the designer needs to specify the type of material to be used.

All the applied loads and the related displacements are stored in file DISP_.DAT, and are used to generate the external reaction values for each individual load condition through the use of the original structural stiffness matrix. The appropriate combinations are performed for each degree of freedom involved. The critical forces can then be identified and printed; these are the maximum values in the positive and negative directions resulting from the corresponding load combinations.

In the printout, for each perimetral node along
with the node identification, the two critical forces for
each degree of freedom are also shown. A revision is made
for non-existing nodes, so that they do not appear in the
printout. If the service area offers structural support,
then all of the nodes which define it will be considered.
A three-story office building is to be designed for construction in Los Mochis Sinaloa, Mexico. It will be located in an urban area, surrounded by structures that are less than three-stories in height. Los Mochis is in a hurricane prone region where the basic wind speed is 125 mi/hr. The computer program has been used to define the optimum configuration of each level. The information that has been input as well as a summary of the results will be presented in the rest of this chapter:

6.1 Input information

The information has been organized and is presented in several tables. The first part of Table 6.1 gives the geometry, the material characteristics, the construction type, the structural role of the service area and the area load values for the three levels. The second part of Table 6.1 gives the information with respect to the concentrated loads that act on the structure at the different levels. Table 6.2 shows the support conditions of the three levels. A value of 1 means that the related degree of freedom is restrained, a 0 that it is free to occur. The locations with no associated values correspond to non-existing nodes,
due to the presence of the service area.

Table 6.1 Building Information

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6.2 Program output information

The information corresponding to the roof composite space truss is summarized in Table 6.3. The first part of Table 6.3 shows the critical slab stresses (allowable values are presented in parentheses), the deflection values, the relative cost of the different types of elements which constitute all the steel work, and the shoring locations which allow the casting of the concrete slab in place. The solution for the construction process is not necessarily the optimum; instead, it is a practical shoring arrangement that prevents any bar member from overstressing. The rest of Table 6.3 gives the information regarding the critical reactions acting on the structure. The values of the reactions take into account the appropriate load factors, depending on what material the supporting structure is to be made of. In this case, the load factors considered are those of the ACI code, since concrete frames and two shear walls are intended to support the composite space trusses.

6.3 Supporting frame model

A typical frame which lies in the Y-Z plane is shown in Fig. 6.1. Only two frames will support the structure and ensure stability in the Y direction, whereas in the X direction stability will be provided by two shear walls. The frames are not symmetric, with the purpose of
minimizing the obstacles in the interior of the building. For the support of levels 2 and 3 only one column will be designed to take the lateral demands, while the other will be subjected only to gravity loads. This can be verified by observing the support conditions in the Y direction for the different levels.

The shear walls are located at the property boundary, and their length is that of the building in that direction. Notice that in the boundaries of the building in the Y-direction there are no laterally supporting frames (they will transmit only gravity loads), while in the X-direction all support is provided at the boundaries. In this fashion full use is made of the great stiffness of the structure in the horizontal (X-Y) plane. The structure is supported continuously on the periphery.
Table 6.3 Example Result Summary

STRESSES IN CONCRETE SLAB

MAXIMUM COMPRESSION : 98.0 psi (1350)
MAXIMUM TENSION : 159.9 psi (329)

MAXIMUM DEFLECTION RESULTS

DEAD LOAD VALUE : 0.75 in.
DOWNWARD SERVICE VALUE : 0.17 in.
UPWARD SERVICE VALUE : 0.32 in.

RELATIVE COST OF THE DIFFERENT ELEMENTS

DIAGONAL MEMBERS : 42.5 %
UPPER GRID MEMBERS : 21.4 %
LOWER GRID MEMBERS : 19.5 %
JOINT PLATES : 16.6 %

CONSTRUCTION PHASE REVISION

NUMBER OF SHORING LOCATIONS : 30
IDENTIFICATION OF SHORING POINTS :
77, 78, 79, 80, 81, 82, 161, 162, 163, 164, 165, 166, 98, 119, 140, 161, 103, 124, 145, 166, 12, 122, 35, 37, 38, 40, 203, 205, 206, 208
LOAD FACTOR : 1.4
MAXIMUM DEFLECTION : 0.01 in
Table 6.3 Example Result Summary--Continued

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<td>0.64</td>
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<td>0.84</td>
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<td>0.35</td>
<td>11.06</td>
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<td>0.43</td>
<td>1.88</td>
<td>0.00</td>
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<td>241</td>
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<td>0.00</td>
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<tr>
<td>242</td>
<td>0.23</td>
<td>0.46</td>
<td>0.00</td>
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Table 6.3 Example Result Summary—Continued

<table>
<thead>
<tr>
<th>NODE</th>
<th>X DIRECTION</th>
<th>Y DIRECTION</th>
<th>Z DIRECTION</th>
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<td></td>
<td>POSIT.</td>
<td>NEGAT.</td>
<td>POSIT.</td>
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<tr>
<td>221</td>
<td>0.00</td>
<td>0.00</td>
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</tbody>
</table>
Fig. 6.1 Typical supporting frame model
CHAPTER 7
CONCLUSIONS

The stresses in the concrete are low, as can be seen from the results of the design example. Therefore, all of the assumptions that were made for the model with respect to the membrane elements are valid.

The structure configuration presents an attractive symmetry, the effect of concentrated loads can be depicted from the structure configuration.

Low yield stress sections are recommended for those elements under compression due to the fact that inelastic buckling is the mode of failure that governs.

Structure deflections are low, serviceability does not control unless very small depth/spans ratios are used.

Considering the roof level in the design example, excluding the concentrated loads and a continuous vertical support along the periphery, several depths have been tried and the resulting cost and maximum dead load deflections have been considered, results are shown in Table 7.1. A span/depth ratio of 20 can be suggested as an initial value in designing composite space trusses.
Table 7.1 Result summary for different depth values

<table>
<thead>
<tr>
<th>DEPTH</th>
<th>DEPTH/L1 RATIO</th>
<th>TOTAL COST</th>
<th>MAXIMUM DEFLECTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>0.1</td>
<td>4068.11</td>
<td>0.132</td>
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<tr>
<td>35</td>
<td>0.0875</td>
<td>3721.12</td>
<td>0.201</td>
</tr>
<tr>
<td>30</td>
<td>0.075</td>
<td>3058.32</td>
<td>0.292</td>
</tr>
<tr>
<td>25</td>
<td>0.0625</td>
<td>2700.39</td>
<td>0.379</td>
</tr>
<tr>
<td>20</td>
<td>0.05</td>
<td>2396.58</td>
<td>0.744</td>
</tr>
<tr>
<td>15</td>
<td>0.0375</td>
<td>SOLUTION NOT FEASIBLE</td>
<td>IN PERSONAL COMPUTERS</td>
</tr>
<tr>
<td>10</td>
<td>0.025</td>
<td>OUT OF MEMORY</td>
<td></td>
</tr>
</tbody>
</table>
CHAPTER 8
RECOMMENDATIONS

The casting of slab on ground requires that the location on which the slab will be cast must be as level as possible, since the surface in contact with the ground will constitute the working surface of the story. Even though some material needs to be placed as a preparation for the installation of tile or any other covering material, the smoother the surface, the less material that is required, and thus the less additional weight to be placed on the structure.

When the slab is cast on site, provisions must be made so that concentrated loads are not applied to individual members. To this end a traffic surface can be supplied. It helps to the bond of the two materials and their interaction to weld the temperature reinforcement to the upper layer at spaced locations (not in all points).

It is advisable to make the bottom grid members continuous in the short span direction to guarantee the transmission of tensile forces.

Advantage can be taken from reducing the live loads; this should be considered in further work on composite space trusses.
Computing time can be saved if a subroutine for the equation solving process is written in machine language and is supported by a math coprocessor. This will be an improvement to the program since a large percentage of execution time is spent in this process.

A computer program that may draw and identify all members and nodes in the composite space truss will ease the visualization of the structure configuration. This may be especially useful to the engineer who is not acquainted with this type of structure.
APPENDIX A

PROGRAM SEGMENT OOMMEEPM

SEGMENT THAT DEFINES ALL COMMON VARIABLES IN THE DIFFERENT OBJECT FILES THAT COMPOSE THE PROGRAM WHICH PERFORMS THE OPTIMUM DESIGN OF COMPOSITE SPACE TRUSSES

COMMON SHARED BN(1), BCN(1), BPN(1), ICN(1), IPN(1), ULN(1), A(1), S1(1), S2(1), S3(1), S4(1), S5(1), S6(1), S7(1), S8(1), SIK, IRCV, _ NOD(1), SM(2), NPE, IGRV, BANDWIDTH, X, _ ND, CH$, NPN, NMAX, GAP, N1, N3, N5, DEPTH, L1, L2, SPAC, _ STOREF, NSTOR, FILENAME$, FILEBAC$, _ CS(1), CDLS(1), CLLS(1), COR(2), LODLS(1), LOLL$ (1), LTYPE2$ (2), _ LTYPE3$ (1), LTYPE6$ (2), LTYPE62$ (2), VONM$ (2), _ DIAM$, AREA$, INERTIA$, WEIGHT$, FY$, MELAST$, STEELPRI$, WELDPRI$, _ WELDV$, RECORDS$, REC4$, CONTYP$, HEIGHT$, L1$, L2$, DEPTH$, _ DEAD$, LIVE$, ROOF$, ND1$, ND2$, ND3$, ND4$, BRA$, FC3$, FC28$, _ THICK$, GAMS$, P$, REC5$, REF$, REFL$, RES$, PLATHEK$, PFLDIM$, _ PFLAY$, PFLAPRI$, RECORD9$, REC8$ _

END OF THIS FILE
APPENDIX B

PROGRAM MODULE EEPM21

REM $DYNAMIC $INCLUDE: 'COMEEPM.BAS'
SUB STORE STATIC
  GENERATION OF STRUCTURE STIFFNESS MATRIX IN GLOBAL COORDINATES
  FOR IA=1 TO NPE
    FOR JA=1 TO 3
      IER=(IA-1)*3+JA
      IN=NOD(IA)
      IGR=IN*3-3+JA: IGRV=(IGR-1)*BANDWIDTH
      FOR KA=1 TO NPE
        FOR LA=1 TO 3
          IEC=(KA-1)*3+LA
          IN=NOD(KA)
          IGO=IN*3-3+LA
          IGC=IGC-IGR+1
          IRCV=IGRV+IGCS
          IF IGR<=IGC THEN
            X=SM(IER,IEC)
            CALL AUXADD
          END IF
        NEXT LA
      NEXT KA
    NEXT JA
  NEXT IA
END SUB

SUB AUXSTO STATIC
  SUBROUTINE TO STORE VALUES OF STIFFNESS IN INDIVIDUAL ARRAYS
  IF IRCV>7*SIK THEN
    IND=IRCV-7*SIK: S8(IND)=X
  ELSEIF (IRCV<7*SIK) AND (IRCV>6*SIK) THEN
    IND=IRCV-6*SIK: S7(IND)=X
  ELSEIF (IRCV<6*SIK) AND (IRCV>5*SIK) THEN
    IND=IRCV-5*SIK: S6(IND)=X
  ELSEIF (IRCV<5*SIK) AND (IRCV>4*SIK) THEN
    IND=IRCV-4*SIK: S5(IND)=X
  ELSEIF (IRCV<4*SIK) AND (IRCV>3*SIK) THEN
    IND=IRCV-3*SIK: S4(IND)=X
  ELSEIF (IRCV<3*SIK) AND (IRCV>2*SIK) THEN
    IND=IRCV-2*SIK: S3(IND)=X
  ELSEIF (IRCV<2*SIK) AND (IRCV>SIK) THEN
    IND=IRCV-SIK: S2(IND)=X

ELSE $S1(IRCV) = X$
END IF
END SUB

SUB ALKADD STATIC
SUBROUTINE TO UPDATE VALUES OF STIFFNESS IN INDIVIDUAL ARRAYS
IF $IRCV > 7 * SIK$ THEN
  IND = IRCV - 7 * SIK; $S8(IND) = X + S8(IND)$
ELSEIF ($IRCV <= 7 * SIK$) AND ($IRCV > 6 * SIK$) THEN
  IND = IRCV - 6 * SIK; $S7(IND) = X + S7(IND)$
ELSEIF ($IRCV <= 6 * SIK$) AND ($IRCV > 5 * SIK$) THEN
  IND = IRCV - 5 * SIK; $S6(IND) = X + S6(IND)$
ELSEIF ($IRCV <= 5 * SIK$) AND ($IRCV > 4 * SIK$) THEN
  IND = IRCV - 4 * SIK; $S5(IND) = X + S5(IND)$
ELSEIF ($IRCV <= 4 * SIK$) AND ($IRCV > 3 * SIK$) THEN
  IND = IRCV - 3 * SIK; $S4(IND) = X + S4(IND)$
ELSEIF ($IRCV <= 3 * SIK$) AND ($IRCV > 2 * SIK$) THEN
  IND = IRCV - 2 * SIK; $S3(IND) = X + S3(IND)$
ELSEIF ($IRCV <= 2 * SIK$) AND ($IRCV > SIK$) THEN
  IND = IRCV - SIK; $S2(IND) = X + S2(IND)$
ELSE $S1(IRCV) = X + S1(IRCV)$
END IF
END SUB

SUB AUXREP STATIC
SUBROUTINE TO GET VALUES OF STIFFNESS FROM INDIVIDUAL ARRAYS
IF $IRCV > 7 * SIK$ THEN
  IND = IRCV - 7 * SIK; $X = S8(IND)$
ELSEIF ($IRCV <= 7 * SIK$) AND ($IRCV > 6 * SIK$) THEN
  IND = IRCV - 6 * SIK; $X = S7(IND)$
ELSEIF ($IRCV <= 6 * SIK$) AND ($IRCV > 5 * SIK$) THEN
  IND = IRCV - 5 * SIK; $X = S6(IND)$
ELSEIF ($IRCV <= 5 * SIK$) AND ($IRCV > 4 * SIK$) THEN
  IND = IRCV - 4 * SIK; $X = S5(IND)$
ELSEIF ($IRCV <= 4 * SIK$) AND ($IRCV > 3 * SIK$) THEN
  IND = IRCV - 3 * SIK; $X = S4(IND)$
ELSEIF ($IRCV <= 3 * SIK$) AND ($IRCV > 2 * SIK$) THEN
  IND = IRCV - 2 * SIK; $X = S3(IND)$
ELSEIF ($IRCV <= 2 * SIK$) AND ($IRCV > SIK$) THEN
  IND = IRCV - SIK; $X = S2(IND)$
ELSE $X = S1(IRCV)$
END IF
END SUB
SUB PERINODE STATIC
  ' Definition of those nodes located in the periphery of the structure, only on these support may exist in service conditions. On them
  WIND LOADS ACT
  NPN=(A(1)+1)*2+(A(2)-1)*2: NMAX=(A(1)+1)*(A(2)+1)+A(1)*A(2)
  GAP=A(1)*2+1
  REDIM BN(NPN)
  IN=1: BN(IN)=1: FOR Z=2 TO Z1: IN=IN+1: BN(IN)=BN(IN-1)+1: NEXT Z
  IN=IN+1: BN(IN)=NMAX-A(1)
  FOR Z=2 TO Z1: IN=IN+1: BN(IN)=BN(IN-1)+1: NEXT Z
  IN=IN+1: BN(IN)=1+GAP
  FOR Z=3 TO A(2): IN=IN+1: BN(IN)=BN(IN-1)+GAP: NEXT Z
  IN=IN+1: BN(IN)=A(1)+1+GAP
  FOR Z=3 TO A(2): IN=IN+1: BN(IN)=BN(IN-1)+GAP: NEXT Z
END SUB

SUB BAFEXIT STATIC
  ' Obtain principal geometric features for a given floor:
  ' L1 : Least plan dimension
  ' L2 : The other dimension
  ' DEPTH : Space truss distance between grid layers
  ' SPAC : Spacing between adjacent members in both grid layers
  ' A(1) : Number of nodes along least dimension in lower grid layer
  ' A(2) : Node number along the other dimension in upper grid layer
  GET #5, STOREF: DEPTH=CVI(DEPTH$)
  GET #5, STOREF: L1=CVI(L1$)
  GET #5, STOREF: L2=CVI(L2$)
  SPAC=2*DEPTH: A(1)=L1/SPAC: A(2)=L2/SPAC
END SUB
SUB SERAVECTORS STATIC

SUBROUTINE TO DEFINE THE SIZE AS WELL AS THE CONTENT OF THE DIFFERENT VECTORS DEFINING THE SERVICE AREA OF THE STORY

ICN : CORNER NODES  IPN : PERIPHERY NODES  ULN : NON-EXISTING NODES

GET #5, STOREF
CALL PERIVECTORS

ND1=CVI(ND1$): ND2=CVI(ND2$): ND3=CVI(ND3$): ND4=CVI(ND4$)

K1SEAR=ND2-ND1: K2SEAR=(ND3-ND1-GAP)/GAP

N3=(K1SEAR-1)*2+K2SEAR*2

REDIM ICN(4), IPN(N3)

ICN(1)=ND1: ICN(2)=ND2: ICN(3)=ND3: ICN(4)=ND4

EXTRAULN=0

IF N3>0 THEN

IND=0

FOR KA=1 TO 2

IF KA=1 THEN DUM=ND1-1

IF KA=2 THEN DUM=ND3-1

FOR IA=1 TO K1SEAR+1

DUM=DUM+1: DUM$="N"

LA=0

WHILE IA<4 AND DUM$="N"

LA=LA+1

IF DUM=ICN(IA) THEN DUM$="Y"

WEND

IF DUM$="N" THEN

IND=IND+1: IPN(IND)=DUM

END IF

NEXT IA

NEXT KA

IF K2SEAR>0 THEN

FOR KA=1 TO 2

IF KA=1 THEN DUM=ND1

IF KA=2 THEN DUM=ND2

FOR IA=1 TO K2SEAR

DUM=DUM+GAP: DUM$="N"

JA=0

WHILE JA<4 AND DUM$="N"

JA=JA+1: IF DUM=ICN(JA) THEN DUM$="Y"

WEND

IF DUM$="N" THEN

IND=IND+1: IPN(IND)=DUM

END IF

NEXT IA

NEXT KA

END IF

FOR JA=1 TO N1

LA=0

WHILE LA<N3

LA=LA+1
IF BPN(JA)=IPN(IA) THEN EXTRAULN=EXTRAULN+1
WEND
NEXT JA
END IF
FOR JA=1 TO 4
  LA=0
  WHILE LA<4
    LA=LA+1
    IF BCN(JA)=ICN(IA) THEN EXTRAULN=EXTRAULN+1
  WEND
NEXT JA

GENERATION OF VECTOR OF NON EXISTING NODES
NA5=(K1SEAR-1)*K2SEAR+EXTRAULN:NB5=(K2SEAR+1)*K1SEAR:N5=NA5+NB5
REDIM ULN(N5)
IND=0
IF K2SEAR>0 AND K1SEAR-1>0 THEN
  DUM=ND1
  FOR IA=1 TO K2SEAR
    DUM=DUM+GAP
    FOR JA=1 TO K1SEAR-1
      IND=IND+1: DUM=DUM+1: ULN(IND)=DUM
    NEXT JA
  NEXT IA
END IF
IF EXTRAULN>0 THEN
  IF N3>0 THEN
    FOR JA=1 TO N1
      LA=0
      WHILE LA<N3
        LA=LA+1
        IF BPN(JA)=IPN(GA) THEN
          IND=IND+1: ULN(IND)=IPN(LA)
        END IF
      WEND
    NEXT JA
  END IF
  FOR JA=1 TO 4
    LA=0
    WHILE LA<4
      LA=LA+1
      IF BCN(JA)=ICN(LA) THEN
        IND=IND+1: ULN(IND)=ICN(LA)
      END IF
    WEND
  NEXT JA
END IF
DUM=ND1
FOR IA=1 TO K2SEAR+1
  DUM=DUM+GAP*(IA-1)
DUM=DUM+A(1)
FOR JA=1 TO K1SEAR: IND=IND+1: DUM=DUM+1: ULN(IND)=DUM: NEXT JA
NEXT IA
END SUB

SUB PERIVECTORS STATIC
' SUBROUTINE TO DISTINGUISH THE CORNER NODES FROM THE REST ON THE
' PERIPHERY AND STORE EACH TYPE SEPARATELY
CALL BAFEAT
CALL PERINODE
NL=NPN-4: REDIM BPN(N1), BCN(4)
BCN(1)=1: BCN(2)=A(1)+1: BCN(3)=NMAX-A(1): BCN(4)=NMAX: IND=0
FOR IA=1 TO NPN
DUM$="N": JA=0
WHILE DUM$="N" AND JA<4
JA=JA+1
IF BN(IA)=BCN(JA) THEN DUM$="Y"
WEND
IF DUM$="N" THEN
IND=IND+1: BPN(IND)=BN(IA)
END IF
NEXT IA
END SUB

SUB LOADCHECK STATIC
' SUBROUTINE TO CHECK THAT A CONCENTRATED LOAD IS NOT PLACED ON A
' NON-EXISTING NODE REGARDING THE EXISTENCE OF A SERVICE AREA
CH$="N": LAUX=0
WHILE LAUX<N5 AND CH$="N"
LAUX=LAUX+1
IF ULN(LAUX)=ND THEN CH$="Y"
WEND
END SUB
SUB OPENBUILD STATIC
' OPEN FILE OF BUILDING CHARACTERISTICS SPECIFYING CORRESPONDING FIELDS
' AS MANY RECORDS AS LEVELS i.e. SPACE TRUSSES TO SOLVE
OPEN "BUILDING.DAT" FOR RANDOM AS #5 LEN=236
FIELD #5,2 AS CONTYP$,4 AS HEIGHT$,2 AS L1$,2 AS L2$,2 AS DEPTH$
FIELD #5,12 AS OFFSET$,4 AS DEAD$,4 AS LIVE$,4 AS ROOF$
FIELD #5,24 AS OFFSET$,2 AS ND1$,2 AS ND2$,2 AS ND3$,2 AS ND4$,2 AS_BRA$
RECL=34
FOR I=1 TO 23
FIELD #5,RECL AS OFS$,2 AS CDL$(I),2 AS LODL$(I),2 AS CLL$(I),2 AS_LOLL$(I)
RECL=RECL+8
NEXT I
FIELD #5,218 AS OFFSET$,4 AS FC3$,4 AS FC28$,4 AS THICK$,2 AS GAM$,4
AS P$
FIELD #5,236 AS REC5$
END SUB

SUB OPENDISP STATIC
' OPEN FILE TO SAVE NODE DISPLACEMENTS CORRESPONDING TO LOADING
' CONDITIONS AS MANY RECORDS AS NODES IN SPACE TRUSS
OPEN FILENAME$ FOR RANDOM AS #6 LEN=338
FIELD #6,2 AS REFL$
RECL=2
FOR IA=1 TO 7
FOR JA=1 TO 3
FIELD #6,RECL AS OFFSET$,8 AS LTYPE6$(IA,JA):RECL=RECL+8
NEXT JA
NEXT IA
FOR IA=1 TO 7
FOR JA=1 TO 3
FIELD #6,RECL AS OFFSET$,8 AS LTYPE62$(IA,JA):RECL=RECL+8
NEXT JA
NEXT IA
END SUB

SUB OPENSLAB STATIC
' OPEN FILE TO SAVE STRESSES CORRESPONDING TO LOADING CONDITIONS
' AS MANY RECORDS AS QUADRILATERAL ELEMENTS MODELING CONCRET SLAB
OPEN FILENAME$ FOR RANDOM AS #7 LEN=58
FIELD #7,2 AS RE$
REC=2
FOR I=1 TO 7
FOR J=1 TO 2
FIELD #7,REC AS OFFSE$,4 AS VONM$(I,J):REC=REC+4
NEXT J
NEXT I
END SUB
APPENDIX D

PROGRAM MODULE OPENEEPM

* PROGRAM SEGMENT WITH THE PURPOSE OF OPENING ALL NEEDED RANDOM FILES
  * REM $DYNAMIC $INCLUDE: 'COMEEM.PAS'
  * SUB OPENSEC STATIC
    * OPEN FILE OF AVAILABLE CROSS SECTIONS SPECIFYING CORRESPONDING FIELDS
      * AS MANY RECORDS AS SECTIONS
      * OPEN "AVSECT.DAT" FOR RANDOM AS #1 LEN=40
      * FIELD #1,4 AS DIAM?,4 AS AREA?,4 AS INERTIA?,4 AS WEIGHT?,4 AS FY$
      * FIELD #1,20 AS OFFSET?,4 AS MELAST?,4 AS STEELPRI?,4 AS WELDPRI$
      * FIELD #1,32 AS OFFSET?,8 AS WELDTY$
      * FIELD #1,40 AS RECORD$
    * END SUB
  * SUB OPENREA STATIC
    * OPEN FILE TO SAVE AXIAL LOADS CORRESPONDING TO LOADING CONDITIONS
      * AS MANY RECORDS AS PERIMETRAL NODES IN SPACE TRUSS
      * OPEN FILENAME$ FOR RANDOM AS #2 LEN=168
      * RECL=0
      * FOR IA=1 TO 7
        * FOR JA=1 TO 3
          * FIELD #2,RECL AS OFFSET?,8 AS LTYPE2$(IA,JA):RECL=RECL+8
        * NEXT JA
      * NEXT IA
    * END SUB
  * SUB OPENSPTIR STATIC
    * OPEN FILE TO SAVE AXIAL LOADS CORRESPONDING TO LOADING CONDITIONS
      * AS MANY RECORDS AS BAR MEMBERS IN SPACE TRUSS
      * OPEN FILENAME$ FOR RANDOM AS #3 LEN=30
      * FIELD #3,2 AS REF$:RECL=2
      * FOR IA=1 TO 7
        * FIELD #3,RECL AS OFFSET$,4 AS LTYPE3$(IA):RECL=RECL+4
      * NEXT IA
    * END SUB
  * SUB OPENSUPPORT STATIC
    * OPEN FILE TO MANAGE SUPPORT CONDITIONS OF EACH SPACE TRUSS
      * OPEN FILENAME$ FOR RANDOM AS #4 LEN=6
      * REC=0
      * FOR I=1 TO 3:FIELD #4,REC AS OFF$,2 AS C$(I):REC=REC+2:NEXT I
      * FIELD #4,6 AS REC4$
    * END SUB

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SUB OPENPLATE STATIC
  ' OPEN AND DEFINITION OF FILE THAT CONTAINS THE INFORMATION WITH
  ' RESPECT TO AVAILABLE PLATES TO BE USED IN THE STRUCTURE JOINTS
  OPEN "AVPLATE.DAT" FOR RANDOM AS #9 LEN=16
  FIELD #9,4 AS PLATHICK$, 4 AS PLADIM$, 4 AS PLAFY$, 4 AS PLAPIR$
  FIELD #9,16 AS RECORD9$
END SUB

SUB OPENBAC STATIC
  ' OPEN FILE TO BACK UP SUPPORT CONDITIONS WHEN DELETING OR ADDING LEVELS
  ' AS MANY RECORDS AS PERIMETRAL NODES
  OPEN FILEBAC$ FOR RANDOM AS #8 LEN=6
  FIELD #8,6 AS REC8$
END SUB
APPENDIX E

PROGRAM MODULE ELENA21

TEXT OF PROGRAM FOR PRINTOUT OF RESULTS FROM THE OPTIMUM DESIGN OF COMPOSITE SPACE TRUSSES

REM $DYNAMIC $INCLUDE: 'COMEEM.BAS'
REDIM A(2),C$(3),CDL$(23),CLL$(23),COR(4,3),LODL$(23),LOLL$(23),
LTYPEE2$(7,3),LTYPEE3$(7),LTYPEE6$(7,3),LTYPEE62$(7,3),NOD(4),VOM$(7,2)
TERM$="N"
CALL OPENBUILD
NSTOR=LOF(5)/236
IF NSTOR=0 THEN
   CLOSE #5
   CLS:LOCATE 5,10:PRINT "BUILDING INFORMATION FILE DOES NOT EXIST"
   E$="":WHILE E$="":E$=INKEY$:WEND
   CHAIN "ECJ021"
END
END IF
WHILE TERM$<>"Y"
   WHILE STOREF<1 OR STOREF>NSTOR
      CLS:LOCATE 10,10:INPUT "LEVEL REFERENCE --> ",STOREF
   WEND
   CLS
   LOCATE 3,30:PRINT "MAIN MENU :"
   LOCATE 5,20:PRINT "1) BAR MEMBERS DEFINITION"
   LOCATE 7,20:PRINT "2) STRUCTURAL JOINT PLATES"
   LOCATE 9,20:PRINT "3) CONCRETE SLAB STRESSES"
   LOCATE 11,20:PRINT "4) EXTERNAL STRUCTURAL REACTIONS"
   LOCATE 13,20:PRINT "5) SERVICIABILITY REVISION"
   LOCATE 15,20:PRINT "6) TERMINATE"
   ELEN$="XX"
   WHILE ELEN$<"1" OR ELEN$>"6"
      LOCATE 20,25:PRINT "SELECTION ? ":ELEN$=INPUT$(1)
   WEND
   ON VAL(ELEN$) GOSUB BARMEDEF,JOINTDEF,CONCSTRES,EXREAC,SERVREV
   IF VAL(ELEN$)=6 THEN TERM$="Y"
WEND
CLS:CLOSE #5
CHAIN "ECJ021"
END
BARMEDF:

Subroutine that organizes the different bar members to show the optimum composite truss configuration

PI=3.14159

CALL BAFEA

GAP=A(1)*2+1

FILENAME$="DISP"+STR$(STOREF)+".DAT"

CALL OPENDISP

FILENAME$="SPTR"+STR$(STOREF)+".DAT"

CALL OPENSPTR

CALL OPENSEC

CALL OPENPLATE

CALL OPENPLATE

IF EOF(1)=0 OR EOF(9)=0 OR EOF(6)=0 OR EOF(3)=0 THEN

GOSUB EWMESSAGE

CLOSE #3,#1,#9,#6

RETURN

ELSE

ACUMTOTAL=0: SCOST=0: NSEC=EOF(1)/40

FOR COTYPE=1 TO 3

REDim DIFS%(NSEC)

ACUMCOST=0: ACUM=ACUMTOTAL: ORG=1: GOSUB CHOOSECONN

MAXN=DIFS%(1): SIZEID=1

FOR I=2 TO NSEC

IF DIFS%(I)>MAXN THEN

MAXN=DIFS%(I): SIZEID=I

END IF

NEXT I

REDim MNODI%(NSEC, MAXN), MNODJ%(NSEC, MAXN), COUNT%(NSEC)

ACUM=ACUMTOTAL: ORG=2: GOSUB CHOOSECONN

APGT=0

FOR I=1 TO NSEC

AXL=DIFS%(I)/40

APGT=APGT+INT(AXL)

IF AXL<INT(AXL) THEN APGT=APGT+1

NEXT I

TOTP=ACUMTP/40: APTG=INT(TOTP)

IF TOTP<INT(TOTP) THEN APTG=APGT+1

APG=0: ACUM=0: COST=0

FOR I=1 TO NSEC

IF DIFS%(I)>0 THEN

ACUM=ACUM+DIFS%(I)

GET #1: DIAM=CVS(DIAM$): FY=CVS(FY$): MEL=CVS(MELAST$)

WEI=CVS(WEIGHT$): RATIO=SQR(CVS(INERTIA$)/CVS(AREA$))

WELD$=WELDTS$: WELDP=CVS(WELDPRI$): STEELP=CVS(STEELPRI$)

IF COTYPE=1 THEN

EL=SQR(3)*DEPTH: LAMDA=EL/(RATIO*PI)*SQR(FY/MEL)

GOSUB NOMRESIST

PULWELD= 9*PNOMTEN: GOSUB WELDREQUIRED

ELSE
EL=SPAC:LAMBDA=EL/(RATIO*PI)*SQR(FY/MEL)
IF COTYPE=2 THEN
    GET #5,STOREF:SEL=CVI(CONTYP$)
    IF SEL=1 THEN LAMBDA=.5*LAMBDA
END IF
GOSUB NOMRESIST
REDIM LFILN(2),RFIL(2)
END IF
PG=0:TOT=DIFS%(I)/40:PGT=INT(TOT)
IF INT(TOT)<>TOT THEN PGT=PGT+1
FOR J=1 TO DIFS%(I)
    IF J=1 OR INT(J/41)=J/41 THEN
        PG=PG+1:APG=APG+1
        GOSUB PMESS
        CLS:GOSUB CHOOSEHEAD
        LPRINT
    END IF
END IF
GOSUB CHOOSEPRINT
COST=COST+WEI*EL*STEELP+WELD*WELDP
NEXT J
LPRINT
LPRINT "NUMBER OF MEMBERS USING THIS CROSS SECTION : ";
LPRINT DIFS%(I):LPRINT
LPRINT TAB(30) "COST = " USING "$####.##";COST
ACUMCOST=ACUMCOST+Cost:COST=0:LPRINT
LPRINT TAB(30) "TOTAL COST = " USING "$####.##";ACUMCOST
ERASE LFILN,RFIL
END IF
NEXT I
ACUMTOTAL=ACUMTOTAL+ACUMT
ERASE MNODI%,MNODJ%,COUNT%
SCOST=SCOST+ACUMCOST
ERASE DIFS%
NEXT COTYPE
LPRINT "TOTAL COST REGARDING STEEL MEMBERS =" USING _
"$####.##";SCOST
LPRINT:CLOSE #1,#3,#6,#9
END IF
RETURN
JOINTDEF:

SUBROUTINE THAT ORGANIZES AND PRINTS THE JOINT PLATES
FILENAME$="DISP"+SHR$(STOREF)+".DAT":CALL OPENDISP
CALL OPENPLATE
IF LOF(6)=0 OR LOF(9)=0 THEN
  GOSUB PMESSAGE
  CLOSE #6,#9
  RETURN
ELSE
  CALL BAFEA!
  SN=(A(1)+1)*(A(2)+1)+A(1)*A(2)
  PDOST=0:NPLA=LOF(9)/16
  REDIM PLAS%(NPLA)
  FOR I=1 TO SIN
    GET #6,I:REF=CVI(REFL$)
    IF REF>0 THEN PLAS%(REF)=PLAS%(REF)+1
    NEXT I
  MAXN=PLAS%(1)
  FOR I=2 TO NPLA
    IF PLAS%(I)>=MAXN THEN MAXN=PLAS%(I)
    NEXT I
  REDIM PLAID%(NPLA,MAXN),COUNT%(MAXN)
  FOR I=1 TO SIN
    GET #6,I:REF=CVI(REFL$)
    IF REF>0 THEN
      COUNT%(REF)=COUNT%(REF)+1
      PLAID%(REF,COUNT%(REF))=1
    END. IF
    NEXT I
  APGT=0
  FOR I=1 TO NPLA
    AX1=CINT((PLAS%(I)+1)/3)
    AX2=AX1/40
    APGT=APGT+INT(AX2)
    IF AX2<>INT(AX2) THEN APGT=APGT+1
    NEXT I
  APG=0
  FOR I=1 TO NPLA
    COST=0
    IF PLAS%(I)>0 THEN
      GET #9,I:THICK=CVS(PLA.THICK$):PLADI=CVS(PLADI$)
      PLAFLY=CVS(PLAFLY$):PLAPRI=CVS(PLAPRI$)
      PG=0:TOT=CINT((PLAS%(I)+1)/3)/40:TOT=INT(TOT)
      IF TOT<>INT(TOT) THEN PG=PGT+1
      FOR J=1 TO PLAS%(I)
        IF J=1 OR INT(J/41)=J/41 THEN
          PG=PG+1:APG=APG+1:GOSUB PMESS
          CLS:GOSUB HEADP
          LPRINT
END IF
K AUX=INT((J-1)/3); JT AB=J
IF K AUX>0 THEN JT AB=J-3*K AUX
LPRINT TAB(JT AB*20-3) USING "#####"; PLA ID& (I,J); COST=COST+THICK*PL ADI^2*PL API*.285
NEXT J
LPRINT:LPRINT "NUMBER OF JOINTS USING THIS PLATE : ";
LPRINT PL AS% (I); LPRINT
LPRINT TAB(30) "COST = " USING "#####.##"; COST:LPRINT
END IF
PCOST=PCOST+COST
NEXT I
ERASE PL AS%, PLA ID%, COUNT%
LPRINT "TOTAL COST REGARDING JOINT PLATES = " USING _
"#####.##"; PCOST
LPRINT:CLOSE #6, #9
END IF
RETURN

CON CST RES:
' CONSIDER STRESS ES IN CONCRETE SLAB FOR DIFFERENT FACTORED LOADS
CALL BAF EAT
GAP=A(1)*2+1
GET #5, STOREF: FC 28 D=CVS(FC 28$)
F TEN=6*SQR(FC 28 D*1000): FCOM=.45*FC 28 D*1000
FILENAME $="SLAB"+STR$(STOREF)+".DAT"
CALL OP ENSLAB
IF LOP(7)=0 THEN
  CLOSE #7
  RETURN
ELSE
  REDIM LF AC(15, 7)
  GOSUB LOAD FACTOR2
  COUNTS=0; COUNTP=0
  ACUMQ=0: ACUM=0: DESIG$="N"; PRINT$="N"; WONLY$="N"
  GOSUB CONNSLAB
  ERASE LF AC; LPRINT: LPRINT
  CLOSE #7
END IF
RETURN
EXREAC:

' CONSIDERATION OF FACTORED EXTERNAL REACTIONS
FILENAME$="STIFF"+STR$(STOREF)+".DAT"
CALL OPENREA
IF LOF(2)=0 THEN
    CLS:LOCATE 5,10: PRINT "FILE " FILENAME$ " IS NOT AVAILABLE"
    LOCATE 18,12: PRINT "** CONTINUATION NOT FEASIBLE **"
    LOCATE 22,40: PRINT "PRESS ANY KEY TO CONTINUE"
    E$="":WHILE E$="":E$=INKEY$:WEND
    CLOSE #2
    RETURN
ELSE
    CLOSE #2
    OPEN FILE TO GET DISPLACEMENTS OF STRUCTURE TO EVALUATE REACTIONS
    FILENAME$="DISP"+STR$(STOREF)+".DAT"
    CALL OPENDISP
    OPEN FILE TO STORE REACTIONS ON STRUCTURE"n
FILENAME$="REAC"+STR$(STOREF)+".DAT"
CALL OPENREA
IF LOF(2)>0 THEN
    CLOSE #2: KILL FILENAME$
    CALL OPENREA
END IF
' COMPUTE REACTIONS FOR EACH INDIVIDUAL LOADING CONDITION
IF STOREF<NSTOR THEN
    CALL SERAVECTORS
ELSE
    CALL PIRIVECTORS
END IF
' EVALUATE AND PRINT CRITICAL VALUES OF REACTIONS BY CONSIDERING
' APPROPRIATE LOAD FACTORS AND COMBINATIONS DEPENDING ON THE MATERIAL
' THE SUPPORTING STRUCTURE IS MADE OF
CLS:LOCATE 5,5
PRINT "STRUCTURE TO BE DESIGNED TO SUPPORT SPACE TRUSS:"n
LOCATE 10,10
PRINT "1) CONCRETE TYPE":LOCATE 15,10: PRINT "2) STEEL TYPE"
REOPT=0
WHILE REOPT<1 OR REOPT>2
    LOCATE 20,30: INPUT "SELECTION --> ",REOPT
WEND
REDIM LFAC(15,7)
ON REOPT GOSUB LOADFACTOR2, LOADFACTOR1
BRA=0
IF STOREF<NSTOR THEN
    GET #5: BRA=CVI(BRA$)
END IF
BANDWIDTH=(GAP+2)*3:STN=NMAX: NEQ=3*NMAX: VECTORSIZE=BANDWIDTH*NEQ
GOSUB REACEVAL
GOSUB REACIMP
CLOSE #2,#6
ERASE BN,BPN,BCN
IF STOREF<NSTOR THEN ERASE ULN,ICN,IPN
END IF
RETURN

SERREV:
' EVALUATE MAXIMUM DEAD LOAD DEFLECTION AND LOCATION OF IT, ALSO
' REGARDING SERVICE CONDITIONS OF LOADING COMPUTE CRITICAL DEFORMATIONS
CALL RAPAT
STN=(A(1)+1)*(A(2)+1)+A(1)*A(2)
FILENAME$="DISP"+$STR$(STOREF)+".DAT"
CALL OPEWDISP
IF LOF(6)=0 THEN
   CLS:LOCATE 10,10:PRINT "DISPLACEMENTS FILE IS NOT READY"
   LOCATE 20,40:PRINT "PRESS ANY KEY TO CONTINUE":E$=""
   CLOSE #6:WHILE E$="":E$=INKEY$:WEND
   RETURN
ELSE
   REDIM SFAC(15,7)
   GOSUB SERFACTOR
   MAXDEADDEF=0:MAXLIVEDEF=0:MINLIVEDEF=0
   FOR I=1 TO SIN
      GET #6,I
      AUX$=CVD(LTYPE6$(I,3))
      IF ABS(AUX$)*1>MAXDEADDEF THEN
         MAXDEADDEF=ABS(AUX$)
         NODEDEAD=I
      END IF
      MAXLDEF=0:MINLDEF=0
      FOR LC=1 TO 15
         DEFLE=0
         FOR J=2 TO 7
            AUX$=CVD(LTYPE6$(J,3)):DEFLE=DEFLE+AUX$*SFAC(LC,J)
         NEXT J
         IF DEFLE<>0 THEN
            IF DEFLE>ABS(DEFLE) THEN
               IF ABS(DEFLE)>MAXLDEF THEN MAXLDEF=ABS(DEFLE)
               ELSE
                  IF DEFLE<MINLDEF THEN MINLDEF=DEFLE
            END IF
         END IF
      NEXT LC
      IF MAXLDEF>MAXLIVEDEF THEN
         MAXLIVEDEF=MAXLDEF
         NODEMAXLIVE=I
      END IF
      IF MINLDEF>MINLIVEDEF THEN

MINLIVEDEF=MINLDEF
NODEMINLIVE=I
END IF
NEXT I
ERASE SFAC
CLOSE #6
CLS:LOCATE 10,20:PRINT "SERVICIBILITY WILL NOW BE CONSIDERED"
LOCATE 20,30:PRINT "PRESS ANY KEY WHEN PRINTER READY"
E$="":WHILE E$="":E$=INKEY$:WEND
LPINT TAB(20) "SERVICE BEHAVIOUR OF SPACE TRUSS":LPINT
LPINT TAB(30) "LEVEL No. " STOREF:LPINT:LPINT:LPINT
LPINT TAB(3) "MAXIMUM DEFLECTION TYPE: "
TAB(30)"OCCURING AT NODE:"
LPINT TAB(60) "MAGNITUDE (in)";LPINT:LPINT
LPINT TAB(10) "DEAD LOAD" TAB(36) NODEDEAD;
LPINT TAB(63) USING "###.###";MAXDEADDEF:LPINT
LPINT TAB(5) " SERVICE LOAD UPWARD " TAB(36) NODEMINLIVE;
LPINT TAB(63) USING "###.###";MINLIVEDEF:LPINT
LPINT TAB(4) " SERVICE LOAD DOWNWARD" TAB(36) NODEMAXLIVE;
LPINT TAB(63) USING "###.###";MAXLIVEDEF:LPINT:LPINT
END IF
RETURN

SLABRESULTS:
GET AND PRINT CRITICAL STRESSES IN CONCRETE SLAB
COUNTS=COUNTS+1
IF COUNTS=1 OR (COUNTS/25=INT(COUNTS/25)) THEN
CLS:PRINT
PRINT TAB(10) "CONCRETE SLAB STRESSES WILL NOW BE CONSIDERED"
E$="":WHILE E$="":E$=INKEY$:WEND
LOCATE 10,20:PRINT "PRESS ANY KEY WHEN PRINTER READY":E$=INKEY$:WEND
GOSUB HEADC
END IF
LPINT TAB(2) NOD(1) TAB(7) NOD(2) TAB(12) NOD(3) TAB(17) NOD(4);
STRESSMIN=0:STRESSMAX=0
FOR IA=1 TO 2
GET #7,ACUMQ
FOR LC=1 TO 15
STRESS=0
FOR JA=1 TO 7
AUX=CVS(VONM$(JA, IA)):STRESS=STRESS+LFAC(LC, JA)*AUX*1000
NEXT JA
IF STRESS<ABS(STRESS) THEN
IF ABS(STRESS)>STRESSMIN THEN STRESSMIN=ABS(STRESS)
ELSE
IF STRESS>STRESSMAX THEN STRESSMAX=STRESS
END IF
NEXT LC
NEXT IA
LPRINT TAB(33) USING "#####.##";STRESSMIN;
LPRINT TAB(58) USING "#####.##";STRESSMAX;
IF STRESSMIN>FTEN OR STRESSMAX>FCOM THEN LPRINT " **WARNING**"
RETURN

PMESS:
CLS:LOCATE 10,20
PRINT "PRESS ANY KEY WHEN PAPER READY TO CONTINUE"
E$="":WHILE E$="":E$=INKEY$:WEND
RETURN

MESSAGE:
CLS:LOCATE 5,10:PRINT "FILES ARE NOT AVAILABLE"
LOCATE 12,10:PRINT "CONTINUATION IS NOT FEASIBLE"
LOCATE 22,40:PRINT "PRESS ANY KEY TO CONTINUE" :E$=""
WHILE E$="":E$=INKEY$:WEND
RETURN

REACIMP:
' GET AND PRINT MAXIMUM AND MINIMUM REACTIONS ON EACH PERIMETRAL NODE
' CONSIDERING FACTORED LOAD COMBINATIONS
FOR I=1 TO NPN
 IF I=1 OR (I/30=INT(I/30)) THEN
  CLS:LOCATE 10,10:PRINT "CONSIDER REACTIONS ON PERIPHERY"
  LOCATE 20,30:PRINT "PRESS ANY KEY WHEN PRINTER READY"
  E$="":WHILE E$="":E$=INKEY$:WEND
  GOSUB HEADR
 END IF
 ID=BN(I):GOSUB REACIMPAUX
NEXT I
IF BRA=1 THEN
CLS:LOCATE 10,10:PRINT "CONSIDER REACTIONS ON SERVICE AREA"
LOCATE 20,30:PRINT "PRESS ANY KEY WHEN PRINTER READY"
E$="":WHILE E$="":E$=INKEY$:WEND
GOSUB HEADRSER
FOR IA=1 TO 4
 I=NPN+IA:ID=ICN(IA):GOSUB REACIMPAUX
NEXT IA
IF N3>0 THEN
 FOR IA=1 TO N3
  I=NPN+IA+4:ID=IPN(IA):GOSUB REACIMPAUX
NEXT IA
NEXT IA
   END IF
END IF
LPRINT:LPRINT
ERASE LFAC
RETURN

REACIMPAUX:
LPRINT TAB(7) ID;:CH$="N"
GET #6, ID; LREF=CV1(REFL$
IF LREF>0 THEN
   GET #2, I
   FOR J=1 TO 3
      REACMIN=0; REACMAX=0
      FOR LC=1 TO 15
         REAC=0
         FOR JA=1 TO 7
            AUX=CVS(LTYPE2$(JA, J)); REAC=REAC+AUX*LFAC(LC, JA)
         NEXT JA
         IF REAC<ABS(REAC) THEN
            IF ABS(REAC)>REACMIN THEN REACMIN=ABS(REAC)
            ELSE
               IF REAC>REACMAX THEN REACMAX=REAC
            END IF
         END IF
      NEXT LC
      LPRINT TAB(19+(J-1)*20) USING "####.##"; REACMAX;
      LPRINT TAB(29+(J-1)*20) USING "####.##"; REACMIN;
   NEXT J .
   END IF
RETURN

HEADC:
LPRINT TAB(26) "COMPOSITE SPACE TRUSS DESIGN";LPRINT
LPRINT TAB(35) "LEVEL No. " STOREF:LPRINT
LPRINT TAB(30) "CONCRETE SLAB MEMBERS";LPRINT
LPRINT TAB(20) "PERMISSIBLE STRESSES (psi) s "
LPRINT TAB(40) " TENSION = " USING "#####.##";FTEN
LPRINT TAB(40) "COMPRESSION = " USING "#####.##";FCOM
LPRINT TAB(4) "CORNER JOINTS" TAB(23) "MAX TENSILE STRESS (psi)";
LPRINT TAB(52) "MAX COMpressive STRESS (psi)";LPRINT
RETURN

CHOOSEHEAD:
ON COTYPE GOSUB HEADD,HEADUPG,HEADLNG
RETURN
HEADD:
  IDEN$="DIAGONAL MEMBERS"
  GOSUB HEADGEN
  LPRINT TAB(35) "WELD FILLET SIZE = " USING "##";RFIL*16;:LPRINT " /16 in";
  LPRINT:LPRINT TAB(5) "CONNECTING JOINTS" TAB(50) "LENGTH (in)";
  RETURN

HEADUPG:
  IDEN$="UPPER GRID LAYER MEMBERS"
  U: GOSUB HEADGEN
  LPRINT TAB(35) "LENGTH = " USING "###.#";SPAC; :LPRINT " in"
  LPRINT:LPRINT TAB(38) "WELDING REQUIREMENTS inches "
  LPRINT TAB(35) "JOINT 1" TAB(60) "JOINT 2"
  LPRINT TAB(5) "CONNECTING JOINTS";
  LPRINT TAB(30) "LENGTH" TAB(40) "FILLET"
  TAB(56) "LENGTH" TAB(66) "FILLET"
  RETURN

HEADLOWG:
  IDEN$="LOWER GRID LAYER MEMBERS"
  GOSUB U;
  RETURN

HEADGEN:
  FOR JA=1 TO 3:LPRINT:NEXT JA
  LPRINT TAB(15) IDEN$;:LPRINT TAB(55) APG " / "APGT: LPRINT
  LPRINT TAB(50) "DIAMETER = " USING "##.##";DIAM;:LPRINT " in"
  LPRINT TAB(50) "CROSS SECTION REFERENCE : " I;
  LPRINT TAB(50) "YIELD STRESS = " USING "###.#";FY;:LPRINT " ksi"
  LPRINT TAB(15) PG " / " PGT;
  LPRINT TAB(50) "YOUNG'S MODULUS = " USING "#####.#";MEL;
  LPRINT " ksi"
  LPRINT TAB(50) "WELD TYPE = " WELD$;LPRINT
  RETURN

CHOOSEPRINT:
  ON COTYPE GOSUB PRINTD, PRINTUPG, PRINTLOWG
  RETURN

PRINTD:
  LPRINT TAB(10) MXODI%(I,J) TAB(17) MNODJ%(I,J);
  GET #6,MXODI%(I,J):REF=CVI(REFL$)
  GET #9,REF:THICK=CVS(PLATHICK$):YCOMP=DEPTH-2.06-THICK
  GET #6,MNODJ%(I,J):REF=CVI(REFL$)
  GET #9,REF:THICK=CVS(PLATHICK$):YCOMP=YCOMP-THICK
  XCOMP=YCOMP/TAN(PI*.19589):LENGTH=SQR(XCOMP^2+XCOMP^2)
  LPRINT TAB(55) USING "#####.#";LENGTH
  RETURN
PRINTUPG:
IF SEL=1 THEN
    PULWELD=.85*PNUMCOMP
ELSE
    PULWELD=.9*PNUMTEN
END IF

PRINTLOMG:
PULWELD=.9*PNUMTEN:GOSUB V:
RETURN

HEADP:
FOR JA=1 TO 2:PRINT :NEXT JA
LPRINT TAB(15) "COMPOSITE SPACE TRUSS JOINTS";
LPRINT TAB(55) APG " / " APGT:LPRINT
LPRINT TAB(50) "THICKNESS = " USING "##.###";THICK;LPRINT " in"
LPRINT TAB(10) "PLATE REFERENCE : " I;
LPRINT TAB(50) "PLAN DIMENSION = " USING "###.#";PLADI;LPRINT " in"
LPRINT TAB(15) PG " / " PGT;
LPRINT TAB(50) "YIELD STRESS = " USING "###.#";PLAFY;LPRINT " ksi"
LPRINT:PRINT TAB(28) "JOINT IDENTIFICATION : "
FOR JA=10 TO 70:LPRINT TAB(JA) "-";:NEXT JA:LPRINT
RETURN

HEADR:
LPRINT TAB(26) "COMPOSITE SPACE TRUSS DESIGN":LPRINT
LPRINT TAB(35) "LEVEL No. " STOREF:LPRINT
LPRINT TAB(20) "FACTORED CRITICAL EXTERNAL REACTIONS ON PERIPHERY"
LPRINT
LPRINT TAB(25) " X DIRECTION" TAB(45) " Y DIRECTION ";
LPRINT TAB(65) " Z DIRECTION";
LPRINT TAB(7) "NODE" TAB(21) "POSITIVE" TAB(31) "NEGATIVE";
LPRINT TAB(41) "POSITIVE" TAB(51) "NEGATIVE" TAB(61) "POSITIVE";
LPRINT TAB(71) "NEGATIVE":LPRINT
RETURN
HEADRSER:
LPRINT TAB(26) "COMPOSITE SPACE TRUSS DESIGN"; LPRINT
LPRINT TAB(35) "LEVEL No. " STOREF; LPRINT
LPRINT TAB(20) "FACTORED CRITICAL EXTERNAL REACTIONS ON SERVICE AREA"
LPRINT LPRINT TAB(25) " X DIRECTION" TAB(45) " Y DIRECTION ";
LPRINT TAB(65) " Z DIRECTION";
LPRINT TAB(7) "NODE" TAB(21) "POSITIVE" TAB(31) "NEGATIVE";
LPRINT TAB(41) "POSITIVE" TAB(51) "NEGATIVE" TAB(61) "POSITIVE";
LPRINT TAB(71) "NEGATIVE"; LPRINT
RETURN

SEFACTOR:
' SUBROUTINE TO PLACE FACTORS IN A MATRIX FASHION TO EASE LOAD
' COMBINATION UNDER SERVICE CONDITIONS
SFAC(2,2)=1: SFAC(2,3)=1: SFAC(3,2)=1: SFAC(3,3)=1
FOR IA=4 TO 7: SFAC(IA,2)=1: SFAC(IA,3)=1: SFAC(IA,IA)=1: NEXT IA
FOR IA=8 TO 11
SFAC(IA,2)=1: SFAC(IA,3)=1: AUX1=IA-4: AUX2=IA+4
SFAC(AUX1,IA)=1: SFAC(AUX2,IA)=1
NEXT IA
RETURN

LOADFACTOR1:
' SUBROUTINE TO PLACE LRFD LOAD FACTORS IN A MATRIX FASHION TO EASE LOAD
' COMBINATION UNDER ULTIMATE CONDITIONS
LFAC(1,1)=1.4: LFAC(2,2)=1.6: LFAC(2,3)=.5: LFAC(3,2)=.5: LFAC(3,3)=1.6
FOR IA=2 TO 11: LFAC(IA,1)=1.2: NEXT IA
FOR IA=12 TO 15: LFAC(IA,1)=.9: NEXT IA
FOR IA=8 TO 11: LFAC(IA,2)=1.6: LFAC(IA,3)=1.6: LFAC(IA,IA)=.8: NEXT IA
FOR IA=8 TO 11
LFAC(IA,2)=.5: LFAC(IA,3)=.5: AUX1=IA-4: AUX2=IA+4
LFAC(AUX1,IA)=1.3: LFAC(AUX2,IA)=1.3
NEXT IA
RETURN

LOADFACTOR2:
' SUBROUTINE TO PLACE ACI LOAD FACTORS IN A MATRIX FASHION TO EASE LOAD
' COMBINATION UNDER ULTIMATE CONDITIONS
LFAC(7,1)=1.4: LFAC(7,2)=1.7: LFAC(7,3)=1.7
FOR IA=8 TO 11: LFAC(IA,1)=1.05: NEXT IA
FOR IA=12 TO 15: LFAC(IA,1)=.9: NEXT IA
FOR IA=8 TO 11
LFAC(IA,2)=1.3: LFAC(IA,3)=1.3: AUX1=IA-4: AUX2=IA+4
LFAC(AUX1,IA)=1.3: LFAC(AUX2,IA)=1.3
NEXT IA
RETURN
NOMRESIST:
' SUBROUTINE TO EVALUATE NOMINAL AXIAL STRENGTH OF A GIVEN MEMBER
GET #1, I
IF LAMBDA <= 1.5 THEN
   FCRITK = .658 * (LAMBDA ^ 2) ' INELASTIC BUCKLING
ELSE
   FCRITK = .877 / LAMBDA ^ 2 ' ELASTIC BUCKLING
END IF
PNOMCOMP = FCRITK * CVS(FY$) * CVS(AREA$)
PNOMTEN = CVS(FY$) * CVS(AREA$) ' YIELDING OF CROSS SECTION
RETURN

WELDREQUIRED:
' SUBROUTINE TO OBTAIN THE AMOUNT OF WELD REQUIRED FOR A GIVEN MEMBER
GET #1, I: W$ = LEFT$ (WELDTYS, 2)
IF W$ = "45" THEN
   FEXX = 45
ELSEIF W$ = "60" THEN
   FEXX = 60
ELSE
   FEXX = 70
END IF
IF OCTYPE > 1 THEN
   WELDAM = 0
   FOR IA = 1 TO 2
      GET #6, NOD(IA): REFP = CVI(REFL$)
      GET #9, REF: RFIL(IA) = CVS (PLATHICK$)
      K2AUX = INT(RFIL(IA) * 16): RFIL(IA) = K2AUX / 16
      LFIL1 = PULWELD / (RFIL(IA) * .45 * FEXX)
      GET #1, I: LFIL2 = PULWELD / (RFIL(IA) * .9 * CVS(FY$))
      IF LFIL1 > LFIL2 THEN
         LFILN(IA) = LFIL1
      ELSE
         LFILN(IA) = LFIL2
      END IF
      WELDAM = WELDAM + PI * RFIL(IA) ^ 2 / 4 * .22 * LFILN(IA)
   NEXT IA
ELSE
   PERIM = PI * SQR(2) * CVS(DIAM$)
   RFIL1 = PULWELD / (PERIM * .45 * FEXX)
   RFIL2 = PULWELD / (PERIM * .9 * CVS(FY$))
   IF RFIL1 > RFIL2 THEN
      RFIL = RFIL1
   ELSE
      RFIL = RFIL2
   END IF
   IF RFIL < .0625 THEN RFIL = .0625
   K2AUX = CINT((RFIL + .025) * 16): RFIL = K2AUX / 16
   WELDAM = PI * RFIL * 2 / 4 * PERIM * .22 * 2
REACEVAL:

' SUBROUTINE TO EVALUATE AND STORE REACTIONS REGARDING INDIVIDUAL LOADING CONDITIONS

SIK=INT(VECTORSIZE/8+1)
REDIM S1(SIK), S2(SIK), S3(SIK), S4(SIK)
REDIM S5(SIK), S6(SIK), S7(SIK), S8(SIK)

' SET ORIGINAL STIFFNESS MATRIX IN INDIVIDUAL ARRAYS
' IT IS MEANT FOR ORIGINAL THOSE VALUES BEFORE FORWARD REDUCTION
FILENAME$="STIFF"+STR$(STOREF)+".DAT"
OPEN "I", 8, FILENAME$
FOR I=1 TO NEQ
  IGRV=(I-1)*BANDWIDTH
  FOR J=1 TO BANDWIDTH
    IRCV=IGRV+J: INPUT #8, X
  CALL AUXSTO
  NEXT J
NEXT I
CLOSE #8

' CONSIDER INDIVIDUAL LOADING CONDITIONS TO SAVE REACTIONS ON STRUCTURE
' VALUES SAVED ARE UNFACTORED
RDGFR=NPN*3
IF BRA=1 THEN RDGFR=RDGFR+12+3*N3
FOR ILC=1 TO 7
  REDIM REA(RDGFR), DF#(NEQ)
  RETRIEVE DISPLACEMENTS FROM CORRESPONDING LOADING CONDITION
  FOR I=1 TO SIN
    GET #6, I
    FOR J=1 TO 3
      AUX#=CVD(LTYPE6$(ILC, J))
      IND=(I-1)*3+J: DF#(IND)=AUX#
    NEXT J
  NEXT I
  GET REACTIONS CORRESPONDING TO PERIMETRAL NODES ONLY
  FIRST FROM STIFFNESS MATRIX AND STRUCTURE DISPLACEMENTS
  FOR IA=1 TO NPN
    FOR JA=1 TO 3
      AUX=(IA-1)*3+JA: I=(BN(IA)-1)*3+JA: GOSUB READISP1
    NEXT JA
  NEXT IA
  IF BRA=1 THEN
    FOR IA=1 TO 4
FOR JA=1 TO 3
    AUX=(IA-1)*3+JA+NPN*3+I=(ICN(IA)-1)*3+JA:GOSUB READISP1
NEXT JA
NEXT IA
IF N3>0 THEN
    FOR IA=1 TO N3
        FOR JA=1 TO 3
            AUX=(IA-1)*3+JA+(NP+4)*3+I=(IPN(IA)-1)*3+JA:GOSUB READISP1
        NEXT JA
    NEXT IA
END IF
END IF
NBM1=WIDTH-1
FOR IA=1 TO NPN
    FOR JA=1 TO 3
        ALK=(IA-1)*3+JA:IND=(BN(IA)-1)*3+JA:GOSUB READISP2
    NEXT JA
END IF
IF BRA=1 THEN
    FOR IA=1 TO 4
        FOR JA=1 TO 3
            AUX=(IA-1)*3+JA+NPN*3+I=(ICN(IA)-1)*3+JA:GOSUB READISP2
        NEXT JA
    NEXT IA
END IF
IF N3>0 THEN
    FOR IA=1 TO N3
        FOR JA=1 TO 3
            AUX=(IA-1)*3+JA+(NP+4)*3+I=(IPN(IA)-1)*3+JA:GOSUB READISP2
        NEXT JA
    NEXT IA
END IF
END IF
ERASE DF#
SECOND FROM APPLIED LOADS
REDIM DF#(NEQ)
OBTAIN LOADS FROM ADEQUATE FILE
FOR I=1 TO SIN
    GET #6, I
    FOR J=1 TO 3
        AUX#=CVD(LTYPE62$,(ILC, J))
        IND=(I-1)*3+J:DF#(IND)=AUX#
    NEXT J
END IF
PLACE LOADS ON NODES WHERE EXTERNAL REACTIONS ARE OF INTEREST
STORE REACTIONS IN PROPER FILE FOR LATER COMBINATIONS
FOR IA=1 TO NPN
    FOR JA=1 TO 3
        GET #2, I
        AUX=(I-1)*3+J:IND=(BN(I)-1)*3+J:REA(AUX)=REA(AUX)−DF#(IND)
LSET LTYPE2$(ILC,J)=MKS$(REA(AUX))
PUT #2,I
NEXT J
NEXT I
IF BRA=1 THEN
FOR IA=1 TO 4
FOR J=1 TO 3
I=IA+NPN+4; GET #2,I
AUX=(1-1)*3+J; IND=(IPN(I)-1)*3+J; REA(AUX)=REA(AUX)-DF#(IND)
LSET LTYPE2$(ILC,J)=MKS$(REA(AUX))
PUT #2,I
NEXT J
NEXT IA
IF N3>0 THEN
FOR IA=1 TO N3
FOR J=1 TO 3
I=IA+NPN+4; GET #2,I
AUX=(1-1)*3+J; IND=(IPN(I)-1)*3+J; REA(AUX)=REA(AUX)-DF#(IND)
LSET LTYPE2$(ILC,J)=MKS$(REA(AUX))
PUT #2,I
NEXT J
NEXT IA
END IF
END IF
ERASE REA,DF#
NEXT ILC
ERASE S1,S2,S3,S4,S5,S6,S7,S8
RETURN

READISP1:
IN EVALUATING EXTERNAL REACTIONS CONSIDER UPPER TRIANGLE OF S MATRIX
IGRV=(I-1)*BANDWIDTH
FOR J=1 TO BANDWIDTH
K=I+J-1
IF K<=NEQ THEN
IRCV=IGRV+J
CALL AIXREP
REA(AUX)=REA(AUX)+X*DF#(K)
END IF
NEXT J
RETURN
READISP2:
' IN EVALUATING EXTERNAL REACTIONS CONSIDER LOWER TRIANGLE OF S MATRIX
FOR L=1 TO NBML
    J=I-BANDWIDTH+L
    IF J>1 THEN
        K=BANDWIDTH+1-L
        IGRV=(J-1)*BANDWIDTH: IRCV=IGRV+K
        CALL ALKREP
        REA(AUX)=REA(AUX)+X*DF#(J)
    END IF
NEXT L
RETURN

DEFGRID:
' SUBROUTINE TO DISPLAY GENERAL GEOMETRY OF STRUCTURE
CLS:PRINT:PRINT TAB(10) "SPACE TRUSS IN LEVEL NO. " STOREF
PRINT:PRINT
A(1)=L1/SPAC:A(2)=L2/SPAC
D: PRINT TAB(20) " DEPTH (inches) : ": DEPTH:PRINT:PRINT
PRINT TAB(15) "IN THE SHORT DIRECTION : " L1:PRINT
PRINT TAB(5) "UPPER MESH CHARACTERISTICS : ";
PRINT TAB(40) " NUMBER OF NODES = " A(1)+1
PRINT TAB(40) " NUMBER OF ELEMENTS = " A(1):PRINT
PRINT TAB(5) "LOWER MESH CHARACTERISTICS : ";
PRINT TAB(40) " NUMBER OF NODES = " A(1)
PRINT TAB(40) " NUMBER OF ELEMENTS = " A(1)-1:PRINT:PRINT
PRINT TAB(15) "IN THE LONG DIRECTION : " L2:PRINT
PRINT TAB(5) "UPPER MESH CHARACTERISTICS : ";
PRINT TAB(40) " NUMBER OF NODES = " A(2)+1
PRINT TAB(40) "NUMBER OF ELEMENTS = " A(2):PRINT
PRINT TAB(5) "LOWER MESH CHARACTERISTICS : ";
PRINT TAB(40) " NUMBER OF NODES = " A(2)
PRINT TAB(40) " NUMBER OF ELEMENTS = " A(2)-1:PRINT
E$="":WHILE E$="":E$=INKEY$:WEND
G: CLS:GRA=A(1)*2+1: NMAX=(A(1)+1)*(A(2)+1)+A(1)*A(2)
RETURN

CHOOSECONN:
ON COTYPE GOSUB CONNDIAG, CONNUPGRID, CONNLOWGRID
RETURN

CONNDIAG:
' GENERATION OF NODES IN THE PERIPHERY WHICH ARE USED TO DEFINE
' BOUNDARY DIAGONAL ELEMENTS
BARTYPE=2: ELEMTYPE=1
NNB=A(1)+A(2)-1
REDIM B(NNB)
K=0
WHILE K<4
  K=K+1
  IF K=1 THEN
    INDDIAGGEN=A(1)+1+GAP
    FOR I=1 TO A(2):B(I)=INDDIAGGEN+(I-1)*GAP:NEXT I
    AUXDIAGGEN=A(2)
    INDDIAGGEN=B(AUXDIAGGEN)-A(1)
    FOR I=1 TO A(1)-1
      B(I+1)=INDDIAGGEN+1:INDDIAGGEN=B(I+1)
    NEXT I
    LIMIT=A(2)+K1AUXDIAGGEN=A(1)+1
  ELSEIF K=2 THEN LIMIT=A(1)-1
  ELSEIF K=3 THEN
    LAST=B(ALKDIAGGEN)+B(AUXDIAGGEN)=A(1)+1:REFDIGE=LAST-A(1)
    INDDIAGGEN=1
    FOR I=1 TO A(1)-1
      B(I+1)=INDDIAGGEN+1:INDDIAGGEN=B(I+1)
    NEXT I
    K1AUXDIAGGEN=A(1)
  ELSEIF K=4 THEN LIMIT=A(2)
END IF
FOR I=1 TO LIMIT
  IF K=1 THEN NOD(2)=(I-1)*GAP+1
  IF K=2 THEN NOD(2)=I+1
  IF K=3 THEN NOD(2)=REFDIGE+I
  IF K=4 THEN NOD(2)=REFDIGE-GAP*(I-1)
  ELIO$="FALSE"
  WHILE ELIO$="FALSE"
    NOD(1)=NOD(2)
    NOD(2)=NOD(1)+K1AUXDIAGGEN
  GOSUB GETCOR
  J=0
  WHILE J<NNB
    J=J+1
    IF B(J)=NOD(2) THEN ELIO$="TRUE"
  WEND
  WEND
NEXT I
ERASE B
RETURN

CONNUPGRID:
  GENERATION OF ELEMENTS IN UPPER GRID IN X AND Y DIRECTION
  BARTYPE=1:ELEMTYPE=1
  FOR I=1 TO A(2)+1
    FOR J=1 TO A(1)
      NOD(1)=(I-1)*GAP+J
      NOD(2)=NOD(1)+1
GOSUB GETCOR
NEXT J
NEXT I
FOR I=1 TO A(1)+1
  NOD(2)=I
FOR J=1 TO A(2)
  NOD(1)=NOD(2)
  NOD(2)=NOD(1)+GAP
  GOSUB GETCOR
NEXT J
NEXT I
RETURN

CONNLONGGRID:
' GENERATION OF ELEMENTS IN LOWER GRID IN X AND Y DIRECTION
BARTYPE=1: ELEMTYPE=1
FOR I=1 TO A(2)
  FOR J=1 TO A(1)-1
    NOD(1)=(I-1)*GAP+J+A(1)+1
    NOD(2)=NOD(1)+1
    GOSUB GETCOR
  NEXT J
NEXT I
FOR I=1 TO A(1)
  NOD(2)=I+A(1)+1
  FOR J=1 TO A(2)-1
    NOD(1)=NOD(2)
    NOD(2)=NOD(1)+GAP
    GOSUB GETCOR
  NEXT J
NEXT I
RETURN

CONNSLAB:
' GENERATION OF QUADRILATERAL TYPE ELEMENTS WHICH MODEL THE CONCRETE
BARTYPE=0
ELEMTYPE=2
FOR I=1 TO A(2)
  NOD(2)=(I-1)*GAP+1
FOR J=1 TO A(1)
  NOD(1)=NOD(2): NOD(2)=NOD(1)+1: NOD(3)=NOD(2)+GAP: NOD(4)=NOD(1)+GAP
  GOSUB GETCOR
NEXT J
NEXT I
RETURN
MEMORG:
' ORGANIZE BAR MEMBERS FOR PRINTOUT
IF ORG<2 THEN
   DIFS%(LREF)=DIFS%(LREF)+1
ELSE
   COUNT%(LREF)=COUNT%(LREF)+1
   MNODI%(LREF,COUNT%(LREF))=NOD(1)
   MNODJ%(LREF,COUNT%(LREF))=NOD(2)
END IF
RETURN

GETCOR:
' MULTIFUNCTIONAL SUBROUTINE DEPENDING ON THE VALUES OF SEVERAL FLAGS
' EXECUTION Comes FROM SUBROUTINE CONNECTIVITY, EXCEPT WHEN COORDINATES
' OF A GIVEN NODE IS DESIRED
' PRINTSTR; TRANSFERS EXECUTION FOR PRINTOUT OF STRUCTURE CONFIGURATION
' NNODE=1
IF ELEMTYPE=1 THEN NNODE=2
IF ELEMTYPE=2 THEN NNODE=4
FOR IAI=X=1 TO NNODE
   KAUX=(NOD(IAUX)-1)/GAP
   KRES=NOD(IAUX)-INT(KAUX)*GAP
   IF KRES>A(1)+1 THEN
      K1=SPAC/2
      COR(IAUX,1)=(KRES-A(1)-2)*SPAC+K1: COR(IAUX,2)=K1+INT(KAUX)*SPAC
      COR(IAUX,3)=0
   ELSE
      COR(IAUX,1)=(KRES-1)*SPAC: COR(IAUX,2)=INT(KAUX)*SPAC
      COR(IAUX,3)=DEPTH
   END IF
NEXT IAI=X
IF ELEMTYPE=0 THEN RETURN
IF ELEMTYPE=1 THEN
   ACUM=ACUM+1
   GET #3,ACUM:LREF=CVI(REF$)
   IF LREF<>Ø THEN GOSUB MEMORG
   RETURN
ELSE
   ACUMQ=ACUMQ+1
   PRINT TAB(15) " QUAD —> " ACUMQ;
   GET #7,ACUMQ:LREF=CVI(RES$)
   IF LREF<>Ø THEN GOSUB SLABRESULTS
END IF
RETURN
APPENDIX F

PROGRAM MODULE ELIO23

TEXT OF PROGRAM TO HANDLE BUILDING INFORMATION FILES
REM $DYNAMIC $INCLUDE: 'COMEERM.BAS'
REDIM A(2), C$(3), CDL$(23), CLL$(23), COR(4, 3), LODL$(23), LOLL$(23), _
LTYPE2$(7, 3), LTYPE3$(7), LTYPE6$(7, 3), LTYPE62$(7, 3), NOD(4)
TECS$="N"
WHILE TECS$="N"
    CLS: LOCATE 3, 40: PRINT "OPTIONS:"
    LOCATE 10, 30: PRINT "1) CHECK STRUCTURE INFORMATION"
    LOCATE 12, 30: PRINT "2) MODIFY ANY FEATURE OF STRUCTURE"
    LOCATE 14, 30: PRINT "3) CREATE FILE DELETING ACTUAL INFORMATION"
    LOCATE 16, 30: PRINT "4) QUIT"
    EL$="XX"
    WHILE EL$<"1" OR EL$>"4"
        LOCATE 20, 40: PRINT "SELECTION -> ": EL$=INPUT$(1)
    WEND
    IF VAL(EL$)=1 THEN GOSUB CHECKST ELSE
        IF VAL(EL$)=2 THEN GOSUB MODST ELSE
            IF VAL(EL$)=3 THEN GOSUB CREAST ELSE
                IF VAL(EL$)=4 THEN GOSUB TECS
    WEND
CHAIN "ELIO21"
END

2: CLS: PRINT TAB(40) "NUMBER OF SPACE STRUCTURES: " NSTOR
    PRINT TAB(5) "LEVEL --- > " STOREF: PRINT
    RETURN

TECS:
TECS$="Y": RETURN
CHECKST:
' DISPLAY OF BUILDING FEATURES ON SCREEN
CALL OPENBUILD
NSTOR=LOF(5)/236
IF NSTOR=1 THEN
STOREF=0
WHILE STOREF<NSTOR
STOREF=STOREF+1
GET #5,STOREF
FILENAME$="SUPP"+STR$(STOREF)+".DAT"
CALL OPENSUPPORT
GOSUB 2
PRINT TAB(20) "HEIGHT" = " CVS(HEIGHT$) TAB(45) " ft"
PRINT TAB(20) "LEAST DIMENSION" = " CVI(L1$) TAB(45) " in"
PRINT TAB(20) "OTHER DIMENSION" = " CVI(L2$) TAB(45) " in"
PRINT TAB(20) "SPACE TRUSS DEPTH" = " CVI(DEPTHS$) TAB(45) " in"
PRINT TAB(20) "DEAD LOAD" = " CVS(DEADS$)
TAB(45) " psf " PRINT "NOT INCLUDING SELF WEIGHT"
PRINT TAB(20) "LIVE LOAD" = " CVS(LIVE$) TAB(45) " psf"
PRINT TAB(20) "ROOF LOAD" = " CVS(ROOF$) TAB(45) " psf"
PRINT TAB(20) "SLAB THICKNESS" = " CVS(THICK$) TAB(45) " in"
PRINT TAB(20) "F'c (3 DAYS)" = " CVS(FC3$) TAB(45) " ksi"
PRINT TAB(20) "F'c (28 DAYS)" = " CVS(FC28$) TAB(45) " ksi"
PRINT TAB(20) "UNIT WEIGHT" = " CVI(GAMS$) TAB(45) " pcf"
PRINT TAB(20) "POISSON RATIO" = " CVS(F$"
GOSUB DESASSIGN
LOCATE 19,15:PRINT "SLAB WILL BE CAST " CONSTYPE$
LOCATE 23,55:PRINT "PRESS ANY KEY TO CONTINUE"
ES$="":WHILE ES$="":ES$=INKEY$:WEND
' SHOW SERVICE AREA NODES IF CONSIDERED STORY IS NOT THE ROOF ONE
IF STOREF<NSTOR THEN
GOSUB 2
LOCATE 6,10:PRINT " THE FOLLOWING NODES DEFINE SERVICE AREA: "
LOCATE 8,30:PRINT "NODE 1 = " CVI(ND1$)
LOCATE 10,30:PRINT "NODE 2 = " CVI(ND2$)
LOCATE 12,30:PRINT "NODE 3 = " CVI(ND3$)
LOCATE 14,30:PRINT "NODE 4 = " CVI(ND4$)
DUM$="NO":BRA=CVI(BRA?):IF BRA=1 THEN DUM$="YES"
LOCATE 18,15:PRINT "OFFERS SUPPORT TO STRUCTURE (Y/N) : " DUM$
ES$="":WHILE ES$="":ES$=INKEY$:WEND
END IF
' EVALUATION OF NUMBER OF NON-ZERO CONCENTRATED APPLIED DEAD LOADS
DUM$="N":LA=0
WHILE DUM$="N" AND LA<23
LA=LA+1:GET #5,STOREF:AUX=CVI(CDL$(LA))
IF AUX=0 THEN
DUM$="Y":LA=LA-1
END IF
WEND
GOSUB 2
PRINT TAB(10) "NUMBER OF CONCENTRATED DEAD LOADS = " LA
IF LA>1 THEN
  PRINT TAB(10) "LOAD MAGNITUDE (Kips)" TAB(50) "NODE OF APLICATION ":PRINT
  FOR KA=1 TO LA
    GET #5,STOREF
    LD=CVI(CDL$(KA))/1000:PRINT TAB(15) USING "###.###";LD;
    GET #5,STOREF;AUX=CVI(LODL$(KA));PRINT TAB(56) AUX
    E$="";WHILE E$="":E$=INKEY$:WEND
  NEXT KA
ELSE
  E$="";WHILE E$="":E$=INKEY$:WEND
END IF
EVALUATION OF NUMBER OF NON-ZERO CONCENTRATED APPLIED LIVE LOADS
DUM$="N":LA=0
WHILE DUM$="N" AND LA<23
  LA=LA+1;GET #5,STOREF:AUX=CVI(CLL$(IA))
  IF AUX=0 THEN
    DUM$="Y":LA=LA-1
  END IF
WEND
GOSUB 2
PRINT TAB(10) "NUMBER OF CONCENTRATED LIVE LOADS = " LA
IF LA>1 THEN
  PRINT TAB(10) "LOAD MAGNITUDE (kips)" TAB(50) "NODE OF APLICATION ":PRINT
  FOR KA=1 TO LA
    GET #5,STOREF
    LOID=KA
    LL=CVI(CLL$(KA))/1000:PRINT TAB(15) USING "###.###";LL;
    GET #5,STOREF;AUX=CVI(LOLL$(LOID));PRINT TAB(56) AUX
    E$="";WHILE E$="":E$=INKEY$:WEND
  NEXT KA
ELSE
  E$="";WHILE E$="":E$=INKEY$:WEND
END IF
IF STOREF<NSTOR THEN
  CALL SERAVECTORS
  CALL BAFEAT
  CALL PERINODE
END IF
TOT=NPN/12;PGT=INT(TOT):RES=0:CON=0
IF TOT<>INT(TOT) THEN
  RES=NPN-INT(TOT)*12
  PGT=PGT+1
END IF
FOR PG=1 TO PGT
LIM=12: IF PG=PGT AND RES<>Ø THEN LIM=RES
GOSUB 2
REDIM SBAC$(3)
PRINT TAB(15) "NUMBER OF PERIMETRAL NODES = " NPN: PRINT: PRINT
PRINT TAB(2) "NODE IDENTIFICATION " TAB(25) "IN X DIRECTION";
PRINT TAB(45) "IN Y DIRECTION" TAB(65) "IN Z DIRECTION": PRINT
FOR JA=1 TO LIM
    CON=CON+1
    ND=BN(CON): IF STOREF<NSتور THEN CALL LOADCHECK
    PRINT TAB(10) ND;
    IF CH$<>"Y" THEN
        FOR KA=1 TO 3
            GET #4,CON:AUX=CVI(C$(KA))
            IF AUX=1 THEN SBAC$(KA)="RESTRICTED"
            IF AUX=Ø THEN SBAC$(KA)="FREE"
        NEXT KA
        FOR KA=1 TO 3: PRINT TAB(8+KA*20) SBAC$(KA);: NEXT KA
    END IF
    NEXT JA
LOCATE 23,70: PRINT "PAGE" PG
E$="": WHILE E$="": E$=INKEY$: WEND
NEXT PG
CLOSE #4
ERASE BN,SBAC$
IF STOREF<NSتور THEN ERASE BPN,BCN,IPN,ICN,ULN
WEND
ELSE
    CLS
    LOCATE 10,10: PRINT "**BUILDING INFORMATION FILE MUST BE CREATED**"
    LOCATE 20,20: PRINT "PRESS ANY KEY TO CONTINUE"
    E$="": WHILE E$="": E$=INKEY$: WEND
END IF
CLOSE #5
RETURN

LOADCHECK:
' SUBROUTINE TO CHECK THAT A CONCENTRATED LOAD IS NOT PLACED ON A
' NON-EXISTING NODE REGARDING THE EXISTANCE OF A SERVICE AREA
CH$="N": LAUX=Ø
WHILE LAUX<NSتور AND CH$="N"
    LAUX=LAUX+1
    IF ULN(LAUX)=ND THEN CH$="Y"
WEND
RETURN
MODST:
' OPTION TO MODIFY STRUCTURE CONFIGURATION SO THAT A NEW FILE DOES NOT
' HAVE TO BE CREATED WHEN INFORMATION OF THE EXISTING ONE CAN BE USED

CLS:KEY(3) ON:KEY(4) ON
KEY(1) ON:KEY(2) ON
ON KEY(1) GOSUB MODLEV
ON KEY(2) GOSUB ADDLEV
ON KEY(3) GOSUB DELLEV
ON KEY(4) GOSUB ENDLEV
TE$="N"
CALL OPENBUILD
M: NSTOR=LOF(5)/236
IF NSTOR=1 THEN
  LOCATE 2,0:PRINT "OPTIONS : "
  LOCATE 5,10:PRINT "F1-> MODIFY CHARACTERISTICS OF ONE OF THE
      ACTUAL LEVELS"
  LOCATE 7,10:PRINT "F2-> ADD A NEW LEVEL TO THE BUILDING"
  LOCATE 9,10:PRINT "F3-> DELETE AN EXISTING LEVEL FROM THE
      BUILDING"
  LOCATE 11,10:PRINT "F4-> END"
  IF TE$="Y" THEN GOTO M:
ELSE
  LOCATE 10,15:PRINT "NON EXISTING FILES"
  LOCATE 15,15:PRINT "CAN NOT MODIFY "
  E$="":WHILE E$="":E$=INKEY$:WEND
END IF
E: CLOSE #5
KEY(1) OFF:KEY(2) OFF:KEY(3) OFF:KEY(4) OFF
RETURN

ENDLEV:
  TE$="Y"
RETURN

MODLEV:
' MODIFICATION OF A GIVEN STORY REGARDING EITHER GEOMETRY, LOADS,
' SUPPORT CONDITIONS, OR CONCRETE CHARACTERISTICS

CLS:E$=""
LOCATE 3,40:PRINT "THE STRUCTURE HAS " NSTOR " LEVELS"
LOCATE 5,10:INPUT "REFERENCE OF THE ONE TO MODIFY ---> ",STOREF
IF STOREF<1 OR STOREF>NSTOR THEN GOTO MODLEV:
CALL BAFEF
GOSUB D
PRINT TAB(10) " OPTIONS : ":PRINT:PRINT
PRINT TAB(35) "1) GEOMETRY"
PRINT TAB(35) "2) ACTING LOADS"
PRINT TAB(35) "3) CONCRETE CHARACTERISTICS"
PRINT TAB(35) "4) SUPPORT CONDITIONS
PRINT TAB(35) "5) CONSTRUCTION PROCESS
PRINT TAB(35) "6) QUIT
EL$="X"
WHILE EL$<"1" OR EL$>"6"
  LOCATE 20,25:PRINT "SELECTION ? ":EL$=INPUT$(1)
  WEND
  IF VAL(EL$)=1 THEN GOSUB MODGEO ELSE
    IF VAL(EL$)=2 THEN GOSUB MODLO ELSE
      IF VAL(EL$)=3 THEN GOSUB MODCONC ELSE
        IF VAL(EL$)=4 THEN GOSUB MODSUPC ELSE
          IF VAL(EL$)=5 THEN GOSUB MODCONPRO
          CLS
          RETURN
MODCONPRO:
  CLS:LOCATE 3,20:PRINT "CONSTRUCTION PHASE PROCESS:" :GOSUB CONSTASSIGN
  AUX$=" CONCRETE CAST "
  LOCATE 10,10:PRINT "BEFORE : ":AUX$ CONSTYPE?
  DUM=1:IF SEL=1 THEN DUM=2
  SEL=DUM:GOSUB CONSTORE
  GOSUB CONSTASSIGN
  LOCATE 20,10: PRINT " NOW : ":AUX$ CONSTYPE?
  E$="":WHILE E$="":E$=INKEY$:WEND
  RETURN
4: LOCATE 63:INPUT "NEW VALUE = ":AUX:RETURN
MODGEO:
  ' EVERY GEOMETRIC CHARACTERISTIC OF THE CHOSEN STORY ARE SHOWN ON
  ' SCREEN AND MODIFICATION CAN BE DONE BY INPUTING THE NEW VALUE
  CLS:E$=" "
  GOSUB 2
  GET #5,STOREF:AUX=CVS(HEIGHT$)
  LOCATE 2,5:PRINT " ACTUAL HEIGHT (ft) = ":USING "##.#";AUX;
  LOCATE 40:INPUT " MODIFY (Y/N): ":E$:IF E$="Y" THEN GOSUB 4
  IF STOREF<1 THEN
    GET #5,STOREF-1:AUXA=CVS(HEIGHT$)
    IF AUXA=AUX THEN
      PRINT TAB(40) "INCORRECT VALUE OF HEIGHT"
      GOTO MODGEO:
    END IF
  END IF
  IF STOREF>NSTOR THEN
    GET #5,STOREF+1:AUXB=CVS(HEIGHT$)
    IF AUXB=AUX THEN
      PRINT TAB(40) "INCORRECT HEIGHT VALUE"
      GOTO MODGEO:
    END IF
END IF
LSET HEIGHT$=MK$(AUX):PUT #5,STORF
GET #5,STORF:AUX=CVI(L1$)
CALL BAFEAT
L1AUX=L1:L2AUX=L2:A1AUX=A(1):A2AUX=A(2)
PRINT TAB(5) " LEAST DIMENSION (in) = " AUX;
LOCATE ,40:INPUT " MODIFY (Y/N): ",E$
IF E$="Y" THEN GOSUB 4
LS=AUX:GET #5,STORF:AUX=CVI(L2$)
PRINT TAB(5) " OTHER DIMENSION (in) = " AUX;
LOCATE ,40:INPUT " MODIFY (Y/N): ",E$
IF E$="Y" THEN GOSUB 4
LB=AUX:GET #5,STORF:AUX=CVI(DEPTH$)
PRINT TAB(5) " DEPTH (in) = " AUX;
LOCATE ,40:INPUT " MODIFY (Y/N): ",E$
GOSUB INPGEO
GET #5,STORF:LSET L1$=MK$(L1):PUT #5,STORF
GET #5,STORF:LSET L2$=MK$(L2):PUT #5,STORF
GET #5,STORF:LSET DEPTH$=MK$(DEPTH):PUT #5,STORF
CALL BAFEAT
IF A(1)<>A1AUX OR A(2)<>A2AUX THEN
FILENAME$="SUPP"+STR$(STORF)+".DAT":KILL FILENAME$
CALL OPSUPPORT
CALL PERINODE
ELEMTYPE=0
FOR ZI=1 TO NPN
   NOD(1)=BN(ZI):GOSUB 18
NEXT ZI
ERASE BN
CLOSE #4
END IF
IF STORF<NSTOR THEN
GOSUB 2
PRINT:PRINT TAB(5) " WITH RESPECT TO SERVICE AREA":PRINT
GET#5,STORF:ND1=CVI(N1$):ND2=CVI(N2$):ND3=CVI(N3$):ND4=CVI(N4$)
PRINT " THE FOLLOWING NODES ARE THE CORNER ONES ":PRINT
PRINT TAB(15) " NODE 1 = " ND1:PRINT TAB(15) " NODE 2 = " ND2:PRINT
PRINT TAB(15) " NODE 3 = " ND3:PRINT TAB(15) " NODE 4 = " ND4:PRINT
LOCATE ,30:INPUT " MODIFY (Y/N) ? ",E$
IF E$="Y" THEN GOSUB INPSEA
END IF
GOSUB 2
GET #5,STORF:AUX=CVS(THICK$)
PRINT TAB(5) " ACTUAL SLAB THICKNESS (in) = " AUX;
LOCATE ,40:INPUT " MODIFY (Y/N) : ",E$:IF E$="Y" THEN GOSUB 4
GET #5,STORF:LSET THICK$=MK$(AUX):PUT #5,STORF
RETURN
MODLO:
' ACTUAL LOADS ARE DISPLAYED AND ANY CHANGE OF A GIVEN VALUE CAN BE DONE
' DEAD LOAD IS ONLY THAT SUPERIMPOSED SINCE SELF-WEIGHT IS TAKEN INTO
' CONSIDERATION IN THE DESIGN, DEPENDING ON THE CHOSEN MEMBERS.
' CONCENTRATED LOADS OF BOTH KINDS CAN BE MODIFIED IN MAGNITUDE AS WELL
' AS IN LOCATION OR MORE LOADS CAN BE ADDED UP TO A TOTAL OF 23 FOR
' EACH TYPE. GRAVITACIONAL LOADS ARE POSITIVE.
CLS:E$="":GOSUB 2
TYK$="E"
GET #5,STOREF:AUX=CVS(DEAD$)
LOCATE 3,12:PRINT "IMPOSED DEAD LOAD (psf) = " AUX;
LOCATE ,50:INPUT "MODIFY (Y/N) : ",E$
IF E$="Y" THEN GOSUB 4
LSET DEAD$=MKS$(AUX):PUT #5,STOREF
ELSE
AUX=CVS(ROOF$)
PRINT:PRINT TAB(10) "ROOF LOAD (psf) = " AUX;
LOCATE ,40:INPUT "MODIFY (Y/N) : ",E$
IF E$="Y" THEN GOSUB 4
LSET ROOF$=MKS$(AUX):PUT #5,STOREF
END IF
CLS
LOCATE 8,10
INPUT "DO YOU WANT TO CONSIDER CONCENTRATED LOADS (Y/N) : ",A$
IF A$="Y" THEN
IF STOREF<NSTOR THEN CALL SERAVECTORS
WHILE TYK$<="D" AND TYK$<="L"
CLS
LOCATE 3,10
INPUT " DEAD OR LIVE CONCENTRATED TYPE LOAD (D/L) : ",TYK$
WEND
IF TYK$="D" THEN
DUM$="N":LA=0
WHILE DUM$="N" AND LA<23
LA=LA+1:AUX=CVI(CDL$(LA))
IF AUX=0 THEN
DUM$="Y":LA=LA-1
END IF
WEND
CLS:LOCATE 3,10
PRINT " THERE ARE " LA " CONCENTRATED DEAD LOADS " :LOID=0
WHILE LOID<1
LOCATE 5,15:PRINT " LOAD TO BE MODIFIED : ";
INPUT "REF — > ", LOID
WEND
IF LOID>LA THEN
    LOCATE 6,50:PRINT " ** LOAD DOES NOT EXIST **"
    LOCATE 7,50:A$="N":INPUT "ADD A NEW ? (Y/N) : ", A$
    IF A$="Y" THEN
        LOID=LA+1:AUX=0
        WHILE AUX<0
            LOCATE 10,20:INPUT " DEAD LOAD MAGNITUD (lb) = ", AUX
        WEND
        GET #5,STOREF:LSET CD$L$(LA)=MKI$(AUX):PUT #5,STOREF
        NAP=0:CH$="N"
        WHILE NAP<1 OR NAP>NMAX OR CH$="Y"
            LOCATE 15,20:INPUT " NODE OF APPLICATION = ", NAP
            ND=NAP:IF STOREF<STOR THEN CALL LOADCHECK
        WEND
        GET #5,STOREF:LSET LOD$L$(LA)=MKI$(NAP):PUT #5,STOREF
    END IF
ELSE
    LOCATE 7,10:PRINT "REGARDING LOAD REF — > ", LOID
    GET #5,STOREF:AUX=CVI(CDL$(LOID))
    LOCATE 10,13:PRINT "MAGNITUD (lb) = ", AUX
    LOCATE 40,INPUT " MODIFY (Y/N) : ", E$
    IF E$="Y" THEN
        AUX=0
        WHILE AUX<0
            GOSUB 4
        WEND
        LSET CD$L$(LOID)=MKI$(AUX):PUT #5,STOREF
    END IF
    GET #5,STOREF:AUX=CVI(LODL$(LOID))
    LOCATE 15,13:PRINT "NODE OF APPLICATION = ", AUX
    LOCATE 40,INPUT " MODIFY (Y/N) : ", E$
    IF E$="Y" THEN
        AUX=0:CH$="N"
        WHILE AUX<1 OR AUX>NMAX OR CH$="Y"
            GOSUB 4
            ND=AUX:IF STOREF<STOR THEN CALL LOADCHECK
        WEND
        GET #5,STOREF:LSET LOD$L$(LOID)=MKI$(AUX):PUT #5,STOREF
    END IF
END IF
ELSE
    DUM$="N":LA=0
    WHILE DUM$="N" AND LA<23
        LA=LA+1:AUX=CVI(CHR$(LA))
        IF AUX=0 THEN
            DUM$="Y":LA=LA-1
        END IF
    END IF
CLS:LOCATE 3,10:PRINT "THERE ARE " LA " CONCENTRATED LIVE LOADS"
LOID=0
WHILE LOID<1
  LOCATE 5,15:PRINT " LOAD TO BE MODIFIED : ";
  INPUT "REF --> ",LOID
  WEND
  IF LOID>LA THEN
  LOCATE 6,50:PRINT " ** LOAD DOES NOT EXIST **"
LOCATE 7,50:AS="N":INPUT "ADD A NEW ? (Y/N) : ",AS
  IF AS="Y" THEN
    LOID=LA+1:AUX=0
    WHILE AUX=0
      LOCATE 10,20:INPUT " DEAD LOAD MAGNITUD (lb) = ",AUX
      WEND
    GET #5,STOREF:LSET CLL$(LA)=MK$(AUX):PUT #5,STOREF
    NAP=0:CH$="N"
    WHILE NAP<1 OR NAP>NMAX OR CH$="Y"
      LOCATE 15,20:INPUT " NODE OF APPLICATION = ",NAP
      ND=NAP:IF STOREF<NSTOR THEN CALL LOADCHECK
    WEND
    IF E$="Y" THEN
      AUX=0sCH$="N"
      WHILE AUX=0
        GOSUB 4
        WEND
      GET #5,STOREF:LSET CLL$(LA)=MK$(AUX):PUT #5,STOREF
    END IF
    END IF
ELSE
LOCATE 7,10:PRINT " REGARDING LIVE LOAD REF --> ":LOID
LOCATE 5,STOREF:ALX=CVI(CLL$(LOID))
LOCATE 10,13:PRINT " MAGNITUD (lb) = ":AUX;
LOCATE 40:INPUT " MODIFY (Y/N) : ",E$
  IF E$="Y" THEN
    AUX=0
    WHILE AUX=0
      GOSUB 4
      WEND
    GET #5,STOREF:LSET CLL$(LOID)=MK$(AUX):PUT #5,STOREF
  END IF
  GET #5,STOREF:ALX=CVI(LOLL$(LOID))
LOCATE 15,13:PRINT " NODE OF APPLICATION = ":AUX;
LOCATE 40:INPUT " MODIFY (Y/N) : ",E$
  IF E$="Y" THEN
    AUX=0:CH$="N"
    WHILE AUX<1 OR AUX>NMAX OR CH$="Y"
      GOSUB 4
      ND=AUX:IF STOREF<NSTOR THEN CALL LOADCHECK
    WEND
    GET #5,STOREF:LSET LOLL$(LOID)=MK$(AUX):PUT #5,STOREF
  END IF
END IF
END IF
IF STOREF<NSTOR THEN ERASE BN,BCN,BPN,ICN,IPN,ULN
CONCRETE CHARACTERISTICS CAN BE MODIFIED, ALL VALUES ARE STORED IN A
LEVEL OR STORY RECORD WHICH BELONGS TO FILE BUILDING.DAT
CLS:GOSUB 2
LOCATE 6,15:PRINT "CONCRETE SLAB CHARACTERISTICS : 
GET #5,STOREF:AUX=CVI(GAM$)
LOCATE 10,5:PRINT "ACTUAL UNIT WEIGHT (pcf) = " AUX;
LOCATE ,40:INPUT "MODIFY (Y/N) ; ",E$:IF E$="Y" THEN GOSUB 4
LSET GAMS=MKS$(ABS(AUX)):PUT #5,STOREF
GET #5,STOREF:AUX=CVS(FC3$)
LOCATE 12,5:PRINT "ACTUAL 3 DAY STRENGTH (ksi) = " AUX;
LOCATE ,40:INPUT "MODIFY (Y/N) ; ",E$:IF E$="Y" THEN GOSUB 4
LSET FC3$=MKS$(ABS(AUX)):PUT #5,STOREF
GET #5,STOREF:AUX=CVS(FC28$)
LOCATE 14,5:PRINT "ACTUAL 28 DAY STRENGTH (ksi) = " AUX;
LOCATE ,40:INPUT "MODIFY (Y/N) ; ",E$:IF E$="Y" THEN GOSUB 4
LSET FC28$=MKS$(ABS(AUX)):PUT #5,STOREF
GET #5,STOREF:AUX=CVS(P$)
LOCATE 16,5:PRINT "ACTUAL POISSON RATIO = " AUX;
LOCATE ,40:INPUT "MODIFY (Y/N) ; ",E$:IF E$="Y" THEN GOSUB 4
LSET P$=MKS$(ABS(AUX)):PUT #5,STOREF
RETURN

SUPPORT CONDITIONS CAN BE MODIFIED, FOR A GIVEN PERIMETRAL NODE THE
THREE EXISTING DEGREES OF FREEDOM CONDITIONS ARE SHOWN AND SO ANY
CHANGE CAN BE PERFORMED AND THEN STORED IN A FILE WHICH EXISTS FOR
EVERY FLOOR. THE CONTRIBUTION OF SERVICE AREA IF ANY CAN BE MODIFIED
REDIM SBAC$(3)
CLS:GOSUB 2
LOCATE 4,10:PRINT "REGARDING SUPPORT CONDITIONS : 
FILENAME$="SUPP"+STR$(STOREF)+".DAT";CALL OPENSUPPORT
CALL PERINODE
IF STOREF<NSTOR THEN CALL SERAVECTORS
LOCATE 7,20:PRINT "NUMBER OF PERIMETRAL NODES —— > " NPN
25 LOCATE 10,30:INPUT "NODE IDENTIFICATION : ",NOID
IF STOREF<NSTOR THEN
ND=NOID:CALL LOADCHECK
END IF
IF CH$="Y" THEN GOTO 25
DUM$="N":LA=∅
WHILE DUM$="N" AND LA<NPN
LA=LA+1:IF NOID=BN(LA) THEN DUM$="Y"
WEND
IF DUM$="N" THEN GOTO 25
26 CLS:LOCATE 10,20:PRINT "CONDITIONS OF NODE —— > " NOID
FOR KA=1 TO 3
    GET #4, LA; AUX=CVI(C$(KA))
    IF AUX=1 THEN SBAC$(KA)="RESTRICTED"
    IF AUX=0 THEN SBAC$(KA)=" FREE "
NEXT KA
LOCATE 15,15:PRINT " X DIRECTION -> " SBAC$(1)
PRINT TAB(15) " Y DIRECTION -> " SBAC$(2)
PRINT TAB(15) " Z DIRECTION -> " SBAC$(3)
M$=""
WHILE M$<>"N" AND M$<>"X" AND M$<>"Y" AND M$<>"Z"
    LOCATE 20,40:INPUT "WHICH ONE TO MODIFY (N/X/Y/Z) ",M$
WEND
IF M$<>"N" THEN
    IF M$="X" THEN KA=1
    IF M$="Y" THEN KA=2
    IF M$="Z" THEN KA=3
    IND=CVI(C$(KA))
    IF IND=0 THEN
        LSET C$(KA)=MKI$(1)
    ELSE
        LSET C$(KA)=MKI$(0)
    END IF
    PUT #4,LA
LOCATE 21,10
INPUT " MODIFY ANOTHER DEGREE OF FREEDOM CONDITION ? (Y/N) : ",F$
IF F$="Y" THEN GOTO 26
END IF
LOCATE 23,20:INPUT " CONSIDER ANOTHER NODE ? (Y/N) : ",A$
IF A$="Y" THEN
    CLOSE #4
    IF STOREF<STOR THEN
        ERASE BBN,SBAC$
        CLOSE #4
    END IF
    ERASE BCN,BPN,ICN,IPN,ULN
    GET #5,STOREF:DUM$="NO";BRA=CVI(BRA$):IF BRA=1 THEN DUM$="YES"
    CLS:LOCATE 10,10:PRINT "REGARDING SERVICE AREA :"
    LOCATE 15,10:PRINT "OFFERS SUPPORT TO STRUCTURE --> " DUM$
    M$="N":LOCATE 20,40:INPUT "MODIFY (Y/N) : ",M$
    IF M$="Y" THEN
        IF BRA=1 THEN
            LSET BRA$=MKI$(1)
        ELSE
            LSET BRA$=MKI$(0)
        END IF
        PUT #5,STOREF
    END IF
END IF
END IF
RETURN
ADDLEV:
A NEW LEVEL CAN BE ADDED TO BUILDING, THE NEW LEVEL CAN BE ANYWHERE
IN THE STRUCTURE, HEIGHT OF REMAINING LEVELS WILL BE UPDATED
CLS:E$="":STOREF=NSTOR
IF NSTOR=23 THEN
  LOCATE 10,20:PRINT "NUMBER OF LEVELS LIMIT HAS BEEN REACHED"
  LOCATE 20,30:PRINT "PRESS ANY KEY TO CONTINUE"
  E$="":WHILE E$="":E$=INKEY$:WEND
  CLS:RETURN
ELSE
  LOCATE 10,30:PRINT "THERE ARE " NSTOR " LEVELS"
  LOCATE 15,10:PRINT "GIVE LEVEL ABOVE WHICH NEW ONE IS TO BE:"
  STOREF=1
  WHILE STOREF<0 OR STOREF>NSTOR
    LOCATE 17,50:INPUT "—> " ,STOREF
  WEND
  IF STOREF=NSTOR THEN
    CLS
    LOCATE 3,5:PRINT "REGARDING FORMER ROOF LEVEL:"
    LOCATE 6,10:INPUT "LIVE LOAD (psf) = " ,AUX
    GET #5,STOREF:LSET LIVE$=MKS$(AUX)
    LSET ROOF$=MKS$(0):PUT #5,STOREF
    LOCATE 10,10
    CALL BAPEAT
    GOSUB G
    GOSUB INPSEA
    STOREF=STOREF+1:NSTOR=STOREF
    AU$="Y": GOSUB 7
  ELSE
    REDIM SBAC$(NSTOR+1)
    IF STOREF>0 THEN
      FOR IA=1 TO STOREF
        GET #5,IA:SBAC$(IA)=REC5$
        FILENAME$="SUPP"+STR$(IA)+".DAT":CALL OPENSUPPORT
        FILEBAC$="SUPP"+STR$(IA)+".BAC":CALL OPENBAC
        NPN=LOF(4)/6
        FOR JA=1 TO NPN
          GET #4,JA:ALUX$=REC4$
          LSET REC8$=ALUX$:PUT #8,JA
        NEXT JA
        CLOSE #4,#8
      NEXT IA
      END IF
    STOREFABOVE=STOREF+1
    FOR IA=STOREFABOVE TO NSTOR
      GET #5,IA:SBAC$(IA+1)=REC5$
      FILENAME$="SUPP"+STR$(IA+1)+".DAT":CALL OPENSUPPORT
      FILEBAC$="SUPP"+STR$(IA+1)+".BAC":CALL OPENBAC
      NPN=LOF(4)/6
    NEXT IA
  END IF
END IF
STOREFABOVE=STOREF+1
FOR IA=STOREFABOVE TO NSTOR
  GET #5,IA:SBAC$(IA)=REC5$
  FILENAME$="SUPP"+STR$(IA)+".DAT":CALL OPENSUPPORT
  FILEBAC$="SUPP"+STR$(IA)+".BAC":CALL OPENBAC
  NPN=LOF(4)/6
NEXT IA
FOR JA=1 TO NPN
    GET #4,JA:AUX$=REC4$
    LSET REC8$=AUX$:PUT #8,JA
NEXT JA
CLOSE #4,#8
NEXT IA
CLOSE #5
KILL "BUILDING.DAT"
FOR KA=1 TO NSTOR
    FILENAME$="SUPP"+STR$(KA)+".DAT";KILL FILENAME$
NEXT KA
CALL OPENBUILD
STOREF=STOREF+1;NSTOR=NSTOR+1
FOR IA=1 TO NSTOR
    LSET REC5$=SBAC$(IA):PUT #5,IA
    IF IA=STOREF THEN
        FILENAME$="SUPP"+STR$(IA)+".DAT";CALL OPENSUPPORT
        FILEBAC$="SUPP"+STR$(IA)+".BAC";CALL OPENBAC
        NPN=LOF(8)/6
        FOR JA=1 TO NPN
            GET #8,JA:AUX$=REC8$
            LSET REC4$=AUX$:PUT #4,JA
        NEXT JA
        CLOSE #4,#8
        KILL FILEBAC$
    END IF
NEXT IA
ERASE SBAC$
AU$="Y";GOSUB 7
GET #5,STOREF;HEAUX1=CVS(HEIGHT$)
IF STOREF=1 THEN
    GET #5,STOREF-1;HEAUX2=CVS(HEIGHT$)
ELSE
    HEAUX2=0
END IF
HEDIF=HEAUX1-HEAUX2
STOREFABOVE=STOREF+1
FOR IA=STOREFABOVE TO NSTOR
    GET #5,IA;HE=CVS(HEIGHT$)
    HE=HE+HEDIF:LSET HEIGHT$=MKS$(HE):PUT #5,IA
NEXT IA
END IF
END IF
CLS
RETURN
DELLEV:

' ANY EXISTING FLOOR CAN BE DELETED, HEIGHTS OF THE REMAINING LEVEL
' ARE UPDATED

IF NSTOR=1 THEN

LOCATE 12,20:PRINT "** ONLY ONE LEVEL EXISTS **"
LOCATE 14,20:PRINT "****** CAN NOT DELETE ******"
E$="":WHILE E$="":E$=INKEY$:WEND
CLS:RETURN

END IF

CLS:E$="" :LOCATE 2,10:PRINT "BUILDING HAS " NSTOR " LEVELS"
REDIM SBAC$(NSTOR-1)
STOREF=-1
WHILE STOREF<0 OR STOREF>NSTOR

LOCATE 10,30:INPUT " LEVEL TO DELETE ----> ",STOREF
WEND

IF STOREF=0 THEN RETURN

' WHEN ROOF LEVEL IS DELETED, NEED TO HAVE ROOF LOAD INSTEAD OF LIVE
' IN THE NEW UPPERMOST LEVEL

IF STOREF=NSTOR THEN

DUM=STOREF:STOREF=STOREF-1
GET #5,STOREF:AUX1=CVS(LIVE$)
CLS:LOCATE 5,10:PRINT "ON LEVEL " STOREF " WHICH WILL BE ROOF LEVEL"
LOCATE 7,5:PRINT "LIVE LOAD (psf) = " AUX1;
K$="E"
WHILE K$<>"Y" AND K$<"N"

LOCATE 9,35:INPUT "DO YOU WANT IT TO BE THE ROOF LOAD (Y/N) : ",K$
WEND

IF K$="Y" THEN

LSET ROOF$=MKS$(AUX1):PUT #5,STOREF
ELSE

LOCATE 11,15:INPUT "ROOF LOAD (psf) = ",AUX
LSET ROOF$=MKS$(AUX):PUT #5,STOREF
END IF

LSET LIVE$=MKS$(0):PUT #5,STOREF
STOREF=DUM

END IF

' BUILDING INFORMATION IS BACKED UP IN A MEMORY ARRAY WHILE FOR STORING
' SUPPORT CONDITIONS TEMPORALY NEW FILES NEED TO BE CREATED

IF STORE>1 THEN

IND1=STOREF-1
FOR IA=1 TO IND1

GET #5,IA:AUX$=REC5$;SBAC$(IA)=AUX$
FILENAME$="SUPP"+STR$(IA)+".DAT" :CALL OPENSUPPORT
NPN=LOF(4)/6
FILEBAC$="SUPP"+STR$(IA)+".BAC" :CALL OPENBAC
FOR JA=1 TO NPN

GET #4,JA:AUX$=REC4$
LSET REC8$=AUX$:PUT #8,JA
NEXT JA
CLOSE #4,#8
NEXT IA
END IF
IF STOREF< NSTOR THEN
IND2=STOREF+1
FOR IA=IND2 TO NSTOR
  GET #5, IA-1: HE=CVS(HEIGHT$)
  GET #5, IA: LSET HEIGHT$=MKGS(HE): PUT #5, IA
  GET #5, IA: AUX$=REC5$: SBAC$(IA-1)=AUX$
  FILENAME$="SUPP"+STR$(IA)+".DAT": CALL OPENSUPPORT
  NPN=LOF(4)/6
  FILEBAC$="SUPP"+STR$(IA-1)+".BAC": CALL OPENBAC
  FOR JA=1 TO NPN
    GET #4, JA: AUX$=REC4$
    LSET REC8$=AUX$: PUT #8, JA
  NEXT JA
  CLOSE #4,#8
NEXT IA
END IF
CLOSE #5
KILL "BUILDING.DAT"
FOR KA=1 TO NSTOR
  FILENAME$="SUPP"+STR$(KA)+".DAT": KILL FILENAME$
NEXT KA
NSTOR=NSTOR-1
NEW FILES ARE CREATED HAVING ONE STORY LESS
CALL OPENBUILD
FOR IA=1 TO NSTOR
  LSET REC5$=SBAC$(IA): PUT #5, IA
  FILENAME$="SUPP"+STR$(IA)+".DAT": CALL OPENSUPPORT
  FILEBAC$="SUPP"+STR$(IA)+".BAC": CALL OPENBAC
  NPN=LOF(8)/6
  FOR JA=1 TO NPN
    GET #8, JA: AUX$=REC8$
    LSET REC4$=AUX$: PUT #4, JA
  NEXT JA
  CLOSE #4,#8
NEXT IA
CLS: ERASE SBAC$
RETURN
INPGEO:
' L1, L2, DEPTH ARE INPUT AND CHECKED TO MEET THE FOLLOWING REQUIREMENTS:
' LEAST SPAN/4 > DEPTH > LEAST SPAN/40
' SPACING IS TWO TIMES DEPTH, L1 AND L2 MUST BE INTEGER MULTIPLES OF
' THE VALUE OF SPACING
IF LS>LB THEN
   L1=LB; L2=LS
ELSE
   L1=LS; L2=LB
END IF
DEPTMIN=L1/40; DEPTMAX=L1/4
IF ES<>"Y" AND L1AUX=L1 AND L2AUX=L2 THEN GOTO S;
IF ES="Y" THEN
   8 INPUT "USE DEPTH=LMIN/20? (Y/N) : ", DS
   IF DS<>"Y" AND DS<>"N" THEN GOTO 8
   ELSE
      DS="Y"
   END IF
   IF DS="Y" THEN
      DEPTH=L1/20
      IF DEPTH<INT(DEPTH) THEN
         DEPTH=CINT(DEPTH); L1=DEPTH*20
      END IF
      SPAC=DEPTH*2; K2=L2/SPAC: IF K2<>INT(K2) THEN L2=CINT(K2)*SPAC
   ELSE
      9 INPUT " DEPTH (inches) = ", DEPTH: DEPTHCINT(DEPTH)
      IF DEPTH<DEPTMIN OR DEPTH>DEPTMAX THEN
         PRINT "*** DEPTH OUT OF RANGE ***"
         GOTO 9
      END IF
   END IF
S: SPAC=2*DEPTH; K1=L1/SPAC: IF K1<>INT(K1) THEN L1=CINT(K1)*SPAC
   K2=L2/SPAC: IF K2<>INT(K2) THEN L2=CINT(K2)*SPAC
END IF
RETURN

INPSEA:
' ALL FLOORS EXCEPT ROOF LEVEL MUST BE GIVEN A SERVICE AREA SO THAT
' COMMUNICATION MAY EXIST BETWEEN LEVEL BELOW AND THE ONE ABOVE.
' BY IDENTIFYING CORNER NODES THE PERIPHERY OF THIS AREA CAN BE DEFINED
' AS WELL AS THOSE NODES WHICH WILL NOT EXIST IN STRUCTURE
' WHILE INPUTTING NODE NUMBERS THESE ARE CHECKED SO THAT A RECTANGLE IS
' DEFINED BY THEM
PRINT " REGARDING SERVICE AREA, GIVE FOUR CORNER NODES : 
10 INPUT " NODE 1 = ", NOD(1): GOSUB GETCOR
   IF COR(1,3)<>DEPTH OR (A(1)+1-KRES)<1 THEN
      PRINT "*** WRONG NODE NUMBER ***"
      GOTO 10
   END IF
   LSET ND1$=MK$(NOD(1)): PUT #5, STOREF: ND1=NOD(1)
11 INPUT " NODE 2 = ",NOD(1):GOSUB GETCOR
   IF COR(1,3)<DEPTH OR (NOD(1)-ND1)<=0 OR (NOD(1)-ND1+1)>A(1) THEN
      PRINT "*** WRONG NODE NUMBER ***"
      GOTO 11
   END IF
   LSET ND2?=MKI?(NOD(1)):PUT #5,STOREF:ND2=NOD(1)
12 INPUT " NODE 3 = ",NOD(1);KAUX1=NOD(1)-ND1
   IF KAUX1/GAP<>INT(KAUX1/GAP) OR KAUX1>GAP*(A(2)-1) THEN
      PRINT "*** WRONG NODE NUMBER ***"
      GOTO 12
   END IF
   LSET ND3?=MKI?(NOD(1)):PUT #5,STOREF:ND3=NOD(1)
13 INPUT " NODE 4 = ",NOD(1):KAUX=*(TOD(1)-ND2)
   IF KAUX/GAP<>INT(KAUX/GAP) OR KAUX<KAUX1 THEN
      PRINT "*** WRONG NODE NUMBER ***"
      GOTO 13
   END IF
   LSET ND4?=MKI?(NOD(1)):PUT #5,STOREF:ND4=NOD(1):CLS:LOCATE 10,10
   INPUT "DOES SERVICE AREA OFFER SUPPORT TO STRUCTURE (Y/N)? ",S?
   LSET BRA?=MKI?(0)
   IF S?="Y" THEN LSET BRA?=MKI$(1)
   PUT #5,STOREF RETURN

CREAST:
  CREATION OF BUILDING INFORMATION FILES
   CLS:AUS="N"
   CALL OPENBUILD
   IF LOF(5)>5 THEN
      LOCATE 10,10
      PRINT "EXISTING INFORMATION ABOUT BUILDING IS BEING LOST"
      CLOSE #5:KILL "BUILDING.DAT"
      CALL OPENBUILD
   END IF
   LOCATE 10,10:PRINT "BUILDING CHARACTERISTICS ARE TO BE INPUT ",NSTOR=0
   WHILE NSTOR<1 OR NSTOR>23
      LOCATE 15,15:INPUT " NUMBER OF LEVELS : ",NSTOR
   END
   FOR STOREF=1 TO NSTOR
      LOCATE 3,20:PRINT "NUMBER OF LEVELS = ",NSTOR
      LOCATE 5,10:PRINT " FOR LEVEL No. " STOREF;
      IF STOREF=NSTOR THEN PRINT " WHICH IS ROOF LEVEL "
      LOCATE 7,15:INPUT " HEIGHT (ft) = ",H
      IF STOREF>1 THEN
         GET #5,STOREF-1;HE=CVS(HEIGHT$)
      END IF
      IF H<=HE THEN
         PRINT "*** INPUT ERROR REGARDING HEIGHT INFORMATION ***"
         E$="":WHILE E$="":E$=INKEY$:WEND
GOTO 7
END IF
END IF
LSET HEIGHT$=MKS$(H):PUT #5,STOREF
LOCATE 9,15:INPUT " LEAST PLAN DIMENSION (ft) = ",LS:LS=LS*12
LOCATE 11,15:INPUT " OTHER DIMENSION (ft) = ",LB:LB=LB*12
ES="Y";GOSUB INPGEO
GOSUB DEFGRID
LSET L1$=MKS$(L1):PUT #5,STOREF:LSET L2$=MKS$(L2):PUT #5,STOREF
LSET DEPTH$=MKS$(DEPTH):PUT #5,STOREF
LOCATE 5,15:INPUT " Slab thickness (inches)= ",THI
LSET THICK$=MKS$(ABS(THI)):PUT #5,STOREF
LOCATE 7,15:INPUT " F'c(3 DAYS) (k/in2) = ",FC
LSET FC3$=MKS$(FC):PUT #5,STOREF
LOCATE 9,15:INPUT " F'c(28 DAYS) (k/in2) = ",FC
LSET FC28$=MKS$(FC):PUT #5,STOREF
LOCATE 11,15:INPUT "Concrete U.Weight (pcf)= ",G
LSET GAMS=MKI$(G):PUT #5,STOREF
LOCATE 13,15:INPUT "Concrete Poisson Ratio = ",P
LSET PS=MKS$(P):PUT #5,STOREF
CLS:LOCATE 5,15:PRINT " THERE ARE TWO TYPES OF CONSTRUCTION : ":
LOCATE 10,25:PRINT "1) SLAB CAST ON GROUND"
LOCATE 15,25:PRINT "2) SLAB CAST ON SITE"
SEL=0:WHILE SEL<1 OR SEL>2
LOCATE 22,45:INPUT "OPTION (1/2) : ",SEL:WEND
GOSUB CONSTASSIGN
CLS:LOCATE 3,15:PRINT " REGARDING LEVEL No. " STOREF
LOCATE 10,25:INPUT "DEAD LOAD IN ADDITION TO SELF-WEIGHT (psf) = ";D
LSET DEAD$=MKS$(D):PUT #5,STOREF
LOCATE 18,20
IF STOREF<NSTOR THEN
  R=0:INPUT "LIVE LOAD (psf) = ";D
ELSE
  D=0:INPUT "ROOF LOAD (psf) = ";R
END IF
LSET LIVE$=MKS$(D):LSET ROOF$=MKS$(R):PUT #5,STOREF
ELEMTYPE=0
IF STOREF<NSTOR THEN
  GOSUB INPSEA
  CALL SERAVECTORS
END IF
CLS:LOCATE 8,15:PRINT "REGARDING LEVEL No. " STOREF
NCL=-1
WHILE NCL<0 OR NCL>23
  LOCATE 12,10:INPUT "NUMBER OF CONCENTRATED DEAD LOADS : ";NCL
  IF NCL>23 THEN PRINT "*** MAXIMUM NUMBER OF LOADS IS 23 ***"
WEND
FOR CL=1 TO 23
  LSET CDL$(CL)=MKS$(0):PUT #5,STOREF
LSET LODL$(CL)=MKI$(0):PUT #5,STOREF
NEXT CL
IF NCL>0 THEN
    FOR CL=1 TO NCL
        CLS:LOCATE 5,10
        LD=0:PRINT "CONCENTRATED VERTICAL DEAD LOAD No. " CL
        WHILE LD=0
            LOCATE 15,30:INPUT "MAGNITUD (lb) : ",LD
            WEND
        LSET CDL$(CL)=MKI$(LD):PUT #5,STOREF
        ND=0:CH$="N"
        WHILE ND<1 OR ND>NMAX OR CH$="Y"
            LOCATE 20,30:INPUT "NODE OF APPLICATION : ",ND
            IF STOREF<NSTOR THEN CALL LOADCHECK
        WEND
        LSET LODL$(CL)=MKI$(ND):PUT #5,STOREF
    NEXT CL
END IF
CLS:LOCATE 8,15:PRINT " REGARDING LEVEL No. " STOREF
NCL=-1
WHILE NCL<0 OR NCL>23
    LOCATE 12,10:INPUT "NUMBER OF CONCENTRATED LIVE LOADS : ",NCL
    IF NCL>23 THEN PRINT "*** MAXIMUM NUMBER OF LOADS IS 23 ***"
WEND
FOR CL=1 TO 23
    LSET CLL$(CL)=MKI$(0):PUT #5,STOREF
    LSET LOLL$(CL)=MKI$(0):PUT #5,STOREF
NEXT CL
IF NCL>0 THEN
    FOR CL=1 TO NCL
        CLS:LOCATE 5,10:PRINT "CONCENTRATED VERTICAL LIVE LOAD No. " CL
        LD=0
        WHILE LD=0
            LOCATE 15,30:INPUT "MAGNITUD (lb) : ",LD
            WEND
        LSET CLL$(CL)=MKI$(LD):PUT #5,STOREF
        ND=0:CH$="N"
        WHILE ND<1 OR ND>NMAX OR CH$="Y"
            LOCATE 20,30:INPUT "NODE OF APPLICATION : ",ND
            IF STOREF<NSTOR THEN CALL LOADCHECK
        WEND
        LSET LOLL$(CL)=MKI$(ND):PUT #5,STOREF
    NEXT CL
END IF
CLS:LOCATE 3,15:PRINT " REGARDING LEVEL No. " STOREF
FILENAME$="SUPP"+STR$(STOREF)+".DAT"
CALL OPENSUPPORT
IF LOF(4)>0 THEN
    CLOSE #4
KILL FILENAME$ 
CALL OPENSUPPORT 
END IF 
CALL PERINODE 
ELEMTYPE=0 
FOR ZI=1 TO NPN 
   NOD(1)=BN(ZI):ND=NOD(1):CH$="N" 
   IF STOREF<INSTOR THEN CALL LOADCHECK 
   IF CH$<>"Y" THEN GOSUB 18 
NEXT ZI 
ERASE BN 
CLOSE #4 
IF AU$="Y" THEN RETURN 
NEXT STOREF 
CLOSE #5 
RETURN 

' INPUT OF SUPPORT CONDITIONS FOR EVERY PERIMETRAL NODE 
18 GOSUB GETCOR 
CLS:LOCATE 2,30:PRINT "THERE ARE " NPN "PERIMETRAL NODES " 
LOCATE 5,25:PRINT "REGARDING SUPPORT CONDITIONS :" 
LOCATE 7,10:PRINT " NODE IDENTIFICATION : " NOD(1) 
LOCATE 9,20:PRINT " X COORDINATE (in) = " COR(1,1) 
LOCATE 10,20:PRINT " Y COORDINATE (in) = " COR(1,2) 
LOCATE 12,5:PRINT "GIVE 0 IF DISPLACEMENT IS : " 
LOCATE 13,30:PRINT "FREE TO OCCUR IN THE INDICATED DIRECTION" 
LOCATE 15,5:PRINT "GIVE 1 IF DISPLACEMENT IS : " 
LOCATE 16,30 
PRINT "RESTRAINED FROM OCCURRING IN THE INDICATED DIRECTION" 
X=2:WHILE X<>0 AND X<>1:LOCATE 18,5:INPUT " X DIRECTION = ",X:WEND 
LSET C$(1)=MKI$(X):PUT #4,ZI 
Y=2:WHILE Y<>0 AND Y<>1:LOCATE 20,5:INPUT " Y DIRECTION = ",Y:WEND 
LSET C$(2)=MKI$(Y):PUT #4,ZI 
Z=2:WHILE Z<>0 AND Z<>1:LOCATE 22,5:INPUT " Z DIRECTION = ",Z:WEND 
LSET C$(3)=MKI$(Z):PUT #4,ZI 
LOCATE 23,60:PRINT "ANY KEY TO CONTINUE" 
E$="":WHILE E$="":E$=INKEY$:WEND 
RETURN 

DEFGRID: 
' SUBROUTINE TO DISPLAY GENERAL GEOMETRY OF STRUCTURE 
CLS:PRINT:PRINT TAB(10) "SPACE TRUSS IN LEVEL No. " 
STOREF:PRINT:PRINT 
A(l)=L1/SPAC:A(2)=L2/SPAC 
D$: PRINT TAB(20) " DEPTH (inches) : ",DEPTH:PRINT:PRINT 
PRINT TAB(15) "IN THE SHORT DIRECTION : " L1:PRINT 
PRINT TAB(5) "UPPER MESH CHARACTERISTICS : "; 
PRINT TAB(40) " NUMBER OF NODES = " A(l)+1 
PRINT TAB(40) " NUMBER OF ELEMENTS = " A(l):PRINT
PRINT TAB(5) "LOWER MESH CHARACTERISTICS : ";
PRINT TAB(40) " NUMBER OF NODES = " A(1)
PRINT TAB(40) " NUMBER OF ELEMENTS = " A(1)-1:PRINT:PRINT
PRINT TAB(15) "IN THE LONG DIRECTION : SPAN (in) : " L2:PRINT
PRINT TAB(5) "UPPER MESH CHARACTERISTICS : ";
PRINT TAB(40) " NUMBER OF NODES = " A(2)+1
PRINT TAB(40) " NUMBER OF ELEMENTS = " A(2):PRINT
PRINT TAB(5) "LOWER MESH CHARACTERISTICS : ";
PRINT TAB(40) " NUMBER OF NODES = " A(2)
PRINT TAB(40) " NUMBER OF ELEMENTS = " A(2)-1:PRINT
E$="": WHILE E$="": E$=INKEY$:WEND
G: CLS: GAP=A(1)*2+ls NMAX=(A(1)+1)*(A(2)+1)+A(1)*A(2)
RETURN

GETCOR:

NNODE=1
FOR IAUX=1 TO NNODE
KAUX=(NOD(IAUX)-1)/GAP
KRES=NOD(IAUX)-INT(KAUX)*GAP
IF KRES>A(1)+1 THEN
   KL=SPAC/2
   COR(IAUX,1)=(KRES-A(1)-2)*SPAC+KL: COR(IAUX,2)=KL+INT(KAUX)*SPAC
   COR(IAUX,3)=0
ELSE
   COR(IAUX,1)=(KRES-1)*SPAC: COR(IAUX,2)=INT(KAUX)*SPAC
   COR(IAUX,3)=DEPTH
END IF
NEXT IAUX
RETURN

CONSTASSIGN:

GET #5, STOREF: SEL=CVI(CONTYP$)
IF SEL=1 THEN
   CONSTYP$="ON GROUND"
ELSE
   CONSTYP$="ON SITE"
END IF
RETURN

CONSTSTORE:

GET #5, STOREF
IF SEL=1 THEN
   LSET CONTYP$=MKI$(1)
ELSE
   LSET CONTYP$=MKI$(2)
END IF
PUT #5, STOREF
RETURN
APPENDIX G

PROGRAM MODULE ELIO21

' COMPILED SO THAT EXECUTION MAY BE STOPPED AT ANY POINT
REM $DYNAMIC $INCLUDE : 'COMEEPM.BAS'
REDIM A(2),C$(3),CDL$(23),CLS$(23),COR(4,3),LODSL$(23),LOLL$(23),_
LTYPE2$(7,3),LTYPE3$(7),LTYPE6$(7,3),LTYPE62$(7,3),NOD(4),VONMS$(7,2)_
KEY(10) ON
ON KEY(10) GOSUB QUIT
TERMS="N"
WHILE TERMS<"Y"
    CLS
    LOCATE 3,30:PRINT "MAIN MENU : "
    LOCATE 5,20:PRINT "1) STRUCTURE INFORMATION"
    LOCATE 7,20:PRINT "2) AVAILABLE CROSS SECTIONS"
    LOCATE 9,20:PRINT "3) AVAILABLE JOINT PLATES"
    LOCATE 11,20:PRINT "4) STRUCTURAL DESIGN ACCORDING TO LRFD"
    LOCATE 13,20:PRINT "5) REVISION DURING CONSTRUCTION PHASE"
    LOCATE 15,20:PRINT "6) PRINT OUT OF DESIGN RESULTS"
    LOCATE 17,20:PRINT "7) TERMINATE"
    ELEN$="XX"
    WHILE ELEN$<"1" OR ELEN$>"7"
        LOCATE 20,25:PRINT "SELECTION ? ":ELEN$=INPUT$(1)
    WEND
    IF VAL(ELEN$)=1 THEN CHAIN "ELIO23"
    IF VAL(ELEN$)=2 THEN GOSUB CROSSECTION ELSE
        IF VAL(ELEN$)=3 THEN GOSUB PLATE ELSE
            IF VAL(ELEN$)=4 THEN GOSUB DESIGN ELSE
                IF VAL(ELEN$)=5 THEN GOSUB CONSCHECK ELSE
                    IF VAL(ELEN$)=6 THEN CHAIN "ELENA21"
                    IF VAL(ELEN$)=7 THEN GOSUB TERMINA
    WEND
    CLS
    END

QUIT:
    CLS:LOCATE 10,10:PRINT "EXECUTION HAS BEEN STOPPED BEFORE TERMINATION"
    LOCATE 22,40:PRINT "PRESS ANY KEY TO RETURN TO SYSTEM"
    E$="":WHILE E$="":E$=INKEY$:WEND
    CLS
    END
    RETURN

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CROSSECTION:

' SUBROUTINE TO HANDLE INFORMATION REGARDING AVAILABLE CROSS SECTIONS
TECS$="N"
WHILE TECS$="N"
    CLS:LOCATE 3,40:PRINT "ALTERNATIVES :
    LOCATE 10,30:PRINT "1) CHECK AVAILABLE CROSS SECTION FILE"
    LOCATE 13,30:PRINT "2) UPDATE THE INFORMATION"
    LOCATE 16,30:PRINT "3) QUIT"
    EL$="XX"
    WHILE EL$<"1" OR EL$>"3"
        LOCATE 20,40:PRINT "SELECTION —> ":EL$=INPUT$(1)
        WEND
    IF VAL(EL$)=1 THEN GOSUB CHECKSEC ELSE
        IF VAL(EL$)=2 THEN GOSUB UPDSEC ELSE
            IF VAL(EL$)=3 THEN GOSUB TECS
        WEND
    RETURN

TECS:

    TECS$="Y":RETURN

PLATE:

' SUBROUTINE TO HANDLE JOINT PLATES INFORMATION
TECS$="N"
WHILE TECS$="N"
    CLS:LOCATE 3,40:PRINT "ALTERNATIVES :
    LOCATE 10,30:PRINT "1) CHECK AVAILABLE JOINT PLATES FILE"
    LOCATE 13,30:PRINT "2) UPDATE THE INFORMATION"
    LOCATE 16,30:PRINT "3) QUIT"
    EL$="XX"
    WHILE EL$<"1" OR EL$>"3"
        LOCATE 20,40:PRINT "SELECTION —> ":EL$=INPUT$(1)
        WEND
    IF VAL(EL$)=1 THEN GOSUB CHECKPLATE ELSE
        IF VAL(EL$)=2 THEN GOSUB UPDPLATE ELSE
            IF VAL(EL$)=3 THEN GOSUB TECS
        WEND
    RETURN
CHECKSEC:
'DISPLAY AVAILABLE CROSS SECTIONS CHARACTERISTICS
CALL OPENSEC
NSEC=LOF(1)/40
IF NSEC>0 THEN
FOR I=1 TO NSEC
   CLS:LOCATE 3,45:PRINT "TOTAL OF AVAILABLE SECTIONS " NSEC
   LOCATE 5,12:PRINT "SECTION REFERENCE NUMBER = " I
   PRINT:GET #1,1
   PRINT:D=CVS(DIAM$):PRINT TAB(20) "DIAMETER = ";
   PRINT USING "##.##";D;:PRINT " in"
   PRINT USING "##.##";D:PRINT " AREA = ";
   PRINT USING "##.##";D:PRINT TAB(20) "INERTIA = ";
   PRINT USING "##.##";D:PRINT TAB(20) "WEIGHT = ";
   PRINT USING "##.##";D:PRINT TAB(20) "YOUNG'S M. = " D " ksi"
   PRINT:D=CVS(FY?):PRINT TAB(20) "Fy = " D " ksi"
   PRINT:D=CVS(STEELPRI?):PRINT TAB(20) "STEEL PRICE= " D " /lb"
   PRINT:D=CVS(WELDPRI?):PRINT TAB(20) "WELD PRICE = " D " /lb"
   PRINT:D?=WELDTY?:PRINT TAB(20) "WELD TYPE = " D?
NEXT I
ELSE
   LOCATE 10,20:PRINT " NO SECTIONS AVAILABLE"
END IF
CLOSE #1
RETURN

UPDSEC:
'UPDATE AVAILABLE CROSS SECTIONS FILE BY ADDING A NEW ONE OR DELETING
'AN EXISTING ONE
CLS:I$="":PI=3.14159:CALL OPENSEC
WHILE I$<"A" AND I$<"D"
   NSEC=LOF(1)/40:NMSUITS=NSEC+1:LOCATE 2,15
   PRINT " THERE ARE " NSEC "AVAILABLE CROSS SECTIONS":LOCATE 4,10
   INPUT "DO YOU WANT TO ADD OR DELETE A CROSS SECTION (A/D) ? : ",I$
   WEND
   IF I$="A" THEN
U:
   CLS:NSEC=NSEC+1
   LOCATE 2,15:PRINT "NEW CROSS SECTION REFERENCE NUMBER = " NSEC
   LOCATE 5,10:D=0
   WHILE D<=0 OR D>1.5:INPUT "Diameter (inches) = ",D:WEND
   LSET DIAMT=MKS$(D):PUT #1,NSEC
   LOCATE 8,10:F=0
   WHILE F<25 OR F>60:INPUT "Fy (ksi) = ",F:WEND
   LSET FYT=MKS$(F):PUT #1,NSEC
   LOCATE 11,10:E=0:WHILE E<20000:INPUT "Young's M. (ksi) = ",E:WEND
LSET MELAST$=MKS$(E): PUT #1,NSEC
LOCATE 14,10:S=0:WHILE S<0:INPUT "Steel Price ($/lb)= ",S:WEND
LSET STEELPRI$=MKS$(S):PUT #1,NSEC
LOCATE 17,10:W=0:WHILE W<0:INPUT "Weld Price ($/lb)= ",W:WEND
LSET WELDPRI$=MKS$(W):PUT #1,NSEC
PRINT:K$="10"
WHILE K$<"45" AND K$<"60" AND K$<"70"
   LOCATE 20,10:INPUT "Weld Type (AWS) = ",W$
   K$=LEFT$(W$,2)
WEND
LSET WELDTY$=W$:PUT #1,NSEC
A=PI*D^2/4:IN=PI*D^4/64:LSET AREA$=MKS$(A):PUT #1,NSEC:A^3.42
LSET INERTIA$=MKS$(IN):PUT #1,NSEC:LSET WEIGHT$=MKS$(A)
PUT #1,NSEC
IF NUMSUITS=0 THEN RETURN
ELSE
   IF NSEC=0 THEN
      CLOSE #1:RETURN
   END IF
   CLS:LOCATE 5,9
   PRINT "GIVE REFERENCE NUMBER FOR CROSS SECTION TO DELETE"
   SEC=-1
   WHILE SEC<0 OR SEC>NSEC
      LOCATE 10,30:INPUT " > ",SEC
   WEND
   IF SEC=0 THEN
      CLOSE #1
      RETURN
   ELSE
      GET #1,NSEC:RECS=RECORD$:LSET RECORDS=RECS:PUT #1,SEC
   END IF
   NSEC=NSEC-1
   REDIM AUX$(NSEC)
   FOR JA=1 TO NSEC:GET #1,JA:AUX$(JA)=RECORDS:NEXT JA
   CLOSE #1:KILL "AVSECT.DAT":CALL OPENSEC
   FOR JA=1 TO NSEC:LSET RECORDS=AUX$(JA):PUT #1,JA:NEXT JA
   ERASE AUXS
END IF
LOCATE 22,40:PRINT "PRESS <ENTER> TO MENU"
ES="":WHILE ES="":ES=INKEY$:WEND
IF ASC(ES)<13 THEN GOTO U:
   CLOSE #1
RETURN
CHECKPLATE:
' DISPLAY AVAILABLE JOINT PLATES CHARACTERISTICS
CALL OPENPLATE
NPLA=LOF(9)/16
IF NPLA>0 THEN
FOR I=1 TO NPLA
CLS:LOCATE 3,45:PRINT "TOTAL OF AVAILABLE PLATES : " NPLA
LOCATE 5,12:PRINT "PLATE REFERENCE NUMBER = " I
PRINT:GET #9,I
LOCATE 10,20:D=CVS(PLATHICK?): PRINT "THICKNESS = "
PRINT USING ".###";D; PRINT " in"
LOCATE 13,20:D=CVS(PLADIM?): PRINT "DIMENSION = "
PRINT USING ".###";D; PRINT " in"
LOCATE 16,20:D=CVS(PLAFY?): PRINT "YIELD STRESS= " D " ksi"
LOCATE 19,20:D=CVS(PLAPRI?): PRINT "STEEL PRICE = " D " $/lb"
ELSE
CLS:LOCATE 10,20:PRINT " NO PLATES AVAILABLE"
ENDIF
CLOSE #9
RETURN

UPDPLATE:
' UPDATE AVAILABLE JOINT PLATES FILE BY ADDING A NEW ONE OR DELETING
' AN EXISTING ONE
CLS:I$="":CALL OPENPLATE
WHILE I$<>"A" AND I$<>"D"
NPLA=LOF(9)/16:NUMSUITP=NPLA+1:LOCATE 2,15
PRINT " THERE ARE " NPLA "AVAILABLE JOINT PLATES"
INPUT "DO YOU WANT TO ADD OR DELETE A PLATE (A/D) ? : ",I$
WEND
IF I$="A" THEN
CLS:NPLA=NPLA+1
LOCATE 2,25:PRINT "NEW PLATE REFERENCE NUMBER = " NPLA
LOCATE 5,10:D=0
WHILE D<.250 OR D>1:INPUT "Thickness (inches) = ",D:WEND
LSET PLATHICK$=MKS$(D):PUT #9,NPLA
LOCATE 8,10:E=0:WHILE E<3.5:INPUT "Dimension (inches) = ",E:WEND
LSET PLADIM$=MKS$(E):PUT #9,NPLA
LOCATE 11,10:F=0
WHILE F<25 OR F>60:INPUT "Fy (ksi) = ",F:WEND
LSET PLAFY$=MKS$(F):PUT #9,NPLA
LOCATE 14,10:S=0:WHILE S<0:INPUT "Steel Price ($/lb) = ",S:WEND
LSET PLAPRI$=MKS$(S):PUT #9,NPLA
IF NUMSUITP=0 THEN RETURN
ELSE
IF NPLA=0 THEN
CLOSE #9
RETURN
END IF
CLS:LOCATE 5,9:PRINT "GIVE REFERENCE NUMBER FOR PLATE TO DELETE"
PLA=-1
WHILE PLA<0 OR PLA>NPLA
   LOCATE 10,30:INPUT "—— > ",PLA
WEND
IF PLA=0 THEN
   CLOSE #9:RETURN
ELSE
   GET #9,NPLA:RECS=RECORD9$:LSET RECORD9$:RECS=RECS:PUT #9,PLA
END IF
NPLA=NPLA-1
REDIM AUX(NPLA)
FOR JA=1 TO NPLA:GET #9,JA:AUX(JA)=RECORD9$:NEXT JA
CLOSE #9:KILL "AVPLATE.DAT";CALL OPENPLATE
FOR JA=1 TO NPLA:LSET RECORD9$=AUX(JA):PUT #9,JA:NEXT JA
ERASE AUX$"...
END IF
LOCATE 22,40:PRINT " PRESS <ENTER> TO MENU"
E$="":WHILE E$="":E$=INKEY$:WEND
IF ASC(E$)<>13 THEN GOTO V:
CLOSE #9
RETURN

OPTIMIZE:
' ONCE ACTIONS IN MEMBERS FROM INDIVIDUAL LOADING CONDITIONS HAVE BEEN
' EVALUATED AND STORED IN ADEQUATE FILE ASSUMING A CONFIGURATION OF THE
' TRUSS, THIS WILL BE REVISED FOR ANY REDUCTION OR INCREASE IN MEMBER
' SIZES THAT MAY BE NECESSARY.
' THE CRITERIA FOR CHOOSING THE OPTIMUM CROSS SECTION IS THAT OF LEAST
' COST REGARDING MEMBER SELFWEIGHT AS WELL AS THE AMOUNT OF WELDING MATE
' RIAL REQUIRED FOR ADEQUATE CONNECTION, FROM THE SIZE OF FILLET WELDS
' THE SIZES OF JOINT PLATES WILL BE OBTAINED AND STORED.
' THE THICKNESS OF THE PLATE WILL BE DEFINED THROUGH CONSIDERATION OF
' DIAGONAL MEMBERS ON THE BASIS OF BEING EQUAL TO FILLET SIZE, AND A MI-
' NIMUM PLANE DIMENSION REGARDING A MINIMUM EDGE DISTANCE OF ONE INCH TO
' ENSURE EASE OF LABOR AND HEAT DISSIPATION DURING WELDING.
' THE PLANES DIMENSION WILL BE CHECKED FOR LAYER GRID MEMBERS SO THAT
' THE SIZE OF THE REQUIRED FILLET DOES NOT EXCEED THE PLATE THICKNESS.
CLS:LOCATE 10,15:PRINT "PERFORMING REVISION OF MEMBERS"
REDIM LFAC(15,7),PLATEREF(STN)
REDIM LFIL1 (NUMGRIDMEM) ,LFIL2 (NUMGRIDMEM),RFILN (NUMDIAGMEM)
' EVALUATION OF LOAD FACTORS FOR THE 15 LOAD COMBINATIONS OF THE
' SEVEN INDIVIDUAL LOADING CONDITIONS
GOSUB LOADFACTOR
' CHECK FOR ANY CHANGE IN MEMBER CROSS SECTIONS
TOTCOST=0;COSTP=0;CALL OPENPLATE
ESTIMATE OF COST OF STEEL WORK IN SPACE TRUSS:

FOR I=1 TO STN
  GET #6, I: REF = CVI (REFL$)
  IF REF > 0 THEN
    GET #9, REF
    COSTP = COSTP + CVS (PLATHICK$) * (CVS (PLADIM$))^2 * CVS (PLAPRI$) * .285
  END IF
NEXT I

REGARDING JOINT PLATES —> COSTP

TOTAL —> TOTCOST

PRESS ANY KEY TO CONTINUE

SUBROUTINE TO OBTAIN STIFFNESS CHARACTERISTICS OF CONCRETE ELEMENTS
AS WELL AS TO GENERATE THE MATRIX THAT DO THE FOLLOWING:
TSLAB : TRANSFORM GLOBAL DISPLACEMENTS TO LOCAL
BASLAB : GENERATE STRAIN FROM LOCAL NODAL DISPLACEMENTS

EE = MELAON / (1 - PORCON*2) : EMAT(1, 1) = EE : EMAT(2, 2) = EE
EMAT(3, 3) = (1 - PORCON) * EE / 2 : EMAT(1, 2) = PORCON * EE / EMAT(2, 1) = EMAT(1, 2)
XG(4) = COR(2, 1) - COR(1, 1) : XG(5) = COR(2, 2) - COR(1, 2)
XG(6) = COR(2, 3) - COR(1, 3) : XG(7) = COR(3, 1) - COR(1, 1)
XG(8) = COR(3, 2) - COR(1, 2) : XG(9) = COR(3, 3) - COR(1, 3)
XG(10) = COR(4, 1) - COR(1, 1) : XG(11) = COR(4, 2) - COR(1, 2)
XG(12) = COR(4, 3) - COR(1, 3)
PQ(1) = XG(4) : PQ(2) = XG(5) : PQ(3) = XG(6)
PR(1) = XG(7) : PR(2) = XG(8) : PR(3) = XG(9)
CA(1) = PQ(2)*PR(3) - PQ(3)*PR(2) : CA(2) = PQ(3)*PR(1) - PQ(1)*PR(3)
CA(3) = PQ(1)*PR(2) - PQ(2)*PR(1)
PN(1) = CA(2)*PQ(3) - CA(3)*PQ(2)
PN(2) = CA(3)*PQ(1) - CA(1)*PQ(3) : PN(3) = CA(1)*PQ(2) - CA(2)*PQ(1)
PQ MAG = SQRT(PQ(1)^2 + PQ(2)^2 + PQ(3)^2) : PN MAG = SQRT(PN(1)^2 + PN(2)^2 + PN(3)^2)
FOR IA = 1 TO 3
  PQ(IA) = PQ(IA) / PQ MAG
  PN(IA) = PN(IA) / PN MAG
NEXT IA
FOR KA = 1 TO 4
  KM1 = KA - 1
  FOR JA = 1 TO 3
TSLAB(2*K-1,3*KM+JA)=PQ(JA):TSLAB(2*K,3*KM+JA)=N(JA)

NEXT JA

NEXT KA

FOR IA=1 TO 8
    FOR KA=1 TO 12
        X=XXL(IA)+TSLAB(IA,KA)*XG(KA)
    NEXT KA

NEXT IA

REDIM BTE(8,3),XII(4),ETI(4),QXL(4),QYL(4),SM(8,8)

XII(1)=1: XII(2)=1: XII(3)=1: XII(4)=1

ETI(1)=1: ETI(2)=1: ETI(3)=1: ETI(4)=1

QXL(1)=X+QXL(2)=X+QXL(3)=X+QXL(5)=X+QXL(4)=X+QXL(7)

QYL(1)=X+QYL(2)=X+QYL(3)=X+QYL(6)=X+QYL(8)

PV=0: PET=0

GOSUB QUADSHAPE

DV=THICK*DETJAC*4

FOR JA=1 TO 4
    LA=2*JA: KA=LA-1
    FOR NR=1 TO 3
        BTE(KA,NR)=BASLAB(1,KA)*EMAT(1,NR)+BASLAB(3,KA)*EMAT(3,NR)
        BTE(LA,NR)=BASLAB(2,LA)*EMAT(2,NR)+BASLAB(3,IA)*EMAT(3,NR)
    NEXT NR

NEXT JA

FOR NROW=1 TO 8
    FOR NCOL=NROW TO 8
        DUM=0
        FOR JA=1 TO 3
            DUM=DUM+BTE(NROW,JA)*BASLAB(JA,NCOL)
        NEXT JA

        SM(NROW,NCOL)=SM(NROW,NCOL)+DUM*DV

    NEXT NCOL

NEXT NROW

REDIM STE(8,12)

FOR KA=1 TO 7
    FOR LA=KA TO 8
        SM(LA)=SM(KA,LA)
    NEXT LA

NEXT KA

FOR IA=1 TO 8
    FOR JA=1 TO 12
        FOR KA=1 TO 8
            STE(IA,JA)=STE(IA,JA)+SM(IA,KA)*TSLAB(KA,JA)
        NEXT KA

    NEXT JA

NEXT IA

ERASE SM

REDIM SMSLAB(12,12)

FOR IA=1 TO 12
    FOR JA=1 TO 12
FOR KA = 1 TO 8
    SMSLAB(IA, JA) = SMSLAB(IA, JA) + TSLAB(KA, IA) * STE(KA, JA)
NEXT KA
NEXT JA
NEXT IA
ERASE CA, P, PR, PN, XG, XXL, STE, XII, ETI, QXL, QYL, STE
RETURN

DEFSIZE:
' DEFINE SIZE OF BANDWIDTH FOR SOLVING EQUATIONS
CALL BAFMAT
GOSUB G
BANDWIDTH = (GAP+2)*3
STN = (A(1)+1)*(A(2)+1)+A(1)*A(2): NEQ = STN*3: VECTORSIZE = BANDWIDTH*NEQ
CLS: LOCATE 2, 5: PRINT "LEVEL No. " STOREF
LOCATE 5, 15: PRINT " NUMBER OF STRUCTURE NODES = " STN
LOCATE 10, 15: PRINT " NUMBER OF UNKNOWN DISPLACEMENTS = " NEQ
LOCATE 15, 15: PRINT " BANDWIDTH = " BANDWIDTH
LOCATE 20, 15: PRINT " SIZE OF VECTOR = " VECTORSIZE
ELS="": WHILE EL$="": EL$=INKEY$: WEND
RETURN

DESIGN:
' STRUCTURE CONFIGURATION WILL BE DEFINED FROM THE AVAILABLE CROSS
' SECTIONS BY CONSIDERING LRFD SPECIFICATION AND ANSI LOADING
' UNDER SERVICE CONDITIONS, NO EARTHQUAKE LOADING IS TAKEN INTO ACCOUNT
PI=3.14159
CLS
' CHECK BUILDING CHARACTERISTICS FILE BEFORE BEGIN
CALL OPENBUIID
NSTOR = DOF(5)/236
IF NSTOR<1 THEN
    LOCATE 15, 20: PRINT " *** BUILDING CHARACTERICS FILE IS NOT READY ***"
    E$="": WHILE E$="": E$=INKEY$: WEND
    CLOSE #5
    RETURN
END IF
' DESIGN STRUCTURE IF MORE THAN TWO AVAILABLE SECTIONS EXIST
CALL OPENSEC
IF LOF(1)/40<3 THEN
    LOCATE 5, 20: PRINT " *** AVAILABLE SECTION FILE IS NOT READY ***"
    LOCATE 15, 20: PRINT " *** THERE MUST BE 3 SECTIONS AT LEAST ***"
    E$="": WHILE E$="": E$=INKEY$: WEND
    CLOSE #5, #1
    RETURN
END IF
' DESIGN STRUCTURE IF MORE THAN ONE AVAILABLE JOINT PLATES EXIST
CALL OPENPLATE
IF LOF(1)/16<2 THEN
LOCATE 5,20:PRINT "*** AVAILABLE PLATE FILE IS NOT READY ***"
LOCATE 15,20:PRINT "*** THERE MUST BE TWO PLATES AT LEAST ***"
E$="":WHILE E$="":E$=INKEY$:WEND
CLOSE #9,#5,#1
RETURN
END IF
CLOSE #9

WIND EFFECTS WILL BE CALCULATED ACCORDING TO ANSI
LOCATE 4,15:PRINT "GIVE THE FOLLOWING INFORMATION ABOUT STRUCTURE:"
CATEG=0
WHILE CATEG<1 OR CATEG>4
   LOCATE 8,20:INPUT "CATEGORY (1<->4):",CATEG
END WEND
EXP$="X"
WHILE EXP$<"A" AND EXP$<"B" AND EXP$<"C" AND EXP$<"D"
   LOCATE 11,20:INPUT "EXPOSURE (A,B,C,D):",EXP$ 
END WEND
HOL$="X"
WHILE HOL$<"Y" AND HOL$<"N"
   LOCATE 14,20:INPUT "AT HURRICANE OCEANLINE (Y/N):",HOL$ 
END WEND
LOCATE 17,20:INPUT "BASIC WIND SPEED (mi/hr):",BWIN
IF BWIN<70 THEN BWIN=70
IF EXP$="A" THEN
   ALFCON=3:ZGCON=1500:DOCON=.025
ELSEIF EXP$="B" THEN
   ALFCON=4.5:ZGCON=1200:DOCON=.01
ELSEIF EXP$="C" THEN
   ALFCON=7:ZGCON=900:DOCON=.005
ELSE
   ALFCON=10:ZGCON=700:DOCON=.003
END IF
IF CATEG=1 THEN
   IF HOL$="Y" THEN IFAC=1.05
   IF HOL$="N" THEN IFAC=1
ELSEIF CATEG=2 OR CATEG=3 THEN
   IF HOL$="Y" THEN IFAC=1.11
   IF HOL$="N" THEN IFAC=1.07
ELSE
   IF HOL$="Y" THEN IFAC=1
   IF HOL$="N" THEN IFAC=.95
END IF
GET #5,NSTOR:ZCOR=CVS(HEIGHT$)
IF ZCOR<15 THEN
   KZON=2.58*(15/ZGCON)^(.5)
ELSE
   KZON=2.58*(ZCOR/ZGCON)^(.5)
END IF
TZON=2.35*SQR(DOCON)/((ZCOR/30)^(.5)):GHCON=.65+.65*TZON
ROOF AND SIDE WALL PRESSURE IS INDEPENDENT OF INDIVIDUAL LEVEL HEIGHTS

ROWIP = 7*GCHON^0.256*KZCON/(IFAC*BWIND)^2

IF DESIRED ONLY A SPECIFIC STORY MAY BE DESIGNED, EVEN MAKING USE OF
THE INFORMATION THAT MAY EXIST FROM PREVIOUS ITERATIONS

CLS: ITERATION=0: SPLEVS="X"

WHILE SPLEVS<>"Y" AND SPLEVS<>"N"

LOCATE 5,10: INPUT "DESIGN A SPECIFIC LEVEL (Y/N) : ", SPLEVS

WEND

IF SPLEVS="Y" THEN

STORF=0

WHILE STOREF<1 OR STOREF>NSTOR

LOCATE 10,10: INPUT "LEVEL NUMBER --> ", STOREF

WEND

FILENAME $="SPTR"+STR$(STOREF)+".DAT": CALL OPENSPTR

K1=LOF(3): CLOSE #3: FILENAME$="SLAB"+STR$(STOREF)+".DAT"

CALL OPENSLAB

K2=LOF(7): CLOSED #7

IF K1>0 AND K2>0 THEN

LOCATE 15,5

PRINT "THERE EXISTS A FILE DEFINING TRUSS CONFIGURATION"

LOCATE 17,5: PRINT "IF IT CORRESPONDS TO THE MENTIONED LEVEL"

LOCATE 20,5: PRINT "DESIGN CAN START USING THAT CONFIGURATION"

LOCATE 23,5: PRINT "* UNPREDICTABLE ERROR MAY OCCUR IF FILE IS NOT CORRECT **"

USEANT$="X"

WHILE USEANT$<>"Y" AND USEANT$<>"N"

LOCATE 22,35: INPUT " USE IT (Y/N) ? --> ", USEANT$ 

WEND

IF USEANT$="Y" THEN ITERATION=1

ENDIF

ENDIF

IF SPLEVS="Y" THEN

STORLIMIT=STOREF

STOREF=STOREF-1

ELSE

STOREF=0

STORLIMIT=NSTOR

ENDIF

END IF

DESIGN OF SPACE TRUSSS REGARDING EACH STORY INDIVIDUALLY

WHILE STOREF<STORLIMIT

STOREF=STOREF+1

DEFINE TYPE OF CONSTRUCTION THAT WILL BE USED

CLS:LOCATE 5,15: PRINT "THERE ARE TWO TYPES OF CONSTRUCTION:"

DEFINE TYPE OF CONSTRUCTION THAT WILL BE USED

CLS: LOCATE 3,40: PRINT "LEVEL No.--> " STOREF

LOCATE 5,15: PRINT "THERE ARE TWO TYPES OF CONSTRUCTION:"

LOCATE 10,25: PRINT "1) SLAB CAST ON GROUND"

LOCATE 15,25: PRINT "2) SLAB CAST ON SITE"

GOSUB CONSTATASSIGN
LOCATE 22,45:PRINT "OPTION: " CONSTYPES
E$="":WHILE E$="":E$=INKEY$:WEND
FILENAME$="SUPP"+STR$(STOREF)+".DAT":CALL OPENSUPPORT
FILENAME$="SPTR"+STR$(STOREF)+".DAT":CALL OPENSPTR
IF LOF(3)>0 AND ITERATION=0 THEN
  CLOSE #3:KILL FILENAME$
  CALL OPENSPTR
END IF
FILENAME$="SLAB"+STR$(STOREF)+".DAT":CALL OPENSLAB
IF LOF(7)>0 AND ITERATION=0 THEN
  CLOSE #7:KILL FILENAME$
  CALL OPENSLAB
END IF
GET #5,STOREF
GAMMA=CVI(GAM$):THICK=CVS(THICK$):PORCON=CVS(P$):FC28D=CVS(FC28$)
MELOON=33*GAMMA^((3/2)*SQR(FC28D*1000)/1000)
MELOON=MELOON/2 'REDUCED MODULUS OF ELASTICITY ACCOUNTING FOR CREEP
GOSUB DEFSIZE
IF VECTORSIZE>128000 THEN
  LOCATE 23,30:PRINT "STRUCTURE IS TOO LARGE TO BE SOLVED"
  ELSE$="":WHILE ELSE$="":ELSE$=INKEY$:WEND
  RETURN
END IF
NUMDIAGMEM=0:NUMGRIDMEM=0:NUMSLABMEM=0
IF STOREF<NSTOR THEN
  CALL SERAVECTORS
ELSE
  CALL PERIVECTORS
END IF
' EVALUATE STORY TRIBUTARY HEIGHT
GET #5,STOREF:ZCOR=CVS(HEIGHT$):L1=CVI(L1$):L2=CVI(L2$)
IF STOREF>1 THEN
  GET #5,STOREF-1:K1=CVS(HEIGHT$)
ELSE
  K1=0
END IF
IF STOREF<NSTOR THEN
  GET #5,STOREF+1:K2=CVS(HEIGHT$)
ELSE
  K2=ZCOR
END IF
INFHE=(K2-K1)/2
' EVALUATE DIFFERENT PressURES ACTING AT STORY HEIGHT:
' ALOAD1 : WINDWARD WALL
' ALOAD2 : LEEWARD WALL FOR WIND ALONG X DIRECTION
' ALOAD3 : LEEWARD WALL FOR WIND ALONG Y DIRECTION
IF ZCOR<15 THEN
  KZCON=2.58*(15/ZGCON)^(2/ALFCON)
ELSE


\[
\begin{align*}
KZCON &= 2.58 \times (ZCOR/ZGOON) \times (2/ALFCON) \\
\end{align*}
\]

END IF

\[
\begin{align*}
TZCON &= 2.35 \times \sqrt{DOC0.M} \times (ZCOR/30) \times (1/ALPCON) \\
\end{align*}
\]

IF USEANT$ < "Y" THEN ITERATIONS

CYCLE$ = "N\$T\$READY"

WHILE CYCLE$ <> "READY"

SIK = INR(VECTORSIZE/8+1)

REDIM S1(SIK), S2(SIK), S3(SIK), S4(SIK)

REDIM S5(SIK), S6(SIK), S7(SIK), S8(SIK)

ITERATION = ITERATION + 1

CLS: LOCATE 5, 20: PRINT "WIND PRESSURES ON BUILDING (psf) : ">

LOCATE 10, 25: PRINT "WINDWARD WALL = " USING "#####.##"; ALQAD1

LOCATE 13, 25: PRINT "LEEWARD WALL = "

LOCATE 15, 30: PRINT "WIND IN X DIRECTION = " USING "#####.##"; ALOAD2

LOCATE 17, 30: PRINT "WIND IN Y DIRECTION = " USING "#####.##"; ALOAD3

LOCATE 20, 25: PRINT "SIDE WALLS = " USING "#####.##"; ROWIP

E$ = "" : WHILE E$ = "" : E$ = INKEY$ : WEND

ITERATIVE PROCESS THAT ENDS WHEN ALL MEMBER HAVE BEEN ASSIGNED THE

OPTIMUM CROSS SECTION

IF USEANT$ <> "Y" THEN ITERATION = 0

CYCLE$ = "N\$T\$READY"

WHILE CYCLE$ <> "READY"

SIK = INR(VECTORSIZE/8+1)

DUE TO THE SIZE OF THE STRUCTURE STIFFNESS MATRIX, IT IS NECESSARY TO

STORE THE COEFFICIENTS IN SMALLER ARRAYS THAT CAN BE HANDLED BY PER-

SONAL COMPUTERS. DOUBLE PRECISION IS USED IN HANDLING THE COEFFICIENTS

REDIM S1(SIK), S2(SIK), S3(SIK), S4(SIK)

REDIM S5(SIK), S6(SIK), S7(SIK), S8(SIK)

ITERATION = ITERATION + 1

CLS: LOCATE 7, 10: PRINT "PERFORMING ITERATION No. " ITERATION

DISPLACEMENTS WILL BE STORED IN FILE FOR LATER USE

FILENAME$ = "DISP" + STR$(STOREF) + ".DAT"

CALL OPENDISP

IF LOF(6) > 0 THEN

CLOSE #6: KILL FILENAME$

CALL OPENDISP

END IF

STRUCTURE STIFFNESS MATRIX IS BEING FORMED

LOCATE 10, 20: PRINT "GENERATION OF STRUCTURE STIFFNESS MATRIX"

NPASS = 1; ACUMD = 0; ACUMG = 0; ACUM = 0

WONLY$ = "N"; DESIG$ = "N"; GOSUB CONNECTIVITY

STIFFNESS MATRIX IS REARRANGED TO ACCOUNT FOR SUPPORT CONDITIONS AND

SO THAT WHEN MULTIPLIED BY THE LOAD VECTOR OF EACH INDIVIDUAL LOADING

DISPLACEMENTS CAN BE EVALUATED AND THEREFORE ACTIONS ON MEMBERS

CLS: LOCATE 11, 20: PRINT "PERFORMING FORWARD REDUCTION OF EQUATIONS"

GOSUB FORSUST

EACH LOADING CONDITION WILL BE TREATED INDIVIDUALLY OBTAINING THE CO-

CORRESPONDING EFFECTS, MEMBER END ACTIONS ARE SAVED IN FILE SPTR_.DAT

FOR ILC = 1 TO 7

CLS: LOCATE 5, 23: PRINT "LOAD COMBINATION No. " ILC

REDIM DF$(NEQ)
' PUT LOADS CORRESPONDING TO THIS CONDITION ON STRUCTURE
   IF (STOREF<NSTOR AND ILC<>3) OR (STOREF=NSTOR AND ILC<>2) THEN
   GOSUB LOADSTR
   ELSE
   FOR I=1 TO NEQ:DF#(I)=0:NEXT I
   END IF

' SAVE STRUCTURE LOADS IN ADEQUATE USE FOR USE WHEN EVALUATING REACTIONS
FOR I=1 TO SIN
   FOR J=1 TO 3
      GET #6,I
      IND=(I-1)*3+J
      LSET LTYPE62$$(ILC,J)=MKD$(DF#(IND))
      PUT #6,I
   NEXT J
NEXT I

' APPLY BOUNDARY CONDITIONS BEFORE EVALUATING DISPLACEMENTS
IF (STOREF<NSTOR AND ILC<>3) OR (STOREF=NSTOR AND ILC<>2) THEN
   GOSUB BCONDOON
   LOCATE 10,10
   PRINT "*** DISPLACEMENTS ARE BEING EVALUATED ***"
   GOSUB BACSUST
   LOCATE 15,15:PRINT "***** DISPLACEMENTS EVALUATED *****"
   ELSE
   FOR I=1 TO NEQ:DF#(I)=0:NEXT I
   END IF
   FOR I=1 TO SIN
      FOR J=1 TO 3
         GET #6,I
         IND=(I-1)*3+J
         LSET LTYPE6$$(ILC,J)=44KD$(DF#(IND))
         PUT #6,I
      NEXT J
   NEXT I

' EVALUATE ACTIONS ON MEMBERS
   LOCATE 20,10
   PRINT "** MEMBER END ACTIONS ARE BEING EVALUATED **"
   ACUMD=0:ACUMG=0
   ACUM=0:ACUMQ=0:NPASS=2:WONLY$="NO":DESIG$="N"
   GOSUB CONNECTIVITY
   ERASE DF#
   NEXT ILC
   ERASE S1,S2,S3,S4,S5,S6,S7,S8
   CYCLE$="READY"
   GOSUB OPTIMIZE
WEND
   ERASE SMSLAB,EMAT,TSLAB
   ERASE BN,BPN,BCN
   IF STOREF<NSTOR THEN ERASE ULN,ICN,IPN
   CLOSE #2,#3,#4,#6,#7,#9
WEND
CLOSE #1, #5
RETURN

CONSTASSIGN:
GET #5, STOREF: SEL = CVI(CONTP$)
IF SEL = 1 THEN
  CONTYP$ = "CN GROUND"
ELSE
  CONTYP$ = "CN SITE"
END IF
RETURN

CONSTSTORE:
GET #5, STOREF
IF SEL = 1 THEN
  LSET CONTYP$ = MKI$(1)
ELSE
  LSET CONTYP$ = MKI$(2)
END IF
PUT #5, STOREF
RETURN

FORREDIM:
SIK = INT (VECTORSIZE/8+1)
REDIM S1(SIK), S2(SIK), S3(SIK), S4(SIK)
REDIM S5(SIK), S6(SIK), S7(SIK), S8(SIK)
RETURN

CONSCHECK:
' SUBROUTINE TO PERFORM THE REVISION OF THE ALREADY DEFINED STRUCTURE
' WHEN SUBJECTED TO CONSTRUCTION PROCESS CONDITIONS AND REQUIREMENTS
PI = 3.14159: CS$ = "N": CLS: LOCATE 5, 10
PRINT "REVISION DURING CONSTRUCTION PHASE IS TO BE PERFORMED"
CALL OPENBUILD
STOREF = 0: NSTOR = LOF(5)/236
WHILE STOREF < 1 OR NSTOR > NSTOR
  LOCATE 12, 35: INPUT "LEVEL REFERENCE --> ", STOREF
WEND
CALL OPENSEC
FILENAME$ = "SUPP" + STR$(STOREF) + " .DAT": CALL OPENSUPPORT
FILENAME$ = "SPTR" + STR$(STOREF) + " .DAT": CALL OPENSPTTR
FILENAME$ = "SLAB" + STR$(STOREF) + " .DAT": CALL OPENSPLAN
IF LOF(1) = 0 OR LOF(7) = 0 OR LOF(3) = 0 THEN
  CLS: LOCATE 10, 10
  PRINT "FILES ARE NOT READY, CONTINUATION NOT POSSIBLE"
  E$ = "": WHILE E$ = "": E$ = INKEY$: WEND
  CLOSE #1, #3, #4, #5, #7
RETURN
CLS:LOCATE 3,10
PRINT "ARE YOU SURE OPTIMUM DESIGN HAS BEEN ATTAINED"
LOCATE 5,5
PRINT "*UNPREDICTABLE ERROR MAY OCCUR IF CONFIGURATION NOT READY*"
LOCATE 8,8
INPUT "IS CONTINUATION FEASIBLE (Y/N) : ", C0$
IF C0$<"Y" THEN
   CLOSE #1,#3,#4,#5,#7:RETURN
END IF
LOCATE 10,25:PRINT "CONSTRUCTION PROCESS INFORMATION : 
LOCATE 12,30:PRINT "1) SLAB CAST ON GROUND"
LOCATE 14,30:PRINT "2) SLAB CAST ON SITE"
GOSUB CONSTASSIGN
LOCATE 20,40:PRINT "OPTION : " CONSTYPE$
E$="":WHILE E$="":E$=INKEY$:WEND
GET #5, STOREF:
GAMMA = CVI(GAM$): THICK = CVS (THICK$): PORCON = CVS (P$)
FC3D = CVS (FC3$): MELCON = 33*GAMMA")^(3/2)*SQR(FC3D*1000)/1000
STRESSMAX = .85*FC3D: STRESSMIN = 6*SQR(FC3D*1000)/1000
GOSUB DEFSIZE
GOSUB FORREDIM
IF STOREF<STOR THEN
   CALL SERAVECTORS
ELSE
   CALL PERIVECTORS
END IF
ITERATIONS
IF SEL=1 THEN
   NPASSOON=1
   NPASS=1:ACUM=0:ACUMG=0:ACUMQ=0:WONLY$="N":DESIG$="N"
   CLS:GOSUB CONNECTIVITY
   GOSUB FORSTORE
   CLS:LOADFACTOR=0:LOADFACTOR=0
   WHILE LOADFACTOR<1.2 OR LOADFACTOR>1.6
      LOCATE 5,10:INPUT "STEEL LOADFACTOR : ",LOADFACTOR
   WEND
   WHILE LOADFACTOR<1.4 OR LOADFACTOR>1.7
      LOCATE 10,10:INPUT "CONCRETE LOADFACTOR : ",LOADFACTOR
   WEND
   CLS:LOCATE 5,9
   PRINT "STRUCTURE IS FLIPPED ABOUT X-COORDINATE OF:"
   LOCATE 7,40:PRINT "1) 0 in"
   LOCATE 9,40:PRINT "2) A(1)*SPAC" " in"
   NPASS=1:OPT=0
   WHILE OPT<1 OR OPT>2
      LOCATE 11,20:INPUT "OPTION (1/2) : ", OPT
   WEND
   NSP=0:XCORF=0:IF OPT=2 THEN XCORF=A(1)*SPAC
   WHILE NSP<1 OR NSP>A(2)+1
LOCATE 13,20: INPUT "NUMBER OF SUPPORTED POINTS : ", NSP
WEND
LOCATE 15,10: NPP = 0
PRINT "REGARDING APPLICATION OF PULLING FORCE IN FIRST 90 DEGREES: 
WHILE NPP < 1 OR NPP > ((A(1)+1)*(A(2)+1))/2
    LOCATE 17,20: INPUT "NUMBER OF POINTS : ", NPP
WEND
NT = NSP + NPP: REDIM SUPPNOD(NT)
CLS: LOCATE 3,10: PRINT "REGARDING SUPPORTING NODES : 
LOCATE 5,50: PRINT "TOTAL = " NSP
ELEMTYPE = 0: NLOCA = 0
FOR IA = 1 TO NSP
    COR(1,1) = -23
    WHILE COR(1,1) <> XCORF OR CH$ = "Y"
        CLS: LOCATE 3, 10: PRINT "INFORMATION ABOUT SUPPORTING POINTS: 
        LOCATE 7, 40: PRINT "NUMBER OF POINTS : ", NSP
        LOCATE 12, 20: PRINT "CONSIDER No. " IA: ND = 0
        WHILE ND < 1 OR ND > STN
            LOCATE 17, 20: INPUT "NODE LOCATION —> ", ND
        WEND
        IF STOREF < NSTOR THEN CALL LOADCHECK
        NOD(1) = ND: GOSUB GETCOR
    WEND
    SUPPNOD(IA) = ND
NEXT IA
FOR IA = 1 TO NPP
    COR(1,1) = XCORF
    WHILE COR(1,1) = XCORF OR CH$ = "Y"
        CLS: LOCATE 3, 10: PRINT "REGARDING FIRST 90 DEGREES: 
        LOCATE 5, 10: PRINT "INFORMATION ABOUT PULLING FORCE POINTS: 
        LOCATE 7, 40: PRINT "NUMBER OF POINTS : ", NPP
        LOCATE 12, 20: PRINT "CONSIDER No. " IA: ND = 0
        WHILE ND < 1 OR ND > STN
            LOCATE 17, 20: INPUT "NODE LOCATION —> ", ND
        WEND
        IF STOREF < NSTOR THEN CALL LOADCHECK
        NOD(1) = ND: GOSUB GETCOR
    WEND
    SUPPNOD(IA + NSP) = ND
NEXT IA
GOSUB FORSUSTCON1
REDIM DF#(NEQ)
GOSUB LOADCONST
FOR I = 1 TO STN: DF#(I*3) = -DF#(3*I): NEXT I
GOSUB BONDONAUX1
GOSUB BACSUST
CONCHECK$="OK"
NPASS=2:ACUMD=0:ACUMG=0:ACUM=0:ACUMQ=0:ONLY$="N":DESIG$="N"
GOSUB CONNECTIVITY
IF CONCHECK$<> "OK" THEN
  CLS:LOCATE 5,10
  PRINT "CONSTRUCTION UNDER GIVEN CONDITIONS IS NOT FEASIBLE".
  LOCATE 8,10
  PRINT "STRUCTURE CANNOT BE FLIPPED FIRST 90 DEGREES"
  TRY$=""
  WHILE TRY$<">Y" AND TRY$<">N"
    LOCATE 11,20:INPUT "TRY NEW LOCATIONS (Y/N)?",TRY$
  WEND
  IF TRY$="Y" THEN
    ERASE DF#,SUPPNOD
    ERASE S1,S2,S3,S4,S5,S6,S7,S8
    GOSUB FORREDIM
    GOSUB FORRETRIEVE
    GOTO R1:
  END IF
ELSE
  FIR$="Y"
  CLS:LOCATE 5,10:PRINT "REGARDING FIRST 90 DEGREES FLIP:"
  LOCATE 10,15:PRINT "STRUCTURE MANIPULATION FEASIBLE"
  LOCATE 15,10:PRINT "EVALUATION OF FORCES IN ACTIVE DEVICES"
  GOSUB EVREAC1
  FIR$="":CLS
  LOCATE 5,5:NPP=0:PRINT "REGARDING APPLICATION OF ";
  PRINT "PULLING FORCE IN SECOND 90 DEGREES:"
  WHILE NPP<1 OR NPP>NT-NSP
    LOCATE 10,20:INPUT "NUMBER OF POINTS : ",NPP
  WEND
  ELEMTYPE=0:NT=NSP+NPP
  FOR IA=1 TO NPP
    COR(1,3)=-23
    WHILE COR(1,1)=XCORF OR COR(1,3)<DEPTH OR CH$="Y"
      CLS:LOCATE 5,10:PRINT "INFORMATION ABOUT PULLING ";
      PRINT "FORCE POINTS:"
      LOCATE 7,40:PRINT "NUMBER OF POINTS : ",NPP
      LOCATE 12,20:PRINT "CONSIDER No. " IA:ND=0
      WHILE ND<1 OR ND>STN
        LOCATE 17,20:INPUT "NODE LOCATION --> ",ND
      WEND
      IF STOREF<NSTOR THEN CALL LOADCHECK
      NOD(1)=ND:GOSUB GETCOR
    WEND
    SUPPNOD(IA+NSP)=ND.
  NEXT IA
R2:
NPASS=1: ERASE S1, S2, S3, S4, S5, S6, S7, S8
GOSUB FORREDIM
GOSUB FORRETRIEVE
GOSUB FORSUSTCON1
ERASE DF#: REDIM DF#(NEQ)
GOSUB LOADCONST
GOSUB BONDCONDUAL1
GOSUB RACSUST
CONCHECK$="OK"
NPASS=2: ACUMD=0: ACUMG=0: ACUM=0
ACUM0=0: WONLY$="N": DESIG$="N"
GOSUB CONNECTIVITY
IF CONCHECK$<>"OK" THEN
  CLS: LOCATE 5, 10
  PRINT "CONSTRUCTION UNDER GIVEN CONDITIONS IS NOT FEASIBLE"
  LOCATE 8, 10
  PRINT "STRUCTURE CANNOT BE FLIPPED SECOND 90 DEGREES"
  TRY$=""
  WHILE TRY$<>"Y" AND TRY$<>"N"
    LOCATE 11, 20: INPUT "TRY NEW LOCATIONS(Y/N)?", TRY$
  WEND
  IF TRY$="Y" THEN GOTO R2:
ELSE
  CLS: LOCATE 5, 10
  PRINT "REGARDING SECOND 90 DEGREES FLIP:"
  LOCATE 10, 15: PRINT "STRUCTURE MANIPULATION FEASIBLE"
  LOCATE 15, 10: PRINT "EVALUATION OF FORCES IN ACTIVE DEVICES"
GOSUB EVREAC1
CLS: LOCATE 5, 10
PRINT "REGARDING LIFT UP OF STRUCTURE FOR INSTALLATION"
WHILE NLOCA<4 OR NLOCA>(A(1)+1)*(A(2)+1)
  LOCATE 13, 20
  INPUT "NUMBER OF ANCHORING LOCATIONS: ", NLOCA
WEND
ERASE SUPPNOD
REDIM SUPPNOD(NLOCA)
ELEMTYPE=43
FOR IA=1 TO NLOCA
  OR(1,3)=-23
  WHILE OR(1,3)<>DEPTH OR CH$="Y"
    CLS: LOCATE 3, 10
    PRINT "INFORMATION ABOUT PULLING FORCE POINTS:"
    LOCATE 7, 40: PRINT "NUMBER OF POINTS : ", NLOCA
    LOCATE 12, 20: PRINT "CONSIDER NO. " IA: ND=0
    WHILE ND<1 OR ND>STN
      LOCATE 17, 20: INPUT "NODE LOCATION —> ", ND
WEND
IF STOREF< NSTOR THEN CALL LOADCHECK
NOD(1)=ND: GOSUB GETCOR
WEND
SUPP NOD(IA)=ND
NEXT IA
NPASS=1: ERASE S1, S2, S3, S4, S5, S6, S7, S8
GOSUB FORREDIM
GOSUB FORRETRIEVE
GOSUB FORSUSTCON1
ERASE DF#: REDIM DF# (NBQ)
GOSUB LOADCONST
GOSUB BCONDONAUX1
GOSUB BAC SUST
CON CHECK$="OK"
NPASS=2: ACUMD=0: ACUMG=0: ACUM=0
ACUMQ=0: WONLY$="N": DESIG$="N"
GOSUB CONNECTIVITY
IF CONCHECK$<"OK" THEN
CLS: LOCATE 5,10: PRINT "CONSTRUCTION UNDER GIVEN ";
PRINT "CONDITIONS IS NOT FEASIBLE": LOCATE 8,10
PRINT "STRUCTURE CANNOT BE LIFTED UP UNDER GIVEN ";
PRINT "CONDITIONS"
TRY$=""
WHILE TRY$<>"Y" AND TRY$<>"N"
LOCATE 11,20: INPUT "TRY NEW LOCATIONS(Y/N)?": TRY$
WEND
IF TRY$="Y" THEN GOTO R3:
ELSE
CLS: LOCATE 5,15
PRINT "REGARDING LIFT UP OF STRUCTURE": LOCATE 10,15
PRINT "STRUCTURE MANIPULATION FEASIBLE": LOCATE 15,10
PRINT "EVALUATION OF FORCES IN ACTIVE DEVICES"
GOSUB EVREAC1
END IF
END IF
END IF
ERASE SMSLAB, EMAT, TSLAB
ELSE
NPASSCON=2
CLS: LOCATE 5,10: INPUT "CONSTRUCTION LOAD (psf) = ", CONLOAD
NSHORP=1
WHILE NSHORP<Ø OR NSHORP>A(1)*A(2)
LOCATE 8,5: INPUT "NUMBER OF SHORING POINTS : ", NSHORP
WEND
IF NSHORP>Ø THEN
REDIM SHOR NOD(NSHORP)
ELSE TYPE=Ø
FOR I=1 TO NSHORP

OOR(1,3)=23

WHILE COR(1,3)<0 OR CH$="Y"

CLS:LOCATE 3,10:PRINT "INFORMATION ABOUT SHORING:"
LOCATE 7,40:PRINT "NUMBER OF POINTS : " NSHORP
LOCATE 12,20:PRINT "CONSIDER No. " I:ND=0
WHILE ND<1 OR ND>STN
LOCATE 17,20:INPUT "NODE LOCATION --> ",ND
WEND
IF STOREF<STOR THEN CALL LOADCHECK
NOD(1)=ND:GOSUB GETCOR
WEND
SHORNOD(I)=ND
NEXT I
END IF

CLS:LOADFACTOR=0
WHILE LOADFACTOR<1.2 OR LOADFACTOR>1.6
LOCATE 5,10:INPUT "LOAD FACTOR TO BE USED --> ",LOADFACTOR
WEND
NPASS=1:ACUMD=0:ACUMG=0:ACUMQ=0:WONLY$="N":DESIG$="N"
GOSUB CONNECTIVITY
GOSUB FORSUSTCON2
REDIM DF#(NEQ)
GOSUB LOADCNST
GOSUB BCONDCONLUX2
GOSUB BACSUST
DEFM=0
FOR IA=1 TO STN
ND=IA:IF STOREF<STOR THEN CALL LOADCHECK
IF CH$<"Y" THEN
IF ABS(DF#(3*IA))>DEFM THEN
DEFM=ABS(DF#(3*IA))
NDDEFM=IA
END IF
END IF
NEXT IA
CONCHECKS="OK"
NPASS=2:ACUMD=0:ACUMG=0:ACUMQ=0:WONLY$="N":DESIG$="N"
GOSUB CONNECTIVITY
IF CONCHECKS<"OK" THEN
CLS:LOCATE 5,10
PRINT "CONSTRUCTION UNDER GIVEN CONDITIONS IS NOT
FEASIBLE"
LOCATE 15,10:PRINT "A NEW ATTEMPT NEEDS TO BE PERFORMED"
E$="":WHILE E$="":E$=INKEY$:WEND
ELSE
CLS:LOCATE 5,10:PRINT "REGARDING STRUCTURE DEFORMATION:"
LOCATE 10,10
PRINT "MAXIMUM DEFLECTION = " USING ".##.##";DEFM;
PRINT "in";E$=""
LOCATE 15,10:PRINT "OCCURRING AT NODE -> " NDDEFM
WHILE E$="":E$=INKEY$:WEND
IF NSHORP>0 THEN
  CLS:LOCATE 5,10:PRINT "CONSTRUCTION IS FEASIBLE"
  LOCATE 8,10:PRINT "UNLESS EXCESSIVE DEFORMATION"
  LOCATE 11,13:PRINT "SHORING REQUIRED"
  E$="":WHILE E$="":E$=INKEY$:WEND
  GOSUB EVREAC2
ELSE
  CLS:LOCATE 5,10:PRINT "CONSTRUCTION IS FEASIBLE"
  LOCATE 8,10:PRINT "UNLESS EXCESSIVE DEFORMATION"
  LOCATE 11,13:PRINT "NO SHORING REQUIRED"
  E$="":WHILE E$="":E$=INKEY$:WEND
END IF
END IF
IF NSHORP>0 THEN ERASE SHORNOD
END IF
CLOSE #1,#3,#4,#5,#7
ERASE S1,S2,S3,S4,S5,S6,S7,S8,BN,DF#
IF STOREF<NSTOR THEN ERASE BCN,BPN,ICN,IPN,ULN
NPASSON=0
RETURN

FORSUSTCON1:
  IF NLOCA=0 THEN
    FOR IA=1 TO NSP
      FOR JA=1 TO 3
        INDICATOR=(SUPPNOD(IA)-1)*3+JA:GOSUB FORSUSAUX1
      NEXT JA
    NEXT IA
    FOR IA=1 TO NPP
      INDICATOR=SUPPNOD(IA-NSP)*3:GOSUB FORSUSAUX1
    NEXT IA
    ELSE
      FOR IA=1 TO NLOCA
        FOR JA=1 TO 3
          INDICATOR=(SUPPNOD(IA)-1)*3+JA:GOSUB FORSUSAUX1
        NEXT JA
      NEXT IA
    END IF
  GOSUB FORSUSPRO
RETURN
LOADCONST:
   IF NPASSCON=1 THEN CONLOAD=0
   GET #5,STOREF:DUMLOAD=CVS(DEAD$):LSET DEAD$=MKS$(CONLOAD)
   PUT #5,STOREF:ILC=1:GOSUB LOADSTR
   GET #5,STOREF:LSET DEAD$=MKS$(DUMLOAD):PUT #5,STOREF
   RETURN

FORSTORE:
   IF NPASSCON=0 THEN
      FILENAME$="STIFF"+STR$(STOREF)+".DAT"
   ELSE
      FILENAME$="STIFF.DAT"
   END IF
   OPEN "O",8,FILENAME$
   FOR IA=1 TO NEQ
      IGRV=(IA-1)*BANDWIDTH
      FOR JA=1 TO BANDWIDTH
         IRCV=IGRV+JA:CALL AUXREP
         WRITE #8,X
      NEXT JA
   NEXT IA
   CLOSE #8
   RETURN

FORRETRIEVE:
   GET ORIGINAL STIFFNESS VALUES FOR EVALUATION OF STRUCTURE REACTIONS
   IF NPASSCON=0 THEN
      FILENAME$="STIFF"+STR$(STOREF)+".DAT"
   ELSE
      FILENAME$="STIFF.DAT"
   END IF
   OPEN "I",8,FILENAME$
   FOR IA=1 TO NEQ
      IGRV=(IA-1)*BANDWIDTH
      FOR JA=1 TO BANDWIDTH
         IRCV=IGRV+JA:INPUT #8,X
         CALL AUXSTO
      NEXT JA
   NEXT IA
   CLOSE #8
   RETURN
EVREA1:
'    SUBROUTINE TO EVALUATE TENSILE FORCES IN ALL ANCHORING DEVICES DURING
'    THE MANIPULATION OF SPACE TRUSS AFTER THIS HAS BEEN CAST ON GROUND
NPASS=1:ERASE S1,S2,S3,S4,S5,S6,S7,S8
GOSUB FORREDIM
GOSUB FORRETRIEVE
IF NLOCA=0 THEN
    REDIM REA(NPP)
    FOR IA=1 TO NPP
        AUX=IA: I=SUPPNOD(IA+NSP)*3: GOSUB STRDISP1
        NEXT IA
    FOR IA=1 TO NPP
        AUX=IA: I=SUPPNOD(IA+NSP)*3: GOSUB STRDISP2
        NEXT IA
    ERASE DF#: REDIM DF#(NEQ)
    GOSUB LOADCONST
    IF FIR$="Y" THEN
        FOR I=1 TO SIN:DF#(I*3)=-DF#(I*3):NEXT I
    END IF
    CLS:LOCATE 3,10:PRINT "UNFACTORED LOADS TO CHECK PULLING DEVICES"
LOCATE 6
PRINT TAB(5) "NUMBER" TAB(30) "AT NODE" TAB(50) "LOAD (kip)"
LOCATE 9
FOR IA=1 TO NPP
    PRINT TAB(6) IA TAB(31) SUPPNOD(IA+NSP)
    IND=3*SUPPNOD(IA+NSP):REA(IA)=REA(IA)-DF#(IND)
    IF FIR$="Y" THEN REA(IA)=ABS(REA(IA))
    PRINT TAB(51) USING "###.###":REA(IA)
    E$="":WHILE E$="":E$=INKEY$:WEND
NEXT IA
ELSE
    REDIM REA(NLOCA)
    FOR IA=1 TO NLOCA
        AUX=IA: I=SUPPNOD(IA)*3: GOSUB STRDISP1
        NEXT IA
    FOR IA=1 TO NLOCA
        AUX=IA: I=SUPPNOD(IA)*3: GOSUB STRDISP2
        NEXT IA
    ERASE DF#: REDIM DF#(NEQ)
    GOSUB LOADCONST
    CLS:LOCATE 3,10:PRINT "UNFACTORED LOADS TO CHECK PULLING DEVICES"
LOCATE 6
PRINT TAB(5) "NUMBER" TAB(30) "AT NODE" TAB(50) "LOAD (kip)"
LOCATE 9
FOR IA=1 TO NLOCA
    PRINT TAB(6) IA TAB(31) SUPPNOD(IA)
    IND=3*SUPPNOD(IA):REA(IA)=REA(IA)-DF#(IND)
    PRINT TAB(51) USING "###.###":REA(IA)
    E$="":WHILE E$="":E$=INKEY$:WEND
**EVREAC2:**

* SUBROUTINE TO EVALUATE THE REACTIVE FORCES IN SHORES USED WHEN SLAB IS
  CAST IN PLACE
  REDIM REA(NSHORP)
  NPASS=1:ERASE S1,S2,S3,S4,S5,S6,S7,S8
  GOSUB FORREDIM
  GOSUB FORRETRIEVE
  FOR IA=1 TO NSHORP
    AUX=IA:I=(SHORNOD(IA)-1)*3+3:GOSUB STRDISP1
  NEXT IA
  FOR IA=1 TO NSHORP
    AUX=IA:I=(SHORNOD(IA)-1)*3+3:GOSUB STRDISP2
  NEXT IA
  ERASE DF#:REDIM DF#(NEQ)
  GOSUB LOADCONST
  CLS:LOCATE 3,10:PRINT "UNFACTORED LOADS TO DESIGN SHORING DEVICES"
  LOCATE 6:PRINT TAB(5) "NUMBER" TAB(30) "AT NODE" TAB(50) "LOAD (kip)"
  LOCATE 9
  FOR IA=1 TO NSHORP
    PRINT TAB(6) IA TAB(31) SHORNOD(IA);
    IND=(SHORNOD(IA)-1)*3+3:REA(IA)=REA(IA)-DF#(IND)
    PRINT TAB(51) USING "###.###":REA(IA)
    ES="":WHILE E$="":E$=INKEY$:WEND
  NEXT IA
  ERASE DF#,REA,S1,S2,S3,S4,S5,S6,S7,S8
  RETURN

**STRDISP1:**

* CONSIDER MATRIX UPPER TRIANGLE IN EVALUATING REACTIOS
  IGRV=(I-1)*BANDWIDTH
  FOR J=1 TO BANDWIDTH
    K=I+J-1
    IF K<=NEQ THEN
      IRCV=IGRV+J:CALL AUXREP
      REA(AUX)=REA(AUX)+X*DF#(K)
    END IF
  NEXT J
  RETURN
STRDISP2:
' CONSIDER MATRIX LOWER TRIANGLE IN EVALUATING REACTIONS
NBM1=BANDWIDTH-1
FOR L=1 TO NBM1
  J=I-BANDWIDTH+L
  IF J>1 THEN
    K=BANDWIDTH*L-1
    IGRV=(J-1)*BANDWIDTH: IRCV=IGRV+K: CALL AUXREP
    REA(AUX)=REA(AUX)+X*DF#(J)
  END IF
NEXT L
RETURN

FORSUSPRO:
' SUBROUTINE TO ACCOMPLISH THE MODIFICATION OF STIFFNESS MATRIX AFTER
' THOSE RESTRAINED DEGREES OF FREEDOM HAVE BEEN IDENTIFIED
FOR R=1 TO NEQ
  NV=(R-1)*BANDWIDTH
  IRCV=NV+1: CALL AUXREP
  DENOMINATOR=X
  FOR L=2 TO BANDWIDTH
    IRCV=NV+L: CALL AUXREP
    NUMERATOR=X
    IF NUMERATOR<>0 THEN
      IA=R+1:L: IV=(IA-1)*BANDWIDTH
      C=NUMERATOR/DENOMINATOR: JA=0
      FOR KA=L TO BANDWIDTH
        JA=JA+1: IRCV=NV+KA: CALL AUXREP
        IRCV=IV+JA: X=-C*X: CALL AUXADD
      NEXT KA
      IRCV=NV+L: X=C: CALL AUXSTO
    END IF
  NEXT L
NEXT R
RETURN

FORSUST:
' SAVE ORIGINAL STRUCTURE STIFFNESS MATRIX FOR LATER COMPUTATION OF
' REACTIONS. THIS WILL BE MODIFIED IN SUCH A WAY THAT BY MULTIPLYING
' IT WITH LOAD VECTORS DISPLACEMENTS ARE EVALUATED
GOSUB FORSTORE
F: FOR IA=1 TO NPN
  GET #4,IA
  FOR JA=1 TO 3
    LRD=CVI(C$(JA))
    IF LRD=1 THEN
      INDICATOR=(BN(IA)-1)*3+JA
      GOSUB FORUSAUX1
    END IF
NEXT JA
NEXT IA
H: IF STORF<NSSTOR THEN GOSUB FORUSAUX2
GOSUB FORUSPRO
RETURN

FORSUSTCON2:
1 MODIFICATION OF STIFFNESS MATRIX WHEN CHECKING CONSTRUCTION PROCESS
1 TYPE 2 ACCOUNTING FOR SUPPORT CONDITIONS
GOSUB FORSTOR
IF NSHORP>0 THEN
FOR IA=1 TO NSHORP
   INDICATOR=SHORNOD(IA)*3: GOSUB FORUSAUX1
NEXT IA
END IF
GOSUB F
RETURN

FORSUSAUX1:
1 SUBROUTINE TO ACCOUNT FOR SUPPORT CONDITIONS IN FORWARD REDUCTIONS
FOR JAX=1 TO NEQ
   IROW=JAX: ICOL=INDICATOR-IROW+1
   IF ICOL>INDICATOR THEN
      ICDL=IODL+IRCW-1: DUM=ICOL: IOOL=IRCW
      IROW=DUM: ICOL=ICOL-IROW+1
   END IF
   IF IOOL<=BANDWIDTH THEN
      IGRV=(IRDW-1)*BANDWIDTH: IRCV=IGRV+ICOL
      X=0: CALL AUXSTO
   END IF
NEXT JAX
IRCV=IGRV+1: X=1: CALL AUXSTO
RETURN

FORSUSAUX2:
1 ACCOUNT FOR SUPPORT OF SERVICE AREA IF ANY
GET #5,STOREF
IF CVI(BRA$)=0 THEN
   RETURN
ELSE
   FOR IA=1 TO 4
      FOR JA=1 TO 4
         INDICATOR=(ICN(IA)-1)*3+JA: GOSUB FORUSAUX1
      NEXT JA
   NEXT IA
   IF N3>0 THEN
      FOR IA=1 TO N3
         FOR JA=1 TO 4
            INDICATOR=(IPN(IA)-1)*3+JA: GOSUB FORUSAUX1
         NEXT JA
      NEXT IA
   END IF
RETURN
NEXT JA
NEXT IA
END IF
END IF
RETURN

BACSUST:
' SOLVE SIMULTANEOUS EQUATIONS OF DISPLACEMENTS
FOR R=1 TO NEQ
  FOR L=2 TO BANDWIDTH
    NV=(R-1)*BANDWIDTH
    IRCV=NV+L: CALL AUXREP
    IF X<>0 THEN
      IA=R+L-1
      DF#(IA)=DF#(IA)-X*DF#(R)
    END IF
    NEXT L
  IRCV=NV+1: CALL AUXREP
  DF#(R)=DF#(R)/X
NEXT R
FOR MK=2 TO NEQ
  R=NEQ+1-MK:NV=(R-1)*BANDWIDTH
  FOR L=2 TO BANDWIDTH
    IRCV=NV+L: CALL AUXREP
    IF X<>0 THEN
      KA=R+L-1
      DF#(R)=DF#(R)-X*DF#(KA)
    END IF
    NEXT L
  NEXT MK
RETURN

BCONDCQNAUX1:
' BOUNDARY CONDITIONS IN LOAD VECTOR IN CHECKING CONSTRUCTION
' PROCESS WHEN CONCRETE SLAB IS CAST ON GROUND
IF NLOCA=0 THEN
  FOR IA=1 TO NSP
    FOR JA=1 TO 3: IND=(SUPPNOD(IA)-1)*3+JA: DF#(IND)=0: NEXT JA
  NEXT IA
  NEXT IA
ELSE
  FOR IA=1 TO NLOCA
    FOR JA=1 TO 3: IND=(SUPPNOD(IA)-1)*3+JA: DF#(IND)=0: NEXT JA
  NEXT IA
END IF
RETURN
BOUNDARY CONDITIONS IN LOAD VECTOR IN CHECKING CONSTRUCTION

PROCESS WHEN CONCRETE SLAB IS CAST ON PLACE

GOSUB BCONDON

IF NSHORP > 0 THEN
    FOR IA = 1 TO NSHORP
        IND = SHORNOD(IA) * 3: DF#(IND) = 0
    NEXT IA
END IF
RETURN

BCONDON:

BOUNDARY CONDITIONS IN LOAD VECTOR IN CHECKING CONSTRUCTION

SUBROUTINE TO MODIFY LOAD VECTOR SO THAT DISPLACEMENTS CAN BE OBTAINED

FOR IA = 1 TO NPN
    GET #4, IA
    FOR JA = 1 TO 3
        DUM = CVI(C$(JA))
        IF DUM = 1 THEN
            IND = (BN(IA) - 1) * 3 + JA: DF#(IND) = 0
        END IF
    NEXT JA
NEXT IA

IF STOREF < NSTOR THEN
    GET #5, STOREF
    IF CVI(BRA$) = 1 THEN
        FOR IA = 1 TO 4
            FOR JA = 1 TO 3
                IND = (ICN(IA) - 1) * 3 + JA: DF#(IND) = 0
            NEXT JA
        NEXT IA
        IF N3 > 0 THEN
            FOR IA = 1 TO N3
                FOR JA = 1 TO 3
                    IND = (IPN(IA) - 1) * 3 + JA: DF#(IND) = 0
                NEXT JA
            NEXT IA
    END IF
END IF
END IF
RETURN
LOADFACTOR:
' SUBROUTINE TO PLACE FACTORS IN A MATRIX FASHION TO EASE LOAD
' COMBINATION UNDER ULTIMATE CONDITIONS
LFAC(1,1)=1.4:LFAC(2,2)=1.6:LFAC(2,3)=.5:LFAC(3,2)=.5:LFAC(3,3)=1.6
FOR IA=2 TO 11:LFAC(IA,1)=1.2:NEXT IA
FOR IA=12 TO 15:LFAC(IA,1)=.9:NEXT IA
FOR IA=4 TO 7:LFAC(IA,2)=1.6:LFAC(IA,3)=1.6:LFAC(IA,IA)=.8:NEXT IA
FOR IA=8 TO 11
LFAC(IA,2)=.5:LFAC(IA,3)=.5:ALIX1=IA-4:AUX2=IA+4
LFAC(IA,AUX1)=1.3:LFAC(AUX2,AUX1)=1.3
NEXT IA
RETURN

NOMRESIST:
' SUBROUTINE TO EVALUATE NOMINAL AXIAL STRENGTH OF A GIVEN MEMBER
GET #1,KA
IF LAMBDA<=1.5 THEN
FCRITK=.658*(LAMBDA^2) 'INELASTIC BUCKLING
ELSE
FCRITK=.877/LAMBDA^2 'ELASTIC BUCKLING
END IF
PNOMCOMP=FCRITK*CVS(FLAT)+CVS(AREA) 'YIELDING OF CROSS SECTION
RETURN

GETOPPLATE:
' CHECK THICKNESS OF PLATES AT JOINTS AND INCREASE THEM IF NECESSARY
' WHEN DEALING WITH DIAGONAL MEMBERS, CHECK PLAN DIMENSION OF PLATES
' FOR DIAGONAL AND MEMBERS IN THE GRIDS
IF PLATEREF(NOD(ND))<>0 THEN
GET #9,PLATEREF(NOD(ND))
PK1=CVS(PLATHICK$:):PK2=CVS(PLADIM$):PK3=CVS(PLAFY$)
IF PK1>=RFIL THEN RFIL=PK1
IF PK2>=MINLE THEN MINLE=PK2
IF PK3>=FXAUX THEN FFAUX=PK3
END IF
B: KAUX=LOF(9)/16:COSTLOW=0:NUMSUITP=0
KANT=0:REDIM K(3)
FOR JA=1 TO KAUX
GET #9,JA
PK1=CVS(PLATHICK$:):PK2=CVS(PLADIM$):PK3=CVS(PLAFY$):PK4=CVS(PLAPRI$)
KANT=0:FOR IA=1 TO 3:KANT=KANT+K(IA):NEXT IA
IF PK1>=RFIL THEN K(1)=K(1)+1
IF PK2>=MINLE THEN K(2)=K(2)+1
IF PK3>=FXAUX THEN K(3)=K(3)+1
KACUM=0:FOR IA=1 TO 3:KACUM=KACUM+K(IA):NEXT IA
KACUM=KACUM-KANT
IF KACUM=3 THEN
NUMSUITP=NUMSUITP+1:COSTP=PK4*PK2^2*PK1*.285
IF NUMSUITP=1 THEN COSTLOW=COSTP
IF COSTP <= COSTLOW THEN
    COSTLOW = COSTP
    PLATEREF(NOD(ND)) = JA
END IF
END IF
NEXT JA

IF NUMSUITP = 0 THEN
    CLS: LOCATE 5, 15
    PRINT "THERE IS NO SUITABLE PLATE FOR JOINT " NOD(ND)
    LOCATE 10, 10: PRINT "TOTAL OF AVAILABLE PLATES = " KAUX
    LOCATE 12, 25: PRINT K(1) " MEET THICKNESS REQUIREMENT ";
    PRINT " —> " USING ".###"; RFIL
    LOCATE 14, 25: PRINT K(2) " MEET DIMENSION REQUIREMENT ";
    PRINT " —> " USING "###.#"; MINLE
    LOCATE 16, 25: PRINT K(3) " MEET STRESS REQUIREMENT ";
    PRINT " —> " USING "#.###"; FXAUX
    LOCATE 21, 30: PRINT "PRESS ANY KEY TO ADD A PLATE TO FILE"
    E$ = ""; WHILE E$ = "": E$ = INKEY$: WEND
    ERASE K
    NPLA = KAUX: GOSUB V
    GOTO B:
ELSE
    ERASE K
END IF
GET #6, NOD(ND); LSET REFLS = MKI$(PLATEREF(NOD(ND))): PUT #6, NOD(ND)
RETURN

GETOPSEC:
' SUBROUTINE TO CHOOSE OPTIMUM SECTION
REDIM LFLIN(2)
IF BARTYPE = 1 THEN
    ACUMG = ACUMG + 1
ELSE
    ACUMD = ACUMD + 1
END IF
' PERFORM FACTORED LOAD COMBINATIONS TO OBTAIN CRITICAL VALUES OF AXIAL
' ACTIONS IN A GIVEN MEMBER, CHECK FOR MAXIMUM COMPRESSION AND MAXIMUM
' TENSION FORCES
GET #3, ACUM
PULIMAX = 0: PULIMIN = 0
FOR IA = 1 TO 15
    PULT = 0
    FOR JA = 1 TO 7
        AUX = CVS(LTYPE3$(JA)): PULT = PULT + LFAC(IA, JA) * AUX
    NEXT JA
    IF ABS(PULT) < > PULT THEN
        IF ABS(PULT) > PULIMIN THEN PULIMIN = ABS(PULT)
        ELSE IF PULT > PULIMAX THEN PULIMAX = PULT
END IF
NEXT KA

SCRUTINIZE AVAILABLE CROSS SECTIONS TO DEFINE THE ONE THAT FULFILLS STRENGTH AND SLENDERNESS REQUIREMENTS AT MINIMUM COST
COSTMIN=0:AUXLREF=LREF
AUX=LOF(1)/40
FOR KA=1 TO KAUX

GET #1,KA
RATIO=SQR(CVS(INERTIA$)/CVS(AREA$))
SRAT=EL/RATIO
LAMBA=EL/(RATIO*PI)*SQR(CVS(FY$)/CVS(MELAST$))
GOSUB CONSTASSIGN
IF BARTYPE=1 AND COR(1,3)=DEPTH AND CONSTYPE$="ON GROUND" THEN
SRAT=.7*SRAT
LAMBA=.5*LAMBA
END IF
GOSUB NOMRESIST
PULWELD=PNOMTEN*.9
IF BARTYPE=1 AND COR(1,3)=DEPTH AND CONSTYPE$="ON GROUND" THEN
PULWELD=PNOMCOMP*.85
END IF
GET #1,KA:WS=LEFT$(WELDIY$,2)
IF WS="45" THEN
FEXX=45
ELSEIF WS="60" THEN
FEXX=60
ELSE
FEXX=70
END IF
IF .85*PNOMCOMP>=PULTMIN AND .9*PNOMTEN>=PULTMIN AND SRAT<275 THEN
GOSUB WELDREQUIRED
COST=CVS(WEIGHT$)*EL/12*CVS(STEELPRI$)+WELDAM*CVS(WELDPRI$)
NUMSUITS=NUMSUITS+1
IF COSTMIN=0 THEN COSTMIN=COST
IF COST<=COSTMIN THEN
COSTMIN=COST
LREF=KA
IF BARTYPE=1 THEN
LFILN1AUX=LFILN(1)+1.5:LFILN2AUX=LFILN(2)+1.5
ELSE
RFILN1AUX=RFIL
IF RFIL>.25 THEN
EXTSP=(RFIL-.25)/TAN(35.26/180*PI)
ELSE
EXTSP=0
END IF
MINLEAUX=2*((.75+1.30+EXTSP+.87*CVS(DIAM$))/SQR(2)+1)
END IF
END IF

NEXT KA

' CHECK IF AT LEAST THERE WAS ONE SUITABLE SECTION, IF NOT UPDATE FILE
' OF AVAILABLE CROSS SECTIONS AND TRY AGAIN

IF NUMSUITS=0 THEN

CLS:LOCATE 10,10
PRINT "ADD A NEW CROSS SECTION SINCE NO ONE IS SUITABLE"
E$="";WHILE E$="";E$=INKEY$:WEND
NSEC=K AUX:GOSUB U
GOTO A:

END IF

FOR ND=1 TO 2

IF BARTYPE=2 THEN

RFILN(ACUMD)=RFILAUX
RFIL=RFILAUX
MINLE=MINLEAUX
ELSE

IF ND=1 THEN

LFIL1(ACUMG)=LFILN1AUX;MINLE=LFIL1(ACUMG)
ELSE

LFIL2(ACUMG)=LFILN2AUX;MINLE=LFIL2(ACUMG)
END IF

END IF

GET #1,LREF
FYAUX=CVS(FY$)
GOSUB GETOPPLEATE

NEXT ND

' NEED TO SOLVE A NEW STRUCTURE IF A NEW CROSS SECTION HAS BEEN FOUND
' AS THE MOST SUITABLE FOR A GIVEN MEMBER

IF LREF<>AUXLREF THEN

LSET REF$=MK$(LREF):PUT #3,ACUM
CYCLE$="NOTREADY"
END IF

TOTCOST=TOTCOST+GOSIMIN
ERASE LFILN
PRINT TAB(20) "MEM -> " ACUM " " LREF
RETURN
WELDREQUIdRED:
' SUBROUTINE TO OBTAIN THE AMOUNT OF WELD REQUIRED FOR A GIVEN MEMBER
IF BARTYPE=1 THEN
    WELDAM=0
    FOR IA=1 TO 2
    GET #9, PLATEREF(NOD(IA)): RFIL=CVS(PLATHICK$)
    K2AUX=INT(RFIL*16): RFIL=K2AUX/16
    LFIL1=PULWELD/(RFIL*.45*EEXX)
    GET #1, KA: LFIL2=PULWELD/(RFIL*.9*CVS(FY$))
    IF LFIL1>LFIL2 THEN
        LFILN(IA)=LFIL1
    ELSE
        LFILN(IA)=LFIL2
    END IF
    WELDAM=WELDAM+PI*RFIL^2/4*.22*LFILN(IA)
    NEXT IA
ELSE
    PERIM=PI*SQR(2)*CVS(DIAM$)
    RFIL1=PULWELD/(PERIM*.45*EEXX)
    RFIL2=PULWELD/(PERIM*.9*CVS(FY$))
    IF RFIL1>RFIL2 THEN
        RFIL=RFIL1
    ELSE
        RFIL=RFIL2
    END IF
    IF RFIL<.0625 THEN RFIL=.0625
    K2AUX=CINT((RFIL+.025)*16): RFIL=K2AUX/16
    WELDAM=PI*RFIL^2/4*PERIM*.22*2
END IF
RETURN

TERMINA:
    TERM$="Y"
RETURN

LOADSTR:
' PUT LOADS ON STRUCTURE, CHOOSE THE ADEQUATE VALUES DEPENDING ON
' LOADING CONDITION UNDER CONSIDERATION
GET #5, STOREF
IF ILC=1 THEN
    ALOAD=CVS(DEADS$): GOSUB VLONO
    ACUM=0: ACUMQ=0: DESIG$="N": WONLY$="Y"
    GOSUB CONNECTIVITY
    IF NPASSCON<1 THEN
        DUM$="N": LA=0
        WHILE LA<23 AND DUM$="N"
            MAGN=CVI(CDL$(LA))
            IF MAGN<>0 THEN
                ALOAD=CVS(LOAD$)
                LA=LA+1
            END IF
        END WHILE
    END IF
END IF
RETURN
NOD=CVI(LODL$(LA))
IND=NOD*3:DF#(IND)=DF#(IND)-MAGN/1000
ELSE
   DUM$="Y"
END IF
WEND
END IF
ELSEIF ILC=2 THEN
ALOAD=CVS(LIVE$):GOSUB VLONO
DUM$="N";LA=0
WHILE LA<23 AND DUM$="N"
   LA=LA+1
   MAGN=CVI(CLIL$(LA))
   IF MAGN<0 THEN
      NOD=CVI(LOLL$(LA))
      IND=NOD*3:DF#(IND)=DF#(IND)-MAGN/1000
   ELSE
      DUM$="Y"
   END IF
WEND
ELSEIF ILC=3 THEN
ALOAD=CVS(ROOF$):GOSUB VLONO
ELSE
   IF STOREF<NSTOR THEN
      ALOAD=0
   ELSE
      ALOAD=-ROWIP:GOSUB VLONO
   END IF
END IF
END IF
IF ILC>3 THEN GOSUB LLONO
RETURN

VLONO:
' VERTICAL LOADS ARE PLACED ON STRUCTURE NODES
ALOAD=ALOAD/144/1000
FOR IA=1 TO A(2)+1
   FOR JA=1 TO A(1)+1
      NODEID=(IA-1)*GAP+JA:ND=NODEID:CH$="N"
      IF STOREF<NSTOR THEN CALL LOADCHECK
      IF CH$="Y" THEN
         PER$="N";CORP$="N"
         LA=0
      WHILE LA<N1 AND PER$="N"
         LA=LA+1
      IF NODEID=BPN(LA) THEN PER$="Y"
      WEND
      LA=0
      WHILE LA<4 AND CORP$="N" AND PER$="N"
         LA=LA+1
IF NODEID=BCN(LA) THEN CORP$="Y"
WEND
IF PER$="Y" THEN
   TRIBA=SPAC"2/2
   DUM$="N"
   IF STOREF<STOR THEN
      AUX=0:GOSUB 45
      AUX=SPAC"2/4:GOSUB 44
   END IF
END IF
IF OORP$="Y" THEN
   TRIBA=SPAC"2/4
   DUM$="N"
   IF STOREF<STOR THEN
      AUX=0:GOSUB 44
   END IF
END IF
IF PER$="N"AND CORP$="N" THEN
   TRIBA=SPAC"2
   DUM$="N"
   IF STOREF<STOR THEN
      AUX=3*SPAC"2/4:GOSUB 44
      AUX=SPAC"2/2:GOSUB 45
      AUX=0:GOSUB 46
   END IF
END IF
KA=NODEID*3
DF#(KA)=DF#(KA)-ALOAD*TRIBA
END IF
NEXT JA
NEXT IA
RETURN

' CHECK FOR NODES IN CORNER OF SERVICE AREA
44:LA=Ø
   WHILE LA<4 AND DUM$="N"
      LA=LA+1
      IF NODEID=ICN(LA) THEN
         TRIBA=AUX:DUM$="Y"
      END IF
   WEND
   RETURN

' CHECK FOR NODES IN PERIPHERY OF SERVICE AREA
45: LA = 0
    WHILE LA < N3 AND DUM$ = "N"
        LA = LA + 1
        IF NODEID = IPN(LA) THEN
            TRIBA = AUX; DUM$ = "Y"
        END IF
    WEND
    RETURN

' CHECK FOR NON EXISTING NODES DUE TO EXISTANCE OF SERVICE AREA
46: LA = 0
    WHILE LA < NA5 AND DUM$ = "N"
        LA = LA + 1
        IF NODEID = ULN(LA) THEN
            TRIBA = AUX; DUM$ = "Y"
        END IF
    WEND
    RETURN

LLNO:
' LATERAL LOADS ARE PLACED ON STRUCTURE NODES
SIDEIND = 1
    IF ILC = 4 THEN ARLD = ALOAD1
    IF ILC = 5 THEN ARLD = ALOAD2
    IF ILC > 5 THEN ARLD = ROWIP
    FOR IA = 1 TO A(2) + 1
        NODEID = (IA - 1) * GAP + 1
        GOSUB 42
        LK = 1: GOSUB 43
    NEXT IA
SIDEIND = 2
    IF ILC = 4 THEN ARLD = ALOAD2
    IF ILC = 5 THEN ARLD = ALOAD1
    IF ILC > 5 THEN ARLD = ROWIP
    FOR IA = 1 TO A(2) + 1
        NODEID = (IA - 1) * GAP + A(1) + 1
        GOSUB 42
        LK = 1: GOSUB 43
    NEXT IA
SIDEIND = 3
    IF ILC < 6 THEN ARLD = ROWIP
    IF ILC = 6 THEN ARLD = ALOAD1
    IF ILC = 7 THEN ARLD = ALOAD3
    FOR IA = 1 TO A(1) + 1
        NODEID = IA
        GOSUB 42
        LK = 2: GOSUB 43
    NEXT IA
SIDEIND = 4
IF ILC<6 THEN ARLD=ROWIP
IF ILC=6 THEN ARLD=ALOAD3
IF ILC=7 THEN ARLD=ALOAD1
FOR IA=1 TO A(1)+1
    NODEID=IA+A(2)*GAP
    GOSUB 42
    LK=2:GOSUB 43
NEXT IA
RETURN

' MODIFY TRIBUTARY WIDTH FOR CORNER NODES
42:IA=0:DUM$="N";TRIWI=SPAC
WHILE IA<4 AND DUM$="N"
    LA=LA+1
    IF NODEID=BCN(LA) THEN
        DUM$="Y";TRIWI=TRIWI/2
    END IF
WEND
IF STOREF<NSTOR THEN GOSUB CHECKSEAP
RETURN

43:IND=(NODEID-1)*3+LK:DF#(IND)=DF#(IND)+ARLD*TRIWI/12*INFHE/1000:RETURN

CHECKSEAP:
' MODIFY TRIBUTARY WIDTH FOR NODES IN PERIPHERY OF SERVICE AREA IF THIS
' IS ON THE STRUCTURE BOUNDARY AND CORRECT NODE OF APPLICATION
' WHEN SERVICE AREA IS IN A CORNER OF THE BUILDING
IF SIDEIND<2 THEN KEP=K2SEAR
IF SIDEIND>=3 THEN KEP=K1SEAR-1
LA=0:COR$="N"
WHILE LA<4 AND COR$="N"
    LA=LA+1
    IF NODEID=ICN(LA) THEN
        COR$="Y"
        TRIWI=TRIWI*(1+KEF/2)
        CORP$="N";IA=0
        WHILE LA<4 AND CORP$="N"
            LA=LA+1:IF NODEID=BCN(LA) THEN CORP$="Y"
        WEND
        IF CORP$="Y" THEN
            IF SIDEIND=1 THEN
                NODEID=NODEID+K1SEAR
            ELSEIF SIDEIND=2 THEN
                NODEID=NODEID-K1SEAR
            ELSEIF SIDEIND=3 THEN
                NODEID=NODEID+(K2SEAR+1)*GAP
            ELSE
                NODEID=NODEID-(K2SEAR+1)*GAP
            END IF
        END IF
    END IF
WEND
END IF
END IF
WEND
LA=0
DUM$="N"
WHILE LA<3 AND COR$="N" AND DUM$="N"
   LA=LA+1
   IF NODEID=IPN(LA) THEN
      DUM$="Y"
      TRIWI=0
   END IF
WEND
RETURN

GETKCON:
' EVALUATE CONSTANT NECESSARY TO EVALUATE LEEWARD WALL PRESSURE
IF RATIO<=1 THEN KCON=.5
IF RATIO>1 AND RATIO<=2 THEN KCON=.3
IF RATIO>2 AND RATIO<=4 THEN KCON=.25
IF RATIO>4 THEN KCON=.2
RETURN

ULNCHECK:
' FORMATION OF INITIAL STRUCTURE CONFIGURATION DETECTING THOSE MEMBERS
' WHICH BELONG TO SERVICE AREA AND THUS DO NOT EXIST, FOR THOSE A NON-
' ZERO BUT NEGLIGIBLE STIFFNESS MATRIX WILL BE ASSIGNED
' COUNT IS DONE OF DIAGONAL AND GRID TYPE MEMBERS
' QUADRILATERAL ELEMENTS AT SERVICE AREA ARE IGNORED SINCE IN THE
' RELATED DEGREES OF FREEDOM NON-ZERO STIFFNESS EXISTS
AUX=0:AUXG$="NO"
WHILE AUX<NODE AND AUXG$="NO"
   LA=LA+1
   WHILE AUXG$="NO" AND LA<N5
      LA=LA+1:IF NOD(AUX)=ULN(LA) THEN AUXG$="YES"
   WEND
WEND
IF NODE=2 THEN
   IF AUXG$="YES" THEN
      LSET REF$=MKI$(0):PUT #3,ACUM
   ELSE
      LSET REF$=MKI$(1):PUT #3,ACUM
      GOSUB COUNTBARS
   END IF
ELSE
   IF AUXG$="YES" THEN
      LSET RE$=MKI$(0):PUT #7,ACUMQ
   ELSE
      LSET RE$=MKI$(1):PUT #7,ACUMQ
      GOSUB COUNTSLABS
   END IF
END IF
END IF
RETURN

COUNTRARS:
' COUNT DIAGONAL AND GRID MEMBERS
IF BARTYPE=1 THEN
    NUMGRIDMEM=NUMGRIDMEM+1
ELSE
    NUMDIAGMEM=NUMDIAGMEM+1
END IF
RETURN

COUNTRALS:
' COUNT QUADRILATERAL ELEMENTS MODELING CONTRIBUTION OF CONCRETE SLAB
NUMSLABMEM=NUMSLABMEM+1
RETURN

DEFGRID:
' SUBROUTINE TO DISPLAY GENERAL GEOMETRY OF STRUCTURE
CLS:PRINT
PRINT TAB(10) "SPACE TRUSS IN LEVEL No. " STOREF:PRINT:PRINT
A(1)=L1/SPAC:A(2)=L2/SPAC
D: PRINT TAB(20) " DEPTH (inches) : ",DEPTH:PRINT:PRINT
PRINT TAB(5) "IN THE SHORT DIRECTION : SPAN (in) : " L1:PRINT
PRINT TAB(40) " NUMBER OF NODES = " A(1)+1
PRINT TAB(40) " NUMBER OF ELEMENTS = " A(1):PRINT
PRINT TAB(5) "LOWER MESH CHARACTERISTICS : ";
PRINT TAB(40) " NUMBER OF NODES = " A(1).
PRINT TAB(40) " NUMBER OF ELEMENTS = " A(1)-1:PRINT:PRINT
PRINT TAB(15) "IN THE LONG DIRECTION : SPAN (in) : " L2:PRINT
PRINT TAB(5) "UPPER MESH CHARACTERISTICS : ";
PRINT TAB(40) " NUMBER OF NODES = " A(2)+1
PRINT TAB(40) "NUMBER OF ELEMENTS = " A(2):PRINT
PRINT TAB(5) "LOWER MESH CHARACTERISTICS : ";
PRINT TAB(40) " NUMBER OF NODES = " A(2)
PRINT TAB(40) " NUMBER OF ELEMENTS = " A(2)-1:PRINT
E$="":WHILE E$="":E$=INKEY$:WEND
G: CLS:GAP=A(1)*2+1:NMAX=(A(1)+1)*(A(2)+1)+A(1)*A(2)
RETURN
CONNECTIVITY:

' SUBROUTINE THAT GENERATES ALL MEMBERS IN STRUCTURE BY
' DEFINING CONNECTING NODES
' GENERATION OF BAR TYPE MEMBERS
ELEMTYPE=1
NNB=A(1)+A(2)-1
REDIM B(NNB)
' GENERATION OF NODES IN THE PERIPHERY
BARTYPE=2
K=0
WHILE K<4
  K=K+1
  IF K=1 THEN
    INDDIAGGEN=A(1)+1+GAP
    FOR I=1 TO A(2):B(I)=INDDIAGGEN+(I-1)*GAP:NEXT I
    AUXDIAGGEN=A(2)
    INDDIAGGEN=B(AUXDIAGGEN)-A(1)
    FOR I=1 TO A(1)-1
      B(I+AUXDIAGGEN)=INDDIAGGEN+1:INDDIAGGEN=B(I+AUXDIAGGEN)
      NEXT I
    LIMIT=A(2):K1ALJXDIAGGEN=A(1)+1
  ELSEIF K=2 THEN LIMIT=A(1)-1
  ELSEIF K=3 THEN
    LAST=S(AUXDIAGGEN):B(AUXDIAGGEN)=A(1)+1:REFDIGE=LAST-A(1)
    INDDIAGGEN=1
    FOR I=1 TO A(1)-1
      B(I+AUXDIAGGEN)=INDDIAGGEN+1:INDDIAGGEN=B(I+AUXDIAGGEN)
      NEXT I
    K1AUXDIAGGEN=-A(1)
  ELSEIF K=4 THEN LIMIT=A(2)
END IF
FOR I=1 TO LIMIT
  IF K=1 THEN NOD(2)=(I-1)*GAP+1
  IF K=2 THEN NOD(2)=I+1
  IF K=3 THEN NOD(2)=REFDIGE+I
  IF K=4 THEN NOD(2)=REFDIGE-GAP*(I-1)
  ELIO$="FALSE"
  WHILE ELIO$="FALSE"
    NOD(1)=NOD(2)
    NOD(2)=NOD(1)+K1AUXDIAGGEN
    GOSUB GETCOR
    J=0
    WHILE J<NNB
      J=J+1
      IF B(J)=NOD(2) THEN ELIO$="TRUE"
    WEND
  WEND
  NEXT I
WEND
ERASE B

* GENERATION OF ELEMENTS IN UPPER GRID IN X DIRECTION
BARTYPE=1
FOR I=1 TO A(2)+1
   FOR J=1 TO A(1)
      NOD(1)=(I-1)*GAP+J
      NOD(2)=NOD(1)+1
      GOSUB GETOOR
   NEXT J
NEXT I

* GENERATION OF ELEMENTS IN UPPER GRID IN Y DIRECTION
FOR I=1 TO A(1)+1
   NOD(2)=I
   FOR J=1 TO A(2)
      NOD(1)=NOD(2)
      NOD(2)=NOD(1)+GAP
      GOSUB GETOOR
   NEXT J
NEXT I

* GENERATION OF ELEMENTS IN LOWER GRID IN X DIRECTION
FOR I=1 TO A(2)
   FOR J=1 TO A(1)-1
      NOD(1)=(I-1)*GAP+J+A(1)+1
      NOD(2)=NOD(1)+1
      GOSUB GETOOR
   NEXT J
NEXT I

* GENERATION OF ELEMENTS IN LOWER GRID IN Y DIRECTION
FOR I=1 TO A(1)
    NOD(2)=I+A(1)+1
    FOR J=1 TO A(2)-1
       NOD(1)=NOD(2)
       NOD(2)=NOD(1)+GAP
       GOSUB GETOOR
    NEXT J
NEXT I

IF DESIG$="Y" OR (NPASSCON=2 AND WONLY$<>"Y") THEN RETURN

* GENERATION OF QUADRILATERAL TYPE ELEMENTS WHICH MODEL THE CONCRETE SLAB WHOSE ROTATIONAL STIFFNESS ARE NEGLECTED
BARTYPE=0
ELEMTYPE=2
FOR I=1 TO A(2)
   NOD(2)=(I-1)*GAP+1
   FOR J=1 TO A(1)
      NOD(1)=NOD(2):NOD(2)=NOD(1)+1:NOD(3)=NOD(2)+GAP:NOD(4)=NOD(1)+GAP
      GOSUB GETOOR
   NEXT J
NEXT I
RETURN
QUADSHAPE:

' SUBROUTINE TO PERFORM GAUSS QUADRATURE INTEGRATION IN THE Attainment
' OF STIFFNESS COEFFICIENTS FOR CONCRETE ELEMENTS, IT IS CONSIDERED
' FOUR NODES AND THREE RELATED DEGREES OF FREEDOM (linear displacements)
REDIM SNXI(4),SNET(4),FJAC(2,2)
FOR LA=1 TO 4
  DUM1=(1+XII(LA)*PXI)/4:DUM2=(1+ETI(LA)*PET)/4
  SNXI(LA)=XII(LA)*DUM2:SNET(LA)=ETI(LA)*DUM1
NEXT LA
FOR LA=1 TO 4
  FJAC(1,1)=FJAC(1,1)+SNXI(LA)*QXL(LA)
  FJAC(1,2)=FJAC(1,2)+SNXI(LA)*QYL(LA)
  FJAC(2,1)=FJAC(2,1)+SNET(LA)*QXL(LA)
  FJAC(2,2)=FJAC(2,2)+SNET(LA)*QYL(LA)
NEXT LA
DETJAC=FJAC(1,1)*FJAC(2,2)-FJAC(1,2)*FJAC(2,1):DUM1=FJAC(1,1)/DETJAC
FJAC(1,1)=FJAC(2,2)/DETJAC:FJAC(1,2)=-FJAC(1,2)/DETJAC
FJAC(2,1)=FJAC(2,1)/DETJAC:FJAC(2,2)=DUM1
FOR JA=1 TO 4
  LA=2*JA:KA=LA-1
  BASLAB(1,KA)=FJAC(1,1)*SNXI(JA)+FJAC(1,2)*SNET(JA)
  BASLAB(2,LA)=FJAC(2,1)*SNXI(JA)+FJAC(2,2)*SNET(JA)
  BASLAB(3,LA)=BASLAB(1,KA):BASLAB(3,KA)=BASLAB(2,LA)
NEXT JA
ERASE SNXI,SNET,FJAC
RETURN

GETCOR:

' MULTIFUNCIONAL SUBROUTINE DEPENDING ON THE VALUES OF SEVERAL FLAGS
' EXECUTION COMES FROM SUBROUTINE CONNECTIVITY, EXCEPT WHEN COORDINATES
' OF A GIVEN NODE IS DESIRED
' NPASS=1 GENERATES STRUCTURE STIFFNESS MATTIX
' NPASS=2 GENERATES ACTIONS ACTING ON MEMBERS
' WONLY$ CONSIDERS MEMBERS SELF-WEIGHT FOR DEAD LOAD CONDITION
' DESIG$ TRANSFERS EXECUTION TO SUBROUTINE THAT GETS OPTIMUM SECTION
NNODE=1
IF ELEMTYPE=1 THEN NNODE=2
IF ELEMTYPE=2 THEN NNODE=4
FOR IAUX=1 TO NNODE
  KAUX=(NOD(IAUX)-1)/GAP
  KRES=NOD(IAUX)-INT(KAUX)*GAP
  IF KRES>A(1)+1 THEN
    KL=SPAC/2
    COR(IAUX,1)=(KRES-A(1)-2)*SPAC+KL:COR(IAUX,2)=KL+INT(KAUX)*SPAC
    COR(IAUX,3)=O
    ELSE
    COR(IAUX,1)=(KRES-1)*SPAC:COR(IAUX,2)=INT(KAUX)*SPAC
    COR(IAUX,3)=DEPTH
  END IF
NEXT IAUX
IF ELEMTYPE=0 THEN RETURN
IF ELEMTYPE=1 THEN
ACUM=ACUM+1
REDIM PRO$(3)
EL=0
FOR IA=1 TO 3
   PRO$(IA)=COR(2,IA)-COR(1,IA):EL=PRO$(IA)^2+EL
NEXT IA
EL=SQR(EL)
FOR IA=1 TO 3
   PRO$(IA)=PRO$(IA)/EL
NEXT IA
IF NPASS=1 AND ITERATIONS AND NPASSCON<1 THEN
   IF ACUM=1 THEN DIAGLEN=EL
   IF STOREF<STOR THEN
      GOSUB UNCHECK
   ELSE
      GOSUB COUNTBARS
      LSET REF$=MKI$(1):PUT #3,ACUM
   END IF
END IF
END IF
GET #3,ACUM:LREF=CVI(REF$)
IF ITERATION=2 AND USEANT$="Y" AND NPASS=1 THEN
   IF ACUM=1 THEN DIAGLEN=EL
   IF LREF>0 THEN GOSUB COUNTBARS
END IF
IF WONLY$="Y" THEN
   ERASE PRO#
   IF LREF<0 THEN
      GET #1,LREF:WEI=CVS(WEIGHT$)
      WONNOD=EL*WEI/24
   ELSE
      WONNOD=0
   END IF
   FOR WAUX=1 TO 2
      IND=NOD(WAUX)*3:DF$(IND)=DF$(IND)-WONNOD/1000
   NEXT WAUX
   RETURN
END IF
IF DESIG$="Y" THEN
   ERASE PRO#
   IF LREF<>0 THEN GOSUB GETOPSEC
   RETURN
END IF
IF LREF=0 THEN
   AREA=.0001:MELAST=.01
ELSE
   GET #1,LREF:AREA=CVS(AREAWS):MELAST=CVS(MELAST$)
END IF
PRINT TAB(10) " MEM —> " ACUM TAB(40) " REF —> " LREF;
GOSUB BARSTIFNES
ELSE
ACUMQ=ACUMQ+1
PRINT TAB(15) " QUAD —> " ACUMQ;
IF ITERATION=1 AND WONLY$<>"Y" AND NPASS=1 AND NPASSCON<1 THEN
   IF STOREF<NSTOR THEN
      GOSUB ULNCHECK
   ELSE
      LSET RE$=MKE$(1):POT #7,ACUMQ
   END IF
END IF
GET #7,ACUMQ:LREF=CVI(RE$)
IF ITERATION=2 AND USEANT$="Y" AND NPASS=1 THEN
   IF LREF=0 THEN GOSUB COUNTSLABS
END IF
PRINT TAB(40) "REF —> " LREF;
IF ITERATION=1 OR (ITERATION=2 AND USEANT$="Y") THEN
   IF NPASS=1 AND WONLY$="N" AND ACUMQ=1 THEN GOSUB QUADRILATERAL
END IF
IF ITERATION>1 OR NPASS=1 THEN
   IF WONLY$="Y" THEN
      IF LREF>0 THEN
         WONNOD=GAMMA/1000/12^3*THICK*SPAC^2/4
      ELSE
         WONNOD=0
      END IF
   FOR VAUX=1 TO 4
      IND=NOD(VAUX)*3:DF#(IND)=DF#(IND)-WONNOD
   NEXT VAUX
   RETURN
END IF
IF LREF=0 THEN RETURN
IF NPASS=1 THEN
   REDIM SM(12,12)
   FOR IA=1 TO 12
      FOR JA=1 TO 12
         SM(IA,JA)=SMSLAB(IA,JA)
      NEXT JA
   NEXT IA
   NPE=4:CALL STORE
   ERASE SM
ELSE
   REDIM UG(12)
   FOR Z=1 TO 4
      ID=(NOD(Z)-1)*3:KA=(Z-1)*3
      FOR JA=1 TO 3
         UG(JA+KA)=DF#(ID+JA)
NEXT JA
NEXT Z
REDIM UL(8)
FOR IA=1 TO 8
    UL(IA)=0
    FOR KA=1 TO 12
        UL(IA)=UL(IA)+TSLAB(IA,KA)*UG(KA)
    NEXT KA
NEXT IA
REDIM STRAIN(3),STRESS(3)
FOR IA=1 TO 3
    FOR KA=1 TO 8
        STRAIN(IA)=STRAIN(IA)+BASLAB(IA,KA)*UL(KA)
    NEXT KA
NEXT IA
FOR IA=1 TO 3
    FOR KA=1 TO 3
        STRESS(IA)=STRESS(IA)+EMAT(IA,KA)*STRAIN(KA)
    NEXT KA
NEXT IA
TAUMAX=SQR((STRESS(1)-STRESS(2))^2+4*STRESS(3)^2)/2
CENT=(STRESS(1)+STRESS(2))/2
SIGMAMAX=CENT+TAUMAX:SIGMAMIN=CENT-TAUMAX
PRINT TAB(70) "**";
IF NPASSCON=1 THEN
    SIGMAUX=LOADFACTORC*SIGAMAX:GOSUB CHECKSLABCON
    SIGMAUX=LOADFACTORC*SIGAMIN:GOSUB CHECKSLABCON
    ERASE STRAIN,STRESS,UG,UL
    RETURN
END IF
GET #7,ACUMQ:LSET VONM$(ILC,1)=MKS$(SIGMAMIN)
LSET VONM$(ILC,2)=MKS$(SIGMAMAX):PUT #7,ACUMQ
ERASE STRAIN,STRESS,UG,UL
END IF
END IF
RETURN
BARSTIFFNESS:
SUBROUTINE TO ASSIGN STIFFNESS CHARACTERISTICS IN THE FORMATION OF
GLOBAL STIFFNESS MATRIX AS WELL AS IN THE FORMATION OF LOCAL STIFF-
NESS MATRIX FOR MEMBER END ACTIONS EVALUATION

REDIM SM(6,6),BA#(2,6)
STL=AREA*MELAST/EL:SM(1,1)=STL:SM(2,2)=STL:SM(1,2)=-STL:SM(2,1)=-STL
BA#(1,1)=PRO#(1):BA#(1,2)=PRO#(2):BA#(1,3)=PRO#(3)
BA#(2,4)=PRO#(1):BA#(2,5)=PRO#(2):BA#(2,6)=PRO#(3)

IF NPASS=1 THEN
  REDIM C#(6,2)
  FOR IA=1 TO 6
    FOR JA=1 TO 2
      FOR KA=1 TO 2
        C#(IA,JA)=C#(IA,JA)+BA#(KA,IA)*SM(KA,JA)
      NEXT KA
    NEXT JA
  NEXT IA

  FOR IA=1 TO 6
    FOR JA=1 TO 6
      SM(IA,JA)=0
      FOR KA=1 TO 2
        SM(IA,JA)=SM(IA,JA)+C#(IA,KA)*BA#(KA,JA)
      NEXT KA
    NEXT JA
  NEXT IA
END IF

ELSE
  REDIM UG(6),UL(2)
  FOR Z=1 TO 2
    ID=(NOD(Z)-1)*3;KA=(Z-1)*3
    FOR JA=1 TO 3
      UG(JA+KA)=DF#(ID+JA)
    NEXT JA
  NEXT Z
  FOR IA=1 TO 2
    FOR KA=1 TO 6
      UL(IA)=UL(IA)+BA#(IA,KA)*UG(KA)
    NEXT KA
  NEXT IA

  DEFORM=UL(1)-UL(2);STRAIN=DEFORM/EL;STRESS=STRAIN*MELAST
  LOADP=STRESS*AREA
END IF

PRINT TAB(70) "*"
GET #3,ACUM
LSET LTYPE3$(ILC) = MKS$(LOADP)
PUT #3,ACUM
ERASE UL,UG
END IF
ERASE SM,BA#,PRO#
RETURN

CHECKSLABCON:
' CHECK CONCRETE SLAB DURING CONSTRUCTION PHASE IF IT WAS CAST ON GROUND
IF SIGMAUX<ABS(SIGMAUX) THEN
  IF STRESSMIN<ABS(SIGMAUX) THEN
    CLS:LOCATE 5,20:CONCHECK$="NOT OK"
    PRINT "QUADRILATERAL ELEMENT No. " ACUMQ " IS OVERSTRESSED IN TENSION"
    LOCATE 15,20:PRINT USING "####.##";ABS(SIGMAUX);" vs ";
    PRINT USING "####.##";STRESSMIN
    LOCATE 22,50:PRINT "ANY KEY TO CONTINUE"
    E$="":WHILE E$="":E$=INKEY$:WEND
  END IF
ELSE
  IF STRESSMAX<SIGMAUX THEN
    CLS:LOCATE 10,20:CONCHECK$="NOT OK"
    PRINT "QUADRILATERAL ELEMENT No. " ACUM " IS OVERSTRESSED IN COMPRESSION"
    LOCATE 15,20:PRINT USING "####.##";SIGMAUX;" vs ";
    PRINT USING "####.##";STRESSMAX
    LOCATE 22,50:PRINT "ANY KEY TO CONTINUE"
    E$="":WHILE E$="":E$=INKEY$:WEND
  END IF
END IF
RETURN
CHECKOON:
' CHECK TRUSS MEMBERS DURING CONSTRUCTION PHASE
GET #1, LREF
AREA=CVS(AREA$)
RATIO=SQR(CVS(INERTIA$)/AREA)
LAMBDA=EL/(RATIO*PI)*SQR(CVS(FY$)/CVS(MELAST$))
KA=LREF:GOSUB NOMRESIST
IF LOADP<>ABS(LOADP) THEN
   IF PNOMTEN<ABS(LOADP) THEN
      CLS:LOCATE 5,20:CONCHECK$="NOT OK"
      PRINT "MEMBER NO. " ACUM " IS OVERSTRESSED IN TENSION"
      LOCATE 15,20:PRINT USING "####.##";ABS(LOADP):PRINT " vs ";
      PRINT USING "####.##";PNOMTEN
      LOCATE 22,50:PRINT "ANY KEY TO CONTINUE"
      E$="":WHILE E$="":E$=INKEY$:WEND
   END IF
ELSE
   IF PNOMCOMP<LOADP THEN
      CLS:LOCATE 10,20:CONCHECK$="NOT OK"
      PRINT "MEMBER NO. " ACUM " IS OVERSTRESSED IN COMPRESSION"
      LOCATE 15,20:PRINT USING "####.##";LOADP:PRINT " vs ";
      PRINT USING "####.##";PNOMCOMP
      LOCATE 22,50:PRINT "ANY KEY TO CONTINUE"
      E$="":WHILE E$="":E$=INKEY$:WEND
   END IF
END IF
RETURN
CREATE FILES

MODIFY ANY FEATURE

GEOMETRY

SUPPORT CONDITIONS

LOADING CONDITIONS

CONCRETE CHARACTERISTICS

CONSTRUCTION PROCEDURE

DISPLAY ON SCREEN
NOMENCLATURE

\( A_c \)  
Area of concrete slab within effective width.

\( A_g \)  
Gross cross sectional area.

\( A_r \)  
Area of longitudinal reinforcing bars.

\( A_{sc} \)  
Cross sectional area of a stud shear connector.

\( A_{sf} \)  
Flange area of steel cross section.

\( A_{sw} \)  
Web area of steel cross section.

\( A_w \)  
Weldment effective area.

\( B \)  
Ellipse minor semi-axis.

\( C \)  
Compressive force for design of shear connectors.

\( C_p \)  
Leeward pressure coefficient defined by Table 4.4.

\( C_l, C_2, C_3 \)  
Numerical coefficients defined in Sec. 2.1.2.

\( D \)  
Bar member diameter. Dead load.

\( D_0 \)  
Surface drag effect coefficient defined by Table 4.3.

\( E \)  
Modulus of Elasticity of steel.

\( E_c \)  
Modulus of elasticity of concrete.

\( F_c' \)  
Ultimate concrete strength.

\( F_{cr} \)  
Critical compressive stress as defined by Eqns. 21 and 22.

\( F_{exx} \)  
Nominal weld metal ultimate stress.

\( F_d \)  
Design force for shear connection in a composite space truss, defined by Eqn. 13.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$F_Y$</td>
<td>Minimum specified yield stress of steel.</td>
</tr>
<tr>
<td>$F_{Yf}$</td>
<td>Minimum specified steel flange yield stress.</td>
</tr>
<tr>
<td>$F_yr$</td>
<td>Specified minimum yield stress of longitudinal reinforcing bars.</td>
</tr>
<tr>
<td>$F_{yw}$</td>
<td>Minimum specified yield stress of web steel.</td>
</tr>
<tr>
<td>$G_h$</td>
<td>Building gust response factor.</td>
</tr>
<tr>
<td>$G_s$</td>
<td>Number of grid interspaces.</td>
</tr>
<tr>
<td>$H$</td>
<td>Major axis of the ellipse defined in Fig. 4.1. Major semi-axis in Eqn. 26</td>
</tr>
<tr>
<td>$I$</td>
<td>Building importance factor defined in Table 4.2.</td>
</tr>
<tr>
<td>$I_{\text{eff}}$</td>
<td>Equivalent section moment of inertia for partially composite beams.</td>
</tr>
<tr>
<td>$I_s$</td>
<td>Moment of inertia of the structural steel section.</td>
</tr>
<tr>
<td>$I_{tr}$</td>
<td>Moment of inertia of the fully composite section.</td>
</tr>
<tr>
<td>$K$</td>
<td>Effective length factor.</td>
</tr>
<tr>
<td>$K_z$</td>
<td>Pressure coefficient defined by Eqns. 16 and 17.</td>
</tr>
<tr>
<td>$l$</td>
<td>Member unbraced length for buckling considerations.</td>
</tr>
<tr>
<td>$L$</td>
<td>Live load.</td>
</tr>
<tr>
<td>$L_w$</td>
<td>Length of weldment.</td>
</tr>
<tr>
<td>$N_c$</td>
<td>Number of stud shear connectors supplied in a composite space truss.</td>
</tr>
<tr>
<td>$N_m$</td>
<td>Number of steel members defining Fd.</td>
</tr>
<tr>
<td>$P_e$</td>
<td>Ellipse perimeter defined by Eqn. 26.</td>
</tr>
<tr>
<td>$P_l$</td>
<td>Building leeward pressure due to wind.</td>
</tr>
<tr>
<td>$P_r$</td>
<td>Building roof pressure due to wind.</td>
</tr>
<tr>
<td>$P_s$</td>
<td>Building side pressure due to wind.</td>
</tr>
<tr>
<td>$P_u$</td>
<td>Maximum ultimate force in bar members used in Figures 4.6 and 4.7.</td>
</tr>
</tbody>
</table>
Pw Building windward pressure due to wind. Weldment required strength.

Pwd Design strength defined as the least of Eqns. 21 and 22.

q\_h Velocity pressure at total building height h.

q\_z Velocity pressure at height z.

Q Nominal load effect.

Q\_n Shear connector strength.

Q\_req Required strength per stud shear connector.

Q\_u Ultimate capacity of stud shear connectors.

r Fillet weld throat dimension. Member radius of gyration.

R Roof load.

R\_n Nominal resistance.

V Basic wind speed.

w Concrete unit weight.

W1, W2, W3, W4 Wind loads in the four possible directions defined by Fig. 4.5.

X1, X2, X3 Geometric characteristics defined in Fig. 4.4.

Xmax Geometric characteristic defined by Fig. 4.2.

Y Geometric characteristic defined by Fig. 4.2.

Zg Gradient height defined by Table 4.3.

\( \alpha \) Power law coefficient defined by Table 4.3

\( \beta \) Reliability index defined in Fig. 2.9.

\( \gamma \) Load factor.

\( \phi \) Resistance factor.
REFERENCES

1. ACI, Building Code Requirements for Reinforced Concrete, ACI 318-83, American Concrete Institute, Detroit, Michigan, 1983.


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